

Environmental Assessment – Al Humaij

Report For: SPB

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REPORT REVIEWS AND COMMENTS

AUTHOR(S)	Munseb Ali-Arshad munseb.muhammad@gulfrl.com	
REVIEWER(S)	Alfonso Martin Alfonso.Martin@GulfRL.com	
APPROVER(S)	Saeed Balhaddad Saeed.Balhaddad@GulfRL.com	
EXPERT COMMENT(S)		

FINAL REPORT

ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT
(CATEGORY 2) FOR CONSTRUCTING & OPERATING A SOLAR
ENERGY PARK IN AL HUMAIJ, MADINA, SAUDI ARABIA

Prepared for



Saudi Arabia

Prepared by

**Applied Research Center for
Environment & Marine Studies**

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King Fahd University of Petroleum & Minerals
Research Institute
Dhahran, Saudi Arabia

NON-TECHNICAL SUMMARY

The National Renewable Energy Program (NREP) of Saudi Arabia aims to increase the share of renewable energy in the country's overall electricity generation as part of Vision 2030 and the National Transformation Program. To support Saudi Arabia's commitment to diversify its energy mix and reduce reliance on conventional sources, a solar energy park is proposed in Al Humaij. The Saudi Power Procurement Company (SPPC), which operates under the Ministry of Energy, SPPC is working under MoE and is actively involved in developing the Al Humaij Solar PV project.

According to preliminary studies, the Al Humaij site presents a significant opportunity for the successful development of a solar PV park, aligning seamlessly with Saudi Vision 2030 and significantly contributing to developing a sustainable and resilient energy landscape in the region. The proposed site is situated approximately east of Al Humaij which is 191 km distance from the city of Madina through Route 60 in the Hizaz Region. Al Humaij experiences arid climatic conditions and environmental features. The project site is dominated by desert and rocky terrain, with sparse vegetation consisting mainly of drought-resistant plants such as acacia trees, shrubs, and grasses.

SPPC has selected the Gulf Renewable Energy Lab (GRL) to undertake the preconstruction study for this work. The GRL has contracted the Center for Environment and Marine Studies (CEMS) at King Fahd University of Petroleum & Minerals Research Institute (KFUPM-RI) to conduct an Environmental and Social Impact Assessments (ESIA) study for this project. This non-technical summary provides an overview of the ESIA study (Category 2, NCEC, and Category B, IFC)) conducted for installing a Solar Energy Park in Al Humaij, Madina, Saudi Arabia as well as measures proposed to mitigate the potential impacts of construction activities and enhance benefits.

POLICY, LEGAL AND ADMINISTRATIVE FRAMEWORK

The Ministry of Environment, Water and Agriculture (MEWA) is responsible for overseeing the environmental legislative framework. According to the environmental law issued all development projects within KSA are required to undergo ESIA. The National Center for Environmental Compliance (NCEC) has been assigned the responsibilities related to reviewing and approving ESIA studies for development projects, granting permits, and issuing licenses.

This ESIA is being conducted by the guidelines of the National Center for Environmental Compliance (NCEC) for the construction of a Solar Energy Park in Al Humaij.

PROJECT DESCRIPTION

A proposal has been made to install a Utility-Scale Photovoltaic (PV) Power Station equipped with single-axis tracking devices and bifacial solar panels, with a total capacity of 3,000 MW AC for an estimated cost of 5.7 Billion Riyals. The station will cover an area of 60 km². It is located at coordinates 25° 07' 81.53" E; 41° 07' 00.29" N, under the ownership of the Ministry of Energy (MoE).

The project facilities include necessary support structures for panels, inverters, transformers, electrical meters, low-voltage relays, circuit breakers, overcurrent relays, and lightning arresters, along with other equipment. The facility will be connected to a new substation that will be constructed according to the rules and regulations approved by the Saudi Electricity Company, which will be located on the edge of the project site.

The works will also include creating additional site facilities such as roads, fencing, parking areas, control rooms, warehouses, security buildings, office buildings, and waste storage tanks. It is expected that 3000 workers will be needed to complete the construction, which will take approximately around 30+ months. A worker's camp will be located near the project site to accommodate the workers.

The project site has a strategic location that enhances sustainable development targets without affecting the surrounding ecosystems. The Al Humaij Site is close to the village of Al Humaij which is 191 Km distance from the city of Madina through Route 60. The potential project site land has been identified and is just east of the village of Al Humaij. As per the rainfall data from MOO4-Al Hinakyah Station, the maximum daily rainfall depth is less than 70 mm (RGF Report, 2024).

AN OVERVIEW OF THE BASELINE CONDITIONS

The site visit revealed that the project area is undeveloped and there are no industrial or agricultural activities within the immediate area. Near the site, there is a camel farm and a few settlements. In Al Humaij, surface water resources are scarce, and groundwater is the sole water source.

The project site is dominated by sand sheets with consolidated soil, rocky patches or gravel sheets were the broad habitat in the Al Humaij site. The baseline flora and fauna diversity and abundance at five selected stations were studied for around 1 week (February 1 to 7, 2024). Acacia trees were dominant in the consolidated sand sheet, and *Lyceum shawii* was the dominant species in the isolated rocky patches. While the habitat is not critical or sensitive, sand sheets with consolidated soil are important habitats for the Acacia trees in the project area. Al Humaij site is represented by 23 plant species, of which *Haloxylon salicornicum* was the most abundant. During the present survey, no high conservation priority plant species were recorded from the site. Any construction activities within this site will not have significant impacts on the vegetation there.

All the fauna species documented during the survey are classified under the Least Concern (LC) category, except for Christie's Big-eared bat, which falls under the Data Deficient (DD) category.

AN OVERVIEW OF THE SIGNIFICANT NEGATIVE ENVIRONMENTAL AND SOCIAL IMPACTS

The major project activities and impacting agents related to the project during construction, commissioning, and operational phases and the sensitive receptors are identified and listed in Table S1. During operation, the project is expected to reduce pressure on fossil fuels, reduce greenhouse gas emissions, and optimize electric supply in the area, resulting in a general improvement in socioeconomic conditions. Although

the project will have overall positive socio-economic impacts, few activities are likely to cause potential adverse impacts.

Table S1. List of major impacting agents/activities associated with the construction and operation phases of this project and the sensitive receptors.

MAJOR PROJECT ACTIVITIES & IMPACTING AGENTS		SENSITIVE RECEPTORS
Construction/Commissioning Phase	Operation Phase	
• Site preparation, excavation, and leveling work for structural works leading to ecological destruction • Dust emission and gaseous emissions from the machines, equipment, and generators used in the construction activities. • Airborne noise generation during construction activities • Light pollution due to the lighting of construction sites at night • Removal of flora and habitat fragmentation • Super-structural work involving steel work, concrete work, masonry work, welding work, etc. • Mechanical erection work for solar panel modules, inverters, buildings, over-head power transmission lines, etc. • Increase in vehicle traffic due to the transportation of workers and construction materials. • Labor management issues • Water utilization for construction and in the workers' camps. • Solid and liquid waste generation from worker's camps and construction activities.	• Increase in air temperature, humidity, etc., due to shading effects • Microclimate changes in the surrounding area due to heat-island effects, potentially impacting local ecosystems and wildlife. • Impact of flash flood risk in the project area due to the new facilities. • Loss and fragmentation of natural habitats, collision and electrocution risk to bird and bat species, disruption to wildlife movement/migrations, and displacement risk to birds. • Visual impact due to the alteration of the landscape of a desert area potentially affecting the aesthetic value and scenic beauty. • Potential glint and glare effects. • Light pollution due to the exterior lighting fixed in and around the solar energy park for security purposes. • Minor noise generation by inverters and transformers, which convert DC electricity generated by the panels to AC electricity. • Water utilization for cleaning solar panels and wastewater generation • Solid and liquid waste generation from the operation and maintenance activities	• Air Quality • Climate • Microclimate • Noise and vibration • Visual and landscape • Soil and Land Use • Ground and Surface water • Flood risk • Flora • Fauna • Waste management • Traffic and transport • Health and safety • Labor management • Community Displacement • National and local economy • Archeology and Cultural Heritage • Inappropriate waste disposal • Accidental spills, fire, etc.

The potential environmental and social impacts during the construction, operation, and decommissioning phases are assessed and presented in matrix format in the ESIA report. The following is a summary of the likely negative impacts that have been assessed for the different phases of the Solar PV power park project:

- *Air Quality and Climate:* Likely impacts are high significance but localized and can be mitigated to low significance or no impact during the construction phase.
- *Microclimate:* Likely impacts are very high significance during the operation phase due to localized increases in temperature compared to surrounding rural areas (Heat Island Effect). The impact can be mitigated to low significance.
- *Noise and vibration:* Likely impacts are moderate significance, but localized and can be mitigated to low significance.
- *Visual and landscape:* As the project site has no aesthetic value, solar PV panels covering a large area will not have any visual impact.
- *Soil and Land Use:* Likely impacts are low to moderate significance as the project site is used only for camel grazing.
- *Ground and Surface water:* Likely impacts are very high significance during the operation if groundwater is used for cleaning the solar panel. The impact can be mitigated to low significance.
- *Flood risk:* Likely impacts are moderate to high significance due to the potential for flash flooding during rainy days. The impact can be mitigated to low significance.
- *Flora:* Likely impacts are moderate to high significance due to flora removal during the construction activities and exposure to altered microclimate during operation. The impact can be mitigated to low significance.
- *Fauna:* Impact can be mitigated to low-medium significance (residual impacts).
- *Waste management:* Likely impacts are moderate to high significance but can be mitigated to low impact levels.
- *Traffic and transport:* Likely impacts are low significance and localized and can be mitigated to no impact level.
- *Health and safety:* Overall likely impacts are moderate to high significance but can be mitigated by implementing strict safety measures.
- *Labor management:* Overall likely impacts are moderate to high significance but can be mitigated to low impact significance.
- *Community Displacement:* Likely impacts are medium significance but can be mitigated to low impact levels.

DECOMMISSIONING IMPACTS

It is expected that the solar power park constructed as part of this project will be decommissioned after approximately 25 years. During the decommissioning phase, there will be negative environmental and social impacts. The impacts identified during the construction phase are likely to recur during the decommissioning phase. The disposal of PV modules involves considerable energy consumption and other adverse environmental effects. The decommissioned solar panels are usually recycled to recover metals. The decommissioning process produces waste that requires effective management by those responsible for decommissioning activity to ensure all waste

produced is legally transported, recycled, reused, or disposed of safely by competent, authorized organisations and personnel.

AN OVERVIEW OF THE MITIGATION AND IMPACT MANAGEMENT PLANS

Mitigation measures are designed to prevent, minimize, and, if possible, reverse the significant negative effects of a project on the environment. Most of the potential negative impacts in this project can be mitigated to insignificant levels (low or no impact) by implementing the mitigation and management measures suggested in this ESIA report.

If flood risks for the project site are not adequately addressed, unexpected flash flooding may result in impacts on project components as well as health and safety risks for workers onsite and nearby. Therefore a flood risk assessment of the project area should be undertaken by the developer as part of the design phase of the project.

To enhance wildlife conservation, and mitigate the potential operational impacts, the proposed solar park should be designed, developed, and operated as a *nature-inclusive*¹ and *landscape-inclusive*² solar park. As a result, the environmental impacts associated with this project can be mitigated and a Biodiversity Net Gain (BNG) can be achieved. This approach will also comply with *Performance Standard 6 (Biodiversity Conservation and the Sustainable Management of Living Natural Resources - PS6)* of IFC, one of its requirements for obtaining funding.

To mitigate the impact on any type of Birds during the installation of a utility-scale PV project, it will be implemented as a several strategies to ensure their safety and habitat protection. First, the solar panels will be designed with adequate spacing between them, preventing the appearance of reflective surfaces that could be mistaken for water bodies, thereby discouraging landing. Additionally, it will be looked into the use of a non-reflective materials for the panels to minimize glare. To further reduce the risk of collisions with transmission lines, clear marking and bird flight diverters will be installed on these lines, making them more visible to the eagles. Monitoring programs will also be established to assess eagle activity in the area and adapt management practices as necessary, ensuring the protection of this important species throughout the project lifecycle.

Impacts on microclimate and local biodiversity can be mitigated by installing solar panels with good ground clearance, maintaining vegetation cover where possible, and spacing panel rows appropriately for air circulation. Modern solar panels that have been designed with measures to minimize heat retention incorporated into the design and layout should be used to mitigate the heat island effect during operation. Barriers to the movement and/or migrations of wildlife should be mitigated by modifying solar park fencing to maintain a gap between the base of the fence and the ground (wildlife-friendly fencing).

To mitigate the impact of trees in Al Humaij during the installation of a utility-scale PV project, a comprehensive reforestation plan will be implemented. This plan will include careful mapping of important fauna habitats to avoid disturbance during construction. Any necessary tree removal will be minimized, and affected areas will be restored post-construction by planting native tree species, to enhance biodiversity.

Additionally, the idea to see if there are any opportunities to build the solar panels around existing trees, treating these trees as an offset to our project's footprint. The project will also incorporate measures to monitor the health and growth of these trees over time, ensuring that ecological balance is maintained and contributing to local environmental sustainability.

Cleaning the solar panels with water may significantly impact groundwater resources in the project area, which is already water-stressed. A water-saving alternative would be to do robotic cleaning without water or to select panels that have anti-soiling coatings to reduce water consumption by about 50%.

Development activities are always accompanied by routine potential impacts, such as the generation of airborne noise, emissions to the atmosphere, greenhouse gas emissions, increased road traffic, excessive nighttime illumination, the generation of solid and liquid waste by construction activities, health and safety impacts, etc. As part of all development activities, these are always incidental. NCEC and many national and international bodies including IFC/WB have developed guidelines to limit their extent. The degrees of impact due to the activities/stressors can be evaluated and compared with the baseline data on indicators and against the maximum allowable limits prescribed by NCEC/MEWA/WHO.

An Environmental and Social Monitoring Program (ESMP) should be implemented during the entire construction phase. Monitoring programs should be designed to provide expert assessments of environmental and Social compliance during the construction phase as well as an assessment of the status of the environment during construction and commissioning activities.

CONCLUSION

It can be concluded from the ESIA that although the proposed project is anticipated to bring about certain negative impacts, such as flood risks, negative impacts on flora and fauna, water environment, and microclimate, these impacts can be mitigated through the adoption of the mitigation measures recommended. The main objective of the proposed solar PV energy park at Al-Humaij is to diversify the Kingdom's energy mix and reduce its carbon footprint. The project is considered to be an important contribution to achieving national goals in terms of renewable energy and climate change. The long-term operational and economic effects of the solar park will outweigh any negative impacts encountered during construction and operation. It is therefore recommended that the proposed PV energy park be developed in Al-Humaij, Saudi Arabia provided that the mitigation measures proposed are adhered to.

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SECTION 1 INTRODUCTION

1.1 GENERAL INFORMATION ABOUT THE STUDY

Gulf Renewable Energy Laboratory (GRL) on behalf of the Principal Buyer, represented by the Saudi Power Procurement Company (SPPC) is going to provide the masterplan for the solar PV energy park in Al-Humaij. Operating under the Ministry of Energy, the Principal Buyer is actively involved in the development of the Al Humaij PV project as part of the National Renewable Energy Program (NREP) (Figure 1.1). SPPC has selected the Gulf Renewable Energy Laboratory (GRL) to undertake the predevelopment works for this project. GRL has contracted the Center for Environment and Marine Studies (CEMS) at King Fahd University of Petroleum & Minerals Research Institute (KFUPM-RI) to conduct an Environmental and Social Impact Assessment (ESIA) study for this project.

1.2 JUSTIFICATIONS FOR PREPARING THE STUDY, ITS OBJECTIVES, AND ITS SCOPE OF WORK

1.2.1 Justification for the Study

In 2021, approximately 61% of Saudi Arabia's energy consumed was produced by burning oil and therefore, the Saudi agency in charge of developing the nation's renewable energy sector, Ka-care, announced in May 2012 that the nation would install 41 gigawatts (GW) of solar capacity by 2032. The program sets out an organized and specific road map to diversify local energy sources, stimulate economic development, and provide sustainable economic stability to the Kingdom in light of the goals set for Vision 2030, which include establishing the renewable energy industry and supporting the advancement of this promising sector while working to fulfill the Kingdom's commitments to reducing carbon dioxide emissions. The proposed project to construct solar energy park Al Humaij will help to decrease the country's dependency on traditional forms of energy by increasing the availability and use of solar energy. The generated electricity will be injected into the national grid, to support the country in meeting its renewable energy targets.

The proposed construction of solar energy parks is likely to have negative social and environmental impacts. All industrial and development projects in the Kingdom of Saudi Arabia are subject to Environmental and Social Impact Assessment (ESIA) as part of the planning and construction of the projects in accordance with the National Centre of Environmental Compliance (NCEC), and local and international environmental regulations. The EIA for this project is carried out by the Applied Research Center for Environment and Marine Studies (ARCEMS), Research Institute at King Fahd University of Petroleum & Minerals (KFUPM-RI) for GRL. This EIA is conducted in accordance with NCEC regulations, the latest Saudi Arabia Environmental Regulations [KSA 2020; 2021].

Based on the Environmental Classification Form submitted to NCEC, NCEC has classified this project as a Category 2 project. Hence, this EIA Report is prepared as per the prescribed structure of the Category 2 Report, restricted to the construction phase of the project.

1.2.2 Objectives of the Study

The primary objective of the proposed study is to prepare an ESIA, identify potential positive and negative environmental and social impacts during the construction phase, and suggest suitable mitigation measures to avoid or reduce the impacts. This ESIA is prepared as per the NCEC guidelines.

The specific objectives are the following:

- i. Conduct required field investigations, to establish baseline conditions.
- ii. Predict the environmental and social impacts associated with the proposed construction activities.
- iii. Predict levels of significance, duration, and mitigation potential of specific short- and long-term impacts during the construction phase based on criteria specified in the regulations of the NCEC.
- iv. Provide guidance to ensure the project complies with national environmental objectives, and support compliance with all applicable environmental standards in the project design.
- v. Determine and address cumulative environmental effects considering other current and planned projects in the area.
- vi. Recommend the required mitigation measures required to mitigate the potential impacts during the construction phase.

1.2.3 Scope of Work

The scope of work for conducting this ESIA is provided by SPB. According to preliminary studies, the Al Humaij site presents a significant opportunity for the successful development of a solar PV plant, aligning seamlessly with Saudi Vision 2030 and significantly contributing to developing a sustainable and resilient energy landscape in the region. The proposed construction activities and commissioning are likely to have adverse environmental impacts throughout its lifespan, which can be substantially mitigated, and will not significantly or irreversibly impact areas beyond the site boundary.

Therefore, the proposed project, before execution, must be preceded by preparation and acceptance from the authorities of a comprehensive EIA report. In response to this, and at the request of GRL, the contractor engaged by SPCC for this project, KFUPM/RI prepared this ESIA report covering the construction phase. This ESIA is categorized as a Category 2 project by NCEC.

1.3 INFORMATION ABOUT THE PERMIT APPLICANT

Gulf Renewable Energy Laboratory (GRL) on behalf of the Saudi Power Procurement Company is going to provide the masterplan for the solar energy park at the Al Humaij in Saudi Arabia. GRL is an independent company in Saudi Arabia that provides professional local third-party inspection, testing, certification, calibration, professional training, international skill certification, and technical engineering services

for all industries. They provide world-class TIC services in the Mena region and the Globe, enable local innovation and knowledge economy, and develop the local workforce.

Key contact details at GRL Lab are presented below for ESIA and environmental compliance.

Name of the Contact Person in GRL	Address with Phone no and e-mail address.
Mr. Firas Mohammed Aldossary	UL-GCCLAB, Gulf Renewables Lab, A UL GCCLAB Joint Venture. 3 rd Industrial City Dammam, Saudi Arabia Mobile: +966 509122888 Email: Firas.Aldossary@GulfRL.com Website: www.Gulfrl.com

1.4 INFORMATION ABOUT THE SERVICE PROVIDER WHO PREPARED THE STUDY

Gulf Renewable Energy Lab has contracted the Applied Research Center for Environment and Marine Studies (ARCEMS) at KFUPM-RI to conduct this EIA. The ARCEMS is a category (A) consulting office and has several years of experience in conducting EIAs and Environmental Monitoring Studies in Saudi Arabia. The ARCEMS has a scientific staff of about 70. Several faculty members from the academic departments of the University also work part-time in the ARCEMS. In addition to the resident team of researchers, the Center also employs the services of consultants who may enhance the expertise of the KFUPM-RI team, as well as former KFUPM-RI scientists who have extensive local experience. The Center's activities include several research projects conducted on behalf of various governmental and industrial clients, as well as internally funded projects to facilitate the development of various branches of environmental science.

ARCEMS is the environmental consultant appointed by Saudi Aramco to undertake Project EIA. Key contact details of ARCEMS are provided below. Appendix A provides information on the CEMS's EIA team for the Project.

Name of the Contact Person in CEMS, KFUPM-RI	Address with Phone no and e-mail id
Dr. Subhajit Sen Project Manager	Applied Research Centre for Environment and Marine Studies King Fahd University of Petroleum & Minerals, Dhahran 31261, Saudi Arabia Office: +966 13 860 4340 Email: subhajit.kumar@kfupm.edu.sa

SECTION 2 POLICY, LEGAL AND ADMINISTRATIVE FRAMEWORK

2.1 BRIEF OVERVIEW OF THE INSTITUTIONAL FRAMEWORK

In Saudi Arabia, Environmental Protection Standards are promulgated by the Meteorology and Environmental Protection Administration (MEPA, 1982, 1988) and the Presidency for Meteorology and Environment (PME, 2001). The first comprehensive Saudi Arabian national environmental legislation came into force on 31 October 2002, with its Implementing Rules being published on 30 September 2003. Under the General Environmental Regulation, the Presidency of Meteorology and Environment (the PME), an agency of the Ministry of Defense, was charged with the general supervision of environmental affairs in Saudi Arabia and had the responsibility of granting environmental permits.

In 2016, the Ministry of Agriculture became the Ministry of Environment, Water and Agriculture (MEWA), and was responsible for environmental sustainability. In 2019, the PME's functions and responsibilities were transferred to four centers for environment sector development. These are The National Center for Environmental Compliance, the National Center for Vegetation Cover and Combating Desertification, the National Center for Wildlife (NCW), and the National Center for Meteorology.

In 2020, the Council of Ministers approved the new National Environmental Law replacing the General Environmental Regulation of 2001. The National Center for Environmental Compliance (NCEC) replacing the General Authority of Meteorology and Environmental Protection (GAMEP) was established. The requirement for Environmental Impact Assessment (EIA) in KSA is set out in The Executive Regulations for Environmental Permits issued by Royal Decree No M/165 of 19 Dhul Qa'dah 1441 Hijra (corresponding to 10 July 2020) which entered into force on 13 January 2021. The NCEC has been assigned responsibilities related to reviewing and approving EIA Studies for development projects, granting of permits, and issuing of licenses.

Roles Defined by the Implementing Regulations of Environmental Permits for Construction Activities are:

- **The Permit Applicant (PA)** - All persons who are owners or operators of any activity that has an environmental impact (new or existing) within the territory of the Kingdom, including construction, modification, addition, expansion, and closing; and

- **The Competent Authority (CA)** - The Ministry, or any of the national centers of the environment sector, each according to its powers, and as determined by the regulations.

The NCEC is furthermore concerned with monitoring the environmental compliance of all establishments that have an impact on the environment in all development sectors, supervising programs for monitoring sources of environmental pollution inspecting installations, and implementing waste management regulations. In line with the Implementing Regulations of Environmental Permits for Construction Activities for the Environmental Law issued by Royal Decree No. (M/165) dated 19/11/1441 AH, developments are classified into three categories according to the resulting environmental impacts. A description of these categories is provided in Table 2.1.

Table 2.1. Classification of development activities by NCEC according to the resulting environmental impacts.

Classification of Activities	Description of Category	Permitting Process
Category I	Activities that are expected to have minimal impacts on the environment that do not exceed the boundaries of the activity site.	A Licensed Service Provider is to prepare an Environmental Management Plan and Environmental Rehabilitation Plan which are to be submitted, together with a fee, to the Competent Authority (CA). On approval of these plans, the CA will issue an Environmental Permit.
Category II	The activities that are expected to have moderate impacts on the environment during the different stages of the activity. These impacts can be reduced and controlled while they do not significantly exceed the limits of the activity site.	A Licensed Service Provider is to undertake a Category II Activity Environmental Permit Process. An EIA is to be undertaken and an EIA Report is to be prepared in accordance with the content requirements stipulated in Annex 2 of the bylaw.
Category III	Activities that are expected to have significant environmental, social, and economic impacts, and these impacts may exceed the boundaries of the activity site and may negatively affect the sustainability of environmentally sensitive areas and receptors.	A Licensed Service Provider is to undertake a Category III Activity Environmental Permit Process. An EIA is to be undertaken and an EIA Report is to be prepared in accordance with the content requirements stipulated in Annex 4 of the bylaw.

The NCEC has been assigned responsibilities related to reviewing and approving EIA Studies for development projects, the granting of permits, and the issuing of licenses. The new environmental permitting process of NCEC is summarized in Table 2.2.

Table 2.2. Procedural steps and the description of the new environmental permitting process of NCEC.

Procedural Steps	Description of Permitting Process
1.	• Submit an online Environmental Classification Form on the NCEC Portal by an approved agency.
2.	• The NCEC may visit the Project site during the review of the Environmental Classification Form. • The NCEC will review the form and provide their comments within a period of ten (10) working days which can be extended for another ten (10) working days if the activity has not been previously classified.
3.	• Prepare a Scoping Report (Annex 3 of implementing regulations) for EIA and submit it to the NCEC. • The NCEC reviews the Scoping Report for EIA once submitted and provides comments within a period of fifteen (15) working days.
4.	• The NCEC may visit the project site to confirm the data contained in the Scoping Report.
5.	• The NCEC either approves the Scoping Report, or requests further information related to the Scoping Report.
6.	• Once the Scoping Study is approved, a comprehensive EIA Report (Annex 4 of implementing regulations) shall be submitted for the approval of the NCEC, per the comments received during the Scoping Phase. NCEC may request a presentation.
7.	• If the EIA study is approved, an Environmental Permit to Construct (EPC) will be issued for the project. • For Category 3 Projects, the timeframe for the approval of the EIA Study by the competent authority is 60 working days from the date of receipt of the EIA Study.

2.2 REGULATORY FRAMEWORK

2.2.1 National Rules, Regulations, Standards, and Requirements

The project site lies within the jurisdiction of NCEC; therefore, NCEC regulations must be applied to this project. The NCEC General Environmental Protection Standards for New Facilities (Standard 7) are outlined as follows:

- i. All new major facilities as well as major modifications to the existing facilities shall be designed, operated, and maintained to avoid exceedances of the ambient environmental standards as promulgated for the Kingdom at the time of approval of the design.
- ii. Each new major facility or major modification of an existing facility shall incorporate the best available technology for the control of pollutant discharges of the facility.
- iii. All new facilities and modifications of an existing facility shall be designed and operated to avoid the discharge of any toxic substance, whether specifically regulated or not, in sufficient quantities to be harmful to public health.

In 2012, GAMEP (now NCEC) developed several guidance standards revising the current General Standards for the Environment (specifically document number 1409-01) issued by the GAMEP (now NCEC) in Annex 1 to the General Environmental Law and Rules for Implementation. These standards came into effect on March 24, 2012, and were updated in 2014 for implementation starting from 2019. These include *Ambient Water Quality Standards, Water Quality and Discharge Standards, Hazardous Material Management and Transport Criteria Standards, Waste Management Standards, Environmental Noise Standards*, etc.

2.2.2 International Regulation, Guidelines, and Policies

I. International and Regional Conventions and Protocols

Kingdom of Saudi Arabia (KSA) has ratified or is a signatory to a number of international agreements and conventions presented in Table 2.3 below, which must be adhered to during the development of the project. Not all may be applicable to the Project at present but have been included herein to provide a comprehensive list in the event that they may become applicable as the Project progresses.

Table 2.3. List of Saudi Arabia's ratified International Agreements and Conventions (terrestrial environment).

INTERNATIONAL AGREEMENTS AND CONVENTIONS	Year	Year in which ratified, acceded or signed
Agreement for the Establishment of a Commission for Controlling the Desert Locust in the Near East (as amended), Rome.	1967	1972
Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention).	1979	1991
Vienna Convention for the protection of the Ozone Layer, Vienna	1985	1993
Montreal Protocol on substances that deplete the ozone layer and its Amendments.	1987	1993
Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal	1989	1990
Cairo Declaration on Human Rights in Islam.	1990	1990
The Arab Declaration on Environment and Development. Adopted by the Arab Ministerial Conference on Environment and Development in Cairo, A/46/632, cited in U.N. Doc. E/CN.4/Sub.2/1992/7, 20. Adopted 1992	1991	1992
Agenda 21 and the Rio Declaration on Environment and Development.	1992	1992
Protocol to the International Convention on Civil Liability for Oil Pollution Damage.	1992	2006
UN Framework Convention on Climatic Change (UNFCCC) New York.	1992	1994
Convention on Biological Diversity, Rio de Janeiro.	1992	2001
United Nations Convention to Combat Desertification.	1994	1994
Cartagena Protocol on Biosafety to the Convention on Biological Diversity, Montreal.	2000	2007
United Nations Convention against Transnational Organized Crime, supplemented by three Protocols; Protocol against Trafficking in Persons, Especially Woman and Children; Protocol against Smuggling of Migrants and Protocol against Illicit Manufacturing of and Trafficking in Firearms, New York.	2000	2005
Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).	2001	1996

INTERNATIONAL AGREEMENTS AND CONVENTIONS	Year	Year in which ratified, acceded or signed
United Nations Convention against Corruption, New York.	2003	2013
Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade.	2000	2004
Kyoto Protocol to the UN Framework Convention on Climate Change	2005	2005
Convention on the Right of Persons with Disabilities, New York.	2006	2008
International Solar Alliance	2015	2019

II. Good International Industry Practice (GIIP) Standards and Guidelines

The proponent of a project should demonstrate how it will conform to relevant environmental standards and international industry best practices. In the event that no national standards are available, the Project will comply with internationally recognized standards relevant to the nature of the project. The Saudi Power Procurement Company (SPPC) aims to follow recognized international standards in terms of environmental and social management, as a guarantee to comply with any national legislation requirement relevant to the Project and as a matter of quality and reputation. Furthermore, SPPC has adopted the International Finance Corporation (IFC) requirements, amongst others, as the guiding principles for assessing potential impacts of the Project.

As the wider project is developed, international investors may look to invest. Financial investors and lenders may be members of the Equator Principles (EP) group of financial institutions. As such, it is good practice to consider the IFC requirements for assessing potential impacts of this Project.

The ESIA will be prepared in line with the following international guidance:

- International Best Practice Standards and guidelines, including the IFC Performance Standards on Environmental and Social Sustainability. This includes guidance published by the World Bank Group, World Health Organization (WHO) and the International Union for the Conservation of Nature (IUCN);
- Good International Industry Practices (GIIPs); and
- Relevant international agreements and conventions to which KSA is a signatory.

III. International Finance Corporation Performance Standards

The IFC Performance Standards (PS) are directed towards this project, providing guidance on how to identify risks and impacts, and are designed to help avoid, mitigate, and manage risks and impacts as a way of doing business in a sustainable way, including stakeholder engagement and disclosure obligations for the Project.

IFC uses a process of environmental and social categorization to reflect the magnitude of risks and impacts. These categories that may be applicable are:

- *Category A:* Project activities with potential significant adverse

environmental or social risks and/or impacts that are diverse, irreversible, or unprecedented;

- *Category B:* Project activities with potential limited adverse environmental or social risks and/or impacts that are few in number, generally site-specific, largely reversible, and readily addressed through mitigation measures; and
- *Category C:* Project activities with minimal or no adverse environmental or social risks and/or impacts.

IFC has established eight performance standards; their applicability to the Project is presented in Table 2.4.

Table 2.4. International Finance Corporation's Performance Standards

IFC	STANDARD	OVERVIEW
PS 1	Assessment and Management of Environmental and Social Risks and Impacts	Establishes requirements for social and environmental performance management throughout the life of a project.
PS 2	Labour and Working Conditions	Highlights the need for workers' rights regarding income generation, employment creation, relationship management, commitment to staff, retention and staff benefits.
PS 3	Resource Efficiency and Pollution Prevention	Defines an approach to pollution prevention and abatement in line with current internationally disseminated technologies and good practice.
PS 4	Community Health, Safety and Security	Specific requirements for mitigating any potential for community exposure to risks and impacts arising from equipment accidents, structural failures and releases of hazardous materials.
PS 5	Land Acquisition and Involuntary Resettlement	Recognizes that project related land acquisition and restrictions could have adverse impact on communities or persons that use the land and outlines a policy to avoid or minimize involuntary physical resettlement as a consequence of development.
PS 6	Biodiversity Conservation and Sustainable Management of Living Natural Resources	Sets out an approach to protect and conserve biodiversity, including habitats, species and communities, ecosystem diversity, and genes and genomes, all of which have potential social, economic, cultural and scientific importance.
PS 7	Indigenous Peoples	Recognizes that Indigenous Peoples can be marginalized and vulnerable (e.g. if their lands and resources are encroached upon by or significantly degraded by a project).
PS 8	Cultural Heritage	Aims to protect irreplaceable cultural heritage and to provide guidance for protecting cultural heritage throughout a project's life cycle.

IV. World Bank Environmental, Health and Safety Guidelines

The ESIA will be guided by the Environmental Health and Safety (EHS) guidelines developed by the World Bank Group and the IFC. The applicable guidelines to be considered include:

- EHS General Guidelines (2007)⁷, including but not limited to:
 - Air Emissions and Ambient Air Quality;
 - Energy Conservation;
 - Wastewater and Ambient Water Quality;
 - Waste Management;
 - Hazardous Materials Management;

- Occupational Health and Safety;
- Water and Sanitation; and
- Community Health and Safety.
- Good Practice Handbook for Cumulative Impact Assessment and Management: Guidance for the Private Sector in Emerging Markets (2013).

V. International Union for the Conservation of Nature (IUCN)

The IUCN Red List of Threatened Species, one of the most well-known objective assessment systems for classifying the status of plants, animals, and other organisms threatened with extinction. It contains explicit criteria and categories to classify the conservation status of individual species based on their probability of extinction. The IUCN Red List (2017)⁹ for KSA is used for the descriptions of flora and fauna within the study area

Like international agreements and conventions, the Kingdom of Saudi Arabia has ratified, acceded to, or is a party to several international agreements and conventions at a regional level. The Kingdom is a signatory to the *Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution*, 1978. The *Regional Organization for the Protection of the Marine Environment* (ROPME), which was established by the Convention in 1978, establishes three protocols for protecting the marine environment. These are as follows:

- 1989, ROPME Protocol Concerning Marine Pollution Resulting from Exploration and Exploitation of the Continental Shelf;
- 1990, ROPME Protocol for the Protection of the Marine Environment Against Pollution from Land-Based Sources;
- 1978, ROPME Protocol Concerning Regional Co-operation in Combating Pollution by Oil and Other Harmful Substances in Cases of Emergency.

The list of Saudi Arabia's ratified International Agreements and Conventions related to the terrestrial environment is given in Table 2.3.

Table 2.3. List of Saudi Arabia's ratified International Agreements and Conventions (terrestrial environment).

International Agreements and Conventions	Year	Year in which ratified, acceded or signed
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Vienna Convention for the Protection of the Ozone Layer, Vienna	1985	1993
Montreal Protocol on substances that deplete the ozone layer and its Amendments.	1987	1993
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UN Framework Convention on Climatic Change (UNFCCC) New York.	1992	1994
Convention on Biological Diversity, Rio de Janeiro.	1992	2001
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Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).	2001	1996
United Nations Convention against Corruption, New York.	2003	2013
Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade.	2000	2004
Kyoto Protocol to the UN Framework Convention on Climate Change	2005	2005
Convention on the Rights of Persons with Disabilities, New York.	2006	2008
International Solar Alliance	2015	2019

2.2.3 International Agreements and Treaties

Membership in the International Solar Alliance

Saudi Arabia is one of the 73 countries who signed the framework agreement of the International Solar Alliance (ISA) which was jointly launched by India and France in 2015. The International Solar Alliance (ISA) is an action-oriented, member-driven, collaborative platform for increased deployment of solar energy technologies as a means for bringing energy access, ensuring energy security, and driving energy transition in its member countries. The ISA strives to develop and deploy cost-effective and transformational energy solutions powered by the sun to help member countries develop low-carbon growth trajectories, with a particular focus on delivering impact in countries categorized as Least Developed Countries (LDCs) and the Small Island Developing States (SIDS). Being a global platform, ISA's partnerships with multilateral development banks (MDBs), development financial institutions (DFIs), private and public sector organizations, civil society, and other international institutions are key to delivering the change it seeks to see in the world going ahead.

Partnership Framework for Advancing Clean Energy

Signed by the Saudi Ministry of Energy and the US Department of Energy, this framework agreement involves substantial investments in clean energy transition, addressing climate change, development of renewable energy, and clean hydrogen.

SECTION 3 PROJECT DESCRIPTION

3.1 DETERMINING THE OBJECTIVES AND JUSTIFICATIONS OF THE ACTIVITIES

The National Renewable Energy Program (NREP), a crucial initiative aligned with Saudi Arabia's Vision 2030 and the National Transformation Program, seeks to substantially enhance the proportion of renewable energy capacity within the country's overall energy portfolio. This strategic program outlines a systematic roadmap aimed at swiftly diversifying the domestic power supply, spurring economic development, and fostering long-term prosperity, consistent with the goals outlined in Vision 2030. The overarching objective is to establish a thriving renewable energy industry and actively contribute to the growth of this promising sector. One of the key players in this transformative journey is the Principal Buyer, represented by the Saudi Power Procurement Company (SPPC), which has been granted the license to facilitate significant transitions and major changes in the energy sector. Functioning as a "Transformation Agent," the Principal Buyer plays a central role in steering the market toward renewable energy adoption. The governance structure of the Principal Buyer is a critical enabler, empowering key government bodies responsible for market transformation to guide the SPPC effectively. This involves integrating the perspectives of relevant stakeholders engaged in energy research, measurement, data acquisition, regulation, and pre-development. Operating under the Ministry of Energy, the Principal Buyer is actively involved in the development of the Al Humaij Solar PV project as part of the broader NREP. This initiative underscores the commitment to realizing Vision 2030's objectives by strategically harnessing renewable energy sources, contributing to sustainable economic growth, and positioning Saudi Arabia as a leader in the global renewable energy landscape. A site master plan is currently being developed for the site of Al Humaij, where the Saudi Power Procurement Company (SPPC) is interested in procuring solar PV power. The objective of this report is to develop a master plan under "Work Package 2" and a way forward on technology selection with respect to the successful long-term deployment of a state-of-the-art solar PV project. It is important to note here that no detailed electrical or civil land-related studies have been carried out yet and the results presented in this work may change once the results from these studies are obtained.

In 2021, approximately 61% of Saudi Arabia's energy consumed was produced by burning oil, and therefore, the Saudi agency in charge of developing the nation's renewable energy sector, Ka-care, announced in May 2012 that the nation would install 41 gigawatts (GW) of solar capacity by 2032. The program sets out an organized and specific road map to diversify local energy sources, stimulate economic development, and provide sustainable economic stability to the Kingdom in light of the goals set for Vision 2030, which include establishing the renewable energy industry and supporting the advancement of this promising sector while working to fulfill the Kingdom's commitments to reducing carbon dioxide emissions. It was proposed to develop 25 GW of solar thermal and 16 GW of photovoltaics. At the time of this announcement, Saudi Arabia had only 0.003 gigawatts of installed solar energy capacity, and a total of 54 GW was expected by 2032.

Despite its abundant resources, Saudi Arabia has limited operational plants producing electricity from renewable energy. The proposed project to construct and

operate solar energy park in the Al Humaij in Saudi Arabia will help decrease the country's dependency on traditional forms of energy by increasing the availability and use of solar energy. The generated electricity will be injected into the national grid to support the country in meeting its renewable energy targets.

3.2 PROPOSED LOCATION OF THE PROJECT SITE

Al Humaij, located near Medina in Saudi Arabia, is situated in a region that is confronted with significant environmental challenges. The location is characterized by its arid climate during the day, with high temperatures and low rainfall. The project design should consider these weather attributes (Figure 3.1).

Saudi Arabia experiences temperatures higher than the global average, and climate change is expected to intensify this trend. The country predominantly has a hyper-arid climate, with summer temperatures often surpassing 40°C in its central regions. According to the Köppen climate classification, Saudi Arabia is categorized as having a "hot desert climate." According to the ERA5 data, the Al Humaij region, in particular, experiences summer (June to August) temperatures ranging from 32°C to 37°C and winter (December to February) temperatures between 12°C and 20°C. During the spring season (March to May), the temperature ranges from 19°C to 33°C and during Autumn (September to November), the temperature ranges from 18°C to 35°C. Additionally, the mean annual temperature has consistently risen, showing an increase of 0.7 to 1.5 degrees Celsius over the years. As solar PV power generation happens during the day, the project equipment sizing and design should be based on 45 to 50°C ambient temperature. The location generally experiences its only low rainfall in either November-December or March-April (Figure 3.2). Meteorological data from the past 2 decades indicate that the annual precipitation has generally been very low and variable, ranging from 0.001 to 45 mm per year according to the GPCP data. Even though it is less, some uneven rain occurred during the years 2016, 2019, and 2023 which created flash floods in some of the regions as per the GPCP data (Figure 3.3).

Access to clean potable water will be a challenge at the project site, ground water aquifers are generally hundreds of meters deep and have saline or brackish water with actual depth and TDS to be based on geotechnical & hydrological studies. The Ministry of Environment, Water, and Agriculture (MEWA) oversees the management of water resources in Saudi Arabia, including groundwater. They set policies and regulations to ensure the sustainable use and conservation of groundwater. Anyone intending to use groundwater for agricultural, industrial, or domestic purposes must obtain a permit from the relevant authorities. These permits typically specify the amount of water that can be extracted and the conditions for its use. Considering the obtained TDS levels of the groundwater through the hydrological study, it may require some treatment before it can be used for PV module cleaning. The design focus should be to emphasize low water use during construction. Sandstorms can occur at the project site. Design should consider the impact of sandstorms on equipment. Appropriate seismic zone to be considered as per project site location and design to factor in requirements as per Saudi Building Code (SBC). Since this is a green field project, an environmental study is to be carried out at the site to minimize the impact on soil, flora, fauna, and water bodies (if any are present, as of now none are present). The design should consider the environmental factors identified in the study to minimize construction impact at the site. Design of the project to incorporate native vegetation/xeriscaping at the site where possible.

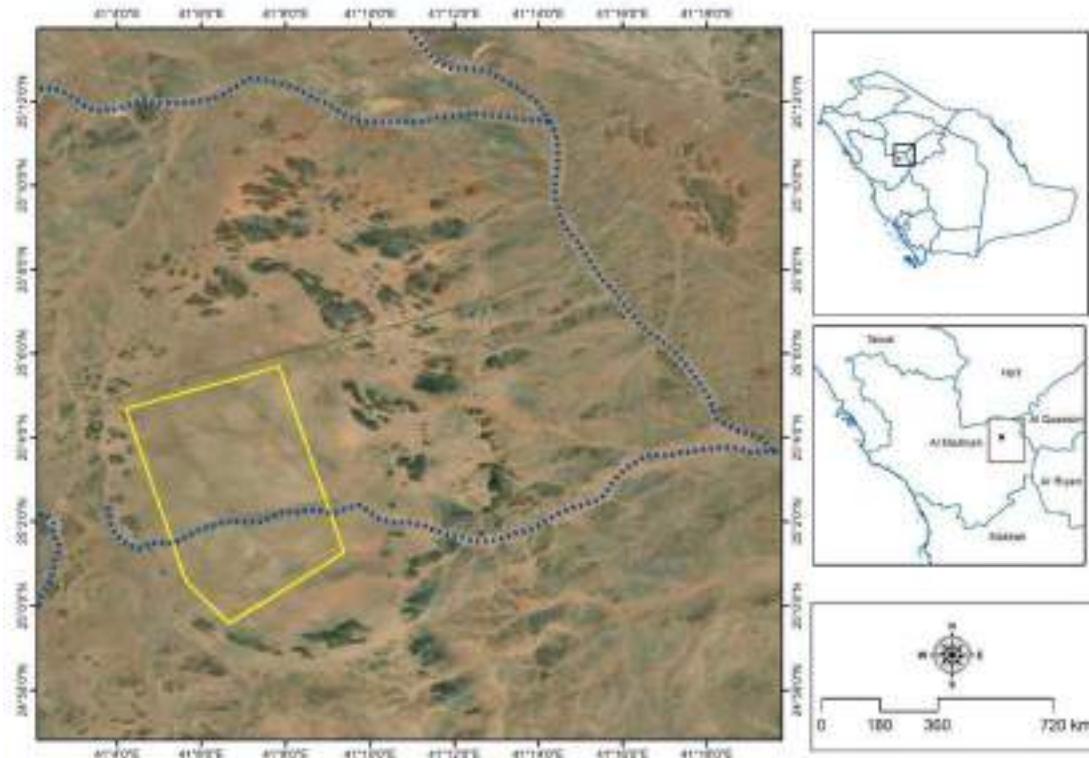


Figure 3.1. Location Map of the project site.

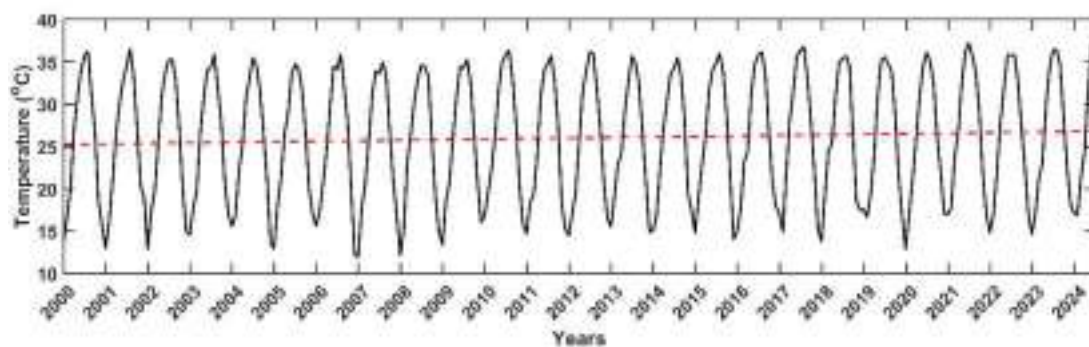


Figure 3.2. Monthly temperature from 2000 to 2024 near Al Humaij region. The trendline is shown in red color line (Air temperature data is sourced from ERA 5)

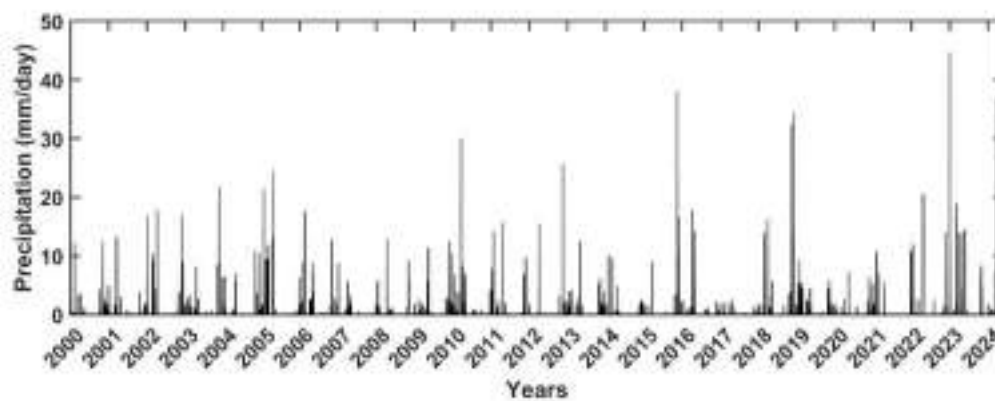


Figure 3.3. Daily Precipitation from 2000 to 2024 near the Al Humaij region (Precipitation data is sourced from GPCP)

3.3 ELEMENTS OF THE PROJECT WITH POTENTIAL IMPACT ON THE ENVIRONMENT

Details are provided in Section 5.

3.3.1 *Technical Details*

Al Humaij Solar PV project is a 3,000 MW (AC) project for an estimated cost of 5.7 Billion Riyals, that will be feeding energy at 380 KV NG SEC substation, which will be built solely for this project and will be located inside the project boundary. As per the current proposed schematic design, the (AC) capacity integrated for each block is 3125 KVA. Bidder may optimize for optimal LCOE based on different manufacturers available in the market. The basis of the design is to consider all local requirements laid down by the SEC in their official publications on minimum requirements. Any deviations are to be specifically listed with technical justification. Grid-side electrical studies are to be carried out together with SEC to finalize the short circuit level against which the plant will be designed. As per SDMS 25KA (1 sec) is to be complied with at 33KV voltage. The main access roads of the project will connect with Route 60 (Madina – Bouraidah Hwy). There will be four access gates, each separated by 1.5 Km approximately that can be used to enter the project site. The main substation and BESS terminal can be accessed via Gate 1 being the closest one. The basis of design for the internal roads within the project will be based on “General Specification for Road and Bridge Construction” updated in November 1998, developed by the Ministry of Transport. All internal & connecting roads within the project site to consider best practices listed in AASHTO standards on the design of highways and roads.

3.3.2 *Construction Scope*

The construction of the proposed solar PV plant involves several key activities. Firstly, an access road needs to be constructed or existing roads improved to enable the transportation of equipment, materials, and personnel to the site. This includes grading, leveling, and compacting the road surface, as well as installing drainage systems and erosion control measures.

Civil construction activities encompass site preparation, such as clearing and grading the land to create a level surface for the solar array installation. Excavation and foundation work could be necessary for installing solar panel mounting structures, inverters, transformers, and other electrical equipment. Buildings are constructed to house control rooms, storage facilities, and maintenance areas, while security fencing is installed around the perimeter to prevent unauthorized access and protect the equipment.

During the construction phase, it is expected that there will be increased heavy vehicle traffic, including trucks transporting solar PV panels, mounting structures, and other equipment to the site.

3.3.3 *Manpower and Duration*

For a utility-scale photovoltaic (PV) project spanning approximately around 30+ months, the manpower requirement is estimated at 3,000 workers. This workforce will

be pivotal in ensuring the timely and efficient execution of various project phases, including site preparation, panel installation, and system integration. The team will consist of skilled professionals, including engineers, electricians, construction workers, and project managers, each essential for addressing the complex demands of the project. The construction schedule will be meticulously planned to optimize labor allocation, ensuring that all activities, from ground clearing and foundation work to module assembly and electrical wiring, are completed on time and to the highest standards. Effective coordination and management of this substantial workforce will be crucial in meeting project milestones and achieving operational readiness for the PV system.

3.4 ACTIVITIES DURING THE ACTIVITY PHASES

The construction of the proposed solar PV plant involves several key activities. Firstly, an access road needs to be constructed or existing roads improved to enable the transportation of equipment, materials, and personnel to the site. This includes grading, leveling, and compacting the road surface, as well as installing drainage systems and erosion control measures.

Civil construction activities encompass site preparation, such as clearing and grading the land to create a level surface for the solar array installation. Excavation and foundation work could be necessary for installing solar panel mounting structures, inverters, transformers, and other electrical equipment. Buildings are constructed to house control rooms, storage facilities, and maintenance areas, while security fencing is installed around the perimeter to prevent unauthorized access and protect the equipment.

During the construction phase, it is expected that there will be increased heavy vehicle traffic, including trucks transporting solar PV panels, mounting structures, and other equipment to the site.

The amount of land required for a solar farm depends on several factors, including panel efficiency, the type of mounting system (fixed-tilt or tracking), spacing between rows to minimize shading and improve airflow, terrain and site characteristics such as topography and environmental constraints, and additional infrastructure like access roads, electrical equipment, and buffer zones. Higher efficiency panels and optimized system design can help reduce the land area needed, while challenging terrain or additional infrastructure requirements may increase the land footprint.

3.5 GEOGRAPHICAL DOMAIN OF THE PROJECT

The Al Humaij Site is close to the village of Al Humaij which is 191 Km distance from the city of Madina through Route 60. The potential project site land has been identified and is just east of the village of Al Humaij.

3.6 THE AREA REQUIRED FOR THE PROJECT

The plan of the panel meticulously maps out (Figures 3.2, and 3.3) the placement of solar PV modules and inverters, the network of internal roads, and cable trenches, a comprehensive vegetation plan featuring native plants, the location of the substation, designated areas for potential Battery Energy Storage Systems (BESS), and provisions for temporary accommodation. Its purpose is to ensure an optimized layout that maximizes energy production efficiency, minimizes environmental impact, and

streamlines construction and maintenance processes. By providing a holistic view of the project's physical components and their interconnections, the Site Master Plan serves as a critical tool for stakeholders to visualize the project's scope, assess its feasibility, and plan for seamless integration into the surrounding environment.

Figures 3.4, and 3.5; show the layout of the panel and infrastructure in the project sites. As per Figure 3.3, Solar panels quantity in one block is 5124. The total block quantity is 945 and the area of one block is 32705 m². Therefore, entire areas of the panel coverage will be the expected panel footprint.

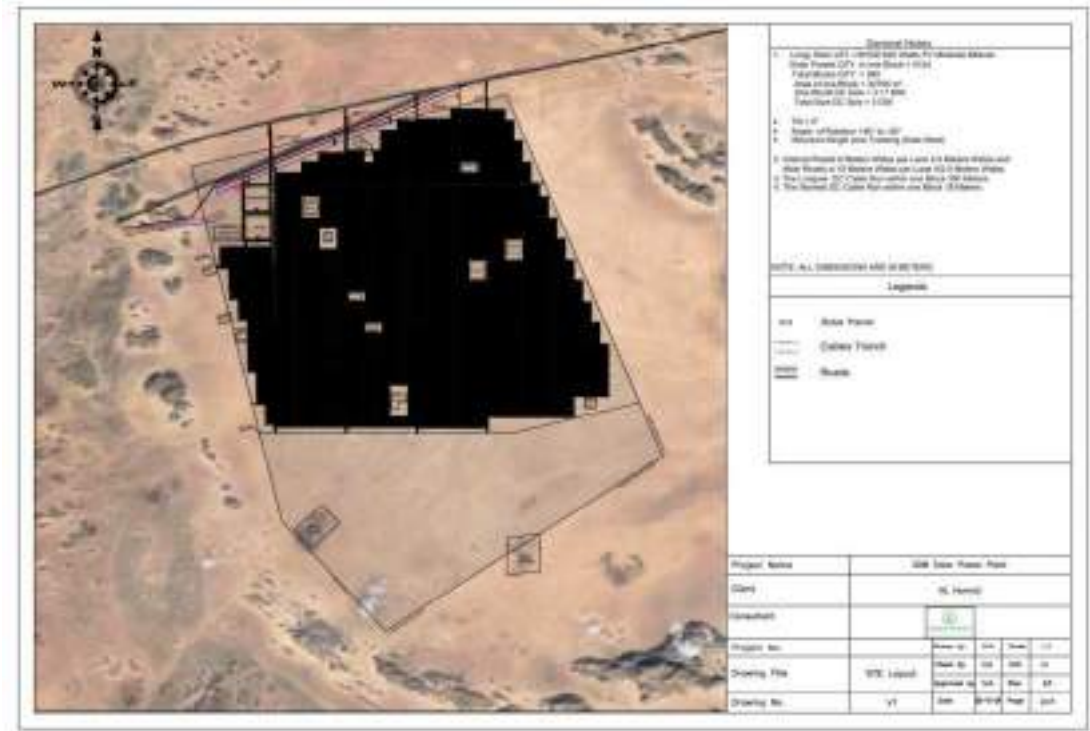


Figure 3.4. Project Site concept and infrastructure layout.

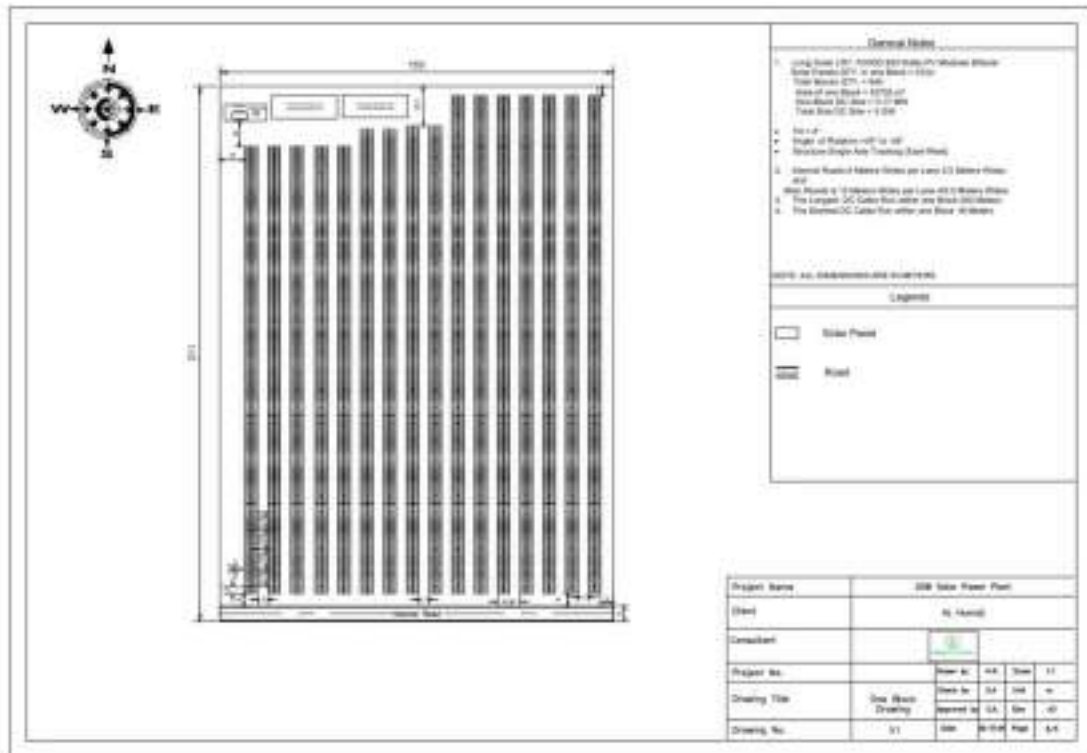


Figure 3.5. Layout idea of one block with an internal road.

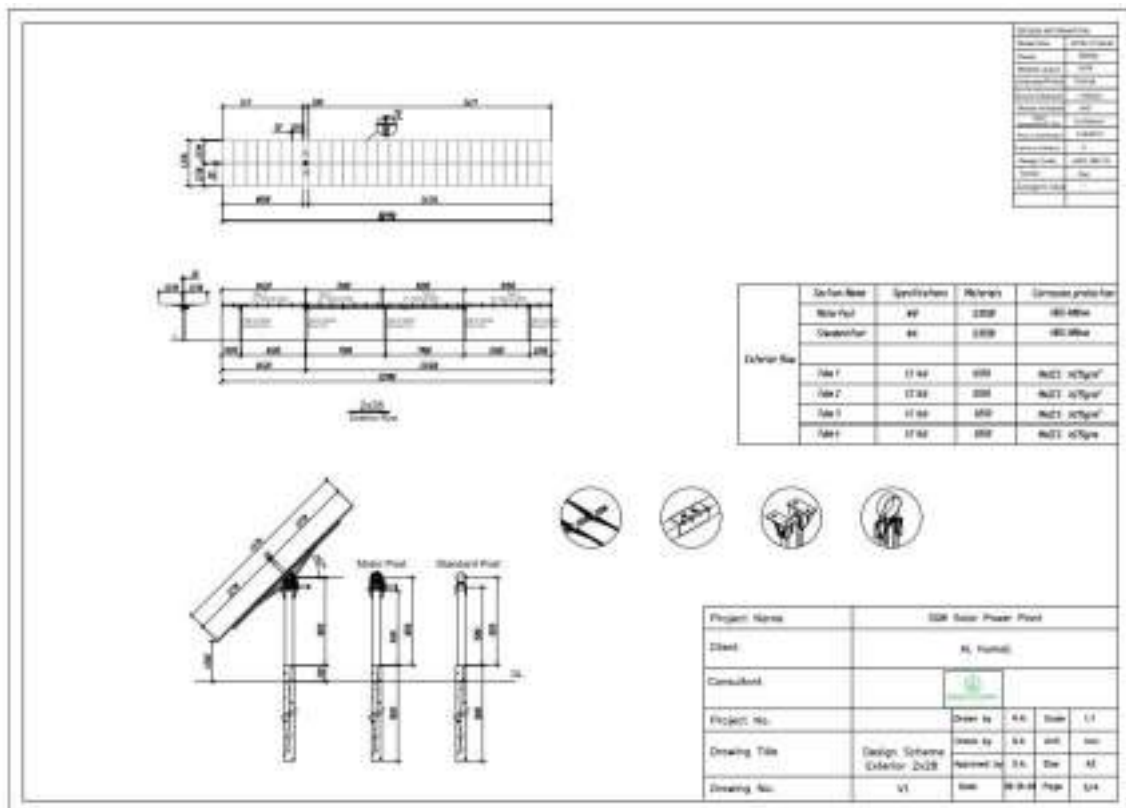


Figure 3.6. Structural Drawing

Concerning Figure 3.4, provided my GRL, the panel inclination is 45°, installed at the height of 2020 mm from the ground level (GL). The length of the panel is 32980 mm. As per the drawing, the basement of the panel structure will be 1000 mm approximately from the ground level.

3.7 ACTIVITY RESOURCES, TYPES AND SOURCES

The main activity resources for solar power projects are natural resources, human resources, and capital resources. Natural resources for solar power projects include substances that are found in nature such as water, sunlight, etc. Human resources include skilled and unskilled workers, and managers, who contribute their knowledge, skills, and effort to operate solar power projects. Man-made resources (capital resources) are man-made resources used in the production process, such as machinery, solar panels, inverters, wiring and connectors, mounting hardware, and battery equipment in the solar power plant. Other activity resources include permits and regulations, safety equipment, and financial resources.

3.8 GASEOUS AND LIQUID EMISSIONS AND WAYS TO REDUCE THEM

- Gas emission: Included in the Air quality impact mitigation section
- Liquid emission: Included in the Waste Management impact mitigation section

3.9 SOLID WASTE (TYPES AND METHODS OF DISPOSAL)

Details are included in the Waste Management Section.

3.10 TIME SCHEDULE OF ACTIVITIES PROGRAM

The utility-scale solar project in Al Humaij, covering 60 square kilometers, is planned for execution over a period of 30 months. The schedule will commence with site preparation and infrastructure development, including land clearing and access road construction, from Q1 to Q2. Following this, the installation of solar panels, inverters, and associated equipment will take place from Q3 to Q6. The final phase will involve commissioning and testing to achieve full operational status by the end of Q7. Throughout the project, regular monitoring and reporting will be conducted to ensure compliance with environmental and safety standards. Ongoing stakeholder engagement will also address any concerns to facilitate smooth progress.

3.11 PROJECT SIZE

The solar project will encompass a substantial area of 60 square kilometers in Al Humaij, underscoring its scale as a major utility-scale initiative. This large area facilitates the installation of a significant number of photovoltaic panels, capitalizing on the region's high solar irradiance to produce substantial amounts of renewable energy. The project's extensive footprint will support the construction of necessary infrastructure, including panel support structures, inverter stations, and access roads, as well as operational facilities. The size of the project is designed to maximize energy output and contribute meaningfully to both regional and national energy grids, in line with sustainability and energy security objectives.

SECTION 4 AMBIENT ENVIRONMENT DESCRIPTION

4.1 GEOLOGY AND GEOMORPHOLOGY

4.1.1 Introduction

The Arabian Peninsula has a complex tectonic setting. It is bordered to the south by the rift zones in the Red Sea and to the west by the Gulf of Aqaba Rift Transform Fault. To the north and east, the Arabian Peninsula is tectonically bounded by the subduction zone in southern Iran and the transform fault in the Arabian Sea. The rifting in the Red Sea leads to the tilting of the Arabian Peninsula. Two main geological units can be distinguished on the Arabian Peninsula [Barth and Schliephake 1998; Thompson 2000; Grainger 2007]. These are the Arabian Shield and the Arabian Platform (Figure 4.1). The geologically oldest unit is the Arabian Shield in the west of the Arabian Peninsula. More recent is the Arabian Platform, which occupies the center and east of the Arabian Peninsula.

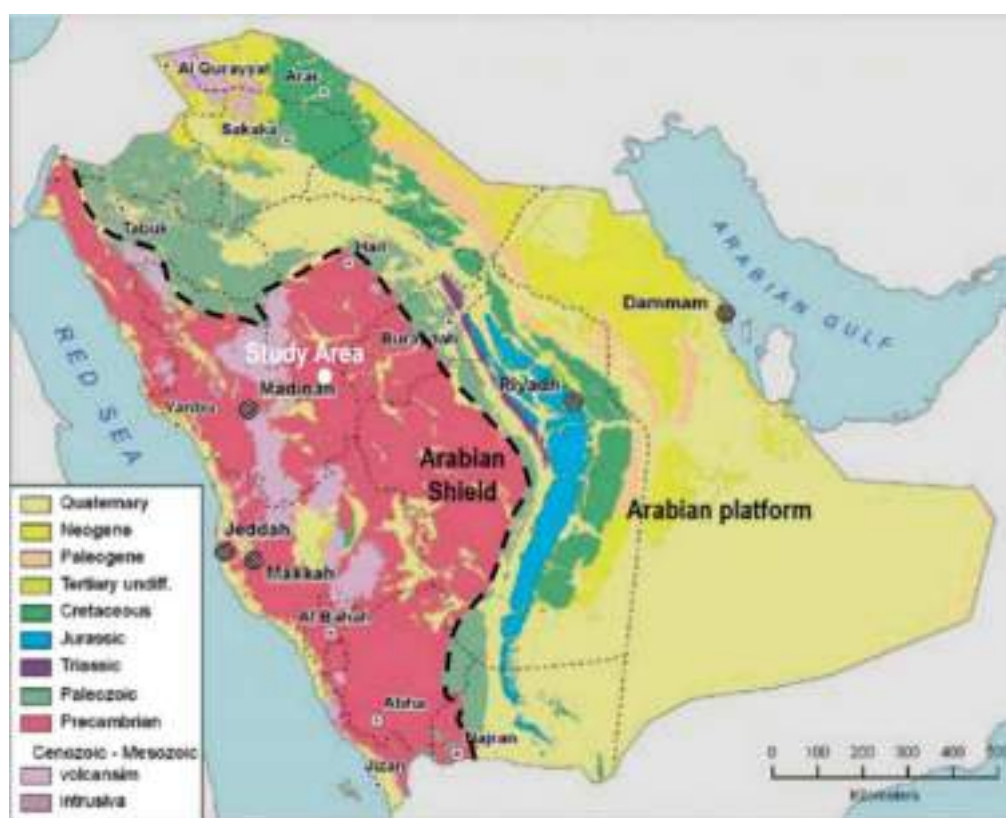


Figure 4.1. The generalized geological map of Saudi Arabia shows the main units of the Arabian Peninsula; Arabian Shield and Arabian Platform. The white dot refers to the Al Humaij site (modified after Al Ajami et al., 2014).

The Arabian Shield occupies the west-central one-third of the KSA and is part of the larger Afro-Arabian Shield [Al-Sayari, 1978]. It is the geologic base of the central Najd, Hejaz, and Asir regions and extends from 50 to 700 km inland from the Red Sea toward Riyadh. This ancient landmass consists of igneous and metamorphic rocks of the Precambrian Era (the oldest of them about 1170 million years old (Figure 4.1). Basalts of mid-Tertiary and Quaternary Periods, 26 million years old or younger, are

spread over western parts of the Shield and form the Harriet [Moufti and Nemeth, 2016]. The main faults on the Arabian Shield strike in a northwest-southeast direction (Figure 4.2).



Figure 4.2. Detailed geological map of the studied site and its neighboring areas (white rectangular) [Modified after Delfour, 1977].

The Phanerozoic sediments of the Arabian Platform dip at $\sim 1^\circ$ to the NE. The constant dip is interrupted on the Arabian Platform by north-south-trending anticlines and synclines, as well as salt diapirs in the Persian Gulf area. Sedimentary rocks of the Paleozoic Era, between 570 million and 225 million years old, and modern alluvium partly overlie the Shield itself.

Along the Red Sea coast, under the Tihamat al Hijaz, lies a great thickness of Tertiary clastic and evaporitic sedimentary rocks [Ramsay, 1986]. These huge sediments are barely exposed and are generally covered by a thin veneer of Quaternary alluvium and aeolian sand and gravel sheets.

Different morphogenic factors contribute to the existing landform shape, such as geology, and environmental factors like wind and waves, which in turn are determined by climate, and weathering processes causing the breakdown of rock outcrops [Bird, 2000]. Many of the reliefs and the geomorphic terrains that have formed on the Red Sea's coastal plain can be attributed to tectonic movements that occurred during the late Quaternary. Also, the manner in which littoral sediments are distributed and transported is affected by the geomorphology, lithology, and tectonics of the coast [Gheith et al., 2005]. Both the arid climate of the region and the erosional processes of the coastline have affected the evolution of the alluvial plain, thereby contributing to the current

scene and geomorphology.

Coastal processes include the after-effects of tidal rise and fall as well as related tidal currents [Bird, 2000]. Sea temperature and salinity are among the oceanographic factors affecting those processes and they are in turn dependent on climate and ocean current patterns. Furthermore,

Several researchers have published seminal studies on the southern Red Sea coast, including Alharbi et al. (2016) and Al-Washmi et al. (2005). Some of the most salient studies were carried out by Gheith and Abou Ouf (1996) and Nabhan (2004), providing data on the geomorphological features, characteristics, and distributions along the eastern Red Sea coast.

4.1.2 Methodology

Al Humaij site is located 200km to the east of Madina on the main asphaltic road between Madinah and Buraydah (Figure 4.1). Al Humaij site has been surveyed to investigate the baseline condition through six stations as shown in Table 1.

Table 4.1. The coordinates of the surveyed station in the Al Humaij site.

Stations	Coordinates	
	Latitude	Longitude
B1	25.064733 N	41.129867 E
B2	25.055229 N	41.081387 E
B3	25.031970 N	41.104648 E
B4	25.035848 N	41.146035 E

4.1.3 Solid Waste Baseline Conditions

Humaij is maintaining the overall baseline conditions; however, some anthropogenic features were recorded during the survey. Although they are unrelated to the ongoing project, they have minimal environmental impact. In some areas, some isolated piled-up debris from the old construction (Figure A). Some isolated patches of the tiers and other plastic material in very small quantities have been recorded (Figure B).



Figure A. A view of the piled-up debris



Figure B. Some isolated patches of tiers.

4.1.4 Results

The area is composed mainly of sandflat with about 25 cm thick of unconsolidated gravely sand on the surface (Figure 4.3).



Figure 4.3. A flat plain of unconsolidated sands spread over the studied site, Al-Humaij, Madina.

The underlying bedrocks are exposed as isolated patches of the Middle Proterozoic Quartz diorite where the feldspars constituent is sericitized, slightly calcareous, chloritised biotite, and syntectonic origin [Brown et al., 1989]. These granitoids rocks are highly weathered and eroded to form the wadi's filling materials (gravel, sand, and silt) is mainly granite which occurs as isolated patches within the sandflat (Figure 4.4) and on the southern side of the site it forms domal structure (Figure 4.5). Human activities are essentially grazing with associated simple camps (Figure 4.6).



Figure 4.4. Isolated granite patched of the bedrock, Al-Humaij, Madina.



Figure 4.5. Domal structure of the highly weathered granite rocks, Al-Humaij, Madina.



Figure 4.6. Grazing camp, Al-Humaij, Madina.

Human activities are very limited, although the site is close to the main road between Hail and Madinah. However, the main evidence of human activity in and around the investigated site is; construction camping, and grazing (Figure 4.7).



Figure 4.7. Isolated vegetation patches and traces of grazing activity.

4.1.5 Conclusion

Along the Red Sea coast, there are great thicknesses of Tertiary clastic and evaporitic sedimentary rocks. These huge sediments are barely exposed and are generally covered by a thin veneer of Quaternary alluvium and aeolian sand and gravel sheets. Different morphogenic factors contribute to the existing landform shape, such as geology, and environmental factors like wind and waves, which in turn are determined by climate, and weathering processes causing the breakdown of rock outcrops.

Al Humaij site is located 200km to the East of Madina on the main asphaltic road between Madinah and Buraydah. The underlying bedrocks are exposed as isolated patches of the Middle Proterozoic Quartz diorite which are highly weathered and eroded to form the wadi's filling materials (gravel, sand, and silt) as sand flat. Human activities are very limited and restricted to construction camping and grazing.

4.2 LIGHT POLLUTION STUDY

4.2.1 Introduction

Artificial light at night (ALAN) poses a significant threat to wildlife, impacting behavior and physiology [Russart & Nelson, 2018; Falcòn et al., 2020]. Artificial light at night (ALAN) poses a significant threat to wildlife, impacting behavior and physiology [Russart & Nelson, 2018; Falcòn et al., 2020]. Studies on various species like marine turtles, seabirds, wallabies, and clownfish have shown detrimental effects of ALAN on critical behaviors and physiological processes [Duffy et al., 2015; Irwin, 2018; Gaston et al., 2017]. It also affects many other nocturnal bats, birds, and invertebrates.

4.2.2 Methodology

4.2.2.1 Study Area

The study area (Figure 4.8a) is located in the eastern part of Madinah province, bordering the Al Qassim province in the east and the Holy city of Madinah Al Munawarah in the west, to the south is the holy city of Makkah Al Mukaramah, and to the north is the Hail Province. It is about 172 km from the holy city of Madinah and around 346 km from the City of Buraidah, and the closest municipality is Al Hunakiyah. The geographical position of the study site is 41.109600 E, 25.069581 N.

The KFUPM research team set up nine SQM-LU-DL light observation posts perpendicular to the ground in each geolocated position, as shown in Figures 4.8 (a) and 4.9. A Unihedron SQM-LU-DL was used to measure the sky brightness along the zenithal direction of the area of interest. The Sky Quality Meter (SQM) device is affordable, lightweight, and portable. It comprises a photometer, visual filter, display, battery, and electronics for night sky measurement. The sky brightness is displayed in visual magnitudes per square arc second (mag/arcsec²) for each measurement, which is recorded and logged every 1 minute for approximately ten days. The use of Unihedron-SQM has been accepted globally for light pollution monitoring and dark sky surveys. For measurements to be taken, the SQM device was fixed to a 3-inch PVC post containing a bubble level so it could point in the zenith direction when fixed 90 degrees perpendicular to the ground. As a result, all measurements were recorded and logged for all nine observation stations at the Al Humaij site.

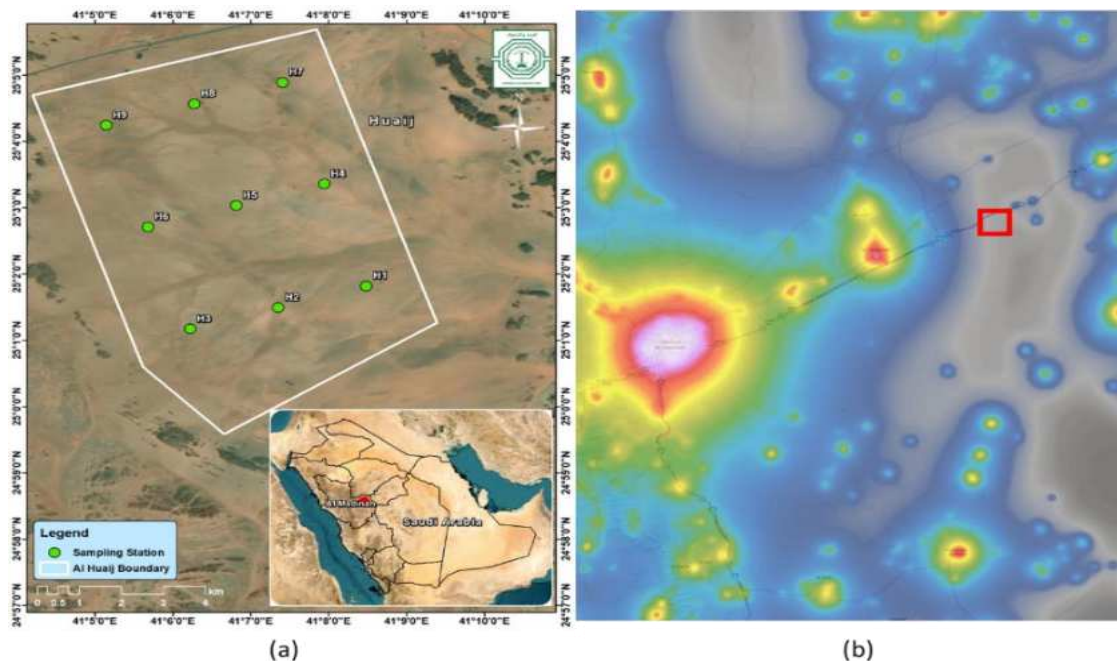


Figure 4.8 (a) Location and functional station and (b) light pollution map of Medina province based on data from the 2016 atlas and visualization by light pollution information website (www.lightpollutionmap.info). The observation area is within the red square.



Figure 4.9 Setting up the SQM-LU-DL equipment to measure night sky brightness in Al Humaij, Madinah, on March 4-12, 2024.

4.2.2.2 Sky Brightness Measurements Using a DSLR Camera

The azimuth of the sky brightness sources can then be determined from these images (Figure 4.10). All the measurements were taken from the site. To locate the source of light pollution that emanates in the observation area, a Sony $\alpha 7v$ DSLR camera was used to take photos, which were taken centered on the four cardinal points and zenithal direction. Additionally, hemispherical photographs were taken using an Insta360 RS-one camera.

The equipment used was:

- Sony $\alpha 7v$ camera
- Sony 24 mm lens
- Insta360 RS-one camera
- Benro TMA28A series 2 mach3 Mg-Aluminum tripod

This combination provided a field of view (FOV) of approximately 84 and 360 degrees that allowed for easy assessment of sky brightness in different directions. All five photographs were taken using the same camera settings, as shown in Table 4.2

Table 4.2. Camera settings for measurement of sky brightness.

Camera Setting	Value
Aperture	f/2.8
Shutter speed	30s
ISO	800

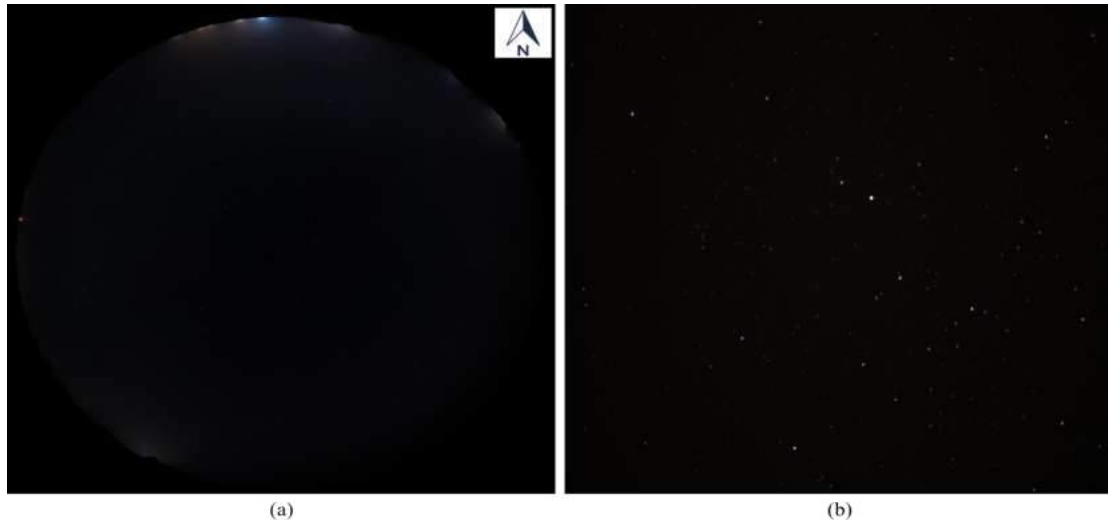


Figure 4.10. (a) Hemispherical and (b) zenithal photograph was taken on the night of March 15, 2024, at Al Humaij.

4.2.3 *Results*

The largest city closest to the area of interest is the Holy City of Madinah. With a population of 995,619, Madinah City plays a pivotal role as an important commercial hub and the provincial capital, making it a crucial destination for any businesses operating in the region. Figure 4.8 (b) shows that the illumination of the neighboring business districts, roadways, highways, and Al Hunakiyah centers mainly influenced the surrounding light environment of the study area. Streetlights from the city center, nearby commercial districts, and street road lights mainly affected the observation area's lighting conditions.

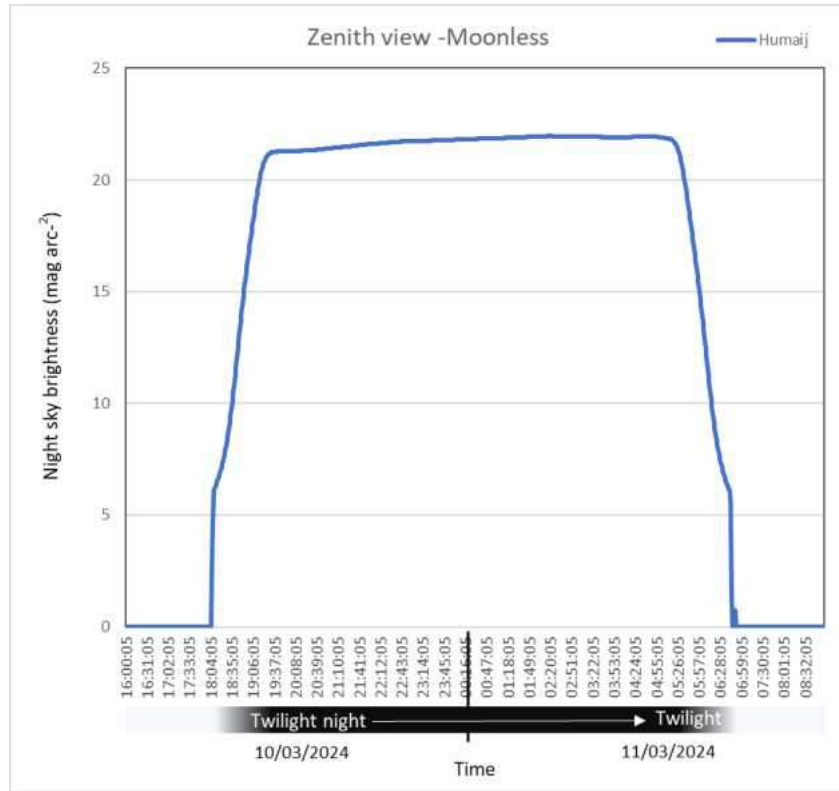


Figure 4.11 Night sky brightness measured using the Sky Quality Meter (SQM-LUDL) instrument was directed along zenithal directions at Al Humaij, Madinah, on March 10-11, 2024.

4.2.3.1 Sky Brightness Measurements Using SQM

As shown in Figure 4.11, the zenithal measurement of the astronomical sky brightness-moonless (new moon) at Al Humaij averaged 21.75 magnitudes per square arc second ($\text{mag}/\text{arcsec}^2$). Figure 4.12 also shows that the daily night-time variation of sky brightness level is roughly the same, with the average brightness in the active stage of artificial lighting (twilight night-twilight) ranging from 21.0 to 21.84 $\text{mag}/\text{arcsec}^2$.

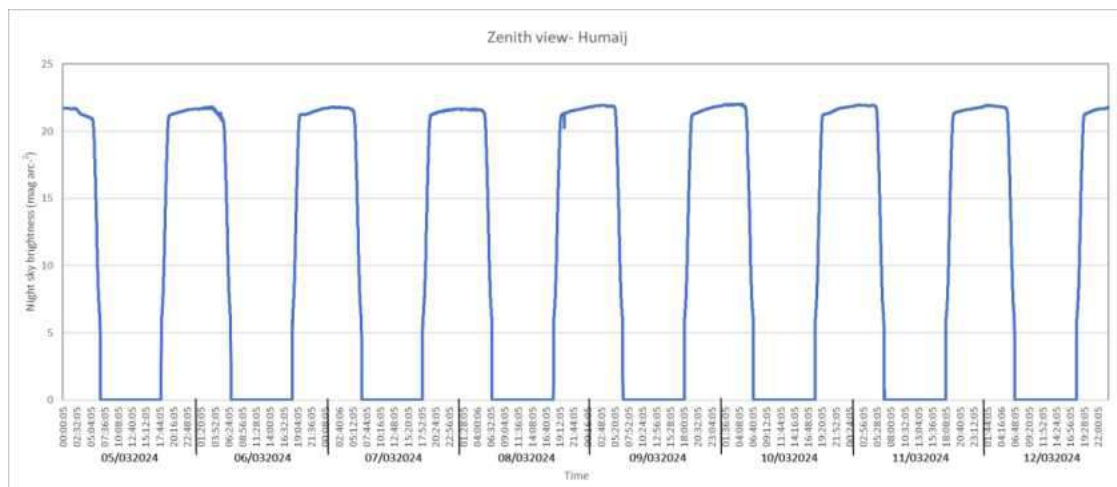


Figure 4.12 Day-to-day variation in sky magnitude brightness in Al Humaij, Madinah, from March 5-12, 2024.

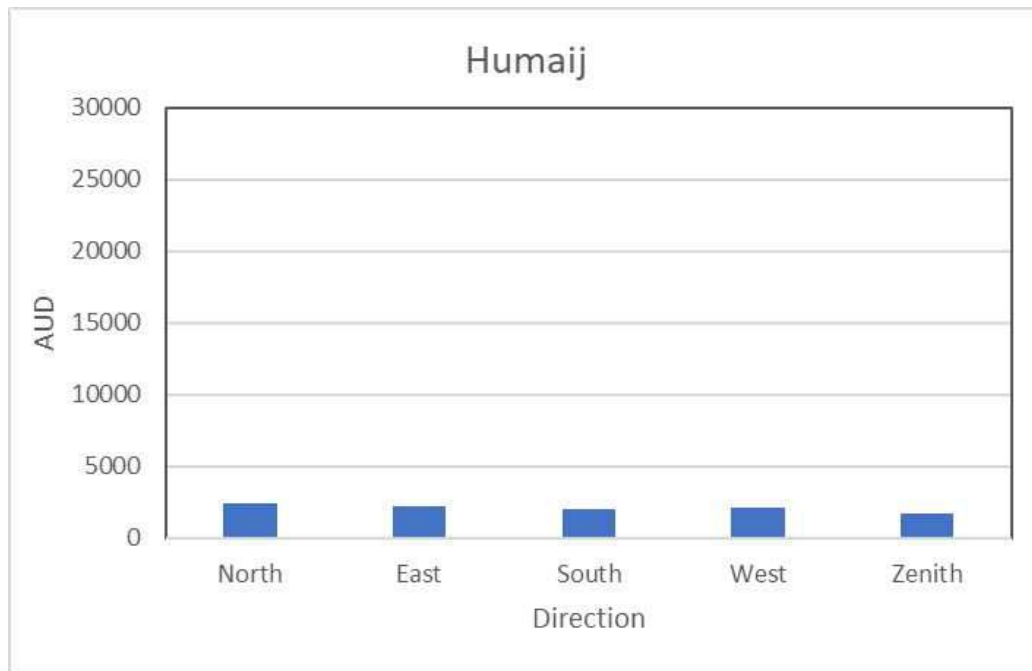


Figure 4.13 Night sky brightness was measured using Sony $\alpha 7v$, with f/2.8 aperture, 30s shutter speed, and 800 ISO settings. Directed toward the zenithal direction of Al Humaij.

Figure 4.13 shows the analysis of night-time image data from the field survey conducted on March 15, 2024. Measurements were made using a technology that calculated pixel values rather than visual ones to compare little brightness variations. Nebulosity software was utilized to measure the average of a 21×21 -pixel matrix instead. Figure 6 shows the night sky brightness data and compares four cardinal orientations (North, South, East, and West) and the Zenithal direction (upward). The measurements are in pixel values (analog to digital units or AUDs).

Figure 4.13 shows that the Al Humaij site's sky brightness and sky glow in the northern directions are increased with pixel values of 2435 AUD. The eastern, southern, and west directions receive darker pixel values of around 2248, 2027, and 2103 AUDs, respectively, and the zenith direction receives significantly darker with pixel values of 1710 AUDs. Comparing the pixel values for four cardinal directions shows that no particular conclusion can be drawn about the influence of the local villages and cities on the visible light pollution in the Al Humaij area. The data indicates that the four cardinal directions exhibit a significant increase in darkness in pixel values. This finding is of great importance in understanding the distribution of light and the factors that influence it. The effects of light pollution are a current and ubiquitous change on a global scale. The study's quantitative data on night sky brightness will provide a baseline for any future effects of light pollution in the area. Regarding the impact of nearby local industries and urban regions on visible light pollution, these localities are anticipated to substantially influence local sky brightness.

The second edition of CIE 150, published in 2017, provides guidelines for various forms of light pollution and describes a series of environmental zones. It also presents guidelines for external lighting in each zone to mitigate unwanted light (CIE 150, 2017). The zone classification ranges from 0 to 4, with zone 0 encompassing natural dark environments such as UNESCO starlight reserves, parks, and astronomical

observatories (see Table 4.3). The proposed GCC solar park developmental in the Al Humaij area falls under the Lighting Environmental Classification of Zone 0, a protected area. The E0 environmental zone applies to the proposed development and follows the lighting criteria in Table 4.3. This table outlines the maximum permissible levels of illumination and light intensity for each specific characteristic. The lighting environmental zones strictly regulate the amount of light that spills beyond a designated area. The CIE 150:2017 presents a measure to protect the environment from harm or adverse effects caused by excessive light spills. Furthermore, these zones can be linked with lighting data mapping to provide a more comprehensive assessment of the impact on specific regions. By incorporating the data from local ecological studies on mapped light pollution, significant enhancement could be achieved in designing outdoor lighting. This supplementary filter will ensure our efforts towards creating a sustainable and eco-friendly environment.

Table 4.3. Lighting environmental zone classification, as adapted by CIE 150:2017

Zone	Surrounding	Lighting environment	Examples
E0	Protected	Dark (SQM 20.5+)	Astronomical observation
E1	Natural	Intrinsically dark (SQM 20-20.5)	Uninhabited rural areas and National parks
E2	Rural	Low district brightness (SQM 15-20)	Sparsely inhabited rural areas
E3	Suburban	Medium district brightness	Inhabited rural and urban settlements, small town center
E4	Urban	High district brightness	Town/City centers

4.2.4 Conclusion

Extensive research in medicine, astronomy, and environmental sciences has unequivocally demonstrated that light pollution is not just a current issue, but a looming threat. It poses a significant danger to our health, dark skies, and the natural environment [Kloog et al., 2009; Galatanu et al., 2019]. Already present but also growing, as global experience has shown that light pollution tends to increase, particularly near the horizon. This escalating trend underscores the urgent need for action, a need that this report aims to address.

The significance of this report is underscored by its unique analysis of the baseline data of the GRL Solar Park. This data, which provides crucial insights into the lighting conditions before development in the area, is a key resource for understanding the impact of light pollution. The report also ensures compliance with the CIE 150:2017 Guide on the Limitation of the Effects of Obtrusive Light from Outdoor Lighting Installation, particularly with respect to the surrounding sensitive receptors and ensuring it is conducive to foraging and commuting wildlife.

The solar park is assessed to be within a Lighting Environmental Classification Zone E0- within protected classification where bats, birds, and invertebrates are the main sensitive receptors taken into consideration. Furthermore, the current measurements indicate that Al Humaij is an intrinsically dark area, with SQM measurements averaging 21.75 mag/arcsec². Lastly, pushing for measures against light

pollution is not just important, it's a global imperative. The research on its impact on human health has garnered significant and widespread attention, underlining the urgency of our advocacy.

4.3 SOIL CONTAMINANT ANALYSIS

4.3.1 *Materials and Methods*

4.3.1.1 *Metals, pH, and Conductivity*

Soil samples were prepared for trace metal analysis using a slightly modified USEPA Method 3050B (USEPA, 1996). Around 1.0 gram of the freeze-dried samples were placed in the digestion vials, and 2.0 mL of distilled water was added to each vial, and the vials were properly shaken. For the quality control samples, 1.0 mL of the standard solution was added, and the vials were left for 2 or 3 hours. Then 5.0 mL of 50% HNO₃ was added step by step following a sequence of 0.5 mL, and the samples were heated for 15 minutes. After this, 5.0 mL of concentrated HNO₃ was added to each sample, and the samples were heated at 95°C for 3.0 hours. The samples were then allowed to cool down, and 2.0 mL of 1% or 2% HNO₃ was added, followed by the addition of 3.0 mL of 30% H₂O₂. The resultant samples were then heated at 95°C for another three hours, and then 5.0 mL of HCl was added. These samples were heated for another 15 minutes and allowed to cool. The volume of the digestion vials was made up to 50.0 mL, and the vials were closed and shaken. The samples were kept for three hours or more to settle down the suspended particles. Then the samples were filtered, diluted, and transferred to sample introduction vials. The samples were analyzed by ICP-OES to determine concentrations of selected trace metals using USEPA method 6010D (USEPA, 2014).

Mercury in the soil samples was analyzed following USEPA method 7473 (USEPA, 2007a) and using direct mercury analyzer Nippon 3000 MA. Briefly, a 200 mg sample was directly burned in an oxygen-rich atmosphere, and thus released mercury was trapped in gold particles. The amalgamated mercury was then heated to release mercury vapor to be measured with an Atomic Absorption Spectrometer.

The pH and conductivity of soil samples were measured using 5% solutions prepared by dissolving 5 g of the soil in water and making volume up to 100 mL. For this purpose, a potentiometer [Oakton PC 2700] along with the relevant electrodes was used. The pH measurement followed a modified US EPA 9045 D method (USEPA, 2004). The conductivity measurement was based on the in-house method.

4.3.1.2 *Polycyclic Aromatic Hydrocarbons (Σ PAHs) and Total Petroleum Hydrocarbons (TPHs) in Soil*

For Polycyclic Aromatic Hydrocarbons (PAHs) and Total Petroleum Hydrocarbons (TPHs) analysis, the freeze-dried soil samples were processed following an in-house modified EPA method 3550 (USEPA, 2007b). Approximately 5 g of homogenized soil samples were weighted in a clean extraction vial, then the PAH and TPH compounds were extracted by adding 30 mL (50:50 % V/V) Hexane: Dichloromethane mixture and sonicating the resulting mixture in an ultrasound water bath for 1 hour. After that, the extract was carefully transferred into another vial to be evaporated to precisely 5 mL.

Later on, the EPA international method 8270E (USEPA, 2018a) was followed for PAHs analysis, about 1 mL of the extract was transferred into a GC vial and introduced into a GC-MS/MS by injecting the sample extract into a GC equipped with a narrow-bore fused-silica capillary column. The GC column is temperature-programmed to separate the 16 US-EPA priority PAHs, which are then detected with an MS detector connected to the GC. Identification of target analytes was accomplished by comparing their mass spectra with the electron impact (or electron impact-like) spectra of authentic standards. Quantification was performed by comparing the response of a major (quantitation) ion relative to an internal standard using an appropriate calibration curve for the intended application. This method includes specific calibration and QC steps that supersede the general recommendations provided in Method 8000 (USEPA, 2018b).

For TPH compounds quantification analysis, the USEPA method 8015D (USEPA, 2003) was followed. The concentrations of various non-halogenated volatile and semivolatile organic compounds, including petroleum hydrocarbons (C10-C36) were determined in the same extract using Gas Chromatography coupled with Flame Ionization Detector (FID).

4.3.1.3 Quality Assurance

Stringent quality control measures are implemented to keep systematic and random errors under control in sampling, analysis, and data reporting. Typically, 10% of the total number of samples analyzed consists of laboratory duplicates and laboratory spikes, regardless of the total number of samples in any batch. Where it is applicable, the spiking of the samples was two to five times the analyte concentration in samples. The calculation was performed using an external calibration approach. After the calibration, an initial calibration verification (ICV) standard was run to verify the applicability of calibration. Continuous calibration verification (CCV) was performed by running a standard after every 10 samples. The integrity of the results was ensured by implementing quality control and quality assurance checks, as per the USEPA protocols (USEPA, 2018b). All the possible precautions were taken in the preparation of samples. Laboratory reagent blanks (LRB) and laboratory calibration standards (LCS) were run routinely. Moreover, the results are validated by analyzing standard reference material CRM 016 from Sigma Aldrich for trace metals. The results of laboratory analyses compared to CRM 016 are given in (Table 4.4).

Table 4.4. Certified values (mg/kg) of sediment reference material for metals (CRM 016) compared with levels determined in the KFUPM laboratory.

Metals	Lab Results (mg/kg)	Recovery (%)	Certified Value (mg/kg)
Aluminium	10574.00	118.54	8920 ± 657
Arsenic	7.00	90.21	7.76 ± 0.44
Barium	87.50	110.34	79.3 ± 2.8
Cadmium	0.50	106.38	0.470 ± 0.080
Cobalt	5.25	88.09	5.96 ± 0.24
Chromium	15.88	109.52	14.5 ± 1.4
Copper	13.25	85.48	15.5 ± 0.4
Iron	16689.63	99.34	16800 ± 517
Mercury (2702)	0.458	102.37	0.4474 ± 0.0069

Metals	Lab Results (mg/kg)	Recovery (%)	Certified Value (mg/kg)
Manganese	186.63	103.68	180 ± 4
Nickel	13.50	80.84	16.7 ± 0.5
Lead	11.00	78.01	14.1 ± 0.7
Vanadium	26.50	117.78	22.5 ± 1.6
Zinc	69.00	99.00	69.7 ± 2.1

4.3.2 Results and Discussions

The purpose of a baseline study is to provide an information base against which to monitor and assess an activity's progress and effectiveness during implementation and after the activity is completed. As a part of the baseline study, assessing the level of contaminants in soil prior to the commencement of any developmental activity is crucial. As the impacting activity in this study involves construction, there is a potential for the release of contaminants into the soil. Hence, to assess the impacts quantitatively two major contaminant groups viz., trace metals and hydrocarbons are analyzed in the soil samples collected from selected stations from the Al Humaij in the Madinah study area.

4.3.2.1 Metals, pH, and Conductivity

A total of 20 metals including silver (Ag), aluminum (Al), arsenic (As), barium (Ba), beryllium (Be), calcium (Ca), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), mercury (Hg), potassium (K), magnesium (Mg), manganese (Mn), sodium (Na), nickel (Ni), lead (Pb), vanadium (V), and zinc (Zn) were analyzed in the soil samples collected from the study area. Ag, As, Be, Cd, and Pb were not detected above their corresponding LOR (Table 5.2) in any sample studied in this area.

The order of mean concentrations of the detected metals in the study area was as follows: Fe > Ca > Al > Mg > K > Mn > Na > Ni > V > Ba > Zn > Cr > Co > Cu > Hg.

Figures (4.14 to 4.16) show the concentrations of different inorganic and general parameters (pH and Electrical Conductivity (EC)) in the soil from the study area. Table 5.2 summarizes and compares these concentrations with NCEC soil quality guidelines (NCEC, 2020). NCEC guidelines define the maximum pollution level of coarse and soft soil pollutants. The pollution level is defined based on the types of land use. The types of lands include natural areas, agricultural, residential/gardens, commercial, and industrial. The allowable limits of various pollutants for each type of land use are provided in (Table 4.5).

Table 4.5. Summary of general and inorganic parameters in soils from the study area and their comparison with NCEC soil quality guidelines (NA denotes not available).

Analyte	LOR	Unit	% Detects	Min	Max	Mean	NCEC Soil Quality Guidelines (NCEC, 2020)									
							Coarse Soil			Soft Soil						
							Natural area	Agricultural	Residential/	Commercial	Industrial	Natural area	Agricultural	Residential/Gardens	Commercial	Industrial
									Gardens							
Ca	0.1	mg/kg	100.00	5882	13470	9288	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Na	0.6		100.00	122	273	165	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Mg	0.1		100.00	6764.00	8832.13	7570.77	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Al	1.3		100.00	7262	9564	8601	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Fe	0.1		100.00	13568	16208	15072	NA	NA	NA	NA	NA	NA	NA	NA	NA	
K	1.3		100.00	1014	1992	1441	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Mn	0.1		100.00	237.12	300.62	263.32	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Ba	0.04		100.00	32.69	42.45	36.75	750	750	500	2000	2000	750	750	500	2000	2000
Zn	0.3		100.00	26.97	32.25	29.05	200	200	200	360	360	200	200	200	360	360
V	0.6		100.00	32.73	42.72	38.71	130	130	130	130	130	130	130	130	130	130
Cr	0.3		100.00	19.26	27.33	22.61	64	64	64	87	87	64	64	64	87	87
As	2.5		0.00	0.00	0.00	#DIV/0!	17	17	17	26	26	17	17	17	26	26
Ni	0.6		100.00	34.68	56.13	44.14	45	45	45	89	89	45	45	45	89	89
Cu	0.5		100.00	2.75	6.75	5.15	63	63	63	91	91	63	63	63	91	91
Co	0.3		100.00	7.32	9.34	7.93	20	20	20	300	300	20	20	20	300	300
Hg	0.005		66.67	0.006	0.007	0.007	12	6.6	6.6	24	50	12	6.6	6.6	24	50
Ag	0.8		0.00	0.00	0.00	#DIV/0!	20	20	20	40	40	20	20	20	40	40
Be	0.1		0.00	0.00	0.00	#DIV/0!	5	5	5	8	8	5	5	5	8	8
Cd	0.1		0.00	0.00	0.00	#DIV/0!	3.8	1.4	10	22	22	3.8	1.4	10	22	22
Pb	1.3		0.00	0.00	0.00	#DIV/0!	70	70	140	260	600	70	70	140	260	600
pH	0.1	pH unit	100.00	8.02	8.61	8.32	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	
Conductivity	0.01	mS	100.00	0.07	0.51	0.16	NA	NA	NA	NA	NA	NA	NA	NA	NA	

In this study, the comparison of detected pollutant concentrations, except for Ba, has been made with the ‘Agricultural area’ values. This is because the agricultural area allowable limits have the lowest values compared to other land types. If the detected concentrations are below the permissible limits for the agricultural area, they are lower than the allowable limits for other types of land [NCEC, 2020]. For Ba, the comparison has been made with the ‘Residential/Gardens area’ values.

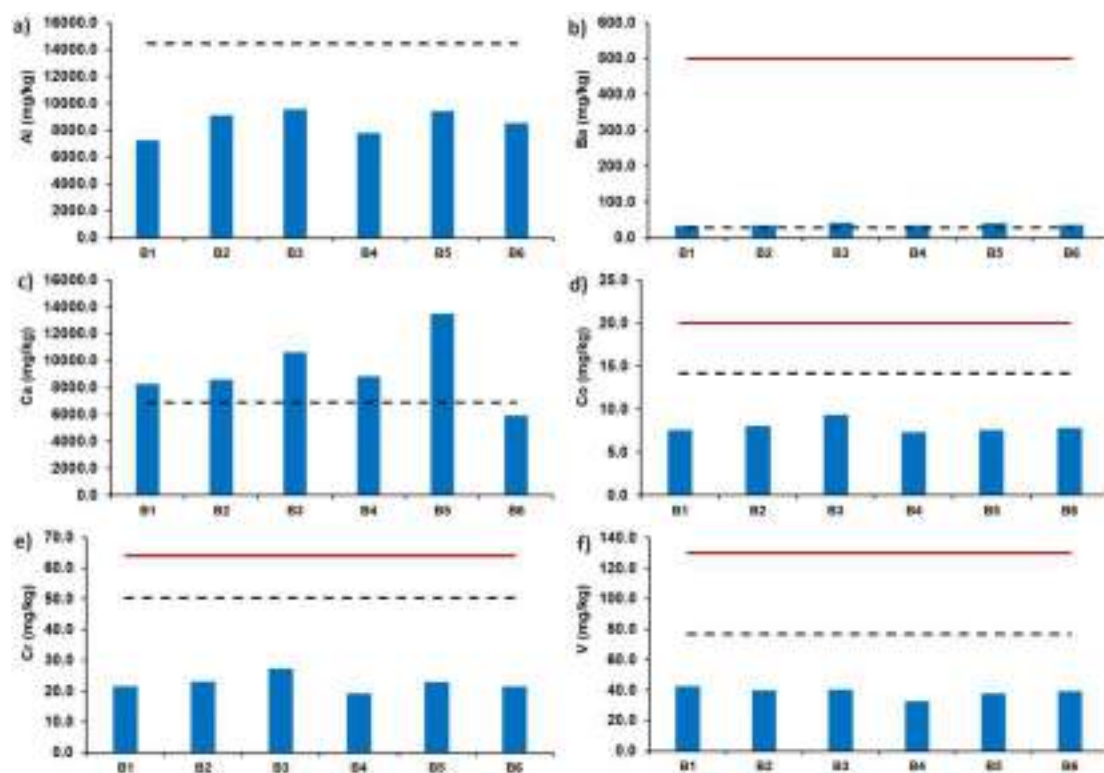


Figure 4.14 a) Al, b) Ba, c) Ca, d) Co, e) Cr, and f) V elements concentrations in the soils collected from the study area. The dashed lines are the means concentrations, and the red line indicates the NCEC maximum permissible limit, where it is applicable.

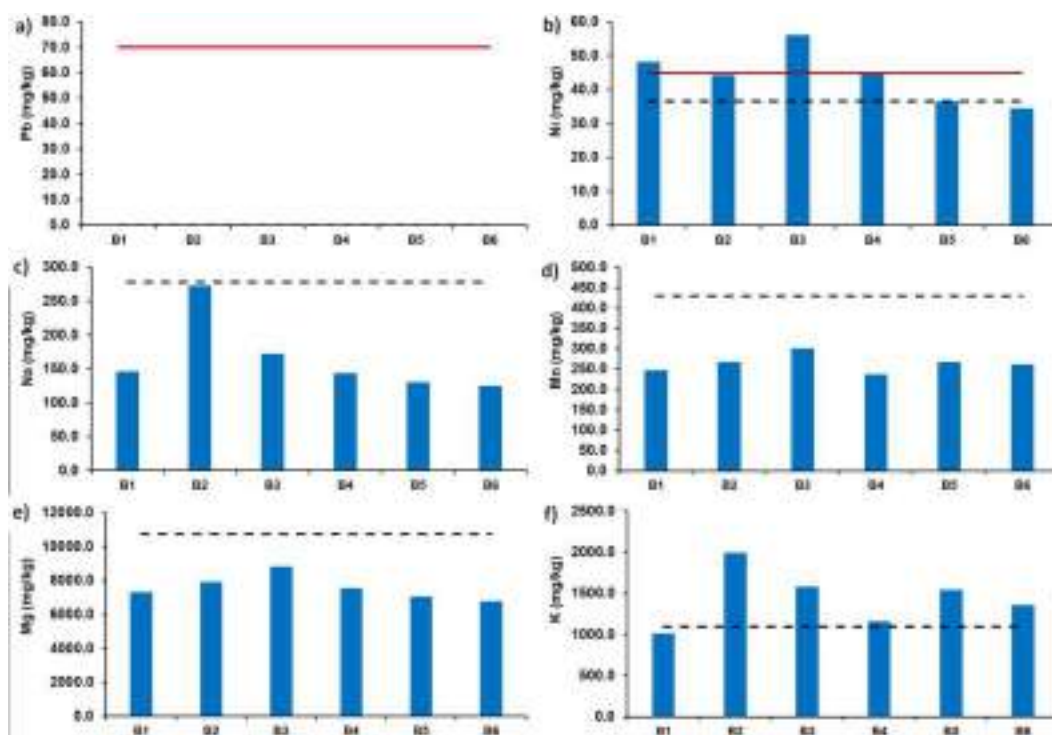


Figure 4.15. a) Pb, b) Ni, c) Na, d) Mn, e) Mg, and f) K elements concentrations in the soils collected from the study area. The dashed lines are the means concentrations, and the red line indicates the NCEC maximum permissible limit, where it is applicable.

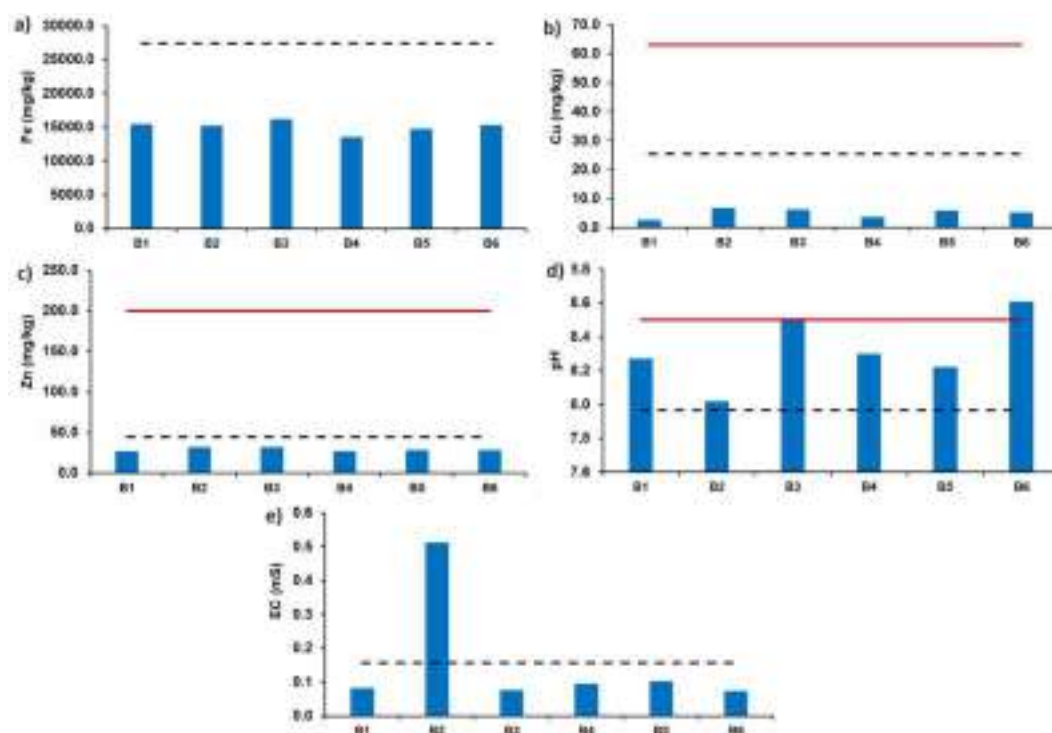


Figure 4.16. a) Fe, b) Cu, c) Zn concentrations, d) pH, and e) EC results in the soils collected from the study area. The dashed lines are the means concentrations, and the red line indicates the NCEC maximum permissible limit, where it is applicable.

Fe, Ca, Al, Mg, K, Mn, Na, Ni, V, Ba, Zn, Cr, Co, and Cu were detected in all the soil samples collected from the study area, while the rest either were not detected or were detected in only some stations. The mean concentration of all metals/ metalloids in the soil was lower than the NCEC soil quality guideline values for the agricultural and residential/garden areas. No NCEC soil quality guidelines exist for Al, Ca, Fe, K, Mg, Mn, and Na.

All the detected concentrations of Ba were below the permissible levels defined by the NCEC for the Residential/Gardens area' value (500 mg/kg). The concentrations of Ba ranged from 32.69 to 42.45 mg/kg, with a mean concentration of 36.75 mg/kg. The concentration of Ca ranged from 5882 to 13470 mg/kg, with a mean concentration of 9288 mg/kg. The mean concentration of Co was below the NCEC soil quality guidelines for the agricultural area (20 mg/kg). Its concentrations ranged from 7.32 to 9.34 mg/kg, with a mean concentration of 7.93 mg/kg. The mean concentration of Cr was below the NCEC soil quality guidelines for the agricultural area (64 mg/kg). Its concentration ranged from 19.26 to 27.33 mg/kg, with a mean concentration of 22.61 mg/kg. All the detected concentrations of Cu were below the permissible levels defined by the NCEC soil quality guidelines for the agricultural area (63 mg/kg). The detected concentrations of Cu ranged from 2.75 to 6.75 mg/kg, with a mean concentration of 5.15 mg/kg. The concentrations of Fe ranged from 13568 to 16208 mg/kg, with a mean concentration of 15072 mg/kg. The concentrations of Hg were below the method limit of reporting (0.005 mg/kg) in all the samples which is far below the NCEC soil quality guidelines for the Residential/Gardens area (6 mg/kg). The mean concentration of Ni was below the NCEC soil quality guidelines for the agricultural area (45 mg/kg). The detected concentrations of Ni in stations B1 (48.3 mg/kg) and B3 (56.1 mg/kg) were slightly higher than the NCEC maximum permissible value (45mg/kg). The concentrations of K ranged from 1014 to 1992 mg/kg, with a mean concentration of 1441 mg/kg. The concentrations of Mg ranged from 6764.00 to 8832.13 mg/kg, with a mean concentration of 7570.77 mg/kg. The concentrations of Mn ranged from 237.12 to 300.62 mg/kg, with a mean concentration of 263.32 mg/kg. The detected concentrations of Na ranged from 122 to 273 mg/kg with a mean concentration of 165 mg/kg. The concentrations of As were below the NCEC soil quality guidelines for the agricultural area (17 mg/kg). All the detected concentrations of V were below the NCEC soil quality guidelines for the agricultural area (130 mg/kg). The concentrations of V ranged from 32.73 to 42.72 mg/kg, with a mean concentration of 38.71 mg/kg. The mean concentration of Zn was below the NCEC soil quality guidelines for the natural area (200 mg/kg). The concentrations of Zn ranged from 26.97 to 32.25 mg/kg, with a mean concentration of 29.05 mg/kg.

The pH of the soil samples was in the range of 8.02 to 8.61, with a mean value of 8.32. The mean value was lower than the NCEC soil quality guidelines for the agricultural area (pH=8.5).

The conductivity of the soil samples ranged from 0.07 to 0.51 mS, with a mean value of 0.16 mS. NCEC soil quality guidelines do not exist for conductivity.

5.3.2.2 Total Petroleum Hydrocarbons (TPHs), and Polycyclic Aromatic Hydrocarbon (PAHs) in Soil

Hydrocarbons are organic compounds that result from the partial combustion of

organic matter (pyrolytic), oil, and its derivative (petrogenic) sources. In this study, the aliphatic hydrocarbons (ΣC_{10-C36}) and TPH concentrations were detected in two out of six locations. The determined (ΣC_{10-C36}) concentrations ranged from 0.69 to 1.09 mg/kg with a mean concentration of 0.89 mg/kg. For TPHs, the concentrations ranged from 1.39 to 4.79 mg/kg with a mean concentration of 3.09 mg/kg.

In Saudi Arabia, the Ministry of Environment, Water and Agriculture (MEWA) classifies the petroleum hydrocarbons in soils into four fractions (i.e. ΣC_6-C_{10} , $\Sigma C_{10-C_{16}}$, $\Sigma C_{16-C_{34}}$, and $\Sigma C_{34-C_{50}}$) and stipulates the intervention limits to be 24 mg/kg of ΣC_6-C_{10} , 130 mg/kg of $\Sigma C_{10-C_{16}}$, 300 mg/kg $\Sigma C_{16-C_{34}}$ and 2,800 mg/kg of $\Sigma C_{34-C_{50}}$ in coarse soil and 210 mg/kg of ΣC_6-C_{10} , 150 mg/kg of $\Sigma C_{10-C_{16}}$, 1,300 mg/kg of $\Sigma C_{16-C_{34}}$, 5,600 mg/kg of $\Sigma C_{34-C_{50}}$ in fine soil (NCEC, 2020). All the detected concentrations were found to be much lower than the NCEC standards (Table 5.3). This indicates that soil from the study area is not contaminated, it can be kept under any category of natural, agricultural, residential/Gardens, commercial, and/or industrial areas, and that no intervention would be required if the current levels were maintained.

Table 4.6. NCEC Standards for Protecting Soil from Pollution with hydrocarbons (NCEC, 2020).

Chemical	Top Coarse Soil					Top Fine Soil				
	Types of Land Use									
	Natural Area	Agricultural	Residential/ Gardens	Commercial	Industrial	Natural Area	Agricultural	Residential/ Gardens	Commercial	Industrial
	Unit (mg/kg)									
$\sum C_6-C_{10}$	210	24	24	270	270	210	210	210	320	320
$\sum C_{10}-C_{16}$	150	130	130	260	260	150	150	150	260	260
$\sum C_{16}-C_{34}$	300	300	300	1700	1700	1300	1300	1300	2500	2500
$\sum C_{34}-C_{50}$	2800	2800	2800	3300	3300	5600	5600	5600	6600	6600
Carcinogenic PAHs	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Naph	0.017	0.017	0.017	0.017	0.017	0.014	0.014	0.014	0.014	0.014
2-mNaph	--	--	--	--	--	--	--	--	--	--
AceThy										
Acenaph	0.38	0.38	0.38	0.38	0.38	0.32	0.32	0.32	0.32	0.32
Flu	0.34	0.34	0.34	0.34	0.34	0.29	0.29	0.29	0.29	0.29
Phen	0.061	0.061	0.061	0.061	0.061	0.051	0.051	0.051	0.051	0.051
Anthra	0.0056	0.0056	0.0056	0.0056	0.0056	0.0046	0.0046	0.0046	0.0046	0.0046
Fluo	0.039	0.039	0.039	0.039	0.039	0.032	0.032	0.032	0.032	0.032
Pyr	0.04	0.04	0.04	0.04	0.04	0.034	0.034	0.034	0.034	0.034
B(a)A	0.083	0.083	0.083	0.083	0.083	0.07	0.07	0.07	0.07	0.07
Chry	6.2	6.2	--	--	--	6.2	6.2	--	--	--
B(b)F	6.2	6.2	--	--	--	6.2	6.2	--	--	--
B(k)F	6.2	6.2	--	--	--	6.2	6.2	--	--	--
B(a)P	0.6	0.6	0.77	0.77	0.77	0.6	0.6	0.7	0.7	0.7
Inde	--	--	--	--	--	--	--	--	--	--
Dib(a,h)A	--	--	--	--	--	--	--	--	--	--
B(g,h,i)P	0.017	0.017	0.017	0.017	0.017	0.014	0.014	0.014	0.014	0.014

The Sum of 17 PAH congeners (Σ PAHs) was detected in only two samples collected from the study area with concentrations (1.59mg/kg and 6.45 mg/kg) higher than the LOR (1.0mg/kg) which is much lower than the acceptable limit (1000 μ g/kg) reported by NCEC (NCEC 2020). NCEC standard values implied that soils from the study area are not contaminated and can be kept under any category of the natural area, agricultural, residential / Gardens, commercial, and/or industrial areas and that no intervention would be required if the current levels were maintained (Table 4.6).

4.3.3 Conclusions

Two major contaminant groups viz., trace metals and hydrocarbons are analyzed in the soil samples collected from selected stations from Al Humaij in the Madinah study area. The results show that five metals/metalloids (i.e. Ag, As, Be, Cd, and Pb) were not detected above their corresponding limit of reporting (LOR). Besides, the order of mean concentrations of the detected metals in the study area was as follows: Fe > Ca > Al > Mg > K > Mn > Na > Ni > V > Ba > Zn > Cr > Co > Cu > Hg. The individual, except for Ni, and mean concentrations of all detected metals/metalloids in the collected samples from the study area were lower than the NCEC guideline values. In this study, the aliphatic hydrocarbons (Σ C10-C36) and TPHs concentrations were detected in only two stations out of six stations. The Sum of 17 PAH congeners (Σ PAHs) was detected in only two collected samples from the study area with concentrations higher than the LOR (1.0mg/kg) which is much lower than the acceptable limit (1000 μ g/kg) reported by NCEC. All the analyzed contaminants in the collected soil from the study area, for which NCEC soil quality guideline exists, were less than the NCEC soil quality guideline levels. This indicates that soil from the study area is not contaminated, it can be kept under any category of natural, agricultural, residential/Gardens, commercial, and/or industrial areas, and that no intervention would be required if the current levels were maintained.

4.4 GROUNDWATER

4.4.1 Introduction

The Arabian Shield consists of igneous and metamorphic rocks of Precambrian age as well as volcanic rocks (so-called “harrats”) of Tertiary and younger age [Brown et al., 1989]. Alluvial fillings can be found in the valleys. There are no regionally significant groundwater resources on the Arabian Shield. The igneous and metamorphic rocks generally have a low water yield. Medium water yields are found in the “harrats” and in the alluvial accumulations of the valleys; however, due to the limited extent, these groundwater resources are only of local importance. For the most part, shield rocks are relatively impermeable and are therefore not significant aquifers [Jasechko et al., 2017]. Locally, however, small yields of water might be found in the heavily jointed or fractured crystalline rock of the shield or the younger basalt. The Shield influences the water resources in other ways; it forms the highest parts of the Kingdom and substantially controls the drainage and distribution of rainfall, which runs off through the wadis and is then available to recharge the groundwater. Because the rocks of the Shield are commonly impermeable, they shed most of the rain that falls on them, shunting relatively large percentages of the rainfall to the adjacent bodies of sedimentary rocks, which can take in and store some of the water [Asmoay, 2023].

4.4.2 Groundwater Resources- Literature Survey

Groundwater is extremely important in a water-scarce country such as Saudi Arabia, where permanent surface water resources are absent. Saudi Arabia is widely known for its scarcity of water and is considered among the most sensitive regions to climate change with a projected increase in the return periods of flooding and drought events in the upcoming decades [Abdelmohsen et al., 2019]. However, previous studies proved that Saudi Arabia has experienced higher precipitation levels in previous Pleistocene wet climatic periods, which recharged their aquifers.

In Saudi Arabia, the groundwater aquifers can be classified into deep non-renewable aquifers (confined aquifers) and shallow renewable aquifers (water table aquifers), which contribute 80% of the freshwater need in this country [Niyazi et al., 2018]. Besides, surface water (10%), desalinated water (5%), and other water resources (5%) are also involved in the total water supply for the different water uses in this country [Ouda et al., 2014].

Al Humaij site is composed of Quaternary alluvium and aeolian sediments with remnants of the older Precambrian granitic intrusions that form most of the surrounding hills. AL Humaij site is located on the downstream side of several wadies (Bidayah, Husailah, and Ajir) which cut through the surrounding hills and mountains (Jabal Bidayah, Jabal Ajir, and Jabal Murrah) The wadi lies entirely within the geological complex of the Arabian Shield in the western area of Saudi Arabia which is highly dissected with multiple structural lineaments (faults, joints, and fractures). The structure lineaments generally promote a shallow ground water table in the lowland areas which is covered by a thick sequence of highly porous and permeable sediments [Othman, 2024].

The main source of the shallow aquifers which are concentrated in the alluvium sediments is the annual rainfall. Rainfall is very low, unpredictable, highly irregular, and sometimes intense during local storms [Al Maghraby et al., 2013]. To measure the rate of precipitation in Saudi Arabia, the Ministry of Environment, Water, and Agriculture (MEWA) installed 914 climate monitoring stations which provide daily 24-hour climate measurements including rainfall data. The maximum, minimum, and mean rate of precipitation of the Al Humaij site and its surrounding areas has been determined as shown in (Table 4.7).

Table 4.7. Average rainfall and temperature for main morphological units in the study area.

Measurement	Minimum	Mean	Maximum
Rainfall (mm/year)	70	325	650
Temp. (°C)	16	22	28

The geology of the study area is considered as a main significant controlling factor that has a direct influence on groundwater and surface water by governing the hydrological characteristics of the catchment such as catchment shape, orders of the stream network, flood flow course, and groundwater recharge [Niyazi et al., 2023].

Natural and anthropogenic influences pose a threat to the shallow aquifer as

hydrological recharge is lower than extraction. Consequently, the ecosystem is imbalanced, leading to significant groundwater contamination from the intrusion of saline water and agricultural chemicals. The most severe and visible problem is the rapid depletion of groundwater resources, attributed to declining water tables, pollution, or a combination of both. Groundwater has become prohibitively expensive to use, resulting in low agricultural yields.

4.5 FLORA

Documenting the existing floristic components of the project site is crucial for predicting the impact of the developmental activities on the vegetation. The presence of high conservation priority plant species on the project site will exacerbate the impact, and suitable mitigation measures must be implemented before the construction phase.

4.5.1 *Methodology*

4.5.1.1 *Field survey*

A floristic survey was conducted at six locations based on the quadrat survey. Each quadrat was 20 m x 20 m in size and distributed randomly at different types of vegetation/habitats (Figure 4.17). At each location, the survey was conducted in two quadrats, hence this report presents the results of the flora survey conducted in a total of 12 quadrats. From each quadrat, data such as species names and their abundance were recorded along with the photographs.

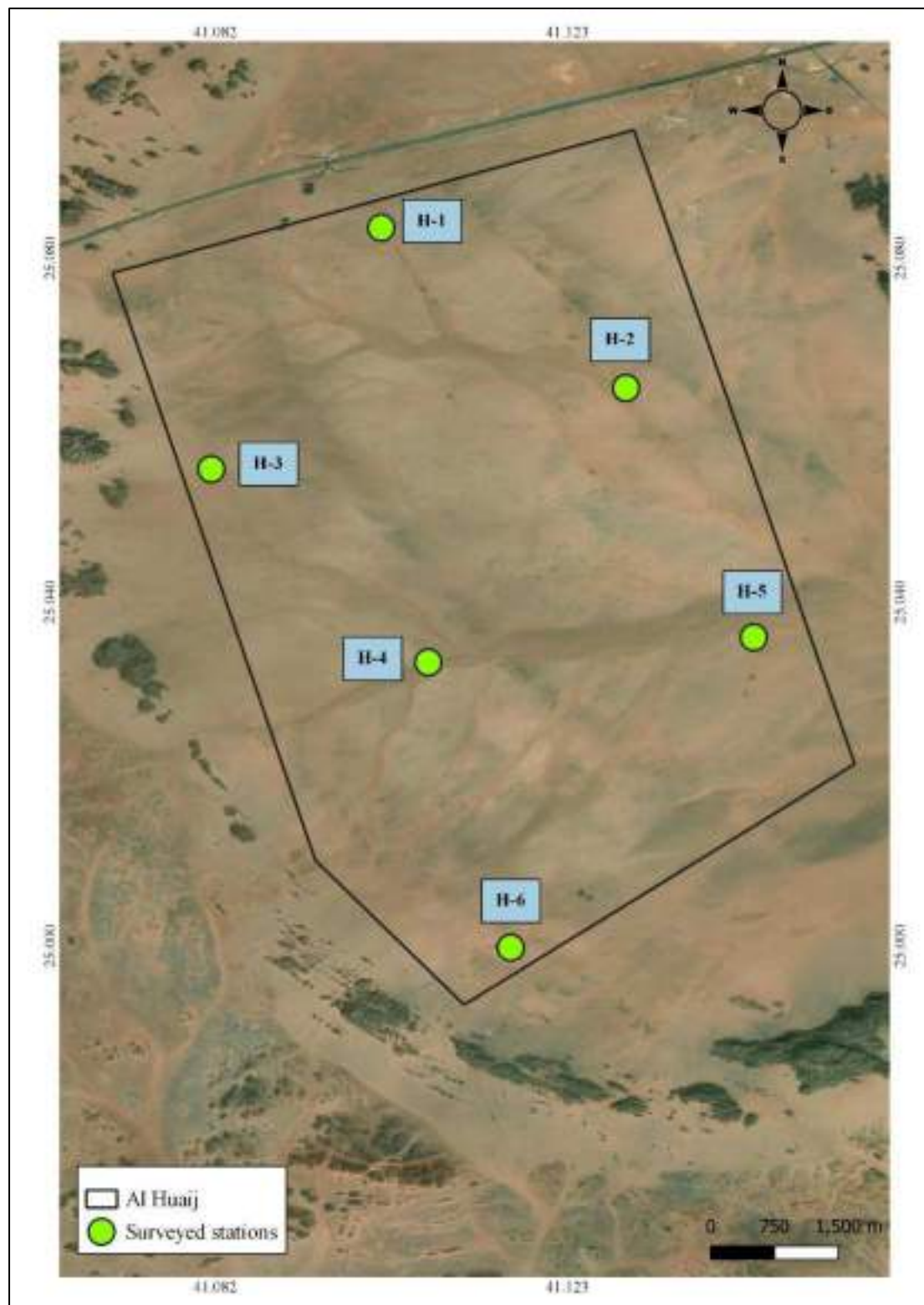


Figure 4.17 Flora survey stations in Al Humaij.

4.5.1.2 Data Processing and Analysis

All field data were transferred to Microsoft ExcelTM spreadsheets. Relative abundance was estimated using MS Excel. Statistical analysis (Margalef Index) was performed using PAST Software 4.03. All the maps were prepared by following the

World Geodetic System (WGS84), the reference coordinate system for the Global Positioning System (GPS).

The results and analysis of the flora and fauna components of Al Humaij are described in the following sections.

4.5.2 Results

4.5.2.1 Species Account

The floristic survey in Al Humaij documented 23 plant species belonging to 17 families (Table 4.8; Figures 4.18-4.21). Brassicaceae and Leguminosae were identified as the most frequent families in this site with three species in each. No High Conservation Priority species or IUCN Red Listed Threatened plant species were recorded from the Al Humaij site.

Table 4.8. Plant species recorded from Al Humaij

Sl. No.	Species	Family	IUCN conservation status
1.	<i>Aizoon canariense</i> L.	Aizoaceae	NL
2.	<i>Haloxylon salicornicum</i> (Moq.) Bunge ex Boiss.	Amaranthaceae	NL
3.	<i>Asphodelus tenuifolius</i> Cav.	Asphodelaceae	NL
4.	<i>Leysera leyseroides</i> (Desf.) Maire	Asteraceae	NL
5.	<i>Arnebia hispidissima</i> (Lehm.) DC.	Boraginaceae	NL
6.	<i>Diploaxis acris</i> (Forssk.) Boiss.	Brassicaceae	NL
7.	<i>Eremobium aegyptiacum</i> var. <i>lineare</i> (Del.) Zohary.	Brassicaceae	NL
8.	<i>Farsetia aegyptia</i> Turra.	Brassicaceae	NL
9.	<i>Polycarpha repens</i> (Forssk.) Asch. & Schweinf.	Caryophyllaceae	NL
10.	<i>Cleome amblyocarpa</i> Barr. & Murb.	Cleomaceae	NL
11.	<i>Citrullus colocynthis</i> (L.) Schrader	Cucurbitaceae	NL
12.	<i>Euphorbia granulata</i> var. <i>granulata</i> Forssk.	Euphorbiaceae	NL
13.	<i>Senna italica</i> Miller	Leguminosae	NL
14.	<i>Trigonella stellata</i> Forssk.	Leguminosae	NL
15.	<i>Vachellia tortilis</i> (Forssk.) Galasso & Banfi	Leguminosae	LC
16.	<i>Cistanche violacea</i> (Desf.) G. Beck.	Orobanchaceae	NL
17.	<i>Schismus barbatus</i> (L.) Thell.	Poaceae	NL
18.	<i>Cenchrus ciliaris</i> L.	Poaceae	NL
19.	<i>Emex spinosa</i> (L.) Campd.	Polygonaceae	NL
20.	<i>Ochradenus baccatus</i> Del.	Resedaceae	NL
21.	<i>Lyceum shawii</i> Roem. & Schult.	Solanaceae	LC
22.	<i>Fagonia indica</i> Burm.f.	Zygophyllaceae	NL
23.	<i>Seetzenia lanata</i> (Willd.) Bullock.	Zygophyllaceae	NL
24.	<i>Kickxia aegyptiaca</i> (L.) Nab.	Plantaginaceae	NL

*NL: Not Listed; LC: Least Concern



Figure 4.18. *Lyceum shawii*.



Figure 4.19. *Kickxia aegyptiaca*.



Figure 4.20. *Diplotaxis acris*.



Figure 4.21. *Cistanche violacea*.

4.5.2.2 Relative Abundance

Haloxylon salicornicum was identified as the most abundant plant species (15.9%) in the Al Humaij site followed by *Asphodelus tenuifolius* (15.25%) and *Schismus barbatus* (14.9%). *Lyceum shawii* was the least abundant plant species in this site which is represented by only one individual within the surveyed quadrats. The relative abundance curve (Figure 4.22) shows a gradual increase in the abundance values from *Lyceum shawii* to *Haloxylon salicornicum*.

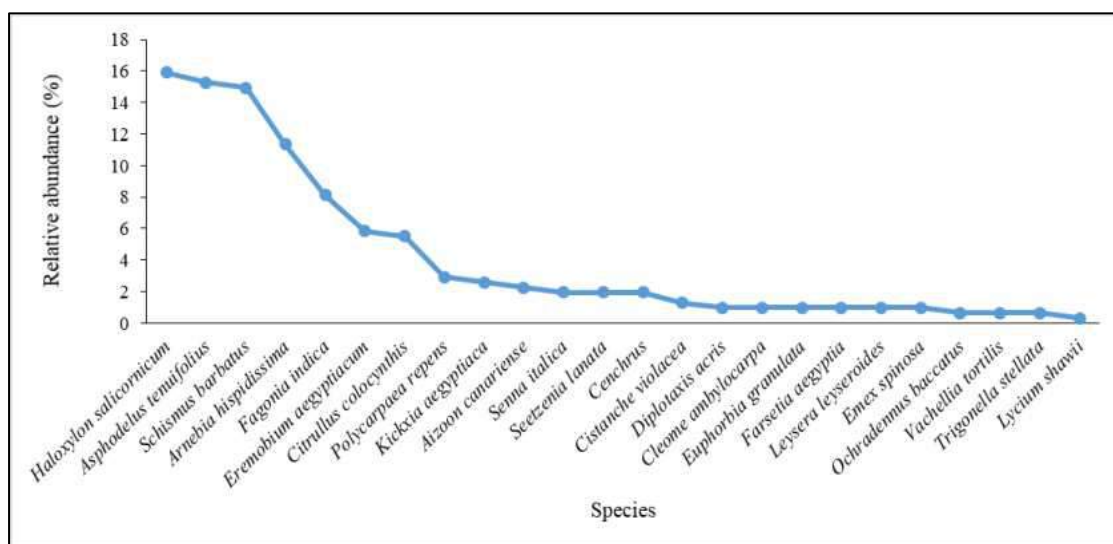


Figure 4.22. Relative abundance curve of plant species in the Al Humaij site.

4.5.2.3 Species Diversity

The highest species diversity in Al Huaij site was observed in quadrat H1Q1 (1.8) and the lowest in H2Q2 (0.64) (Figure 4. 23). Quadrat HIQ1 was located within a vegetated mud-flat while Quadrat H2Q2 was in a mud-flat with rocky exposure, where the vegetation is dominated by *Haloxylon salicornicum* without any other plant species except *Asphodelus tenuifolius*.

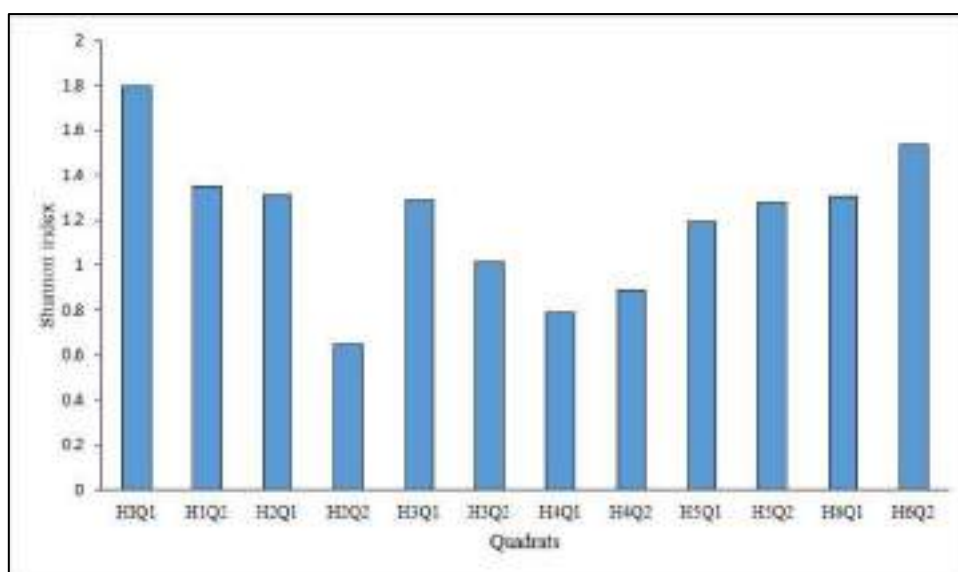


Figure 4.23. Species diversity of surveyed quadrats in the Al Humaij site.

4.5.2.4 Species Distribution

None of the recorded plant species was distributed in all of the surveyed quadrats. *Haloxylon salicornicum* and *Arnebia hispidissima* were recorded from five quadrats (Figure 4.24 & 4.25). Most of the species are locally rare as sixteen species were recorded only from one or two quadrats. Species were mostly restricted to wadis of this region with the rest of the terrain almost bare soil.

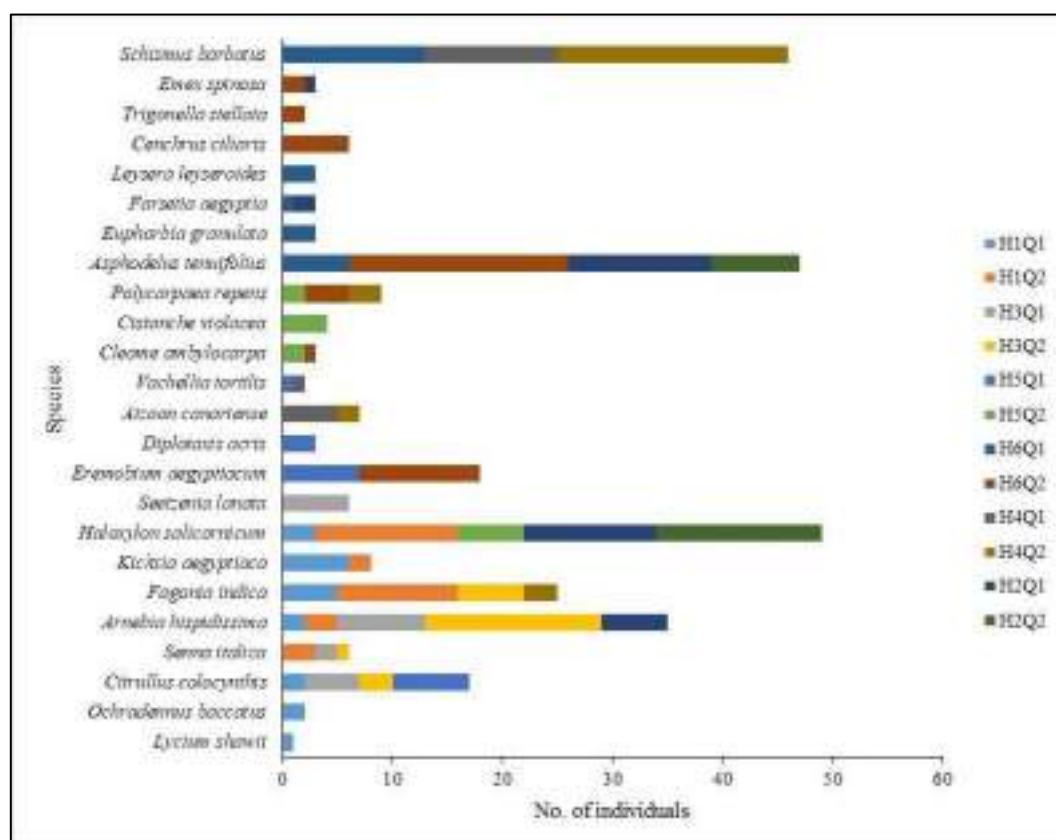


Figure 4.24. Plant species distribution in Al Humaij.

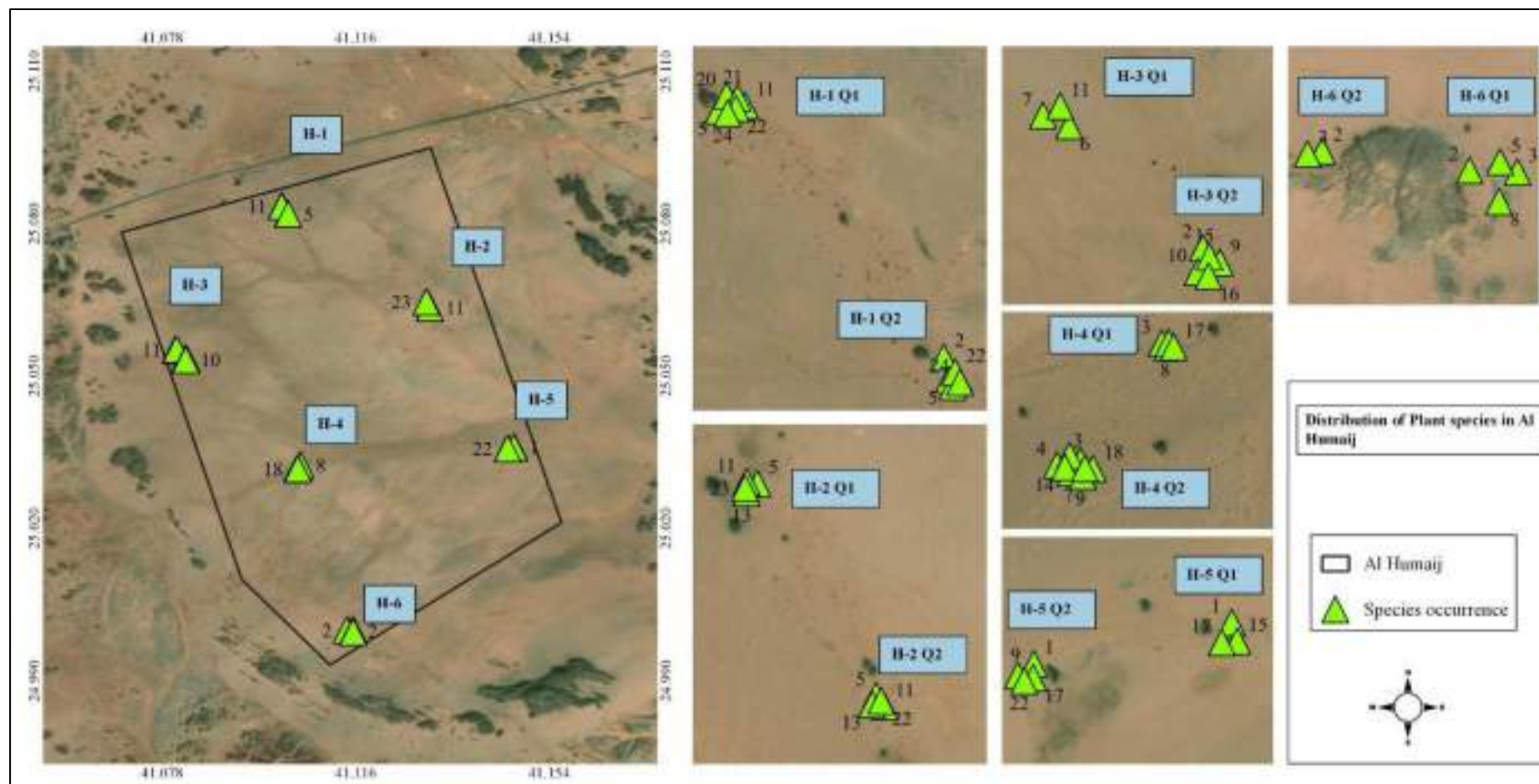


Figure 4.25. Map showing the occurrences of the plant species recorded from Al Humaij (species label corresponds to that of Table 4.8).

4.5.3 Summary and Conclusions

Al Humaij site is represented by 23 plant species, of which *Haloxylon salicornicum* was the most abundant. Quadrat H1Q1 (vegetated wadi) was identified as the most species-diverse quadrat in this site. During the present survey, no high conservation priority plant species were recorded from the site. Any construction activities within this site will not have significant impacts on the vegetation there. However, clearing the *Vachellia tortilis* (Acacia trees) is not advisable as they are the only tree species there that form a habitat for the birds and other fauna elements.

4.6 FAUNA

It is essential to accurately document the current fauna on the project site to anticipate how the development might affect the fauna communities. If there are IUCN red-listed fauna species present, their presence will magnify the impact, necessitating proactive mitigation measures before construction begins.

4.6.1 Methodology

4.6.1.1 Survey

Fauna surveys were conducted along the same transects where flora survey was conducted (Figure 4.26 and Table 4.9)

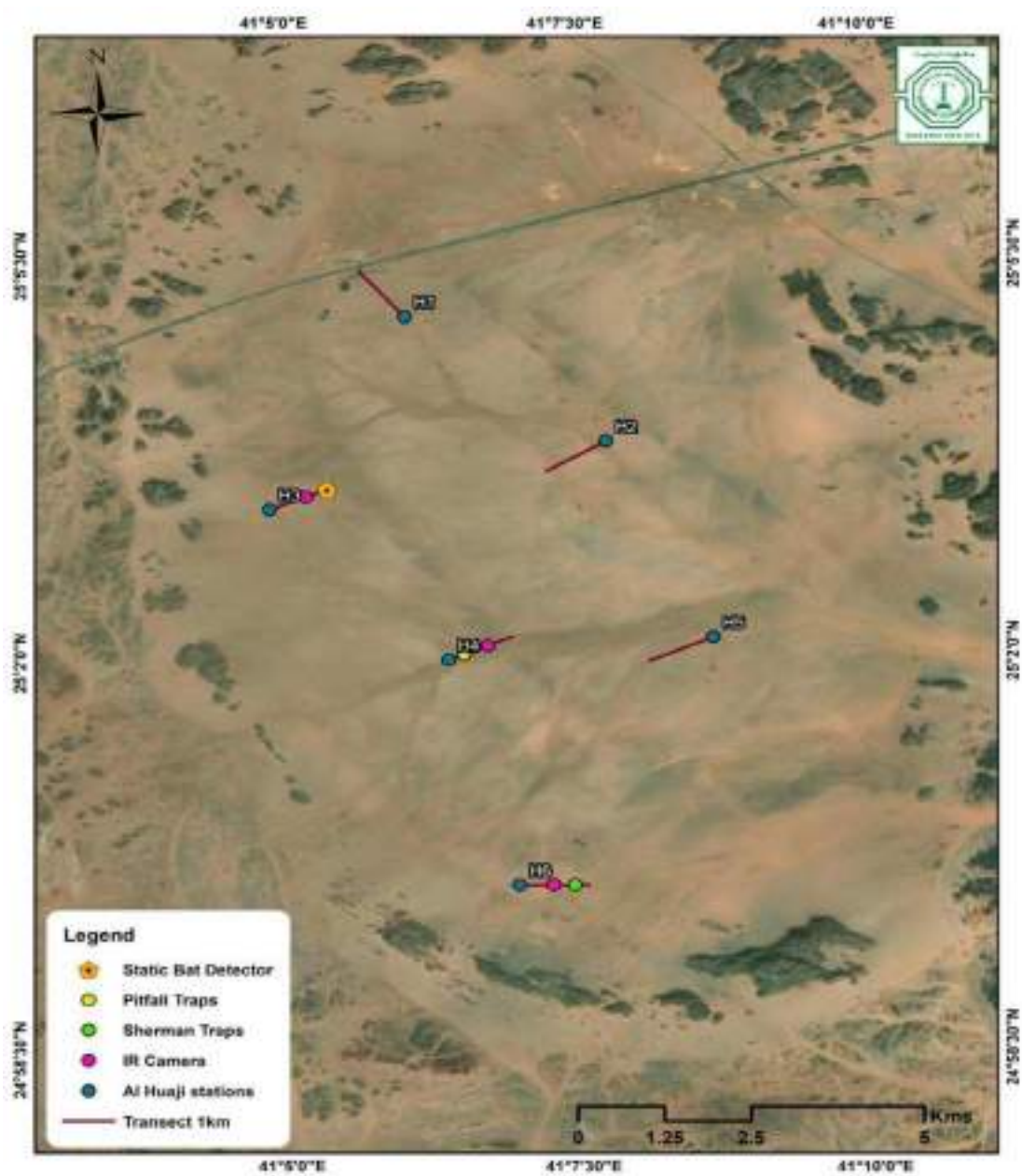


Figure 4.26. Survey locations (fauna) at Al Humaij.

Table 4.9. Deployment of IR Cameras, Pitfall funnel traps, Sherman traps, and Static Bat Recorders across the sites.

Survey	Easting	Northing	Site Name
IR Camera (on Transect 03)	714092.8	2766631	Al Humaij
IR Camera (on Transect 04)	719989.8	3028305	Al Humaij
IR Camera (on Transect 06)	722034.4	3029651	Al Humaij
Pitfall traps (on Transect 4)	712797.8	2770383	Al Humaij
Sherman traps (on Transect 6)	714402.9	2766632	Al Humaij
Static Bat Detector (on Transect 3)	710819.7	2773065	Al Humaij

Daytime walk-through transects surveys: Each transect was surveyed slowly/cautiously between February 1, 2024, to February 7, 2024, during daylight, by two surveyors and on foot with the aid of binoculars. The weather was windy and cool. The survey at one transect took a minimum of three hours and all fauna observed were recorded. In addition, incidental sightings of fauna, footprints, burrows, tracks, scats, and calls, were recorded. During each transect survey, a minimum of four (4) × twenty (20) minute passive ‘sit-and-watch’ surveys and four (4) × twenty (20) minute active (active-search) surveys were conducted to identify and record reptiles.

Night-time drive-through transect surveys: The survey covered the entire transect in both directions, at night between February 1, 2024, to February 7, 2024, to record nocturnal species. These surveys were undertaken from vehicles, aided by high-powered torches/spotlights and stopping at regular intervals along each transect. The survey was carried out between 19:00 and 01:00 hrs. The weather conditions were windy and cool. A passive automated bat detector was used across the transects during night surveys.

An infrared (IR) camera trap (Reconyx HF2X II PERSPIRE) was deployed on February 1, 2024, at Al Humaij, for three days at three stations within each site in areas of vegetation, thereby increasing the likelihood of recording fauna. The weather conditions were generally windy and cool throughout the survey period. The IR Camera was deployed between 0.2 m to 0.5 m in height to detect a range of species, including reptiles and birds. The cameras ran on 12 AA-cell batteries, with Ultimate Lithium Energizer batteries used alongside 512 GB SD cards for each camera trap. The cameras were deployed with the following settings: (1) advanced setting for continuous high-quality images, (2) high sensitivity, (3) three pictures per trigger, and (4) infrared illuminator for nocturnal pictures. The camera traps were mounted on tripods/tree trunks as well as on the ground/sand to capture small mammal and reptile species. Baiting using animal remains from abattoirs and/or fresh chicken was conducted to attract carnivores. A total of 1190 images, including videos, were analyzed. Population density of animals was estimated from the expected number of encounters during the given time period [Nakashima et al., 2018]. An independent event on the IR camera is considered as the detection or non-detection of an animal for each 24-hour sampling interval [Bhattacharya et al; 2022].

Trapping small mammals and reptiles: Two Sherman traps and two Pitfall traps (with an inverted funnel fitted over the trap) were deployed for trapping small mammals and reptiles in the same location. The Sherman traps (model XLF15 - large folding traps, aluminium body, stainless steel springs, and wires; dimensions 10.2 x 11.4 x 38.1 cm, approx. 1.3 cm thick when folded and weigh 544 gm) and Pitfall traps (with inverted funnels) were deployed at each sampling station during the morning time and were retrieved in the following morning. Trap operations procedures were completed within 24 hours and trapped animals were carefully removed.

Avian survey: The transect (1 km) was surveyed from February 1, 2024, to February 7, 2024, between 06:00 and 16:30 hrs. in the Al Humaij areas. The vantage point survey was performed by the count in a 360° area. Direct observations of birds from the transect were recorded. Five-point counts (five to ten minutes) and five vantage point surveys (five to ten minutes) were also completed on the transect. The survey equipment included binoculars (15 x 56), a spotting scope (Swarovski ATX 30-70 x115), and a Global Positioning System (GPS-Garmin GPSMAP 276 CX). The surveyor performed

the count in a 360° area around a fixed survey station. Vantage Point surveys were employed to record flight activity and distribution of avian fauna over the survey area, mainly targeting raptors and other birds in flight. Bird calls heard were used to assist species identification, based on the professional judgment of experienced Ecologists. Cameras were used for digiscoping. These were high-end digital single-lens reflex cameras (DSLRs 0 Sony A9 Full Frame and 200-600 mm teli), and point-and-shoot cameras. Smartphone cameras were also used. This photographic evidence was used to improve the accuracy of species identification/documentation. Any nests found during the surveys were also recorded. Species-level identification was carried out with reference to the relevant field guides [Jennings, 1995].

Manual and automated bat surveys: A mobile bat detector (Anabat Walkabout Bat Detector made by Titley Scientific) was used to record bat calls during the transect survey from a vehicle at night (February 1, 2024, at Al Huaij). The recorded data was transferred to the computer for analysis to identify bats to species or genus level. Four software packages (AnalookW, Anabat Insight, Raven Pro, and Bat explorer) were used to analyze bat calls and identify them at the species level, primarily relying on AnalookW.

4.6.1.2 Relative Abundance

The relative abundance of each species was calculated: $100 \times (\text{Total number of individuals}) / (\text{Total number of individuals (all species) in the sample})$.

4.6.1.3 Data Processing and Analysis

All field data were transferred to Microsoft Excel™ spreadsheets. Statistical analyses (Margalef Index and Shannon Index) were performed using PAST Software 4.03. The Margalef Index was applied to estimate species richness, while the Shannon Index was employed to evaluate the overall diversity of fauna. Species distribution maps were prepared using QGIS based on the GPS locations recorded in the field. All the maps were prepared by following the World Geodetic System (WGS84), the reference coordinate system for the Global Positioning System (GPS).

4.6.2 Results

4.6.2.1 Species Count

Three groups of taxa were recorded at the Al Humaij (Table 4.10): reptiles (two species), birds (16 species), and mammals (six species) (Figures 4.27 to 4.42).

Reptiles

The night survey at Al Humaij observed three Snake-tailed Fringe-toed Lizards (*Acanthodactylus opheodurus*). This species is classified as Least Concern according to the IUCN's conservation status. Additionally, the Rough-tail Rock Agama (*Stellagama stellio*) was also spotted during the survey. It, too, holds a Least Concern status according to the IUCN's conservation assessments.

Birds

A total of 16 species of birds were recorded in the study area and all are within the Least Concern (LC) category of the IUCN Red List. Thirteen species of birds are residents and three are winter visitors. None of the documented species belongs to the high conservation priority based on the first KSA report on the Convention on Biological Diversity.

In Al Humaij, Spanish Sparrow (*Passer hispaniolensis*) (n=154) was noticed in significant numbers.

Mammals

Arabian red fox (*Vulpes vulpes arabica*) (n=2) is a large mammal and was recorded by IR camera. This species is categorized Least Concern of IUCN.

Arabian Wolf (*Canis lupus arabs*) (n=2) was recorded from the site. The Arabian wolf is a subspecies of the gray wolf (*Canis lupus*) that is native to the Arabian Peninsula and nearby areas in the Middle East. Its distribution includes countries such as Saudi Arabia, Jordan, Oman, Yemen, and possibly other neighboring countries in the region. The Arabian wolf, also known as *Canis lupus arabs*, typically has a length of about 1 to 1.3 meters and a height of about 60-70 centimeters at the shoulder.

Cheesman Jerbil (n=16) (*Gerbillus cheesmani*) was also recorded during the survey. Cheesman's Jerbil comes from the whole of the Arabian Peninsula and the sandy areas of Southern Iraq, Southern Iran, and Pakistan, and extends to South Western Afghanistan.

During the survey in the Al Humaij Region, numerous avian species were encountered, with some being residents and others being winter visitors. Additionally, an abandoned nest was documented, and multiple foottracks of Desert Hedgehogs (*Paraechinus aethiopicus*) were observed.



Figure 4.27. Snake tailed fringe toed Lizard *Acanthodactylus opheodurus*.



Figure 4.28. Rough-tailed Rock Agama *Stellagama stellio*.



Figure 4.29. Arabian Great Shrike *Lanius excubitor aucheri*.



Figure 4.30. Bar-tailed Lark *Ammomanes cincturus*.



Figure 4.31. Crested Lark *Galerida cristata*.



Figure 4.32 Desert Wheatear *Oenanthe deserti*.



Figure 4.33. Mourning Wheatear *Oenanthe lugens*.



Figure 4.34. Greater Hoopoe Lark *Alaemon alaudipes*.



Figure 4.35. Isabelline Wheatear *Oenanthe isabellina*.



Figure 4.36. Lesser Whitethroat *Sylvia curruca*.



Figure 4.37. Spanish Sparrow *Passer hispaniolensis*.



Figure 4.38. Golden Spiny Mouse *Acomys russatus*.



Figure 4.39. Abandoned nest (probably Long-legged Buzzard).



Figure 4.40. Arabian Red Fox *Vulpes vulpes arabica* in IR Camera.



Figure 4.41. Arabian Woolf Red Fox *Canis lupus arabs* in IR Camera.



Figure 4.42. Deployment of Sherman traps for smaller mammals.

4.6.2.2 *Relative Abundance*

Birds

Birds were the most diverse and abundant group of fauna recorded during the surveys, The most abundant bird species was Spanish Sparrow (n=154) (Figure 4.14). followed by mammals (including bat species) and reptiles.

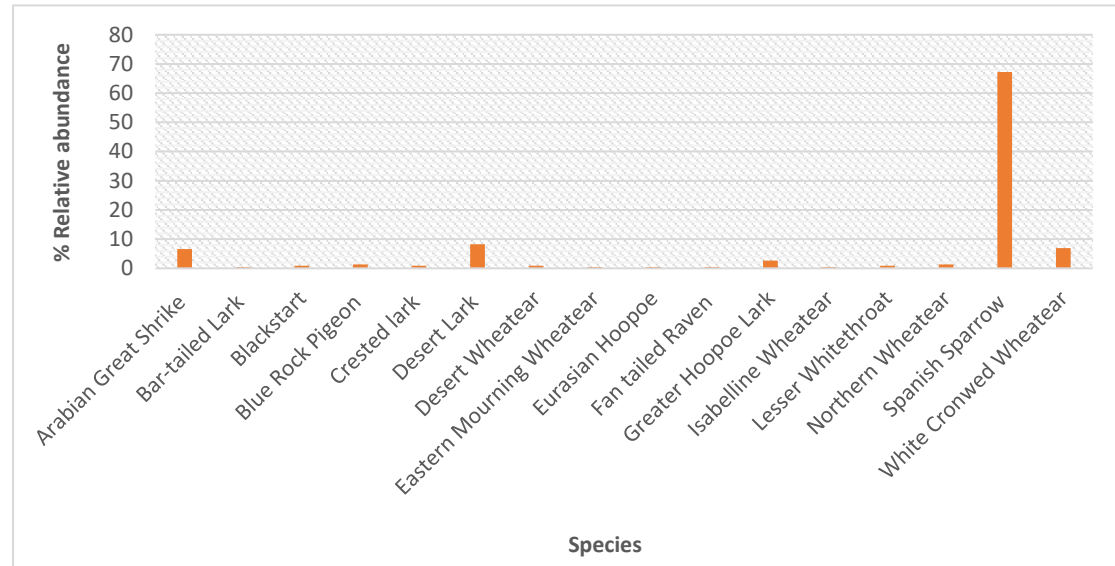


Figure 4.44. Relative abundance of birds from Al Humaij.

Reptiles

Two species of reptile were encountered during the survey (Figure 4.43).

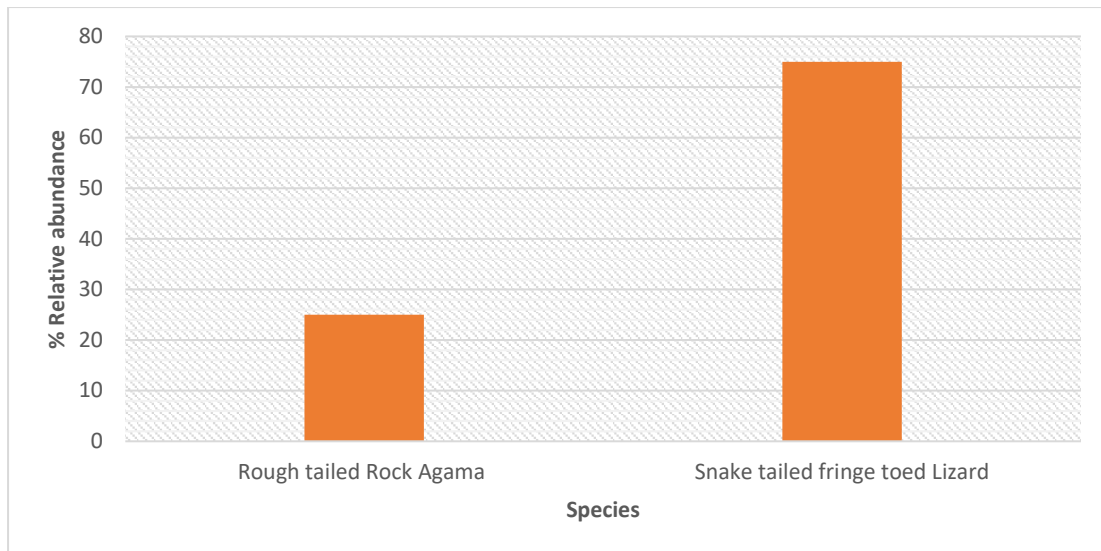


Figure 4.43. Relative abundance of reptiles from Al Humaij.

Mammals

Four mammal species (excluding bats) were recorded (Figure 4.45).

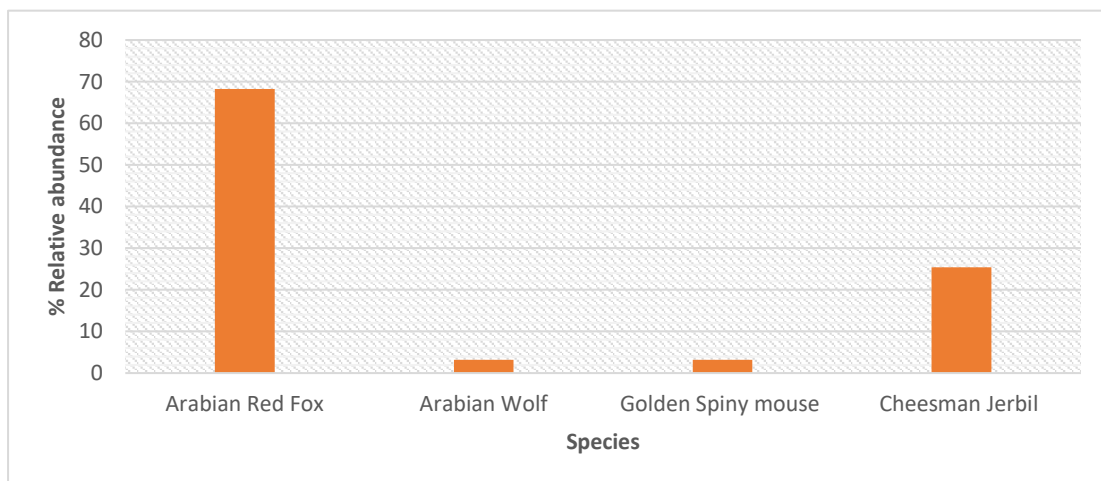


Figure 4.45. Relative abundance of mammals from Al Humaij.

4.6.2.3 Species Richness

Overall species-richness (Margalef Index, Figure 4.46) recorded by the surveys, combining birds, reptiles and mammals and excluding bats which are described separately below, was highest at Transect 1 (3.107), followed by Transect 3 (2.377), Transect 2 (2.216), Transect 5 (1.504), Transect 4 (0.8909) and Transect 6 (0.6139).

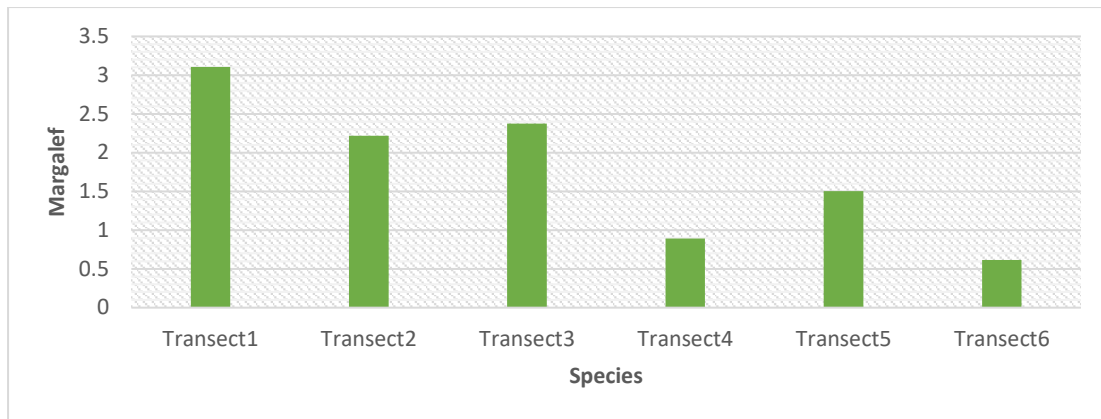


Figure 4.46. Species richness (birds, mammals, amphibians, reptiles combined): Al Humaij

4.6.2.4 Species Diversity

Overall diversity (Shannon Index, Figure 4.47) recorded by the surveys, combining birds, reptiles, and mammals and excluding bats which are described separately below, was highest at Transect 1 (2.192), followed by Transect 3 (1.777), Transect 5 (1.088), Transect 4 (0.9695), Transect 6 (0.7913) and Transect 2 (0.731).

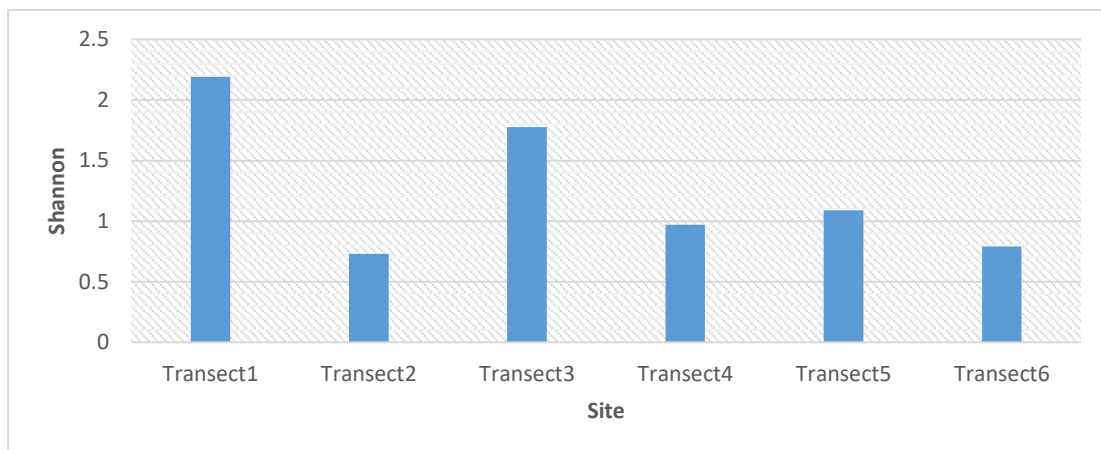


Figure 4.47. Species diversity (birds, mammals, reptiles combined): Al Humaij

4.6.2.5 Bats

Bat call structures and characteristic metrics were analysed using AnalookW Sound Analysis Software and compared with those included in published scientific literature and libraries of bat calls/acoustics [Benda et al. 2008; Chakravarty, 2020; Hackett et al., 2016 and Maktom et al., 2021]. This included an analysis of 4770 Call Pulses, across 118 potential ultrasound files, out of a total of 1230 files recorded during the period 19th January 2024 - 24th January 2024 from the Al-Humaij study area. This revealed the presence of three bat species: Christie's Big-eared bat / Christie's Long-eared bat (*Plecotus christii*), Greater Mouse-tailed bat (*Rhinopoma microphyllum*), and Geoffroy's Trident Leaf-nosed bat (*Asellia tridens*); out of which first one is considered in the Data Deficient (DD) whereas the other two are in the least Concerned (LC) categories of IUCN Red List. The ultrasonic calls emitted by these species (Figure 4.48 to 4.49) are in the frequency range of 18.901 kHz (Kilohertz) to 118.967 kHz.

Christie's Big-eared bat / Christie's Long-eared bat, *Plecotus christii* is found at one geographical location across the entire study area with a sea level of 1145 Meter. It emitted FM Calls (Frequency Modulated Calls) with pulse duration varying in the range of 8.2 To 16.4 ms and range of frequency noted as FSTART 40.4 ± 2.1 through FEND 15.9 ± 1.5 kHz (Figures 4.50 & 4.51; Hackett et al., 2016).

The Greater Mouse-tailed bat, *Rhinopoma microphyllum* is found at one location across the entire study area with a sea level of 1119 Meter. It emitted FM (Frequency Modulated) multi-harmonic calls with pulse duration of its dominant second harmonic varying in the range of 10.2 to 18.3 ms and range of frequency noted as FSTART 33.1 ± 1.2 kHz through FEND 29.1 ± 1.5 kHz respectively (Figures 4.52 & 4.53). The observed characteristics of the calls are similar to what has been reported for *Rhinopoma microphyllum* (Chakravarty, 2020).

Geoffroy's Trident Leaf-nosed bat, *Asellia tridens* is found at one geographical location in the entire study area with a sea level of 1108 Meter. It emitted CF - FM Calls (Constant Frequency - Terminal Frequency Modulated Calls) multi-harmonic calls with the pulse duration of its dominant second harmonic varying in the range of 7.68 to 8.26 ms and range of constant frequency (CF) noted as Starting Frequency (FSTART) 118 ± 0.8 through End Frequency (FEND) 115 ± 1.6 kHz. The observed call characteristics are similar to what has been reported for *Asellia tridens* (Benda et al. 2008; Hackett et al., 2016 and Maktom et al., 2021).

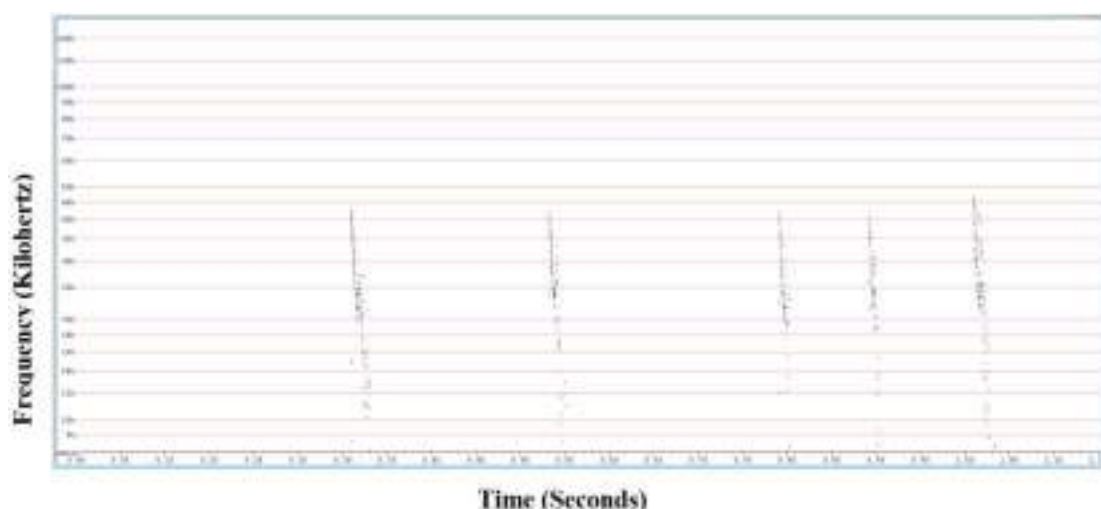


Figure 4.48. Graphical Zero Crossing (ZC) representation of the calls of Christie's Big-eared bat / Christie's Long-eared bat, *Plecotus christii* observed in AnalookW Sound Analysis Software for recorded Zero Crossing (ZC) Ultrasound File No.: 2024-01-21_15-18-18.

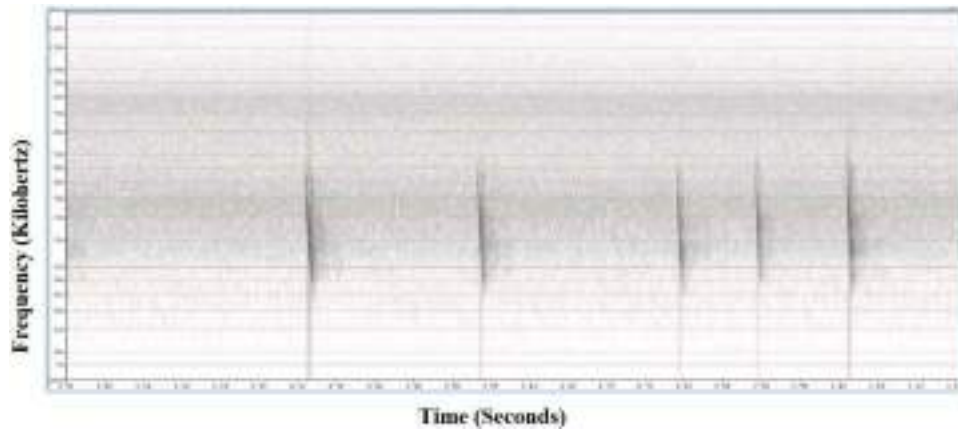


Figure 4.49. Graphical Fast Fourier Transform (FFT) representation of the calls of Christie's Big-eared bat / Christie's Long-eared bat, *Plecotus christii* observed in AnalookW Sound Analysis Software for recorded Wave Ultrasound File No.: 2024-01-21_15-18-18.

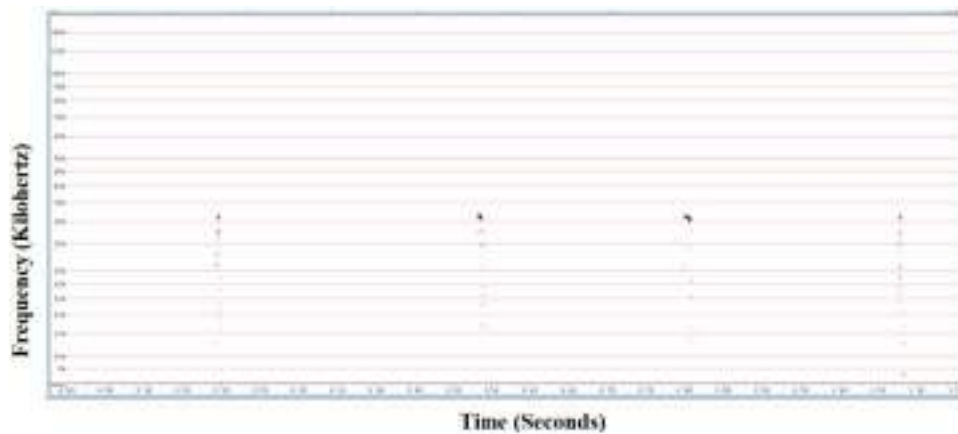


Figure 4.50. Graphical Zero Crossing (ZC) representation of the calls of Greater Mouse-tailed bat, *Rhinopoma microphyllum* observed in AnalookW Sound Analysis Software for recorded Zero Crossing (ZC) Ultrasound File No.: 2024-01-22_21-46-32.

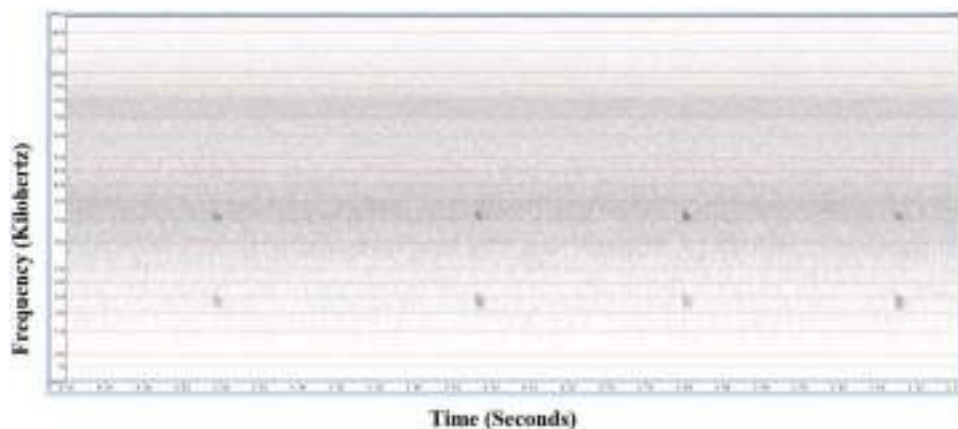


Figure 4.51. Graphical Fast Fourier Transform (FFT) representation of the calls of Greater Mouse-tailed bat, *Rhinopoma microphyllum* observed in AnalookW Sound Analysis Software for recorded Wave Ultrasound File NO.: 2024-01-22_21-46-32.

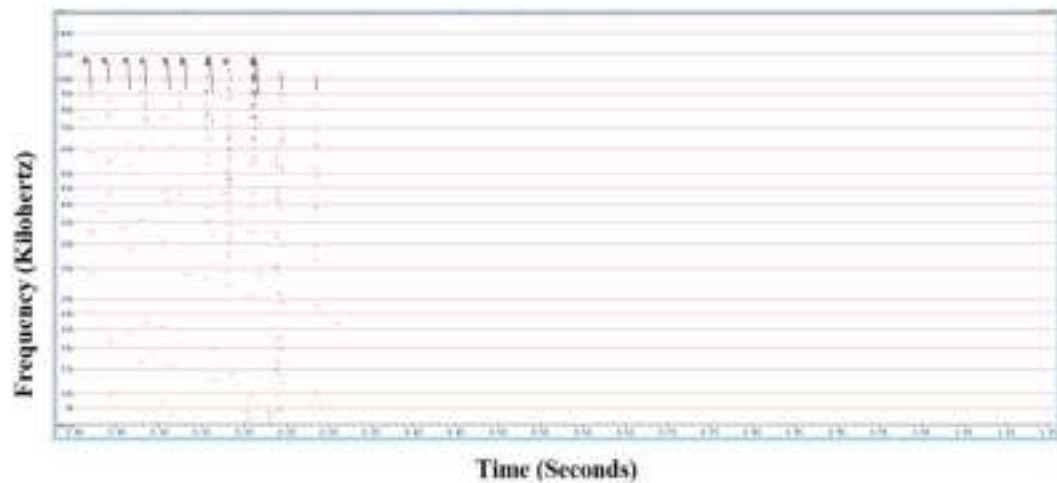


Figure 4.52. Graphical Zero Crossing (ZC) representation of the calls of Geoffroy's Trident Leaf-nosed bat, *Asellia tridens* observed in AnalookW Sound Analysis Software for recorded Zero Crossing (ZC) Ultrasound File No.: 2023-09-15_07-43-00.

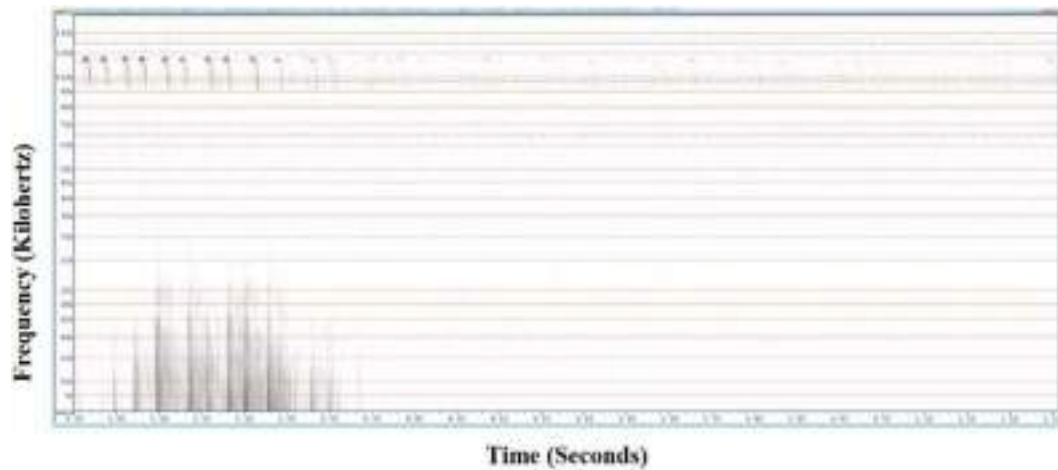


Figure 4.53. Graphical Fast Fourier Transform (FFT) representation of the calls of Geoffroy's Trident Leaf-nosed bat, *Asellia tridens* observed in AnalookW Sound Analysis Software for recorded Wave Ultrasound File No.: 2023-09-15_07-43-00.

Table 4.10. List of fauna recorded from the Al Humaij

Sl. No	Taxa	Species	Scientific Name	IUCN Ver 3.1	First Biodiversity Report KSA	Updated KSA Report (Boland and Burwell, 2020) Ranking*	Updated KSA Report (Boland and Burwell, 2021) Ranking*
1	Reptile	Rough tailed Rock Agama	<i>Stellagama stellio</i>	LC	-	-	-
2	Reptile	Snake tailed fringe toed Lizard	<i>Acanthodactylus opheodurus</i>	LC	-	-	90 (LC)
3	Bird	Arabian Great Shrike	<i>Lanius excubitor aucheri</i>	LC	-	-	-
4	Bird	Bar-tailed Lark	<i>Ammomanes cincturus</i>	LC	-	-	-
5	Bird	Blackstart	<i>Oenanthe melanura</i>	LC	-	101 (LC)	-
6	Bird	Blue Rock Pigeon	<i>Columba livia</i>	LC	-	-	-
7	Bird	Crested lark	<i>Galerida cristata</i>	LC	-	86 (LC)	-
8	Bird	Desert Lark	<i>Ammomanes deserti</i>	LC	-	-	-
9	Bird	Desert Wheatear	<i>Oenanthe deserti</i>	LC	-	-	-
10	Bird	Mourning Wheatear	<i>Oenanthe lugens</i>	LC	-	-	-
11	Bird	Eurasian Hoopoe	<i>Upupa epops</i>	LC	-	-	-
12	Bird	Fan tailed Raven	<i>Corvus ruficollis</i>	LC	-	-	-
13	Bird	Greater Hoopoe Lark	<i>Alaemon alaudipes</i>	LC	-	-	-
14	Bird	Isabelline Wheatear	<i>Oenanthe isabellina</i>	LC	-	98 (LC)	-
15	Bird	Lesser Whitethroat	<i>Sylvia curruca</i>	LC	-	-	-
16	Bird	Northern Wheatear	<i>Oenanthe oenanthe</i>	LC	-	-	-
17	Bird	Spanish Sparrow	<i>Passer hispaniolensis</i>	LC	-	-	-
18	Bird	White Crowned Wheatear	<i>Oenanthe leucopyga</i>	LC	-	100 (LC)	-
19	Mammal	Arabian Red Fox	<i>Vulpes vulpes arabica</i>	LC	-	-	-
20	Mammal	Arabian Wolf	<i>Canis lupus arabs</i>	LC	-	-	-
21	Mammal	Golden Spiny mouse	<i>Acomys russatus</i>	LC	-	-	77 (LC)
22	Mammal	Cheesman Jerbil	<i>Gerbillus cheesmani</i>	LC	-	-	-
23	Mammal	Greater Mouse-tailed bat	<i>Rhinopoma microphyllum</i>	LC	-	-	79 (LC)
24	Mammal	Christie's Big-eared bat	<i>Plecotus christii</i>	DD	-	-	-
25	Mammal	Geoffroy's Trident Leaf-nosed bat	<i>Asellia tridens</i>	LC	-	-	-

NL - Not Listed as HCP species in the First KSA Report; LC – Least Concern; EN- Endangered; VU – Vulnerable; DD – Data Deficient **Mentioned as species requiring special attention;

*Regional conservation status provided

4.6.2.6 *Species Distribution*

The species distribution of fauna recorded at Al Humaij is summarized in Figures (4.54-4.56).

Arabian Great Shrike and Desert Lark were the most abundant bird species. Arabian Great Shrike was observed from Transect 1, Transect 2, Transect 4, and Transect 5. Desert Lark was observed at all sites. Steppe Eagle was observed from Transect 1, Transect 2, and Transect 3.

Cheeseman Jerbil was observed from Transect 5. A single individual of Snake-tailed fringe toed lizard was observed from Transect 1 and Transect 2.

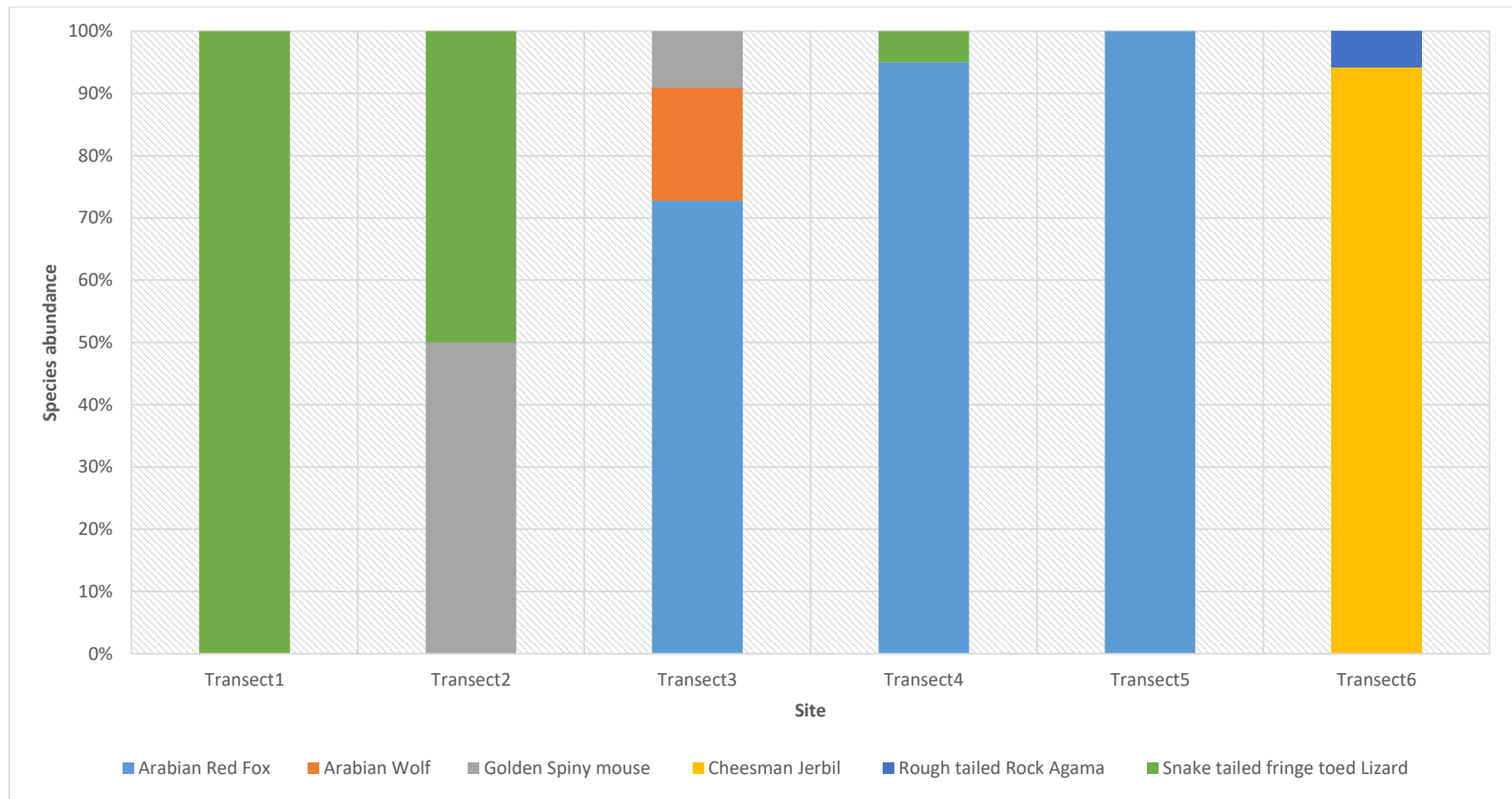


Figure 4.54. Species distribution of fauna (mammals and reptiles) across survey stations: Al Humaij.

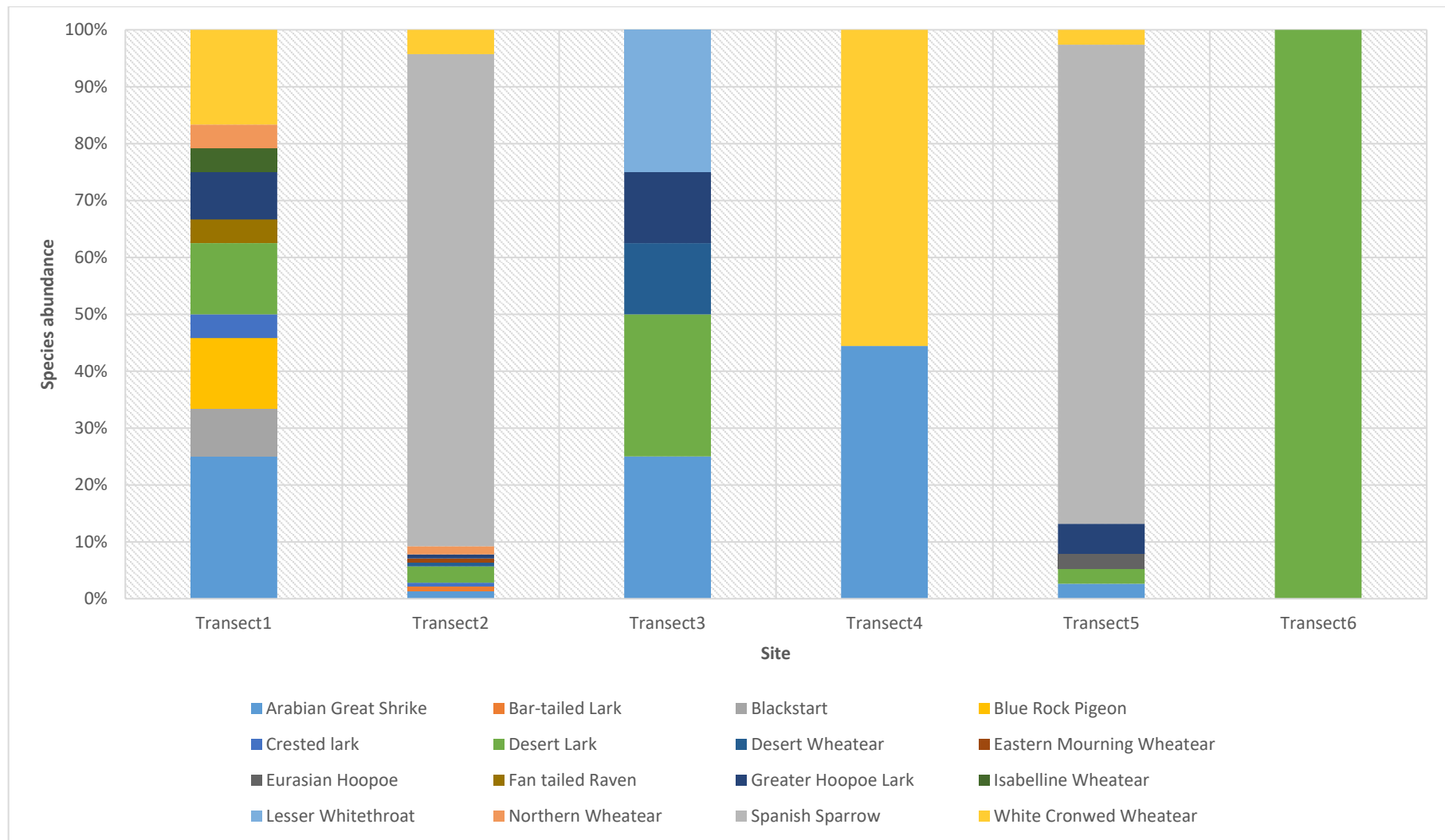


Figure 4.55. Species distribution of avian fauna across survey stations: Al Humaij.

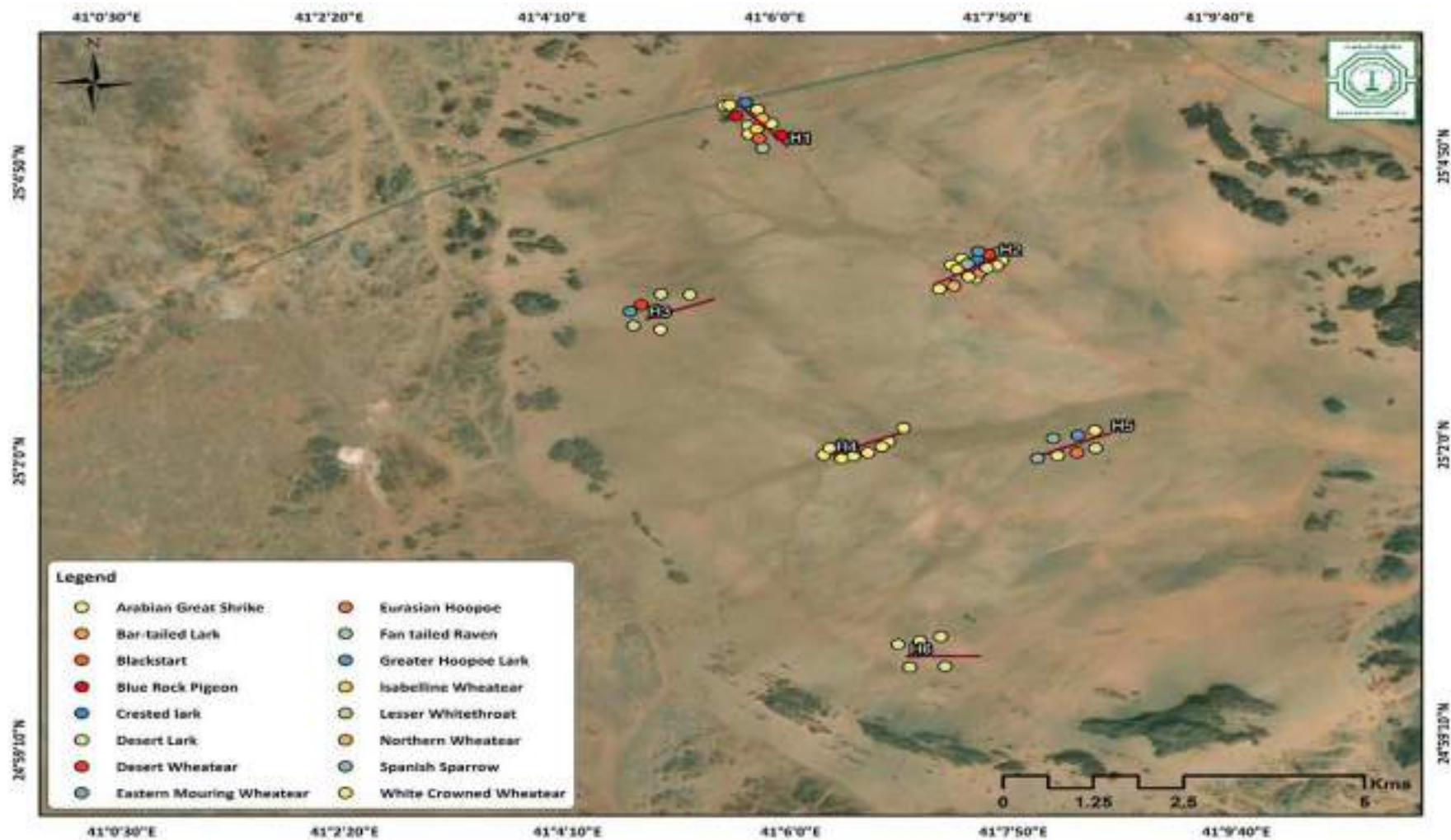


Figure 4.56. Species distribution of avian fauna across survey stations: Al Humaij.

4.6.2.7 Migrant and Resident Birds

Out of the 16 species of birds recorded from the Al Humaij region, 10 are resident species and 06 are winter visitors (Table 4.11).

The Arabian (Great) Grey Shrike subspecies that occur in Saudi Arabia, *aucheri* (mainly in eastern areas), have been reported from areas in close proximity, such as eastern Egypt, and northeast Sudan, indicating the possibility of gene flow between them. Interbreeding occurs freely between *Pallidirostris* and the locally breeding Great Grey Shrike subspecies *aucheri*, with an intermediate population occurring in northeast Iran. These birds could quite easily occur in the Eastern Province of Saudi Arabia as well. They were common in the Al Humaij region.

The Blackstart (*Cercomela melanura*) is a common resident of rocky desert areas, except in the east and northeast regions of the Kingdom. Birds occur eastwards to Riyadh, where they are relatively common at the base of the escarpment, mainly recorded at Acacia trees. This species was common in the Al Humaij region.

Blue Rock Pigeons (*Columba livia*) had an extensive primordial distribution in Eurasia and North Africa prior to the human development of domesticated strains and their feral offshoots. Pigeons (Columbiformes: Columbidae) are found around the world except at the poles. They are known to show significant variation in size geographically. The population in the Arabian Peninsula is estimated to be over 950,000 pairs. They were common at Al Humaij.

Two lark species were encountered during the survey. The Crested Lark (*Galerida cristata*) is a resident bird found in a variety of desert and coastal habitats. Desert Lark (*Ammomanes deserti*) is a bird that spends most of its life on dry, rocky slopes, avoiding sandy areas. Crested Lark and Desert Lark were common in the survey regions of Al Humaij.

The Greater Hoopoe Lark (*Alaemon alaudipes*) is found in arid, hot desert or semi-desert conditions and can survive in temperatures of up to 50 degrees Celsius.

Five species of Wheatear were encountered during the survey. The Desert Wheatear (*Oenanthe deserti*) inhabits rocky or sandy dry steppes, desert, and semi-desert plains with sparse vegetation. The Mourning Wheatear (*Oenanthe lugens*) is found in desert, semi-desert, rocky valleys and ravines, and dry riverbeds or wadis. The Northern Wheatear (*Oenanthe oenanthe*) uses a variety of open habitats while migrating, including cultivated areas and deserts, farmlands as well as human settlements. The White-crowned Wheatear (*Oenanthe leucopyga*) breeds in stony deserts from the Sahara and Arabia across to Iraq. Desert Wheatear and Northern Wheatear are common winter visitors and passage migrants in various regions of the Kingdom. Isabelline Wheatear (*Oenanthe isabellina*) is a ground-dwelling bird that prefers open arid plains.

The Eurasian Hoopoe (*Upupa epops*) population in the Arabian Peninsula is around 100,000. While few are considered native, many migrate from equatorial Africa to Eurasia to breed. They were commonly observed in the Al Humaij Region.

The Lesser Whitethroat (*Sylvia curruca*) is found in Acacias and mature urban gardens during migration. They were observed in the Al Humaij Region.

The Spanish Sparrow (*Passer hispaniolensis*) is found in dry/arid areas, often near cultivated areas, with a range extending into the Mediterranean region and southwest and central Asia. They were observed in Al Humaij.

Table 4.11. Migration status of birds recorded from the Al Humaij

Sl. No	Taxa	Species	Migration Status*
1	Bird	Arabian Great Shrike	R/NB
2	Bird	Bar-tailed Lark	R/NB
3	Bird	Blackstart	R/NB
4	Bird	Blue Rock Pigeon	R/NB
5	Bird	Crested lark	R/NB
6	Bird	Desert Lark	R/NB
7	Bird	Desert Wheatear	WV
8	Bird	Eastern Mourning Wheatear	R/NB
9	Bird	Eurasian Hoopoe	R/NB
10	Bird	Fan tailed Raven	R/NB
11	Bird	Greater Hoopoe Lark	R/NB
12	Bird	Isabelline Wheatear	WV
13	Bird	Lesser Whitethroat	PM/WV
14	Bird	Northern Wheatear	WV
15	Bird	Spanish Sparrow	WV
16	Bird	White Crowned Wheatear	R/NB

R- Resident; NB- Non-Breeding, PM- Passage migrant, WV- Winter Visitor * Based on field experiences

4.6.2.8 Species Conservation Importance

All species documented during the survey are classified under the Least Concern (LC) category, except for Christie's Big-eared bat, which falls under the Data Deficient (DD) category.

4.6.3 Summary and Conclusions

The Madeena Region's Al Humaij showcases notable species diversity, featuring a broad array of flora and fauna thriving in its diverse ecosystems. This variety is credited to the region's diverse terrain, encompassing mountains, valleys, and desert plains, which offer distinctive habitats for a multitude of plant and animal species.

Three groups of fauna taxa were recorded in the Al Humaij Region: birds (16 species), reptiles (two species), and mammals (six species). Birds were the most abundant fauna recorded, followed by mammals and reptiles. Except for Christie's Big-eared bat (*Plecotus christii*), which is Data Deficient, the rest of the recorded species are within the 'Least Concern' category of the IUCN Red List. Therefore, more studies are required to be carried out to get a clear picture of the abandoned nest and the above-mentioned species, including autumn and spring migratory movements.

4.7 TERRESTRIAL HABITAT

4.7.1 Methodology

A field survey was conducted to identify the major habitats at the project site. The GPS location was recorded along with photographs of the habitat and the associated plant species. Associated fauna species in each habitat were recorded.

4.7.2 Results

The broad habitat type in the Humaij site is a sand sheet. The sand is consolidated, semi-consolidated, with isolated rocky patches or sometimes mixed with gravel at different locations within the site. Accordingly, vegetation composition varies based on the soil characteristics.

Sand sheet with consolidated soil supports the Acacia vegetation along with other species such as *Haloxylon salicornicum*, and *Citrullus colocynthis* (Figure 4.57). Sand sheet mixed with gravel in this site was devoid of Acacia trees but with other herbs and shrubs such as *Arnebia hispidissima*, *Haloxylon salicornicum*, and *Senna italica*.

Sand sheets with isolated rocky patches were less vegetated (Figure 4.58). *Lyceum shawii* was one of the species growing there along with other species such as *Haloxylon salicornicum*, and *Citrullus colocynthis*.

The habitat at the Al Humaij site lacks sensitivity or criticality and does not support any plant species listed as threatened by the IUCN. Nonetheless, the presence of numerous healthy Acacia trees within the sand sheet, where the sand is consolidated, highlights the significance of this habitat for birds (Figures 4.59 and 4.60).



Figure 4.57. Sand sheet with consolidated sand associated with Acacia vegetation.



Figure 4.58 Sand sheet with isolated rocky patches with scattered vegetation



Figure 4.59. Resident House Sparrow species in Acacia tree.



Figure 4.60. Resident Greater Hoopoe lark in Acacia tree trunk.

4.7.3 Conclusion

Sand sheet with consolidated soil, rocky patches, or gravel sheets was the broad habitat in the Al Humaij site. Acacia trees were dominant in the consolidated sand sheet, *Lyceum shawii* was the dominant species in the isolated rocky patches. Though habitat is not critical or sensitive, sand sheets with consolidated soil are important habitats as the Acacia trees are economically and ecologically important.

4.8 SOCIO-ECONOMY, ARCHAEOLOGICAL AND CULTURAL HERITAGE ASPECTS

The socioeconomic impact assessment aims to identify and evaluate the potential impact of the solar power project on nearby communities. Residents of neighborhoods in the vicinity of the project are directly affected by the establishment of the solar power project, either positively or negatively. The impact also extends to the future settlement near the solar power project and is related to the rehabilitation of the settlement.

This section provides a summary of various socioeconomic variables for the communities around the solar power project. Mainly, it provides summary statistics of the population, dwellings, and value of real estate properties near the project area. The section also provides a statistical analysis of the key environmental issues faced by solar power projects and a summary of the geological and cultural heritage of the project site.

The baseline data described in this section give insights into the potential socioeconomic impact and possible mitigation measures, which are discussed later in section 6.6.

The socioeconomic impact of the project is evaluated qualitatively and quantitatively depending on the availability of the data. The data used in this section is collected from various publicly available administrative data for the area of the project.

4.8.1 Population

The data on the population and dwellings of the communities in and around solar power was obtained from the latest Saudi Population Census [2022] which has been conducted by the General Authority for Statistics (GASTAT)(Table 4.12). The online portal of the census provides the population for small grids that can be accessed using an interactive map [Interactive Map, 2022]. The data also provides the number of different types of dwellings that exist in the grid (grid reference 1.6×1.6 kilometers), such as the number of total dwellings, total population, and household average size (Figure 4.61). The source also allows us to identify the number of rented versus owned residential properties in the area. The data shows a limited population in and around the project area. However, comparing satellite images and field observation indicates the temporary settlement at the project site, which is been evacuated.



Figure 4.61. Limited number of household Saudi Population Census [2022].

Table 4.12. Grid-wise population in and around the project site.

Grid 1	Category	Nos
	Total Population	96
	Population Density	150.00/sq.km
	Male Population	44
	Female Population	52
	Median Age (Male)	20
	Median Age (Female)	22

*Source: Saudi Census 2022

4.8.2 Socio-Cultural Features

Key Socio-economic Features in the Project Sites area:

- Electric lines and communication lines have been recorded on the project site (Figure 4.62).
- The roads connect to the project site with the nearby city and settlement.
- Local camps of the people for the grazing activity in the project areas (Figures 4.63 and 4.64)
- No significant agricultural and industrial activity has been observed at the project site.
- No significant archaeological and heritage sites have been observed in the project site.
- Some settlement areas have been identified within 1.0 km of the boundary of the project site.
- During the survey ruins of the waste of the old farm were recorded.



Figure 4.62. Electric tower and line in the project site.



Figure 4.63. Camel grazing activity in the project site.

4.8.4 Unemployment

The General Authority for Statistics reports labor statistics quarterly, including unemployment¹ for different regions in the Kingdom. According to the latest report², the unemployment rate in the first quarter of 2024 in the Makkah region for Saudi citizens was 9%. Figure 4.65 compares the unemployment rate for Saudi citizens in the Makkah region with the national unemployment average by sex. As can be seen, the unemployment rate among male Saudi nationals was around 4%, which was in line with the national average. However, unemployment among female job seekers was strikingly higher at 18%. Furthermore, unemployment among females in Makkah region is higher than the national average of 14%.

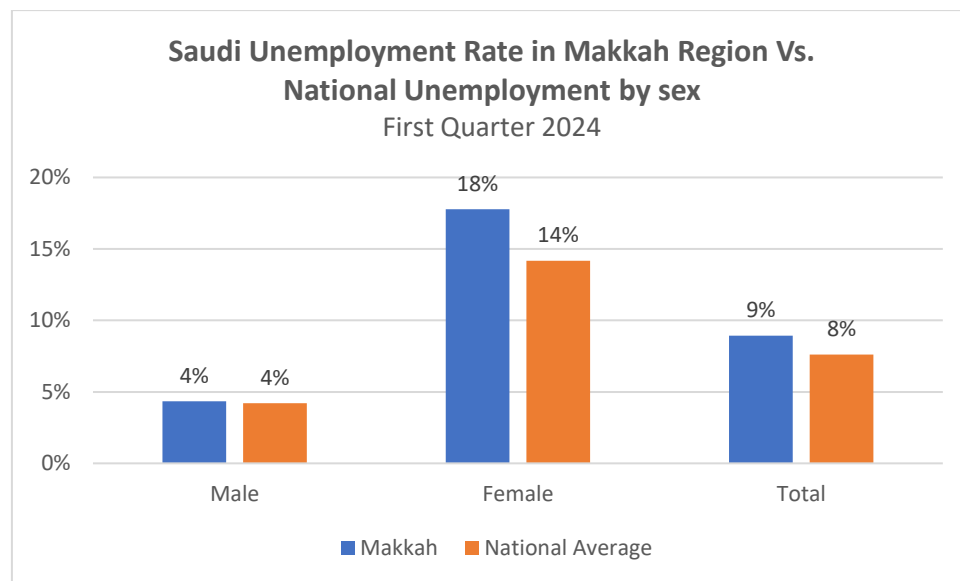


Figure 4.65. Saudi Unemployment Rate in Makkah Region Vs. National Unemployment by sex in the First Quarter of 2024

4.8.5 Conclusion

Settlement: the population in and around the project site is around 96 people, which is extracted from the Saudi Census 2022. During the field survey ruins of the temporary camps were identified,

Cultural features: cultural features include the camps, farms, and the transport and communication line. No major archeological and cultural features have been identified that have a potential effect during the construction.

Industry and Agricultural Activity: No significant industry and agricultural activity has been observed except the private farm.

¹ Unemployment is defined as the proportion of jobseekers (actively searching for job opportunities) who cannot find jobs. It is normally calculated as the ratio of the jobseekers to the total labor force. The total labor force is calculated the sum of the number of jobseekers (unemployed) and employed.

² Source: [Labor Market Statistics Q1/2024](#), General Authority for Statistics

Unemployment: The Makkah region has an unemployment rate of 9% among Saudis, which is higher than the national average of 8%. However, disparities in unemployment by gender exist. While unemployment among Saudi males is 4%, it is 18% among Saudi females.

4.9 WASTE MANAGEMENT AND MINIMIZATION

4.9.1 Introduction

The proposed construction and installation activities for the solar energy parks at Al Humaij, Al Madinah are expected to generate a significant amount of waste. The general categories of expected waste are waste generated during construction and installation activities. Quantification of waste generation is possible by three independent means i.e. (i) by obtaining records of wastes generated from the contractor(s) daily, (ii) by making estimates of the likely quantities of wastes generated by the workforce, and (iii) by obtaining data from project proponents. However, this data is not provided by the client. Therefore, only the estimation of project waste is made, and general guidelines for the proper management of waste are provided.

This sub-section discusses waste management focusing on the following elements.

- Identification of the potential type of generated solid waste during construction, activities of the Project.
- Assessment of the potential environmental impacts that are associated with the handling and disposal of wastes.
- Recommendation of suitable measurement and good practices based on applicable legislation and guidelines for waste handling, storage, and disposal.

Waste Generated during construction, Activities

A significant amount of Class-I (hazardous) and Class-II (non-hazardous) waste is expected to be generated during the construction activities. The expected hazardous waste may include used oil, waste paint, contaminated cans, used oil filters, chemicals, and electronic waste (*E-Watse*). The expected non-hazardous waste includes metal scrap, glass, paper products, plastic, wood pallets, trash, and food waste. The expected types of hazardous, non-hazardous, inert, and municipal waste are tabulated in Tables 4.13, 4.14, 4.15, and 4.16 respectively.

The general categories of expected waste are:

- Sanitary and domestic waste
- Waste generated during construction activities

Relevant Legislation, Standards and Guidelines

The following legislation relates to the handling, treatment, and disposal of wastes in the Kingdom of Saudi Arabia has to be used to assess potential environmental impacts:

Adherence to stringent environmental standards is imperative in the handling, treatment, and disposal of wastes, several key regulations govern these processes, such as Executive Regulations for Waste Management System approved by National Center for Waste Management in 2021 [MWAN, 2021], Executive Regulations for the Protection of Aqueous Media from Pollution approved by Ministry of Environment, Water, and Agriculture in 2019 [MEWA, 2019], the International Finance Corporation (IFC) Performance Standards on Environmental and Social Sustainability [IFC, 2012], world bank group environmental, health and safety guidelines (EHS Guidelines, 2007), are playing a crucial role in assessing and mitigating potential environmental impacts.

4.9.2 *Impact Assessment*

Construction personnel are expected to generate a considerable amount of solid and liquid waste. The expected number of people to be involved in the construction phase is around 1,100, and the amount of waste generated per person per day can be estimated based on previous observations.

4.9.2.1 *Solid Waste*

Solid waste generation from the workforce includes sanitary waste and food waste. The expected types of municipal waste are tabulated in Table 4. Solid waste generation would range between 0.16 and 5.7 kg/capita/day with an average value of 1.1 kg/capita/day.

Before disposal, food waste shall be comminuted or ground to pass a screen with openings not greater than 25mm. Where impracticable food refuse shall be stored in nonabsorbent and easily cleaned containers, fitted with tight covers; after each emptying, each container shall be thoroughly scrubbed, washed, and treated with disinfectant.

4.9.2.2 *Liquid Waste*

Sanitary and domestic wastewater will be generated by the workforce involved in the construction phase. Assuming a daily use rate of 50-100 gallons per person, the quantity of wastewater to be generated can be estimated. While this results from the need for personal hygiene (bath, garment cleaning, etc.), there could also be a generation of wastewater from the kitchen. The specific characteristics of these waste streams are unknown. However, the expected categories of wastewater produced will be black water and grey water. On average, a human being eliminates 128g of faeces and, with this average, the total excreta generation can be estimated.

Table 4.13. Potentially Hazardous

Waste Type	Waste Stream	Estimated Quantity	Disposal Option	Recycling Company/Disposal Location
Waste Oil	Construction & Commissioning	8 to 12 ton	Recycle & Reuse	Licensed Waste Collector
Paint & Thinner	Construction (Surface Preparation)	< 2 ton	Dispose or Reuse	Licensed Waste Collector

Waste Type	Waste Stream	Estimated Quantity	Disposal Option	Recycling Company/Disposal Location
Fuel (Diesel, Petrol & Grease)	Camps, Construction & Commissioning (General)	2 to 5-ton	Recycle & Reuse	Licensed Waste Collector
Oil Filters	Construction (dredging)	< 1 ton	Incineration	Licensed Waste Collector
E-Waste	Construction (Solar panels installation)	< 5 ton	Recycle / Dispose	Licensed Waste Collector
Oily Rags & Spill Absorbent Pads	Construction (Maintenance & Commissioning)	< 1 ton	Incineration	Licensed Waste Collector

Table 4.14. Potential Non-Hazardous Industrial Waste

Waste Type	Waste Stream	Estimated Quantity	Disposal Option	Recycling Company/Disposal Location
Air Filters	Construction & Commissioning	< 2 ton	Landfill	Licensed Waste Collector
Water Filters	Construction & Commissioning	2 to 5-ton	Landfill	Licensed Waste Collector
PPE & Clothing	Construction & Commissioning	< 3 ton	Landfill	Licensed Waste Collector

Table 4.15. Potential Inert Waste

Waste Type	Waste Stream	Estimated Quantity	Disposal Option
Cut & Excavation Material	Site Preparation & Surface Grading	100,000 to 150,000 M ³	Landfill or backfill if not contaminated
Plastics	Warehouse	10 to 15-ton	Recycle (Plastics) Landfill (Foams)
Wood pellets	Solar cells packaging	20 to 40-ton	Recycle
Cables/Copper	Site Preparation & Electrical	5 to 10-ton	Recycle

Table 4.16 Potential Municipal Waste

Waste Type	Waste Stream	Estimated Quantity	Disposal Option	Recycling Company/Disposal Location
Food and Vegetable Scraps	Kitchen	5 to 10 to per month	Landfill	Licensed Waste Collector
Cooking Oil	Kitchen	0.5 to 1 ton per month	Recycle	Licensed Waste Collector
Waste Paper, Cardboard	Office and Warehouse	< 2 ton	Reuse Recycle	
Plastic Containers, Drums, and Bottles	Construction and Warehouse	10 to 15-ton	Recycle	Licensed Waste Recycler
Glass	Office, Kitchen, Camps	8 to 10-ton	Recycle, Landfill	Licensed Waste Collector
Metal Containers, Drums, and Drink Cans	Office/Camp	2 to 5-ton	Recycle	Licensed Waste Collector

4.9.3 Mitigation Measures

4.9.3.1 General Guidelines

Adopt the required waste management protocols, and standards during the construction phase Adopt the four R's (Reduce, Reuse, Recycle, and Recover) strategy to minimize waste requiring disposal.

For all project activities, including the following measures to reduce waste generation, but not limited to:

1. Make efforts to minimize waste generation and disposal, where feasible. Use a Waste Management System to manifest any hazardous waste.
2. Collect and dispose of all hazardous wastes strictly as per MWAN and IFC Environmental Standards.
3. Utilize the services of MWAN licensed waste collector contractors to manage waste.
4. Recycle or reclaim materials where possible.
5. If recycling or reclamation is not practical, dispose of wastes in an environmentally acceptable manner and compliance with local laws and regulations.
6. If recycling or reclamation is not practical, dispose of wastes in an environmentally acceptable manner and compliance with local laws and regulations. Arrange for the wastewater generated from the construction camp to be channelized to an existing wastewater treatment system that meets the requirements of MEWA. Alternatively, install a new wastewater treatment system that conforms to the specifications given in the Design Guide for Wastewater Treatment Plants in Saudi Arabia (MEWA, 2007).
7. Training workers on the correct transfer and handling of fuels and chemicals and the response to spills

Ensure that an operating Hazard Communication HAZCOM program is in place. This action will ensure that site chemicals are properly labeled, and health hazards are communicated to employees.

In addition to the above, the following measures must be taken to reduce waste generation and properly dispose of the generated waste.

4.9.3.2 Waste Generated During Construction Activities

As a general guideline, make efforts to minimize waste generation and disposal where feasible. Use the Waste Management system to manifest any hazardous waste. Collect and dispose of all hazardous wastes strictly as per the Waste Management system. Tables 4.15 & 4.16 respectively depict the disposal plan for expected hazardous and non-hazardous waste generated during the project activities. Non-hazardous must be disposed to MWAN-approved disposal sites. Recycle some of the non-hazardous waste such as metal scrap and paper products. The hazardous waste must be disposed of at designated disposal sites.

4.10 AIR QUALITY, NOISE AND DUST BASELINE CONDITIONS

4.10.1 Introduction

As per the requirement of DCC and NCEC to evaluate the baseline local air quality, KFUPM through Gulf Advanced System Controls, Al-Khobar conducted an ambient air quality study around Al-Humaij to determine future mitigation measures. The study

consists of monitoring the ambient air at 5 selected locations for four days for one location (H-1) and twenty-four hours at four other locations with a mobile station equipped with instruments to measure wind speed, wind direction, relative humidity, temperature, noise, particle matter (PM₁₀ & PM_{2.5}), sulfur dioxide (SO₂), carbon monoxide (CO), ozone (O₃), and nitrogen dioxide (NO₂). The station is also equipped with sensors to measure the main meteorological parameters.

The measurements were conducted from May 09, 2024, to May 23, 2024, to establish the air quality, noise, and dust baseline conditions. During the site survey, 5 monitoring locations were selected inside the proposed Al-Humaij solar park construction site. The *Latitude-Longitude* coordinates of the five selected monitoring stations are given in (Table. 4.17). Figure 4.66 presents the location of the monitoring sites inside the proposed construction boundaries. Figures 4.67 and 4.68, depict photos showing different views of the equipment for weather, noise, and dust monitoring in the measurement locations. Figure 4.66 shows a general view of the area that includes the 5 locations and the coordinates and measurement periods at each site are shown below.

Table 4.17. Showed the Geographical (*Latitude-Longitude*) Coordinates of the selected locations in Al-Humaij

Sr. No.	Site	Latitude	Longitude	Measurement dates
1	H-1	25.074864	41.077272	May 09 th to 13 th 2024
2	H-2	25.088579	41.127089	May 13 th to 14 th 2024
3	H-3	25.023322	41.149167	May 17 th to 18 th 2024
4	H-4	25.000622	41.112370	May 19 th to 20 th 2024
5	H-5	25.049993	41.113644	May 21 st to 23 rd 2024

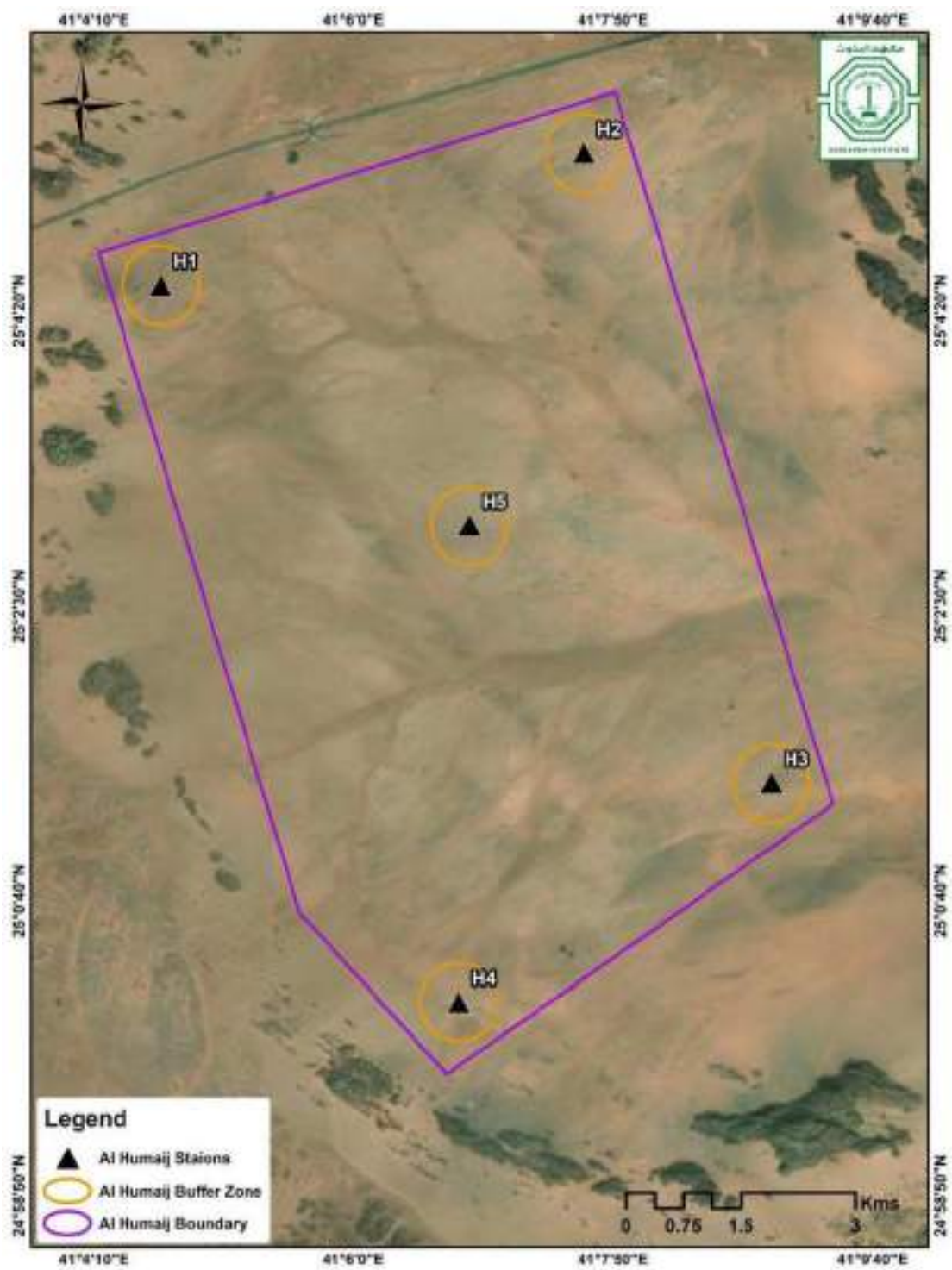


Figure 4.66. General view of the selected monitoring locations in the Al-Humaij study area.



Figure 4.67. Photos showing views of the equipment for air quality, and weather monitoring in the study area.



Figure 4.68. Photos showing noise and dust monitoring equipment used in the study.

4.10.2 Measurement Approach

The objective is to assess the status of noise levels and air quality (i.e. gases and dust emissions) within the proposed area of Al-Humaij before the execution of the planned major construction activities during the day and night to establish the noise levels and dust emissions baseline conditions in the existing terrestrial areas.

4.10.2.1 Measurement of Noise Levels

Terrestrial noise measurements were conducted for 24 hours at locations. The following acoustical indicators were measured simultaneously during the monitoring time.

- i. **Time-weighted level L_{Aeq}** , the equivalent continuous level, is the sound pressure level of a steady sound that has, over a given time period the same energy as the fluctuating sound in question. This is the preferred measure of environmental noise-varying with time.
- ii. **Maximum and minimum levels L_{Amx} , L_{Amin}** ; the overall A-weighted **SPL** dB(A) of acoustical events to establish the ambient and/or dominant noise.
- iii. **Percentile levels**; these are indications of the sound level that is exceeded for a stated percentage of a measurement period. **L_{A90}** ; the level exceeded 90% of the time for a stated time period. This is often taken as an indication of residual or background noise from unidentifiable sources. It is widely used as the descriptor of background noise or ambient noise. **L_{A10}** is also measured. It is more likely to reflect the presence of loud sounds. **L_{Aeq} , L_{A90} , and L_{A10}** can be

used to estimate the noise pollution, and **LNP** in the environment where **LNP** = $[L_{Aeq} + (L_{A10} - L_{A90})]$.

- iv. Other required information such as the time of measurement, description of the noises heard and their sources, any events that may affect the readings (e.g., traffic, etc.), and weather conditions including relative humidity and wind speed/direction were also be recorded utilizing an air quality monitoring station (weather station) from **Teledyne** company.

4.10.2.2 Measurement of Air Quality

Ambient air quality measurements were conducted on five sites. Mainly, PM_{2.5} (i.e. ≤ 2.5 μm particle matter), PM₁₀ (i.e. < 10.0 μm particle matter) and Total Particulate Matter, TPM (i.e. ≤ 10.0 μm particle matter), are the dust indicators used to quantify fugitive dust as a result of natural sandstorms and from any other activities (traffic, construction, etc). In addition, air temperature, relative humidity, wind direction and speed were also recorded. PM_{2.5}, PM₁₀ and TPM levels of dust emissions were measured using a state-of-the-art particulate matter counter (MetOne BAM 1020). It is a mass flow dust monitor capable of detecting low concentrations of fugitive dust emissions in ambient air.

The weather station is capable of measuring wind speed, wind direction, relative humidity, temperature, noise, sulfur dioxide (SO₂), carbon monoxide (CO), ozone (O₃), and nitrogen dioxide (NO₂). The measurements were conducted using a mobile station equipped with the instruments, sensors and auxiliary systems necessary to carry out air quality measurements. Includes sampling, calibration, and data collection systems. The station was powered by a gasoil generator, located downwind of the station.

All analyzers(sensors) designed to measure each specific parameter are USEPA approved for Air Quality measurement. Figure 4.67 shows an overview of the racks of instruments and Table 4.18 lists the parameters, instruments by manufacturer, model, principle of measurement, and reference method of measurement.

Following the USEPA guidelines, the concentrations in this report are expressed as “< LDL” when the recorded value is below the detection limit, and for statistics calculation, it is replaced by LDL/2.

Once the mobile station is deployed on the site, the day before the measurements, the following tasks were performed:

1. The air quality analyzers were turned ON to allow a warm-up period (2-4 hours).
2. After completing the warm-up period, a multi-point calibration was performed on all analyzers. The calibration consisted of challenging the analyzers to sample 3 known target concentrations (80% of full scale, 50% of full scale, and zero), using certificated (NIST traceable) gas mixtures, to verify the response of the analyzers which should have an acceptable deviation of +/- 10 %. If the analyzer deviation exceeded this value, the analyzer response is adjusted, and the calibration is repeated.
3. The meteorological sensors' responses were checked against a handheld met station (Kestrel).

The day after the measurements were completed, a zero/span check was performed on each analyzer to verify that the responses remained within the acceptable deviation.

4.10.2.3 Noise Standards and Measurement Equipment

The following standards were consulted and utilized in conducting the field measurements, data reporting, and analysis stages (when applicable):

- **ASTM E 1014-12 (2012):**
Standard Guide for Measurement of Outdoor A-Weighted Sound Levels.
- **ASTM E 1686-10 (2010):**
Standard Guide for Selection of Environmental Noise Measurements and Criteria.
- **ANSI/ASA S1.13-2005 (R2010):**
Acoustics- Descriptors, Measurement and Assessment of Environmental Noise – Determination of Environmental Noise Levels.
- **Noise Standards/Code of Noise Regulations**, in countries of the Gulf Cooperation Council (GCC). i.e. "Noise Levels in Indoor and Outdoor Environments in the Countries of GCC", April 2006.

Noise and dust surveys were conducted over a typical working day. The on-site observed activities (if any) were recorded. The noise and dust measurements were taken during the daytime (08:00-20:00) and nighttime (20:00 – 08:00)

The measurement locations of the noise and dust, (See Figure 4.65) were chosen taking into account (1) accessibility, (2) the actual route of the surrounding zone, (3) ease of equipment setup, (4) barriers to noise propagation (if any), (5) and existing noise sources and their characteristics.

To obtain accurate results and to give an indication of sound pressure levels (**SPL**) that are encountered in a typical day or situation, the following aspects were considered:

1. Calibrations of used equipment were performed according to the instructions given in their respective operation manuals. The calibration process was conducted before conducting a particular measurement set. The calibration on-site was conducted using an acoustical calibrator with a current certificate. (e.g. with ≤ 0.02 dB deviations).
2. Manual calibration of the particulate matter equipment (i.e. BAM 1020) was done before conducting the planned set of measurements.
3. Outdoor measurements may be affected by the wind developing turbulence and streams around the microphone. This is minimized by fitting a standard foam windscreen to the microphone as recommended by the manufacturer.
4. Measurements were taken when the steady wind speed is below 5 m/s as per standards and/or when the atmospheric conditions are not significantly affecting sound propagation. Measurements conducted during significantly higher wind speed were noted for cautious interpretation or exclusion. Weather conditions such as dry bulb temperature (T, °C), relative humidity (RH, %), and wind speed

(WS, m/s), and direction are recorded at 1-min intervals during a particular measurement set at each monitoring location. The wind direction is measured in degrees (°) clockwise from the north using the built-in instrument of the weather station.

5. The safety of the on-site investigating team, in addition to safeguarding the equipment, was also a great concern. Health safety-related PPE was utilized as appropriate.

Table 4.18. List of monitoring parameters, manufacturer, equipment, reference method employed for air quality, weather, particulate matter, and noise monitoring.

Sr No.	Pollutant	Manufacturer/Model	Techniques	Reference Method
1	Sulfur Dioxide (SO ₂)	Teledyne T100	UV Fluorescence	US EPA-EQSA - 0495-100
2	Carbon Monoxide (CO)	Teledyne T300	NDIR Photometry	US EPA: RFCA -1093-093
3	Nitrogen Dioxide (NO ₂)	Teledyne T200	Chemiluminescence	US EPA: RFCA -1194-099
4	Ozone (O ₃)	Teledyne T400	UV Absorption	US EPA: EQOA -0992-087
5	Particulate Matter (PM ₁₀)	MetOne BAM1020	Beta Ray Attenuation	FEM -EQPM- 0798-122
6	Particulate Matter (PM _{2.5})	MetOne BAM1020	Beta Ray Attenuation	FEM -EQPM- 0798-170
7	Wind Speed	MetOne MSO Weather Station	Cup Air Speed	MetOne 7500 Protocol
8	Wind Direction	MetOne MSO Weather Station	Vane	MetOne 7500 Protocol
9	Noise	Cirrus Optimus	Microphone	--
10	GPS Device	GARMIN	--	--
11	Digital Compass	Citizen, Dx8177-A	--	--

The calibrated Cirrus Optimus noise meter with a data logging capability was used to measure the sound/noise broadband and spectra levels at the chosen measurement locations. The setup was pre-stored with the required operation and the essential acoustical indicators. The setup was set to measure broadband linear (dB) and A-weighted sound/noise levels (dBA). The **SLM** was set to record the following parameters for sounds measured over the duration of a pre-set time period (T_m)

- **L_{Aeq}** = Equivalent continuous level, with current frequency **A**-weighting.

- **L_{Amx}** = Maximum level, with time weighting (**F**=Fast) and frequency **A**-weighting.

- **L_{Amn}** = Minimum level, with time weighting (**F**=Fast) and frequency **A**-weighting.

- **L_{A10}** = Percentile value (10%), with time weighting (**F**=Fast) and frequency **A**-weighting. The level that exceeded 10% of the measurement time.
- **L_{A90}** = Percentile value (90%), with time weighting (**F**=Fast) and frequency **A**-weighting. The level that exceeded 90% of the measurement time.

4.11 RESULTS & DISCUSSIONS

The complete results of wind speed, wind direction, noise, temperature, PM₁₀, PM_{2.5}, SO₂, NO₂, O₃, and CO of all stations with dates and times. The results of temperature, wind speed, wind direction, relative humidity, and no NCEC-regulated values are presented in the following section. The environmentally significant parameters regulated by NCEC will be described in the successive paragraphs.

The noise standard does not specify a defined time period (**T_m**) for conducting outdoor measurements since it depends on the characteristics of the noise source(s). Observing (on-site) these characteristics, time periods, and frequency of occurrences of noise events, it was decided that, at the measurement locations, a time period of twenty-four hours of recording of data was considered representative of the respective occurring acoustical events. Observations were recorded for distinct noise events that occurred during each measurement (Figure 4.69). Other pertinent information, such as weather conditions, was also recorded and averaged to represent the weather conditions during the measurement. Table 4.19 provides the measurement results indicating the data of weather conditions, and noise indicators measured at the selected locations during the site investigation. The overall baseline noise pollution indicator ($LNP = LA_{eq} + (LA_{10} - LA_{90})$) (Figure 4.70) for all the observations in the Al-Humaij was found to be around 65.9 dB. It was also observed that the weighted average of noise- LA_{eq} at all the sites was high at 57.4, 61.7, 55.6, 55.5, and 50.9 dB in the Al-Humaij area. This value is above the NCEC-regulated value of 50 dB (daytime). It was noticed that during air quality, dust, and noise monitoring studies of the Al-Humaij area the average wind speed was high (4.48 m/s). The exceedance of noise level can be related to the average high speed of the wind. Although proper required shielding (foam screen at mike) of the noise meter was done. However, the noise generated by the high wind contributed to the elevated noise levels observed in Al-Humaij area. This was also reflected in the high particulate matter measurement.

Table 4.19. The measurements results indicating the data of **weather** conditions, and **noise** indicators at the measurement locations.

Weather Condition	Monitoring Stations					Average of 5 stations	NCEC regulated value	IFC regulated value
Location	H-1	H-2	H-3	H-4	H-5			
Latitude(N)	25.074864	25.088579	25.023322	25.000622	25.049993	--	--	--
Longitude (E)	41.077272	41.127089	41.149167	41.11237	41.113644	--	--	--
Temperature °C (AVR)	30.5	29.0	28.8	28.4	31.1	29.6	--	--
RH% (AVR)	28.4	19.8	19.7	17.9	14.6	20.1	--	--
Wind Speed m/s(AVR)	4.1	4.8	5.9	4.1	3.1	4.4	--	--
Wind Direction Deg (AVR)	121.4	193.7	83.1	234.4	118.1	150.1	--	--
Wind Direction (TXT)	ESE	S	ENE	SW	ESE	SE	--	--
LAeq	57.4	61.7	55.6	55.5	50.9	54.2	50	55
LAmx	75.6	77.9	70.0	70.8	70.6	73.1	ns	ns
LAmn	46.3	50.6	52.4	42.1	29.9	38.1	ns	ns
LA10	59.2	64.1	57.2	44.4	52.2	55.7	ns	ns
LA90	50.4	51.8	52.7	39.0	35.0	42.7	ns	ns
LNP (=LAeq + (LA ₁₀ -LA ₉₀))	66.3	73.9	60.1	60.9	68.2	65.9	ns	ns

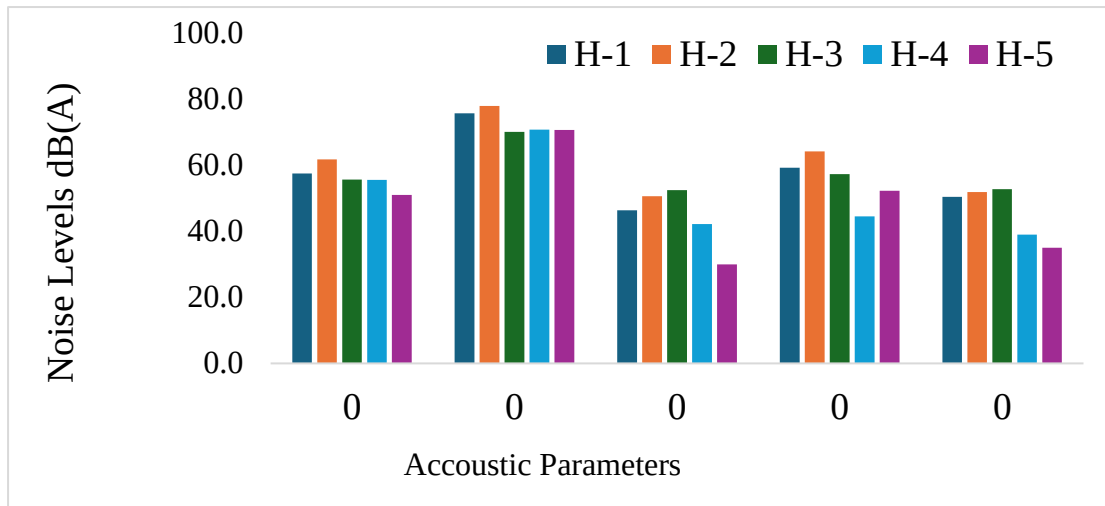


Figure 4.69. Intercomparison of noise levels at five different measurement locations.

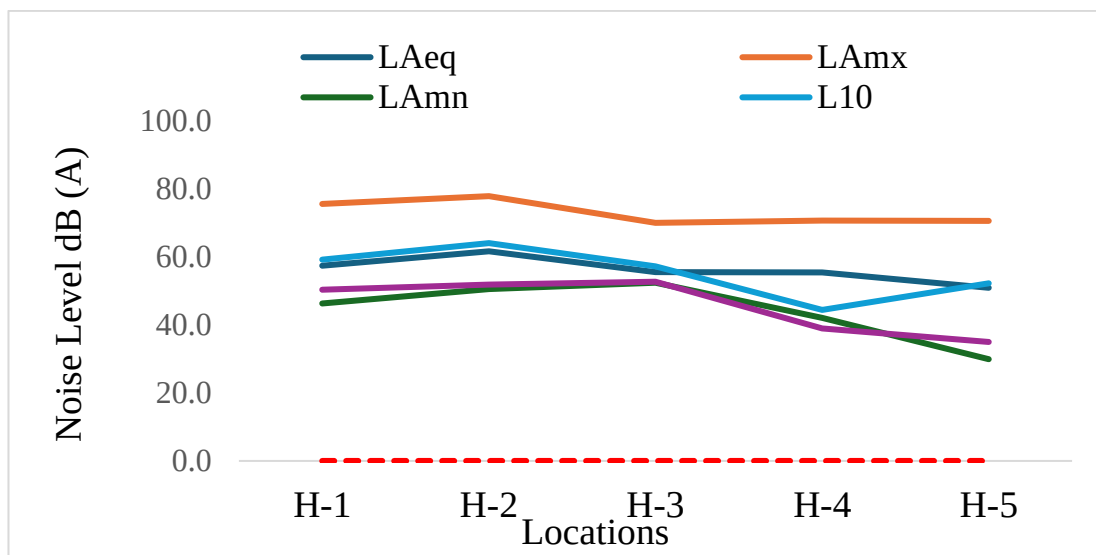


Figure 4.70. The measurements of L_{Aeq} , L_{Amax} , L_{Amin} , L_{10} , and L_{90} in dB(A) at the measurement locations compared with the daytime NCEC regulated Value shown in red dashed line.

The summary of particulate matter concentrations ($\mu\text{g}/\text{m}^3$) of $\text{PM}_{2.5}$ and PM_{10} at different measurement locations within the site are given in Table 4.20. The data is illustrated in Figure 4.71 and Figure 4.72.

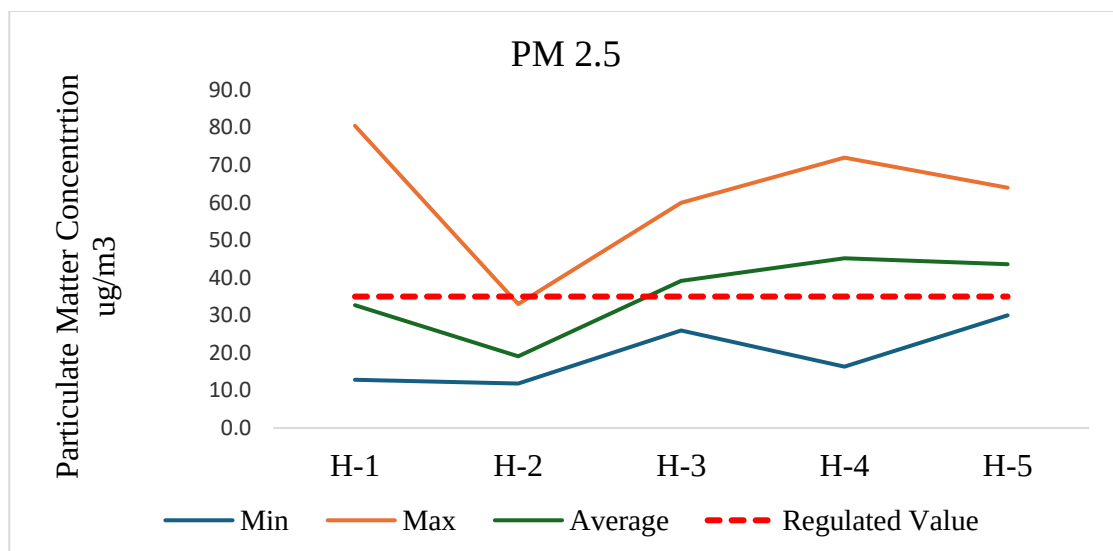


Figure 4.71. The measurements of particulate matter PM_{2.5} concentration at the measurement locations compared to NCEC regulated value shown in red dashed line.

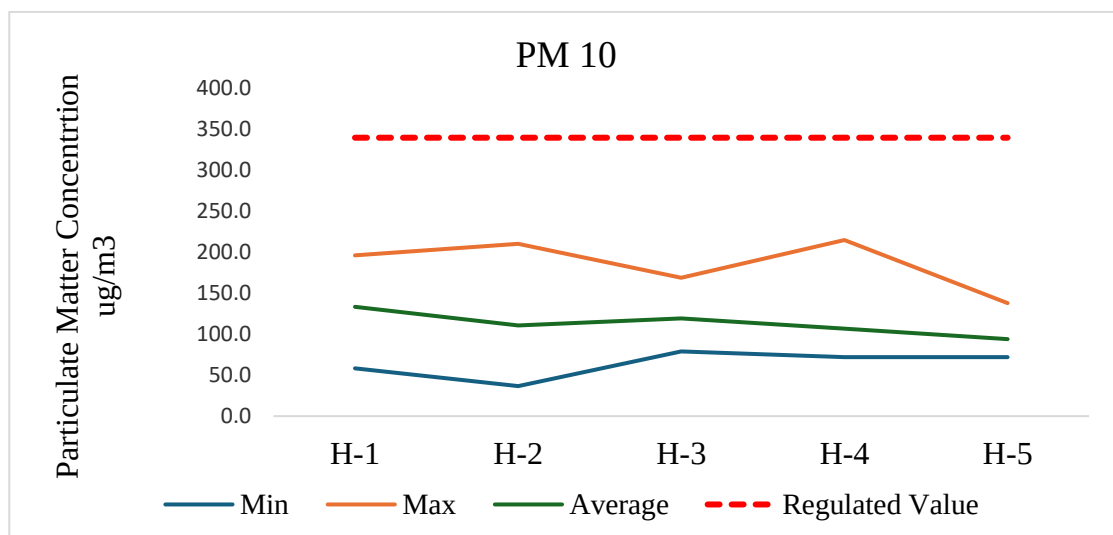


Figure 4.72. The measurements of particulate matter PM₁₀ concentration at the measurement locations compared to NCEC regulated value are shown in red dashed line.

The larger size particulate matter (PM₁₀) did not show exceedance when compared to the NCEC-regulated value of 340 $\mu\text{g}/\text{m}^3$ at all five locations. The concentration of PM₁₀ was in the range of 36.7 to 215.0 $\mu\text{g}/\text{m}^3$ with an average of 112.9 $\mu\text{g}/\text{m}^3$. However, it was noticed that particulate matter of small size PM_{2.5}, was found to exceed the NCEC regulated limit. The particulate matter was in the range of 11.0 $\mu\text{g}/\text{m}^3$ to 80.5 $\mu\text{g}/\text{m}^3$ with an average of 36.0 $\mu\text{g}/\text{m}^3$ at all locations. The sites where the particulate matter of small size was found to exceed the NCEC regulated limit were H-1, H-3, H-4, and H-5 (80.5, 60.0, 72.0, and 64.0 $\mu\text{g}/\text{m}^3$ respectively). It was noticed that the average PM_{2.5} was lower than the regulated limit of 35 $\mu\text{g}/\text{m}^3$ at locations H-1 and H-2, and for all other locations, it was higher than the NCEC regulated limit.

Table 4.20. Summary of all Weather and Air Quality parameters at different measurement locations of the Al-Humaij study area.

Parameters	Unit	H-1			H-2			H-3			H-4			H-5			Average	NCEC Regulation	IFC Regulation
		Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave			
Temperature	°C	21.2	37.0	30.5	22.0	34.9	29.0	23.4	35.1	28.8	20.2	35.8	28.4	24.5	37.2	31.1	29.6	--	--
Barometric Pressure	mbar	890.0	897.0	894.6	888.0	894.0	889.6	893.0	899.0	896.1	891.0	898.0	895.8	889.0	893.0	891.0	893.4	--	--
Wind Direction	Deg	0.0	351.5	121.4	17.8	339.7	193.7	28.4	225.9	83.1	4.9	348.5	234.4	0.0	351.2	118.1	150.1	--	--
Wind Speed	m/s	0.3	12.8	4.1	0.5	11.0	4.8	1.6	10.5	5.9	0.6	11.6	4.1	0.3	7.3	3.1	4.4	--	--
Rainfall	mm	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--	--
Relative Humidity	%	9.0	55.0	28.4	9.0	34.0	19.8	6.0	25.0	19.7	5.0	40.0	17.9	9.0	22.0	14.6	20.1	--	--
PM ₁₀	µg/m ³	58.4	196.4	133.5	36.7	210.3	110.8	79.0	169.0	119.4	72.0	215.0	106.9	72.0	138.0	94.0	112.9	340	150 (Interim target-1)* 100 (Interim target-2) 75 (Interim target-3) 50 (guideline)
PM _{2.5}	µg/m ³	12.8	80.5	32.7	11.8	33.0	19.1	26.0	60.0	39.2	16.3	72.0	45.2	30.0	64.0	43.6	36.0	35	75 (Interim target-1) 50 (Interim target-2) 37.5 (Interim target-3) 25 (guideline)
Carbon Monoxide CO	µg/m ³	526.7	927.5	603.7	503.8	732.8	580.3	160.3	698.5	596.6	297.7	1706.1	477.0	629.8	1271.0	771.6	605.8	10,000	--
Nitric Oxide NO	µg/m ³	0.0	73.7	2.1	0.0	107.3	3.9	0.3	5.2	0.5	0.0	47.5	0.7	0.1	46.3	0.9	1.6	--	--
Nitrogen dioxide NO ₂	µg/m ³	0.0	274.4	6.8	0.0	107.3	13.3	0.2	19.5	2.4	0.0	66.3	10.8	0.0	59.0	4.6	7.6	200	1 year 40

Parameters	Unit	H-1			H-2			H-3			H-4			H-5			Average	NCEC Regulation	IFC Regulation
		Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave			
																			1 hour 200
Ozone O₃	µg/m ³	11.2	149.8	86.3	16.1	121.1	78.8	76.3	121.1	98.8	65.2	138.7	100.8	38.5	116.0	89.3	90.8	157	160 (Interim target-1) 100 (guideline)
Sulfur dioxide SO ₂	µg/m ³	32.8	45.2	36.9	27.2	54.3	36.7	0.0	35.3	6.0	0.1	69.0	23.7	9.7	32.8	30.4	26.7	440	125 (Interim target-1) 50 (Interim target-2) 20 (guideline)

The overall average value ($36.0 \mu\text{g}/\text{m}^3$) was slightly higher than the regulated limit of $35.0 \mu\text{g}/\text{m}^3$. The exceedance can be related to the site terrain, which was mostly sandy and desert-like. It was also noticed that during air quality, dust, and noise monitoring studies of the Al-Humaij area the average wind speed was high (4.4 m/s), which carries loose sand particles and dust in the air. This might be the cause of high dust ($\text{PM}_{2.5}$) and high noise values and may be one of the possible reasons for the high $\text{PM}_{2.5}$ content.

Table No.4.20 also provides a summary and comparison of the average measurement results of dust and the baseline levels of gases with NCEC-regulated concentrations.

The concentration of carbon monoxide was found to range from 160.3 to $1271.0 \mu\text{g}/\text{m}^3$. The overall average concentration of CO was $605.8 \mu\text{g}/\text{m}^3$. The NCEC-regulated value for CO is $10,000 \mu\text{g}/\text{m}^3$. The concentration of nitrogen dioxide ranged from 0.0 to $274.4 \mu\text{g}/\text{m}^3$. The average concentration of NO_2 at all locations was found to be $7.6 \mu\text{g}/\text{m}^3$. The NCEC-regulated value for NO_2 is $200 \mu\text{g}/\text{m}^3$. Similarly, the concentration of Ozone in the Al-Humaij region was found in the range of 11.2 to $149.8 \mu\text{g}/\text{m}^3$. The overall O_3 concentration at all locations was $90.8 \mu\text{g}/\text{m}^3$ and the NCEC-regulated value of O_3 was $157 \mu\text{g}/\text{m}^3$. The concentration of sulfur dioxide was found in the range of 0.0 to $69.0 \mu\text{g}/\text{m}^3$ with an average of $26.7 \mu\text{g}/\text{m}^3$. The NCEC-regulated value for SO_2 is $440 \mu\text{g}/\text{m}^3$, which is well above the average SO_2 concentration in the Al-Humaij area. The results of CO, NO_2 , O_3 , and SO_2 gases did not show any exceedance when compared to NCEC regulations and were found to be well below the regulated values.

4.12 AIR QUALITY

1. Primary Sources of Air Pollution:

- **Dust and Particulate Matter:** The re-suspension of soil particles and windblown dust are significant contributors to PM_{10} levels in Khulais. This aligns with findings from studies in nearby Jeddah, where similar sources were identified as major contributors to particulate matter concentrations. [Habeebullah, 2013].
- **Vehicular Emissions:** Road traffic is a primary source of nitrogen oxides (NO_x), carbon monoxide (CO), and particulate matter. Traffic-related emissions peak during morning hours, correlating with increased vehicular activity. Habeebullah, T. M. (2013), (2022)
- **Industrial Activities:** Local industries contribute to air pollution through emissions of sulfur dioxide (SO_2) and other pollutants. The burning of fossil fuels in restaurants and homes is also a notable source of particulate matter. Habeebullah, T. M. (2022).
- Air pollution in Khulais is linked to various health issues, including respiratory and cardiovascular diseases. The inhalation of particulate matter and other pollutants poses significant health risks to the local population. Habeebullah, T. M. (2022).

2. Climatic Influences:

- The region's dry climate and limited rainfall contribute to the persistence of air pollution, with significant seasonal variations in pollutant concentrations influenced by meteorological conditions (Khan, M. Y. A., *et al*, 2022)

4.12.1 Air Quality Monitoring:

A study conducted in Al Humaij, utilized a continuous air quality monitoring station to assess various pollutants, including nitrogen dioxide (NO₂), sulfur dioxide (SO₂), ozone (O₃), carbon monoxide (CO), and particulate matter (PM₁₀). The findings suggest that air quality may be compromised due to high levels of these pollutants, especially during peak traffic hours and adverse meteorological conditions (Rehan, M., & Munir, S. (2022).

Another study showed During the winter season, air quality modeling for Khulais indicates that pollutant levels can exceed 35 µg/m³, which raises concerns regarding compliance with International Finance Corporation (IFC) standards. Specifically, these levels surpass the annual average limits for PM₁₀ (20 µg/m³) and PM_{2.5} (10 µg/m³), as well as the 24-hour value for sulfur dioxide (SO₂) (20 µg/m³). However, the predicted levels remain below the 24-hour threshold for PM₁₀ (50 µg/m³) and the 1-hour limit for nitrogen dioxide (NO₂) (200 µg/m³). (Othman, A. M.,*et.al*,2021)

The study on air pollution in Al Humaij provides relevant insights that can be applied to understanding the air quality dynamics in Al Humaij, given the closeness of their proximity:

1. **Elevated PM₁₀ Levels:** The study found high PM₁₀ concentrations in Jeddah, often exceeding 100 µg/m³, more than double the levels at remote sites, it is likely that PM₁₀ levels are also elevated in the region due to shared environmental factors and proximity to urban emissions.
2. **Seasonal Variations:** The study observed seasonal cycles in pollutant concentrations, with NO_x peaking in winter and O₃ generally peaking in summer. These seasonal patterns can also be expected in Khulais, where similar meteorological conditions prevail, influencing air quality throughout the year.
3. **Weekend Effect:** The study found a significant "weekend effect" in Jeddah, where urban concentrations of NO_x were reduced by 19-25% on weekends, while O₃ levels increased by 12-15%. As Khulais is located within the broader Jeddah metropolitan area, a similar weekend effect on air quality can likely be observed in the region.
4. **Proximity to Urban Emissions:** The study highlighted the differences in pollutant concentrations between urban Jeddah and more remote areas. Khulais, being located near Jeddah, is likely to be influenced by the urban emissions from the city, leading to higher levels of pollutants like NO_x and PM₁₀ compared to more remote areas.

The location in Al Humaij indicates that the project area is situated in the middle of the desert, characterized by minimal to no traffic and a lack of established roads. The remote nature of this location, combined with the absence of significant cultural or economic landmarks nearby, suggests that the traffic impact during the construction phase will be negligible. Our extensive site visits have confirmed that there are very

few residents in the area, further indicating that construction activities will not disrupt local traffic patterns or community access. Therefore, the traffic-related impacts of the project are not considered a significant concern, allowing for a smooth and efficient construction process without adverse effects on the surrounding environment or communities.

4.13 DUST SOURCES, MANAGEMENT AND MITIGATIONS MEASURES

The objective of this section is to provide specific noise and dust mitigation measures (based on the potential impacts identified) during the survey. One of the major impacts related to the project development/construction activities includes air emissions resulting from dust generation. Development/Construction phase activities such as site preparation, site clearance, grading, excavations, cut and fill operations, and stockpiling will result in the generation of dust movement of soil during site clearance, and grading and excavations will be the principal source of dust emissions at the site. The generation of dust may impact public health, valuable environmental habitats, and, secondarily, visual amenities.

4.13.1 Sources-Activities of Dust Emissions

The main activities that may generate dust are the following:

1. Excavating, earthworks, pneumatic rock breaking
2. Earth-moving activities from cranes, excavators, bulldozers
3. Wind passing over ground and dusty materials
4. Handling and localized stockpiling of soil
5. General aggregate handling
6. Cement handling, open bags of dry cement, and disposal of cement bags and sacks;
7. Sandblasting activities.
8. Delivery of bedding and fill material to the site.
9. Leveling and rehabilitation of disturbed surfaces.
10. Grit-blasting activities, performed on the various above-ground pipes to smooth and clean their surfaces its surfaces
11. Clean the surfaces before the pipes coating and painting using abrasive substances and air activities
12. Vehicles driving on unsealed roads and unconsolidated soil surfaces
13. Vehicle movement to transport labor workforce and materials

Fugitive dust emissions from vehicles on the site are dependent on the following factors:

1. Type of road (paved, unpaved, type of soil)
2. Type and number of vehicles.

4.13.2 Dust Monitoring and Management

The recommended environmental management monitoring programs for Dust during the survey are as follows:

- Visual inspection of development/construction sites for dust generation severity and application of suppressing techniques, as required.
- Daily/Weekly audits in development/construction sites to confirm contractor/sub-contractor and site personnel compliance to dust mitigation requirements, adherence to PPE requirements
- Periodic dust monitoring (every month) at the development/construction site boundary and work areas to determine compliance with dust control standards.

4.13.3 Mitigation Measures

The following mitigation measures are proposed for the development/construction phase:

1. To the extent possible, only existing roads shall be used where the soils are compacted, and dust emissions are likely to be lower compared to new tracks;
2. Any new access roads shall be constructed and identified as a designated route with traffic movement restricted to such routes
3. Tracks and roads shall be graded and watered regularly to minimize airborne dust
4. All on-site development/construction areas shall be watered sufficiently and at required intervals to minimize fugitive dust emissions
5. Excavation and grading operations shall be suspended during dust storms or very high wind speeds to prevent dust generation
6. Soils shall be maintained moist when loading or unloading into dump trucks to minimize fugitive dust emissions
7. Drop heights shall be reduced when loaders dump soil into trucks
8. During transportation, trucks should not be overloaded with sand, gravel, and aggregate and ensure sufficient freeboard. Trucks traveling to and from the project site with these materials will be covered with tarpaulin to minimize dust
9. All project activities must be carried out within the project boundary, as appropriate. No lay-down or temporary holding will be permitted outside the boundary
10. Excavated areas shall be compacted and contoured to minimize fugitive dust emissions. The height of temporary stockpiles will be limited and aligned parallel to the prevailing wind direction
11. Bulk storage of excavated material shall be avoided to the extent possible
12. Enclosed waste chutes into enclosed skips shall be used where possible to reduce dust levels
13. Ensure dust/sand on roads leading to the site are cleared periodically
14. All vehicles used for the project shall have valid Motor Vehicle Periodic Inspection (MVPI) certificates

15. Vehicle wheels shall be washed down at the site exit points to prevent tracking of soils onto surrounding roads and highways

Tables 4.21 and 4.22 list specific mitigation measures that may be applicable (as appropriate) to reduce fugitive dust emissions and vehicle exhaust emissions from development/construction activities to a less-than-significant-level

Table 4.21. Fugitive dust emissions control measures.

No.	Fugitive Dust Source Category	Control Actions
1	Earth-moving (except construction cutting and filling areas and mining operations)	For any earth moving which is more than 100 feet (30.5 m) from all property lines, conduct watering as necessary to prevent visible dust emissions from exceeding 100 feet (30.5 m) in length in any direction.
2	Earth-moving - construction cut areas	Conduct watering as necessary to prevent visible emissions from extending more than 100 feet (30.5 m) beyond the active cut areas unless the area is inaccessible to watering vehicles due to slope conditions or other safety factors.
3	Disturbed surface areas (except completed grading areas)	Apply dust suppression in a sufficient quantity and frequency to maintain a stabilized surface; any area that cannot be stabilized, as evidenced by wind-driven dust, must have an application of water <u>at least twice per day</u> to at least 80 percent of the un-stabilized area.
4	Disturbed surface areas - completed grading areas	Consider applying chemical stabilizers within 5 working days of grading completion.
5	Inactive disturbed surface areas	- Apply water to at least 80 percent of all inactive disturbed surface areas <u>on a daily basis</u> when there is evidence of wind-driven fugitive dust, excluding any areas which are inaccessible due to excessive slope or other safety conditions, OR - Consider applying dust suppressants in sufficient quantity and frequency to maintain a stabilized surface, OR - Establish a vegetative ground cover after active operations have ceased; ground cover must be of sufficient density to expose less than 30 percent of un-stabilized ground within 90 days of planting and at all times thereafter.
6	Unpaved roads	- Water all roads used for any vehicular traffic at least once per every two hours of active operations; OR - Water all roads used for any vehicular traffic once daily and restrict vehicle speed to 15 mph (24 Km/h); OR - Apply chemical stabilizer to all unpaved road surfaces in sufficient quantity and frequency to maintain a stabilized surface.

No.	Fugitive Dust Source Category	Control Actions
7	Open storage piles	• Apply chemical stabilizers, • Apply water to at least 80 percent of the surface areas of all open storage piles on a daily basis when there is evidence of wind-driven fugitive dust; OR • Install a three-sided enclosure with walls with no more than 50 percent porosity that extends, at a minimum, to the top of the pile.
8	Track-out control	• Pave or apply chemical stabilization at sufficient concentration and frequency to maintain a stabilized surface starting from the point of intersection with the public paved surface, and extending for a centerline distance of at least 100 feet (30.5 m) and width of at least 20 feet (6.0 m); OR • Pave from the point of intersection with the public paved road surface and extending for a centerline distance of at least 25 feet (7.6 m) and a width of at least 20 feet (6.0 m), and install a track-out control device immediately adjacent to the paved surface such that exiting vehicles do not travel on any unpaved road surface after passing through the track-out control device.

The U.S. Environmental Protection Agency (US EPA) has defined the following Action Levels which are listed in Table 4.22.

Table 4.22. Dust monitoring alerts and actions

Contaminant EPA	EPA Air Quality Standard Action Level	Required Action
Air-borne Particulates (PM10)	Any visible dust emissions from work activities	• Implement corrective measures to control dust (e.g., water sprays).
	> 75 ug/m ³ (5-minute average data or equivalent)	• Increase the application rate of dust controls
	> 150 ug/m ³ (5-minute average data or equivalent)	• Continue wetting of source area • Suspend project activities and notify Field Engineer, Contractor, and Owner
	> 100 ug/m ³ (10-hour Time Weighted Average, TWA)	• Continue wetting of source area. • Suspend project activities and notify Field Engineer, Contractor, and Owner

Notes:

- The real-time dust monitoring data is reviewed immediately upon collection and evaluated against EPA Air Quality Standard Action Level described above as approved by the U.S. Environmental Protection Agency,
- Real-time alerts above the Action Level are sent to the Contractor and the Field Engineer for an immediate investigation by both parties.
- The cause or source of the alert is identified, and dust suppression techniques are evaluated as necessary.

- The source of the alert is evaluated to determine whether it is a false positive attributable to weather conditions (fog, mist, humidity, rain, etc.) or otherwise not related to development/construction activities at the site.
- If on-site development/construction activities are identified as the source of an alert, corrective action (application of water) will be implemented to mitigate the potential airborne dust.
- In case real-time data indicates the presence of particulate concentrations of contaminants of concern (e.g., dust) in excess of an Action Level, an alert is sent to the Field Engineer-in-charge and a Corrective Action Plan (developed by the Owner's Contractor and reviewed and approved by the Owner, and the Owner's Consultant) to control and mitigate fugitive dust is implemented.
- In the event that the dust monitors detect a concentration over the 150 ug/m³ action level for a 5-minute average, then the regulatory notification is undertaken, site operations are halted and more intense application of dust suppression activities is undertaken until the dust levels are reduced to levels below action levels.

4.13.4 Management Plan and Monitoring for Dust Dispersal

To retain the ambient air quality of the protected areas it is required to follow the guidelines of the national and international, which is applicable to protect the biodiversity. Dust Dispersal Model executed considering one industrial source point of the Dust Dispersal. Therefore, a detailed management plan is proposed that needs to be followed to maintain the air quality of the protected areas.

MEWA Guideline for Air Quality

The air quality of the protected area needs to be monitored regularly following the MEWA guidelines (Table 4.23). Various parameters of pollutants like CO, NO₂, SO₂, O₃, PM₁₀, PM_{2.5}, and Lead in Particle Matters need to be checked regularly.

Table 4.23. Ambient Air Quality Standard for Primary Pollutants, MEWA Guideline.

#	Pollutant	Averaging Period	Proposed Standards ($\mu\text{g}/\text{m}^3$) ^a	Allowed Exceedances
1	Carbon monoxide (CO)	1-hour	40,000	3X per year
2		8-hour	10,000	2X per month
3	Nitrogen dioxide (NO ₂)	1-hour	200	24X per year
4		1-year	100	-
5	Sulphur dioxide (SO ₂)	1-hour	441	24X per year
6		24-hour	237	3X per year
7		1-year	53	-
8	Ozone (O ₃) ^{**}	8-hour	157	25 days per year averaged over 3 years
9	Particle Matters (less than 10 μm) (PM ₁₀)	24-hour	540	12X per year***
10		1-year	50	-
11	Particle Matters (less than 2.5 μm) (PM _{2.5})	24-hour	35	12X per year***
12		1-year	35	-
13	Lead in Particle Matters Pb (in TSP)	3 months	0.15	3-month rolling average with no exceedances allowed

Source: Ministry of Environment Water & Agriculture, for Air Quality, No (m/165), dated 19/11/1441 Hijri

EMEP/EEA Guideline

Due to the lack of available local data, it is not possible to provide appropriate guidelines for emission control. However, the present study recommends following the guidelines of the EMEP/EEA guidebook., 2019. This guideline book is intended to assist Parties to the Convention in meeting their emission reporting obligations under the Convention and its protocols and to assist Member States of the European Union in fulfilling their emissions reporting requirements under the NEC Directive. In addition, the Guidebook may be used to estimate emissions of selected indirect greenhouse gases of relevance to the UNFCCC and to other international bodies.

Methodological Approach

Tier 1 methods assume a simple linear relation between activity data and emission factors. The activity data are derived from readily available statistical information (energy statistics, production statistics, traffic counts, population sizes, etc.). The

default tier 1 emission factors are chosen to represent ‘typical’ or ‘averaged’ process conditions — they tend to be technology independent.

Tier 2 methods use the same or similar activity data to tier 1 methods, but apply country-specific emission factors; country-specific emission factors need to be developed, using country-specific information on process conditions, fuel qualities, abatement technologies, etc. In many cases, these methods could also be applied at a higher level of detail, where the activity statistics are further split into sub-activities with more or less homogeneous process characteristics.

Tier 3 methods go beyond the above; these may include using facility-level data and/or sophisticated models. Examples might include the use of pollutant release and transfer register data or data from emission trading schemes for industrial emissions or models such as COPERT for road transport emissions.

Reporting under the Convention on Long-range Transboundary Air Pollution

Reporting of emission data is required in order to fulfill obligations regarding the general requirements of the Convention and the more specific reporting requirements under the protocols under the Convention. The protocols with reporting requirements are:

- 1985 Helsinki Protocol on the reduction of sulphur emissions or their transboundary fluxes;
- 1988 Sofia Protocol concerning the control of emissions of nitrogen oxides or their transboundary fluxes;
- 1991 Geneva Protocol on the control of emissions of volatile organic compounds or their transboundary fluxes;
- 1994 Oslo Protocol on further reduction of sulphur emissions;
- 1998 Aarhus Protocol on heavy metals and its 2012 amended version;
- 1998 Aarhus Protocol on persistent organic pollutants and its 2009 amended version;
- 1999 Gothenburg Protocol to abate acidification, eutrophication, and ground-level ozone and its 2012 amended version.

Reporting under the United Nations Framework Convention on Climate Change

All Parties to the UNFCCC and the Kyoto Protocol shall ‘develop, periodically update, publish and make available to the Conference of the Parties national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies to be agreed upon by the Conference of the Parties’. Consequently, Parties are required to annually report emissions and sinks (and any recalculations that have occurred) of several greenhouse gases, including carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and various fluorinated chemicals. Parties should also provide information on emissions of carbon monoxide (CO), NO_x and NMVOCs and are encouraged to provide information on emissions of sulphur oxides (SO_x/SO₂). The 2006 IPCC Guidelines contain links to information on methods, used under other agreements and conventions, for the estimation of emissions of tropospheric precursors that may be used to supplement the reporting of emissions and removal of greenhouse gases for

which methods are provided here. Volume 1, Sections 7.1 and 7.2, for example, refers inventory developers to the EMEP/CORINAIR Guidebook (now this Guidebook) to estimate emissions of SO₂, CO, NO_x, NH₃, and NMVOCs.

Dust Control Equipment

It is very important to monitor the air quality of the environmentally protected areas, especially, if it is close to any industrial area. The work of Abu-Allaban and Abu-Qudais 2011, provided various suggestions which can apply to the Banui Muarid Protected area. Environmental Management Plan Dust Control Equipment The emissions of particulate matter from all the units will be limited to 50 mg/Nm³ to ensure healthy air quality in the vicinity of the project. Details of stacks and proposed dust control equipment are presented. To control the fugitive emissions, the following measures are proposed:

- All the conveyors will be provided with conveyor covers and hoods to offset any trapping of material in the wind stream.
- The sprinkling of water will be done along the internal roads in the plant to control the dust arising due to the movement of vehicular traffic;
- All the workers and officers working inside the plant will be provided with disposable dust masks; and
- A thick greenbelt will be developed around the plant to arrest the fugitive emissions. Gasses Control Equipment
- The cement kiln has to be designated as the best available

Emission Control Measures

Online particulate and gasses monitor will be installed for the Kiln/Raw mill stack in order to provide instantaneous measurements for TSP, PM₁₀, PM_{2.5}, CO, SO₂, and NO₂;

- Process interlocking system will be provided to trip off the complete system in case of a rise in temperature of the gases and dust particulate across the glass fiber bag house and bag filters, which will trip the entire system.
- Fugitive dust will be measured continuously at two locations;
 - i. The farthest point to the west of the project (upwind) in order to establish a reference point
 - ii. The farthest point to the east of the project (downwind) in order to assess the impact of the project on ambient dust.

4.14 NOISE AND VIBRATION

4.14.1 Noise Potential Sources

Noise coming from various activities may be generated. Heavy equipment and construction methods on site are intrinsically very noisy and lead to vibration. Noise generation is expected throughout the development/construction phase of the project. Major potential noise emission sources include:

- Noise generated from Site preparation, construction activities, and equipment/vehicle movement/operation.

- Stationary sources such as plants are positioned at a certain location on a temporary basis.
- Operation of heavy machinery, construction equipment, power tools, and vehicles
- Heavy construction equipment such as trucks, excavators and piling and drilling rigs.
- Vehicular traffic to and from the construction site zones.

4.14.2 Noise Monitoring and Management

- Periodic monitoring of noise shall be conducted by the Environmental Coordinator and HSE Supervisors in coordination with discipline managers or superintendents.
- Control measures shall be implemented immediately by concerned managers or superintendents to protect personnel from excessive exposure to noise.
- For noise control management, SAES-A-105 shall be complied with together with other relevant COMPANY and Saudi Arabian Government regulations.
- Check the level of noise generated in work areas, and propose/implement appropriate actions as required with proper frequency.
- Noise levels generated during development/construction activities shall be monitored periodically, and results shall be recorded using a properly developed Environmental Monitoring Record Form or FIS: Field Inspection Sheet.

4.14.3 Noise Mitigation Measures

The following measures are proposed for noise mitigation during the development/construction phase:

1. -High-noise areas should be identified during the development/construction phase (with designated signage and markers) to provide protective equipment. All personnel (employees, contractors, subcontractors, and visitors) working or passing through these areas should be provided with appropriate hearing protection such as ear plugs or earmuffs.
2. High-noise activities should be carried out only during daylight hours (07:00-16:00), avoiding prayer timings and public holidays, where feasible.
3. Soundproofing equipment and machinery should be used where possible.
4. Development/Construction personnel using high-noise equipment or working over prolonged periods should be provided with both ear plugs and ear muffs. Personnel working in high-noise areas or trades should have their work activities frequently rotated between work shifts.
5. Heavy machinery, equipment, and tools should be selected, taking into consideration their noise emission levels, where possible.
 - Contractors should consider renting newer equipment, vehicles, or machinery as they are generally quieter than older models.
 - Older equipment can be made quieter through simple modifications such as adding new mufflers or sound-absorbing materials.

- Where possible, noisy equipment should be sited as far as possible from workers and the private farm at the southeast of the refinery boundary as noise levels drop considerably with distance.
 - Where machinery, equipment, or processes emit high noise levels, special noise attenuation controls should be implemented – where feasible – such as:
 - A. **Elimination:** Elimination provides a permanent solution and should be attempted first (e.g., selecting or purchasing machinery with low noise levels)
 - B. **Substituting:** This involves substituting a noise hazard with one that presents a lower risk (e.g., pile driving is a very loud process and can be replaced with a boring, much quieter process).
 - C. **Engineering controls:** Adopting engineering controls involves providing some structural change to the work environment or work process to place a barrier to or interrupt the transmission path between the worker or the environment and the noise hazard from the generating source. Barriers can be constructed from commonplace construction materials such as plywood, blocks, stacks, or commercial panels. To be effective, the length of the barriers should be greater than its height and placed as close to the noise source or receiver as possible.
 - D. **Administrative controls:** These are procedural controls in the form of written procedures or instructions – to be adhered to by all personnel working at the site – to control, reduce, or eliminate individual exposure to particular noise hazards. Noise Perimeter Zones (NPZ) are an effective administrative control to limit exposure to noisy processes. NPZ's are zones where high-noise areas are roped off to keep out all workers who don't have to be there.
6. To minimize dredging impacts such as noise and vibration on the marine environment in the area, it is recommended to identify suitable work periods (avoiding a 24-hour schedule) to enable fish and other species to feed and remain in their habitat.
 7. Provide proper silencers/mufflers for mobile and engine-driven equipment.
 8. Replace or repair defective equipment/parts with abnormal noise and/or vibration.
 9. Minimize not to operate high-noise machines like a pile driver at night.
 10. Controlled blasting: Underground blasting shall be executed using relayed and controlled blasting techniques. Noise shall be controlled using the most feasible engineering control, such as sound-absorbing material in the area where the blasting activities are going to take place.
 11. Traffic transportation along nearby residence areas (if any) shall be limited or prohibited at night.

4.14.4 Summary of Environmental Regulatory Requirements

The following are the Environmental Regulatory Requirements of NCEC with regard to compliance during the development/construction phase. Noise level standards for residential, business, and industrial areas and roadside areas are presented in Tables 4.24, 4.25, and 4.26.

Table 4.24. Permitted Free-Field External Noise Limits for Community Noise

Designation	Day	Evening	Night
	L _{Aeq} , T(dBA)	L _{Aeq} , T(dBA)	L _{Aeq} , T(dBA)
A .Sensitive	50	45	40
B. Mixed	55	50	45
C. Non-Sensitive	60	55	50

(*Measured at any noise sensitive property within the appropriate area designation)

Table 4.25. Maximum Permissible Façade Noise Limits for General Construction Activities

Area Classification	Day	Evening	Night
	L _{Aeq} , T(dBA)	L _{Aeq} , T(dBA)	L _{Aeq} , T(dBA)
A, B, C	75	65	45
D	80	80	80

4.14.5 General Comments

A: Quiet areas; B: Sensitive areas; C: Mixed areas; D: Non-Sensitive areas

Three segments (Day, Evening and Night) to which the 24-hour day is split into need to conform to the CCG Noise Regulations (2006) and consistently be utilized by the different proponents for the purpose of noise monitoring and results reporting. Table 5 indicated the daytime (7:00-16:00), evening time (16:00-23:00) and nighttime (23:00-7:00) periods, as well as the maximum allowable received-noise limits for specified land uses (Table 4.26).

Table 4.26. Maximum allowable noise limits for specified land uses

Time Period →	Limits of Noise Levels (L _{Aeq}), dB(A) during the "daily" specified time periods								
	Day time			Evening time			Night time		
	7:00-16:00			16:00-23:00			23:00-7:00		
Noise Type →	Traffic	Industrial	Community	Traffic	Industrial	Community	Traffic	Industrial	Community
↓ Type of Area/Zone exposed to outdoor noise									
Ideal residential areas (Villas)	55	50	50	55	45	45	50	40	45
Urban residential areas	62	55	55	60	50	50	55	45	45
Urban residential areas with some commercial and workshops activities	65	60	60	65	55	55	60	50	50
Industrial and Commercial Areas	70	70	70	65	70	70	60	65	70

Source: "Noise Levels in Indoor and Outdoor Environments in Countries of the Gulf Cooperation Council (GCC)", April, 2006. Article (2) Standards of Exposure to Outdoor Noise levels

Additionally, the applicable noise limits were obtained from the *World Bank Noise Guidelines' Noise Control*. For the assessment of noise, the limits from both sources are summarized in Table 4.27

Table 4.27. Maximum allowable noise limits for specified land uses.

	Noise limits, L_{Aeq} , dB(A)			
Source →	World Bank		Saudi Aramco Limit	
Time period →	Day-Time	Night-Time	Day-Time	Night-Time
Type of location ↓				
Industrial (site boundary)	70	70	70	70
Residential Areas	55	45	65	55

Source: World Bank Noise Guidelines and Saudi ARAMCO Standard SAES-A-105 'Noise Control')

4.15 CONCLUSIONS

The results of different parameters of air quality, noise, and dust monitoring of the Al-Humaij area were found to be below the NCEC-regulated limit. However, due to the prevalent high speed of the wind (average 4.4 m/s) in the desert area that carries sand and dust, the noise recorded and small dust particles ($PM_{2.5}$) were found high and exceeding the NCEC regulated values.

Noise levels of the baseline conditions during the day and nighttime were typical with an average L_{Aeq} equal to around 54.2 dB(A), a maximum L_{Amx} , of 73.1 dB(A), and a minimum L_{Amin} of 38.1 dB. The L_{A10} is around 55.7 dB(A). There are no nearby noise-sensitive areas and/or communities. The Noise Pollution indicator (LNP) is around 65.9 dB(A). Background noise levels indicated by L_{90} were around 42.7 dB(A) (indicating 90 % of the noise recorded was 42.7 dB) indicating a quiet outdoor noise condition.

Average fugitive dust mass concentration indicators of $PM_{2.5}$, and PM_{10} showed the value of 148.9 $\mu\text{g}/\text{m}^3$. The TPM ($\leq 10 \mu\text{m} + \leq 2.5 \mu\text{m}$) was around 320.3 and 287.0 $\mu\text{g}/\text{m}^3$ at H-2 and H-4, which is slightly higher, however, it is expected because of wind speed and dust emissions as a result of strong wind flow near few measurement locations. The average particulate matter of size $< 2.5 \mu\text{m}$ inhalable was found high at site H-3, H-4, and H-5 (39.2, 45.2, and 43.6 $\mu\text{g}/\text{m}^3$ respectively), and the minimum was 32.7 and 19.1 $\mu\text{g}/\text{m}^3$ at H-1 and H-2 respectively. Similarly, the dust of $<10 \mu\text{m}$ was found higher at H-2 and H-4 (210.3 and 215.0 $\mu\text{g}/\text{m}^3$ respectively). However, this value is much lower than the NCEC-regulated value of 340 $\mu\text{g}/\text{m}^3$. The overall PM_{10} was found to be 112.0 $\mu\text{g}/\text{m}^3$.

4.16 EXPECTED IMPACTS AND RECOMMENDATION DURING CONSTRUCTION PHASE

Following are some expected impacts and recommendations to reduce the impact related to the construction activities,

4.16.1 Noise Levels

Considering that a noise environment of $L_{Aeq} > 60$ and ≤ 70 dB(A) is considered “normally acceptable” during the daytime, the following potential Construction Noise Impacts (CNI) can be considered:

- Planned construction activities intermittently and temporarily generate noise levels above existing ambient levels in the project vicinity. However, since the project construction site/location is very far away from many noise-sensitive occupants/zones, the impacts can be considered insignificant.
- During the construction period, a wide variety of construction equipment is used, and material transported to and from the site by heavy trucks. These activities intermittently and temporarily increased ambient noise levels in the project vicinity over the duration of construction period. Construction-related noise levels at different active construction zones and near locations in the project development site greatly fluctuated depending on the particular types, number, and duration of use of various pieces of construction equipment. The effect of construction noise depends on the level of construction activity on a given day and the related noise generated by that activity, the distance between construction activities and the nearest noise-sensitive uses (which is not applicable in the project case, i.e., desert area) and the existing noise levels at those usages.
- Noise from construction activities generally decreases at a rate of **6.0-7.5 dB(A)** per doubling of distance. Construction associated with the project's current developments took place very far away from the nearest existing noise-sensitive receptors (e.g., residential camps, administrative offices). Conservatively assuming an attenuation of **6 dB(A)** per doubling of distance, un-attenuated construction noise levels could be as high as **75-95 dB(A)**. Truck movements for material delivery and hauling also led to an increase in un-paved road tracks and roadside noise levels over the construction period.
- At noise levels above **85 dB(A)**, normal conversation is extremely difficult. During the observed construction activities, noise levels (**L_{Aeq}**) near the point of source can be as high as **85 dB(A)**. Consequently, it would have the potential to exceed the normally acceptable noise levels (i.e., **L_{Aeq} > 60** and **≤ 70 dB(A)**).
- As construction activities mainly occur during daytime hours, construction noise would not be disruptive to local residential camps. Given the fact that there are no nearby noise-sensitive receptors to the current construction areas/zones, and the anticipated variable durations of project construction activities and based on the significance criteria, compliance with the noise standards is achieved. One can conclude that the construction noise levels from project development so far are local to the extent possible, and thus project construction impacts can be considered less significant.
- Noise at the measurement locations is mainly caused by local noise sources, passing vehicles, construction trucks, construction equipment, and wind. Hence no nearby sensitive locations are impacted. However, elevated levels are temporary in nature and localized, which require the concerned contractors to apply protection measures due to occupational noise exposure to protect their employee and laborers on site as part of their Environmental Protection Engineers' responsibility. The **85 dB(A)** is indicated as the threshold limit of occupational noise exposure and subsequent actions are communicated to the contractors' HSE engineers.

4.16.2 Dust Emission

Mass concentrations of dust emissions during construction indicate that the ambient dust (Mass Concentration of PM₁₀) emitted at the measurement locations can be

significantly low i.e. $<340 \mu\text{g}/\text{m}^3$ except for a very slightly higher average value of TPM reaching $320.3 \mu\text{g}/\text{m}^3$ during daytime. However, it is expected to elevate to higher values during the planned construction activities and processes such as soil excavation, trenching, loading, and unloading, backfilling, soil compaction, and grade leveling. In addition to fugitive dust as a result of mobilization activities and movements of construction trucks, particularly on unpaved roads with loose sand layers, trenching (i.e. excavation and soil handling) should be professionally executed to avoid excessive dust emission in air and the surrounding areas. Leading unpaved (soil) roads need to be regularly watered to reduce dust emissions during vehicles and construction equipment movements.

4.17 HYDROLOGY STUDY

4.17.1 Introduction

The Solar Assessment Project in Saudi Arabia is a strategic initiative designed to tap into the unique characteristics of nine specific locations across the country. These locations have been carefully chosen based on their distinct attributes, each playing a vital role in meeting the region's power demand through solar energy. In essence, the Solar Assessment Project in Saudi Arabia is not only a pursuit of renewable energy but also a nuanced understanding of the distinctive features that contribute significantly to meeting the region's power demand. The hydrology study plays a critical role in ensuring the sustainable development of solar parks that align with the broader vision of responsible energy use in the region.

The solar assessment project in Saudi Arabia encompasses nine different locations distributed across various regions. Each location has its unique characteristics that contribute to the overall hydrology and water resources of the area. The figure provided below illustrates the relative location of Al-Humaij Solar Park within their respective regions in Saudi Arabia (Figure 4.73).

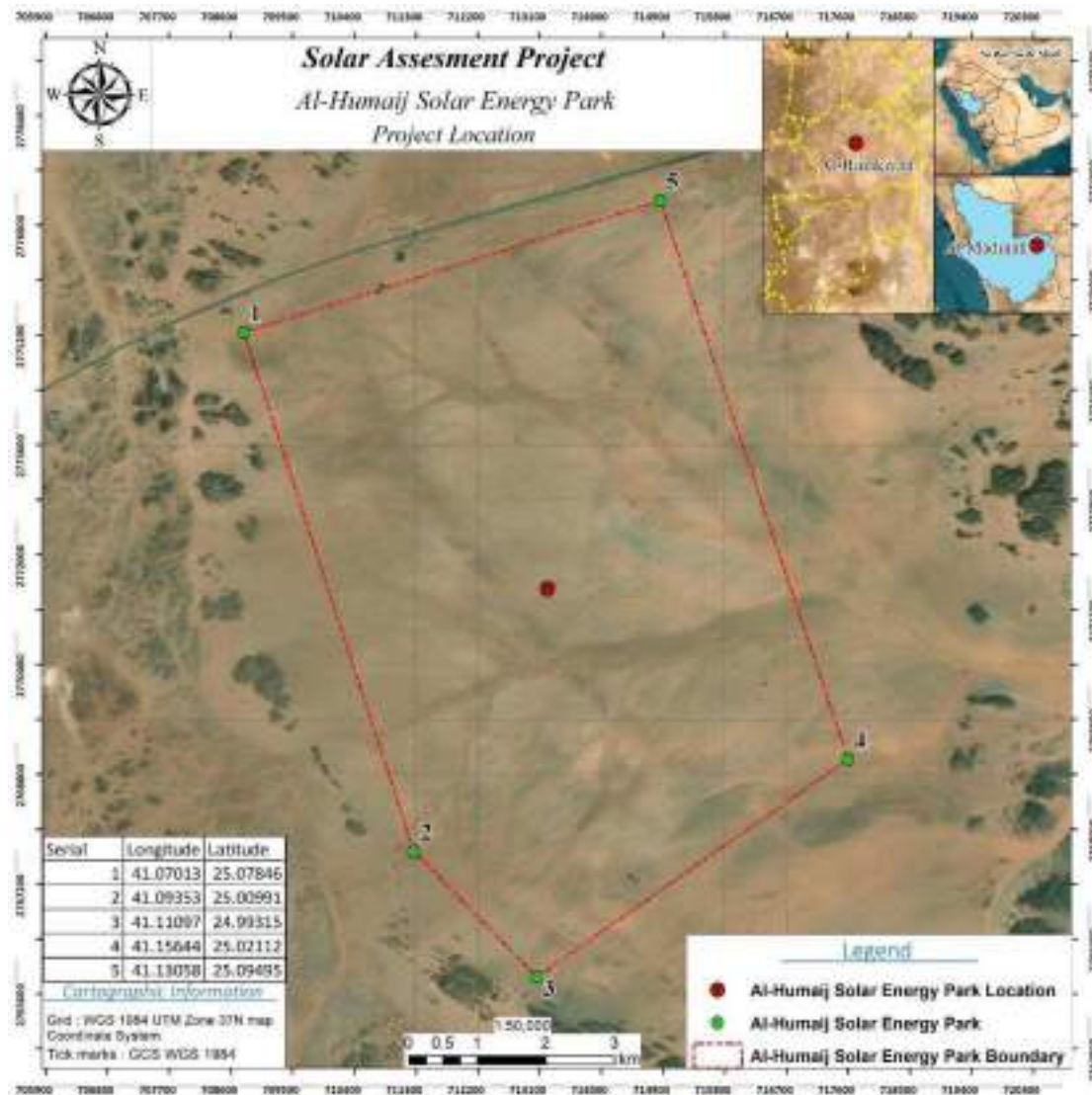


Figure 4.73. Project Location in AL-Humaij

4.17.2 Study Objectives and Scope of Work

The objectives of this study are resembled in carrying out all the hydrological analyses, related to the determination of the external wadis affecting the project boundary to determine the extent of its exposure to flood hazards and therefore to take the necessary measures and propose the necessary protection works to prevent against major flood risks, and consider these works during the master planning for the project site in case needed.

4.17.3 Methodology and Work Plan

The methodology starts with the identification of the collection of data and information needed to develop the design. Then computer models and software packages to conduct hydrological and hydraulic analysis of the catchment areas and proposed protection works. Accordingly, the design of the flood protection works can begin, including the design of wadi and riprap revetments.

4.17.4 Codes & Standards International References Regarding Methodologies

All works will be performed in accordance with the standards, specifications, practices, and drawings that are referenced in this Scope of Work.

The hydrological and hydraulic designs are based on the design criteria conforming to the following standards and design manuals:

- Ministry of Municipal and Rural Affairs (MOMRA) Design Standards.
- Saudi Geological Survey (SGS) Design Standards.
- Ministry of Transport (MOT) Standards.
- ER07.8.12 NEOM-NEN-PRC-012_01.00 - Hydrological Study Procedure”
- Urban Hydrology for Small Watershed, Technical Release 55, TR55, NRCS, 1986.
- Hydraulic Engineering Circular (HEC) no. 22 – Urban Drainage Design Manual.

4.17.5 Available Data Collection and Site Visits

The section "Available Data Collection and Site Visits" provides information on the sources of data and information that were collected and used in the study. This section highlights the data collected from various sources such as site visits, surveys, and existing records. The information gathered from these sources was used to perform the hydrological and hydraulic analysis, flood risk assessment and to make recommendations for flood protection works and mitigation measures. The purpose of this section is to give a comprehensive overview of the data collected and used in the study to support the findings and recommendations made.

4.18 DATA COLLECTED

4.18.1 Topography and Survey

The primary purpose of utilizing topographic maps is to identify and verify the names of wadis and other physical features within the project area, particularly in determining the paths of wadis and establishing thresholds of flow accumulation.

The sources of topographic maps include:

- DEM Data which is the Digital Elevation Model (DEM). It provides a three-dimensional representation of the topography of the area. DEM collected from the Ministry of Municipal and Rural Affairs (MOMRA) with a resolution of 10x10 meters (Figure 4.74).
- Topographic Maps which mainly based on (SGS) with scale of 1:50000 (Topo Maps No. 3922-23 Ash Shubah, 3922-24 Ad Duwwarah, 3922-31 Al Buraykah, 3922-32 Khulais, 3922-33 Wadi Thuwal & 3922-34 Thuwal).

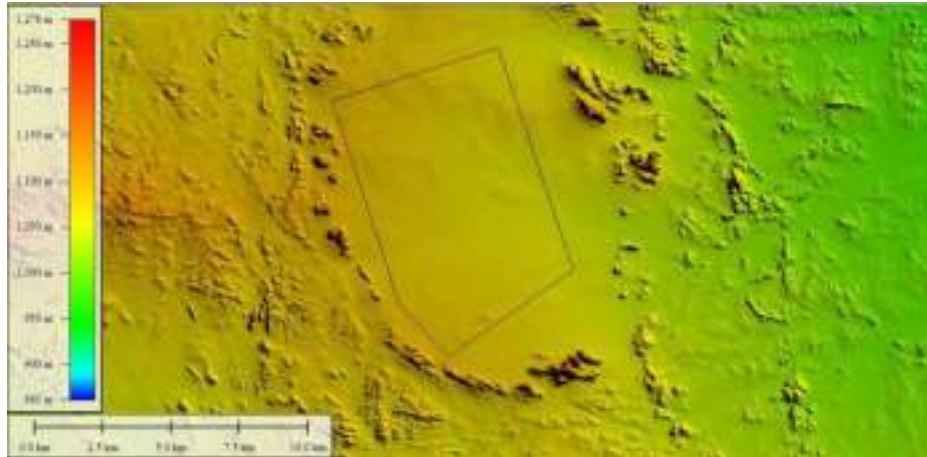


Figure 4.74. DEM map of 10 x10 m Resolution for Al-Humaij study area.

4.18.2 Rainfall Data

The information obtained from the historic rainfall data is used to estimate the rainfall intensity, duration, and frequency of the design storm. This information is then used to calculate the runoff volume, which is essential in determining the design storm return period and the required size of the drainage elements. The data for the rainfall analysis was collected from the Ministry of Environment, Water and Agriculture (MEWA). This data was used to determine the rainfall patterns and intensity in the area near the project location and to make informed decisions about the potential impact of rainfall on the project.

The project has used historic rainfall data collected from the J M004 – Alhinakyah Station, which are the influencing stations as per Thiessen polygon analysis. This data provides valuable information about the rainfall patterns and intensities in the region and is used in the rainfall data analysis (Figure 4.75).

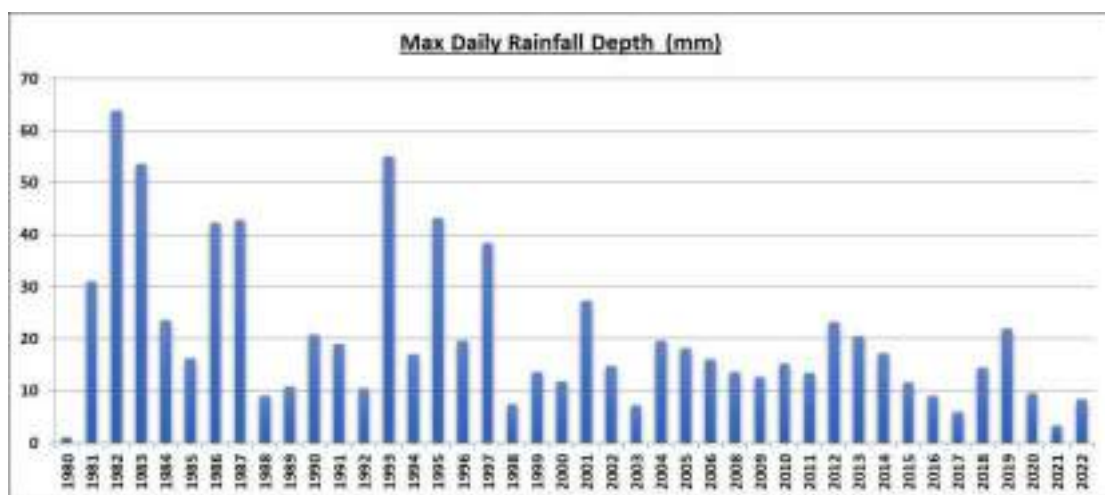


Figure 4.75. Chart for Max Daily Rainfall Depth (mm)- AlHinakyah Station

4.18.3 Geological Data

Geological data was collected from various sources to gain a comprehensive understanding of the geology of the project area. The sources of geological data included, but were not limited to:

- The Saudi Geological Survey.
- Previous geological studies and reports.
- On-site observations.

The geological data collected provide information about the soil types, rock formations, and geological structures that may impact the proposed flood protection works. The data was also used to identify any potential geological hazards that may need to be addressed during the design and construction of the project.

The project location is located within the boundaries of the geological map labeled Nuqrah (GM-28), as shown in the below figure no.6-8 Shows the whole Nuqrah (GM-28). This information is important to understand the geological conditions and potential impact on the project design.

4.18.4 Recent Satellite Images

Satellite images can provide a comprehensive view of the study area, including its topography, land cover, and other features that can impact surface runoff and other hydrological processes (Figure 4.76). The satellite images were processed and analyzed to identify key features and patterns that can impact the flow of water, such as drainage systems, vegetation, and human infrastructure. This information was then used to inform the design of stormwater management systems and other infrastructure, ensuring that they are properly configured to handle the specific conditions of the study area.

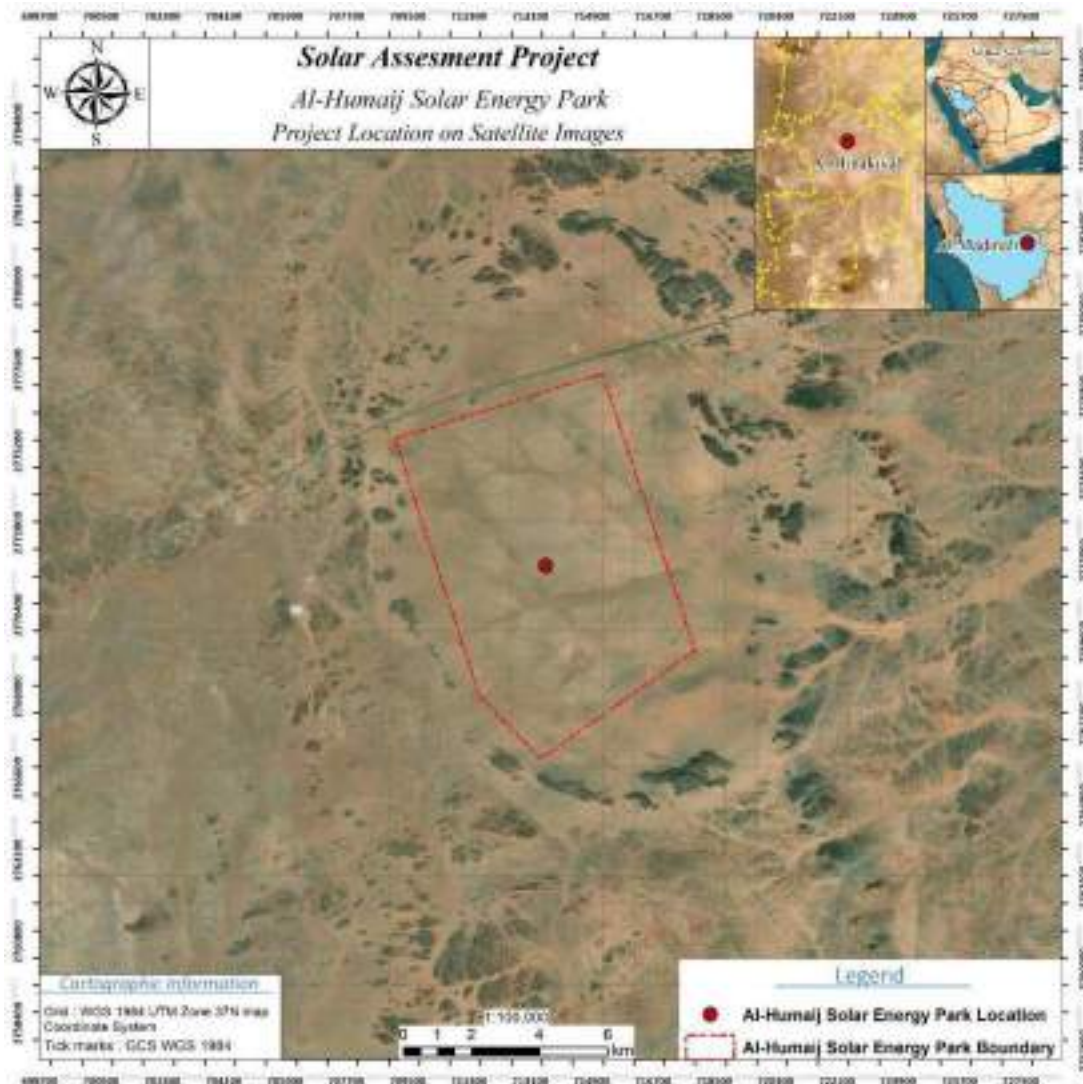


Figure 4.76. Recent Satellite Image shows the project area.

4.19 SITE VISIT REQUIREMENTS

In this hydrology study, site visits are required to collect data and information on various aspects of the study area, including but not limited to topography, geology, soil characteristics, land use, surface water resources, and the presence of any flood-prone areas.

Objectives of these visits are:

- Identifying the flood hazards & hot spots/critical areas.
- Identifying the existing flood mitigation measures in the project area.
- Understanding the general topography of the project region.

The site visit outcomes, including observations and measurements made during the visit, are typically documented in a separate report.

4.20 GEOLOGICAL AND GEOTECHNICAL STUDIES

4.20.1 Geological Aspects

The project location is depicted on a geological map, showing that the surface geology is dominated by these specific rock types. From a hydrological standpoint, the presence of peralkalic and alkaline granite formations can significantly influence surface hydrology processes. Peralkalic and alkaline granites typically exhibit low porosity and permeability, which can lead to reduced groundwater recharge and increased surface runoff. Additionally, these rock types are often associated with rugged topography and steep slopes, further affecting surface water flow patterns and erosion potential. Therefore, it is essential to consider the implications of these geological conditions on surface water management strategies and infrastructure design within the project area (Figures 4.77 and 4.78).

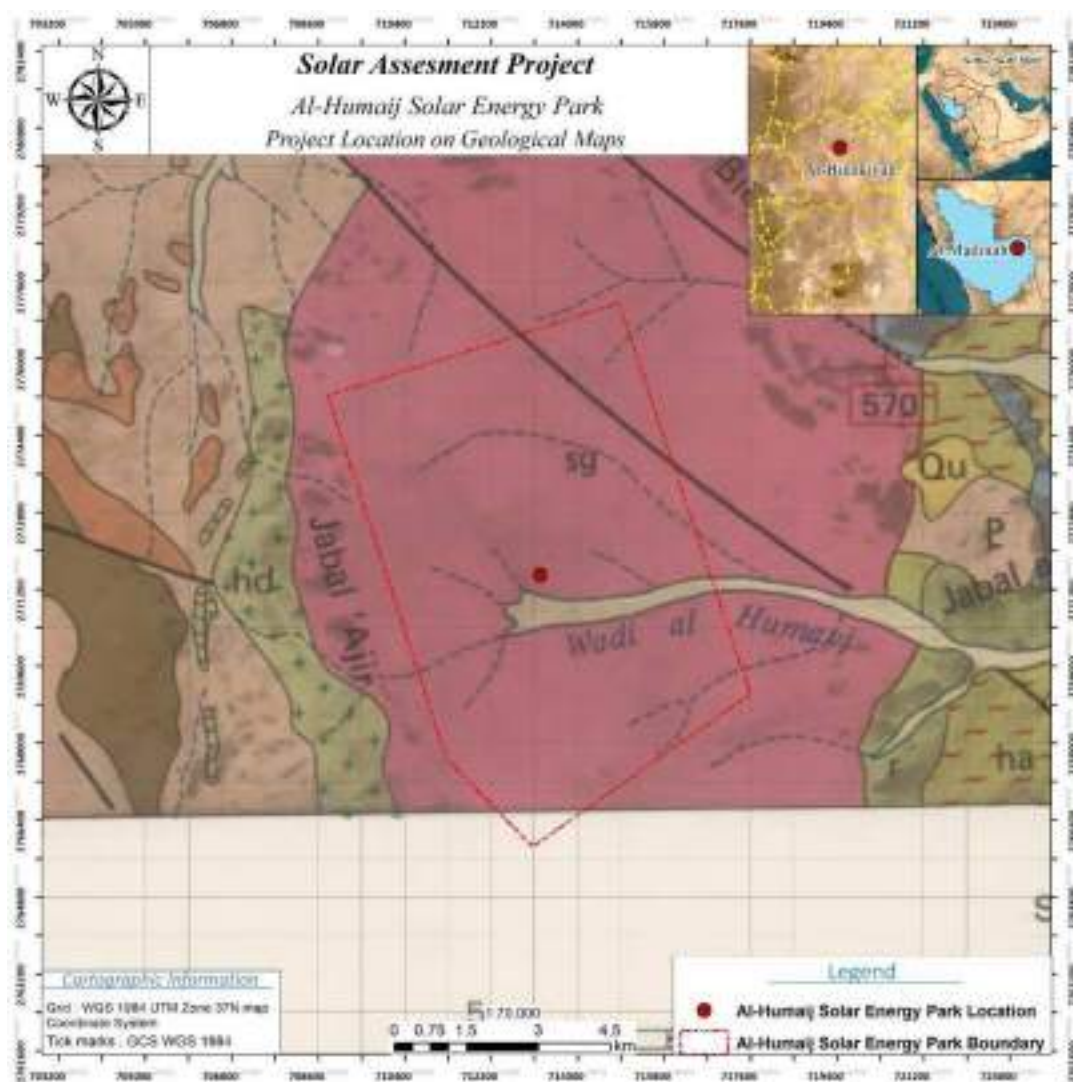


Figure 4.77. Geologic map of the project area.

After overlaying the catchment boundaries onto the geological maps and cross-referencing them, it became evident that the Catchment area is characterized by the dominance of PERALKALIC and ALKALIC GRANITE formations.

The legend of the map helps understand the geological composition of the terrain and provides valuable information for various applications, including land use planning, natural resource management, and environmental assessments.

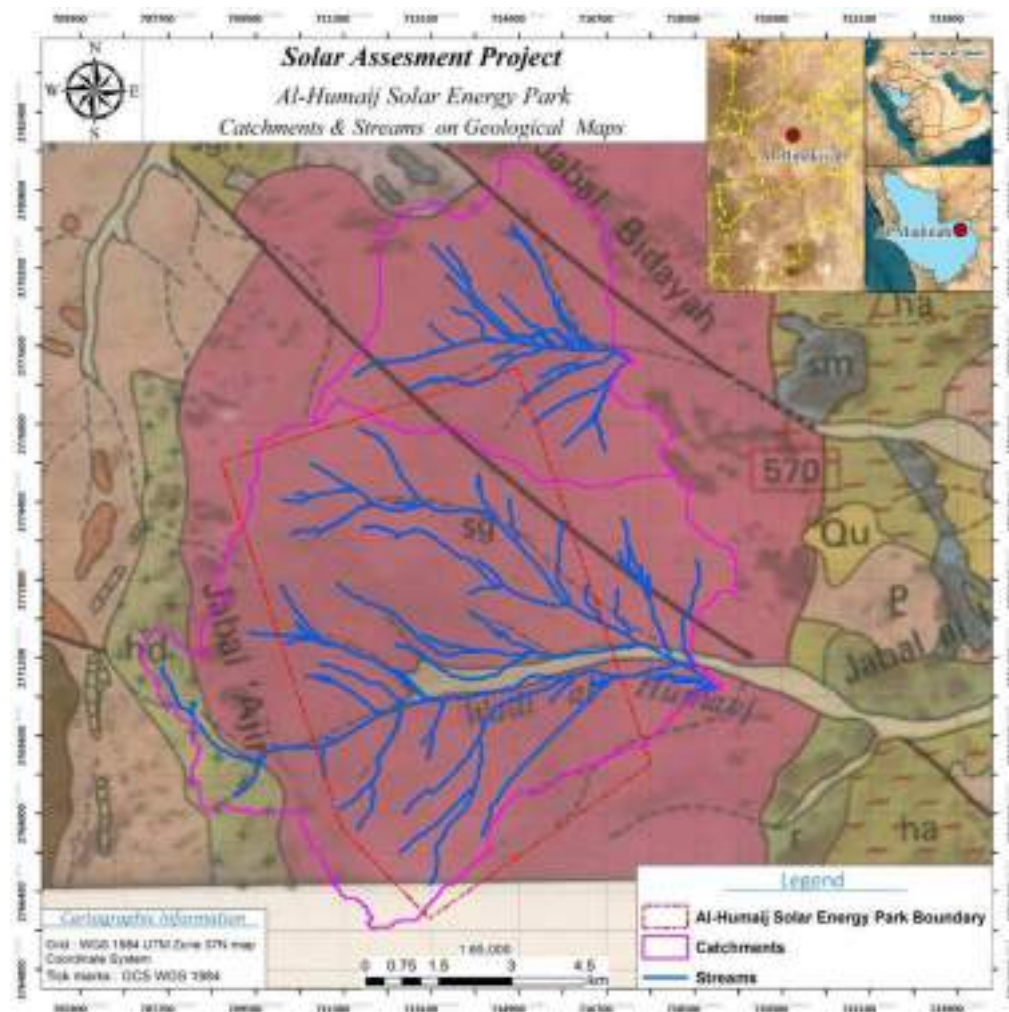


Figure 4.78. Catchments and Streams on Geological Map

4.21 RAINFALL DATA ANALYSIS

The rainfall data collected from the effective rainfall stations in the study area was analyzed and the IDF (Intensity-Duration-Frequency) curves were developed for different design return periods.

4.21.1 Daily Maximum Rainfall Analysis

Daily maximum rainfall analysis involves the examination of the largest amount of precipitation that occurred on a given day within a certain location. This type of analysis is important for understanding the potential for flooding, erosion, landslides, and other natural hazards that can occur as a result of intense rainfall. Statistical analysis can be used to quantify the daily maximum rainfall and its variability. This can include calculating the mean, standard deviation, and other descriptive statistics. It can also involve fitting probability distributions to the data to estimate the likelihood of extreme rainfall events.

Rainfall data analysis aims to achieve the following results:

- Analyzing the rainfall data of each station by using and testing more than statistical distribution method and selecting the best fit of them which gives greater values for the design precipitation rates.
- Deducting the cumulative daily precipitation depths (24 hours) will be predicted using Hyfran Plus corresponding to different return periods of 25, 50, 100, and 500 years in order to be used in a SCS method.
- Deducting curves of the intensity- Duration- Frequency (IDF Curve) for the meteorological stations and estimating the extreme values precipitation (mm) for durations 10 min, 20 min, 30 min, 60 min, and 2 hours. These IDF Curves will be used in the rational method.

4.21.2 Short Duration Rainfall Analysis

Short-duration rainfall analysis refers to the study of rainfall intensity and duration over a short period, usually ranging from 5 minutes to 2 hours. This type of analysis is important for understanding the potential for flash flooding or runoff from high-intensity storms. The analysis is typically performed using rainfall data from rain gauges or other meteorological instruments and can include calculating the maximum rainfall intensity, peak rainfall rate, and cumulative rainfall over the duration of the storm event. The results of the short-duration rainfall analysis can be used to design and evaluate stormwater management systems, such as drainage systems and detention ponds, to ensure they can effectively manage and control runoff during extreme rainfall events.

To produce the IDF (intensity-duration-frequency) curves, the available rainfall data for short periods from different stations near the study area shall be used. Frequency analysis on short-duration data is to be undertaken similar to the procedure for daily rainfall.

4.21.3 Adjustment to Fixed Duration

Adjustments are necessary to account for discretization. In this case, the rainfall frequency analysis is based on annual maximum daily (1-day) rainfall data, which are not expected to be as large as those based on annual maximum 24-hour rainfall data. Since daily gauges record over a fixed period, adjustments must be made to reflect a 'sliding' duration.

4.21.4 Design Storm Profile

To perform hydrological and hydraulic modeling, the design rainfall depths need to be distributed over specified durations. However, the distribution of rainfall over time varies from storm to storm during observed storms, hence, a suitable "design" storm profile is necessary. If a sub-daily gauge is available, typical storm profiles can be determined through empirical analysis, but a large sample of recorded storm events is required. In the absence of local sub-daily rainfall data, a synthetic profile must be used.

The hydrological and hydraulic modeling process will involve determining the appropriate method for creating storm profiles, which will be based on factors such as

the size of the catchment, the critical storm duration, and the impact on the hydrograph volume.

4.21.5 Daily Maximum Rainfall Analysis of J-106 Khulais- Station

The station J-106 Khulais is the first station that impacts the study area. The results of the analysis for the rainfall stations were obtained by using the Hyfran software to process the raw data. Various distribution models were employed to determine the most suitable distribution for the data, as shown in the comparison criteria figure below. The Pareto distribution was identified as the best-fit distribution for the station's data, based on AIC and BIC methods (Figure 4.79).

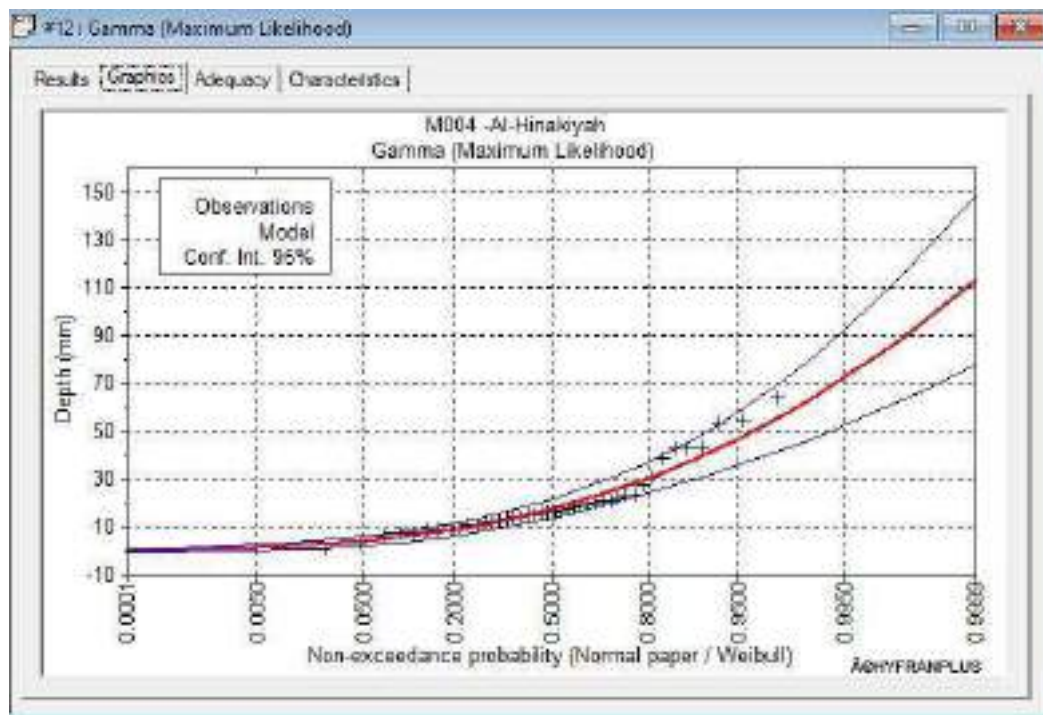


Figure 4.79. Gamaa distribution for M004 – Alhinakyah

The rainfall depth values were used to develop intensity, duration, and frequency (IDF) curves of the station as shown in the following figure using Bells' ratios shown in the following table due to the absence of short-term rainfall data in the study area (Figure 4.80).

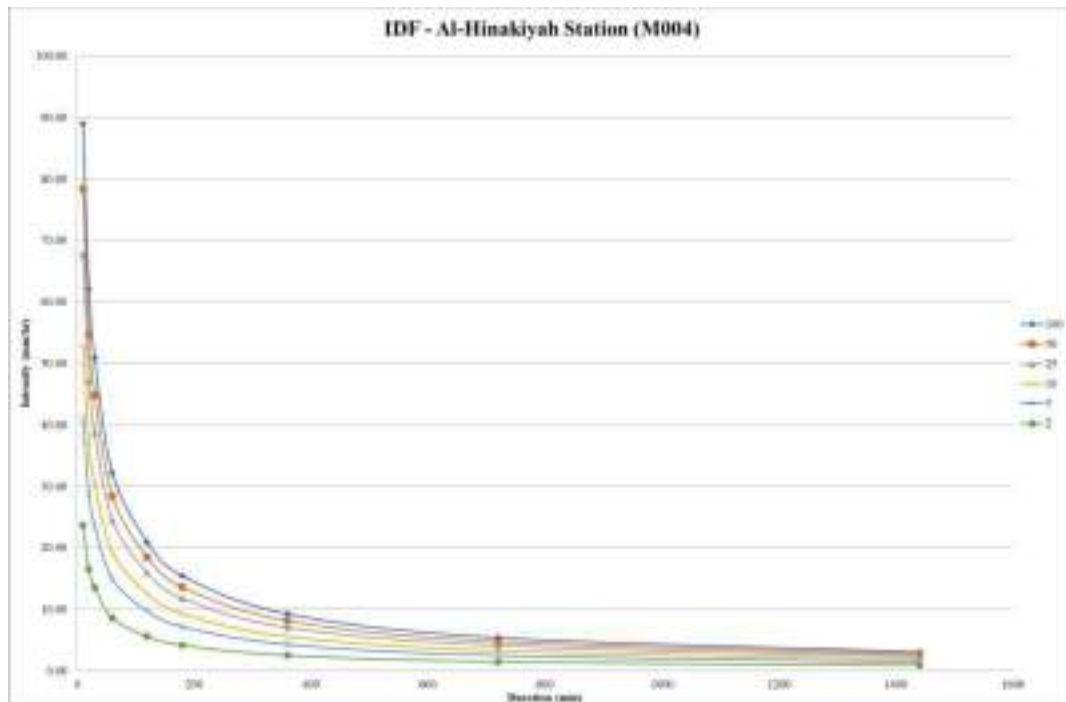


Figure 4.80. IDF curves for M004 - Alhinakyah Station

4.22 HYDROLOGICAL ANALYSIS

Hydrological studies are considered the foundation stone for the selection of the required protection works. Meteorological, morphological and geological studies and site visits are considered as inputs for the hydrological study. The peak flow and runoff hydrograph are the main outputs of the hydrological study, which is used in the hydraulic design of flood protection works.

4.22.1 Identification of Drainage Basins

The main/secondary drainage basins and their characteristics shall be determined using digital elevation models (DEM).

In order to determine drainage basins and waterways, the digital elevation model shall be analyzed using WMS and Arc Hydro software packages according to the following steps:

- Terrain pre-processing
- Filling the sinks
- Flow direction
- Flow accumulation
- Determination of the threshold for the start of stream definition
- Stream segmentation
- Catchment grid delineation
- Catchment polygon processing
- Drainage Line Processing

4.22.2 *Geographic Information System (GIS) and Digital Elevation Models (DEMs)*

The appropriate accuracy of the digital elevation model data depends on a number of factors, mainly the topography of the land and the availability of data and costs. When determining the scope of work, the availability of data and the accuracy of the models shall be evaluated.

4.22.3 *Rainfall-Runoff Calculations*

There are several methods for estimating and calculating the peak flows and runoff hydrographs resulting from the catchment areas affecting the project boundary. The most common methods used in Saudi Arabia are (the Rational Method) and (SCS Unit Hydrograph).

The SCS Unit Hydrograph method is used in calculating the peak flows and runoff hydrographs for each catchment area greater than 1 km², while the Rational Method is used to calculate the peak flows for each catchment area smaller than or equal to 1 km².

4.22.4 *Morphological Analysis*

The contributing catchments shall be modeled using the Watershed Modelling System (WMS) and exported to HEC-HMS to run the hydrological model.

4.23 HYDROLOGIC MODELLING

4.23.1 *HEC-HMS*

For the (SCS Unit Hydrograph) method, RGF used the Hydrologic Modeling System (HEC-HMS) to model the surface runoff for the external catchments that affect the project boundary. HEC-HMS is a hydrologic modeling system used to simulate precipitation runoff processes in a catchment.

4.23.2 *Peak Flows and Runoff Hydrographs*

Calculating the peak flow and runoff hydrographs for the catchments is a fundamental aspect of selecting the necessary measures for flood protection. These studies rely on inputs such as meteorological, morphological, and geological data, in addition to site visits. The peak flow and runoff hydrograph are crucial outputs from the hydrological study and serve as the basis for designing hydraulic flood protection and storm drainage systems.

4.24 FLOOD RISK ASSESSMENT

The flood risk assessment aims to identify flood hazards, assess their potential impact on the project, and develop appropriate measures to mitigate these risks. The flood hazard was mapped based on the hydraulic modeling results obtained from HEC-RAS software, combined with Digital Elevation Models (DEMs) and GIS techniques.

The flood hazard map was generated to identify the areas within the project site that are susceptible to flood hazards. The mapping also aimed to determine the depth and velocity of the floodwaters and the potential risk to human life, property, and infrastructure.

The maps below show the maximum flood depth and velocity and the flood hazard zones for the project area, with different colors indicating different levels of flood risk (Figure .4.81)

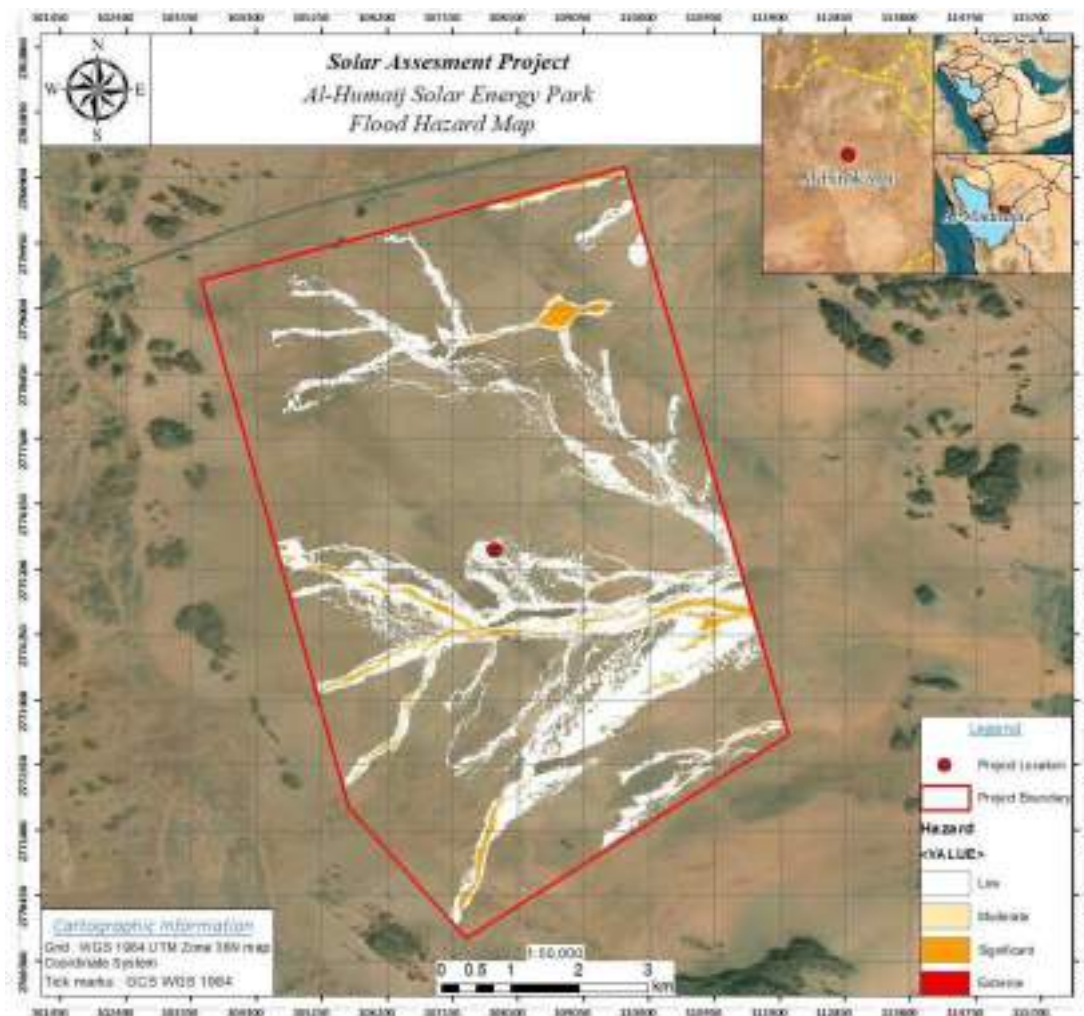


Figure 4.81. Flood Risk Mapping of Al-Humaij project area.

4.25 CONCLUSION AND RECOMMENDATIONS

The Hydrology Study conducted for the Al Humaij Solar Energy Park has yielded valuable insights into the flood hazards and potential risks associated with the site. Key conclusions drawn from the study include:

- **Flood Hazard Identification:** The analysis identified specific areas within the solar energy park that are prone to flooding, especially during extreme weather events.
- **Hydrological Vulnerabilities:** The hydrological assessment highlighted vulnerabilities in the site's drainage infrastructure, emphasizing the need for tailored flood mitigation measures.
- **Site-Specific Characteristics:** Unique features of the Al Humaij Solar Energy Park, such as topography and land use, significantly influence flood dynamics, necessitating site-specific flood risk management strategies.

Based on the identified flood risks flood protection has been proposed. That option aims to ensure the safety of the solar energy park while allowing for its continued development. The recommendations are as follows:

Flood Compatibility Zones:

- **Development Suitability:** Areas compatible with development have been clearly defined based on flood depth and velocity assessments.
- **Restrictions with Mitigation:** Certain zones, while initially restricted, can be deemed compatible with the implementation of appropriate scour protection and flood mitigation measures.
- **Non-Compatible Zones:** Some areas are deemed unsuitable for development due to high flood risk and are recommended to be avoided.

In addition to the identification of flood compatibility zones to mitigate the impact of external flood events, it is imperative to implement internal grading measures within the site itself. This internal grading aims to address potential hazards arising from internally generated flows, ensuring comprehensive flood protection for the Al Humaij Solar Energy Park. Internal grading measures may include:

- **Surface Drainage Enhancement:** Improve the surface drainage system within the solar energy park to efficiently channel rainwater away from critical infrastructure and vulnerable areas.
- **Erosion Control Measures:** Implement erosion control measures, such as reinforced vegetation or stabilizing structures, to prevent soil erosion and the formation of hazardous conditions during heavy rainfall.
- **Stormwater Management:** Develop a robust stormwater management plan to capture and control excess rainwater.
- **Internal Flow Path Optimization:** Analyze and optimize the internal flow paths to guide water away from sensitive areas, reducing the risk of flooding within the solar energy park.
- **Regular Maintenance Protocols:** Establish routine maintenance protocols for drainage to ensure ongoing effectiveness and resilience against internally generated flood scenarios.

By incorporating these internal grading measures, the Al Humaij Solar Energy Park can further enhance its flood resilience, safeguarding against both external and internally generated flood hazards. Regular monitoring and maintenance of these measures will contribute to the long-term effectiveness of the flood protection strategy.

SECTION 5 IDENTIFICATION OF IMPACTS, ANALYSIS AND ASSESSMENT

Gulf Renewable Energy Laboratory (GRL) on behalf of the MoE, represented by the Saudi Power Procurement Company (SPPC) is going to provide the masterplan for the solar PV energy park in Al-Humaij. Operating under the Ministry of Energy, the Principal Buyer is actively involved in the development of the Al-Humaij Solar PV project as part of the National Renewable Energy Program (NREP).

The project focuses on harnessing solar energy through photovoltaic (PV) technology, contributing to the broader goal of diversifying the energy mix in the region. The proposed site is situated approximately east of Al Humaij which is 191 km distance from the city of Madina through Route 60 in the Hizaz Region. Al Humaij, located near Medina in Saudi Arabia, is situated in a region that is confronted with significant environmental challenges. The location is characterized by its arid climate during the day, with high temperatures and low rainfall.

It is proposed to install a solar PV park having single-axis trackers and bifacial solar panels, with a total capacity of 3,000 MW (AC). As per the current proposed schematic design, the (AC) capacity integrated for each block is 3125 KVA. The main access roads of the project will connect with Route 60 (Madina – Bouraidah Hwy). There will be four access gates, each separated by 1.5 Km approximately that can be used to enter the project site. The total block quantity is 945, and each area is 32705 m². Associated facilities include a super-structure for panels, inverters, transformers, electric meters, under voltage relays, circuit breakers, over-current relays, lightning arrestors, etc. The plant will be connected to the nearest electrical substation located at the edge of the site, just a few meters away. For linking to the existing power grid, power transmission lines will be constructed to the nearest electrical substation. Additional facilities like roads, fencing, parking area, control room, warehouse, security building, office building, waste tanks, etc., will be constructed on the site. A total of approximately 3,000 workers will be required for the construction activities lasting for approximately 24 months.

The proposed construction activities are likely to have adverse environmental impacts, which can be substantially mitigated, and will not significantly or irreversibly impact areas beyond the site boundary. Therefore, this EIA project is classified as a Category-2 EIA. Industrial and development projects within KSA are subject to an Environmental Impact Assessment (EIA) as part of the planning and permitting process in accordance with the Environmental Law of 2020 and its implementing regulations released in 2021 [KSA, 2020; 2021].

5.1 CATEGORIZATION OF PROJECTS AS PER IFC GUIDELINE

As part of its review of a project's expected social and environmental impacts, IFC uses a system of social and environmental categorization. This categorization is used to reflect the size of impacts understood as a result of the client's social and environmental assessment and to specify IFC's institutional requirements. The categories used by the IFC are:

- **Category A Projects:** Projects with potentially significant adverse social or environmental risks and/or impacts that are diverse, irreversible, or unprecedented.
- **Category B Projects:** Projects with potential limited adverse social or environmental risks or/and impacts that are few, generally site-specific, largely reversible, and readily addressed through mitigation measures.
- **Category C Projects:** Projects with minimal or no adverse social or environmental risks and/or impacts, including certain financial intermediary (FI) projects with minimal or no adverse risks.

- **Category FI Projects:** Business activities involving investments in financial institutions (FIs) or through delivery mechanisms involving financial intermediation.

IFC therefore categorizes the project primarily according to the significance and nature of its impacts. IFC defines the project's area of influence as the primary project site(s) and related facilities that the client (including its contractors) develops or controls associated facilities that are not funded as part of the project (funding may be provided separately by a client or a third party including the government), and whose viability and existence depend exclusively on the project and whose goods or services are essential for the successful operation of the project; areas potentially impacted by cumulative impacts from further planned development of the project, and areas potentially affected by impacts from unplanned but predictable developments caused by the project that may occur later or at a different location. The area of influence does not include potential impacts that would occur without the project or independently of the project.

The category of the proposed project “Installing and Operating a Solar Energy Park in Khulais, Makkah, Saudi Arabia” is determined based on the project categorization criteria of IFC. With respect to the intensity of impacts due to project activities on the environment, resources, biodiversity, labor, and community, the project can be categorized as **Category B** (as per IFC categorization of projects), which specifies that this project is expected to have limited adverse environment and social impacts, which can be mitigated by adopting suitable mitigating measures.

5.2 METHODOLOGY USED FOR IMPACT IDENTIFICATION, ANALYSIS AND ASSESSMENT

The impact assessment process begins with the identification of key environmental features from the baseline information on the physical, chemical, biological, and socioeconomic components of the project area. The potential positive and negative changes resulting from the defined project activities on environmental receptors are then predicted for the study area and the entire life cycle of the project. These predicted changes (impacts) are then evaluated and assessed by using standard criteria.

5.2.1 *Valued Environmental and Social Components (VECs)*

Valued Environmental and Social Components (VECs) are environmental and social attributes or receptors that are important in assessing impacts and they may be:

- Physical environment (air, climate, land, water, noise, etc.),
- Environment (flora, fauna, etc.),
- Social environment (health, economics, traffic, transport, etc.), or
- Non-routine events (accidental fire, chemical spill, etc.).

VECs are the ultimate recipients of impacts because they tend to be at the ends of environmental pathways. The VECs are also parts of the environment or society that are considered to be important by the developer, operator, general public, or any non-governmental or governmental organization involved in the environmental impact

assessment process. To understand the baseline (ambient) environmental conditions and identify the VECs from the project areas, field surveys, and sampling studies were conducted in January 2024. The results are provided under Section 5 (Ambient Environment Description) of this EIA report. The initial step in the baseline characterisation is the definition of the Project Area of Influence (AoI) of the study area, Al Humaij (Appendix C).

In the EIA, the sensitivity of the receptor or VECs to change is determined using professional judgment, consideration of existing designations (such as Sites of Special Scientific Interest -SSSIs), and quantifiable data, where possible. The scale is very high, high, medium, low, and negligible criteria were used. The sensitivity or value of a receptor can depend, for example, on its nature, location, rarity, quality, extent, or conservation status at an international, national, regional, or local level. While determining sensitivity, factors such as vulnerability of the receptor, recoverability of the receptor, and value/importance of the receptor are also considered. The VECs thus identified as specific to this project are listed by category together with their characteristics of sensitivity in Table 5.1.

Table 5.1. Complete list of VECs identified for the project area (Al Humaij) together with their characteristics of sensitivity

CATEGORY	VECs	Characteristics of Sensitivity			Sensitivity
		Existing regulations and guidance	Societal value	Vulnerability for changes	
Physical Environment	Air Quality	Very high	Very high	High	High
	Climate	High	High	High	High
	Microclimate	High	High	High	High
	Noise and vibration	High	Moderate	High	High
	Visual and landscape	Moderate	Moderate	Moderate	Moderate
	Soil and Land Use	High	Very high	High	High
	Ground and Surface water	High	Very high	High	High
	Flood risk	High	Very high	High	High
Biological Environment	Flora	High	High	High	Moderate
	Fauna	Very high	High	High	Moderate
Social Environment	Waste management	Very high	High	Moderate	High
	Traffic and transport	High	High	Moderate	Moderate
	Health and Safety	Very high	High	High	High
	Labor management	High	Moderate	Moderate	Moderate
	Community Displacement	High	High	Moderate	High
	National and local economy	High	High	High	High
	Archeology and Cultural Heritage	High	Moderate	High	Moderate

CATEGORY	VECs	Characteristics of Sensitivity			Sensitivity
		Existing regulations and guidance	Societal value	Vulnerability for changes	
Non-routine events	Inappropriate waste disposal	Very high	High	High	High
	Accidental spills, fire, etc.	Very high	Very high	High	Very high

5.2.2 Identification of Impacts

The important impacting activities related to the project during the construction and commissioning phase are identified and listed in Table 5.2. The identified Impact Agents/Activities may affect the environment of the project area, including VECs, in adverse or beneficial ways, either within or outside the study area. Similarly, some non-routine events (accidental releases) are also likely to adversely impact the environment.

Table 5.2 List of major impacting agents/activities associated with the construction phases of this project and the sensitive receptors

Construction/Commissioning Phase	Operation Phase	Sensitive Receptors
- Site preparation, excavation, and levelling work for structural works leading to ecological destructions - Dust emission and gaseous emissions from the machines, equipment and generators used in the construction activities. - Airborne noise generation during construction activities - Light pollution due to the lighting of construction sites at night - Removal of flora and habitat fragmentation - Super-structural work involving steel work, concrete work, masonry work, welding work etc. - Mechanical erection work for solar panel modules, inverters, buildings, over-head power transmission lines etc. - Increase in vehicle traffic due to the transportation of workers and the construction materials. - Labor management issues - Water utilization for construction and in the workers camps.	- Increase in air temperature, humidity etc., due to shading effects - Microclimate changes in the surrounding area due to heat-island effects, potentially impacting local ecosystems and wildlife. - Impact of flash flood risk in the project area due to the new facilities. - Loss and fragmentation of natural habitats, collision and electrocution risk to bird and bat species, disruption to wildlife movement/migrations and displacement risk to birds. - Visual impact due to the alteration of landscape of a desert area potentially affecting the aesthetic value and scenic beauty. - Light pollution due to the exterior lighting fixed in and around the solar energy park for security purposes. - Minor noise generation by inverters and transformers, which convert DC electricity	- Air Quality - Climate - Microclimate - Noise and vibration - Visual and landscape - Soil and Land Use - Ground and Surface water - Flood risk - Flora - Fauna - Waste management - Traffic and transport - Health and safety - Labor management - Community Displacement

Construction/Commissioning Phase	Operation Phase	Sensitive Receptors
• Solid and liquid waste generation from workers camp and construction activities.	- generated by the panels to AC electricity. • Water utilization for cleaning solar panels and wastewater generation • Solid and liquid waste generation from the operation and maintenance activities	• National and local economy • Archeology and Cultural Heritage • Inappropriate waste disposal • Accidental spills, fire etc.

5.2.3 Impact Assessment and Evaluation

The multi-criteria decision analysis (MCDA) tool called ARVI developed in the EU LIFE+ IMPERIA project Imperia 2015 (IMPERIA, 2015; EU, 2017) was used in the impact assessment. This Excel-based tool is the product of an EU project, *Improving Environmental Assessment by Adopting Good Practices and Tools of Multi-criteria Decision Analysis* [IMPERIA, 2015; EU, 2017].

The fundamental principle of the ARVI approach is that for each impact (for instance noise, landscape or water quality) one first assesses the sensitivity of the target receptor in its baseline state, and then the magnitude of the change, which would probably affect the target receptor as a result of the proposed project. An overall estimate of the significance of an impact is derived from these judgments. Both the sensitivity of the target receptor and the magnitude of the change are evaluated systematically based on more detailed sub-criteria (Figure 5.1). These criteria are described in more detail on the following pages.

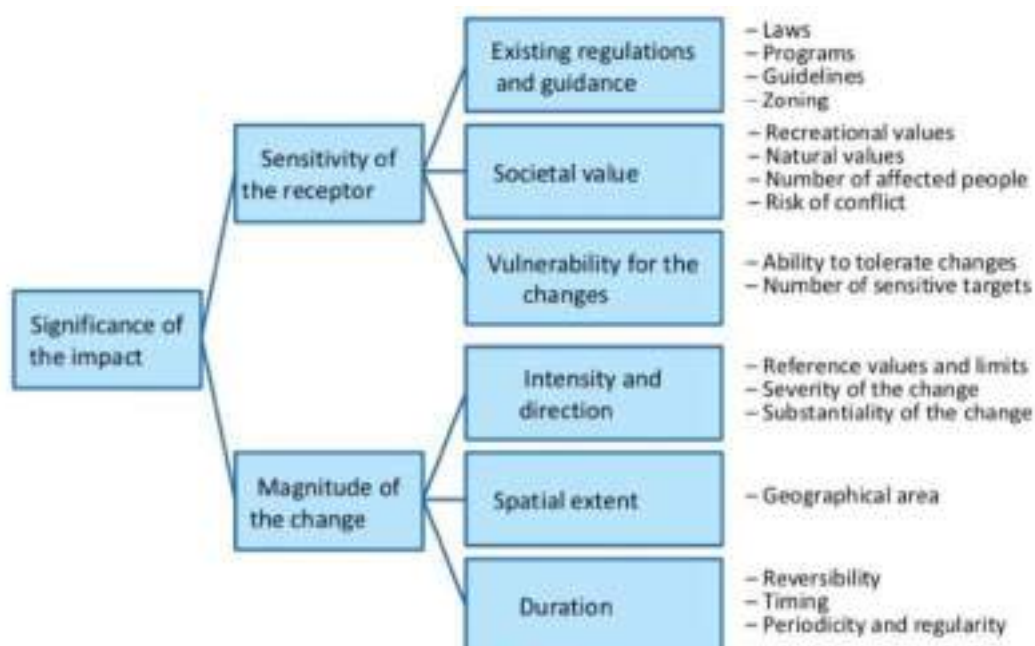


Figure 5.1. The structure of the ARVI approach.

The assessment process is described in Figure 5.2. For each alternative and impact combination under evaluation, an assessment form is filled including all the factors in the figure. Typically, each impact is assessed by an expert of the particular field, who evaluates all the alternatives with respect to this impact. Besides evaluation, it is important to also document the basis and rationale for reaching the conclusion in the evaluation form.

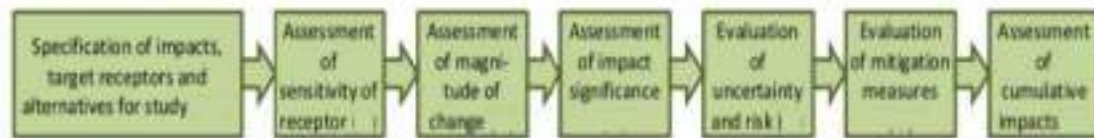


Figure 5.2. The assessment process with the ARVI approach.

Existing regulations and guidance describe whether there are any such objects in the impact area, which have some level of protection by law or other regulations (e.g. prohibition against polluting groundwater and natural areas), or whose conservation value is increased by programs or recommendations (e.g. landscapes designated as nationally valuable). In the ARVI approach, the assessment of impact significance is based on the sensitivity of the target and the changes that might result from the project as follows:

- The sensitivity of the target is assessed based in its characteristics (existing legislation, social significance and vulnerability to change)
- The magnitude of change resulting from the project is assessed based on its characteristics (magnitude and direction, scope and duration, including timing and periodicity)
- An assessment is formed of the significance of impacts based in the above assessments of target sensitivity and the magnitude of the change utilizing, for example, an indicative table (Table 5.3)

Table 5.3. Indicative table for impact significance assessment based on the sensitivity of the receptor and magnitude of change caused by the project.

Impact significance		Magnitude of change								
		Very high	High	Moderate	Low	No change	Low	Moderate	High	Very high
Sensitivity of the receptor	Low	High*	Moderate*	Low	Low	No impact	Low	Low	Moderate*	High*
	Moderate	High	High*	Moderate	Low	No impact	Low	Moderate	High*	High
	High	Very high	High	High*	Moderate*	No impact	Moderate*	High*	High	Very high
	Very high	Very high	Very high	High	High*	No impact	High*	High	Very high	Very high

* Especially in these cases, significance might get a lower estimate, if sensitivity or magnitude is near the lower bound of the classification.

The following discussion of potential environmental impacts is based on the project details provided by GRL. Here the emphasis has been placed on major impacting activities/agents.

5.3 ANALYSIS AND ASSESSMENT OF THE POTENTIAL IMPACTS

As part of this project, construction and commissioning activities will be undertaken in The Al Humaij solar power plant will be built for 945 blocks, the area of each block is 32,705 m² of land area.

The potential impacts resulting from this project on the sensitive receptors were evaluated with reference to the relevant national and international Environmental Standards. The national environmental standards for air, noise, and water were updated in 2014. A new Water Law was issued by MEWA in 2020 along with its executive regulations. These executive regulations include updated standards for treated wastewater quality, commercial wastewater quality, sludge, unbottled drinking water quality, and non-potable water quality, including irrigation water quality. New standards for soil quality were recently published by MEWA in March 2021.

The potential environmental impacts of the construction and activities on the valued environmental and social components (VECs) are briefly described below. The environmental and social impacts of manufacturing solar panels are not considered in this ESIA. Similarly, the operation and the decommissioning impacts are not included in this ESIA.

5.3.1 *Potential Environmental Impacts During Construction Phases*

AIR QUALITY IMPACTS

Air quality is considered as a highly sensitive receptor. Release of gases or airborne particles from a specific source into the air may adversely impact the air quality of the project area.

Construction and commissioning impacts:

Environmental concerns for air quality from the construction and commissioning phase of the project include:

1. Particulate matter fugitive dust emissions construction activities.
2. Exhaust emissions (NOX, SOX, CO, PM) from vehicles, trucks and construction equipment and machinery.

Dust generation and vehicle and equipment exhaust emissions largely are the only potential construction phase impacts on ambient air quality mainly limited to the construction site.

Dust Emissions:

Dust emissions are expected from the construction activities like site preparation, excavation and levelling work for structural work, mechanical erection work for solar panel modules, concrete work, road construction etc. The movement of vehicles carrying construction equipment will also result in some dust emissions. Higher vehicle speeds on unpaved roads will lead to higher particulate matter emissions to the air. Additionally, the use of concrete, cement, wood stone, and silica and other construction materials will lead to generation of dust at the construction zones and temporary construction areas. Airborne soil dust is typically coarse and therefore remains airborne

only for short periods. USEPA reports that in excess of 90% of the total airborne dust returns to the earth's surface within 100 m of the emission source.

Excessive dust is a health and safety concern to workers and the public. The main hazards related to dust include reduction in visibility and respiratory illnesses [such as bronchitis (OSHA, 2010)]. The impact from dust emissions on ambient air quality from the proposed project will be minimal considering the minimal nature of activities and the temporary duration of construction.

Exhaust Emissions:

During the construction phase, particulate matter emissions and other gaseous releases to the environment will occur from operation of diesel and gasoline engines, construction machinery and vehicular movement. Diesel particulate matter (consisting of soot, sulfates, and silicates) will be generated from diesel engine exhausts from barges, vehicles and other heavy equipment and machinery. Other exhaust emissions from vehicles will include carbon monoxide, nitrogen oxide, sulfur oxides, and volatile organics.

Welding required for the structural work and mechanical erection work for solar panel modules etc., could produce hazardous air emissions. It can generate fumes, dust, vapors and gases, including ozone. The amounts and types of fumes produced vary greatly depending on the process involved and the materials being used - metals, solvents, flux, paint and plastics. The health effects of exposure to fumes, dust, vapor and gases can vary. Most of the potential impacts, due to welding emission can be mitigated to insignificant levels by implementing proper mitigation measures.

There are few adjacent receptors in relation to the project site, like the construction workers, settlements and camel farm. Construction workers at the site are likely to be exposed to the limited dust emissions from construction activities and welding and vehicle exhaust emissions. These impacts are reversible and the air quality would revert back to baseline conditions after construction works is completed. Air quality impacts will be temporary during the construction and commissioning activities, and mitigation measures can reduce the impacts to insignificant levels.

Air Quality Impact- Summary

The following Table 5.4, and 5.5 present the results of the air quality impacts assessment for the construction/commissioning and operation phase. The tables present the VER's sensitivity and magnitude of impacts on air quality. In the Tables, potential impacts are quantified using the ARVI tool, which is a multi-criteria decision analysis (MCDA) tool used for impact assessment in ESIA's.

The potential negative effects on air quality are assessed as high significance during the construction/commissioning phase, before implementing mitigation measures.

Table 5.4. Summary of potential impacts on air quality during the construction/commissioning phase, before implementing any mitigation measures.

Env. Receptor	CHARACTERISTICS OF MAGNITUDE			MAGNITUDE	SIGNIFICANCE
	Intensity and direction	Spatial extent	Duration		
Air Quality	High -	High	Low	High -	High -

Table 5.5. Summary of potential impacts on air quality during the operation phase, before implementing any mitigation measures.

Env. Receptor	CHARACTERISTICS OF MAGNITUDE			MAGNITUDE	SIGNIFICANCE
	Intensity and direction	Spatial extent	Duration		
Air Quality	No impact	Low	Moderate	No impact	No impact

CLIMATE IMPACTS

The climate is considered a sensitive receptor. The release of GHG into the atmosphere leads to global warming. Globally, almost 80% of GHG emissions from human sources come from the burning of fossil fuels and industrial processes.

The potential sources of GHG emissions related to project activities in the project areas include mobile combustion sources, venting, and fugitive emissions during the construction stages.

Construction and commissioning Impacts:

Construction and commissioning activities can generate greenhouse gas emissions from stationary and mobile sources of combustion, venting, fugitive emissions, and indirect emissions (such as electricity). The main source of greenhouse gas emissions will be fuel combustion by vehicles, trucks construction equipment, and machinery. Emissions include carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O), as well as carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs), sulphur dioxide (SO₂), particulate matter (PM) and nitrogen oxides (NO_x).

During construction and commissioning, GHG emissions will have a temporary negative impact on the climate, which will disappear after the completion of the project.

Climate Change Risk Assessment (CCRA):

A separate climate change risk assessment (CCRA) study is conducted for the Project to evaluate and understand the potential impacts and vulnerabilities posed by climate change. The CCRA report is included as Technical Appendix 3 with this ESIA report.

Operation impacts:

The operation of solar power plants does not cause greenhouse gases to be released into the atmosphere. Residential solar panels emit around 41 grams of CO₂ equivalent emissions per kilowatt-hour of electricity generated. Most of these lifecycle emissions are tied to the process of manufacturing panels and are offset by clean energy production within the first three years of operation. The lifetime emissions of rooftop solar are 12 times less than electricity generated by gas plants and 20 times less than electricity generated by coal.

Climate Impacts - Summary

The following Table 5.6 and Table 5.7 present the results of the climate impacts assessment for the construction/commissioning and operation phases respectively. The tables present the VER's sensitivity and magnitude of impacts on climate. In the Tables, potential impacts are quantified using the ARVI tool, which is a multi-criteria decision analysis (MCDA) tool used for impact assessment in ESIA's.

The potential negative effects on climate are assessed as moderate significance during the construction/commissioning phase and no impact during the operation phase, before implementing mitigation measures.

Table 5.6. Summary of potential impacts on climate during the construction/commissioning phase, before implementing any mitigation measures.

Env. Receptor	CHARACTERISTICS OF MAGNITUDE			MAGNITUDE	SIGNIFICANCE
	Intensity and direction	Spatial extent	Duration		
Climate	Low -	Moderate	Low	Low -	Moderate -

Table 5.7. Summary of potential impacts on climate during the operation phase, before implementing any mitigation measures.

Env. Receptor	CHARACTERISTICS OF MAGNITUDE			MAGNITUDE	SIGNIFICANCE
	Intensity and direction	Spatial extent	Duration		
Climate	No impact	Low	Moderate	No impact	No impact

MICROCLIMATE- IMPACTS

Microclimate is the suite of climatic conditions measured in localized areas. These environmental variables—which include temperature, light, wind speed, and moisture—provide meaningful indicators for habitat selection and other ecological activities.

The PV arrays may give rise to variations in solar radiation fluxes (temperature), wind speed, and moisture level within the solar farm. Thus, this may have consequences in microclimate and even interrupt the ecosystem function.

Construction and commissioning impacts:

Construction activity may result in some minor microclimatic changes in the construction sites due to changes in temperature, light, wind speed, moisture, etc. The changes, however, will be temporary and will disappear once the construction is completed.

Operation impacts:

During operation, solar PV parks can affect the local microclimate by altering the albedo of the ground surface, which is a measure of how much sunlight is reflected without being absorbed. Dark solar panels absorb more sunlight than typical ground cover, potentially increasing local temperatures. On average solar PV module surface temperatures generally exceed ambient temperature by 35 to 40 °C in the summers and 25 to 30 °C in the winters (owing to the difference in radiation potential in summers and winters). However, this effect is usually localized and may not significantly impact the broader regional climate.

Similar to urban heat islands, large solar farms might create a localized increase in temperature compared to surrounding rural areas. The solar photovoltaic heat islanding effect produces heat and increases the temperature of the installation place. This heat generated by solar panels warms up the environment and is not suitable for natural vegetation. Another main issue with solar heat islanding is the land use and land cover which directly affects the natural vegetation and reduces greenery. Research suggests that the impact is minimal and primarily confined to the area directly under and immediately surrounding the solar panels [Rabaia et al., 2021].

The PV array is predicted to alter the solar reflectivity (albedo) of the region's surface where they are installed, and in turn affect the typical microclimate characteristics of that region such as the local air temperatures, humidity, pressure, and wind speed. Considering the additional heat that the modules radiate while producing electricity, the main probable result should be the Heat Island Effect (HIE). HIE has been particularly discussed for about last 10 years in connection with solar plant operation [Barron-Gafford et al. 2016]. Barron-Gafford et al. (2016) observed air temperature at a utility-scale PV array in southern Arizona to be warmer than a nearby reference station throughout the year and across the diurnal cycle. The authors called this effect the PV heat island (PVHI), drawing a comparison to the urban heat island (UHI). The PVHI was observed to be larger at night (3°C) than during the day (~1.5°C).

Vervloesem et al [2022] reported that solar parks had clear effects on microclimate. It is observed that the microclimatic conditions between panel mounts were more extreme than in the surrounding desert yet beneath the panel's temperature is lower and relative humidity higher than outside the panel area. If the panels were high enough from the ground, they could lower the surface temperature by providing shade and enough airflow [Vervloesem et al., 2022].

Modern solar panel designs and layout planning incorporate measures to minimize heat retention and impact on local temperatures. This includes maintaining vegetation cover where possible and ensuring adequate spacing between panel rows for air circulation.

Microclimate Impacts - Summary

The following Table 5.8 and Table 5.9 present the results of the microclimate impacts assessment for the construction/commissioning and operation phases respectively. The tables present the VER's sensitivity and magnitude of impacts on microclimate. In the Tables, potential impacts are quantified using the ARVI tool, which is a multi-criteria decision analysis (MCDA) tool used for impact assessment in ESIA's.

The potential negative effects on microclimate are assessed as no impact during the construction/commissioning phase and high significance during the operation phase, before implementing mitigation measures.

The potential negative effects on microclimate are assessed as no impact during the construction phase.

Table 5.8. Summary of potential impacts on microclimate during the construction/commissioning phase, before implementing any mitigation measures.

Env. Receptor	CHARACTERISTICS OF MAGNITUDE			MAGNITUDE	SIGNIFICANCE
	Intensity and direction	Spatial extent	Duration		
Microclimate	No impact	Low	Low	No impact	No impact

Table 5.9. Summary of potential impacts on microclimate during the operation phase, before implementing any mitigation measures.

Env. Receptor	CHARACTERISTICS OF MAGNITUDE			MAGNITUDE	SIGNIFICANCE
	Intensity and direction	Spatial extent	Duration		
Microclimate	High -	High	Very high	High -	High -

NOISE AND VIBRATION IMPACTS

Construction noises have the potential to disturb people at home in their residences, in office buildings, and workers in open construction sites. Noise from construction-related activities can also affect non-human species such as animals and birds in a variety of ways. This assessment addresses the impacts of airborne noise associated with the proposed construction activities in Al Humaij.

Construction and Commissioning Impacts:

Workers at the construction site, adjacent land users conducting grazing activities and terrestrial fauna including nesting birds, if any, will be the primary sensitive receptors that may be negatively affected by noise and vibration associated with construction activities. There are no existing noise and vibration emission sources within the project area. However, the construction activities will introduce new sources of noise and vibration in an area currently devoid of activities generating this type of impact.

The use of construction machinery and vehicles will generate noise within the Project Area. The use of vehicles to transport personnel and materials is a further source of noise during construction along the public road network. These are likely to increase the overall baseline noise load and vibrations for the area. They present a potential nuisance for the construction workers and adjacent land users conducting grazing activities. However, this will be short-lived and restricted to the construction period.

Excessive airborne noise and vibration are an occupational hazard with many adverse effects, not only to the workers involved with noisy operations but also to those around them. Its effects can lead to temporary or permanent hearing damage and can impair workers' efficiency. When individuals are exposed to high levels of noise in the workplace, they can suffer from various adverse health effects. These health effects can be caused by a single exposure to a very loud noise or by exposure to raised levels of noise over a prolonged period of time.

Typical ground vibration from civil construction activities occurs in the frequency range of approximately 8 Hz to 100 Hz. Within this frequency range, building contents such as blinds and pictures would commence visible movement at PPV 0.5 mm/s. At vibration levels higher than 0.9 mm/s, rattling of windows, crockery or loose objects would be audible and annoying. The potential impacts from vibrations during the construction activities on sensitive receptors will be insignificant after taking the required mitigation measures.

Noise and vibration impacts will be short-lived and restricted to the construction and commissioning phase, and mitigation measures can reduce the impacts to insignificant levels.

Operation Impacts:

Solar panels in and of themselves do not generate sound during operation. However, associated facilities like inverters (string or central type), medium voltage transformers and tracking motors (if any) may produce noise during operation.

The operation of the solar inverters converting the direct current (DC) electrical power collected in the solar panels into alternating-current (AC) power usually generates noise pollution. Inverters rapidly switch polarities to achieve an AC power cycle of 60 hertz or 60 cycles per second. As a result, it creates a tonal sound of 120 hertz with harmonics reaching 240, 360, 480 hertz, or higher. Movements in other mechanical components in the inverter and transformer, like coil vibrations and high-speed cooling fans, contribute to the body and level of noise. There is a possibility that workers involved in operation and maintenance may be adversely affected by the noise emissions during operation.

The noise and vibration generated during the operational phase of this project will be within the guideline values prescribed by MEWA, if the mitigation measures are implemented.

Airborne Noise and Vibration Impacts - Summary

The following Table 5.10 and Table 5.11 present the results of the noise and vibration impacts assessment for the construction/commissioning and operation phases respectively. The tables present the VER's sensitivity and magnitude of noise and

vibration impacts. In the Tables, potential impacts are quantified using the ARVI tool, which is a multi-criteria decision analysis (MCDA) tool used for impact assessment in ESIA's.

During the construction and commissioning phase, potential negative impacts due to noise and vibration are assessed as moderate significance, and during the operation phase also as moderate significance, before implementing mitigation measures.

Table 5.10. Summary of potential noise and vibration impacts during the construction/commissioning phase, before implementing any mitigation measures.

Env. Receptor	Characteristics of Magnitude			MAGNITUDE	SIGNIFICANCE
	Intensity and direction	Spatial extent	Duration		
Noise and vibration	Moderate -	Low	Low	Low -	Moderate -

Table 5.11. Summary of potential noise and vibration impacts during the operation phase, before implementing any mitigation measures.

Env. Receptor	Characteristics of Magnitude			MAGNITUDE	SIGNIFICANCE
	Intensity and direction	Spatial extent	Duration		
Noise and vibration	Low -	Low	Moderate	Low -	Moderate -

VISUAL AND LANDSCAPE IMPACTS

The objective of this visual and landscape impact assessment is to identify the existing and proposed landscape elements and the visual quality within the limits of the primary visual envelope of the study area and provide an evaluation of the impacts on the landscape and visual aspects due to the project. The assessment covered the landscape and visual impact on the surroundings during the construction phases.

The site visit revealed that the project area is predominantly undeveloped and there are no industrial or agricultural activities within the immediate area. Near the site, there is a camel farm and a few settlements.

Construction and Commissioning Impacts:

The project site consists of areas that are sparsely vegetated or have no major vegetative and tree covers, and hence no trees or bushes will need to be removed as part of construction. Also, there are no close communities that would be within the visual radius of the project. Hence, the visual effects of the construction will be of low significance within the project area and potentially the employees.

Site preparation activities will include the installation of arrays and the various project components, including transmission cables, access roads and internal road network, storage buildings, etc. These activities will result in land clearance, ground levelling, excavations, and grading. From the start of construction activities, visual

changes will occur from the modified ground surface and the presence of construction equipment and machinery (excavators, trucks, front end loaders, compactors, and others). During the construction phase, medium significant impacts on visual and landscape can be expected.

The nature of development interventions under the proposed project will not generate negative impacts on the scenic and visual beauty of the project land and its vicinity. The project land is a bare desert land with very few vegetation and therefore it does not have special scenic beauty to be lost due to its clearance for project implementation.

Operation Impacts:

A temporary impact on the landscape and visual quality of the site would be created during the operation phase. Given the height of the PV arrays not exceeding 3-4 m and the low-lying of the PV Plant, the Project will be visible within the immediate vicinity and up to some kilometres around the Project site only, and thus is likely to create medium visual impacts.

The site, after completion of construction, would consist of built structures, landscaped to give a different outlook, where many would consider being pleasing. The potential impacts could be change of visual appearance mainly. However, as the project site and the surrounding areas provide no significant aesthetic value, the sights of a large area covered with solar PV panels will have no visual impact.

With the design of solar PV arrays, reflected sunlight may cause problems if the system is close to an access road and is facing in a direction which the reflected sunlight may cause vehicular driving or movement problems. This problem can be mitigated by carefully planning the orientation of solar panels in relation to the access road placement. Furthermore if bifacial solar panels are used the light transmission factor will be enhanced that reduces reflection. It must also be added the access roads developed for this project are not designed for any type of unduly fast forms of driving and the speeds will have to be controlled in the access road, in and outside of the solar power park.

Glint and Glare Impacts:

To assess the possible effects of glint and glare from the proposed single-axis tracking solar photovoltaic (PV) park has been conducted by GCC. The assessment pertains to the possible impact upon aviation activity associated with King Abdulaziz International Airport and Rabigh Airport. Study showed that no solar reflections are geometrically possible towards any aircraft approaches or Air Traffic Control Towers at King Abdulaziz International Airport or Rabigh Airport located nearby to Al-Khulais.

There is a perceived issue of glint and glare surrounding the reflectivity of the proposed PV solar panels. As a result of the perceived reflection levels, there is a concern of possible distractions to motorists, aircraft and the hazard of eye damage. The Poly-Crystalline Solar Panels proposed for the installation are designed to absorb the sun's energy and directly convert it to electricity. The PV modules will absorb approximately 82-90% of the light received. The Solar Panels will be designed using two anti-reflective coatings which significantly reduces the reflectivity. Thin slivers of

metal stripping on the face of the panels further reduce any potential glare issues that may occur.

Extensive site visits have confirmed that there are very few residents and settlements in the project area and the area is characterized by minimal to no traffic and a lack of established roads. Therefore significant visual and landscape impacts or impacts due to glint and glare are not expected during the construction and operation phase of this project.

Visual and Landscape Impact - Summary

The following Table 5.12 and Table 5.13 present the results of the visual and landscape impact assessment for the construction/commissioning and operation phases respectively. The tables present the VER's sensitivity and magnitude of impacts. In the Tables, potential impacts are quantified using the ARVI tool, which is a multi-criteria decision analysis (MCDA) tool used for impact assessment in ESIA's.

During the construction and commissioning phase, potential visual and landscape impacts are assessed as low significance, and during the operation phase as medium significance, before implementing mitigation measures.

Table 5.12. Summary of potential visual and landscape impacts during the construction/commissioning phase, before implementing any mitigation measures.

Env. Receptor	Characteristics of Magnitude			Magnitude	Significance
	Intensity and direction	Spatial extent	Duration		
Visual and Landscape	Low -	Low	Low	Low -	Low -

Table 5.13. Summary of potential visual and landscape impacts during the operation phase, before implementing any mitigation measures.

Env. Receptor	Characteristics of Magnitude			Magnitude	Significance
	Intensity and direction	Spatial extent	Duration		
Visual and Landscape	Low -	Low	Moderate	Moderate -	Moderate -

IMPACTS ON SOIL AND LAND USE

The objective of this soil and land use impact assessment is to identify the existing soil and land use patterns in the project area, as well as to assess the potential impacts of the proposed construction activities of the Al Humaij Solar PV project.

As a result of the site visit, it was determined that the project area is primarily undeveloped and that there is no industrial or agricultural activity within or in the immediate vicinity. A camel farm and a few settlements are located near the site. So, the area may be used for only camel grazing. The quality of the soil in the project area is not unique in the area and does not have significant agricultural value.

Construction and Commissioning Impacts:

The land use patterns in the area are not likely to change due to construction activities since it is not used for agriculture or industry, except for camel grazing.

Construction activities are also not expected to result in significant soil loss, however, excavation, leveling, and other earthworks may disturb the soil due to the minimal removal of topsoil during the construction of office and control room buildings; however, soil erosion triggered by such activities may happen.

The construction of roads within the project area will involve sub-grade earthworks and any required foundations and structural works. The roads will be constructed with adequate width and strength with sub-grade earthworks for roads being compacted to 95% maximum dry density for the top 500 mm. The physical and chemical structure of the soil will be affected by the construction activities. In the absence of proper site stabilisation, stockpile management, and erosion control, soil and surface water, if available, will be affected, and sediment runoff will adversely affect the local environment.

The other source of impact on soil is waste generation from construction material, accidental leakage of fuel, oil, or chemicals stored within a bunded area causing direct contamination to soil which may degrade lower layers of soil depending on the amount of spills. However proper spill response procedures implemented by the contractor will minimize the impact magnitude. The soil contamination due to unsuitable disposal or accidental spillages of hazardous waste (such as fuels, oils, chemicals, or sewage) could percolate into areas of soft soil and subsequently contaminate surface water and the underlying groundwater.

Operation Impacts:

The Khulais solar power plant will be built on a 40 km² land area. The project area is used for camel grazing and is not being used for agriculture or industrial purposes. The main impact on land use could be a reduction in the amount of grazing land. This is because the site will be permanently fenced off and camels will no longer have access to the grazing areas within it. This could lead to a potential loss of grazing livelihoods. As there is a relatively large amount of camel grazing land in the nearby areas, the absence of 40 km² won't have a significant impact on the area's land use.

Recent studies showed that PV arrays can alter soil moisture and soil physicochemical properties during operation [Choi et al., 2023]. Another impact is from the accidental spillage of lubricant, fuel, and other chemicals that may potentially cause soil degradation. However, the impact is not considered significant given the spill response procedures in place, and the magnitude of the spill is expected to be minimal.

Impacts on Soil and Land Use - Summary

The following Tables 5.14 and Table 5.15 present the results of the impact assessment for soil and land use during the construction/commissioning and operation phases respectively. The tables present the VER's sensitivity and magnitude of impacts. In the Tables, potential impacts are quantified using the ARVI tool, which is a multi-criteria decision analysis (MCDA) tool used for impact assessment in ESIA's.

During the construction and commissioning phase, potential negative impacts on soil and land use are assessed as moderate significance, and during the operation phase as moderate significance, before implementing mitigation measures.

Table 5.14. Summary of potential negative impacts on soil and land use during the construction/commissioning phase, before implementing any mitigation measures.

Env. Receptor	Characteristics of Magnitude			Magnitude	Significance
	Intensity and direction	Spatial extent	Duration		
Soil and land use	Low -	Moderate	Low	Low -	Moderate -

Table 5.15. Summary of potential negative impacts on soil and land use during the operation phase, before implementing any mitigation measures.

Env. Receptor	Characteristics of Magnitude			Magnitude	Significance
	Intensity and direction	Spatial extent	Duration		
Soil and land use	High -	Low	Moderate	Moderate -	Moderate -

IMPACTS ON GROUNDWATER AND SURFACE WATER

The purpose of this assessment is to evaluate the impact of construction, and commissioning activities on the groundwater and surface water resources in the project area in Al Humaij.

In Humaij, surface water resources are scarce, and groundwater is the sole water source. Wadis are originated from the nearby hills and passing through the project site, which is marked by the surface flow mark in the satellite images.

The groundwater sampling wells were not available in the project area for sample collection and analysis. Therefore, a desktop study is conducted to collect baseline information about groundwater in the project area. Groundwater is available at the coastal aquifer located in the Buraykah alluvial fan which is being used to provide water supply for villages and several scattered farms.

Construction and Commissioning Impacts:

Water requirements for the construction phase are limited to sanitary use by site workers in the nearby labour camps (drinking, showering, etc.) and preparation of raw materials such as concrete, cleaning of machinery and equipment, dust control, etc. Water will be used to suppress dust emission during ground leveling and road construction. The estimated water requirement during the construction phase for this project is not available while writing this report.

Probably groundwater available in the project area will be exploited for construction activities and potable water will be obtained from the nearby desalination plants for drinking and use in the workers camps. Potable water will be consumed for different purposes including drinking, cooking, laundry, showering, bathing, and cleaning, during the construction phase. Usually for such projects, the fixture units, such as toilets and urinals use treated wastewater or seawater while the wash sinks, dishwashing machines, bath/shower, and laundry use potable water.

The groundwater in the project area is likely to be impacted by the proposed construction activities. The major potential groundwater impacts are abstraction from aquifers, physical disturbance of aquifers creating pathways for groundwater flow or creating barriers to groundwater flow and discharges to groundwaters.

The project is expected to generate wastewater streams during the construction phase. Wastewater is mainly expected to include black water (sewage water from toilets and sanitation facilities), as well as grey water (from sinks, showers, etc.) generated from workers during the construction. Wastewater will be treated regularly and disposed of as per the NCEC guidelines by the construction contractors.

Groundwater could be contaminated through inadequate storage and handling of hazardous materials, spillages from equipment and plant and poor management of waste, wastewater and cement mixing. Wastewater from project activity may contain potential pollutants such as bitumen, hydrocarbons and aggregates that can pollute local groundwater sources. Potential impacts on groundwater will be short-lived and restricted to construction activities, and mitigation measures can reduce the impacts to insignificant levels.

Operation Impacts:

Solar power plants are facing a real challenge of soiling which manifests by the accumulation of dust, dirt and birds dropping on their surfaces. In desert areas like Khulais, cleaning is of utmost importance to recover the performance of the solar panels. There are different cleaning methods of dust removal for PV panels [Boeing et al., 2022]. These methods include passive natural means (wind power, gravitation, and rainwater), mechanical techniques (brushing, blowing, vibrating, and ultrasonic driving), self-cleaning nano-film (surface covered with a pellucid nano-film), and electrostatic methods (electric curtain).

The methods of cleaning and the water requirements for cleaning the Khulais Solar Power Project are not available while preparing this document. The Khulais is located in a water-stressed area. Therefore, if water is used to clean the panels, a source of water needs to be identified. The amount of water needed to clean a single solar panel is 3-5 liters per panel in normal areas and 7-8 litres in arid areas [Renewable Watch, 2020]. Assuming 8 L water is required for cleaning 4117,680 modules in the Khulais project, the total water required for one time cleaning will be approximately 32.9 million L (32,941 m³). Hence water cleaning of the solar panels during the operational phase will have significant impacts on groundwater resources in the area. The water requirement for cleaning may, however, be avoided using alternative methods such as robotic cleaning without water, however, this will increase the project cost. Another possibility is to select panels with anti-soiling coating to reduce water consumption by around 50%.

It is assumed that during operation, approximately 50 persons will work on the project site, and their water consumption will be approximately 128 m³/Year. The solar panel cleaning will generate wastewater which can be collected and recycled. Any leakage or spillage of oil, chemicals, paint etc., during the maintenance phase may pollute local groundwater sources. Similarly, accidental release of fuel or chemicals may lead to spills having the possibility to contaminate groundwater. These potential impacts can be avoided or controlled by implementing strict mitigation measures.

Summary of Impacts on Groundwater and Surface Water:

The following Table 5.16 and Table 5.17 present the impact assessment results for groundwater and surface water during the construction/commissioning and operation phases respectively. The tables also present the VER's sensitivity and magnitude of impacts. In the Tables, potential impacts are quantified using the ARVI tool, which is a multi-criteria decision analysis (MCDA) tool used for impact assessment in ESIA's.

During the construction and commissioning phase, potential negative impacts on groundwater and surface water are assessed as moderate significance and during the operation phase as high significance, before implementing mitigation measures

Table 5.16. Summary of potential negative impacts on groundwater and surface water during the construction/commissioning phase, before implementing any mitigation measures.

Env. Receptor	Characteristics of Magnitude			Magnitude	Significance
	Intensity and direction	Spatial extent	Duration		
Groundwater and surface water	Low -	Low	Low	Low -	Moderate -

Table 5.17. Summary of potential negative impacts on groundwater and surface water during the operation phase, before implementing any mitigation measures.

Env. Receptor	Characteristics of Magnitude			Magnitude	Significance
	Intensity and direction	Spatial extent	Duration		
Groundwater and surface water	High -	High	Moderate	High -	High -

IMPACTS ON FLOOD RISKS

The purpose of this assessment is to evaluate the impact of construction and commissioning on the flood risk in the project area in Al Humaij. Over the past few years, several cities in Saudi Arabia have experienced unusually heavy rainfall that has resulted in floods [Shah et al., 2023]. Changes in topography, land use, surface runoff, and other factors may lead floods. Accordingly, an assessment of project activities related to flood risks is conducted in the project area.

Probably the site is subjected to flash flooding during the rainy season due to its land terrain, proximity to water accumulation in the depression areas (Figure 5.3), and the presence of a waterlogged area to the east of the site.

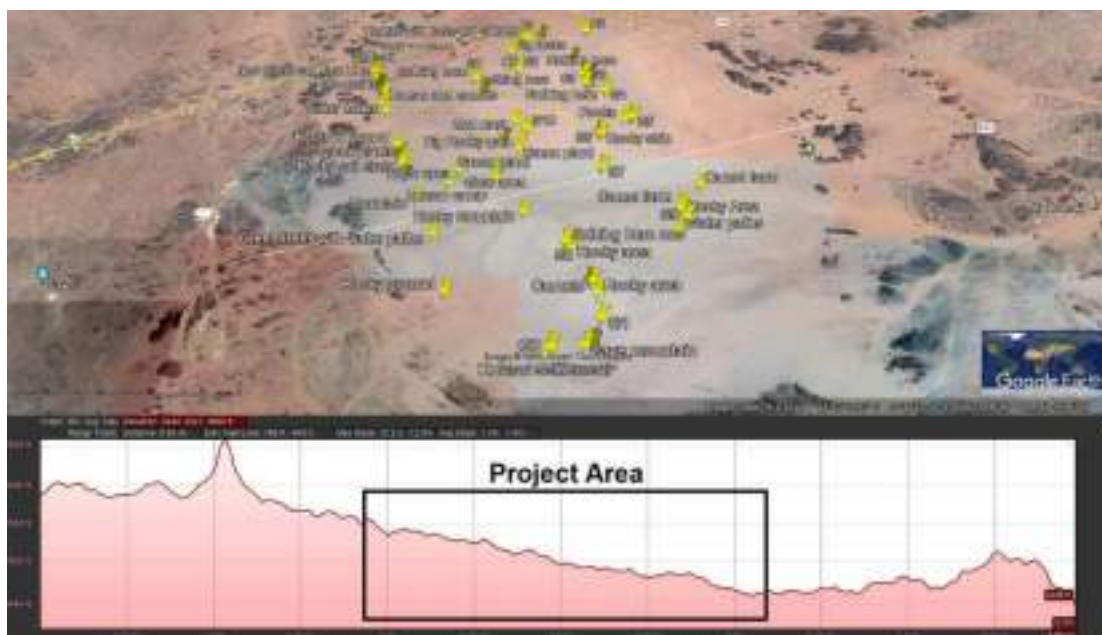


Figure 5.3. The cross profile of the topography, showing the general surface flow direction and comparatively low land for water accumulation.

Construction and Commissioning Impacts:

Direct runoff from heavy rainfall is considered the only source of water flowing in the project area. Altering or blocking the existing stormwater flow during construction may lead to water logging in the area and even flooding. Therefore, proper hydrological investigation should be conducted for this project area before starting the construction activities to avoid flood risks. During construction (road construction, ground leveling, installation of panels, erecting buildings etc.), flood risks can be avoided by implementing good construction practices and procedures on site.

Operation Impacts:

During the operation phase, if flood risks are not adequately considered, unexpected flooding may result in impacts on project components (resulting in the destruction of equipment and machinery onsite) as well as health and safety risks for workers onsite and nearby. PV parks and associated facilities should be developed in the project area without destroying natural drainage patterns. Altering the natural drainage patterns may negatively impact nearby land users due to changes in flood water flows. These potential impacts can be avoided or controlled by implementing strict mitigation measures.

Summary of Impacts on Flood Risk:

The following Table 5.18 and Table 5.19 present the impact assessment results for flood risk during the construction/commissioning and operation phases respectively.

The tables also present the VER's sensitivity and magnitude of impacts. In the Tables, potential impacts are quantified using the ARVI tool, which is a multi-criteria decision analysis (MCDA) tool used for impact assessment in ESIA's.

During the construction and commissioning phase, potential impacts on flood risk are assessed as moderate significance and during the operation phase as high significance, before implementing mitigation measures.

Table 5.18. Summary of potential negative impacts on flood risk during the construction/commissioning phase, before implementing any mitigation measures.

Env. Receptor	Characteristics of Magnitude			Magnitude	Significance
	Intensity and direction	Spatial extent	Duration		
Flood risk	Low -	Low	Low	Low -	Moderate -

Table 5.19. Summary of potential negative impacts on flood risk during the operation phase, before implementing any mitigation measures.

Env. Receptor	Characteristics of Magnitude			Magnitude	Significance
	Intensity and direction	Spatial extent	Duration		
Flood risk	Moderate -	Moderate	Moderate	Moderate -	High -

IMPACTS ON FLORA

This assessment examines the impacts of construction/commissioning activities on the flora of the project area. A survey was conducted from 1-7 February 2024 to study and record the baseline flora diversity and abundance. Five stations were selected for the study.

A floristic survey conducted in Al Humaij identified 23 plant species. Brassicaceae and Leguminosae were identified as the most frequent families in this site with three species in each. No High Conservation Priority species or IUCN Red Listed Threatened plant species were recorded from the Al Humaij site.

Construction and Commissioning Impacts:

Construction activities like site preparation, excavation and levelling work for structural work, mechanical erection work for solar panel modules, concrete work, building construction, road construction etc., have the potential to negatively impact flora present in the area. Potential impacts on flora include direct removal and physical disturbances associated with the construction activities. and loss of flora and fauna will inevitably occur when site preparation activities commence, the dune areas are levelled, and vegetation is removed. Most of the wildlife can be found around the plants (flora) that provide food, water and cover. Direct permanent impacts on animal species can occur as vegetation is removed by project activities.

Short-term impacts will be experienced on flora during construction and commissioning activities, but these impacts will be limited to a small area, and mitigating measures can significantly reduce these impacts.

Operation Impacts:

During operation, vegetation is significantly lost or altered. Solar plants typically require some form of vegetation management under and in the gaps between solar panel arrays. Unwanted vegetation is sometimes discouraged using herbicides, or by covering the ground with gravel to facilitate facility operations. In other cases, some form of vegetation cover is grown but mowed frequently to keep it short. For example, in western North America, solar developments were estimated to have the largest impacts on shrublands compared to other ecosystem types, resulting in the conversion of between 0.60 to 19.9 million ha of the ecosystem [Bennun et al. 2021].

The most significant impacts of solar photovoltaic panels on the microenvironments of dryland ecosystems are the stimulation of surface soil moisture and decreased soil temperature due to the shadows cast by the panels [Yue et al., 2021; Wu et al., 2022]. Such shifts decrease the rate of water loss by inhibiting evapotranspiration, leading to increased water availability for plants in the entire growing season and indirectly promoting vegetation biomass and coverage.

Additionally, the alternations in microenvironments have been found to enhance the survival of plant species' seed banks in shaded areas [Hernandez et al., 2020]. Shadow effects caused by solar panels can alter the species composition and diversity of underlying habitats as a result of air and soil microclimate variation. A study of a UK solar plant revegetated with grassland showed that species diversity was lower under PV panels as a result of differences in soil and air temperature [Armstrong et al., 2016]. Furthermore, Li et al. [2018] demonstrated that the implementation of large-scale wind and solar farms in the Sahara could induce localized rainfall, particularly in the nearby Sahel region. This effect is attributed to increased surface drag, reduced albedo, and subsequent vegetation expansion, creating a positive feedback loop for increased precipitation. Consequently, the installation of solar power plant facilities has been regarded as a “win-win” strategy, as it simultaneously reduces carbon emissions and prevents desertification in arid regions [Li et al., 2018; Liu et al., 2019, 2020].

However, positive impacts of solar parks on bird population have been reported from Central Europe. Jarcuska et al., [2024] investigated the impact of ground-mounted solar parks on species richness, abundance, Shannon diversity and composition of bird communities in Slovakia (Central Europe), by surveying 32 solar park plots and 32 adjacent control plots in Slovakia during a single breeding season. According to that study, bird species richness, diversity, and invertebrate-eater species richness and abundance were higher in the solar parks than in the control plots. Among the reasons provided is the food availability for insectivorous birds, as the PV panels attract various species of water-seeking aquatic insects. Researchers stressed that the solar parks considered for the study were designed and managed primarily to produce renewable electricity and the biodiversity benefits would be greater if they were managed synergistically, with a stronger focus on wildlife.

Summary of Impacts on Flora

The following Table 5.20 and Table 5.21 present the results of the impact assessment for floral communities during the construction/commissioning and operation phases respectively. The tables also present the VER's sensitivity and magnitude of impacts. In the Tables, potential impacts are quantified using the ARVI tool, which is a multi-criteria decision analysis (MCDA) tool used for impact assessment in ESIA's.

Potential impacts on flora are assessed at a low significance during construction and commissioning, and at a medium significance during operation before mitigation measures are implemented.

Table 5.20. Summary of potential negative impacts on flora during the construction/commissioning phase, before implementing any mitigation measures.

Env. Receptor	Characteristics of Magnitude			Magnitude	Significance
	Intensity and direction	Spatial extent	Duration		
Flora	Low -	Low	Low	Low -	Low -

Table 5.21. Summary of potential negative impacts on flora during the operation phase, before implementing any mitigation measures.

Env. Receptor	Characteristics of Magnitude			Magnitude	Significance
	Intensity and direction	Spatial extent	Duration		
Flora	Low -	Low	Moderate	Low -	Moderate -

IMPACTS ON FAUNA

This assessment examines the impacts of construction and commissioning activities on the fauna of the project area. A survey was conducted during 1-7 February 2024 to study and record the baseline faunal diversity and abundance. Five stations were selected for the study.

A Critical Habitat Assessment (CHA) is required to comply with international lender performance standards, particularly those of the International Finance Corporation (IFC), specifically Performance Standard 6 (PS6), which is relevant to biodiversity conservation and sustainable management of living natural resources. The CHA report is prepared and included as Technical Appendix D.

At the project site, 16 species of birds were recorded, and all are classified as Least Concern (LC) on the IUCN Red List. Thirteen bird species are residents and three winter visitors. From the project area, none of the fauna species, including birds, are listed on the IUCN red list

The CHA study indicated that the project is not located in a critical habitat for any faunal species. The project area does not support any highly threatened ecosystem(s) (under IFC Criterion 4) or key evolutionary processes (under IFC Criterion 5). No Project infrastructure is planned within any legally protected areas nor internationally recognised areas of high biodiversity value (LPA/IRA).

Construction And Commissioning Impacts:

Installation of PV plants and their associated facilities typically requires the removal of vegetation and surface grading across large areas of land. This may cause habitat loss, degradation and fragmentation, leading to a reduction in species richness and density. Most of the wildlife can be found around the plants (flora) that provide food, water and cover. Direct permanent impacts on animal species can occur as vegetation is removed during construction. Small burrowing reptiles and mammals are vulnerable to potential fatalities from vehicle collisions and damage to burrows from heavy machinery.

Increased noise, night lighting, vehicle operation and human activity will temporarily disrupt the normal movement of animals. Airborne noise associated with the construction activities may negatively impact the noise-sensitive fauna such as birds, if any, inhabiting the area for nesting. When light is visible in an open environment, it may affect the behaviour or disorient terrestrial fauna, including nesting birds that use light for natural responses. All species active at night (nocturnal animals) are vulnerable as artificial light can disrupt their normal activities. Artificial light can disorient birds causing collision, entrapment, stranding, grounding, and interference with navigation (being drawn off course from the usual migration route). These behavioural responses may cause injury and/or death. Birds may starve because of disruption to foraging, hampering their ability to prepare for breeding or migration.

Movement of equipment, people or components may facilitate the introduction of invasive alien species (IAS) by various pathways, for example, by being transported in soil on machinery or attached to clothing. The creation of new habitats, for instance by land disturbance during construction or creating open spaces, may also facilitate the spread of IAS already present on the site.

During construction and commissioning activities, there will be short-term impacts on fauna in the project, but these impacts will be limited to a small area and mitigation measures may reduce these impacts significantly.

Operation Impacts:

Solar farms can have both negative and positive impacts on wildlife, depending on various factors such as the location of the solar farm, the design of the solar panels, and the measures taken to mitigate the impact on wildlife. One of the main negative impacts of solar farms on wildlife is the loss and fragmentation of natural habitats. Solar facility construction and operation, directly and indirectly, alter habitat use via functional habitat fragmentation, dispersal limitations, population isolation, and altered habitat quality [Chock et al., 2020].

Solar farms often require a large amount of land to be cleared and levelled, which can lead to the destruction of ecosystems and the displacement of wildlife populations. For example, solar farms can impact the migration patterns of birds and disrupt the breeding and foraging patterns of desert tortoises. However, some measures can be taken to minimize the impact of solar farms on wildlife. For example, solar panels can be installed on raised platforms to create shaded areas that can provide habitat for wildlife [Bennun et al., 2021]. Additionally, measures such as bird diverters and wildlife fencing can be implemented to help reduce the risk of bird and animal collisions with solar panels.

In the solar park, light will be used at night for safety and security, and this may negatively affect nocturnal animals. Light from artificial sources may cause birds to become disoriented, resulting in collisions, entrapments, strandings, groundings, and interference with navigation (being thrown off course from their usual migration route). Light from artificial sources may cause flying birds to become disoriented, affect their stopover choice, and result in their death due to collisions with structures. When foraging is disrupted, birds may starve, impeding their ability to prepare for breeding or migration. Artificial light may, however, be beneficial to some species, particularly those that forage at night, as they may have easier access to food. Light is also attractive to birds, especially those on migratory paths during the darkness of the night. The tendency of birds to circle light sources reduces their energy reserves and makes them unable to reach the next destination, decreasing their ability to survive the winter or reproduce.

Like glass or reflective surfaces on buildings, PV panels could present a collision risk to bird and bat species, especially if the surfaces are vertically oriented and/or reflect light. The extent and significance of these impacts are largely unknown and limited to a small number of studies. Results from fatality monitoring studies across 13 years at 10 PV plants in California and Nevada, USA, estimated an average annual fatality of 2.49 birds per MmW per year [Bennun et al., 2021]. Collisions with a PV plant with large continuous arrays (that water birds might mistake for water bodies) in Southern California, USA, resulted in a relatively high number of water bird fatalities. Collisions with the (thin and hard to see) earth wire of transmission lines may lead to significant fatalities for some species such as bustards.

There is also a risk of bird and bat mortality through electrocution on distribution lines during operation. Electrocution rates on pylons (or poles) of low- or medium-voltage lines can be high and disproportionately affect some species that use pylons of low-voltage lines as perches when hunting or for nesting. An annual mortality rate of around 0.7 birds per pole was estimated as a result of electrocution on a distribution line in southern Morocco [Bennun et al., 2021]. Electrocutions may also be partially responsible for the decline of some long-lived species. For example, the electrocution of Egyptian Vultures (*Neophron percnopterus*) over a 31-km stretch of powerline in Sudan is thought to have resulted in sufficient deaths to partially explain their population declines. Electrocutions are rarely significant on high-voltage transmission lines. There is limited evidence of risks to bats, although electrocution of large bat species, particularly fruit bats, has been identified as an issue associated with distribution lines.

There is anecdotal evidence that birds can mistake the flat surfaces of PV panels for water bodies and attempt to land on them – termed the ‘lake- -effect’ hypothesis [Chock et al., 2020]. This can risk injury and be detrimental to certain birds that cannot take off without a water body. Aquatic insects can also be attracted to the polarised light reflected by PV panels, and display maladaptive behaviour mistaking the panels for water surfaces.

Large areas of PV panels and their associated facilities can disrupt wildlife movement and/or migrations by acting as a barrier. For example, important stopover sites for migratory birds may be lost due to cumulative impacts from several large PV plants along their flyway. Solar plants typically have security perimeter fencing installed. In some cases, existing ground clearance under fences, gaps in the fence

weave, and gates allow small to medium-sized mammals to pass. However, such fencing could still pose a barrier to large mammal movement and/or migrations. Although direct evidence of the barrier effect of solar facilities is largely unquantified, the barrier effects related to large-scale developments and infrastructure components, such as fencing, have been demonstrated to impact species movement and reduction of range size.

Humaij Solar PV project may have significant impacts on fauna, including birds if mitigation measures are not implemented. During the operational phase, measures should be taken to protect and safeguard fauna including birds in the project area.

Summary of Impacts on Fauna:

The following Tables 5.22 and Table 5.23 present the results of the impact assessment for the fauna during the construction/commissioning and operation phases respectively. The tables also present the VER's sensitivity and magnitude of impacts. In the Tables, potential impacts are quantified using the ARVI tool, which is a multi-criteria decision analysis (MCDA) tool used for impact assessment in ESIA's.

Potential impacts on fauna from the project area are assessed at a high significance during construction and commissioning, and again at a high significance during operation before mitigation measures are implemented.

Table 5.22. Summary of potential negative impacts on fauna during the construction/commissioning phase, before implementing any mitigation measures.

Env. Receptor	Characteristics of Magnitude			Magnitude	Significance
	Intensity and direction	Spatial extent	Duration		
Fauna	High -	Moderate	Low	High -	High -

Table 5.23. Summary of potential negative impacts on fauna during the operation phase, before implementing any mitigation measures.

Env. Receptor	Characteristics of Magnitude			Magnitude	Significance
	Intensity and direction	Spatial extent	Duration		
Fauna	Very high -	Moderate	Moderate	Very high -	High -

IMPACT ON WASTE MANAGEMENT

This assessment examines how the construction and commissioning of the proposed project affect waste management. During the construction, a lot of liquids and solid wastes will be generated and normal waste management will be negatively impacted, if mitigation measures are not implemented.

The types and quantities of waste expected to be generated for this project have been approximated based on experience in similar EIA projects. Proper management of waste is mandatory for sustainable development and a healthy environment. Appropriate management of waste is considered here as a sensitive receptor.

Construction and Commissioning Impacts:

The main waste sources include waste generated from the workforces living in the nearby camp and waste associated with construction activities. The proposed construction activities will generate both liquid and solid waste. The expected hazardous waste may include used oil, abrasive blast and garnet, waste paint, contaminated cans, used oil filters, fluorescent lamps, chemicals, and medical waste. The non-hazardous waste includes metal scrap, paper products, plastic, trash, and food waste.

It is assumed that approximately 3000 workers will be required for the construction activities. Most of these workers will be living in the camp near the project site. The worker's camp may cause impacts on the environment, mainly in the form of generation of (solid, liquid, and hazardous) wastes. Apart from waste generation, unsustainable exploitation of natural resources (e.g., fresh water, vegetables, fruits, meat, fish, etc.) also will happen due to the boarding of the workforce in the area during the construction phase.

Usually, the camp will be equipped with treatment plants for the generated sanitary wastewater and the treatment process will be reviewed by a concerned party of GRL. The treated effluent will be reused for the purpose of dust suppression. Greywater from the worker's camp will be collected from the same sewage network and treated at the Sewage Treatment Plant (STP) of the camp. The construction camp will be demobilized upon completion of the project. Safe collection, treatment, and disposal/reuse of wastewater from the construction camps, and industrial operations are necessary for the protection of public health. If construction camps are made and operated as per the NCEC regulations and guidelines, there will not be any significant environmental impacts.

A significant amount of Class-I (hazardous) and Class-II (non-hazardous) waste is expected to be generated during the construction activities. The expected hazardous waste may include used oil, abrasive blast and garnet, waste paint, contaminated cans, used oil filters, chemicals, and medical waste. The non-hazardous waste includes metal scrap, paper products, plastic, trash, and food waste. The general categories of expected waste are:

- Sanitary and domestic waste
- Waste generated during construction and demolition activities

Wastes that will be generated during the construction of the project will comprise one of the following main groups of waste types:

Non-Hazardous Wastes

- Municipal Waste
- Non-Hazardous Industrial Waste
- Inert Waste
- Hazardous Waste

The details of Potential Non-Hazardous Industrial Waste likely to be generated from this project are summarized in Table 5.24, Potential Inert Waste in Table 5.25, and Potential Municipal Waste in Table 5.26 and Table 5.27.

Municipal wastes including garbage, refuse, office waste, and other materials resulting from non-construction operations. Recyclable municipal waste materials such as paper/cardboard, plastic, and metal will be segregated/sorted and sent to a recycling company. Wastewater will be collected and treated on-site in the Sewage and Waste Management Facility located close to the worker's accommodation camp area.

Non-hazardous industrial wastes can be liquid, semi-liquid, and solid. Such waste is collected and either recycled or disposed of in a landfill by a licensed Contractor. A waste consignment note is generated for each consignment of waste. Licensed Contractors are engaged in the collection and disposal of non-hazardous industrial waste in available landfills.

Waste generated through construction activities that are not biologically or chemically active in the natural environment is regarded as inert. Examples include concrete and brick materials, broken clay, timber, and most plastics and manufactured rubber products. Inert waste also includes excavated waste material and topsoil.

Construction inert waste will be carefully segregated before collection and disposal. At least 80% of the construction inert waste destined for landfill will be reduced to a size of less than 50 cm in diameter. A dumping permit may be obtained from licensed contractors. A waste manifest/inventory will be submitted to the Licensed Contractors. The Contractor HSE Team will certify waste shipments.

Table 5.24. Estimated quantity of Potential Non-Hazardous Industrial Waste to be generated, their types, sources, and disposal plan.

Waste Type	Waste Stream	Estimated Quantity	Disposal Option	Recycling Company/Disposal Location
Air Filters	Construction & Commissioning	< 2 ton	Landfill	Licensed Waste Collector
Water Filters	Construction & Commissioning	2 to 5-ton	Landfill	Licensed Waste Collector
PPE & Clothing	Construction & Commissioning	<3 ton	Landfill	Licensed Waste Collector

Table 5.25. Estimated quantity of potential inert waste to be generated, their types, sources, and disposal plan.

Waste Type	Waste Stream	Estimated Quantity	Disposal Option
Cut & Excavation Material	Site Preparation & Surface Grading	100,000 to 150,000 M3	Landfill or backfill if not contaminated
Plastics Foams	Warehouse	10 to 15-ton	Recycle (Plastics) Landfill (Foams)
Insulation Materials	Piping	20 to 40-ton	Landfill
Cables/Copper	Site Preparation & Electrical	5 to 10-ton	Recycle

Table 5.26. Estimated quantity of potential municipal waste to be generated, their types, sources, and disposal plan.

Waste Type	Waste Stream	Estimated Quantity	Disposal Option	Recycling Company/Disposal Location
Food and Vegetable Scraps	Kitchen	5 to 10 to per month	Landfill	Licensed Waste Collector
Cooking Oil	Kitchen	0.5 to 1 ton per month	Recycle	Licensed Waste Collector
Waste Paper, Cardboard	Office and Warehouse	< 2 ton	Reuse Recycle	
Plastic Containers, Drums, and Bottles	Construction and Warehouse	10 to 15 ton	Recycle	Licensed Waste Recycler
Glass	Office, Kitchen, Camps	8 to 10 ton	Recycle, Landfill	Licensed Waste Collector
Metal Containers, Drums, and Drink Cans	Office/Camp	2 to 5 ton	Recycle	Licensed Waste Collector

Hazardous Waste

Hazardous waste is defined by virtue of its concentration of constituents and characteristics such as flammability, corrosiveness, reactivity, toxicity, mutagenicity, and radioactivity that could pose a hazard to human health or the environment if improperly managed. Table 5.27 below summarizes all potentially hazardous waste, the estimated quantity generated during the construction phase, and management options.

Table 5.27. List of estimated potentially Hazardous Waste.

Waste Type	Waste Stream	Estimated Quantity	Disposal Option	Recycling Company/Disposal Location
Waste Oil	Construction & Commissioning	8 to 12- ton	Recycle & Reuse	Licensed Waste Collector
Paint & Thinner	Construction (Surface Preparation)	< 2 ton	Dispose or Reuse	Licensed Waste Collector
Fuel (Diesel, Petrol & Grease)	Camps, Construction & Commissioning (General)	2 to 5-ton	Recycle & Reuse	Licensed Waste Collector
Oil Filters	Construction (dredging)	< 1- ton	Incineration	Licensed Waste Collector
E-Waste	Construction (Solar panels installation)	< 5- ton	Recycle / Dispose	Licensed Waste Collector
Oily Rags & Spill Absorbent Pads	Construction (Maintenance & Commissioning)	< 1- ton	Incineration	Licensed Waste Collector

Operational Impacts:

Due to its extremely low operational greenhouse gas emissions, solar power plants have long been hailed as a clean and environmentally beneficial energy source. Atmospheric emissions impacting the air quality or climate are not expected from the operation of the solar park.

During operations, very small quantities of waste will be generated, and these will be managed as part of the routine operation waste management procedure. Hazardous waste mainly such as broken PV modules will be generated which can be recycled by an accredited facility according to all applicable environmental laws. All third-party waste transporters or waste treatment/disposal facilities will be inspected prior to their use, to ensure that on-site and off-site transportation of waste should be conducted to prevent or minimize spills, releases, and exposures to employees and the public. All waste containers designated for off-site shipment should be secured and labeled with the contents and associated hazards, be properly loaded on the transport vehicles before leaving the site, and be accompanied by a shipping paper (i.e., manifest) that describes the load and its associated hazards.

If water is used to clean the solar panels in this project, approximately 32.9 million L of water will be required (Assuming 8 L of water is required for cleaning 4117,680 modules). Therefore, the routine cleaning of panels/modules in the Khulais PV Park will generate wastewater. The wastewater produced by the regular cleaning will be gathered and recycled to conserve water and reduce waste.

It is assumed that approximately 45-50 workers/staff will be required for the operation and maintenance of the solar park. Most of these workers will be accommodated near the facility. The worker's camp may cause impacts on the environment, mainly in the form of generation of (solid, liquid, and hazardous) wastes. It is assumed that the plant will be equipped with treatment plants (STP) for the generated sanitary wastewater and the treatment process. Greywater from the

accommodation will be collected from the same sewage network and treated at the Sewage Treatment Plant (STP). The treated effluent will be reused to clean the solar panel and irrigation.

During the operation phase, waste management operations will be impacted, but these effects will be localized and can be mitigated by implementing management measures.

Impact on Waste Management- Summary

The following Table 5.28 presents the impact assessment results for waste management during the construction/commissioning. The table also presents the VER's sensitivity and magnitude of impacts. In the Table, potential impacts are quantified using the ARVI tool, which is a multi-criteria decision analysis (MCDA) tool used for impact assessment in ESIA's.

During the construction/commissioning phase, the potential negative impacts on waste management are assessed as high significance, before implementing mitigation measures.

Table 5.28. Summary of potential negative impacts on waste management during the construction/commissioning phase, before implementing any mitigation measures.

Env. Receptor	Characteristics of Magnitude			Magnitude	Significance
	Intensity and direction	Spatial extent	Duration		
Waste management	High -	Moderate	Low	High -	High -

IMPACTS ON TRAFFIC AND TRANSPORT

Traffic congestion is one of the important issues associated with major development projects. During the construction activities, it is required to transport workers and construction materials either using vehicles/trucks or even by sea and air. Therefore, road traffic congestion can be expected during most of the construction activities. This assessment examines the impacts of construction and commissioning activities on road traffic in the Al Humaij area.

The location in Al Humaij indicates that the project area is situated in the middle of the desert, characterized by minimal to no traffic and a lack of established roads. The remote nature of this location, combined with the absence of significant cultural or economic landmarks nearby, suggests that the traffic impact during the construction phase will be negligible.

The strategic location of the Al Humaij Solar PV Park ensures optimal connectivity with key cities, namely Madinah and Riyadh. The project site is located on the main Highway connecting Madinah and Riyadh.

Construction and Commissioning Impacts:

Road traffic is expected to witness a temporary surge during construction, transportation, and the installation of solar modules. The impact of this increased road

traffic will be temporary (limited to mobilization and demobilization phases) and is not considered to be of significance.

The movement of construction personnel will not lead to significant impacts on surrounding roads, communities, or infrastructure as construction personnel will be housed on-site in the worker's camp for the duration of construction.

Ongoing and planned development projects using the Highway connecting Madinah and Riyadh could place pressure on the local road network, particularly during the construction phases of the projects, and therefore there is an increased potential for accidents and disruption to the road traffic network for local users associated with increased traffic movements from overlapping construction works. It is recommended that a road traffic management plan is put in place before the works begin. In coordination with the relevant administrative and municipal authorities, this plan will manage the fluidity of possible routes and access roads.

If proper mitigation measures are followed, most of the predicted traffic and transportation impacts can be avoided or reduced to insignificant levels.

Operation Impacts:

There are no specific concerns expected during the operations phase for traffic and transport given that the project involves just the operation of the Solar PV Park and produce electricity.

Impacts on Traffic and Transport- Summary

The following Table 5.19 present the impact assessment results for traffic and transport during the construction/commissioning. The table also present the VER's sensitivity and magnitude of impacts. In the Table, potential impacts are quantified using the ARVI tool, which is a multi-criteria decision analysis (MCDA) tool used for impact assessment in ESIA's.

During the construction/commissioning phase the potential negative impacts on traffic and transport are assessed as low significance, before implementing mitigation measures.

The following Table 5.29 and Table 5.30 present the impact assessment results for traffic and transport during the construction/commissioning and operation phases respectively. The tables also present the VER's sensitivity and magnitude of impacts. In the Tables, potential impacts are quantified using the ARVI tool, which is a multi-criteria decision analysis (MCDA) tool used for impact assessment in ESIA's.

During the construction/commissioning phase the potential negative impacts on traffic and transport are assessed as moderate significance and during the operation phase as low significance, before implementing mitigation measures.

Table 5.29. Summary of potential negative impacts on traffic and transport during the construction/commissioning phase, before implementing any mitigation measures.

	CHARACTERISTICS OF MAGNITUDE	MAGNITUDE	SIGNIFICANCE

Env. Receptor	Intensity and direction	Spatial extent	Duration		
Traffic and transport	Low -	Low	Low	Low -	Low -

Table 5.30. Summary of potential negative impacts on traffic and transport during the operation phase, before implementing any mitigation measures.

Env. Receptor	CHARACTERISTICS OF MAGNITUDE			MAGNITUDE	SIGNIFICANCE
	Intensity and direction	Spatial extent	Duration		
Traffic and transport	No impact	Low	Low	No impact	No impact

HEALTH AND SAFETY IMPACTS

It is crucial to emphasize the significance of identifying and prioritizing the health and safety of workers and communities located in the project site and its vicinity. This assessment examines the impacts of construction and commissioning activities on the health and safety of the workers in the project area as well as the neighboring communities. The potential health hazards or impacts in industry covers five major groups: physical, chemical, biological, ergonomic and psychological impacts or hazards.

Construction Impacts:

Workers Health and Safety:

Throughout the construction phase there will be generic occupational health and safety risks to workers, as working onsite increases the risk of injury or death due to accidents. The following risks are generally associated with solar PV development projects:

- Slips and falls.
- Working at heights.
- Working with powered and hand-held tools.
- Struck-by objects.
- Moving machineries.
- Working in confined spaces and excavations.
- Exposure to increased noise
- Exposure to dust storm and wind.
- Exposure to chemicals, hazardous or flammable materials.
- Working in sunny conditions and high temperatures.
- Exposure to electric shocks and burns when touching live components.

One of the major potential physical impacts during the construction and commissioning phase on health and safety of the workers are noise and vibration. Noise and vibration can both independently pose significant health risks.

The use of hand-held vibrating tools is widespread in installations (e.g. grinders, needle guns, impact wrenches, air drills and chipping hammers). This creates the possibility for hand–arm vibration syndrome in workers who use these tools routinely. Exposure to extreme heat and direct sunlight in tropical areas and to extreme cold in high latitudes can become significant sources of health risk depending on the geographical region of the world.

Ergonomic hazards generally refers to health problems due to the interaction between the following: (i) the postures people are forced to adopt to reach, act on or operate the objects and equipment they work with and (ii) the nature and time history of the application of force on those objects. Ergonomic health issues are usually associated with the musculoskeletal system and principally the upper limbs, neck and lower back. They can also be associated with impaired visual function arising from working on visually demanding tasks over extended durations with inappropriate task lighting. The critical factor that identifies a health issue as being ‘ergonomic’ is that the injury arises because the way the environment and equipment are arranged requires people to adopt postures, movements, apply force and read material in conditions that are potentially damaging to health in order to complete what is expected of them in the normal course of their work..

Psychological hazards or impacts are different from other occupational hazards (e.g. noise and chemicals) because The level of stress within an organization varies both rapidly and significantly over time. Stress to workers occurs in hot spots in an organization and is rarely uniform. The effort required to conduct a full objective assessment of stress and controls is high and should not be undertaken lightly.

Certain biological impacts may affect the health and safety of the workers. Food-poisoning outbreaks are typical manifestations of biological hazards in the isolated workplace. They tend to occur more commonly in less developed areas, often related to poor hygiene associated with water dispensers, ice makers and ice cream machines.

Legionnaires disease is a serious type of pneumonia (lung infection) caused by *Legionella* bacteria. Robust health risk management is required to control health risk from potential *Legionella* contamination of water pipes, particularly in showers of accommodation blocks and air-conditioning plants.

There is a risk that contractors may violate labour and working conditions (e.g., long working hours, unstable employment, low pay). Additionally, there is the risk that contractors may not manage and monitor workers’ camps/accommodations properly, which poses a high risk for transmitted/communicable diseases.

Community Health and Safety:

Impacts associated with construction-related activities include noise, dust and disruption to adjacent properties. Noise in this regard can be described as any loud, unpleasant or disagreeable sounds that occur as a result of demolishing activities, transport and movement and construction. These noises can be of great irritation to those residing close to the proposed site.

Site clearing for Solar Energy facilities increases the risk of dust being generated, which can in turn impact adjacent properties. The potential impacts can be addressed by implementing effective mitigation measures.

The movement of heavy construction vehicles during the construction phase also has the potential to create noise, damage to roads and dust. The primary sources of noise during construction would be from the construction equipment and vehicles. The generation of dust would come from construction activities. Short-term increases in the use of local roads would occur during the construction period. However, heavy equipment would most likely remain at the site for the construction period.

Some changes in the quality of the living environment for the nearby residents could be expected from the disruptions. Impacts from these nuisances could impact on project workforce as well as the surrounding community.

Most of the predicted health and safety impacts can be avoided or reduced to insignificant levels if proper mitigation measures are implemented during the construction and commissioning phase.

Operation Impacts:

Some of the health and safety impacts identified for the construction phase on workers will be repeated during the operation phase with reduced intensity. This includes risk associated with slips and falls, working at heights, working with powered and hand-held tools, working in sunny conditions and high temperatures, exposure to dust storms and heat waves, exposure to flash flood, exposure to electric shocks and burns when touching live components etc. Some of these risks will be associated with cleaning the solar panels and regular maintenance of the facilities. Low significance health and safety impacts on the nearby communities are not expected during the operation of the solar park.

If proper mitigation measures are followed, most of the identified health and safety impacts can be avoided or reduced to insignificant levels.

Health and safety Impacts- Summary

The following Table 5.31 and Table 5.32 present the impact assessment results for health and safety during construction/commissioning and operation phases respectively. The tables also present the VER's sensitivity and magnitude of impacts. In the Tables, potential impacts are quantified using the ARVI tool, which is a multi-criteria decision analysis (MCDA) tool used for impact assessment in ESIA's.

During the construction/commissioning phase the potential negative impacts on health and safety are assessed as high significance and during the operation phase as moderate significance, before implementing mitigation measures.

Table 5.31. Summary of potential negative impacts on health and safety during the construction/commissioning phase, before implementing any mitigation measures.

Env. Receptor	CHARACTERISTICS OF MAGNITUDE			MAGNITUDE	SIGNIFICANCE
	Intensity and direction	Spatial extent	Duration		

Health and safety	High -	Moderate	Low	High -	High -

Table 5.32. Summary of potential negative impacts on health and safety during the operation phase, before implementing any mitigation measures.

Env. Receptor	CHARACTERISTICS OF MAGNITUDE			MAGNITUDE	SIGNIFICANCE
	Intensity and direction	Spatial extent	Duration		
Health and safety	Moderate -	Low	Moderate	Low -	Moderate -

LABOR MANAGEMENT

Total of 3000 workers will be required for the construction and commissioning activities in the Al Humaij project area lasting for approximately, 20-24 months (information received from GRL).

Construction and Commissioning Impacts:

A Local Employment Plan will be developed in order to guarantee the creation and the maximization of jobs for local communities as a result of the diagnosis of specific local needs and of highlighting the community development. The individuals employed during the construction stage, and their household members, will benefit from increased income that is likely to increase their overall standard of living, access to healthcare and educational resources, and reduce their socio-economic vulnerability.

However, there is a potential for local tensions to arise if residents within local communities incorrectly perceive that people from outside the local area (expatriates) are being provided with employment opportunities. Whilst local employment is generally a positive impact, a loss of reputation and negative perceptions towards the Project could occur if the local recruitment process is not adequately managed and negative perceptions arise. In this case, management of expectation with respect to the duration of work and opportunities after construction has been completed need will be taken into consideration to avoid occurrence of such tensions.

There is an opportunity for women to become a substantial part of the workforce, benefitting from the vocational training and earned income. This has the potential to work towards gender-include economic growth and increase the ability of women to influence decisions in the households associated with spending decisions. Given that the employment will be important during construction phase and the low number of skilled labor among the local community, the chance is given to men considering the nature of construction activities.

The use of a supply chain introduces the potential for labour violations to occur. This include, for example, poor working conditions, a lack of written worker contracts being used, low-levels of occupational health and safety, child labour, forced labour and other forms of labour-related exploitation. Similar to mitigation measures adopted for construction activities, project owner and its contractors will implement a Supply Chain Management Plan.

All workers including direct workers, contract workers and supply chain workers will be treated by the project owner and its contractors in compliance.

Construction and commissioning activities are likely to have temporary labor management impacts, which mitigation measures can reduce to an insignificant extent.

Operation Impacts:

During the operation phase, approximately 50 workers/staff will be required for this project. Therefore no impacts are expected on labor management during the operation phase.

Human Rights Risk Assessment (HRIA)

Several potential human rights risks may arise as a result of project activities, mainly related to labour rights (e.g. migrant workers, women's rights, equality, gender equality, overtime, rest time, rest days, etc.); working conditions; forming and joining labour unions, child labour and forced labour; disability and discrimination in the workplace, gender bias, common etc. The brief analysis of project related human right risks are summarised in Table 5.33 below:

If this human right is mismanaged, it can cause discontent among workers. Therefore, the contractor should be encouraged to implement internal and external grievance mechanism at the project site to employees as a means of complaints and to fully implement the Human Resources Policy Manual. In addition, a number of potential human rights risks may raise public concerns such as the environment, safety and health, including worker safety and health, and public health.; impacts on local communities (e.g. livelihoods and access to water); and security. The project activities will also affect the economic and social aspects of the local communities in and around the project area, local workers and business owners. This project will benefit small businesses. These potential impacts on human rights issues can be avoided and should be managed through proper management planning, mitigation and active monitoring throughout the life of the project.

Table 5.33. Summary of project related human right risks on workers involved in the construction and operation activities.

Thematic Area and potential risk	Potential Human Rights risk	Project features	Project Potential issues and risks
Labour related Rights Potential Risks: • Terms and Conditions of Employment • Conflicts between labour and contractor • Non-discrimination and Equal Opportunity	• Right of Minimum wage • Right of pensions and insurance • Right of Life and Personal Liberty • Right to Equality, and Non-discrimination • Right to housing and an adequate standard of living • Freedom of Speech and Expression	Construction activities will include site preparation, foundation laying, fencing, cleaning, piling and erection of solar panels, and commissioning of mounting structures. Some of these activities can also be construed as high- risk activities such as working at height, working in confined spaces, electrical hazards, suspended loads etc.	• Occupational Health and Safety risks during construction and operations leading to serious injuries and fatalities • Discrimination of workers in wages, working conditions and facilities, and differential access to remedy to complaints/grievances • Sexual Harassment at the workplace

Thematic Area and potential risk	Potential Human Rights risk	Project features	Project Potential issues and risks
Working Conditions and setting of labour camps	Freedom of Assembly;	Improper and inadequate occupational safety controls may lead to worker injuries and in worst cases, fatalities. Discrimination may occur due to unfair treatment of migrant workers based on their religion, ethnicity, sex or region they belong to.	- Workers forming associations or unions for collective bargaining - Engagement of child ad forced labor may lead to cases of exploitation, trafficking or modern slavery.

Impacts on Labor management- Summary

The following Table 5.34 presents the impact assessment results for labor management during construction/commissioning. The table also present the VER's sensitivity and magnitude of impacts. In the Table, potential impacts are quantified using the ARVI tool, which is a multi-criteria decision analysis (MCDA) tool used for impact assessment in ESIAs.

During the construction/commissioning phase the impact on labor management are assessed as high significance, before implementing mitigation measures.

Table 5.34. Summary of potential negative impacts on labor management during the construction/commissioning phase, before implementing any mitigation measures.

Env. Receptor	Characteristics of Magnitude			Magnitude	Significance
	Intensity and direction	Spatial extent	Duration		
Labor management	High -	Moderate	Low	High -	High -

COMMUNITY DISPLACEMENT IMPACTS

The solar power plant will be built on 60 km² land owned by the Saudi's Ministry of Energy (MoE). Community settlement and the presence of camel farms is reported close to the project site [Sunshine Middle East, 2024].

The objective of this assessment is to evaluate the community displacement and livelihood impacts related to the construction and operation of this project.

Construction and Commissioning Impacts:

The project land is owned by MoE and it is not occupied by people or any economic or social activities. The project site is used for only camel grazing. Therefore the displacement of settlements is not applicable to this project.

Development-induced community displacement is a social problem affecting multiple levels of human organization, from tribal and village communities to well-developed urban areas. Development is widely viewed as an inevitable step towards modernization and economic growth in developing countries, however, for those who are displaced, the result is most often loss of livelihood and impoverishment [Chris, 2006].

During construction and operation, the project site will not be available for camel grazing. However, the adjacent areas will be available for camel grazing and setting up camel farms. There can be some income generation opportunities for the interested community members from the neighboring communities during the construction phase of the project. These opportunities can be offered to the project affected community members, if any.

Operation Impacts:

The project land is currently used by occasional livestock farmers who frequent the site during certain periods of the year with livestock, mainly camels. The establishment of the solar PV park, will result in the reduction of grazing land in the area. This is because the site will be permanently fenced off and livestock farmers will no longer have access to the grazing areas within it. This could lead to a potential loss of grazing livelihoods.

The employment opportunities in the proposed project during its operation phase will be limited and such limited opportunities will have to be naturally offered to the project affected communities, if any. As a positive impact the region's residents will have access to a sustainable power supply as long as the solar power plant remains

operational. Similarly, the communities in the vicinity of the project will have opportunities to enjoy the benefits of having improved roads to the project site.

Community Displacement Impacts- Summary

The following Table 5.35 and Table 5.36 present the impact assessment results for community displacement during construction/commissioning and operation phases respectively. The tables also present the VER's sensitivity and magnitude of impacts. In the Tables, potential impacts are quantified using the ARVI tool, which is a multi-criteria decision analysis (MCDA) tool used for impact assessment in ESIA's.

There are no settlement or significant cultural or economic activities present in the project area located in the middle of the desert. The project area is used for camel grazing by the local people. During the construction/commissioning phase and the operation phase, the community displacement impacts are assessed as moderate significance, before implementing mitigation measures.

Table 5.35. Summary of potential negative impacts on community displacement during the construction/commissioning phase, before implementing any mitigation measures.

Env. Receptor	Characteristics of Magnitude			Magnitude	Significance
	Intensity and direction	Spatial extent	Duration		
Community Displacement	Low -	Low	Low	Low -	Moderate -

Table 5.36. Summary of potential negative impacts on community displacement during the operation phase, before implementing any mitigation measures.

Env. Receptor	Characteristics of Magnitude			Magnitude	Significance
	Intensity and direction	Spatial extent	Duration		
Community Displacement	Low -	Low	Low	Low -	Moderate -

IMPACT ON NATIONAL AND LOCAL ECONOMY

This assessment examines the impacts of construction, commissioning and operation activities on the national and local economy. In general, socio-economic impacts focus on how the activity affects human or societal well-being, as well as the use and benefit of any site.

Construction and commissioning Impacts:

The Project will positively influence the regional and national economy during construction from the direct procurement and supply of materials and services from companies based in the region and elsewhere in Saudi Arabia. This includes for example, companies providing earth moving equipment, workers to complete general civil works, logistics services to transport the solar panels to the Project area, and

construction of the worker accommodation camp etc. Other companies located outside of Saudi Arabia will be responsible for the supply of the solar panel components, such as the panels, inverters and supporting structures and cables.

The impact is positive because construction activities will generate economic growth at a local, regional and national level through the procurement of services and materials. The increased demand for business-to-business services to small-to-medium enterprises (SMEs) will generate increased revenue across the region, resulting in higher turnover for the SMEs involved. The impact is reversible as it will be only limited to the construction phase.

This project may generate some employment opportunities for the local community. During the construction phase, job opportunities will be created. These jobs will be insignificant at both local and national levels, since a portion of these positions are envisaged to be filled by expatriate workers. This is expected to be of low magnitude, creating positive impact benefitting the local and regional community however, the impact will be temporary, as the workers will no longer be required once the construction is completed.

The most workers required for the construction will be housed in the labor camps. Services required here in this accommodation include provision of catering and services which will be supplied by local contractors. Alongside this, the increase in number of people will result in demand for local goods and services which will directly benefit the local community. This is expected to be of low magnitude, creating positive impact that directly benefits the local community; however, the impact will be temporary, as the workers will no longer be required once the construction is completed.

This project may create some secondary employment (jobs created indirectly). If the construction activities attract workers to the area, local stores will likely see an increase in business, which may lead to new jobs at the stores. The magnitude of indirect employment effects is largely determined by the new project and are dependent on factors such as employee wages and the company's likelihood of purchasing local goods.

Operation Phase Impacts:

During the operations phase, the economy will be stimulated although to a far smaller degree since operational expenditure is expected to be significantly lower than the construction phase. Additional energy generation has knock-on effects on economic stimulation, income generation, etc. The opportunity costs also need to be taken into consideration in this regard. The opportunity costs associated with the development of the site for solar energy can be defined as the potential foregone benefits that would be associated with the next best alternative land use.

The project will provide much needed clean energy to the region, and will also improve the infrastructure of the area by way of enhanced electricity supply and improved roadways. Apart from this project derived benefits include employment opportunities. It is envisaged that this inclusive approach will greatly reduce socio-political barriers which may arise out of the project.

Impacts on National and Local Economy- Summary

The following Table 5.37 and Table 5.38 present the impact assessment results for national and local economy during construction/commissioning and operation phases respectively. The tables also present the VER's sensitivity and magnitude of impacts. In the Tables, potential impacts are quantified using the ARVI tool, which is a multi-criteria decision analysis (MCDA) tool used for impact assessment in ESIA's.

During the construction/commissioning phase and operation phase the potential positive impacts on national and local economy are assessed as moderate significance, before implementing mitigation measures. During the construction/commissioning phase and operation phase, the negative impacts on national and local economy are not predicted (no impact).

Table 5.37. Summary of potential negative impacts on national and local economy during the construction/commissioning phase, before implementing any mitigation measures.

Env. Receptor	Characteristics of Magnitude			Magnitude	Significance
	Intensity and direction	Spatial extent	Duration		
National and local economy	Low +	Low	Low	Low +	Moderate +

Table 5.38. Summary of potential negative impacts on national and local economy during the operation phase, before implementing any mitigation measures.

Env. Receptor	Characteristics of Magnitude			Magnitude	Significance
	Intensity and direction	Spatial extent	Duration		
National and local economy	Low +	Low	High	Low +	Moderate +

IMPACT ON Archaeology AND CULTURAL HERITAGE

This assessment examines the impacts of construction, commissioning and operation activities on the archaeology and cultural heritage of the project area if any. Archaeological and cultural heritage refers to any relics, structures, deposits and discoveries preserved on land or in water, created through human activities during the prehistoric or historical periods.

A desk-based assessment and walkover survey were conducted within the project area and the area of influence (10 km). There was no evidence for prehistoric activity or presence of any archaeological and cultural heritage sites within the site boundary.

Construction and Commissioning Impacts:

Evidence of any tangible or intangible heritage in the project area is not reported. Usually, the proposed construction activities will be designed to avoid direct impacts on known heritage assets where possible. During construction, the chances of finding tangible cultural heritage, which includes movable or immovable objects, sites,

structures, groups of structures, and natural features and landscapes that have archaeological, paleontological, historical, architectural, religious, aesthetic, or other cultural significance cannot be ruled out.

Therefore, a Chance Find Procedure (CFP) is a project-specific procedure which is to be followed if previously unknown cultural heritage is encountered during project activities. The CFP sets out how chance finds associated with the project will be managed. The procedure includes a requirement to notify relevant authorities of found objects or sites by cultural heritage experts; to fence off the area of finds or sites to avoid further disturbance; to conduct an assessment of found objects or sites by cultural heritage experts; to identify and implement actions consistent with the requirements of international and national law; and to train project personnel and project workers on chance find procedures.

Operation Impacts:

During the operations phase, impact on archaeological and cultural heritage is not expected in this project.

Impacts on Archaeology and Cultural Heritage - Summary

The following Table 5.39 and Table 5.40 present the impact assessment results for archaeological and cultural heritage during construction/commissioning and operation phases respectively. The tables also present the VER's sensitivity and magnitude of impacts. In the Tables, potential impacts are quantified using the ARVI tool, which is a multi-criteria decision analysis (MCDA) tool used for impact assessment in ESIA's.

During the construction/commissioning phase, the impact on archaeological and cultural heritage are assessed as low significance and during operation phase as no impact, before implementing mitigation measures.

Table 5.39. Summary of potential negative impacts on archeology and cultural heritage during the construction/commissioning phase, before implementing any mitigation measures.

Env. Receptor	Characteristics of Magnitude			Magnitude	Significance
	Intensity and direction	Spatial extent	Duration		
Arch and Cultural Heritage	Low -	Low	Low	Low -	Low -

Table 5.40. Summary of potential negative impacts on archeology and cultural heritage during the operation phase, before implementing any mitigation measures.

Env. Receptor	Characteristics of Magnitude			Magnitude	Significance
	Intensity and direction	Spatial extent	Duration		
Arch and Cultural Heritage	No impact	Low	Low	No impact	No impact

5.3.2 Analysis and Assessment of the Potential Impacts- Accidental Releases (Non-Routine Events)

The accidental releases (non-routine events) include all incidents that were not foreseen and which may result from an accident. Events such as inappropriate waste disposal and minor leaks and spills are seen as non-routine events that could negatively impact the environment, including air, water and terrestrial. Large scale accidental releases of fuel oil (diesel) or fire will also have significant negative socioeconomic impacts. Some of the possible non-routine events applicable to this project and their potential environmental impacts are discussed below:

INAPPROPRIATE WASTE DISPOSAL IMPACTS

During construction there can be an impact caused by inappropriate waste disposal including the inappropriate disposal of hazardous solar panel wastes. Disposal of hazardous waste can be a concern due to health impacts on population and on the environment. Under normal conditions, solid or untreated liquid waste is not expected to reach or impact the terrestrial environment. Accidental release of solid wastes from the solar park (potentially contaminated paper, plastic, cardboard) may cause negative environmental impacts.

Inappropriate waste disposals are expected to have significant negative impacts, if mitigation measures are not implemented during construction.

Inappropriate Waste Disposal Impacts- Summary

The following Table 5.41 and Table 5.42 present the impact assessment results for Inappropriate waste disposals during construction/commissioning and operation phases respectively. The tables also present the VER's sensitivity and magnitude of impacts. In the Tables, potential impacts are quantified using the ARVI tool, which is a multi-criteria decision analysis (MCDA) tool used for impact assessment in ESIA's.

During the construction/commissioning phase the potential negative impacts of inappropriate waste disposal are assessed as high significance and during the operation phase as moderate significance, before implementing mitigation measures.

Table 5.41. Summary of potential negative impacts of inappropriate waste disposals during the construction/commissioning phase, before implementing any mitigation measures.

Env. Receptor	Characteristics of Magnitude			Magnitude	Significance
	Intensity and direction	Spatial extent	Duration		
Inappropriate waste disposal	Low -	Low	Low	Moderate -	High -

Table 5.42. Summary of potential negative impacts of inappropriate waste disposals during the operation phase, before implementing any mitigation measures.

Env. Receptor	Characteristics of Magnitude			Magnitude	Significance
	Intensity and direction	Spatial extent	Duration		
Inappropriate waste disposal	Low -	Low	High	Low -	Moderate -

5.3.3 Analysis and Assessment of the Potential Impacts During the Decommissioning Phase

It is expected that the solar power park constructed as part of this project will be decommissioned after approximately 25 years. Almost all industrial facilities undergo decommissioning at some point during their lifetime. The facility must be dismantled when it no longer serves a useful social or economic purpose so that the site can be used for other purposes. The decommissioning of the project may have several environmental impacts. During decommissioning, most of the impacts identified during construction may resurface.

Hereafter, the term “decommission” will refer to the fate of a structure following cessation of operations and/or activities for which it was originally deployed, and will encompass all possible strategies and options from removal and disposal to repurposing and recycling.

Solar panels are guaranteed to produce at least 80% of their original power rating after 25 years. Panels may be re-used or re-sold: There is an emerging market for second generation panels, often for off-grid applications or electrification in developing countries. Panels may also be refurbished or recycled. Eighty-five percent of the weight of a solar panel is glass and aluminium: materials commonly recycled. There is a growing network of waste management firms in the United States that offer options for panel recycling.

Potential Environmental Impacts of the Decommissioning Phase:

The multi-criteria decision analysis (MCDA) tool called ARVI developed in the EU LIFE+ IMPERIA project Imperia 2015 (IMPERIA, 2015; EU, 2017) was used in the impact assessment during the decommissioning phase as described in Section 5.2.3 of this ESIA report. The potential environmental impacts of the decommissioning

activities on the valued environmental and social components (VECs) are briefly described below.

Air Quality and Climate:

As a result of emissions from vehicles, trucks, generators, large cranes, and demolition equipment, there may be a temporary reduction in air quality during decommissioning. Vehicle and equipment operations may emit hazardous air pollutants and greenhouse gases into the atmosphere.

Airborne Noise:

Planned decommissioning activities intermittently and temporarily generate noise levels above existing ambient levels in the project vicinity. Increased airborne noise may negatively impact the site workers and nesting birds if any located within the footprint area.

Terrestrial Ecology:

Activities such as site clearing, grading, and excavation can be expected to occur during the decommissioning phase in the project area. Demolition and removal of the solar panels, inverters, transformers, cables, supporting structures and associated structures are likely to cause impacts on the terrestrial environment including flora and fauna. Impacts on animal species within the project area will naturally be connected to impacts to floral communities. Direct impacts on animal species can occur as vegetation is removed or disturbed during the decommissioning activities. Decommissioning will produce large quantities of hazardous and non-hazardous waste requiring careful handling and safe disposal without impacting the flora and fauna.

Soil, water, and Groundwater:

During the decommissioning process, spills and leaks of gasoline, diesel fuel, crude oil, and other petroleum-based liquids may cause contamination of soil, surface water and groundwater. The water will be used both for drinking purposes and in the labor camps. Consequently, valuable resources, such as water, may be exploited.

Waste Management:

Large quantities of hazardous and non-hazardous waste will be generated from the decommissioning of solar panels and the associated structures. The decommissioning process produces waste that requires effective management by those responsible for decommissioning activity to ensure all waste produced is legally transported, recycled, reused or disposed of safely by competent, authorized organisations and personnel.

Disposal of PV-modules come with considerable energy consumption and other harmful environmental impacts not to be neglected (Rabaia et al., 2021). Although solar panel recycling has not become a major issue yet, it will in the coming decades as solar panels need to be replaced. Currently, solar modules can be disposed of with other standard e-waste. Countries without robust e-waste disposal means are at a higher risk of recycling related issues. Standard solar modules' silicon wafers are encapsulated, commonly by ethyl vinyl acetate (EVA). This layer protects the silicon wafer. If modules are not disposed of properly and exposed to specific test conditions is it possible some leaching may occur. Under normal operating conditions these materials will not be released.

Socioeconomics:

At the local level, positive benefits for the local community in terms of limited employment and income are expected during the decommissioning phase. The need for some specific equipment and supplies during decommissioning would also be an economic boost to the local traders and would produce a small positive impact.

The significant potential impacts during the decommissioning phase on selected environmental receptors are evaluated and summarized in Table 5.43.

Table 5.43. Evaluation of potential impacts during the decommissioning activities on selected environmental aspects, before implementing the mitigation measures.

Impact	Characteristics of Sensitivity			Sensitivity	Characteristics of Magnitude			Magnitude	Significance
	Existing regulations and guidance	Societal value	Vulnerability for changes		Intensity and direction	Spatial extent	Duration		
Air Quality	Very high	Very high	High	High	High -	High	Low	High -	High -
Climate	High	High	High	High	Low -	Moderate	Low	Low -	Moderate -
Noise and vibration	High	Moderate	High	High	Moderate -	Low	Low	Low -	Moderate -
Visual and landscape	Moderate	Moderate	Moderate	Moderate	Low -	Low	Low	Low -	Low -
Soil and Land Use	High	Very high	High	High	Low -	Low	Low	Low -	Moderate -
Ground and Surface water	High	Very high	High	High	Low -	Low	Low	Low -	Moderate -
Flora	High	High	High	Moderate	Moderate -	Low	Low	Moderate -	Moderate -
Fauna	Very high	High	High	Moderate	High -	Moderate	Low	High -	High -
Waste management	Very high	High	Moderate	High	High -	Moderate	Low	High -	High -
Traffic and transport	High	High	Moderate	Moderate	Low -	Low	Low	Low -	Low -
Health and safety	Very high	High	High	High	High -	Moderate	Low	High -	High -
Labor management	High	Moderate	Moderate	Moderate	High -	Moderate	Low	High -	High -
Inappropriate waste disposal	Very high	High	High	High	Low -	Low	Low	Moderate -	High -
Accidental spills, fire etc.	Very high	Very high	High	Very high	Very high -	Very high	Moderate	Very high -	Very high -

IMPACTS FROM ACCIDENTAL SPILLS & FIRE

Accidental releases of chemicals such as solvents, metals, hydrocarbons and chlorine could have negative impacts on a number of receptors including air quality, flora, fauna and groundwater. Hazardous substances persist in the soil harm the flora and fauna and cause health and safety impacts on workers and even the nearby communities.

In addition to producing smoke, fire can incapacitate or kill by reducing oxygen levels, either by consuming the oxygen, or by displacing it with other gases. Heat is also a respiratory hazard, as superheated gases burn the respiratory tract. Property destruction is the most evident and direct result of fire. Buildings, facilities, solar panels, transformers, inverters etc., can be destroyed by fire, leaving behind a tremendous amount of debris and smoke damage.

Accidental spills and fires are expected to have negative impacts, if mitigation measures are not implemented during construction.

Accidental Spills and Fire Impacts- Summary

The following Table 5.44 and Table 5.45 present the impact assessment results for accidental spills and fire during construction/commissioning. The table also presents the VER's sensitivity and magnitude of impacts. In the Table, potential impacts are quantified using the ARVI tool, which is a multi-criteria decision analysis (MCDA) tool used for impact assessment in ESIAs.

During the construction/commissioning phase the potential negative impacts of accidental spills and fire are assessed as very high significance, before implementing mitigation measures.

Table 5.44. Summary of potential negative impacts of accidental spills and fire during the construction/commissioning phase, before implementing any mitigation measures.

Env. Receptor	Characteristics of Magnitude			Magnitude	Significance
	Intensity and direction	Spatial extent	Duration		
Accidental spills & fire	Very high -	Very high	Moderate	Very high -	Very high -

Table 5.45. Summary of potential negative impacts of accidental spills and fire during the operation phase, before implementing any mitigation measures.

Env. Receptor	Characteristics of Magnitude			Magnitude	Significance
	Intensity and direction	Spatial extent	Duration		
Accidental spills & fire	Very high -	Very high	High	Very high -	Very high -

5.3.4 Cumulative Impact Assessment (CIA)

Cumulative impacts are those that result from the successive, incremental, and/or combined effects of an action, project, or activity (developments) when added to other existing, planned, and/or reasonably anticipated future ones [IFC, 2013]. For practical reasons, the identification and management of cumulative impacts are limited to those effects generally recognized as important on the basis of scientific concerns and/or concerns of affected communities.

Setting the Geographical and Temporal Boundaries

For the CIA, it is required to define geographical and temporal boundaries. The suggested rules of thumb to determine the geographic boundaries are as follows [IFC, 2013]:

- a) Include the area that will be directly affected by the project or activity, called Direct Area of Influence (DAI).
- b) List the important resources or Valued Environmental and Social Component (VECs) within the DAI.
- c) Define if these VECs occupy a wider area beyond the DAI
- d) Consider the distance an effect can travel, and other impacts the VEC may be exposed to within its range.

For this project, the geographical boundary used for CIA is prepared and shown in Figure 5.4.



Figure 5.4. Map showing the approximate geographical boundary used for cumulative impact assessment.

The proposed basic rules of thumb to determine the temporal boundaries for the CIA are as follows (IFC, 2013):

- i. Use the time frame expected for the complete life cycle of the proposed development.

- ii. Specify whether the expected time frame of the potential effects of proposed development can extend beyond (I).
- iii. Use the most conservative time frame between (I) and (III).
- iv. Using professional judgment to balance between overestimating and underestimating, and make sure to document the justification or rationale.
- v. Exclude future actions if (i) they are outside the geographical boundary, (ii) they do not affect VECs, or (iii) their inclusion cannot be supported by technical or scientific evidence.

Some of the past actions that are no longer active yet continue to represent a disturbance to VECs. It is possible that the effects may no longer be readily observable (e.g., review of maps or aerial photos show little evidence of the action). In practice, past actions often become part of the existing baseline conditions. It is important, however, to ensure that the effects of these actions are recognized. For CIA, construction projects implemented during the last 10 years and project in the foreseeable future (5 years from now) are considered.

Existing and potential Future Projects:

Currently, no operational, under-construction or proposal-stage projects have been identified in or around the project area in Al-Khulais. However, existing conditions such as land use pattern, traffic or air emissions from nearby settlements etc., can contribute to cumulative impacts.

5.3.5 Anticipated Cumulative Impacts

Air Quality

The air emissions from the traffic or from the nearby settlements in and around Al Khulais area are likely to cause some cumulative impacts on air quality. The air emission mitigating measures are for the most part limited to implementing control measures. It is very difficult to quantify the cumulative impacts on air quality without having complete details of air emissions from the nearby areas. However, due to the absence of major industries in the nearby areas, the cumulative impacts on the air due to the emissions from the construction activities will be insignificant.

Noise Impacts

The increased noise (airborne) emission related to traffic in and around the Al Khulais area is likely to cause some cumulative impacts on baseline noise quality in the project site. The noise-sensitive fauna as well as human beings will be impacted due to noise emissions. The cumulative noise impact may adversely affect the local population (including work force) and wildlife located in the project area and its vicinity. If proper mitigation measures are implemented, local population, terrestrial fauna and other sensitive wildlife in the area may not succumb to any significant impacts.

Water

The surface and ground water quality of the entire region will be significantly impacted due to the cumulative impact of existing land uses, agricultural activities and simultaneous constructions activities. The cumulative residual impact will be insignificant, if proper mitigation measures are implemented for these activities.

Biodiversity

The flora, fauna and the local biodiversity of the entire region will be significantly impacted due to the cumulative impact of existing land uses, agricultural activities and simultaneous constructions activities. The cumulative residual impact will be insignificant, if proper mitigation measures are implemented for these activities.

5.3.6 Conclusion

The cumulative impacts of the anthropogenic activities (past, existing and future activities) in the identified geographical area are likely to negatively impact the environment and ecosystems. The most serious cumulative impacts would be on the air quality, surface and groundwater, flora, fauna and wildlife. However, such overall cumulative impacts will be low to medium significance since the selected project area is located in an underdeveloped area.

5.3 SUMMARY OF EXPECTED IMPACTS BEFORE MITIGATION

The summary of the predicted impacts during the construction and commissioning phase before implementing mitigation is presented with the predicted significance of impacts as scoped in the ESIA process.

The potential impacts of different project activities during construction and commissioning on Valuable Environmental and Social Receptors (VCRs) such as: air quality, climate, microclimate, noise, visual and landscape, soil and land use, ground and surface water, flood risk, flora, fauna, waste management, traffic and transport, health and safety, labor management, etc., are assessed using a multi-criteria decision analysis (MCDA) tool, ARVI. The significance of impacts is computed by taking account of the size and severity of impacts (magnitude) in combination with the importance and value of the receptor affected, sensitivity of the receptor to the change, the timeframe of impacts and the reversibility of impacts.

For the construction and commissioning phase, the ARVI tool identified significant impacts on 19 sensitive receptors, out of which 18 were negative impacts and one was positive impact. Out of the 18 negative impacts, one (1) were very high, six (6) were high and seven (7) were moderate, three (3) were low significance and one (1) was no impact before implementing mitigation.

For the operation phase, the ARVI tool identified significant impacts on 19 sensitive receptors, out of which 18 were negative impacts and one was positive impact. Out of the 18 negative impacts, two (2) were very high, five (5) were high, six (6) were moderate and five (5) were no impact, before implementing mitigation.

Table 5.46. The summary of the predicted impacts on environmental and social receptors, during the construction and commissioning phase, before implementing mitigation.

IMPACTS/ RECEPTORS	CHARACTERISTICS OF SENSITIVITY			SENSITIVITY	CHARACTERISTICS OF MAGNITUDE			MAGNITUDE	SIGNIFICANCE
	Existing regulations and guidance	Societal value	Vulnerability for changes		Intensity and direction	Spatial extent	Duration		
Air Quality	Very high	Very high	High	High	High -	High	Low	High -	High -
Climate	High	High	High	High	Low -	Moderate	Low	Low -	Moderate -
Microclimate	High	High	High	High	No impact	Low	Low	No impact	No impact
Noise and vibration	High	Moderate	High	High	Moderate -	Low	Low	Low -	Moderate -
Visual and landscape	Moderate	Moderate	Moderate	Moderate	Low -	Low	Low	Low -	Low -
Soil and Land Use	High	Very high	High	High	Low -	Low	Low	Low -	Moderate -
Ground and Surface water	High	Very high	High	High	Low -	Low	Low	Low -	Moderate -
Flood risk	High	Very high	High	High	Low -	Low	Low	Low -	Moderate -
Flora	High	High	High	Moderate	Moderate -	Low	Low	Moderate -	Moderate -
Fauna	Very high	High	High	Moderate	High -	Moderate	Low	High -	High -
Waste management	Very high	High	Moderate	High	High -	Moderate	Low	High -	High -
Traffic and transport	High	High	Moderate	Moderate	Low -	Low	Low	Low -	Low -
Health and safety	Very high	High	High	High	High -	Moderate	Low	High -	High -
Labor management	High	Moderate	Moderate	Moderate	High -	Moderate	Low	High -	High -
Community Displacement	High	High	Moderate	High	Low -	Low	Low	Low -	Moderate -

National and local economy	High	High	High	High	Low +	Low	Low	Low +	Moderate +
Arch. and Cultural Heritage	High	Moderate	High	Moderate	Low -	Low	Low	Low -	Low -
Inappropriate waste disposal	Very high	High	High	High	Low -	Low	Low	Moderate -	High -
Accidental spills, fire etc.	Very high	Very high	High	Very high	Very high -	Very high	Moderate	Very high -	Very high -

Positive impacts= +; Negative impacts -

Table 5.47. The summary of the predicted on environmental and social receptors, during the operation phase, before implementing mitigation.

IMPACTS/ RECEPTORS	CHARACTERISTICS OF SENSITIVITY			SENSITIVITY	CHARACTERISTICS OF MAGNITUDE			MAGNITUDE	SIGNIFICANCE
	Existing regulations and guidance	Societal value	Vulnerability for changes		Intensity and direction	Spatial extent	Duration		
Air Quality	Very high	Very high	High	High	No impact	Low	Moderate	No impact	No impact
Climate	High	High	High	High	No impact	Low	Moderate	No impact	No impact
Microclimate	High	High	High	High	High -	High	Very high	High -	High -
Noise and vibration	High	Moderate	High	High	Low -	Low	Moderate	Low -	Moderate -
Visual and landscape	Moderate	Moderate	Moderate	Moderate	Low -	Low	Moderate	Moderate -	Moderate -
Soil and Land Use	High	Very high	High	Moderate	High -	Low	Moderate	Moderate -	Moderate -
Ground and Surface water	High	Very high	High	High	High -	High	Moderate	High -	High -
Flood risk	High	Very high	High	High	Moderate -	Moderate	Moderate	Moderate -	High -
Flora	High	High	High	High	Moderate -	Moderate	Moderate	Moderate -	High -
Fauna	Very high	High	High	High	Very high -	Moderate	Moderate	Very high -	Very high -
Waste management	Very high	High	Moderate	High	High -	Moderate	Moderate	High -	High -
Traffic and transport	High	High	Moderate	Moderate	No impact	Low	Moderate	No impact	No impact
Health and Safety	Very high	High	High	High	Moderate -	Low	Moderate	Low -	Moderate -
Labor management	High	Moderate	Moderate	Moderate	No impact	None	Moderate	No impact	No impact
Community Displacement	High	High	Moderate	High	Low -	Low	Low	Low -	Moderate -
National and local economy	High	High	High	High	Low +	Low	High	Low +	Moderate +
Arch. and Cultural Heritage	High	Moderate	High	Moderate	No impact	Low	Low	No impact	No impact
Inappropriate waste disposal	Very high	High	High	High	Low -	Low	High	Low -	Moderate -
Accidental spills, fire etc.	Very high	Very high	High	Very high	Very high -	Very high	High	Very high -	Very high -

Positive impacts= +; Negative impacts -

SECTION 6 PLANS (FOR IMPACT MITIGATION)

This section presents plans for mitigating and managing the impacts of construction activities on different social and environmental receptors within the project area, as well as environmental monitoring and auditing procedures. It includes: 1) Emergency preparedness and response plan; 2) Environmental rehabilitation and treatment plan; 3) Proposed plan to mitigate environmental impacts; and 4) Proposed environmental management and audit plan.

6.1 EMERGENCY PREPAREDNESS AND RESPONSE PLAN

Preparedness Emergency Response Plan (PERP) document is a principal emergency policy, procedure, and plan for all activities involved during the construction phases of this project. The objectives of the PERP are to ensure that immediate and appropriate actions are directed towards any emergency that interrupts normal safe working conditions so that:

- Problems arising and risks are dealt with utmost urgency;
 - The emergency incident is kept under control and does not spread to adjacent premises;
 - An effective state of cooperation exists during an emergency amongst the different occupants surrounding the project site as well as local government authorities;
 - To minimise loss of life or injuries, property damage, environmental degradation including water, noise, and air pollution, and business interruption;
 - To provide the basis for training and emergency preparedness for all personnel involved;
 - To identify potential environmental, health, and safety-related emergencies and to be able to respond appropriately to such situations; and
 - To take measures to prevent the occurrence and recurrence of such situations.
- The PERP document may include the following but is not limited to:

Description of reasonably foreseeable emergencies: spillage, accidents, and fires;

Emergency operational procedures including: containment and suppression, rescue and first aid, communication and command structure, relationship with public emergency response services, termination of emergency response and statutory requirements including approvals, notifications and reporting; and Training and competencies.

A detailed emergency response plan shall be prepared and submitted to GRL by the Construction Contractors for testing and approval at least three (3) months before commencement of the construction activities. The PERP should be reviewed and revised from time to time. Ongoing amendment is to ensure the PERP is effective and up-to-date with changing environmental standards and regulations. The main components of the PERP include:

6.1.1 *Emergency Response Set-Up*

In line with the PERP, an emergency response set-up shall be established. This includes emergency reporting system and emergency response equipment. Set-up components that should be considered are as follows:

Emergency Control Centre – location, central control, base control, etc.;

Emergency Reporting and Declaration;

Evacuation and Assembly Point;

Search and Rescue/ First Aid;

Emergency Response Equipment – emergency siren, fire alarm system, fire pumps, emergency water system, break glass alarm, fire extinguishers, emergency communication, etc.; and

Personal Protective Equipment.

6.1.2 *Emergency Response Procedure*

A procedural or step-by-step action plan for the following emergency incidents shall also be formulated:

Fire; and

Oil Spillage.

6.1.3 *Emergency Preparedness Training and Drills*

The most effective method to evaluate an emergency response plan is to conduct drills by simulating an emergency event and having several observers to watch and record what is happening in actual. Drills are excellent training aids as it can show any weaknesses in the emergency response plan so that the plan can be revised and improved from time to time.

Emergency preparedness training is required to prepare all personnel and workers to handle an emergency situation. The types of training include fire control, use of self-contained breathing apparatus, first aid, etc. Training exercises are to be carried out regularly, at least on annual basis with the local Fire and Rescue Department.

6.1.4 *Incident/ Accident Reporting*

Incident/ accident reporting shall be established in a systematic manner inclusive of an investigation procedure so that appropriate response action can be provided and to avoid recurrence of similar accident. All incident reports and lessons learned should be shared for continuous personnel/workers improvement.

The safety management systems documentation envisaged for the proposed construction activities shall be comprehensive and specifically cover all the aspects. As such, it should cover:

- Safe construction and operating procedures; and
- Environmental protection objectives.

6.2 ENVIRONMENTAL REHABILITATION AND TREATMENT PLAN

Environmental Rehabilitation Plans (ERP) outline the requirements to return an area that has been disturbed due to an activity or development to a state which approximates the state prior to the afore mentioned activity/development. Where disturbance to biodiversity or ecosystem services has occurred, remediation may be possible in the form of rehabilitation and restoration. The aim of the ERP is to ensure that the project area is returned to a safe and ecologically stable condition.

The project site is dominated by desert and rocky terrain, with sparse vegetation consisting mainly of drought-resistant plants such as acacia trees, shrubs, and grasses. The project does not require extensive tree and plant removal during construction, so there is little scope for environmental rehabilitation or treatment after construction. It is reported that *nature inclusive* and *landscape-inclusive* solar parks can provide sustainable energy and contribute to improving local biodiversity, based on extensive field studies [Oudes et al., 2022; Zaplata and Dullau, 2022; Jarcuska et al., 2024]. Thus, when designing parks, it is essential to pay close attention to their integration into the landscape and to take various measures to encourage the local flora and fauna. Oudes et al., [2022] proposed a solar power park typology that consists of four dimensions: energy, economic, nature and landscape. These dimensions lead to three main types of multifunctional solar parks: mixed-production, nature-inclusive, landscape-inclusive, and their combinations.

There is a growing recognition among governments and the private sector that conservation and development need to go hand in hand. During the operating phase, operators should take serious measures in the area to ensure a green management of the park. Hence the proposed Al Humajj Solar PV Park can be developed into a *nature inclusive* and *landscape-inclusive* solar park resulting in biodiversity net gain (BNG), an approach used to improve a sites biodiversity value. This concept seeks measurable improvements for biodiversity by creating or enhancing habitats in association with development.

6.3 A PROPOSED PLAN TO MITIGATE ENVIRONMENTAL IMPACTS (FOR EACH ENVIRONMENTAL COMPONENT)

Mitigation and impact management plans are designed to minimize, avoid, and, if possible, reverse adverse environmental impacts. In practice, mitigation measures are adapted simultaneously to different ends (avoidance, reduction, or remedy), depending on the importance of the project, the availability of environmental resources, as well as the short- and long-term socioeconomic and national perspectives. The project is assumed to be necessary, and certain impacts are inevitable. Accordingly, mitigation should be applied in a manner that avoids adverse impacts, minimizes them to an insignificant level, and compensates for them when they are unavoidable.

The following section gives the detailed mitigation procedures to be implemented by the Project Owners, GRL and its contractors during the construction and

commissioning to address those potential impacts described in the previous sections of this report (Section 5).

6.3.1 General Mitigation Measures

It has been demonstrated that solar parks can improve bird abundance and diversity while producing renewable energy as an example of improving habitat [Zaplata and Dullau, 2022; Jarcuska et al., 2024].

To enhance wildlife conservation, including that of local bird species, it is recommended that Al Humaij Solar PV Park be designed, developed and operated as a *nature-inclusive* and *landscape-inclusive* solar park. It will mitigate any residual environmental impacts associated with this project and attain biodiversity net gain (BNG). The BNG refers to an approach that leaves biodiversity in a measurably better condition than it was before the development.

6.3.2 Specific Mitigation Measures

6.4 AIR QUALITY- IMPACTS MITIGATION

During Construction and Commissioning:

Adopt the below-listed management and control measures to manage air emissions during the construction and commissioning activities:

Atmospheric Emissions

- Standards on Emissions from Mobile Sources [KSA, 2012] should be met by all mobile plants such as generators.
- All vehicles, generators and equipment should follow the national standards as set out by NCEC prior to deployment on site and then tested as per manufacturer requirements to ensure compliance with National Emission Standards.
- Generator exhausts must also have appropriate discharge heights in accordance with national Guideline.
- No equipment should be left idling for more than 10 minutes, unless in an emergency (approximate idling time as per best available technique (BAT) is 2-4 minutes). Shut down equipment and machinery or throttle down to a minimum when not being used.
- Conduct visual inspections for emissions from any engine and exhaust for the presence of black smoke. Vehicles/ equipment with excessive exhaust emissions or visible black smoke should be removed from service and proper maintenance should be carried out.
- All machinery and equipment should be calibrated and standardized as per the timeline approved for it from the competent authority in this field.
- All contractors shall prepare a transportation plan and minimize journey distance and number of journeys.
- Investigation of any complaints and review of equipment against relevant NCEC air quality standards / requirements.

Dust Emissions

- Always comply with the requirements of the MEWA/NCEC ambient air quality standards for dust and exhaust emissions from construction activities, equipment and vehicles.
- Control the dust generation during excavation and right-of-way clearing activities by watering and/or covering the area.
- All on-site development/construction areas shall be watered sufficiently and at required intervals to minimize fugitive dust emissions.
- Excavation and grading operations shall be suspended during dust storms or very high wind speeds to prevent dust generation.
- Soils shall be maintained moist when loading or unloading into dump trucks to minimize fugitive dust emissions.
- Drop heights shall be reduced when loaders dump soil into trucks, if applicable.
- During transportation trucks should not be overload with sand, gravel and aggregate and ensure sufficient free board. Trucks travelling to and from the project site with these materials will be covered with tarpaulin to minimize dust
- All project activities must be carried out within the project boundary, as appropriate. No lay-down or temporary holding will be permitted outside the boundary.
- Utilize the temporarily constructed enclosures to limit fugitive dust while stockpiling of earth materials for construction. Properly cover the stockpiles or fines on windy days.
- Seal the mixing equipment and equip the vibrating equipment with dust removing devices.
- Cover the construction materials (sand, cement etc.) and waste carried by vehicles to prevent spread of dust particles.
- Avoid unnecessary journeys and adopt a policy of switching off machinery and equipment when not in use.
- Conduct visual inspection of development/construction sites for dust generation severity and application of suppressing techniques, as required.

During Operation:

No significant air quality impact has been predicted during the operation phase and therefore separate mitigation measures are not suggested.

CLIMATE- IMPACTS MITIGATION

During Construction and Commissioning:

Implement the Energy Efficiency and Greenhouse Gas Emissions Principles, and Transportation strategy to target zero net carbon emissions. This entails the following measures:

- Use sustainable sourced fuels, such as organic-based biofuels or clean output fuels like hydrogen, use of electric vehicles that are, as far as reasonably possible, charged using renewable non-emitting power sources.
- Use hydrochlorofluorocarbon blend refrigerants for cooling production purposes. Chlorofluorocarbons (CFCs) are not to be used for any purpose.
- Prohibit the burning in open air and use incinerators to burn toxic wastes.
- Utilize machinery, equipment, vehicles and materials that have the lowest CO₂ emissions possible.
- Make use of energy sources/fuels for equipment that produce the least amount of CO₂ and other greenhouse gas emissions.
- Ensure that the air conditioning refrigerants are in-line with this policy's requirements.
- All chilled water and cooling production units to have systems for refrigerant monitoring and refrigerant leaking alarms.
- Regular maintenance practices for fuel combusting equipment and air conditioning, as per the supplier's recommendation. Systems maintenance information must be provided.
- Regular maintenance of transport carriers and, over time, transitioned toward electric propulsion technologies charged using renewable non-emitting technologies.
- All waste with greenhouse gas emissions potential (e.g., organic waste), must be diverted from landfill to be used for other purposes, minimizing the generation of landfill gases, including methane.

During Operation:

No significant impact on climate has been predicted during the operation phase and therefore mitigation measures are not suggested.

MICROCLIMATE- IMPACTS MITIGATION

During Construction and Commissioning:

During the construction and commissioning phases, no significant microclimate impacts have been predicted, and therefore mitigation measures are not recommended.

During Operation:

The following mitigation measures are recommended to reduce the microclimate impacts during operation:

NOISE AND VIBRATIONS- IMPACT MITIGATION

During Construction and Commissioning:

The following mitigation measures are recommended to reduce the airborne noise and vibration level during the construction phase to comply with MEWA/NCEC guidelines and international standards for noise emissions:

- Conduct construction activities in compliance with NCEC guidelines and international standards for noise emissions.

- Contractor to prepare a Noise and Vibration Control Plan that includes measures to minimize the impacts on noise levels and vibrations from the construction activities.
- Conduct periodic monitoring of noise and implement control measures to protect personnel from excessive exposure to noise.
- Contractor should provide Noise and Vibration awareness training for all site staff including subcontractors as part of general site induction and toolbox talk activities.
- Use of less noise generating equipment and machinery. Machinery and equipment selected and procured considering low sound pressure/power levels, while meeting the requirements.
- Ensure that all noisy equipment including generators are fitted with engine covers, silencers, mufflers, and other forms of acoustic linings/attenuators.
- Employ machinery and equipment that conform to relevant national and/or international standards, directives and recommendations on noise and vibration emissions.
- Ensure that vehicles, vessels, and equipment are properly maintained and in good working order.
- Plant and equipment inspections to identify any maintenance requirements. Follow manufacturer's manual for maintenance procedures of all equipment.
- Locate noise and vibration generating components away from sensitive habitat where possible, provision of adequate acoustic buffer or setback area.
- High vibratory machinery and equipment should be mounted on absorbing surfaces to minimise vibrations.
- Continuous noise sources to have noise hoarding installed if national ambient noise standards are exceeded.
- All machines and equipment must be calibrated and standardised as per the timeline approved for it from the competent authority in this field.
- Shut down equipment and machinery or throttle down to a minimum when not being used. Prevent idling (approximate idling time as per best available technique (BAT) is 2-4 minutes).
- Identify workers who may be exposed to elevated noise levels and brief them of occupational risks from noise exposure. Provide noise reduction PPEs to workers and respond to any noise related complaints from workers.

During Operation:

Should additional mitigation be required during operation – the following would be considered:

- Installation of acoustic enclosures for equipment causing radiating noise (this would typically give 3 dB attenuation).
- Installing acoustic barriers without gaps and with a continuous minimum surface density of 10 kg/m² in order to minimize the transmission of sound through the barrier. Barriers should be located as close to the source or to the receptor location to be effective.
- Periodical maintenance of plant components such as inverters, transformers and other equipment and vehicles used for transportation to and from the site will be carried out to ensure their good working conditions.

- In addition, the Project grievance mechanism should be implemented. This will be utilised to record, monitor and respond to / mitigate any noise related impacts raised by nearby farmers and ensure compliance with noise limits is achieved at NSRs.
- Adherence to low-speed limits and regular maintenance of vehicles utilising the road during operation.

VISUAL AND LANDSCAPE-IMPACT MITIGATION

During Construction:

The following mitigation measures are required to reduce the visual and landscape impacts during construction and commissioning:

- Confine all construction activities to the designated area only and avoid unnecessary use of the nearby areas that may cause additional impacts on existing habitats, vegetation, and wildlife.
- Regularly clean all equipment in a designated cleaning area to exclude the possibility of invasion of the project site by exotic species.
- Use the existing road and transportation system and avoid uncontrolled off-road driving during construction as this may disturb the adjacent habitats.
- Transport all hazardous wastes generated, if any, to the designated waste disposal facilities. Transport the hazardous wastes in full compliance with the applicable MEWA/NCEC/SPPC and International laws. Implement a recycling policy for all solid wastes including office materials where possible.
- Re-use, recycle or dispose the waste lubricants, lube oil and/or solvents in environmentally appropriate ways.
- Make containment facilities for non-hazardous solid waste prior to commencing site work, and regularly remove waste from site to prevent unacceptable accumulations.
- Implement safe materials and product storage and handling practices to reduce uncontrolled releases into the terrestrial environment.
- Keep the stack heights of materials and construction items to a minimum to prevent visual intrusion.
- The earth material generated due to excavation should be used to optimum quantity to reduce impact on land resources.
- Road layout should ensure that as much as possible avoidance of disturbance of natural drainage.
- The proposed access roads inside the project area do cut across several non-perennial drainage channels and would require the construction of an adequate number of cross-drainage structures to mitigate the adverse impacts on the surface runoff.
- It should be ensured that no additional access roads other than those proposed as per the layout plan are created.
- It should be ensured that no trees are required to be cut while installation of solar PV panels.
- The Construction camps should be located preferably on barren land and sufficiently away from settlements and water bodies.
- The Construction camp should be provided with necessary sanitation arrangements and basic facilities.

- After dismantling of camp the natural condition of the land should be restored.
- No site will be left unattended after excavation activity.

During Operation:

The following mitigation measures are recommended to reduce the visual and landscape impacts during operation:

- Develop landscaping and planting protocols within the CEMP (Construction Environment Management Plan) to provide further screening developed prior to the operational phase.
- Include site rehabilitation and landscaping / planting where feasible, implemented in the first active growing season following construction.

SOIL AND LAND USE- IMPACT MITIGATION

During Construction

Implement the following mitigation measures to reduce the impacts on soil and land use during the construction phase:

- Clearly demarcate storage and staging areas and store all materials, equipment and vehicles in demarcated area to reduce soil damage.
- Establish native grasses (where appropriate) in erosion control channels and in other areas immediately after final disturbance.
- Salvage and store topsoil and subsoil before areas are excavated, with topsoil stripped and stockpiled separately.
- Segregate excavated soils into stockpiles dependent on material type and provide erosion control while stockpiled.
- On completion of earthworks, backfill material in the same stratigraphic sequence.
- When damage to wet soil occurs, repair once dry conditions return.
- Monitor erosion controls and repair as needed and where possible, maintain grass cover on berms and ditches.
- Re-stabilize existing eroded tracks and restore grass cover as needed.
- Stormwater drainage culverts should be built at an early stage during construction to avoid soil erosion.
- Excavations should be backfilled, as soon as possible to minimise soil erosion.
- Any contaminated soil must be considered as an industrial waste and disposed at an approved disposal site after proper manifesting.
- The earth material generated due to excavation will be used to optimum quantity to reduce impact on soil environment.
- Proper stripping and stockpiling of soil layers to reduce dust pollution.
- The construction camp will be provided with necessary sanitation arrangements and basic facilities to avoid soil contamination.
- Designated storage site for fill materials and adequate stockpiling to prevent erosion and runoff related problem.
- Garland drains around excavated soil will trap silt. Silt trap will reduce siltation load in the nearby drainage and surface water body.

GROUND AND SURFACE WATER- IMPACT MITIGATION

During Construction:

The following mitigation measures are required to reduce the impacts on the water environment during construction and commissioning:

Potable Water

- Reduce water consumption through installation of water efficient products such as low flow tap, shower heads and dual flush toilet system.
- Implement the rationalizing approach by ensuring that the quantity of water supplied periodically to the personnel shall be proportional to the number of people on site and associated activities at the time of supply.
- Conduct regular inspections and servicing of water appliances and the condition of water system components to reduce water loss in the water distribution system.
- Conduct continuous measurements of flow rate of the taps and shower head to check and reduce potential water loss.
- Separate the greywater from blackwater, and reuse the treated greywater for toilet flushing, landscaping irrigation or/and agriculture irrigation.

Groundwater

- Take preventive measures to avoid the release of any materials that may contaminate groundwater;
- Conduct regular site inspections and enforce spill and pollution prevention procedures for handling and storage of materials and containers; and
- Have the spill response in place that includes the placement of emergency spill kits in storage areas.
- Build artificial ground water recharge structures through rain water harvesting.
- Provide lined drains with cut in between to facilitate ground water recharging.
- Requisite permissions need to be obtained before withdrawing ground water from bore wells/ tube wells from the competent authority.

During Operation:

Implement the following mitigation measures to mitigate the impact on the water environment of the project area during the operation phase:

- If water is used to clean the panels, waste water should be properly channelled to the settling tank for stabilization and treatment, so that the water can be reused for PV washing, thus reducing the pressure on groundwater.
- Automated cleaning systems are becoming more and more well-liked as a practical and effective way to keep solar panels clean. These systems use robotic arms or brushes that move across the panels' surface to remove dirt and dust. Some cutting-edge systems use water-less cleaning methods, like the application of microfiber or electrostatic cleaning tools. Automated cleaning systems offer regular cleaning, reduce the need for manual labor, and lower the chance of panel damage.
- Application of anti-soiling coatings on the surface of solar panels is another method for reducing the effects of dust and soil. The dirt is more easily

washed away by rain or dew because of these coatings' ability to repel it. With the help of hydrophobic coatings, surfaces can be made to be less sticky and easier to clean. Anti-soiling coatings help maintain optimal panel performance by lowering the need for routine human or automated cleaning.

FLOOD RISK-IMPACT MITIGATION

During Construction and Commissioning:

To reduce the impact on flood risks during construction and commissioning, the following mitigation measures should be implemented:

- A flood risk assessment of the project area should be undertaken by the developer as part of the design phase of the project.
- On site roads to avoid ephemeral drainage channels where possible.
- Installation of culverts or other drainage control features where crossings are unavoidable.
- Surface water should be controlled with appropriate drainage and bunded areas as appropriate.
- Infrastructure that is most vulnerable to flooding, should be located in areas of lowest flood risk (i.e. areas of solar PV panels should be situated outside of the main flood risk corridors).
- As far as possible, construction and access roads should be routed outside of areas of highest flood risk (noting that at some locations roads, should need to cross high flood risk corridors). Where this is not possible, flood mitigation measures should need to be defined as part of ongoing scheme design.

FLORA- IMPACT MITIGATION

During Construction and Commissioning:

To reduce the impact on flora during construction and commissioning, the following mitigation measures should be implemented:

- The pre-construction survey should include a re-check for plant species of conservation concern. In the unlikely event that species listed at IUCN Endangered or above are noted then works should cease until a plan to protect these species has been agreed.
- This should firstly look to use micro-siting and protective fencing during works to avoid any interference. Where this is not possible, translocation of individual plants to suitable habitat or seed gathering of other plants of the same species and sowing in the area (depending on which is most suitable for the species) should take place. In this scenario, monitoring of the species within the entire area should take place (including full re-survey of the site to look for other individuals of this species) critical habitat will need to be revisited and methods to protect the species, and enhance its population as appropriate, agreed.
- Potential invasive flora species to be identified and action taken to clear these if they occur in or around areas designated for bush clearance.
- The potential establishment of invasive species will be monitored and should their numbers proliferate, measures to control this must be implemented.

- Measures to control the species will depend on the species noted and best international practice for this species removal. Cutting and removal of individuals will be in preference to poisoning of saplings which will only be used when this is the most appropriate possible control measure.
- Vegetation clearance should be minimized. If removed, replace the vegetation within the landscaping with drought tolerant, native species, where possible.
- Undertake nesting birds checks before vegetation clearance (within 48 hours).
- If clearance works involving the removal of vegetation and a planned strip of surface soil are required, stripped soil should either be reused or mulched and reused in a suitable manner.
- Cleared areas no longer required for construction activities will be rehabilitated by reseeded with locally found grasses and shrubs (where appropriate) to increase soil stability.
- Clearance of all areas to be completed in a single direction from one side to another in order to allow mobile species to escape ahead of clearance works.
- All terrestrial vehicles to use defined roads to prevent unnecessary impact to the terrestrial ecology.
- Impacts on the local climate and biodiversity can be mitigated by installing solar panels at a suitable height above the ground, preserving vegetation cover where possible.
- Spacing rows of panels to allow air ventilation. Modern solar panels designed with heat retention reduction measures should be used.
- Wildlife movement and/or migration impacts can be mitigated by modifying the solar park's fencing to maintain a gap between the base of the fence and the ground (wildlife-friendly fencing).
- To mitigate the impact of trees in Al Humaij during the installation of a utility-scale PV project, a comprehensive reforestation plan will be implemented. This plan will include careful mapping of important fauna habitats to avoid disturbance during construction.
- Any necessary tree removal will be minimized, and affected areas will be restored post-construction by planting native tree species, to enhance biodiversity.
- Additionally, the idea to see if there are any opportunities to build the solar panels around existing trees, treating these trees as an offset to our project's footprint. The project will also incorporate measures to monitor the health and growth of these trees over time, ensuring that ecological balance is maintained and contributing to local environmental sustainability.

During Operation:

The following mitigation measures are recommended to reduce the impacts on flora during operation:

- Maintain natural vegetation on solar sites to improve on soil conditions and vegetation diversity.
- Create and operate a solar park that stimulates the local flora and fauna and encourages biodiversity through nature and landscape-inclusive design [Oudes et al., 2022].

- Use native vegetation to reduce habitat impacts of solar facilities. Vegetation choices can preserve habitat as well as provide support for pollinators and assist with the infiltration of stormwater.
- Utilize mowing as vegetation management practices and minimize the use of herbicide.
- During routine maintenance any invasive flora species should be removed. Cutting of saplings is an effective control measure. Measures should be included to ensure that a set protocol is followed to avoid the risk of spread to other areas.

FAUNA- IMPACT MITIGATION

During Construction and Commissioning:

To mitigate the negative impacts on fauna during construction and commissioning, the following mitigation measures should be implemented:

- A recent study in Europe reported that bird species richness, diversity, species richness and abundance were higher in the solar parks than in the control plots [Jarcuska et al., 2024]. Therefore it is recommended that Al Humaij Solar PV Park be designed as a nature-inclusive and landscape-inclusive solar park managed synergistically to enhance wildlife conservation [Biro-Varga et al. 2024].
- Undertake site preparation works so as to discourage animals from using the Project area.
- Conduct initial preparatory works, where possible, outside of the breeding bird season.
- If works are required within the breeding season, preconstruction survey should be carried out to check for animals (active bird nests). If any are identified, construction activities are to be programmed to avoid such features until they have been moved or natural cessation of breeding effort.
- Any fauna (not including nests) directly threatened by construction activities should be relocated by relevant personnel.
- No capture, handling or intentional disruption of wild animals to occur on site by workers.
- Clearance of all areas to be completed in a single direction from one side to another in order to allow mobile species to escape ahead of clearance works.
- A strict 'no approach' policy to all wildlife is to be implemented and no feeding of wild animals to occur under any circumstances.
- All terrestrial vehicles to use defined roads to prevent unnecessary impact to the terrestrial ecology.
- Staff should be briefed on risks of exposure to fauna inhabiting the area as well as on preventive measures to be undertaken.
- Any snakes encountered at the site must not be handled or harmed by Project workers. Animals must be relocated by appointed personnel.
- The collection, harvesting or hunting of any plants or animals must be strictly prohibited. A 'no tolerance' policy must be adopted with respect to construction workers. Any culprits guilty of poaching must be apprehended.

- Fires must be controlled and only allowed in fire permitted areas. Staff training must be carried out in relation to fire safety and firefighting equipment such as fire extinguishers and sand buckets available at every site.
- A policy whereby the animals have “right of way” during construction would reduce incidents of conflict.
- Should any animals get trapped or be harmed in anyway, the relevant personnel must be informed.
- Any excavated areas must be temporarily demarcated and fenced off to bar access to animals; following the construction phase, those areas need to be re-filled and rehabilitated. Where not possible, tapered sides or a ramp must be in place to allow animals out and checks undertaken prior to filling in.
- Vehicle speed limits must be imposed and adhered to, with the aim of reducing vehicles’ dust production and potential for collision with local biodiversity.
- Construction vehicles must remain on the access roads and not drive in the uncleared bush.
- Reduce artificial lighting to reduce impacts on birds, mammals, and reptiles during construction.
- Incorporate the following best practice lighting design into all construction infrastructure to mitigate the light pollution impacts on fauna during construction:
 - Start with natural darkness and only add light for specific purposes.
 - Use adaptive light controls to manage light timing, intensity, and colour.
 - Light only the object or area intended – keep lights close to the ground, directed and shielded to avoid light spill.
 - Use the lowest intensity lighting appropriate for the task and use non-reflective, dark-coloured surfaces.
 - Use lights with reduced or filtered blue, violet, and ultra-violet wavelengths.
- To mitigate the impact on any type of Birds during the installation of a utility-scale PV project, it will be implemented as a several strategies to ensure their safety and habitat protection.
 - First, the solar panels will be designed with adequate spacing between them, preventing the appearance of reflective surfaces that could be mistaken for water bodies, thereby discouraging landing.
 - Additionally, it will be looked into the use of a non-reflective materials for the panels to minimize glare. To further reduce the risk of collisions with transmission lines, clear marking and bird flight diverters will be installed on these lines, making them more visible to the eagles.
 - Monitoring programs will also be established to assess eagle activity in the area and adapt management practices as necessary, ensuring the protection of this important species throughout the project lifecycle.
 - Finally, a Wildlife Management Plan for the construction will be implemented that outlines strategies to protect local fauna, with a focus on bird species, during the construction phase. It includes pre-construction studies to identify nests, critical habitats, and sensitive vegetation. Construction activities will be adjusted to avoid key

migratory seasons and breeding periods, with buffer zones established around sensitive areas. Continuous monitoring during construction will track wildlife behavior, and adaptive management measures will be implemented if unforeseen impacts are detected. Post-construction and early operations monitoring will ensure the ongoing protection of local ecosystems, with regular reporting to stakeholders. This plan aims to minimize environmental impacts while ensuring the project's sustainability.

WASTE MANAGEMENT- IMPACT MITIGATION

During Construction and Commissioning:

The following mitigation measures should be implemented to reduce the impacts of construction and commissioning activities on waste management:

- Collect and dispose all hazardous wastes strictly as per the MEWA/NCEC guidelines.
- Utilize the services of the approved waste management contractors to hazardous and electronic waste management.
- Recycle or reclaim materials where possible and send the materials such as spent catalysts for regeneration or metals recovery wherever possible by return to suppliers.
- If recycling is not practical, dispose wastes in an environmentally acceptable manner and in compliance with local laws and regulations.
- Avoid littering or dumping of any solid wastes (garbage or construction debris).
- Dispose biologically degradable waste (camp waste) at an approved Class II landfill and dispose inert waste generated during construction in an approved Class III landfill.
- Use non-phosphate detergents and degreasers that have minimal environmental impact and are considered biodegradable.
- Arrange for the wastewater generated from the construction camp to be channelized to an existing wastewater treatment system that meets the requirements of MEWA/NCEC. Alternatively, install a new wastewater treatment system that conforms to specifications given by MEWA/NCEC.

During Operation:

The following mitigation measures should be implemented to manage and mitigate the impacts of operation on waste management.

- When water is used to clean the panels, the wastewater should be channeled to the settling tank for treatment and stabilization, so that the water can then be reused for PV washing.
- The black water, if any originating from the park should be treated to comply with USCG Type II standards i.e. total suspended solids of 150 mg/l and fecal coliforms of 200 MPN (most probable number) per 100 ml);

- The grey water from the park, if any, should be treated in the STP under routine conditions. The STP should be designed to ensure >90% of the biodegradable surfactants present degrade prior to discharge;
- Sewage sludge should be transported for disposal to an appropriately licensed facility;
- Ensure secondary containment in hazardous waste storage areas.

TRAFFIC AND TRANSPORT- IMPACT MITIGATION

During Construction and Commissioning:

To mitigate the negative impacts on traffic and transport during construction and commissioning, the following mitigation measures should be implemented:

- Develop and implement a Construction Traffic Management Plan (CTMP) prior to commencement of construction. This plan should include, but not be limited to, the following action plan to reduce the impacts during the construction phase:
- Identification of those responsible for carrying out and managing the procedures;
- Details of hazard identification and traffic risk assessments undertaken and their outcomes;
- Consideration of vehicle movements;
- Reference to the procedures and activities that are required to be developed and implemented;
- Access routes for construction plant and materials, including temporary access roads to be provided for movement of equipment, machinery, and workforce;
- Transport routes for the workforce and pedestrian-only routes within the construction area;
- On-site traffic management;
- Employ only licensed and well-experienced drivers;
- Vehicle operators shall use markers and signboards in order to mitigate risk caused by blind spots;
- Conduct regular maintenance of all vehicles, equipment, and machinery with manufacturer specifications;
- Fit with reversing alarm for all construction vehicles and prohibit overloading of the trucks;

- Implement a disciplinary action plan against workers for not wearing seatbelts.
- Outline speed limits and methods of enforcement;
- Develop a strategy for moving materials and people to/ from and within the proposed development area, including abnormal loads, e.g. ensuring that delivery of materials does not coincide with the start/end of the highway network peak periods;
- Implement measures to ensure that employees traveling to and from the site are able to do so in a safe manner, e.g. provision of minibusses;
- Identify key sensitivities along proposed access routes;
- Take measures to prevent the use of unsuitable roads;
- Develop a notification process to give residents/affected people warning of abnormal deliveries; and
- Implement good management practices such as the provision of wheel washing facilities for all departing vehicles and sheeting of HGVs carrying loads likely to shed debris.
- Consultation with affected communities to make aware of schedule prior to HGV movements.
- Construction times to avoid local peak times and routing arrangements, particularly for HGVs.
- Traffic movements in settlement areas to be limited to daytime only.
- All drivers should be made aware of sensitive receptors potentially identified en route

During Operation:

To mitigate the negative impacts on traffic and transport during operation, the following mitigation measures should be implemented:

- Vehicles only permitted to use designated routes with no off-road driving permitted.
- Regular maintenance of vehicles and use of manufacturer-approved parts.
- Maintain / repair of access roads as required.
- Temporary site compound to have appropriate parking, HGV manoeuvring space and holding and unloading areas.
- Training program conducted before site activities commence for all drivers.

- Procedure for check of licences and permits for all drivers with suitable training conducted.
- Measures to control delivery / departure of all HGVs to reduce conflict with other road users.

HEALTH AND SAFETY –IMPACT MITIGATION

During Construction:

To reduce the impact on health and safety during construction/ commissioning the following mitigation measures should be implemented:

- The plants and equipment should be installed sufficiently away from the settlement.
- All the construction equipment and vehicles should conform with the emission standards stipulated by the NCEC.
- Safe working techniques should be followed up and all the workers should be trained
- All the workers should be provided with proper personal safety equipment at construction as well as plant site
- Proper caution signage, barricading, delineators, etc. should be installed at the Construction zone, and temporary diversions
- Proper traffic management should be ensured at the Construction zone as per IRC.
- An Emergency Response system in case of any incidence should be developed and implemented.
- Periodical health check facility should be provided at camp sites.
- Contractor should provide noise and vibration awareness training for all site staff including subcontractors as part of general site induction and toolbox talk activities.
- Identify workers who may be exposed to elevated noise levels and brief them of occupational risks from noise exposure. Provide noise reduction PPEs to workers and respond to any noise related complaints from workers.
- Implement the control measures at all welding workshops to ensure all welders/assistants are protected while they are performing their daily activities and the work environment is safe and healthy.
- Provide, maintain and enforce use of personal protective equipment (PPE) described in Chapter I-3, Personal Protective Equipment to the workers.

- Comply with all PPE requirements stipulated by the local and international regulations.
- Implement community health and safety measures developed for construction within relevant management plans (including TTMP, Security and Human Rights Management Plan, elements of the OHSP and EPRP).
- Development and implementation of EPRP.
- Communicate Project risk to local communities and address concerns accordingly.
- Monitor any complaints filed via grievance redress mechanism.

During Operation:

The same mitigation measures as given above

LABOR MANAGEMENT- IMPACT MITIGATION

During Construction and Commissioning:

The following mitigation measures should be implemented to reduce the negative impacts on labor-management during construction and commissioning:

- The Project needs to develop and implement a Construction Local Employment Plan that includes:
- Details of the Project Company's policies towards working conditions, anti-harassment and bullying, and legislative compliance.
- A summary of the numbers and job description profile required for the construction phase.
- Preparation of a future register that contains details of the active workforce, including personnel within contractor supply chains, broken down by:
- Permanent, part-time, temporary, seasonal, and migrant workers.
- Number of companies currently involved in the supply chain.
- Permanent, part-time, temporary, seasonal, and migrant workers (by gender) in the supply chain.
- A description of the process used to recruit the construction workforce based upon the low-skilled and skilled workers and how this is to be disclosed to local communities, if necessary;
- A prohibition of recruitment of local people at the gatehouse, or any other entry point to the site to prevent people from moving towards the site expecting work. Any person wishing to apply for an employment position

must follow the appropriate procedure and people should not be employed ‘on the spot’.

- How the legal rights and terms and conditions of employment are to be provided to workers at the start and periodically during their employment. This should include details of their salary, right for freedom of association, severance pay, working hours, overtime payments, tax and other types of deductions, and provision of insurance from a Project- related health and safety incident. In addition, emphasize shall be made that the employment positions are temporary in nature and should continue during a portion, or all, of the construction stage. The offer of an employment position during construction does also not mean they should be provided with a suitable position during operations.
- Wages, benefits, and conditions of work offered (including hours of work) should, overall, be at least comparable to those offered by equivalent employers in the region to prevent public sector workers leaving key posts (such as teachers, etc.) and seeking local employment for the Project.
- Targets for women to form a substantial part of the low-skilled and skilled construction workforce, and details as to how women should be encouraged to apply for employment positions.
- How labor relations are to be managed during the construction period to ensure the workplace is suitable for the presence of women and potentially others who are legally eligible to be employed. This should include a Worker’s Code of Conduct that is presented individually during their initial HSE induction process for their review and signature to reflect their acceptance. Adherence to the Worker’s Code of Conduct shall be mandatory.
- Details of a worker grievance mechanism that should be available (and disclosed) during the recruitment process and regularly during their employment (which should include an anonymous ‘whistle-blower hotline’ where allegations of bullying or harassment can be reported).
- Providing workers with regular information about the temporary nature of their position, during their employment, and ensuring they are provided with enough notice so that when termination of their contract does occur, notification does not come as a sudden shock and trigger resentment or protests amongst the workforces.
- How the above arrangements should apply to contractors used within the EPC Contractor’s primary supply chain; and
- Reporting and monitoring indicators covering the recruitment process and ongoing management of the workforce.
- Specific assistance measures shall be provided to vulnerable groups and specific measures shall be developed to work towards gender equality, poverty eradication and gender-inclusive economic growth.

During Operation:

The following mitigation measures should be implemented to mitigate some of the impacts during the construction phase.

- Encourage the contractor to create job opportunities during construction for the local population and promote engagement of the local suppliers during the construction phase.
- Encourage and support the use of local and provincial suppliers of goods and services, where possible.
- Provide induction training to all foreign workers and non-Muslim workers on the local culture and practices that are acceptable and unacceptable.
- Develop a grievance mechanism and maintain it so that the resident worker 'communities' have a means of communicating any concerns regarding the facility's construction or operation to project management.
- Develop a Construction Environmental Management Plan (CEMP) and implement it by the Contractor covering what action should be taken in the unlikely event that any archaeological and cultural artifacts are discovered during the construction.

COMMUNITY DISPLACEMENT- IMPACT MITIGATION

During construction/commissioning and operation:

There are no settlements or significant cultural or economic activities present in the project area located in the middle of the desert. The following mitigation measures should be implemented to mitigate the community displacement impacts during the construction/commissioning and operation phases.

- Affected people, if any, should be identified in advance prior to commencement of construction works.
- If necessary, alternative areas for camel grazing and establishment of camel farms should be made available to the impacted people.

NATIONAL AND LOCAL ECONOMY- IMPACT MITIGATION

No negative impacts are predicted for national and local economy during construction. Therefore mitigation measures are not required.

No negative impacts are predicted for national and local economy during construction or operation phases of this project. Therefore mitigation measures are not required.

PROCEDURES FOR ACCIDENTAL DISCOVERY OF CULTURAL RESOURCES (CHANCE FINDS)

This Chance Finds Procedure covers the actions to be taken from the discovery of a heritage site or item to its investigation and assessment by a professional archaeologist or other appropriately qualified person to its rescue or salvage.

If cultural resources (e.g. archaeological sites, historical sites, remains, objects, graveyards, or individual graves) are discovered when undertaking the construction activities, and civil works, the following procedure should be executed:

- Halt the construction activities around the chance find to avoid any (or further) damage;
- Report the discovery to your supervisor or the Environmental Control Officer (or project equivalent) immediately;
- Delineate and fence the discovered site or area and provide a 25 m buffer zone around all sides of the find;
- Secure the site to prevent any damage or loss of removable objects. In cases of removable antiquities or sensitive remains, a night guard should be arranged until the responsible local authorities the District/ Provincial Department of Culture, or the local Institute of Archaeology, if available, can take over;
- Forbid any removal of the objects by the workers or other parties;
- Note the type of archaeological materials that have been encountered, their location (GPS), and if possible, the depth below the surface where the find occurred;
- Photograph the exposed materials, preferably with a scale (e.g. a file binder, coin, rules, etc.);
- Notify the responsible local authorities and the relevant Institute of Archaeology immediately (within 24 hours or less);
- Responsible local authorities would oversee protecting and preserving the site before deciding on subsequent appropriate procedures. This would require a preliminary evaluation of the findings to be performed by the local Institute of Archaeology. The significance and importance of the findings should be assessed according to the various criteria relevant to cultural heritage; these include the aesthetic, historic, scientific or research, social, and economic values;
- Decisions on how to handle the finding shall be taken by the responsible authorities. This could include changes in the physical investment layout (such as when finding an irremovable remain of cultural or archaeological importance) conservation, preservation, restoration, and/or salvage;
- Implementation of the authority decision concerning the management of the finding shall be communicated in writing by relevant local authorities;
- The mitigation measures could include the change of proposed Project design/ layout, protection, conservation, restoration, and/or preservation of the sites and/or objects;

- Construction work at the site could resume only after permission is given from the responsible local authorities concerning the safeguard of the heritage; and
- The physical investment proponent is responsible for cooperating with the relevant local authorities to monitor all construction activities and ensure that the adequate preservation actions are taken and hence the heritage sites protected.

INAPPROPRIATE WASTE DISPOSAL - IMPACT MITIGATION

Inappropriate (improper) waste management has serious consequences for the environment, human health, wildlife, and the economy. By implementing effective waste management solutions as given above under Section 11. Waste Management-Impact Mitigation), these impacts can be mitigated and work towards a sustainable future. It is vital that contractors and workers work together to address the challenges posed by improper waste management.

ACCIDENTAL SPILLS, FIRE ETC. - IMPACT MITIGATION

During Construction

Accidental spills and leaks or fire are difficult to mitigate even though they represent one of the most significant potential impacts attributable to the project. Proper liquid spill or gas leak contingency planning has perhaps the best chance of minimizing the impacts. Chemical or Oil spill containment and clean-up materials should be available near potential target areas of the project.

Have emergency response plans to immediately respond to potential accidental events such as fire, explosion, and releases. Good oil spill contingency planning has perhaps the best chance of minimizing the impacts of a spill or leak. Periodically review the plans and identify the target areas of oiling based on simulation studies. Make available the necessary oil spill containment and clean-up materials near potential target areas along the coastline.

In case of a spill or leak of gasoline or oil from construction equipment, control the spill as quickly as possible at the source. Prevent it from spreading, contaminating soil and groundwater, or entering sewage and drainage systems or any water body. Cover the spill with absorbing material and then place in compatible storage containers for appropriate disposal.

Fully train all employees to execute the relevant emergency response plans in the event of an emergency. Make available a well-designed Spill Contingency Plan to deal with accidental oil spills or leak of any magnitude.

Volatilization of Spills and Leaks

Volatilization is the evaporative loss of a chemical from the evaporative surface based on vapor pressure of the chemical and the ambient environment. Volatilization is an important source of airborne pollution. Should a leak or spill occur, and volatilization is evident, try to stop the leak or spill by using an appropriate material as specified by the Safety Department. Shut off all ignition sources such as flares, flames, or smoking. Use a water spray to reduce vapours. Isolate the area until the released gas

is dispersed. If the spill is coming from a small container, turn the leaking container so that gas escapes rather than liquid.

RESIDUAL IMPACTS (AFTER IMPLEMENTING THE MITIGATION MEASURES)

Residual impacts refer to those environmental effects predicted to remain after the application of mitigation outlined in this ESIA. The residual impact assessment (RIA) is defined as an estimation of potential impacts on environmental and social receptors after the application of the first three steps in the mitigation hierarchy such as avoidance, minimization and restoration. The predicted residual effects of the proposed project are considered for each project phase (Construction and Operation, and Unplanned Events) after implementing the mitigation measures. As per the criteria established in Section 5.2, the significance has been determined for each residual adverse effect.

Most of the potential negative social and environmental impacts of this project can be mitigated to insignificant (low or no impact) levels by implementing the mitigation and management measures suggested in this EIA report. As shown in Tables 6.1 and 6.2, the predicted and residual impacts on environmental and social receptors during construction and commissioning, and the operational phases, respectively, are summarized.

During construction and commissioning phase, out of the 18 negative impacts, one (1) were very high, six (6) were high and seven (7) were moderate, three (3) were low significance and one (1) was no impact, before implementing mitigation. After applying mitigation (Table 6.1), the negative impact such as very high, high and moderate significances were reduced to either low significance (8 receptors) or no impacts (10 receptors).

During operation phase, out of the 18 negative impacts, two (2) were very high, five (5) were high, six (6) were moderate and five (5) were no impact, before implementing mitigation. After applying mitigation (Table 6.2), the negative impact such as very high, high and moderate significances were reduced to either low significance (7 receptors) or no impacts (11 receptors).

Table 6.1 The summary of the predicted residual impacts on environmental and social receptors, during the construction and commissioning phase (after implementing mitigation).

IMPACTS/ RECEPTORS	CHARACTERISTICS OF SENSITIVITY			SENSITIVITY	CHARACTERISTICS OF MAGNITUDE			MAGNITUDE	SIGNIFICANCE
	Existing regulations and guidance	Societal value	Vulnerability for changes		Intensity and direction	Spatial extent	Duration		
Air Quality	Very high	Very high	High	High	Low -	Low	Low	No impact	No impact
Climate	High	High	High	High	Low -	Low	Low	No impact	No impact
Microclimate	High	High	High	High	Low -	Low	Low	No impact	No impact
Noise and vibration	High	Moderate	High	High	Low -	Low	Low	No impact	No impact
Visual and landscape	Moderate	Moderate	Moderate	Moderate	Low -	Low	Low	No impact	No impact
Soil and Land Use	High	Very high	High	High	Low -	Low	Low	No impact	No impact
Ground and Surface water	High	Very high	High	High	Low -	Low	Low	No impact	No impact
Flood risk	High	Very high	High	High	Low -	Low	Low	No impact	No impact
Flora	High	High	High	Moderate	Low -	Low	Low	No impact	No impact
Fauna	Very high	High	High	Moderate	Low -	Low	Low	Low -	Low -
Waste management	Very high	High	Moderate	High	Low -	Low	Low	Low -	Low -
Traffic and transport	High	High	Moderate	Moderate	Low -	Low	Low	Low -	Low -
Health and safety	Very high	High	High	High	Low -	Low	Low	Low -	Low -
Labor management	High	Moderate	Moderate	Moderate	Low -	Low	Low	Low -	Low -
Community Displacement	High	High	Moderate	High	Low -	Low	Low	Low -	Low -
National and local economy	High	High	High	High	Low +	Low	Low	Low +	Moderate +
Arch and Cultural Heritage	High	Moderate	High	Moderate	Low -	Low	Low	No impact	No impact
Inappropriate waste disposal	Very high	High	High	High	Low -	Low	Low	Low -	Low -
Accidental spills, fire etc.	Very high	Very high	High	Very high	Low -	Low	Low	Low -	Low -

Positive impacts= +; Negative impacts -

Table 6.2 The summary of the predicted residual impacts on environmental and social receptors, during the operation phase (after implementing mitigation).

IMPACTS/ RECEPTORS	CHARACTERISTICS OF SENSITIVITY			SENSITIVITY	CHARACTERISTICS OF MAGNITUDE			MAGNITUDE	SIGNIFICANCE
	Existing regulations and guidance	Societal value	Vulnerability for changes		Intensity and direction	Spatial extent	Duration		
Air Quality	Very high	Very high	High	High	No impact	Low	Moderate	No impact	No impact
Climate	High	High	High	High	No impact	Low	Moderate	No impact	No impact
Microclimate	High	High	High	High	Low -	Low	Low	Low -	Low -
Noise and vibration	High	Moderate	High	High	Low -	Low	Low	No impact	No impact
Visual and landscape	Moderate	Moderate	Moderate	Moderate	Low -	Low	Moderate	Low -	Low -
Soil and Land Use	High	Very high	High	High	Low -	Low	Low	No impact	No impact
Ground and Surface water	High	Very high	High	High	Low -	Low	Low	Low -	Low -
Flood risk	High	Very high	High	High	Low -	Low	Low	Low -	Low -
Flora	High	High	High	Moderate	Low -	Low	Low	Low -	Low -
Fauna	Very high	High	High	Moderate	Low -	Low	Moderate	Low -	Low -
Waste management	Very high	High	Moderate	High	Low -	Low	Low	No impact	No impact
Traffic and transport	High	High	Moderate	Moderate	Low -	Low	Low	No impact	No impact
Health and safety	Very high	High	High	High	Low -	Low	Low	No impact	No impact
Labor management	High	Moderate	Moderate	Moderate	Low -	Low	Low	No impact	No impact
Community Displacement	High	High	Moderate	High	Low -	Low	Low	No impact	No impact
National and local economy	High	High	High	High	Moderate +	Low	Low	Moderate +	Moderate +
Arch and Cultural Heritage	High	Moderate	High	Moderate	Low -	Low	Low	No impact	No impact

IMPACTS/ RECEPTORS	CHARACTERISTICS OF SENSITIVITY			SENSITIVITY	CHARACTERISTICS OF MAGNITUDE			MAGNITUDE	SIGNIFICANCE
	Existing regulations and guidance	Societal value	Vulnerability for changes		Intensity and direction	Spatial extent	Duration		
Inappropriate waste disposal	Very high	High	High	High	Low -	Low	Low	No impact	No impact
Accidental spills, fire etc.	Very high	Very high	High	Very high	Low -	Low	Low	Low -	Low -

Positive impacts= +; Negative impacts -

6.5 PROPOSED ENVIRONMENTAL AND SOCIAL MANAGEMENT AND AUDIT PLAN

The Environmental and Social Management Plan (ESMP) outlines the environmental protection measures to be implemented on the project site to eliminate or reduce the environmental effects of the project activities. The scope of an ESMP will vary depending on the scale and type of the development project. The ESMP helps to translate the recommended mitigation measures into specific actions that will be carried out by the proponent during the construction and operational phases.

The ESMP document can be used throughout the project life cycle - commissioning, mobilization and construction, operation and maintenance, and decommissioning. It is regularly updated to be aligned with the project's progress from commissioning to mobilization to construction to operation to decommissioning. The ESMP broadly describes the processes that an organization will follow to maximize compliance with environmental regulations and minimize harm to the environment. This plan also helps an organization to map its progress toward achieving continual improvements in safeguarding the environment. As SPPC (representing Principal Buyers) may already have an ESMP and Environment and Social Management System (ESMS) in place because of other projects in operation, the focus is given to an ESMS applicable to this project.

ENVIRONMENT AND SOCIAL MANAGEMENT SYSTEM (ESMS)

It is required to develop a framework for the Environment and Social Management System (ESMS) for SPPC/GCC Lab and its contractor to manage and ensure environmental statutory compliance, consistency with internal and external standards, and promotion of effective environmental management at the proposed facilities during the construction and operational phases. The EMS is a set of processes and practices that enable an organization to reduce environmental impacts and increase operating efficiency. Hence, EMS should focus on pollution prevention, resource management, and continuous improvement in environmental performance, and provide the means to demonstrate ongoing environmental compliance. The overall objectives of the EMS are:

- To ensure the environmental statutory compliance during construction;
- To strengthen the ability to comply with external standards and expectations that may arise in the future; and
- To suggest a guide for the systems to be implemented at the facility and how they combine to achieve effective environmental management.

The basic Elements of an EMS can be summarized as given below [Stapleton *et al.*, 2001; EPA, 2009]:

- i. Reviewing the company's environmental goals;
- ii. Analyzing the environmental impacts of its projects and legal requirements;

- iii. Setting environmental objectives and targets to reduce environmental impacts and comply with legal requirements;
- iv. Establishing programs to meet these objectives and targets;
- v. Monitoring and measuring progress in achieving the objectives;
- vi. Ensuring employees' environmental awareness and competence; and
- vii. Reviewing the progress of the EMS and making improvements.

Documentation and Records

For the EMS to be effective documentation and record systems are essential and these should cover the following aspects:

- i. Project records;
- ii. ESIA documents;
- iii. Compliance and monitoring records and reporting;
- iv. Incident reporting;
- v. Training manuals and records;
- vi. Project records;
- vii. Operations manuals; and
- viii. Materials Management System (raw, in-process, waste).

Management Makeup

Suggested responsibilities regarding environmental management applicable to this project are briefly mentioned below:

- i. All workers must be aware of their environmental responsibilities under the Saudi Arabian legislations, and all SPPC contractors must undergo the required Induction/Orientation Program, which includes a section on Environmental Awareness.
- ii. Each work supervisor is responsible for management of environmental issues under his/her supervision.
- iii. SPPC or its contractor will oversee the waste management system, determine how much waste the new facilities produce and find efficient ways of minimizing the waste produced.
- iv. SPPC or its contractor is responsible for the co-ordination of the Environmental Management System.

- v. SPPC or its contractor has the overall responsibility for environmental performance at the site and
- vi. SPPC or its contractor will assign dedicated resources to coordinate all aspects of the Environmental Management System.

Employee Training and Education

SPPC or its contractor should arrange training programs for the staff under their supervision on the following aspects, during construction:

- i. Responsible Care;
- ii. Security;
- iii. Incident Reporting;
- iv. Emergency Response and Notification;
- v. Environmental Protection and Compliance Requirements;
- vi. Site Hazards;
- vii. Personal Protective Equipment;
- viii. General Safety Rules & Safety Program, and;
- ix. Work Permit System/ Hazard Identification.

Compliance with Laws and Regulations

Documents dealing with approvals, permits, consents, licenses, etc., relating to the environment should be sorted out and filed in appropriate places which are readily available to the appropriate staff. All applicable approvals, permits, consents, licenses, etc., related to the construction of the new facilities should be obtained from the concerned authorities, including but not limited to the following:

- i. Discharges to air;
- ii. Discharges to land;
- iii. Land Use permits;
- iv. Planning Permission;
- v. Transport of Waste;
- vi. Hazardous Substance test Certificates; and
- vii. Transport of Dangerous Goods.

All other remaining approvals or permits, if any, required for new activities, should be obtained prior to the commencement of the activities. Updated copies of all relevant

national and international compliance standards/guideline values related to air emission, noise levels and ambient water quality, hydrotest water discharge, transport of waste etc. should be obtained and circulated among EMS staff.

6.5.1 *Roles and Responsibilities for the Environmental and Social Management Plan Implementation*

Organizational Structure and Responsibilities

GRL (Contractor/Proponent) and SPPC (Project Owner) leadership is accountable for the protection of the environment with reference to this project. This accountability is delivered through a clear set of responsibilities assigned to their functions and its supply chain delivering the programmes. Implementation of the ESIA recommendations is the responsibility of the construction contractor(s), while GRL and SPPC (project owner) will undertake reviews and audits to ensure the ESIA recommendations and the contractor's *Construction Environmental and Social Management Plans* (CESMP) are implemented. These plans summaries the specific actions, procedures or mitigation measures that will be implemented to reduce the potential impacts. The plans also identify the personnel responsible for implementing the required procedures or mitigation actions and monitoring, reporting and documentation requirements and the key indicator(s) of compliance with the mitigation measures. The key project and environmental and social management responsibilities during the construction works are described in the following sections.

Overview of key Project and Environmental Management Responsibilities

The ESIA recommendations and construction permit conditions must be implemented by the construction contractor with oversight from GRL and SPPC as follows:

- Construction contractor must implement and adhere to their detailed project specific CESMP, which must align with the ESIA recommendations, construction permit conditions and SPPC/GRL Engineering Procedures/Standards, if any. Any uncertainties about the ESIA recommendations must be clarified with GRL and SPPC prior to commencing work.
- Construction contractor must make the necessary resources available to address implementation of all the ESIA recommendations, construction permit conditions and CESMP requirements.
- Construction contractor must ensure the appointment of appropriate personnel to implement the ESIA recommendations and construction contractor's CESMP successfully.
- Construction contractor must ensure that roles, responsibilities, and authorities have been defined, documented and communicated to facilitate compliance with their CESMP.
- Where required by GRL and SPPC, construction contractor must provide a "method statement" stating how the requirement of the ESIA recommendations, construction permit conditions and CESMP will be implemented.

- Construction contractor must ensure that all staff members engaged by the contractor including suppliers and service providers understand and adhere to the ESIA recommendations, Permit Conditions and CESMP.
- Construction contractor must ensure that all their staff are appropriately trained.

The construction contractor is required to include their organization chart in their CESMP. The main responsibilities of key staff from GRL, SPPC and construction contractors are described in Tables 7.8 and 7.9 respectively.

SPPC and GRL

Saudi Power Procurement Company (SPPC) is representing the Principal Buyer. SPPC (Company) has selected GRL (Contractor) for the construction and commissioning of the Al-Humaij Solar PV Park as part of the National Renewable Energy Program (NREP). GRL is an independent company in Saudi Arabia that provide professional local third-party inspection, testing, certification, calibration, professional training, international skill certification, and technical engineering services for all industries. The *Project Owner* is SPPC (Company) and the *Project Proponent* on behalf of SPPC is GRL (Contractor).

GRL and SPPC are accountable, as Project proponent, with the overall responsibility of environmental and social management and compliance with the ESIA recommendations and permit conditions. It is also responsible for any interface with regulatory authorities.

Construction Contractor

The specific construction contractors should carry out the project activities, under the supervision of GRL and SPPC. The construction contractor has obligations under KSA's environmental laws under its contract with SPPC. The responsibility for implementation of the ESIA recommendations and their detailed CESMP rests with the specific construction contractor(s). It is expected that the construction contractor(s) will:

- Assign responsibilities, documented through signed job descriptions, to individuals within their project teams to facilitate the implementation of the CESMP and allow for effective communication between GRL and SPPC's project management and the environmental management roles within their project teams;
- Develop a site specific CESMP compliant with the ESIA recommendations and permit conditions.
- Have their CESMP as well as their quality assurance processes approved by GRL and SPPC prior to commencement of construction or as early as is practicable thereafter.
- Develop the CESMP consistent with the level of environmental specifications and safeguards set out in ESIA recommendations and Permit Conditions; and
- Provide project personnel and workers with appropriate training to implement and monitor implementation of the ESIA recommendations and their site-

specific CESMP; the construction contractor's internal HSE guidelines and standards and SPPC's contract requirements.

Construction contractor must provide adequate resources to implement and monitor compliance with the ESIA recommendations, and their site-specific CESMP. Table 6.1 and Table 6.2 provides an indicative organization of roles and responsibilities for GRL and SPPC and the construction contractor respectively.

Table 6.1. GRL and SPPC's Organization Roles and Responsibilities during the construction phase

Organization and Designation	Responsibilities	Operating Documents
Construction Director	Has ultimate accountability and authority (i.e. GRL and SPPC) for environmental and regulatory compliance Provides mandate and resources so that GRL and SPPC can deliver its responsibilities Participates in monthly environmental meetings	SPPC Contract with the construction contractor The Approved ESIA report NCEC Construction Permits Construction contractor's CESMP
Project Manager	Has responsibility to ensure that ESIA recommendations and permit conditions are implemented Regularly engages with third party monitoring contractor's HSE Manager to seek feedback on construction contractors' environmental performance Participate in monthly and weekly environmental meetings Reviews construction contractors' periodic communication on their environmental performance and proactively engages with the construction contractor at the leadership level for continual improvement	SPPC Contract with the construction contractor The Approved ESIA report NCEC Construction Permits Construction contractor's CESMP Construction contractors' weekly environmental reports (WERs) and monthly environmental reports (MERs) GRL's construction progress reports and schedule
Site Environmental Manager	Coordinates with the Construction Director, Project Manager and Construction Contractors Environmental Manager on environmental management requirements Ensures that the SPPC corporate environmental policy is understood by the construction contractor's Project leadership in relation to their activities Reviews and approves construction contractors' site-specific environmental management plans (SSEMPs) which are part of their CESMPs Ensures that findings from the SPPC environmental audit are closed in a timely manner Assists construction contractor's Environmental Manager by advising on environmental issues Provides oversight on construction contractor's monitoring activities Undertakes a periodic review of the construction contractor's CESMP to verify their effectiveness and provides advice and feedback to the construction contractor Participates in Environmental Meetings	SPPC Contract with the construction contractor The Approved ESIA report NCEC Construction Permits Construction contractor's CESMP GRL and SPPC Environmental Audit reports Construction contractor's environmental reports (ERs)

Organization and Designation	Responsibilities	Operating Documents
Corporate Environmental/Social Compliance Lead	Coordinates with the SPPC Construction Director on the environmental management Undertakes a periodic review of the ESIA recommendations, Permit Conditions, CESMPs and SSEMPs to verify their effectiveness and provides advice and feedback to construction contractors Participates in Environmental Meetings	The Approved ESIA report SPPC Policies and Standards SPPC Audit reports Construction contractor's CESMP Construction contractors WERs and MERs SEZ Requirements (as they evolve and develop) NCEC Construction Permit
Construction Supervision Superintendent	Reports to GRL and SPPC Project Manager Connects with construction contractor's Environmental Officer/Engineer during field supervision to understand status of environmental compliance Provides feedback to the GRL and SPPC HSE Manager on incidents, hazards or other environmental related deficiencies observed during field supervision	The Approved ESIA report NCEC Construction Permits Construction contractors CESMP and SSEMPs Construction contractors WERs and MERs

Table 6.2. Organization Roles and Responsibilities of Construction Contractors

Organization and Designation	Responsibilities	Operating Documents
Project Director/Site Operations Manager	Has overall responsibility of environmental governance and for implementation of construction contractor's environmental obligations Provides mandate and resources to ensure compliance with the ESIA recommendations, Permit Conditions and CESMP is delivered Participates in monthly environmental meetings	SPPC Contract with the construction contractor The Approved ESIA report NCEC Construction Permits SPPC Policies and Standards Construction contractor's Policies and Standards Construction contractor's CESMP KSA National Laws and Regulations
Project Manager	Responsible for the implementation of ESIA recommendations, Permit Conditions and CESMP Ensures satisfactory and compliant workforce management Communicates with GRL and SPPC Project Manager and their HSE Manager to convey project environmental compliance Ensures personnel/workforce are competent and have necessary skills to conduct environmental management functions and requirements of the CESMP Ensures construction contractor's workforce has adequate knowledge and training in line with ESIA recommendations, Permit Conditions and CESMP Participates in monthly environmental meetings	SPPC Contract with the construction contractor The Approved ESIA report NCEC Construction Permits SPPC Policies and Standards Construction contractor's Policies and Standards Construction contractor's CESMP KSA National Laws and Regulations Construction contractor's self-assurance audit reports
Environmental and Social Manager	Responsible for developing CESMP and Site-Specific Environmental Management Plans (SSEMPs) to meet the requirements of the ESIA recommendations and permit conditions Responsible for ensuring the preparation of site specific environmental and regulatory documentation and for regular review and improvement of such documentation, as appropriate. Responsible for ensuring that appropriate levels of environmental expertise and resources are available to conduct environmental management functions Responsible for delivering appropriate training to the workforce in line with ESIA recommendations, permit conditions and CESMP Responsible for developing format and schedule for the construction contractor's self-assurance audit Reviewing daily and weekly environmental reports Issue non-compliance letters to concerned parties as required and audit Implementation of Corrective Action Plans (CAP) Responsible for undertaking and reporting monthly self-assurance audit findings	The Approved ESIA report NCEC Construction Permits SPPC Policies and Standards Construction contractor's Policies and Standards Construction contractor's CESMPs Construction contractor's WERs and MERs Construction contractor's self-assurance audit reports

Organization and Designation	Responsibilities	Operating Documents
	Provides management support for identification, correction, and resolution of instances of environmental non-compliance and to prevent future recurrences Participates in weekly and monthly environmental meetings	
Environmental and Social Officer/Engineer	Assists Environmental and Social Manager in delivering compliance with the ESIA recommendations, permit conditions, and CESMP including reporting and documentation Conducts environmental site training and inductions Conducts environmental inspections, as required, by the CESMP, and reports accordingly Verifies Non-Compliance Record (NCR) issued by Environmental Field Monitor and issues it concurrently to the Environmental Manager, Construction Manager the GRL /SPPC Project Manager, and HSE Managers Participates in weekly and monthly environmental meetings Maintains an environmental incident register, documenting all incidents of compliance/non-compliance with the CESMP, and keeps the Environmental Manager appropriately informed. Liaises with Construction contractor's site management to ensure that environmental implications of any proposed change in scope are reviewed and discussed.	The Approved ESIA report NCEC Construction Permits Construction contractor's CESMP Construction contractor's WERs and MERs Construction contractor's self-assurance audit reports
Environmental Field Monitor	Report to Environmental Officer/Engineer Monitors Construction contractor's activities in the field daily as required by the monitoring program. Prepares Non-Compliance Record (NCR) and issues it for verification to Environmental Officer/Engineer Contributes to the daily monitoring report	The Approved ESIA report Construction contractor's CESMP CESMP Environmental Monitoring Plan Checklists/reporting forms/NCR form NCEC Construction Permit

6.5.2 Capacity Building

The main objective of the environmental awareness and training program is to ensure that all personnel involved in the project activities are aware of their individual responsibilities under the ESIA recommendations, Permit Conditions, CESMP, but it also serves to help build capacity, knowledge, and skills in the Project workforce. Additional contractor specific HSE training and induction programs for all staff must be provided, as needed. Specific training components must focus on receptor awareness and sensitivities. The need for follow-up training must be based on the incidences of non-compliance documented in the environmental monitoring reports.

Training Requirements

Training and competence are essential to the effective implementation of the CESMP. Training and competencies must be split to reflect competency requirements for designers, managers, engineers, and workers. Training materials must be submitted to SPPC for review and approval to ensure their adequacy. The training programs identified may be superseded based on actual construction activities and standard operating procedures; however, the intent of these recommended training must be met. The Construction Environment and Social Manager must establish the Environmental/Social training programs schedule, and must be responsible for:

- The development of training materials or the oversight of the preparation of such material by a competent person to effectively conduct environmental and social training;
- Development of an environmental and social training program;
- The preparation and updating of the schedule for environmental and social training;
- Carrying out environmental and social training for site personnel in accordance with this procedure;
- Training the sub-contractors nominated trainers; and
- The collation and retention of training records.

All site personnel must attend and participate in the scheduled training sessions, as applicable. Arrangements must be made which allow the contractor to identify everyone who has successfully completed the required training. Those who cannot be identified must not be allowed to work on site. Records must be kept for auditing purposes. Guidance on how to present the talks must be prepared by the Environmental and Social Manager and issued to those giving the talk.

Environmental and Social Training

Environmental/Social training must be provided to all staff involved in project activities and to the Contractor's senior staff. This training must include topics related to overall project environmental, social and sustainability goals, site environmental controls measures that will be implemented and reporting program in addition to general site and project environmental requirements. With respect to the social aspects of the Project, training should be provided on the appropriate way to interact with the community for various scenarios.

Environmental Training for HSE Supervisor

Selected site supervisors who oversee critical activities or activities with relatively higher potential for environmental impacts or incidents must be provided with specific training to understand the ESIA recommendations, Permit Conditions, CESMP requirements, and good site environmental practices. As a minimum, this must include personnel who will be supervising the following works:

- Chemicals/ Fuel/ Hazardous materials storage and handling, and spill response;
- Waste Management (including sewage and other wastewater);
- Workers Accommodations;
- Workers welfare;
- Community interactions; and
- Wildlife management.

6.5.3 Communication

Communications and consultations are an integral part of the CESMP and the project work. This involves communications aimed at keeping GRL and SPPC project management, the Construction contractors and other key stakeholders and potential external parties (if required) informed about the progress of the work and environmental monitoring activities.

Internal Communication

Effective and timely communication is critical to the effective implementation of the ESIA recommendations, Permit Conditions and CESMP. Therefore, all personnel including SPPC/ GRL and the construction contractor's site personnel must attend an awareness induction prior to starting work in order to gain a better understanding of the environmental issues and associated main mitigation measures related to the Project.

Environmental and Social Performance/ HSE Status Meetings

Matters concerning environmental protection and related issues should be discussed during weekly HSE meetings which should be chaired by the contractor's Environment/Social Manager or the HSE Manager. Participants of these meetings must include Construction contractor's Project Manager and Environmental and Social Officers and representatives of subcontractors and suppliers (when required considering the type of material supplied such as chemicals which may have environmental implications). Items to be discussed should include topics such as environmental incidents and their management, worker and community grievances, monitoring requirements, spill response procedures, operational controls developed under the CESMP and roles and responsibilities of employees under the CESMP.

External Communications

A billboard with the details of the Project must be erected at the entrance to the Project site (if applicable) to communicate important details to external parties. The billboard must, as a minimum cite the following information:

- The name of the Project and the number of the contract.
- The name of the party supervising the Project and its address (number of offices, fax number) the name of the head of the unit, and his mobile number.
- The name of the Construction contractor, and its address (number of office, fax number), and the head of the department and his mobile phone.

Incident Reporting

Any major incident such as spills or uncontrollable fire, if occurs must be reported to concerned authorities as discussed. The responsibility for reporting to external entities should primarily be that of GRL and SPPC. The contractor should fully support GRL/SPPC by providing adequate information related to the incident for the purpose.

Community Grievance Feedback

During construction, local community or other stakeholders may raise complaints or submit their grievance as a result of construction activities. Ideally, community grievances should be addressed to GRL /SPPC being the Project Proponent considering that multiple contractors should be interacting with the stakeholders. Based on the nature of the grievance and upon identifying the party responsible for addressing the grievances, the Construction contractor should ensure that grievances are addressed in accordance with the approved Project grievance protocol and provide feedback to the complainant in consultation with GRL /SPPC where required.

Findings of Noncompliance

Compliance with the ESIA recommendations, Permit Conditions, and contractor's CESMP is a requirement and mandatory. Failure to comply (noncompliance) will result in the issuance of a non-compliance record (NCR). The purpose of an NCR is to:

- Provide clear communication between environmental monitoring personnel, contractor's management, and GRL /SPPC;
- Ensures responsible personnel are kept informed regarding any gaps in the contractor's environmental performance; and
- Helps effectively and expeditiously resolve environmental non-compliance situations.

The following procedure is proposed for the issuance of NCR, to give complete and accurate documentation.

NCR Issuance

A tiered approach for communication and response to non-compliance situations should be implemented. When an issue is identified, the contractor must be informed of a potential discrepancy between its activity and the CESMP. If the situation is immediately corrected, the concern and response are reported in the monitoring report and no further action may be necessary. However, if the situation is not corrected immediately, an NCR may be issued, depending on the severity of the situation. Three categories are proposed:

- Level I NCR—A non-compliance situation that is not consistent with CESMP requirements, but not considered to represent an immediate threat to an identified important resource. This includes environmental near misses.
- Level II NCR—A non-compliance situation that has not yet resulted in a ‘clearly identified damage’ or irreversible impact to a sensitive or important resource but requires expeditious corrective action and site- specific attention to prevent such effects, or an unresolved Level I NCR.
- Level III NCR—A major non-compliance situation, typically including observed damage to a specifically protected sensitive resource or a reasonable expectation of impending damage or an unresolved Level II NCR.

Issuance of an NCR requires notification to GRL and SPPC at increasing levels of urgency, depending on severity. Similarly, resolution of corrective action will also involve elevated levels of management on both sides. Once the issue has been resolved, an incident investigation team, comprising both of GRL/SPPC and contractor personnel, may need to be formed, to determine if process changes are required. Contractor is required to develop a detailed NCR Issuance procedure as part of their CESMP. All NCRs must be reported to GRL /SPPC with the weekly environmental report.

6.5.4 Monitoring and Report Writing

Daily Environmental Observation Checklist

The Construction contractor must submit daily reports to GRL and SPPC which will contain the observations recorded from the project site. The Construction contractor must utilize an appropriate site inspection checklist for the purpose which will address the items mentioned in Table 6.3, the compliance status checking and monitoring program to be implemented during construction/commissioning phase. This report should be submitted the same day after completion of the site visit.

Weekly Report

Weekly report must be submitted in a suitable format developed by the Construction contractor which must show a compilation of the observations conducted during the period, with data collected during the daily visits (if applicable) and supported by verifiable evidence. It must include an aggregate summary of observations and progress during the week including, but not limited to, the following matters:

- Waste shipment records (broken down by waste stream including sewage);
- Water consumption;
- Water discharge volume;
- Fuel consumption;
- Non-conformances recorded and their status (closed/open);
- Trainings conducted; and
- Any environmental issues or concerns identified.

Monthly Reports

Contractors must submit monthly reports highlighting the environmental monitoring activities carried out during the month with the information specified in the

compliance status checking and monitoring program (Table 6.3) and in accordance with the format presented in the Construction contractor's approved CESMP. Monthly reports must be submitted to GRL and SPPC within the first week of every month. The Contractors' monthly report will contain the following information at a minimum:

- A brief description of the construction works completed during the month;
- Updated logistics map showing locations of the following (if updated and applicable);
 - Waste collection areas (all types of waste including wastewater);
 - Sanitary facilities (e.g. toilets) and rest areas;
 - Hazardous materials storage areas (e.g. chemical stores, fuel tanks, gas cylinders); and
 - Construction access roads, if applicable.
- Air quality monitoring results (where monitoring is required);
- Environmental and occupational noise monitoring results;
- Fuel and water consumption quantities;
- Vehicle and equipment maintenance and inspection records;
- Summary of findings from the daily site inspections highlighting good practices and non-compliance;
- Any revisions of Project environmental and social-related documents during the period and comment on adaptive management initiatives implemented;
- Updated complaints/grievance register (if any) with actions taken to resolve such complaints;
- Community interactions (e.g. employment requests and employment register);
- A summary of waste disposal volumes for all types of wastes, transporter and final receiving facility details for all types of wastes;
- Results of sample (water, soil, etc.) analyses if conducted;
- Trainings records (site induction and any specialized environmental training conducted);
- Drinking water test reports;
- Worker accommodation inspection reports;
- Summary of health monitoring conducted and report of any work health-related incidents;
- Hazardous Materials Inventory (including materials awaiting flight departures/transfers); and,
- Internal and external audit reports.

6.5.5 Data Management and Documentation

Accurate documentation and data management are essential for tracking and evaluating the implementation and effectiveness of the ESIA recommendations, Permit Conditions, and Construction contractor CESMP. The Construction contractor's CESMP must identify the specific reporting, data, and documentation requirements. Processes must be in place for controlling documentation/data and to ensure that it is available at all times, valid, and current. All documentation/data becomes a part of the environmental site history file. The Construction contractor will maintain records and track performance. The following documents/data that are to be kept onsite include, but are not limited to:

- Approved record of amendments to the CESMPs or other plans;
- Copies of all plans, procedures, lists, and reports or documents required by the CESMP;
- Permits and authorizations issued by SPPC and regulatory/local authorities;
- List of chemicals stored on-site including Material Safety Data Sheets (MSDS);
- Non-compliance, corrective action, and incident reports;
- Medical records;
- Environmental and social training records;
- Complaints and incident register (i.e., through Grievance mechanisms);
- Audit and inspection reports;
- Monitoring and inspection checklists;
- Quantitative waste metrics, by waste stream;
- Change Management/Review records; and
- Waste disposal/transfer note

6.5.6 Auditing and Inspection

Self-assurance audits/reviews should be conducted by the Construction Contractor(s) to verify the implementation and effectiveness of ESIA recommendations, Permit Conditions and their CESMP. The section of the CESMP must provide details/schedule of construction contractors' self-assurance plan. GRL and SPPC may also choose to implement an Audit Program to ensure that this CESMP is being implemented. They may identify their internal resources or deploy teams from their environmental supply chain to undertake these audits. As mentioned earlier, it is also required to appoint a third-party Environmental Monitoring team to conduct compliance monitoring during the construction phase. The audit and inspection report should provide a tabular detail as given in Table 6.3.

Table 6.3. Format of the proposed Audit and Inspection Plan

Category	Type of Activity	Frequency	Responsibility	Reporting
Self-Assurance Audit	Review of the daily environmental field inspection reports, weekly environmental and social performance reports, and the monthly environmental report.	Weekly	Construction Contractor HSE/ Environmental/ Social Manager	Through Weekly Environmental and Social Performance Report
GRL /SPPC	Validate Construction Contractors' Environmental governance, weekly environmental reports, and monthly environmental reports	Regularly	GRL and SPPC Corporate Environmental Compliance Lead	Audit Report

SECTION 7 SUMMARY

7.1 A SUMMARY OF HOW NEGATIVE IMPACTS WILL BE ADDRESSED AND TO WHAT EXTENT THEY WILL BE MITIGATED, IMPROVED OR CONTROLLED, HOW TO ENHANCE POSITIVE IMPACTS

The number of operational plants producing electricity from renewable energy to date are limited in Saudi Arabia, despite the abundant resources. The proposal to construct and operate solar energy park in Al-Humaij will help to decrease the country's dependency on traditional forms of energy by increasing the availability and use of solar energy. The generated electricity will be injected into the national grid, to support the country in meeting its renewable energy targets.

This project-specific ESIA study (Category 2 as per NCEC guideline and Category B as per IFC guideline) has been undertaken to assess the overall impacts on the environment and social components due to the construction and operation of the proposed 3 GW Solar PV Park project at Al Humaij in Saudi Arabia. Generally, the project is expected to reduce pressure on fossil fuels, reduce greenhouse gas emissions, and optimize electric supply in the area, resulting in a general improvement in socioeconomic conditions. Although the project will have overall positive socio economic impacts, few activities are likely to cause potential adverse impacts.

The project site in Humaij is dominated by desert and rocky terrain, with sparse vegetation consisting mainly of drought-resistant plants such as acacia trees, shrubs, and grasses (23 plant species). At the project site, 16 bird species, which are within the Least Concern (LC) category of the IUCN Red List. Moderately negative impacts of construction and operation on wildlife during operation are the loss and fragmentation of natural habitats, disruption to wildlife movement and/or migrations etc.

Barriers to the movement and/or migration of wildlife should be mitigated by modifying solar park fencing to maintain a gap between the base of the fence and the ground (wildlife-friendly fencing). Although no significant species are observed, the proposed solar park should be designed, developed, and operated as a *nature-inclusive*

and *landscape-inclusive* solar park [Jarcuska et al., 2024; Biro-Varga et al. 2024]. As a result, the residual environmental impacts associated with this project will be mitigated and a biodiversity net gain (BNG) will be achieved.

The proposed project area is devoid of significant ecological features, significant vegetation or protected areas and is mainly used for camel grazing. Despite its undeveloped nature and the absence of industrial or agricultural activity within the immediate vicinity, a camel farm and some settlements are located nearby.

Most of the potential negative social and environmental impacts of this project can be mitigated to insignificant (low or no impact) levels by implementing the mitigation and management measures suggested in this EIA report. As shown in Table 7.1 the predicted and residual impacts on environmental and social receptors during construction and commissioning, are summarized. During construction and commissioning phase, out of the 18 negative impacts, one (1) were very high, six (6) were high and seven (7) were moderate, three (3) were low significance and one (1) was no impact, before implementing mitigation. After applying mitigation (Table 7.1), the negative impact such as very high, high and moderate significances were reduced to either low significance (8 receptors) or no impacts (10 receptors). The moderate positive impact was predicted for socioeconomic conditions.

During operation phase, out of the 18 negative impacts, two (2) were very high, five (5) were high, six (6) were moderate and five (5) were no impact, before implementing mitigation. After applying mitigation (Table 7.2), the negative impact such as very high, high and moderate significances were reduced to either low significance (7 receptors) or no impacts (11 receptors). The moderate positive impact was predicted for socioeconomic conditions.

Table 7.1. Summary of potential impacts (before mitigation) and the residual effects after applying mitigation, on environmental and social receptors during the construction and commissioning phase

Construction and Commissioning Phase				Change (+/-)
Impact Type	Significance	Before Mitigation	After Mitigation	
POSITIVE	Very high	Nil	Nil	Nil
	High	Nil	Nil	Nil
	Moderate	- National and local economy	- National and local economy	Nil
	Low	Nil	Nil	Nil
X	No impact	- Microclimate	-Air Quality -Climate -Microclimate -Noise and vibration -Visual and landscape -Soil and Land Use -Ground and Surface water -Flood risk -Flora -Archelogy and Cultural Heritage	+9

Construction and Commissioning Phase				Change (+/-)
Impact Type	Significance	Before Mitigation	After Mitigation	
NEGATIVE	Low	- Visual and landscape - Traffic and transport - Arch and Cultural Heritage	- Fauna -Waste management -Traffic and transport -Health and Safety -Labor management -Community Displacement -Inappropriate waste disposal -Accidental spills, fire, etc.	+5
	Moderate	- Climate - Noise and vibration - Soil and Land Use - Ground and Surface water - Flood risk - Flora - Community Displacement	Nil	-7
	High	- Air Quality - Fauna - Waste management - Health and Safety - Labor management - Inappropriate waste disposal	Nil	-6
	Very high	- Accidental spills, fire, etc.	Nil	-1

Table 7.2. Summary of initial effects (impacts before mitigation) and the residual effects after applying mitigation, on environmental and social receptors during the operation phase

OPERATION PHASE				Change (+/-)
Impact Type	Significance	Before Mitigation	After Mitigation	
POSITIVE	Very high	Nil	Nil	Nil
	High	Nil	Nil	Nil
	Moderate	- National and local economy	- National and local economy	Nil
	Low	Nil	Nil	Nil
X	No impact	- Air Quality - Climate - Traffic and transport - Labor management - Arch and Cultural Heritage	-Air Quality -Climate -Noise and vibration -Soil and Land Use -Waste management -Traffic and transport -Health and Safety -Labor management -Community Displacement -Arch and Cultural Heritage -Inappropriate waste disposal	+6
NEGATIVE	Low	Nil	-Microclimate -Visual and landscape -Soil and Land Use -Ground and Surface water -Flood risk -Flora -Fauna -Accidental spills, fire, etc.	+8
	Moderate	- Noise and vibration - Visual and landscape - Soil and Land Use - Health and safety - Community Displacement - Inappropriate waste disposal	- Fauna	-6
	High	-Microclimate - Ground and Surface water - Flood risk - Flora - Waste management	Nil	-5
	Very high	- Fauna - Accidental spills, fire etc.	Nil	-2

An Environmental and Social Monitoring Program (ESMP) should be implemented during the entire construction phase. The primary objective of this ESMP is to ensure that the prescribed mitigation measures and permit conditions are met, as well as to provide a sustained assessment of the environmental impacts associated with the construction phase.

The main objective of the proposed solar PV energy park at Al-Humaij is to diversify the Kingdom's energy mix and reduce its carbon footprint. The project is considered to be an important contribution to achieving national goals in terms of renewable energy and climate change. The long-term operational and economic effects of the solar park will outweigh any negative impacts encountered during construction and operation. It is therefore recommended that the proposed PV energy park be developed in Al Humaij provided that the mitigation measures proposed are adhered to.

7.2. A SUMMARY OF ROLES, RESPONSIBILITIES AND BUDGET TO EXECUTE THE ENVIRONMENTAL AND SOCIAL MANAGEMENT PLAN.

A typical management process is structured around six (6) steps: ‘policy, organize, plan, implement, monitor and review’, to ensure continuous improvement in performance’ as depicted Figure 7.1. The contractor’s Construction Environmental and Social Management Plan (CESMP) and other environmental management plans are expected to follow a similar management approach. The requirements by the contractor to follow this process is outlined in this ESIA report.

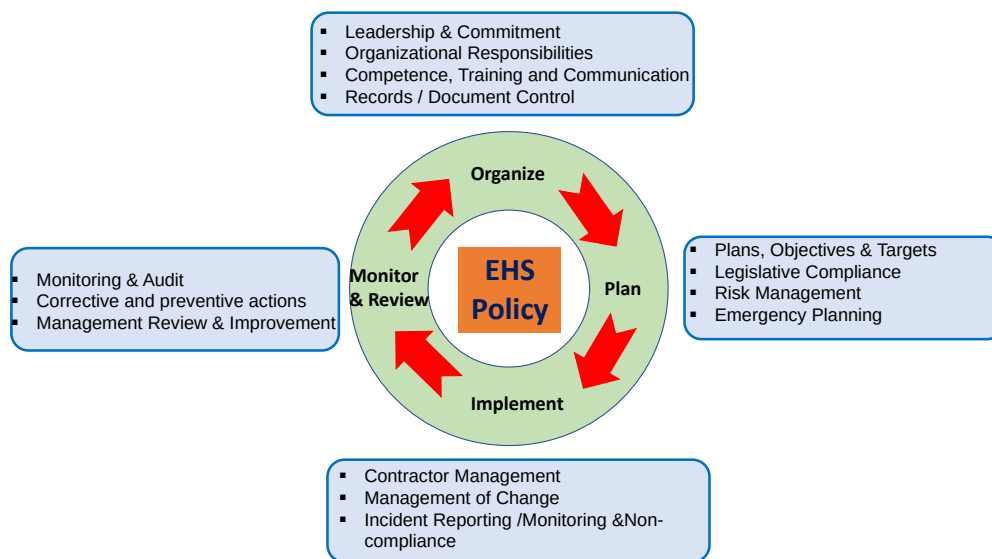


Figure 7.1. EHS Management System Framework (Adapted from management systems principles of ISO14001 and OSHA S18001).

In summary, the environmental and social management of the project should be conducted within a comprehensive framework, based on this model, comprising:

- Construction contractor’s EHS Policies;
- Dedicated contractor personnel to implement mitigation measures and to provide oversight and support of the construction contractors' activities;
- Construction Environmental and Social Management Plan (CESMP);
- Training Programs;

- Specific Management Plans developed by construction contractors; and
- Monitoring Programs.

7.2.1 Roles of the various stakeholders in the environmental management plan

During the EIA process, key Project stakeholders have been consulted to understand the Project design elements and construction details. The key stakeholders include, but are not limited to:

- Project Management Team, Saudi Power Procurement Company (SPPC);
- Project Contractors (GRL);
- Construction Contractors;
- National Center for Environmental Compliance (NCEC);
- Ministry of Energy.
- National Center for Wildlife (NCW).

In summary, the environmental and social management of the Project will be conducted within a comprehensive framework, based on this model, comprising:

- GRL, Project Contractor
- Project Management Team, SPCC;
- Environmental Compliance Monitoring Team (Third-party Contractor);
- Dedicated contractor personnel to implement mitigation measures and to provide oversight and support of the construction contractor's activities. and
- KFUPM's Modeling Team.

Further engagement outside of GRL and SPCC, their appointed designers and contractors, with interested and affected individuals and organization, falls outside of this ESIA and is the responsibility of GRL's established Environmental, Social, and Governance (ESG) Taskforce.

During the construction phase a grievance mechanism allows stakeholders affected by or interested in the Project to present their input (e.g., opinions, requests, suggestions, feedback and grievances) for consideration and, if required, seek redress. Implementation of the grievance mechanism is the responsibility of the Proponent and should be designed to devolve redress to their contractors as required but must remain informed through regular reporting on grievances.

7.2.2 Third Party Environmental Monitoring Contractor

A third-party monitoring contractor should be appointed by the proponent (GRL) or the owner of the project (SPPC) to conduct an independent *Compliance Monitoring and Reporting* of Overall Environmental Status during the entire construction period. The major monitoring tasks and schedules/responsibilities for the construction phase are listed in Table 7.3.

Table 7.3. The suggested compliance status checking and monitoring program to be implemented during construction phase.

SI No	Receptor(s) affected	Construction Contractor's Mitigation Commitments and Actions	Compliance Status Checking and Monitoring			
			Implementation Responsibility	Conducted By	When	Frequency
-	General	- For project regulatory requirements, see Section 2 <i>Institutional and regulatory Framework of the Study</i> of the EIA report. This should be reviewed and implemented during the construction and commissioning phases. - Implement an <i>Environmental Monitoring Program</i> by a third party during the entire construction phase.	Construction Contractors and GRL/SPPC	Third-Party Compliance Monitoring Team	During Construction and commissioning Phases.	During Construction
-	General	- Develop and Implement a Construction Environmental Management Plan (CEMP) and submit to GRL and SPPC for approval. - Use Best Available Technologies (BAT) for construction and installation.	Construction Contractors and GRL/SPPC	Third-Party Compliance Monitoring Team	During Construction and commissioning Phases.	During Construction
-	General	- Identify sustainability benefits through design, especially in line with corporate policy; - Prevent or minimize environmental pollution, conserve natural resources and minimize waste; - Develop objectives and targets to monitor achievement of goals established for the Project and progress towards sustainable development; and - Implement continual improvement program as identified by Environmental Management Plan and associated monitoring, review and auditing.	Construction Contractors and GRL/SPPC	Third Party Compliance Monitoring Team	At the beginning of the project	During Construction
1	Air Quality	Mitigation measures given in Section 6.3 for air quality impacts	Construction Contractors	Third Party Compliance Monitoring Team	During Construction and commissioning Phases.	Monthly
2	Climate and Microclimate	Mitigation measures given in Section 6.3 for air climate impacts	Construction Contractors	Third Party Compliance Monitoring Team	During construction	Monthly

SI No	Receptor(s) affected	Construction Contractor's Mitigation Commitments and Actions	Compliance Status Checking and Monitoring			
			Implementation Responsibility	Conducted By	When	Frequency
3	Noise and vibration	Mitigation measures given in Section 6.3 for noise and vibration	Construction Contractors	Third Party Compliance Monitoring Team	During construction	Monthly
4	Visual and landscape	Mitigation measures given in Section 6.3 for Visual and landscape impacts	Construction Contractors	Third Party Compliance Monitoring Team	During construction	Monthly
5	Soil and Land Use	Mitigation measures given in Section 6.3 for Soil and Land Use impacts	Construction Contractors	Third Party Compliance Monitoring Team	During construction	Monthly
6	Ground and Surface water	Mitigation measures given in Section 6.3 for impact on Water Environment	Construction Contractors	Third Party Compliance Monitoring Team	During construction	Monthly
7	Flood risk	Mitigation measures given in Section 6.3 for Flood Risk impacts	Construction Contractors	Third Party Compliance Monitoring Team	During construction	Monthly
8	Flora	Mitigation measures given in Section 6.3 for impact on Flora	Construction Contractors	Third Party Compliance Monitoring Team	During construction	Monthly
9	Fauna	Mitigation measures given in Section 6.3 for impact on Fauna	Construction Contractors	Third Party Compliance Monitoring Team	During construction	Monthly
10	Waste management	Mitigation measures given in Section 6.3 for impact on Waste management	Construction Contractors	Third Party Compliance Monitoring Team	During construction	Monthly

SI No	Receptor(s) affected	Construction Contractor's Mitigation Commitments and Actions	Compliance Status Checking and Monitoring			
			Implementation Responsibility	Conducted By	When	Frequency
11	Traffic and transport	Mitigation measures given in Section 6.3 for impact on Traffic and Transport	Construction Contractors	Third-Party Compliance Monitoring Team	During construction	Monthly
12	Health and Safety	Mitigation measures given in Section 6.3 for Health and Safety Impacts	Construction Contractors	Third-Party Compliance Monitoring Team	During construction	Monthly
13	Labor management	Mitigation measures are given in Section 6.3 for impact Labor Management	Construction Contractors	Third-Party Compliance Monitoring Team	During construction	Three monthly
14	Community Displacement	Mitigation measures are given in Section 6.3 for Community Displacement	Construction Contractors	Third-Party Compliance Monitoring Team	During construction	Beginning of the Project
15	Archeology and Cultural Heritage	Mitigation measures are given in Section 6.3 for Archeology and Cultural Heritage	Construction Contractors	Third-Party Compliance Monitoring Team	During construction	Need-based
16	Inappropriate waste disposal	Mitigation measures are given in Section 6.3 for impacts due to inappropriate waste disposal	Construction Contractors	Third-Party Compliance Monitoring Team	During construction	Need-based
17	Accidental spills & fire	Mitigation measures are given in Section 6.3 for impacts due to Accidental spills and Fire	Construction Contractors	Third-Party Compliance Monitoring Team	During construction	Need-based

SECTION 8 REFERENCES

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APPENDICES

APPENDIX A
RESUME OF THE SECTION WRITERS

DR. SUBHAJITH SEN

Dr. Subhajit Sen is working as Lab Specialist in the Center for Environment and Marine Studies of the Research Institute of the King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia.

He obtained Master degree and Ph.D. in Geography and Disaster Management from Tripura University, Tripura State, India with specialization in Environmental Geomorphology, Tectonic Geomorphology and Environmental Planning from Tripura University, India in 2018. Subsequently he completed a 1 year-PG diploma course in Applied Remote Sensing and GIS (Geoinformatics) from Jadavpur University in 2018. The title of his PhD thesis is “Geomorphic Processes leading to the present-day landform features with particular reference to *Tilla-Lunga* Topography and their impact on the habitats in the West District of Tripura “. He worked on the genesis of a unique topography i.e. *Tilla-lunga* which is found in the Tripura State (India). After submitting his thesis, he was engaged with the landscape mapping of archeological sites in Indian States of Bihar, Odisha and Jharchand.

He has published 10 research papers in peer reviewed journal. He also written 3 books as coauthor in Geoarcheology. He has presented research papers in 7 national and international conferences.

DR. MOHAMED OMAR ABOUELRESH

Dr. Mohamed Omar Abouelresh is presently working as a Research Scientist II in the Terrestrial Group at Center for Environment & Marine Studies, Research Institute. He moved to the Center in 2019 from CPG, KFUPM where he was working since 2013.

Dr. Mohamed obtained his Ph.D. from Suez Canal University, Egypt in 2005. His dissertation was about the seismic sequence stratigraphy of offshore Egyptian gas field. In 2008, he joined the University of Oklahoma, USA as a Post Doc. to work on basin sedimentary analysis. From 2008 to 2011, he worked in the Institution of Reservoir Characterization, University of Oklahoma as an Associate Research Professor. Dr. Abouelresh was a team leader in this institute where he led the geological assessment of the unconventional shale gas resources (Barnett and Woodford shales).

Dr. Mohamed has a wide range of research areas of interest include; sedimentology, depositional environments, wetlands and quaternary deposits. He also published 26 papers in peer-reviewed journals and presented his research results at more than 20 regional and international conferences. Dr. Abouelresh have taught unconventional shale gas course to graduate students from the Geoscience and Petroleum Engineering Depts.

DR. MAZEN KHALED NAZAL

Dr. Mazen Nazal is a Research Scientist III in the Marine Studies Section (MSS) at Center for Environment & Water (CEMS), Research Institute at King Fahd University of Petroleum & Minerals (KFUPM) Dhahran, Saudi Arabia. Dr. Nazal got his Ph.D. in Chemistry specializing in Analytical and Environmental Chemistry in 2016 from King Fahd University of Petroleum and Minerals KFUPM. He received his MS and BS degrees in Chemistry from The University of Jordan, Jordan in 2006 and 2003, respectively.

Between 2003 and 2010, Dr. Nazal worked as an analyst, senior analyst and study director in a private research unit and as a laboratories supervisor in The University of Jordan. Dr. Nazal also worked as a Lecturer in the chemistry department at Al-Jouf University in Saudi Arabia, before his joining the Ph.D program at King Fahd University of Petroleum and Minerals (KFUPM) in 2012. He taught many chemistry courses (i.e. General chemistry, analytical chemistry, laboratory management, separation science and inorganic chemistry).

Dr. Nazal joined the Research Institute at KFUPM in June 2016. As a Research Scientist III and deputy supervisor of the Environmental Chemistry and Analytical Laboratories ECAL at CEMS. Dr. Nazal's research interests are focused on the development of efficient and selective materials and methods for removal of pollutants from different matrices. In addition, employing these materials for extraction and enrichment of analytes of interest in environmental, food and biological samples prior to their instrumental analysis. The analytes of interest include organic sulfur compounds, polycyclic aromatic hydrocarbons, organochlorine pesticides, polychlorinated biphenyls, heavy metals, etc. His research domains broadly extend into Environmental Analytical Chemistry. Additionally, he is interested in the fabrication of sensors and biosensors for detection of biologically important molecules.

Dr. Nazal has published many research papers in refereed ISI journals and 3 main application patents registered in US patent office. He attended and participated in many international conferences. He has participated in writing technical reports and research proposals. He is member of a number of professional societies.

DR. AARIF K MUHAMMED

Dr Aarif K. Muhammed has joined the Center for Environment and Water, RI/KFUPM, as a Laboratory Specialist in September 2019 and working on diversified aspects of terrestrial fauna. Aarif has obtained his PhD degree from Kannur University, India in 2014. It was carried out with UGC-CSIR Fellowship, Govt of India. His MSc, PhD and Post doc research were on ecology and behaviour of Avian fauna. A total of 16 years of research experiences in ecology of shorebirds, he was engaged in a conservation project in United Arab Emirates. They are Gazelles and comes under in IUCN Red List.

International network for collaborative research undertaken with Smithsonian Conservation Biology Institute USA, Lakehead University Canada, Edith Cowan University Australia, Messy University New Zealand, Czech university of Life Science Czech Republic, Bialystok University of Tech Poland, Port and Airport Research institute Japan, University of Science of Tunis Tunisia, UAE university UAE and University of Bahrain, Bahrain.

Aarif has published 20 research papers both international and national ISI indexed journals, 30 popular articles published in leading newspapers between 2005 to 2019. He has authored two books (Silent shores and migration). Reviewed many papers from Avian Research, and Stilt journals. Supervised few students master dissertations and as of now, three PhD candidates working under his co-supervision in versatile aspects of avian ecology and behaviour. Aarif was consultant of a research project entitled as Ecology of Wetland birds in Kerala, India and funded by University Grant Commission, India.

DR. AHSAN M. SHEMSI

Dr. Shemsi is a Research Scientist II in the Center for Environment and Marine Studies, RI/KFUPM. He obtained his BS in analytical chemistry and MS in Analytical Environmental Chemistry from Quaid-e-Azam University, Islamabad, Pakistan. He got his Ph. D (Chemistry) from King Fahd University of Petroleum and Minerals, Daharan, Saudi Arabia.

Before joining RI-KFUPM he worked as scientist and Senior Scientist in The National Institute for Biotechnology and Genetic Engineering, Faisalabad Pakistan 1991-2002 (An affiliate of ICGEB, Trieste, Italy) and remained involve in the downstream processing of minerals and ores, bioremediation of contaminated arable land, microbial enhanced oil recovery, microbial assisted mineral recovery, bioaccumulation of heavy metals, development of biosensors and toxicity testing kits and on GMOs.,

He has also worked as investigator with Mc Mott International for River Indus water contamination studies (1994-1995).

Dr. Shemsi has published 17 research papers in international refereed journals and attended many conferences. These publications cover the areas of *Industrial and environmental biotechnology, genetic engineering, protein chemistry, radionuclide chemistry, inorganic and analytical chemistry, magnetometry and X-ray crystallography*. In addition to that he is co-author of a book entitled “*Handbook of industrial chemistry, organic Chemicals*” by McGraw-Hill for industrial chemistry students.

In CEMS Dr. Shemsi is involved in many studies related with baseline environmental, environmental impact assessment and continuous monitoring projects. He is also collaborating in different project with other Centers of research institute.

DR. SYED MASIUR RAHMAN

Dr. Syed Masiur Rahman is working as a Research Engineer in the Center for Environment and Marine Studies (CEMS) at the Research Institute of King Fahd University of Petroleum & Minerals (KFUPM). Dr. Rahman earned his Ph.D. in Civil Engineering from KFUPM in 2010. He joined the Department of City & Regional Planning at KFUPM in 2002 and obtained Master of City & Regional Planning in 2004. He earned B.Sc. in Civil Engineering from Bangladesh University of Engineering & Technology (BUET) in 2000.

Dr. Rahman is actively involved with the environmental impact assessment studies conducted by CEMS since 2003. Dr. Rahman was awarded with a Certificate of Distinction-KFUPM (2005-2006), as a member of the research team for the project titled *Environmental Impact Assessment – contract Area A in Northern Part of Rub Al-Khali, Stage 1-2D and 3D Seismic Operation*. Dr. Rahman already published more than fifty scientific articles in international referred journals, two book chapters, and thirteen articles in international conference proceedings. He is a co-author of two books which address both human resources management and planning aspects in the context of Saudi Arabia. He actively took part in many academic projects which addressed transportation and data science related problems. He contributed in developing different machine learning based models for different disciplines.

Dr. Rahman contributed to the national project titled *2000 National Inventory of Direct Greenhouse Gas Emissions for the Kingdom of Saudi Arabia*. He was also a senior member of the projects related to the national greenhouse gas inventories for the years 2010 and 2012, greenhouse gas emissions impact of Energy to Kingdom (E2K) scenarios and supporting studies for national climate change strategies. His critical investigation of appropriate mitigation measures to reduce greenhouse gas emissions for the Kingdom is also published in prestigious scientific journals including *Renewable and Sustainable Energy Review*.

Dr. Rahman contributed in the Environmental Impact Assessment (EIA) studies, which were mainly focused on the oil and gas development projects in the Rub Al-Khali desert. He was involved with those projects from the initial stage. He also contributed in developing a team specialized on spatial analysis. He published a few articles on Geographical Information System (GIS) and conducted a short course titled *Different Features of GIS and its Applications for Petroleum Industry Practices* in an international conference. His enthusiastic learning capability supported by multi-disciplinary experiences made it possible to contribute significantly in the area of environmental assessment including theoretical accomplishments. His articles on EIA and strategic environmental assessment (SEA) are well-accepted among the scientific community.

Currently, Dr. Rahman is investigating the existing approaches of EIA studies in the Kingdom to develop sustainable approach along with the modification of the environmental policy making process. He is also working with a multi-disciplinary team including national and international experts for developing advanced artificial intelligence (AI) based air quality and greenhouse gas models. He is investigating the applicability of those spatial and temporal models in the context of Saudi Arabia.

ENG. ALI HASSAN ALMUSABEH

Mr. Ali Hassan Almusabeh joined in Center of Environment & Water, King Fahd University of Petroleum and Minerals in 2019. Mr. Ali completed Bachelor of Science in 2004 and Master of Soil & Water Science from College of Agricultural and Food Sciences, King Faisal University, Kingdom of Saudi Arabia in 2012. He has completed training program on Measurement of soil and water Atomic Absorption, Spectrophotometer and Server Program for 3D Geological Map Drawing.

Mr. Ali has published a research paper in 3 peer reviewed journals. The title of his MS thesis is “Effect of Compost, Irrigation and Nitrogen Fertilizer levels on Turf-grass Management 2012”. He has attended 3 conferences in Saudi Arabia. He is also a member of the Media-Committee at the Charity Society of Al-Ahsa.

Mr. Ali has 15 years work experience in testing soil, various fields of agriculture and floristic survey. He has experience in testing several soil parameters like Atomic Absorption Spectrophotometer, GC/MS, TOC-Analyzer, Spectrophotometer, Turbidity Meter, pH Meter, EC Meter, Flame Photometer, Kjeldahl Apparatus, Pressure Plate Extractor.

DR. NAVEEN KUMAR V.V.

Dr. Naveen Kumar working as Lab Specialist in the Center for Environment and Marine Studies of the Research Institute of the King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia.

Before joining KFUPM/RI, he worked as project Scientist at the plant taxonomy and genetic resources division of Centre for Medicinal Plants Research, Arya Vaidya Sala, Kottakal where he conducted floristic research in all the habitats throughout south India.

He received his MS degree in 2012 from Mahatma Gandhi University, Kerala in Botany and currently pursuing his doctoral degree titled 'Species diversity and resource mapping of Angiosperms in Ernakulam District, Kerala' from the same university. He has more than 8 years of research experience in floristics and explored remote areas as well as coastal areas of Kerala and introduced and named more than 10 plant species to science.

He has published more than 30 research papers in various international journals and presented research papers in various national and international conferences. He is also serving as a reviewer for the international journal 'Phytotaxa'.

MR. MUHAMED KABEER. K

Mr. Muhamed Kabeer. K is recently joined as (Position) in the Center for Environment and Marine Studies, Research Institute of the King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia.

He received his Master degree in Hydrochemistry from Cochin University of Science and Technology, India in 2014. After his masters he joined in the Chemical Oceanography Division of CSIR-National Institute of Oceanography, India as a researcher. Kabeer specializes in marine chemistry (Biogeochemistry). There his duties were processing of marine and freshwater samples, mooring and core sediment samples. Analysis of Dissolved and particulate trace metals in water samples, Inorganic carbon, biogenic silica and trace metals in sediment samples. Collection of water samples from different depth during field work.

He participated in different cruises during his short research career, finished more than hundred sea days in Arabian Sea and Bay of Bengal, also participated in different Field Works conducted by Chemical Oceanography Division, NIO in different rivers, estuaries, lakes and dam reservoirs in Goa, Maharashtra and Karnataka states of India for chemical and biological sample collection.

Done his MSc Dissertation for a period of three months at CSIR-National Institute Of Oceanography (NIO), Goa on “Distribution of Mercury in Water, Sediment and Biological Components : A Case Study in Mandovi-Zuari Estuarine Complex, off Goa” under the guidance of Mr. Durbar Ray senior Scientist, NIO, GOA. Also did summer dissertation for a two months at Indian National Centre for Ocean Information and Services (INCOIS) on "Comparing Dissolved Oxygen Concentration in the sub surface waters of the North Indian Ocean" under the guidance of Dr. Sathyaprakash, Ocean Sciences and Information Services Group (ISG), Hyderabad.

MR. MOHAMMAD ASIF MOHAMMAD ZAHID KHAN

Mr. Mohammad Asif is a researcher with the background in Analytical Chemistry. He has more than ten years' experience offer technical expertise in analytical & environmental laboratories. He has demonstrated experience in operation, corrective maintenance and troubleshooting of analytical equipment. He has conducted development, validation and assessment of analytical methods. He works on trace element analysis in seawater, sediments and biota by spectroscopic analytical techniques such as ICP-MS, ICP-OES and Hg analyzer. He has extensively worked on routine extraction and sample preparation of seawater for trace element. His work includes identification of technical issues and development of new analytical methods to resolve issues. He is excellent at analytical data interpretation and review quality of reports in order to fulfill compliance of quality control and quality assurance. He has worked for many clients funded Environmental Impact Assessment (EIA) projects and performed technical and non-technical research tasks. He has been involved in periodical offshore & onshore sample collection and their preservation. He has also trained laboratory technical staff and students from KFUPM & local universities & colleges.

He has contributed in research & development activities and published five-(05) research paper in refereed journal. He has also attended certified training program/workshop at national & international level.

DR. P. K. KRISHNAKUMAR

Dr. Krishnakumar works in the Center for Environment and Marine Studies, RI/KFUPM, as consultant since April 2019. Prior to this position he was serving the Center as Research Scientist since April 2008.

He obtained his Masters (Marine Biology) and PhD (Marine Pollution) degrees from the Cochin University of Science and Technology, India. He has completed his post-doctoral study (1992-93) on “biomarkers of marine pollution” from the Environmental Conservation Division, Northwest Fisheries Science Center (NOAA), Seattle, USA.

Dr. Krishnakumar’s specialization includes Environmental Impact Assessment (EIA), Coastal pollution monitoring, Biomarkers of Marine Pollution, Contaminant Monitoring using marine organisms, Eco-toxicology, Metal and hydrocarbon toxicity. As Project Manager, he has successfully completed around 24 client funded projects and as Lead Technical Expert, worked for around 60 client funded projects in CEMS. As principal investigator, he received the KACST funding (*Annual Research Grant Program*) during 2013-2015. He also received two outstanding Applied Researcher Awards (2011-2012 and 2016-2017), outstanding Applied Research Management Award (2012-2013) and two distinguished Applied Research Team Member Awards (2012-2013 and 2013-2014);

Prior to joining KFUPM, Dr. Krishnakumar worked for 22 years (1986-2008) as Senior Scientist/Principal Scientist in the Fisheries Environment Management Division of Central Marine Fisheries Research Institute (www.cmfri.org.in), Cochin, India. He is an experienced researcher and worked as Principal Investigator (PI) and Co-PI in various research projects dealing with fisheries oceanography, coastal pollution monitoring, marine EIA and EIM studies, coastal productivity, marine biodiversity assessment, impact of climate change on fisheries, marine mammals, mussel farming etc.

Dr. Krishnakumar was a recipient of prestigious IFS research grant (2000-03) from the International Foundation for Science (IFS), Stockholm, Sweden for young scientists in developing countries. He was a selected member of Roster of Experts established by the Scientific and Technical Advisory Panel of the GEF, UNEP since 1996.

Dr. Krishnakumar has published around 60 research papers in peer reviewed international journals and presented papers in several international conferences.

He is a member of the Editorial Board of the *Journal of the Marine Biological Association of India* since 2011 and *Review Editor* (Marine Pollution) of the journal *Frontiers in Marine Science* since 2015. He is the selected member the "Marine Science Committee" of Society for Conservation Biology (SCB) since July 2017.

APPENDIX B

AREA MAPS OF THE ACTIVITY SITE

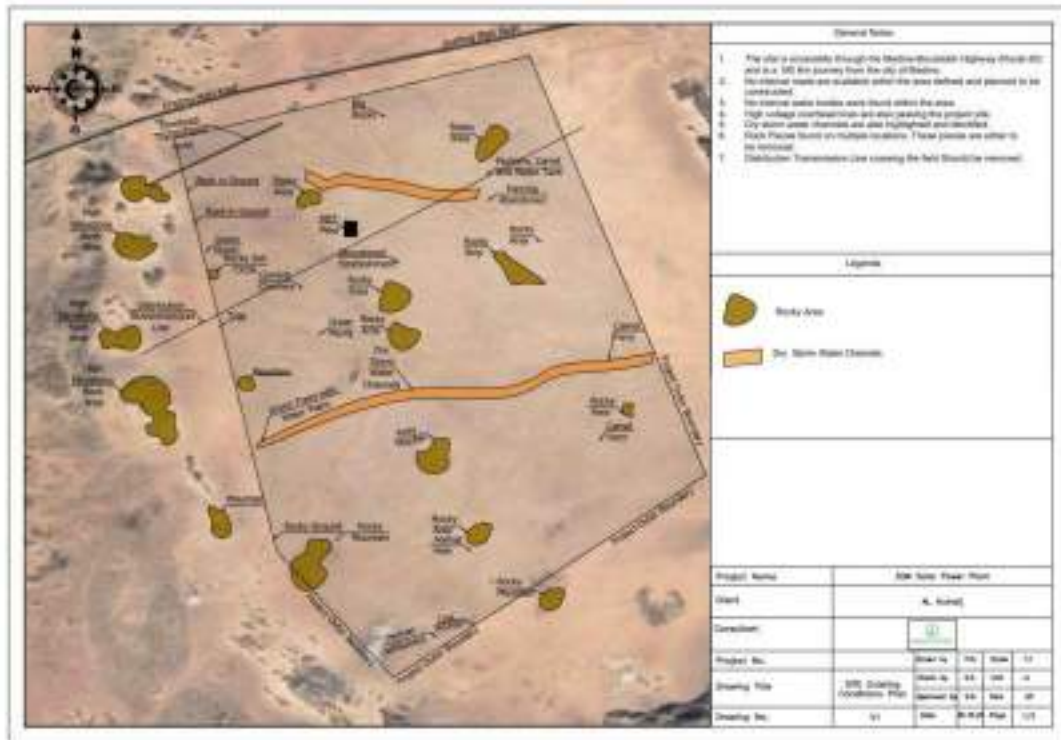


Figure1: Project Area

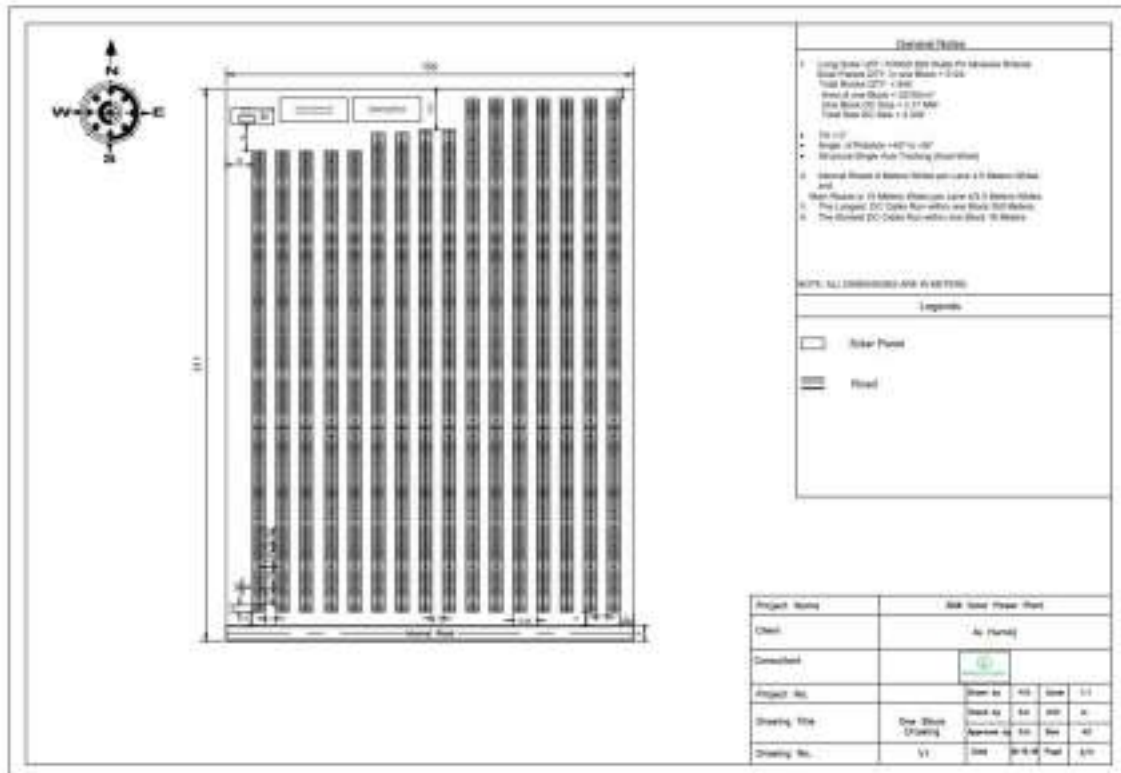


Figure1. : Solar PV design

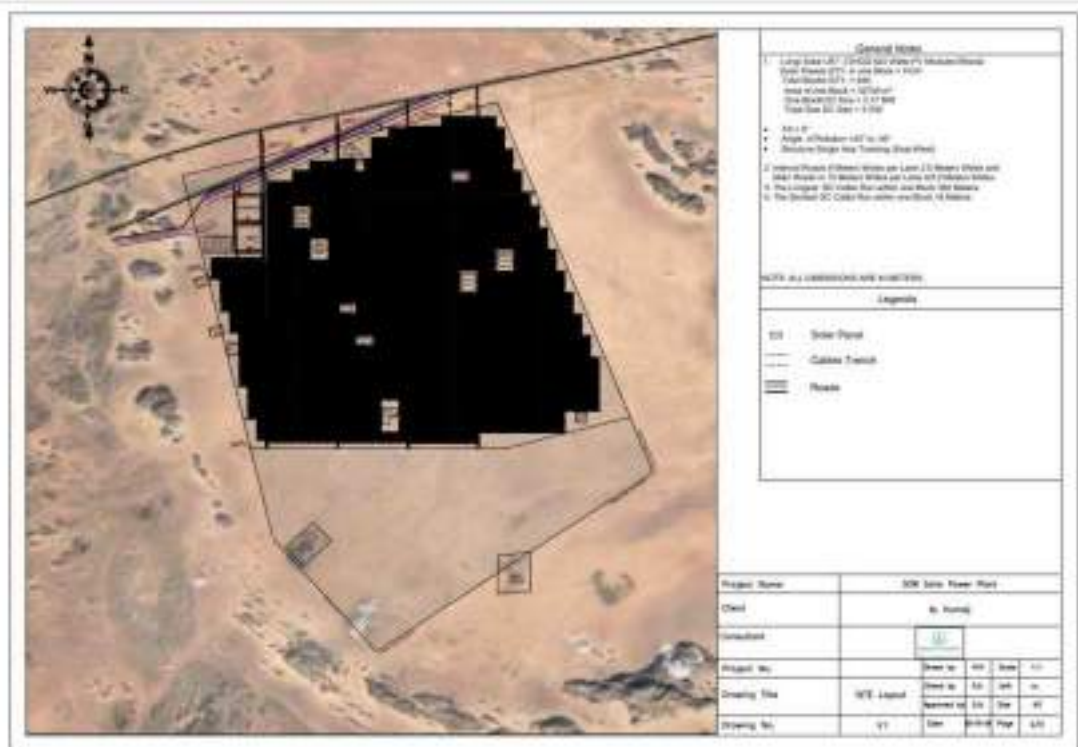


Figure 2: Solar PV Blocks considering exclusions



PVsyst V7.4.5

VC0. Simulation date: 02/16/24 15:08
with v7.4.5

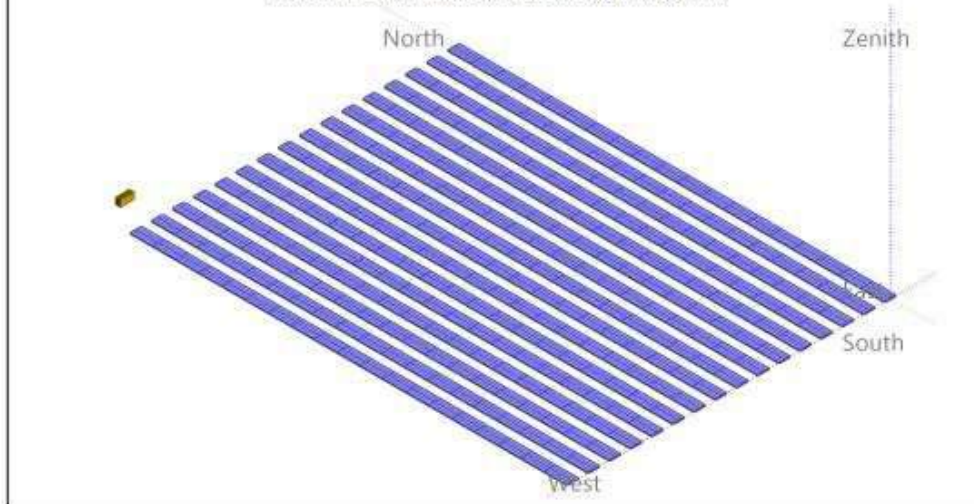
Project: Al Humajj - WP2 -3 GW_AIKO 635

Variant: One Block_3.18 MW Simulation_Aiko 635 W

Energy Futures Consulting (Pakistan)

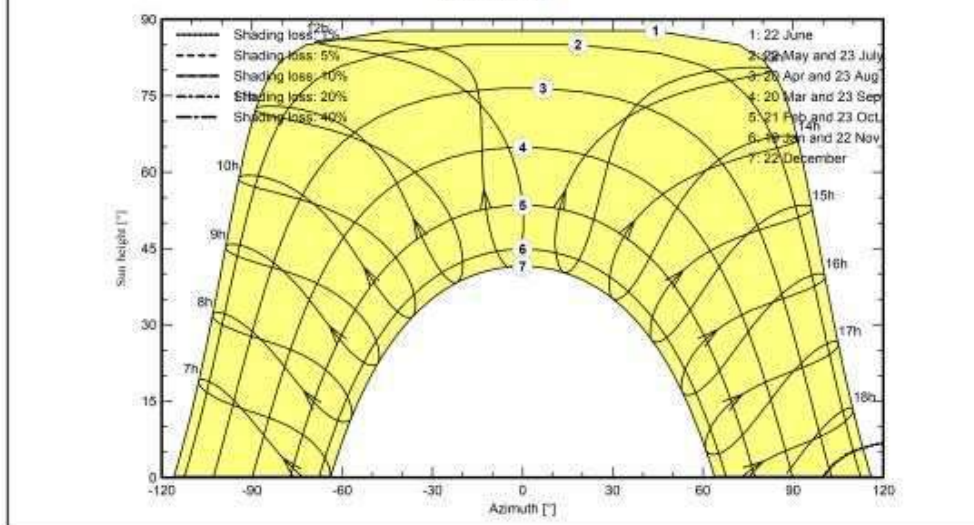
Near shadings parameter

Perspective of the PV-field and surrounding shading scene



Iso-shadings diagram

Orientation #1



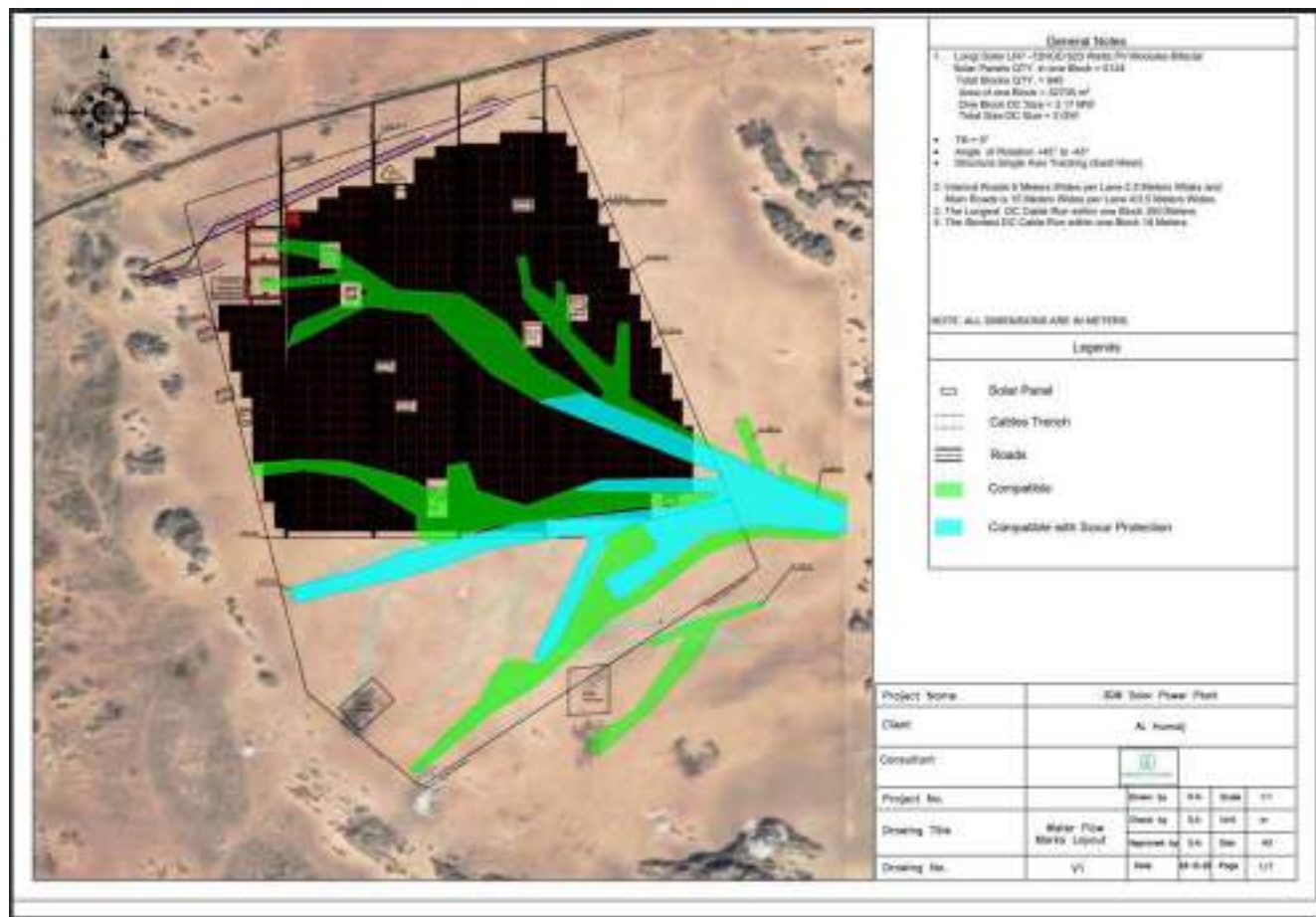


Figure 4: Water Flow Map

APPENDIX C
AREA OF INFLUENCE

Technical Appendix C: Area of Influence

**Environmental and Social Impact Assessments (ESIA) for
Installing and Operating a Solar Energy Park in Humaij,
Madena, Saudi Arabia**

**Applied Research Center for Environment and Marine Studies (CEMS)
King Fahd University of Petroleum & Minerals
Research Institute**

July 2024

1. Introduction

The areas of direct and indirect influence were defined in order to obtain a comprehensive view of the project emplacement area, as were the areas of sensitivity for each of the environmental components analysed in this study. This made it possible to identify environmental and social impacts and risks properly. Thus we can comply with the provisions of the Performance Standards (PS) administered by the IFC and to provisions of PS1, which indicates that the area of influence includes cumulative impacts or result of incremental impact on the areas or resources used or affected by the activity. This transcends the traditional concept of the “area of direct influence” and emphasizes the need to analyze indirect and cumulative effects as well as the need to expand the geographic limits in assessing the impact and/or the time framework used for the analysis.

2. Area of Influence

According to Canter et al. (1998), the area of influence is “The space where possible environmental and social impacts occur that are due to a project’s implementation”; however, the scope of the area of influence concept may be significantly relative. The area of influence is the fraction of the environment that interacts with project facilities and activities (resources, raw materials, labor, space) and their output (waste, emissions and jobs). The simple decision of establishing a circle of influence within a more or less broad radius around the unit being studied has no validity [Conesa, 1995], so methodological criteria established by the National Environmental Authority are used as described below.

The basic criterion to identify project areas of influence will be to recognize environmental components and the socioeconomic medium directly and indirectly affected by the activities developed as part of the project in all stages. In this respect, we must take into account that the environment related to the project includes the physical environment (soil, water and air components) where it exists and where biodiversity develops (flora and fauna components) as well as the socioeconomic medium with their cultural manifestations.

3. Project Area of Influence and Study Area

The initial step in the baseline characterisation is the definition of the Project Area of Influence (AOI) and the Study Area (Al-Humaij). The AOI (based on the definition in IFC PS1 (IFC, 2012) adopted by the Project is:

The area likely to be affected by:

- Project activities and facilities that are directly owned, operated, or managed (including by contractors) by the Project Proponent and that are a component of the Project;
- Impacts from unplanned but predictable developments caused by the Project that may occur later or at a different location; or
- Indirect Project impacts on biodiversity or on ecosystem services upon which ‘Affected Communities livelihoods are dependent.
- Associated facilities, which are facilities that are not funded as part of the Project and that would not have been expanded if the Project did not exist and without which the Project would not be viable. It is anticipated there will not be any associated facilities for the Project; and

- Cumulative impacts that result from the incremental impact, on areas or resources used or directly impacted by the Project, from other existing, planned or reasonably defined developments at the time the risks and impacts identification process is conducted.

Using this definition of the Project components an AoI was identified using the following criteria:

- Physical footprint of the Project, overhead lines and substation
- Area where noise effects may be experienced
- Area local to the Project that may be used as a resting/stopover point for migrating birds
- Area within the zone of theoretical visibility of the solar panels
- Area of 100 m either side of roads and access tracks
- Area of 100 m either side of overhead lines

4. Study Area

The study area is Al- Humaij, Madena, Saudi Arabia. The area of up to 5 km radius from the project boundary (solar plant area) has been demarcated as study area for the project by considering the extent of project impact in terms of noise, water resources, human settlement, cultural heritage sites, location of labour sites, location of the access roads besides considering the actual land area which has been procured for the project and its utility footprints.

5. Project Footprint Area

The Project Footprint is the area that may reasonably be expected to be physically touched by Project activities, across all phases. The Project Footprint for Project includes land used for the setting up the Solar PV's, transformer rooms, storage of materials, site office, access roads, and internal and external transmission lines.

6. Area of Influence (AoI)

The effects of the project and project activities on a particular resource or receptor will have spatial (distance) and temporal (time) dimensions, the scale of which is dependent on a number of factors. These factors are incorporated in the definition of the Project's Area of Influence (AoI). The AoI considered for the existing Project with respect to the environmental and social resources was based on the following reach of impacts:

Environmental parameters: Project site boundary, immediate vicinity, Access road and surroundings, i.e. a study area of approximately 5 km (here after referred to as the AoI) distance from project line has been used to depict these parameters;

- *Air Quality:* Dust emissions, fugitive dust- typically up to 500 m from a construction area and 100 m from operations and maintenance area;
- *Noise:* Noise impact area (defined as the area over which an increase in environmental noise levels due to the Project can be detected) –typically 1,000 m from operations;

- *Land environment*: The impacts on soil and land- typically up to 500 m from the project footprint area;
- *Ecological Environment (Terrestrial)*: The direct footprint of the project comprising the Solar park; (b) The areas immediately adjacent to the project footprint within which a zone of ecological disturbance is created through increased dust, human presence and project-related activities (e.g., trampling, transportation activities). The AoI for the project is identified as the area within a 10 km radius of the project footprint area;

Social and Cultural: The AoI for the project is identified as the area within a 10 km radius of the project footprint area and/or area identified beyond 10 km that is directly impacted by project activities.

Table 1. Area of Influence Applicable to the Solar Park Project

Si. No.	Environmental and Social Receptors	Area of Influence (AoI)	Justification
1	Air Quality	500 m	Dust emissions, fugitive dust, etc. is typically observed within 100-200 m from the construction/operation area. A minimum of 500 m AoI has been taken to capture all sources of these emissions including vehicular movement across access roads
2	Noise Pollution	1000 m	Noise can often be detected up to 800-1000 m from any operation
3	Water Environment	500 m	Water bodies located in the vicinity of the project area may be impacted due to activities at the project footprint and allied sites.
4	Terrestrial Environment	500 m	Impacts on soil and land are often restricted to the Project footprint area. An AoI of 500m taking into account indirect effects usually occur due to vehicular/ heavy machinery movements and activities at allied sites .
5	Socio-economic Conditions	10,000 m	An AoI of 10 km radius is considered for socio-economic consultations to determine perceived impacts due to the Project including employment opportunities, loss of livelihood (grazing and agricultural land) and increased anthropogenic/vehicular activity in remote areas
6	Ecology	10,000 m	An AoI of 10 km radius is considered for the ecological study. The 10 km radius provides an understanding use of desert habitat around the proposed Solar Park

7. Core and Buffer Zone:

This AoI is in turn, divided into a core and buffer zone. This division of the AoI into two zones is based on the understanding that the majority of the impacts from the project (during the project lifecycle) would be contained within a 1 km radius (core zone) from the Project Footprint in terms of spread and intensity, with the buffer zone (10 km radius) appearing to have limited interaction with the project.

The Buffer Zone is the area that does not have a direct impact on land or the environment, however, it is demarcated in case the impact on the core zone is sometimes/often extended to near-by areas. Usually, the impact on buffer zone is more inclined towards, noise, air and water pollution. In some cases it also has an impact on labour, land ownership, migration and accessibility to any natural resources.

For socio-economic baseline assessment, core (5 km from the project site) and buffer zones (beyond 5 km and within 10 km of the project site) as shown in Figure 1 below.

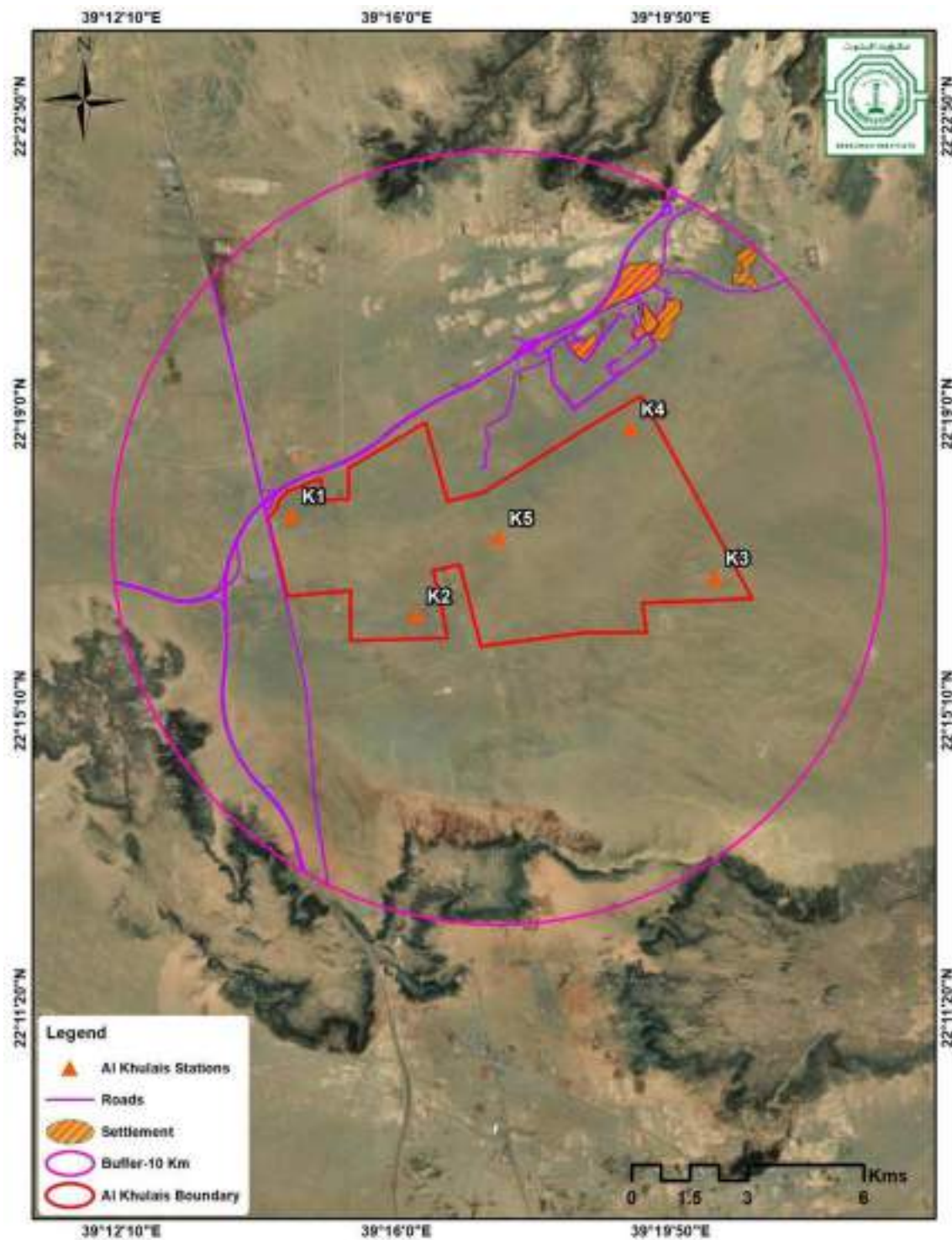


Figure 1: Core Zone and Buffer Zone of Study Area

APPENDIX D
CRITICAL HABITAT ASSESSMENT

Technical Appendix D: Critical Habitat Assessment

**Environmental and Social Impact Assessments (ESIA) for
Installing and Operating a Solar Energy Park in Khulais,
Madena, Saudi Arabia**

**Center for Environment and Marine Studies (CEMS) at King Fahd University of
Petroleum & Minerals Research Institute**

July 2024

APPENDIX D: CRITICAL HABITAT ASSESSMENT

1.1 INTRODUCTION

A Critical Habitat Assessment (CHA) is required to comply with international lender performance standards, particularly those of the International Finance Corporation (IFC), specifically Performance Standard 6 (PS6), which is relevant to biodiversity conservation and sustainable management of living natural resources. This report comprises a CHA as required by PS6 and includes classification of the Project Area habitats as Natural and Modified.

This CHA provides an assessment of critical habitat applicable to the Proposed Project. This appendix is based on the baseline information provided in *Section 4: Ambient Environment Description*. The ESIA Report was informed by an extensive literature review and in-field data collection.

Definition of Critical Habitat

Critical habitat is defined in Paragraph 16 of the 2012 version of IFC Performance Standard 6 (IFC PS6) as an area with high biodiversity value. This includes areas that meet one or more of following criteria:

- Criterion 1: Critically Endangered (CR) and/or Endangered (EN) species;
- Criterion 2: Endemic and/or restricted range species;
- Criterion 3: Migratory and/or congregatory species;
- Criterion 4: Highly threatened and/or unique ecosystems; and
- Criterion 5: Key evolutionary processes.

However, as specified by GN56 of the IFC's Guidance Note 6, the determination of critical habitat can include other recognized high biodiversity values which are to be evaluated on a case-by- case basis. GN56 provides the following seven examples:

- Areas required for the reintroduction of CR or EN species and refuge sites for these species (habitat used during periods of stress (e.g. flood, drought or fire);
- Ecosystems of known special significance to EN or CR species for climate adaptation purposes;
- Concentrations of Vulnerable (VU) species in cases where there is uncertainty regarding the listing, and the actual status of the species may be EN or CR;
- Areas of primary/old-growth/pristine forests and/or other areas with especially high levels of species diversity;
- Landscape and ecological processes (e.g. water catchments, areas critical to erosion control, disturbance regimes (e.g. fire, flood)) required for maintaining critical habitat;

- Habitat necessary for the survival of keystone species; and
- Areas of high scientific value such as those containing concentrations of species new and/or little known to science.

Furthermore, GN57 states that in general, internationally and/or nationally recognised areas of high biodiversity value will likely qualify as critical habitat, including the following:

- Areas that meet the criteria of the IUCN 's Protected Area Management Categories Ia, Ib and II, although areas that meet criteria for Management Categories III-VI may also qualify depending on the biodiversity values inherent to those sites;
- UNESCO Natural World Heritage Sites that are recognized for their Global Outstanding Value;
- The majority of Key Biodiversity Areas (KBAs), which encompass inter alia Ramsar Sites, Important Bird Areas (IBA), Important Plant Areas (IPA) and Alliance for Zero Extinction Sites (AZE);
- Areas determined to be irreplaceable or of high priority/significance based on systematic conservation planning techniques carried out at the landscape and/or regional scale by governmental bodies, recognized academic institutions and/or other relevant qualified organizations (including internationally recognized NGOs); and
- Areas identified by the client as High Conservation Value (HCV) using internationally recognized standards, where criteria used to designate such areas is consistent with the high biodiversity values listed in paragraph 16 of IFC PS6.

GRADIENT OF CRITICAL HABITAT

IFC Guidance Note 6 recognizes that there are gradients of critical habitat based on relative vulnerability (degree of threat) and irreplaceability (rarity or uniqueness). For Criteria 1-3, listed in this Appendix, quantitative thresholds are provided to assign critical habitat into either Tier 1 or Tier 2. Table 1 details the relevant quantitative thresholds for tiers 1 and 2 of Critical Habitat Criteria 1 – 3.

Table 1: Quantitative Thresholds for Tiers 1 and 2 of Critical Habitat Criteria 1 – 3

CRITERION	TIER 1	TIER 2
1. CR/ EN Species	(a) Habitat required to sustain $\geq 10\%$ of the global population of a CR or EN species/subspecies where there are known, regular occurrences of the species and where that habitat could be considered a discrete management unit for that species. (b) Habitat with known, regular occurrences of CR or EN species where that habitat is one of 10 or fewer discrete management sites globally for that species.	(c) Habitat that supports the regular occurrence of a single individual of a CR species and/or habitat containing regionally- important concentrations of a Red-listed EN species where that habitat could be considered a discrete management unit for that species/ subspecies. (d) Habitat of significant importance to CR or EN species that are wide-ranging and/or whose population distribution is not well understood and where the loss of such a habitat could potentially impact the long-term survivability of the species. (e) As appropriate, habitat containing nationally/regionally important concentrations of an EN, CR or equivalent national/regional listing.
2. Endemic/ Restricted Range Species	(a) Habitat known to sustain $\geq 95\%$ of the global population of an endemic or restricted-range species where that habitat could be considered a discrete management unit for that species (e.g. a single-site endemic).	(b) Habitat known to sustain $\geq 1\%$ but $< 95\%$ of the global population of an endemic or restricted-range species where that habitat could be considered a discrete management unit for that species, where data are available and/or based on expert judgment.
3. Migratory/ Congregatory Species	(a) Habitat known to sustain, on a cyclical or otherwise regular basis, $\geq 95\%$ of the global population of a migratory or congregatory species at any point of the species' lifecycle where that habitat could be considered a discrete management unit for that species.	(b) Habitat known to sustain, on a cyclical or otherwise regular basis, $\geq 1\%$ but $< 95\%$ of the global population of a migratory or congregatory species at any point of the species' lifecycle and where that habitat could be considered a discrete management unit for that species, where adequate data are available and/or based on expert judgment. (c) For birds, habitat that meets BirdLife International's Criterion A4 for congregations and/or Ramsar Criteria 5 or 6 for Identifying Wetlands of International Importance. (d) For species with large but clumped distributions, a provisional threshold is set at $\geq 5\%$ of the global population for both terrestrial and marine species. (e) Source sites that contribute $\geq 1\%$ of the global population of recruits.

Neither IFC Performance Standards nor Guidance Note 6 define what constitutes a nationally/regionally important concentration. However, as Tier 1 critical habitat under Criterion 1 is defined by $\geq 10\%$ of the global population of a CR or EN species, Tier 2 Critical Habitat has been defined by $\geq 10\%$ of the national/regional population of a CR or EN species.

UNIT OF ANALYSIS

The scale at which the critical habitat determination takes place depends on underlying ecological processes for the habitat and species in question and is not limited to the footprint of the Proposed Project. GN65 of IFC's Guidance Note 6 states that for Criteria 1-3, the determination of critical habitat should be based on a "discrete management unit" (DMU) which is an area that has a definable boundary within which the biological communities have more in common with each other than they do with those outside the boundary. GN65 goes on to provide the following additional guidance on the selection of the DMU:

"A discrete management unit may or may not have an actual management boundary (e.g. legally protected areas, World Heritage sites, KBAs, IBAs, community reserves) but could also be defined by some other sensible ecologically definable boundary (e.g. watershed, interfluvial zone, intact forest patch within patchy modified habitat, seagrass habitat, coral reef, concentrated upwelling area, etc.). The delineation of the management unit will depend on the species (and, at times, subspecies) of concern".

METHODOLOGY

CRITERION 1: CRITICALLY ENDANGERED AND/OR ENDANGERED SPECIES

Biodiversity identifies threatened species that have the potential to be present within the Proposed Project Area. This has been completed with reference to the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (RL) [IUCN, 2013]. The classification system used by the IUCN RL for representing the extinction risk of species is presented in Table 2. Species classified as VU or above on the IUCN RL are often referred to as 'threatened' species.

Table 2: IUCN Categories of Extinction Risk [IUCN, 2012]

IUCN Category	Definition
Extinct in the Wild (EXW)	A taxon is Extinct in the Wild when it is known only to survive in cultivation, in captivity or as a naturalised population (or populations) well outside the past range.
Critically Endangered (CR)	Species facing an extremely high risk of extinction in the wild.
Endangered (EN)	Species facing a very high risk of extinction in the wild.
Vulnerable (VU)	Species facing a high risk of extinction in the wild.
Near Threatened (NT)	A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.
Data Deficient (DD)	Inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status.

Least Concern (LC)	A taxon is Least Concern when it has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are included in this category.

CRITERION 2: ENDEMIC AND/OR RESTRICTED-RANGE SPECIES

IFC's Guidance Note 6 provides the following definitions for Endemic and restricted-range species as follows:

- *“Endemic species: defined as one that has ≥95% of its global range inside the country or region of analysis.*
- *Restricted-range species:*
 - *For terrestrial vertebrates, a restricted-range species is defined as those species which have an extent of occurrence of 50,000 km² or less.*
 - *For marine systems, restricted-range species are provisionally being considered those with an extent of occurrence of 100,000 km² or less.*
 - *For freshwater systems, standardized thresholds have not been set at the global level. However an IUCN study of African freshwater biodiversity applied thresholds of 20,000 km² for crabs, fish, and molluscs and 50,000 km² for odonates (dragonflies and damselflies). These can be taken as approximate guidance, although the extent to which they are applicable to other taxa and in other regions is not yet known.*
 - *For plants, restricted-range species may be listed as part of national legislation. Plants are more commonly referred to as “endemic,” and the definition provided in paragraph GN79 would apply.”*

Species listed in *Section 4: Ambient Environment Description* of the ESIA report were screened to identify whether they meet the definition of either endemic or range-restricted species. Species list was prepared based on field survey, published sources and in liaison with experts. Criterion 1 and 2 are addressed at the same time in Section 3 of this appendix.

CRITERION 3: MIGRATORY AND CONGREGATORY SPECIES

IFC Guidance Note 6 defines migratory and congregatory species in the following way:

- *Migratory species:*
 - *“any species of which a significant proportion of its members cyclically and predictably move from one geographical area to another (including within the same ecosystem).”*
- *Congregatory species:*
 - *“species whose individuals gather in large groups on a cyclical or otherwise regular and/or predictable basis;*
 - *Species that form colonies;*

- *Species that form colonies for breeding purposes and/or where large numbers of individuals of a species gather at the same time for non-breeding purposes (e.g., foraging, roosting);*
- *Species that move through bottleneck sites where significant numbers of individuals of a species pass over a concentrated period of time (e.g., during migration);*
- *Species with large but clumped distributions where a large number of individuals may be concentrated in a single or a few sites while the rest of the species is largely dispersed (e.g., wildebeest distributions); and*
- *Source populations where certain sites hold populations of species that make an inordinate contribution to recruitment of the species elsewhere (especially important for marine species)."*

For birds, habitat that meets Birdlife International's Criterion A4 for congregations and/or Ramsar Criteria 5 or 6 for Identifying Wetlands of International Importance meet the Tier 2 classification for critical habitat. Section 4: Ambient Environment Description identifies a few migratory bird species that have been recorded within the Proposed Project Area.

CRITERION 4: HIGHLY THREATENED AND/OR UNIQUE ECOSYSTEMS

IFC Guidance Note 6 defines highly threatened or unique ecosystems as:

- *"at risk of significantly decreasing in area or quality;*
- *with a small spatial extent; and/or*
- *containing unique assemblages of species including assemblages or concentrations of biome-restricted species."*

A working group has been established by the IUCN to develop a system of quantitative categories and criteria, analogous to those used for species, for assigning levels of threat to ecosystems at local, regional, and global levels (IUCN, 2016) [Bland et al., 2016]. Ecosystems that fall within the Proposed Project Area and meet the definition of EN or CR according to IUCN (2016) are assumed to meet Criterion 4 for critical habitat (Table 3). For many habitat types, data on distribution, quality and functioning are lacking. In these instances estimates have been made based on available evidence, professional judgement and levels of protection (e.g. habitats specifically protected by law, or proportion of habitat types occurring within protected areas).

Table 3: Summary of IUCN Ecosystem Red List Criteria

CRITERION	CR	EN
A: Reduction in geographic distribution	Reduction in geographic distribution of >80% in any 50 year time period.	Reduction in geographic distribution of >50% in any 50 year time period.
B: Restricted geographic distribution	Extent of Occurrence (EOO) of <2000 km ² Area of Occurrence (AOO) <2 10x10 km grid cells	EOO of <20,000 km ² AOO <20 10x10 km grid cells

C: Environmental degradation	Reduction in an abiotic variable affecting more than 80% of ecosystem in 50 year time period.	Reduction in an abiotic variable affecting more than 50% of ecosystem in 50 year time period.
D: Disruption of biotic processes or interactions	Reduction in a biotic variable affecting more than 80% of ecosystem in 50 year time period.	Reduction in a biotic variable affecting more than 50% of ecosystem in 50 year time period.
E: Quantitative analysis that estimates the probability of ecosystem collapse	Quantitative analysis that estimates the probability of ecosystem collapse to be >50% in 50 years.	Quantitative analysis that estimates the probability of ecosystem collapse to be >20% in 50 years.

CRITERION 5: KEY EVOLUTIONARY PROCESSES

Evolutionary processes are often strongly influenced by structural attributes of a region, such as its topography, geology, soil and climate over a period of time. IFC Guidance Note 6 suggests that this criterion is defined by:

- *“the physical features of a landscape that might be associated with particular evolutionary processes; and/or*
- *sub-populations of species that are phylogenetically or morphogenetically distinct and may be of special conservation concern given their distinct evolutionary history.”*

For the purposes of this assessment, the Proposed Project Area has been screened against the following factors:

- Level of isolation (e.g. islands, mountaintops, lakes are associated with populations that are phylogenetically distinct);
- Extent of endemism (areas of high endemism often contain flora and/or fauna with unique evolutionary histories);
- Spatial heterogeneity;
- Presence of environmental gradients (ecotones produce transitional habitat which has been associated with the process of speciation and high species and genetic diversity);
- Edaphic interfaces; and
- Connectivity between habitats (e.g. biological corridors).

Criterion 5 is usually considered at a relatively fine scale (TBC and FFI, 2012) and thus the most appropriate unit of analysis is that which may potentially experience direct, primary impacts from the Proposed Project (i.e. the Proposed Project Area).

DETERMINATION AND RESULTS SCREENING FOR CRITERIA 1

The species identified by the ESIA Report as being likely to be present within the Proposed Project Area have been screened to identify species that are classified as either Critically

Endangered or Endangered, as well as endemic or range restricted species (Table 4). Total of 51 species comprising 24 plant species, 16 avifauna species, 6 mammal species, 2 reptile species, and 3 bat species occurring in the project area in Al Humaij was compiled in Table 4. All these species were screened out as a result of no known records from the vicinity of the Project Area, lack of suitable habitat, or, if there are records from the vicinity of the Project Area, insufficient suitable habitat being present to support enough individuals to be within the quantitative thresholds for classifying CH.

Table 4. Screening of Species Relevant to Criteria 1 (CR / EN Species) and 2 (Restricted-range Species) from the project area.

Group	Common Name	Scientific Name	Red List Status	Extend of Occurrence (EOO) km2	Global Population Estimate	Screened In / Out	Rationale
FLORA	Plant	<i>Aizoon canariense</i> L.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Haloxylon salicornicum</i> (Moq.) Bunge ex Boiss.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Asphodelus tenuifolius</i> Cav.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Leysera leyseroides</i> (Desf.) Maire	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Arnebia hispidissima</i> (Lehm.) DC.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Diploaxis acris</i> (Forssk.) Boiss.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Eremobium aegyptiacum</i> var. <i>lineare</i> (Del.) Zohary.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Farsetia aegyptia</i> Turra.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Polycarpaea repens</i> (Forssk.) Asch. & Schweinf.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Cleome amblyocarpa</i> Barr. & Murb.	NL		Unknown	Out	Recorded from the project area

Group	Common Name	Scientific Name	Red List Status	Extend of Occurrence (EOO) km2	Global Population Estimate	Screened In / Out	Rationale
	Plant	<i>Citrullus colocynthis</i> (L.) Schrader	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Euphorbia granulata</i> var. <i>granulata</i> Forssk.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Senna italica</i> Miller	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Trigonella stellata</i> Forssk.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Vachellia tortilis</i> (Forssk.) Galasso & Banfi	LC		Unknown	Out	Recorded from the project area
	Plant	<i>Cistanche violacea</i> (Desf.) G. Beck.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Schismus barbatus</i> (L.) Thell.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Cenchrus ciliaris</i> L.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Emex spinosa</i> (L.) Campd.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Ochradenus baccatus</i> Del.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Lyceum shawii</i> Roem. & Schult.	LC		Unknown	Out	Recorded from the project area

Group	Common Name	Scientific Name	Red List Status	Extend of Occurrence (EOO) km2	Global Population Estimate	Screened In / Out	Rationale
	Plant	<i>Fagonia indica</i> Burm.f.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Seetzenia lanata</i> (Willd.) Bullock.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Kickxia aegyptiaca</i> (L.) Nab.	NL		Unknown	Out	Recorded from the project area
FAUNA	Rough tailed Rock Agama	<i>Stellagama stellio</i>	LC		Unknown	Out	Recorded from the project area
Reptile	Snake tailed fringe toed Lizard	<i>Acanthodactylus opheodurus</i>	LC		Unknown	Out	Recorded from the project area
Reptile	Arabian Great Shrike	<i>Lanius excubitor aucheri</i>	LC		Unknown	Out	Recorded from the project area
Bird	Bar-tailed Lark	<i>Ammomanes cincturus</i>	LC		Unknown	Out	Recorded from the project area
Bird	Blackstart	<i>Oenanthe melanura</i>	LC		Unknown	Out	Recorded from the project area
Bird	Blue Rock Pigeon	<i>Columba livia</i>	LC		Unknown	Out	Recorded from the project area
Bird	Crested lark	<i>Galerida cristata</i>	LC		Unknown	Out	Recorded from the project area
Bird	Desert Lark	<i>Ammomanes deserti</i>	LC		Unknown	Out	Recorded from the project area

Group	Common Name	Scientific Name	Red List Status	Extend of Occurrence (EOO) km2	Global Population Estimate	Screened In / Out	Rationale
Bird	Desert Wheatear	<i>Oenanthe deserti</i>	LC		Unknown	Out	Recorded from the project area
Bird	Mourning Wheatear	<i>Oenanthe lugens</i>	LC		Unknown	Out	Recorded from the project area
Bird	Eurasian Hoopoe	<i>Upupa epops</i>	LC		Unknown	Out	Recorded from the project area
Bird	Fan tailed Raven	<i>Corvus ruficollis</i>	LC		Unknown	Out	Recorded from the project area
Bird	Greater Hoopoe Lark	<i>Alaemon alaudipes</i>	LC		Unknown	Out	Recorded from the project area
Bird	Isabelline Wheatear	<i>Oenanthe isabellina</i>	LC		Unknown	Out	Recorded from the project area
Bird	Lesser Whitethroat	<i>Sylvia curruca</i>	LC		Unknown	Out	Recorded from the project area
Bird	Northern Wheatear	<i>Oenanthe oenanthe</i>	LC		Unknown	Out	Recorded from the project area
Bird	Spanish Sparrow	<i>Passer hispaniolensis</i>	LC		Unknown	Out	Recorded from the project area
Bird	White Crowned Wheatear	<i>Oenanthe leucopyga</i>	LC		Unknown	Out	Recorded from the project area
Bird	Arabian Red Fox	<i>Vulpes vulpes arabica</i>	LC		Unknown	Out	Recorded from the project area

Group	Common Name	Scientific Name	Red List Status	Extend of Occurrence (EOO) km2	Global Population Estimate	Screened In / Out	Rationale
Mammal	Arabian Wolf	<i>Canis lupus arabs</i>	LC		Unknown	Out	Recorded from the project area
Mammal	Golden Spiny mouse	<i>Acomys russatus</i>	LC		Unknown	Out	Recorded from the project area
Mammal	Cheesman Jerbil	<i>Gerbillus cheesmani</i>	LC		Unknown	Out	Recorded from the project area
Mammal	Greater Mouse-tailed bat	<i>Rhinopoma microphyllum</i>	LC		Unknown	Out	Recorded from the project area
Mammal	Christie's Big-eared bat	<i>Plecotus christii</i>	DD		Unknown	Out	Recorded from the project area
Mammal	Geoffroy's Trident Leaf-nosed bat	<i>Asellia tridens</i>	LC		Unknown	Out	Recorded from the project area
Bat	Christie's Big-eared bat / Christie's Long-eared bat	<i>Plecotus christii</i>	DD		Unknown	Out	Recorded from the project area
Bat	Greater Mouse-tailed bat	<i>Rhinopoma microphyllum</i>	LC		Unknown	Out	Recorded from the project area
Bat	Geoffroy's Trident Leaf-nosed bat	<i>Asellia tridens</i>	LC		Unknown	Out	Recorded from the project area

NL - Not Listed as HCP species in the First KSA Report; LC – Least Concern; EN- Endangered; VU – Vulnerable; DD – Data Deficient **Mentioned as species requiring special attention;

*Regional conservation status provided

Criterion 1a relates to areas that support globally important concentrations of a CR or EN species/subspecies. Under this sub-criterion none of the species were found to be qualifying. Criterion 1b focuses on areas that support globally important concentrations of a VU species, the loss of which would result in up listing to CR or EN. No species were found to possibly, or likely qualify the AoA as Critical Habitat under Criterion 1b. Criterion 1c, which assesses the areas containing important concentrations of a nationally or regionally listed CR or EN species, No species were found, or possibly qualifies the AoA as Critical Habitat (Table 4).

SCREENING FOR CRITERIA 2

Criterion 2 is triggered by habitats of significant importance for endemic or restricted-range species. IFC quantitative definitions (paragraph 80, GN6: IFC 2012b) were used to define restricted-range species. Global extent of occurrence was used to define range and was determined using IUCN data (IUCN 2013), existing literature, and consultation with taxonomic specialists. There were no species that qualify the AoA as CH under Criterion 2.

CRITICAL HABITAT DETERMINATION

Discrete Management Unit

The Discrete Management Unit (DMU) of the project area is shown in Figure 1.

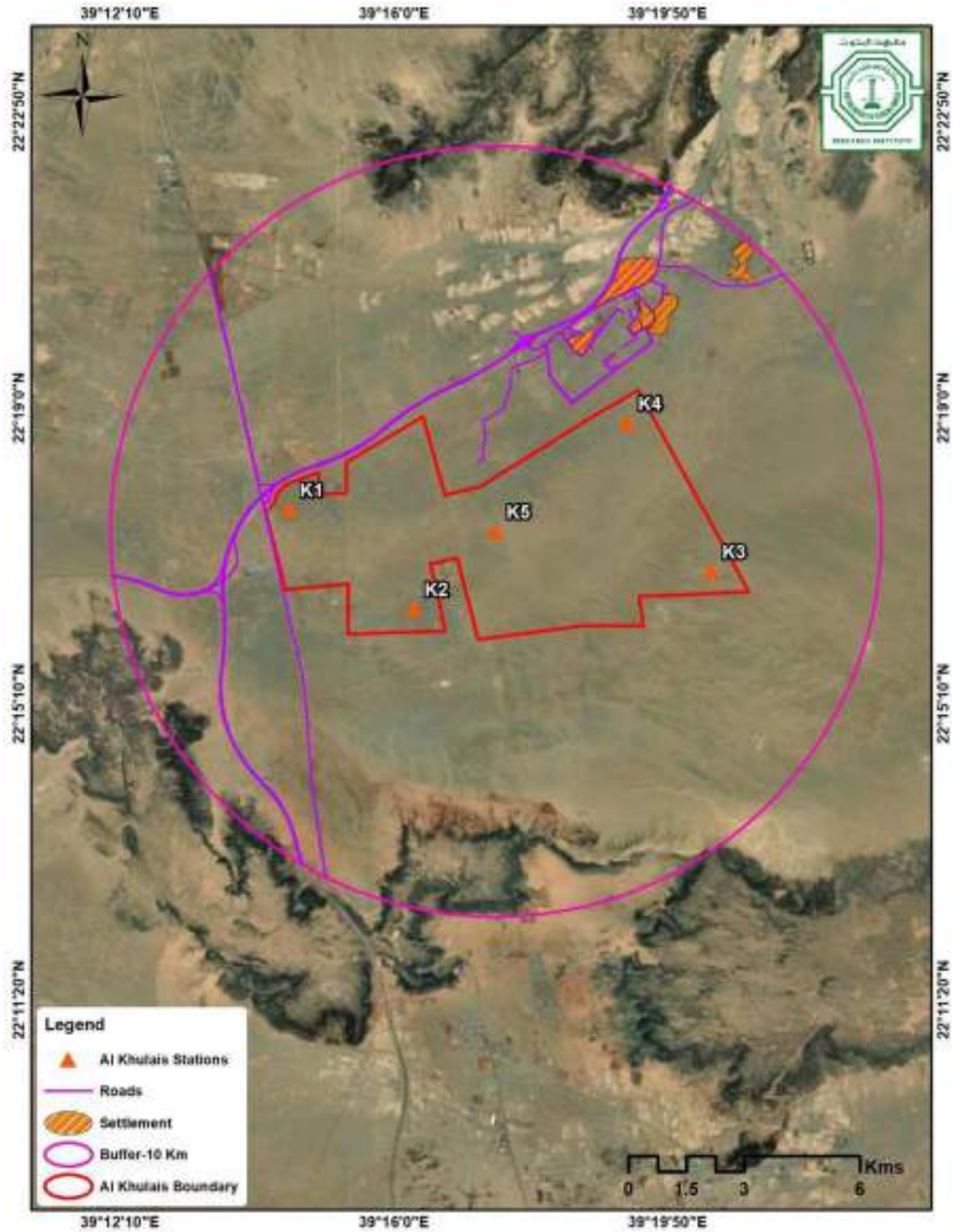


Figure 1: Discrete Management Unit for Critical Habitat Determination for Species in Al Humaij.

CRITERION 3 MIGRATORY AND CONGREGATORY SPECIES

Criterion 3 is triggered by migratory and/or congregatory species occurring in the CHA. All migratory or congregatory species were screened to determine if the CHA contained irreplaceable and/or extremely vulnerable habitats used either periodically or consistently. Migratory birds were identified using information from BirdLife International (2013) and other species were identified using information from IUCN listings (IUCN 2013) and other published literature.

19 migratory / congregatory bird species are known to occur within the vicinity of the Project Area and these were selected for the screening process (Table 5).

Table 5: Migratory / congregatory bird species recorded and global population estimates

Bird Species	Migration Status*	IUCN Status	Numbers recorded in AOI	Global Population No. (%)
Arabian Great Shrike	R/NB	LC	15	Unknown
Bar-tailed Lark	R/NB	LC	1	Unknown
Blackstart	R/NB	LC	2	Unknown
Blue Rock Pigeon	R/NB	LC	3	Unknown
Crested lark	R/NB	LC	2	Unknown
Desert Lark	WV	LC	19	Unknown
Desert Wheatear	WV	LC	2	Unknown
Eastern Mourning Wheatear	R/NB	LC	1	Unknown
Eurasian Hoopoe	R/NB	LC	1	Unknown
Fan tailed Raven	WV	LC	1	Unknown
Greater Hoopoe Lark	WV	LC	6	Unknown
Isabelline Wheatear	R/NB	LC	1	Unknown
Lesser Whitethroat	WV	LC	2	Unknown
Northern Wheatear	R/NB	LC	3	Unknown
Spanish Sparrow	R/NB	LC	154	Unknown
White Crowned Wheatear	R/NB	LC	16	Unknown

CRITERION 4: HIGHLY THREATENED AND/OR UNIQUE ECOSYSTEMS

Screening of Criterion Indicating Highly Threatened and/or Unique Ecosystems is given in Table 6. The project site (Al Humaij) is dominated by desert and rocky terrain, with sparse vegetation consisting mainly of drought-resistant plants. These habitats are natural habitats with low biodiversity. The natural habitats within the Proposed Project Area do not meet the criteria for EN or CR ecosystems as detailed by IUCN, 2015. Therefore, the critical habitat is not triggered under criterion 4 of IFC PS6.

Table 6: Screening of Criterion Indicating Highly Threatened and/or Unique Ecosystems

Criterion Indicating Highly Threatened and/or Unique Ecosystems	Relevance to Proposed Project Area	Critical Habitat Triggered?
A: Reduction in geographic distribution	Not relevant	No
B: Restricted geographic distribution	Not relevant	No
C: Environmental degradation	Not enough data exists to quantify abiotic degradation.	No
D: Disruption of biotic processes or interactions	Not enough data exists to quantify biotic degradation.	No
E: Quantitative analysis that estimates the probability of ecosystem collapse	Not enough data exists to quantitatively model the likelihood of ecosystem collapse over the next 50 years. However, it is considered unlikely that there is a 20% or higher probability that the ecosystem would collapse within the next 50 years.	No

CRITERION 5: KEY EVOLUTIONARY PROCESSES

The importance of the Proposed Project Area from an evolutionary perspective is assessed by screening its features against factors that indicate importance for evolutionary processes. Table 7 details the factors considered likely to indicate importance for evolutionary processes and their relevance to the Proposed Project Area. In summary, there is no indication that the Proposed Project Area is important for evolutionary processes and therefore critical habitat is not triggered under Criterion 5 of IFC PS6.

Table 7: Screening of Criterion Indicating Importance for Evolutionary Processes

Criterion Indicating Importance for Evolutionary Processes	Relevance to Proposed Project Area	Critical Habitat Triggered?
Level of isolation (e.g., islands, mountaintops, lakes are associated with populations that are phylogenetically distinct)	The Proposed Project Area lacks the extreme topography required to isolate populations.	No
Extent of endemism (Areas of high endemism often contain flora and/or fauna with unique evolutionary histories)	Endemism is not observed from the Proposed Project Area or from the buffer zone.	No
Spatial heterogeneity	The habitats present in the Proposed Project Area are relatively homogenous without any spatial heterogeneity.	No

Presence of environmental gradients (ecotones produce transitional habitat which has been associated with the process of speciation and high species and genetic diversity)	The habitats present in the Proposed Project Area are relatively homogenous and lack marked ecotones that could drive evolutionary processes.	No
Edaphic interfaces	The habitats present in the Proposed Project Area are relatively homogenous and lack marked edaphic interfaces that could drive evolutionary processes.	No
Connectivity between habitats (e.g. biological corridors).	The habitats within the Proposed Project Area do not provide significant connectivity between other nearby habitats known to be of evolutionary importance.	No

CRIERION 6: INTERNATIONALLY AND/OR NATIONALLY RECOGNISED AREAS

The Proposed Project Area does not include whole or parts of any internationally recognized areas. Hence accordance with IFC PS6, the project areas are not confirmed to be critical habitats.

SUMMARY

This Technical Appendix provides an assessment of critical habitat applicable to the Proposed Project. Critical habitat is defined by IFC Performance Standard 6 (PS6) as areas with high biodiversity value. This includes areas that meet one or more of following criteria:

- Criterion 1: Critically Endangered (CR) and/or Endangered (EN) species;
- Criterion 2: Endemic and/or restricted-range species;
- Criterion 3: Migratory and/or congregatory species;
- Criterion 4: Highly threatened and/or unique ecosystems;
- Criterion 5: Key evolutionary processes; and
- Criterion 6: Internationally and/or nationally recognised areas.

FINDINGS OF THE CHA

- Flora and fauna species reported from the project area do not qualify as Critical Habitat.
- There is currently no evidence found that suggests that the project area supports highly threatened ecosystem(s) (under Criterion 4) or key evolutionary processes (under Criterion 5).
- No Project infrastructure is planned within any legally protected areas nor internationally recognised areas of high biodiversity value (LPA/IRA) and therefore Paragraph 20 of PS6 does not apply. While a number of LPA/IRAs overlap with or are located within the AoA, none of these areas will qualify as CH as they are unlikely to contain biodiversity features that qualify under the CH criteria.

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APPENDIX E
CCRA AL HUMAIJ

Technical Appendix E: Climate Change Risk Assessment

**Environmental and Social Impact Assessments (ESIA) for
Installing and Operating a Solar Energy Park in Al Humaij,
Madena, Saudi Arabia**

**Center for Environment and Marine Studies (CEMS) at King Fahd University of
Petroleum & Minerals Research Institute**

July 2024

1.1 INTRODUCTION

The Solar Energy Park in Humaij, Madena, is a pivotal initiative within Saudi Arabia's renewable energy strategy, aiming to capitalize on the region's high solar irradiance and support the country's transition towards a more sustainable energy future. This Climate Change Risk Assessment (CCRA) aims to evaluate potential climate-related risks, including both physical risks like extreme heat, dust storms, and flooding, as well as transition risks such as regulatory changes and market shifts. Situated in a desert environment, the solar park's design and operational strategy should be resilient to these risks while aligning with Saudi Arabia's Nationally Determined Contributions (NDCs) and the broader goals of the Paris Agreement. The assessment provides an analysis to ensure the project not only withstands potential climate impacts but also contributes positively to national and global climate objectives.

1.2 PHYSICAL RISKS

The project is exposed to various physical risks due to its geographic location and climatic conditions. According to the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6), the region is expected to experience an increase in extreme heat events and prolonged periods of high temperatures (IPCC, 2021). Humaij region has a dry climate, with summer temperatures ranging from 30 to 36°C and winter temperatures between 20 and 24°C. Concurrently, the mean annual temperature has shown a consistent upward trend, increasing by 0.7 to 1.3 degrees Celsius over the years (Alsherif and Almaghrabi, 2022). These conditions can negatively affect the efficiency and lifespan of solar panels, as high temperatures can reduce the efficiency of photovoltaic cells, leading to lower power output (Sun et al., 2022). Additionally, extreme heat can cause thermal expansion in materials, potentially leading to structural damage over time.

The climate of Saudi Arabia is significantly influenced by Saharan cyclones, which move across North Africa during the non-summer seasons (Prospero et al. 2002). These cyclones are responsible for peak dust activity in spring over Saudi Arabia, particularly in the northern parts (Ackerman and Cox 1989; Alpert and Ziv 1989; Ganor et al. 1991; Trigo et al. 1999; Shao 2001; Washington et al. 2003; Notaro et al. 2013; Yu et al. 2013). Research using an objective tracking scheme found that out of 688 Sahara cyclone tracks from 1958 to 2018, 53 reached Saudi Arabia. The 53 cyclone tracks that passed through or abated over Saudi Arabia are categorized into five key routes. Although these tracks primarily affect the northern part of Saudi Arabia, they can generate dust storms that impact regions further south, including Jeddah, Humaij and Khulais. This highlights the broader influence of Saharan cyclones on dust storm activity across Saudi Arabia, even in regions not directly along the main cyclone tracks (Almazroui et al., 2019).

Dust storms in Saudi Arabia are most frequent from mid-winter to early summer, with 77% of them occurring between February and June. March is the most active month for dust storms, accounting for 19% of the total, while November is the least active, with only 1% of storms occurring during that month (Notaro et al., 2013). The timing of dust storms varies across the country, reflecting a heterogeneous pattern. Dust storms, which are common in desert environments like Humaij, pose another significant risk. The accumulation of dust on solar panels can significantly reduce their efficiency by blocking sunlight, a phenomenon well-documented in solar energy research. Frequent cleaning is required to maintain optimal performance, which increases operational costs and water usage. Makkah, located in the western region of Saudi

Arabia, experiences dust storms, although their frequency is relatively moderate compared to other regions like Al-Ahsa. The average daily rate of dust storms in Makkah ranges from approximately 0.05 to 0.1 per day, with the highest occurrence from March to May. During these months, the percentage of days with dust storms can range from about 2% to 10% monthly. This frequency is significant for photovoltaic energy projects, as dust storms can impact the efficiency and maintenance of solar panels (Alhajji et al., 2024). According to the report "Analysis and Prediction of Dust Storms across Saudi Arabia during 1980 to 2007" by Mohammad M. Alharbi (2010), Jeddah, Humaij and Khulais are categorized under classes C or D, with annual total blowing dust events ranging from 9 to 16 and 8 events, respectively. In terms of annual dust storm events, these areas are specifically categorized under class D, which experiences 8 storm events per year. A study by Sarah Albugami et al. (2019) analyzing data from 2000 to 2016 highlighted the significant impact of dust storms over Saudi Arabia. The year 2003 recorded the highest number of dust storm events, totaling 203, and representing 10.74% of the total dust storms recorded between 2000 and 2016. The study observed a gradual increase in dust events in Jeddah, with a significant linear regression slope of 0.37 ± 0.10 events per year.

Furthermore, the IPCC AR6 reports an increased likelihood of extreme weather events, including flash floods, due to climate change (IPCC, 2021). The Rainfall of Al Humaij plain varies across the region, with the western flat areas receiving an average of 60 mm per year, while the eastern mountainous regions receive over 170 mm per year (Gabr et al., 2017; Khan et al., 2022). However, the overall annual average rainfall over the region is 35.1 mm, and it is both irregular and unpredictable (Alsherif & Almaghrabi, 2022). For example, sporadic rainfall events resulted in 777 mm of rain on February 12, 2010, and March 15-16, 2011 (Al-Sherif et al., 2013). Meteorological data from the past decade indicate that the annual precipitation has generally been very low and variable, ranging from 0.001 to 86.4 mm per year. But, flash floods can damage infrastructure and disrupt operations, particularly in regions with poorly developed drainage systems. Robust infrastructure planning is needed to mitigate the impacts of such extreme events. Flooding in this region is primarily caused by intense rainfall events over short periods, which, combined with the low water absorptive capacity of the soil, leads to increased overland flow and potential flooding (Shi, 2014).

Additionally, the study by Almaliki et al. (2023) estimates the vulnerability of coastal zones in Jeddah Province to inundation by the year 2100 under various sea level rise (SLR) scenarios. The results indicated that SLR scenarios of 1, 2, 5, and 10 meters could inundate approximately 1.6%, 4.7%, 14.9%, and 30.6% of the coast, respectively, impacting built-up and road areas significantly. Future projections suggest that large stretches of Saudi Arabia's coastline, including the Red Sea and Gulf coasts, will likely undergo regime shifts, with substantial shoreline retreats anticipated by 2100 under both RCP scenarios (Almaliki et al., 2023).

Given these anticipated changes, it is crucial to integrate adaptive measures into the solar park's design and operational plans to enhance resilience against these physical risks. For instance, utilizing more heat-resistant materials, implementing dust mitigation technologies, and enhancing infrastructure to withstand extreme weather events could reduce vulnerability and maintain the project's long-term viability.

1.3 TRANSITION RISKS

As part of its Vision 2030 initiative, Saudi Arabia aims to achieve net zero greenhouse gas emissions by 2060, with interim goals for 2030 including an annual reduction of 278 million tons of CO₂ equivalent (Saudi Arabia, 2021). The Kingdom aims to significantly increase the share of renewable energy in the national grid, with a target of 50% renewable energy in its energy mix by 2030 (Ministry of Energy, 2023). This project could encounter transition risks such as increased operational costs and the need for infrastructure modifications as Saudi Arabia strengthens its environmental policies to meet international climate commitments. However, due to the Power Purchase Agreement (PPA) often associated with renewable energy projects, which provides a stable and predictable revenue stream, this solar project might be less exposed to financial uncertainties related to these regulatory changes.

1.4 ALIGNMENT WITH NATIONAL AND INTERNATIONAL CLIMATE GOALS

This project is strategically positioned to support Saudi Arabia's evolving energy policies and climate commitments under the Paris Agreement. This project aligns with these national initiatives by contributing to the expansion of renewable energy capacity, a core component of Saudi Arabia's strategy to meet its climate goals. By directly contributing to these capacity goals, the Humaij Solar Park supports the national strategy of enhancing energy security, reducing carbon emissions, and fostering economic diversification.

1.5 PRELIMINARY NATIONAL CLIMATE COMMITMENT COMPATIBILITY REVIEW

The Humaij Solar Energy Park in Makkah aligns with Saudi Arabia's National Climate Commitments (NCCs) including its Nationally Determined Contributions (NDCs) under the Paris Agreement by enhancing renewable energy capacity and reducing greenhouse gas emissions. Additionally, the park supports Saudi Arabia's transition to a low-GHG economy and contributes to the country's goal of achieving net zero emissions by 2060, benefiting from stable revenue streams through Power Purchase Agreements (PPAs). By incorporating innovative technologies and participating in programs like the Greenhouse Gas Crediting and Offsetting Mechanism (GCOM) to generate carbon credits, the project enhances its financial resilience while ensuring alignment with national climate objectives and promoting sustainable energy production in the region. It is expected that the project will address physical climate risks such as extreme heat, dust storms, and flash floods through adaptive measures like heat-resistant materials and dust mitigation technologies, aligning with national adaptation goals to increase resilience.

1.6 RISK MANAGEMENT OPPORTUNITIES

This project offers several risk management opportunities that can support the project's resilience against regulatory and transition risks while aligning with Saudi Arabia's broader climate objectives. A significant opportunity lies in proactively implementing advanced environmental management practices and technologies that exceed current regulatory standards. By adopting best practices in sustainability, such as using water-efficient cleaning systems for solar panels and incorporating heat-resistant materials, the project can minimize its environmental impact and lower operational costs over time. Additionally, conducting regular environmental audits and sustainability reporting not only demonstrates the project's commitment to continuous

improvement but also enhances its reputation with regulators and investors focused on environmental, social, and governance (ESG) criteria.

Furthermore, the solar park can leverage its alignment with Saudi Arabia's Nationally Determined Contributions (NDCs) and net-zero targets to capitalize on emerging market opportunities, such as those provided by the Greenhouse Gas Crediting and Offsetting Mechanism (GCOM) introduced by the Ministry of Energy (2023b). Through GCOM, the project can generate and sell carbon credits, enhancing its revenue streams and gaining a competitive edge in the local market. This mechanism allows the solar park to monetize its emissions reductions, providing a financial incentive to exceed compliance requirements and contribute to the country's climate goals. By actively participating in this program and engaging with stakeholders in the renewable energy sector, the solar park can not only mitigate regulatory risks but also position itself as a leader in sustainable energy production, attracting additional investments and fostering growth in the green economy.

1.7 OPPORTUNITIES

The solar park can enhance its market position by adopting innovative technologies and practices that improve operational efficiency and environmental performance. By exceeding current regulatory standards and demonstrating leadership in sustainability, the project can access green financing and incentives offered by both domestic and international financial institutions that prioritize ESG-focused investments. Engaging in these initiatives not only helps mitigate risks but also opens doors to partnerships and collaborations that can drive further expansion in the renewable energy sector. By positioning itself as a frontrunner in the green economy, the Humaij Solar Park can attract additional investments, foster local economic development, and contribute to Saudi Arabia's transition to a sustainable energy future.

1.8 CONCLUSIONS

The Solar Energy Park in Humaij, Madena, will play a critical role in advancing Saudi Arabia's renewable energy strategy and aligning with its climate commitments under the Paris Agreement. This assessment highlights several physical risks, such as extreme heat, dust storms, and flash floods, which could impact the efficiency and longevity of solar panels and the overall infrastructure. These risks necessitate the integration of adaptive measures, including heat-resistant materials, dust mitigation technologies, and robust infrastructure designs to enhance resilience against extreme weather events. Additionally, the project is exposed to transition risks, including market fluctuations and increased competition in the renewable energy sector. However, the project's alignment with national climate goals and the stable revenue stream provided by Power Purchase Agreements (PPAs) mitigate some of these financial uncertainties (Table 1).

Furthermore, this project presents significant opportunities for growth and sustainability. By adopting innovative technologies and practices, the project can improve operational efficiency, reduce environmental impact, and access green financing. Participation in the Greenhouse Gas Crediting and Offsetting Mechanism (GCOM) provides an additional opportunity to generate and sell carbon credits, enhancing revenue and supporting Saudi Arabia's climate goals. Overall, this solar park not only contributes to the expansion of renewable energy capacity in Saudi Arabia but

also positions itself as a leader in sustainable energy production. By leveraging these opportunities and effectively managing the identified risks, Humaij Solar Park can ensure its long-term viability and support the country's transition to a sustainable energy future.

Table 1. Climate Change Risk Assessment of Humaij Solar Project.

Risk Category	Risk Description	Likelihood	Impact	Mitigation Strategy
Physical Risks	The project is exposed to extreme heat, dust storms, and flash floods, which can affect efficiency and infrastructure.	High	High	Integrate heat-resistant materials, dust mitigation technologies, and robust infrastructure to withstand extreme weather events.
Transition Risks	Potential market fluctuations and increased competition in the renewable energy sector as Saudi Arabia and other nations rapidly expand their renewable energy capacities.	Medium	Moderate	Secure long-term Power Purchase Agreements (PPAs) to ensure stable revenue streams and continuously monitor market trends to adapt strategies as needed.
Alignment Risks	Although the project is aligned with Saudi Arabia's NDCs and the Paris Agreement, changes in global renewable energy policies could impact market dynamics.	Low	Moderate	Maintain flexibility in project operations and engage with policymakers to stay updated on international climate policies and market opportunities.
Opportunities	Adopting innovative technologies and practices to improve efficiency, leveraging GCOM for carbon credits, and accessing green financing opportunities.	High	High	Adopt advanced environmental management practices, exceed regulatory standards, and capitalize on market opportunities provided by GCOM.

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APPENDIX G
BASELINE REPORT ON AIR QUALITY AND NOISE

APPENDIX H
HYDROLOGICAL STUDY

Technical Appendix 2: Area of Influence

**Environmental and Social Impact Assessments (ESIA) for
Installing and Operating a Solar Energy Park in Humaij,
Madena, Saudi Arabia**

**Applied Research Center for Environment and Marine Studies (CEMS)
King Fahd University of Petroleum & Minerals
Research Institute**

July 2024

1. Introduction

The areas of direct and indirect influence were defined in order to obtain a comprehensive view of the project emplacement area, as were the areas of sensitivity for each of the environmental components analysed in this study. This made it possible to identify environmental and social impacts and risks properly. Thus we can comply with the provisions of the Performance Standards (PS) administered by the IFC and to provisions of PS1, which indicates that the area of influence includes cumulative impacts or result of incremental impact on the areas or resources used or affected by the activity. This transcends the traditional concept of the “area of direct influence” and emphasizes the need to analyze indirect and cumulative effects as well as the need to expand the geographic limits in assessing the impact and/or the time framework used for the analysis.

2. Area of Influence

According to Canter et al. (1998), the area of influence is “The space where possible environmental and social impacts occur that are due to a project’s implementation”; however, the scope of the area of influence concept may be significantly relative. The area of influence is the fraction of the environment that interacts with project facilities and activities (resources, raw materials, labor, space) and their output (waste, emissions and jobs). The simple decision of establishing a circle of influence within a more or less broad radius around the unit being studied has no validity [Conesa, 1995], so methodological criteria established by the National Environmental Authority are used as described below.

The basic criterion to identify project areas of influence will be to recognize environmental components and the socioeconomic medium directly and indirectly affected by the activities developed as part of the project in all stages. In this respect, we must take into account that the environment related to the project includes the physical environment (soil, water and air components) where it exists and where biodiversity develops (flora and fauna components) as well as the socioeconomic medium with their cultural manifestations.

3. Project Area of Influence and Study Area

The initial step in the baseline characterisation is the definition of the Project Area of Influence (AOI) and the Study Area (Al-Humaij). The AOI (based on the definition in IFC PS1 (IFC, 2012) adopted by the Project is:

The area likely to be affected by:

- Project activities and facilities that are directly owned, operated, or managed (including by contractors) by the Project Proponent and that are a component of the Project;
- Impacts from unplanned but predictable developments caused by the Project that may occur later or at a different location; or
- Indirect Project impacts on biodiversity or on ecosystem services upon which ‘Affected Communities livelihoods are dependent.
- Associated facilities, which are facilities that are not funded as part of the Project and that would not have been expanded if the Project did not exist and without which the

Project would not be viable. It is anticipated there will not be any associated facilities for the Project; and

- Cumulative impacts that result from the incremental impact, on areas or resources used or directly impacted by the Project, from other existing, planned or reasonably defined developments at the time the risks and impacts identification process is conducted.

Using this definition of the Project components an AoI was identified using the following criteria:

- Physical footprint of the Project, overhead lines and substation
- Area where noise effects may be experienced
- Area local to the Project that may be used as a resting/stopover point for migrating birds
- Area within the zone of theoretical visibility of the solar panels
- Area of 100 m either side of roads and access tracks
- Area of 100 m either side of overhead lines

4. Study Area

The study area is Al- Humaij, Madena, Saudi Arabia. The area of up to 5 km radius from the project boundary (solar plant area) has been demarcated as study area for the project by considering the extent of project impact in terms of noise, water resources, human settlement, cultural heritage sites, location of labour sites, location of the access roads besides considering the actual land area which has been procured for the project and its utility footprints.

5. Project Footprint Area

The Project Footprint is the area that may reasonably be expected to be physically touched by Project activities, across all phases. The Project Footprint for Project includes land used for the setting up the Solar PV's, transformer rooms, storage of materials, site office, access roads, and internal and external transmission lines.

6. Area of Influence (AoI)

The effects of the project and project activities on a particular resource or receptor will have spatial (distance) and temporal (time) dimensions, the scale of which is dependent on a number of factors. These factors are incorporated in the definition of the Project's Area of Influence (AoI). The AoI considered for the existing Project with respect to the environmental and social resources was based on the following reach of impacts:

Environmental parameters: Project site boundary, immediate vicinity, Access road and surroundings, i.e. a study area of approximately 5 km (here after referred to as the AoI) distance from project line has been used to depict these parameters;

- *Air Quality:* Dust emissions, fugitive dust- typically up to 500 m from a construction area and 100 m from operations and maintenance area;

- *Noise*: Noise impact area (defined as the area over which an increase in environmental noise levels due to the Project can be detected) –typically 1,000 m from operations;
- *Land environment*: The impacts on soil and land- typically up to 500 m from the project footprint area;
- *Ecological Environment (Terrestrial)*: The direct footprint of the project comprising the Solar park; (b) The areas immediately adjacent to the project footprint within which a zone of ecological disturbance is created through increased dust, human presence and project-related activities (e.g., trampling, transportation activities). The AoI for the project is identified as the area within a 10 km radius of the project footprint area;

Social and Cultural: The AoI for the project is identified as the area within a 10 km radius of the project footprint area and/or area identified beyond 10 km that is directly impacted by project activities.

Table 1. Area of Influence Applicable to the Solar Park Project

Si. No.	Environmental and Social Receptors	Area of Influence (AoI)	Justification
1	Air Quality	500 m	Dust emissions, fugitive dust, etc. is typically observed within 100-200 m from the construction/operation area. A minimum of 500 m AoI has been taken to capture all sources of these emissions including vehicular movement across access roads
2	Noise Pollution	1000 m	Noise can often be detected up to 800-1000 m from any operation
3	Water Environment	500 m	Water bodies located in the vicinity of the project area may be impacted due to activities at the project footprint and allied sites.
4	Terrestrial Environment	500 m	Impacts on soil and land are often restricted to the Project footprint area. An AoI of 500m taking into account indirect effects usually occur due to vehicular/ heavy machinery movements and activities at allied sites .
5	Socio-economic Conditions	10,000 m	An AoI of 10 km radius is considered for socio-economic consultations to determine perceived impacts due to the Project including employment opportunities, loss of livelihood (grazing and agricultural land) and increased anthropogenic/vehicular activity in remote areas
6	Ecology	10,000 m	An AoI of 10 km radius is considered for the ecological study. The 10 km radius provides an understanding use of desert habitat around the proposed Solar Park

7. Core and Buffer Zone:

This AoI is in turn, divided into a core and buffer zone. This division of the AoI into two zones is based on the understanding that the majority of the impacts from the project (during the project lifecycle) would be contained within a 1 km radius (core zone) from the Project Footprint in terms of spread and intensity, with the buffer zone (10 km radius) appearing to have limited interaction with the project.

The Buffer Zone is the area that does not have a direct impact on land or the environment, however, it is demarcated in case the impact on the core zone is sometimes/often extended to near-by areas. Usually, the impact on buffer zone is more inclined towards, noise, air and water

pollution. In some cases it also has an impact on labour, land ownership, migration and accessibility to any natural resources.

For socio-economic baseline assessment, core (5 km from the project site) and buffer zones (beyond 5 km and within 10 km of the project site) as shown in Figure 1 below.

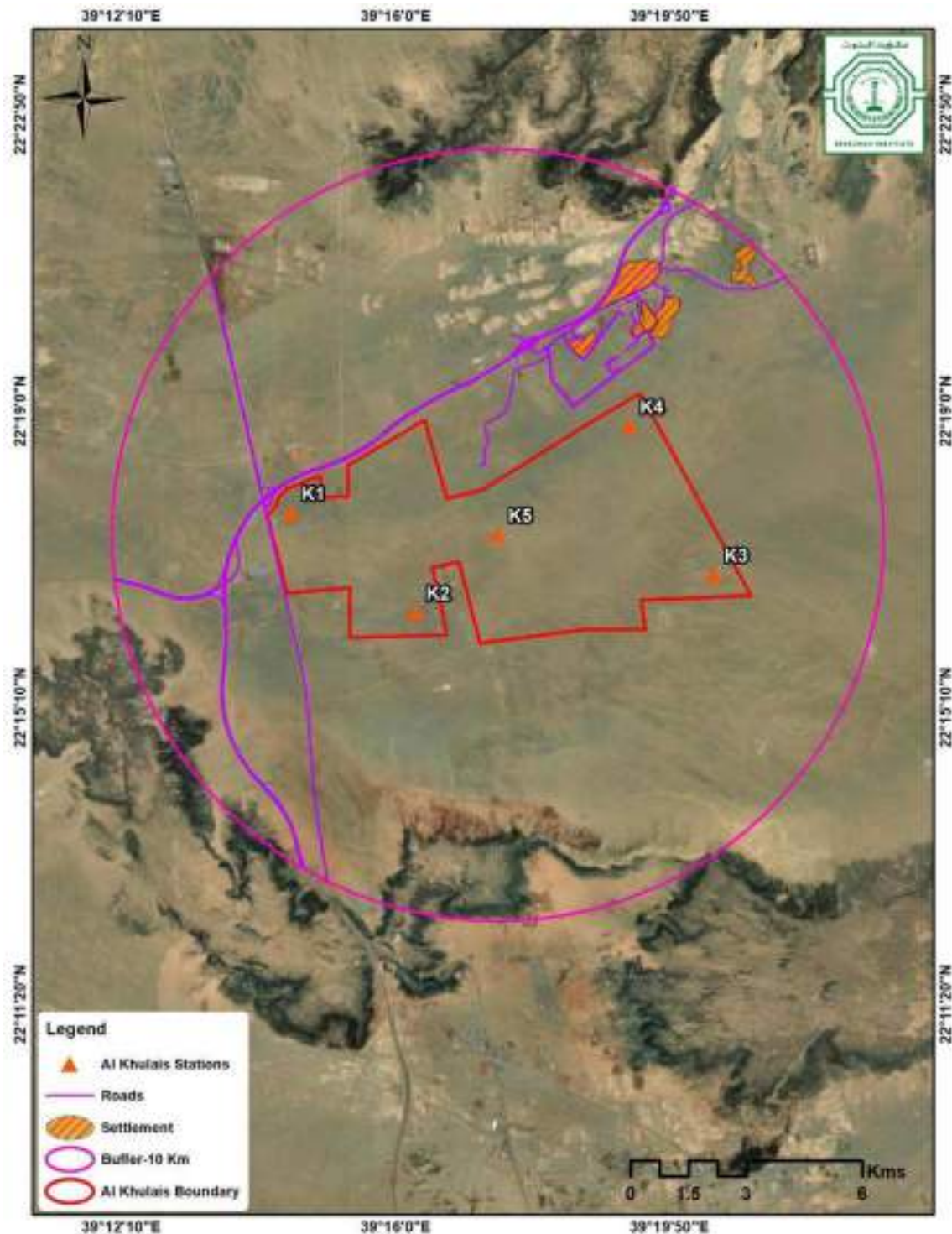


Figure 1: Core Zone and Buffer Zone of Study Area

Technical Appendix D: Critical Habitat Assessment

**Environmental and Social Impact Assessments (ESIA) for
Installing and Operating a Solar Energy Park in Khulais,
Madena, Saudi Arabia**

**Center for Environment and Marine Studies (CEMS) at King Fahd University of
Petroleum & Minerals Research Institute**

July 2024

APPENDIX 1: CRITICAL HABITAT ASSESSMENT

1.1 Introduction

A Critical Habitat Assessment (CHA) is required to comply with international lender performance standards, particularly those of the International Finance Corporation (IFC), specifically Performance Standard 6 (PS6), which is relevant to biodiversity conservation and sustainable management of living natural resources. This report comprises a CHA as required by PS6 and includes classification of the Project Area habitats as Natural and Modified.

This CHA provides an assessment of critical habitat applicable to the Proposed Project. This appendix is based on the baseline information provided in *Section 4: Ambient Environment Description*. The ESIA Report was informed by an extensive literature review and in-field data collection.

Definition of Critical Habitat

Critical habitat is defined in Paragraph 16 of the 2012 version of IFC Performance Standard 6 (IFC PS6) as an area with high biodiversity value. This includes areas that meet one or more of following criteria:

- Criterion 1: Critically Endangered (CR) and/or Endangered (EN) species;
- Criterion 2: Endemic and/or restricted range species;
- Criterion 3: Migratory and/or congregatory species;
- Criterion 4: Highly threatened and/or unique ecosystems; and
- Criterion 5: Key evolutionary processes.

However, as specified by GN56 of the IFC's Guidance Note 6, the determination of critical habitat can include other recognized high biodiversity values which are to be evaluated on a case-by- case basis. GN56 provides the following seven examples:

- Areas required for the reintroduction of CR or EN species and refuge sites for these species (habitat used during periods of stress (e.g. flood, drought or fire);
- Ecosystems of known special significance to EN or CR species for climate adaptation purposes;
- Concentrations of Vulnerable (VU) species in cases where there is uncertainty regarding the listing, and the actual status of the species may be EN or CR;
- Areas of primary/old-growth/pristine forests and/or other areas with especially high levels of species diversity;
- Landscape and ecological processes (e.g. water catchments, areas critical to erosion control, disturbance regimes (e.g. fire, flood)) required for maintaining critical habitat;
- Habitat necessary for the survival of keystone species; and

- Areas of high scientific value such as those containing concentrations of species new and/or little known to science.

Furthermore, GN57 states that in general, internationally and/or nationally recognised areas of high biodiversity value will likely qualify as critical habitat, including the following:

- Areas that meet the criteria of the IUCN 's Protected Area Management Categories Ia, Ib and II, although areas that meet criteria for Management Categories III-VI may also qualify depending on the biodiversity values inherent to those sites;
- UNESCO Natural World Heritage Sites that are recognized for their Global Outstanding Value;
- The majority of Key Biodiversity Areas (KBAs), which encompass inter alia Ramsar Sites, Important Bird Areas (IBA), Important Plant Areas (IPA) and Alliance for Zero Extinction Sites (AZE);
- Areas determined to be irreplaceable or of high priority/significance based on systematic conservation planning techniques carried out at the landscape and/or regional scale by governmental bodies, recognized academic institutions and/or other relevant qualified organizations (including internationally recognized NGOs); and
- Areas identified by the client as High Conservation Value (HCV) using internationally recognized standards, where criteria used to designate such areas is consistent with the high biodiversity values listed in paragraph 16 of IFC PS6.

1.2 Gradient of Critical Habitat

IFC Guidance Note 6 recognizes that there are gradients of critical habitat based on relative vulnerability (degree of threat) and irreplaceability (rarity or uniqueness). For Criteria 1-3, listed in this Appendix, quantitative thresholds are provided to assign critical habitat into either Tier 1 or Tier 2. Table 1 details the relevant quantitative thresholds for tiers 1 and 2 of Critical Habitat Criteria 1 – 3.

Table 1: Quantitative Thresholds for Tiers 1 and 2 of Critical Habitat Criteria 1 – 3

CRITERION	TIER 1	TIER 2
1. CR/ EN Species	(a) Habitat required to sustain $\geq 10\%$ of the global population of a CR or EN species/subspecies where there are known, regular occurrences of the species and where that habitat could be considered a discrete management unit for that species. (b) Habitat with known, regular occurrences of CR or EN species where that habitat is one of 10 or fewer discrete management sites globally for that species.	(c) Habitat that supports the regular occurrence of a single individual of a CR species and/or habitat containing regionally- important concentrations of a Red-listed EN species where that habitat could be considered a discrete management unit for that species/ subspecies. (d) Habitat of significant importance to CR or EN species that are wide-ranging and/or whose population distribution is not well understood and where the loss of such a habitat could potentially impact the long-term survivability of the species. (e) As appropriate, habitat containing nationally/regionally important concentrations of an EN, CR or equivalent national/regional listing.
2. Endemic/ Restricted Range Species	(a) Habitat known to sustain $\geq 95\%$ of the global population of an endemic or restricted-range species where that habitat could be considered a discrete management unit for that species (e.g. a single-site endemic).	(b) Habitat known to sustain $\geq 1\%$ but $< 95\%$ of the global population of an endemic or restricted-range species where that habitat could be considered a discrete management unit for that species, where data are available and/or based on expert judgment.
3. Migratory/ Congregatory Species	(a) Habitat known to sustain, on a cyclical or otherwise regular basis, $\geq 95\%$ of the global population of a migratory or congregatory species at any point of the species' lifecycle where that habitat could be considered a discrete management unit for that species.	(b) Habitat known to sustain, on a cyclical or otherwise regular basis, $\geq 1\%$ but $< 95\%$ of the global population of a migratory or congregatory species at any point of the species' lifecycle and where that habitat could be considered a discrete management unit for that species, where adequate data are available and/or based on expert judgment. (c) For birds, habitat that meets BirdLife International's Criterion A4 for congregations and/or Ramsar Criteria 5 or 6 for Identifying Wetlands of International Importance. (d) For species with large but clumped distributions, a provisional threshold is set at $\geq 5\%$ of the global population for both terrestrial and marine species. (e) Source sites that contribute $\geq 1\%$ of the global population of recruits.

Neither IFC Performance Standards nor Guidance Note 6 define what constitutes a nationally/regionally important concentration. However, as Tier 1 critical habitat under Criterion 1 is defined by $\geq 10\%$ of the global population of a CR or EN species, Tier 2 Critical Habitat has been defined by $\geq 10\%$ of the national/regional population of a CR or EN species.

1.3 Unit of Analysis

The scale at which the critical habitat determination takes place depends on underlying ecological processes for the habitat and species in question and is not limited to the footprint of the Proposed Project. GN65 of IFC's Guidance Note 6 states that for Criteria 1-3, the determination of critical habitat should be based on a "discrete management unit" (DMU) which is an area that has a definable boundary within which the biological communities have more in common with each other than they do with those outside the boundary. GN65 goes on to provide the following additional guidance on the selection of the DMU:

"A discrete management unit may or may not have an actual management boundary (e.g. legally protected areas, World Heritage sites, KBAs, IBAs, community reserves) but could also be defined by some other sensible ecologically definable boundary (e.g. watershed, interfluvial zone, intact forest patch within patchy modified habitat, seagrass habitat, coral reef, concentrated upwelling area, etc.). The delineation of the management unit will depend on the species (and, at times, subspecies) of concern".

1.4 Methodology

Criterion 1: Critically Endangered and/or Endangered Species

Biodiversity identifies threatened species that have the potential to be present within the Proposed Project Area. This has been completed with reference to the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (RL) [IUCN, 2013]. The classification system used by the IUCN RL for representing the extinction risk of species is presented in Table 2. Species classified as VU or above on the IUCN RL are often referred to as 'threatened' species.

Table 2: IUCN Categories of Extinction Risk [IUCN, 2012]

IUCN Category	Definition
Extinct in the Wild (EXW)	A taxon is Extinct in the Wild when it is known only to survive in cultivation, in captivity or as a naturalised population (or populations) well outside the past range.
Critically Endangered (CR)	Species facing an extremely high risk of extinction in the wild.
Endangered (EN)	Species facing a very high risk of extinction in the wild.
Vulnerable (VU)	Species facing a high risk of extinction in the wild.
Near Threatened (NT)	A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.
Data Deficient (DD)	Inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status.
Least Concern (LC)	A taxon is Least Concern when it has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are included in this category.

Criterion 2: Endemic and/or Restricted-Range Species

IFC's Guidance Note 6 provides the following definitions for Endemic and restricted-range species as follows:

- *“Endemic species: defined as one that has $\geq 95\%$ of its global range inside the country or region of analysis.*
- *Restricted-range species:*
 - *For terrestrial vertebrates, a restricted-range species is defined as those species which have an extent of occurrence of 50,000 km² or less.*
 - *For marine systems, restricted-range species are provisionally being considered those with an extent of occurrence of 100,000 km² or less.*
 - *For freshwater systems, standardized thresholds have not been set at the global level. However an IUCN study of African freshwater biodiversity applied thresholds of 20,000 km² for crabs, fish, and molluscs and 50,000 km² for odonates (dragonflies and damselflies). These can be taken as approximate guidance, although the extent to which they are applicable to other taxa and in other regions is not yet known.*
 - *For plants, restricted-range species may be listed as part of national legislation. Plants are more commonly referred to as “endemic,” and the definition provided in paragraph GN79 would apply.”*

Species listed in Section 4: *Ambient Environment Description* of the ESIA report were screened to identify whether they meet the definition of either endemic or range-restricted species. Species list was prepared based on field survey, published sources and in liaison with experts. Criterion 1 and 2 are addressed at the same time in Section 3 of this appendix.

Criterion 3: Migratory and Congregatory Species

IFC Guidance Note 6 defines migratory and congregatory species in the following way:

- *Migratory species:*
 - *“any species of which a significant proportion of its members cyclically and predictably move from one geographical area to another (including within the same ecosystem).”*
- *Congregatory species:*
 - *“species whose individuals gather in large groups on a cyclical or otherwise regular and/or predictable basis;*
 - *Species that form colonies;*
 - *Species that form colonies for breeding purposes and/or where large numbers of individuals of a species gather at the same time for non-breeding purposes (e.g., foraging, roosting);*
 - *Species that move through bottleneck sites where significant numbers of individuals of a species pass over a concentrated period of time (e.g., during migration);*

- *Species with large but clumped distributions where a large number of individuals may be concentrated in a single or a few sites while the rest of the species is largely dispersed (e.g., wildebeest distributions); and*
- *Source populations where certain sites hold populations of species that make an inordinate contribution to recruitment of the species elsewhere (especially important for marine species)."*

For birds, habitat that meets Birdlife International's Criterion A4 for congregations and/or Ramsar Criteria 5 or 6 for Identifying Wetlands of International Importance meet the Tier 2 classification for critical habitat. Section 4: Ambient Environment Description identifies a few migratory bird species that have been recorded within the Proposed Project Area.

Criterion 4: Highly Threatened and/or Unique Ecosystems

IFC Guidance Note 6 defines highly threatened or unique ecosystems as:

- *"at risk of significantly decreasing in area or quality;*
- *with a small spatial extent; and/or*
- *containing unique assemblages of species including assemblages or concentrations of biome-restricted species."*

A working group has been established by the IUCN to develop a system of quantitative categories and criteria, analogous to those used for species, for assigning levels of threat to ecosystems at local, regional, and global levels (IUCN, 2016) [Bland et al., 2016]. Ecosystems that fall within the Proposed Project Area and meet the definition of EN or CR according to IUCN (2016) are assumed to meet Criterion 4 for critical habitat (Table 3). For many habitat types, data on distribution, quality and functioning are lacking. In these instances estimates have been made based on available evidence, professional judgement and levels of protection (e.g. habitats specifically protected by law, or proportion of habitat types occurring within protected areas).

Table 3: Summary of IUCN Ecosystem Red List Criteria

CRITERION	CR	EN
A: Reduction in geographic distribution	Reduction in geographic distribution of >80% in any 50 year time period.	Reduction in geographic distribution of >50% in any 50 year time period.
B: Restricted geographic distribution	Extent of Occurrence (EOO) of <2000 km ² Area of Occurrence (AOO) <2 10x10 km grid cells	EOO of <20,000 km ² AOO <20 10x10 km grid cells
C: Environmental degradation	Reduction in an abiotic variable affecting more than 80% of ecosystem in 50 year time period.	Reduction in an abiotic variable affecting more than 50% of ecosystem in 50 year time period.
D: Disruption of biotic processes or interactions	Reduction in a biotic variable affecting more than 80% of ecosystem in 50 year time period.	Reduction in a biotic variable affecting more than 50% of ecosystem in 50 year time period.

E: Quantitative analysis that estimates the probability of ecosystem collapse	Quantitative analysis that estimates the probability of ecosystem collapse to be >50% in 50 years.	Quantitative analysis that estimates the probability of ecosystem collapse to be >20% in 50 years.

Criterion 5: Key Evolutionary Processes

Evolutionary processes are often strongly influenced by structural attributes of a region, such as its topography, geology, soil and climate over a period of time. IFC Guidance Note 6 suggests that this criterion is defined by:

- *“the physical features of a landscape that might be associated with particular evolutionary processes; and/or*
- *sub-populations of species that are phylogenetically or morphogenetically distinct and may be of special conservation concern given their distinct evolutionary history.”*

For the purposes of this assessment, the Proposed Project Area has been screened against the following factors:

- Level of isolation (e.g. islands, mountaintops, lakes are associated with populations that are phylogenetically distinct);
- Extent of endemism (areas of high endemism often contain flora and/or fauna with unique evolutionary histories);
- Spatial heterogeneity;
- Presence of environmental gradients (ecotones produce transitional habitat which has been associated with the process of speciation and high species and genetic diversity);
- Edaphic interfaces; and
- Connectivity between habitats (e.g. biological corridors).

Criterion 5 is usually considered at a relatively fine scale (TBC and FFI, 2012) and thus the most appropriate unit of analysis is that which may potentially experience direct, primary impacts from the Proposed Project (i.e. the Proposed Project Area).

1.5 DETERMINATION AND RESULTS

Screening for Criteria 1

The species identified by the ESIA Report as being likely to be present within the Proposed Project Area have been screened to identify species that are classified as either Critically Endangered or Endangered, as well as endemic or range restricted species (Table 4). Total of 51 species comprising 24 plant species, 16 avifauna species, 6 mammal species, 2 reptile species, and 3 bat species occurring in the project area in Al Humaij was compiled in Table 4. All these species were screened out as a result of no known records from the vicinity of the

Project Area, lack of suitable habitat, or, if there are records from the vicinity of the Project Area, insufficient suitable habitat being present to support enough individuals to be within the quantitative thresholds for classifying CH.

Table 4. Screening of Species Relevant to Criteria 1 (CR / EN Species) and 2 (Restricted-range Species) from the project area.

Group	Common Name	Scientific Name	Red List Status	Extend of Occurrence (EOO) km2	Global Population Estimate	Screened In / Out	Rationale
FLORA	Plant	<i>Aizoon canariense</i> L.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Haloxylon salicornicum</i> (Moq.) Bunge ex Boiss.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Asphodelus tenuifolius</i> Cav.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Leysera leyseroides</i> (Desf.) Maire	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Arnebia hispidissima</i> (Lehm.) DC.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Diplotaxis acris</i> (Forssk.) Boiss.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Eremobium aegyptiacum</i> var. <i>lineare</i> (Del.) Zohary.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Farsetia aegyptia</i> Turra.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Polycarpaea repens</i> (Forssk.) Asch. & Schweinf.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Cleome amblyocarpa</i> Barr. & Murb.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Citrullus colocynthis</i> (L.) Schrader	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Euphorbia granulata</i> var. <i>granulata</i> Forssk.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Senna italica</i> Miller	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Trigonella stellata</i> Forssk.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Vachellia tortilis</i> (Forssk.) Galasso & Banfi	LC		Unknown	Out	Recorded from the project area
	Plant	<i>Cistanche violacea</i> (Desf.) G. Beck.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Schismus barbatus</i> (L.) Thell.	NL		Unknown	Out	Recorded from the project area

Group	Common Name	Scientific Name	Red List Status	Extend of Occurrence (EOO) km2	Global Population Estimate	Screened In / Out	Rationale
	Plant	<i>Cenchrus ciliaris</i> L.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Emex spinosa</i> (L.) Campd.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Ochradenus baccatus</i> Del.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Lyceum shawii</i> Roem. & Schult.	LC		Unknown	Out	Recorded from the project area
	Plant	<i>Fagonia indica</i> Burm.f.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Seetzenia lanata</i> (Willd.) Bullock.	NL		Unknown	Out	Recorded from the project area
	Plant	<i>Kickxia aegyptiaca</i> (L.) Nab.	NL		Unknown	Out	Recorded from the project area
FAUNA	Rough tailed Rock Agama	<i>Stellagama stellio</i>	LC		Unknown	Out	Recorded from the project area
Reptile	Snake tailed fringe toed Lizard	<i>Acanthodactylus opheodurus</i>	LC		Unknown	Out	Recorded from the project area
Reptile	Arabian Great Shrike	<i>Lanius excubitor aucheri</i>	LC		Unknown	Out	Recorded from the project area
Bird	Bar-tailed Lark	<i>Ammomanes cincturus</i>	LC		Unknown	Out	Recorded from the project area
Bird	Blackstart	<i>Oenanthe melanura</i>	LC		Unknown	Out	Recorded from the project area
Bird	Blue Rock Pigeon	<i>Columba livia</i>	LC		Unknown	Out	Recorded from the project area
Bird	Crested lark	<i>Galerida cristata</i>	LC		Unknown	Out	Recorded from the project area
Bird	Desert Lark	<i>Ammomanes deserti</i>	LC		Unknown	Out	Recorded from the project area
Bird	Desert Wheatear	<i>Oenanthe deserti</i>	LC		Unknown	Out	Recorded from the project area
Bird	Mourning Wheatear	<i>Oenanthe lugens</i>	LC		Unknown	Out	Recorded from the project area
Bird	Eurasian Hoopoe	<i>Upupa epops</i>	LC		Unknown	Out	Recorded from the project area
Bird	Fan tailed Raven	<i>Corvus ruficollis</i>	LC		Unknown	Out	Recorded from the project area

Group	Common Name	Scientific Name	Red List Status	Extend of Occurrence (EOO) km2	Global Population Estimate	Screened In / Out	Rationale
Bird	Greater Hoopoe Lark	<i>Alaemon alaudipes</i>	LC		Unknown	Out	Recorded from the project area
Bird	Isabelline Wheatear	<i>Oenanthe isabellina</i>	LC		Unknown	Out	Recorded from the project area
Bird	Lesser Whitethroat	<i>Sylvia curruca</i>	LC		Unknown	Out	Recorded from the project area
Bird	Northern Wheatear	<i>Oenanthe oenanthe</i>	LC		Unknown	Out	Recorded from the project area
Bird	Spanish Sparrow	<i>Passer hispaniolensis</i>	LC		Unknown	Out	Recorded from the project area
Bird	White Crowned Wheatear	<i>Oenanthe leucopyga</i>	LC		Unknown	Out	Recorded from the project area
Bird	Arabian Red Fox	<i>Vulpes vulpes arabica</i>	LC		Unknown	Out	Recorded from the project area
Mammal	Arabian Wolf	<i>Canis lupus arabs</i>	LC		Unknown	Out	Recorded from the project area
Mammal	Golden Spiny mouse	<i>Acomys russatus</i>	LC		Unknown	Out	Recorded from the project area
Mammal	Cheesman Jerbil	<i>Gerbillus cheesmani</i>	LC		Unknown	Out	Recorded from the project area
Mammal	Greater Mouse-tailed bat	<i>Rhinopoma microphyllum</i>	LC		Unknown	Out	Recorded from the project area
Mammal	Christie's Big-eared bat	<i>Plecotus christii</i>	DD		Unknown	Out	Recorded from the project area
Mammal	Geoffroy's Trident Leaf-nosed bat	<i>Asellia tridens</i>	LC		Unknown	Out	Recorded from the project area
Bat	Christie's Big-eared bat / Christie's Long-eared bat	<i>Plecotus christii</i>	DD		Unknown	Out	Recorded from the project area
Bat	Greater Mouse-tailed bat	<i>Rhinopoma microphyllum</i>	LC		Unknown	Out	Recorded from the project area
Bat	Geoffroy's Trident Leaf-nosed bat	<i>Asellia tridens</i>	LC		Unknown	Out	Recorded from the project area

NL - Not Listed as HCP species in the First KSA Report; LC – Least Concern; EN- Endangered; VU – Vulnerable; DD – Data Deficient **Mentioned as species requiring special attention;

*Regional conservation status provided

Criterion 1a relates to areas that support globally important concentrations of a CR or EN species/subspecies. Under this sub-criterion none of the species were found to be qualifying. Criterion 1b focuses on areas that support globally important concentrations of a VU species, the loss of which would result in up listing to CR or EN. No species were found to possibly, or likely qualify the AoA as Critical Habitat under Criterion 1b. Criterion 1c, which assesses the areas containing important concentrations of a nationally or regionally listed CR or EN species, No species were found, or possibly qualifies the AoA as Critical Habitat (Table 4).

Screening for Criteria 2

Criterion 2 is triggered by habitats of significant importance for endemic or restricted-range species. IFC quantitative definitions (paragraph 80, GN6: IFC 2012b) were used to define restricted-range species. Global extent of occurrence was used to define range and was determined using IUCN data (IUCN 2013), existing literature, and consultation with taxonomic specialists. There were no species that qualify the AoA as CH under Criterion 2.

Critical Habitat Determination

Discrete Management Unit

The Discrete Management Unit (DMU) of the project area is shown in Figure 1.

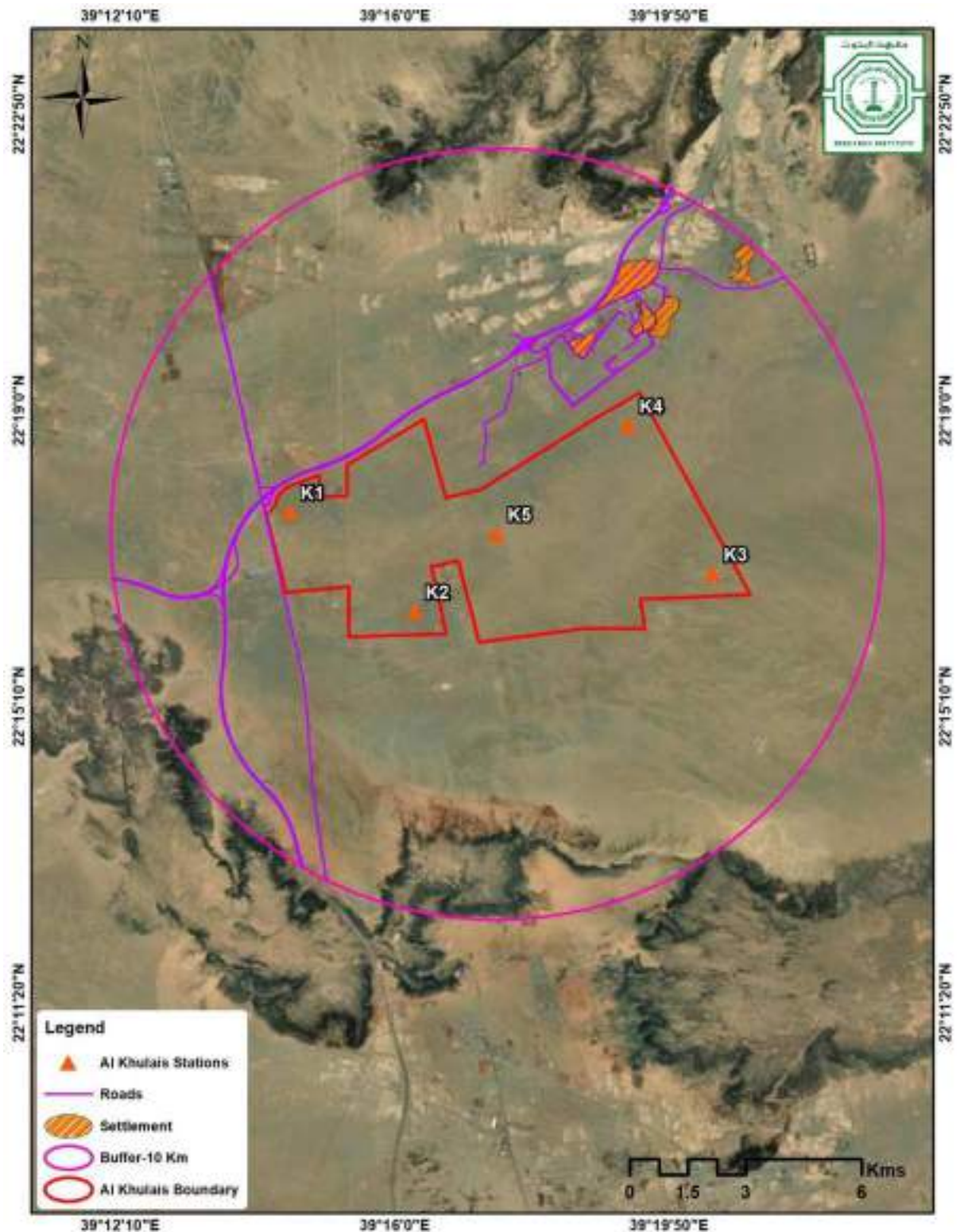


Figure 1: Discrete Management Unit for Critical Habitat Determination for Species in Al Humaij.

Criterion 3 Migratory and Congregatory Species

Criterion 3 is triggered by migratory and/or congregatory species occurring in the CHA. All migratory or congregatory species were screened to determine if the CHA contained irreplaceable and/or extremely vulnerable habitats used either periodically or consistently.

Migratory birds were identified using information from BirdLife International (2013) and other species were identified using information from IUCN listings (IUCN 2013) and other published literature.

19 migratory / congregatory bird species are known to occur within the vicinity of the Project Area and these were selected for the screening process (Table 5).

Table 5: Migratory / congregatory bird species recorded and global population estimates

Bird Species	Migration Status*	IUCN Status	Numbers recorded in AOI	Global Population No. (%)
Arabian Great Shrike	R/NB	LC	15	Unknown
Bar-tailed Lark	R/NB	LC	1	Unknown
Blackstart	R/NB	LC	2	Unknown
Blue Rock Pigeon	R/NB	LC	3	Unknown
Crested lark	R/NB	LC	2	Unknown
Desert Lark	WV	LC	19	Unknown
Desert Wheatear	WV	LC	2	Unknown
Eastern Mourning Wheatear	R/NB	LC	1	Unknown
Eurasian Hoopoe	R/NB	LC	1	Unknown
Fan tailed Raven	WV	LC	1	Unknown
Greater Hoopoe Lark	WV	LC	6	Unknown
Isabelline Wheatear	R/NB	LC	1	Unknown
Lesser Whitethroat	WV	LC	2	Unknown
Northern Wheatear	R/NB	LC	3	Unknown
Spanish Sparrow	R/NB	LC	154	Unknown
White Crowned Wheatear	R/NB	LC	16	Unknown

Criterion 4: Highly threatened and/or unique ecosystems

Screening of Criterion Indicating Highly Threatened and/or Unique Ecosystems is given in Table 6. The project site (Al Humaij) is dominated by desert and rocky terrain, with sparse vegetation consisting mainly of drought-resistant plants. These habitats are natural habitats with low biodiversity. The natural habitats within the Proposed Project Area do not meet the criteria for EN or CR ecosystems as detailed by IUCN, 2015. Therefore, the critical habitat is not triggered under criterion 4 of IFC PS6.

Table 6: Screening of Criterion Indicating Highly Threatened and/or Unique Ecosystems

Criterion Indicating Highly Threatened and/or Unique Ecosystems	Relevance to Proposed Project Area	Critical Habitat Triggered?
A: Reduction in geographic distribution	Not relevant	No
B: Restricted geographic distribution	Not relevant	No

Criterion Indicating Highly Threatened and/or Unique Ecosystems	Relevance to Proposed Project Area	Critical Habitat Triggered?
C: Environmental degradation	Not enough data exists to quantify abiotic degradation.	No
D: Disruption of biotic processes or interactions	Not enough data exists to quantify biotic degradation.	No
E: Quantitative analysis that estimates the probability of ecosystem collapse	Not enough data exists to quantitatively model the likelihood of ecosystem collapse over the next 50 years. However, it is considered unlikely that there is a 20% or higher probability that the ecosystem would collapse within the next 50 years.	No

Criterion 5: Key Evolutionary Processes

The importance of the Proposed Project Area from an evolutionary perspective is assessed by screening its features against factors that indicate importance for evolutionary processes. Table 7 details the factors considered likely to indicate importance for evolutionary processes and their relevance to the Proposed Project Area. In summary, there is no indication that the Proposed Project Area is important for evolutionary processes and therefore critical habitat is not triggered under Criterion 5 of IFC PS6.

Table 7: Screening of Criterion Indicating Importance for Evolutionary Processes

Criterion Indicating Importance for Evolutionary Processes	Relevance to Proposed Project Area	Critical Habitat Triggered?
Level of isolation (e.g., islands, mountaintops, lakes are associated with populations that are phylogenetically distinct)	The Proposed Project Area lacks the extreme topography required to isolate populations.	No
Extent of endemism (Areas of high endemism often contain flora and/or fauna with unique evolutionary histories)	Endemism is not observed from the Proposed Project Area or from the buffer zone.	No
Spatial heterogeneity	The habitats present in the Proposed Project Area are relatively homogenous without any spatial heterogeneity.	No
Presence of environmental gradients (ecotones produce transitional habitat which has been associated with the process of speciation and high species and genetic diversity)	The habitats present in the Proposed Project Area are relatively homogenous and lack marked ecotones that could drive evolutionary processes.	No
Edaphic interfaces	The habitats present in the Proposed Project Area are relatively homogenous and lack marked edaphic interfaces that could drive evolutionary processes.	No
Connectivity between habitats (e.g. biological corridors).	The habitats within the Proposed Project Area do not provide significant connectivity between other nearby habitats known to be of evolutionary importance.	No

Criterion 6: Internationally and/or Nationally Recognised Areas

The Proposed Project Area does not include whole or parts of any internationally recognized areas. Hence accordance with IFC PS6, the project areas are not confirmed to be critical habitats.

Summary

This Technical Appendix provides an assessment of critical habitat applicable to the Proposed Project. Critical habitat is defined by IFC Performance Standard 6 (PS6) as areas with high biodiversity value. This includes areas that meet one or more of following criteria:

- Criterion 1: Critically Endangered (CR) and/or Endangered (EN) species;
- Criterion 2: Endemic and/or restricted-range species;
- Criterion 3: Migratory and/or congregatory species;
- Criterion 4: Highly threatened and/or unique ecosystems;
- Criterion 5: Key evolutionary processes; and
- Criterion 6: Internationally and/or nationally recognised areas.

Findings of the CHA

- Flora and fauna species reported from the project area do not qualify as Critical Habitat.
- There is currently no evidence found that suggests that the project area supports highly threatened ecosystem(s) (under Criterion 4) or key evolutionary processes (under Criterion 5).
- No Project infrastructure is planned within any legally protected areas nor internationally recognised areas of high biodiversity value (LPA/IRA) and therefore Paragraph 20 of PS6 does not apply. While a number of LPA/IRAs overlap with or are located within the AoA, none of these areas will qualify as CH as they are unlikely to contain biodiversity features that qualify under the CH criteria.

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Technical Appendix E: Climate Change Risk Assessment

Environmental and Social Impact Assessments (ESIA) for Installing and Operating a Solar Energy Park in Al Humaij, Madena, Saudi Arabia

**Center for Environment and Marine Studies (CEMS) at King Fahd University of Petroleum &
Minerals Research Institute**

July 2024

1.1 Introduction

The Solar Energy Park in Humaij, Madena, is a pivotal initiative within Saudi Arabia's renewable energy strategy, aiming to capitalize on the region's high solar irradiance and support the country's transition towards a more sustainable energy future. This Climate Change Risk Assessment (CCRA) aims to evaluate potential climate-related risks, including both physical risks like extreme heat, dust storms, and flooding, as well as transition risks such as regulatory changes and market shifts. Situated in a desert environment, the solar park's design and operational strategy should be resilient to these risks while aligning with Saudi Arabia's Nationally Determined Contributions (NDCs) and the broader goals of the Paris Agreement. The assessment provides an analysis to ensure the project not only withstands potential climate impacts but also contributes positively to national and global climate objectives.

1.2 Physical Risks

The project is exposed to various physical risks due to its geographic location and climatic conditions. According to the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6), the region is expected to experience an increase in extreme heat events and prolonged periods of high temperatures (IPCC, 2021). Humaij region has a dry climate, with summer temperatures ranging from 30 to 36°C and winter temperatures between 20 and 24°C. Concurrently, the mean annual temperature has shown a consistent upward trend, increasing by 0.7 to 1.3 degrees Celsius over the years (Alsherif and Almaghrabi, 2022). These conditions can negatively affect the efficiency and lifespan of solar panels, as high temperatures can reduce the efficiency of photovoltaic cells, leading to lower power output (Sun et al., 2022). Additionally, extreme heat can cause thermal expansion in materials, potentially leading to structural damage over time.

The climate of Saudi Arabia is significantly influenced by Saharan cyclones, which move across North Africa during the non-summer seasons (Prospero et al. 2002). These cyclones are responsible for peak dust activity in spring over Saudi Arabia, particularly in the northern parts (Ackerman and Cox 1989; Alpert and Ziv 1989; Ganor et al. 1991; Trigo et al. 1999; Shao 2001; Washington et al. 2003; Notaro et al. 2013; Yu et al. 2013). Research using an objective tracking scheme found that out of 688 Sahara cyclone tracks from 1958 to 2018, 53 reached Saudi Arabia. The 53 cyclone tracks that passed through or abated over Saudi Arabia are categorized into five key routes. Although these tracks primarily affect the northern part of Saudi Arabia, they can generate dust storms that impact regions further south, including Jeddah, Humaij and Khulais. This highlights the broader influence of Saharan cyclones on dust storm activity across Saudi Arabia, even in regions not directly along the main cyclone tracks (Almazroui et al., 2019).

Dust storms in Saudi Arabia are most frequent from mid-winter to early summer, with 77% of them occurring between February and June. March is the most active month for dust storms, accounting for 19% of the total, while November is the least active, with only 1% of storms occurring during that month (Notaro et al., 2013). The timing of dust storms varies across the country, reflecting a heterogeneous pattern. Dust storms, which are common in desert environments like Humaij, pose another significant risk. The accumulation of dust on solar panels can significantly reduce their efficiency by blocking sunlight, a phenomenon well-documented in

solar energy research. Frequent cleaning is required to maintain optimal performance, which increases operational costs and water usage. Makkah, located in the western region of Saudi Arabia, experiences dust storms, although their frequency is relatively moderate compared to other regions like Al-Ahsa. The average daily rate of dust storms in Makkah ranges from approximately 0.05 to 0.1 per day, with the highest occurrence from March to May. During these months, the percentage of days with dust storms can range from about 2% to 10% monthly. This frequency is significant for photovoltaic energy projects, as dust storms can impact the efficiency and maintenance of solar panels (Alhajji et al., 2024). According to the report "Analysis and Prediction of Dust Storms across Saudi Arabia during 1980 to 2007" by Mohammad M. Alharbi (2010), Jeddah, Humaij and Khulais are categorized under classes C or D, with annual total blowing dust events ranging from 9 to 16 and 8 events, respectively. In terms of annual dust storm events, these areas are specifically categorized under class D, which experiences 8 storm events per year. A study by Sarah Albugami et al. (2019) analyzing data from 2000 to 2016 highlighted the significant impact of dust storms over Saudi Arabia. The year 2003 recorded the highest number of dust storm events, totaling 203, and representing 10.74% of the total dust storms recorded between 2000 and 2016. The study observed a gradual increase in dust events in Jeddah, with a significant linear regression slope of 0.37 ± 0.10 events per year.

Furthermore, the IPCC AR6 reports an increased likelihood of extreme weather events, including flash floods, due to climate change (IPCC, 2021). The Rainfall of Al Humaij plain varies across the region, with the western flat areas receiving an average of 60 mm per year, while the eastern mountainous regions receive over 170 mm per year (Gabr et al., 2017; Khan et al., 2022). However, the overall annual average rainfall over the region is 35.1 mm, and it is both irregular and unpredictable (Alsherif & Almaghrabi, 2022). For example, sporadic rainfall events resulted in 777 mm of rain on February 12, 2010, and March 15-16, 2011 (Al-Sherif et al., 2013). Meteorological data from the past decade indicate that the annual precipitation has generally been very low and variable, ranging from 0.001 to 86.4 mm per year. But, flash floods can damage infrastructure and disrupt operations, particularly in regions with poorly developed drainage systems. Robust infrastructure planning is needed to mitigate the impacts of such extreme events. Flooding in this region is primarily caused by intense rainfall events over short periods, which, combined with the low water absorptive capacity of the soil, leads to increased overland flow and potential flooding (Shi, 2014).

Additionally, the study by Almaliki et al. (2023) estimates the vulnerability of coastal zones in Jeddah Province to inundation by the year 2100 under various sea level rise (SLR) scenarios. The results indicated that SLR scenarios of 1, 2, 5, and 10 meters could inundate approximately 1.6%, 4.7%, 14.9%, and 30.6% of the coast, respectively, impacting built-up and road areas significantly. Future projections suggest that large stretches of Saudi Arabia's coastline, including the Red Sea and Gulf coasts, will likely undergo regime shifts, with substantial shoreline retreats anticipated by 2100 under both RCP scenarios (Almaliki et al., 2023).

Given these anticipated changes, it is crucial to integrate adaptive measures into the solar park's design and operational plans to enhance resilience against these physical risks. For instance, utilizing more heat-resistant materials, implementing dust mitigation technologies, and enhancing

infrastructure to withstand extreme weather events could reduce vulnerability and maintain the project's long-term viability.

1.3 Transition Risks

As part of its Vision 2030 initiative, Saudi Arabia aims to achieve net zero greenhouse gas emissions by 2060, with interim goals for 2030 including an annual reduction of 278 million tons of CO₂ equivalent (Saudi Arabia, 2021). The Kingdom aims to significantly increase the share of renewable energy in the national grid, with a target of 50% renewable energy in its energy mix by 2030 (Ministry of Energy, 2023). This project could encounter transition risks such as increased operational costs and the need for infrastructure modifications as Saudi Arabia strengthens its environmental policies to meet international climate commitments. However, due to the Power Purchase Agreement (PPA) often associated with renewable energy projects, which provides a stable and predictable revenue stream, this solar project might be less exposed to financial uncertainties related to these regulatory changes.

1.4 Alignment with National and International Climate Goals

This project is strategically positioned to support Saudi Arabia's evolving energy policies and climate commitments under the Paris Agreement. This project aligns with these national initiatives by contributing to the expansion of renewable energy capacity, a core component of Saudi Arabia's strategy to meet its climate goals. By directly contributing to these capacity goals, the Humaij Solar Park supports the national strategy of enhancing energy security, reducing carbon emissions, and fostering economic diversification.

1.5 Preliminary National Climate Commitment Compatibility Review

The Humaij Solar Energy Park in Makkah aligns with Saudi Arabia's National Climate Commitments (NCCs) including its Nationally Determined Contributions (NDCs) under the Paris Agreement by enhancing renewable energy capacity and reducing greenhouse gas emissions. Additionally, the park supports Saudi Arabia's transition to a low-GHG economy and contributes to the country's goal of achieving net zero emissions by 2060, benefiting from stable revenue streams through Power Purchase Agreements (PPAs). By incorporating innovative technologies and participating in programs like the Greenhouse Gas Crediting and Offsetting Mechanism (GCOM) to generate carbon credits, the project enhances its financial resilience while ensuring alignment with national climate objectives and promoting sustainable energy production in the region. It is expected that the project will address physical climate risks such as extreme heat, dust storms, and flash floods through adaptive measures like heat-resistant materials and dust mitigation technologies, aligning with national adaptation goals to increase resilience.

1.6 Risk Management Opportunities

This project offers several risk management opportunities that can support the project's resilience against regulatory and transition risks while aligning with Saudi Arabia's broader climate objectives. A significant opportunity lies in proactively implementing advanced environmental management practices and technologies that exceed current regulatory standards. By adopting best

practices in sustainability, such as using water-efficient cleaning systems for solar panels and incorporating heat-resistant materials, the project can minimize its environmental impact and lower operational costs over time. Additionally, conducting regular environmental audits and sustainability reporting not only demonstrates the project's commitment to continuous improvement but also enhances its reputation with regulators and investors focused on environmental, social, and governance (ESG) criteria.

Furthermore, the solar park can leverage its alignment with Saudi Arabia's Nationally Determined Contributions (NDCs) and net-zero targets to capitalize on emerging market opportunities, such as those provided by the Greenhouse Gas Crediting and Offsetting Mechanism (GCOM) introduced by the Ministry of Energy (2023b). Through GCOM, the project can generate and sell carbon credits, enhancing its revenue streams and gaining a competitive edge in the local market. This mechanism allows the solar park to monetize its emissions reductions, providing a financial incentive to exceed compliance requirements and contribute to the country's climate goals. By actively participating in this program and engaging with stakeholders in the renewable energy sector, the solar park can not only mitigate regulatory risks but also position itself as a leader in sustainable energy production, attracting additional investments and fostering growth in the green economy.

1.7 Opportunities

The solar park can enhance its market position by adopting innovative technologies and practices that improve operational efficiency and environmental performance. By exceeding current regulatory standards and demonstrating leadership in sustainability, the project can access green financing and incentives offered by both domestic and international financial institutions that prioritize ESG-focused investments. Engaging in these initiatives not only helps mitigate risks but also opens doors to partnerships and collaborations that can drive further expansion in the renewable energy sector. By positioning itself as a frontrunner in the green economy, the Humaij Solar Park can attract additional investments, foster local economic development, and contribute to Saudi Arabia's transition to a sustainable energy future.

1.8 Conclusions

The Solar Energy Park in Humaij, Madena, will play a critical role in advancing Saudi Arabia's renewable energy strategy and aligning with its climate commitments under the Paris Agreement. This assessment highlights several physical risks, such as extreme heat, dust storms, and flash floods, which could impact the efficiency and longevity of solar panels and the overall infrastructure. These risks necessitate the integration of adaptive measures, including heat-resistant materials, dust mitigation technologies, and robust infrastructure designs to enhance resilience against extreme weather events. Additionally, the project is exposed to transition risks, including market fluctuations and increased competition in the renewable energy sector. However, the project's alignment with national climate goals and the stable revenue stream provided by Power Purchase Agreements (PPAs) mitigate some of these financial uncertainties (Table 1).

Furthermore, this project presents significant opportunities for growth and sustainability. By adopting innovative technologies and practices, the project can improve operational efficiency,

reduce environmental impact, and access green financing. Participation in the Greenhouse Gas Crediting and Offsetting Mechanism (GCOM) provides an additional opportunity to generate and sell carbon credits, enhancing revenue and supporting Saudi Arabia's climate goals. Overall, this solar park not only contributes to the expansion of renewable energy capacity in Saudi Arabia but also positions itself as a leader in sustainable energy production. By leveraging these opportunities and effectively managing the identified risks, Humaij Solar Park can ensure its long-term viability and support the country's transition to a sustainable energy future.

Table 1. Climate Change Risk Assessment of Humaij Solar Project.

Risk Category	Risk Description	Likelihood	Impact	Mitigation Strategy
Physical Risks	The project is exposed to extreme heat, dust storms, and flash floods, which can affect efficiency and infrastructure.	High	High	Integrate heat-resistant materials, dust mitigation technologies, and robust infrastructure to withstand extreme weather events.
Transition Risks	Potential market fluctuations and increased competition in the renewable energy sector as Saudi Arabia and other nations rapidly expand their renewable energy capacities.	Medium	Moderate	Secure long-term Power Purchase Agreements (PPAs) to ensure stable revenue streams and continuously monitor market trends to adapt strategies as needed.
Alignment Risks	Although the project is aligned with Saudi Arabia's NDCs and the Paris Agreement, changes in global renewable energy policies could impact market dynamics.	Low	Moderate	Maintain flexibility in project operations and engage with policymakers to stay updated on international climate policies and market opportunities.
Opportunities	Adopting innovative technologies and practices to improve efficiency, leveraging GCOM for carbon credits, and accessing green financing opportunities.	High	High	Adopt advanced environmental management practices, exceed regulatory standards, and capitalize on market opportunities provided by GCOM.

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Solar Photovoltaic Glint and Glare Study

Gulf Renewables Lab Services

Khulais

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ADMINISTRATION PAGE

Job Reference:	13563A
Author:	Michael Sutton
Email:	michael@pagerpower.com

Reviewers:	Phillip Charhill
Email:	phillip@pagerpower.com

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Stour Valley Business Centre, Brundon Lane, Sudbury, CO10 7GB

T: +44 (0)1787 319001 E: info@pagerpower.com W: www.pagerpower.com

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EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the possible effects of glint and glare from a proposed single-axis tracking solar photovoltaic (PV) development located south of Qudaid, Saudi Arabia. The assessment pertains to the possible impact upon aviation activity associated with King Abdulaziz International Airport and Rabigh Airport.

Pager Power

Pager Power has undertaken over 1,400 glint and glare assessments in the UK, Europe and internationally. The company's own glint and glare guidance is based on industry experience and extensive consultation with industry stakeholders including airports and aviation regulators.

Conclusion

No solar reflections are geometrically possible towards any aircraft approaches or Air Traffic Control Towers at King Abdulaziz International Airport or Rabigh Airport.

No impacts upon aviation activity are predicted, and no mitigation is required.

Guidance and Studies

Guidelines exist in the USA (produced by the Federal Aviation Administration) with respect to solar developments and aviation activity. Pager Power has reviewed existing guidelines and the available studies in the process of defining its own glint and glare assessment guidance document and methodology for solar photovoltaic developments, which was published in early 2017, with the fourth edition published in 2022. This methodology defines a comprehensive process for determining the impact upon aviation activity which is in line with the FAA guidance.

Pager Power's approach is to undertake geometric reflection calculations and, where a solar reflection is predicted, consider the screening (existing and/or proposed) between the receptor and the reflecting solar panels. For aviation activity, where a solar reflection is predicted, solar intensity calculations are undertaken in line with the Sandia National Laboratories' FAA methodology¹. The scenario in which a solar reflection can occur for all receptors is then identified and discussed, and a comparison is made against the available solar panel reflection studies to determine the overall impact.

The available studies have measured the intensity of reflections from solar panels with respect to other naturally occurring and manmade surfaces. The results show that the reflections produced are of intensity similar to or less than those produced from still water and significantly less than reflections from glass and steel².

¹ Formerly mandatory for on-airfield solar developments in the USA under the FAA's interim policy, superseded in 2021 with a policy that effectively requires individual airports to sign off on their on-airfield development as they see fit.

² SunPower, 2009, SunPower Solar Module Glare and Reflectance (appendix to Solargen Energy, 2010).

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ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 59 countries within Europe, Africa, America, Asia and Australasia.

The company comprises a team of experts to provide technical expertise and guidance on a range of planning issues for large and small developments.

Pager Power was established in 1997. Initially the company focus was on modelling the impact of wind turbines on radar systems. Over the years, the company has expanded into numerous fields including:

- Renewable energy projects.
- Building developments.
- Aviation and telecommunication systems.

Pager Power prides itself on providing comprehensive, understandable and accurate assessments of complex issues in line with national and international standards. This is underpinned by its custom software, longstanding relationships with stakeholders and active role in conferences and research efforts around the world.

Pager Power's assessments withstand legal scrutiny and the company can provide support for a project at any stage.

1 INTRODUCTION

1.1 Overview

Pager Power has been retained to assess the possible effects of glint and glare from a proposed single-axis tracking solar photovoltaic (PV) development located south of Qudaid, Saudi Arabia. The assessment pertains to the possible impact upon aviation activity associated with King Abdulaziz International Airport and Rabigh Airport.

This report contains the following:

- Solar development details.
- Explanation of glint and glare.
- Overview of relevant guidance and studies.
- Overview of Sun movement.
- Assessment methodology.
- Identification of receptors.
- Glint and glare assessment for identified receptors.
- Results discussion.

1.2 Pager Power's Experience

Pager Power has undertaken over 1,400 Glint and Glare assessments in the UK, Europe and internationally. The studies have included assessment of civil and military aerodromes, railway infrastructure and other ground-based receptors including roads and dwellings.

1.3 Glint and Glare Definition

The definition of glint and glare is as follows³:

- Glint – a momentary flash of bright light typically received by moving receptors or from moving reflectors.
- Glare – a continuous source of bright light typically received by static receptors or from large reflective surfaces.

The term 'solar reflection' is used in this report to refer to both reflection types i.e. glint and glare.

³These definitions are aligned with the Federal Aviation Administration (FAA) in the United States of America.

2 SOLAR DEVELOPMENT LOCATION AND DETAILS

2.1 Proposed Development Layout

Figure 1 below shows the proposed development layout for Khulais⁴.



Figure 1 Proposed development layout

⁴ MR_AXD-INF.168M.60-(2278x1134)_Saudi Arabia-KHULAIS LAYOUT_v01.4 (cropped)

2.2 Proposed Development Location – Aerial Image

The location of the proposed development relative to the two airports is shown in Figure 2 below.



Figure 2 Proposed development location relative to airports – aerial image

2.3 Solar Panel Technical Information

The technical information used for the modelling is presented in Table 1 below.

Solar Panel Technical Information	
Assessed centre-height	2.207m agl (above ground level)
Tracking	Horizontal Single Axis tracks Sun East to West
Tilt of tracking axis (°)	0
Orientation of tracking axis (°)	180
Offset angle of module (°)	0
Tracker Range of Motion (°)	±60
Resting angle (°)	0
Backtracking Method	Instant (for modelling purposes) ⁵
Surface material	Smooth glass with an anti-reflective coating (ARC)

Table 1 Solar panel technical information

2.3.1 Solar Panel Backtracking

Shading considerations dictate the panel tilt. This is affected by:

- The elevation angle of the Sun.
- The vertical tilt of the panels.
- The spacing between the panel rows.

This means that early in the morning and late in the evening, the panels will not be directed exactly towards the Sun, as the loss from shading of the panels (caused by facing the Sun directly when the Sun is low in the horizon), would be greater than the loss from lowering the panels to a less direct angle in order to avoid the shading Figure 3 on the following page illustrates this.

The graphics in Figure 3 on the following page shows two lines illustrating the paths of light from the Sun towards the solar panels. In reality, the lines from the Sun to each panel would be effectively parallel due to the large separation distance. The figure is for illustrative purposes only.

⁵ See Section 2.3.2 and Appendix I for further details.

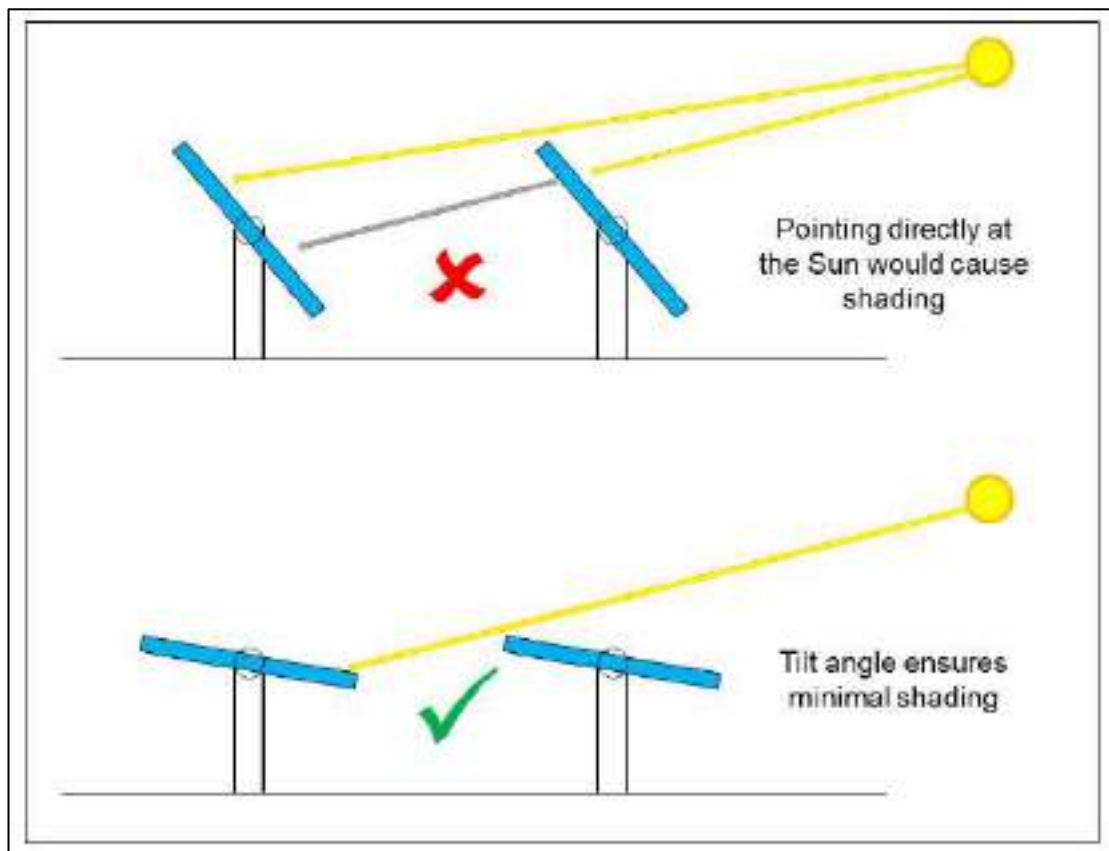


Figure 3 Shading Considerations

Later in the day, the panels can be directed towards the Sun without any shading issues. This is illustrated in Figure 4 below.

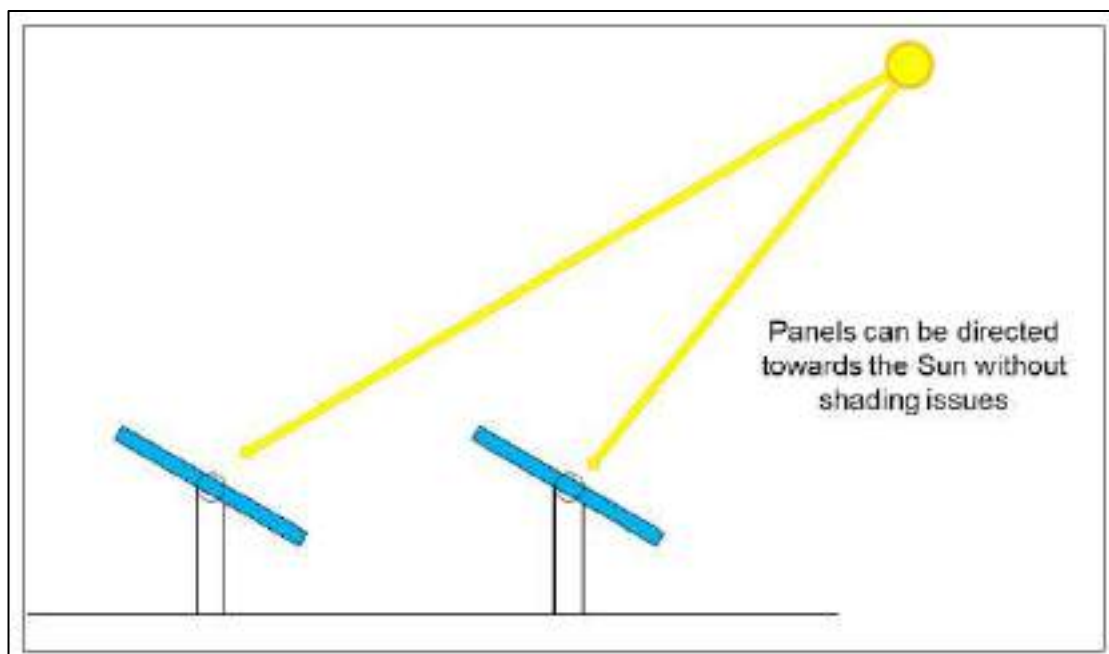


Figure 4 Panel alignment at high solar angles

The solar panels backtrack (where the panel angle gradually declines to prevent shading) by reverting to 0 degrees (flat) once the maximum elevation angle of the panels (60 degrees) becomes ineffective due to the low height of the Sun above the horizon and to avoid shading.

2.3.2 Back Tracking Solar Panel Model

Back tracking systems are sensitive to panel length, row spacing, topography and the level of shading which varies throughout the year. The Forge Solar model used in this assessment is a widely accepted model within this area. The model approximates a backtracking system by assuming the panels instantaneously revert to its resting angle of 0 degrees whenever the sun is outside the rotation range (60 degrees in this instance). Panels with a maximum tracking angle of 60 degrees and resting angle of 0 degrees would therefore lie horizontally from sunrise until the Sun enters the rotation range, and immediately after the sun leaves the rotation range until sunset daily. This definition is taken from Forge (see Appendix E) and by rotation range it is assumed the panels remain at 0 degrees until the Sun reaches 30 degrees above the horizon – when the Sun is at right angles to the panels at 60 degrees. It is understood that this option was created specifically to account for backtracking to the extent possible.

Whilst this model simplifies the backtracking process to be used by the solar panels within the solar development, panels that revert to their resting angle immediately in many cases present a worst-case scenario for reflectors. This is because flatter panels can produce solar reflections in a much greater range of azimuth angles at ground level. The results would in most cases be more conservative than modelling a detailed back tracking system.

2.4 Reflector Areas

The bounding co-ordinates for the proposed solar development have been extrapolated from the site plans. The data can be found in Appendix G.

The assessed reflector areas are shown in Figure 5 below.



Figure 5 Assessed reflector areas

3 GLINT AND GLARE ASSESSMENT METHODOLOGY

3.1 Guidance and Studies

Appendices A and B present a review of relevant guidance and independent studies with regard to glint and glare issues from solar panels. The overall conclusions from the available studies are as follows:

- Specular reflections of the Sun from solar panels are possible.
- The measured intensity of a reflection from solar panels can vary from 2% to 30% depending on the angle of incidence.
- Published guidance shows that the intensity of solar reflections from solar panels are equal to or less than those from water. It also shows that reflections from solar panels are significantly less intense than many other reflective surfaces, which are common in an outdoor environment.

3.2 Background

Details of the Sun's movements and solar reflections are presented in Appendix C.

3.3 Methodology

3.3.1 Pager Power's Methodology

The glint and glare assessment methodology has been derived from the information provided to Pager Power through consultation with stakeholders and by reviewing the available guidance and studies. The methodology for a glint and glare assessments is as follows:

- Identify receptors in the area surrounding the solar development.
- Consider direct solar reflections from the solar development towards the identified receptors by undertaking geometric calculations.
- Consider the visibility of the panels from the receptor's location. If the panels are not visible from the receptor then no reflection can occur.
- Based on the results of the geometric calculations, determine whether a reflection can occur, and if so, at what time it will occur.
- Consider both the solar reflection from the solar development and the location of the direct sunlight with respect to the receptor's position.
- Consider the solar reflection with respect to the published studies and guidance - including intensity calculations where appropriate.
- Determine whether a significant detrimental impact is expected in line with the process presented in Appendix D.

3.3.2 Sandia National Laboratories' Methodology

Sandia National Laboratories developed the Solar Glare Hazard Analysis Tool (SGHAT) which is no longer freely available however it is now developed by Forge Solar. Pager Power uses this model where required for aviation receptors. Whilst strictly applicable in the USA and to solar photovoltaic developments only, the methodology is widely used by aviation stakeholders internationally.

3.4 Assessment Methodology and Limitations

Further technical details regarding the methodology of the geometric calculations and limitations are presented in Appendix E and F.

4 IDENTIFICATION OF RECEPTORS

4.1 King Abdulaziz International Airport

4.1.1 Overview

King Abdulaziz International Airport (KAIA) is a General Authority of Civil Aviation (GACA) licensed aerodrome. KAIA has three runways, the details of which are presented below:

- 16C/34C measuring 4,000m by 60m (asphalt).
- 16L/34R measuring 4,000m by 60m (asphalt).
- 16R/34L measuring 3,800m by 60m (asphalt).

KAIA has two Air Traffic Control (ATC) Towers, with one being located between runway 16R/34L and 16C/34C and the other being located between 16L/34R and 16C/34C.

The aerodrome chart⁶ is presented in Figures 6 on the following page.

⁶ Source: Saudi Air Navigation Services (SANS). "AIP Saudi Arabia is published by authority of the General Authority of Civil Aviation (GACA)."

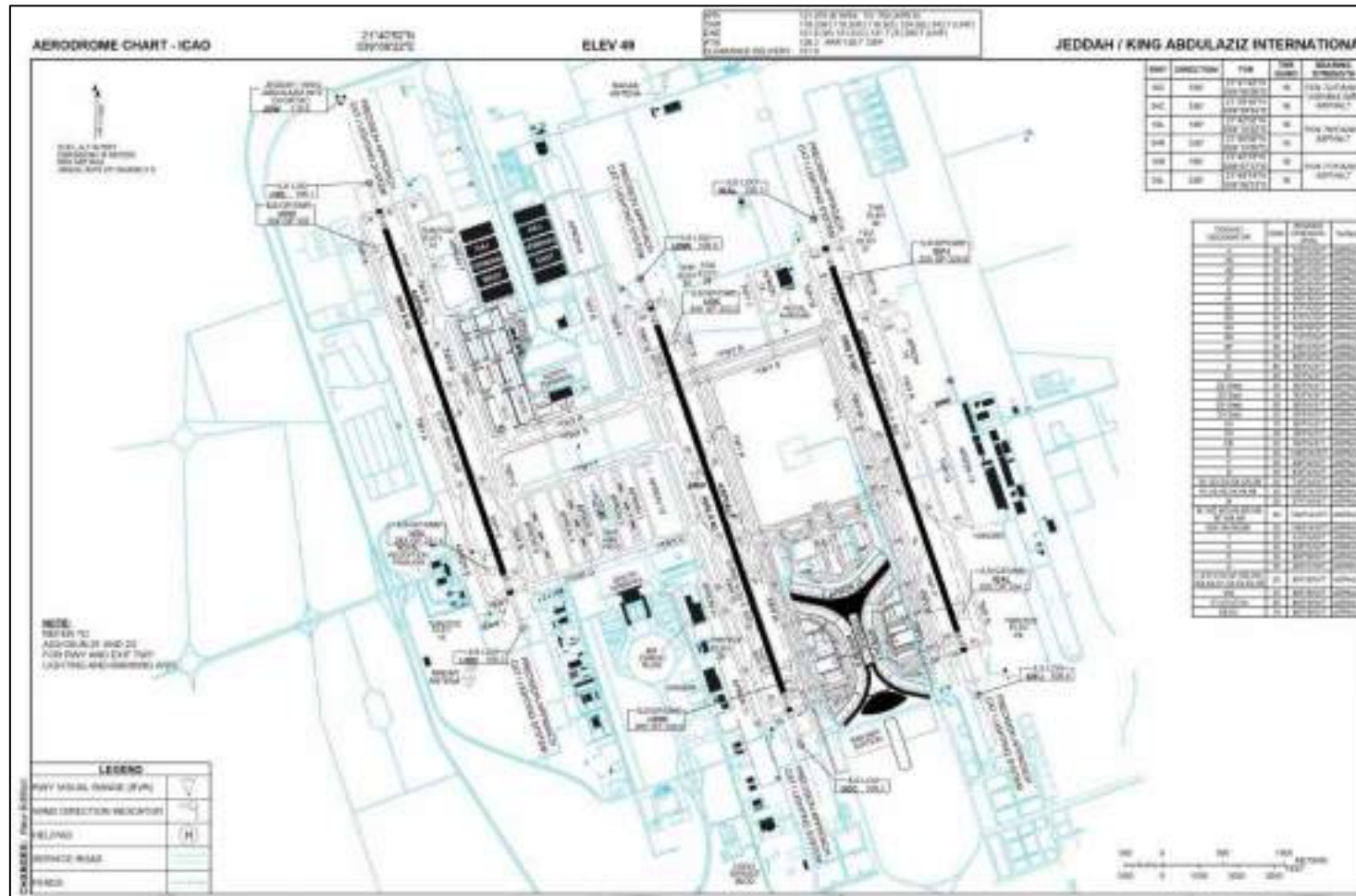


Figure 6 King Abdulaziz International Airport Aerodrome Chart

4.1.2 Approaching Aircraft

Each of the three runways have two associated approach paths, one for each bearing. It is Pager Power's methodology to assess whether a solar reflection can be experienced on the approach paths for the associated runways. This is considered to be the most critical stage of the flight.

A geometric glint and glare assessment has been undertaken for all six aircraft approach paths. The Pager Power approach for determining receptor (aircraft) locations on the approach path is to select locations along the extended runway centre line from 50ft above the runway threshold out to a distance of 2 miles. The altitude of the aircraft is determined by using a 3-degree descent path relative to the runway threshold heights. The receptor details for each runway approach are presented in Appendix G.

The assessed aircraft approach paths are shown in Figure 6 on the following page.

4.1.3 ATC Tower

It is standard practice to determine whether a solar reflection can be experienced by personnel within an ATC Tower.

Two ATC Tower locations at KAIA have been assessed. The ATC tower heights above ground level have been identified in the Aeronautical Information Publication (AIP) and are as follows:

- New ATC Tower – 145.69m.
- ATC Tower – 57.91m.

The ground height has been determined based upon SRTM terrain data. The detailed receptor details are presented in Appendix G.

The locations of the ATC Towers are shown within Figure 7 on the following page.



Figure 7 KAIA approaches and ATC tower receptors

4.2 Rabigh Airport

4.2.1 Overview

Rabigh Airport is a General Authority of Civil Aviation (GACA) licensed aerodrome with one runway, the details of which are presented below:

- 15/33 measuring 2,370m by 32m (asphalt).

Rabigh Airport has one ATC Tower, which is located to the west of the runway centre point.

The aerodrome chart⁷ is presented in Figures 8 on the following page.

⁷ Source: Saudi Air Navigation Services (SANS). "AIP Saudi Arabia is published by authority of the General Authority of Civil Aviation (GACA)."

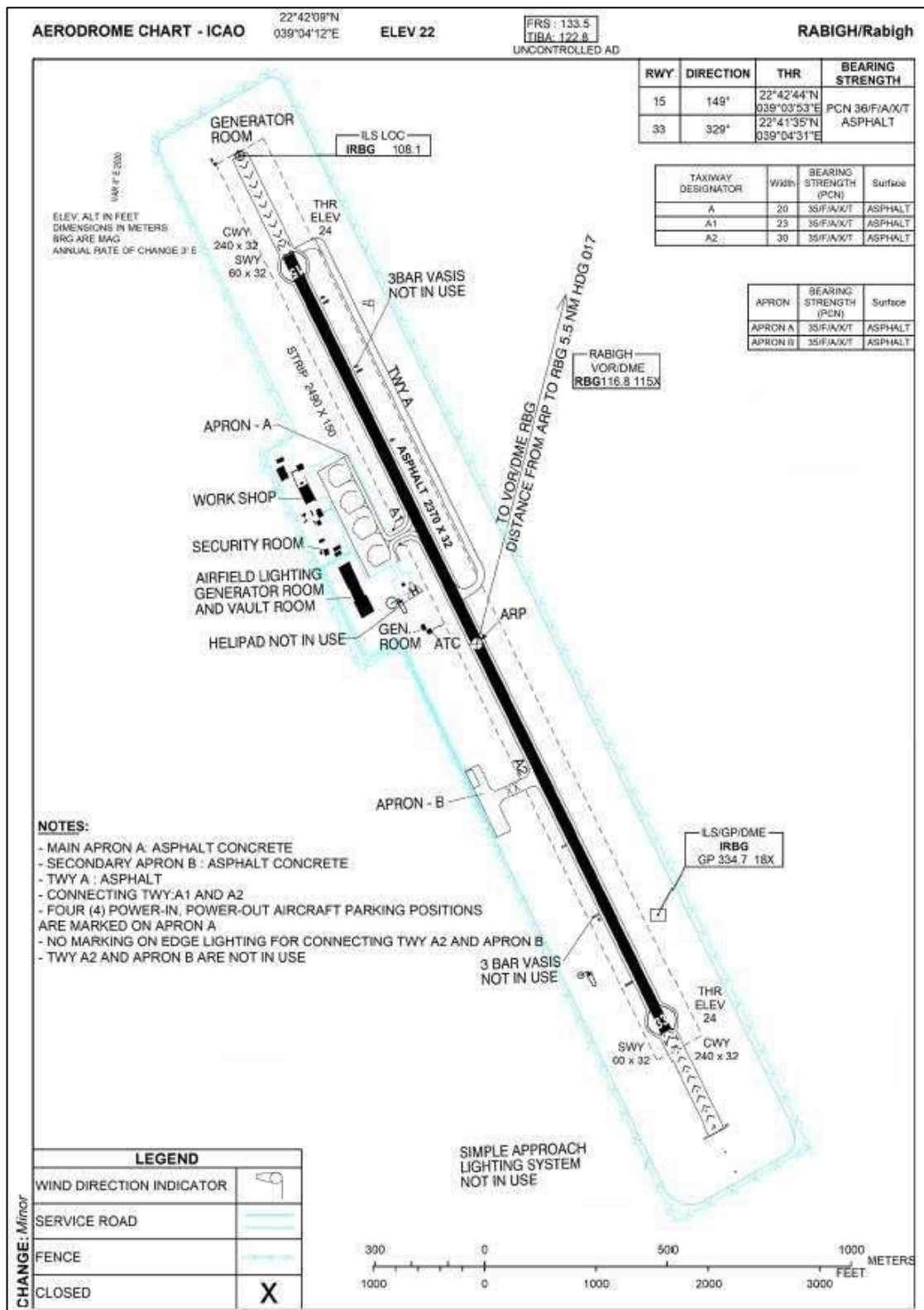


Figure 8 Rabigh Airport Aerodrome Chart

4.2.2 Approaching Aircraft

The runway has two associated approach paths, one for each bearing. It is Pager Power's methodology to assess whether a solar reflection can be experienced on the approach paths for the associated runways. This is considered to be the most critical stage of the flight.

A geometric glint and glare assessment has been undertaken for both aircraft approach paths. The Pager Power approach for determining receptor (aircraft) locations on the approach path is to select locations along the extended runway centre line from 50ft above the runway threshold out to a distance of 2 miles. The altitude of the aircraft is determined by using a 3-degree descent path relative to the runway threshold heights. The receptor details for each runway approach are presented in Appendix G.

The assessed aircraft approach paths are shown in Figure 8 on the following page.

4.2.3 ATC Tower

It is standard practice to determine whether a solar reflection can be experienced by personnel within an ATC Tower.

One ATC Tower location at Rabigh Airport has been assessed. The ATC tower height above ground level has been estimated to be 20m above ground level. The ground height has been determined based upon SRTM terrain data. The detailed receptor details are presented in Appendix G.

The location of the ATC Tower is shown within Figure 9 on the following page.



Figure 9 Rabigh Airport approaches and ATC tower receptor

5 GEOMETRIC ASSESSMENT RESULTS

5.1 Glare Intensity Designation

The Forge model has been used to determine whether reflections are possible. If solar reflections are possible, intensity calculations in line with the Sandia National Laboratories methodology are undertaken. These calculations are routinely required for solar photovoltaic developments on or near aerodromes. The intensity model calculates the expected intensity of a reflection with respect to the potential for an after-image (or worse) occurring. The designation used by the model is presented in Table 2 below along with the associated colour coding.

Coding Used	Intensity Key
Glare beyond 50°	'Glare occurs outside of a pilot's primary field-of-view (50 degrees horizontally either side of the direction of travel)'
'Green glare'	'Low potential for temporary after-image'
'Yellow glare'	'Potential for temporary after-image'
'Red glare'	'Potential for permanent eye damage'

Table 2 *Glare intensity designation*

In addition, the intensity model allows for assessment of a variety of solar panel surface materials. In the first instance, a surface material of 'smooth glass with an anti-reflective coating' is assessed. It is understood that this is the most commonly used solar panel surface material.

5.2 King Abdulaziz International Airport

The geometric modelling has shown that no solar reflections are geometrically possible towards any of the six approaches or the two ATC Towers at KAIA.

No impacts upon aviation activity associated with KAIA are predicted and no mitigation is required.

5.3 Rabigh Airport

The geometric modelling has shown that no solar reflections are geometrically possible towards either of the approaches or the ATC Tower at Rabigh Airport.

No impacts upon aviation activity associated with Rabigh Airport are predicted and no mitigation is required.

APPENDIX A – OVERVIEW OF GLINT AND GLARE GUIDANCE

Overview

This section presents details regarding the relevant guidance and studies with respect to the considerations and effects of solar reflections from solar panels, known as 'Glint and Glare'. The guidance is taken from the UK and USA and is for reference purposes only.

This is not a comprehensive review of the data sources, rather it is intended to give an overview of the important parameters and considerations that have informed this assessment.

UK Planning Policy

Renewable and Low Carbon Energy

The National Planning Policy Framework under the planning practice guidance for Renewable and Low Carbon Energy⁸ (specifically regarding the consideration of solar farms, paragraph 013) states:

'What are the particular planning considerations that relate to large scale ground-mounted solar photovoltaic Farms?

The deployment of large-scale solar farms can have a negative impact on the rural environment, particularly in undulating landscapes. However, the visual impact of a well-planned and well-screened solar farm can be properly addressed within the landscape if planned sensitively.

Particular factors a local planning authority will need to consider include:

...

- *the proposal's visual impact, the effect on landscape of glint and glare (see guidance on landscape assessment) and on **neighbouring uses and aircraft safety**;*
- *the extent to which there may be additional impacts if solar arrays follow the daily movement of the sun;*

...

The approach to assessing cumulative landscape and visual impact of large scale solar farms is likely to be the same as assessing the impact of wind turbines. However, in the case of ground-mounted solar panels it should be noted that with effective screening and appropriate land topography the area of a zone of visual influence could be zero.'

⁸ Renewable and low carbon energy, Ministry of Housing, Communities & Local Government, date: 18 June 2015, accessed on: 01/11/2021

National Policy Statement for Renewable Energy Infrastructure

The National Policy Statement for Renewable Energy Infrastructure (EN-3)⁹ sets out the primary policy for decisions by the Secretary of State for nationally significant renewable energy infrastructure. Sections 2.10.102-106 state:

- ‘2.10.102 Solar panels are specifically designed to absorb, not reflect, irradiation. However, solar panels may reflect the sun’s rays at certain angles, causing glint and glare. Glint is defined as a momentary flash of light that may be produced as a direct reflection of the sun in the solar panel. Glare is a continuous source of excessive brightness experienced by a stationary observer located in the path of reflected sunlight from the face of the panel. The effect occurs when the solar panel is stationed between or at an angle of the sun and the receptor.*
- 2.10.103 Applicants should map receptors to qualitatively identify potential glint and glare issues and determine if a glint and glare assessment is necessary as part of the application.*
- 2.10.104 When a quantitative glint and glare assessment is necessary, applicants are expected to consider the geometric possibility of glint and glare affecting nearby receptors and provide an assessment of potential impact and impairment based on the angle and duration of incidence and the intensity of the reflection.*
- 2.10.105 The extent of reflectivity analysis required to assess potential impacts will depend on the specific project site and design. This may need to account for ‘tracking’ panels if they are proposed as these may cause differential diurnal and/or seasonal impacts.*
- 2.10.106 When a glint and glare assessment is undertaken, the potential for solar PV panels, frames and supports to have a combined reflective quality may need to be assessed, although the glint and glare of the frames and supports is likely to be significantly less than the panels.’*

The EN-3 does not state which receptors should be considered as part of a quantitative glint and glare assessment. Based on Pager Power’s extensive project experience, typical receptors include residential dwellings, road users, aviation infrastructure, and railway infrastructure.

Sections 2.10.134-136 state:

- ‘2.10.134 Applicants should consider using, and in some cases the Secretary of State may require, solar panels to comprise of (or be covered with) anti-glare/anti-reflective coating with a specified angle of maximum reflection attenuation for the lifetime of the permission.*
- 2.10.135 Applicants may consider using screening between potentially affected receptors and the reflecting panels to mitigate the effects.*
- 2.10.136 Applicants may consider adjusting the azimuth alignment of or changing the elevation tilt angle of a solar panel, within the economically viable range, to alter the angle of incidence. In practice this is unlikely to remove the potential impact altogether but in marginal cases may contribute to a mitigation strategy.’*

⁹ National Policy Statement for Renewable Energy Infrastructure (EN-3), Department for Energy Security & Net Zero, date: January 2024, accessed on: 23/08/2024.

The mitigation strategies listed within the EN-3 are relevant strategies that are frequently utilised to eliminate or reduce glint and glare effects towards surrounding observers. The most common form of mitigation is the implementation of screening along the site boundary.

Sections 2.10.158-159 state:

2.10.158 Solar PV panels are designed to absorb, not reflect, irradiation. However, the Secretary of State should assess the potential impact of glint and glare on nearby homes, motorists, public rights of way, and aviation infrastructure (including aircraft departure and arrival flight paths).

2.10.159 Whilst there is some evidence that glint and glare from solar farms can be experienced by pilots and air traffic controllers in certain conditions, there is no evidence that glint and glare from solar farms results in significant impairment on aircraft safety. Therefore, unless a significant impairment can be demonstrated, the Secretary of State is unlikely to give any more than limited weight to claims of aviation interference because of glint and glare from solar farms.

The EN-3 goes some way in acknowledging that the issue is more complex than presented in the early draft issues; though, this is still unlikely to be welcomed by aviation stakeholders, who will still request a glint and glare assessment on the basis that glare may lead to a potentially significant impact upon aviation safety.

Finally, the EN-3 relates solely to nationally significant renewable energy infrastructure and therefore does not apply to all planning applications for solar farms.

Aviation Assessment Guidance

The UK Civil Aviation Authority (CAA) issued interim guidance relating to Solar Photovoltaic Systems (SPV) on 17 December 2010 and was subject to a CAA information alert 2010/53. The formal policy was cancelled on September 7th, 2012¹⁰ however the advice is still applicable¹¹ until a formal policy is developed. The relevant aviation guidance from the CAA is presented in the section below.

CAA Interim Guidance

This interim guidance makes the following recommendations (p.2-3):

'8. It is recommended that, as part of a planning application, the SPV developer provide safety assurance documentation (including risk assessment) regarding the full potential impact of the SPV installation on aviation interests.

9. Guidance on safeguarding procedures at CAA licensed aerodromes is published within CAP 738 Safeguarding of Aerodromes and advice for unlicensed aerodromes is contained within CAP 793 Safe Operating Practices at Unlicensed Aerodromes.

10. Where proposed developments in the vicinity of aerodromes require an application for planning permission the relevant LPA normally consults aerodrome operators or NATS when aeronautical

¹⁰ Archived at Pager Power

¹¹ Reference email from the CAA dated 19/05/2014.

interests might be affected. This consultation procedure is a statutory obligation in the case of certain major airports, and may include military establishments and certain air traffic surveillance technical sites. These arrangements are explained in Department for Transport Circular 1/2003 and for Scotland, Scottish Government Circular 2/2003.

11. In the event of SPV developments proposed under the Electricity Act, the relevant government department should routinely consult with the CAA. There is therefore no requirement for the CAA to be separately consulted for such proposed SPV installations or developments.

12. If an installation of SPV systems is planned on-aerodrome (i.e. within its licensed boundary) then it is recommended that data on the reflectivity of the solar panel material should be included in any assessment before installation approval can be granted. Although approval for installation is the responsibility of the ALH¹², as part of a condition of a CAA Aerodrome Licence, the ALH is required to obtain prior consent from CAA Aerodrome Standards Department before any work is begun or approval to the developer or LPA is granted, in accordance with the procedures set out in CAP 791 Procedures for Changes to Aerodrome Infrastructure.

13. During the installation and associated construction of SPV systems there may also be a need to liaise with nearby aerodromes if cranes are to be used; CAA notification and permission is not required.

14. The CAA aims to replace this informal guidance with formal policy in due course and reserves the right to cancel, amend or alter the guidance provided in this document at its discretion upon receipt of new information.

15. Further guidance may be obtained from CAA's Aerodrome Standards Department via aerodromes@caa.co.uk.

FAA Guidance

The most comprehensive guidelines available for the assessment of solar developments near aerodromes has been produced by the United States Federal Aviation Administration (FAA). The first guidelines were produced initially in November 2010 and updated in 2013. A final policy was released in 2021, which superseded the interim guidance.

The 2010 document is entitled 'Technical Guidance for Evaluating Selected Solar Technologies on Airports'¹³, the 2013 update is entitled 'Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports'¹⁴, and the 2021 final policy is entitled 'Federal Aviation Administration Policy: Review of Solar Energy System Projects on Federally-Obligated Airports'¹⁵.

Key excerpts from the final policy are presented below:

¹² Aerodrome Licence Holder.

¹³ Archived at Pager Power

¹⁴ [Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports](#), Department of Transportation, Federal Aviation Administration (FAA), date: 10/2013, accessed on: 08/12/2021.

¹⁵ [Federal Aviation Administration Policy: Review of Solar Energy System Projects on Federally-Obligated Airports](#), Federal Aviation Administration, date: May 2021, accessed on: 08/12/2021.

Initially, FAA believed that solar energy systems could introduce a novel glint and glare effect to pilots on final approach. FAA has subsequently concluded that in most cases, the glint and glare from solar energy systems to pilots on final approach is similar to glint and glare pilots routinely experience from water bodies, glass-façade buildings, parking lots, and similar features. However, FAA has continued to receive reports of potential glint and glare from on-airport solar energy systems on personnel working in ATCT cabs. Therefore, FAA has determined the scope of agency policy should be focused on the impact of on-airport solar energy systems to federally-obligated towered airports, specifically the airport's ATCT cab.

The policy in this document updates and replaces the previous policy by encouraging airport sponsors to conduct an ocular analysis of potential impacts to ATCT cabs prior to submittal of a Notice of Proposed Construction or Alteration Form 7460-1 (hereinafter Form 7460-1). Airport sponsors are no longer required to submit the results of an ocular analysis to FAA. Instead, to demonstrate compliance with 14 CFR 77.5(c), FAA will rely on the submittal of Form 7460-1 in which the sponsor confirms that it has analyzed the potential for glint and glare and determined there is no potential for ocular impact to the airport's ATCT cab. This process will enable FAA to evaluate the solar energy system project, with assurance that the system will not impact the ATCT cab.

FAA encourages airport sponsors of federally-obligated towered airports to conduct a sufficient analysis to support their assertion that a proposed solar energy system will not result in ocular impacts. There are several tools available on the open market to airport sponsors that can analyze potential glint and glare to an ATCT cab. For proposed systems that will clearly not impact ATCT cabs (e.g., on-airport solar energy systems that are blocked from the ATCT cab's view by another structure), the use of such tools may not be necessary to support the assertion that a proposed solar energy system will not result in ocular impacts.

The excerpt above states where a solar PV development is to be located on a federally obligated aerodrome with an ATC Tower, it will require a glint and glare assessment to accompany its application. It states that pilots on approach are no longer a specific assessment requirement due to effects from solar energy systems being similar to glint and glare pilots routinely experience from water bodies, glass-façade buildings, parking lots, and similar features. Ultimately it comes down to the specific aerodrome to ensure it is adequately safeguarded, and it is on this basis that glint and glare assessments are routinely still requested.

The policy also states that several different tools and methodologies can be used to assess the impacts of glint and glare, which was previously required to be undertaken by the Solar Glare Hazard Analysis Tool (SGHAT) using the Sandia National Laboratories methodology.

In 2018, the FAA released the latest version (Version 1.1) of the 'Technical Guidance for Evaluating Selected Solar Technologies on Airports'¹⁶. Whilst the 2021 final policy also supersedes this guidance, many of the points are still relevant because aerodromes are still safeguarding against

¹⁶ Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 08/12/2021.

glint and glare irrespective of the FAA guidance. The key points are presented below for reference:

- *Reflectivity refers to light that is reflected off surfaces. The potential effects of reflectivity are glint (a momentary flash of bright light) and glare (a continuous source of bright light). These two effects are referred to hereinafter as "glare," which can cause a brief loss of vision, also known as flash blindness¹⁷.*
- *The amount of light reflected off a solar panel surface depends on the amount of sunlight hitting the surface, its surface reflectivity, geographic location, time of year, cloud cover, and solar panel orientation.*
- *As illustrated on Figure 16¹⁸, flat, smooth surfaces reflect a more concentrated amount of sunlight back to the receiver, which is referred to as specular reflection. The more a surface is polished, the more it shines. Rough or uneven surfaces reflect light in a diffused or scattered manner and, therefore, the light will not be received as bright.*
- *Because the FAA has no specific standards for airport solar facilities and potential glare, the type of glare analysis may vary. Depending on site specifics (e.g., existing land uses, location and size of the project) an acceptable evaluation could involve one or more of the following levels of assessment:*
 - *A qualitative analysis of potential impact in consultation with the Control Tower, pilots and airport officials;*
 - *A demonstration field test with solar panels at the proposed site in coordination with FAA Tower personnel;*
 - *A geometric analysis to determine days and times when an impact is predicted.*
- *The extent of reflectivity analysis required to assess potential impacts will depend on the specific project site and system design.*
- **1. Assessing Baseline Reflectivity Conditions** – *Reflection in the form of glare is present in current aviation operations. The existing sources of glare come from glass windows, auto surface parking, rooftops, and water bodies. At airports, existing reflecting surfaces may include hangar roofs, surface parking, and glassy office buildings. To minimize unexpected glare, windows of air traffic control towers and airplane cockpits are coated with anti-reflective glazing. Operators also wear polarized eye wear. Potential glare from solar panels should be viewed in this context. Any airport considering a solar PV project should first review existing sources of glare at the airport and the effectiveness of measures used to mitigate that glare.*
- **2. Tests in the Field** – *Potential glare from solar panels can easily be viewed at the airport through a field test. A few airports have coordinated these tests with FAA Air Traffic Controllers to assess the significance of glare impacts. To conduct such a test, a sponsor can take a solar panel out to proposed location of the solar project, and tilt the panel in different*

¹⁷ Flash Blindness, as described in the FAA guidelines, can be described as a temporary visual interference effect that persists after the source of illumination has ceased. This occurs from many reflective materials in the ambient environment.

¹⁸ First figure in Appendix B.

directions to evaluate the potential for glare onto the air traffic control tower. For the two known cases where a field test was conducted, tower personnel determined the glare was not significant. If there is a significant glare impact, the project can be modified by ensuring panels are not directed in that direction.

- **3. Geometric Analysis** – Geometric studies are the most technical approach for reflectivity issues. They are conducted when glare is difficult to assess through other methods. Studies of glare can employ geometry and the known path of the sun to predict when sunlight will reflect off of a fixed surface (like a solar panel) and contact a fixed receptor (e.g., control tower). At any given site, the sun moves across the sky every day and its path in the sky changes throughout year. This in turn alters the destination of the resultant reflections since the angle of reflection for the solar panels will be the same as the angle at which the sun hits the panels. The larger the reflective surface, the greater the likelihood of glare impacts.
- Facilities placed in remote locations, like the desert, will be far from receptors and therefore potential impacts are limited to passing aircraft. Because the intensity of the light reflected from the solar panel decreases with increasing distance, an appropriate question is how far you need to be from a solar reflected surface to avoid flash blindness. It is known that this distance is directly proportional to the size of the array in question¹⁹ but still requires further research to definitively answer.
- **Experiences of Existing Airport Solar Projects** – Solar installations are presently operating at a number of airports, including megawatt-sized solar facilities covering multiple acres. Air traffic control towers have expressed concern about glint and glare from a small number of solar installations. These were often instances when solar installations were sited between the tower and airfield, or for installations with inadequate or no reflectivity analysis. Adequate reflectivity analysis and alternative siting addressed initial issues at those installations.

Air Navigation Order (ANO) 2016

In some instances, an aviation stakeholder can refer to the ANO 2016²⁰ with regard to safeguarding. Key points from the document are presented below.

Lights liable to endanger

224. (1) A person must not exhibit in the United Kingdom any light which—

(a) by reason of its glare is liable to endanger aircraft taking off from or landing at an aerodrome;
or

(b) by reason of its liability to be mistaken for an aeronautical ground light is liable to endanger aircraft.

¹⁹ Ho, Clifford, Cheryl Ghanbari, and Richard Diver. 2009. Hazard Analysis of Glint and Glare From Concentrating Solar Power Plants. SolarPACES 2009, Berlin Germany. Sandia National Laboratories.

²⁰ The Air Navigation Order 2016. [online] Available at: <<https://www.legislation.gov.uk/uksi/2016/765/contents/made>> [Accessed 4 February 2022].

(2) If any light which appears to the CAA to be a light described in paragraph (1) is exhibited, the CAA may direct the person who is the occupier of the place where the light is exhibited or who has charge of the light, to take such steps within a reasonable time as are specified in the direction—

(a) to extinguish or screen the light; and

(b) to prevent in the future the exhibition of any other light which may similarly endanger aircraft.

(3) The direction may be served either personally or by post, or by affixing it in some conspicuous place near to the light to which it relates.

(4) In the case of a light which is or may be visible from any waters within the area of a general lighthouse authority, the power of the CAA under this article must not be exercised except with the consent of that authority.

Lights which dazzle or distract

225. A person must not in the United Kingdom direct or shine any light at any aircraft in flight so as to dazzle or distract the pilot of the aircraft.'

The document states that no 'light', 'dazzle' or 'glare' should be produced which will create a detrimental impact upon aircraft safety.

Endangering safety of an aircraft

240. A person must not recklessly or negligently act in a manner likely to endanger an aircraft, or any person in an aircraft.

Endangering safety of any person or property

241. A person must not recklessly or negligently cause or permit an aircraft to endanger any person or property.

Civil Aviation Authority consolidation of UK Regulation 139/2014

The Civil Aviation Authority (CAA) published a consolidating document²¹ of UK regulations, (Implementing Rules, Acceptable Means of Compliance and Guidance Material), in 2023. A summary of material relevant to aerodrome safeguarding is presented below:

(a) The aerodrome operator should have procedures to monitor the changes in the obstacle environment, marking and lighting, and in human activities or land use on the aerodrome and the areas around the aerodrome, as defined in coordination with the CAA. The scope, limits, tasks and responsibilities for the monitoring should be defined in coordination with the relevant air traffic services providers, and with the CAA and other relevant authorities.

(b) The limits of the aerodrome surroundings that should be monitored by the aerodrome operator are defined in coordination with the CAA and should include the areas that can be visually monitored during the inspections of the manoeuvring area.

(c) The aerodrome operator should have procedures to mitigate the risks associated with changes on the aerodrome and its surroundings identified with the monitoring procedures. The scope, limits,

²¹ <https://regulatorylibrary.caa.co.uk/139-2014-pdf/PDF.pdf>

tasks, and responsibilities for the mitigation of risks associated to obstacles or hazards outside the perimeter fence of the aerodrome should be defined in coordination with the relevant air traffic services providers, and with the CAA and other relevant authorities.

(d) The risks caused by human activities and land use which should be assessed and mitigated should include:

1. obstacles and the possibility of induced turbulence;
2. the use of hazardous, confusing, and misleading lights;
3. the dazzling caused by large and highly reflective surfaces;
4. sources of non-visible radiation, or the presence of moving, or fixed objects which may interfere with, or adversely affect, the performance of aeronautical communications, navigation and surveillance systems; and
5. non-aeronautical ground light near an aerodrome which may endanger the safety of aircraft and which should be extinguished, screened, or otherwise modified so as to eliminate the source of danger.

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

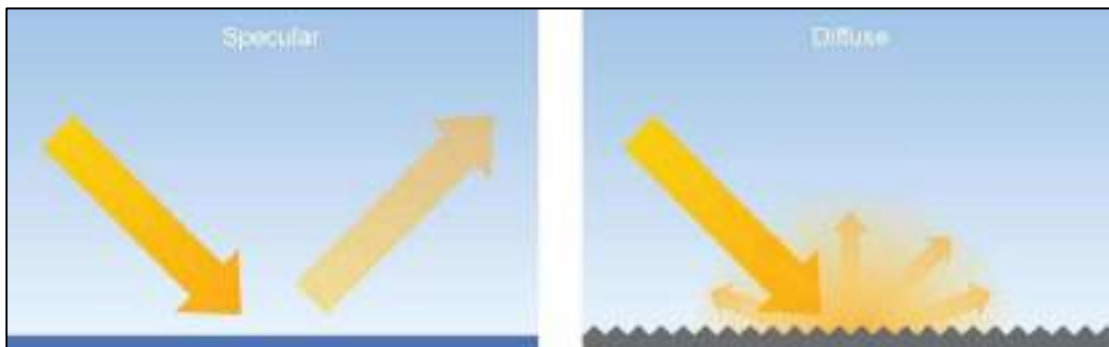
Overview

Studies have been undertaken assessing the type and intensity of solar reflections from various surfaces including solar panels and glass. An overview of these studies is presented below.

The guidelines presented are related to aviation safety. The results are applicable for the purpose of this analysis.

Reflection Type from Solar Panels

Based on the surface conditions reflections from light can be specular and diffuse. A specular reflection has a reflection characteristic similar to that of a mirror; a diffuse will reflect the incoming light and scatter it in many directions. The figure below, taken from the FAA guidance²², illustrates the difference between the two types of reflections. Because solar panels are flat and have a smooth surface most of the light reflected is specular, which means that incident light from a specific direction is reradiated in a specific direction.



Specular and diffuse reflections

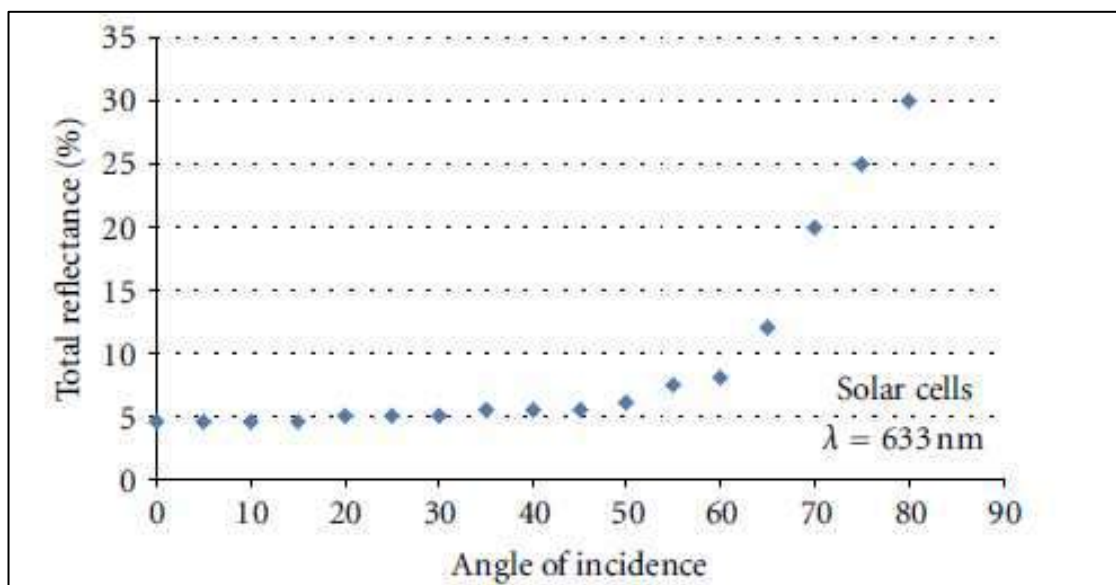
²² Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 08/12/2021.

Solar Reflection Studies

An overview of content from identified solar panel reflectivity studies is presented in the subsections below.

Evan Riley and Scott Olson, "A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems"

Evan Riley and Scott Olson published in 2011 their study titled: *A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems*²³. They researched the potential glare that a pilot could experience from a 25-degree fixed tilt PV system located outside of Las Vegas, Nevada. The theoretical glare was estimated using published ocular safety metrics which quantify the potential for a postflash glare after-image. This was then compared to the postflash glare after-image caused by smooth water. The study demonstrated that the reflectance of the solar cell varied with angle of incidence, with maximum values occurring at angles close to 90 degrees. The reflectance values varied from approximately 5% to 30%. This is shown on the figure below.



Total reflectance % when compared to angle of incidence

The conclusions of the research study were:

- The potential for hazardous glare from flat-plate PV systems is similar to that of smooth water;
- Portland white cement concrete (which is a common concrete for runways), snow, and structural glass all have a reflectivity greater than water and flat plate PV modules.

²³ Evan Riley and Scott Olson, "A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems," *ISRN Renewable Energy*, vol. 2011, Article ID 651857, 6 pages, 2011. doi:10.5402/2011/651857

FAA Guidance – “Technical Guidance for Evaluating Selected Solar Technologies on Airports”²⁴

The 2018 FAA Guidance included a diagram which illustrates the relative reflectance of solar panels compared to other surfaces. The figure shows the relative reflectance of solar panels compared to other surfaces. Surfaces in this figure produce reflections which are specular and diffuse. A specular reflection (those made by most solar panels) has a reflection characteristic similar to that of a mirror. A diffuse reflection will reflect the incoming light and scatter it in many directions. A table of reflectivity values, sourced from the figure within the FAA guidance, is presented below.

Surface	Approximate Percentage of Light Reflected ²⁵
Snow	80
White Concrete	77
Bare Aluminium	74
Vegetation	50
Bare Soil	30
Wood Shingle	17
Water	5
Solar Panels	5
Black Asphalt	2

Relative reflectivity of various surfaces

Note that the data above does not appear to consider the reflection type (specular or diffuse).

An important comparison in this table is the reflectivity compared to water which will produce a reflection of very similar intensity when compared to that from a solar panel. The study by Riley and Olsen study (2011) also concludes that still water has a very similar reflectivity to solar panels.

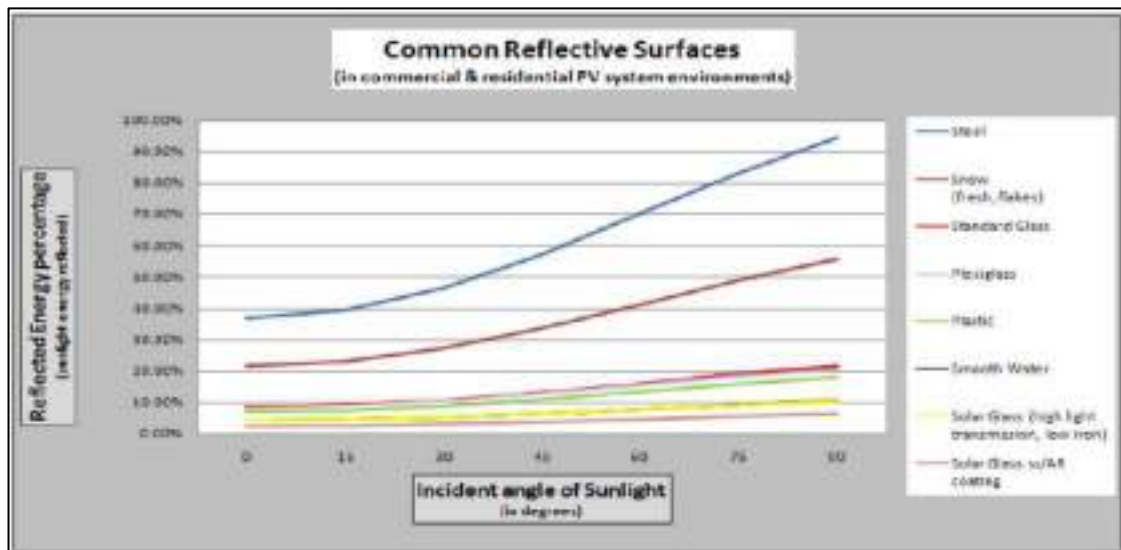
²⁴ Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 08/12/2021.

²⁵ Extrapolated data, baseline of 1,000 W/m² for incoming sunlight.

SunPower Technical Notification (2009)

SunPower published a technical notification²⁶ to 'increase awareness concerning the possible glare and reflectance impact of PV Systems on their surrounding environment'.

The figure presented below shows the relative reflectivity of solar panels compared to other natural and manmade materials including smooth water, standard glass and steel.



Common reflective surfaces

The results, similarly to those from Riley and Olsen study (2011) and the FAA (2010), show that solar panels produce a reflection that is less intense than those of 'standard glass and other common reflective surfaces'.

With respect to aviation and solar reflections observed from the air, SunPower has developed several large installations near airports or on Air Force bases. It is stated that these developments have all passed FAA or Air Force standards with all developments considered "No Hazard to Air Navigation". The note suggests that developers discuss any possible concerns with stakeholders near proposed solar farms.

²⁶ Source: Technical Support, 2009. SunPower Technical Notification – Solar Module Glare and Reflectance.

APPENDIX C – OVERVIEW OF SUN MOVEMENTS AND RELATIVE REFLECTIONS

The Sun's position in the sky can be accurately described by its azimuth and elevation. Azimuth is a direction relative to true north (horizontal angle i.e. from left to right) and elevation describes the Sun's angle relative to the horizon (vertical angle i.e. up and down).

The Sun's position can be accurately calculated for a specific location. The following data being used for the calculation:

- Time.
- Date.
- Latitude.
- Longitude.

The following is true at the location of the solar development:

- The Sun is at its highest around midday and is to the south at this time.
- The Sun rises highest on 21 June (longest day).
- On 22 December, the maximum elevation reached by the Sun is at its lowest (shortest day).

The combination of the Sun's azimuth angle and vertical elevation will affect the direction and angle of the reflection from a reflector.

APPENDIX D – GLINT AND GLARE IMPACT SIGNIFICANCE

Overview

The significance of glint and glare will vary for different receptors. The following section presents a general overview of the significance criteria with respect to experiencing a solar reflection.

Impact Significance Definition

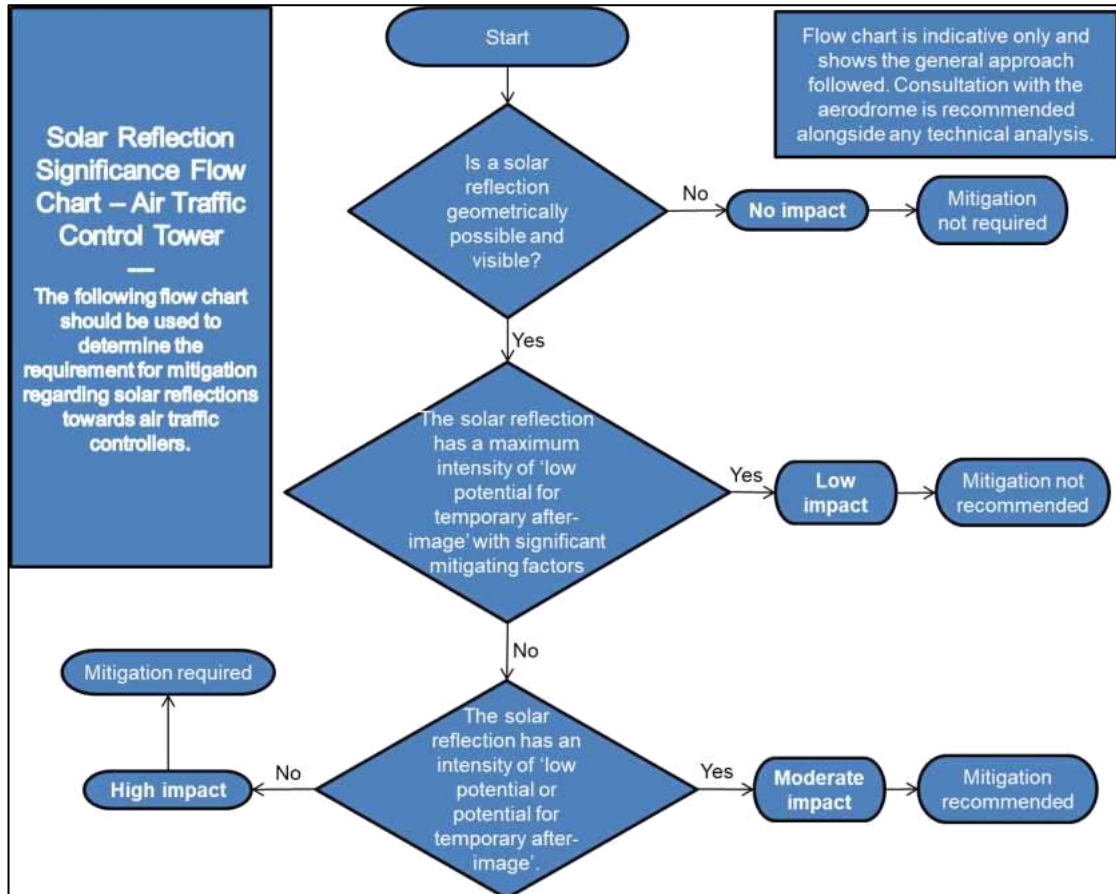
The table below presents the recommended definition of 'impact significance' in glint and glare terms and the requirement for mitigation under each.

Impact Significance	Definition	Mitigation Requirement
No Impact	A solar reflection is not geometrically possible or will not be visible from the assessed receptor.	No mitigation required.
Low	A solar reflection is geometrically possible however any impact is considered to be small such that mitigation is not required e.g. intervening screening will limit the view of the reflecting solar panels.	No mitigation recommended.
Moderate	A solar reflection is geometrically possible and visible however it occurs under conditions that do not represent a worst-case.	Mitigation recommended.
High	A solar reflection is geometrically possible and visible under conditions that will produce a significant impact. Mitigation and consultation is recommended.	Mitigation required.

Impact significance definition

Assessment Process for ATC Tower

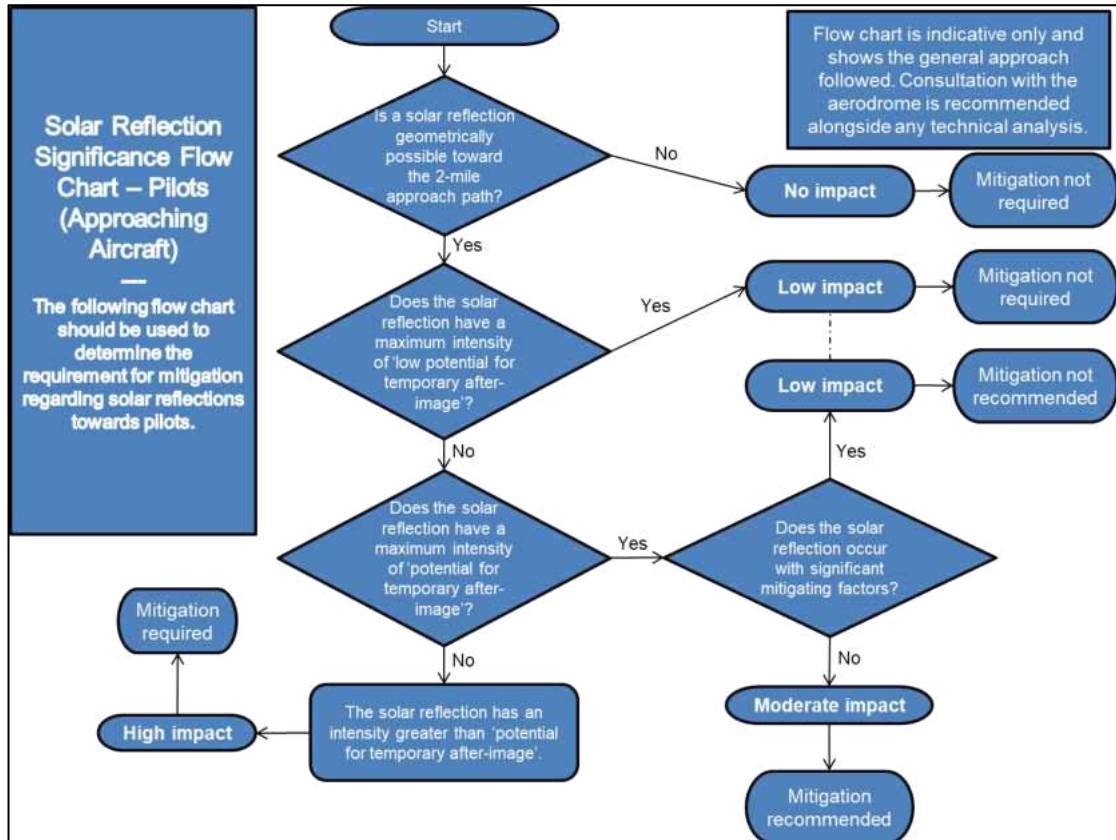
The flow chart presented below has been followed when determining the impact significance and mitigation recommendation/requirement for an ATC Tower.



ATC tower impact significance flow chart

Assessment Process for Approaching Aircraft

The flow chart presented below has been followed when determining the impact significance and mitigation recommendation/requirement for approaching aircraft.



Pilots (approaching aircraft) impact significance flow chart

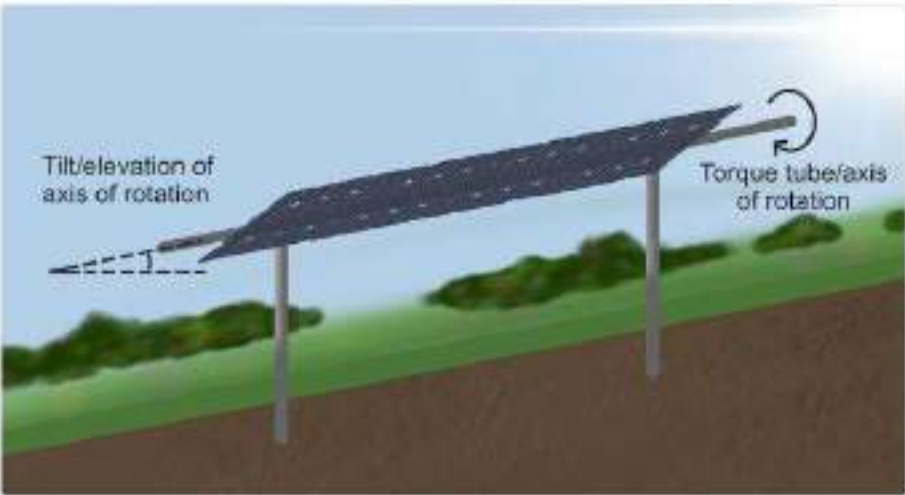
APPENDIX E – REFLECTION CALCULATIONS METHODOLOGY

Forge Reflection Calculations Methodology

Extracts taken from the Forge Solar Model.

Tracking System Parameters

Single-axis module tracking systems are described by a unique set of parameters. These angular inputs model the tracking axis, rotation range and backtracking behavior. Dual-axis module tracking systems are assumed to track the sun at all times.



Single-axis tracking system with torque tube tilted due to geography

Tilt of tracking axis (°)
Tilt above flat ground of axis over which panels rotate (e.g. torque tube). System on flat level ground would have axis tilt of 0°.

Orientation of tracking axis (°)
Azimuthal angle of axis over which panels rotate. Angle represents the facing of the axis and system. For example, typical tracking system in northern hemisphere has tracking axis oriented north-south with an orientation of 180°, allowing panels to rotate east-west with potential south-facing tilt. Typical tracking system in southern hemisphere runs south-north with axis orientation of 0°, yielding east-west rotation with potential north-facing tilt.

Offset angle of module (°)
Additional tilt angle of PV module elevated above tracking axis/torque tube. Offset angle is measured from the torque tube.

Maximum tracking angle (°)
Maximum angle of rotation of tracking system in one direction. For example, a typical system with a 120° range of rotation has a max tracking angle of 60° (east/west).

Resting angle (°)
Angle of rotation of panels when sun is outside tracking range. Used to model backtracking. Panels will revert to the position described by this rotation angle at all times when the sun is outside the rotation range. Setting this equal to the maximum tracking angle implies the panels do not backtrack.

! ForgeSolar utilizes a simplified model of backtracking which assumes panels instantaneously revert to the resting angle whenever the sun is outside the rotation range. For example, panels with max tracking angle of 60° and resting angle of 0° would be flat from sunrise until the sun enters the rotation range, and immediately after the sun leaves the rotation range until sunset daily.

Tracking System Parameters

APPENDIX F – ASSESSMENT LIMITATIONS AND ASSUMPTIONS

Forge's Sandia National Laboratories' (SGHAT) Model

The following text is taken from Forge²⁷ and is presented for reference.

Summary of assumptions and abstractions required by the SGHAT/ForgeSolar analysis methodology

1. Times associated with glare are denoted in Standard time. For Daylight Savings, add one hour.
2. Result data files and plots are now retained for two years after analysis completion. Files should be downloaded and saved if additional persistence is required.
3. The algorithm does not rigorously represent the detailed geometry of a system; detailed features such as gaps between modules, variable height of the PV array, and support structures may impact actual glare results. However, we have validated our models against several systems, including a PV array causing glare to the air-traffic control tower at Manchester-Boston Regional Airport and several sites in Albuquerque, and the tool accurately predicted the occurrence and intensity of glare at different times and days of the year.
4. Several calculations utilize the PV array centroid, rather than the actual glare spot location, due to algorithm limitations. This may affect results for large PV footprints. Additional analyses of array sub-sections can provide additional information on expected glare. This primarily affects analyses of path receptors.
5. Random number computations are utilized by various steps of the annual hazard analysis algorithm. Predicted minutes of glare can vary between runs as a result. This limitation primarily affects analyses of Observation Point receptors, including ATCTs. Note that the SGHAT/ForgeSolar methodology has always relied on an analytical, qualitative approach to accurately determine the overall hazard (i.e. green vs. yellow) of expected glare on an annual basis.
6. The subtended source angle (glare spot size) is constrained by the PV array footprint size. Partitioning large arrays into smaller sections will reduce the maximum potential subtended angle, potentially impacting results if actual glare spots are larger than the sub-array size. Additional analyses of the combined area of adjacent sub-arrays can provide more information on potential glare hazards. (See previous points on related limitations.)
7. The algorithm assumes that the PV array is aligned with a plane defined by the total heights of the coordinates outlined in the Google map. For more accuracy, the user should perform runs using minimum and maximum values for the vertex heights to bound the height of the plane containing the solar array. Doing so will expand the range of observed solar glare when compared to results using a single height value.
8. The algorithm does not consider obstacles (either man-made or natural) between the observation points and the prescribed solar installation that may obstruct observed glare, such as trees, hills, buildings, etc.
9. The variable direct normal irradiance (DNI) feature (if selected) scales the user-prescribed peak DNI using a typical clear-day irradiance profile. This profile has a lower DNI in the mornings and evenings and a maximum at solar noon. The scaling uses a clear-day irradiance profile based on a normalized time relative to sunrise, solar noon, and sunset, which are prescribed by a sun-position algorithm and the latitude and longitude obtained from Google maps. The actual DNI on any given day can be affected by cloud cover, atmospheric attenuation, and other environmental factors.
10. The ocular hazard predicted by the tool depends on a number of environmental, optical, and human factors, which can be uncertain. We provide input fields and typical ranges of values for these factors so that the user can vary these parameters to see if they have an impact on the results. The speed of SGHAT allows expedited sensitivity and parametric analyses.
11. The system output calculation is a DNI-based approximation that assumes clear, sunny skies year-round. It should not be used in place of more rigorous modeling methods.
12. Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.
13. Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.
14. Glare vector plots are simplified representations of analysis data. Actual glare emanations and results may differ.
15. PV array tracking assumes the modules move instantly when tracking the sun, and when reverting to the rest position.

²⁷ Source: <https://www.forgesolar.com/help/#assumptions>

APPENDIX G – RECEPTOR AND REFLECTOR AREA DETAILS

King Abdulaziz International Airport Receptor Details

ATC Towers

The details of the ATC Towers at KAIA are presented in the table below.

Receptor	Longitude (°)	Latitude (°)	Ground Height Altitude (m) (amsl)	ATC Tower Height (m)	Overall Assessed Height (m)
New ATC Tower	39.16880	21.67326	9.81	145.69	155.50
ATC Tower	39.14775	21.67731	5.59	57.91	63.50

KAIA ATC Tower receptor details

The Approach for Aircraft Landing on Runway 16C

The table below presents the details for the runway 16C approach.

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Threshold	39.15154	21.69507	21.30
2 miles	39.14090	21.72238	188.67

Runway 16C approach details

The Approach for Aircraft Landing on Runway 34C

The table below presents the details for the runway 34C approach.

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Threshold	39.16492	21.66118	23.62
2 miles	39.17555	21.63386	199.67

Runway 34C approach details

The Approach for Aircraft Landing on Runway 16L

The table below presents the details for the runway 16L approach.

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Threshold	39.16713	21.70044	24.26
2 miles	39.15649	21.72776	187.56

Runway 16L approach details

The Approach for Aircraft Landing on Runway 34R

The table below presents the details for the runway 34R approach.

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Threshold	39.18049	21.66654	30.05
2 miles	39.19113	21.63923	202.17

Runway 34R approach details

The Approach for Aircraft Landing on Runway 16R

The table below presents the details for the runway 16R approach.

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Threshold	39.12688	21.70276	19.51
2 miles	39.11624	21.73007	183.92

Runway 16R approach details

The Approach for Aircraft Landing on Runway 34L

The table below presents the details for the runway 34L approach.

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Threshold	39.13959	21.67056	19.57
2 miles	39.15023	21.64324	191.17

Runway 34L approach details

Rabigh Airport Receptor Details

ATC Tower

The details for the ATC Tower at Rabigh Airport are presented in the table below.

Longitude (°)	Latitude (°)	Ground Height Altitude (m) (amsl)	ATC Tower Height (m)	Overall Assessed Height (m)
39.068608	22.702897	2.39	20.00	22.39

Rabigh Airport ATC Tower receptor details

The Approach for Aircraft Landing on Runway 15

The table below presents the details for the runway 15 approach.

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Threshold	39.06461	22.71216	22.56
2 miles	39.05039	22.73806	186.22

Runway 15 approach details

The Approach for Aircraft Landing on Runway 33

The table below presents the details for the runway 33 approach.

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Threshold	39.07523	22.69303	22.49
2 miles	39.08945	22.66713	184.98

Runway 33 approach details

Modelled Reflector Area Details

The coordinate data for the assessed reflector areas are presented in the following tables.

Area A

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	39.239612	22.288571	15	39.242782	22.299370
2	39.245264	22.294865	16	39.242772	22.298492
3	39.245817	22.295664	17	39.240123	22.298488
4	39.245815	22.296710	18	39.239708	22.297616

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
5	39.243672	22.296708	19	39.239714	22.296562
6	39.243671	22.297486	20	39.243648	22.296569
7	39.246914	22.297472	21	39.243654	22.295781
8	39.246923	22.298297	22	39.239377	22.295797
9	39.248672	22.298327	23	39.239377	22.294963
10	39.248692	22.301215	24	39.237844	22.294982
11	39.245859	22.301198	25	39.237622	22.294062
12	39.245871	22.300290	26	39.237625	22.292970
13	39.243570	22.300268	27	39.238738	22.288567
14	39.243561	22.299360			

Modelled reflector data - Area A

Area B

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	39.253653	22.279062	5	39.241503	22.287986
2	39.253548	22.295247	6	39.240199	22.286212
3	39.252008	22.296996	7	39.240194	22.284346
4	39.249755	22.296989	8	39.241669	22.278990

Modelled reflector data - Area B

Area C

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	39.256841	22.268976	7	39.279119	22.284065
2	39.277375	22.268841	8	39.279147	22.286056
3	39.277264	22.271667	9	39.271836	22.312863

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
4	39.275222	22.280530	10	39.270573	22.312819
5	39.274507	22.280526	11	39.257783	22.305744
6	39.274491	22.284117	12	39.256812	22.304810

Modelled reflector data – Area C

Area D

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	39.287188	22.269012	12	39.346691	22.277857
2	39.302053	22.268962	13	39.346697	22.280641
3	39.302053	22.269870	14	39.345254	22.283273
4	39.308418	22.269886	15	39.323727	22.319349
5	39.308374	22.270807	16	39.322545	22.319349
6	39.310774	22.270831	17	39.312643	22.314102
7	39.310802	22.272573	18	39.287541	22.299663
8	39.314087	22.272571	19	39.286814	22.297761
9	39.314227	22.270823	20	39.281230	22.297740
10	39.323356	22.270815	21	39.281210	22.290572
11	39.323358	22.277849			

Modelled Reflector Data – Area D

APPENDIX H – DETAILED MODELLING RESULTS

Forge Charts

No solar reflections are predicted and therefore no modelling results charts are presented²⁸.

Results Tables

The tables below and on the following pages show the total duration of glare.

A no glare found

Component	Green glare (min)	Yellow glare (min)
FP-15	0	0
FP-15C	0	0
FP-15L	0	0
FP-16R	0	0
FP-33	0	0
FP-34C	0	0
FP-34L	0	0
FP-34R	0	0
OP-1-A/TCT	0	0
OP-2-A/TCT	0	0
OP-3-A/TCT	0	0

No glare found

Forge results table - Area A

B no glare found

Component	Green glare (min)	Yellow glare (min)
FP-15	0	0
FP-15C	0	0
FP-15L	0	0
FP-16R	0	0
FP-33	0	0
FP-34C	0	0
FP-34L	0	0
FP-34R	0	0
OP-1-A/TCT	0	0
OP-2-A/TCT	0	0
OP-3-A/TCT	0	0

No glare found

Forge results table - Area B

²⁸ When no solar reflections are geometrically possible, there is no chart presented in the Forge modelling results as it simply states 'No glare predicted'.

C no glare found

Component	Green glare (min)	Yellow glare (min)
FP-10	0	0
FP-15C	0	0
FP-15L	0	0
FP-15R	0	0
FP-33	0	0
FP-34C	0	0
FP-34L	0	0
FP-34R	0	0
OP-1-ATCT	0	0
OP-2-ATCT	0	0
OP-3-ATCT	0	0

No glare found

Forge results table - Area C

D no glare found

Component	Green glare (min)	Yellow glare (min)
FP-10	0	0
FP-15C	0	0
FP-15L	0	0
FP-15R	0	0
FP-33	0	0
FP-34C	0	0
FP-34L	0	0
FP-34R	0	0
OP-1-ATCT	0	0
OP-2-ATCT	0	0
OP-3-ATCT	0	0

No glare found

Forge results table - Area D

APPENDIX I – BACKTRACKING METHOD DISCUSSION

Modelling Solar Reflections

Modelling output for glint and glare modelling must quantify – at a minimum – the dates and times at which reflections are possible.

To do this requires some assumptions. Assumptions that are applied by Pager Power in its modelling include:

- That the sun is always unobstructed.
- That the panels are exactly aligned as proposed.
- The panels are perfectly smooth.

Responsible assumptions should ensure that the output presents a ‘realistic worst-case scenario’, that is the most significant impact that could reasonably be expected in real life.

Modelling Tracker Systems vs Modelling Fixed Systems

For fixed systems, the appropriate assumptions for generating a realistic worst-case scenario are relatively apparent and their consequences are quite straightforward to evaluate.

Quantifying predicted reflections from tracker systems leaves space for further assumptions with consequences that are more complex. The industry-standard model for evaluating tracker systems is based on the SGHAT model originally devised by Sandia Laboratories and currently hosted most prolifically by Forge Solar.

Factors that influence modelling output for tracker systems include:

1. Whether the system is a single or dual axis tracker.
2. The range of motion of the panels.
3. The backtracking behaviour of the system.

Point 3 above warrants particular attention. In general terms, the purpose of a tracker system is to keep the panels facing the Sun directly as far as possible for as long as possible. Backtracking is a mechanism by which the panel arrays are tilted to minimise shading each other – because the losses due to shading outweigh the gains from directing the array towards the Sun.

Backtracking occurs when the Sun is relatively low in the sky, this is also the time at which the majority of solar reflections are possible, particularly for ground-based receptors.

Therefore, changes to how backtracking is modelled have significant consequences for the level of predicted impact. This causes a non-linear trade-off between capturing the most realistic backtracking behaviour and ensuring that the results represent a realistic worst-case scenario.

Things that influence backtracking behaviour in a real system include:

- a. How it is programmed.
- b. The dimensions of the panels on each array.

- c. The spacing between the arrays.
- d. The slope of the terrain.

The most effective way of quantifying backtracking within the Forge Solar model has historically been via the 'resting angle', which relates to the panel configuration when the Sun's elevation is outside the tracker's range of motion.

More recently, options for more sophisticated parameters have been introduced, that allow incorporation of points a-d above to some extent (but not to their complete extent).

Pager Power's default approach is to model tracker systems using the original method i.e. based on the resting angle only. The predominant reasons for this are threefold:

- The additional modelling options are relatively new.
- The accuracy of the new options is difficult to independently verify.
- To optimise the output with reference to backtracking using the new options can require a level of partitioning that compromises other aspects of the output – specifically the cumulative intensity considerations.

Further evaluation of the effects of backtracking remains a viable option where significant impacts are predicted based on the worst-case.



Pager Power Limited
Stour Valley Business Centre
Sudbury
Suffolk
CO10 7GB

Tel: +44 1787 319001 Email: info@pagerpower.com Web: www.pagerpower.com



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Environmental, Laboratory, Analytical And Testing Instruments Supply & Service

Summary Report

Air Quality & Noise Monitoring
at Al Humaij

Elaborated for:

KFUPM
Kingdom of Saudi Arabia

Report #:
230-13158-01

29th May 2024

Disclaimer:
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CR: 2066002065 – Tel. +966-3-667 4210 / 667 2135 – P.O. Box: 578
Ras Tanura 31941, Kingdom of Saudi Arabia
sales@gacsarabia.com - www.gacsarabia.com



Executive Summary

King Fahd University of Petroleum and Minerals (branded as KFUPM) is a nonprofit research university in Dhahran, Eastern Province, Saudi Arabia. Established in 1963 by King Saud bin Abdulaziz as the College of Petroleum and Minerals, it is ranked among the most prestigious academic institutions in Saudi Arabia and its science, engineering, business, and management programs are highly regarded in the country as well as in the member states of the Gulf Cooperation Council.

To assess the impacts of the facility on local air quality, and in response to requirements established by the NCEC, KFUPM contracted with Gulf Advanced Control System (GACS) to perform a short air quality study to evaluate the air quality around the facility and determinate future actions.

The ambient air measurements at al humaij were carried out between May 10th to May 21st, 2024, with a mobile station placed in 5 locations within Al Humaij site, equipped with instruments to measure Sulfur dioxide (SO₂), Carbon monoxide (CO), Ozone (O₃), Nitrogen Dioxide (NO₂), and Particle Matter (PM₁₀ & PM_{2.5}) and Noise. The station also measured the main meteorological parameters like Wind Speed, Wind Direction, Temp & humidity.

Periodic assessments over longer periods during each season, for at least a full year of measurements, are recommended to better understand seasonal trends, identify potential emission source areas for pollutants, and determine compliance with NCEC standards.



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1. BACKGROUND

King Fahd University of Petroleum and Minerals (branded as KFUPM) is a nonprofit research university in Dhahran, Eastern Province, Saudi Arabia. Established in 1963 by King Saud bin Abdulaziz as the College of Petroleum and Minerals, it is ranked among the most prestigious academic institutions in Saudi Arabia and its science, engineering, business, and management programs are highly regarded in the country as well as in the member states of the Gulf Cooperation Council.

The university was ranked 3rd globally, by the American National Academy of Inventors, among the top 100 worldwide universities for granting US Utility Patents in 2022.[3] Stanford University has recently released a list of the top 2 percent of the most-cited scientists in various disciplines.[4] The exhaustive list has 186,177 researchers, of which 81 conducted research at KFUPM.

To assess the impacts on local air quality, and in response to requirements established by the NCEC, KFUPM contracted Gulf Advanced Control System (GACS) to perform an ambient air quality study to evaluate the air quality around Al humaij and determinate future actions. The study consisted of monitoring the ambient air in 5 locations for 24 hours per location, with a mobile station equipped with instruments to measure Sulfur dioxide (SO₂), Carbon monoxide (CO), Ozone (O₃), Nitrogen Dioxide (NO₂), and Particle Matter (PM₁₀ & PM_{2.5}) and Noise. The station is also equipped with sensors to measure the main meteorological parameters.

Figure 1 shows a general view of the area that includes the 5 locations and the coordinates and measurement periods at each site are shown below.

Location	Latitude	Longitude	Measurement dates
Site #H1	25.07472222	41.07722222	May 10 th to 13 th , 2024
Site #H2	25.08833333	41.12694444	May 14 th , 2024
Site #H3	25.02305556	41.14888889	May 17 th 2024
Site #H4	25.00055556	41.11222222	May 19 th , 2024
Site #H5	25.04972222	41.11361111	May 21 st , 2024

Figure 2 shows a general view of the mobile station used in the study.

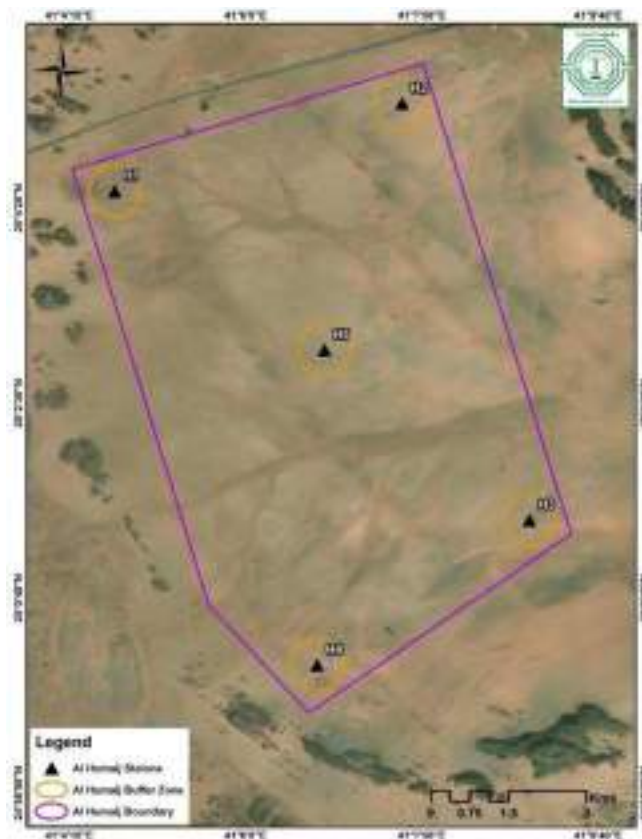


Fig. 1. Al Humaij general view and station locations



Fig. 2. General view of the AQ mobile station

2. METHODOLOGY

2.1. Description of the system

The measurements were conducted using a mobile station equipped with the instruments, sensors, and auxiliary systems necessary to carry out air quality measurements. Includes sampling, calibration, and data collection systems. The station was powered by a gasoil generator, located downwind of the station.

All analyzers designed to measure each specific parameter are USEPA approved for Air Quality measurement. Figure 3 shows an overview of the racks of instruments and Table 1 list the instruments, by manufacturer, model and principle of measurement.

The Lower Detection Limit (LDL) of each instrument is also reported in Table 1. Following the USEPA guidelines, the concentrations in this report are expressed as “< LDL” when the recorded value is below to such limit, and for statistics calculation, it is replaced by LDL/2.



Fig. 3. Overview of the rack of instruments at AQ mobile

TABLE 1. Air Quality and Noise instruments used in this study.

Parameter	Manufacturer / Model	Principle of Measurement	LDL ($\mu\text{g}/\text{m}^3$)
SO ₂	Teledyne / T100	UV Fluorescence	5.7
NO ₂	Teledyne / T200	Chemiluminescence	0.8
O ₃	Teledyne / T400	UV Photometric	1.3
CO	Teledyne / T300	Gas Filter Correlation	50
PM10/PM2.5	MetOne / BAM1020	Beta Attenuation	4
Noise	Cirrus Sound Meter	Acoustic	-

2.2. Operation

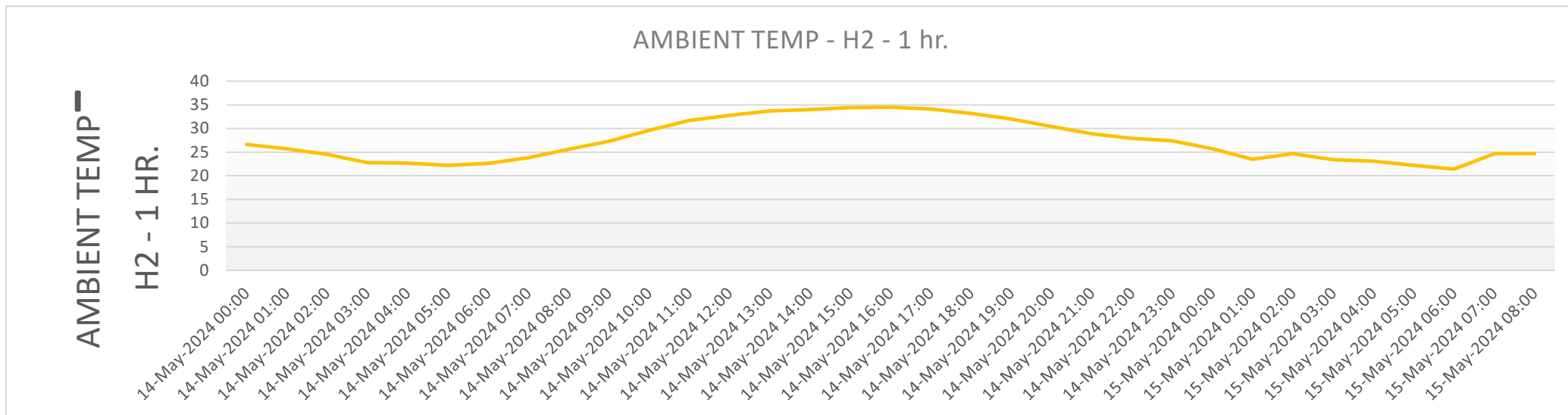
The operation and maintenance of the mobile station was performed following the GACS' QA/QC Manual, which includes the operation, calibration and maintenance of the analyzers, sensors and auxiliary systems.

Once the mobile station was deployed on the site, the day before to start the measurements the following task were performed:

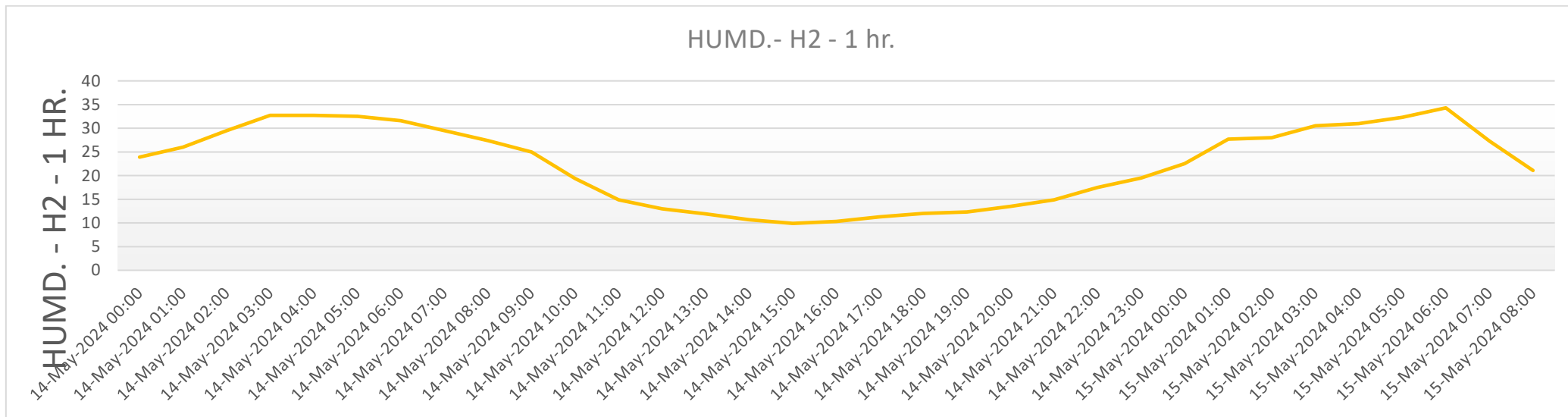
1. The air quality analyzers were turned ON to allow a warm-up period (2-4 hours).
2. After completing the warm-up period, a multi-point calibration was performed on all analyzers. The calibration consisted of challenging the analyzers to sample 3 known target concentrations (80% of full scale, 50% of full scale and zero), using certificated (NIST traceable) gases mixtures, to verify the response of the analyzers which should have an acceptable deviation of +/- 10 %. If the analyzer deviation exceeded this value, the analyzer response is adjusted, and the calibration repeated.
3. The meteorological sensors responses were checked against a handheld met station (Kestrel).

The day after the measurements were completed, a zero/span check was performed on each analyzer to verify that the responses remained within the acceptable deviation.

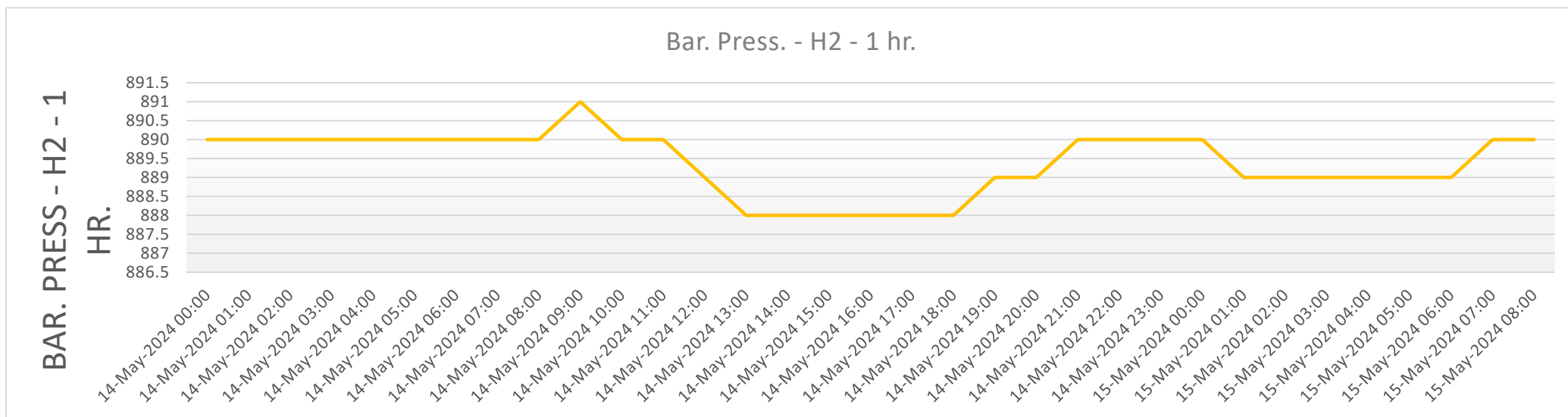
3. Histograms of the Air Quality Data in Al Humaij :



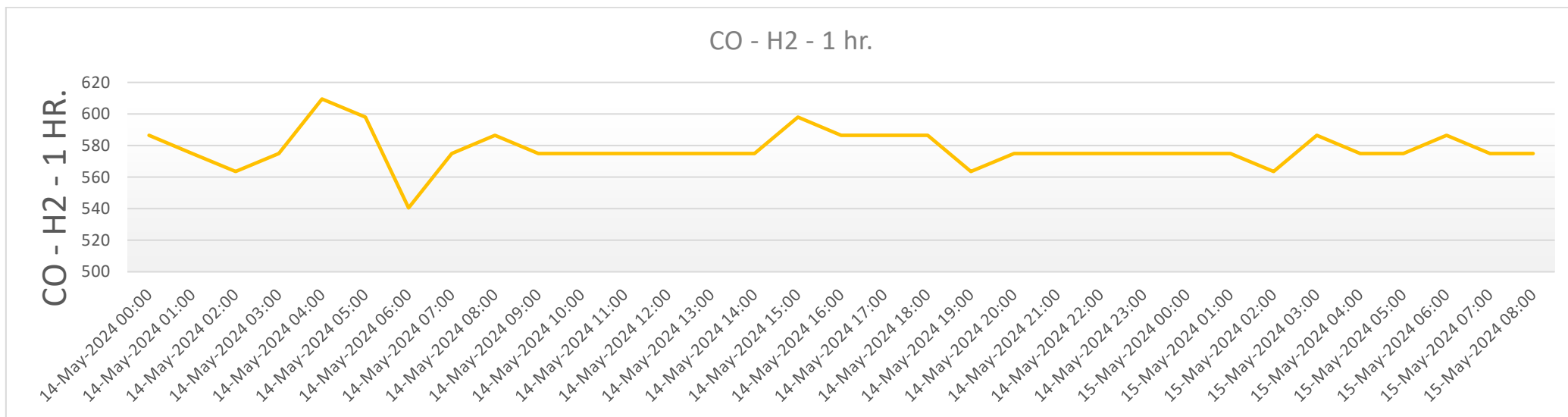
Ambient temperature – H 2 – 1 HR



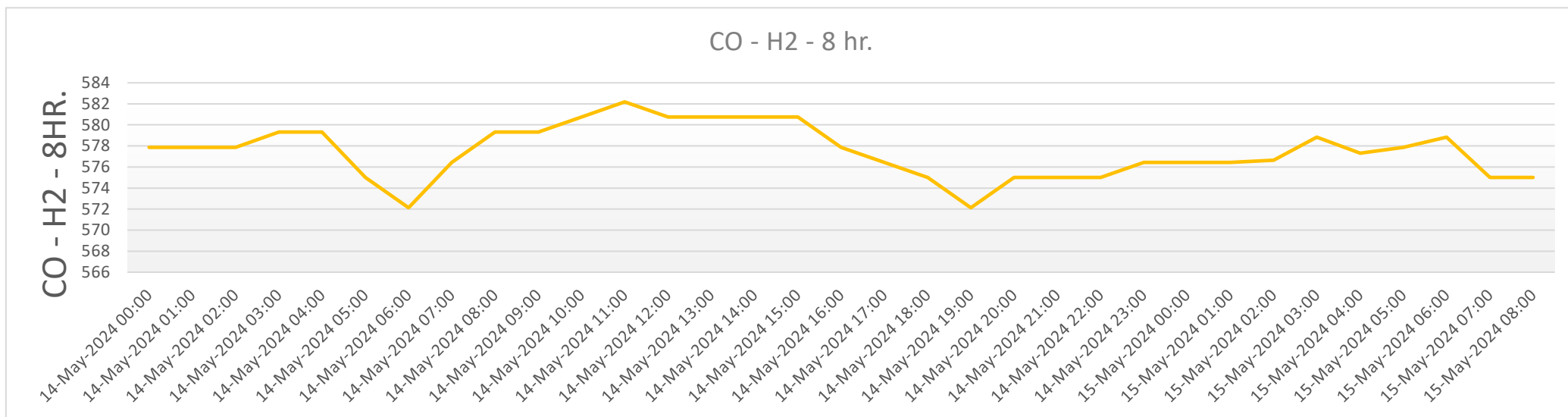
Relative Humidity – H2 – 1 HR



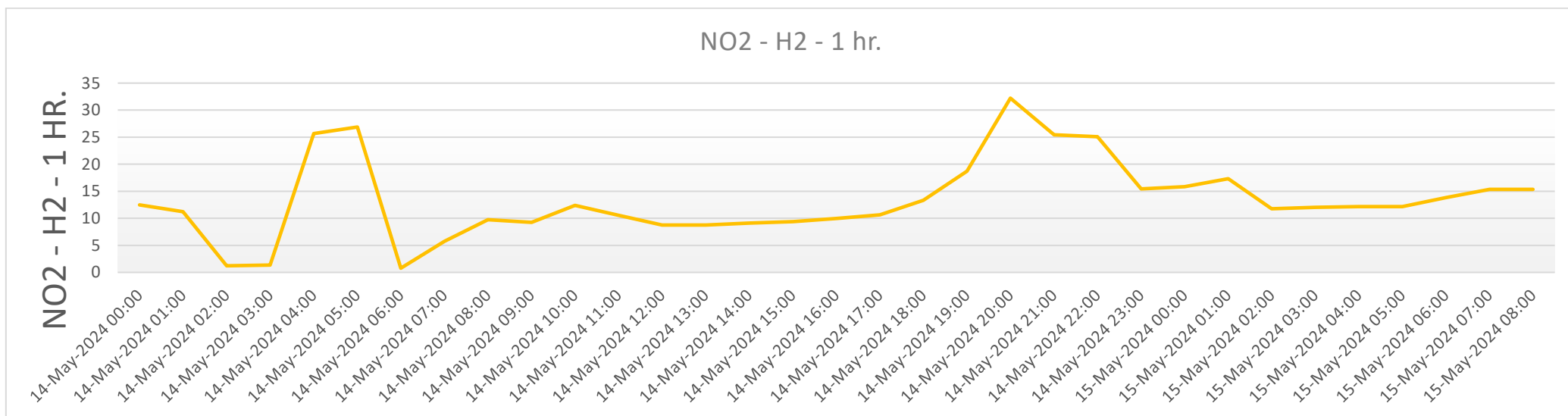
Barometric Pressure -- H 2 -- 1 HR



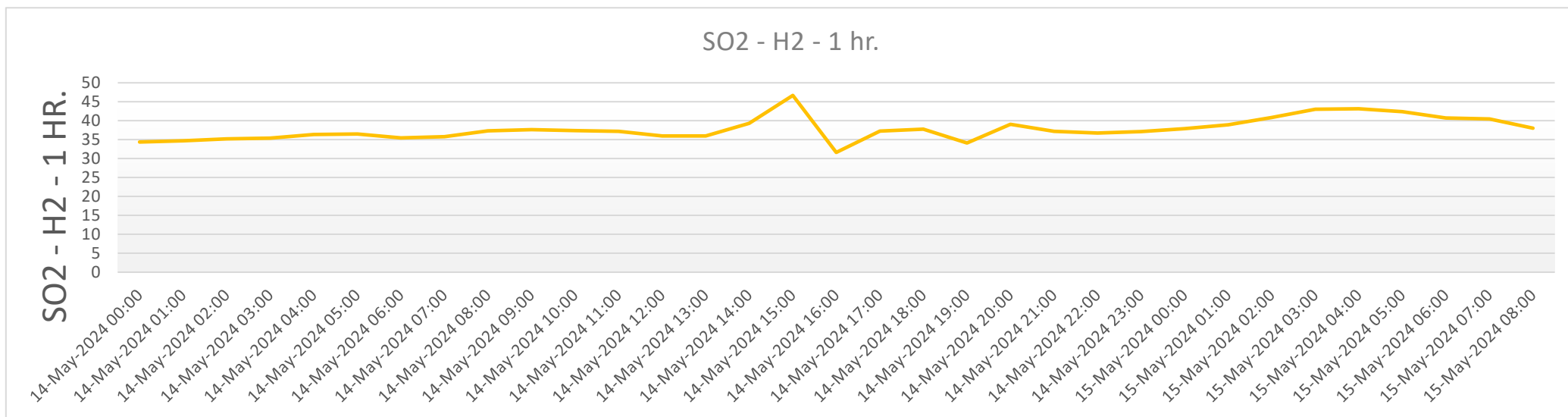
CO - H2 - 1 hr.



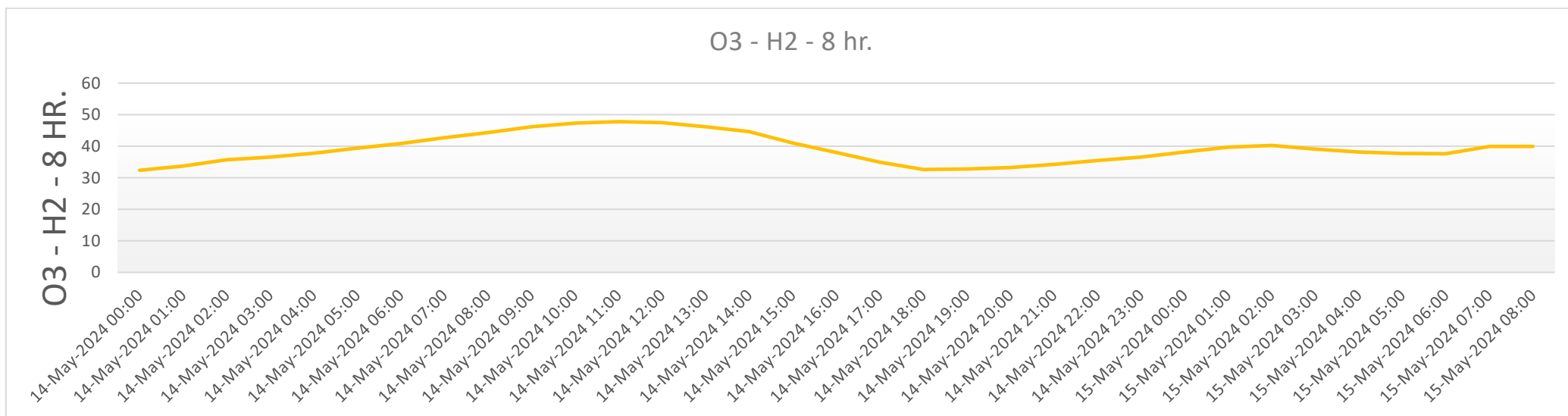
CO pollutant at site H1 – 8 hr.



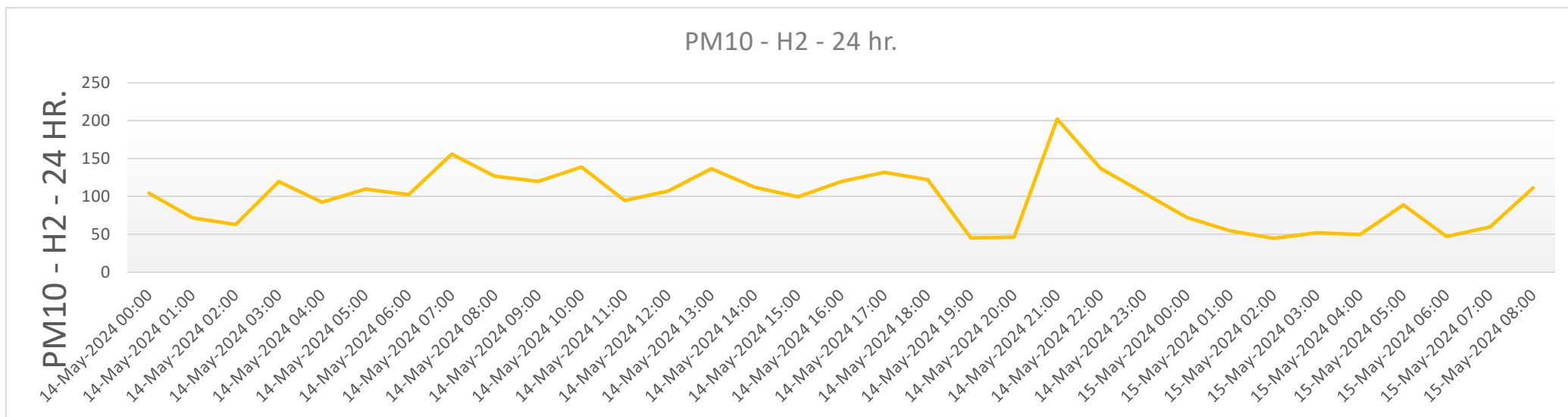
NO2 pollutant at site H2 – 1 hr.



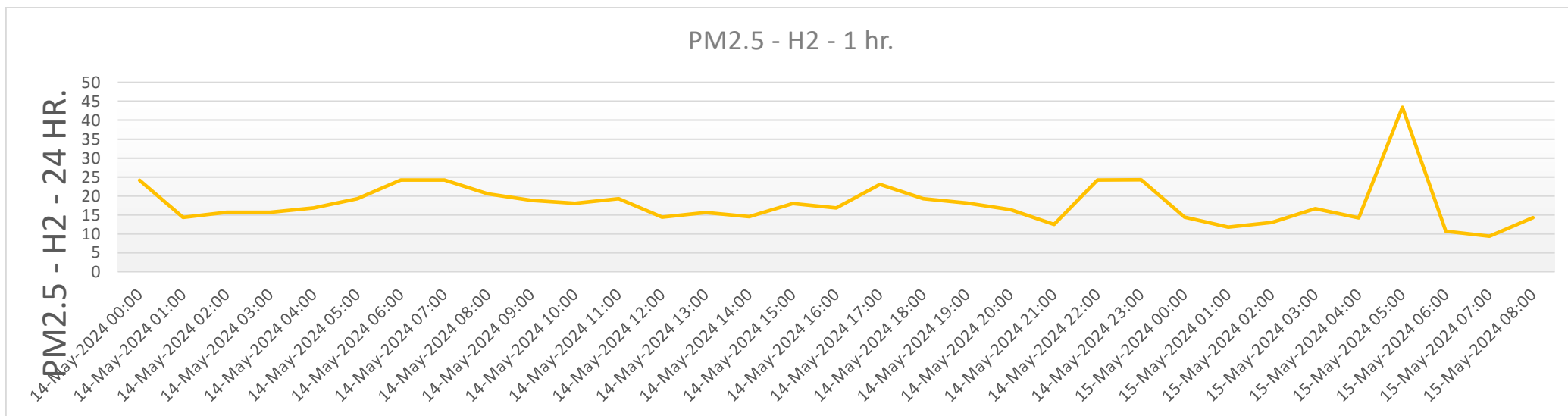
SO2 pollutant at site H2 -1hr.



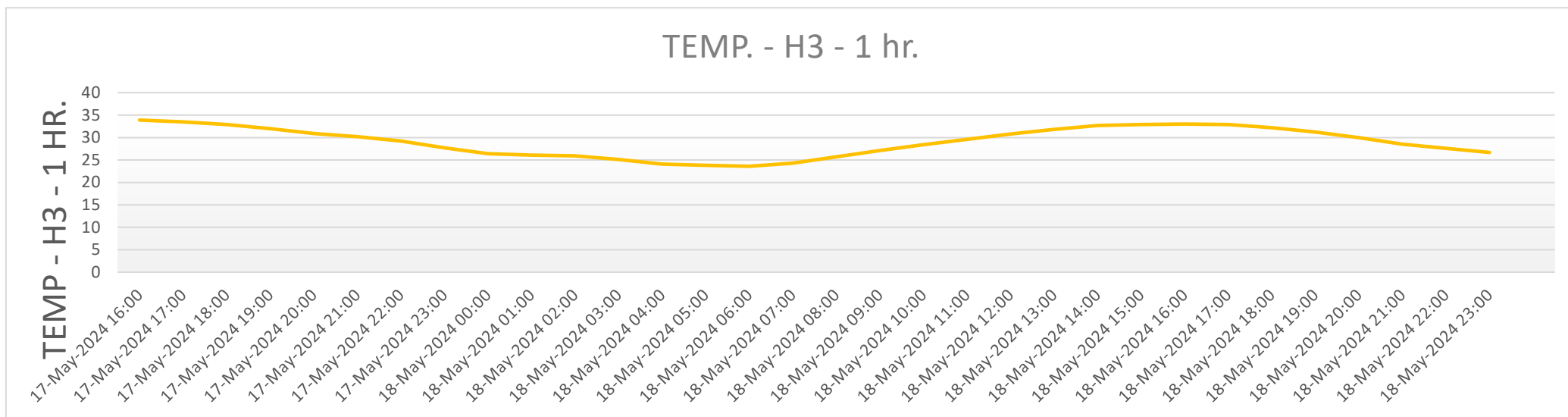
O3 pollutant at site H2 - 8 hr.



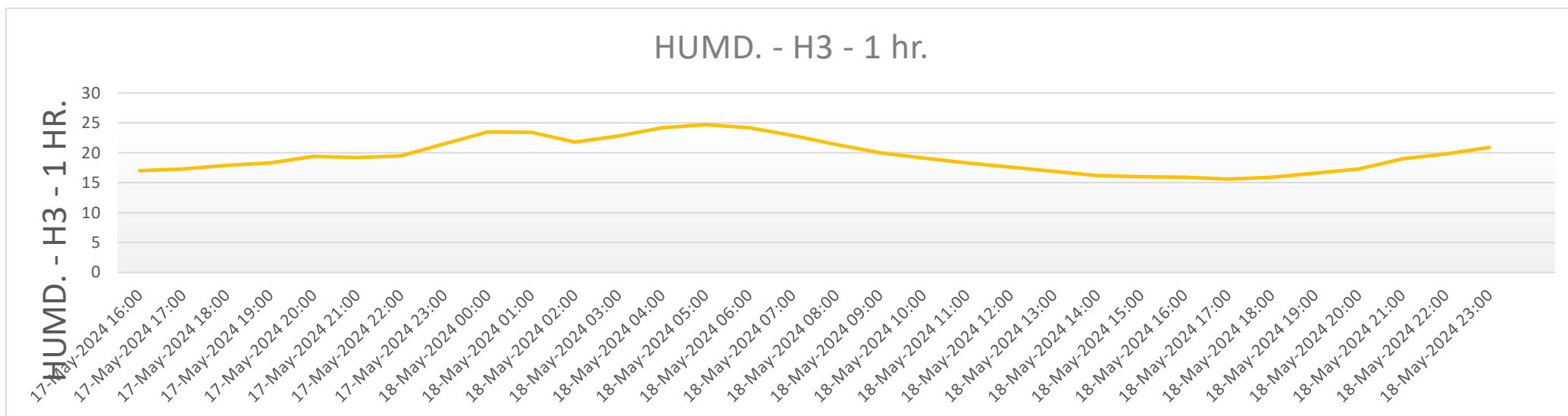
PM10 pollutant at site H2 – 24 hr.



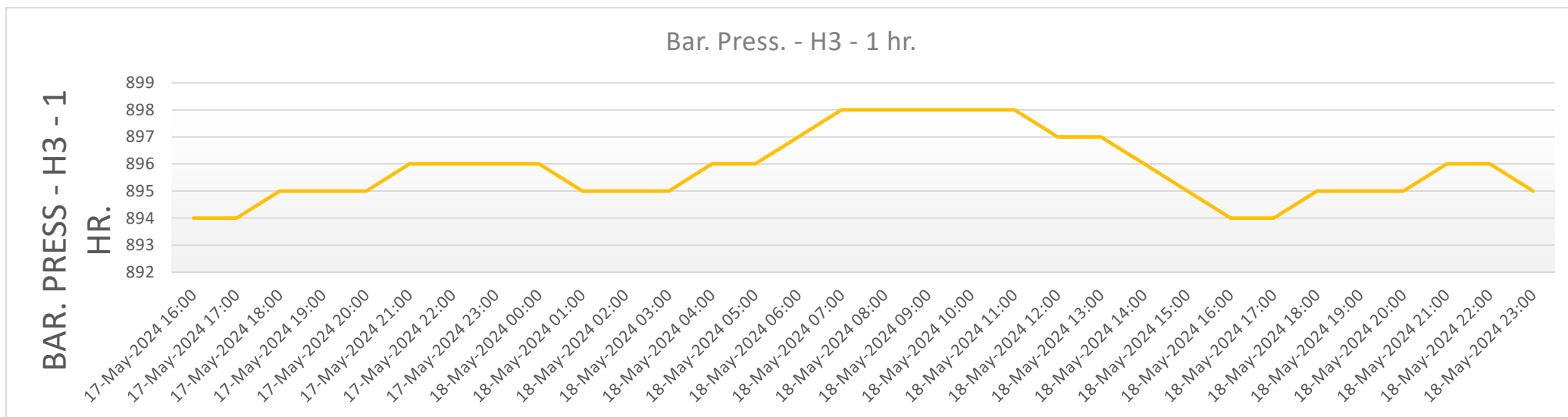
PM2.5 pollutants at site H2 – 24hr.



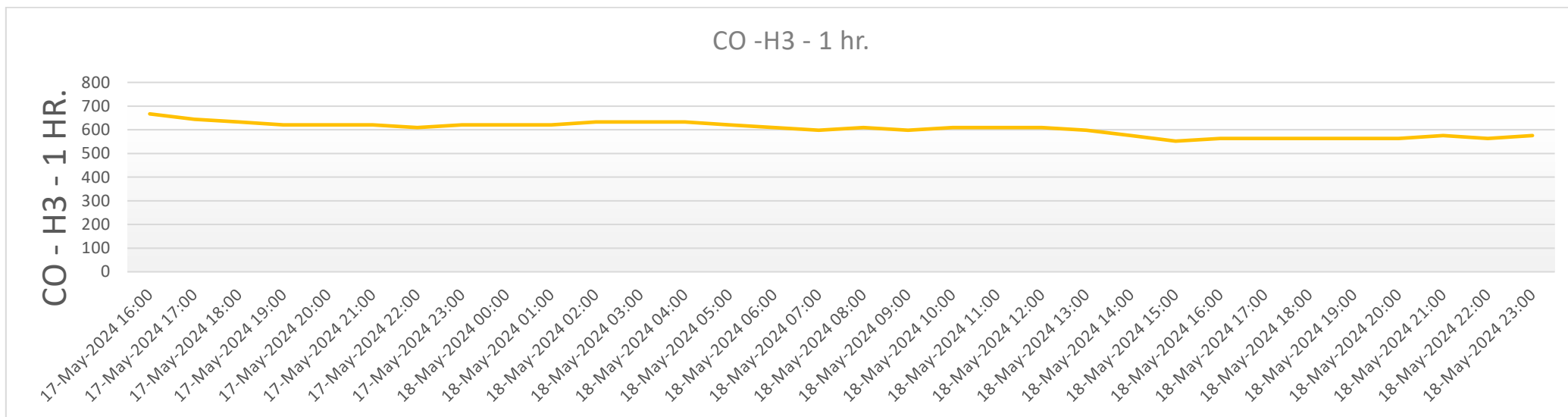
Ambient temperature – H3 – 1 HR



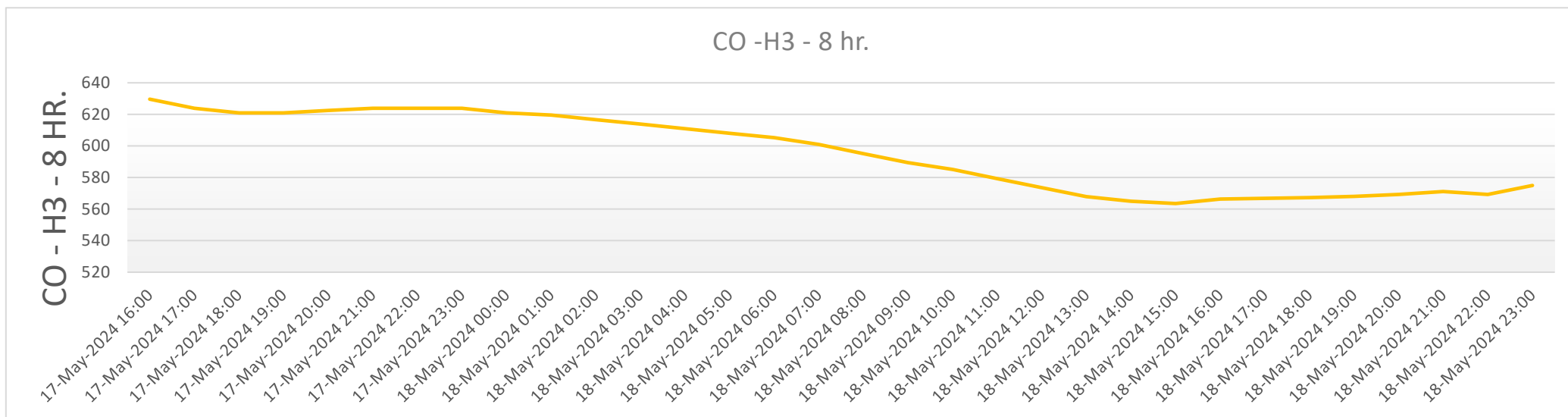
Relative Humidity – H3 – 1 HR



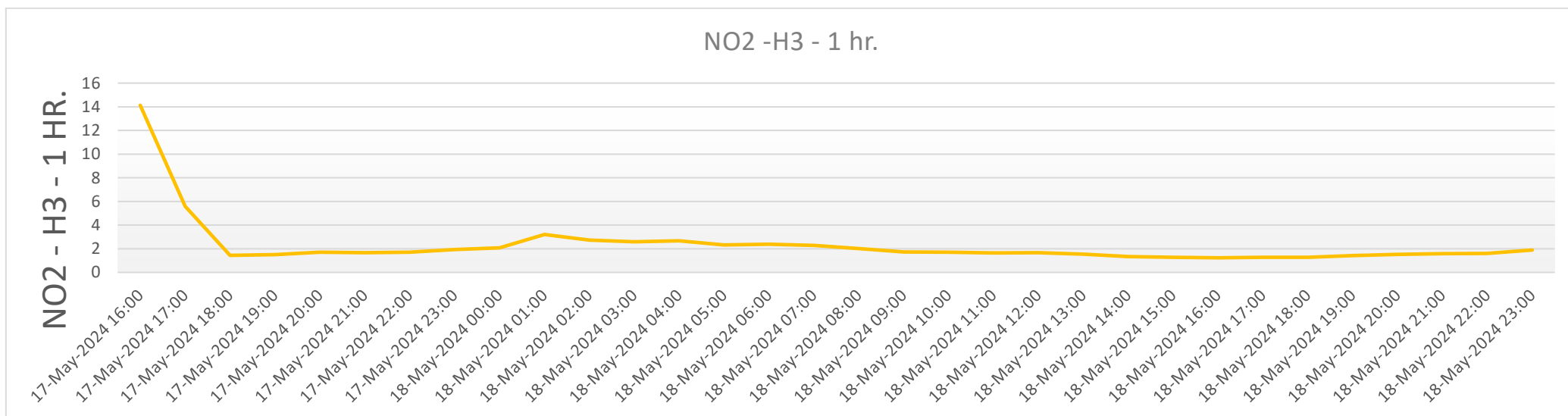
Barometric Pressure -- H 3 -- 1 HR



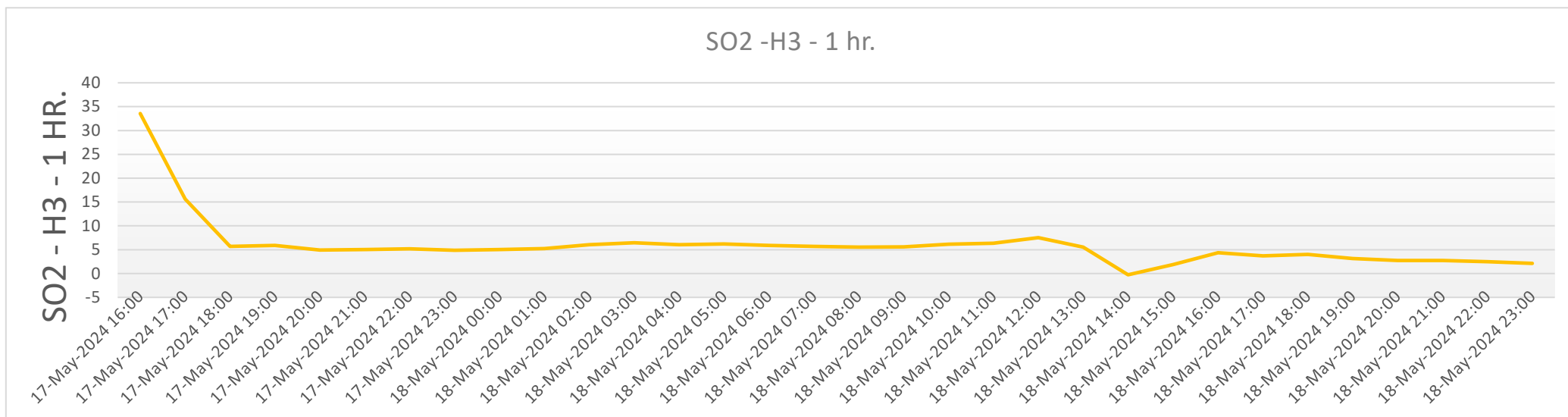
CO - H3 - 1 hr.



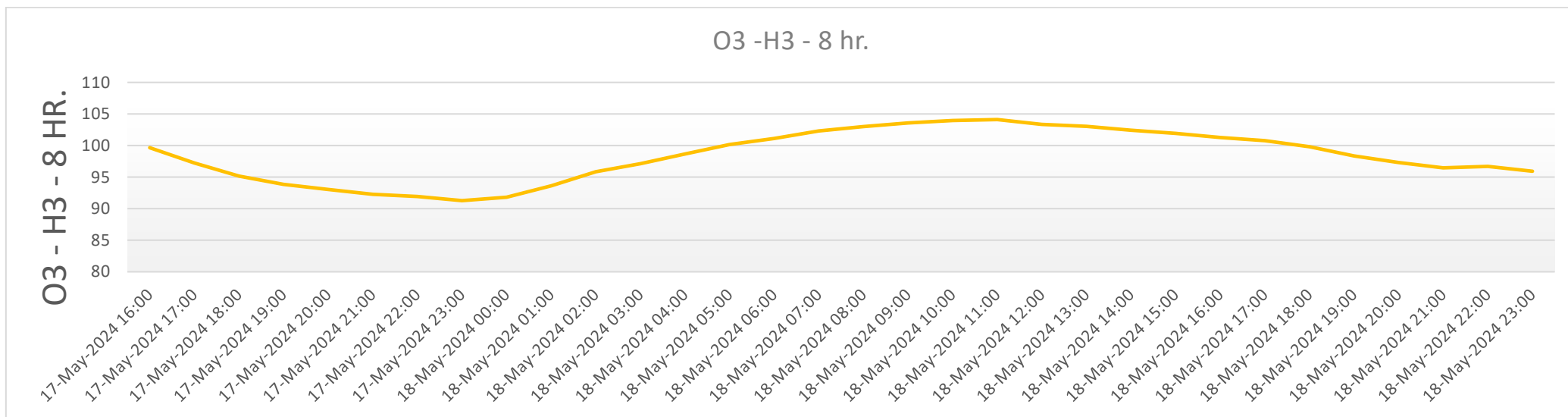
CO pollutant at site H3 – 8 hr.



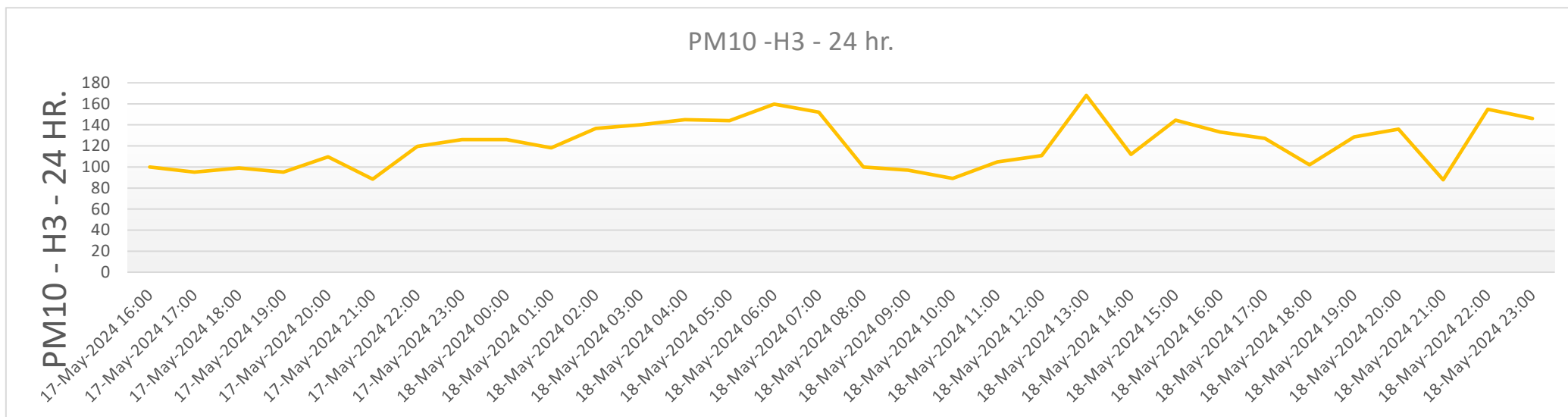
NO2 pollutant at site H3 – 1 hr.



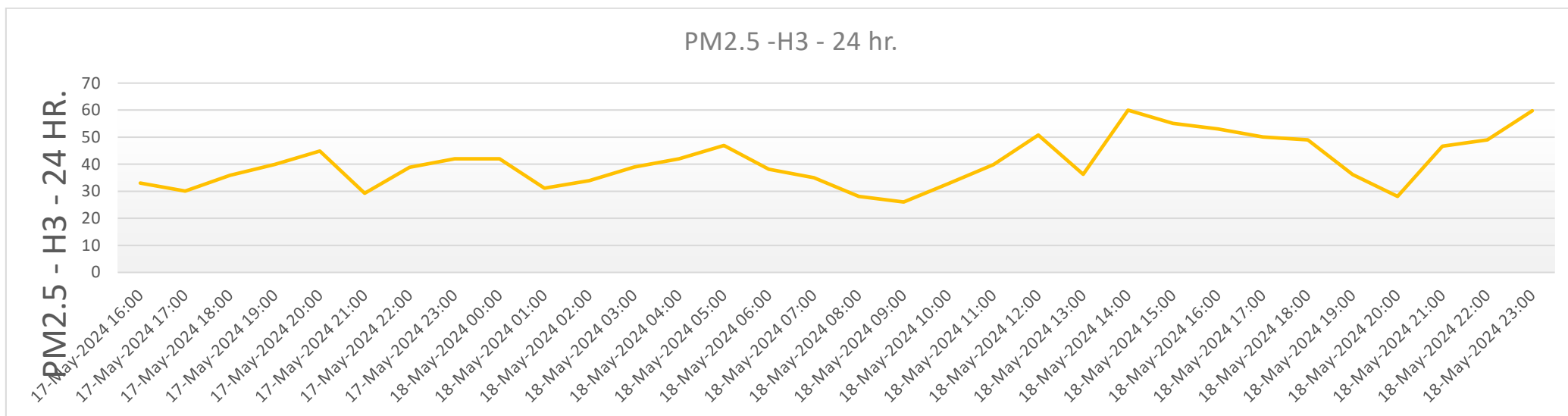
SO2 pollutant at site H3 -1hr.



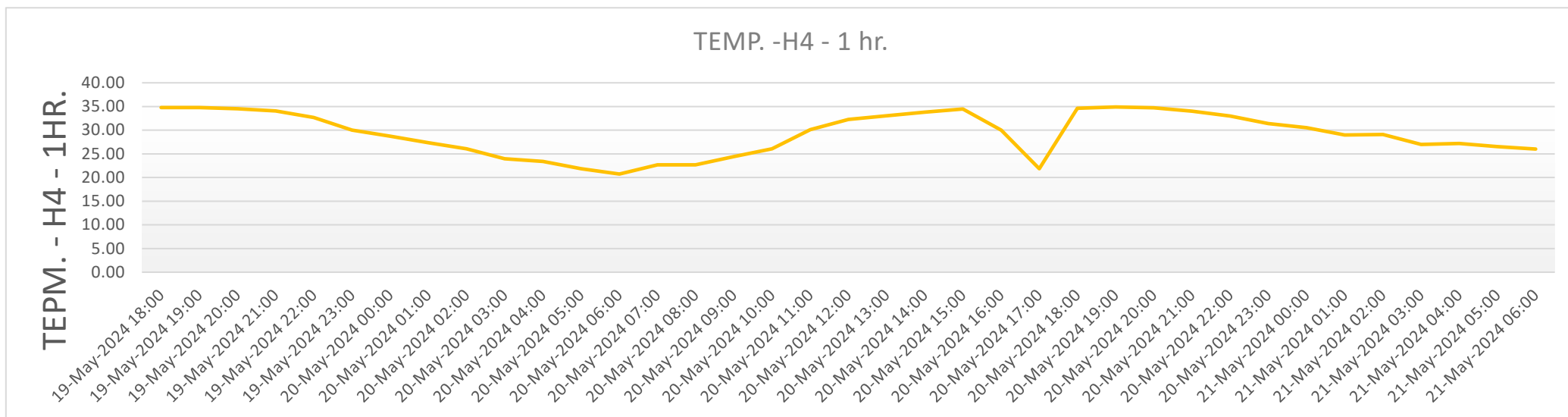
O3 pollutant at site H3 - 8 hr.



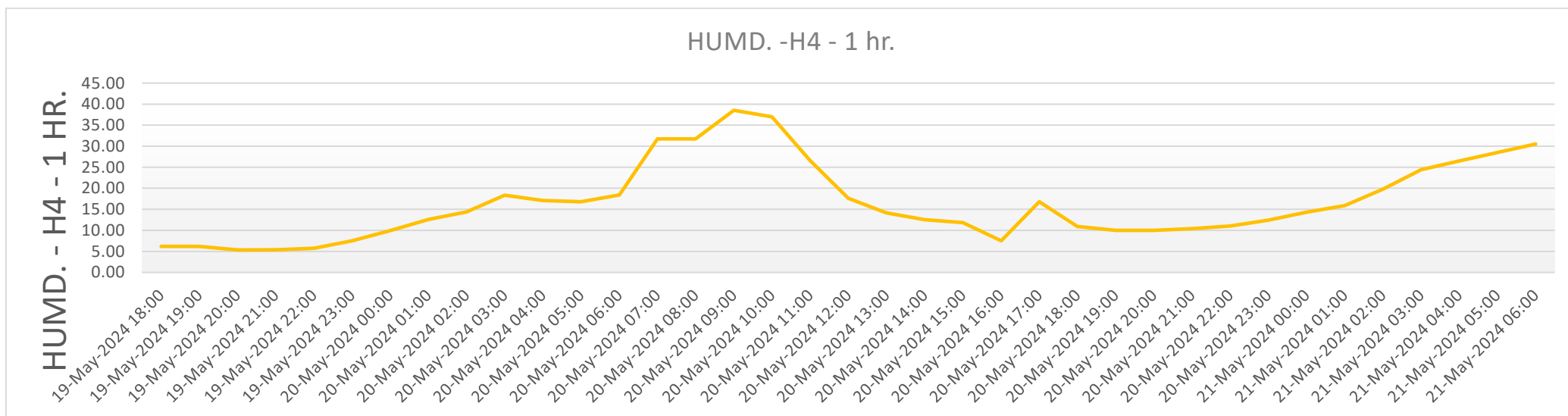
PM10 pollutant at site H3 – 24 hr.



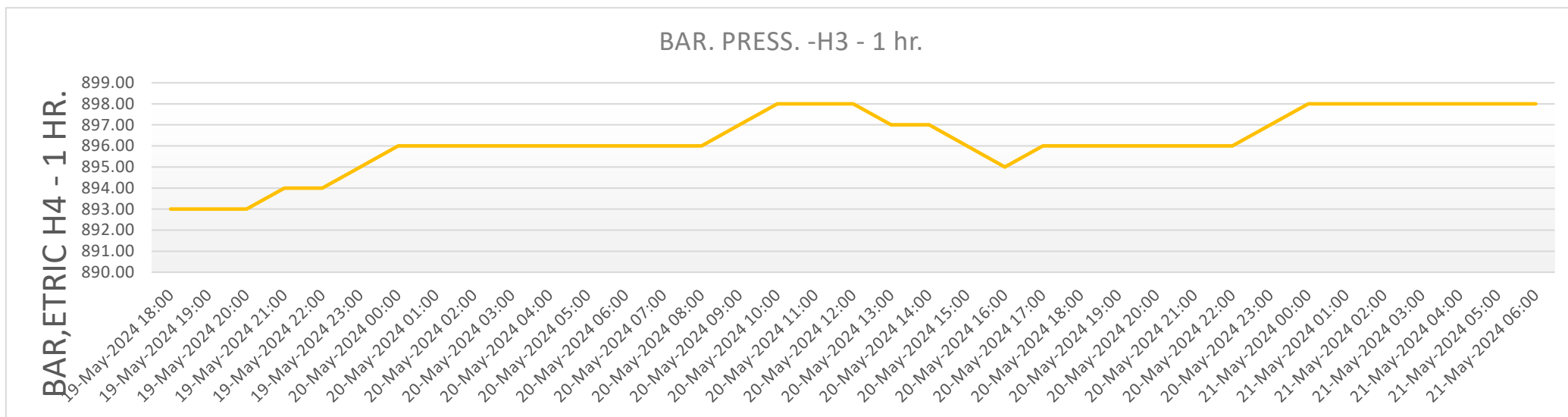
PM2.5 pollutants at site H3 – 24hr.



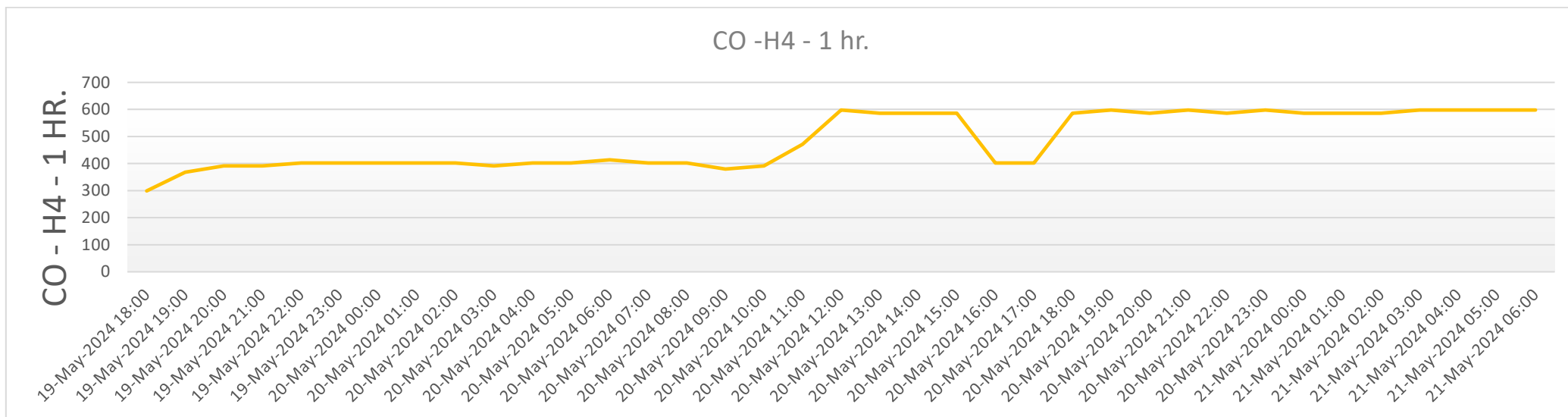
Ambient temperature – H4 – 1 HR



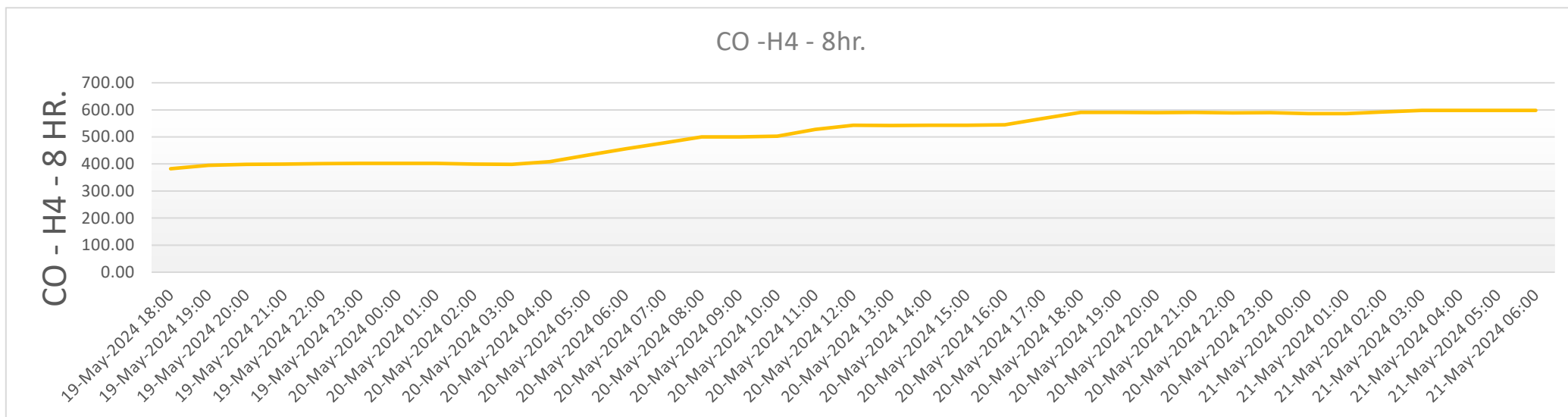
Relative Humidity – H4 – 1 HR



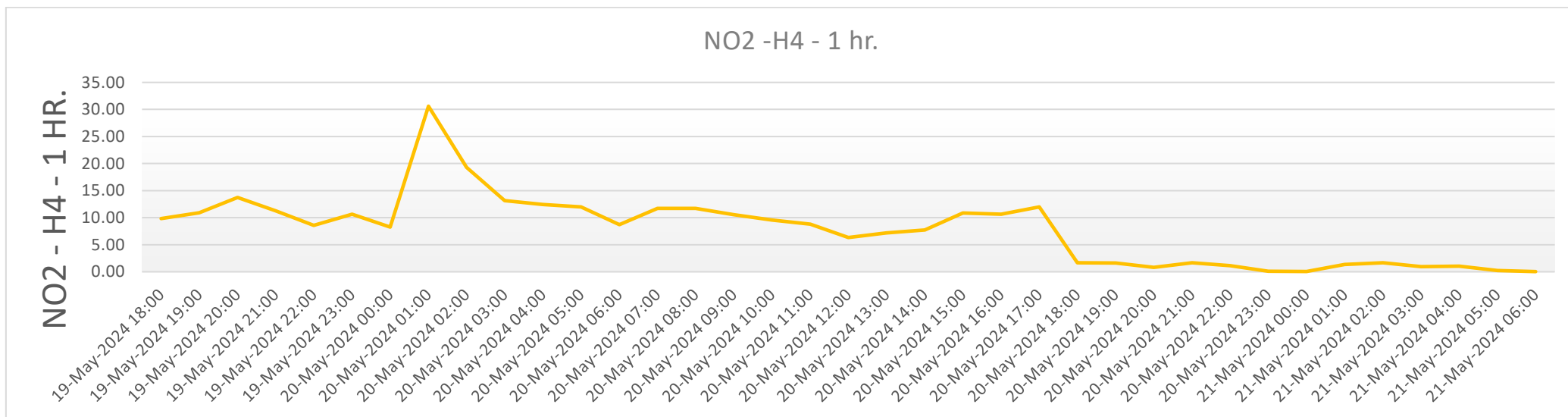
Barometric Pressure -- H 4 -- 1 HR.



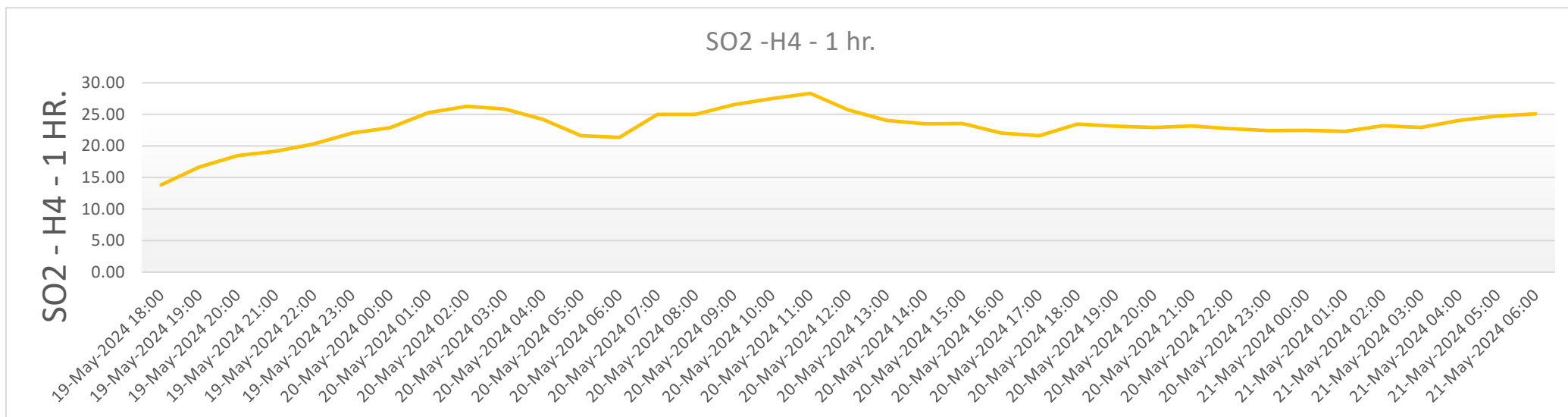
CO -- H4 -- 1 hr.



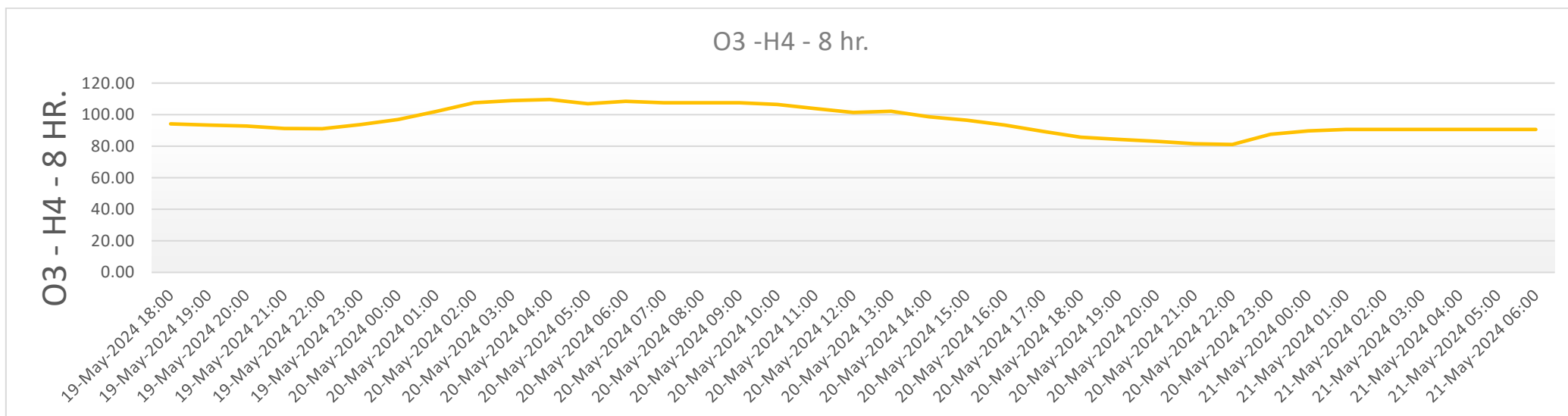
CO pollutant at site H4 – 8 hr.



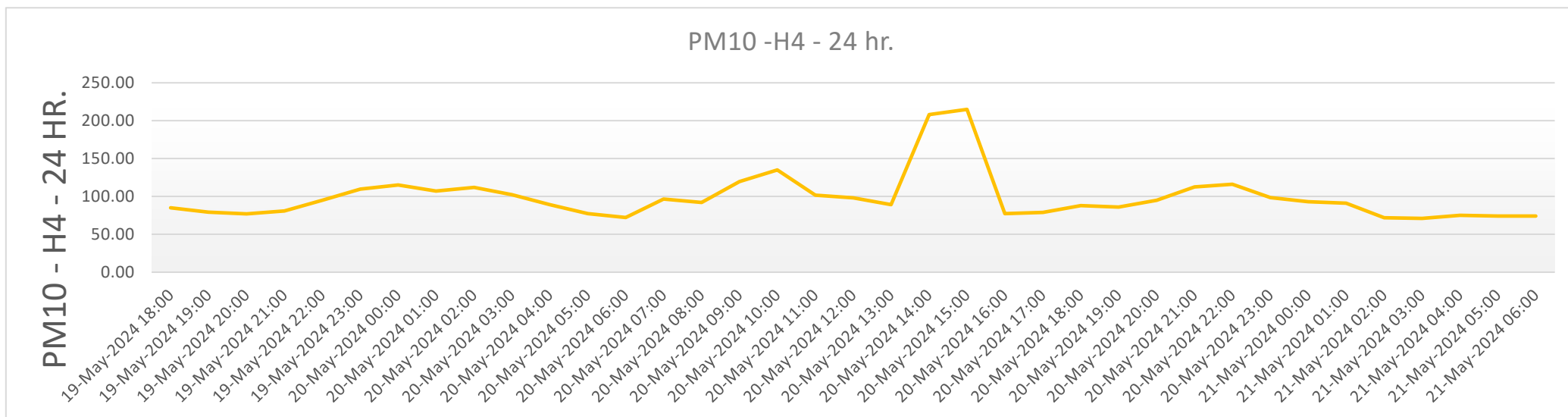
NO2 pollutant at site H4 – 1 hr.



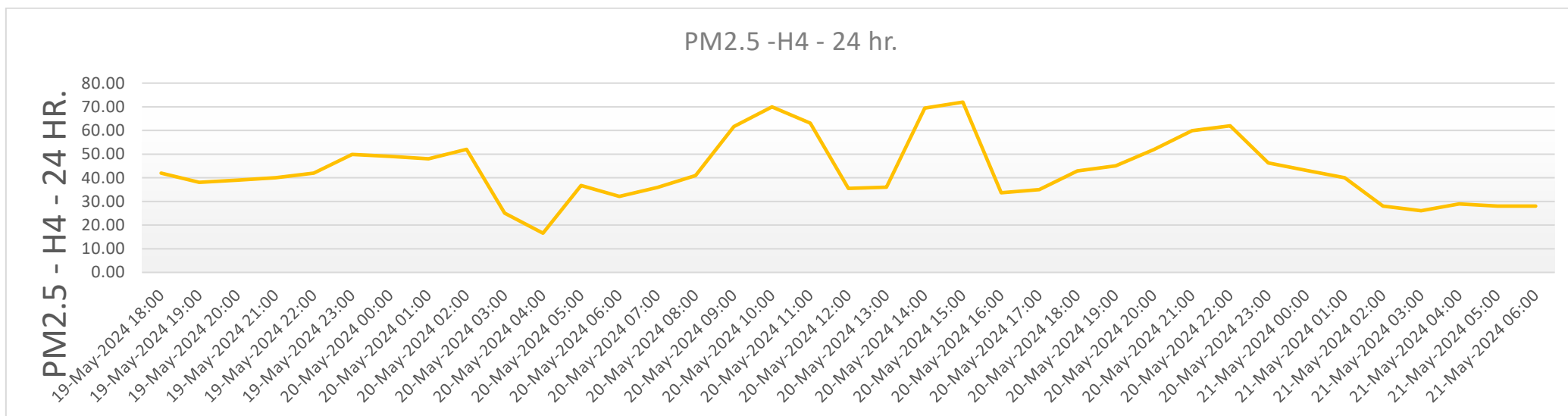
SO2 pollutant at site H4 -1hr.



O3 pollutant at site H4 - 8 hr.



PM10 pollutant at site H4 – 24 hr.



PM2.5 pollutants at site H4 – 24hr.

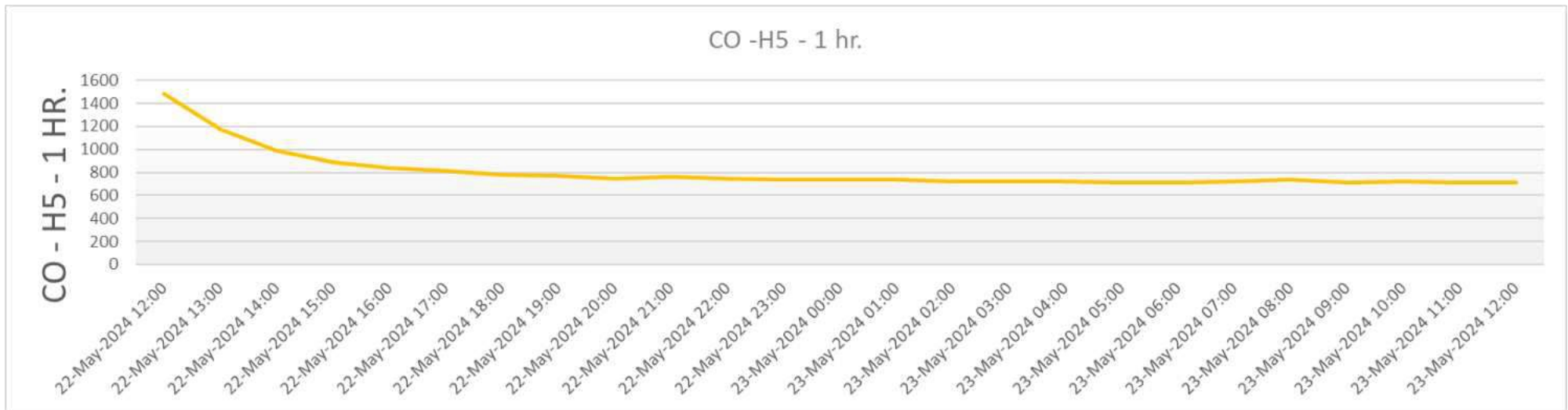


Figure 32 CO – site H5 – 1 hr.

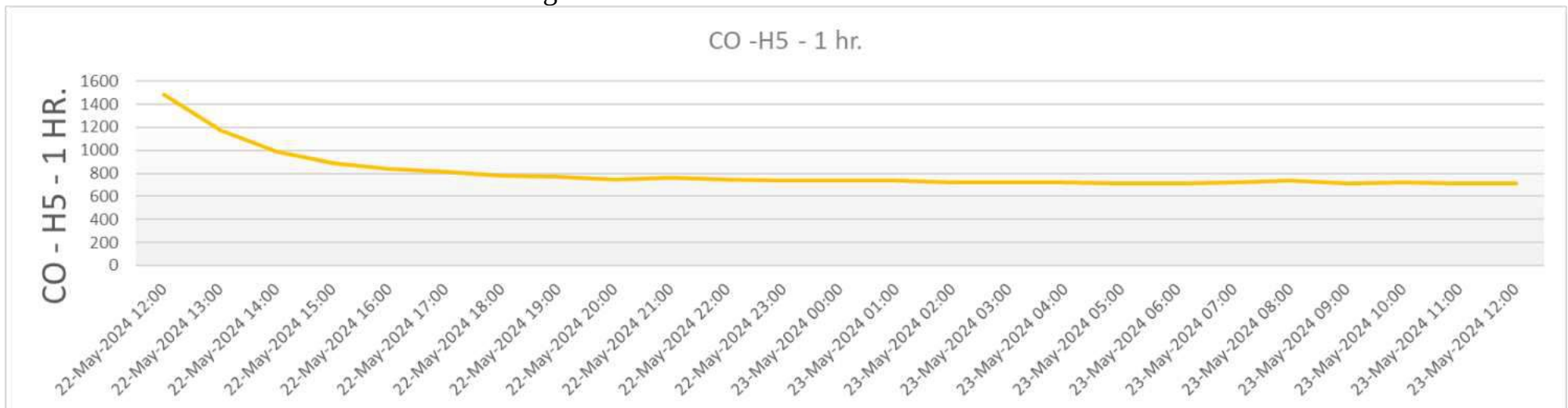


Figure 33 CO –site H5 – 8 hr.

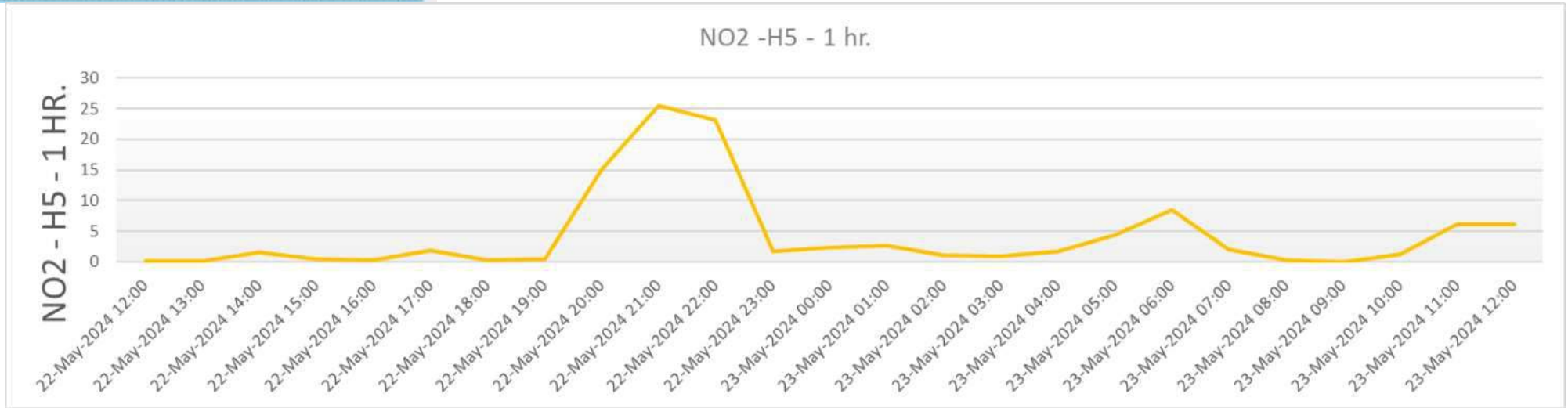


Figure 34 NO₂ – site H5 –I hr.

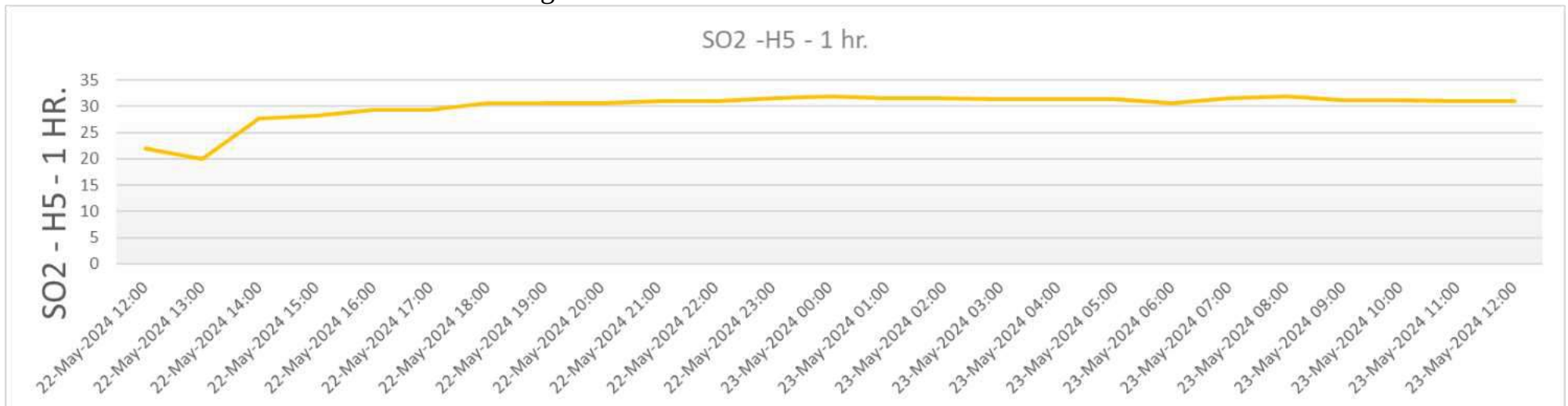


Figure 35 SO₂ –site H5 -1hr.

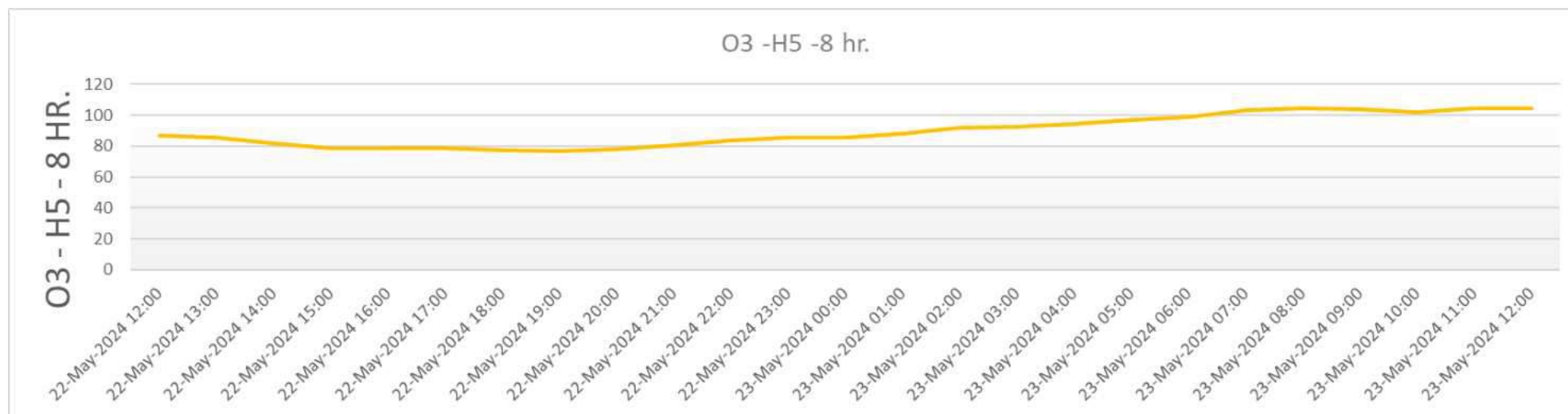


Figure 36 O3 – site H5 - 8 hr.

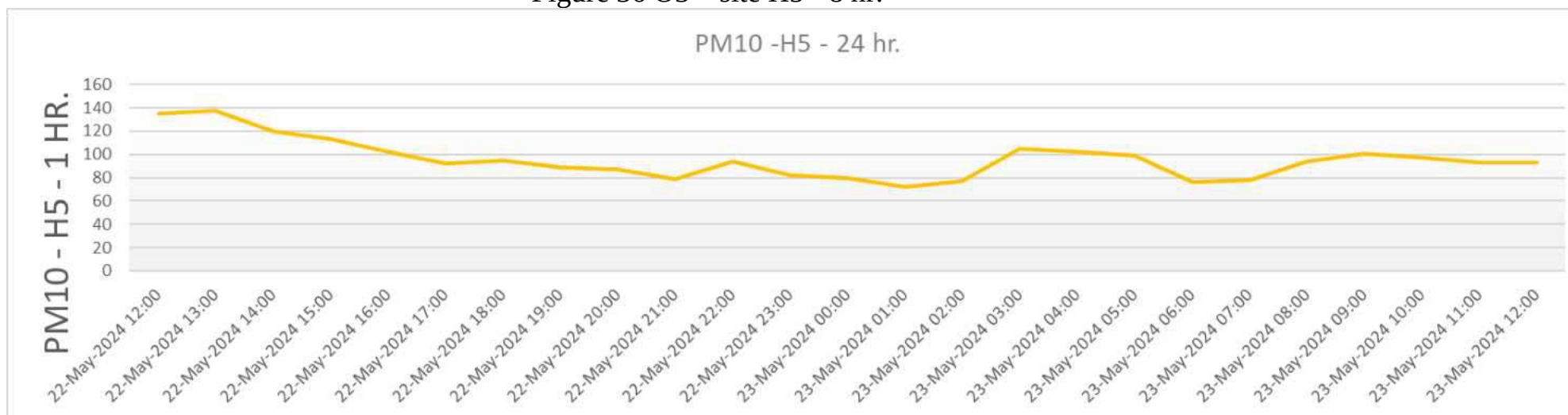


Figure 37 PM10 – site H5 – 1 hr.



انظمة التحكم الخليجية المتقدمة

GULF ADVANCED CONTROL SYSTEMS

GACS Environmental & Laboratory Instrumentations....

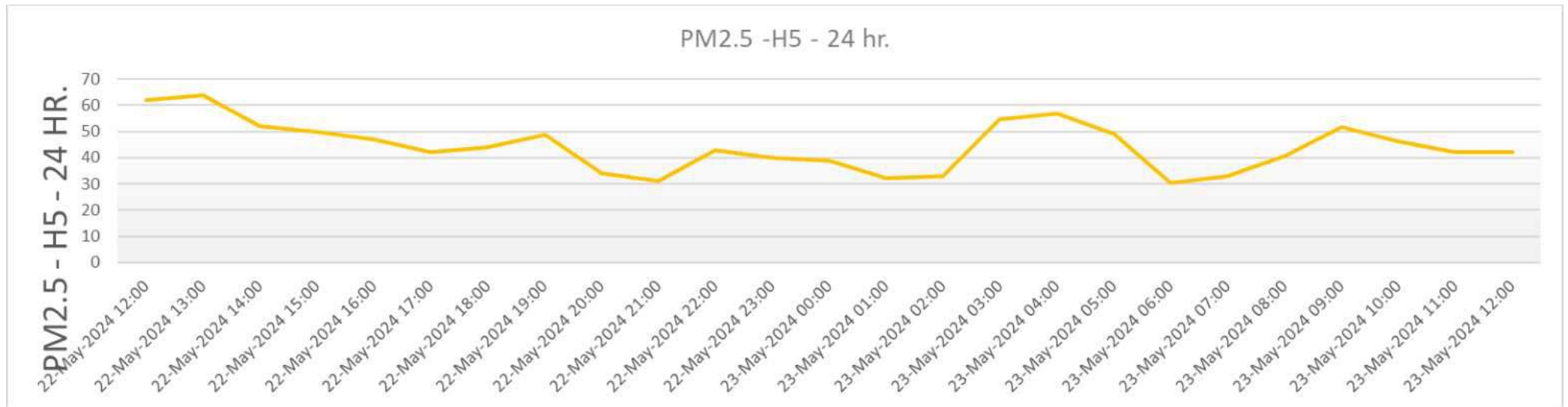
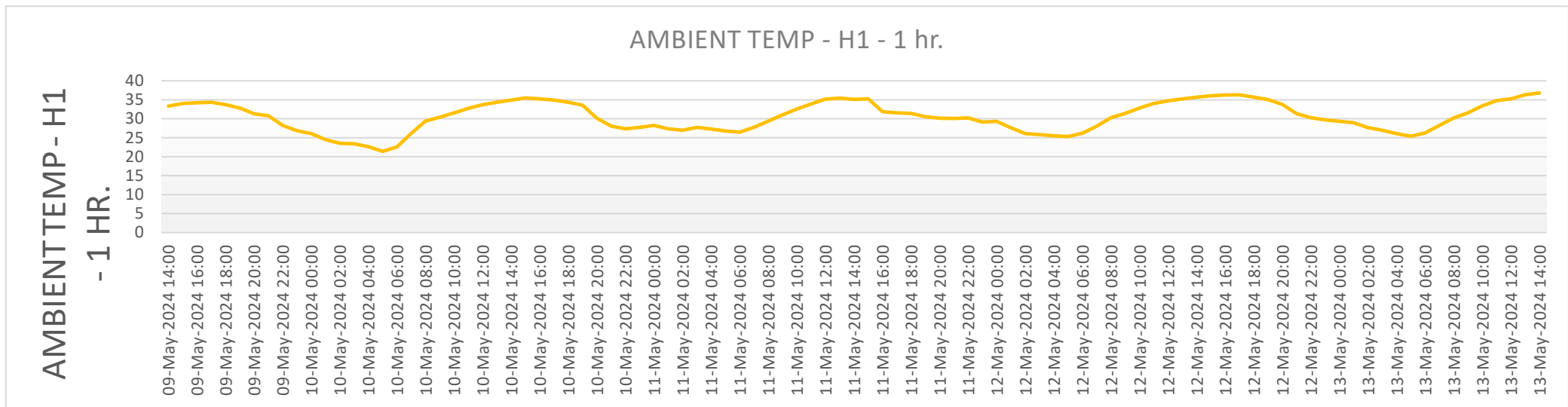
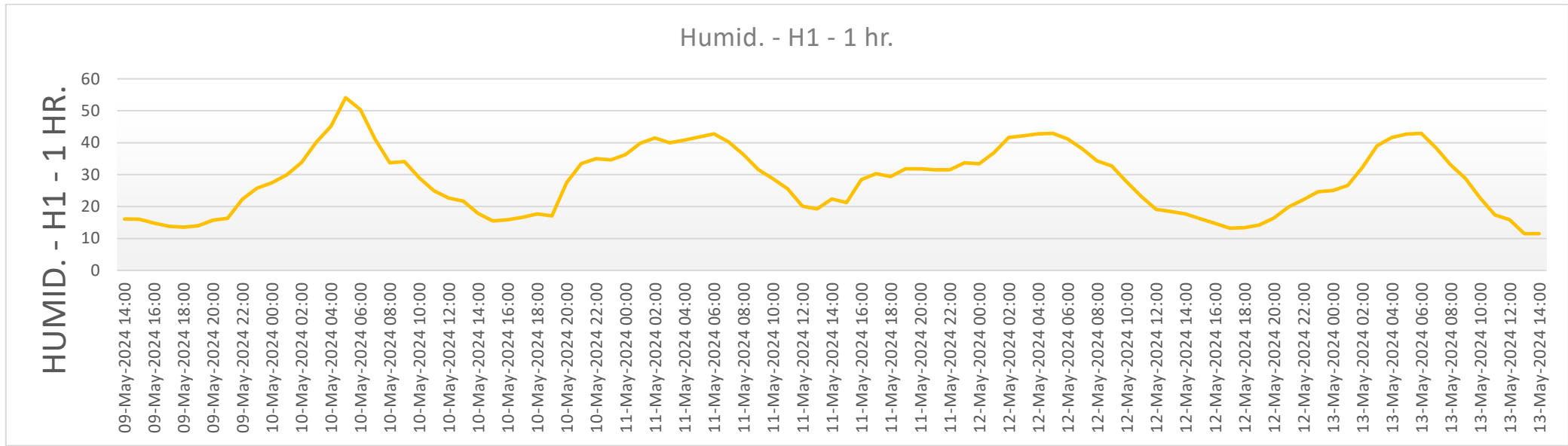


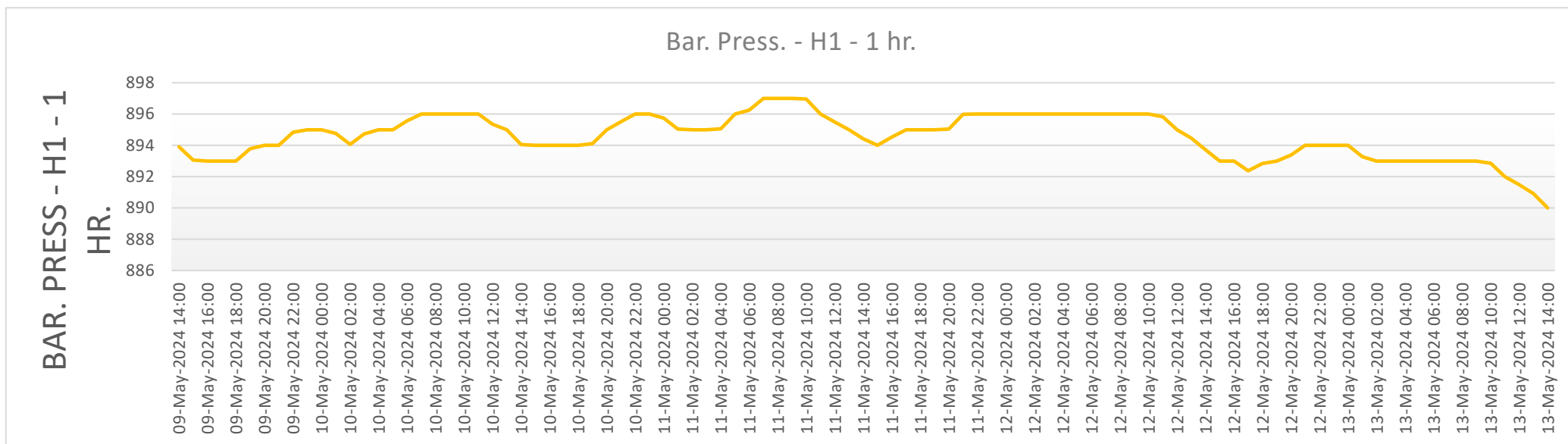
Figure 38 PM_{2.5} – site H5 – 1hr.



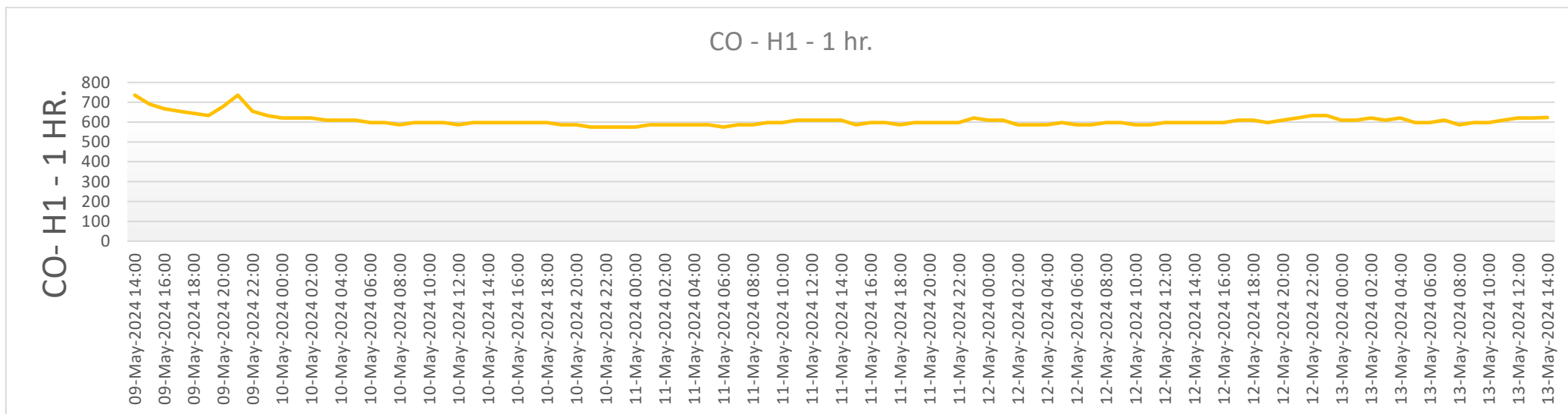
Ambient temperature – H 1 – 1 HR



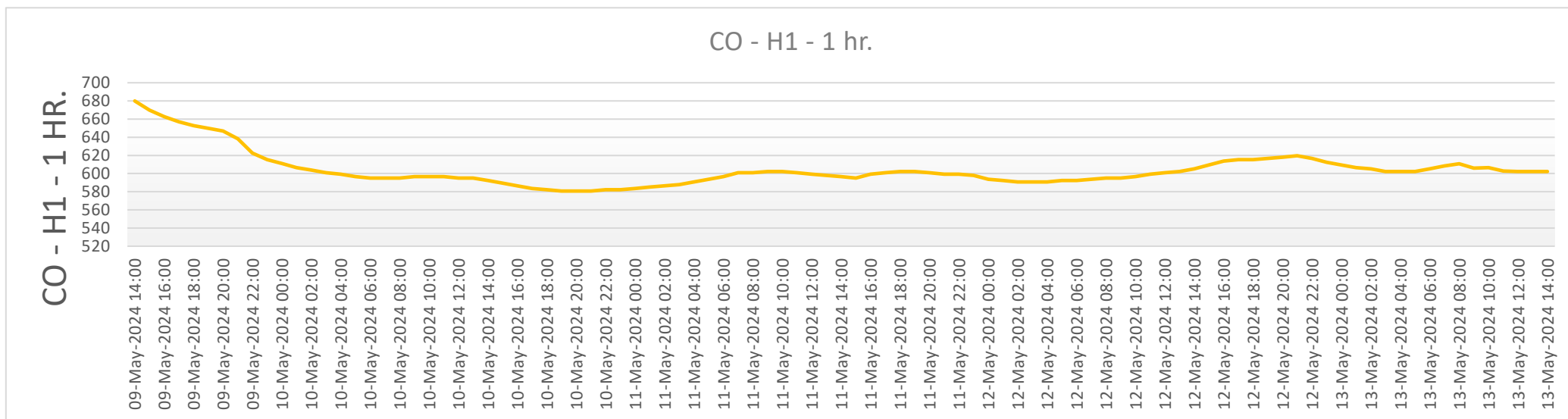
Relative Humidity – H1 – 1 HR



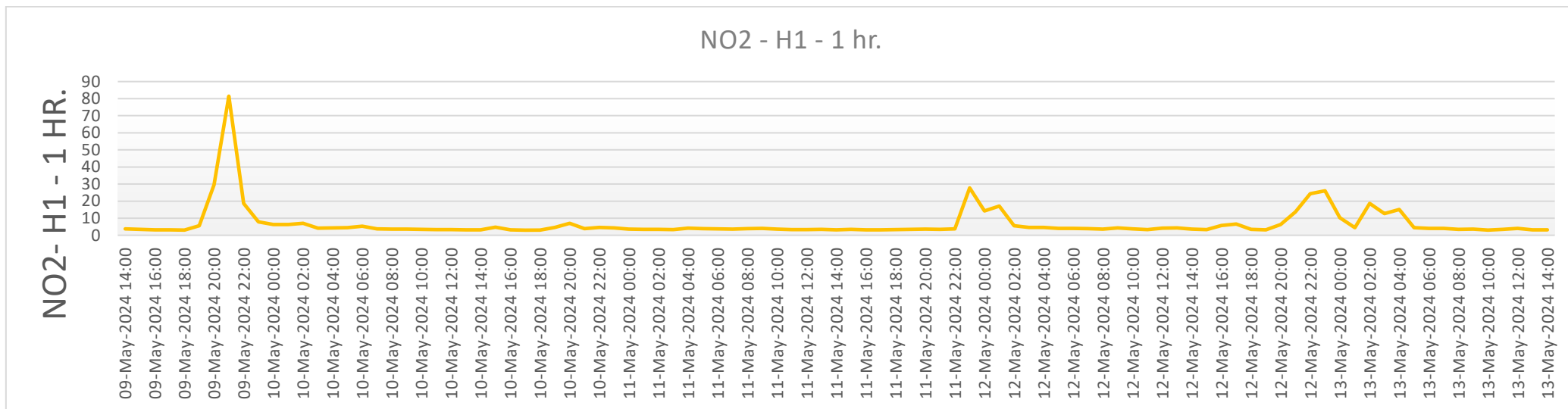
Barometric Pressure -- H 1 -- 1 HR



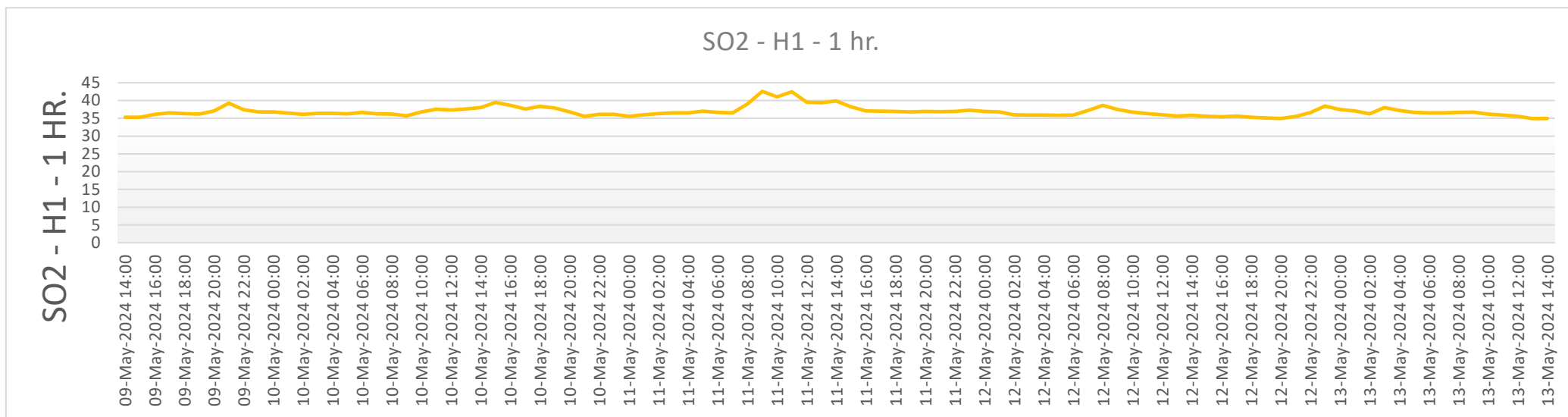
CO - H1 - 1 hr.



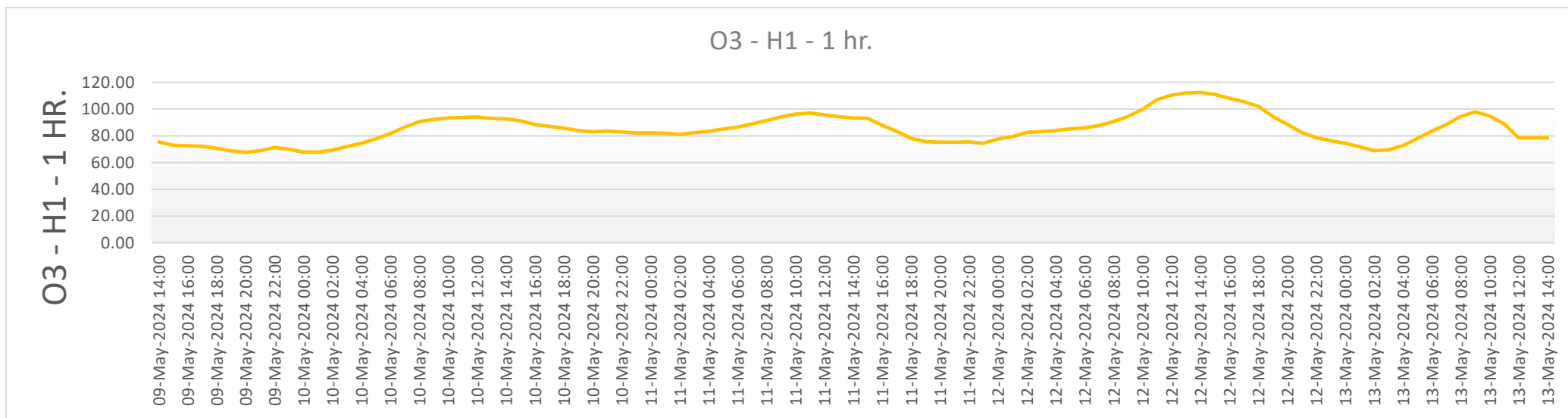
CO pollutant at site H1 – 8 hr.



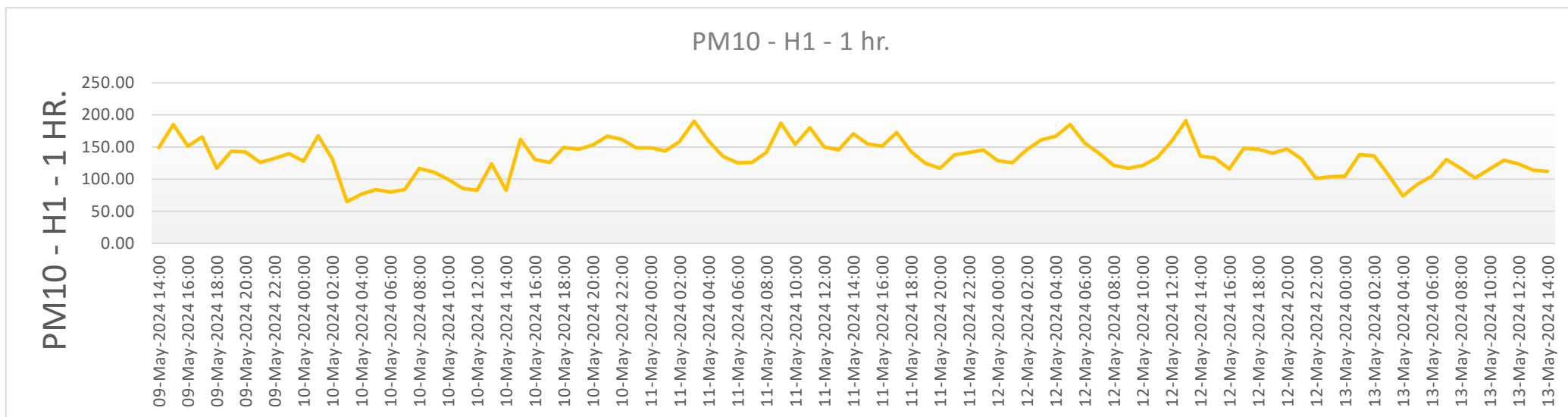
NO2 pollutant at site H1 – 1 hr.



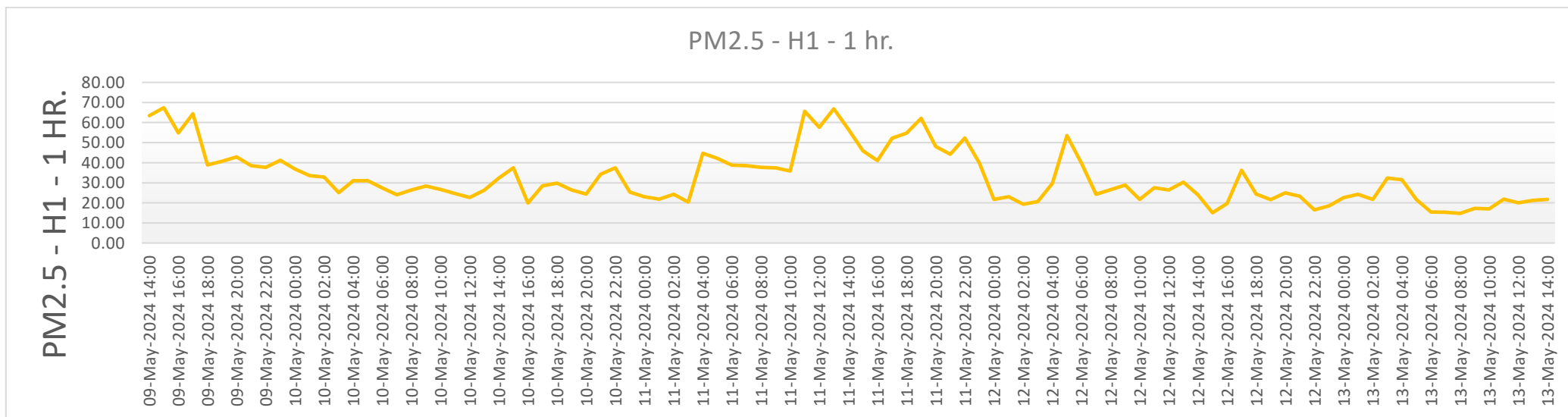
SO2 pollutant at site H1 -1hr.



O3 pollutant at site K1 - 8 hr.



PM10 pollutant at site H1 – 1 hr.



PM2.5 pollutants at site H1 – 1hr.

4. Noise

The Noise measurements were conducted on 5 locations with Al Humaij at the same location of Air Quality Monitoring.

4.1 Methodology

4.1.1 Scope of Work

The measurements were conducted according to the scope of work, which include the followings items:

- 1) To perform noise measurements on 5 monitoring locations.
- 2) At each location, to measure 24 hr. continuous monitoring.
- 3) To use a calibrated Type 1/ Class 1 noise meter to conduct the measurements, with certificate of calibration.
- 4) To perform the measurements when the wind speed is below 5m/s and it is not raining.
- 5) To avoid taking measurements where contractors (e.g., drillers, surveyors) are working close to the location. If noisy works are present nearby, move the location so that noise source is not prominent or take the measurement when the work has stopped.
- 6) To measure the following noise variables: LAeq, LAFmax, LAF10, LAF90, and LAFmin.

4.2 Description of the system

The measurements of noise were conducted using a Sound Level Meter (Optimus Cirrus CR171B) equipped with a Type 1 microphone and installed on a tripod. It was continue monitoring the noise during the 24 hour on each site, and values of LAeq, LAFmax, LAF10, LAF90 and LAFmin were taken

To measure the wind speed, a handheld vane anemometer manufactured by Kestrel was used. Before starting the measurements, this parameter was recorded.

Figure 2 shows the noise meter mounted on the tripod when measurements were being performed in some of the sites during the day or nighttime.

The Sound Level Meter was calibrated before initiating the study, sending it to a calibration lab.

The Sound Level Meter was checked on each site using a field calibrator (Cirrus CR:515), which released a fixed sound level of 94 dB. The meter was slightly adjusted after checked.

4.3 Raw data of the Noise Measurements:

H1 Site:

Location	Date	Time	Hour	LAEQ	LAFmax	Lamin	L10	L90
H1	10.5.2024	8:00 AM	0	58.2	71.9	52.9	61.9	63
H1	10.5.2024	9:00 AM	1	66.3	89.1	53.1	65	75.6
H1	10.5.2024	10:00 AM	2	61	84.5	53.9	59.3	55
H1	10.5.2024	11:00 AM	3	59.9	82.9	54.8	57.3	56.3
H1	10.5.2024	12:00 PM	4	54.9	80.2	37.5	52.7	48.4
H1	10.5.2024	1:00 PM	5	62.7	90.1	46.8	65.5	48.4
H1	10.5.2024	2:00 PM	6	55.2	65.7	44.7	55.3	35.8
H1	10.5.2024	3:00 PM	7	52.1	69.6	44.6	50.5	45.4
H1	10.5.2024	4:00 PM	8	55.1	77.4	47.1	50.1	47.8
H1	10.5.2024	5:00 PM	9	65.6	74.9	48.8	63.5	50.2
H1	10.5.2024	6:00 PM	10	54.7	68.8	49	57.6	49.2
H1	10.5.2024	7:00 PM	11	59.1	81.3	56.9	61.6	53.8
H1	10.5.2024	8:00 PM	12	59	80.8	52.9	61.5	53.5
H1	10.5.2024	9:00 PM	13	64.8	77.2	52.2	67.9	53.6
H1	10.5.2024	10:00 PM	14	66.6	77.8	52.2	70.1	54.1
H1	10.5.2024	11:00 PM	15	67.2	73.3	52.5	70.2	54.2
H1	11.5.2024	12:00 AM	16	66.8	88.4	52.9	70.4	50
H1	11.5.2024	1:00 AM	17	52.2	71.7	52.2	61.2	53
H1	11.5.2024	2:00 AM	18	58.4	72.3	51.8	69.1	53.4
H1	11.5.2024	3:00 AM	19	59.2	83.7	29	61.4	53.7
H1	11.5.2024	4:00 AM	20	57.7	82.1	27	64.7	53.7
H1	11.5.2024	5:00 AM	21	43.3	56.1	39	44.7	41
H1	11.5.2024	6:00 AM	22	38.3	55.1	22	40.7	22
H1	11.5.2024	7:00 AM	23	40.1	59.6	38	38.7	38

H2 Site:

Location	Date	Time	Hourly	LAeq	LAFmax	Lamin	L10	L90
H2	14.5.2024	8:00 AM	0	57.3	72.1	43.4	50.4	52
H2	14.5.2024	9:00 AM	1	64.5	86.7	52.2	76.2	52.2
H2	14.5.2024	10:00 AM	2	62.7	80.2	49.9	66.1	49.9
H2	14.5.2024	11:00 AM	3	59.8	89.7	53.2	53.7	53.2
H2	14.5.2024	12:00 PM	4	57.9	70.5	47.2	59.7	47.2
H2	14.5.2024	1:00 PM	5	58.4	71.9	46.8	60.7	46.8
H2	14.5.2024	2:00 PM	6	63.1	77.6	54.4	66	54.4
H2	14.5.2024	3:00 PM	7	65	82.2	52.2	68.8	52.2
H2	14.5.2024	4:00 PM	8	64.9	77.6	53.3	69	53.3
H2	14.5.2024	5:00 PM	9	59.8	70.4	51.7	62.8	51.7
H2	14.5.2024	6:00 PM	10	66.1	79.2	51.5	67.5	56.1
H2	14.5.2024	7:00 PM	11	65.3	77.5	53.1	62.5	59.4
H2	14.5.2024	8:00 PM	12	66.1	80.7	50.5	65.7	55.6
H2	14.5.2024	9:00 PM	13	68.9	82.5	51.8	68.5	57.9
H2	14.5.2024	10:00 PM	14	70.1	80.1	54.2	67.2	54.2
H2	14.5.2024	11:00 PM	15	61.5	96.4	52.4	64.9	52.5
H2	15.5.2024	12:00 AM	16	63	79.4	46.5	57.6	52.4
H2	15.5.2024	1:00 AM	17	58	77.1	47.7	59	47.9
H2	15.5.2024	2:00 AM	18	61.2	50.9	47.6	64.9	46.5
H2	15.5.2024	3:00 AM	19	61	69.7	51.8	66.4	47.7
H2	15.5.2024	4:00 AM	20	60.1	71.1	52.2	83.2	47.6
H2	15.5.2024	5:00 AM	21	57.7	79.2	49.3	60.9	51.8
H2	15.5.2024	6:00 AM	22	55.4	80	52.5	57.1	52.2
H2	15.5.2024	7:00 AM	23	52.3	87	47.9	59.2	49.3

H3 Site:

Location	Date	Time	Hourly	LAeq	LAFmax	LAFmin	L10	L90
H3	17.5.2024	4:00 PM	0	60.2	81.6	53.4	54.6	53.8
H3	17.5.2024	5:00 PM	1	70	94.4	74.3	73.2	56.7
H3	17.5.2024	6:00 PM	2	67.8	81.4	64.9	72.1	56.6
H3	17.5.2024	7:00 PM	3	54.5	77.3	53.2	55.2	53.7
H3	17.5.2024	8:00 PM	4	55.2	93.3	52.4	55.7	54.1
H3	17.5.2024	9:00 PM	5	54.6	61.6	51.8	77.5	53.8
H3	17.5.2024	10:00 PM	6	54.6	62.4	52	55.3	53.6
H3	17.5.2024	11:00 PM	7	55.2	66.4	50	56.2	53.7
H3	18.5.2024	12:00 AM	8	54.8	66.3	51.3	55.5	53.7
H3	18.5.2024	1:00 AM	9	54.7	68.1	50.1	55.2	53.7
H3	18.5.2024	2:00 AM	10	54.5	60	50.2	55	51.1
H3	18.5.2024	3:00 AM	11	54.2	63.1	51.2	54.7	53.8
H3	18.5.2024	4:00 AM	12	54.2	55.9	53	54.6	53.6
H3	18.5.2024	5:00 AM	13	54.4	83.1	50.5	54.8	53.7
H3	18.5.2024	6:00 AM	14	59.4	67	46.8	61.1	53.9
H3	18.5.2024	7:00 AM	15	51.9	68.6	46.9	63.3	52
H3	18.5.2024	8:00 AM	16	52.4	62.5	48	53.9	49.6
H3	18.5.2024	9:00 AM	17	52.4	77.5	48.4	53.8	49.5
H3	18.5.2024	10:00 AM	18	52.8	59.8	47.1	53.6	50.6
H3	18.5.2024	11:00 AM	19	51.8	57.4	47.2	52.1	50.7
H3	18.5.2024	12:00 PM	20	51.6	68.1	47.7	54.8	50.7
H3	18.5.2024	1:00 PM	21	53.1	70.6	48.5	48.5	50.9
H3	18.5.2024	2:00 PM	22	55.3	65.5	49	53.6	51
H3	18.5.2024	3:00 PM	23	54.2	69.1	70.4	49.2	51

H4 Site:

Location	Date	Time	Hourly	LAEQ	LAFmax	L Amin	L10	L90
H4	19.5.2024	5:00 PM	0	52.9	70.4	49.2	54.4	50.9
H4	19.5.2024	6:00 PM	1	54.2	65.8	49.3	56.5	51.1
H4	19.5.2024	7:00 PM	2	52.9	70.4	51.3	54.4	50.9
H4	19.5.2024	8:00 PM	3	58.1	72.4	45.3	61.5	52.5
H4	19.5.2024	9:00 PM	4	62.2	71.1	45.2	40.4	35.8
H4	19.5.2024	10:00 PM	5	54.5	77.2	45.4	41.6	37.6
H4	19.5.2024	11:00 PM	6	52.5	69.7	45.8	45.6	38.1
H4	20.5.2024	12:00 AM	7	52.3	73.7	47.2	44.5	37.6
H4	20.5.2024	1:00 AM	8	52.7	73.4	49.1	41.6	37.1
H4	20.5.2024	2:00 AM	9	53.5	65.9	49.8	42.5	38.4
H4	20.5.2024	3:00 AM	10	53.3	69.9	51.2	42.1	36.9
H4	20.5.2024	4:00 AM	11	53.2	56.3	51.1	41.5	37.4
H4	20.5.2024	5:00 AM	12	53.3	59.8	50.5	42.8	36.5
H4	20.5.2024	6:00 AM	13	53.7	64.3	51	41.2	35.1
H4	20.5.2024	7:00 AM	14	53.5	57.7	50.3	42.3	36.9
H4	20.5.2024	8:00 AM	15	53.4	57.7	39.2	42.7	37.4
H4	20.5.2024	9:00 AM	16	70.5	57.7	33.6	41.8	36.2
H4	20.5.2024	10:00 AM	17	63.2	99.8	32.6	41.9	35.6
H4	20.5.2024	11:00 AM	18	61.9	78.7	28.5	42.5	34.6
H4	20.5.2024	12:00 PM	19	56.5	75.7	28.3	42.6	36.2
H4	20.5.2024	1:00 PM	20	56	75.7	27.9	40.2	34.5
H4	20.5.2024	2:00 PM	21	53.4	75	28.3	39.9	36.4
H4	20.5.2024	3:00 PM	22	50.2	80.2	28.7	41.5	35.6
H4	20.5.2024	4:00 PM	23	51.2	79.6	32	40.4	36.7

H5 Site:

Location	Date	Time	Hourly	LAeq	LAFmax	Lamin	L10	L90
H5	21.5.2024	1:00 PM	0	44.6	64.5	21.4	49.1	23.9
H5	21.5.2024	2:00 PM	1	43	63	20	47	25.7
H5	21.5.2024	3:00 PM	2	49	68.8	16.9	53	34.5
H5	21.5.2024	4:00 PM	3	53.4	67.4	18.7	57	44.8
H5	21.5.2024	5:00 PM	4	64.2	84.5	34.6	62.7	49.8
H5	21.5.2024	6:00 PM	5	67.5	73.6	46.6	69.8	62.9
H5	21.5.2024	7:00 PM	6	41.3	57	60.8	45.3	30.4
H5	21.5.2024	8:00 PM	7	48.2	66.7	21.2	52.6	20
H5	21.5.2024	9:00 PM	8	37.5	40.7	14.7	20.2	20.2
H5	21.5.2024	10:00 PM	9	38.9	77.9	14	34.1	20
H5	21.5.2024	11:00 PM	10	43.8	66.9	25.4	47.8	30.9
H5	22.5.2024	12:00 AM	11	47.4	64.8	27.5	51.6	31.3
H5	22.5.2024	1:00 AM	12	51.5	68.1	26.4	55.7	30.9
H5	22.5.2024	2:00 AM	13	44.9	71.6	22.4	42.1	26
H5	22.5.2024	3:00 AM	14	44.7	67.2	22.3	45.3	26.1
H5	22.5.2024	4:00 AM	15	45	74.3	24.1	45.3	25.9
H5	22.5.2024	5:00 AM	16	81.9	105.1	25.9	74.1	30.8
H5	22.5.2024	6:00 AM	17	64.2	88.1	41	66	43.2
H5	22.5.2024	7:00 AM	18	52	61.4	48.8	54.4	49.5
H5	22.5.2024	8:00 AM	19	51.4	57.7	47.6	52.7	48.4
H5	22.5.2024	9:00 AM	20	64.3	82.9	34.2	68.3	49.4
H5	22.5.2024	10:00 AM	21	55.2	73.8	33	59.3	38.2
H5	22.5.2024	11:00 AM	22	50.2	74	34.7	49.5	38.7
H5	22.5.2024	12:00 PM	23	51.7	74.3	36.1	50.4	38.4



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شركة الرياض للجيو تكنولوجية والأساسات

RIYADH GEOTECHNIQUE & FOUNDATIONS CO.

CONSULTANCY SERVICES FOR SOLAR ASSESSMENT PROJECT - AL HUMAIJ SOLAR ENERGY PARK

HYDROLOGY STUDY

PREPARED BY

RIYADH GEOTECHNIQUE & FOUNDATIONS (RGF)

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02/06/2024	REV 00	DRAFT HYDROLOGY REPORT
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02/09/2024	REV 02	DRAFT HYDROLOGY REPORT

RIYADH P.O. Box 15297 Riyadh 11444 Tel : (+966-11) 4773601 (+966-11) 4773601 Fax: 4784558 Email: rgf-cp@engeosciences.com	الرياض ص.ب 15297 الرياض 11444 تليفون : (+966-11) 4773601 (+966-11) 4773601 فاكس : 4784558 البريد الإلكتروني : rgf-cp@engeosciences.com	AL-KHOBAR P.O. Box 2870 Al-Khobar 31952 Tel : (+966-13) 8598503 (+966-13) 8598503 Fax: 8598507 Email: rgf-ep@engeosciences.com	الخبر ص.ب 2870 الخبر 31952 تليفون : (+966-13) 8598503 (+966-13) 8598503 فاكس : 8598507 البريد الإلكتروني : rgf-ep@engeosciences.com	JEDDAH P.O. Box 9182 Jeddah 21412 Tel : (+966-12) 6715621 (+966-12) 6715621 Fax: 6715426 Email: rgf-wp@engeosciences.com	جدة ص.ب 9182 جدة 21412 تليفون : (+966-12) 6715621 (+966-12) 6715621 فاكس : 6715426 البريد الإلكتروني : rgf-wp@engeosciences.com

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EXECUTIVE SUMMARY

The Hydrology Study report for the Al Humaij Solar Energy Park serves as a technical document aimed at evaluating hydrological conditions and potential flood hazards within the designated area. This comprehensive analysis aims to identify flood risks and formulate effective strategies for risk management and mitigation, focusing on the unique characteristics of the solar energy park.

Key elements covered in the report include a detailed examination of rainfall and runoff patterns, an assessment of drainage infrastructure, and mapping of flood-prone areas specifically relevant to the solar energy park. The study also considers external factors such as land use changes and human activities that may influence the hydrological dynamics of the region, with a specific focus on how these factors impact the solar energy facility.

The flood risk assessment involved the collection of pertinent data, including rainfall statistics, topographical information, and existing infrastructure details specific to the Al Humaij Solar Energy Park. A thorough site visit was conducted to gather relevant data, complemented by analyses such as topographical and morphological assessments tailored to the solar energy park's characteristics. Hydrological analyses were performed for different return periods, and a 2D hydraulic model was created to visualize potential flood scenarios and generate flood risk maps. The recommendations derived from these analyses are specifically tailored to address the unique challenges of flood risk within the context of a solar energy facility.

The primary goal of the study was to evaluate flood risk and provide strategic recommendations to minimize the impact of flooding on the Al Humaij Solar Energy Park. By conducting a detailed assessment and offering mitigation suggestions, the study equips project management with valuable insights for informed decision-making related to the solar energy park. The overall objective is to enhance flood risk management practices and contribute to the development of effective flood risk mitigation measures tailored to the solar energy facility. The report provides a comprehensive understanding of flood risk within the context of the Al Humaij Solar Energy Park and offers guidance for improved risk management specific to the solar energy facility.

1. INTRODUCTION

1.1 Preface

This report presents the findings of a preliminary hydrological study aimed at assessing the susceptibility of the study area to flood hazards.

A brief outline of the report's primary sections is provided below:

1. **PROJECT LOCATION:** In this section, the description of the study area's geographic location of the project area is presented and the limit of work is explained.
2. **STUDY OBJECTIVES AND SCOPE OF WORK:** In this section outlines the purpose of the study, the specific goals and objectives of the hydrological analysis.
3. **METHODOLOGY AND WORK PLAN:** This section include a block diagram to visually represent the steps and processes involved in conducting the hydrological study. The diagram may show the flow of information and data, the various tasks involved, and the interrelationships between different components of the study. This helps to clearly illustrate the methodology and make it easier for readers to understand and follow the work plan.
4. **CODES & STANDARDS INTERNATIONAL REFERENCES REGRADING METHODOLOGIES:** This section provides information on the codes, standards, and guidelines used to conduct the hydrological study, including references to international best practices and relevant technical specifications. This section highlights the standards used to ensure the quality and reliability of the study results and provides a basis for comparison with similar studies.
5. **COOPERATING WITH OTHER PARTIES:** This section describes the involvement of other organizations, agencies, or stakeholders in the hydrological study, including their role and responsibilities, and any agreements or arrangements made with them. This section also outlines any communication and coordination efforts made between the various parties to ensure the success of the study.
6. **AVAILABLE DATA COLLECTION AND SITE VISITS:** This section of the report describes the sources of data and information used in the hydrological study, including data collected from site visits, remote sensing, and other sources. This section details the methods and techniques used for data collection, such as field surveys, topographic maps, and aerial photos, and provides an overview of the results of any site visits.
7. **GEOLOGICAL AND GEOTECHNICAL STUDIES:** This section of the report presents the results of any geological and geotechnical investigations that were conducted to assess the impact of the area's geology and soil characteristics on flood hazards.
8. **RAINFALL DATA ANALYSIS:** This section of the report presents the results of the analysis of rainfall data collected for the study area, including data on rainfall intensity, duration, and frequency. This section includes information on the methods used to collect and analyze rainfall data, such as weather stations, rain gauges, and provides an overview of the patterns and trends observed in

the data. The results of the rainfall data analysis are used to inform the hydrological modeling and flood risk assessment.

- 9. HYDROLOGICAL ANALYSIS:** This section presents the results of the hydrological analysis conducted as part of the study, including information on the catchment area, runoff, and river flow characteristics.
- 10. HYDRAULIC ANALYSIS:** This section presents the results of the hydraulic analysis, which involves the simulation of the flow of water in a river or channel. The hydraulic analysis includes information on the water depth, velocity, and flow patterns, as well as the analysis of any flooding scenarios.
- 11. FLOOD RISK ASSESMENT:** This section presents the results of the flood risk assessment, which involves evaluating the likelihood and consequences of flooding in the study area. The flood risk assessment takes into account the results of the hydrological and hydraulic analysis, as well as other relevant factors such as the location of vulnerable communities and infrastructure
- 12. PROPOSED FLOOD PROTECTION WORKS:** in this section, the proposed flood protection works for the site are presented, in addition to the sizing for the proposed protection elements.
- 13. CONCLUSION AND RECOMMENDATIONS:** This section presents a summary of the main findings and conclusions of the study, as well as the recommendations for further actions and measures to reduce the risk of flooding in the study area. The section may also include suggestions for future research and monitoring activities.

1.2 Background

The Solar Assessment Project in Saudi Arabia is a strategic initiative designed to tap into the unique characteristics of nine specific locations across the country. These locations have been carefully chosen based on their distinct attributes, each playing a vital role in meeting the region's power demand through solar energy. In essence, the Solar Assessment Project in Saudi Arabia is not only a pursuit of renewable energy but also a nuanced understanding of the distinctive features that contribute significantly to meeting the region's power demand. The hydrology study plays a critical role in ensuring the sustainable development of solar parks that align with the broader vision of responsible energy use in the region.

1.3 Project Location

The solar assessment project in Saudi Arabia encompasses nine different locations distributed across various regions. Each location has its own unique characteristics that contribute to the overall hydrology and water resources of the area. The table below summarizes the information about three locations:

Table 1-1 Project Locations Information

Serial	Name	Total Area Km ²	Provenance	Governorate
1	Khulais Solar Energy Park	40.3	Makkah	Khulays
2	Al-Humaij Solar Energy Park	60	Al Madinah	Al Hinakiyah
3	Mawqaq Solar Energy Park	11	Hail	Mawqaq

This Report Focuses on the Al Humaij Solar Energy Park.

The figure provided below illustrates the relative locations of Al Humaij solar park within their respective regions in Saudi Arabia.

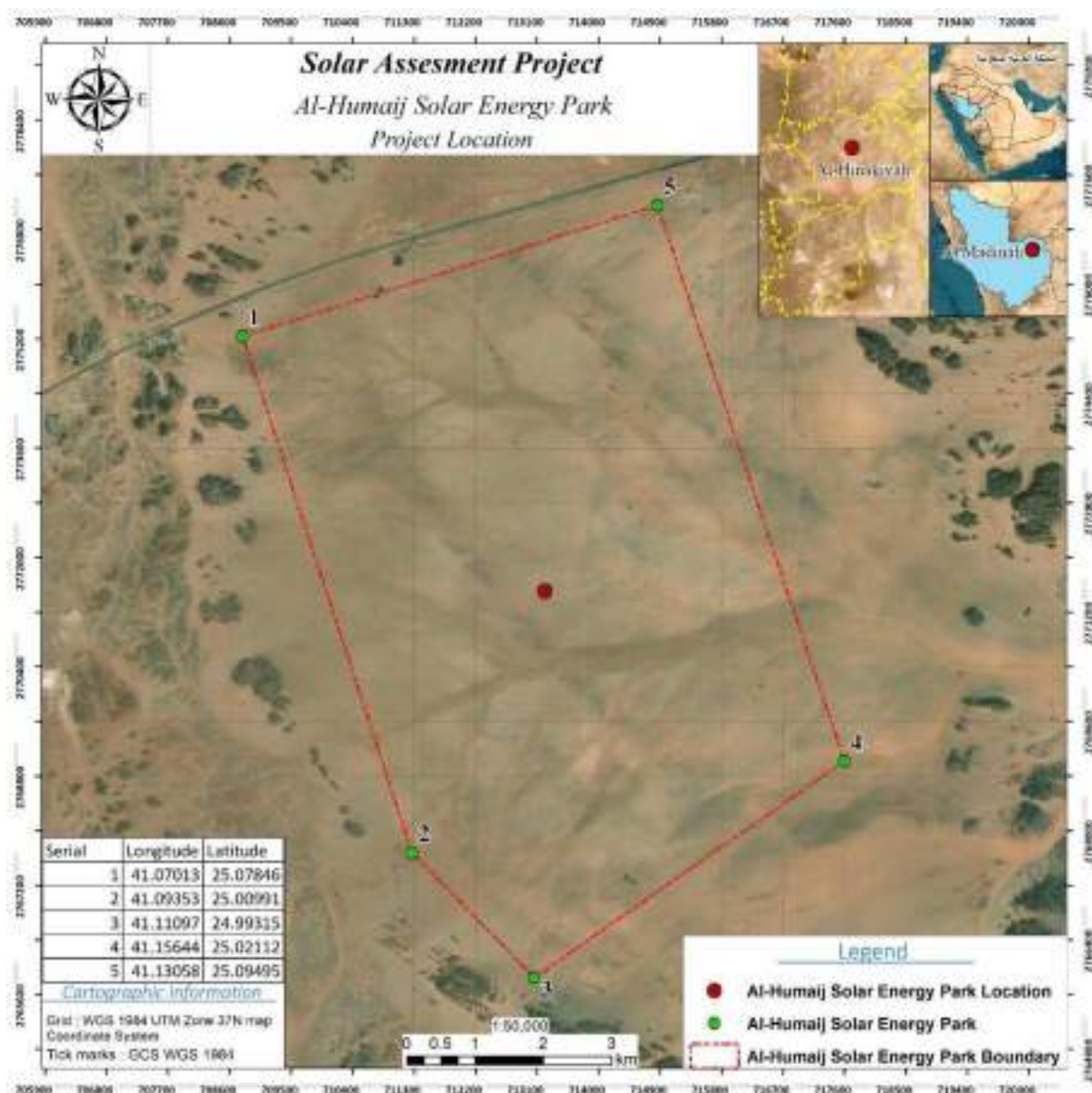


Figure 1-1 Project Location

2. Study Objectives and Scope of Work

The objectives of this study are resembled in carrying out all the hydrological and analysis, related to the determination of the external wadis affecting the project boundary to determine the extent of its exposure to flood hazards and therefore to take the necessary measures and propose the necessary protection works to prevent against major flood risks, and consider these works during the master planning for the project site in case needed.

The outlined scope of work includes several tasks and objectives. Here is a summary of each point:

1. Site visit and data collection: Conduct a visit to the site to gather relevant information and data necessary for the hydrological study.

2. Adopting international standards and software: Utilize internationally recognized standards and software tools for conducting the hydrological analysis.
3. Identify streams and external catchments: Determine the streams and catchments that have an impact on the proposed project boundary and delineate their watershed boundaries.
4. Determine morphological parameters and rainfall-runoff analysis: Analyse the morphological parameters of each catchment area and perform a rainfall-runoff analysis to determine the peak flow hydrograph for different design return periods.
5. Rainfall analysis and IDF curve development: Collect rainfall data from effective rainfall stations in the study area and analyse the data statistically to develop Intensity-Duration-Frequency (IDF) curves for various return periods.
6. Verification of model results: Validate the results obtained from the hydrological model against real-world data to ensure accuracy and reliability.
7. Evaluate existing flood structures/routes: Assess the efficiency of existing flood structures and routes within the study area under different return periods.
8. Propose flood protection works: Recommend appropriate flood protection measures, such as open channels, culverts, bridges, side slope protections, and dikes, to safeguard the proposed project area against expected flood risks. Provide supporting calculations for these proposals.

3. METHODOLOGY AND WORK PLAN

A methodology and work program block diagram is a visual representation of the various tasks and steps involved in a project, along with their interdependencies.

The block diagram typically starts with the identification of the collection of data and information needed to develop the design. The next step involves the use of computer models and software packages to conduct hydrological and hydraulic analysis of the catchment areas and proposed protection works.

Once the analysis is completed, the design of the flood protection works can begin, including the design of wadi and riprap revetments.

The work program block diagram breaks down the project into specific tasks, it also highlights the dependencies between tasks, indicating which tasks must be completed before others can begin. This allows the project team to effectively manage the project, ensuring that it stays on schedule and within budget.

Overall, the methodology and work program block diagram are essential tools for managing a complex project like a flood protection study, providing a clear roadmap for the project team to follow and ensuring that all tasks are completed in a timely and efficient manner.

As shown in the following block diagram, the methodology and work program were divided into several phases to ensure a comprehensive and efficient study.

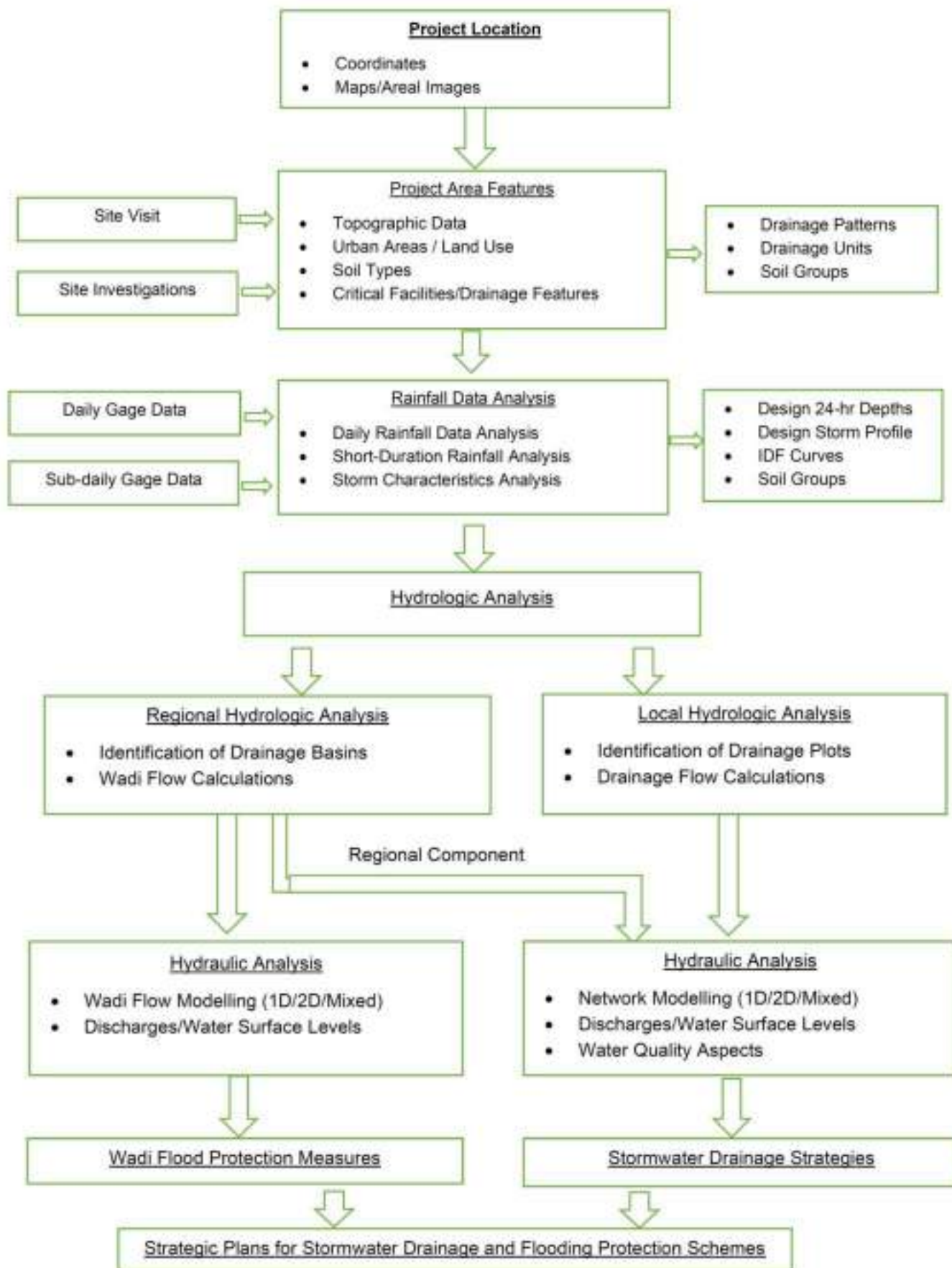


Figure 3-1. Methodology and work plan Block Diagram

4. CODES & STANDARDS INTERNATIONAL REFERENCES REGRADING METHODOLOGIES.

All works will be performed in accordance with the standards, specifications, practices and drawings that are referenced in this Scope of Work.

The hydrological and hydraulic designs are based on the design criteria conforming to the following standards and design manuals:

- ❑ Ministry of Municipal and Rural Affairs (MOMRA) Design Standards.
- ❑ Saudi Geological Survey (SGS) Design Standards.
- ❑ Ministry of Transport (MOT) Standards.
- ❑ ER07.8.12 NEOM-NEN-PRC-012_01.00 - Hydrological Study Procedure"
- ❑ Urban Hydrology for Small Watershed, Technical Release 55, TR55, NRCS, 1986.
- ❑ Hydraulic Engineering Circular (HEC) no. 22 – Urban Drainage Design Manual.

Table 4-1 Design Criteria Summary

Activity and standard	Design Basics	Software Used
Topographic and geomorphological studies		
Paths of wadis and drainage basins	<u>Maps</u> *Topographic 1:50000 * DEM 10x10, 30x30, and 90x90 * Site visits	* Watershed Management System, WMS * Geographic Information Systems GIS
Rainfall data and statistical analysis		
Rainfall Analysis	* Maximum daily rainfall depth for different frequency periods * Intensity Duration Frequency curves IDF	* HyfranPlus
Spatial Distribution of Rainfall	* Thiessen Polygon	* Geographic Information Systems GIS
Hydrological studies		
Flow Estimate	* Rational Method for A< 100 hectares * SCS Method for A>100 hectares	* HEC-HMS for SCS Method
Time of concentration	* Kirpich Equation	
Flood Plain		
Flood Plain	* Return Period 100 yrs. * DEM 10 x 10 M	* HEC-RAS 2D
Open Channels		
Open Channels	* Return Period 100 yrs.	* Hydraulic Tool Box * Sewer GEMS for 1D Dynamic Modelling
Culverts		
Culverts	* Return Period 100 yrs. * Minimum size (1.5 m x 1.5m) * H/d < 1.2	* Culvert Master
This Table Ends here		

5. COOPERATING WITH OTHER PARTIES

The flood risk assessment requires cooperation with various government agencies, including:

- Ministry of Environment, Water and Agriculture for Rainfall Data.

The key objectives of this cooperation are to secure necessary permits, comply with local regulations, and avoid any potential conflicts. The report lists the following parties involved in the project:

- Client: GCC Lab – Gulf Renewable Energy Lab.

6. AVAILABLE DATA COLLECTION AND SITE VISITS

The section "Available Data Collection and Site Visits" provides information on the sources of data and information that were collected and used in the study. This section highlights the data collected from various sources such as site visits, surveys, and existing records. The information gathered from these sources was used to perform the hydrological and hydraulic analysis, flood risk assessment and to make recommendations for flood protection works and mitigation measures. The purpose of this section is to give a comprehensive overview of the data collected and used in the study to support the findings and recommendations made.

6.1 Data Collected

6.1.1 Topography and Survey

A. DEM Data

Definition: Digital Elevation Model (DEM).

Purpose: The Digital Elevation Model (DEM) data is an important source of information for this project. It provides a three-dimensional representation of the topography of the area.

1. DEM From MOMRA

Source: Ministry of Municipal and Rural Affairs (MOMRA).

Resolution: 10x10 meter.



Figure 6-1 DEM of 10 x10 m Resolution

1. Topographical survey.

Source: GCC lab

Resolution: 0.5x0.5 meter.

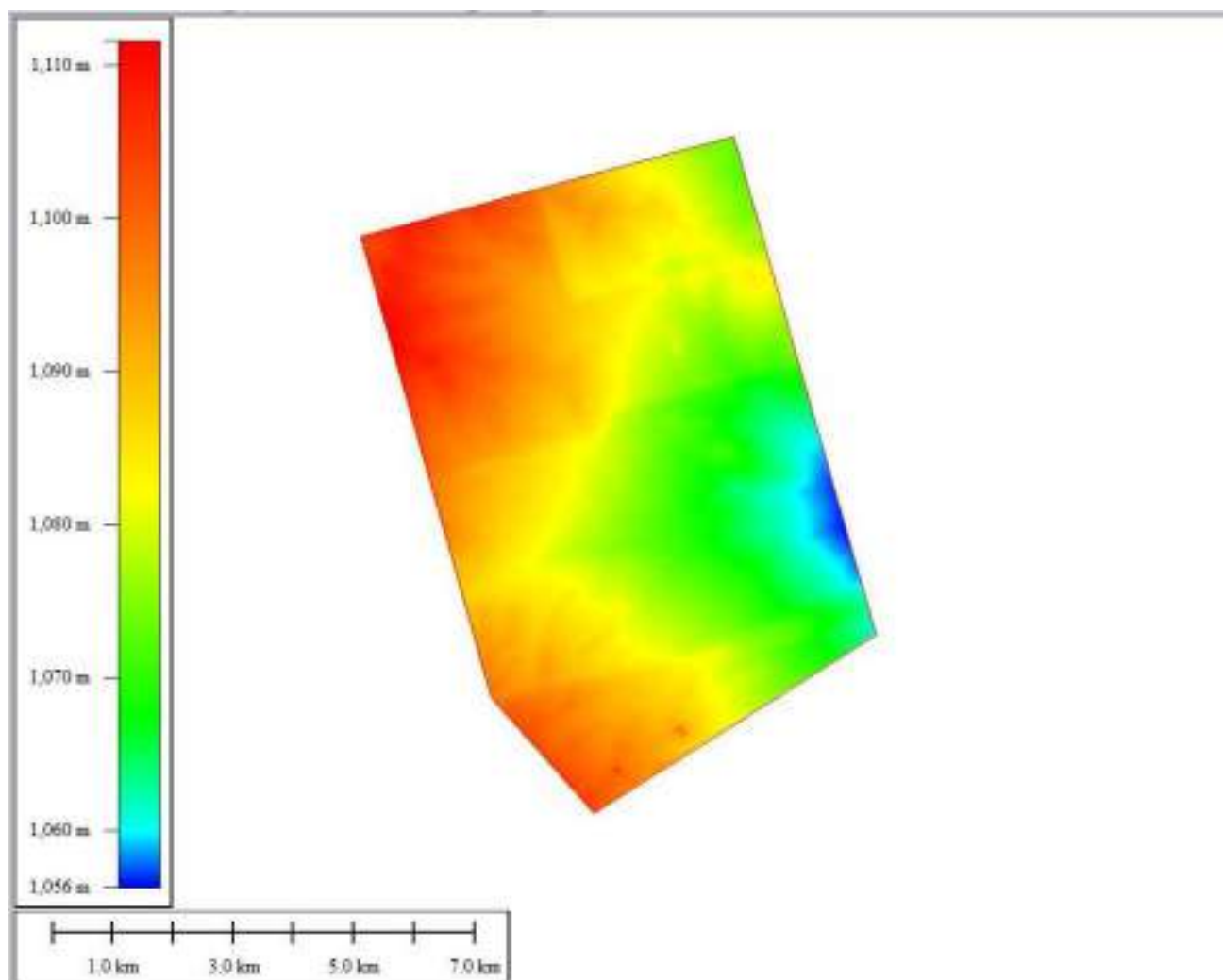


Figure 6-2 Topographical survey DEM.

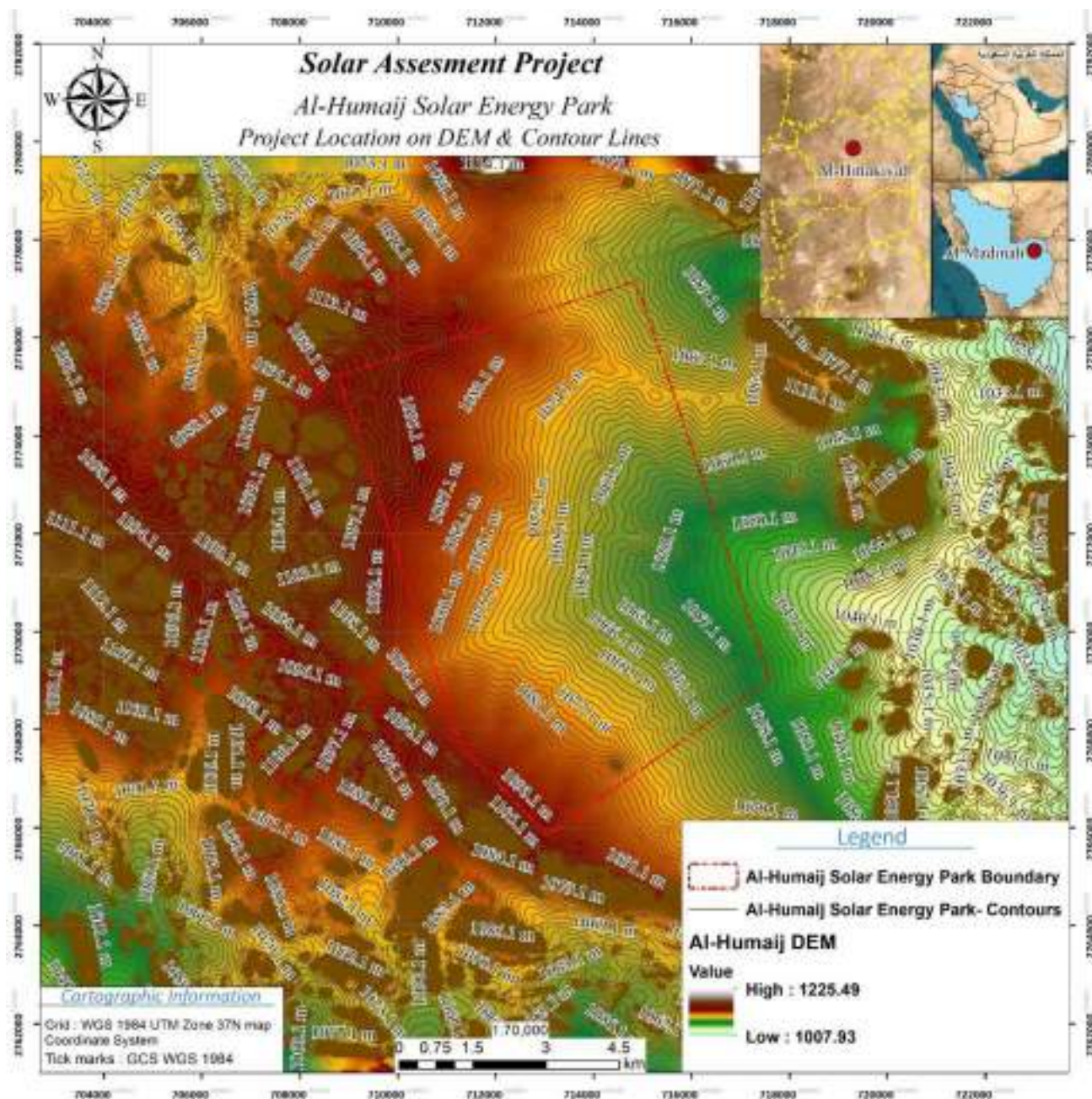


Figure 6-3 Project Location on DEM Contour Lines

B. Topographic Maps:

Source: Collected from (SGS) with scale 1:50000 (Topo Maps No. 4125-33 AL Humayj & 4124-44 Dulu (Dilan) Ash Shuwayman.

While the 1:50,000 scale may not offer the highest resolution, it still provides valuable insights into terrain characteristics and elevation variations crucial for our assessments.

Purpose: The primary purpose in utilizing topographic maps is to identify and verify the names of wadis and other physical features within the project area, particularly in determining the paths of wadis and establishing thresholds of flow accumulation.

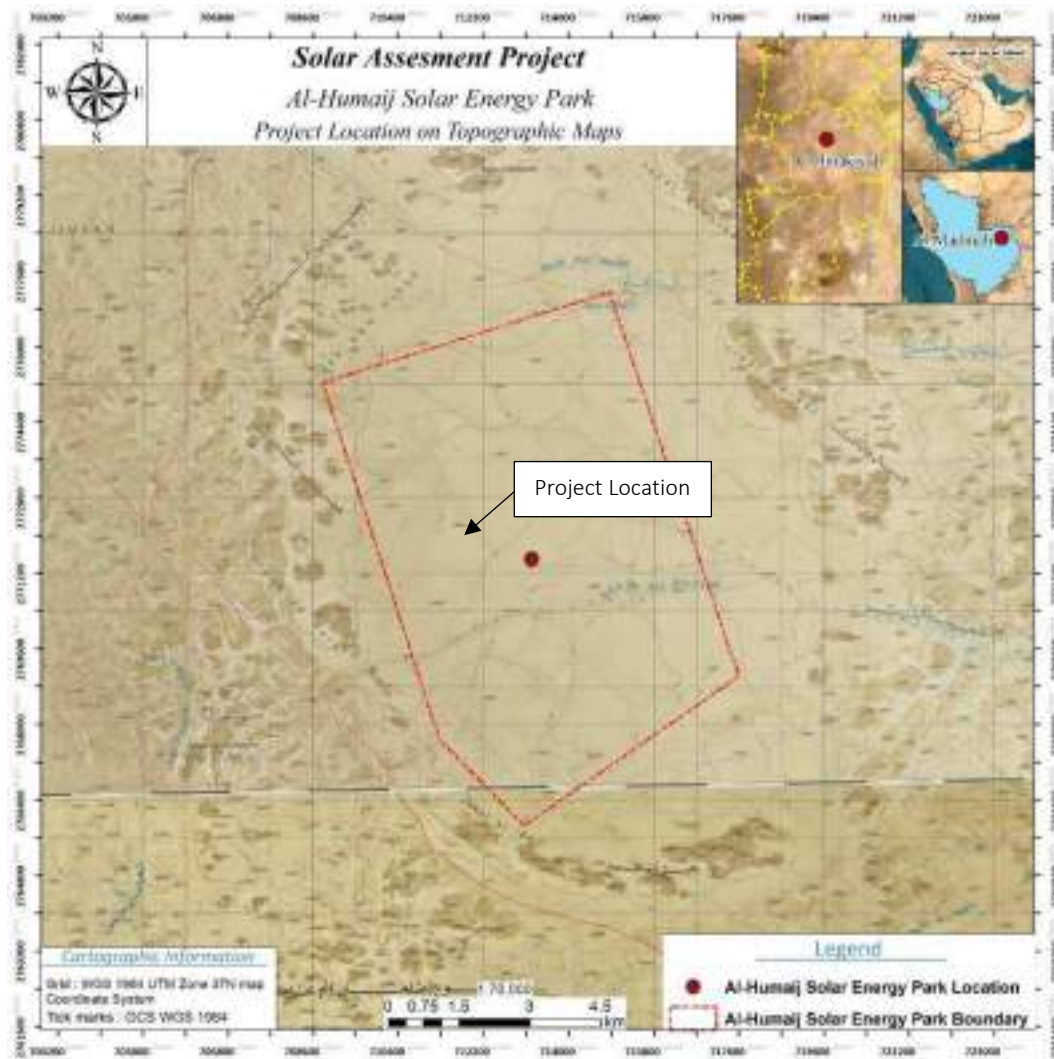


Figure 6-4 Project Location on Topographic Maps

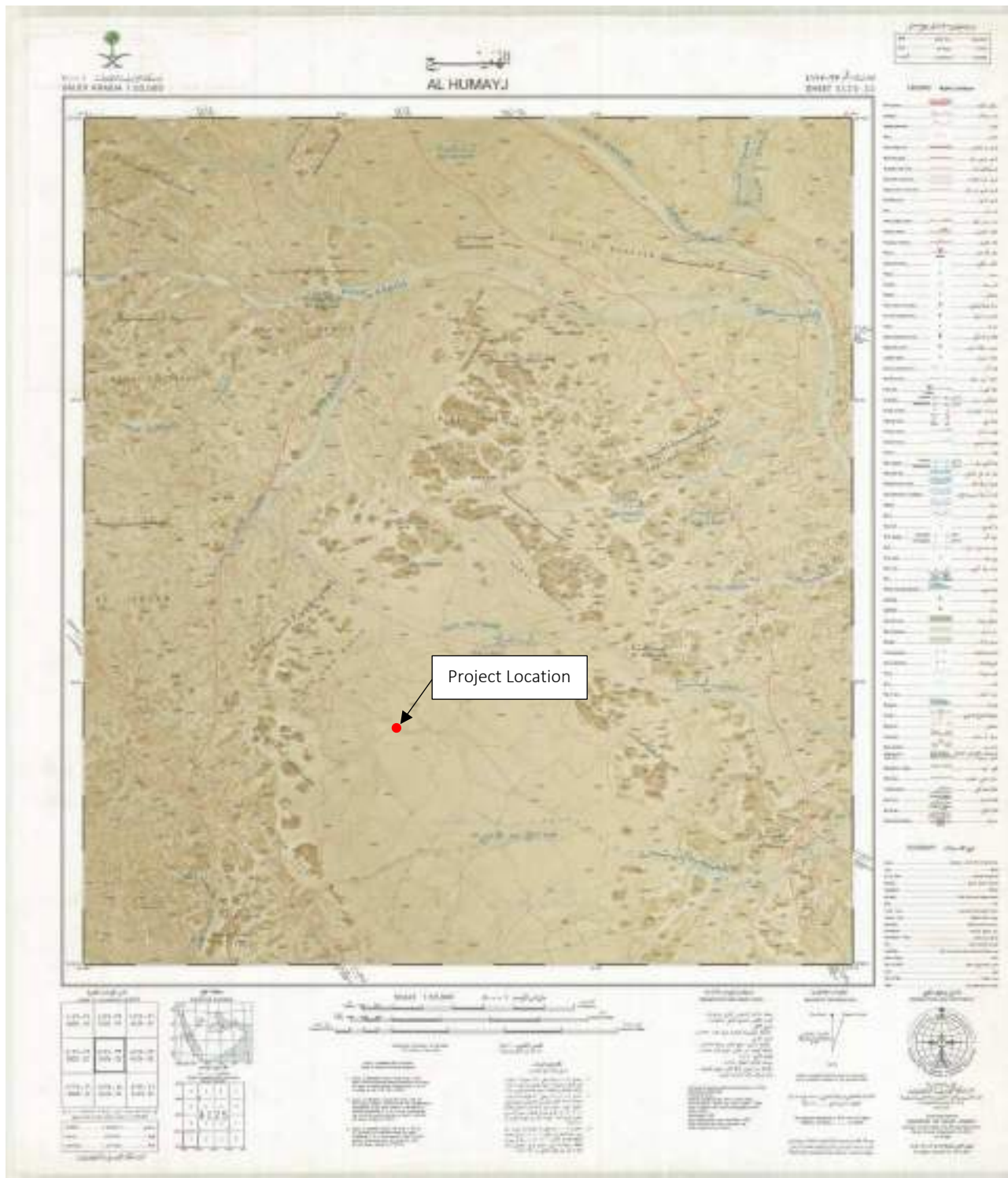


Figure 6-5 Topographic Map no. 4125-33 AL Humayj

6.1.2 Rainfall Data

Rainfall data is a crucial component of the hydrological analysis and plays a key role in determining the design storm return period. The information obtained from the historic rainfall data is used to estimate the rainfall intensity, duration and frequency of the design storm. This information is then used to calculate the runoff volume, which is essential in determining the design storm return period and the required size of the drainage elements.

The data for the rain fall analysis was collected from the Ministry of Environment, Water and Agriculture (MEWA). This data was used to determine the rainfall patterns and intensity in the area near the project location and to make informed decisions about the potential impact of rainfall on the project. The Thiessen polygon method was also used to identify the influencing rainfall stations, ensuring that all relevant data was taken into consideration for the analysis.

Thiessen Polygon is a method used to identify the most influencing rainfall station for a particular location. It involves constructing equidistant lines between the rainfall stations and calculating the weighted average rainfall based on the area of each station's influence. This helps in determining the most appropriate rainfall station to use for the project area. The Thiessen Polygon method is commonly used in hydrological and hydraulic analysis studies to determine the precipitation inputs.

The project has used historic rainfall data collected from the J M004 – Alhinakyah Station, which are the influencing stations as per Thiessen polygon analysis. This data provides valuable information about the rainfall patterns and intensities in the region and is used in the rainfall data analysis.

The figure 6-5 displays the locations of the rainfall stations whose data was collected using Thiessen polygon.

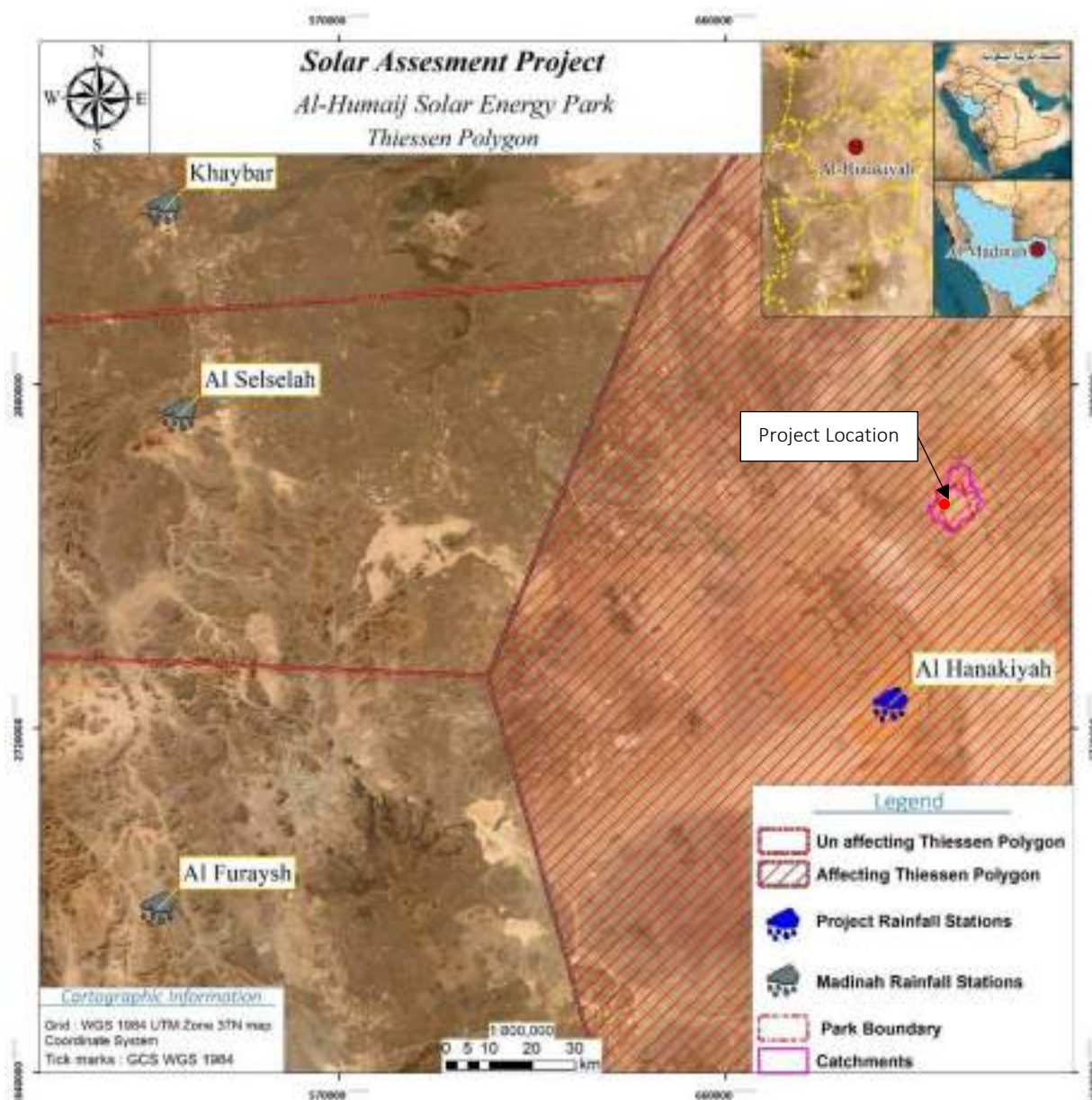


Figure 6-6 Thiessen Polygon & Location of rainfall stations affecting the study area

The below chart illustrates the Raw data collected M004 – Alhinakyah Station.

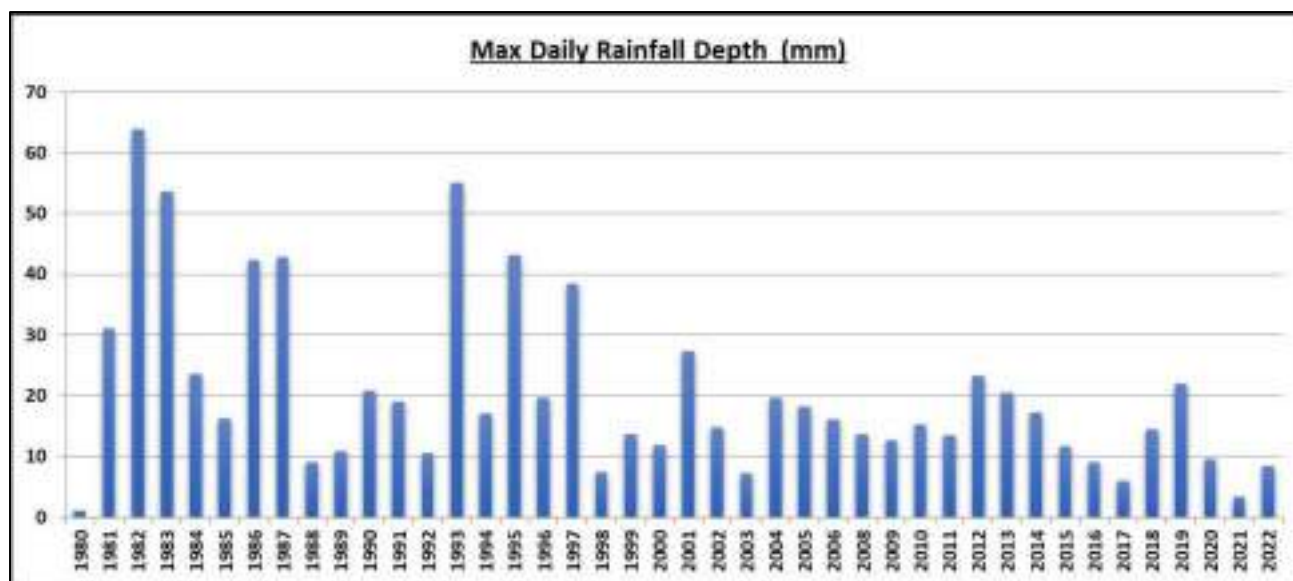


Figure 6-7 Chart for Max Daily Rainfall Depth (mm)- M004 - AlHinakyah Station

6.1.3 Geological Data

Geological data was collected from various sources to gain a comprehensive understanding of the geology of the project area. The sources of geological data included, but were not limited to:

- The Saudi Geological Survey.
- Previous geological studies and reports.
- On-site observations.

The geological data collected was used to determine the soil types, rock formations, and geological structures that may impact the proposed flood protection works. The data was also used to identify any potential geological hazards that may need to be addressed during the design and construction of the project.

The project location is located within the boundaries of the geological map labeled Nuqrah (GM-28), as shown in the below figure no.6-7 Shows the whole Nuqrah (GM-28). This information is important to understand the geological conditions and potential impact on the project design.

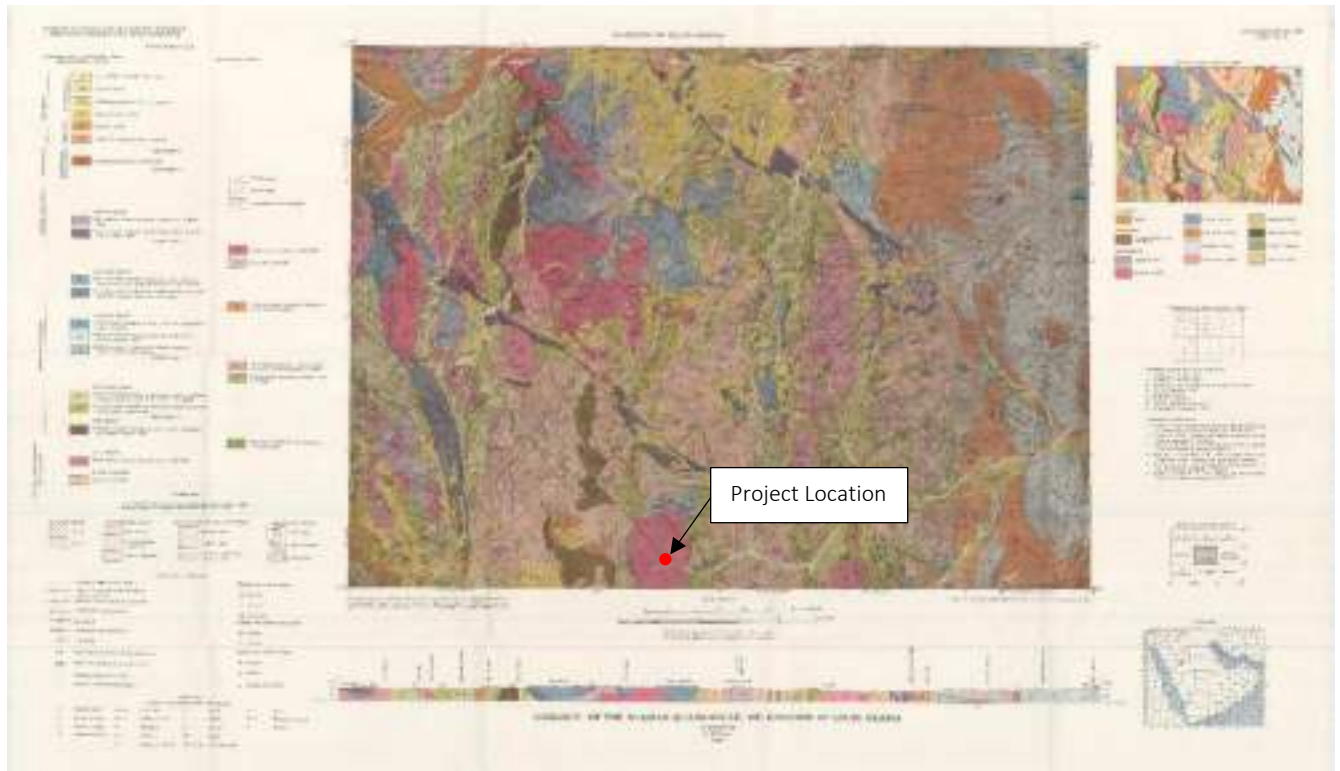


Figure 6-8 Map Nuqrah (GM-28)

6.1.4 Geotechnical Data

In order to determine the impact of surface runoff on the project area, the focus of this hydrology study is on the top soil in the project area. The significance and impact of top soil in this study was recognized, leading the consultant to request soil maps from the Ministry of Environment, Water and Agriculture (MEWA). The soil maps obtained had a scale of 1:250000 and were produced by the United States and Saudi Arabian Joint Commission for Economic Development for the then known Ministry of Agriculture and Water, Land Management Department. The project area is located within the vicinity of soil map number 95 and a figure showing the project location superimposed on the soil maps is presented in Figure Below.

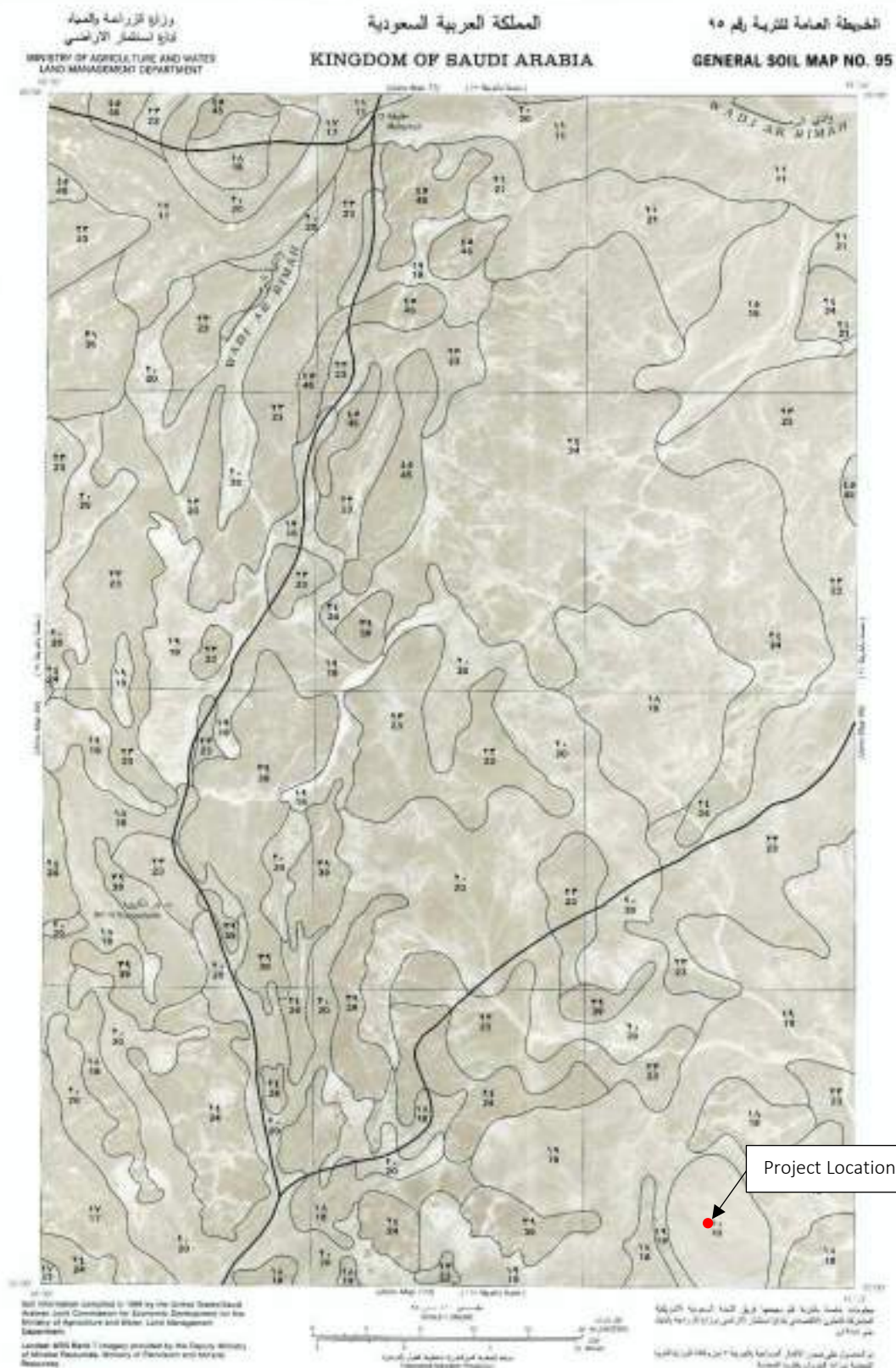


Figure 6-9 GENERAL SOIL MAP NO. 95

6.1.5 Recent Satellite Images

Satellite images can provide valuable information for geotechnical and hydrological studies. These images can offer a comprehensive view of the study area, including its topography, land cover, and other features that can impact surface runoff and other hydrological processes.

In the case of this study, recent satellite images were utilized to better understand the study area and inform the analysis of the surface runoff. The satellite images were processed and analyzed to identify key features and patterns that can impact the flow of water, such as drainage systems, vegetation, and human infrastructure. This information was then used to inform the design of storm water management systems and other infrastructure, ensuring that they are properly configured to handle the specific conditions of the study area.

Overall, the use of recent satellite images provides valuable insights into the hydrology of the study area, helping to ensure that the systems designed to manage its water resources are well-suited to its specific conditions and provide adequate protection against the effects of heavy rainfall.

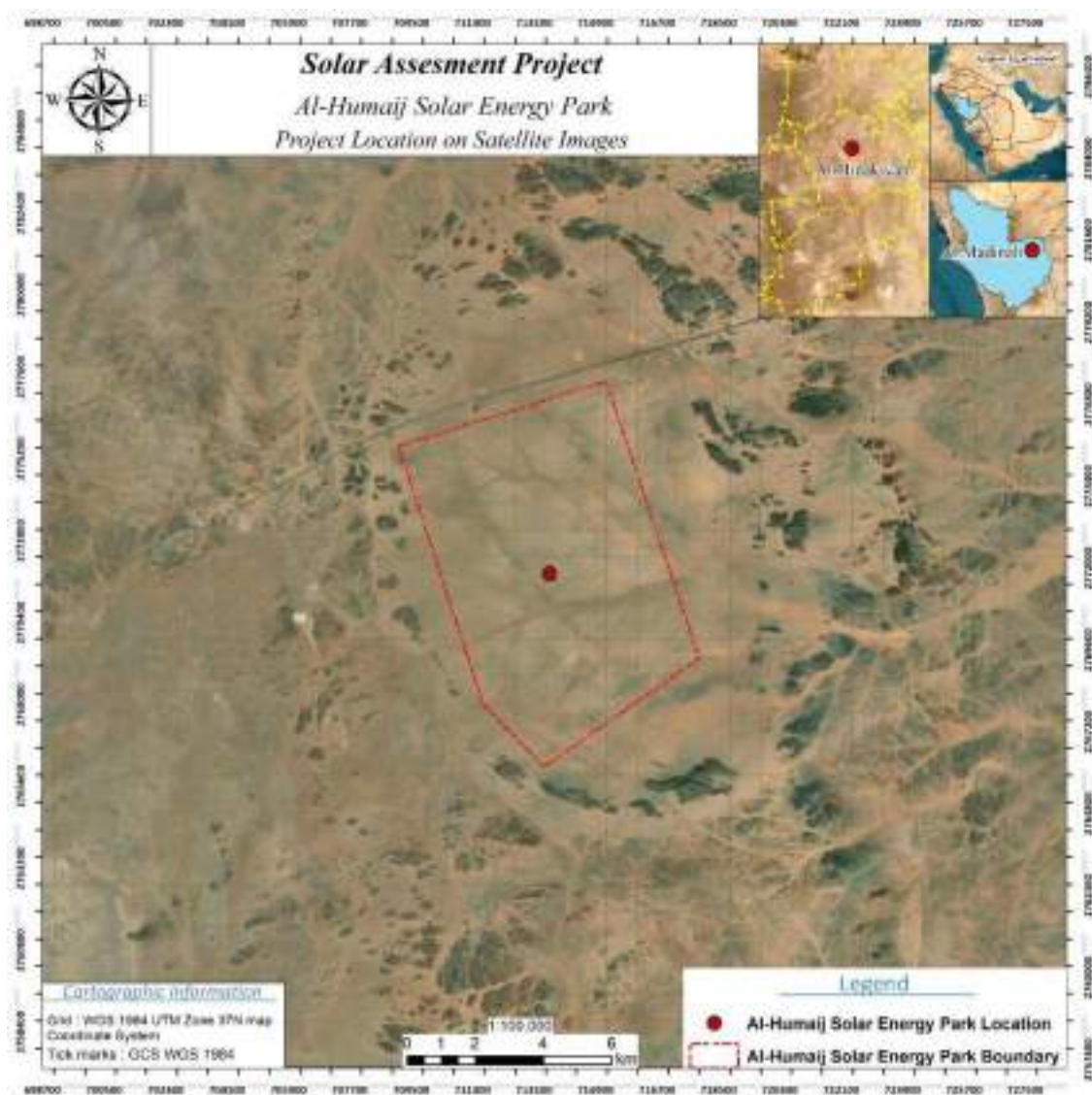


Figure 6-10 Recent Satellite Images

6.2 Site Visit Requirements

Site visits are an important aspect of hydrology studies, as they allow the consultant to gather valuable field data and information that can inform their analysis and recommendations. In this hydrology study, site visits are required to collect data and information on various aspects of the study area, including but not limited to: topography, geology, soil characteristics, land use, surface water resources, and the presence of any flood-prone areas.

The site visit outcomes, including observations and measurements made during the visit, are typically documented in a separate report. This report serves as a comprehensive record of the site visit and provides a valuable reference for the consultant as they conduct their analysis and make recommendations. The site visit report typically includes details such as the location and size of the study area, the methods used to collect data and information, and a description of the findings and observations made during the visit.

In summary, site visits are an important part of hydrology studies and the site visit outcomes are documented in a separate report to provide a comprehensive record of the visit and support the consultant's analysis and recommendations.

Objectives of these visits are:

- Identifying the flood hazards & hot spots/critical areas.
- Identifying the existing flood mitigation measures in the project area.
- Understanding the general topography of project region.

7. GEOLOGICAL AND GEOTECHNICAL STUDIES

7.1 GEOLOGICAL ASPECTS

This study focuses on analyzing flooding from nearby wadis and its impact on surface water resources in the region. While the region's geology affects wadi formation and behavior, our study specifically examines flooding's impact on surface water resources. We concentrate on analyzing flood events and their effects on both the quantity and quality of surface water resources.

Upon cross-referencing the catchment area with the geological maps, it was observed that the project area primarily consists of sg PERALKALIC and ALKALIC GRANITE formations. This finding suggests that the surface geological conditions in the project area are dominated by these specific rock types. From a hydrological standpoint, the presence of peralkalic and alkaline granite formations can significantly influence surface hydrology processes. Peralkalic and alkaline granites typically exhibit low porosity and permeability, which can lead to reduced groundwater recharge and increased surface runoff. Additionally, these rock types are often associated with rugged topography and steep slopes, further affecting surface water flow patterns and erosion potential. Therefore, it is essential to consider the implications of these geological conditions on surface water management strategies and infrastructure design within the project area.

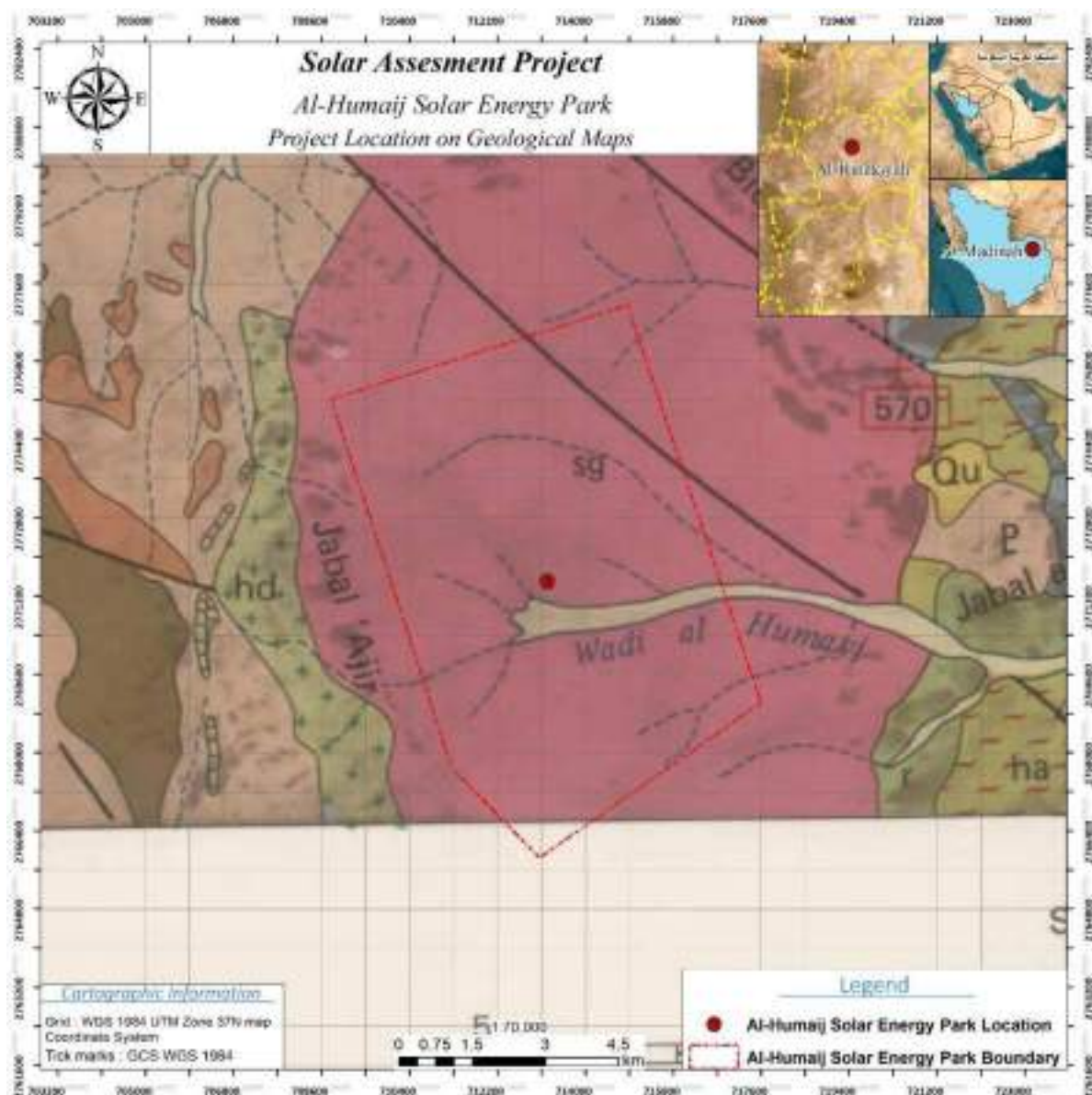


Figure 7-1 Project Location on Geological Map

After overlaying the catchment boundaries onto the geological maps and cross-referencing them, it became evident that the Catchment area is characterized by the dominance of sg PERALKALIC and ALKALIC GRANITE formations.

1. **PERALKALIC:** This term refers to igneous rocks that have an excess of alkalis (potassium and sodium) compared to silica. Peralkaline rocks typically contain minerals such as feldspar, amphibole, and pyroxene. These rocks are often associated with volcanic activity and can have distinct chemical compositions and mineralogy.
2. **ALKALIC GRANITE:** Alkaline granites are a type of granitic rock that contains elevated levels of alkalis, particularly potassium and sodium. These rocks typically have a coarse-grained texture and are rich in minerals like feldspar, quartz, and mica. Alkaline granites often form in intrusions associated with

volcanic or tectonic activity and may exhibit unique geochemical signatures compared to other granite types.

The legend of the map helps understand the geological composition of the terrain and provides valuable information for various applications, including land use planning, natural resource management, and environmental assessments.

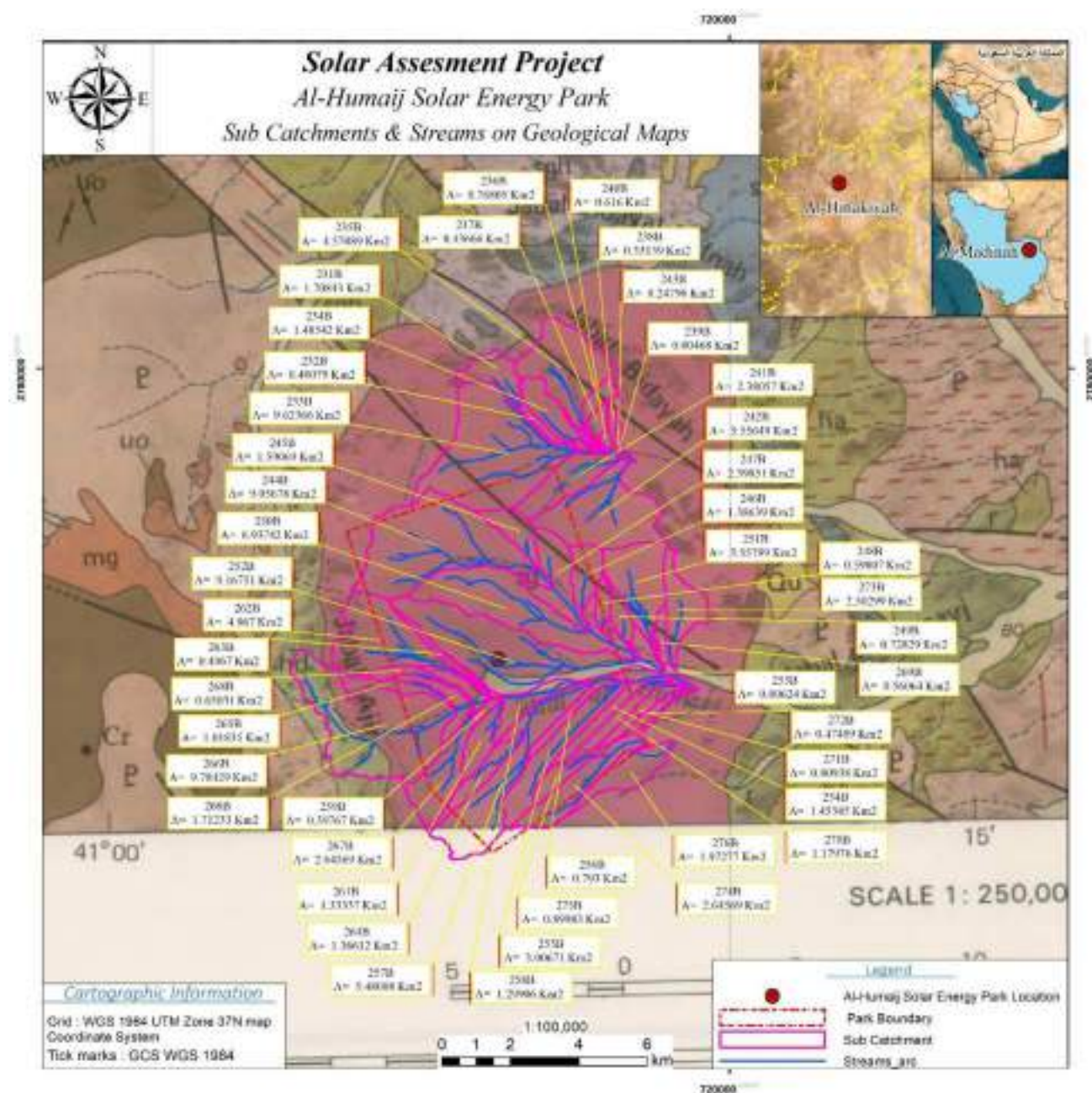


Figure 7-2 Catchments & Streams on Geological Map

7.2 GEOTECHNICAL ASPECTS.

In this hydrology study, the primary focus is on determining the surface runoff affecting the project area. Given this focus, the top soil has major significance and impact on the study, and accordingly the consultant has obtained soil maps for the study area from the MEWA (Ministry of Environment, Water, and Agriculture). The soil maps available for the study area were produced by the United States/Saudi Arabian joint commission for economic development and have a scale of 1:250000. The project area is located within the vicinity of Soil Map No.122, and Figure 7-3 shows the project location superimposed on the soil maps. By analyzing the top soil characteristics and their impact on the surface runoff, this study aims to provide a clear and concise evaluation of the impact of top soil on the surface runoff.

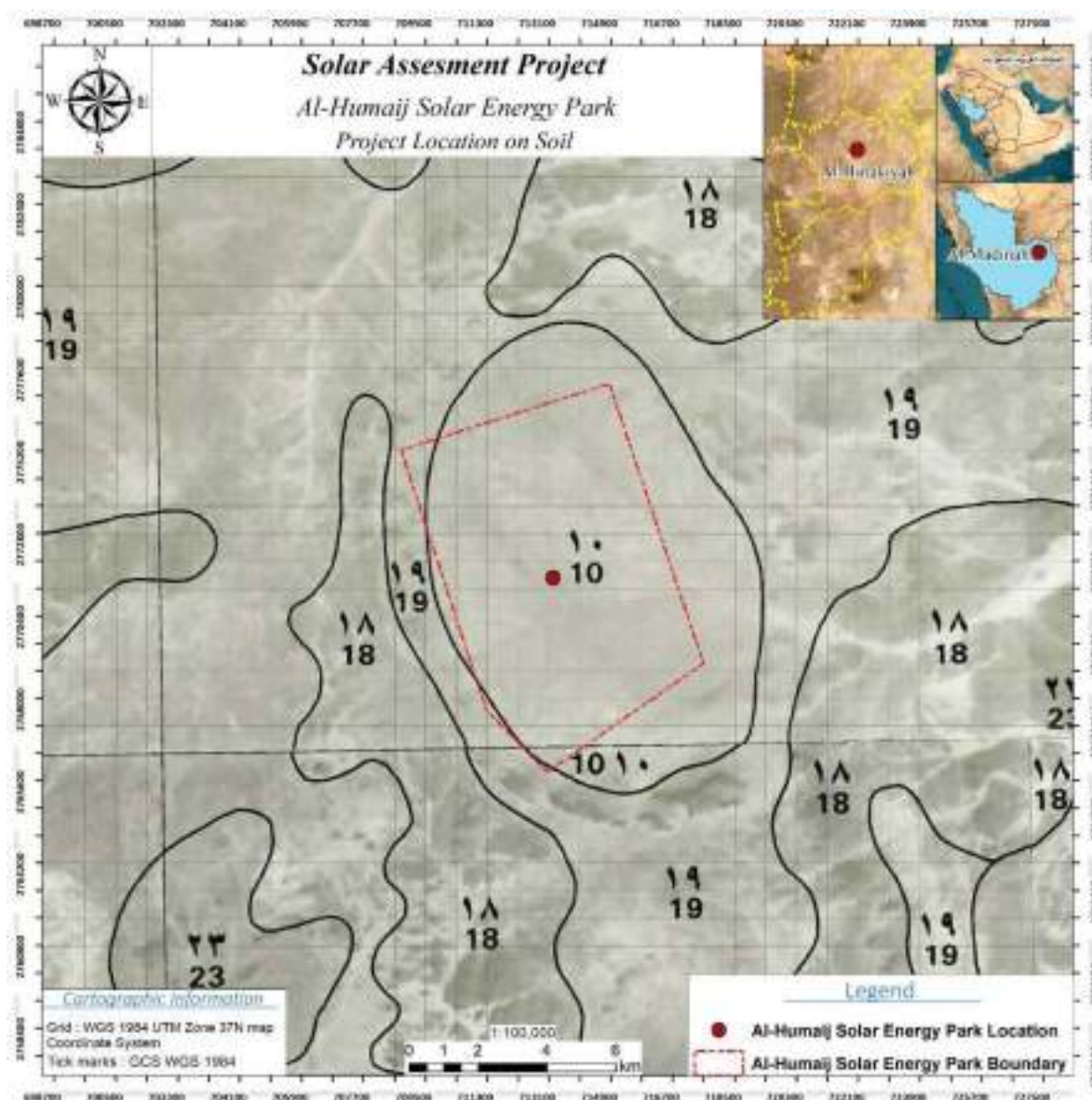


Figure 7-3 Project location superimposed on the soil maps

Overlaying the catchment area on soil maps is a crucial step in understanding the geotechnical aspects of hydrology studies. The catchment area falls within regions characterized by specific soil types, each with its own set of properties and implications for hydrology.

The figure below shows the catchment areas overlaid on the soil maps.

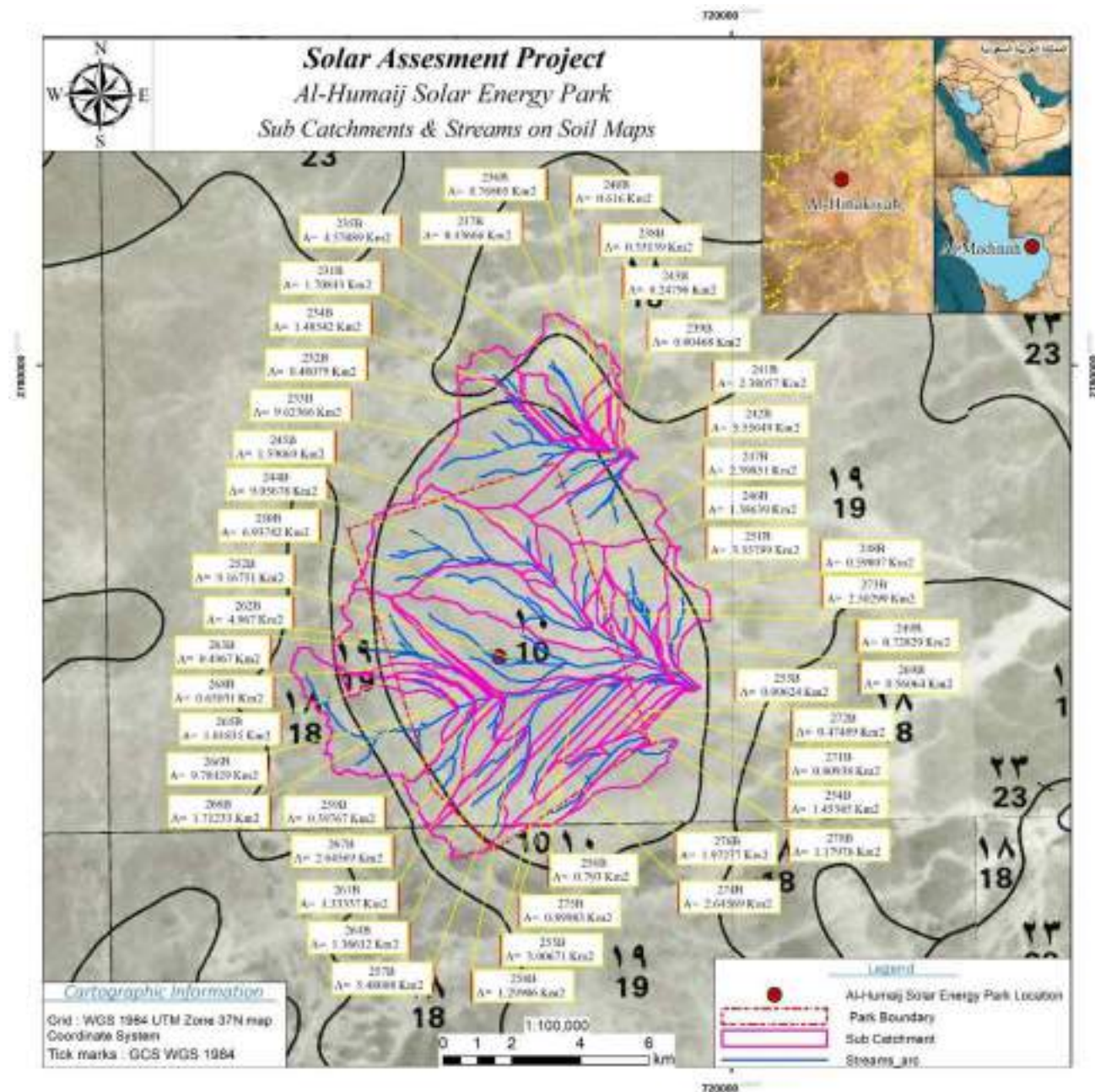


Figure 7-4 Catchment areas overlaid on the soil maps no.122

The below figure illustrates the legend corresponding to each number on the soil maps.

Symbol	Name
10 —	Calciorthids: loamy, deep soils, 0 to 3 percent slopes
18 —	Calciorthids-Rock outcrop: loamy, deep, nearly level and gently sloping soils and hills of rock
19 —	Calciorthids-Rock outcrop: plains of loamy, deep soils and knolls and hills of rock

Figure 7-5 Soil Maps Legend

Soil types identified on the maps include:

1. **Calciorthids (10):** These are loamy, deep soils with slopes ranging from 0 to 3 percent. They are relatively flat and have good water retention properties due to their loamy texture. This type of soil is likely to facilitate some infiltration and groundwater recharge.
2. **Calciorthids-Rock outcrop (18):** Similar to type 10, these soils are loamy and deep. However, they are found in areas with nearly level or gently sloping terrain and may contain outcrops of rock. The presence of rock outcrops can affect water infiltration and flow patterns, potentially leading to increased runoff and erosion in these areas.
3. **Calciorthids-Rock outcrop (19):** This type is found in plains with loamy, deep soils as well as knolls and hills of rock. Similar to type 18, the presence of rock outcrops can impact water movement and soil stability. The combination of deep soils and rock formations may result in varied hydrological behavior within this area.

8. RAINFALL DATA ANALYSIS

In this section of the hydrology study, the rainfall data collected from the effective rainfall stations in the study area was analyzed and the IDF (Intensity-Duration-Frequency) curves were developed for different design return periods.

8.1 Daily Maximum Rainfall Analysis

Daily maximum rainfall analysis involves the examination of the largest amount of precipitation that occurred in a given day within a certain location. This type of analysis is important for understanding the potential for flooding, erosion, landslides, and other natural hazards that can occur as a result of intense rainfall.

Statistical analysis can be used to quantify the daily maximum rainfall and its variability. This can include calculating the mean, standard deviation, and other descriptive statistics. It can also involve fitting probability distributions to the data to estimate the likelihood of extreme rainfall events.

There are several statistical distributions that can be used to model and analyze rainfall data, including:

- **The Normal (Gaussian) distribution:** This is a symmetric distribution that is often used to model data that is approximately normally distributed. It is defined by its mean and standard deviation, and is characterized by a bell-shaped curve.
- **The Log-Normal distribution:** This is a distribution that is often used to model data that has a right-skewed shape, such as rainfall data. It is defined by its mean and standard deviation on a logarithmic scale, and is characterized by a skewed curve with a long tail on the right side.
- **The Gamma distribution:** This is a distribution that is often used to model data that is right-skewed and has a shape similar to the log-normal distribution. It is defined by its shape and scale parameters, and is characterized by a skewed curve with a long tail on the right side.
- **The Weibull distribution:** This is a distribution that is often used to model data that has a shape similar to the exponential distribution. It is defined by its shape and scale parameters, and is characterized by a curve that is skewed to the right and has a long tail on the right side.
- **The Gumbel distribution:** This is a distribution that is often used to model extreme events such as extreme precipitation. It is defined by its location and scale parameters, and is characterized by a curve that is skewed to the right and has a long tail on the right side.
- **The Exponential Distribution:** is used to model data that is continuous and positive and that has a constant rate of occurrence, such as the frequency of rainfall events.
- **The Poisson Distribution:** is used to model data that is discrete and non-negative, such as the number of rainfall events in a given period of time.
- **The Pearson III distribution:** is a probability distribution that is often used in extreme value analysis, particularly in the context of flood frequency analysis. It is a three-parameter distribution that is capable of modeling both the upper and lower tail of a data set. It is a generalization of the Gumbel

and Weibull distributions, which are typically used to model the upper and lower tails of a data set, respectively.

- **The Generalized Extreme Value (GEV):** distribution is a probability distribution that is used to model the behavior of extreme values, such as the maximum or minimum values of a dataset. It is a three-parameter distribution that can be used to model both the upper and lower extremes of a dataset.
- **The 3-parameter lognormal distribution:** is a probability distribution that is used to model data that is positively skewed and has a long tail. It is often used in hydrology and other fields to model extreme events such as floods, heavy rainfall, and high river flows.
- **The Generalized Pareto (GP) distribution:** is a probability distribution that is commonly used in the field of hydrology and other fields to model extreme events such as floods, heavy rainfall, and high river flows. It is a two-parameter distribution that can be used to model the tail of a distribution, that is, the behavior of the extreme values.

It's important to note that different distributions may be more appropriate depending on the characteristics of the data, and that the choice of distribution should be based on a careful examination of the data and the underlying assumptions of the distribution.

RGF will use the rainfall data, from the various meteorological stations around the study area, to analyze the rainfall data using the Hyfran Plus program. Using the statistical analysis software HyFran Plus and the application of a set of different statistical distributions and the most common in the Kingdom to choose the most appropriate to represent the data of each station.

HYFRAN-PLUS" is a software tool used for statistical analysis of rainfall data. The software is used to analyze and model rainfall data in order to better understand and predict the distribution and intensity of rainfall in a given area. It can be used to generate probability distributions and statistical models of rainfall, as well as to generate maps and graphs to visualize the data. It can be used for many applications like hydrology, meteorology, water resources management, and civil engineering.

Rainfall data analysis aims to achieve the following results:

1. Analyzing the rainfall data of each station by using and testing more than statistical distribution method and selecting the best fit of them which gives greater values for the design precipitation rates.
2. Deducting the cumulative daily precipitation depths (24 hours) will be predicted using Hyfran Plus corresponding to different return periods of 25, 50, 100 and 500 years in order to be used in a SCS method.
3. Deducting curves of the intensity- Duration- Frequency (IDF Curve) for the meteorological stations and estimating the extreme values precipitation (mm) for durations 10 min, 20 min, 30 min, 60 min, 2 hours. These IDF Curves will be used in Rational method.

Bells' ratios shown in the following table can be used for developing IDF curves.

Table 8-1 Bell's Ratios

Duration (minutes)	10	20	30	60	120	180	360	720	1440
Bell's Ratios	0.24	0.33	0.40	0.52	0.67	0.71	0.79	0.89	1.00

4. Thiessen Polygons method is used to determine the area of influence nearby the meteorological stations. The area of each polygon is used to weight the rainfall amount of the station in the center of the polygon.

8.2 Short Duration Rainfall Analysis

Short duration rainfall analysis refers to the study of rainfall intensity and duration over a short period of time, usually ranging from 5 minutes to 2 hours. This type of analysis is important for understanding the potential for flash flooding or runoff from high-intensity storms. The analysis is typically performed using rainfall data from rain gauges or other meteorological instruments and can include calculating the maximum rainfall intensity, peak rainfall rate, and cumulative rainfall over the duration of the storm event. The results of the short duration rainfall analysis can be used to design and evaluate stormwater management systems, such as drainage systems and detention ponds, to ensure they can effectively manage and control runoff during extreme rainfall events.

To produce the IDF (intensity-duration-frequency) curves, the available rainfall data for short periods from different stations near the study area shall be used. Frequency analysis on short duration data is to be undertaken similar to the procedure for daily rainfall. If sub-daily gauges are not available, the nearest sub-daily information will be used by generating ratios between sub-daily values and daily values and multiplying these ratios by the daily value for the station of interest. In case there is no stations in the project vicinity, it is possible to rely on the Bell ratio curves, SCS type II distribution, or any other known method with its description and full reference.

In situations where there are no weather stations available in the vicinity of the project location, various methods can be employed to estimate the required hydrological parameters. One approach is to rely on the Bell ratio curves or the Soil Conservation Service (SCS) Type II distribution. These methods are commonly used in hydrology to estimate rainfall intensities and design storms in areas lacking adequate data.

Bell Ratio Curves: Bell ratio curves are graphical representations that help estimate design storm rainfall intensities based on statistical analysis of available rainfall data from nearby regions with similar climatic conditions. These curves provide a relationship between the rainfall intensity, duration, and return period. By selecting an appropriate return period and duration, the corresponding rainfall intensity can be determined from the curve.

SCS Type II Distribution: The SCS Type II distribution, also known as the "Chicago IDF Curves," is a widely used method to estimate rainfall intensities for various durations and return periods. It's based on statistical analysis of historical rainfall data and is particularly useful in the absence of specific local data. The SCS Type II distribution provides a relationship between intensity, duration, and return period, allowing engineers and hydrologists to estimate design rainfall for a given project.

8.3 Adjustment to Fixed Duration

In order to reconcile rainfall estimates for different durations, adjustments are necessary to account for discretization. In this case, the rainfall frequency analysis is based on annual maximum daily (1-day) rainfall data, which are not expected to be as large as those based on annual maximum 24-hour rainfall data. Since daily gauges record over a fixed period, adjustments must be made to reflect a 'sliding' duration. The UK Flood Estimation Handbook recommends a factor of 1.16, and the WMO 1045 (which concerns the determination of the Probable Maximum Precipitation (PMP)) recommends a factor of 1.13. This study will apply the 1.14 factor, which was based on Hershfield (1961) study of thousands of station-years of rainfall data and found that multiplying the results of a frequency analysis on annual maximum rainfall for a single fixed time interval (of any duration from 1 to 24 hours) by 1.14 will yield values closely approximating those to be obtained from an analysis based on true maxima.

8.4 Design Storm Profile

To perform hydrological and hydraulic modeling, the design rainfall depths need to be distributed over specified durations. However, the distribution of rainfall over time varies from storm to storm during observed storms, hence, a suitable "design" storm profile is necessary. If a sub-daily gauge is available, typical storm profiles can be determined through empirical analysis, but a large sample of recorded storm events is required. In the absence of local sub-daily rainfall data, a synthetic profile must be used.

The hydrological and hydraulic modeling process will involve determining the appropriate method for creating storm profiles, which will be based on factors such as the size of the catchment, the critical storm duration, and the impact on the hydrograph volume. The Areal Reduction Factor will also be taken into consideration during this process. The SCS Type II method will be evaluated further.

8.5 Daily Maximum Rainfall Analysis of M004 – Al Hinakyah Station

As mention in section 6.1.2 Rainfall data of this report, Thiessen polygon method was used to determine the influential rainfall station on the project area.

Based on this method, it was determined that the station M004 - Alhinakyah is the station that impacts the study area.

The results of the analysis for the rainfall stations were obtained by using the Hyfran software to process the raw data.

Various distribution models were employed to determine the most suitable distribution for the data, as shown in the comparison criteria figure below. The Pareto distribution was identified as the best fit distribution for the station's data, based on AIC and BIC methods.

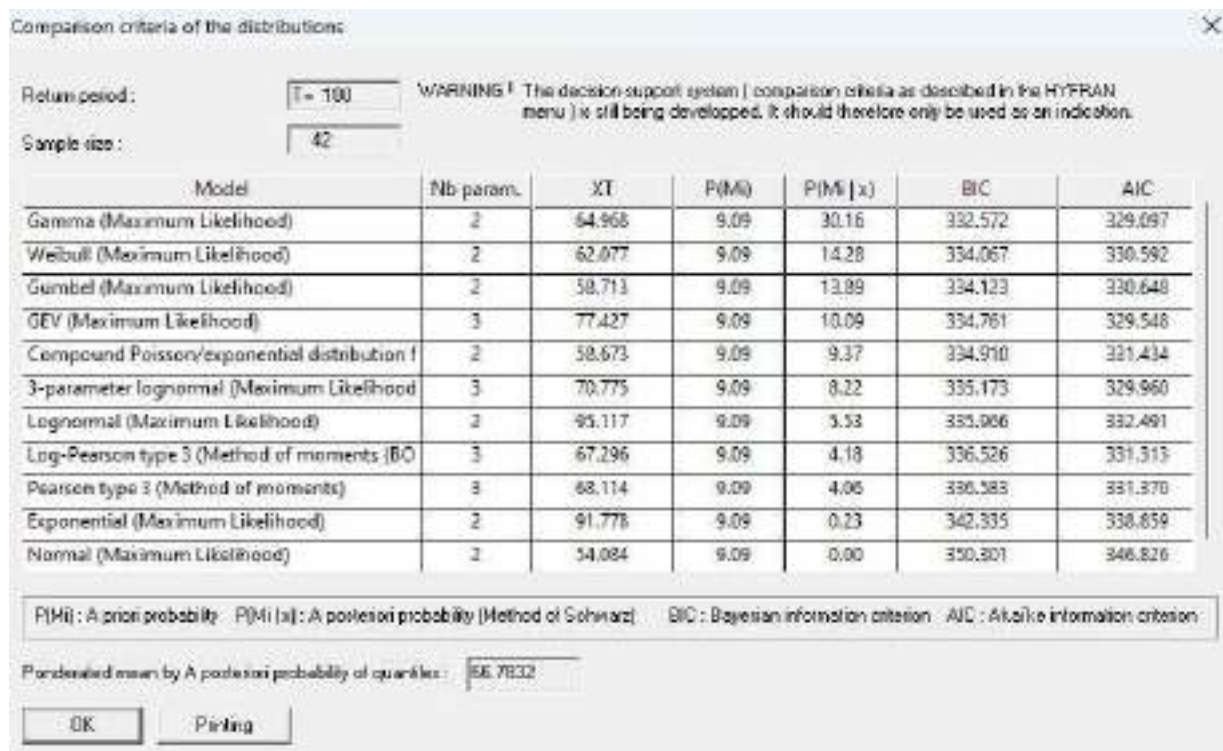


Figure 8-1 the comparison criteria of the Distributions

The below figure shows the Gamma distribution for M004 - Alhinakyah

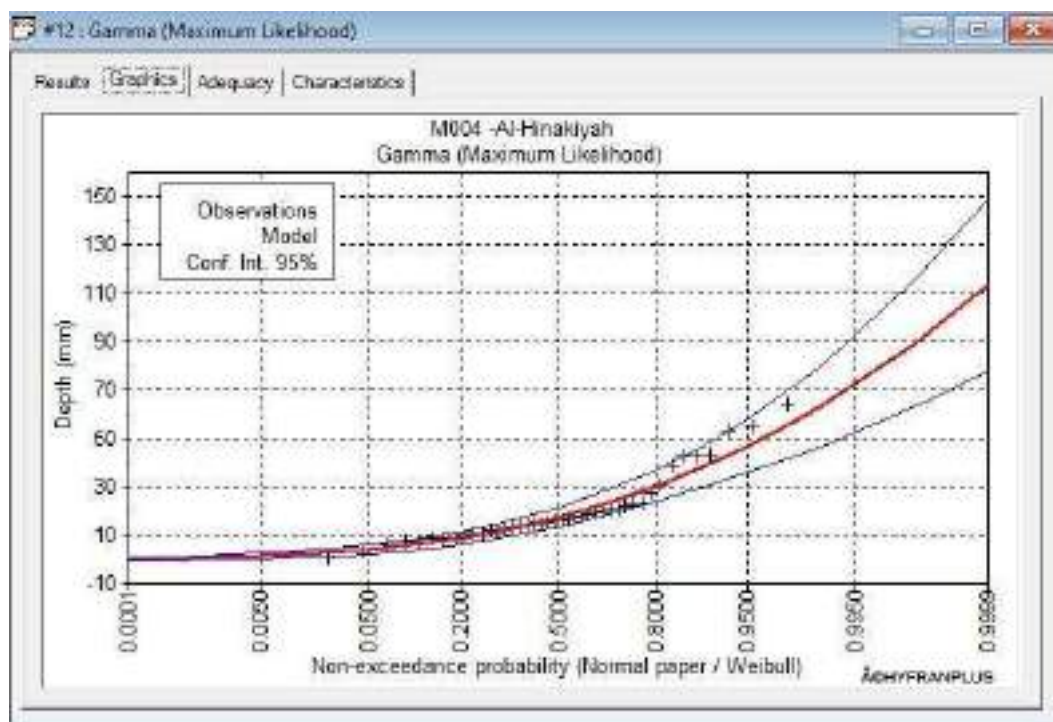


Figure 8-2 Gamaa distribution for M004 - Alhinakyah

The following table presents the results of the statistical analysis and the design storm values for the station for different return periods.

Table 8-2 Maximum daily annual rainfall depth corresponding to different return periods for M004 – Alhinakyah.

Return Period 1: year	Depth (mm)	Adjusted to Fixed Duration *1.14
100	65.00	74.10
50	57.30	65.32
25	49.50	56.43
10	38.80	44.23
5	30.10	34.31
2	17.30	19.72
This Table Ends Here		

These values were used to develop the design storm profile for SCS type II distribution shown in the following table.

The table for SCS (Soil Conservation Service) Type 2 rainfall distribution cumulative is commonly referred to as the "SCS Type 2 Rainfall Distribution Table." This table provides cumulative rainfall depths for various durations and probabilities of occurrence, based on the SCS Type 2 rainfall distribution model. The SCS Type 2 method is widely used in hydrology and water resources engineering for estimating rainfall depths for a given storm even.

Table 8-3 SCS Type 2 Rainfall Distribution Table

Time (min)	Depth (mm)		Time (min)	Depth (mm)
0	0.00		780	57.21
60	0.78		840	60.76
120	1.63		900	63.24
180	2.56		960	65.21
240	3.56		1020	66.82
300	4.67		1080	68.25
360	5.93		1140	69.49
420	7.34		1200	70.54
480	8.89		1260	71.49
540	10.89		1320	72.40
600	13.41		1380	73.27
660	17.41		1440	74.10
720	49.13			
This Table Ends Here				



Figure 8-3 SCS Type 2 Rainfall Distribution Curve

Also, the rainfall depth values were used to develop intensity, duration and frequency (IDF) curves of the station as shown in the following figure using Bells' ratios shown in the following table due to the absence of short-term rainfall data in the study area.

Table 8-4 Intensity-Duration-Frequency Developed for M004 - Alhinakyah

		Duration (min.)								
		10	20	30	60	120	180	360	720	1440
Return Period	100	88.92	62.02	50.83	32.23	20.93	15.46	9.26	5.42	3.09
	50	78.39	54.67	44.81	28.42	18.45	13.63	8.17	4.77	2.72
	25	67.72	47.23	38.71	24.55	15.94	11.78	7.05	4.12	2.35
	10	53.08	37.02	30.34	19.24	12.50	9.23	5.53	3.23	1.84
	5	41.18	28.72	23.54	14.93	9.69	7.16	4.29	2.51	1.43
	2	23.67	16.51	13.53	8.58	5.57	4.12	2.47	1.44	0.82

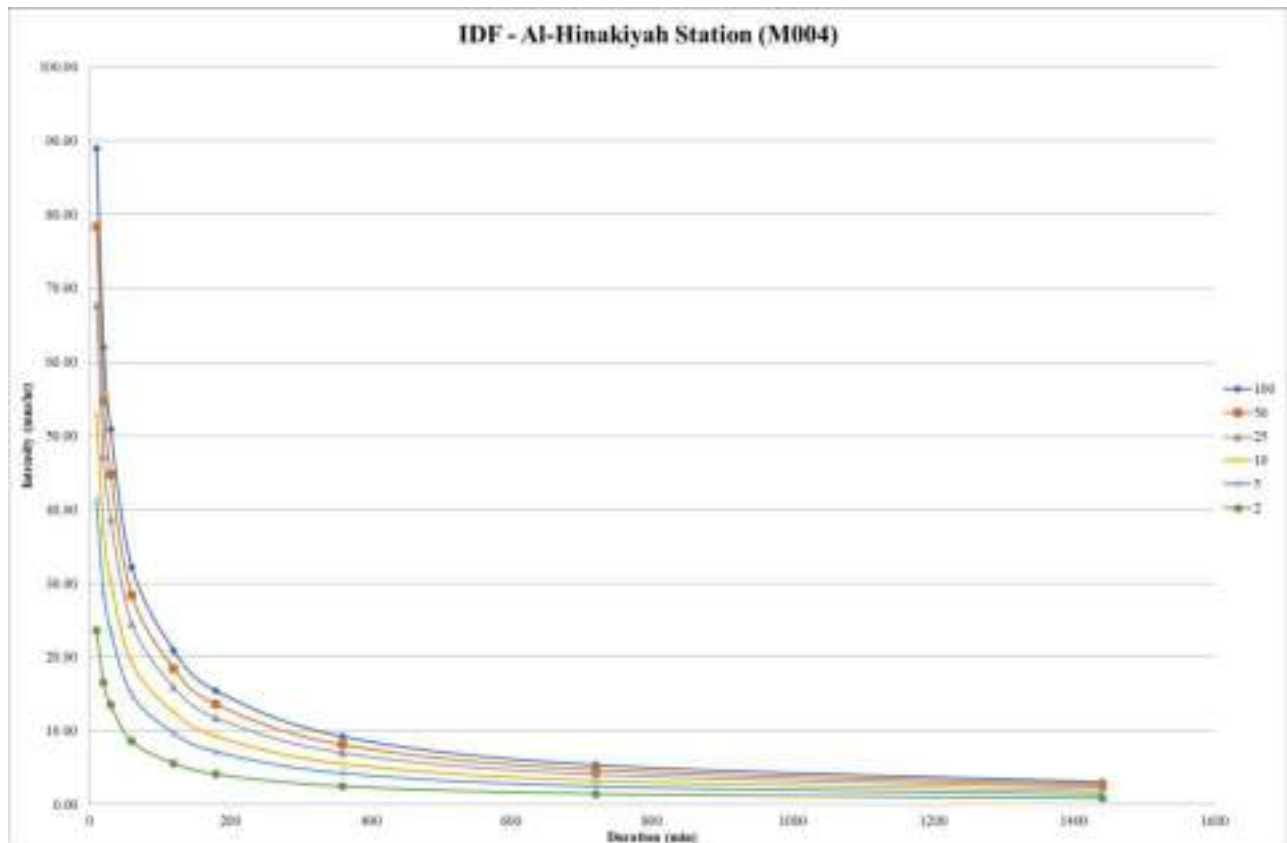


Figure 8-4: IDF curves for M004 - Alhinakyah Station

9. HYDROLOGICAL ANALYSIS

This section presents the methods used in the hydrological analysis of the project catchment. The ultimate aim of the hydrological analysis shall be to transform the design rainfall obtained in the previous section to peak discharges at the points of interest. The catchment response shall be calculated for the design rainfall values changing spatially (if needed) and temporally to achieve the best possible representation of water runoff processes in the studied drainage basins and shall present the results of the hydrological analysis for the project area. The analysis shall identify the characteristics of the secondary drainage basins contributing to the main drainage basin and wadis including the calculation of the morphological characteristics, the time of concentration, the soil types, and the nature of the vegetation cover and the different patterns of land use for each secondary basin. These characteristics are of great importance in the hydrological analysis process. For coastal areas at the wadi's outfalls, the modelling shall also consider sea surges, and the impact on the wadis and floodplains at their peaks. In this section, the digital elevation model (DEM), topographic maps and recent satellite images were used to identify the external attacking streams (if any) and delineate their watershed boundaries. Moreover, a rainfall-runoff analysis was conducted to determine the peak runoff flow for each catchment for the corresponding design return periods.

Hydrological studies are considered the foundation stone for the selection of the required protection works. Meteorological, morphological and geological studies and site visits are considered as inputs for the hydrological study. The peak flow and runoff hydrograph are the main outputs of the hydrological study, which is used in the hydraulic design of flood protection works.

9.1 Identification of Drainage Basins

The main/secondary drainage basins and their characteristics shall be determined using digital elevation models (DEM). In order to determine drainage basins and waterways, the digital elevation model shall be analyzed using WMS and Arc Hydro software packages according to the following steps:

- Terrain pre-processing:

This is the first stage of processing on WMS software. It shall be used to check and prepare the digital elevation model (DEM) through the Terrain Pre-processing tools. The main and secondary drainage systems of the basin area are determined to identify the sub-basins and the downstream discharge point associated with each of them.

- Filling the sinks:

The aim of this step is to fill the sinks that obstruct water flow between points in the digital elevation model, causing water flow to stop at a cell with lower elevations than all its surrounding cells. In this step, these sinks are raised and a new grid is created.

- Flow direction:

This function computes the flow direction for a given grid. The values in the cells of the flow direction grid indicate the direction of the steepest descent from that cell.

The flow direction tool determines the direction in which the water will flow from each cell to its adjacent cells by comparing the height of the cell with neighboring cell levels to determine the steepest slope in water flows from the original and sub-directions, converts the free digital elevation file to a Raster file with each cell containing the flow direction value.

- Flow accumulation:

This function computes the flow accumulation grid that contains the accumulated number of cells upstream of a certain cell, for each cell in the input grid.

- Determination of the threshold for the start of stream definition:

Based on the minimum number of cells or the area from which a water stream is defined as one, the drainage network is determined from the flow accumulation automatically. There is no fixed value for the minimum indicated for any drainage basin, so many attempts shall be made to compare the selected minimum results with a watercourse network from other sources that are reliable in their validity, such as a stream network derived from aerial images of an appropriate scale or from a topographical map.

- Stream segmentation:

This function creates a grid of stream segments that have a unique identification. Either a segment may be a head segment, or it may be defined as a segment between two segment junctions. All the cells in a segment have the same grid code that is specific to that segment.

- Catchment grid delineation:

This step depends on the previous step. When splitting the tributaries, the program gives each tributary an identification number (ID) that begins by determining its drainage basin.

- Catchment polygon processing:

The program converts the drainage basins of each extension from grid to Polygons. In this step, the program extracts maps for each basin as per the initial inputs of the step that preceded it.

- Drainage Line Processing:

The Drainage Line Processing function converts the input Stream Link grid into a Drainage Lines vector layer. Based on the above, the drainage basin features along with their topographical characteristics including their areas and length of streams have been estimated. Other variables need to be estimated to calculate the expected peak discharge and its methodology is discussed in forthcoming paragraphs.

9.2 Geographic Information System (GIS) and Digital Elevation Models (DEMs)

The appropriate accuracy of the digital elevation model data depends on a number of factors, mainly the topography of the land and the availability of data and costs. When determining the scope of work, the availability of data and the accuracy of the models shall be evaluated. In some cases, especially in urban areas, it may be necessary to obtain the latest new data for the digital elevation model (DEM) or supplement the

data with LIDAR systems or topographic surveys. More accurate digital elevation models (DEM) will be needed in locations where urban structures that can divert the surface water pathway and significantly affect the location, depth, and velocity of the flow. Accordingly, the digital elevation models (DEMs) require initial planning to match with the available data, the study objectives and the available budget.

The following is an explanation of both methods and how they are applied to estimate peak flows and runoff hydrograph for catchment areas affecting the project boundary.

9.3 Rainfall-Runoff Calculations

There are several methods for estimating and calculating the peak flows and runoff hydrographs resulting from the catchment areas affecting the project boundary. The most common methods used in Saudi Arabia are (Rational Method) and (SCS Unit Hydrograph).

The SCS Unit Hydrograph method is used in calculating the peak flows and runoff hydrographs for each catchment area greater than 1 km², while the Rational Method is used to calculate the peak flows for each catchment area smaller than or equal to 1 km².

Table 9.1 shows the standards and limitations for using these methods according to the area of the catchment affecting the proposed project location.

Table 9-1 Limitations for the rainfall-runoff calculation methods

Catchments Area	Proposed Equation
$A \leq 100$ Ha.	Rational Method
$A > 100$ Ha.	SCS Method

9.4 Hydrologic Method

For large watersheds, the SCS Unit Hydrograph method shall be used. The method transforms the runoff depth into the full runoff hydrograph. The SCS Unit Hydrograph method requires as input the runoff depth calculated by the SCS curve number method and the lag time.

On the other hand, the Rational method could be used to calculate the peak discharges of drainage basins whose area is less than 100 hectares (1 km²). The data and maps provided by the Saudi Geological Survey (SGS) shall be used to determine the surface runoff coefficient, to be verified through field visits. The consultant shall calculate the values of the surface runoff coefficient based on the soil types and land uses within each basin. Afterward, the peak discharge values shall be calculated using the average surface runoff coefficient for each drainage basin and the rainfall intensity.

9.4.1 Rational method

As shown in Table 9.1, the rational method is recommended for catchments areas less than or equal to 100 hectares. It is a simple empirical formula that relates rainfall intensity to runoff, and yields a peak discharge. The formula reads:

$$Q = \frac{C.I.A}{360}$$

Where:

Q, is the peak discharge, m³/s;

I, Precipitation intensity or precipitation abundance (mm /hr.) which is calculated from the IDF Curves.

A, is the drainage area, ha.

C, Runoff Coefficient: Runoff coefficient is the ratio of rainfall flowing from drainage basins.

The Runoff coefficient (C) is available from the Ministry of Transport (MOT) design manual is determined according to the conditions of the site as shown in Tables (9.2) & (9.3).

Table 9-2 Runoff Coefficient Urban Areas for Rational method

Description Of Area	Runoff Coefficients
Business	
Downtown Areas	0.70-0.95
Neighbourhood Areas	0.50-0.70
Residential	
Single-Family Areas	0.30-0.50
Multiunit, Detached	0.40-0.60
Multiunit, Attached	0.60-0.75
Residential (Suburban)	0.25-0.40
Apartment Dwelling Areas	0.50-0.70
Industrial	
Light Areas	0.50-0.80
Heavy Areas	0.60-0.90
Parks, Cemeteries	0.10-0.25
Playgrounds	0.20-0.35
Railroad Yard Areas	0.20-0.40
Unimproved Areas	0.10-0.30
Streets	
Asphaltic	0.70-0.95
Concrete	0.70-0.85
Brick	0.80-0.95
Drives and Walks	0.75-0.85
Roofs	0.75-0.95
Lawns; Sandy Soil	
Flat, 2%	0.05-0.10
Average, 2-7%	0.15-0.20
steep, 7%	0.10-0.15
Lawns; Heavy Soil	
Flat, 2%	0.13-0.17
Average, 2-7%	0.25-0.35
steep, 7%	0.18-0.22
This Table Ends Here	

Table 9-3 Runoff Coefficient Rural Areas for Rational method

A Relief	B Soil Infiltration	C Vegetal Cover	D Surface Storage
0.4 Steep rugged terrain Average slopes greater than 30%	0.2 No effective soil cover; either rock or thin mantle; negligible infiltration capacity	0.2 No effective plant cover; bare or very sparse soil cover	0.2 Negligible: surface depression few and shallow; drainage ways steep and small, no ponds or marshes 30%
0.3 Hilly with average slopes of 10 to 30%	0.15 Slow to take up water; clay; or other soil of low infiltration capacity such as heavy gumbo	0.15 Poor to fair; clean cultivated crops or poor natural cover; less than 10% of area under good cover	0.15 Low; well defined system of small drainage ways, no ponds or marshes.
0.2 Rolling with average slopes of 5 to 10%	0.1 Normal, deep loam	0.1 Fair to good, about 50% of area in good grass land woodland or equivalent cover	0.1 Normal; considerable surface depression storage; typical of prairie lands, lakes, ponds, and marshes less than 20% of area
0.1 Relatively flat land average slopes 0 to 5%	0.05 High, deep sand or other soil that takes up water readily and rapidly	0.05 Good to excellent; about 50% of area in good grass land; woodland or equivalent	0.05 High, surface depression storage high; drainage system not sharply defined, large flood plain storage; large number of ponds and marshes
This Table Ends Here			

In case of variable type areas then the average areal runoff coefficient is calculated as follows:

$$C = \frac{C_1A_1 + C_2A_2 + \dots + C_nA_n}{A_1 + A_2 + \dots + A_n}$$

Whereas C1...Cn are the runoff coefficients for the sub-catchment's areas A1...An respectively.

9.4.1.1 Time of Concentration Estimation

Time of concentration is defined as the interval of time from the beginning of the rainfall event to the time when water from the furthestmost point in the catchment reaches the point under consideration (basin's outlet). Its value depends on the nature of the surface and the length of the possible pathways to reach the end of the basin. It also depends on the type of water flow on the basin surface in terms of sheet flow, shallow-concentrated, or complete open channel flow. For drainage basins with area less than 1 km² and located within urban areas, the time of concentration shall be calculated using the Kirpich equation (Kirpich, 1940).

$$T_c = 0.0195 \left(\frac{L}{\sqrt{S}} \right)^{0.77}$$

Tc: time of concentration (minutes).

L, is the horizontally projected length of flow, in m; and

S, is the longitudinal slope of the water path, in m/m, between the furthest point of the catchment and the outlet.

9.4.2 Rainfall Runoff Transformation Soil Conservation Service Curve Number Method

The method of the Soil Conservation Service (SCS), currently the Natural Resources Conservation Service (NRCS), (USDA, 1986) is a widely used method to estimate surface runoff depth after deducting the different losses of rainwater falling on the drainage basin.

The SCS-CN method is a universally acknowledged procedure in hydrological practices. The method does not only depend on rainfall values, but also on the characteristics of the drainage basin, its soil moisture content, soil type and properties, initial losses as well as land use. These losses are expressed by a factor called the Runoff Curve Number (CN). This number typically ranges from 25 (for low runoff depressions) to 98 (for paved impervious areas).

This method is used to estimate surface runoff, determine the peak flows and runoff hydrographs after estimating the value of the different losses of rainfall falling on the catchment area according to soil characteristics and land uses. These losses are expressed by a factor called the (Runoff Curve Number), This method is used to calculate flows from catchments of area more than 100 ha or 1 km².

This method is based mainly on the accurate estimation of the following hydrological processes of the design storm:

- Storm distribution over time.
- Initial abstraction losses of rainfall and initial storage of the drainage basins (I_a) related to the quantity of water stored in ponds and low areas of the basin as well as those depleted in the process of initial saturation of the surface of the basin.

Infiltration Rate, which gradually decreases with time from the beginning of the storm until it reaches a fixed value that depends mostly on the physical properties of the soil and its structural formation and the proportion of organic matter in it. The maximum loss or storage that may occur in soil of drainage basin(S) as well as the initial abstraction value (I_a) expected to occur in the drainage basin is determined using the following equation:

The values of the curve number are estimated according to the Soil maps and the aerial photographs and according to the following table taken from the values of arid and semi-arid areas as mentioned in technical release No. 55 (TR-55), which is one of the most widely used standards in the field of hydrology.

Runoff Depth (R), which is expected to occur on a unit area of the drainage basin (mm), is calculated using the following equation:

$$R = \frac{(P - I_a)^2}{(P + 0.8S)}$$

whereas:

P - maximum daily rainfall rate corresponding to design return period, mm;

I_a = The amount of precipitation that must fall before excess precipitation results.

$$I_a = 0.2xS$$

S = maximum retention in the watershed in mm as defined by

$$S = 25.4 \frac{1000}{CN} - 10$$

CN = SCS curve number for the watershed as defined by the loss method.

$$CN_{(II)} = \frac{\sum A_i CN_i}{\sum A_i}$$

$$CN_{(I)} = \frac{4.2 \times CN_{(II)}}{10 - 0.058 \times CN_{(II)}}$$

The runoff hydrograph form resulted from (SCS-Unit hydrograph method) depends on the area of the drainage basin and the Lag time (Tlag),

Tlag: SCS Lag Time Equation

$$Tlag = \frac{L^{0.8}(S + 1)^{0.7}}{1900\sqrt{Y}}$$

Tlag = lag time in hours.

L = hydraulic length of watershed in feet.

Y = watershed slope in percent.

9.4.2.1 Soil Classification by Infiltration Rate

The characteristics and structure of drainage basins directly affect the relationship between the amount of rainfall on the basin and the amount of surface runoff resulting from these precipitation values. In the Curve Number method, soil shall be classified into four main categories according to the value of the infiltration rate through its granules. The main structural features and physical properties of each category can be explained as follows:

Group A: It includes sandy soils or gravel. These soils have low runoff potential and high infiltration rates even when thoroughly wet. As it is clear, surface runoff over drainage basins of such soils will be weak.

Group B: It includes medium sandy, sandy loam and medium- and moderately coarse soil, characterized by medium to high infiltration rates in case of soil saturation. Surface runoff over drainage basins consisting of such soils will range between weak and average.

Group C: It includes clay Loam soil. Its surface layer is thick and does not contain a high percentage of organic matter, and its grains are fine to moderately fine. This soil is characterized by medium to low infiltration rates. It is evident that runoff over drainage basins consisting of such soil will be between medium and high.

Group D: It includes clay soil with high swelling potential, shallow soil followed by an impervious layer, or soil where the level of groundwater is always high, characterized by very low infiltration rates.

Table 9-4 The Curve Number for Arid and Semi-arid Regions as reported in Technical Release No. 55 (TR-55)

Cover description		Curve numbers for hydrologic soil group			
Cover Type	Hydrologic condition ²				
		A ³	B	C	D
Herbaceous—mixture of grass, weeds, and low-growing brush, with brush the minor element.	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Oak-aspen—mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Pinyon-juniper—pinyon, juniper, or both; grass understory	Poor		75	85	89
	Fair		58	73	80
	Good		41	61	71
Sagebrush with grass understory.	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub—major plants include saltbush, greasewood, creosote bush, black brush, bursage, Palo Verde, mesquite, and cactus.	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

¹ Average runoff condition, and $I_a = 0.2S$.

² Poor: <30% ground cover (litter, grass, and brush).

Fair: 30 to 70% ground cover.

Good: > 70% ground cover.

³ Curve numbers for group A have been developed only for desert shrub.

9.4.2.2 Extracting curve numbers from soil maps

In the context of extracting curve numbers from soil maps, it is important to note that the soil maps obtained from the Ministry of Agriculture play a crucial role in optimizing the process of obtaining accurate curve number values. These soil maps provide valuable information about the distribution and characteristics of different soil types, allowing for effective cross-matching with curve number data sources. By leveraging the Ministry of Agriculture's soil maps, the accuracy and reliability of the extracted curve number values are significantly enhanced, enabling more precise hydrological analysis and modeling.

The process of extracting curve numbers from soil maps involves collecting soil data, cross-matching it with relevant curve number values, adding the curve numbers to the soil maps, creating a raster representation, and performing spatial analysis to identify mean curve number values for specific catchments.

The Below is an elaboration of the process for extracting the curve number from soil maps:

- 1 Collect Soil Maps in SHP File Format: Gather the soil maps in Shapefile (SHP) format, which contain spatial information about different soil types.
- 2 Identify Soil Attributes: Explore the attribute table within the SHP file to find the description or attribute that specifies the soil type for each feature area.
- 3 Cross-Match with Curve Number Values: Refer to Technical Release No. 55 (TR-55) to obtain the Curve Number values corresponding to the identified soil types. Cross-match the soil type descriptions from the SHP file with the Curve Number values to determine the appropriate values for each soil type.
- 4 Add Curve Number to SHP Files: Update the attribute table in the SHP file to include an additional field for the Curve Number. Populate this new field with the corresponding Curve Number values obtained in the previous step.
- 5 Create a Raster from the SHP File: Convert the SHP file into a raster format. This process assigns the Curve Number values to the cells or pixels based on their spatial location.
- 6 Select the Curve Number Field: Specify the field containing the added Curve Number values as the attribute to be associated with the raster cells.
- 7 Process Catchments via Hydrologic Modeling: Utilize hydrologic modeling techniques to delineate catchments or watershed boundaries based on terrain characteristics and drainage patterns. This step involves simulating the flow of water across the landscape.
- 8 Perform GIS Spatial Analysis: In a GIS software, employ spatial analysis tools to overlay the catchment boundaries with the Curve Number raster. This analysis allows for the spatial association of each catchment with the corresponding Curve Number values.
- 9 Identify Mean Curve Number Values: Calculate the mean value of the Curve Number within each catchment by aggregating the Curve Number values assigned to the cells/pixels within the catchment boundaries. This provides an average Curve Number representative of the catchment's soil characteristics.
- 10 By following these steps, you can successfully extract and utilize the Curve Number data from soil maps to enhance hydrological modeling and analysis.
- 11 The curve number (CN) and rational runoff coefficient of these internal catchments are estimated taking into consideration that these areas are future urbanized areas.

The below figure depicts the curve number map produce for the KSA from the soil maps.

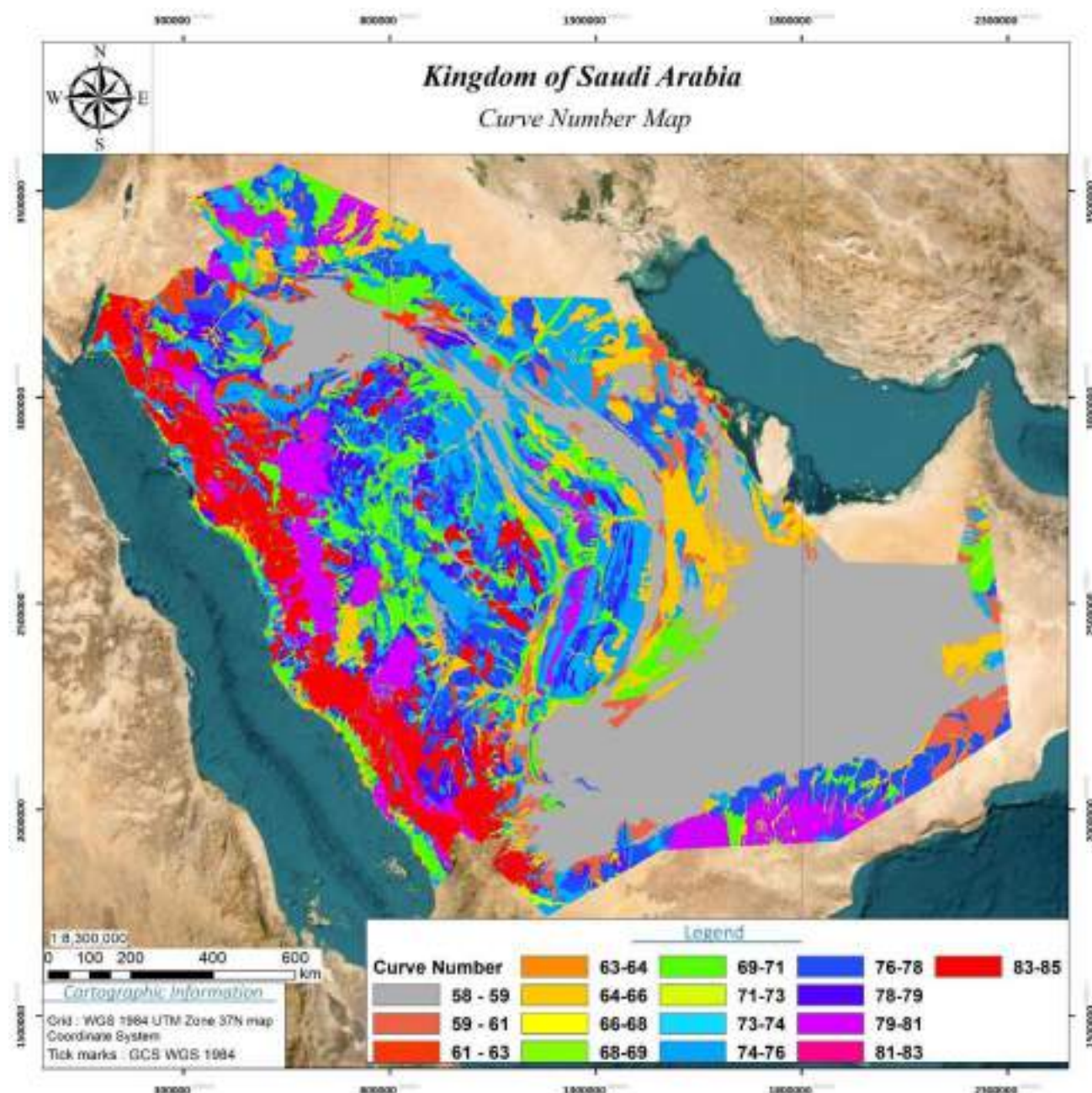


Figure 9-1 Curve number maps for the Kingdom of Saudi Arabia

9.5 Morphological Analysis

The contributing catchments shall be modelled using Watershed Modelling System (WMS) and exported to HEC-HMS to run the hydrological model.

9.5.1 WMS

Streams and their correspondent external catchment areas affecting the boundaries of the study area will be determined using Digital Elevation Models (DEM) models in Watershed Modeling System (WMS).

Watershed Modelling System (WMS) is a comprehensive graphical modelling environment for all phases of catchment hydrology and hydraulics.

The software provides tools to automate basin and sub-basins delineation using digital elevations model generated based on topographic maps or any other related sources.

The topographic maps collected with scale 1:50,000 and recent satellite images will be used to check the results of the WMS software. Topographic maps are widely used in determining the paths of streams in various areas, especially in areas that are not accessible. The names of major streams can be identified through the maps showing the names in each region and also the topographic maps show the elevations and contour lines, which is used in the identification of streams and watercourses in areas where there is no clear stream path and also used to determine the different morphological characteristics of all catchments such as (area, longest flow path, slope, etc.).

9.5.2 External Watersheds Analysis

9.5.2.1 Catchment

External Watershed Analysis is a crucial aspect of hydrological studies as it helps in identifying the contribution of external watersheds to the main watershed under study. In this study, the Watershed Modelling System (WMS) was used to perform external watershed analysis using DEM (10 x 10 m).

The below figure illustrates the interface of the WMS software.

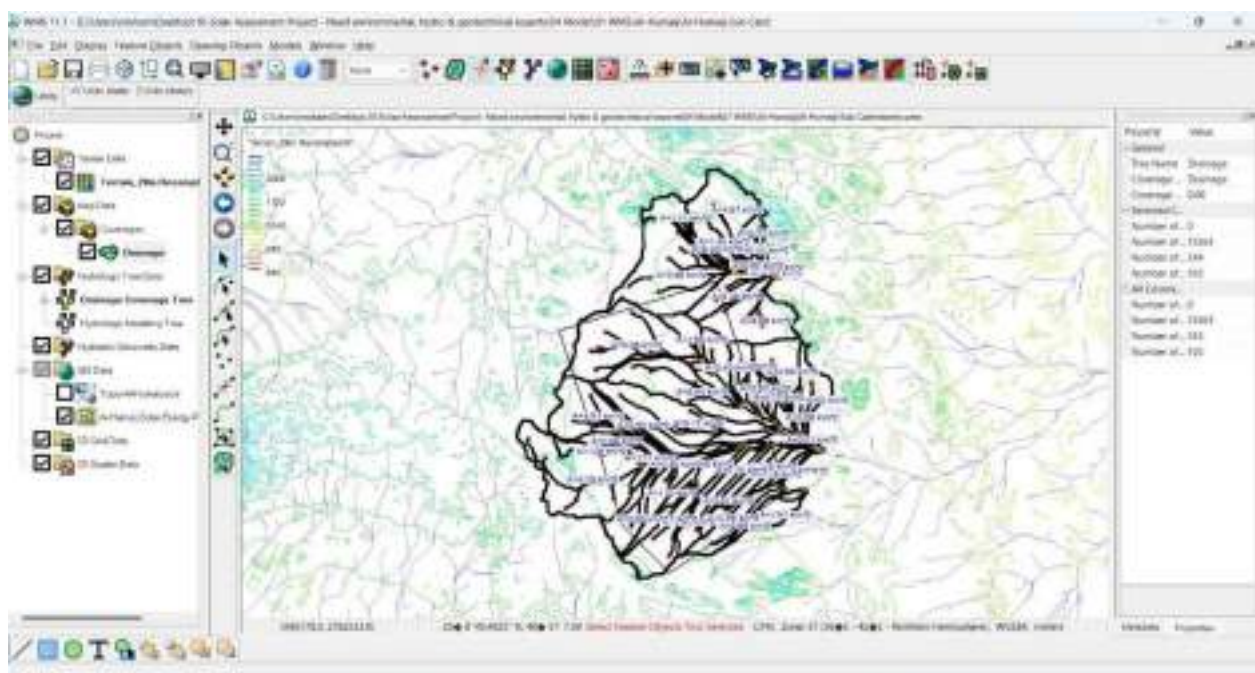


Figure 9-2 WMS software Interface

WMS, a hydrological software, utilized the input DEM (Digital Elevation Model) to delineate the catchment areas and compute various catchment parameters such as area, elevation, basin slopes, and longest flow paths. These parameters are crucial in estimating the peak flow of each catchment area using the rational method or the SCS (Soil Conservation Service) method based on the catchment area. In addition to the DEM,

recent satellite images were employed to verify the modelled catchment areas. Moreover, topographic maps were also used to ensure the accuracy of the catchment parameters.

This figure below demonstrates the catchments overlaid on top of satellite images.

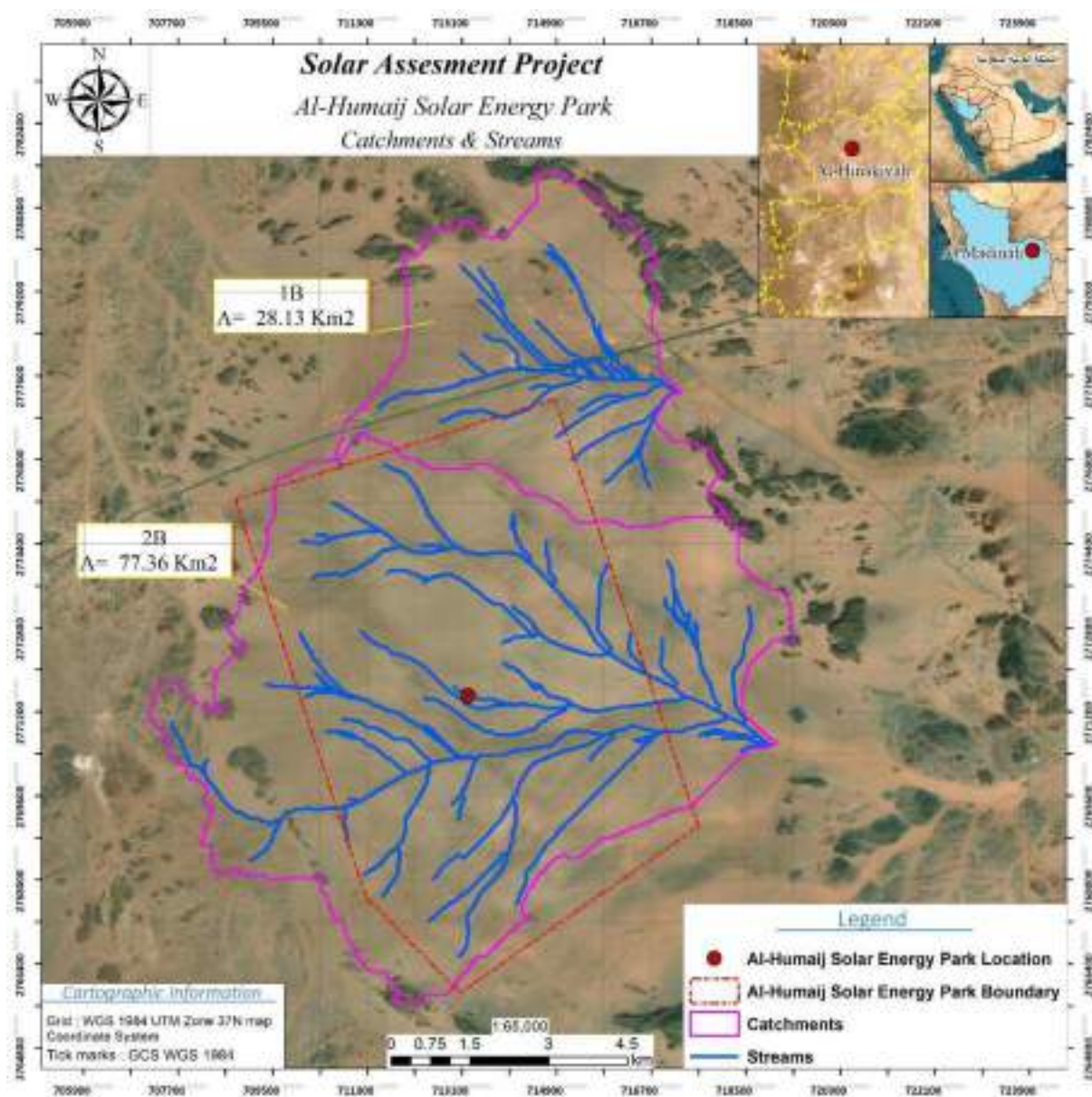


Figure 9-3 Catchments and Streams overlaid on top of satellite images

In the hydrological modeling approach, the zonal statistics method was employed, utilizing the Curve Number (CN) raster to extract precise CN values for each catchment area. This methodology involved overlaying catchment boundaries, as illustrated in the accompanying figure, onto the Curve Number maps. Through this process, we associated each catchment with the corresponding CN values based on their spatial location. The zonal statistics method allowed us to efficiently derive accurate and localized Curve Number data for subsequent analysis, contributing to a more detailed understanding of the hydrological characteristics within each catchment area.

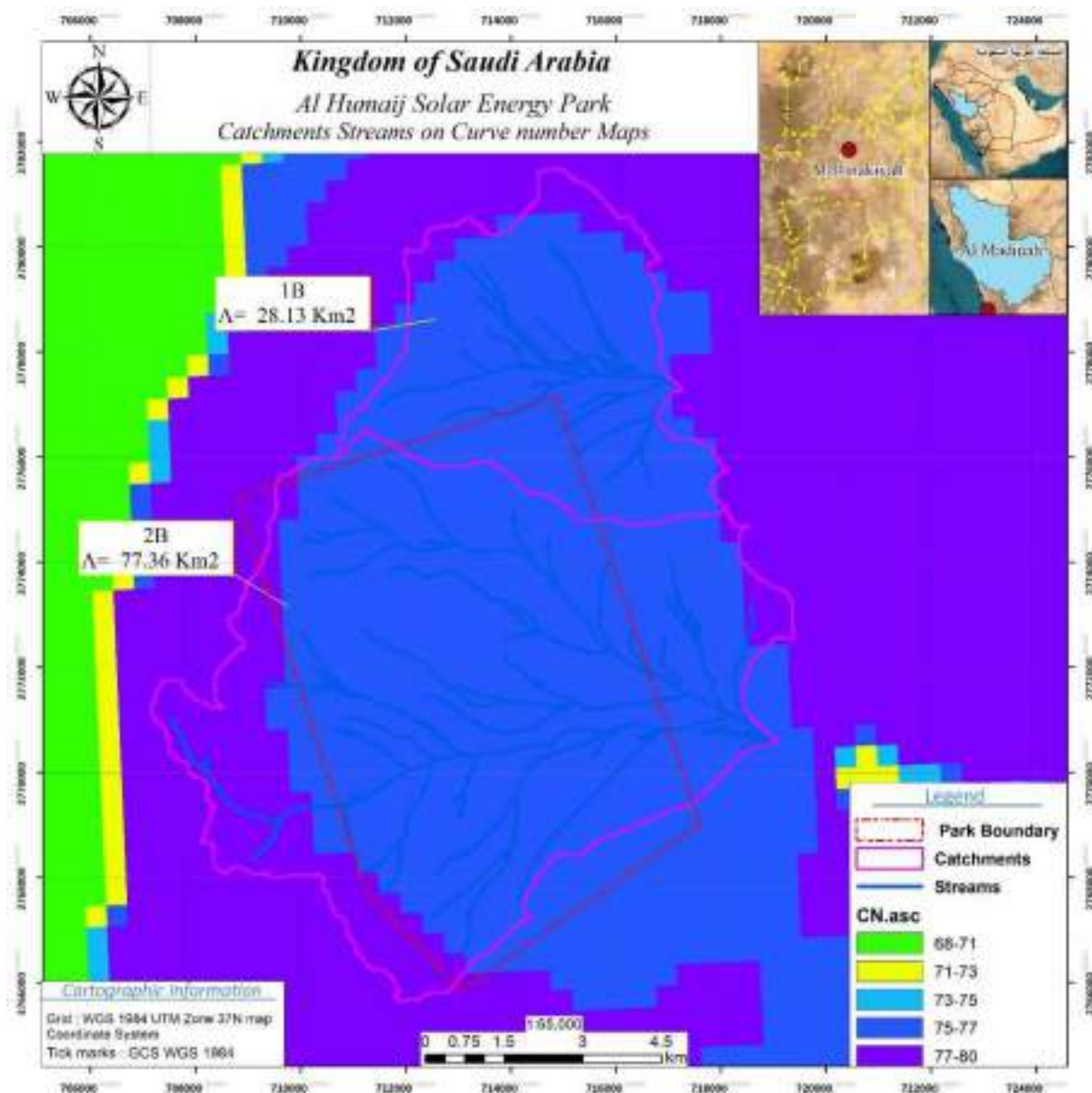


Figure 9-4 Catchments and Streams overlaid on top of Curve Number Maps

All the catchment parameters were compiled and listed in a table for easy reference and utilization in the subsequent phases of the hydrological analysis.

Table 9-5 Catchment parameters

CM Name	Area Km ²	Slope (m/m)	Max. Flow Distance (m)	Max. Flow Slope (m/m)	Curve number AMC CN(II)	Curve number AMC CN(I)	Run off Coefficient	Flow Calculation method	Lag time (hr)	Time of Concentration (min)
1B	28.13	0.0305	7821.8	0.0059	76.5	57.8	N/A	SCS	3.71	N/A
2B	77.36	0.0167	14986.5	0.0055	76.5	57.8	N/A	SCS	8.46	N/A
This Table Ends Here										

9.5.2.2 Sub-Catchment

The catchments were divided into sub-catchments to enhance the accuracy of routing calculations, including determining maximum flow distance and other parameters, which tend to be less precise when dealing with large catchment areas.

This figure below demonstrates the Sub catchments overlaid on top of satellite images.

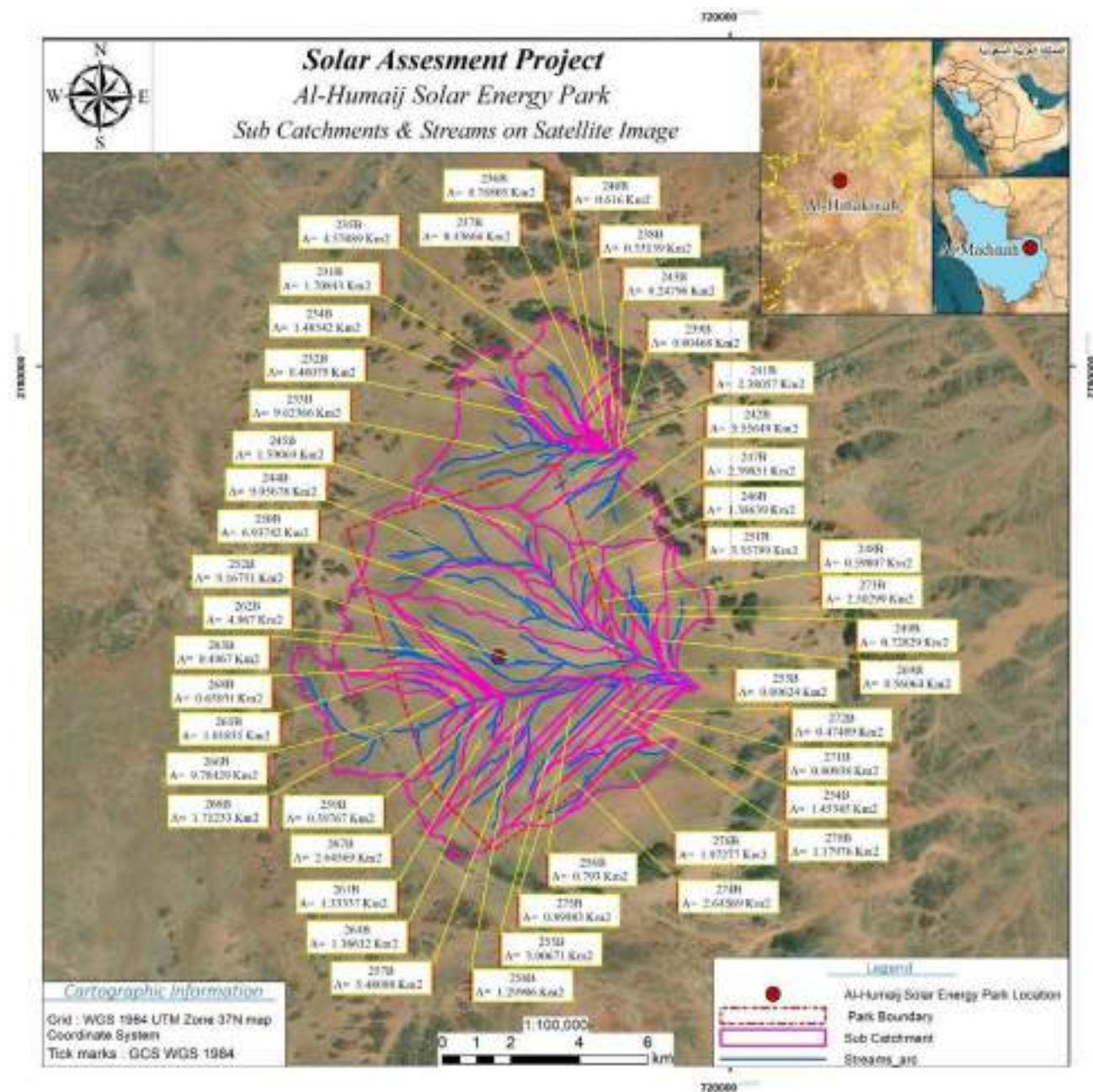


Figure 9-5 Sub Catchments and Streams overlaid on top of satellite images

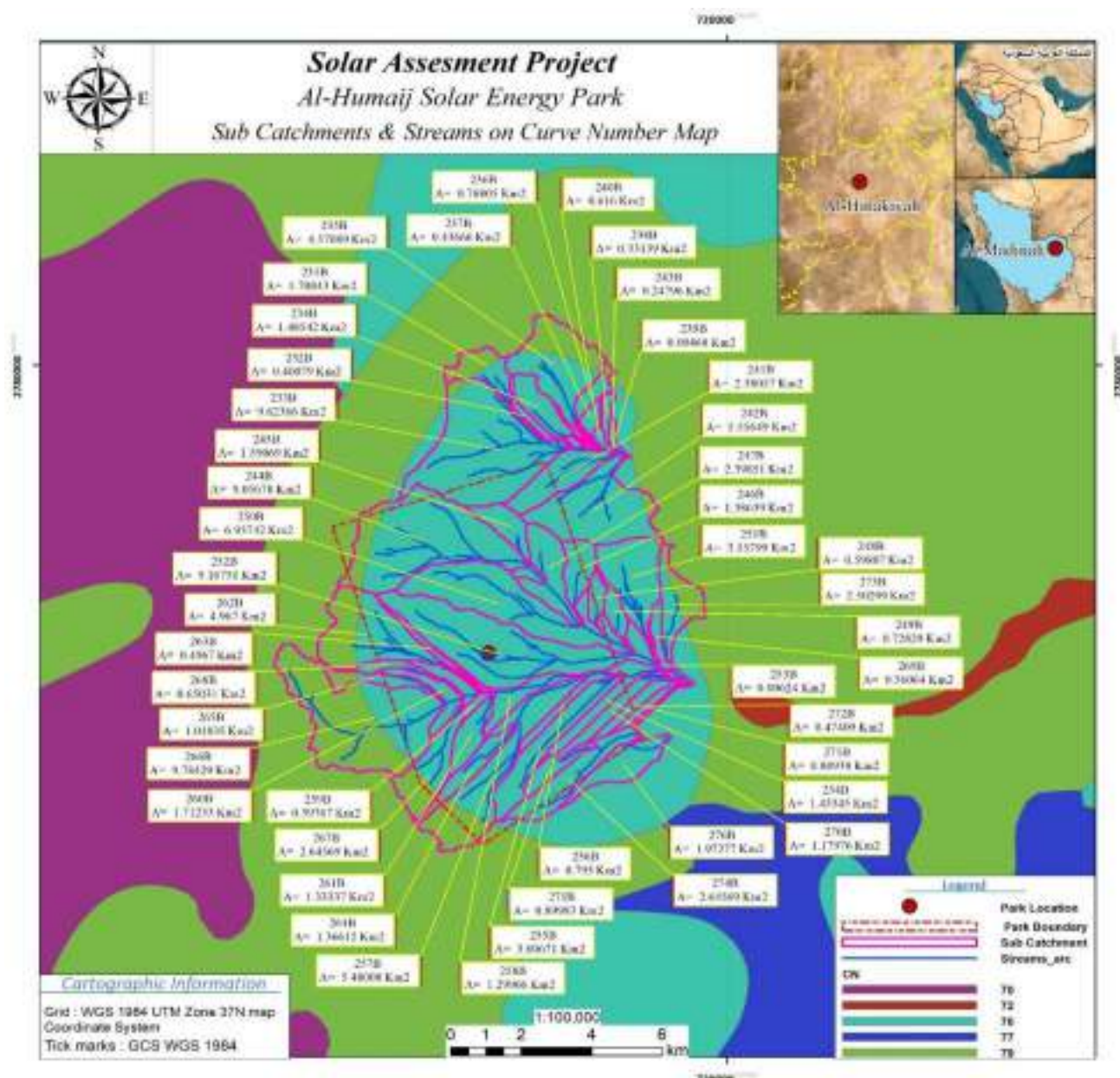


Figure 9-6 sub-Catchments and Streams overlaid on top of Curve Number Maps

All the sub catchment parameters were compiled and listed in a table for easy reference and utilization in the subsequent phases of the hydrological analysis.

Table 9-6 Sub-Catchment parameters

CM Name	Area Km2	Slope (m/m)	Max. Flow Distance (m)	Max. Flow Slope (m/m)	Curve number AMC CN(I)	Run off Coefficient	Flow Calculation method	Lag time (hr)	Time of Concentration (min)
231B	1.708	0.070	4919.549	0.008	59.1	N/A	SCS	1.96	N/A
232B	0.401	0.009	3113.839	0.012	N/A	0.4	Rational Method	N/A	52.02
233B	9.624	0.016	6016.975	0.005	57.1	N/A	SCS	5.14	N/A
234B	1.485	0.015	3392.883	0.008	57.1	N/A	SCS	3.37	N/A

CM Name	Area Km2	Slope (m/m)	Max. Flow Distance (m)	Max. Flow Slope (m/m)	Curve number	Run off Coefficient	Flow Calculation method	Lag time (hr)	Time of Concentration (min)
235B	4.571	0.062	4822.460	0.008	58.7	N/A	SCS	2.08	N/A
236B	0.768	0.090	3277.569	0.010	N/A	0.4	Rational Method	N/A	58.96
237B	0.437	0.029	2398.891	0.018	N/A	0.2	Rational Method	N/A	36.82
238B	0.331	0.077	1798.200	0.005	N/A	0.2	Rational Method	N/A	47.75
239B	0.005	0.037	137.100	0.183	N/A	0.2	Rational Method	N/A	10.00
240B	0.616	0.014	2410.485	0.010	N/A	0.2	Rational Method	N/A	46.50
241B	2.381	0.009	3927.983	0.005	57.1	N/A	SCS	4.91	N/A
242B	5.556	0.025	4015.602	0.004	57.1	N/A	SCS	2.95	N/A
243B	0.248	0.018	1592.077	-0.004	N/A	0.4	Rational Method	N/A	47.17
244B	9.057	0.013	6402.239	0.005	58.1	N/A	SCS	5.89	N/A
245B	1.591	0.010	3430.357	0.007	57.1	N/A	SCS	4.21	N/A
246B	1.386	0.008	2902.639	0.006	57.1	N/A	SCS	4.06	N/A
247B	2.399	0.012	3698.703	0.007	57.1	N/A	SCS	3.94	N/A
248B	0.598	0.008	2430.570	0.006	N/A	0.2	Rational Method	N/A	57.01
249B	0.728	0.008	2739.404	0.008	N/A	0.3	Rational Method	N/A	56.78
250B	6.937	0.011	8143.535	0.005	57.1	N/A	SCS	7.91	N/A
251B	3.558	0.017	4615.747	0.007	57.1	N/A	SCS	4.05	N/A
252B	9.168	0.010	9302.633	0.006	57.1	N/A	SCS	9.20	N/A
253B	0.006	0.010	135.576	-0.113	N/A	0.4	Rational Method	N/A	10.00
254B	1.453	0.011	4902.507	0.006	57.1	N/A	SCS	5.11	N/A
255B	3.007	0.008	6044.837	0.008	57.1	N/A	SCS	7.29	N/A
256B	0.793	0.011	4066.898	0.007	N/A	0.2	Rational Method	N/A	79.24
257B	5.480	0.024	7774.605	0.006	58.7	N/A	SCS	4.94	N/A
258B	1.299	0.012	3976.148	0.007	57.1	N/A	SCS	4.23	N/A
259B	0.398	0.006	2300.693	0.005	N/A	0.4	Rational Method	N/A	60.44
260B	1.712	0.009	3476.243	0.006	57.1	N/A	SCS	4.45	N/A
261B	1.333	0.013	3211.154	0.006	57.1	N/A	SCS	3.39	N/A
262B	4.967	0.020	5651.027	0.006	58.7	N/A	SCS	4.14	N/A
263B	0.497	0.007	4317.210	0.009	N/A	0.2	Rational Method	N/A	76.76
264B	1.366	0.017	4501.120	0.008	57.9	N/A	SCS	3.88	N/A
265B	1.018	0.033	3929.447	0.007	59.1	N/A	SCS	2.40	N/A
266B	9.784	0.036	7035.557	0.006	59.6	N/A	SCS	3.61	N/A

CM Name	Area Km2	Slope (m/m)	Max. Flow Distance (m)	Max. Flow Slope (m/m)	Curve number	Run off Coefficient	Flow Calculation method	Lag time (hr)	Time of Concentration (min)
267B	2.646	0.020	4240.662	0.005	59.1	N/A	SCS	3.30	N/A
268B	0.650	0.008	4141.221	0.007	N/A	0.2	Rational Method	N/A	82.43
269B	0.561	0.017	2302.113	0.015	N/A	0.2	Rational Method	N/A	38.21
270B	1.180	0.007	4691.607	0.006	57.1	N/A	SCS	6.37	N/A
271B	0.809	0.007	3691.599	0.007	N/A	0.4	Rational Method	N/A	74.44
272B	0.474	0.008	2906.338	0.011	N/A	0.4	Rational Method	N/A	50.75
273B	2.503	0.024	5043.356	0.006	59.3	N/A	SCS	3.38	N/A
274B	2.646	0.015	5478.498	0.007	57.1	N/A	SCS	4.82	N/A
275B	0.900	0.015	2977.600	0.009	N/A	0.4	Rational Method	N/A	57.43
276B	1.973	0.013	4197.697	0.005	57.1	N/A	SCS	4.21	N/A

9.6 Hydrologic Modelling

9.6.1 HEC-HMS

For the (SCS Unit Hydrograph) method, RGF will use the Hydrologic Modeling System (HEC-HMS) to model the surface runoff for the external catchments that affect the project boundary, it's a numerical model for the study of surface runoff and the calculation of the expected flows from the catchment of the streams affecting the study area, as well as the total resultant flood volume and the time of occurrence of peak flow since the beginning of the storm.

HEC-HMS is a hydrologic modelling system used to simulate precipitation runoff processes in a catchment. It includes procedures that can be used for simulating large streams or for limited runoff processes within rural or urban areas.

RGF use the morphological characteristics of each sub catchment, the metrological data, wadis stream order, and boundary conditions of the existing dams in estimating the flow rate of each wadi affecting the project area. This shall be performed using HEC-HMS software for estimating the flow rate for the SCS method.

This method is used to estimate surface runoff, determine the peak flows and runoff hydrographs.

The values of the curve number are estimated according to the geological maps and the aerial photographs and according to the following table taken from the values of arid and semi-arid areas as mentioned in technical release No. 55 (TR-55), which is one of the most widely used standards in the field of hydrology.

9.6.2 Peak flows and runoff hydrographs

Calculating the peak flow and runoff hydrographs for the catchments are a fundamental aspect in selecting the necessary measures for flood protection. These studies rely on inputs such as meteorological, morphological, and geological data, in addition to site visits. The peak flow and runoff hydrograph are crucial outputs from the hydrological study, and serve as the basis for designing hydraulic flood protection and storm drainage systems. The method used for calculating peak flows and runoff hydrographs varied based on catchment area size and design criteria established in section 9.4 Hydrologic method. The SCS Unit Hydrograph method was employed for catchment areas larger than 1 km², while the Rational Method was used for those smaller than or equal to 1 km².

9.6.3 SCS method calculation using HEC HMS (Sub-catchment)

As mentioned in section 9.6.1 HEC HMS, the software HEC HMS a hydrologic modelling system, was used by RGF to model surface runoff for external catchments that impact the project boundary that has areas more than 1 km². The catchments for which this method was used are specified in table 9-5, which includes catchment parameters defining the calculation method that will be used for each catchment.

This numerical model is used to calculate expected flows from streams affecting the study area, as well as the total flood volume and time of peak flow occurrence from the beginning of the storm. The rainfall data from Alhinakiyah Station analysis was utilized for the project area, with the calculated depth for 1 in 100 years rainfall return period used to develop SCS type 2 distribution curves for rainfall. In addition, the catchment area and corresponding curve number were used as inputs, allowing the software to compute the runoff hydrograph for the catchment. The software outputs include various important factors such as peak flow rate, time to peak flow, and total runoff volume.

The program's main window and catchments impacting the project boundary are depicted in Figure 9-4, while Figure 9-5 exhibits global summary results of the SCS method using HEC HMS. The resulting hydrographs generated by HEC HMS are presented below:

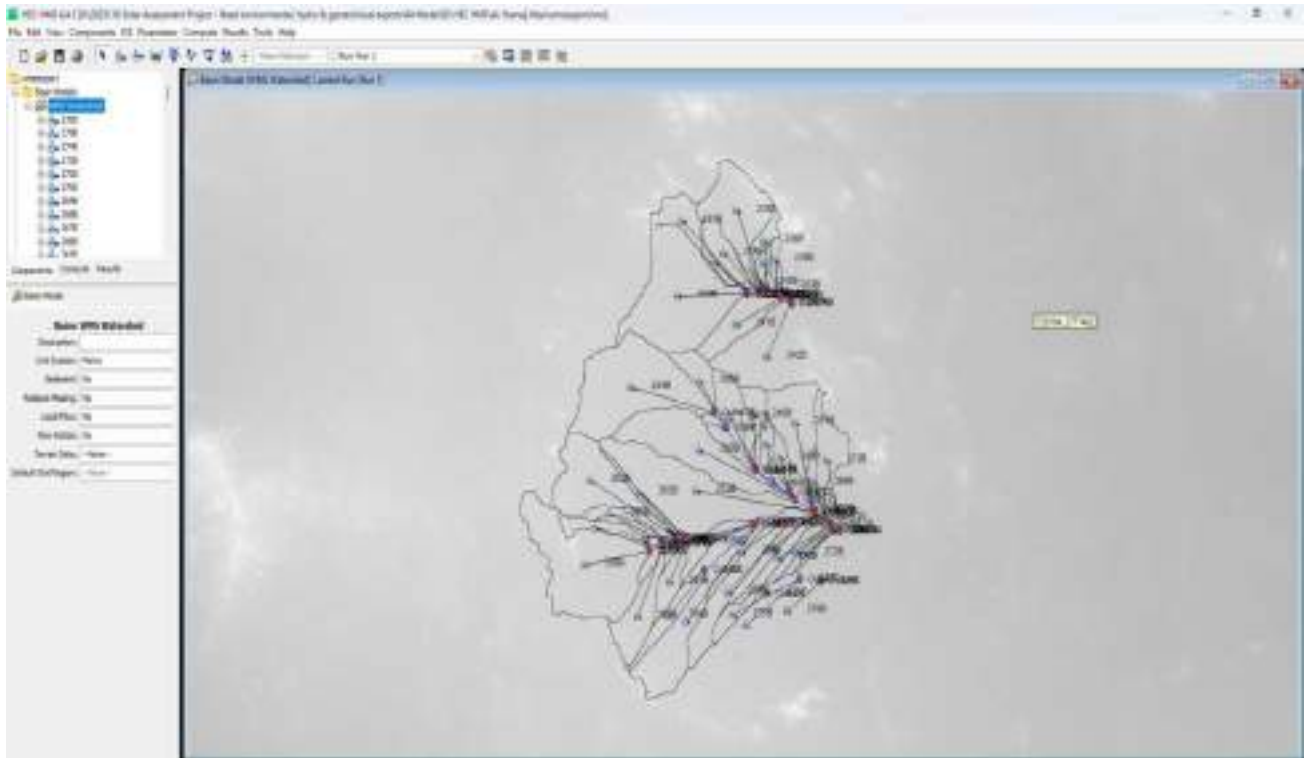


Figure 9-7 Catchments impacting the project boundary on HEC HMS interface

Global Summary Results for Run "Run 1"

Project: wmsreport Simulation Run: Run 1

Start of Run: 01Jan2024, 00:00 Basin Model: WMS Watershed
End of Run: 01Jan2024, 00:00 Meteorologic Model: WMS Meteorologic Data
Compute Time: 21Aug2024, 05:42:26 Control Specifications: WMS Control Info

Show Elements: Initial Selection Value Units: ☐ MM ☒ 1000 M3 Sorting: Hydrologic

Hydrologic Element	Drainage Area (KM2)	Peak Discharge (M3/s)	Time of Peak	Volume (1000 M3)
2700	1.9728	0.3	01Jan2024, 28:08	11.2
2708	0.8998	0.2	01Jan2024, 26:35	5.1
2740	2.6457	0.4	01Jan2024, 28:59	15.1
2750	0.4741	0.1	01Jan2024, 17:54	2.7
2758	0.8094	0.1	01Jan2024, 29:31	4.6
2760	1.1798	0.1	01Jan2024, 21:15	6.7
2648	1.3661	0.3	01Jan2024, 17:31	8.5
2660	0.8503	0.1	01Jan2024, 28:51	3.8
2670	2.6457	0.4	01Jan2024, 26:34	18.7
2680	9.7843	2.1	01Jan2024, 26:57	72.7
2690	1.0384	0.3	01Jan2024, 18:38	7.2
2608	1.7123	0.3	01Jan2024, 28:27	9.7
2630	0.4987	0.1	01Jan2024, 20:38	2.8
2630	4.9670	0.9	01Jan2024, 17:48	23.7
2638	1.3334	0.3	01Jan2024, 26:54	7.6
2590	0.3977	0.1	01Jan2024, 17:24	2.3
2580	1.2991	0.2	01Jan2024, 28:08	7.4
2570	5.4811	0.9	01Jan2024, 28:57	37.1
2560	0.7930	0.1	01Jan2024, 29:23	4.5
2580	1.0067	0.3	01Jan2024, 21:34	17.1
2530	3.5890	0.9	01Jan2024, 17:52	20.3
2490	0.7283	0.1	01Jan2024, 17:52	4.1
2480	0.9981	0.1	01Jan2024, 17:04	5.4
2468	1.3864	0.2	01Jan2024, 17:53	7.9
2440	9.0568	1.3	01Jan2024, 20:23	57.6
2458	1.5907	0.2	01Jan2024, 18:06	9.1
2478	2.3885	0.4	01Jan2024, 17:42	13.7
2500	6.5374	0.7	01Jan2024, 23:27	39.5
2538	9.1675	0.9	02Jan2024, 01:12	52.2
2548	1.4535	0.2	01Jan2024, 19:25	8.3
2538	0.0062	0.0	01Jan2024, 12:21	0.0
2690	0.5006	0.1	01Jan2024, 15:17	3.2
2738	2.5030	0.5	01Jan2024, 16:40	18.0
2408	5.5865	1.0	01Jan2024, 16:15	31.6
2418	2.3806	0.3	01Jan2024, 19:06	13.6
2380	0.3334	0.1	01Jan2024, 13:12	1.9
2378	0.4367	0.1	01Jan2024, 14:35	2.5
2368	0.7681	0.2	01Jan2024, 13:47	4.7
2300	4.5709	1.2	01Jan2024, 14:51	31.0
2348	1.4854	0.2	01Jan2024, 16:52	8.5
2338	9.6237	1.3	01Jan2024, 19:28	54.8
2308	0.4008	0.1	01Jan2024, 17:58	2.3
2318	1.7094	0.5	01Jan2024, 14:39	12.1
2408	0.6160	0.1	01Jan2024, 15:42	3.5
2398	0.0047	0.0	01Jan2024, 12:08	0.0
2408	0.2490	0.1	01Jan2024, 14:16	1.5

Figure 9-8 Global Summary Results From HEC-HMS Software

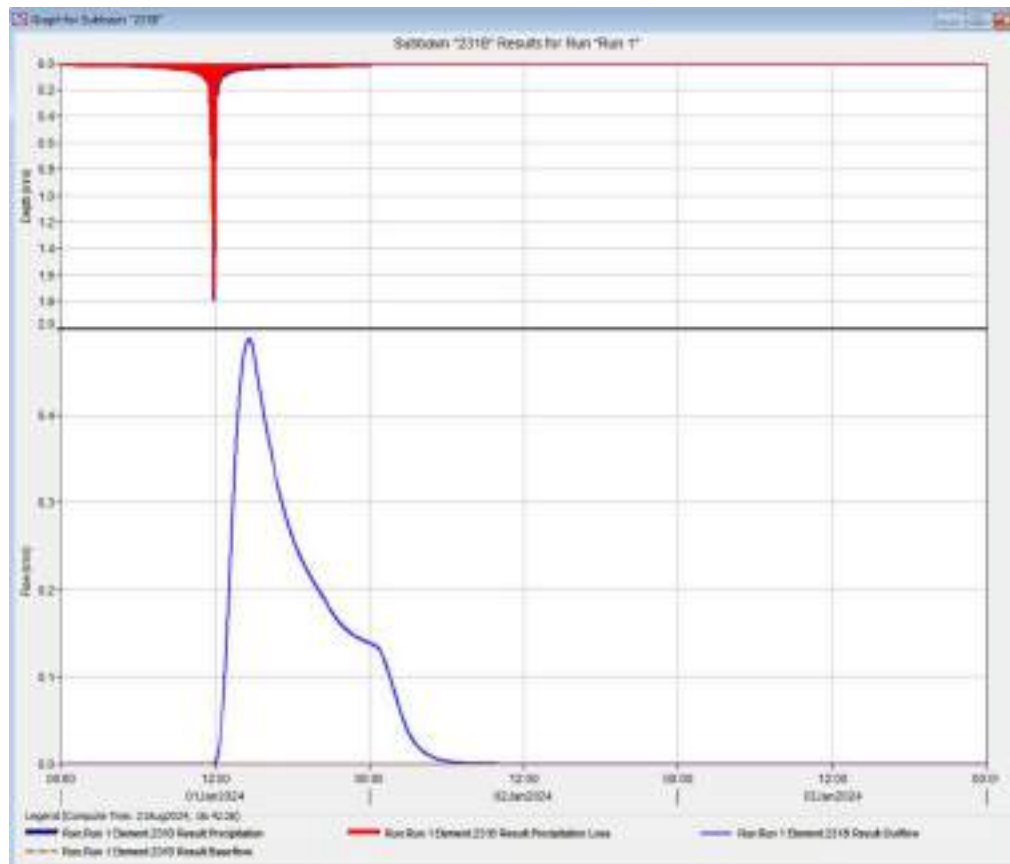


Figure 9-9 Runoff hydrograph from HEC HMS CM-231B

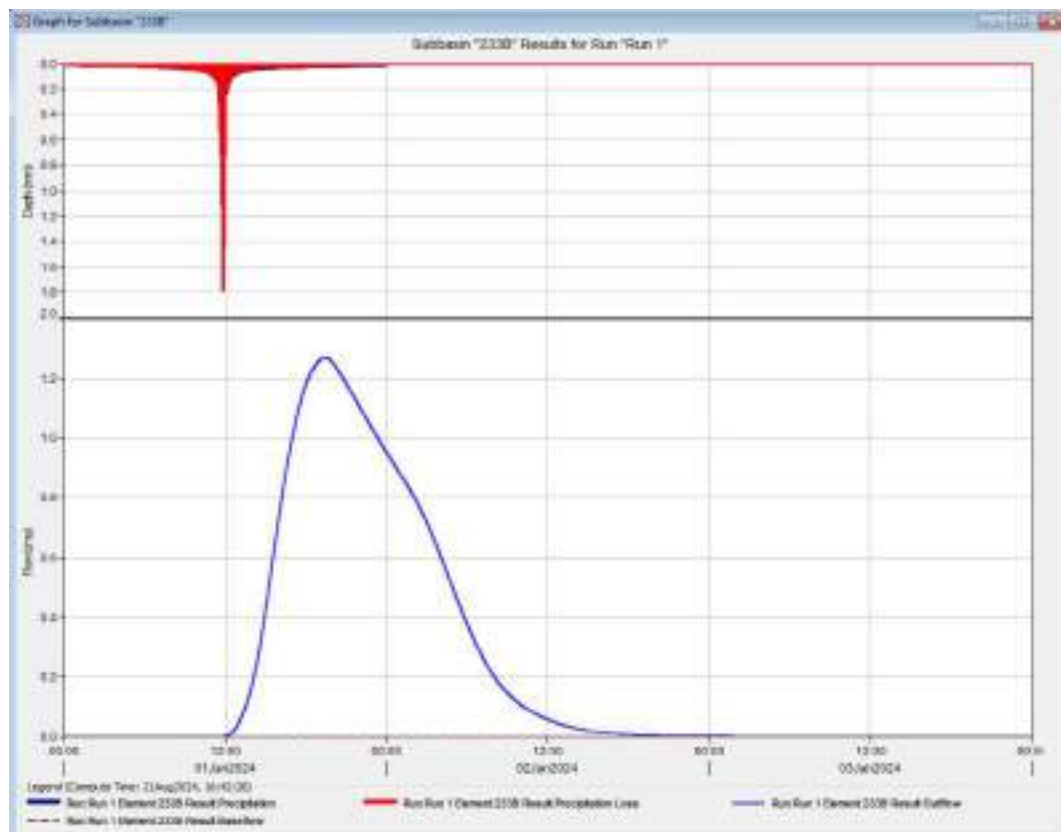


Figure 9-10 Runoff hydrograph from HEC HMS CM-233B

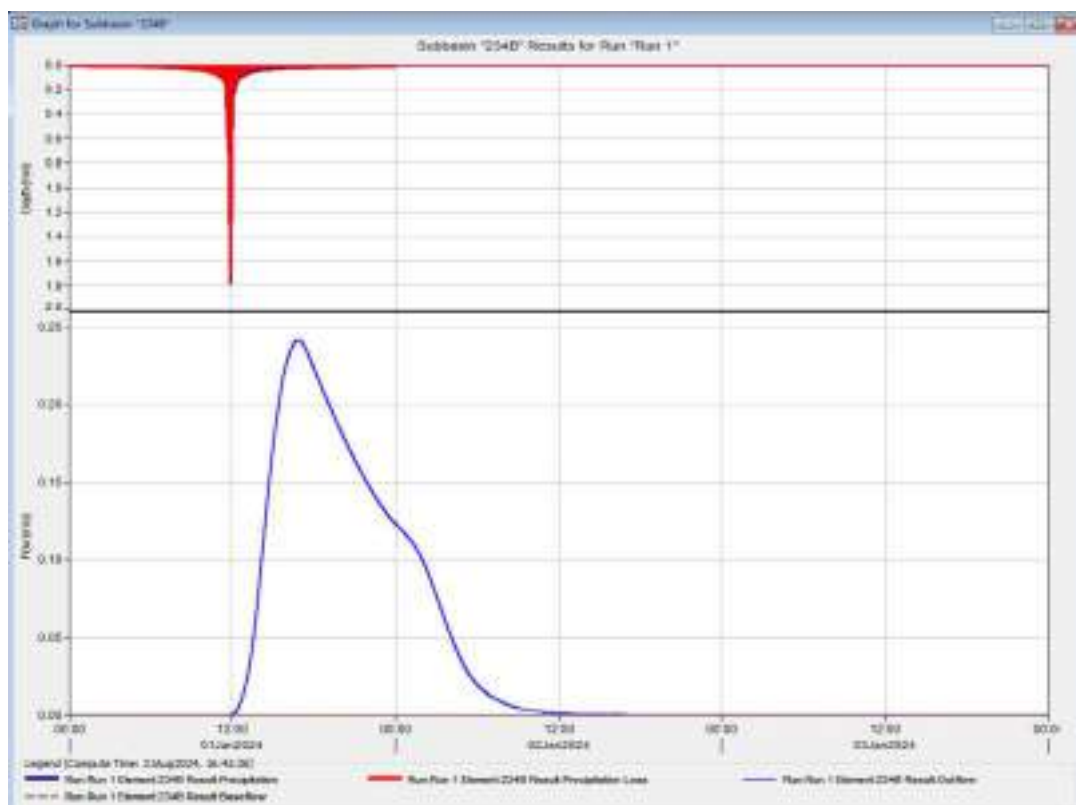


Figure 9-11 Runoff hydrograph from HEC HMS CM-234B

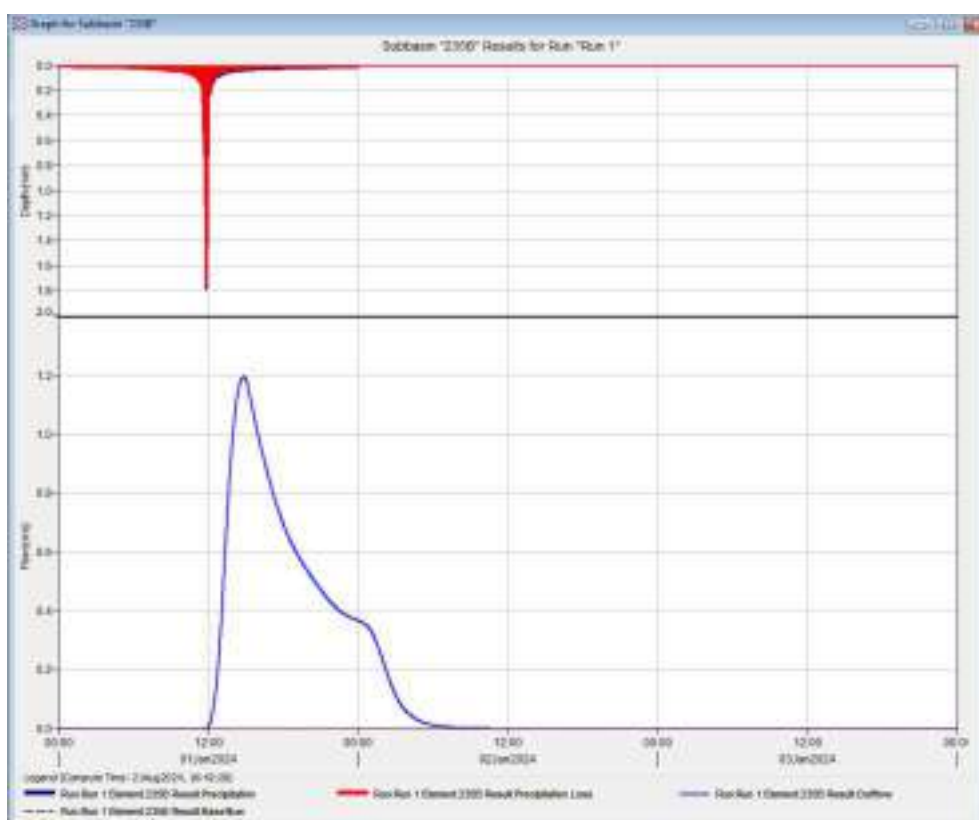


Figure 9-12 Runoff hydrograph from HEC HMS CM-235B

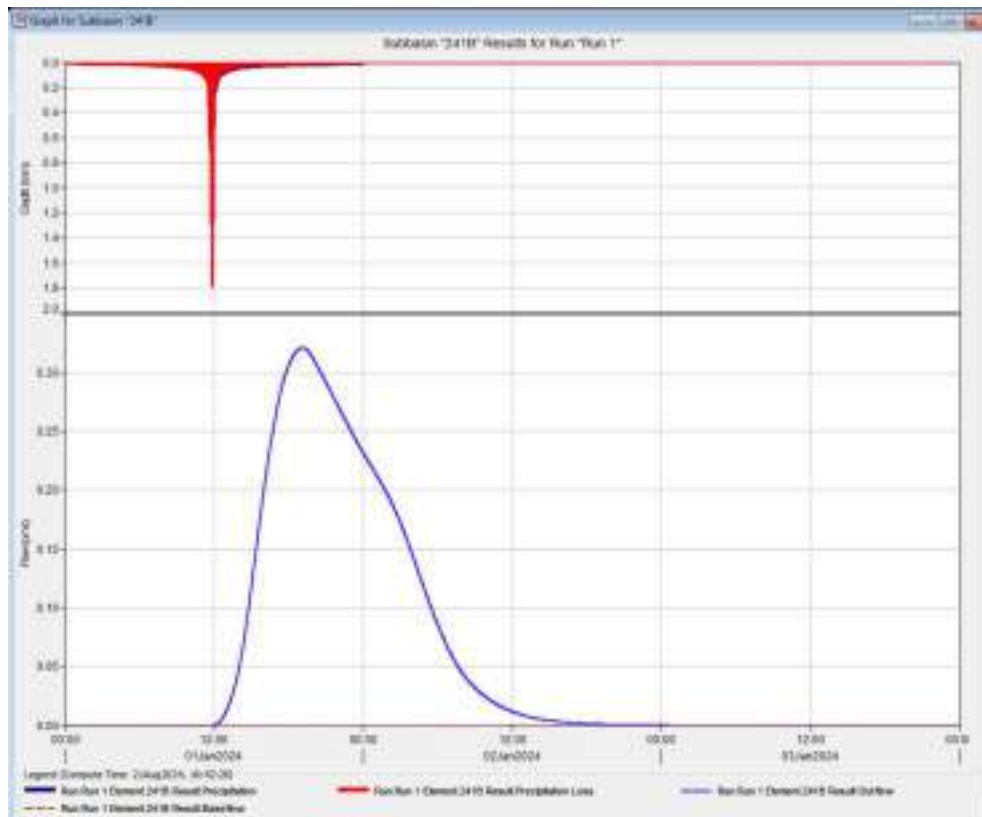


Figure 9-13 Runoff hydrograph from HEC HMS CM-241B

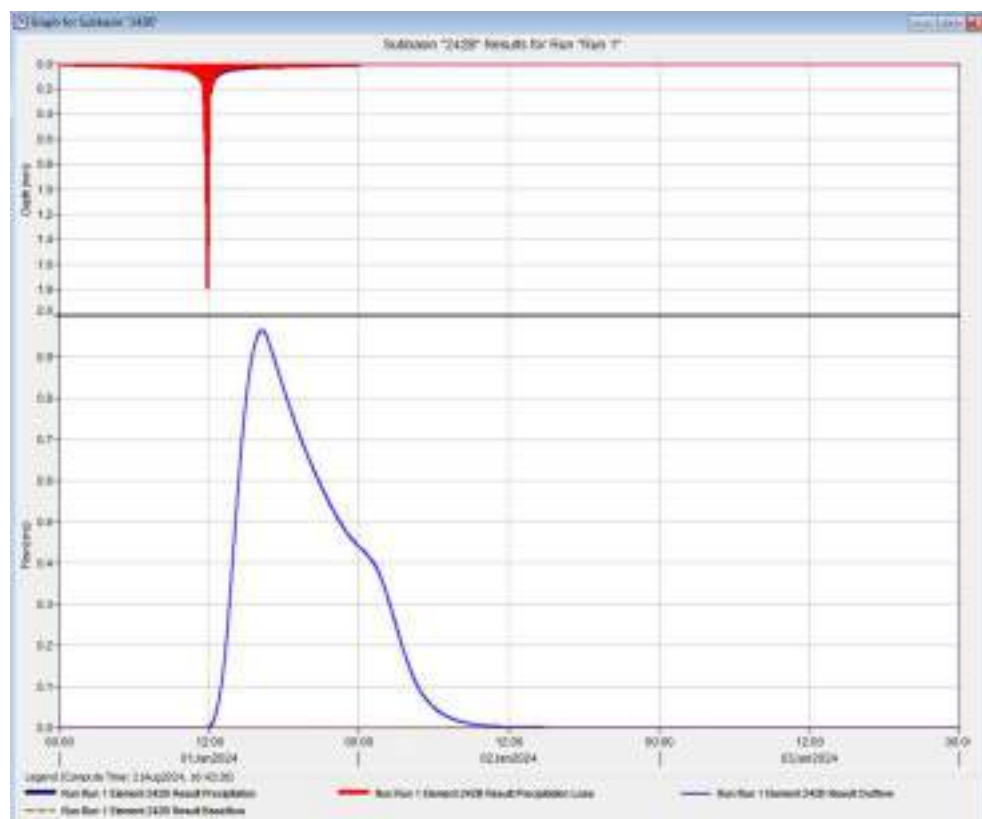


Figure 9-14 Runoff hydrograph from HEC HMS CM-242B

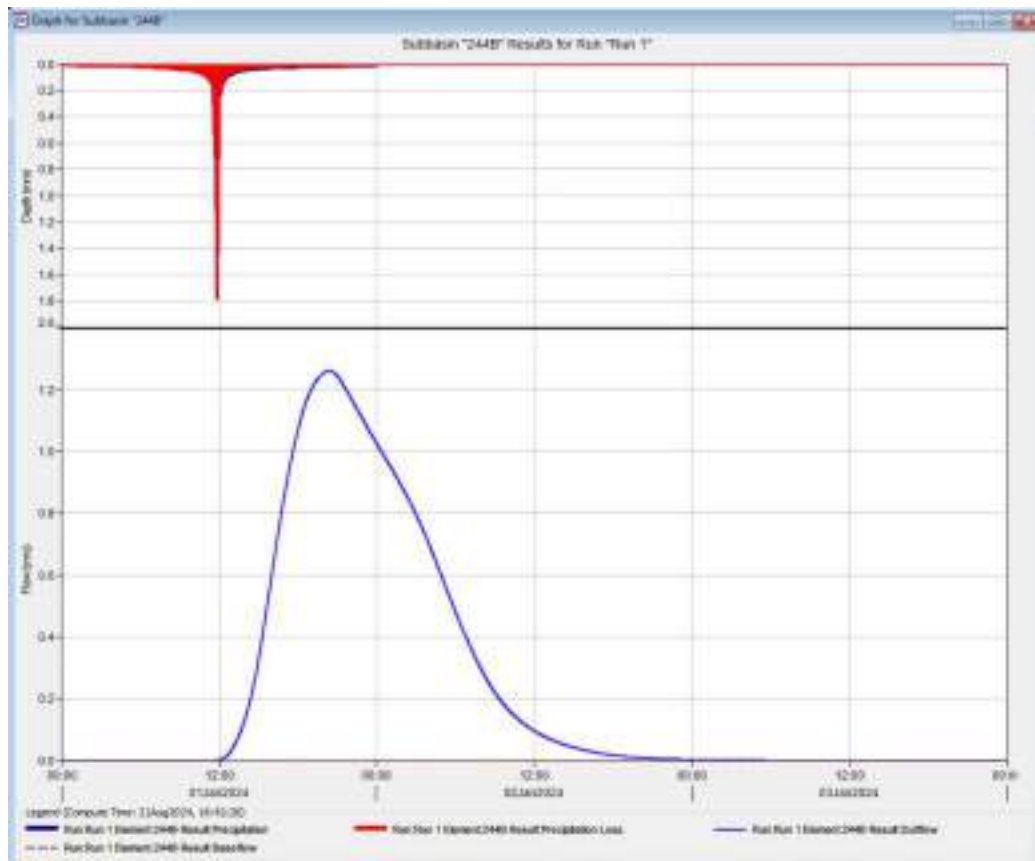


Figure 9-15 Runoff hydrograph from HEC HMS CM-244B

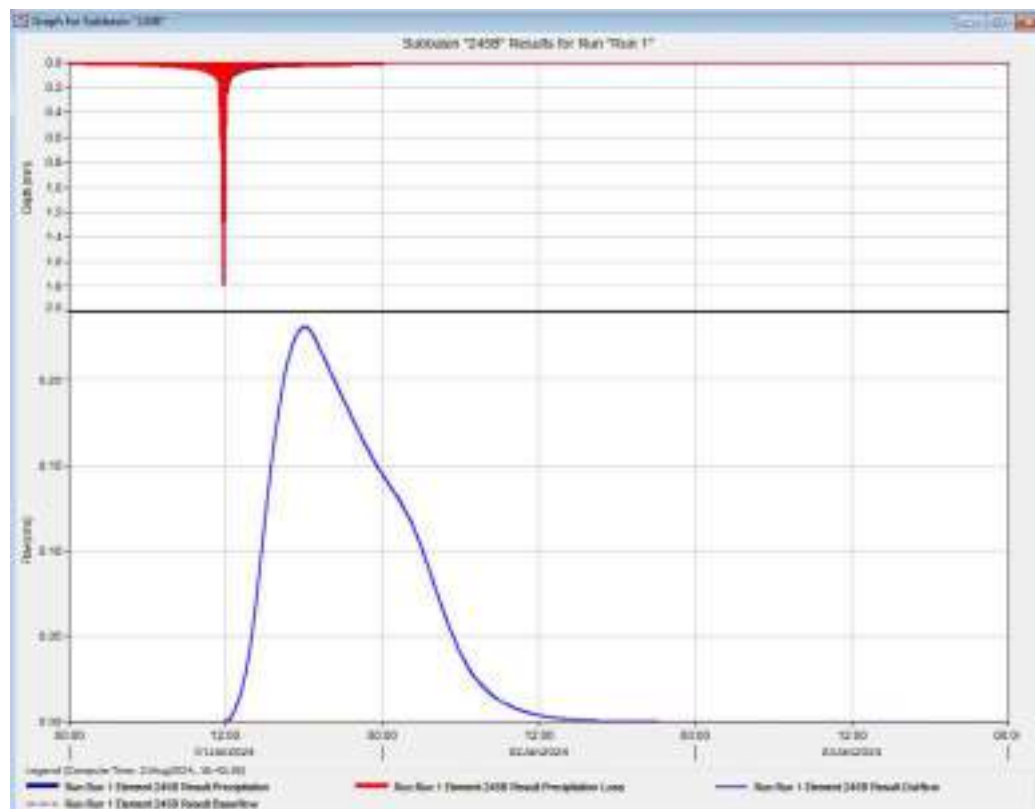


Figure 9-16 Runoff hydrograph from HEC HMS CM-245B

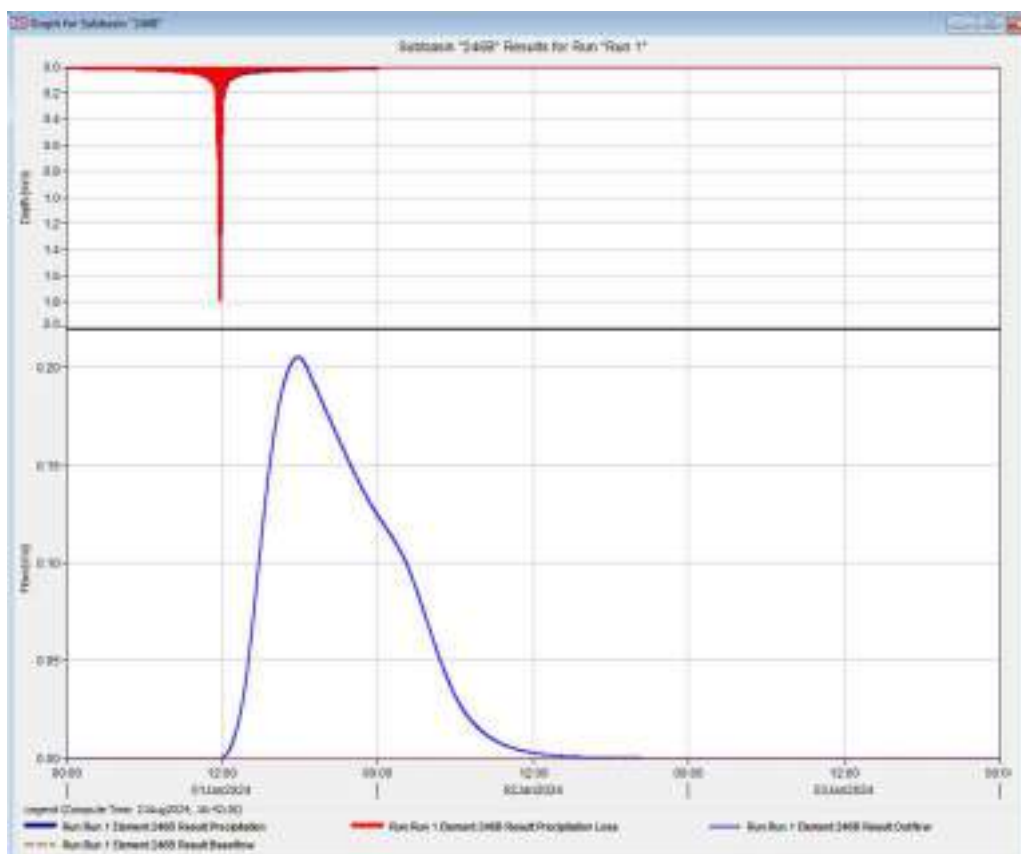


Figure 9-17 Runoff hydrograph from HEC HMS CM-246B

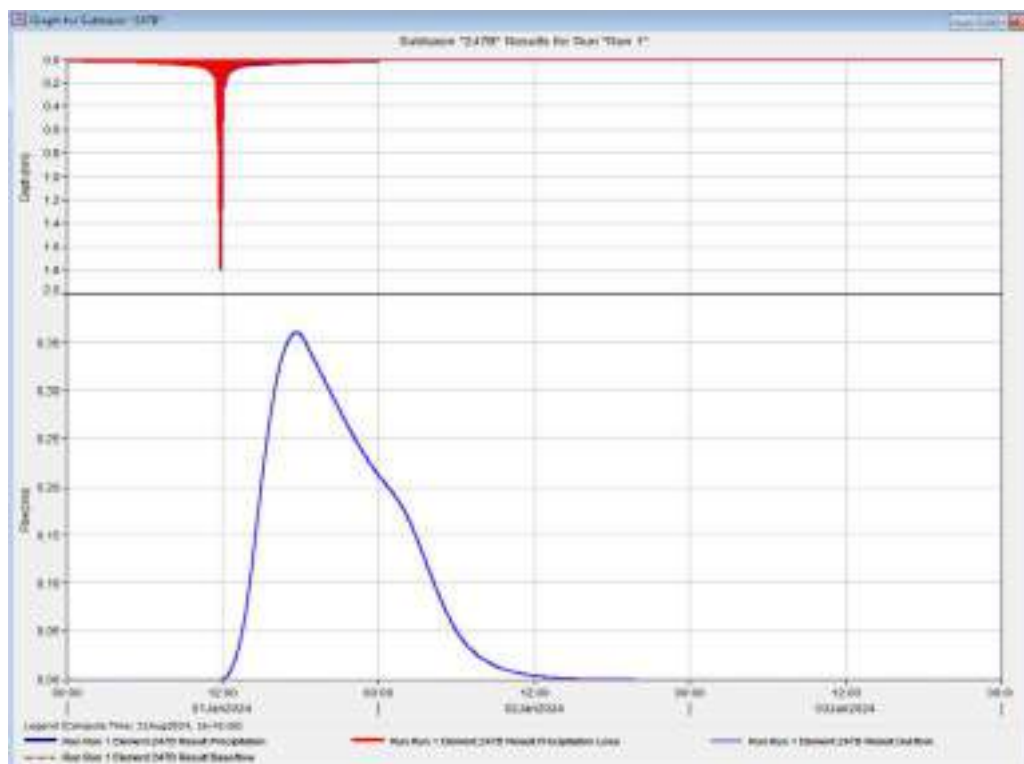


Figure 9-18 Runoff hydrograph from HEC HMS CM-247B

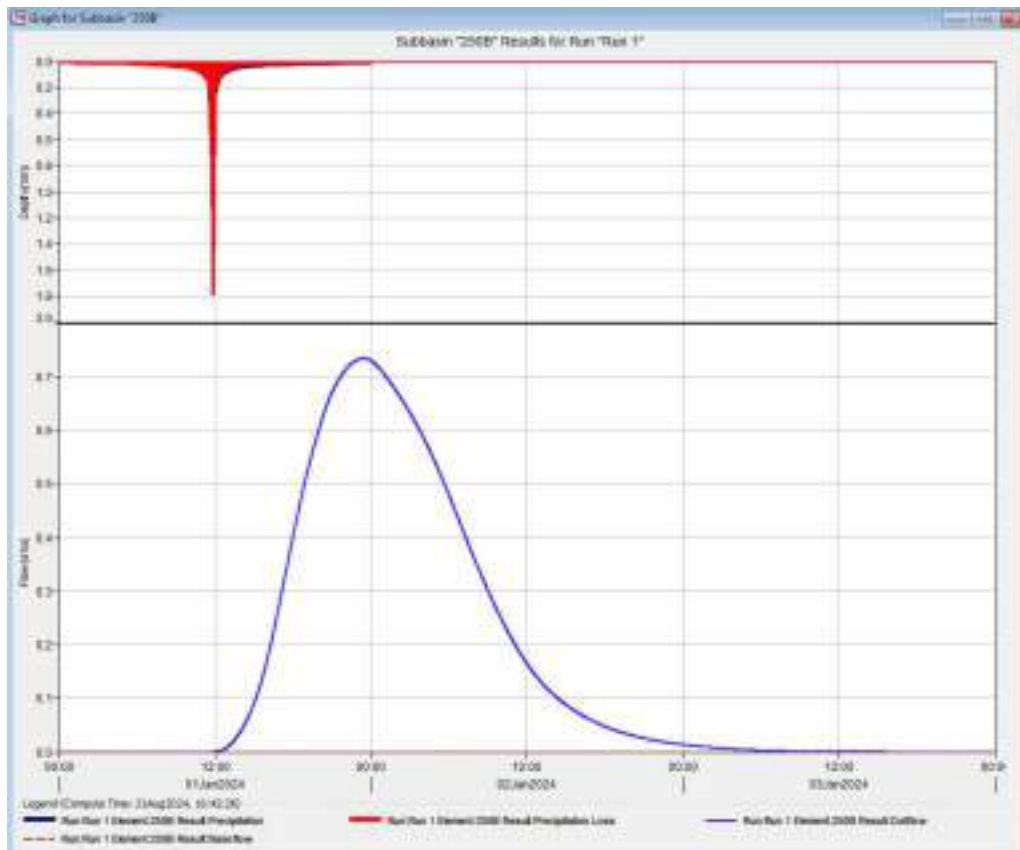


Figure 9-19 Runoff hydrograph from HEC HMS CM-250B

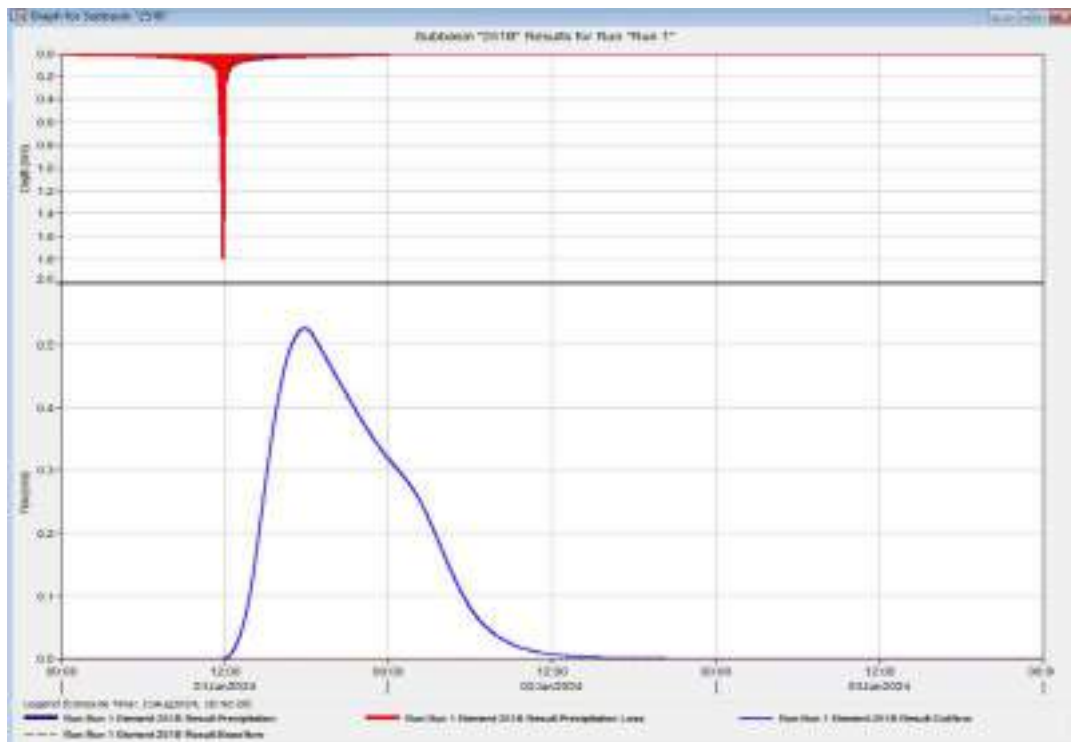


Figure 9-20 Runoff hydrograph from HEC HMS CM-251B

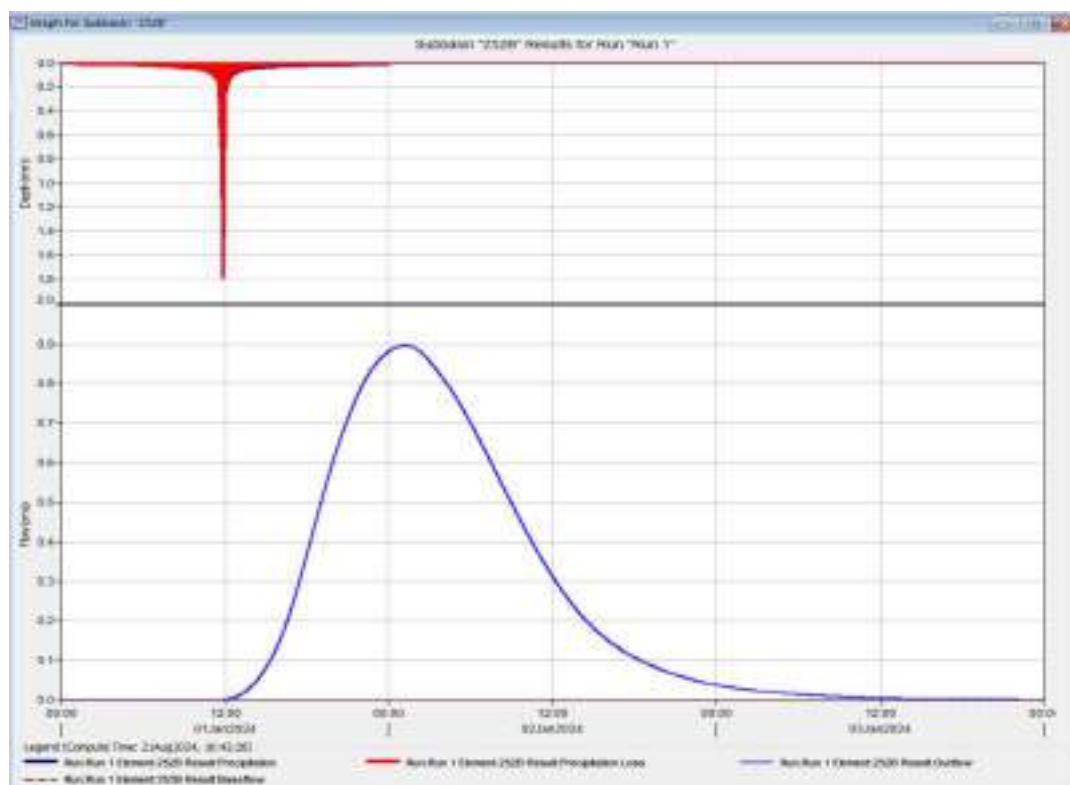


Figure 9-21 Runoff hydrograph from HEC HMS CM-252B

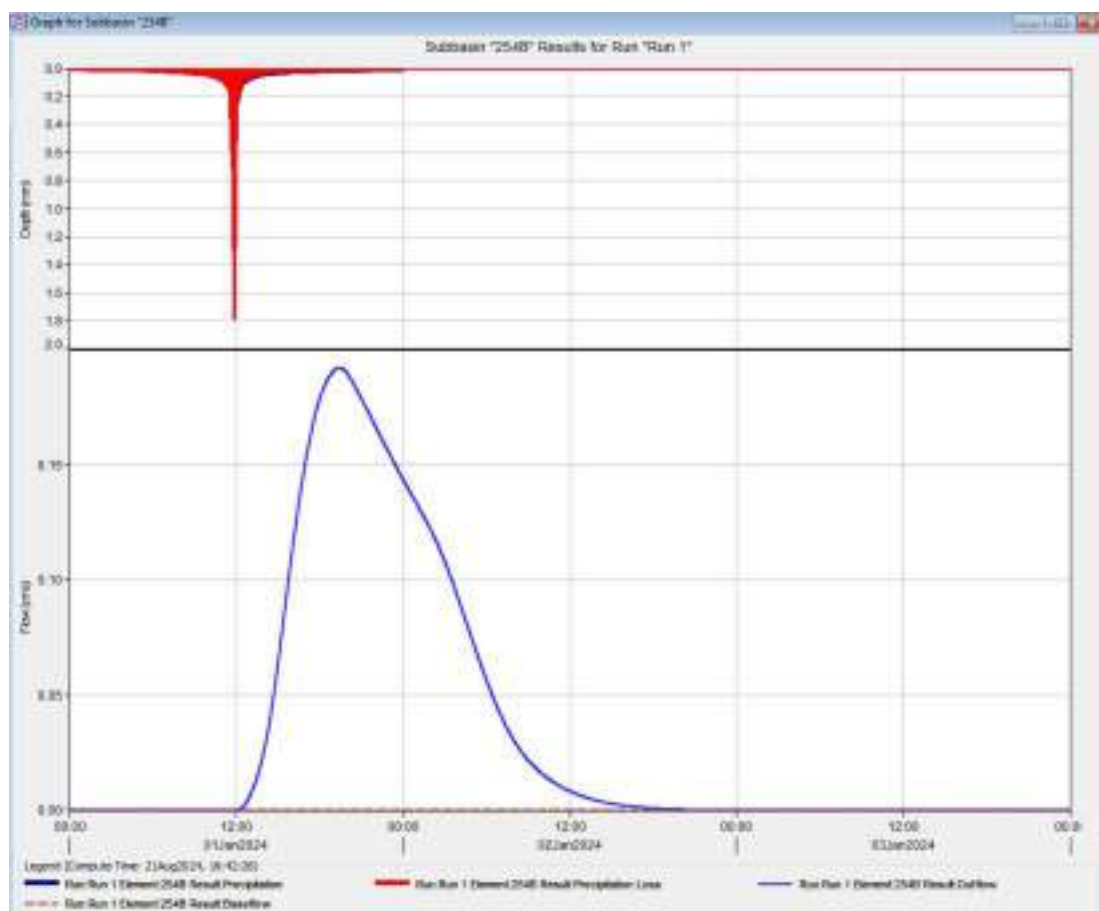


Figure 9-22 Runoff hydrograph from HEC HMS CM-254B

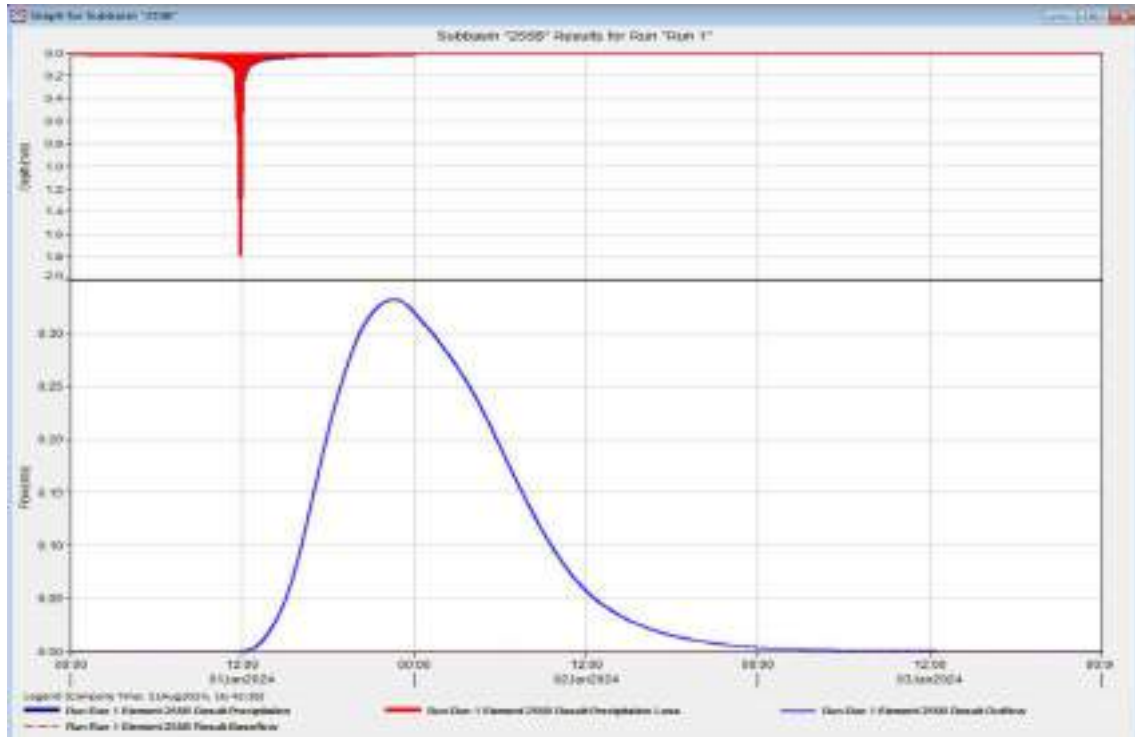


Figure 9-23 Runoff hydrograph from HEC HMS CM-255B

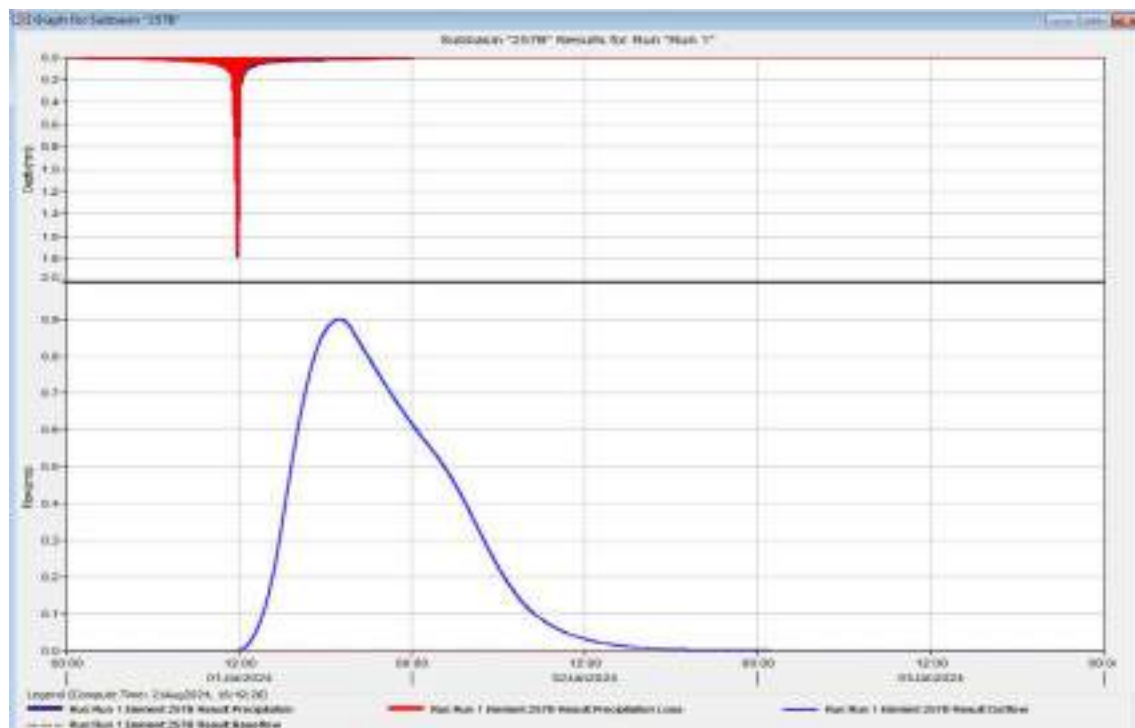


Figure 9-24 Runoff hydrograph from HEC HMS CM-257B

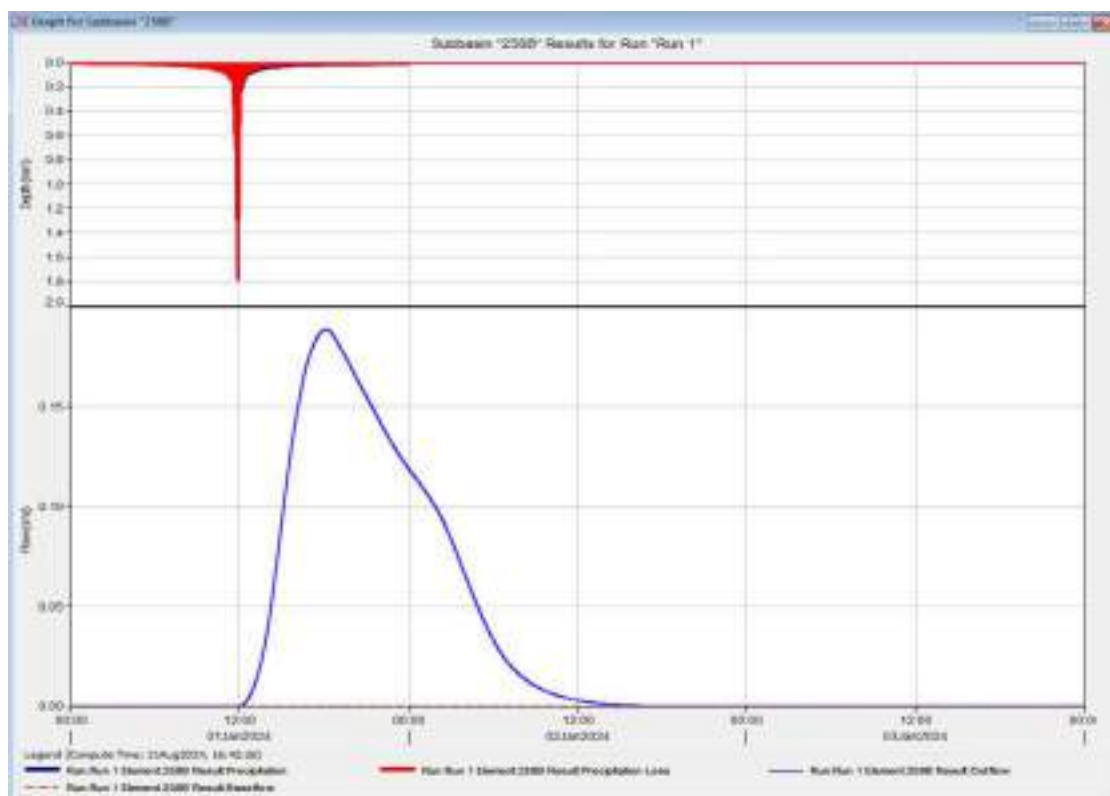


Figure 9-25 Runoff hydrograph from HEC HMS CM-258B

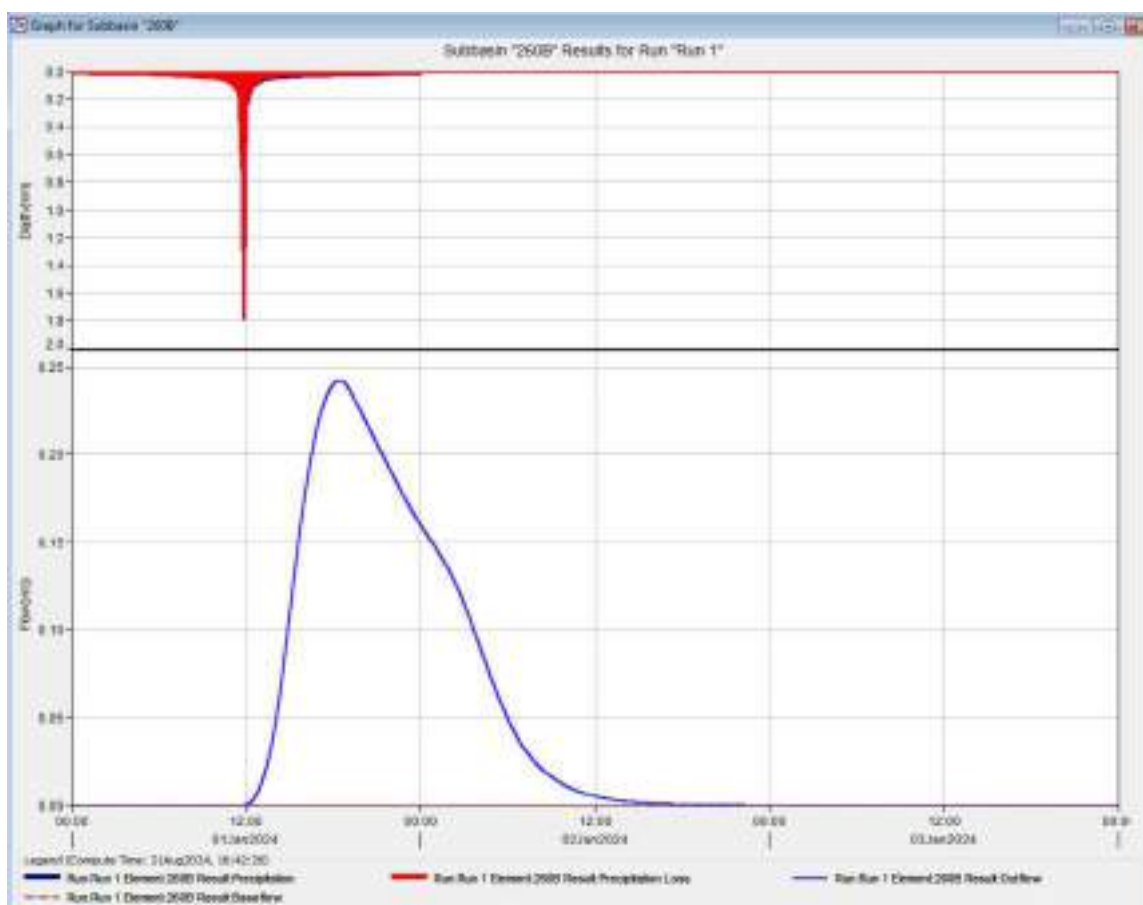


Figure 9-26 Runoff hydrograph from HEC HMS CM-260B

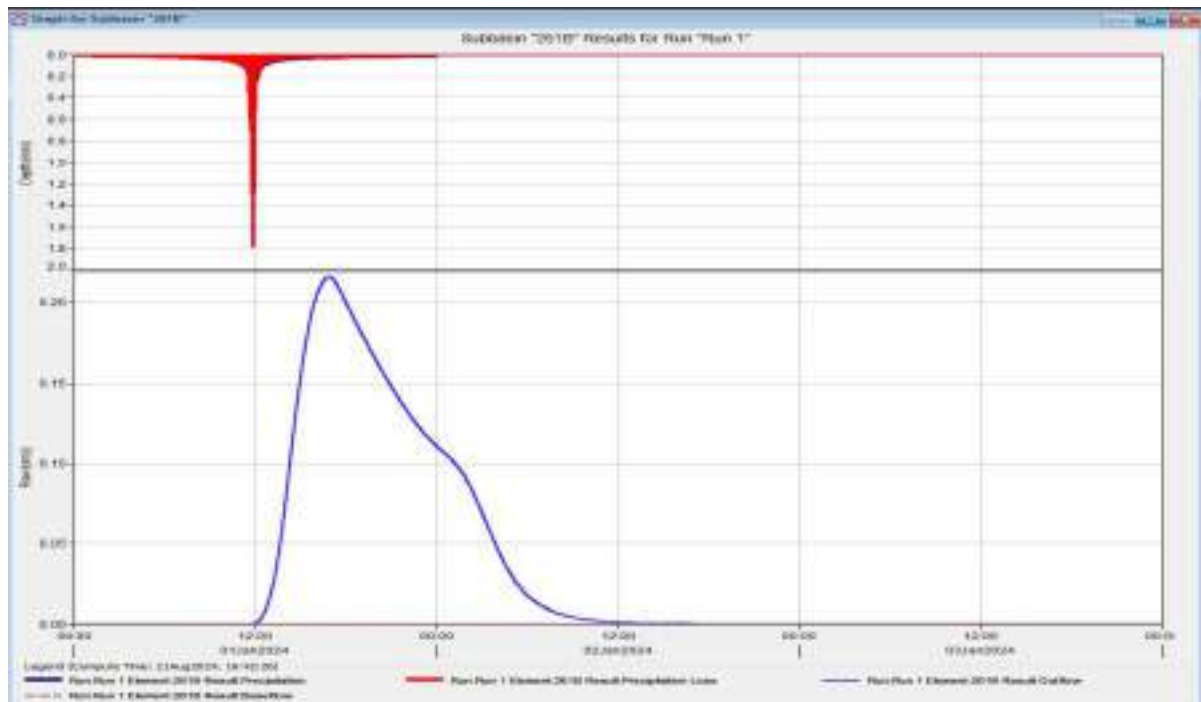


Figure 9-27 Runoff hydrograph from HEC HMS CM-261B

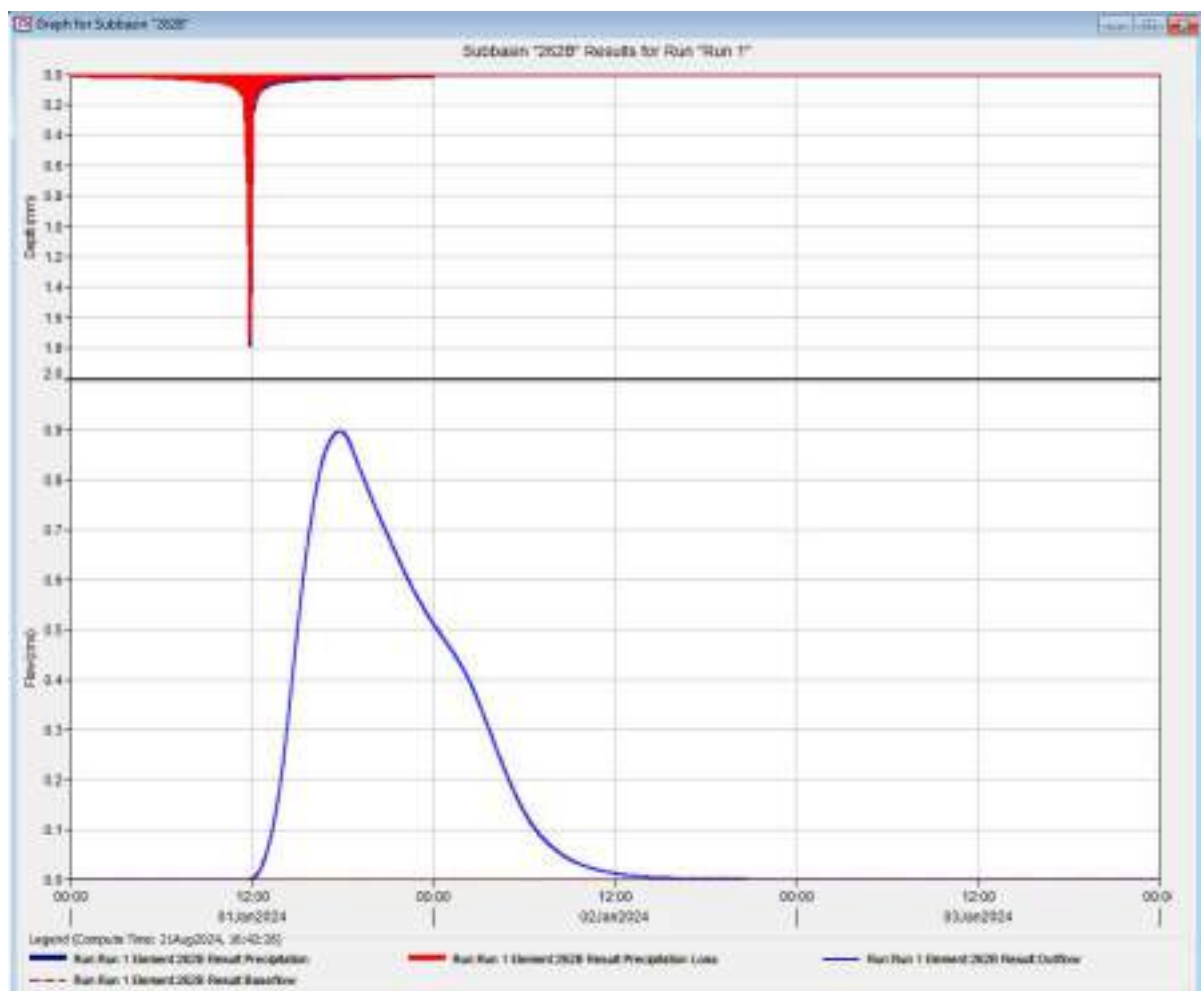


Figure 9-28 Runoff hydrograph from HEC HMS CM-262B

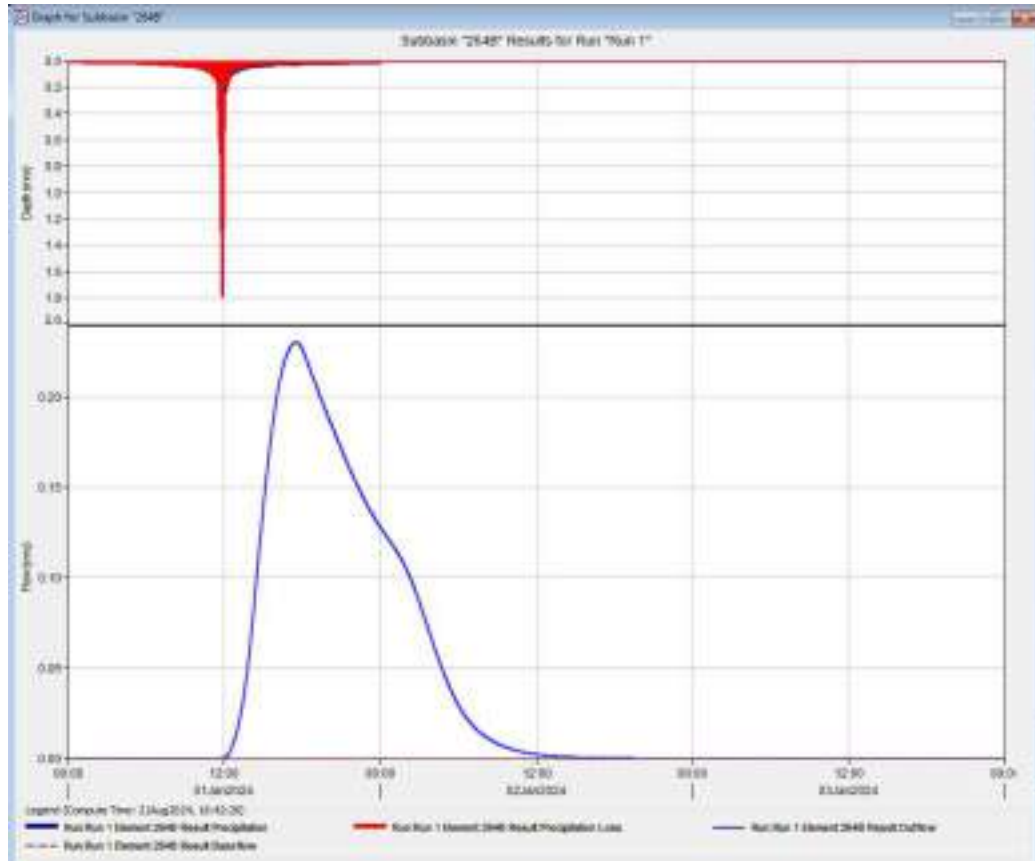


Figure 9-29 Runoff hydrograph from HEC HMS CM-264B

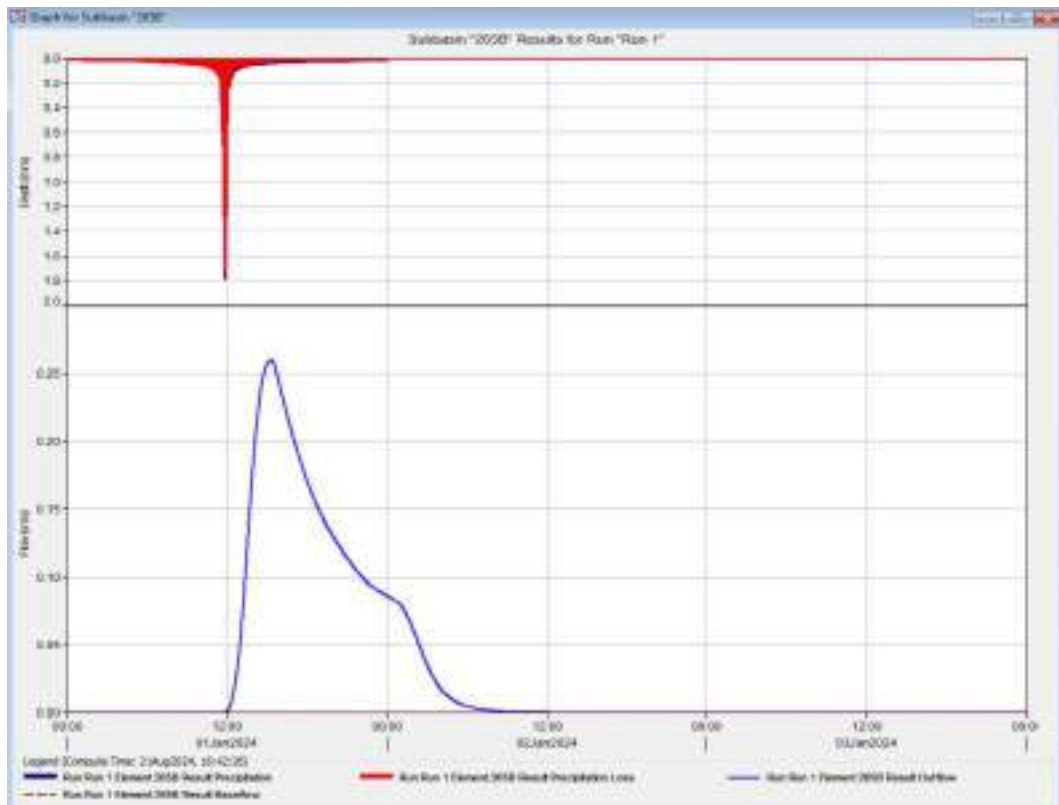


Figure 9-30 Runoff hydrograph from HEC HMS CM-265B

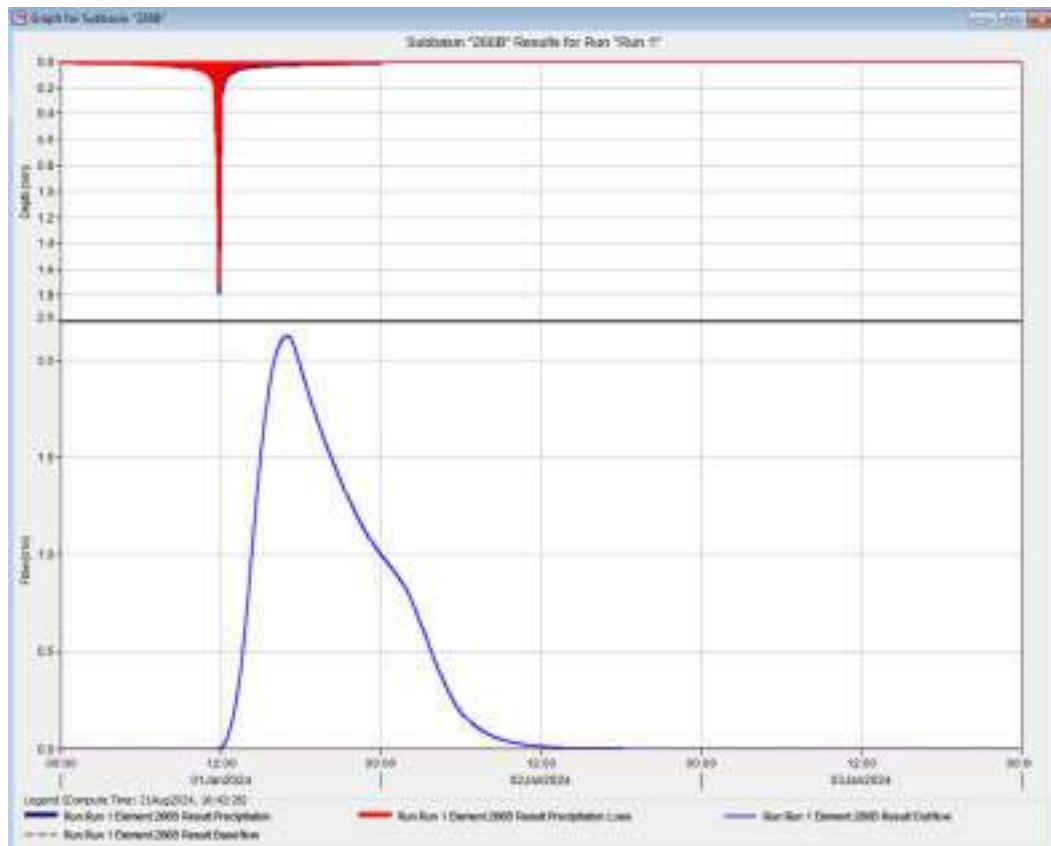


Figure 9-31 Runoff hydrograph from HEC HMS CM-266B

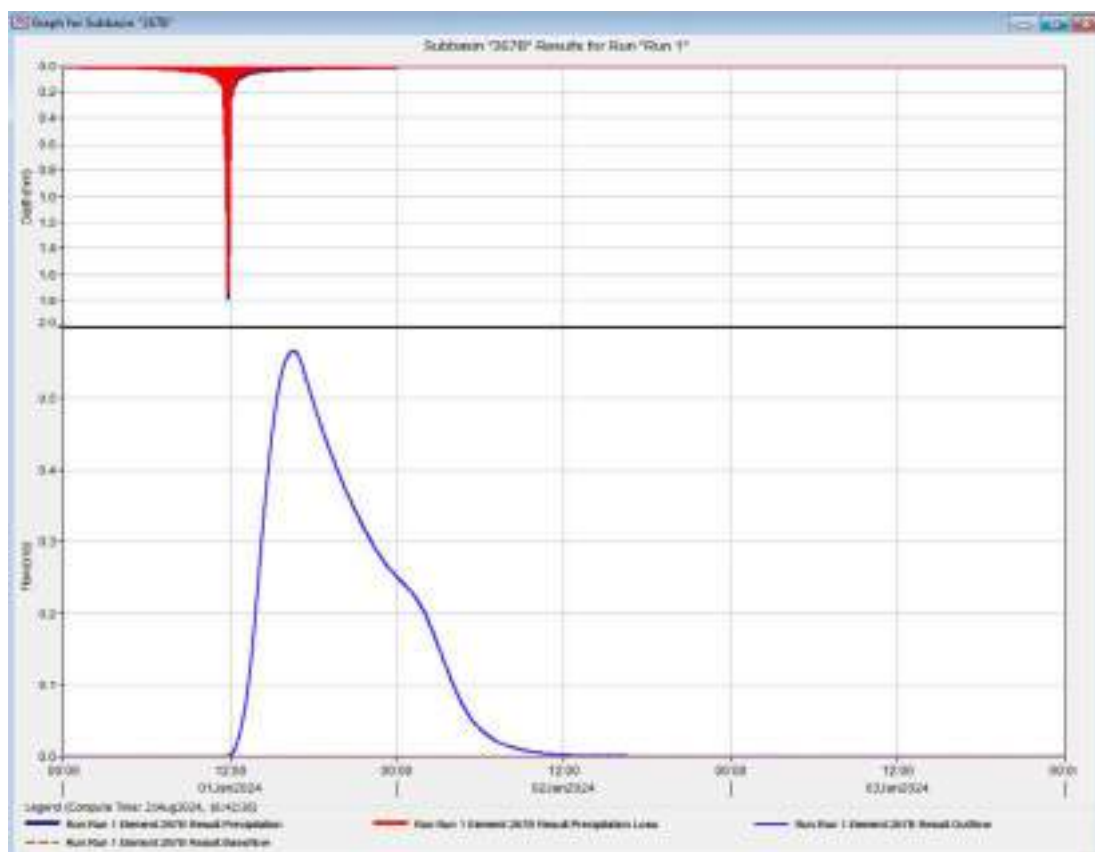


Figure 9-32 Runoff hydrograph from HEC HMS CM-267B

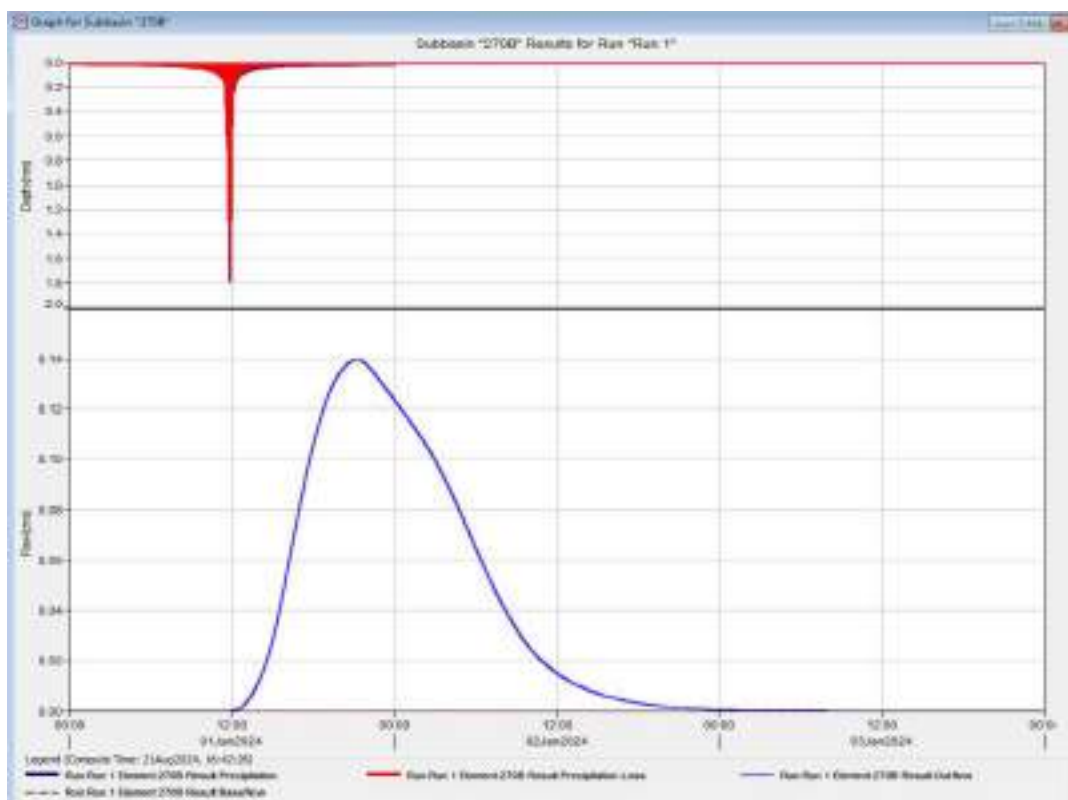


Figure 9-33 Runoff hydrograph from HEC HMS CM-270B

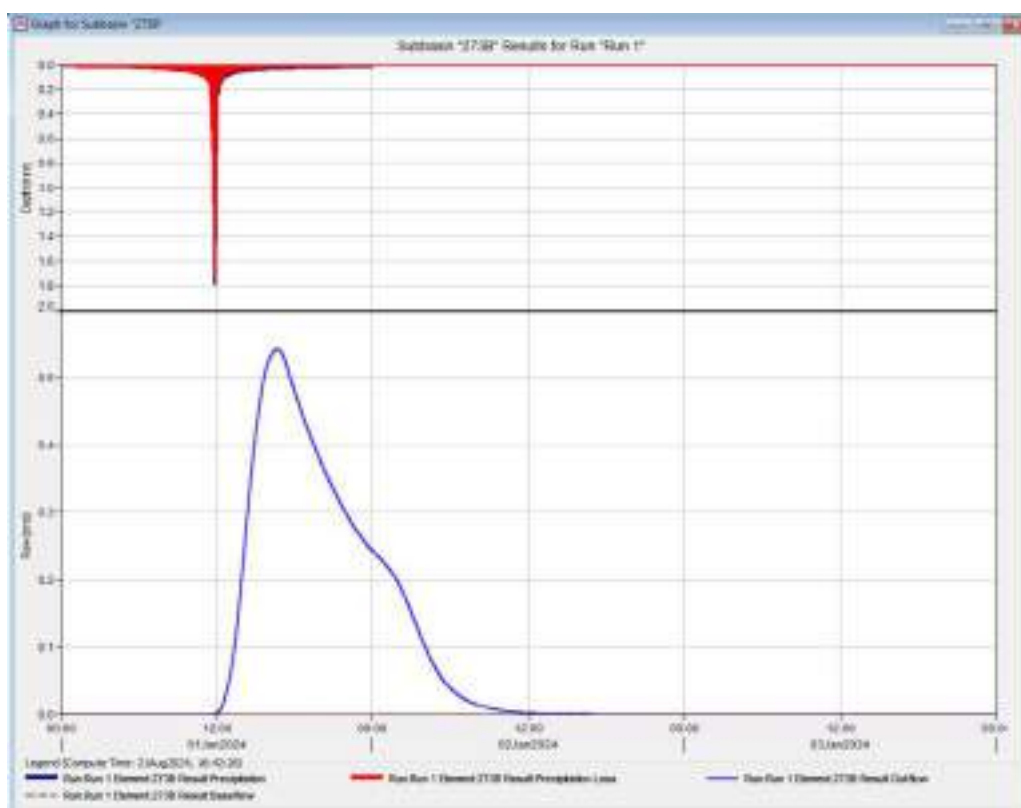


Figure 9-34 Runoff hydrograph from HEC HMS CM-273B

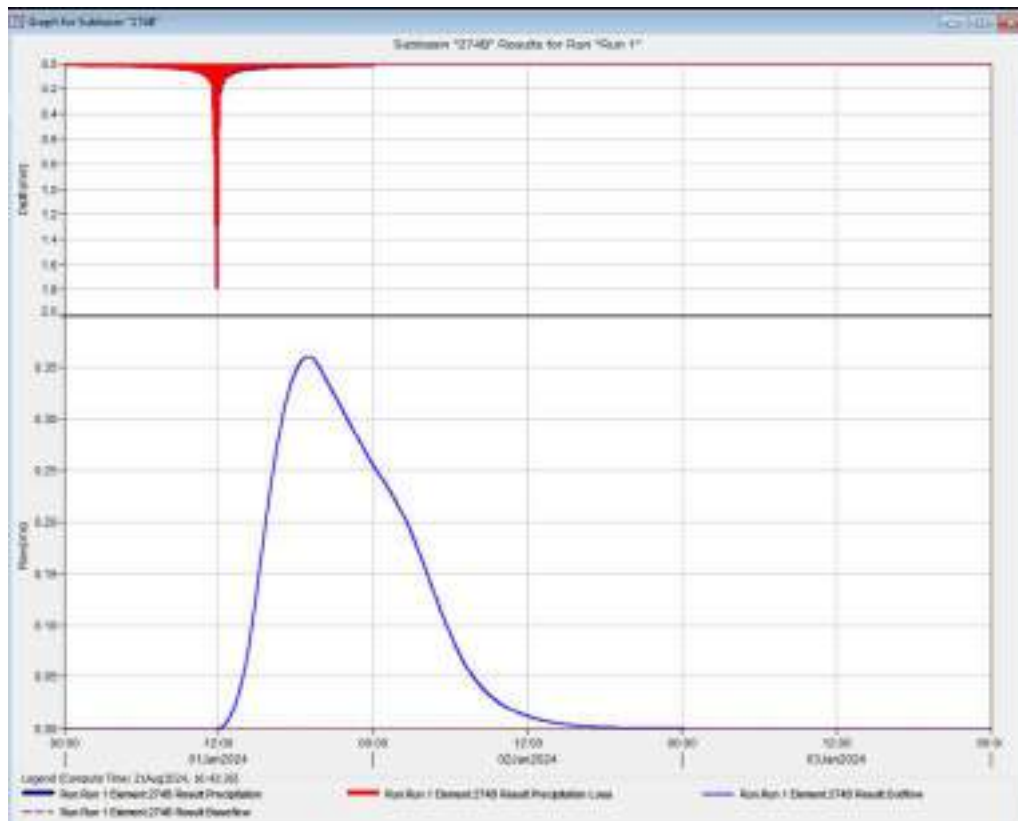


Figure 9-35 Runoff hydrograph from HEC HMS CM-274B

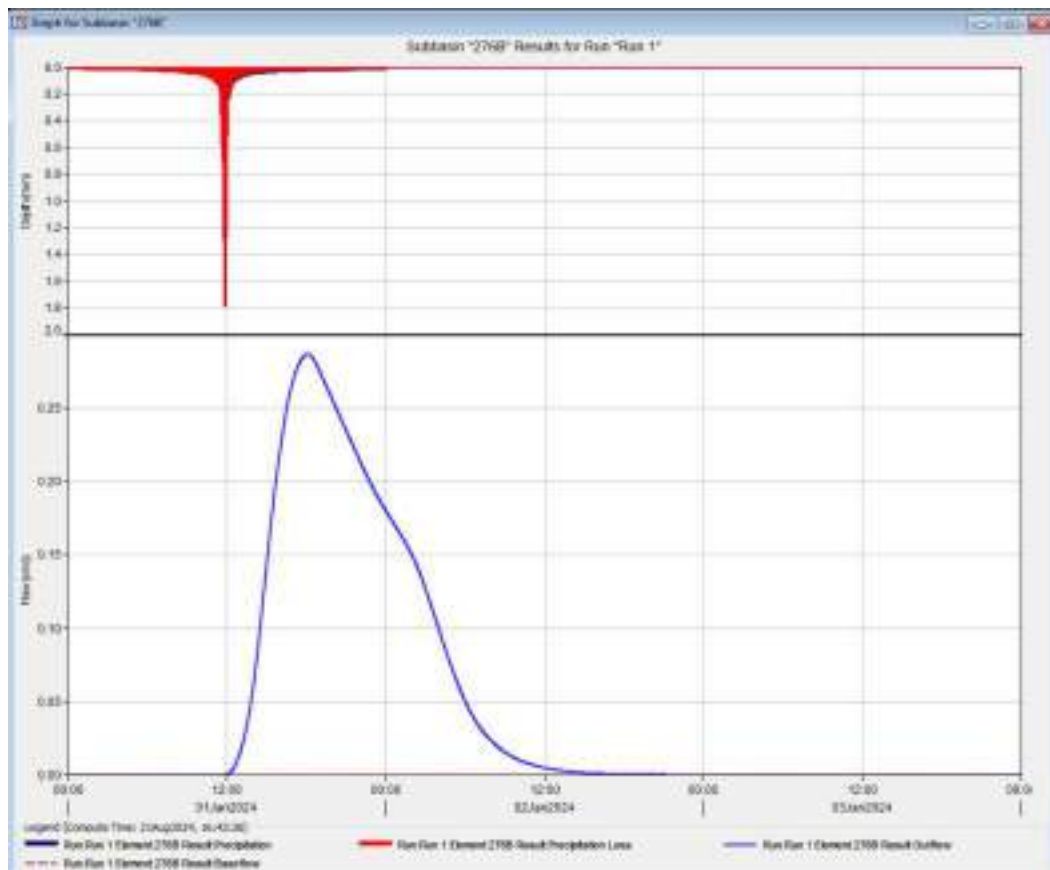


Figure 9-36 Runoff hydrograph from HEC HMS CM-276B

9.6.4 Rational method Calculation at RP 100 years (sub catchment)

Based on the established design criteria in section 9.4 Hydrologic method of the report, the Rational Method was utilized to calculate peak flow for catchments with an area of less than 1 Km². The catchments for which this method was used are specified in table 9-6, which includes catchment parameters defining the calculation method that will be used for each catchment. The Rational Method is based on the assumption that the intensity of rainfall is constant throughout the duration of the storm, and the rate of runoff from the catchment is proportional to the amount of rainfall that falls on it. This method uses a rational runoff coefficient to quantify the fraction of rainfall that will become runoff, and the catchment area and rainfall intensity to calculate the peak flow rate. The peak flow rates calculated using this method were used in the hydraulic design of flood protection works.

The table presented below displays the outcomes of the computation carried out using the Rational Method.

Table 9-7 Rational Method Calculation (sub catchment)

CM Name	Area Km ²	Area (ha)	L (m)	S (m/m)	Tc (min)	I (mm/hr)- 1in 100 Years	Rational (C)	Rational Q (m ³ /s)
232B	0.401	40.08	3113.8	0.012	52.02	33.32	0.4	1.48
236B	0.768	76.81	3277.6	0.010	58.96	30.60	0.4	2.61
237B	0.437	43.67	2398.9	0.018	36.82	42.14	0.2	1.02
238B	0.331	33.14	1798.2	0.005	47.75	35.32	0.2	0.65
239B	0.005	0.47	137.1	0.183	10.00	88.92	0.2	0.02
240B	0.616	61.60	2410.5	0.010	46.50	35.96	0.2	1.23
243B	0.248	24.80	1592.1	0.004	47.17	35.62	0.4	0.98
248B	0.598	59.81	2430.6	0.006	57.01	31.31	0.2	1.04
249B	0.728	72.83	2739.4	0.008	56.78	31.40	0.3	1.91
253B	0.006	0.62	135.6	0.113	10.00	88.92	0.4	0.06
256B	0.793	79.30	4066.9	0.007	79.24	25.03	0.2	1.10
259B	0.398	39.77	2300.7	0.005	60.44	30.09	0.4	1.33
263B	0.497	49.67	4317.2	0.009	76.76	25.57	0.2	0.71
268B	0.650	65.03	4141.2	0.007	82.43	24.36	0.2	0.88
269B	0.561	56.06	2302.1	0.015	38.21	41.10	0.2	1.28
271B	0.809	80.94	3691.6	0.007	74.44	26.12	0.4	2.35
272B	0.474	47.41	2906.3	0.011	50.75	33.88	0.4	1.78
275B	0.900	89.98	2977.6	0.009	57.43	31.15	0.4	3.11

9.6.5 Final peak flows at RP 100 years (sub catchment)

The following table shows the results of the hydrological study for the catchments affecting the project boundary.

Table 9-8 Catchments Peak Flow (sub catchment)

CM Name	Area Km2	Q peak (m3/s) (1 in 100 years)
231B	1.708	0.5
232B	0.401	1.48
233B	9.624	1.3
234B	1.485	0.2
235B	4.571	1.2
236B	0.768	2.61
237B	0.437	1.02
238B	0.331	0.65
239B	0.005	0.02
240B	0.616	1.23
241B	2.381	0.3
242B	5.556	1
243B	0.248	0.98
244B	9.057	1.3
245B	1.591	0.2
246B	1.386	0.2
247B	2.399	0.4
248B	0.598	1.04
249B	0.728	1.19
250B	6.937	0.7
251B	3.558	0.5
252B	9.168	0.9
253B	0.006	0.06
254B	1.453	0.2
255B	3.007	0.3
256B	0.793	1.10
257B	5.480	0.9
258B	1.299	0.2
259B	0.398	1.33
260B	1.712	0.2
261B	1.333	0.2
262B	4.967	0.9
263B	0.497	0.71
264B	1.366	0.2
265B	1.018	0.3
266B	9.784	2.1
267B	2.646	0.6

CM Name	Area Km2	Q peak (m3/s) (1 in 100 years)
268B	0.650	0.88
269B	0.561	1.28
270B	1.180	0.1
271B	0.809	2.35
272B	0.474	1.78
273B	2.503	0.5
274B	2.646	0.4
275B	0.900	3.11
276B	1.973	0.3

10. HYDRAULIC ANALYSIS

10.1.1 1D/2D Hydraulic Modeling

Hydraulic modeling shall be used to calculate surface water rise, flood depth, velocity and flood extent. Models may represent one-and two-dimensional flowing water. In general, two-dimensional modeling is required in flat urban areas. 2D models are more accurate in determining stream limits, flow depths and velocities compared to the 1D modeling.

The one-dimensional model is suitable for deep valleys surrounded by steep slopes with minimal flows running outside the main stream. It is also suitable for the design of stormwater drainage networks including open channels, boxes, pipes, etc. The one-dimensional model is easy to build on the computer and consumes less time to run the model. However, time and cost shall not outweigh the advantage of better accuracy provided by the 2D models in flat urban sites where demarcation of the boundaries may be subject to many restrictions and constraints.

As for the two-dimensional model, it is allowable to use flood reduction techniques such as trenches, barriers, sidewalks, etc. that are placed at the best locations to reduce land acquisition on both sides of the valley.

The use of 2D model is recommended if the valley is frequently flooding towards populated areas, causing damage to properties and endangering lives. In many studies, the one-dimensional model can be used in some parts of the study (in uninhabited or deep valleys) and then the model results are exported into a two-dimensional one in urban areas.

The 2D modeling capability is available in recent versions of HEC-HMS and HEC-RAS software.

For modeling, various results should be produced as follows:

1. Maximum Flood depth inundation map (Maximum water depth in (m) at each mesh element which occurred during the whole simulation).
2. Maximum Velocity distribution arrows (arrow lengths represent the max velocity value in (m/s) at each mesh element which occurred during the whole simulation while the arrows direction represents the flow direction at each mesh element).
3. Flood Hazard Rating (Maximum Flood Hazard Rating value during simulation).

The definition of "Flood Hazard Rating", based on Defra document FD2321/TR1 phase 1 (Defra, 2006), is a broad consensus that the degree of hazard that floodwaters present to people (and to vehicles and property) is a function of both velocity and depth. There is a number of other physical characteristics that may affect the safety of people during flooding such as water temperature, the presence of "slip" and "trip" hazards such as "blown" manholes covers and the presence of debris. Flood Hazard Rating is calculated using the DEFRA Hazard formula presented in technical reports FD2320/TR2 and FD2321/TR2 along with the "supplementary note on flood hazard rating and thresholds" (Surendran et. Al, 2008):

$$HR = d (v + 0.5) + DF$$

Where:

- d = depth of flooding (m).
- v = velocity of floodwaters (m/s).
- DF = Debris Factor.

Where Debris Factor is assumed to be:

- 0.5 for depths $< 0.25\text{m}$
- 1.0 for depths $> 0.25\text{m}$

Thresholds for Flood Hazard Rating are to be evaluated according to Defra (2006) and Surendran et. al, (2008).

10.1.2 Mixed Hydraulic Models (1D and 2D)

Due to the complexities of the urban and rural environment, the integration between the various hydraulic elements provides accurate and more realistic results compared to reality. In addition, mixed hydraulic models require much less time for calculations than 2D-only models.

Thus, one-dimensional hydraulic modeling can be performed for the stormwater networks, culverts, dams, main valleys or even rivers, as single-dimensional elements where the main flow is in one direction and maintains assumptions of the Saint Vincent equation of the one-dimensional model. However, the two-dimensional model can be used in the case of complex flows.

10.2 2D Hydraulic Analysis using HEC RAS

A 2D hydraulic model can be used in designing of flood protection by providing detailed information about the flow behavior and hydraulic characteristics of the area. The model can simulate the behavior of water during floods and predict the potential areas of erosion and deposition around the project area. With this information, the design of the flood protection can be optimized to provide the required level of protection while minimizing the amount of material needed for construction. The model can also evaluate the performance of different configurations and help in selecting the most suitable design based on the site-specific conditions.

The development of a 2D hydraulic model for flood plains and critical flood hazard areas was based on the results of the hydrologic modelling of the catchment areas and streams.

A Digital Elevation model with an accuracy of $10 \times 10 \text{ m}$ was used for this purpose.

HEC-RAS was utilized to develop the 2D model, which determined the flood plains and critical flood hazards within the study area.

The maximum flood extents and maximum flow velocity for a 1 in 100 years storm event were shown in the figures below for the wadi located within the project area.

These findings provide a high level of confidence in the outcomes of the modelling, ensuring accurate results and appropriate flood hazard mitigation measures.

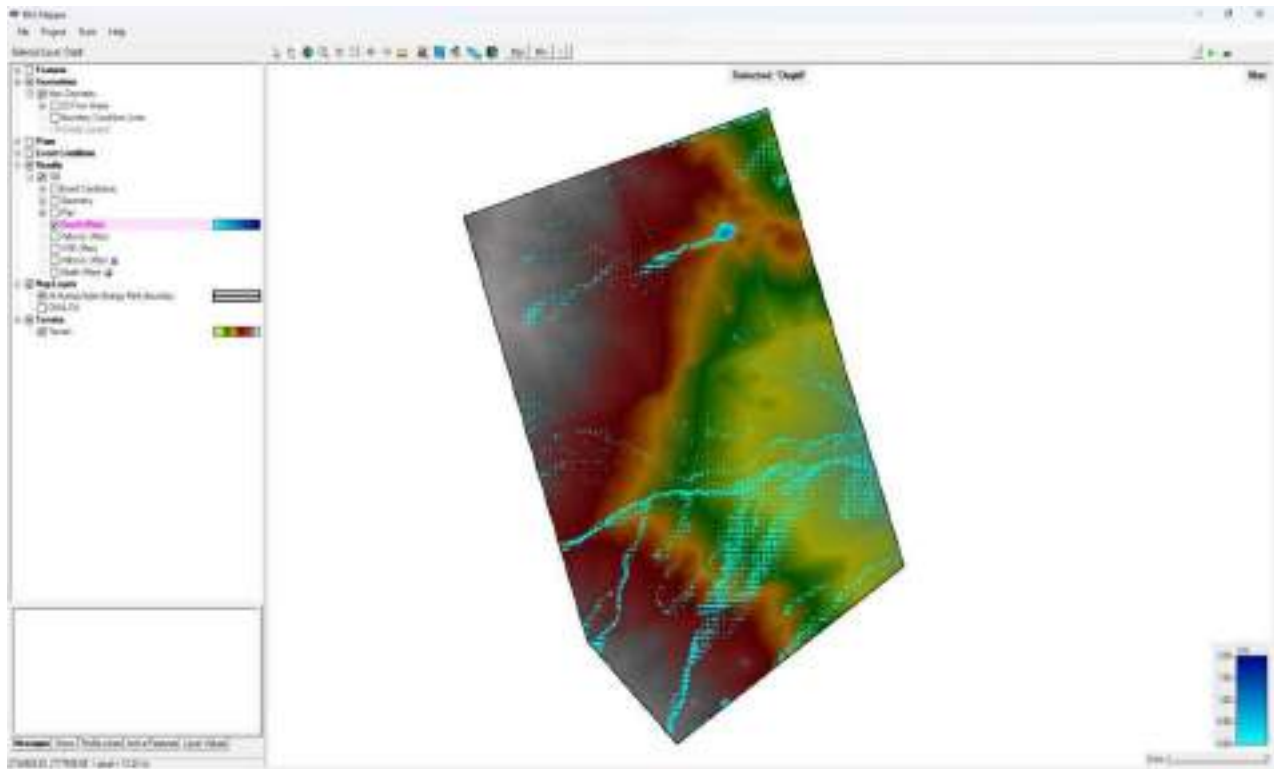


Figure 10-1 Maximum Flood Depth from HEC-RAS

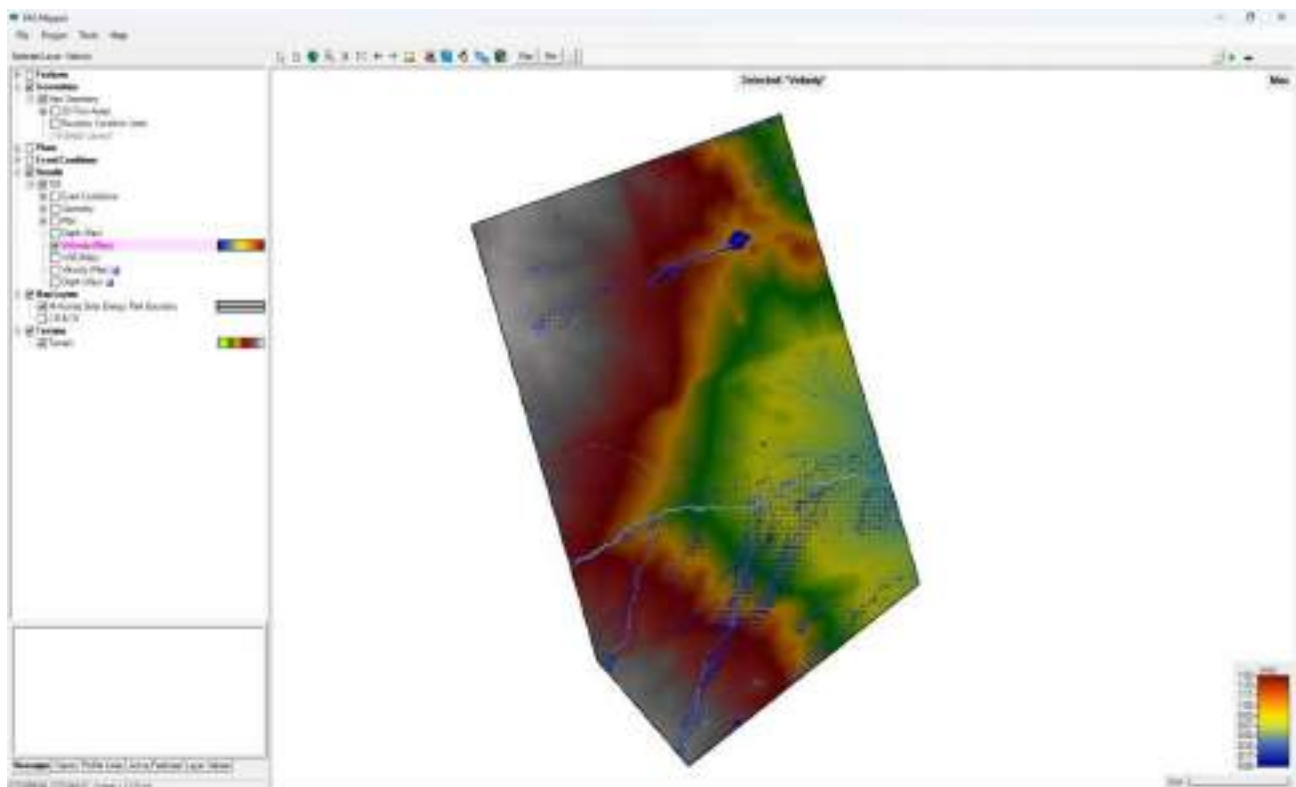


Figure 10-2 Maximum Flow Velocity from HEC-RAS

11. FLOOD RISK ASSESMENT

The flood risk assessment is an essential step in evaluating the potential impact of floods on the project and developing appropriate mitigation measures. The previous sections of the report provide the necessary data and information, including topography, hydrology, geology, and soil types, which are crucial inputs in flood risk assessment. The flood risk assessment aims to identify flood hazards, assess their potential impact on the project, and develop appropriate measures to mitigate these risks. The following sections will describe the methodology and results of the flood risk assessment for the project area.

In order to assess the flood risk associated with the project area, a detailed flood hazard mapping was carried out. This section outlines the methods and procedures employed in mapping the flood hazard in the project area. The flood hazard was mapped based on the hydraulic modeling results obtained from HEC-RAS software, combined with Digital Elevation Models (DEMs) and GIS techniques. The flood hazard map was generated to identify the areas within the project site that are susceptible to flood hazards. The mapping also aimed to determine the depth and velocity of the floodwaters and the potential risk to human life, property, and infrastructure. The flood hazard map will be a useful tool for decision-makers to develop effective flood risk management strategies for the project area.

To generate the flood hazard map, we used depth raster and velocity raster data from HEC-RAS software. The DEFRA equation was applied, $H_r = d(v + 0.5) + DF$, where H_r is the flood hazard, d is the depth of floodwater, v is the velocity of floodwater, and DF is the debris factor.

By following these steps, the flood hazard map can be created using HEC RAS and ArcGIS:

1. Prepare the depth and velocity raster in HEC RAS for the specific design event.
2. Calculate the debris factor based on the depth raster using the DEFRA equation. A debris factor of 0.5 is assumed for depths less than 0.25m, and 1.0 is assumed for depths greater than 0.25m.
3. Use the "Con" function in ArcGIS to convert the depth raster to a debris raster using the calculated debris factor.
4. Use the "Raster Calculator" in ArcGIS to combine the depth, velocity, and debris raster into a single hazard raster using the DEFRA equation $HR = d(v + 0.5) + DF$.
5. Classify the hazard raster into different hazard zones based on predefined hazard levels, such as low, medium, and high hazard.
6. Generate a flood hazard map based on the classified hazard zones.

The map can provide valuable information for decision-making, risk assessment, and emergency planning related to flooding in the study area.

The maps below show the maximum flood depth and velocity and the flood hazard zones for the project area, with different colors indicating different levels of flood risk.

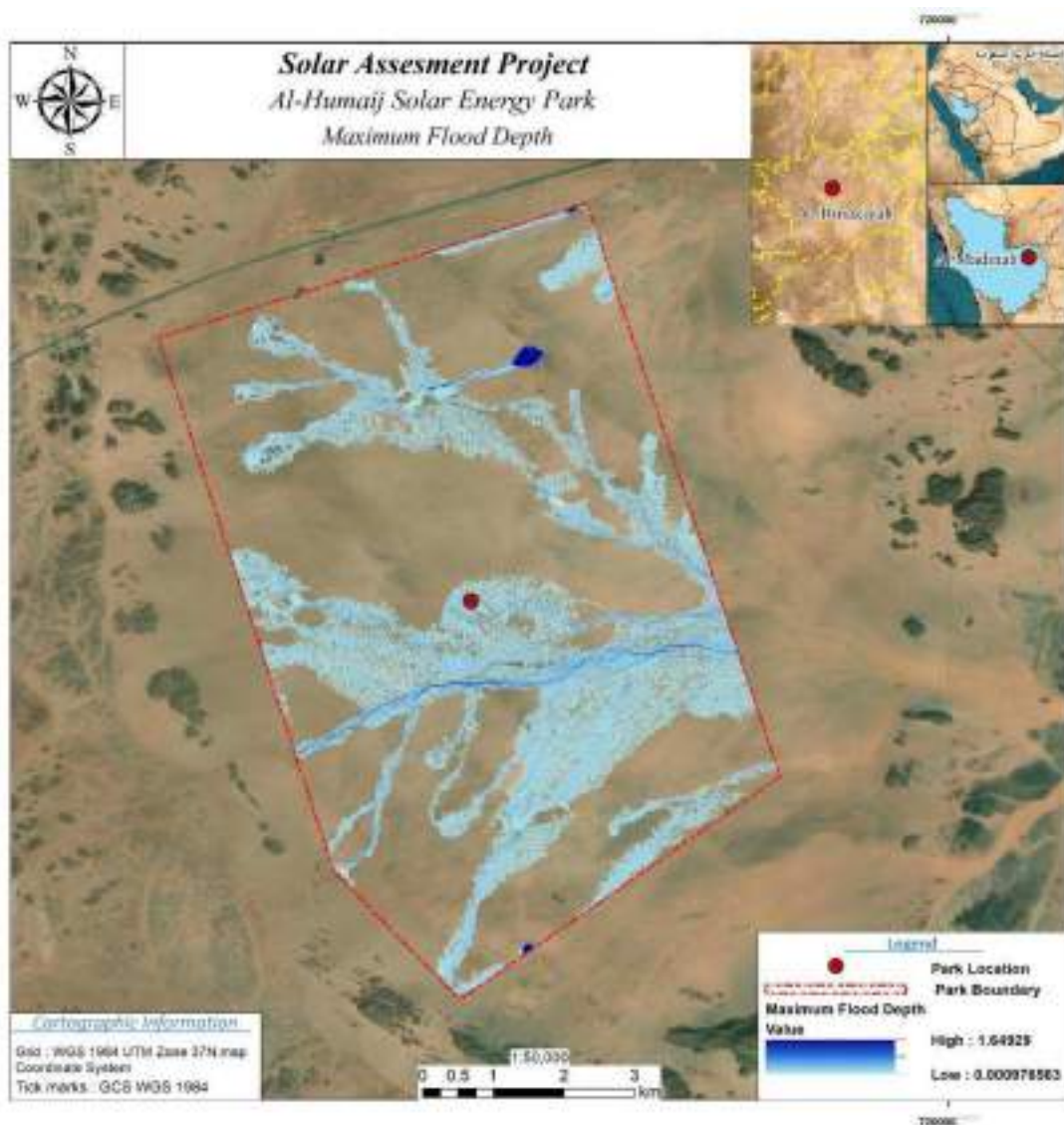


Figure 11-1 Maximum Water Depth in 100 Year

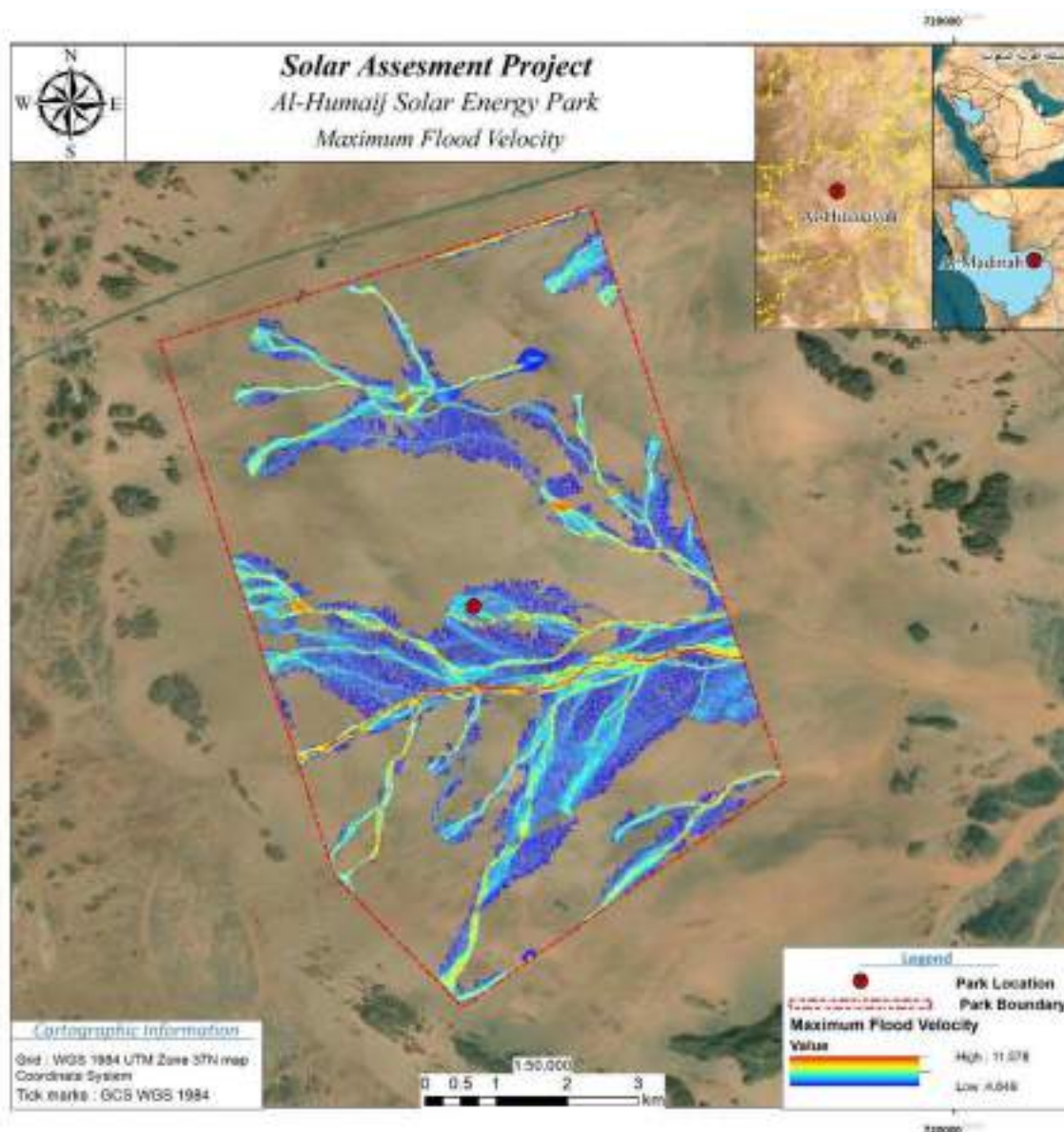


Figure 11-2 Maximum Water Velocity in 100 Year

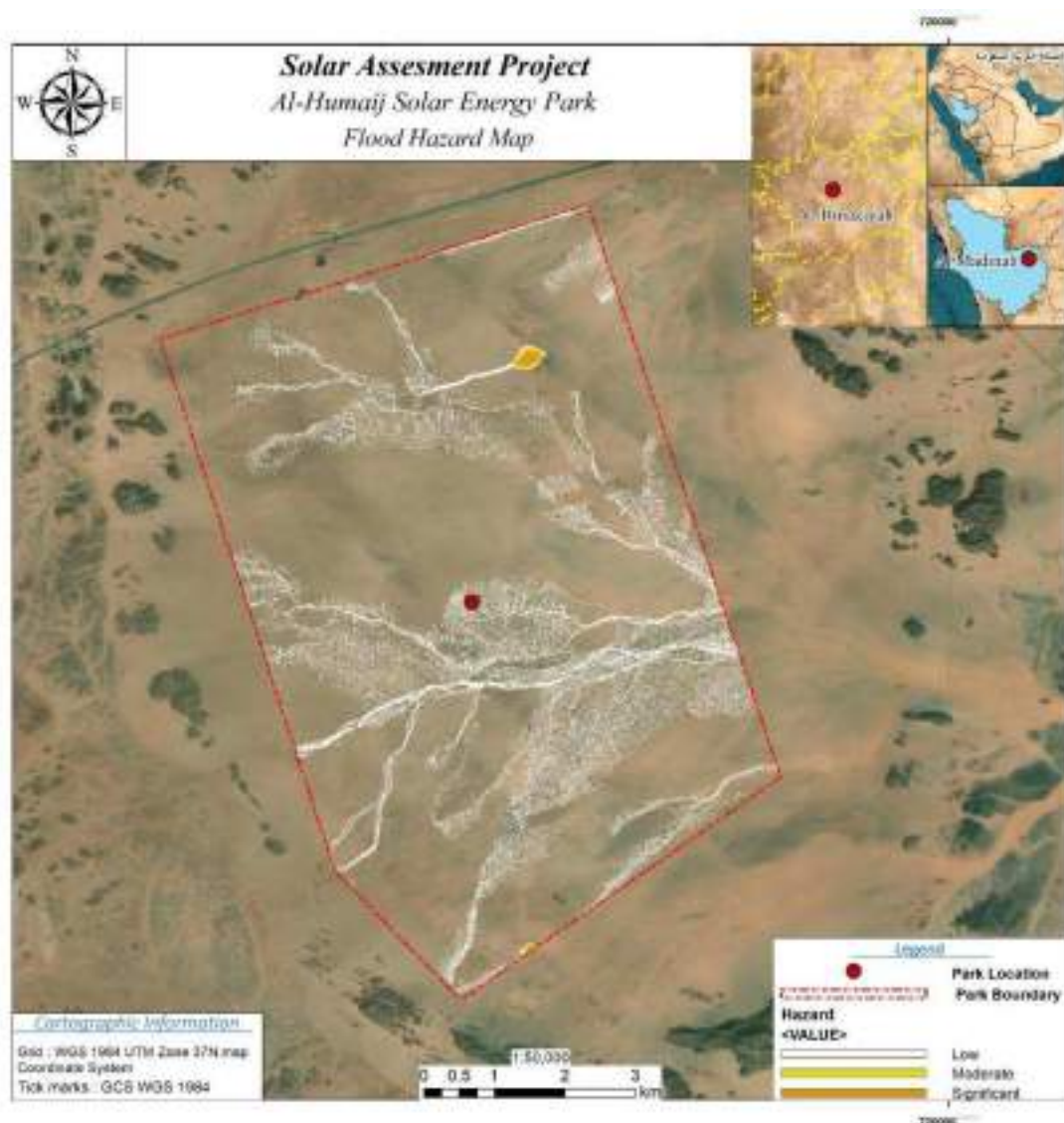


Figure 11-3 Flood Risk Mapping

Table 11-1 Flood Risk Classification

Value of Risk [m ² /s]	Risk Rating Level	Description of Risk
$d \cdot v < 0.75$	Low	Caution. Flood zone with shallow flowing water or deeper standing water, potential trip hazard to pedestrians.
$0.75 \leq d \cdot v \leq 1.25$	Moderate	Danger for some. Potential danger to weaker pedestrians including children and the elderly
$1.25 \leq d \cdot v \leq 2.50$	Significant	Danger for most. Potential danger to most pedestrians and some vehicular users, due to deep or fast flowing water.
$d \cdot v > 2.50$	Extreme	Danger for all. Danger to all pedestrians and vehicular users due to deep and/or fast flowing water.

Table 11-1 Flood risk classification in the Interim Flood Hazard and Mitigation Guidelines by the DEFRA describes the classification based on the value of risk.

According to the data in the table and the flood hazard mapping results for the project area, the level of risk rating is classified as low, and it is described as a "caution" zone with the presence of shallow flowing water or deeper standing water, which could pose a potential trip hazard to pedestrians.

Based on the flood risk assessment, it has been determined that the flood risk level for the project area is low.

This assessment takes into account the topography and drainage patterns of the area, eliminating the need for additional flood protection measures.

12. PROPOSED FLOOD PROTECTION WORKS

As a result of the flood risk assessment, in response to the identified flood hazards and expansive floodplain coverage within the Al Humaij Solar Energy Parks, a flood mitigation plan has been devised.

The design of these measures will take into consideration the potential hazards identified in the flood risk assessment, as well as the expected flood intensity and frequency.

The goal is to provide immunity against flooding events and ensure the safety of the Al Humaij Solar energy parks' assets. The flood protection works will be designed and implemented in accordance with the local and international standards and guidelines, and will be subject to continuous monitoring and maintenance.

Based on the flood hazard mapping results and site observations, it is recommended that the Al Humaij Solar energy park should have flood protection measures in place.

The proposed flood protection method involves the use of flood compatibility zones as the primary strategy. These zones are identified to delineate areas where construction and development should be avoided due to their susceptibility to flooding. By adhering to these zones, the risk of flood-induced damages can be minimized, as potential inundation is confined within predetermined boundaries.

No other options are being proposed because the majority of floods are generated internally. This implies that the main focus is on containing the flooding within the site. The identification of flood compatibility zones serves this purpose by indicating locations where construction is not advisable, thus constraining potential inundation within predefined boundaries. Conversely, the addition of hydraulic structures would not result in significant improvement in flood containment, thereby rendering their inclusion unjustified in terms of cost. Hence, prioritizing flood compatibility zones alone is deemed sufficient, as they effectively mitigate flood risks without necessitating supplementary structures.

12.1 -option 1 Flood Compatibility Zones.

Like flood hazard, flood compatibility mapping is based on estimated flood depths and velocities to inform the suitability for new development or structures based on its vulnerability to flooding.

The flood depth and velocity results for the Design flood event 24-hour event have been used to derive as flood compatibility map as shown in figure below,

The compatibility matrix illustrates the depth and velocity bands at which each vulnerability classification is either:

- Compatible for development;
- Restricted for development, but deemed compatible if the requires scour protection appropriate flood mitigation in placed (Scour and Wash off protection), addressing soil erosion in the highlighted areas by implementing grouted riprap around the footings or using mixed polymer stabilization.
- Not compatible for development

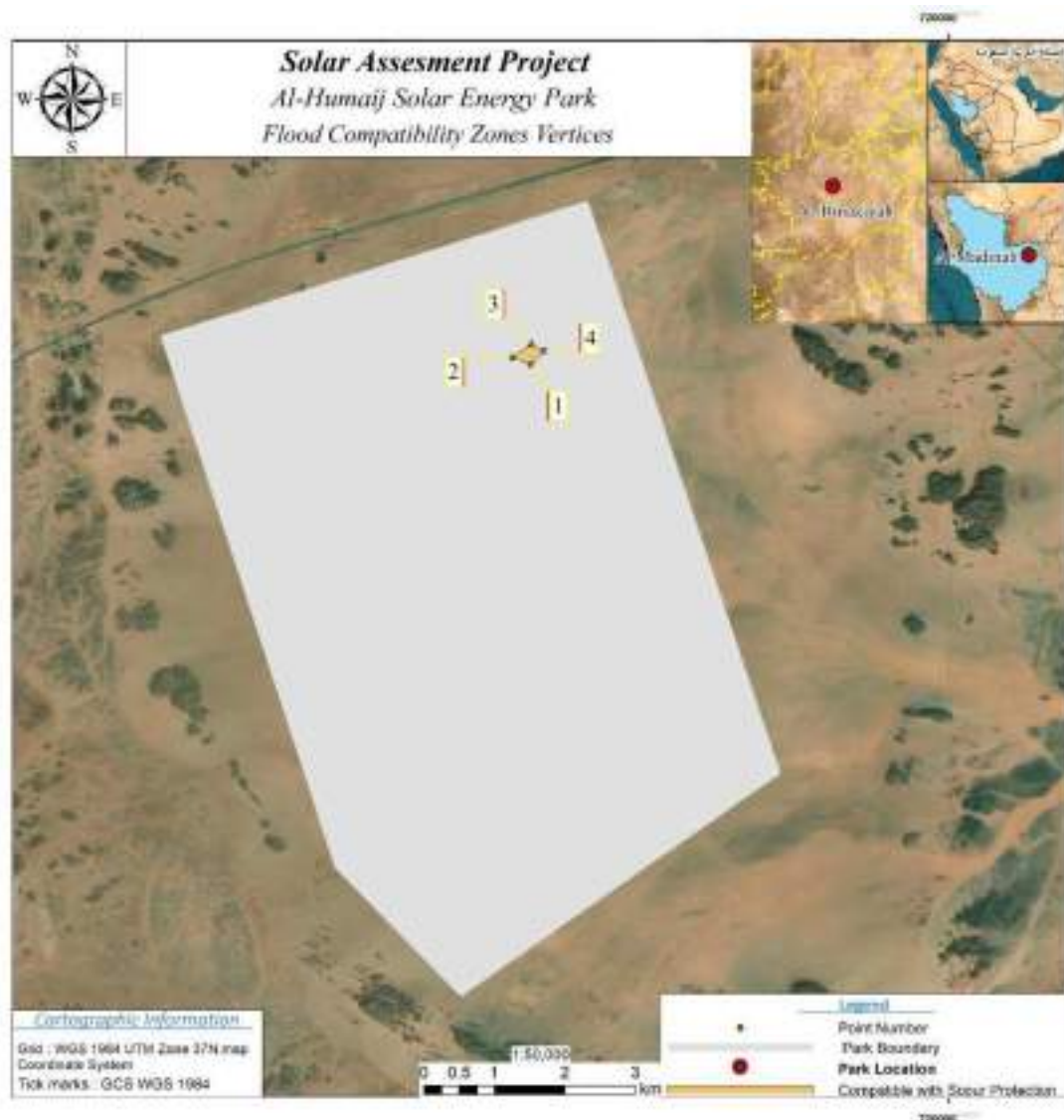


Figure 12-1 Flood Compatibility Zones

Table 12-1 flood compatibility Matrix

Value of Risk [m^2/s]	Risk Rating Level	Compatibility
$d*v < 0.75$	Low	Compatible
$0.75 \leq d*v \leq 1.25$	Moderate	Compatible
$1.25 \leq d*v \leq 2.50$	Significant	Compatible with appropriate flood Protection
$d*v > 2.50$	Extreme	Not Compatible

The Below table Illustrates the vertices of the flood compatibility zones and their coordinates.

Table 12-2 Compatible with Scour Protection Flood Zones Points

Point	Easting (m)	Northing (m)
1	714052.8	2774825.8
2	713790.0	2774921.4
3	714052.8	2775112.5
4	714243.9	2775016.9

12.2 Option2 Grading

The area shaded in orange (Significant) on the map indicates a low-lying region where water accumulates, posing a potential risk to the site.

To mitigate this risk, we recommend raising the ground level in this area by 1.5 meters to a level of [+1080.5m], which will prevent water accumulation and effectively reduce the risk of flooding.



Figure 12-2 option 2 Grading

12-3 Location of Grading Area

Point	Easting (m)	Northing (m)
1	714052.8	2774825.8
2	713790.0	2774921.4
3	714052.8	2775112.5
4	714243.9	2775016.9

13. CONCLUSION AND RECOMMENDATIONS

13.1 Conclusions

The Hydrology Study conducted for the Al Humaij Solar Energy Park has yielded valuable insights into the flood hazards and potential risks associated with the site. Key conclusions drawn from the study include:

- 1 **Flood Hazard Identification:** The analysis identified specific areas within the solar energy park that are prone to flooding, especially during extreme weather events.
- 2 **Hydrological Vulnerabilities:** The hydrological assessment highlighted vulnerabilities in the site's drainage infrastructure, emphasizing the need for tailored flood mitigation measures.
- 3 **Site-Specific Characteristics:** Unique features of the Al Humaij Solar Energy Park, such as topography and land use, significantly influence flood dynamics, necessitating site-specific flood risk management strategies.

13.2 Recommendations:

Based on the identified flood risks flood protection have been proposed. That option aim to ensure the safety of the solar energy park while allowing for its continued development. The recommendations are as follows:

Option1 Flood Compatibility Zones:

- **Development Suitability:** Areas compatible for development have been clearly defined based on flood depth and velocity assessments.
- **Restrictions with Mitigation:** Certain zones, while initially restricted, can be deemed compatible with the implementation of appropriate scour protection and flood mitigation measures.
- **Non-Compatible Zones:** Some areas are deemed unsuitable for development due to high flood risk and are recommended to be avoided.

Option2 Grading:

- A low-lying area on the site has been observed where water accumulates, posing a potential risk to the project. The hydrological consultant has recommended grading this area to ensure proper drainage and mitigate water-related hazards.
- The consultant recommends this solution as it is the most suitable for managing the observed hydrological issues.

In addition to identification of flood compatibility zones to mitigate the impact of external flood events, it is imperative to implement internal grading measures within the site itself. This internal grading aims to address potential hazards arising from internally generated flows, ensuring comprehensive flood protection for the Al Humaij Solar Energy Park. Internal grading measures may include:

1. **Surface Drainage Enhancement:** Improve the surface drainage system within the solar energy park to efficiently channel rainwater away from critical infrastructure and vulnerable areas.
2. **Erosion Control Measures:** Implement erosion control measures, such as reinforced vegetation or stabilizing structures, to prevent soil erosion and the formation of hazardous conditions during heavy rainfall.
3. **Stormwater Management:** Develop a robust stormwater management plan to capture and control excess rainwater.
4. **Internal Flow Path Optimization:** Analyze and optimize the internal flow paths to guide water away from sensitive areas, reducing the risk of flooding within the solar energy park.
5. **Regular Maintenance Protocols:** Establish routine maintenance protocols for drainage to ensure ongoing effectiveness and resilience against internally generated flood scenarios.

By incorporating these internal grading measures, the Al Humaij Solar Energy Park can further enhance its flood resilience, safeguarding against both external and internally generated flood hazards. Regular monitoring and maintenance of these measures will contribute to the long-term effectiveness of the flood protection strategy.

Humaij PV Kingdom of Saudi Arabia

ESIA Addendum



April 2025

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5Cs PROJECT DIRECTOR	Max Burrow

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LIST OF ABBREVIATIONS

ABBREVIATION	MEANING
5 Capitals	5 Capitals Environmental and Management Company
AoI	Area of Influence
CCPI	Climate Change Performance Index
CCRA	Climate Change Risk Assessment
CIA	Cumulative Impacts Assessment
CO₂-eq	Carbon Dioxide Equivalent
CRI	Climate Risk Index
E&S	Environmental & Social
EPC	Engineering, Procurement, and Construction
EPFI	Equator Principles Financial Institutions
EPs	Equator Principles
ESIA	Environmental and Social Impact Assessment
ESMS	Environmental and Social Management Systems
GBVH	Gender Based Violence and Harassment
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GRM	Grievance Redress Mechanism
HR	Human Resource
HRGPs	Guiding Principles on Business and Human Rights
HSE	Health, Safety, and Environment
IFC	International Finance Corporation
ILO	International Labour Organization
IRENA	International Renewable Energy Agency
KSA	Kingdom of Saudi Arabia
KWh	Kilowatt Hours
MEWA	Ministry of Environment, Water and Agriculture
MoL	Ministry of Labour
Mt	Megatonnes
NGSA	National Grid SA
ODS	Ozone Depleting Substances
OHS	Occupational Health and Safety
OHTL	Overhead Transmission Line
PPE	Personal Protective Equipment
PS	Performance Standard
PV	Photovoltaic
REPDO	Renewable Energy Project Development Office
SEA	Sexual Exploitation and Abuse

ABBREVIATION	MEANING
SEC	Saudi Electricity Company
SEP	Stakeholder Engagement Plan
SGI	Saudi Green Initiative
SH	Sexual Harassment
SPPC	Saudi Power Procurement Company
SSP	Shared Socioeconomic Pathways
TCFD	Task Force on Climate-related Financial Disclosures
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
VEC	Vulnerable Environmental Components
VOC	Volatile Organic Compound
WHO	World Health Organization

1 INTRODUCTION

The Kingdom of Saudi Arabia (KSA) has a distinct geographical and climatic location that makes utilizing renewable energy sources economically attractive, supporting KSA's efforts to diversify the domestic energy mix under the strategic initiative "the National Renewable Energy Program (NREP)", launched at the direction of His Majesty the King as part of Vision 2030, which aims to increase the Kingdom's share of renewable energy production, achieve a balance in the mix of local energy sources, and fulfil the Kingdom's obligations towards reducing greenhouse gas emissions. The Humaij Photovoltaic (PV) Project (the Project) is one of the solar PV projects that are being developed by ACWA Power and the Public Investment Fund (PIF) in the Kingdom as part of PIF's commitment to develop 70% of Saudi Arabia's renewable energy by 2030.

An Environmental and Social Impact Assessment (ESIA) Report for the "Humaij Solar Power Plant" was completed in October 2024 by the Applied Research Centre for Environment & Marine Studies at King Fahd University of Petroleum & Minerals. The Project has been permitted the national regulator, the National Centre for Environmental Compliance (NCEC). ACWA Power is preparing an ESIA Addendum to fulfil identified gaps in the original ESIA.

As a result, 5 Capitals Environmental and Management Consultancy (5 Capitals) has been engaged by ACWA Power to prepare this ESIA Addendum with a focus on the following areas:

- Land Use, Social Impacts, and Ecosystem Services;
- Human Rights;
- Climate Change; and
- Cumulative Impacts.

To address the scope of the ESIA Addendum, this Report is structured in the following format:

- **Chapter 1 Introduction** (this chapter): provides a brief introduction of the Project, its location, and the purpose of the Report;
- **Chapter 2 Land Use and Social Impacts:** assesses the impact on land use and social aspects, including ecosystem services;
- **Chapter 3 Human Rights Impacts Assessment:** provides the human rights risk assessment for the Project;
- **Chapter 4 Climate Change Risk Assessment:** provides the climate change impact and vulnerability assessment;
- **Chapter 5 Cumulative Impacts Assessment:** outlines the potential cumulative impacts of the Project; and
- **Chapter 6 References:** Provides the list of references used to inform and prepare this report.

1.1 Project Description

Note: the description below is intentionally brief and for the purpose of context in this ESIA Addendum.

The Project, developed by Saudi Power Procurement Company (SPPC) (Principal Buyer), will comprise the installation of solar photovoltaic (PV) generating panels and on-site energy storage facilities together with grid connection infrastructure. The Project utilises bifacial PV modules with trackers. It is expected to operate for 25 years, under a Power Procurement Agreement (PPA) with Saudi Power Procurement Company. The Project Company who has the overall responsibility for developing the Project is Humaij One Renewable Energy Company with the Commercial Registration No. 1009170138. The company responsible for operation and maintenance (O&M) of the Project will be NOMAC.

1.1.1 Associated Facilities

The Project will be connected to a substation owned by National Grid SA (NGSA) which will have an overhead transmission line (OHTL) connection to the grid. The development and operation of this substation and OHTL are not within the scope of this Project, or financed under this Project, therefore are considered as Associated Facilities.

1.2 Project Location

The Humaij Project is located at coordinates 25° 07' 81.53" E; 41° 07' 00.29" N, in the eastern part of Madinah Province, bordering the Al Qassim province in the east and the Holy city of Madinah Al Munawarah in the west, as indicated in the figures below. The area available for the project is approximately 60.0 km².

1.3 Project Timeline

The key development timeline for the Project as per the schedule estimate at the time of preparing this report is as follows:

Table 1-1 Tentative Project Schedule

MILESTONE	SCHEDULE
Financial Close	31 August 2025
Notice to Proceed (NTP)	1 Sep 2025
Initial Commercial Operation Date (ICOD) 1	NTP + 18 Months
ICOD 2	NTP + 19 Months
PCOD	NTP + 28 Months



Figure 1-1 Project Location - National Context



Figure 1-2 Project Location - Local Context

1.4 Construction Phase

It is estimated that approximately 3,475 workers, which will include both skilled and unskilled workers, will be required on-site at the peak of construction. This will include the EPC contractor and subcontractors.

The workforce will be accommodated at the town of Al Hinakiyah, approximately 70 km to the west of the Project site.

1.5 Operation Phase

As outlined earlier, the Project will be operational for a duration of 25 years. Considering the fully atomised systems that will be installed at the plant, such as the robotic panel cleaning, limited number of workers (approximately 14 to 16 workers) will be required during operation phase. Operational staff will be mainly responsible for the routine O&M activities, to undertake overall plant monitoring, ensure safe operation, maintenance and repairs abiding by PV industry's best practices in order to maximize the performance, availability and reliability of the PV Plant.

2 LAND USE AND SOCIAL IMPACTS

2.1 Standards and Regulations

2.1.1 National Context and Regulations

There are no statutory requirements in KSA's legal system for land acquisition and resettlement related to informal land users. Processes are in place for legal title holders only.

2.1.2 Lenders Requirements

IFC PERFORMANCE STANDARD 5-LAND ACQUISITION AND INVOLUNTARY RESETTLEMENT

This standard recognises that project-related land acquisition and restrictions on land use can have adverse impacts on communities and persons that use this land. Involuntary resettlement refers both to physical displacement (relocation or loss of shelter) and to economic displacement (loss of assets or access to assets that leads to loss of income sources or other means of livelihood) because of project-related land acquisition and/or restrictions on land use. Where involuntary resettlement is unavoidable, it should be minimised, and appropriate measures to mitigate adverse impacts on displaced persons and host communities should be carefully planned and implemented.

2.2 Baseline

2.2.1 Land Ownership

The land is owned by the Government and is Head Leased to Saudi Power Procurement Company (SPPC) who will lease the land to the Project Company, therefore no land acquisition is required for the Project.

2.2.2 Land Use at and near the Project Site

The Humaij project is located in the eastern part of Madinah province, bordering the Al Qassim province in the east. There is a small community (about 25 buildings) 400 m northeast of the Project site.

As per the ESIA prepared by Applied Research Center for Environment & Marine Studies, the Project site is used for camel grazing. Livestock enclosures and mobile homes were observed near the Project site. Observations made during recent site visit conducted as part of the ESIA addendum are discussed in the following section.

2.2.3 Site Visit Observations

During a joint site visit on February 25th, 2025, conducted by 5 Capitals and ACWA Power, the site was observed for signs of settlements, herders, and any other land use.

No permanent settlements were observed on the Project site. The land is predominantly a barren, sandy landscape with small areas of gravel, and areas of sparse vegetation. The typical landscape of the site can be seen in the figure below.



Figure 2-1 Typical Landscape at the Project Site

Fourteen areas with temporary structures, tents, and portable accommodation were observed, most of which had livestock (mainly sheep) either fenced in or roaming nearby. All the sheep were seen feeding and drinking from metal troughs filled with animal feed. Trucks and cars were also observed near the structures. Additionally, some unoccupied permanent structures, ramming test posts, two overhead transmission lines, and a marker indicating a possible buried utility, such as water connection were observed on or near the Project site as indicated on the map and in the figures below. At the time of the visit, certain survey activities were ongoing at the site.

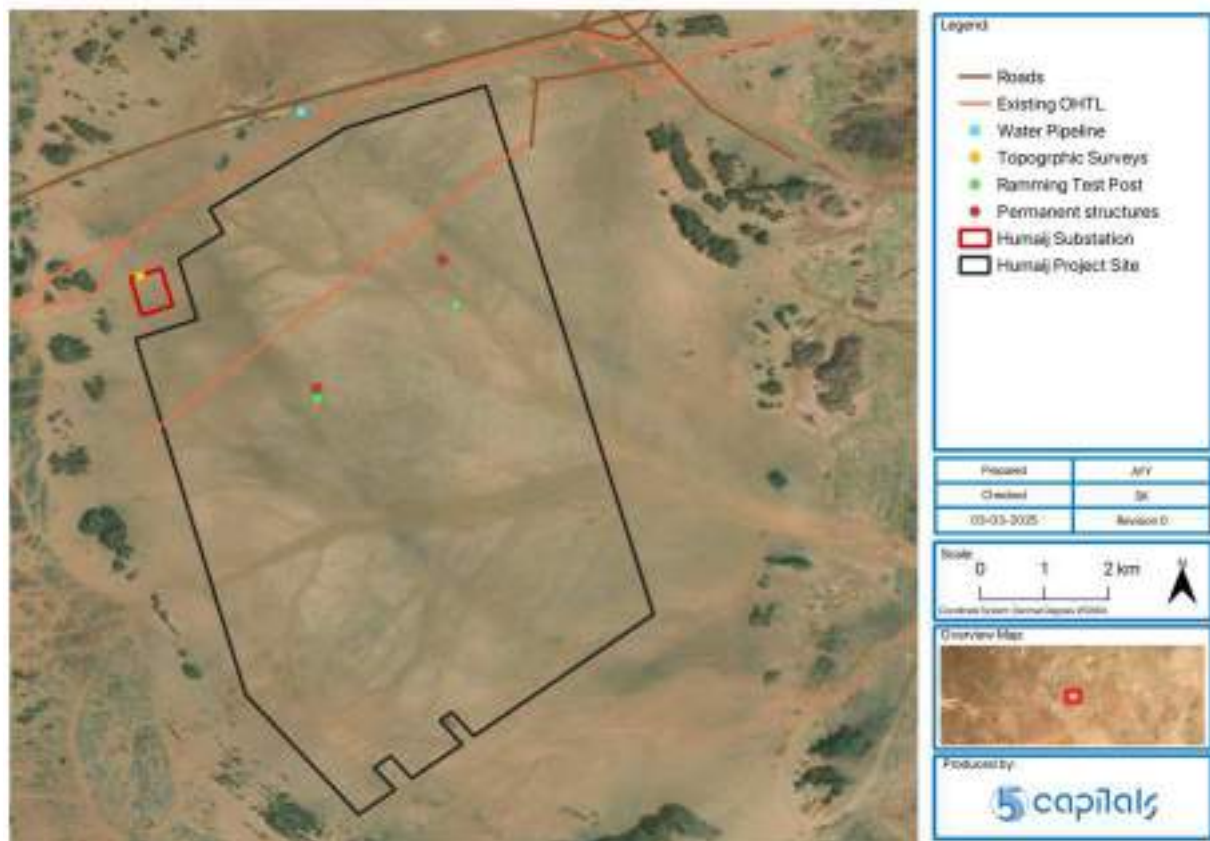


Figure 2-2 Locations of Existing Structures on the Project Site



Figure 2-3 Existing Structures on the Project Site

2.2.4 Site Visit Consultations

During 5 Capitals' and ACWA Power's site visit on February 25th, 2025, consultations were held with a herder (if present) from each area of livestock and structures observed on or close to the site. Prior to the site visit, 5 Capitals prepared a consultation questionnaire in line with the stakeholder engagement guidelines (See Appendix A) for ACWA Power and 5 Capitals to engage with people on or adjacent to the Project site, should any be observed. It was important to consider

the complex cultural context in Saudi Arabia when preparing the questionnaire, and hence the extent and type of questions was tailored to suit this.

The primary purpose of the questionnaire-based consultation was to gain an overview of the baseline situation of such people at the site and to understand their land uses, livelihoods, and access to ecosystem services, hence, to consequently determine what potential effects the Project might have, if any. The responses to the questionnaires are presented in Appendix B.

As outlined earlier, total of fourteen areas of structures were identified. Eight herders were present on or near the site and responded to the questionnaires. Herder H-1 was merely passing through the site, while herder H-2 declined to be interviewed. The remaining herders were not present near their structures. The locations of herder structures are indicated in the figure below.

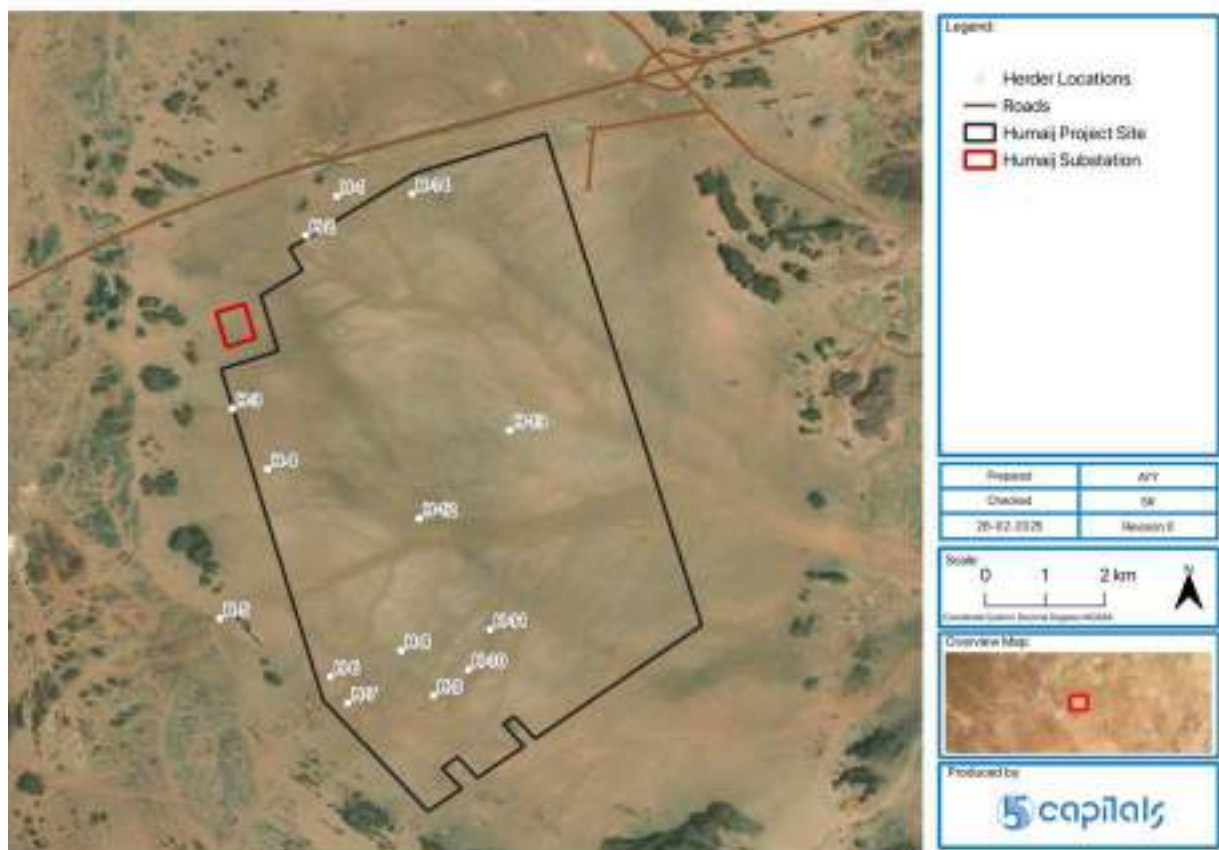


Figure 2-4 Identified Herder Locations





Figure 2-5 Identified Herders H-1 to H-14

Based on the consultations it was noted that all eight herders use the Project site for grazing. The number of livestock animals owned by the herders is shown in the following table.

Table 2-1 Herders' Livestock Numbers

HERD ID	SHEEP	CAMELS	HORSES
H-3	0	20	0
H-4	0	100	0
H-5	3	70	0
H-7	0	unspecified	0
H-8	150	0	0
H-12	0	5	0
H-13	0	35	0
H-14	0	50	1

Herders for H-3 and H-7 are employees hired by the owners of the livestock, while other herders interviewed are owners themselves. All herders use the site seasonally and had only been on the site for a short time (1 day to 3 months) by the time of the site visit. Owners for H-8 and H-14 stated that herding is their only source of income, while others mostly have jobs or other sources of income. It is noted that the livestock owners do not have land use rights or other agreements, and all herders are aware that the land is owned by the government. All herders stated that moving sites is not an issue, and they will not require help to move sites. They do not perceive any issues arising because of the Project. In general, this is considered to be accurate given that this is a common occurrence for such herders to move with their livestock and vehicles. All camps observed with the herders were temporary in the way of tents, or vehicles. No permanent structures were observed with the herders.

During the consultation with the herders ACWA Power presented the Project boundary, showing them around the perimeter for their understanding. All herders stated that other land is available in the immediate vicinity of the Project, and relocation would not cause any impact on their livelihood. The herders confirmed their understanding that the land would no longer be accessible throughout the construction and operational phases.

Throughout KSA, herders are allowed to graze undeveloped land with livestock without formal contracts, however this comes with an understanding that should the land be required for development purposes, they must move off the land. Herders are typically aware of such projects through word of mouth between herders and other local people and understand their requirement to relocate when needed. It is also typical that these herders are nomadic or can easily relocate due to the vast expanse of very similar landscape and vegetation in proximity.

2.3 Potential Project Impacts

2.3.1 Land Use Change

At the time of the site visit in February 25th, eight herders were observed on the site or close to it. Based on the engagement responses with these herders it is understood that the site presents very limited grazing opportunity which was evident as the animals were being fed via metal troughs. Due to the Project development, the site will be fenced and Project structures (i.e., the solar field) will be constructed. Consequently, the site will no longer be accessible.

The area being used for grazing within the Project site is understood to be limited as most of the Project site was observed to be an open sand and gravel habitat with little vegetation.

Given the abundance of open, available land outside of the site within proximity, and expected grazing areas available for use by herders, the loss of land due to the Project for grazing activities is expected to be very minimal.

2.3.2 Relocation

The Project area will be fenced, and therefore access to that area will no longer be possible. As such, any people, structures, and livestock on the Project site will require to be relocated outside of the Project's footprint.

All herders confirmed that the Project will not affect their livelihoods, and they have no permanent structures that require relocation. They all stated that they use the site only for short periods of time, and they will be moving to new locations in search of pasture as is the normal practice with nomadic herders. SPCC confirmed as part of the bid clarification that they are responsible for the relocation of herders.

2.3.3 Livelihood

Owners for H-8 and H-14 stated that herding is their only source of income, while other owners have additional jobs or sources of income. Owners for H-3 and H-7 have one employee each, who answered the questionnaires on site. Although the employees do not own the livestock, if relocation generates a surplus of employees or affects the productivity of livestock, their livelihoods may be affected. However, the livelihoods of the herders/workers are not expected to be affected because no disruption to herding activities is expected. This is because the herders are nomadic in nature and regularly move to new locations in search of new pasture regardless of the Project.

The owners of the livestock and are also not expected to be affected by the Project for the same reasons above. The livestock and herders will move to new pastures as they typically do, and the livestock rearing will continue as normal.

2.3.4 Access

During the consultations, it was established that the site is not used as a transportation or migration route. However, wheel tracks from cars and trucks, left by the herders, were observed on the Project site. Once the herders have been relocated, there will be no longer any need to access the site. The Project will not impact the roads near the Project site, therefore any vehicles that use the roads as access route can continue to do so during and after the Project is constructed.

2.3.5 Ecosystem Services

Ecosystem services are the benefits that people, including businesses derive from ecosystems. A decline or loss of any of these services and their benefits can result in socio-economic impacts that extend beyond environmental damages (World Resources Institute, 2013). These are organised into: (i) provisioning services which are products people obtain from the ecosystem (ii) regulating services which are benefits people obtain from regulation of ecosystem services (iii) cultural services which are non-material benefits from the ecosystem (iv) supporting services which are natural processes that maintain other services (IFC PS6). These are discussed below in the context of the Project site and its area of influence.

Provisioning Services - The direct area of influence of the Project is not considered to be host to natural resources that may be considered ecosystem services. For example, the site does not provide food, fuel or other raw materials to the local or the wider population.

Regulating Services – The Project site consists of sparse vegetation and therefore does not support any considerable regulating services such as erosion control, temperature regulation or carbon sequestration.

Cultural services – The desert environment at the Project site does not provide any non-material benefits from the ecosystems, such as contributing to cultural identity, spiritual enrichment or tourism.

Supporting services – There are certain supporting services such as nutrient cycling, primary production and soil formation that are applicable for the Project site, however these foundational processes are expected to continue to function effectively despite potential disturbances from Project activities.

Considering the construction and operational aspects of the Project, any impacts that will result in major impacts to ecosystem services have not been identified. As such, the Project is not expected to result in any notable changes to ecosystem services dependencies that requires a detailed analysis.

IFC PS6 outlines that ecosystem services valued by humans are often underpinned by biodiversity and hence impacts to biodiversity can adversely affect the delivery of ecosystem services.

The ecosystem services available to (and in use by) humans at the Project site are limited, primarily due to the lack of any permanent land users, lack of valuable vegetation, or other ecological features that are commonly used to derive benefits. The consultation questionnaire (ref. Appendix A) included a question (#2) that was targeted towards identifying provision and benefits of ecosystem services to people on or close to the site. The responses provided by all herders specified that there are not specific derived benefits from the site to these herders.

Based on the site observations and details provided in sections above, the habitat is of low grazing importance due to the lack of suitable vegetation.

As seen in **Error! Reference source not found.**, there were limited observed trees on site that would produce substantial firewood provisions. In areas of thicker vegetation, shrubs were most predominant, which give little to no firewood provision. The habitat is representative of typical large regional arid ecosystems within KSA, and the loss in ecosystem services are envisaged to be minimal.

Based on the baseline sections, the Project site will not impact any significant ecosystem services.

2.4 Mitigation Measures

To reduce potential land use and social impacts, appropriate measures should be implemented as follows.

2.4.1 Herders

During the consultation, the Project Company has offered its full support to assist the herders in case of any issues. The contact details of the Project Company have been provided in case of any assistance that may be required.

2.4.2 Access to the Grievance Mechanism

The livestock owners and their herders/workers will continue to have access to the Grievance Redress Mechanism (GRM) throughout the Project's lifespan in line with the Project Stakeholder Engagement Plan (SEP). This will allow them to raise any concerns or issues they have in relation to the Project. The details of the Project GRM will be posted in strategic locations in both Arabic and English, where it is visible to external stakeholders including herders and their employers.

The GRM established for the Project will allow for:

- Verbal complaints/concerns received in person or through phone calls; and
- Written complaints/concerns received through emails or grievance boxes located:
 - At the main gate;
 - At the gate of the temporary site facilities; and

- Around the site.

The grievance mechanism will allow parties to raise concerns or complaints against the Project without cost, retribution, or fear of negative consequences.

2.5 Monitoring

Table 2-2 Land Use and Social Monitoring Requirements – Construction and Operation

MONITORING	PARAMETER	FREQUENCY & DURATIONS
External Party Grievances	Issues Concerning Socioeconomic Factors or Land Use/Ownership	On-going

3 HUMAN RIGHTS IMPACTS ASSESSMENT

3.1 Overview

With new requirements under EP IV, an increased attention is being given to the accountability of businesses for their impact on human rights and it necessitates the inclusion of a 'Human Rights Impact Assessment' as part of the ESIA for projects financed by Equator Principles Financial Institutions (EPFIs). Accordingly, a Human Rights Impact Assessment has been conducted to evaluate:

- The rights of the local community and herders who live and work in the surrounding area to a healthy, safe, and secure environment;
- The rights of the labourers to adequate healthy and safe living conditions; and
- The rights of the labourers to healthy, safe, and fair working environments and conditions.

3.2 Standards and Regulations

3.2.1 National Context and Regulations

Saudi labour law is governed by Royal Decree No. M/51 (23 Sha'ban 1426 / 27th September 2005). The labour law includes terms and conditions of employment in Saudi Arabia required by employers and includes details of worker rights.

The Ministry of Labour (MOL) approved amendments to the Labour Law on 5th April 2015 (Resolution No. 258) which was first published in the official gazette on 24th April 2015.

The Ministry of Labour and Social Development was later merged with Ministry of Civil Service to establish the Ministry of Human Resources and Social Development in 2019, which is the governing Ministry in Saudi Arabia responsible for providing development, support, and protection for the community.

Section 26 of the Basic Law of Governance states the Government is responsible for protecting human rights in accordance with the Shari'a Law that governs the country. Human Rights treaties ratified by the Kingdom include (Treaty Body Database, 2020):

- Convention against Torture and Other Cruel Inhuman or Degrading Treatment or Punishment (23 September 1997);
- Convention on the Elimination of All Forms of Discrimination against Women (7 September 2000);

- International Convention on the Elimination of All Forms of Racial Discrimination (23 September 1997);
- Convention on the Rights of the Child (26 January 1996);
 - Optional Protocol to the Convention on the Rights of the Child on the involvement of children in armed conflict (10 June 2011);
 - Optional Protocol to the Convention on the Rights of the Child on the sale of children child prostitution and child pornography (18 August 2010);
- Convention on the Rights of Persons with Disabilities (24 June 2008);
- The Arab Charter of Human Rights; and
- Geneva Convention (18 May 1963).

In addition, Saudi Arabia is an International Labour Organisation (ILO) member state and has ratified 16 ILO Conventions out of which 6 are part of the IFC Performance Standard 2 – Labour and Working Conditions.

3.2.2 Lender Requirements

IFC PERFORMANCE STANDARD 4-COMMUNITY HEALTH, SAFETY AND SECURITY

This standard establishes requirements for the safeguard of the local community from potential risks associated with the project including impacts associated with the introduction of communicable disease, loss of ecosystem function, site access and operation, material use etc. It requires the Client (and Project) to avoid or minimise the risks and impacts to community health, safety, and security that may arise from Project related activities, with particular attention to vulnerable groups.

IFC PERFORMANCE STANDARD 2-LABOUR AND WORKING CONDITIONS

IFC PS2 recognises that the pursuit of economic growth through employment creation and income generation should be accompanied by protection of the fundamental rights of workers. This includes rights for direct, contracted, and supply chain workers (as applicable for key primary supply chains).

PS2 is in part guided by several ILO conventions, as follows:

- ILO Convention 87 on Freedom of Association and Protection of the Right to Organize;
- ILO Convention 98 on the Right to Organize and Collective Bargaining;
- ILO Convention 29 on Forced Labour (ratified by KSA);
- ILO Convention 100 on Equal Remuneration (ratified by KSA);
- ILO Convention 105 on the Abolition of Forced Labour (ratified by KSA);
- ILO Convention 111 on Discrimination (Employment and Occupation) (ratified by KSA);
- ILO Convention 138 on Minimum Age (of Employment) (ratified by KSA);

- ILO Convention 182 on the Worst Forms of Child Labour (ratified by KSA);
- UN Convention on the Rights of the Child, Article 32.1; and
- UN Convention on the Protection of the Rights of all Migrant Workers and Members of their Families.

In addition to this, PS2 outlines certain requirements for projects linked to Human Resource (HR) policies, management, working conditions, and terms of employment (other elements not linked to the ILO conventions above) as well as key processes for occupational health and safety (OHS) management, and grievance redress.

UNITED NATIONS HUMAN RIGHTS GUIDING PRINCIPLES (HRGPs)

- HRGP II on “The corporate responsibility to respect human rights” recognises that it is the responsibility of businesses and corporations to respect human rights. It is a global standard of expected conduct for all business enterprises wherever they operate. It exists independently of a States’ ability and/or willingness to fulfil their human rights obligations and does not diminish those obligations. The Foundational principles to take into consideration are:
- Principle 11: Business enterprises should avoid infringing on the human rights of others and should address adverse human rights impacts with which they are involved;
- Principle 12: The responsibility of business enterprises to respect human rights refers to internationally recognized human rights – understood, at a minimum, as those expressed in the International Bill of Human Rights and the principles concerning fundamental rights set out in the International Labour Organization’s Declaration on Fundamental Principles and Rights at Work;
- Principle 13: The responsibility to respect human rights requires that business enterprises avoid causing or contributing to adverse human rights impacts through their activities and address such impacts when they occur;
- Principle 14: The responsibility of business enterprises to respect human rights applies to all enterprises regardless of their size, sector, operational context, ownership, and structure. Nevertheless, the scale and complexity of the means through which enterprises meet that responsibility may vary according to these factors and with the severity of the enterprise’s adverse human rights impacts;
- Principle 15: Business enterprises should have policies and processes appropriate to their size and circumstances in place.
- Principle 16: Policy commitment
- Principle 17 to 21: Human rights due diligence
- Principle 22: Remediation

IFC GUIDANCE ON GENDER BASED VIOLENCE AND HARASSMENT (GBVH) IN THE CONSTRUCTION SECTOR

The assessment, prevention, monitoring, and response measures with regards to GBVH should be underpinned by the following principles:

- Survivor Centred: The rights of GBVH survivors need to be consistently prioritised and used as the starting point for all decisions on efforts to assess, prevent, monitor, and respond to GBVH.
- Safe: Survivors, witnesses, and those who report and seek to address GBVH can be at risk of retaliation, including threatening and violent behaviour, often from those who do not like their position of power being challenged. Companies should prioritise the safety of those who have experienced, witnessed, and reported GBVH.
- Context specific: All measures need to be rooted in a thorough understanding of the local context. Investors and companies should understand the legal and social context, and identify the support mechanisms that are in place.
- Collaborative: Companies should seek inputs from a range of internal and external stakeholders to increase the likelihood of broader buy-in and make GBVH prevention more effective.
- Inclusive: Companies should recognise the heightened risks of GBVH faced by certain groups who are subject to discrimination and marginalisation. High risk groups often include people with disabilities, single parents, migrants and ethnic minorities, and sexual and gender minorities. The system should also account for illiterate or non-literate people who may not be able to access written information on GBVH reporting mechanisms.
- Integrated: Processes and efforts to assess, prevent, monitor, and respond to GBVH need to be integrated as much as possible into existing processes and management systems, such as occupational health safety, security management systems, environmental and social management systems (ESMS), and HR policies and procedures.
- Non-discriminatory: All survivors need to be listened to and treated equally whilst promoting diversity in the workplace.
- Well-informed: Companies should draw on relevant expertise when developing prevention and response measures. The grievance mechanism and investigation procedures should be set up to ensure they are appropriate, relevant, and safe in the local context.

According to the guidance, the benefits of addressing GBVH include:

- Improves workers' physical and emotional wellbeing and strengthens occupational health and safety.
- Avoids reputational damage, financial risks, and legal liabilities for companies, investors, and construction contractors.
- Builds relationships and social license to operate in communities. This can result from regular dialogue to understand and track project GBVH risks as well as the effective use of measures to prevent and respond to GBVH.
- Broadens the pool of potential workers that companies can draw upon, including women workers from nearby communities because of lower perceived risk of GBVH.

3.3 Project Affected People

3.3.1 Local Communities and Herders

As outlined earlier, the Project is located in the eastern part of Madinah province. The Project activities can potentially result in direct or indirect impacts to users of the adjacent roads and communities.

During a site visit on 25th February 2025 conducted by 5 Capitals and ACWA Power the site was observed for signs of settlements, herders, and any other land use. No permanent structures were noted on the Project site.

Note: Refer to the *Land Use and Social Impacts* chapter above for further information.

3.3.2 Project Workers

It is estimated that there will be up to 3,745 workers on-site at the peak of construction. The Project will equate to 33,381 worker-months and 3,300 staff man-months. It is expected that about 50% of the workers and staff will be expatriates, likely to be predominantly from India and China.

The workforce will be accommodated at the town of Al Hinakiyah, approximately 70 km to the West of the Project site.

During the operational phase, it is expected that there will be 14-16 workers, which will include Saudi nationals.

Certain parties may also engage contract staff (e.g., from agencies) where additional manpower is required. There will also be suppliers and/or service providers for deliveries, waste management etc., who will have access to the site and will be exposed to certain risks.

Accordingly, Project related activities, management processes, living conditions, and work environments can result in potential adverse impacts to employees and workers listed above.

3.4 Potential Project Impacts on Human Rights

3.4.1 Construction Phase

COMMUNITY SAFETY AND SECURITY

All construction projects have potential risks to public safety due to the use of high-powered equipment, heavy construction equipment, excavation activities, transportation, fire incidents, and pollution releases. Additionally, unauthorised access to the construction site, including the public presents a safety and security concern. There is a small community (about 25 buildings) 400 m northeast of the Project site. However, the overall risk is inherently low, as the nature of a PV project's construction phase is not typically hazardous.

Public risks during the construction phase of a project have the potential to result in isolated incidents, which could be highly dangerous to a person or group of people, however, this rarely occurs. Such impacts are very unlikely during this Project due to the distance from receptors, and lack of receptors.

It is noted that a Grievance Mechanism will be established for the Project to allow third parties to raise concerns or complaints against the Project without cost, retribution, or fear of negative consequences.

The Project will ensure that the right of local communities to a clean and safe environment is safeguarded through the implementation of mitigation and management measures detailed in the ESIA and this ESIA Addendum.

OCCUPATIONAL HEALTH AND SAFETY

Common activities undertaken during construction such as civil works, the movement of heavy machinery, excavation, welding, handling of chemicals, and works undertaken at height, in confined space or with electrical hazards etc. can introduce risk to the health and safety for the workforce. Risks are more likely to be apparent for those who are not familiar, applicably qualified, or otherwise well trained with the type of works undertaken and/or the associated hazards.

The type of hazards attributable to a construction site will vary significantly depending on the construction methods employed and the degree of control implemented by the contractor. Health, Safety, and Environment (HSE) personnel will be on site during the project construction. These personnel will be dedicated HSE professionals to ensure the Engineering, Procurement and Construction (EPC) workers and affiliated sub-contractors demonstrate consideration of health and safety risks as part of their chosen construction methods and that these risks are appropriately mitigated during the construction phase.

COMMUNICABLE DISEASES

Impacts on Workforce

The risk associated with the spread of communicable diseases within workforces is prominent in construction working environments that require the sharing of equipment, accommodation, sanitary facilities, canteens, and means of transportation between workers. A high number of workers working in such proximity or confined spaces such as for this Project also increases the risk of infection.

Impacts on Surrounding Community

The location of employees' accommodation may also have a possible impact on community health where integration with local communities takes place, should either party become infected with a communicable disease.

WORKING CONDITIONS, WELFARE & ACCOMMODATION

Unfair wages, education, and opportunities among the workforce can result in opportunistic immoral practices with labourers and site staff who consequently suffer.

The quality of living accommodation, living areas, the number of workers per room, facilities and amenities available to workers, maintenance accommodation areas, and provisions of associated services (e.g., catering, waste management, etc.) can significantly impact the lives and wellbeing of Project workers. This may include the lack of welfare provisions on-site such as clean drinking water, hygienic and ample toilet facilities, hand basins (with soaps/hand wash), temperate rest areas, food, and other amenities necessary to the works and the environment.

WORKER AND WORKFORCE EXPLOITATION

The Project will have several parties contributing as part of the construction phase, of which there will likely be varying internal processes and procedures for each concerning HR, labour/workforce employment, and other related elements.

However, labour exploitation on construction sites has been common for decades, especially in environments where the workers may not be part of a syndicate or a cooperative. Examples from other projects within the region have shown that there can be instances of forced labour, labour with poor contracting conditions, or lacking processes in place to manage such elements. Therefore, potential risks exist regarding the above and are expected to be more prevalent at lower ends of the Project hierarchy, particularly for sub-contractors and agency/contracted manpower that may need to be engaged.

GENDER INEQUALITY & DISCRIMINATION

Saudi Arabia has eliminated restrictions on women's employment in industrial sectors including construction, however, the construction industry remains lacking in gender diversity, being dominated by men. Women are generally more likely to face discrimination in terms of employment or wages, even when they engage in the same tasks as men.

In addition, income earning opportunities for women through direct employment during the construction phase or through indirect employment has the potential to increase household tensions and expose women to cultural pressure, or harassment and violence in their homes or communities, considering them 'home makers' who should not be engaged in construction work.

The Project should guarantee the right of all Project workers including women to just and favourable work conditions, free of discrimination.

GENDER BASED VIOLENCE AND HARASSMENT, SEXUAL EXPLOITATION & ABUSE, AND SEXUAL HARASSMENT

Members of the workforce, their family members, or the neighbouring communities can potentially face harassment in the workplace or at home in forms of GBVH, Sexual Exploitation &

Abuse (SEA), and Sexual Harassment (SH). The influx of workers from outside of the Project region may increase the likelihood of GBVH. The constructions workers are likely to be predominantly young males coming from other regions and outside of the country. These workers will be away from their families and removed from their normal social spheres. This could potentially result in peer pressure and involvement in unlawful behaviour. Such behaviour can lead to unwanted aggressive advances and harassment.

During the construction phase, workers will also be vulnerable to various forms of harassment, exploitation, and abuse, which could be aggravated by the traditional male working environment.

3.4.2 Operational Phase

COMMUNITY SAFETY AND SECURITY

Although they are expected to be minimal for a Solar PV project, the Project will carry certain risks that could result in impacts to public or external party safety where such impacts are transferred or received outside of the Project boundaries. Such impacts are unlikely to occur, but may relate to fire, Volatile Organic Compound (VOC) fumes, explosions, spills of back-up generator fuels, and un-warranted or accidental releases of sanitary wastewater. The extent of such impacts may range outside of the boundaries of the Project and require the involvement of external agencies to help manage and abate such impacts (e.g., Civil Defence, Police, and Army).

As outlined earlier, there is a small community 400 m away from the Project site which is the closest receptor. Potential risks can arise from non-authorised parties (including the public) accessing the Project, such as electrocution. Several measures are considered to reduce those risks including fencing the site, installing monitored gates, and hiring security guards either through a 3rd party or direct employees of the company to prevent the public from trespassing to the site and any malicious intrusion during operation.

OCCUPATIONAL HEALTH AND SAFETY

The risks generally associated with the operational phase of the Project are anticipated to be less than during the construction phase due to reduced site activity and requirements for heavy vehicles, equipment, and machinery. During the operational phase there will be a limited workforce, their work will be predominantly office based, and the cleaning of the solar panels is going to be largely automated. However, there will remain occupational health and safety risks attributable to the operational phase associated with maintenance and inspection requirements.

The severity and likelihood of risks during the operational phase will also depend on the frequency and requirements for planned and unplanned maintenance. The O&M team should develop and implement a robust plan to appropriately manage these risks.

A grievance mechanism has been established for the Project and will be implemented to allow employees to express their concerns or complaints without cost, retribution, or fear of negative consequences.

COMMUNICABLE DISEASES

Even though the required number of workers is limited during operation, there is potential for the spread of diseases among workers, or within the local community and vice-versa to the workforce.

WORKING CONDITIONS

The number of staff required during operation is limited at approximately 14, however, a lack of welfare provisions on-site such as clean drinking water, hygienic and ample toilet facilities, hand basins (with soaps/hand wash), temperate rest areas, food, and other amenities necessary to the works and the environment can impact the lives of Project workers.

GENDER BASED VIOLENCE AND HARASSMENT

Much of the staff will be direct employees of the Project Company, therefore the potential risks associated with violence and harassment are anticipated to be limited due to consistent processes in place as part of the respective HR management systems, assuming they are appropriately designed and resourced.

3.5 Mitigation Measures

3.5.1 Construction Phase

To reduce potential impacts on health and safety of the community and site personnel, and to ensure the provision of the required human rights during the construction phase, appropriate measures should be implemented. The table below presents the relevant mitigation measures.

Table 3-1 Human Rights Mitigation & Management Measures – Construction

POTENTIAL IMPACT	MITIGATION AND MANAGEMENT MEASURES
Public/Community Safety	- Risks to public safety will be appropriately addressed and prepared for in an 'Emergency Preparedness and Response Plan'. - The plan will include the appropriate procedure to respond to any such incidents, as well as site-specific contact details and details of external agencies who may be required. - Site personnel should be trained in emergency procedures and plans, and the potentially affected receptors should be notified of procedures to follow via relevant communication channels. - Employees shall undergo a Code of Conduct (COC) training to ensure smooth coordination with the neighbouring community. - Project induction training will include a section on COC when engaging with local community members. This will include an overview of culturally appropriate measures and etiquette to bear in mind.

POTENTIAL IMPACT	MITIGATION AND MANAGEMENT MEASURES
	- All high-risk areas including fuel storage areas will be secured with internal fencing and will be patrolled by security throughout the day. - Appropriate mechanisms for emergency control (e.g., firefighting equipment) will be placed at suitable positions around the site. - The implementation of a robust grievance mechanism will be ensured.
Public/Community Security	- The EPC Contractor shall prepare a Security Plan consistent with its Security Risk Assessment. - The Project will employ its security staff to provide 24/7 security control across the Project site and dedicated security staff at gatehouses. - All vehicles entering the site will require pre-approved clearance and will need to be registered. - The Project site will be guarded during the enabling work's stage and security will manage visitors as per the Security Management Plan. - Project security will record all instances of incoming vehicles. - CCTV will be installed at key locations around the site and gatehouses. - Appropriate lighting will be provided at gatehouses for security personnel to prevent unauthorised access. - Project personnel will only be provided access to the construction site with valid ID cards and permits to work in line with HSE requirements. - People trying to gain unauthorised access to the site without appropriate permits and PPE will not be permitted or will be removed from site if identified, an investigation shall be carried out on how they were able to access the site, and corrective action taken. - The security personnel will be regularly trained on GBVH COC including how to handle grievances related to GBVH from the community.
Occupational Health and Safety	- The EPC Contractor will provide all workers with a safe and healthy work environment, considering inherent risks and specific classes of hazards associated with the Project. - The EPC Contractor shall implement and maintain an OHS management system considering specific risks associated with the Project, legal requirements, and duty of care. - The EPC Contractor shall be responsible for ensuring that all affiliated sub-contractors comply with the OHS management system. The OHS management system shall be in-line with recognised international best practice and as a minimum, this plan shall include: - Means of identifying and minimising, so far as reasonably practicable, the causes of potential H&S hazards to workers. - Provision of preventive and protective measures, including modification, substitution, or elimination of hazardous conditions or substances. - Provision of appropriate protective equipment to minimise risks, and the requirement and enforcement of its use. - Training of workers, and the provision of appropriate incentives for them to use and comply with OHS procedures and protective equipment. - Documentation and reporting of occupational accidents, diseases, and incidents. - Emergency prevention, preparedness, and response arrangements.
Staff/Community Exposure to	Staff and workers shall have access to medical insurance, health professionals, and suitable medical facilities, which will aim to prevent the spread of diseases internally and externally.

POTENTIAL IMPACT	MITIGATION AND MANAGEMENT MEASURES
Communicable Diseases	- Any reportable disease shall be diagnosed by the authorised medical centre doctors. Diagnosis includes identifying any new symptoms or any significant worsening of existing symptoms. - The potential for exposure to water-borne, water-based, vector-borne diseases and communicable diseases as a result of Project activities will be prevented, avoided, and minimised to the extent possible through following good hygienic practices. - Any external and internal spreading of diseases shall be diagnosed and the precautions as per the instructions from the national or local medical authority shall be implemented. - The Health and Safety Team on site should provide advice during training or inductions on exposure to diseases, including national and project requirements for any infectious disease that may be present. - Provide a 24hr emergency hotline. - Isolate/care for sick and potentially infected staff and workers. - Identify any vulnerable groups (i.e., those with pre-existing conditions) working in the Project site (for the EPC and sub-contractors) and take precautionary measures in accordance with the national and World Health Organization (WHO) guidelines. - Provide testing for staff as required at no cost to them. - Promote personal hygiene among the workers and provide training and posters to remind workers to wash their hands regularly, clean their work areas and equipment, sanitize properly, etc. - Ensure suitable distancing, proper ventilation, and hygiene within workers accommodation. - Coordinate and regulate transportation of workers and access to the site i.e., through reduced bus occupancy, and temperature and PPE checks etc. - Provide a flexible working regime for employees who may prefer to work from home due to health issues, childcare, home schooling, etc. without fear of victimisation.
Worker's Welfare On-Site	- Ensure that welfare provisions are available on-site, including but not limited to: - Hygienic and regularly cleaned toilets (commensurate to applicable requirements or good practices for the quantity required on-site, or in areas of the site); - Basins and running clean water, with hand-wash/soap for hand cleaning; - Rest areas (with air conditioning, chairs, and tables); and - Clean drinking water available in working areas (at a suitable temperature). - If applicable, suitable and hygienic areas for eating and storing food (including refrigerators, heating devices [ovens/microwaves] etc.)
Workers' Accommodation	Provide accommodation that complies with the IFC & EBRD Workers Accommodation: Processes and Standards (2009).
Workers' Terms of Employment, Non-Discrimination and Equal Opportunities, Working Relationships	- Project parties will establish HR Policies and processes to ensure working conditions and terms of employment are compliant with the requirements of National Labour Law, IFC PS 2, and associated ILO conventions. - Project employment relationships shall be on the principle of equal opportunity and fair treatment and will not discriminate concerning any aspects of the employment relationship, including recruitment and

POTENTIAL IMPACT	MITIGATION AND MANAGEMENT MEASURES
	hiring, compensation (including wages and benefits), working conditions and terms of employment, access to training, promotion, termination of employment, retirement, and discipline. - Project parties will not make employment decisions based on personal characteristics, such as gender, race, nationality, ethnic origin, religion or belief, disability, age, or sexual orientation, unrelated to inherent job requirements. - Project parties will document and communicate to all workers their working conditions and terms of employment including their entitlement to wages, hours of work, overtime arrangements and overtime compensation, and any benefits (such as leave for illness, maternity/paternity, or holiday). <i>Special measures of protection or assistance to promote local employment opportunities or selection for a particular job based on the inherent requirements of the job, which are per national law, will not be deemed discrimination.</i>
Workers' Forced Labour	- Project parties will not employ forced labour, which consists of any work or service not voluntarily performed that is exacted from an individual under threat of force or penalty. This covers any kind of involuntary or compulsory labour, such as indentured labour, bonded labour, or similar labour-contracting arrangements. - Such requirements are also applicable in the hiring of agency/other contracted manpower, for which processes should be in place by the Project party to undertake due diligence on the agency providing the manpower. Where potential risks of forced labour are identified other suppliers with reputable processes and controls should be sought. - HR policies and procedures will be adapted appropriately to the size of the workforce required for the Project. Policies and procedures must be prepared to demonstrate consistency with the requirements of national legislation and IFC PS 2.
Child Labour	- Project parties will comply with all relevant national laws and provisions related to the employment of minors. - In any event, Project parties will not employ children in a manner that is economically exploitative, or is likely to be hazardous or to interfere with the child's education, or to be harmful to the child's health or physical, mental, spiritual, moral, or social development. - Young people below the age of 18 years will not be employed in hazardous work and all work of persons under the age of 18 shall be subject to an appropriate risk assessment. - Such requirements are also applicable in the hiring of agency/other contracted manpower, for which processes should be in place by the Project party to undertake due diligence on the agency providing the manpower. Where potential risks of child labour are identified other suppliers with reputable processes and controls should be sought.
Workers' Wages, Benefits, Conditions of Work and Retrenchment	- HR policies and procedures will be adapted appropriately to the size of the workforce required for the Project. Policies and procedures must be prepared to demonstrate consistency with the requirements of national legislation and IFC PS 2 and include a COC on GBVH. - Wages, benefits, and conditions of work offered should be overall comparable to those offered by equivalent employers in the relevant region of that country/region and sector concerned. - If Project parties anticipate collective dismissals associated with the proposed Project, the parties shall develop a plan to mitigate the adverse impacts of retrenchment in line with national law and good

POTENTIAL IMPACT	MITIGATION AND MANAGEMENT MEASURES
	industry practice and based on the principles of non-discrimination and consultation. Without prejudice to more stringent provisions in national law, such consultation will involve reasonable notice of employment changes to the workers' representatives and, where appropriate, relevant public authorities so that the retrenchment plan may be examined jointly to mitigate adverse effects of job losses on the workers concerned. The outcome of the consultations will be reflected in the final retrenchment plan.
Workers Conditions- Key Supply Chain (i.e., PV Module Suppliers)	- Project parties shall devise and implement applicable controls to ensure the measures herein are implemented by any sub-contractors and the requirements for workers conditions are included in the pre-qualifications criteria for selection of key contractors and suppliers. - Project parties will take reasonable steps to inquire about the use of child labour and forced labour in their supply chains and try to exert influence where possible or identify other suppliers.
Grievance Mechanism	- A grievance mechanism for workers will be provided to raise reasonable workplace concerns. - Workers will be informed of the grievance mechanism at the time of hiring and make it easily accessible to them. - The mechanism will involve an appropriate level of management and address concerns promptly, using an understandable and transparent process that provides feedback to those concerned, without any retribution. - The mechanism will not impede access to other judicial or administrative remedies that might be available under law or through existing arbitration procedures, or a substitute for grievance mechanisms provided through collective agreements. - The grievance mechanism should be used to monitor worker morale, understand how workers are affected and what their concerns are in relation to communicable diseases, and address pressing matters promptly. - The grievance mechanism shall be provided for confidential reporting and a support system for any workers reporting issues relating to GBVH. It will also allow for reporting through word of mouth for those who cannot write. - A grievance mechanism for community members will be provided to raise concerns or complaints. - Community members will be informed of the grievance mechanism through stakeholders' engagement, and it will be made easily accessible to them. - Complaints will be acknowledged, addressed, and closed out in a timely manner.
Violence and Harassment	- The Project parties will conduct a GBVH risk assessment in consultation with relevant stakeholders including women leaders and those working with young adolescent girls and boys. This will also include the identification of potential interventions and risk mitigation measures. - Awareness training will be mandatory for all Project workers regarding the GBVH risks and the workers responsibilities and the legal consequences of being a perpetrator. - Information will be provided on how to report any cases of violence or harassment and the services that will be made available to offer support to any of the survivors.

POTENTIAL IMPACT	MITIGATION AND MANAGEMENT MEASURES
	- Approach towards GBVH prevention, mitigation and response will be survivor centred and ensure confidentiality, dignity, and respect to them. - The Project staff will be trained on how to preserve the safety of the women, girls, and boys when interviewing them and collecting information about their experiences on GBVH. - The Project will provide essential services for survivors such as access to counselling services, support groups, legal support etc. at no cost to them. - All determined cases of GBVH will be referred to relevant legal entities in the Project area for further investigation and prosecution. - The Project grievance mechanism will be made available to project workers and community members and will ensure that survivors' information is confidential and kept anonymous. - All cases relating to GBVH shall be documented and closed.

3.5.2 Operational Phase

To reduce the impacts on health and safety of the community and site personnel, and to ensure the provision of the required human rights during the operation phase, appropriate measures should be implemented. The following table presents the relevant mitigation measures.

Table 3-2 Human Rights Mitigation & Management Measures – Operation

POTENTIAL IMPACT	MITIGATION AND MANAGEMENT MEASURES
Public/Community Safety	- Risks to public safety will be appropriately addressed and prepared for in the operational phase 'Emergency Preparedness and Response Plan' and training. - The plan will include the appropriate procedure to respond to any such incidents, as well as site-specific contact details and details of external agencies who may be required. - All high-risk areas including fuel storage areas (such as at the Emergency Generator) will be secured. - Appropriate mechanisms for emergency control (e.g., firefighting equipment) will be placed at suitable positions around the site. - The employees during the operational phase shall undergo a COC training to ensure smooth coordination with any neighbouring community. - Grievance Redress Mechanism shall be made accessible to the community to ensure that community members raise grievances to the Project leadership.
Public/Community Security	- The Project will employ its security staff who will provide 24/7 security control across the Project site and dedicated security staff at gatehouses. - The security personnel will be regularly trained on GBVH COC including how to handle grievances related to GBVH from the community. - All vehicles entering the site will require pre-approved clearance and will need to be registered. Project security will record all instances of incoming vehicles. - CCTV will be installed at key locations around the site and gatehouses. - Appropriate lighting will be provided at gatehouses for security personnel to prevent unauthorised access.

POTENTIAL IMPACT	MITIGATION AND MANAGEMENT MEASURES
	- Project personnel will only be provided access to the construction site with valid ID cards and permits to work in line with HSE requirements. - Security arrangements will be in line with the KSA National Standards. In addition to this, security personnel will receive internal training aligned to the UN requirements on the control of force by law enforcement officials. Additional training will be provided to access gate staff regarding grievances, reporting such grievances and dialogue with any members of the local community.
Occupational Health and Safety	- The Project Company will provide the workers with a safe and healthy work environment, considering inherent risks and specific classes of hazards associated with the Project. - The Project Company shall implement and maintain an OHS management system considering specific risks associated with the Project, legal requirements, and duty of care. - The Project Company shall be responsible for ensuring that all affiliated sub-contractors comply with the OHS management system. The OHS management system shall be in-line with recognised international best practice and as a minimum, this plan shall include: - Means of identifying and minimising, so far as reasonably practicable, the causes of potential H&S hazards to workers. - Provision of preventive and protective measures, including modification, substitution, or elimination of hazardous conditions or substances. - Provision of appropriate equipment to minimise risks, and requirement and enforcement of its use. - Training of workers, and the provision of appropriate incentives for them to use and comply with H&S procedures and protective equipment. - Documentation and reporting of occupational accidents, diseases, and incidents. - Emergency prevention, preparedness, and response arrangements
Staff/Community Exposure to Communicable Diseases and Associated Risks	- Staff and workers shall have access to medical insurance, health professionals, and suitable medical facilities, which will aim to prevent the spread of diseases internally and externally. - Any reportable disease shall be diagnosed by the authorised medical centre doctors. Diagnosis includes identifying any new symptoms or any significant worsening of existing symptoms. - The potential for exposure to water-borne, water-based, vector-borne diseases, and communicable diseases as a result of project activities will be avoided or minimised. - Any external and internal spreading diseases shall be diagnosed and the precautions as per the instructions from the national/local medical authority shall be implemented. - Provide a 24hr emergency hotline. - Isolate and/or care for sick and potentially infected staff and workers. - Identify any vulnerable groups (i.e., those with pre-existing conditions) working in the Project site and take precautionary measures in accordance with the national and WHO guidelines. - Provide testing for staff at no extra cost to them. - Promote personal hygiene among the workers and provide training, posters to remind workers to wash their hands regularly, clean their work areas and equipment, and sanitize properly etc.

POTENTIAL IMPACT	MITIGATION AND MANAGEMENT MEASURES
	- The transportation of workers and access to the site shall be coordinated and regulated i.e., through reduced bus occupancy, temperature, and PPE checks etc. - Provide a flexible working regime for those workers who may prefer and are able to work from home due to health issues, childcare, home schooling etc. without fear of victimisation. - Address mental health issues during induction and provide information on how to seek help from local experts.
Worker Welfare (on site)	- Project parties will ensure that welfare provisions are available on-site, including but not limited to: - Hygienic and regularly cleaned toilets (commensurate to applicable requirements or good practices for the quantity required on-site, or in areas of the site), - Basins and running clean water, with hand, wash for hand cleaning, - Rest areas (with air conditioning, chairs, and tables), - Clean drinking water available in working areas (at a suitable temperature) - If applicable suitable and hygienic areas for eating and storing food (including refrigerators, heating devices [ovens/microwaves] etc).
Workers' Terms of Employment, Non-Discrimination and Equal Opportunities, Working Relationships	- Project parties will establish HR Policies and processes consistent with the requirements of National Labour Law, IFC PS 2, and associated ILO conventions. - Project parties will provide a plan detailing how working conditions and terms of employment are compliant with national labour, social security, and occupational health and safety laws. - Employment relationships shall be on the principle of equal opportunity and fair treatment and will not discriminate concerning any aspects of the employment relationship, including recruitment and hiring, compensation (including wages and benefits), working conditions and terms of employment, access to training, promotion, termination of employment or retirement, and discipline. - Project parties will not make employment decisions based on personal characteristics, such as gender, race, nationality, ethnic origin, religion or belief, disability, age, or sexual orientation, unrelated to inherent job requirements. - Project parties will document and communicate to all workers their working conditions and terms of employment including their entitlement to wages, hours of work, overtime arrangements and overtime compensation, and any benefits (such as leave for illness, maternity/paternity, or holiday). <i>Special measures of protection or assistance to promote local employment opportunities or selection for a particular job based on the inherent requirements of the job, which are following national law, will not be deemed discrimination.</i>
Workers' Forced Labour	- Project parties will not employ forced labour, which consists of any work or service not voluntarily performed that is exacted from an individual under threat of force or penalty. This covers any kind of involuntary or compulsory labour, such as indentured labour, bonded labour, or similar labour-contracting arrangements. - HR policies and procedures will be adapted appropriately to the size of the workforce required for the Project. Policies and procedures must

POTENTIAL IMPACT	MITIGATION AND MANAGEMENT MEASURES
	be prepared to demonstrate consistency with the requirements of national legislation and IFC PS 2 and include a COC on GBVH. Such requirements are also applicable in the hiring of agency/other contracted manpower, for which processes should be in place by the Project party to undertake due diligence on the agency providing the manpower. Where potential risks of forced labour are identified other suppliers with reputable processes and controls should be sought.
Child Labour	- Project parties will comply with all relevant national laws and provisions related to the employment of minors. - In any event, Project parties will not employ children in a manner that is economically exploitative, or is likely to be hazardous or to interfere with the child's education, or to be harmful to the child's health or physical, mental, spiritual, moral, or social development. - Young people below the age of 18 years will not be employed in hazardous work and all work of persons under the age of 18 shall be subject to an appropriate risk assessment. - Such requirements are also applicable in the hiring of agency/other contracted manpower, for which processes should be in place by the Project party to undertake due diligence on the agency providing the manpower. Where potential risks of child labour are identified other suppliers with reputable processes and controls should be sought.
Workers' Wages, Benefits, Conditions of Work and Retrenchment	- Wages, benefits, and conditions of work offered should, overall, be comparable to those offered by equivalent employers in the relevant region of that country/region and sector concerned. - If Project parties anticipate collective dismissals associated with the proposed Project, the parties shall develop a plan to mitigate the adverse impacts of retrenchment in line with national law and good industry practice, and based on the principles of non-discrimination and consultation. Without prejudice to more stringent provisions in national law, such consultation will involve reasonable notice of employment changes to the workers' representatives and, where appropriate, relevant public authorities so that the retrenchment plan may be examined jointly to mitigate adverse effects of job losses on the workers concerned. The outcome of the consultations will be reflected in the final retrenchment plan. - The workers/representatives shall be involved on any labour reduction measures.
Key Supply Chain (if any)	- Project Company shall devise and implement applicable controls to ensure the measures herein are implemented by any sub-contractors and are internally checked/audited. - Project Company shall take reasonable steps to inquire about the use of child labour and forced labour in their supply chains and try to exert influence where possible or identify other suppliers.
Grievance Mechanism	- A grievance mechanism for workers will be provided to raise reasonable workplace concerns. - Workers will be informed of the grievance mechanism at the time of hiring and make it easily accessible to them. - The mechanism will involve an appropriate level of management and address concerns promptly, using an understandable and transparent process that provides feedback to those concerned, without any retribution. - The mechanism will not impede access to other judicial or administrative remedies that might be available under law or through

POTENTIAL IMPACT	MITIGATION AND MANAGEMENT MEASURES
	existing arbitration procedures, or a substitute for grievance mechanisms provided through collective agreements. • A grievance mechanism for community members will be provided to raise concerns or complaints. • Community members will be informed of the grievance mechanism through stakeholders' engagement and make it easily accessible to them. • All complaints will be acknowledged, addressed, and closed out in a timely manner.
Violence and Harassment	• The Project parties will conduct a GBVH risk assessment in consultation with relevant stakeholders including women leaders and those working with young adolescent girls and boys. This will also include the identification of potential interventions and risk mitigation measures. • Awareness training will be mandatory for all Project workers regarding the GBVH risks and the workers responsibilities and the legal consequences of being a perpetrator. • Information will be provided on how to report any cases of violence or harassment and the services that will be made available to offer support to any of the survivors. • Approach towards GBVH prevention, mitigation and response will be survivor centred and ensure confidentiality, dignity, and respect to them. • The Project staff will be trained on how to preserve the safety of the women, girls, boys when interviewing them and collecting information about their experiences on GBVH. • The Project will provide essential services for survivors such as access to counselling services, support groups, legal support etc. at no cost to them. • All determined cases of GBVH will be referred to relevant legal entities in the Project area for further investigation and prosecution. • The Project grievance mechanism will be made available to project workers and community members and will ensure that survivors' information is confidential and kept anonymous. • All cases relating to GBVH shall be documented and closed.

3.6 Monitoring

The protection of human rights is an on-going process, and this should be reflected in the Project's internal management policies.

The EPC Contractor during construction, and the O&M Company during operations are expected to be the primary parties for ensuring that mitigation measures are internally audited, and processes are in place to protect labourers, subcontractors, suppliers, as well as the surrounding community. Monitoring required is provided in the table below.

Table 3-3 Key Monitoring Indicators during Construction and Operation

MONITORING	PARAMETER	FREQUENCY & DURATION	MONITORING LOCATIONS
Worker Contracts & HR	Records of contracts, payments, receipt of benefits, leave entitlements, retrenchment etc.	On-going	For all Project workers (direct staff) and oversight of sub-contractor staff dedicated to the project
Women employed in the Project	Number of women employed in the Project including their rank and remuneration compared to men occupying the same positions.	On-going	For all female Project personnel including those employed by the sub-contractors.
Worker Welfare	Quality, appropriate numbers and suitable locations of Sanitation Facilities, Office Spaces, Welfare and Rest Areas	On-going	At all such facilities on-site
Quality of Accommodation	Inspection/internal audit of worker accommodation facilities vs. IFC & EBRD standards	Monthly	All accommodation facilities provided to direct and full time sub-contracted labour.
OHS Near Misses (involving external parties)	Any classified near miss	On-going	n/a
OHS Emergency Situations and Incidents	Any classified emergency situation or incident	On-going	n/a
Grievances and disputes including those relating to gender-based violence and harassment, sexual exploitation & abuse, and sexual harassment	Grievances received	On-going	Project site and any other grievances received from communities in reference to Project workforce including suppliers.
Health of the workers	Records of the illnesses the workers are suffering from and an analysis of top diseases.	On-going	Project site clinic or first aid facility
Human rights complaints/violations as reported by Project workers including workers hired through third-parties or in the supply chain	Grievances received	On-going	As defined in the Stakeholder Engagement Plan (SEP)
Emergency Situations and Incidents	Any classified emergency situation or incident	On-going	n/a

4 CLIMATE CHANGE IMPACT ASSESSMENT

4.1 Overview

ACWA Power is seeking finance for the Project from international lenders who are understood to be signatories of the Equator Principles, hence are EPFIs, which necessitates compliance with the Equator Principles (EPs). This chapter has been prepared in compliance with the Equator Principles volume IV which requires the inclusion of a 'Climate Change Risk Assessment' (CCRA) as part of the ESIA studies for projects financed by EPFIs.

4.1.1 Objectives of the CCRA

The objectives of the CCRA are to:

- Review and outline the KSA national regulations and standards, and lenders requirements;
- Review the climate change context and trends of KSA, highlighting the main issues;
- Identify and describe the potential vulnerabilities of the Project to climatic risks;
- Identify and describe the potential impacts of the Project or its activities on the climate;
- Propose project alternatives for potential lesser climatic impacts; and
- Propose actionable recommendations and mitigations to reduce the risks of adverse impacts.

4.1.2 Scope of the CCRA

The CCRA focuses on the climatic risks and impacts to the Project, associated facilities, and workforce during the Construction and Operational phases of the Project.

It considers potential impacts of the Project on the climate also.

4.1.3 Methodology

To address the scope of the CCRA, the following methodology was followed:

- Data collection & baseline development;
 - Desktop background research of national regulations and standards
 - Collation of lenders' requirements for CCRA's
 - Desktop background research of climate risks in KSA, current climatic situations, and future trends
- Scoping of climate risks identified in lenders' requirements for relevance against national desktop background research information to identify potential hazards;
- Analysis of the Project specific level of risk of each identified national hazard;

- Outline of the potential Project alternatives; and
- Proposal of mitigation measures to limit the effects of these potential climatic hazards on the Project and methods of monitoring.

4.2 Standards and Regulations

4.2.1 National Context and Regulations

The Paris Agreement came into force on 4th November 2016. The KSA signed and ratified the Agreement on 3rd November 2016 (UNTC, 2023). To date, the Kingdom of Saudi Arabia has not released a national climate action plan, however, the country has established several initiatives to address climate change issues, including:

- Establishing a Renewable Energy Project Development Office (REPDO) by the Ministry of Energy in 2017 which outlined plans for the kingdom to develop 58.7GW of renewable energy capacity by 2030, in line with Saudi's Vision 2030. In 2019 they also increased the 2023 clean energy target almost threefold to 27.3GW, from the previous target of 9.5GW (MEED, 2019);
- Launched the Saudi Green Initiative (SGI) in 2021 which *"aims to combat climate change, improve quality of life and protect the planet for future generations"*, overseen by The Energy and Climate Change Committee and The Environment Committee (Saudi and Middle East Green Initiatives, 2022);
- Establishing a National Committee for the Clean Development Mechanism and Designated National Authority in 2009, which oversees the development process of Clean Development Mechanism projects;
- Establishing a Saudi Energy Efficiency Program launched by Saudi Energy Efficiency Centre, which aims at designing and implanting energy efficiency initiatives for the country; and
- Oil and Gas Climate Initiative lead by Saudi Aramco to help member companies support the Paris Agreement and its aims
 - (<https://oilandgasclimateinitiative.com/about-us/#guidingprinciples>).

4.2.2 Lenders Requirements

Equator Principles volume IV establishes that impacts on the climate should be avoided where possible, and in support of the 2015 Paris Agreement recognises that EPFIs have a role to play in improving the availability of climate-related information, such as the recommendation by the Task Force on Climate-related Financial Disclosures (TCFD).

More specifically, Principle 1 states that factors such as climate change are required for the project categorisation based on the International Finance Corporation's (IFC) environmental and social categorisation process.

Principle 2 outlines the need for a climate change risk assessment, stating a requirement to “include assessments of potential adverse [...] climate change risks as part of the ESIA or other Assessment”. It further states that “The Climate Change Risk Assessment should be aligned with the Climate Physical Risk and Climate Transition Risk categories of the TCFD”. These are (TCFD, 2017):

- **Physical Risk:** Risks related to the physical impacts of climate change; and
 - Acute Physical Risk: those that are event-driven, including increased severity of extreme weather events, such as cyclones, hurricanes, or floods etc; and
 - Chronic Physical Risk: longer-term shifts in climate patterns (e.g., sustained higher temperatures) that may cause sea level rise or chronic heat waves.
- **Transition Risk:** Risks related with a transition to a lower-carbon economy.

EP 2 delineates emissions into two scopes:

- **Scope 1 Emissions:** direct emissions from the project owned facilities, or facilities controlled within the physical project boundary; and
- **Scope 2 Emissions:** indirect emissions associated with the off-site production of energy used by the project, such as connection to the grid.

For projects with combined scope 1 & 2 GHG emissions of over 100,000 tonnes CO₂-eq per annum, Principle 2 states requirements for analysis of alternatives which evaluates low GHG intense alternatives, and Principle 10 states that projects should report their GHG emissions annually.

IFC's PSs underpin EP 2. PS 1 states that the clients “risks and impacts identification process will consider the emissions of greenhouse gases, the relevant risks associated with a changing climate and the adaptation opportunities, and potential transboundary effects.”

PS 3 continues that clients should “consider alternatives and implement technically and financially feasible and cost-effective options to reduce Project-related GHG emissions during the design and operation of the Project”. For projects producing in excess of 25,000 tonnes CO₂-eq per annum, PS3 states a requirement for the client to quantify scope 1 and 2 emissions.

4.3 Baseline Data

4.3.1 National Climate Change Context

The mean global temperature has increased by an estimated 1.09 °C since the pre-industrial era. Climate observation and analysis in recent decades indicate that the globe is warming up at an average rate of 0.2°C per year (IPCC, 2021). Regarding long-term projections, the IPCC estimates a global mean surface temperature increase of 3.3 to 5.7°C in the period 2080-2100. The warming effect of progressive GHG emissions on the global climate has caused an upturn in the frequency and intensity of extreme weather events. Indirectly, these effects have also induced the

occurrence of climate-sensitive natural disasters and hazards such as droughts, floods, sea-level rise, and landslides.

By the end of 2021, KSA was reported to have a population of 35.46 million people and Gross Domestic Product (GDP) totalling 833.5 billion US Dollars. While the oil and gas industry accounts for 50% of the country's GDP, the country's economy is also significantly reliant on climate sensitive sectors such as agriculture (OPEC, 2023).

For 2023, KSA scored a Climate Change Performance Index (CCPI) score of 22.41%, rating them as 'very low' and ranking 62nd of 63 countries evaluated (Germanwatch, 2023). KSA also scored a Climate Risk Index (CRI) index of 73, ranking 57th in terms of average fatalities, and 51st in terms of economic losses in relation to extreme weather events (Germanwatch, 2022).

With a growing urban population, increasing temperatures, dwindling groundwater resources, rising sea levels, and recurrent flood events, KSA is faced with growing biophysical and socioeconomic vulnerabilities to climate change. In response to the climate emergency, the country launched a coordinated move towards decarbonisation with its entry into the Paris Climate Accords in 2015, and they have also been part of the United Nations (UN) Framework Convention on Climate Change (UNFCCC) since 1994.

In a movement towards a greener environment, KSA launched the SGI in 2021 which *"aims to combat climate change, improve quality of life and protect the planet for future generations"*. To date, it is reported (Arab News, 2023) that this initiative has led to:

- 150,000 homes powered by renewable energy;
- 18 million trees planted in 2022 in KSA;
- 62 sites approved for tree planting;
- 60,000 hectares of land rehabilitated in 2022;
- 250,000 cultivated shrubs in AlUla nurseries;

4.3.2 National Climate

Standing amongst the world's hottest and most arid countries, Saudi Arabia is characterised by a desert climate. In terms of climatic zones defined by the Köppen climate classification system, most of the country falls within the hot, arid desert zone. There are remote patches of cold, arid steppe, and hot, arid steppe, and also areas of cold, arid desert climates, much of which represent mountainous pockets in the country's western reaches.



Figure 4-1 Köppen Geiger climate classification for Saudi Arabia

Source: Beck, H.E. et al. (2018)

The climate mostly consists of high daytime temperatures, inversely low night-time temperatures, and little, irregular precipitation. With climatological influences from both tropical and extra-tropical weather systems, the country experiences the four seasons of winter (December-February), spring (March-May), summer (June-August) and fall (September-November) (Odnoletkova and Patztek, 2021), with a wet season in March and April.

4.3.3 Natural Hazards

Climatic hazards can be divided into natural climatic hazards, and induced climatic hazards.

- **Natural Climatic Hazards** are those hazards that are directly related to the changing climate, such as temperature or rainfall. The climatic changes that are causing the hazards to occur are being directly caused by climate change.
- **Induced Climatic Hazards** are those that can be indirectly related to the changing climate, such as floods and forest fires. The hazards are being caused by other climatic changes, such as sea level rise being induced by increasing temperatures that are the result of climate change.

CLIMATIC NATURAL HAZARDS

Temperature

Baseline and Historic Trends

Summers in the central region are extremely hot and dry, ranging from 27°C to 43°C in the inland areas and 27°C to 38°C in coastal areas. In winter, the temperature ranges between 8°C to 20°C

in the interior parts while higher temperatures of 19°C - 29°C have been recorded in the coastal areas of Red Sea (Climate Change Knowledge Portal, 2021). A graph illustrating the variation in mean annual temperature levels in the period 1991 to 2020 is shown below.

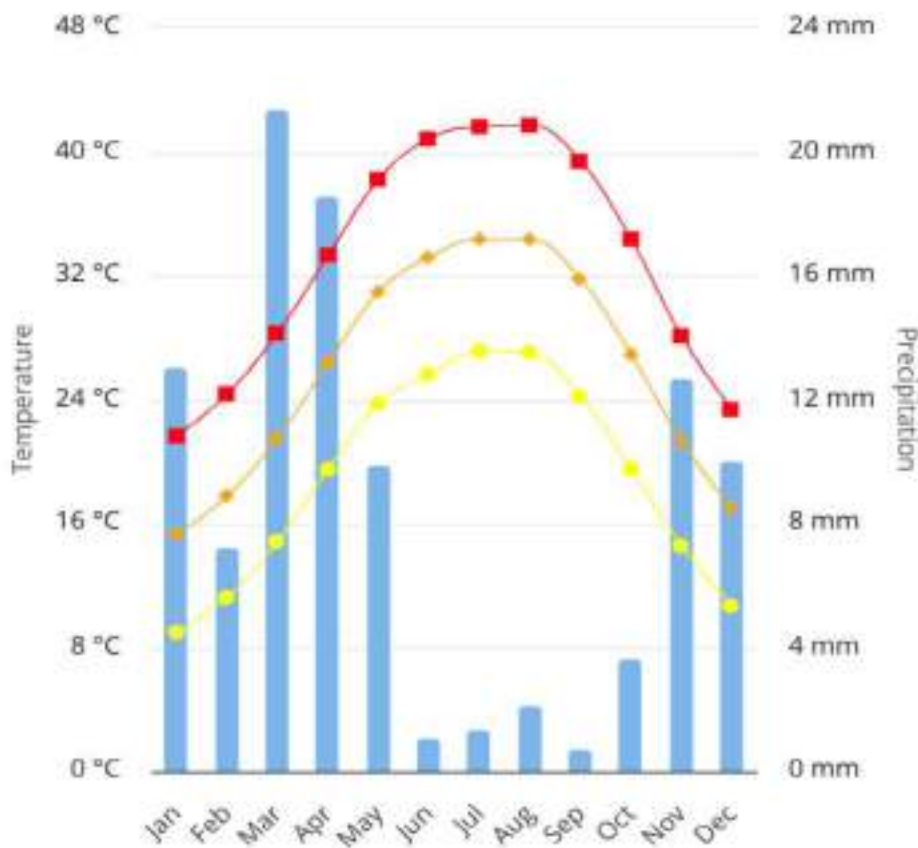


Figure 4-2 Observed Monthly Average Temperatures (Maximum – red; mean – orange, minimum – yellow), and rainfall (blue) in Saudi Arabia 1991-2020

Source: Climate Change Knowledge Portal (2021)

Projections

Below are projected temperatures for KSA using a range of Shared Socioeconomic Pathways (SSPs), future climate change scenarios based on broad socioeconomic trends that could shape future society. Modelling for the most severe SSP5-8.5 scenario predicts that maximum surface temperatures will rise by 16.8% from 2023 – 2100 to an average of 38.66 °C, and to at least 33.88 °C under SSP1-2.6

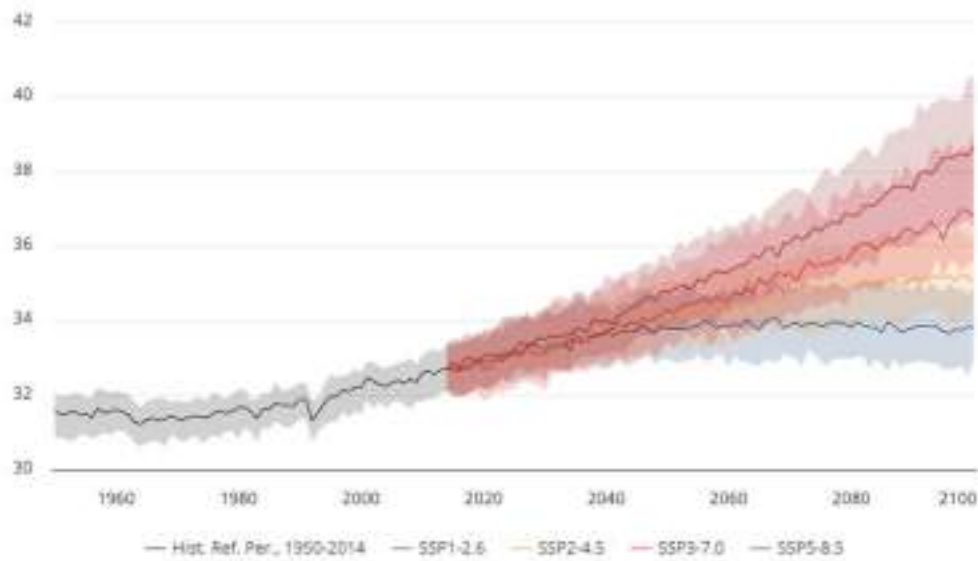


Figure 4-3 Projected Average Maximum Surface Air Temperature, Saudi Arabia

Source: Climate Change Knowledge Portal (2021)

Precipitation

Baseline and Historic Trends

KSA has a rainy season of March and April, as seen in Figure 4-2. The average annual rainfall in most parts of the country is below 150 mm throughout the year, except in the southwest part where the rainfall occurs between 400 – 600 mm annually (Climate Change Knowledge Portal, 2021). The annual average precipitation for 2010 – 2021 can be seen below, as well as monthly variations above in Figure 4-2.

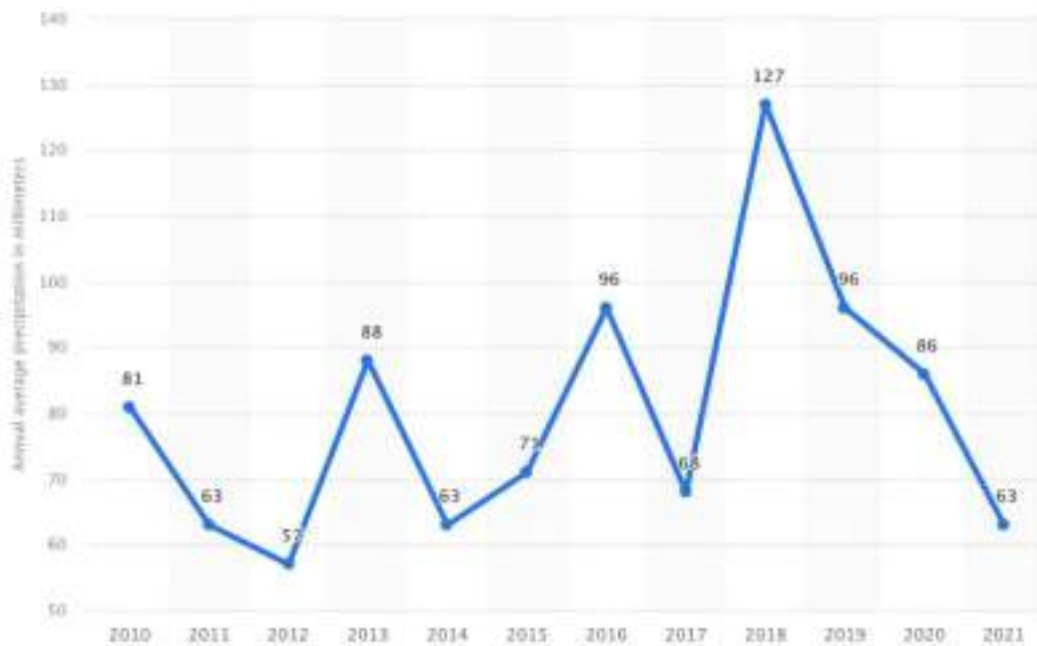


Figure 4-4 Annual Average Precipitation in KSA 2010 – 2021

Source: Statista (2023)

Projections

Using the SSP5-8.5 model, precipitation is estimated to rise by approximately 12 mm per annum, although there appears to be much variation in these estimations, as seen in the figure below.

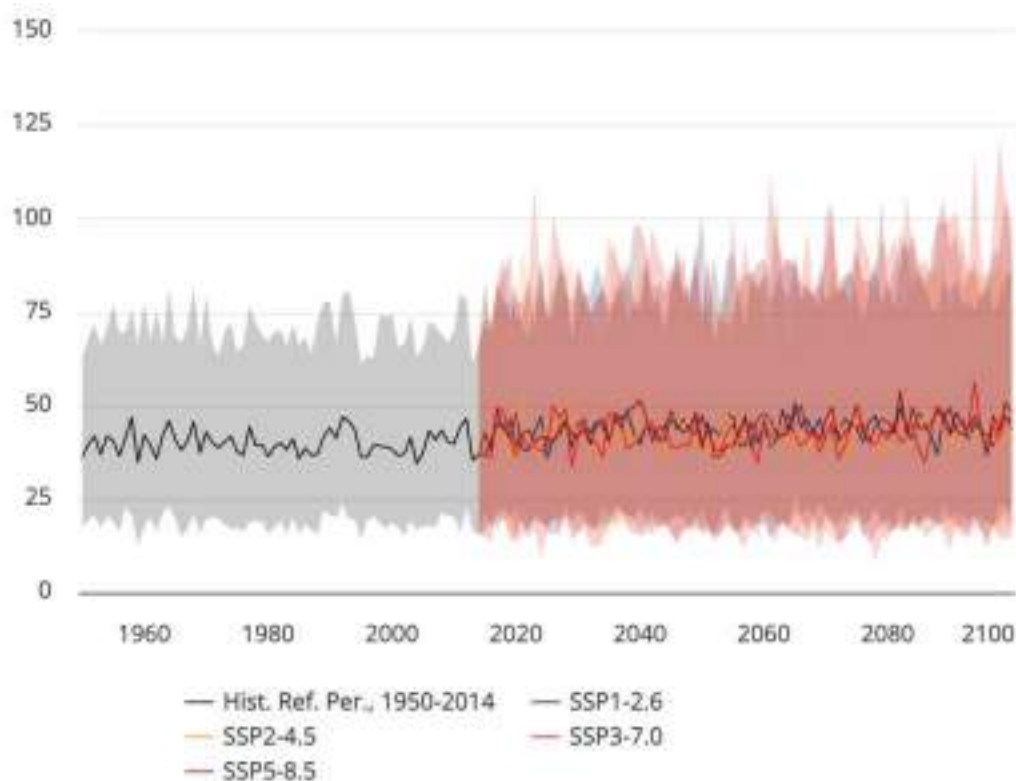


Figure 4-5 Project Precipitation in KSA

Source: Climate Change Knowledge Portal (2023)

The frequency of intense rainfall events is increasing for the majority of Saudi Arabia, while the frequency of weak events is decreasing. The contribution of extreme events (daily rainfall of ≥ 26 mm) to the total rainfall amount varies, but in one case was found to be up to 56%, and this is expected to increase, causing more large scale, intense rainfall events (Almazroui, 2020).

CLIMATE-INDUCED HAZARDS

Flooding

Flash floods are caused by slow-moving weather patterns (convective systems) that generate intense rainfall over a poorly drained area in a short space of time (less than six hours). As outlined above, KSA is observing a trend of more intense rainfall which leads to more extreme flooding.

Severe flash flooding events have been observed in Saudi Arabia in the recent years, especially in Western parts of the country. In August of 2023, the Makkah neighbourhood of Al-Kakiyyah recorded 45 millimetres of rain within 24 hours, causing large scale flooding (Al Jazeera, 2023). A total of 11 extensive flash floods have occurred in KSA since 1985.

Floods are observed to be the most significant key natural hazard for the period of 1980 – 2020 in KSA.

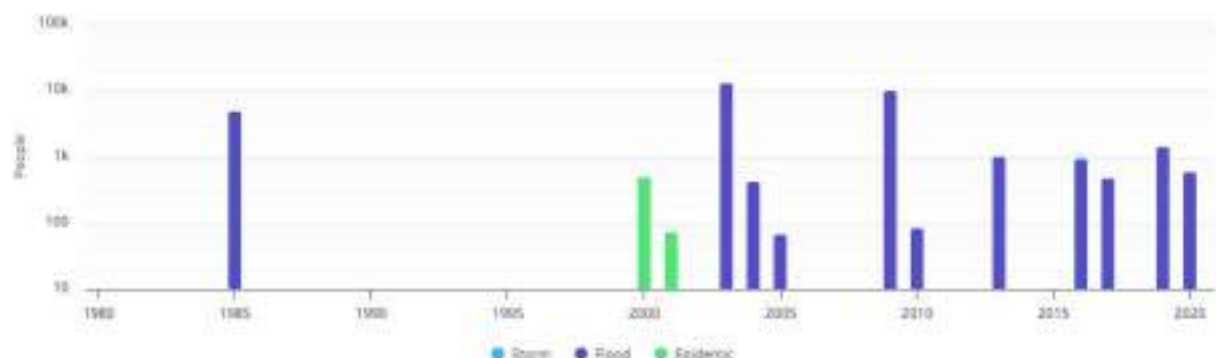


Figure 4-6 Number of People Affected by Key Natural Hazards in KSA 1980 – 2020

Source: Climate Change Knowledge Portal (2023).

Sea Level Rise

Sea level rise is a significant national concern. However, since the Project site is approximately 300 km from the nearest coastline, it will not be affected by it.

Landslide

Think Hazard (2023) have classified the risk of landslides in KSA as 'Medium'. KSA's rainy season of March and April increases the risks of landslides throughout the country. Landslides are one of the biggest environmental risks to the northwest of KSA (Kahal et al., 2021), and are common in the west and southwest (Youssef et al., 2022).

Heat Waves and Drought

Over the past four decades, the mean annual temperature in Saudi Arabia has risen at a rate that is 50% higher than that of the remaining landmass of the Northern Hemisphere. KSA's mean temperature increased by 2.18°C between 1979 and 2019, which is threefold the global average. This trend has been paralleled by an increase in humidity.

The total duration of heat waves in a year (prolonged periods of maximum temperature records) is growing exponentially in most of the big cities in Saudi Arabia (Odnoletkova & Patzek, 2021). Such heatwaves are the most significant weather-related cause of mortality in the world (Gronlund et al., 2018).

The increase in temperatures will also cause an increase in distribution of vector organisms such as malarial mosquitoes, and therefore the transmission of numerous vector-borne diseases like malaria and dengue fever (McMichael et al. 2003).

Alongside heat waves, the rising temperatures are inducing more drought periods. KSA lies in a region of great water stress, and "is highly vulnerable to recurring droughts" (Syed et al., 2022). Eight drought years (1990, 2003, 2007, 2008, 2009, 2011, 2012 and 2017) are identified by Syed et

al. (2002), the most extreme being 2007, and the longest period being from 2007 to 2012 when approximately 70% of KSA land area was under drought conditions (ibid.)

It is predicted that in KSA climate change will cause decreased regular national rainfall patterns and increased evaporation rates. More extensive dry periods are expected that will result in further depletion of groundwater reserves, and the worsening of water scarcity.

Water Scarcity

Water scarcity is a key challenge in KSA which depends heavily on desalinated water. According to the US - Saudi Business Council (2021), KSA is the largest country in the world without running surface water, but it has the third-highest per capita freshwater consumption in the world (2022), at over 8 million m³/day, forecast to reach 12.3 million m³/day by 2040.

As per the World Future Energy Summit, the Ministry of Environment, Water and Agriculture (MEWA) announced the launch of the Qatrah program in 2019 to rationalise water consumption and address the overuse and waste of water resources (WaterWorld, 2019). The mission of the program is to reduce 24% of the country's daily per capita consumption rate by 2022 and 43% by 2030.

Dust Storms

Dust storms refer to extensive dust dispersion events caused by strong winds that raise dust and sand from deserts and surrounding areas and carry it over large distances. KSA is situated on the Arabian Peninsula, the world's largest source of dust. Together with North Africa, these two regions account for 70% of global dust emissions (Ginoux et al., 2012). Most dust storms are found in the east of KSA, which experiences between 10 and 60 per annum (Albugami et al., 2019).

The increasing temperatures and prolonged dry periods can increase the severity or frequency of dusty days and hence the risk of dust storms. This may include increased wind velocity over current speeds.

Forest Fires

With warmer temperatures and drier climates, the risk of forest fires is increasing throughout KSA, particularly in the southern regions with more vegetation, where the risk is rated as 'high' by Think Hazard (2023).

Erosion and Desertification

It is believed that between 70 and 90 percent of the Arabian Peninsula is under threat of desertification. This desertification is leading to greater levels of erosion in KSA due to the dry, windy conditions, resulting in reduced land productivity and increased unwanted sedimentation.

4.4 Project Vulnerability

In line with EP 2 and IFC PS 2, this CCRA will assess the potentially adverse impacts of climate change risks to the Project, specifically. The potential impacts have been categorised according to the 'Climate Physical Risk and Climate Transition Risk' categories of the TCFD, as required by IFC PS 2.

The acute and chronic climate-related hazards are defined following the major hazard groups as defined in EU Taxonomy¹. The Equator Principles Guidance Note on Climate Change Risk Assessment² states that these hazards should "*be taken into account as a minimum in the climate risk and vulnerability assessment*". These hazards have been scoped for national risk (See Appendix C) based to the desktop review of baseline data in Section 4.3, but not explicitly for the Project itself. The risks that are found to be relevant to KSA are assessed for Project relevance and vulnerability are discussed below. Additional risks to those from the EU Taxonomy have been added to the Project vulnerability assessment below based on the findings of the national baseline study.

4.4.1 Climate Physical Risk

ACUTE PHYSICAL RISK

Extreme Heat Events

The Project province of Madinah is rated as high risk of extreme heat events (Think Hazard, 2023). If these events occur, Project workers' health and safety may be at risk, particularly if safety measures are not integrated for their protection when working outdoor in heat. The Project site is open, with no natural shade, so extreme heat events could have severe effects.

It is reported that solar panel efficiency is reduced during high heats by 0.3% to 0.5% for every degree above 25 °C (Ecoflow, 2023), so extreme heat events will impair the electricity generation capacity of the Project.

Extreme Precipitation Events

The Project is located inland in an area of the country that experiences relatively stable weather patterns. The province of Madinah which the Project is located in receives moderate levels of rainfall at 101 mm average per annum between 1991 and 2020, and the most rainfall during March, with an average of 17.21 mm (Climate Change Knowledge Portal, 2021). Extreme precipitation events are not expected to affect the Project.

¹ https://finance.ec.europa.eu/system/files/2020-03/200309-sustainable-finance-teg-final-report-taxonomy-annexes_en.pdf

² https://equator-principles.com/app/uploads/Guidance-CCRA_May-2023.pdf

Drought and Water Scarcity

No water sources are available on site, hence all water will be provided from water source such as water trucks by local suppliers.

During construction, water will be used for construction activity purposes as well as for consumption. During operation, water will be for consumption and for the semi-automated cleaning system. Considering the above combined with the number of construction and operational workers, and from 5 Capitals' experience of working in KSA, drought and water scarcity impacts are not anticipated to pose a significant risk to the Project.

Flooding

The Project is located inland in an area of the country that experiences relatively stable weather patterns. The province of Madinah which the Project is located in receives moderate levels of rainfall. There are no permanent surface water bodies or signs of water accumulation within the area.

ACWA Power confirmed that a complete site study will be conducted by the EPC Contractor before the engineering phase and prior to construction to identify the requirements associated with the site conditions (i.e. wind speed, corrosion category, and flooding) as depicted in the Construction Schedule – Preliminary Works.

Over the timescale of the Project, the changing climatic patterns will not significantly change the level of the risk to flooding, therefore the current low risks are accepted throughout the Project.

Extreme Mass Movement

Although landslides and other mass movements have occurred within KSA, the Project site is flat and stable. Therefore, there is believed to be no overall risk of mass movement events at the Project site.

Dust and Sandstorms

In the event of warmer temperatures and any prolonged dry periods (i.e., during the summer), this could potentially result in the increase in the severity or frequency of dusty days, and dust or sandstorms. Severe dust or sandstorms can affect the workers' health if mitigation measures are not put into place. Furthermore, the PV panels may require more regular cleaning.

CHRONIC PHYSICAL RISK

Mean Temperature Change

Temperature rise is a national issue for KSA, suggesting that average temperatures could rise by as much as another 16% by 2100. The Project is expected to have 2,317 workers at the peak construction period, the majority of which are expected will have to work outdoors. During the

operation phase, it is expected that there will be about 14 to 16 workers, some of which will also be working outdoors. Working outdoors in high temperatures for extended periods is dangerous to the health and wellbeing of the workers. It is expected that the number of these staff working outdoors will be limited where possible and the Project will incorporate resting periods during peak seasons.

The increase in temperature due to climate change will not be observed during the timescale of the Project, therefore the current risks are accepted throughout the Project.

Erosion

The Project is in a predominantly flat, dry, sandy area. Although extreme wind events are not expected, it is expected that every day winds will frequently move material around, off, or on to the Project site. Winds may remove other material in sections, potentially exposing sub material, or it may gather up against the PV installation footings.

4.4.2 Climate Transitional Risk

As the Project is a Solar PV project and is aligned with wider strategies for a transition to a lower carbon economy (such as those in line with Saudi Vision 2030), there are not expected to be any climate transitional risks related to future low carbon economies (policy, regulations etc.), or future public perceptions of the Project that are considered risks at this stage.

4.5 Project Effects

4.5.1 Construction Phase

SCOPE 1 GHG EMISSION

The stationary combustion sources used during the construction phase of the Project will primarily relate to temporary diesel generators, which will be located around the site in the EPC Contractor and sub-contractors administration and office areas.

Additionally, the construction phase of the Project will necessitate an amount of mobile equipment, vehicles, and machinery to facilitate works. Equipment such as excavators, rollers, cranes, pneumatic compressors, and other vehicles will be abundant on the site, and are expected to be used in most construction processes. Such equipment will be fuelled mostly by diesel.

It is estimated that approximately 1,798KL of diesel will be required for the entire construction duration which equates to about 69,150 L of diesel per month.

Using the GHG Protocol calculation tool for GHG Emissions from Stationary Combustion (World Resources Institute, 2015), the GHG emissions during construction were calculated in carbon dioxide equivalent (CO₂-eq) and are summarised in the table below.

Table 4-1 Generators-GHG Emissions During Construction of the Project

FUEL TYPE	VOLUME OF FUEL (L/MONTH)	GHG EMISSIONS (TONNES/MONTH)			TOTAL GHG (TONNES CO ₂ -EQ /MONTH) *
		CO ₂	CH ₄	N ₂ O	
Liquid Fossil (Diesel)	69,150	185.079	7.4932e-3	1.499e-3	185.686
Total GHG emissions from fossil fuels (tonnes CO₂-eq) per year					2,228.23
*If/when the generators are operational					

4.5.2 Operational Phase

GHG ABATEMENT

As a renewable energy project, there is essentially a neutral operational impact on GHGs when the Project is generating, as the Project will not combust fossil fuels, other than for the potential running of generators for required operational functionality tests. A key benefit of the Project is the resulting lowering of the carbon intensity of the grid produced electricity in KSA.

It is possible to make a comparison of GHGs mitigated against a grid factor for GHG emissions in KSA. This is based on the KSA default grid factor of 569 gCO₂/KWh from Climate Scorecard (Climate Scorecard, 2023).

It is expected that the Project will generate an average of 9,564,259 MWh per year for the entire 25-year operating period, generating an estimated relative net emissions saving of 5,442,063.4 tonnes of CO₂ equivalent per year (tCO₂-eq /year). Over this 25-year operating period this will result in an estimated total net saving of approximately 136.1 million tCO₂-eq when compared to conventional grid energy source.

GHG EMISSION - GRID ELECTRICITY USAGE

Although being a renewable energy project, the generation of solar power is intermittent and restricted to daylight hours only. As such the Project will draw power from the grid during the night to provide electricity for lighting, security purposes, (e.g., security systems, CCTV etc.) and any site office, workshop or other requirements being undertaken at night.

Given that it is only expected that security staff will be present at night and there are no operational processes that will require large quantities of power to be drawn from the KSA grid, the amount of power usage is expected to be 23,832 KWh/month.

According to Climate Scorecard, the energy sector in KSA generates 569 gCO₂/kWh. Based on an estimated 23,832 KWh monthly electricity consumption, a total of 162.7 tons of CO₂-eq are expected to be generated annually.

SCOPE 1 GHG EMISSIONS

The Project has emergency diesel generators that will be located on-site. These generators are not expected to be used except during grid blackout conditions where the generator would provide an amount of power load to enable the safe operation of the plant in such circumstances.

It is estimated that approximately 2,500 L of diesel fuel will be required annually (which includes regular functionality testing) per generator. Using the Greenhouse Gas Protocol calculation tool for GHG Emissions from Stationary Combustion (Greenhouse Gas Protocol, 2015), the GHG emissions during operation were calculated and are summarised in the table below.

Table 4-2 Generator-GHG Emissions During Operation of the Project – Per Generator

FUEL TYPE	VOLUME OF FUEL (L/YEAR/GENERATOR)	GHG EMISSIONS (TONNES/YEAR)			TOTAL GHG (TONNES CO ₂ -EQ /YEAR/GENERATOR)
		CO ₂	CH ₄	N ₂ O	
Liquid Fossil (Diesel)	2,500	6.691	2.709e-4	5.418e-5	6.713

USE OF OZONE DEPLETING SUBSTANCES (ODS)

Sulphur hexafluoride (SF₆) is to be used in high voltage electrical equipment as the insulating gas, as part of the gas insulated switchgear, and associated facility of the main PV project. There may be some leakage from the gas insulated switchgear, or where mishandled. SF₆ switchgear is widely used in the electrical network and under normal operational conditions leakage should not occur. Management of ODS shall comply with the industry international good practices.

REFRIGERANTS

Trace amounts of refrigerants will be used in chiller packages where needed on-site for air conditioning, refrigerators etc. Where applicable, the requirements of the Montreal Protocol are applicable concerning the use and application of ODS. Any leakage of refrigerants would be negligible.

4.5.3 Decommissioning Phase

WASTE

End-of-life management requirements for PV panels still largely falls under the general waste classification rather than dedicated to PV. Resource Media (2023) have estimated that solar panel waste is set to increase by more than 4,000 per cent in the next decade. The International Renewable Energy Agency (IRENA) (2022) have further estimated that cumulative waste from PV

plant decommissioning will increase from 0.2 Mt (megatonnes³) in 2021 to 4 Mt by 2030, 50 Mt by 2040, and more than 200 Mt by 2050 (See figure below).

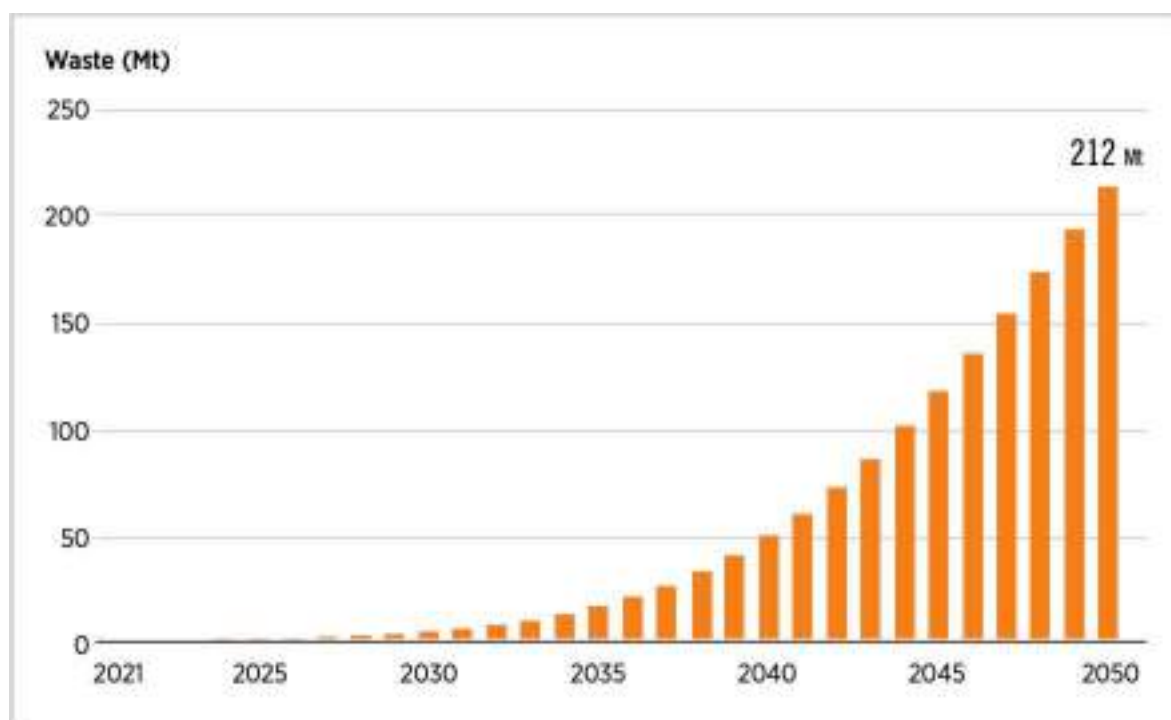


Figure 4-7 Projected Cumulative Waste from Solar Photovoltaic Projects

Source: IRENA (2022).

A country specific breakdown was presented by IRENA and IEA (2016), which specifies that even without 'early loss' waste, Saudi Arabia could have 450,000 tonnes of solar PV waste by 2050, a 149,900% increase.

Table 4-3 Modelled results of cumulative waste volumes of end-of-life PV panels for KSA, in tonnes (IRENA & IEA, 2016)

YEAR	2020	2030	2040	2050
End-of-life waste PV panels in tonnes (no early losses)	300	3,500	70,000	450,000

IRENA (2022) believes that by unlocking the full potential of a circular economy, solar PV panel waste can be restored, reused, and recycled, saving more than 17.7 Mt of raw materials from waste by 2050, generating a value of 8.8 billion US dollars.

The Project will be using polycrystalline solar panels, which contain approximately 0.5 kg of silicon (Sah et al., 2023). Silicon wafer manufacturing is energy intensive and producing 1 kg of wafer requires up to approximately 440 kWh of power.

³ Millions of tonnes

It should be noted that over the lifespan of solar panels, the green energy produced does outweigh the energy consumption used for their manufacturing, when sourced responsibly.

Following decommissioning the materials will need to be removed. These materials, if not restored, reused, or recycled, will add to the cumulative waste issue, and not aid in deterring the generation of more solar PV panels, which is energy intensive and adds to the effects of global warming.

4.6 Mitigation Measures

4.6.1 Resource Efficiency

The following measures can be implemented in subsequent stages of project planning to minimise GHG emissions over the course of the Project's lifetime:

The Project should implement comprehensive resource efficiency measures to reduce scope 1 and scope 2 GHG emissions during the Project's construction and operational phases. These measures generally include, but are not limited to the following:

- The procurement of equipment for the Project's construction and operational phases that give priority consideration to power efficiency, durability, and water conservation;
- During construction and operation, energy conservation measures for electricity-powered equipment should be promoted, and power consumption should be monitored. Economical use of fuel-powered equipment should be encouraged and monitored on the same basis; and
- During construction, resource efficiency in relation to construction materials should be promoted and monitored in the same manner.

4.6.2 Extreme Heat

The following mitigation measures shall be implemented to mitigate against heat-related medical conditions, for operational labour:

- Workers assigned to operations outside of the buildings and shaded areas will be provided with appropriate Personal Protective Equipment (PPE) (e.g., sun hats and cooling vests).
- Shaded resting areas (ideally with air conditioning) and adequate access to potable water will be provided for workers stationed outside of the Plant's buildings (e.g., guard houses).
- Work locations (and duration, to the extent possible) will be restricted during periods of extreme heat to lessen the risk of heat-related health effects. Maintenance work within high-temperature units will be avoided during days with inordinately high temperatures.

- Staff rooms on the plant's premises will be equipped with HVAC or fans to enable operations at workstations during periods of extreme heat.

4.6.3 Dust

To effectively manage dust-related issues in the context of climate change, it's recommended to maintain diligent visual and secondary monitoring (i.e., weather station reports or other publicly available sources) of dust levels, and ensure outdoor staff are not exposed to hazardous dust levels.

4.6.4 Water Availability

Although not identified as a significant risk to this Project, to reduce impacts on water resources, a water management plan/programme could be implemented to include the following:

- Installing smart water management systems (faucets with sensors, water meters, leakage detection systems etc.);
- Monitoring water consumption;
- Conducting regular maintenance of faucets, plumbing, water tanks etc.; and
- Raising awareness on water conservation among workers.

5 CUMULATIVE IMPACTS ASSESSMENT

Cumulative impacts are defined as those that result from the successive, incremental, and/or combined effects of an action, project, or activity when added to other existing, planned, and/or reasonably anticipated future ones. For any given project, a Cumulative Impact Assessment (CIA) serves to identify resultant environmental and social impacts that can synergize with equivalent impacts of proximate developments, and with natural stressors, such as climate change.

As such, the CIA process primarily consists of the following two aspects:

- Identification and characterisation of potential impacts that can be expected to ensue from the project activities, other developments, and environmental drivers within the temporal and special boundaries of the project in focus; and
- Development of actionable measures for effective prevention, mitigation, and alleviation of negative cumulative impacts and risks, and enhancement initiatives for any positive cumulative impacts.

5.1 Objectives of the Cumulative Impact Assessment

The objectives and outcomes of the CIA study for the Project are as follows:

- Identification of Project components, coincident developments, and natural/unplanned dynamics that bare mutual Environmental & Social (E&S) impacts, which may arise and/or intensify within the Project's lifetime and influence areas;
- Identification of Vulnerable Environmental Components (VECs) that are subject to E&S impacts brought on by the Project in synergy with external drivers;
- Overview of the current state of the VECs identified, with a focus on baseline attributes of particular relevance to the Project;
- A description and assessment of cumulative E&S impacts foreseen to affect established VECs, relative to baseline conditions, legal requirements, and internationally recognised benchmarks;
- Recommendation of effective mitigation measures to prevent, abate, and/or alleviate negative E&S impacts, alongside enhancement actions to reinforce anticipated Project benefits; and
- Development of a management and monitoring plan with a specific focus on the Project's E&S impacts, which should set out the timing, monitoring indicators, and responsible implementing parties for consistent impact management and performance evaluation in relation to established indicators and targets.

5.2 Identification of Concurrent Developments and Environmental Drivers

Coincident developments that might have E&S impacts are listed below, it is understood the construction phases of this Project and the below activities are concurrent.

Table 5-1 Activities and Developments Included in CIA

PROJECTS/ ENVIRONMENTAL STRESSORS	DESCRIPTION	STATUS
SEC Sub-station (Associated Facilities)	The Project will be connected to adjacent SEC substation.	Design Phase
Overhead transmission line (OHTL) (Associated Facilities)	Overhead transmission line from the SEC sub-station.	Design Phase

5.3 Identification of Valued Environmental Components

The impacts on the main VECs that have been considered for the purpose of this CIA during construction and operation are:

- **Air Quality** – due to the arid nature of the site and surrounding areas there are potential cumulative air quality impacts (particularly with regards to particulate matter) should the construction phases of the projects overlap;
- **Noise** – concurrent construction activities have the potential to result in elevated noise levels across the wider area. Noise levels will be elevated because of construction activities and construction vehicles;
- **Ecology** – Cumulative land take for PV projects resulting in habitat loss and fragmentation. Further, the erection and presence of numerous transmission lines has the potential to result in cumulative impacts to ecology, primarily avifauna, who are at risk of electrocution and collision with transmission lines;
- **Grazing Land** - Cumulative land take for PV projects resulting in loss of grazing land;
- **Landscape/Visual Amenity** – Largescale cumulative impacts on landscape character from the PV projects;
- **Waste Utilities** – Additional pressure on available waste services and utilities due to the large-scale construction projects;
- **Socio-economics** – Employment and other business benefits and opportunities; and
- **Traffic and Road Infrastructure** – Cumulative impacts during construction of multiple projects in the same area.

5.4 Assessment of Cumulative Impacts on VECs

Project activities set for the construction and operational phases were overlaid with respect to the biophysical and socioeconomic context within the Project area to identify interfaces and potential impacts that could grow in magnitude as a result of commonalities amongst the Project components and other local developments (identified above). Potential cumulative impacts derived from this analysis are itemised in correspondence to their respective VECs for the Project's construction and operation phases, in the following table.

Table 5-2 Assessment of Cumulative Impacts on VECs

VALUED ENVIRONMENTAL COMPONENTS	IMPACT-GENERATING PROJECTS	CUMULATIVE IMPACTS	
		CONSTRUCTION PHASE	OPERATION PHASE
Air Quality	- Humaij PV Project (the Project – planned) - SEC Substation (planned) - OHTL connection (planned)	- As a worst-case scenario it has been assumed that the construction periods of all the developments will coincide to an extent. - Local ambient air quality will be potentially affected by increased dust during site clearance and earthworks, as well as by gaseous emissions from the exhaust of construction vehicles, equipment, and temporary power generators. - With the adoption of typical and common management practices (mitigation measures) outlined in the ESIA Report, the cumulative impacts are anticipated to have only minor significance. This is mainly attributed to the remote location of the site, which has limited external sensitive receptors.	None expected.
Noise	- Humaij PV Project (the Project – planned) - SEC Substation (planned) - OHTL connection (planned)	- As a worst-case scenario it has been assumed that the construction periods of all the developments will coincide to an extent. - Construction activities will result in temporary and short duration increases in the noise and vibration levels emanating from construction site noise and construction vehicle noise. With coinciding construction activities there is the potential for cumulative noise impacts. - With the adoption of typical and common management practices (mitigation	None expected.

VALUED ENVIRONMENTAL COMPONENTS	IMPACT-GENERATING PROJECTS	CUMULATIVE IMPACTS	
		CONSTRUCTION PHASE	OPERATION PHASE
		measures) outlined in the ESIA Report, the cumulative impacts are anticipated to have only minor significance. This is mainly attributed to the remote location of the site, which has limited external sensitive receptors.	
Ecology	- Humaij PV Project (the Project – planned) - SEC Substation (planned) - OHTL connection (planned)	- Project land take will reduce the available land in the Project area. - Areas of gravel plain and sand that comprise much of the site would be largely unaffected as limited construction works will be required that affect the morphology and topography of such habitats.	The erection and presence of transmission lines has the potential to result in cumulative impacts to ecology, primarily to avifauna which are at risk of collision and electrocution impacts.
Grazing Land	- Humaij PV Project (the Project – planned) - SEC Substation (planned)	- Project land take will reduce the available land in the Project area. - The quality of grazing vegetation within the Project site and locally is limited, and when the local herders were questioned, they stated that they almost exclusively feed their livestock with animal feed due to the lack of volume, species, and quality. Overall, the availability of land is ample, and the consultations with the local herders identified they have areas suitable that they can relocate to.	
Landscape/Visual Amenity	- Humaij PV Project (the Project – planned) - SEC Substation (planned) - OHTL connection (planned)	- Through construction, and sustained during operations, the land in the Project area will change from typical KSA desert landscape to one of a more industrialized character. In particular, the extensive installation of dark coloured PV modules for the Project will make a significant change to the visual amenity, particularly when viewed from above. - There are certain identified local receptors such as the two nearby communities and nearby local road users that could be affected by visual amenity. This is because the views across the largely flat land will be reduced due to the installation of fences, and tracker foundations, PV modules, and other structures.	

VALUED ENVIRONMENTAL COMPONENTS	IMPACT-GENERATING PROJECTS	CUMULATIVE IMPACTS	
		CONSTRUCTION PHASE	OPERATION PHASE
		- Lighting from the projects, although expected to be limited to certain areas (e.g., security entrances and control buildings) will likely be evident at distance, although this is not expected to result in light spill outside of the project areas. - The new OHTL also presents a vertical intrusion to a landscape that did not include this previously.	
Waste Utilities	1. Humaij PV Project (the Project – planned) 2. SEC Substation (planned) 3. OHTL connection (planned)	The construction phase of the project will likely overlap with the construction of the OHTL connection and SEC substation, which is located adjacent to the Project site. The generation of liquid, solid, and hazardous waste by the projects could potentially impose additional demands on the existing waste management facilities in the region.	None expected.
Socioeconomics	1. Humaij PV Project (the Project – planned) 2. SEC Substation (planned) 3. OHTL connection (planned)	- The outset and progress of construction on the Humaij PV Project will create an influx of workers as all the construction phase workers are expected to be foreign workers, predominantly from India and China. - In the absence of proper management, the influx of workers for the Humaij project may potentially result in adverse impacts. These impacts are associated with the risk of social conflict due to different cultures, increased demand and pressure on public infrastructures, facilities and recourses, increased risk of communicable diseases or local inflation of prices.	- The main socio-economic advantage of the Project (including the substation and OHTL) is the benefit of grid stability for economic purposes. - The Projects will also create some (but limited) new employment opportunities in the operations phase.
Traffic and Road Infrastructure	1. Humaij PV Project (the Project – planned) 2. SEC Substation (planned)	It is anticipated that there will be a period when construction activities for the projects will overlap, and shared routes may be used for transporting construction personnel,	None expected.

VALUED ENVIRONMENTAL COMPONENTS	IMPACT-GENERATING PROJECTS	CUMULATIVE IMPACTS	
		CONSTRUCTION PHASE	OPERATION PHASE
	3. OHTL connection (planned)	materials, and equipment. Given the collective magnitude of these construction operations, an increase in transportation activity can be expected. During periods of significant construction-related traffic, there is the potential for road congestion in specific areas or placing physical stress on the existing road infrastructure.	

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APPENDIX A – STAKEHOLDER ENGAGEMENT GUIDELINE

PV IPPs, KSA STAKEHOLDER ENGAGEMENT GUIDELINE FOR PROJECT COMPANY HSSE TEAM

STAKEHOLDER ENGAGEMENT - OVERVIEW

Stakeholder engagement can be described as the systematic method to understand and involve stakeholders and their concerns in project activities and decision-making processes. It identifies the appropriate approach to be used for consultation and information disclosure. Stakeholders include persons or groups that may be directly or indirectly affected by the project, as well as those that may have interest in the project and/or those that may influence the projects outcome either positively or negatively.

OVERARCHING REQUIREMENTS

In order to meet Equator Principles IV (Principle 5 & 6) and IFC Performance Standard (PS 1) requirements, the Project is required to conduct stakeholder engagement.

GUIDELINES

The table below provides a guideline on how the consultation process should be undertaken by the PV IPP Project Company – HSSE Team.

It is recommended that bi-lateral meetings are arranged and held with identified stakeholders. This will avoid open public events/gatherings. It can be explained that the key purpose of the consultations are:

- To share an overview of project information,
- To seek feedback on the project itself.
- To gather specific information on targeted issues.
- To seek advice on any issues in the area (or at the land) that may be of concern or that may have been overlooked.
- To advise on the availability of a third-party grievance mechanism (and how to access it).

ELEMENT	GUIDELINE
Meeting/Consultation Agenda	
Project information	Advise the stakeholder on the following: - Overarching requirement and context of the project – (i.e. in line with REPDOs targets under Vision 2030, Saudi Green Initiative, other strategy etc). - The project parties (including ACWA Power, the PC, EPC, O&M, Sub-Contractors, other relevant 3rd parties). - Project location (include maps showing the geographic location of the site, total area and project boundaries) - Summary of project components/facilities - Details and location of associated facilities (where available), such as access roads, sub-stations and locations of these. Also advise who is responsible for these works.
General overview of the project Construction	- Nature and scale of construction works, any phasing that is planned. - Expected numbers of workforce during construction and operational phases. - Location of project construction facilities such as temporary construction laydown areas, accommodation facilities etc. - Timeline and schedule of construction works. - Any expectation on traffic/vehicle flows. - Any specific facilities that may only be necessary for construction (e.g. temporary access roads, batching plants etc.)
General overview of the project Operation	- General overview of day-to-day operations (such as SCADA operations, typical maintenance, cleaning etc.) - Number of O&M staff
Project Impacts	<u>Positive Impacts</u> - Example of positive impacts include employment opportunities, diversification of existing skill base, contribution to KSA renewable energy targets, and reduction on reliance on fossil fuels, benefits towards KSA international targets and commitments linked to the Paris Climate Agreement. etc. <u>Negative Impacts</u> - Example of negative impacts include i.e., dust, noise & traffic during construction, landscape change, community health & safety risks etc. - To include a summary of key mitigation and management measures the project will put in place in order to minimise the negative impacts i.e., Note: the positive & negative impacts should match those identified in the ESIA and ESIA Addendum.
Discussions	During the consultations, stakeholders will be given time to ask for clarifications, additional project information or raise their concerns, or give their general feedback. Where available any requested information should be provided immediately, or where not possible the PC shall revert to them at a later agreed time.
Targeted Questions and Information Gathering	
Guidance Note: For this important part of the consultation process, please refer to the specific questions in the Annex.	
Grievance Mechanism	

ELEMENT	GUIDELINE						
Implementation of the Grievance Mechanism	An important part of the engagement process is to advise that there is a third-party grievance mechanism in place and how it can be accessed. The Project specific Stakeholder Engagement Plan (SEP) should include details of the grievance mechanism for the Project. In order to implement it, please ensure that the SEP is completed by including the following details: <table border="1" data-bbox="464 488 1442 757"> <thead> <tr> <th data-bbox="464 488 959 524">COMPANY</th><th data-bbox="959 488 1442 524">DETAILS</th></tr> </thead> <tbody> <tr> <td data-bbox="464 524 959 640"> ACWA Power or Project Company Name of contact person </td><td data-bbox="959 524 1442 640"> Email: XX Work: XX Mob: XX </td></tr> <tr> <td data-bbox="464 640 959 757"> EPC Contractor Name of contact person </td><td data-bbox="959 640 1442 757"> Email: XX Work: XX Mob: XX </td></tr> </tbody> </table> The grievance mechanism will need to be publicised and available at the project entrance, Project website (if any) & during the consultation meetings. It is suggested that a handout on this is provided to the stakeholders so there is firmer evidence that this has been communicated.	COMPANY	DETAILS	ACWA Power or Project Company Name of contact person	Email: XX Work: XX Mob: XX	EPC Contractor Name of contact person	Email: XX Work: XX Mob: XX
COMPANY	DETAILS						
ACWA Power or Project Company Name of contact person	Email: XX Work: XX Mob: XX						
EPC Contractor Name of contact person	Email: XX Work: XX Mob: XX						
Grievance Mechanism	Advise the stakeholders that the purpose of the grievance mechanism is to evaluate and address stakeholders' problems and concerns regarding project activities and impacts. During the stakeholder consultation process, the participants will be made aware of the following: • That the grievance mechanism is available to all third parties (with a separate process for all staff to also raise grievances). • How to access the grievance mechanism (i.e., name of project personnel in charge, contact details including email, phone, office location (if applicable)) • Where stakeholders can file their complaints in person or anonymously (through a suggestion box outside the project entrance) • What type of response the complainants can expect to receive. • Duration of time it will take to receive a response (this should be aligned with the SEP).						
Record of Meetings/Consultations							
Minutes of Meetings	• Please document the proceedings of all meetings held with the different stakeholders and provide a list of participants including a signed attendance sheet where it is possible. • All feedback, queries (and the responses provided to these) must be documented. • Consultations through the phone, telecommunication channels such as Zoom, Microsoft Teams or messaging apps should also be documented. • A summary of informal consultations and general /side discussions should also be documented (in the event that formal meetings cannot be arranged).						
Photographs	If permitted by the stakeholder, timestamped photographs of the meeting should be taken – as evidence of the consultation undertaken.						

TARGETED CONSULTATION QUESTIONS

ID	QUESTION
Targeted Stakeholder Group	Herders and community leaders
1.	Have you used the land at the Project site in the past and what purpose did you use the land for? (Grazing, camping, transportation route, watermelon cultivation etc.)
2.	Do you obtain any services from the Project site (such as firewood, water, crops, or any cultural or spiritual benefits?)
3.	How long did you/the community use the project site?
4.	Was the land at the project site used seasonal or all year round? If it was seasonal, which months was the land used?
5.	Did you have any formal or informal agreement/contract to access or use the project site? If so, who was this agreement with?
6.	If the land was grazed, what type of herds and approximately how many livestock did you graze on the project site? - Camels - Goats - Sheep - Other etc
7.	Do you own the livestock or are you employed to graze them? If owned, do you employ any workers to assist you and are they on a formal working contracts?
8.	If the person is employed to graze the herds, please specify - Who owns the livestock you graze? - How much do you receive for grazing cattle? - Do you have an agreement with your employer?
9.	How and when were you notified about the project development and that you could no longer use the site?
10.	Who informed you?
11.	Do you have access to alternative land for grazing in the area close to your communities?
12.	Did you own any camps/structures on the project site? If yes, were you able to relocate them to a new site?
13.	Who owns this land and what are the terms of use (formal or informal agreements)?
14.	Were you provided with any support to move from the project site? If yes, what type of support was provided?
15.	What is your main source of income?
16.	What has the impact been on your livelihood as a result of relocating from the project site?
17.	What are your perceived impacts of the project?

APPENDIX B – QUESTIONNAIRE RESPONSES

QUESTIONNAIRE RESPONSE H-3

ID	QUESTION
Targeted Stakeholder Group	Herders and community leaders
1.	Have you used the land at the Project site in the past and what purpose did you use the land for? (Grazing, camping, transportation route, watermelon cultivation etc.) The herder has on occasion used the project for grazing
2.	Do you obtain any services from the Project site (such as firewood, water, crops, or any cultural or spiritual benefits?) The herder only uses the site for Grazing, with all other provisions such as food, firewood, water, etc. being brought in from outside.
3.	How long did you/the community use the project site? The herder has been on the site for 1 month at the time of the site visit
4.	Was the land at the project site used seasonal or all year round? If it was seasonal, which months was the land used? Seasonally
5.	Did you have any formal or informal agreement/contract to access or use the project site? If so, who was this agreement with? The owner does not have any formal agreement to access or use the site.
6.	If the land was grazed, what type of herds and approximately how many livestock did you graze on the project site? - Camels x 20 - Goats - Sheep - Other etc. The Owner has around 20 camels grazing on the site.
7.	Do you own the livestock or are you employed to graze them? If owned, do you employ any workers to assist you and are they on a formal working contracts? Owner was not available, but his employee answered all question.
8.	If the person is employed to graze the herds, please specify - Who owns the livestock you graze? - o Salman Al Alharbi - How much do you receive for grazing cattle? - o N/A - Do you have an agreement with your employer? - o Yes

ID	QUESTION
Targeted Stakeholder Group	Herders and community leaders
9.	How and when were you notified about the project development? Employee was aware of the project, heard from other people entering the site.
10.	Who informed you? Heard from other people using the site.
11.	Do you have access to alternative land for grazing in the area close to your communities? Yes, other land is available in the immediate vicinity of the project
12.	Did you own any camps/structures on the project site? If yes, were you able to relocate them to a new site? Herder has one temporary structure that can easily be relocated.
13.	Who owns this land and what are the terms of use (formal or informal agreements)? Government
14.	Were you provided with any support to move from the project site? If yes, what type of support was provided? No support will be required
15.	What is your main source of income? Owner has another job
16.	What has the impact been on your livelihood as a result of relocating from the project site? No impact is expected on the herders livelihood
17.	What are your perceived impacts of the project? No impact is expected on the herders livelihood

QUESTIONNAIRE RESPONSE H-4

ID	QUESTION
Targeted Stakeholder Group	Herders and community leaders
1.	Have you used the land at the Project site in the past and what purpose did you use the land for? (Grazing, camping, transportation route, watermelon cultivation etc.) The herder has on occasion used the project for grazing
2.	Do you obtain any services from the Project site (such as firewood, water, crops, or any cultural or spiritual benefits?) The herder only uses the site for Grazing, with all other provisions such as food, firewood, water, etc. being brought in from outside.
3.	How long did you/the community use the project site? The herder has been on the site for only 1 day at the time of the site visit
4.	Was the land at the project site used seasonal or all year round? If it was seasonal, which months was the land used? It was the herders first time using the site but may return seasonally to the area.
5.	Did you have any formal or informal agreement/contract to access or use the project site? If so, who was this agreement with? The owner does not have any formal agreement to access or use the site.
6.	If the land was grazed, what type of herds and approximately how many livestock did you graze on the project site? - <u>Camels x 100</u> - Goats - Sheep - Other etc The Owner has around 100 camels grazing on the site.
7.	Do you own the livestock or are you employed to graze them? If owned, do you employ any workers to assist you and are they on a formal working contracts? Owner
8.	If the person is employed to graze the herds, please specify - Who owns the livestock you graze? - o Misha - How much do you receive for grazing cattle? - o N/A - Do you have an agreement with your employer? - o N/A

ID	QUESTION
Targeted Stakeholder Group	Herders and community leaders
9.	How and when were you notified about the project development? Owner was aware of the project, heard from other people in the community
10.	Who informed you? Heard from other people using the site.
11.	Do you have access to alternative land for grazing in the area close to your communities? Yes, other land is available in the immediate vicinity of the project
12.	Did you own any camps/structures on the project site? If yes, were you able to relocate them to a new site? Herder has no temporary or permanent structures that need to be relocated.
13.	Who owns this land and what are the terms of use (formal or informal agreements)? Government
14.	Were you provided with any support to move from the project site? If yes, what type of support was provided? No support will be required
15.	What is your main source of income? Owner has another job
16.	What has the impact been on your livelihood as a result of relocating from the project site? No impact is expected on the herders livelihood
17.	What are your perceived impacts of the project? No impact is expected on the herder's livelihood

QUESTIONNAIRE RESPONSE H-5

ID	QUESTION
Targeted Stakeholder Group	Herders and community leaders
1.	Have you used the land at the Project site in the past and what purpose did you use the land for? (Grazing, camping, transportation route, watermelon cultivation etc.) The herder has on occasion used the project for grazing
2.	Do you obtain any services from the Project site (such as firewood, water, crops, or any cultural or spiritual benefits?) The herder only uses the site for Grazing, with all other provisions such as food, firewood, water, etc. being brought in from outside.
3.	How long did you/the community use the project site? The herder has been on the site for three months at the time of the site visit
4.	Was the land at the project site used seasonal or all year round? If it was seasonal, which months was the land used? The herder has been using the site seasonally for a long time.
5.	Did you have any formal or informal agreement/contract to access or use the project site? If so, who was this agreement with? The owner does not have any formal agreement to access or use the site.
6.	If the land was grazed, what type of herds and approximately how many livestock did you graze on the project site? - <u>Camels x 70</u> - Goats - <u>Sheep X 3</u> - Other etc The Owner has around 70 camels and 3 sheep grazing on the site.
7.	Do you own the livestock or are you employed to graze them? If owned, do you employ any workers to assist you and are they on a formal working contracts? Owner
8.	If the person is employed to graze the herds, please specify - Who owns the livestock you graze? - o N/A - How much do you receive for grazing cattle? - o N/A - Do you have an agreement with your employer? - o N/A

ID	QUESTION
Targeted Stakeholder Group	Herders and community leaders
9.	How and when were you notified about the project development? Owner was not aware of the project at the time of the site visit.
10.	Who informed you? N/A
11.	Do you have access to alternative land for grazing in the area close to your communities? Yes, other land is available in the immediate vicinity of the project
12.	Did you own any camps/structures on the project site? If yes, were you able to relocate them to a new site? Herder has temporary infrastructure such as tents and trucks that need to be relocated.
13.	Who owns this land and what are the terms of use (formal or informal agreements)? Government
14.	Were you provided with any support to move from the project site? If yes, what type of support was provided? No support will be required
15.	What is your main source of income? Owner has another job
16.	What has the impact been on your livelihood as a result of relocating from the project site? No impact is expected on the herders livelihood
17.	What are your perceived impacts of the project? No impact is expected on the herder's livelihood

QUESTIONNAIRE RESPONSE H-7

ID	QUESTION
Targeted Stakeholder Group	Herders and community leaders
1.	Have you used the land at the Project site in the past and what purpose did you use the land for? (Grazing, camping, transportation route, watermelon cultivation etc.) The herder has on occasion used the project for grazing
2.	Do you obtain any services from the Project site (such as firewood, water, crops, or any cultural or spiritual benefits?) The herder only uses the site for Grazing, with all other provisions such as food, firewood, water, etc. being brought in from outside.
3.	How long did you/the community use the project site? The herder has been on the site for three months at the time of the site visit
4.	Was the land at the project site used seasonal or all year round? If it was seasonal, which months was the land used? The herder has been using the site seasonally for a long time.
5.	Did you have any formal or informal agreement/contract to access or use the project site? If so, who was this agreement with? The owner does not have any formal agreement to access or use the site.
6.	If the land was grazed, what type of herds and approximately how many livestock did you graze on the project site? - <u>Camels x 70</u> - Goats - <u>Sheep X 3</u> - Other etc The Owner has around 70 camels and 3 sheep grazing on the site.
7.	Do you own the livestock or are you employed to graze them? If owned, do you employ any workers to assist you and are they on a formal working contracts? Owner
8.	If the person is employed to graze the herds, please specify - Who owns the livestock you graze? - o N/A - How much do you receive for grazing cattle? - o N/A - Do you have an agreement with your employer? - o N/A

ID	QUESTION
Targeted Stakeholder Group	Herders and community leaders
9.	How and when were you notified about the project development? Owner was not aware of the project at the time of the site visit.
10.	Who informed you? N/A
11.	Do you have access to alternative land for grazing in the area close to your communities? Yes, other land is available in the immediate vicinity of the project
12.	Did you own any camps/structures on the project site? If yes, were you able to relocate them to a new site? Herder has temporary infrastructure such as tents and trucks that need to be relocated.
13.	Who owns this land and what are the terms of use (formal or informal agreements)? Government
14.	Were you provided with any support to move from the project site? If yes, what type of support was provided? No support will be required
15.	What is your main source of income? Owner has another job
16.	What has the impact been on your livelihood as a result of relocating from the project site? No impact is expected on the herders livelihood
17.	What are your perceived impacts of the project? No impact is expected on the herder's livelihood

QUESTIONNAIRE RESPONSE H-8

ID	QUESTION
Targeted Stakeholder Group	Herders and community leaders
1.	Have you used the land at the Project site in the past and what purpose did you use the land for? (Grazing, camping, transportation route, watermelon cultivation etc.) The herder has on occasion used the project for grazing
2.	Do you obtain any services from the Project site (such as firewood, water, crops, or any cultural or spiritual benefits?) The herder only uses the site for Grazing, with all other provisions such as food, firewood, water, etc. being brought in from outside.
3.	How long did you/the community use the project site? The herder has been on the site for 1 day at the time of the site visit
4.	Was the land at the project site used seasonal or all year round? If it was seasonal, which months was the land used? The herder has been using the site seasonally
5.	Did you have any formal or informal agreement/contract to access or use the project site? If so, who was this agreement with? The owner does not have any formal agreement to access or use the site.
6.	If the land was grazed, what type of herds and approximately how many livestock did you graze on the project site? - Camels - Goats - Sheep x 150 - Other etc The Owner advised that he has around 150 sheep grazing on site.
7.	Do you own the livestock or are you employed to graze them? If owned, do you employ any workers to assist you and are they on a formal working contracts? Owner
8.	If the person is employed to graze the herds, please specify - Who owns the livestock you graze? - o N/A - How much do you receive for grazing cattle? - o N/A - Do you have an agreement with your employer? - o N/A

ID	QUESTION
Targeted Stakeholder Group	Herders and community leaders
9.	How and when were you notified about the project development? The owner was not aware of the project at the time of the site visit.
10.	Who informed you? N/A
11.	Do you have access to alternative land for grazing in the area close to your communities? Yes, other land is available in the immediate vicinity of the project
12.	Did you own any camps/structures on the project site? If yes, were you able to relocate them to a new site? Herder has temporary infrastructure such as tents, water tanks and trucks that need to be relocated.
13.	Who owns this land and what are the terms of use (formal or informal agreements)? Government
14.	Were you provided with any support to move from the project site? If yes, what type of support was provided? No support will be required
15.	What is your main source of income? Owner advised that this was his only source of income
16.	What has the impact been on your livelihood as a result of relocating from the project site? No impact is expected on the herders livelihood
17.	What are your perceived impacts of the project? No impact is expected on the herder's livelihood

QUESTIONNAIRE RESPONSE H-12

ID	QUESTION
Targeted Stakeholder Group	Herders and community leaders
1.	Have you used the land at the Project site in the past and what purpose did you use the land for? (Grazing, camping, transportation route, watermelon cultivation etc.) It was the 1st time that the herder has used the project site for grazing.
2.	Do you obtain any services from the Project site (such as firewood, water, crops, or any cultural or spiritual benefits?) The herder only uses the site for Grazing, with all other provisions such as food, firewood, water, etc. being brought in from outside.
3.	How long did you/the community use the project site? The herder has been on the site for 2 weeks at the time of the site visit
4.	Was the land at the project site used seasonal or all year round? If it was seasonal, which months was the land used? It was the herders first time using the site but may return seasonally to the area
5.	Did you have any formal or informal agreement/contract to access or use the project site? If so, who was this agreement with? The owner does not have any formal agreement to access or use the site.
6.	If the land was grazed, what type of herds and approximately how many livestock did you graze on the project site? - Camels x 5 - Goats - Sheep - Other etc The herder advised that he has 5 camels grazing on site.
7.	Do you own the livestock or are you employed to graze them? If owned, do you employ any workers to assist you and are they on a formal working contracts? Employee
8.	If the person is employed to graze the herds, please specify - Who owns the livestock you graze? - o Turki - How much do you receive for grazing cattle? - o N/A - Do you have an agreement with your employer? - o N/A

ID	QUESTION
Targeted Stakeholder Group	Herders and community leaders
9.	How and when were you notified about the project development? The employee was not aware of the project at the time of the site visit.
10.	Who informed you? N/A
11.	Do you have access to alternative land for grazing in the area close to your communities? Yes, other land is available in the immediate vicinity of the project
12.	Did you own any camps/structures on the project site? If yes, were you able to relocate them to a new site? Herder has temporary infrastructure such as tents and trucks that need to be relocated.
13.	Who owns this land and what are the terms of use (formal or informal agreements)? Government
14.	Were you provided with any support to move from the project site? If yes, what type of support was provided? No support will be required
15.	What is your main source of income? Owner has another source of income
16.	What has the impact been on your livelihood as a result of relocating from the project site? No impact is expected on the herders livelihood
17.	What are your perceived impacts of the project? No impact is expected on the herder's livelihood

QUESTIONNAIRE RESPONSE H-13

ID	QUESTION
Targeted Stakeholder Group	Herders and community leaders
1.	Have you used the land at the Project site in the past and what purpose did you use the land for? (Grazing, camping, transportation route, watermelon cultivation etc.) The herder has on occasion used the project for grazing
2.	Do you obtain any services from the Project site (such as firewood, water, crops, or any cultural or spiritual benefits?) The herder only uses the site for Grazing, with all other provisions such as food, firewood, water, etc. being brought in from outside.
3.	How long did you/the community use the project site? The herder has been on the site for 10 days at the time of the site visit
4.	Was the land at the project site used seasonal or all year round? If it was seasonal, which months was the land used? The herder has been using the site seasonally
5.	Did you have any formal or informal agreement/contract to access or use the project site? If so, who was this agreement with? The owner does not have any formal agreement to access or use the site.
6.	If the land was grazed, what type of herds and approximately how many livestock did you graze on the project site? - Camels x 35 - Goats - Sheep - Other etc The herder advised that he has 35 camels grazing on site.
7.	Do you own the livestock or are you employed to graze them? If owned, do you employ any workers to assist you and are they on a formal working contracts? Employee
8.	If the person is employed to graze the herds, please specify - Who owns the livestock you graze? - o Nasser - How much do you receive for grazing cattle? - o N/A - Do you have an agreement with your employer? - o Yes

ID	QUESTION
Targeted Stakeholder Group	Herders and community leaders
9.	How and when were you notified about the project development? The employee was not aware of the project at the time of the site visit.
10.	Who informed you? N/A
11.	Do you have access to alternative land for grazing in the area close to your communities? Yes, other land is available in the immediate vicinity of the project
12.	Did you own any camps/structures on the project site? If yes, were you able to relocate them to a new site? Herder has temporary infrastructure such as tents and trucks that need to be relocated.
13.	Who owns this land and what are the terms of use (formal or informal agreements)? Government
14.	Were you provided with any support to move from the project site? If yes, what type of support was provided? No support will be required
15.	What is your main source of income? The employee did not know
16.	What has the impact been on your livelihood as a result of relocating from the project site? No impact is expected on the herders livelihood
17.	What are your perceived impacts of the project? No impact is expected on the herder's livelihood

QUESTIONNAIRE RESPONSE H-14

ID	QUESTION
Targeted Stakeholder Group	Herders and community leaders
1.	Have you used the land at the Project site in the past and what purpose did you use the land for? (Grazing, camping, transportation route, watermelon cultivation etc.) It was the 1st time that the herder has used the project site for grazing.
2.	Do you obtain any services from the Project site (such as firewood, water, crops, or any cultural or spiritual benefits?) The herder only uses the site for Grazing, with all other provisions such as food, firewood, water, etc. being brought in from outside.
3.	How long did you/the community use the project site? The herder has been on the site for 1 week at the time of the site visit
4.	Was the land at the project site used seasonal or all year round? If it was seasonal, which months was the land used? It was the herders first time using the site but may return seasonally to the area
5.	Did you have any formal or informal agreement/contract to access or use the project site? If so, who was this agreement with? The owner does not have any formal agreement to access or use the site.
6.	If the land was grazed, what type of herds and approximately how many livestock did you graze on the project site? - <u>Camels x 50</u> - Goats - Sheep - <u>Other etc x 1 Horse</u> The herder advised that he has 50 camels and 1 horse grazing on site.
7.	Do you own the livestock or are you employed to graze them? If owned, do you employ any workers to assist you and are they on a formal working contracts? Owner
8.	If the person is employed to graze the herds, please specify - Who owns the livestock you graze? - o N/A - How much do you receive for grazing cattle? - o N/A - Do you have an agreement with your employer? - o N/A

ID	QUESTION
Targeted Stakeholder Group	Herders and community leaders
9.	How and when were you notified about the project development? The employee was not aware of the project at the time of the site visit.
10.	Who informed you? N/A
11.	Do you have access to alternative land for grazing in the area close to your communities? Yes, other land is available in the immediate vicinity of the project
12.	Did you own any camps/structures on the project site? If yes, were you able to relocate them to a new site? Herder advised that he has no structure that require relocating
13.	Who owns this land and what are the terms of use (formal or informal agreements)? Government
14.	Were you provided with any support to move from the project site? If yes, what type of support was provided? No support will be required
15.	What is your main source of income? The owner advised that this is his main source of income.
16.	What has the impact been on your livelihood as a result of relocating from the project site? No impact is expected on the herders livelihood
17.	What are your perceived impacts of the project? No impact is expected on the herder's livelihood

APPENDIX C – CLIMATE CHANGE RISK SCREENING

CATEGORY		HAZARD	APPLICABILITY TO THE PROJECT	REASONS
Acute	Temperature Related	Extreme Heat Event	Applicable	- Extreme heat events found to be common in KSA. - ThinkHazard (2023) classes KSA at high risk of extreme heat.
	Water Related	Extreme Precipitation Events	Not Applicable	- Extreme precipitation events are not common within KSA. - Future projections vary in the possibilities of the worsening or bettering of these events, but changes are seen to be limited.
		Drought	Applicable	- Droughts are very common within KSA. - Droughts are causing greater water scarcity in KSA, which could affect the project and its workers.
		Flood	Applicable	- Floods are seen to be very common within KSA from the baseline study. - Coastal flooding is classed as high risk by Think Hazard (2023).
	Wind Related	Extreme Wind Events	Not Applicable	The baseline study found no evidence of extreme wind events that occur regularly, or any evidence of future trends to suggest this might occur.
	Solid Mass Related	Extreme Mass Movement	Applicable	- Landslides have occurred within KSA. - ThinkHazard (2023) classes KSA at moderate risk of landslides.
	Wildfires	Change In Fire Condition	Applicable	- Saudi Arabia has launched a project aimed at preventing forest fires in the kingdom's southern and southwestern regions. - ThinkHazard (2023) classes KSA at high risk of wildfires.
Chronic	Temperature Related	Mean Temperature Change	Applicable	Temperatures are currently very high throughout KSA, and the projections suggest this could rise by as much as another 16% by 2100.
	Water Related	Mean Precipitation Change	Not Applicable	Projections for KSA show no signs of the changes in precipitation levels.
		Sea Level Rise	Applicable	- Think Hazard (2023) classifies KSA as at high risk to coastal flooding. - Baseline desk study suggests that areas in KSA are at risk of sea level rise.

CATEGORY		HAZARD	APPLICABILITY TO THE PROJECT	REASONS
	Wind Related	Mean Wind Change	Not Applicable	Not significant trends in wind speed changes were found during the baseline study.
	Solid Mass Related	Erosion	Applicable	- Coastal erosion was found to be an issue in KSA during the baseline study. - Desertification is also leading to greater inland erosion.