Project: Aqaba-Amman Water Desalination and Conveyance (AAWDC)

2025 Environmental and Social Impact Assessment

Chapter 12: Climate Vulnerability Risk Assessment

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12 Climate Vulnerability Risk Assessment

This Climate Vulnerability Risk Assessment (CVRA) was conducted in the context of Jordan experiencing the effects of climate change in recent years, including recurring droughts, flash floods, and landslides, and, most crucially, the country's severe water shortage. Jordan ranked 5th among countries in terms of water stress (Resourcewatch, 2022). Climate change-induced increases in temperature, decreases in precipitation, and heightened evaporation will continue to reduce water availability and further exacerbate water scarcity, posing a substantial risk to the country's people, natural resources, and economy (Ministry of Environment, 2022).

The CVRA has been conducted to update the CVRA performed as part of the 2022 AAWCD Project ESIA (Tetra Tech International Developments, 2022), reflecting the following:

- Project design changes since 2022, that were known at the time of the CVRA, including the addition of the Renewable Energy facility and relocation of the Desalination Plant
- Update to the climate risk assessment methodology
- Updates to regional and country climate change risk profiles in the published literature
- Latest climate change projections.

The CVRA aimed to follow the recognised methodology of the 'risk propeller' comprising climate hazard, exposure and vulnerability. Whilst climate hazards and exposure of the Project's permanent facilities could be evaluated, vulnerability, which entails understanding the safeguards accounted for in the design, could not be ascertained due to the early stages of the Project and the limited engineering information available. Therefore, this CVRA update provides recommendations for further studies and factors that shall be considered in informing the design and strengthening the Project's resilience to climate change-induced risks.

12.1 Introduction

The Fourth Intergovernmental Panel on Climate Change (IPCC) Assessment Report drew solid conclusions, attributing most of the global warming observed over the last 50 years to human activities (IPCC, 2007). The IPCC Sixth Assessment Report concluded that human-induced climate change, including more frequent and intense extreme events, has caused widespread adverse impacts and related losses and damages to nature and people, beyond natural climate variability (IPCC, 2022).

Jordan is a Mediterranean country that relies primarily on rainfall for its water supply. In recent years, rainfall has been scarce across different parts of the country. As a result, numerous streams have dried up, underground water levels have fallen to critical levels, and most aquifers are experiencing high salinity or concentrations of Total Dissolved Solids (TDS), making them unsuitable for domestic or irrigation use. Additionally, extreme weather conditions, such as winter flash floods and summer heatwaves, are becoming increasingly frequent in the region. These conditions are direct consequences of global climatic changes that have recently affected many locations, dramatically impacting a wide range of ecosystems (Walther *et al.,* 2007; Hamdi *et al.,* 2009).

12.2 Methodology

12.2.1 Scope of the CVRA

The scope of the CVRA covers the following permanent Project facilities:

- Intake and Outfall Facilities in the Gulf of Aqaba (GoA) comprising intake towers and pipelines, outfall pipeline and diffuser configuration and onshore Intake Pumping Station (IPS)
- Desalination Plant on the coast of GoA within the Aqaba Special Economic Zone (ASEZ)
- Conveyance pipeline comprising an approximately 438km long buried pipeline to convey desalinated water from the Desalination Plant to the existing reservoirs of Abu Alanda and Al Muntazah near Amman
- Above Ground Installations (AGIs) along the Conveyance pipeline, comprising four pumping stations (booster stations BPS1, BPS2 and BPS3 and pumping station PS ADC), two regulating tank facilities (RGT1 and RGT3), one break pressure tank (BPT) and existing Abu Alanda and Al Muntazah water storage reservoirs in Amman
- A new Renewable Energy Facility, comprising a solar photovoltaic plant with an electrical substation less than 5 km to the east of Qweirah, and a new Overhead Transmission Line (OHTL) to connect the Renewable Energy Facility to the Desalination Plant and one of the pumping stations.

This CRVA covers both physical risks applicable to the Project and provides a screening of transition risks.

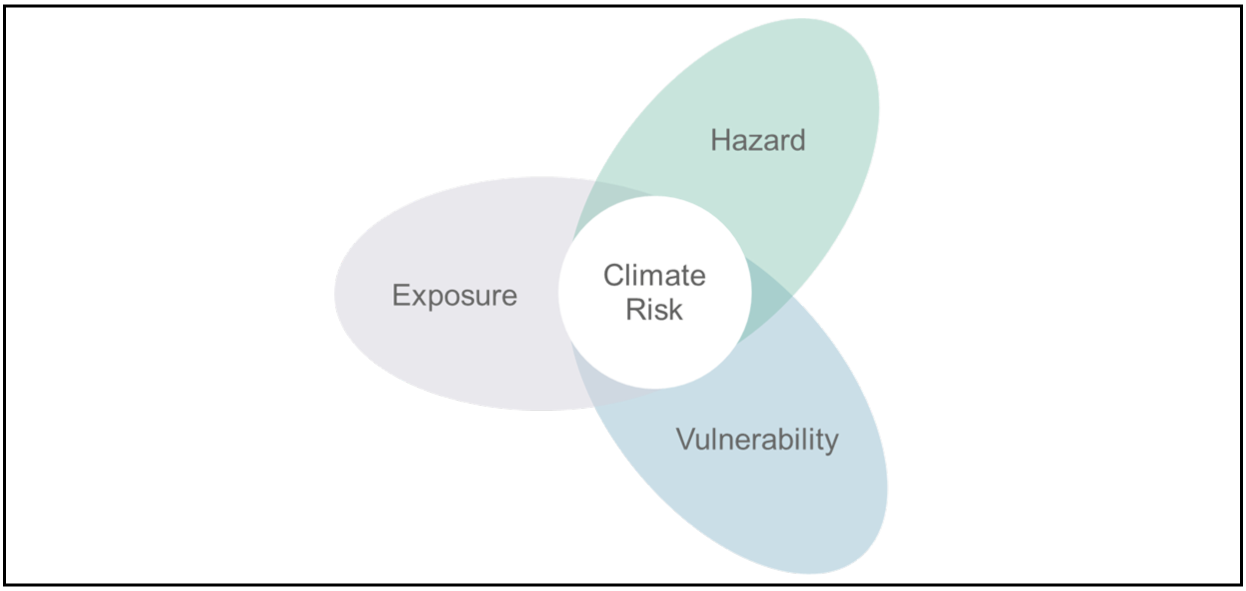
12.2.2 Risk Propeller

The methodology of this climate vulnerability risk assessment has been aligned with the following established frameworks and relevant associated guidance:

- Recommendations of Taskforce on Climate-related Financial Disclosures (TCFD), June 2017
- TCFD Implementation Guidance, October 2021
- TCFD Guidance: Risk-Management, Integration and Disclosure, October 2020
- TCFD Guidance: Scenario Analysis, October 2020
- Institute of Sustainability and Environmental Professionals (ISEP) Climate Change Adaptation Practitioner Guidance, November 2022

Recognised climate risk assessment frameworks and methodologies such as TCFD, ISEP and IPCC apply three parameters for the determination of climate risk: Hazard, Exposure and Vulnerability, known as the ‘risk propeller’ (Figure 12-1).

Figure 12-1: Climate Risk Propeller



12.2.2.1 Climate Hazards

Acute (short-term, event-driven) physical climate hazards are sudden, extreme events that can cause immediate damage or disruption. These include coastal flooding and storm surges, extreme rainfall and flash floods, heatwaves, strong winds, and wildfires, among others. Acute climate hazards may threaten the operational continuity and safety of the Project facilities.

Chronic physical climate hazards are slow-onset changes that degrade performance or increase costs over time. These include sea-level rise, rising air and sea temperatures, changes in precipitation patterns, soil movement (shrink–swell, subsidence), accelerated corrosion, increased dust and soiling, shifting storm and wave patterns, and others.

Transition climate hazards arise from shifts towards a low-carbon, sustainable economy and include policy/regulatory changes, market and financial dynamics and technological and supply-chain evolution.

Climate hazards were screened and selected based on applicability to the Project, as presented in Sections 12.4.1 and 12.5.1.

12.2.2.2 Exposure

Exposure refers to the severity of the impact and speed of onset upon Project facilities located within the climate hazard zone. For physical risks, exposure is assessed based on the Project's permanent facilities' geographical location and the frequency and magnitude of the climate hazard event. The exposure criteria for physical risks are provided in Table 12-1.

Table 12-1: Exposure Criteria for Physical Climate Risks

Level	Definition
High	Material increase in climate variable with potential shutdown of Project for >1 week
Medium	Material increase in climate variable with potential shutdown of Project for <1 week
Low	Non-material increase in climate variable with no impact on Project operations

For transition climate risks, exposure takes into account legislated policies or lender requirement changes, aspirational policy statements, and the speed of onset (i.e. short or long-term). The exposure criteria for transition risks are provided in Table 12-2.

Table 12-2: Exposure Criteria for Transition Climate Risks

Level	Definition
High	Legislated/lender requirement with impact on the Project in the short term
Medium	Legislated/lender requirement with impact on the Project in the long term
Low	Legislated / non-lender / aspiration requirement with potential impact on the Project

12.2.2.3 Vulnerability

Vulnerability refers to the predisposition (or sensitivity) to be adversely affected by a climate hazard, as well as the inability to cope with or adapt to it. For physical risks, vulnerability considers the design of the Project's permanent facilities and the availability of adaptation/response mechanisms (such as drainage capacity for peak rainfall, design contingencies for operating parameters, flood pumps, etc.), as well as monitoring programs and emergency preparedness. The vulnerability criteria for physical risks are provided in Table 12-3.

Given the early stages of design, if the vulnerability of Project facilities to climate hazards cannot be fully ascertained, and CVRA provides actions for further studies and design factors that shall be considered in the Project design (Section 12.4.3).

Table 12-3: Vulnerability Criteria for Physical Climate Risks

Level	Definition
High	Project facility design threshold exceeded, no adaptation/response mechanisms available
Medium	Project facility design threshold exceeded, adaptation/response mechanisms available within 24 hours to mobilise/implement
Low	Project design threshold not exceeded, immediate adaptation/response mechanisms implemented

For transition risks, vulnerability takes into account safeguards and flexibility under agreements, the ability to decarbonise and management system processes. The vulnerability criteria for transition risks are provided Table 12-4.

Table 12-4: Vulnerability Criteria for Transition Climate Risks

Level	Definition
High	No safeguards under design, agreements or management system identified
Medium	Safeguards under design, agreements/management system are being actively explored
Low	Safeguards under design, agreements/management system already implemented

12.2.2.4 Risk Rating

The risk levels can be determined for relevant climate hazards using the formula below:

Level of Risk = Exposure Level x Vulnerability Level

Table 12-5: Risk Matrix

		Vulnerability		
		Low	Medium	High
Exposure	High	Low	Medium	High
	Medium	Low	Medium	Medium
	Low	Low	Low	Low

12.2.3 Climate Scenarios

Scenario analysis is a critical component of a climate risk assessment. A scenario describes a plausible, yet hypothetical, path of development that leads to a particular future outcome. Scenarios are not intended to provide a comprehensive description of the future, but rather to highlight central elements of a possible future and draw attention to the key factors that will drive future developments. Scenarios are not forecasts or predictions; they are "what if" narratives designed to inform and challenge strategic thinking.

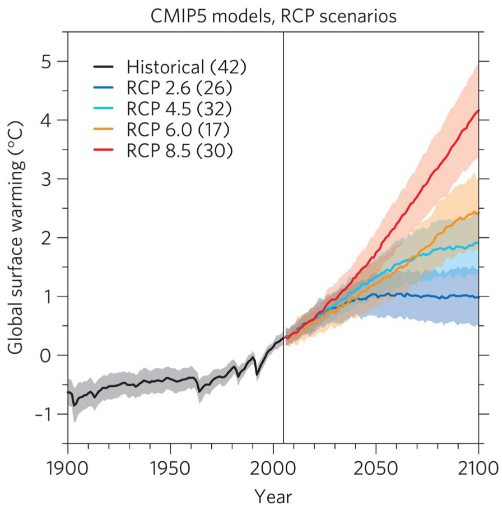
There are four Representative Concentration Pathways (RCPs) developed and formally adopted by the IPCC and widely used in climate modelling and research. The scenarios are named in accordance with their expected radiative forcing, expressed in watts per square metre (W/m^2), namely RCP 2.6, RCP 4.5, RCP 6.0, and RCP 8.5 (Table 12-6). Higher values indicate greater greenhouse gas (GHG) emissions, which in turn lead to higher global surface temperatures and more pronounced effects of climate change. The lower RCP values, on the other hand, are more desirable for humans but would require more stringent climate change mitigation efforts to achieve.

Table 12-6: Representative Concentration Pathways

Pathway	Radiative Force	CO_2 Equivalent Concentration in 2010	Rate of Change in Radiative Force
RCP 8.5 High Emissions	8.5 W/m^2	1370 ppm	Rising
RCP 6.0 Intermediate Emissions	6.0 W/m^2	850 ppm	Stabilising
RCP 4.5 Intermediate Emissions	4.5 W/m^2	650 ppm	Stabilising
RCP 2.6 Low Emissions	2.6 W/m^2	490 ppm	Declining

Each RCP represents a trajectory of GHG concentrations over time that leads to a specific radiative forcing in 2100. As such, RCPs make no assumptions about policy changes that may affect the climate; instead, they only delimit the range of possible forcings. Figure 12-2 Illustrates the corresponding global surface temperature changes projected under these four RCPs, which were used to generate climate modelling outputs for the IPCC.

Figure 12-2: Global Temperature Change Projections for RCP Scenarios



For this CVRA, the following sources, based on IPCC RCPs, have been used for climate projections at the regional and country levels:

- RCP 4.5 and RCP 8.5 projections from the 2017 Arab Climate Change Assessment Report by the Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR) (RICCAR, 2017)
- RCP 2.6 and RCP 6.0 projections from the 2017 Weathering Risk Climate Risk Profile: Jordan

The scenarios were selected with the key principle so that the differences between scenarios are sufficiently significant to capture the impacts and uncertainties of the key risks to the Project.

12.2.4 Time Horizons

The IPCC and other regional climate modelling experiments generally run climate simulations for two to three future time periods, which are compared with a historical reference period. For physical risks, the following 20-year time periods are generally used: 1986–2005 (reference period), 2016–2035 (near future), 2046–2065 (intermediate future) and 2081–2100 (far future).

This CVRA presents climate change analysis for the IPCC reference period, the near future, and the intermediate future. The period from 2081 to 2100 is excluded, as the design life of the permanent Project facilities is 30 years from the start of planned operations in 2030.

Transition risks are considered for both near-term (up to 2030) and long-term (beyond 2030) outlooks with consideration of current and projected policy changes.

12.3 Physical Climate Hazards

12.3.1 Historic Climate Trends

An overview of Jordan's climatology at the country and governorate levels is provided in Chapter 6, Environmental Description.

Based on long-term historical data published by the Jordan Metrology Department (JMD), climatic variables are changing significantly at both national and station levels, indicating that climate change is becoming more apparent (GEF/UNDP, 2014). Both the Mann-Kendall rank trend test and linear regression indicate that annual precipitation tends to decrease significantly over time at a rate of 1.2mm per year. Simultaneously, the mean, maximum, and minimum air temperatures tend to increase by 0.02, 0.01, and 0.03°C per year, respectively.

On the other hand, relative humidity tends to increase by an average of 0.08% per year, while Class A pan evaporation appears to show unrealistic decreases of 0.088mm/year. The number of days of dust storms tends to decrease significantly by 0.09 days per year and 0.06 days per year for visibility less than 1km and 5km, respectively.

In addition, historical data, tested both annually and monthly, indicated that precipitation reduction is highly significant throughout the entire rainy season, except in January. Similarly, during the dry seasons of June, July, and August, precipitation tended to increase over time. However, this increase is considered negligible in terms of quantity, as indicated by the slope magnitude (GEF/UNDP, 2014).

12.3.1.1 Temperature

Figure 12-3 shows the mean historical annual temperature for the country for the period 1950-2023, indicating a trend of increasing 0.41°C per decade (World Bank Climate Knowledge Portal, 2025). Evolving seasonal cycle and variability in average mean surface air temperatures for the period of 1951-2020 are presented in Figure 12-4. The following trends in temperature have been observed by the Climatic Research Unit of the University of East Anglia (Tetra Tech International Development, 2022):

- The annual maximum temperature has increased by 0.3-1.8°C since the 1960s
- The annual minimum temperature has increased by 0.4-2.8°C since the 1960s
- The mean annual temperature has increased by 0.89°C since 1900

Trends since the 1960s include (USAID, 2017):

- Rise in annual maximum temperature of 0.3-1.8°C and rise in annual minimum temperature of 0.4–2.8°C across all regions (minimum temperatures rose at a faster pace than maximum temperatures).
- Increase in the average number of heat waves across the country, particularly in the desert.
- Increase in the number of consecutive dry days nationwide (highest in the desert, followed by the highlands and then the Jordan Valley.

Figure 12-3: Observed Changes in Annual Average Mean Surface Air Temperature (1950-2023)

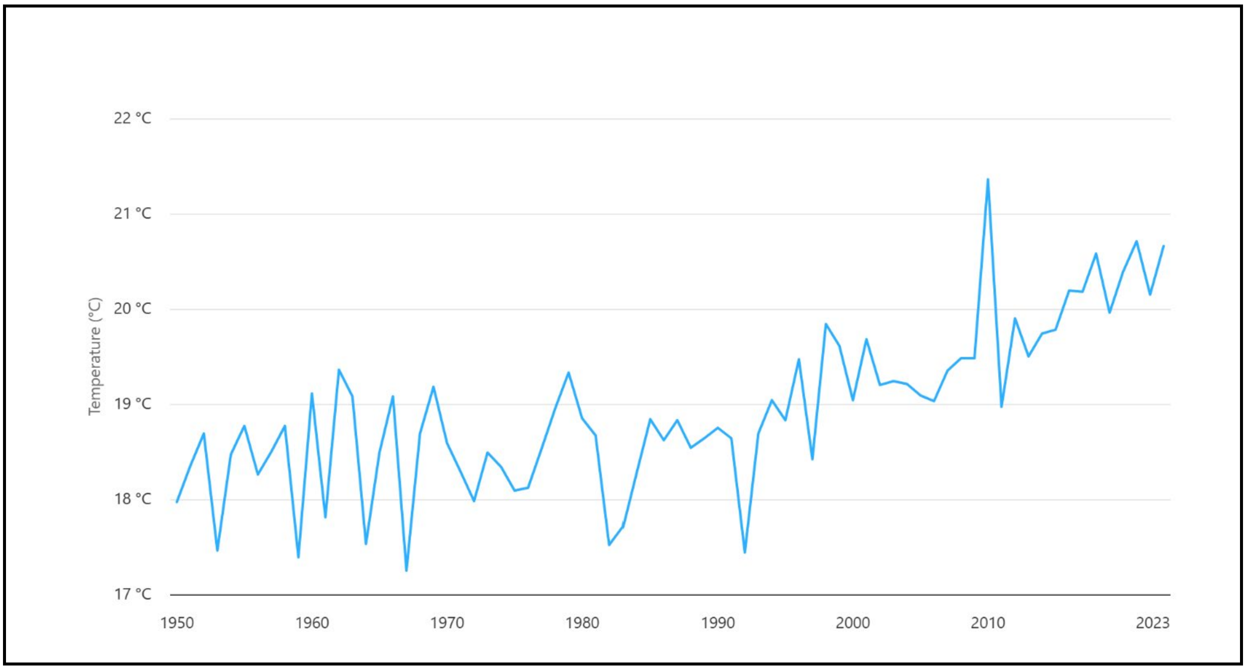
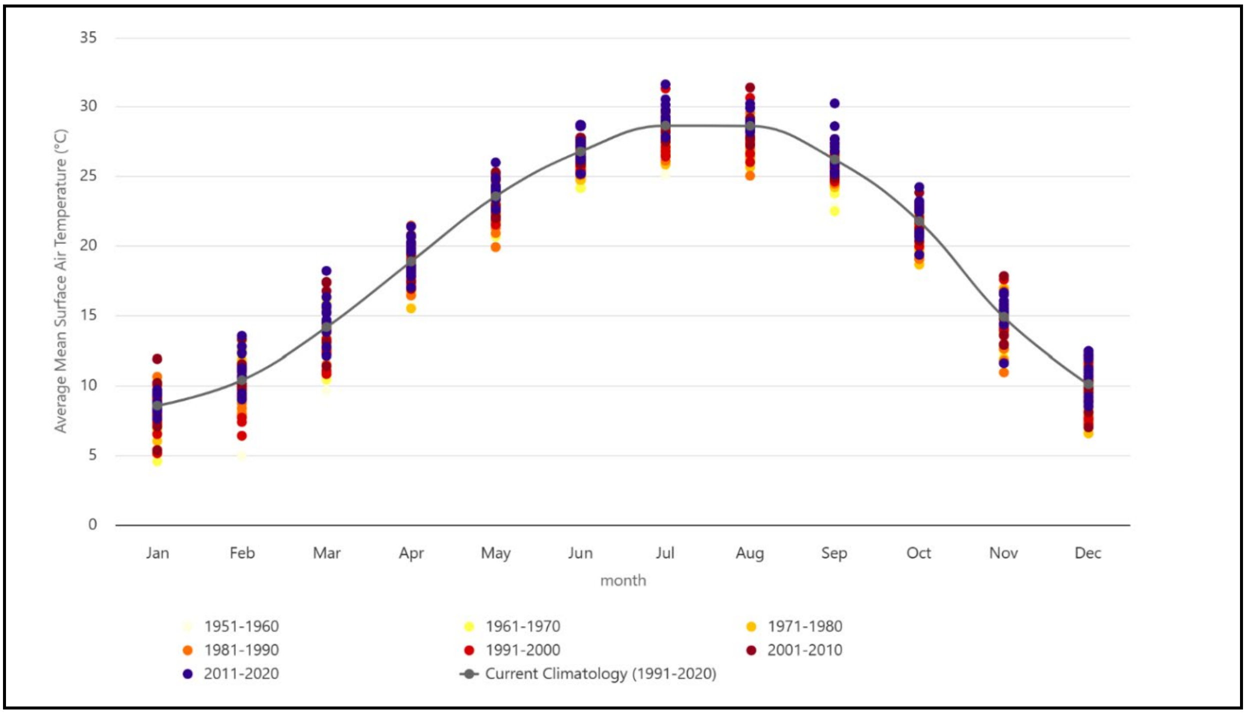


Figure 12-4: Evolving Seasonal Cycle and Embedded Variability in Average Mean Surface Air Temperature (1951-2020)



12.3.1.2 Precipitation

Figure 12-5 shows the mean historical annual precipitation for Jordan during the period of 1950 to 2023, indicating the trend of increase by 1.03mm every decade (World Bank Climate Knowledge Portal, 2025). Seasonal variability in precipitation for the period of 1951-2020 is presented in Figure 12-6.

Figure 12-5: Observed Timeseries in Annual Precipitation (1950-2023)

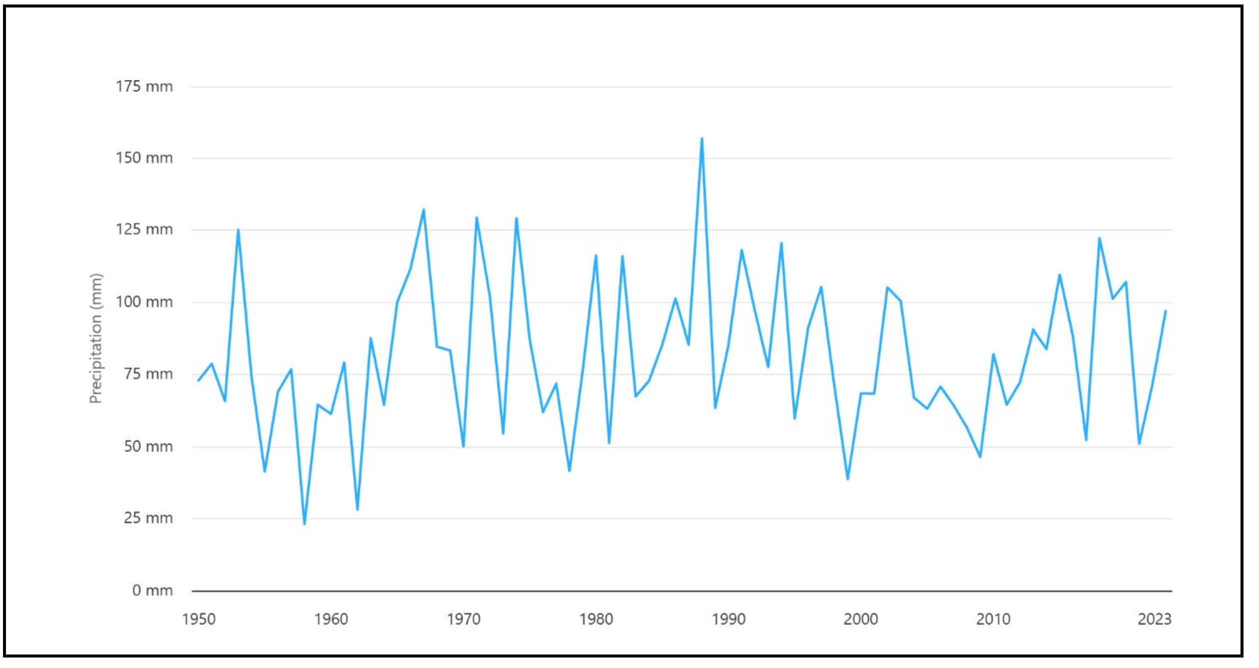
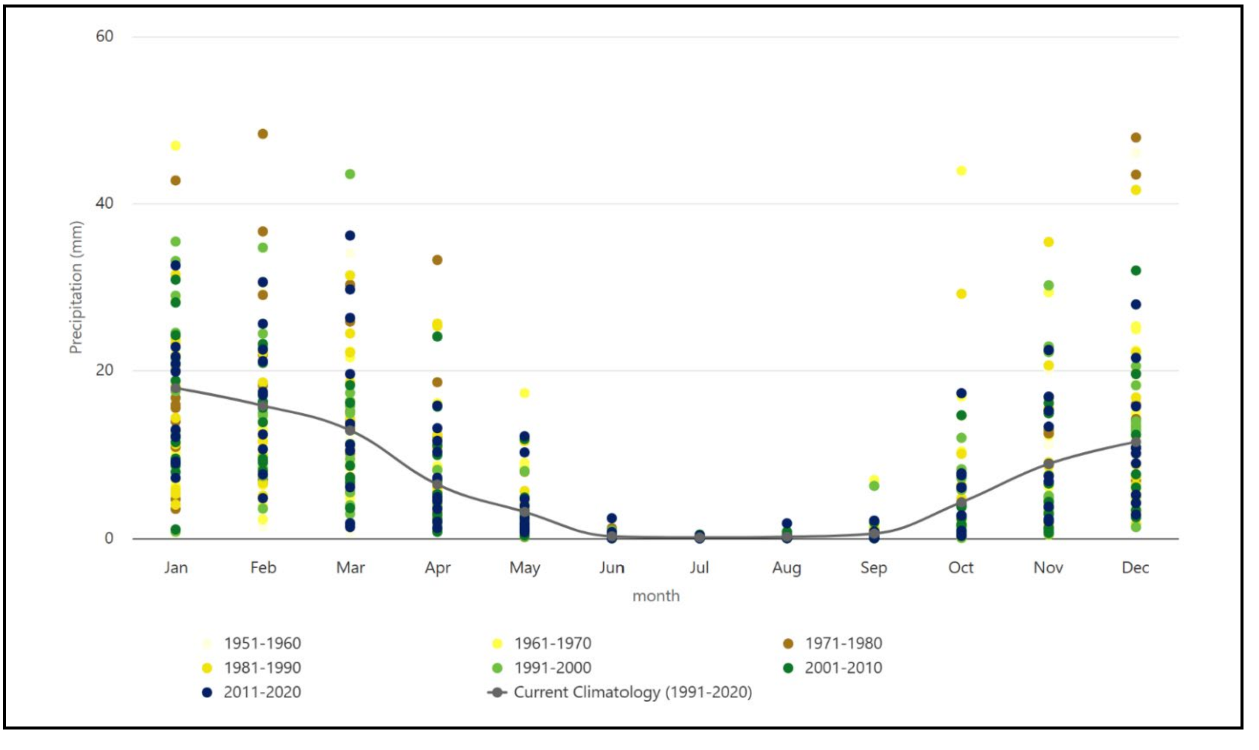


Figure 12-6: Evolving Seasonal Cycle and Embedded Variability in Precipitation (1951-2020)



The following trends in precipitation have been observed:

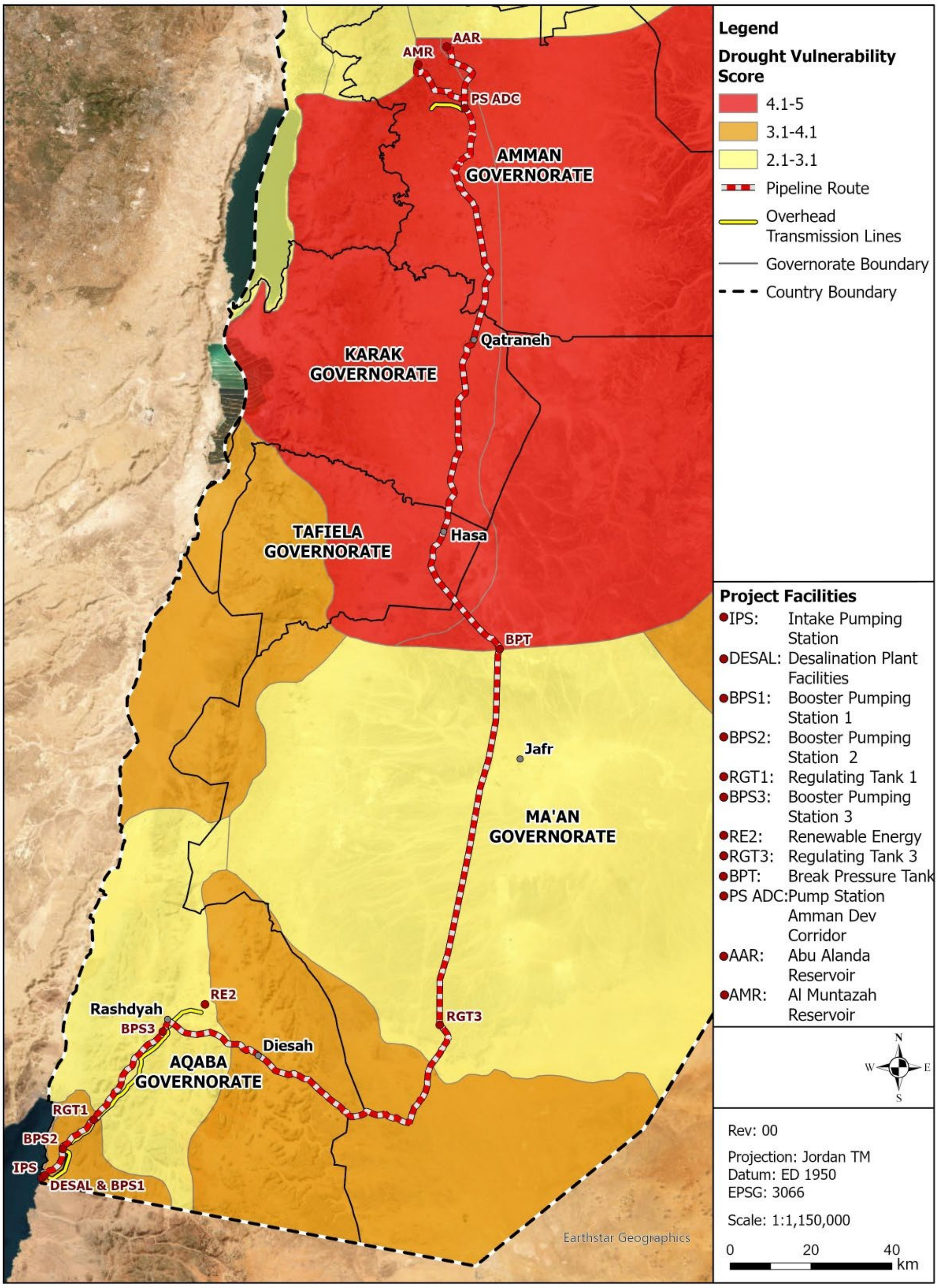
- Global Historical Climatology Network data for the country indicates a 2.92mm/month per century reduction in average annual precipitation since 1900.
- Most local station records indicate that annual precipitation dropped from 94mm to 80mm during the last 10 years for the period 1937 to 2005.

- Annual precipitation rates show decreases at most meteorological stations.

While there are differences in the analysis of precipitation trends, there is convergence that drought frequency is increasing and that this trend will continue. Al Adaileh *et al.* (2019) generated a Drought Vulnerability Map (Figure 12-7) with an emphasis on the severity and probability of drought occurrence, and proposed adaptation measures based on groundwater sector impact analysis by incorporating numerical scorings for exposure, sensitivity, and adaptive capacities at groundwater basin and Jordanian district levels.

Drought impacts on groundwater basins were investigated based on measurements of drought severity and probability of drought occurrence, and drought exposure across the entire country was computed using a combined drought index (CDI) that incorporated precipitation, temperature, and vegetation drought indices from 1980 to 2017. Results indicated that drought in Jordan is characterised by temporal and spatial variability in terms of probability and severity. The most prolonged drought events ranged from mild to moderate, with long periods of exposure that may extend for up to 13 consecutive years.

Figure 12-7: Drought Vulnerability Score Map, Jordan



12.3.1.3 Floods

Although floods do not occur regularly in Jordan, the Kingdom has recently witnessed a sharp increase in both flood severity and frequency, as observed by relevant government officials. Floods are formed on a seasonal basis in some areas of the kingdom, either at the beginning or end of the rainy season, during periods of unstable weather conditions. Floods and flash floods remain the leading cause of death due to natural disasters in the country, representing around 53% of disaster-related mortality between 1980 and 2012 (UNISDR, 2013).

Like in any other arid to semi-arid countries, flash floods pose a threat to many of the settlements in the country that are located in the low land areas of the mountainous ranges, such as the archaeological city of Petra, and cities located downstream of a catchment area in a flat topography (e.g. Ma'an city) or in alluvial fans (e.g. Aqaba city). Despite the significant threat posed by floods to certain parts of the country, there is limited documented literature on floods in Jordan, and available data are based on news reports, online publications, and a few references provided by the Disaster Reduction Unit (DRR) in ASEZ (Sustainable Water Integrated Management, 2014).

One of the wadis ranked with the highest potential for risk and damage in Jordan is Wadi Yutum (including its tributary Wadi Umran, covering a watershed area of nearly 4,000 km^2), a tributary to the Red Sea at the GoA, notorious for producing extreme flood events that have damaged structures located in the active flood channel. In February 2006, both Aqaba and Ma'an in Southern Jordan experienced a large flood in the lower Wadi Yutum and in Wadi Ouhadah, west of Ma'an city. The peak flow reached approximately 550 m^3/s in Wadi Yutum (estimated to be between a 10- and 40-year event), and around 320 m^3/s in Wadi Ouhadah (USAID, 2011). The incident, which had a regional impact, destroyed part of the Disi-Aqaba water transmission pipeline, disrupting water supply for two weeks and causing scour and erosion that affected concrete revetments and gabion structures within the Wadi channel. The floods also disrupted the Aqaba Wastewater Treatment Plant (WWTP) for several months, as well as the Aqaba airport, due to water flow and sediments being transported to the runway (SWIM, 2014). To mitigate the risk of flash flooding from this wadi, the Aqaba Development Corporation (ADC) constructed multiple successive dams and upgraded conveyance and protection measures.

In 2013, an extreme flood event affected the entire country, particularly in the north (Mafraq, Zarqa, Amman, and the Yarmouk River), the Jordan Rift Valley (JRV) in the west (including the Dead Sea and Jordan River), and the south (Ma'an and Aqaba). The floods submerged the streets in the main cities of Amman and Zarqa with rainwater. In the Jordan Rift Valley, approximately 8,500 acres of agricultural land adjacent to the Jordan River were submerged in water. Floods also destroyed all Plantations affected by heavy runoff and soil erosion, from Adasiyeh in the North of the Jordan River Valley to Damia. Fish farms in Manshiyeh and Abu Obaida were also destroyed. In the southern part of the country, the road linking Aqaba to the Dead Sea was closed due to eroded sediments, while Aqaba Airport was closed for two days (SWIM, 2014).

The Jordanian coast of the Gulf of Aqaba is characterised by rocky coral reef structures interspaced by valleys running down from the surrounding mountains. These valleys are dry for most of the year but experience occasional floods. The Aqaba Special Economic Zone Authority (ASEZA) has established a system of dams to harvest rainwater and reduce the impact of floods on coastal developments and habitats. The terrestrial area of the Project lies within a flooding zone, and the exposure of the Project is characterised as medium (baseline and future) according to the United Nations World Food Programme (UNWFP) (2019) study (refer to Figure 12-8).

The Red Sea is a long, narrow body of water between northeast Africa and the Arabian Peninsula. The northern end splits around the Sinai Peninsula, separating the shallow Gulf of Suez to the west from the much deeper Gulf of Aqaba to the east. Drews (2015) modelled the response in surge height to wind direction for cities exposed along a straight coastline. Surge height depends on the cosine of the angle between the wind direction and the central axis of the narrow gulf. Southeastern winds (from 300° Cartesian) generated the maximum surge at Suez, and the minimum surge height at Aqaba, with a level of 0.55m.

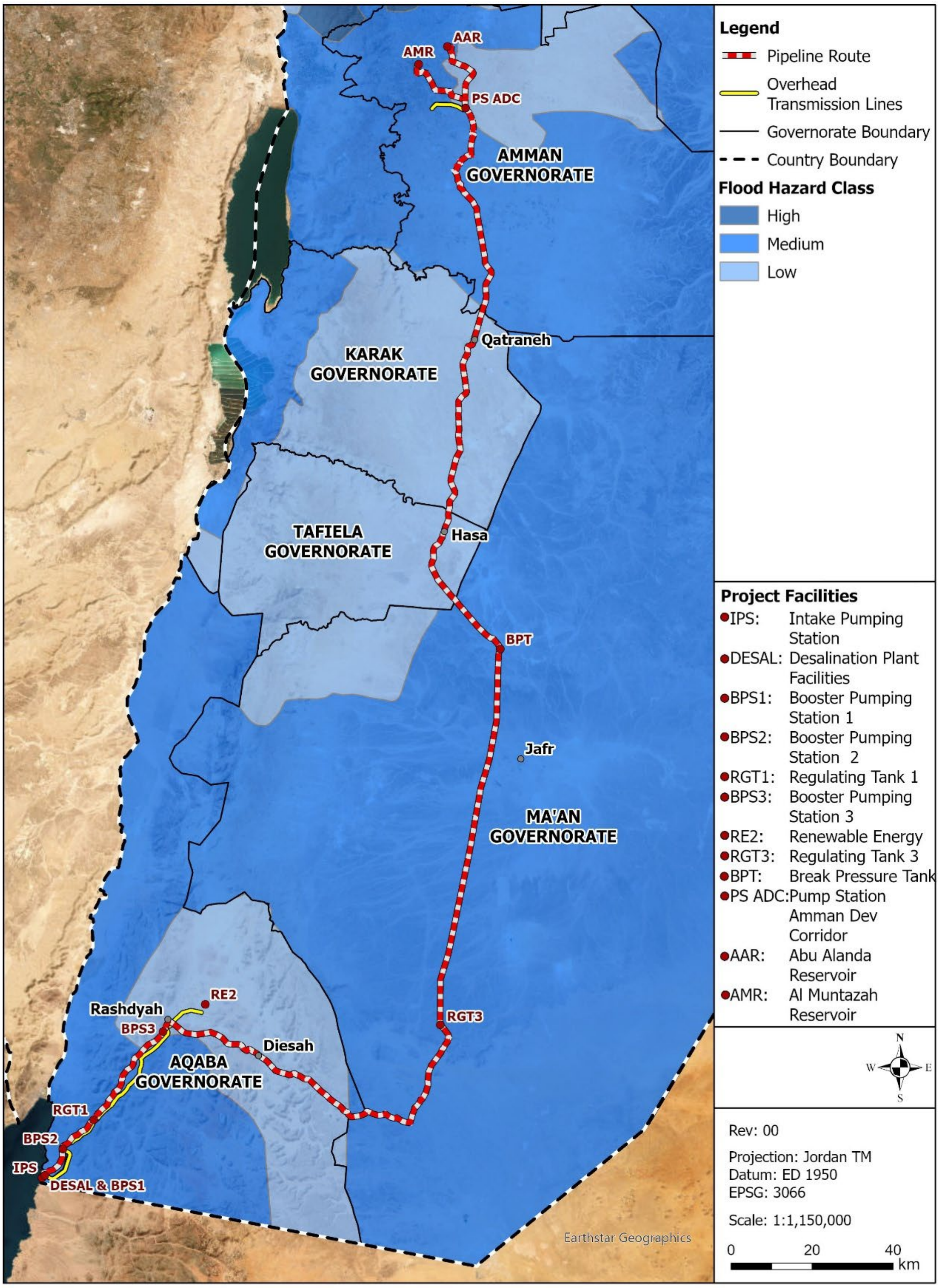
12.3.1.4 Sea Level Rise

The GoA is located on the Red Sea, which is one of the extensions of the Indian Ocean, and it connects to the Indian Ocean through the Arabian Sea. The Red Sea water is highly saline and dense due to its high evaporation rate, low precipitation, and limited freshwater input (Alawad *et al.,* 2019).

Values for the 20th-century global sea level rise (SLR) based on tide gauge records published during the 1990s are in the range 1 to 2mm/year (Church and White, 2011). The most significant contribution of SLR arises from thermal expansion driven by ocean warming, which has occurred primarily since the 1950s. Although changes in global mean sea-level could reflect changes in sea level of GoA, the relationship between global mean SLR and local SLR depend on a combination of factors, including changes in ocean circulation (which can alter sea-levels at local and regional scales), variations in oceanic levels due to thermal expansion and relative sea-level change associated with land movements (i.e. geological uplift and/or subsidence) (Nicholls and Klein, 2005; Harvey and Nicholls, 2006). The GoA is an extension of the Levantine or Dead Sea Fault and part of the Red Sea Rift, both of which are tectonically active, leaving the possibility of sea-level rise.

Monismith and Genin (2004) discussed observations of tidal variations in currents and elevation taken over the fringing coral reef at Eilat, Palestine. Tidal currents and water levels in the northern GoA show the effects of remote forcing clearly, with annual variations in sea surface height in the Gulf driven by wind-induced setup in the central part of the Red Sea. However, winds on the Gulf itself are also significant. It appears that observed tidal currents are the result of internal tides generated at the Strait of Tiran. This may be attributed to annual variations in currents, as well as to variations in generation and propagation associated with changes in stratification strength and structure throughout the year. When the GoA is strongly stratified in summer, tidal currents are strong; when stratification is weak, they are also weak.

Figure 12-8: Flood Hazard Map



12.3.2 Future Climate Projections

Several sources are available for extracting climate change projections, with the IPCC Assessment Reports and the World Bank Climate Knowledge Portal being the most recognised and utilised. To provide more relevant data, this assessment presents projections specific to the Middle East, setting the context for Project location climatology and particular forecasts for Jordan, at the country level only, as further downscaled projections for separate governorates are not available.

12.3.2.1 Temperature

Regional projections (RICCAR, 2017) indicate that temperatures in the Arab region are expected to rise over the course of this century. The general temperature change under RCP 4.5 shows an increase of 1.2°C–1.9°C at mid-century and 1.5°C–2.3°C by the end of the century. For RCP 8.5, temperatures increase to 1.7°C–2.6°C for mid-century and 3.2°C–4.8°C towards end-century (Figure 12-9).

The range of these values reflects variation in results across different areas of the region. The higher increase at mid-century is shown in the non-coastal areas. When focusing on seasonal changes, results show no clear tendency for temperature to increase more in any particular season. The warming is roughly evenly distributed across all seasons.

At the country level (Weathering Risk, 2017), the air temperature over Jordan is very likely to rise by between 1.7°C and 4.5°C by 2080, relative to the year 1876 and depending on the future GHG emissions scenario (Figure 12-10).

The increase in air temperature is expected to affect the entire country with high certainty. Under the lower-emissions scenario, RCP 2.6, the temperature increase will be slightly greater in southern and northeastern Jordan. By 2030, temperatures are expected to increase by 0.77°C in central Jordan and up to 0.97°C in the south compared to 2000. Temperature rises between 2030 and 2080 are expected to be small. By 2080, models project a rise of up to 1.3°C and 1.4°C for northeastern and southern Jordan, respectively, and of up to 1.1°C to 1.2°C for the rest of the country.

Under the medium-to-high emissions scenario RCP 6.0, temperature changes by 2030 will develop very similarly to those under RCP 2.6 (increasing by between 0.8°C in central Jordan and 1°C in the northeast and south). In the long term, however, RPC 6.0 projects a temperature increase of 2.4°C to 2.9°C by 2080, compared to 2000. Again, the arid south will be most affected, with an increase of up to 2.9°C. Temperatures are expected to rise by approximately 2.6°C in the northeastern desert and by around 2.4°C in the more densely populated semi-arid northwest of the country.

Figure 12-9: Mean change in annual temperature (°C) under RCP 4.5 and RCP 8.5 – Regional Level

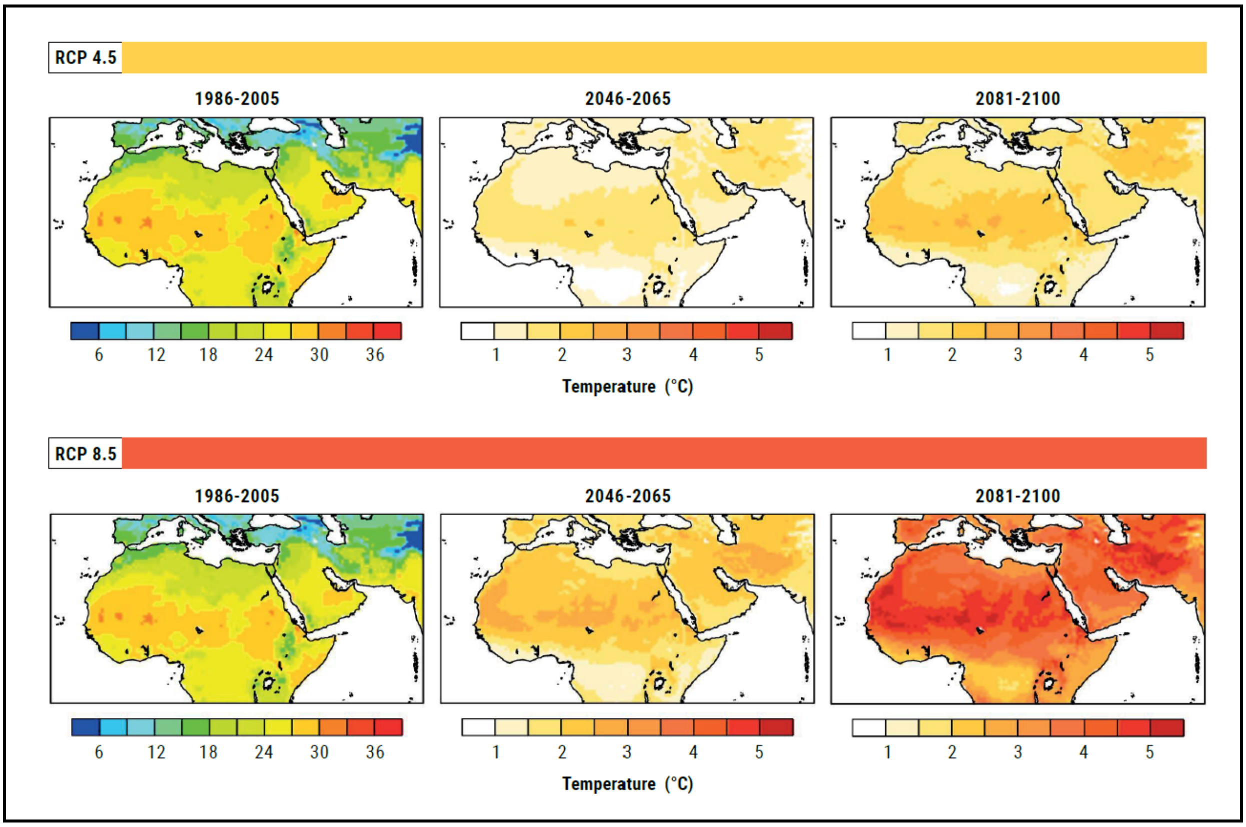
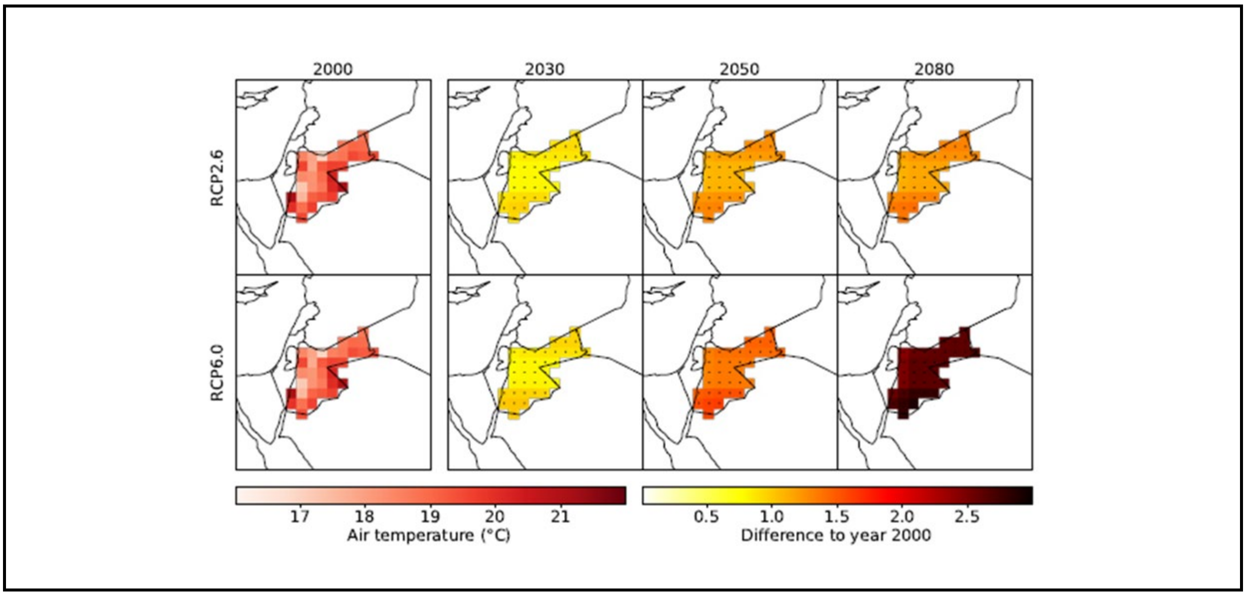


Figure 12-10: Annual temperature (°C) Projections under RCP 2.6 and RCP 6.0 – Country Level



12.3.2.2 Extreme Heat

Examining the extremes in temperature, all indices related to hot days exhibit increasing trends as expected (RICCAR, 2017). Changes in the number of very hot days (SU40) show generally the most significant increases. The latter finding is not surprising, as the number of summer days for the present climate is already high over most of the region. Changes for the SU40 indicator show strong projected warming for RCP 8.5, indicating that the increase in extreme temperatures in coastal areas would be lower than in the inland areas of the region for both RCP 4.5 and 8.5 scenarios (Figure 12-11).

Concurrent with rising annual mean temperatures at the country level, the annual number of very hot days (defined as days with temperatures above 35°C) is projected to rise with high certainty all over Jordan, with the highest long-term increases in the west, including Jordan's populated northwest under RCP6.0 (Weathering Risk, 2017) (Figure 12-12).

Under RCP 2.6, the number of very hot days is expected to increase by 20-26 days in most parts of Jordan, with a maximum of 28 additional very hot days per year until 2030 in the southeast, compared to 2000. Thereafter, the number of days surpassing the 35°C threshold will continue to grow steadily. In 2050, there will be between 23 and 32 additional very hot days annually, while by 2080, the increase will range between 25 and 35 days annually, compared to 2000.

Under RCP 6.0, very hot days are projected to increase by 2030, as they do under RCP 2.6, by an additional 15 to 25 days. Until 2080, however, the incline will be stronger: comparatively smaller increases in hot days are projected for the northeast, amounting to around 45 additional days per year, while northwestern and central Jordan will experience a rise of up to 71 very hot days annually by 2080.

Figure 12-11: Mean change in the number of very hot days (days/year) under RCP 4.5 and RCP 8.5 – Regional Level

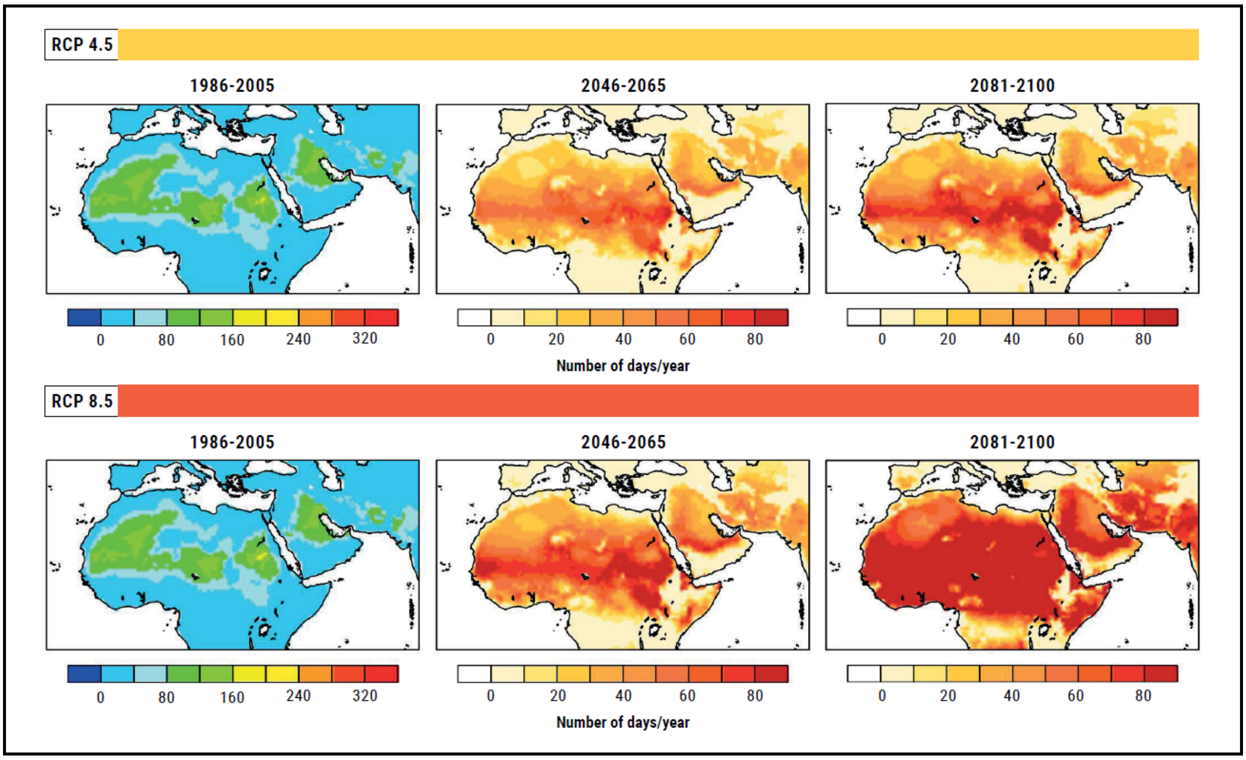
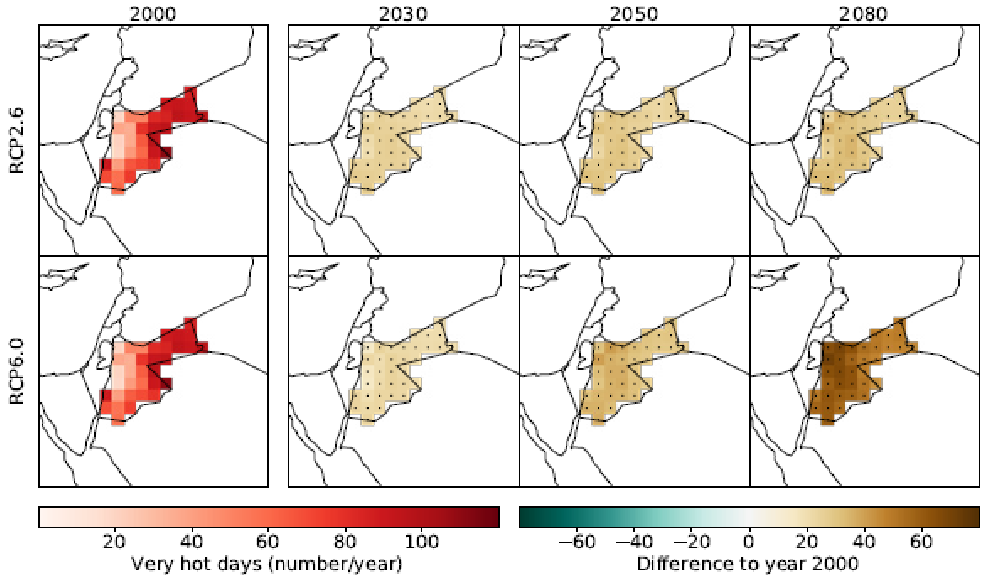


Figure 12-12: Number of very hot days (days/year) Projections under RCP 2.6 and RCP 6.0 – Country Level



12.3.2.3 Precipitation

Precipitation changes vary considerably across the region, with no universal trend evident in annual or seasonal results (RICCAR, 2017). Decreasing trends can be seen in most of the Arab region at mid-century (Figure 12-13). By the end of the century, both scenarios suggest a reduction in average monthly precipitation to 8–10mm in coastal areas. At the seasonal level, the more substantial precipitation changes are projected for countries along the Mediterranean coast during the winter months.

Higher GHG emissions will lead to a drier future for Jordan (Weathering Risk, 2017). All models project an apparent decrease in mean annual precipitation over Jordan, in comparison to the year 2000 (Figure 12-14). However, future decreases in precipitation projections are subject to uncertainties and natural year-to-year variability. The mean model projections for RCP 2.6 show a decrease until about mid-century, though this decrease is highly uncertain. Annual precipitation is expected to decrease by between 1.6 and 14.2mm (best estimate: -3 mm) by 2030 and by between 7.2 and 13.9mm (best estimate: -10.8mm) by 2050, compared to 2000. Despite interannual variability, long-term median precipitation stabilises from 2050 onward.

Under RCP 6.0, precipitation will decrease more strongly than under RCP 2.6. Annual rainfall is expected to decline by between 2 and 20.3 mm until 2030 (best estimate: -12.5mm), and by between 12.8 and 23.22mm by 2050 (best estimate: -17.1mm). By 2080, precipitation is expected to decline by 12.5 to 26.1 mm annually (with a best estimate of -20 mm), compared to 2000 (very likely range).

Figure 12-13: Mean Change in Annual Precipitation (mm/month) under RCP 4.5 and RCP 8.5 – Regional Level

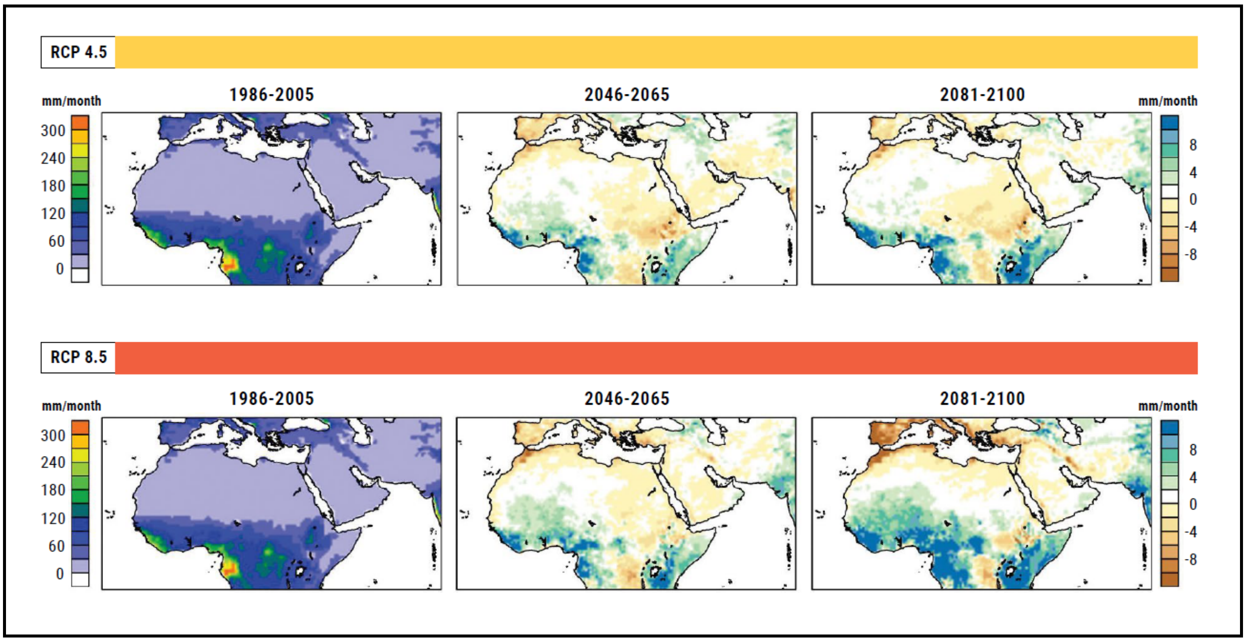
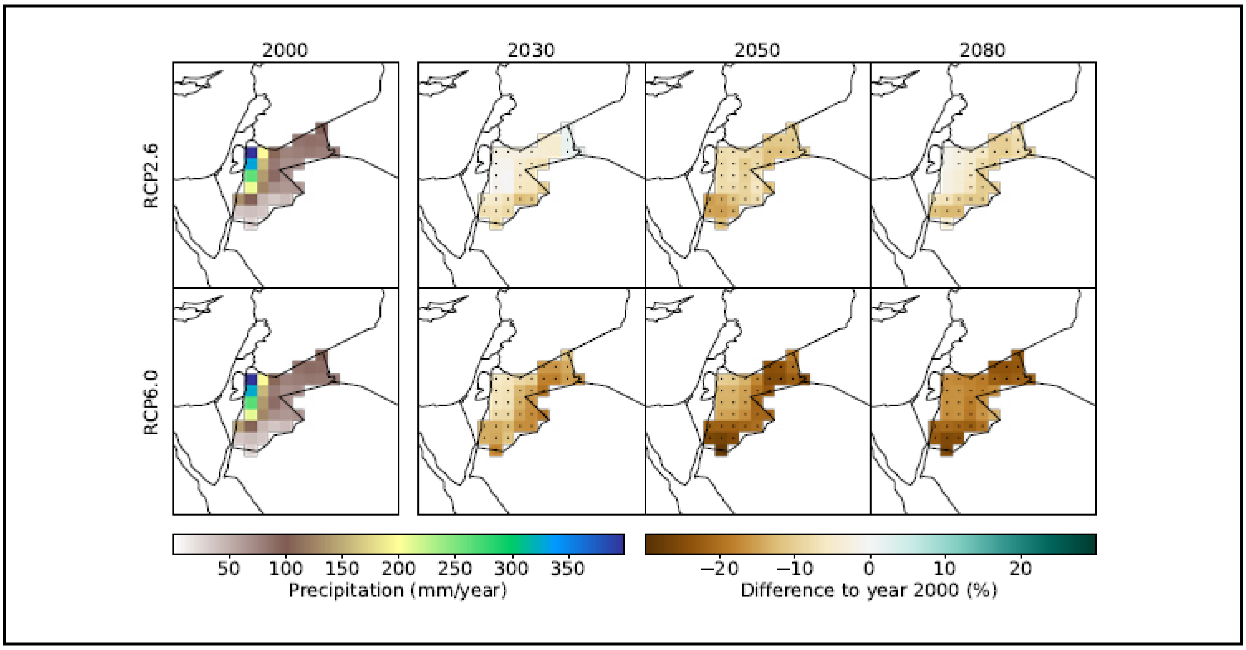


Figure 12-14: Annual Precipitation (mm/year) Projections under RCP 2.6 and RCP 6.0 – Country Level



12.3.2.4 Extreme Precipitation

Projections of precipitation extremes vary considerably across the region. Changes in the annual number of 10mm precipitation days (R10) indicate decreasing trends over time compared to the baseline period (Figure 12-15). Similarly, results for the annual number of 20mm precipitation days (R20) (Figure 12-16) for the end of the century are similar to the R10 index, suggesting a projected overall reduction in rainy days with these intensities over the region. The simple precipitation intensity index (SDII) shows increasing trends across the majority of the area.

At the country level, the trend towards more frequent extreme precipitation events cannot be confirmed (Weathering Risk, 2017). All models agree on a declining trend in heavy precipitation, though the projected decline is much higher in one model than in the others (Figure 12-17).

Under RCP 2.6, heavy precipitation days will slightly decrease to between 5.1 and 6.6 days by 2030, and between 4.5 and 6.3 days by 2050. Under RCP 6.0, the frequency of heavy precipitation is expected to decline comparatively significantly. Heavy rainfall events are projected to decrease to 5-5.9 days per year by 2030. Due to a growing discrepancy between the models, modelling uncertainty strongly increases from 2030 onwards. Hence, while the best estimate projects 5.5 heavy precipitation days per year by 2050, the very likely range is 3.9-5.7 days per year. Projections for the year 2080 are similar (3.8 to 5.6 days/year). Particularly under RCP 2.6, geographically explicit projections of heavy precipitation events are uncertain in many regions.

Overall, country variations are expected to be relatively small. Certainty is significantly higher under RCP 6.0, with heavy precipitation events projected to decline nationwide. The most substantial decrease can be expected in the arid east across all time frames, and in the very south of Jordan in the long term. By 2080, the projected median decrease is expected to be around 1.1 to 1.4 days in the populated Mountain Heights Plateau, 1.6 days in the northeast, and up to 2.2 days in the very south, compared to the year 2000.

Figure 12-15: Mean Change R10 Precipitation Days (days/year) under RCP 4.5 and RCP 8.5 – Regional Level

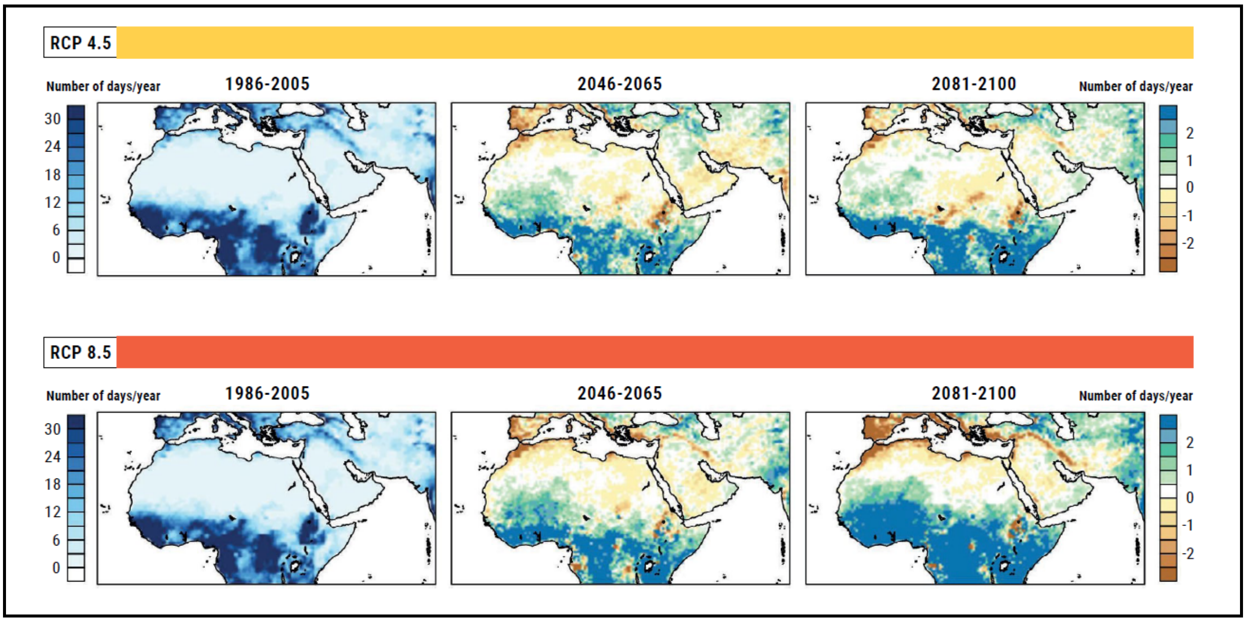


Figure 12-16: Mean Change R20 Precipitation Days (days/year) under RCP 4.5 and RCP 8.5 – Regional Level

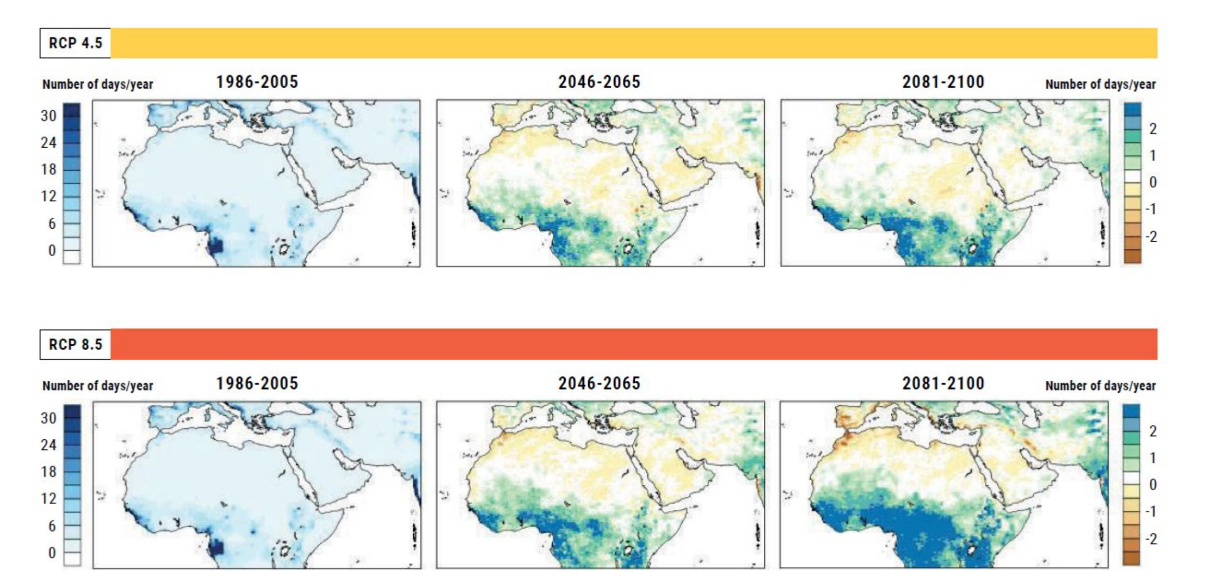
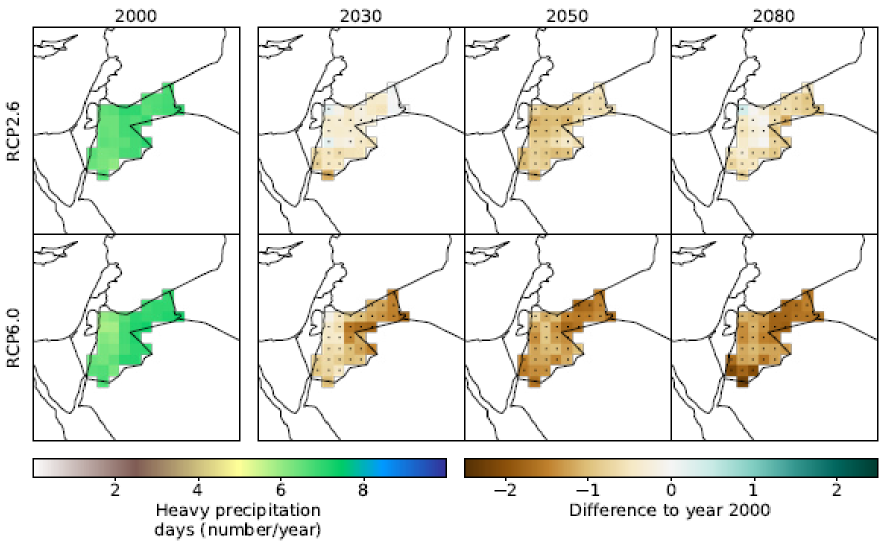


Figure 12-17: Days with Heavy Precipitation (days/year) Projections under RCP 2.6 and RCP 6.0 – Country Level



12.3.2.5 Drought

Jordan is projected to face worsening drought conditions driven by climate change, particularly through increased temperatures and reduced rainfall. While precise numeric forecasts are not continuously published, the trend is clear: droughts will likely be more prolonged, deeper, and cover a larger area.

Research indicates that Jordan will experience increasing drought severity under climate change. A recent study found that, for the period 2070-2099 under RCP 8.5, droughts will become longer in duration, more spatially extensive, and somewhat less frequent (Alkhasoneh and Rowe, 2025). Projected changes indicate a significant rise in temperature and a tendency towards drought, accompanied by anticipated reductions in precipitation. Future drought characteristics indicate a substantial increase in severity, with a decrease in frequency but an increase in duration, and an expanding spatial extent of drought conditions.

12.3.2.6 Dust Storms

In Jordan, a study found that over 31 years, the average number of dust storms was ~17.2 per year, with much higher values in the south/east of the country (e.g., ~182 in Al-Jafr, ~102 in Safawi over the whole period) and most storms occurring in spring (Ghanem, 2020). A comprehensive review of the Middle East and North African region reveals that dust storms are already increasing in frequency/intensity due to a combination of aridity, wind erosion, land-use changes, and climate drivers (Chibani, 2022).

A 2025 forthcoming study (Abadi *et al.,* 2025) explicitly covers the Middle East and dust storms. The outputs of three CMIP6 models were analysed over the period 2015–2100. Additionally, surface dust concentration was studied in two sub-periods: 2024–2060 and 2061–2100, under three scenarios, optimistic (RCP 2.6), intermediate (RCP 4.5) and pessimistic (RCP 8.5). The spatial distribution of changes in dust concentration from 2024 to 2060 indicates that all climatic scenarios predict the activation of new dust sources, particularly in Oman and Yemen. Moreover, all scenarios agree that the expansion of dust source areas will accelerate during the 2061–2100 period compared to the 2024–2060 period. The combined models indicate a positive trend in surface dust concentration (0.05 $\mu g\, m^{-3}$ per year), suggesting an increase in dust activity over the Middle East. The mean monthly values of temperature, relative humidity, wind speed, and precipitation, projected from nine models across the fourteen dust-source areas and the entire Middle East from 2015 to 2100, showed strong consistency and low discrepancies between model outputs. However, across all dust sources, greater discrepancies in precipitation between the models occurred during the cold period, as did greater discrepancies in temperature and surface wind speed during the warm period.

12.3.2.7 Solar Radiation

Climate data portals (e.g., the World Bank Climate Knowledge Portal for Jordan) display projected changes in various variables (e.g., temperature and precipitation), but do not provide detailed estimates of changes in solar irradiance.

Jordan already enjoys a high solar resource, with daily averages around 5.5 kWh/m² in many locations (Al-Rousan et *al.,* 2021). There are also local studies that model solar radiation for different climates in Jordan (e.g., Irbid, Amman, Aqaba, Ma'an), establishing baseline solar irradiation and regression relationships. Based on similar climates, a 5% increase in solar resource by 2050 can be considered (Badran *et al.,* 2018).

12.3.2.8 Seawater Temperature

A study by M. Shaltout (2019) found that the mean standard seawater temperature (SWT) in the Red Sea was ~27.88°C, with a reported warming trend of 0.029°C/year (~+0.29°C per decade) for the studied period. The same study projects a future increase in seawater temperature in the Red Sea, ranging from 0.6°C to 3.2°C per century across various scenarios.

A more recent study (Sengupta *et al.,* 2024) found that in the Gulf of Aqaba:

- Sea temperatures are rising at "a few hundredths of a degree Celsius per year" across a range of depths

- The warming is attributed in part to reduced winter mixing and lateral heat advection from the southern Gulf region

While not providing exact future values for Jordan's coast alone, the national climate risk profile for Jordan notes an increase in marine heat-stress hazards (in coastal waters) due to warming seas (Weathering Risk, 2017).

12.3.2.9 Seawater Salinity

Current data indicate high baseline salinity in the Gulf of Aqaba, with surface salinities ranging from ~40.3 ‰ to 46.6 ‰ reported for the Jordanian coastline in summer (Al-Taani *et al.,* 2020). Key drivers for the high salinity include very high evaporation (~400 cm/year in some locations) and minimal freshwater input (minimal rainfall and negligible river flow).

Whilst there are hydrodynamic studies of the region (e.g., modelling of circulation and exchange flows) that illustrate how salinity and temperature structures behave under current conditions, no robust modelling study for the Jordan coast has been conducted that sets out future salinity changes under climate change scenarios. Salinity in the region is controlled by multiple interacting processes: evaporation, precipitation, ocean exchange/outflow, mixing, and possibly anthropogenic abstraction/discharge. The modelling of how these will shift under climate change remains complex. Because baseline salinity is already high, a modest increase in salinity (e.g., by +0.5-2 % by mid-century) can be assumed in the absence of significant freshwater flow changes or mixing regime shifts, driven by increased evaporation from warming and reduced rainfall.

12.3.2.10 Seawater pH

In the Jordan coast of the Gulf of Aqaba, measured seawater pH values are around ~8.3 and show "very minor temporal and spatial variations" (Manasrah *et al,* 2019). The region (Red Sea/Gulf of Aqaba) has relatively high alkalinity and buffering capacity compared to many ocean basins, which suggests it may be more resistant to acidification than more open or low-buffered seas (Centre Scientifique de Monaco, 2017).

There are no regional-specific quantitative projections for seawater pH decline for Jordan's coast in the available literature. The standard global predictions of ocean acidification (e.g., for broad ocean basins) may not translate directly to the GoA, as local factors (water circulation, evaporation, input from the seas, and alkalinity) differ. The region's deep bathymetry, high salinity and evaporation, and limited mixing may buffer acidification differently than in open seas, so caution is recommended when using global averages.

12.3.2.11 Humidity

An observational study at the Amman Airport Meteorological Station found an upward trend in relative humidity of approximately 0.13% per year, which was statistically significant during the summer and autumn seasons (Abu-Taleb *et al.,* 2007). However, this trend observed in Amman may not hold uniformly across all of Jordan (coastal, highlands and desert zones differ). Models for the broader Middle East suggest minimum increases (night-time) temperatures and changes in moisture/atmospheric circulation that may lead to higher humidity at night. National climate risk assessments for Jordan highlight increases in evapotranspiration and atmospheric dryness as part of the changing climate, which could alter humidity profiles (even if relative humidity may not drop) (Weathering Risk, 2017).

12.3.2.12 Sea Level Rise

Sea level rise generally has several consequences, including coastal retreat and land loss, which affect coastal establishments such as tourism, recreational activities on beaches, industries, and marinas, as well as ecosystems and biodiversity. Specifically, for the GoA, predicting sea level changes is not easy. As noted in Section 12.3.1.4, the sea level in the GoA is mainly controlled by remote wind stress over the Red Sea, internal waves generated at the Strait of Tiran, and local sedimentation.

Satellite altimetry indicates that the Red Sea has been rising at ~3.9 mm/yr since the early 1990s, a rate broadly similar to the global mean and accelerating (Abdullah and Al-Subhi, 2021). Annual sea-level variability in the Red Sea is ~15–20 cm (Alothman *et al.,* 2020). For the Red Sea, the IPCC Sixth Assessment Report (IPCC, 2022) indicates a rise of ~0.32–0.62m by 2100 under RCP 2.6, 0.44–0.76m by 2100 under RCP 4.5, and 0.63–1.02m by 2100 under RCP 8.5.

Tectonics around Aqaba exhibit low uplift/subsidence rates (≤0.15 mm/yr uplift cited for parts of the region), which are insignificant compared to climate-driven sea-level rise but significant for very long design lives (Khanna *et al.*, 2021).

As downscaled data for the short Aqaba coast is limited, the IPPC and National Aeronautics and Space Administration (NASA) Sea Level Projection Tool (NASA, 2025) can be used for projections at a selected location. For the coast of Aqaba, the NASA Tool indicates sea-level rise rates of 4mm/year under RCP 2.6, 5mm/year under RCP 4.5, and 6mm/year under RCP 8.5 relative to a 1995-2014 baseline.

12.3.2.13 Coastal Erosion

The interplay of sea-level rise, changes in the wave climate, storm frequency/intensity, sediment supply (or lack thereof), and tectonic movement (uplift/subsidence) complicates projections of future coastal erosion rates. Because much of the Jordan coast of the Gulf is rocky/reef-influenced rather than purely sandy, typical sandy-beach erosion models may be less applicable.

A recent study (Abdo, 2024) assessing the average regression of the western shoreline of the GoA during the period 1848-2022 found an average shoreline retreat (erosion) of ~0.62m/year. The study attributes this retreat to a combination of factors, including global warming (sea-level rise), storm- and sea-level-related events, possibly subsidence, and shoreline processes. It is noted that this rate is site-specific and may not be uniformly applicable across all shoreline types (e.g., rocky reef vs. sandy beach) or for the entire Jordan coast segment.

12.3.2.14 Soil Erosion

Erosion projections depend heavily on land-use management, such as terracing, conservation agriculture, and grazing control, which are policy/behavioural variables rather than purely climate variables. Therefore, outcomes vary widely depending on adaptation. The local drivers of erosion (wind vs. water, surface geology, vegetation cover, land management) differ widely across Jordan, meaning that national-average projections may mask significant subregional variability. Much of the modelling involves spatial hazard mapping (identifying areas where erosion risk is currently high) rather than future scenario modelling, which links climate change (e.g., precipitation intensity, vegetation change) to changes in erosion rates.

Jordan’s climate risk profile notes that unsustainable land use, overgrazing, and drier conditions under climate change are likely to exacerbate soil degradation and erosion (Weathering Risk, 2017). A recent study (Abuhamoor *et al.,* 2025) aimed to provide a detailed spatial assessment of soil erosion risk across Jordan and identify zones prone to erosion, thereby supporting informed decision-making in land management. The Revised Universal Soil Loss Equation (RUSLE) model, integrated with Geographic Information System (GIS) tools, was employed to estimate soil loss and map erosion severity. The model incorporated essential factors including rainfall erosivity, soil erodibility, slope length and steepness, vegetation cover, and conservation practices. Erosion rates were categorised into three classes: low (0–10 tons ha/year), moderate (10–50 tons ha-1 year-1), and high (>50 tons ha-1 year-1). Results revealed that 94% of Jordan's land is subject to low erosion risk, 5% to moderate risk, and approximately 1% to high risk (see Figure 12-18 and Figure 12-19). The areas most vulnerable to erosion are in the northern and central highlands, as well as parts of the Jordan Valley, primarily due to their steep topography and higher precipitation.

A global assessment of soil erosion under climate change (to 2070) reveals that water erosion could increase by more than 60% in many regions under high-emissions scenarios (Borelli *et al.,* 2020). The study suggests that socioeconomic developments impacting land use will either decrease (by 10% under RCP 2.6) or increase (by 2% under RCP 4.5 and 10% under RCP 8.5) water erosion by 2070. Climate projections, for all global dynamics scenarios, indicate a trend, moving toward a more vigorous hydrological cycle, which could increase global water erosion (+30 to +66%).

Figure 12-18: Soil Erosion Map Jordan

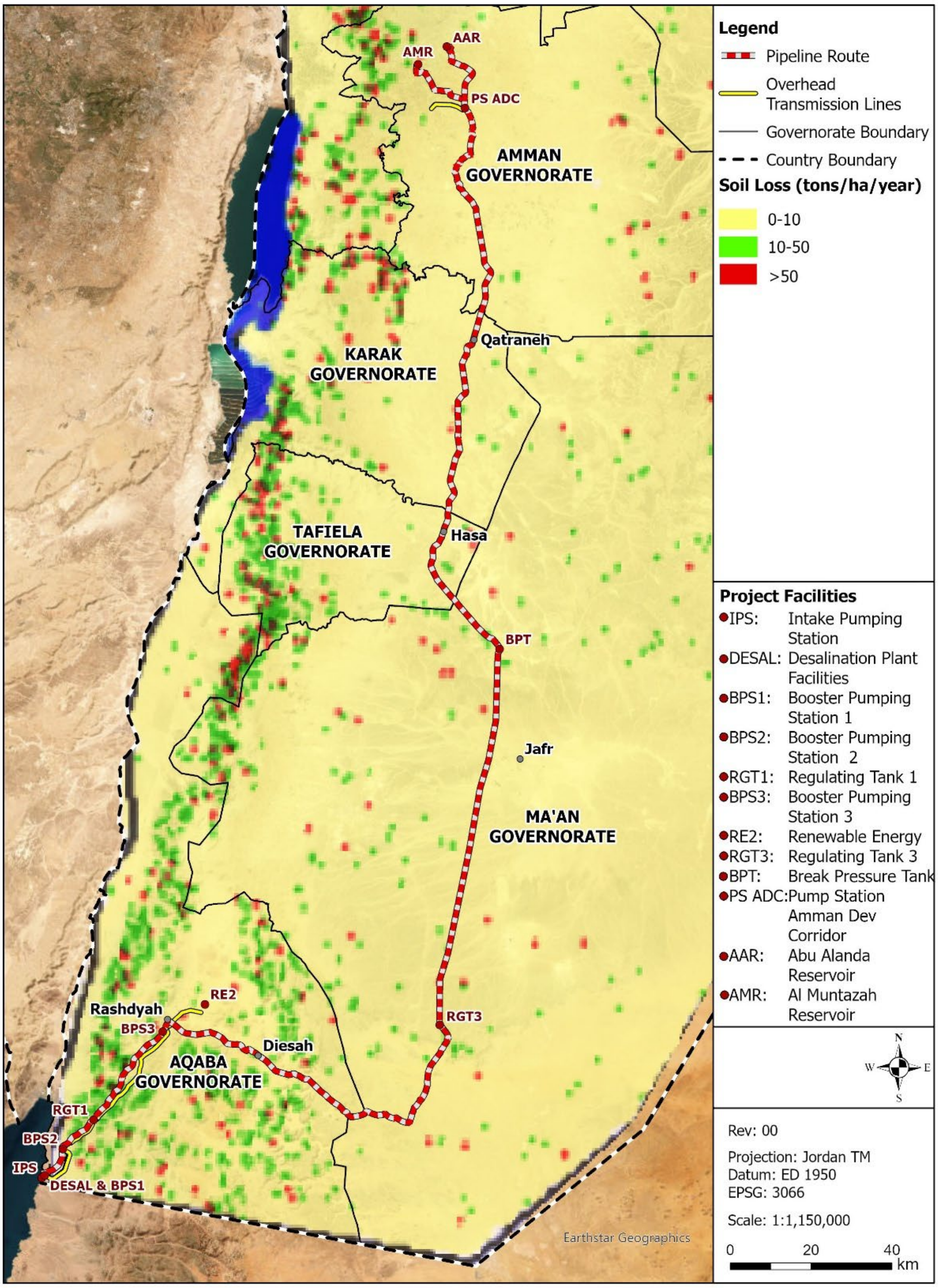
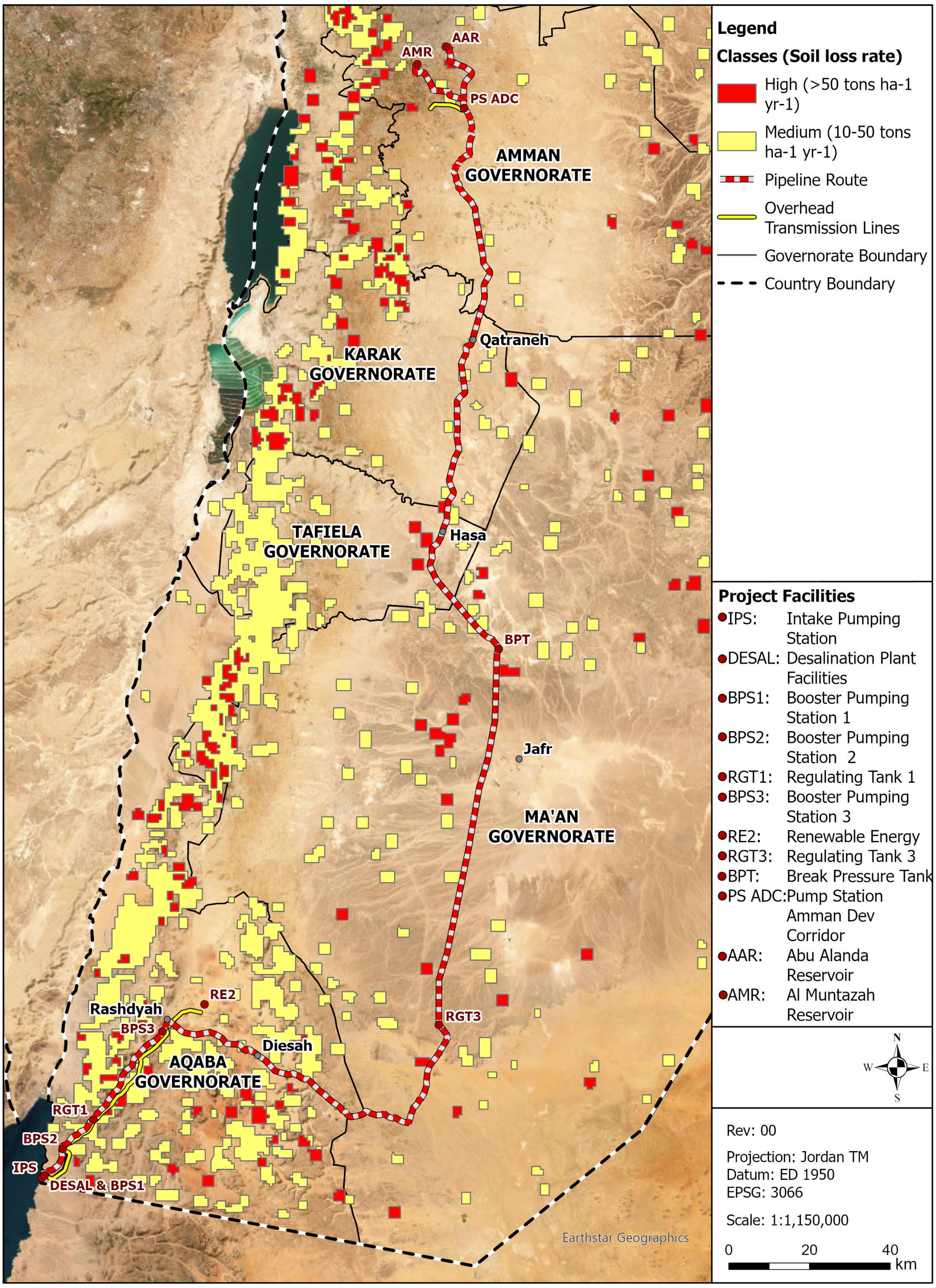


Figure 12-19: Hotspots Susceptible to Soil Erosion



12.4 Assessment of Physical Climate Risks

12.4.1 Screening of Hazards

The following literature sources were used to establish the list of commonly assessed acute and chronic physical climate-related hazards:

- Recommendations of Taskforce on Climate Related Financial Disclosures (TCFD) 2017
- Special Report by Intergovernmental Panel on Climate Change (IPCC) on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, 2012
- IPPC 6th Assessment Report on Climate Change: Impacts, Adaptation and Vulnerability, 2022
- United Nations Environment Programme (UNEP) Climate Risk Landscape Report, 2023
- Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR) Arab Climate Change Assessment Report 2017
- Weathering Risk 2022 Climate Risk Profile Jordan.

Table 12-7 and Table 12-8 present physical climate hazards that were screened for applicability to the Project and selected for evaluation of the physical climate risk. Physical climate hazards as such apply both to construction and operation phases of the Project; climate change risks apply to the long term and therefore mainly to the operation phase.

Climate hazards relevant for the construction phase are identical to the acute climate hazards mentioned below, and apply as follows:

- Extreme heat: worker health and safety impacts during construction and operation
- Extreme precipitation and flash floods: destruction of onshore construction works before appropriate protection is built; destruction of equipment
- Storm surges and extreme wind: destruction of onshore construction works before finalization; destruction of equipment and risks to offshore workers

Table 12-7: Screening of Acute Climate Hazards applying to the operation phase

Acute Climate Hazard	Screening Result	Justification	Relevant Project Facility
Extreme heat	Screened in	Reduction in solar PV efficiency, strain on equipment cooling.	Renewable Energy Facility Desalination Plant
Extreme precipitation and flash floods	Screened in	Overwhelming of drainage systems, flooding of facility rooms and foul intakes with sediment/organic loads.	Desalination Plant AGIs Renewable Energy Facility
Floods (coastal and fluvial)	Screened in	Scour at wadi crossings can undercut and expose the pipeline, leading to mechanical stress and potential rupture,	Conveyance Pipeline AGIs in low-lying areas

Acute Climate Hazard	Screening Result	Justification	Relevant Project Facility
		including loss of protective cover or riprap. Shifts in wadi plans alter erosion zones. Loss of soil bearing capacity. Access restrictions.	
Storm surges	Screened in	Higher total water levels increase the risk of overtopping and inundation for intake/outfall structures.	Intake and Outfall Facilities
Landslides / Mudslides	Screened in	Ground displacement. Loss of support or exposure of the pipeline. Compound hazard of scour and instability.	Conveyance Pipeline
Extreme wind	Screened in	Increase wind loading and debris damage to physical structures.	Desalination Plant AGIs Renewable Energy Facility
Dust Storms	Screened in	Affect the performance of the solar PV panels, increasing maintenance needs.	Renewable Energy Facility
Wildfire	Screened out	Project facilities are not located within heavily vegetated areas.	-
Cold spells	Screened out	Project facilities are not located within a climate with cold spells	-
Freeze-thaw damage	Screened out	Project facilities are not located within climatic zones with freezing temperatures.	-
Tropical cyclone	Screened out	Project facilities are not located within climatic zones characterised by tropical cyclones.	-
Hurricanes and typhoons	Screened out	Project facilities are not located within climatic zones characterised by hurricanes or typhoons.	-

Table 12-8: Screening of Chronic Climate Hazards

Chronic Climate Hazard	Screening Result	Justification	Relevant Project Facility
Increase in Mean Annual Surface Temperature	Screened in	Long-term yield suppression via temperature coefficient, accelerated component ageing of physical structures, increase in extreme heat events, higher cooling loads, reduction in brine dispersion capacity and increase in discharge temperature.	Renewable Energy Facility Desalination Plant AGIs
Urban Heat Island (UHI) effect	Screened In		
Solar radiation	Screened In	Variability management (inverters, storage sizing, reserve margin).	Renewable Energy Facility
Decrease in mean annual precipitation.	Screened out	Increased salinity and turbidity of intake water raise osmosis pressures and pretreatment load, increasing power demand and reducing cooling efficiency.	Intake and Outfall Facilities Desalination Plant
Droughts	Screened in		
Seawater temperature	Screened in	Reducing seawater viscosity increases scaling and biofouling potential and raises energy use for cooling and post-treatment.	Intake and Outfall Facilities Desalination Plant
Seawater salinity	Screened in	Increased salinity and turbidity of intake water raise osmosis pressures and pretreatment load, increasing power demand and reducing cooling efficiency.	Intake and Outfall Facilities Desalination Plant
Seawater pH increase	Screened in	An increase in pH can reduce coagulation and flocculation efficiency, affecting the de-chlorination of discharge, membrane/filter performance, scaling, membrane/filter integrity, and increased corrosion of steel structures.	Intake and Outfall Facilities Desalination Plant
Humidity	Screened In	Acceleration of corrosion of steel structures and electrical components.	Desalination Plant AGIs Renewable Energy Facility and OHTL
Relative sea level change	Screened in	Gradual increase in coastal flood risk, shoreline erosion near desalination intakes/outfalls, increasing turbidity of intake water, and exposure of the pipeline.	Intake and Outfall Facilities Transfer pipelines (between Intake and Outfall Facilities and Desalination Plant)
Coastal erosion	Screened In		

Chronic Climate Hazard	Screening Result	Justification	Relevant Project Facility
Soil erosion	Screened in	Loss of pipeline protection cover.	Conveyance Pipeline
Soil salinity	Screened out	Operation of the Project facilities is not dependent on soil salinity.	-
Air quality	Screened out	Operation of the Project facilities is not dependent on air quality.	-
Permafrost / glacial retreat	Screened out	Project facilities are not located within climatic zones characterised by permafrost or glaciers.	-
Growing season length	Screened out	Operation of the Project facilities is not dependent on the growing season.	-
Surface water availability	Screened out	Operation of the Project facilities is not dependent on surface water	-
Surface water temperature	Screened out	Operation of the Project facilities is not dependent on surface water	-

12.4.2 Exposure Assessment

Exposure assessment of the Project facilities is summarised in Table 12-9. These are based on available climate projections for each applicable climate hazard, with exposure levels assigned as per the criteria in Section 12.2.2.2.

Table 12-9: Exposure Assessment for Physical Climate Risks

Climate Hazard	Exposure Level[1]	Projection	Relevant Project Facility
Extreme heat	High	RCP 2.6: Between 23 and 32 additional very hot days annually by 2050. RCP 6.0: 45 additional very hot days per year by 2050.	Desalination Plant Renewable Energy Facility
Extreme precipitation and flash floods	Medium	RCP 2.6, decrease in heavy precipitation days to 5.1 - 6.6 days by 2030, and to 4.5 - 6.3 days by 2050. RCP 6.0: decrease in heavy precipitation days to 3.9 and 5.7 days by 2050. Flood hazard level for most of the Project infrastructure locations is medium. Dry, compact soil characteristics in arid and semi-arid climates contribute to fast runoff rates.	Desalination Plant AGIs Renewable Energy Facility

Climate Hazard	Exposure Level[1]	Projection	Relevant Project Facility
Floods (coastal and fluvial)	High	The terrestrial area of the Project lies within a flooding zone (UNWFP, 2019): the main Wadi Yutum Interchange and along its Wadi bank for approximately 5km. Despite the reductions in peak flow rates that the flood attenuation dams might achieve, the flood risk remains high.	Conveyance Pipeline AGIs in low-lying areas
Storm surges	Low	Studies determined that the GoA is too deep to generate significant storm surge or wind set-down: 0.55m for the Aqaba coast, based on a modelling study (Drews, 2015).	Intake and Outfall Facilities
Landslides / Mudslides	Medium	Extreme rainfall is projected to decrease, thereby reducing the risk of landslides and mudslides induced by extreme precipitation. Flood hazard level for most of the Project infrastructure locations is medium. Dry, compact soil characteristics in arid and semi-arid climates contribute to rapid runoff rates.	Conveyance Pipeline
Extreme wind	Low	The absence of specific studies on increasing extreme winds in Jordan suggests no trends; however, this finding is qualified by low confidence.	Desalination Plant AGIs Renewable Energy Facility
Dust Storms	Medium	All climatic scenarios for 2024-2060 predict activation of new dust sources (Abadi *et al.,* 2025).	Renewable Energy Facility
Increase in Mean Annual Surface Temperature	High	RCP 2.6: increase by 0.77°C in central Jordan and by up to 0.97°C in the south by 2030; increase to 1.3°C for northeastern Jordan and 1.4°C for southern Jordan, respectively, and by up to 1.1 to 1.2°C for the rest of the country by 2080. RCP 6.0: increase by 0.8°C in central Jordan and 1°C in the northeast and the south by 2030; increase by 2.9°C by 2080.	Renewable Energy Facility Desalination Plant AGIs
Urban Heat Island (UHI) effect	High		Renewable Energy Facility Desalination Plant AGIs
Solar radiation	Low	Based on similar climates, an increase of 5% in solar resources by 2050 can be considered (Al-Rousan et *al.,* 2021).	Renewable Energy Facility
Decrease in mean annual precipitation	Low	RCP 2.5: Decrease in annual precipitation by 1.6 - 14.2mm (best estimate of -3 mm) by 2030, and by 7.2 - 13.9mm (best estimate of -10.8mm) by 2050. RCP 6.0: decrease in annual precipitation by 2 - 20.3 mm until 2030 (best estimate of -12.5mm), and by 12.8 - 23.22mm by 2050 (best estimate of -17.1mm).	Intake and Outfall Facilities Desalination Plant

Climate Hazard	Exposure Level[1]	Projection	Relevant Project Facility
Droughts	Low	RCP 8.5: droughts longer in duration, more spatially extensive, though somewhat fewer in frequency by 2070 (Alkhasoneh and Rowe, 2025).	
Seawater temperature	Medium	Increase by 0.029°C/year (approximately 0.29°C per decade) (Shaltout 2019).	Intake and Outfall Facilities Desalination Plant
Seawater salinity	Medium	As baseline salinity is already high, it is assumed to increase from 0.5 to 2% by 2050 in the absence of significant freshwater flow changes or shifts in the mixing regime, driven by increased evaporation from warming and reduced rainfall.	Intake and Outfall Facilities Desalination Plant
Seawater pH	Low	GoA is prone to alkalinity and resistance to acidification. Seawater pH is assumed to decrease by 0.10 pH units by 2050 and by 0.20 pH units by 2100, unless local buffering/stabilisation limits change.	Intake and Outfall Facilities Desalination Plant
Humidity	Low	Given higher temperature projections, assumed to modestly increase 1-3% in populated / urban zones, particularly at night (Weathering Risk, 2017).	Desalination Plant AGIs Renewable Energy Facility and OHTL
Relative sea level change	Low	Projections based on IPPC / NASA Sea Level Projection Tool (NASA, 2025): RCP 2.6: 4mm/year RCP 4.5 5mm/per RCP 8.5 6mm/year	Intake and Outfall Facilities Transfer pipelines (between Intake and Outfall Facilities and Desalination Plant)
Coastal erosion	Medium	Assumed ~0.62 m/year erosion rate as a maximum case for vulnerable shoreline segments (sandy beaches, where sediment supply is low and wave/climate forces are increasing) (Abdo, 2024)	
Soil erosion	Medium	RCP 2.6: decrease in water soil erosion by 10% RCP 4.5: increase in water soil erosion by +2% RCP 8.5: increase in water soil erosion by +10% (Borelli *et. al.,* 2020)	Conveyance Pipeline

[1] Exposure Levels:

High - Material increase in climate variable with potential shutdown of Project for >1 week

Medium - Material increase in climate variable with potential shutdown of Project for <1 week

Low – Non-material increase in climate variable with no impact on Project operations

12.4.3 Vulnerability Assessment and Mitigation

As noted earlier, vulnerability entails an understanding of safeguards accounted for in the design of Project permanent facilities, which could not be established due to the early stages of the Project, and limited engineering information available.

Actions in Table 12-10 will be completed prior to completion of detailed design to ensure adequate contingencies and tolerances are built into the design for resilience of the Project facilities to physical climate hazards.

Upon completion of the detailed design, this CRVA will be revisited to finalise the vulnerability assessment and determine physical climate risk levels.

Table 12-10: Actions Prior to Completion of Detailed Design

Climate Hazard	Action Prior to Completion of Detailed Design
All hazards	• A review of physical climate hazards and exposure levels identified within this CRVA shall be undertaken to demonstrate that the risks are addressed through the inclusion of appropriate design safeguards and tolerances
All hazards	• Selection of one or more of the four Representative Concentration Pathway (RCP) climate scenarios and the associated future climate projections for inclusion within the overall Project Basis of Design
All hazards	• A natural hazards risk assessment will be completed for temporary and permanent facilities in relation to natural hazards (earthquakes, floods, landslides, extreme storm events, etc.). Risk assessment will consider risks to local communities and the Project workforce • Selection of site temporary and permanent facilities shall take into account the findings and mitigation measures of the natural hazards risk assessment
Extreme heat and increases in mean annual surface temperatures, solar radiation and humidity	• With a view to projected changes, confirm the suitability of the Desalination Plant design criteria to operate in the following outdoor ambient temperature conditions: ○ Maximum Ambient Temperature: 50 °C ○ Minimum Ambient Temperature: -2 °C Design considerations: • External components of permanent facilities to make allowances for the projected increases in ambient temperature • Power supply to account for increased demand during extreme heat events • Shading of structures and use of materials rated for higher ambient temperatures • Selection of pumps, inverters, and switchgear with extended temperature operating ranges • Combining a regular PV panel cleaning program with temperature sensors to reduce soiling and overheating • Use of PV modules with low temperature coefficient and rated for high-UV zones • Installation of irradiance, temperature and performance sensors to track actual gain vs degradation • Build operational/maintenance allowances for higher humidity-driven impacts (higher corrosion rates, increased cooling loads, possibly more challenging solar panel cleaning)

Climate Hazard	Action Prior to Completion of Detailed Design
Extreme precipitation and associated flood events, including coastal and fluvial flood risk	• Flood risk modelling shall take into account existing flood protection dams constructed by Aqaba Development Corporation (ADC) and whether diverted flood waters present a source of flood risk to the Project facilities • The extent and magnitude of a flood shall be determined by establishing catchment areas from mapping and verified by site reconnaissance • Peak flood flow shall be the highest value estimated using one or more of the following methods: o Historic record: The 1 in 100-year flood peak is to be estimated o Unit Hydrograph Convolution: An estimate of the 1 in one hundred (100) year flood peak is to be estimated from the convolution of a nested effective rainfall from the estimated one hundred (100) year return period storm with a synthetic triangular unit hydrograph proposed by the U.S. Soil Conservation Service and as described in the U.S. Bureau of Reclamation's Design of Small Dams. Estimates of the 1 in one hundred (100) year storm event may be extrapolated from the data contained in "Professional Paper No. 3, Rainfall Intensity-Duration-Frequency in Jordan" by Eng. Al Sa´ad, April 1986, MWI, Department of Water Resources Development – Surface Water Division. • A computational model shall be used to estimate channel flows, depths, and velocities for the wadis on-site (if applicable). The model will be used to identify wadi reaches requiring protection to maintain platform stability • The pipeline and permanent structures shall be protected against damage from the one hundred (100) year flood event by appropriate erosion and scour protection. • Erosion protection will be required where the flood flow velocities exceed 1 m/s in the following circumstances: o Pipeline crossing or running along a wadi channel o Pipeline crossing terrain prone to sheet flooding • At wadi and channel crossings, the protection shall consist of concrete encasement of the pipeline or any other method. Where the pipeline runs along a wadi channel, the protection system shall comprise riprap in accordance with US Army Corps of Engineers HEC-11 recommendations. • Pipelines shall be protected where they cross areas identified as being prone to sheet flooding. Protection systems shall be designed in accordance with actual site conditions. Still, standardised measures that may be considered in such locations are riprap, concrete encasement, or rock-filled mattresses laid over the pipeline. • The following criteria shall be used to design the site drainage system: o Rainfall intensity shall be defined per "Professional Paper No. 3, Rainfall Intensity-Duration-Frequency in Jordan" by Eng. Ali Sa´ad, April 1986, MWI, Department of Water Resources Development – Surface Water Division: o 1 in 25-year storm for roads and hardstanding areas o 1 in 50-year storm for gutters and downpipes o 1 in 100-year storm for erosion protection of Project structures
Geotechnical hazards including landslides or mudslides, and soil erosion	• Completion of geotechnical survey and geotechnical hazard mapping along the Conveyance Pipeline route, identifying landslide susceptibility zones • An erosion risk assessment will be conducted assuming that soil erosion in key exposed areas will increase relative to present conditions by 2050 due to more intense rainfall events, reduced vegetation cover and increased aridity. A 10-30%

Climate Hazard	Action Prior to Completion of Detailed Design
	increase in erosion by 2050 will be considered if land-use remains unchanged and climate drivers worsen • Erosion and scour protection shall be provided in the form of riprap, soil nail, prefabricated drainage mat, shotcrete facing, and mattresses for wadi areas and areas susceptible to erosion • Erosion and sedimentation control barriers shall be installed and maintained during the Project lifecycle to reduce erosion on slopes due to rainfall and superficial runoff Design considerations: • Design of pipelines, AGI foundations, drainage systems, and access roads to include margins for increased sedimentation, scour, bank collapse/slide risk due to higher erosion rates • Installation of geotechnical sensors to detect ground movement
Increases in extreme wind events and dust storm intensity and frequency	• The facilities shall be designed to sustain an hourly mean value wind velocity of one hundred twenty (120) km/hour Design considerations: • Reinforcement of roof and cladding fixings • Definition of wind-speed shutdown thresholds for RE Facility • Utilise wind-rated racking systems and secure fasteners for the PV panels. • Enabling automatic stow mode (horizontal or feathered position) during high winds • OHTL design to consider shorter spans and cross-arm strength, brace connections and heavier foundations in the windiest sections of the roof • RE Facility design to consider modular tilt optimisation to promote natural dust shedding
Decrease in mean annual precipitation / droughts	Design considerations: • Membranes and pumps to be designed with operational flexibility • Use high-pressure RO membranes tolerant of higher osmotic loads • Implementation of real-time monitoring of chlorophyll, temperature and turbidity • Desalination Plant design to account for seasonal intake flushing and backwash capacity • Intake screening system designed for debris and organics • Adaptive dosing systems to be provided using real-time conductivity and silt density index (SDI) • Selection of antiscalants optimised for high salinity
Changes in seawater characteristics (temperature, pH and salinity)	Design considerations: • Design allowance for a 1–2°C feedwater temperature increase when sizing membranes, energy loads, and cooling systems • Design of the outfall assuming worst-case ambient salinity, assuming a modest increase (by 0.5-2 % by 2050). • When considering a no-change scenario (i.e., salinity remains at current levels), incorporate a margin into the design (such as membrane tolerance and pretreatment capacity) to ensure that small increases are manageable. Because salinity influences osmotic pressure and energy consumption, consider designing

Climate Hazard	Action Prior to Completion of Detailed Design
	for the upper bound of possible salinity increases (e.g., ~46.6 ‰ to ~48–50 ‰) to ensure resilience. • Establishment of a baseline salinity time series at intake depths and monitoring trends (annual and seasonal) to detect upward drift and trigger mitigation if salinity rises faster than assumed • Conduct a stress-case assumption for design: how would the system perform if pH shifts downward moderately (leading to increased corrosivity, changed scaling/chemical behaviours)
Relative sea level change and coastal erosion	Design considerations: • Intake/outfall pipelines to be designed with allowances for shoreline retreat + loss of protective beaches/reef • The observed ~0.62 m/year erosion rate will be used as a *maximum* edge case for vulnerable shoreline segments (sandy beaches, where sediment supply is low and wave/climate forces are increasing) • For more conservative central cases, 0.3-0.5 m/year shoreline retreat will be assumed, recognising local rock/reef shoreline may retreat more slowly • Over a 30-year design lifespan, ~15 m of landward intrusion (at 0.5 m/year) will be assumed, and ~9 m landward intrusion (at 0.3 m/year) will be assumed • Sea-level rise and storm surge/wave setup factors will be added to the shoreline erosion risk estimates

12.5 Transition Climate Hazards

Long-term infrastructure investment, such as the Project, may face transition risks, i.e. risks arising from shifts toward a low-carbon, sustainable economy.

12.5.1 Screening of Hazards

The following literature sources were used to establish the list of commonly assessed climate transition-related hazards:

- Recommendations of Taskforce on Climate Related Financial Disclosures (TCFD) 2017
- Special Report by Intergovernmental Panel on Climate Change (IPCC) on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, 2012
- IPPC 6th Assessment Report on Climate Change: Impacts, Adaptation and Vulnerability, 2022
- United Nations Environment Programme (UNEP) Climate Risk Landscape Report, 2023
- Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR) Arab Climate Change Assessment Report 2017
- Weathering Risk 2022 Climate Risk Profile Jordan
- World Bank Group Country Climate and Development Report: Jordan, 2022

Table 12-11 presents the results of the climate hazards that were screened for applicability to the Project and selected for evaluation of the climate risk.

Table 12-11: Screening of Transition Climate Hazards

Climate Hazard	Screening Result	Justification	Relevant Project Facility
Policy and Regulation			
Climate Policy Commitments	Screened in	70% dependence of the Project's power supply on the national grid	Entire Project
International Climate Policy Drivers	Screened in	70% dependence of the Project's power supply on the national grid	Entire Project
Market and Finance			
Energy Prices, Subsidies and Carbon Cost	Screened in	70% dependence of the Project's power supply on the national grid	Entire Project
Technology and Supply Chain			
Renewable Energy Technology and Grid Integration	Screened in	Technological advances, regulated renewable energy targets and carbon neutrality pressure	RE Facility

12.5.2 Exposure Assessment

Exposure assessment of the Project is summarised in Table 12-12. It is based on potential scenarios for changes in climate policies and priorities, with exposure levels assigned as per the criteria in Section 12.2.2.2.

Table 12-12: Exposure Assessment for Transition Risks

Climate Hazard	Exposure Level[1]	Projection
Climate Policy Commitments	Medium	In the near term, the Project is seen as both a climate adaptation (water security) and a mitigation measure (via its RE component). However, the Project may have to adapt to increasingly stringent GHG limits as climate commitments evolve over its lifespan.
International Climate Policy Drivers	Medium	Potential introduction of domestic carbon pricing or stricter emission controls in the 2030s to maintain trade competitiveness due to CBAM affecting Jordan’s cement and fertiliser industries.
Energy Prices, Subsidies and Carbon Cost	Medium	Renewable energy equipment prices are projected to remain volatile in the near term. The phase-out of energy subsidies is ongoing, and higher grid electricity prices can be imposed due to global fossil fuel price spikes.
Renewable Energy Technology and Grid Integration	Medium	Performance of RE technology is projected to remain high in the near term. In the long term, technological evolution in energy could render the initial setup suboptimal, necessitating retrofits to keep pace with best practices or future regulatory pressure toward carbon neutrality.

[1] Exposure Levels:

High - Legislated/lender requirement with impact on the Project in the short term

Medium - Legislated/lender requirement with impact on the Project in the long term

Climate Hazard	Exposure Level[1]	Projection
Low – Non-legislated / non-lender / aspiration requirement with potential impact on the Project		

12.5.3 Vulnerability Assessment and Mitigation

Vulnerability assessment for transition climate risks is summarised in Table 12-13. It is based on contractual and management processes, with vulnerability levels assigned as per the criteria in Section 12.2.2.2.

Table 12-13: Vulnerability Assessment for Transition Risks

Category of Transition Risk	Vulnerability Level[1]	Safeguards / Management System Processes
Policy and Regulation	Medium (until implementation of mitigation) Low (after implementation of mitigation)	• The Project will establish a regulatory watch and compliance team to monitor evolving climate and water policies, ensuring the Project adapts promptly to new rules on emissions standards, water/brine discharge limits, etc. • Proactive engagement with regulators and ministries will be carried out as part of the Project Stakeholder Engagement Plan to align the Project with national strategies and timely permitting, preventing policy surprises through continuous dialogue • Ongoing government–PPP governance committees will be set up to review regulatory changes annually and implement necessary design or operational adjustments
Market and Financial Risks	Medium (until implementation of mitigation) Low (after implementation of mitigation)	• The concept of energy efficiency for optimum energy monitoring and power control has been taken into consideration in the Desalination Plant Design, including: ○ Use of premium high-efficiency motors/pumps, variable frequency drives (VFDs), where possible. ○ Use of a high-efficiency isobaric energy recovery system to recover energy from the high-pressure brine leaving the RO membrane units to reduce the power consumption of the RO system significantly. ○ All process elements will be designed so that the elements in service operate within their optimum efficiency ranges at the desalination-plant-rated capacity
Technology and Supply Chain Risks	Medium (until implementation of mitigation) Low (after implementation of mitigation)	• The Project will establish long-term O&M contracts and warranties with key suppliers (e.g. membrane and pump suppliers) for performance and longevity and require best-practice maintenance regimes (frequent membrane cleaning, panel cleaning, etc). • A proactive asset management strategy will be adopted for the Desalination Plant and RE Facility, including the use of proven technologies (state-of-the-art RO membranes, pumps, and PV panels with manufacturer guarantees) to avoid early obsolescence.

Category of Transition Risk	Vulnerability Level[1]	Safeguards / Management System Processes
		• Supply chain dependence will be mitigated by diversifying suppliers and stockpiling critical spares: maintaining an inventory of spare RO membranes, high-pressure pump parts, and critical electronics, given these components must often be imported. • The Project will aim to build a local maintenance workforce through investing in training Jordanian technicians and engineers in Desalination and solar PV upkeep to reduce reliance on overseas experts and ensure a quick response to issues
[1] Vulnerability Levels: High - No safeguards under design, agreements or management system identified Medium - Safeguards under design, agreements/management system being actively explored Low – Safeguards under design, agreements/management system already implemented		

12.5.4 Risk Levels

Exposure to the transition risks is rated as medium: in the near term (up to 2030) the Project is seen as both a climate adaptation (water security) and a mitigation measure (via its RE component), with potential changes to climate policy taking place in the long-term (after 2030).

Vulnerability level is rated as medium since safeguards under design, agreement and management system are being actively explored.

Given the medium exposure and medium vulnerability for climate-related transition hazards, there current risk levels are considered medium. Once these safeguards under design, agreements and management system (Table 12-13) are implemented and vulnerability levels are reduced, the risk levels are expected to reduce to low.

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