Global Water Security Center

28 Oct 2024
www.ua-gwsc.org
gwsc@ua.edu
(205) 348-5888
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Jordan Water Crisis

Groundwater Depletion, Desalination Limits, and Population-Driven Scarcity

Water Scarcity Hits Households Even as Jordan Over-Exploits Groundwater (see page 2)

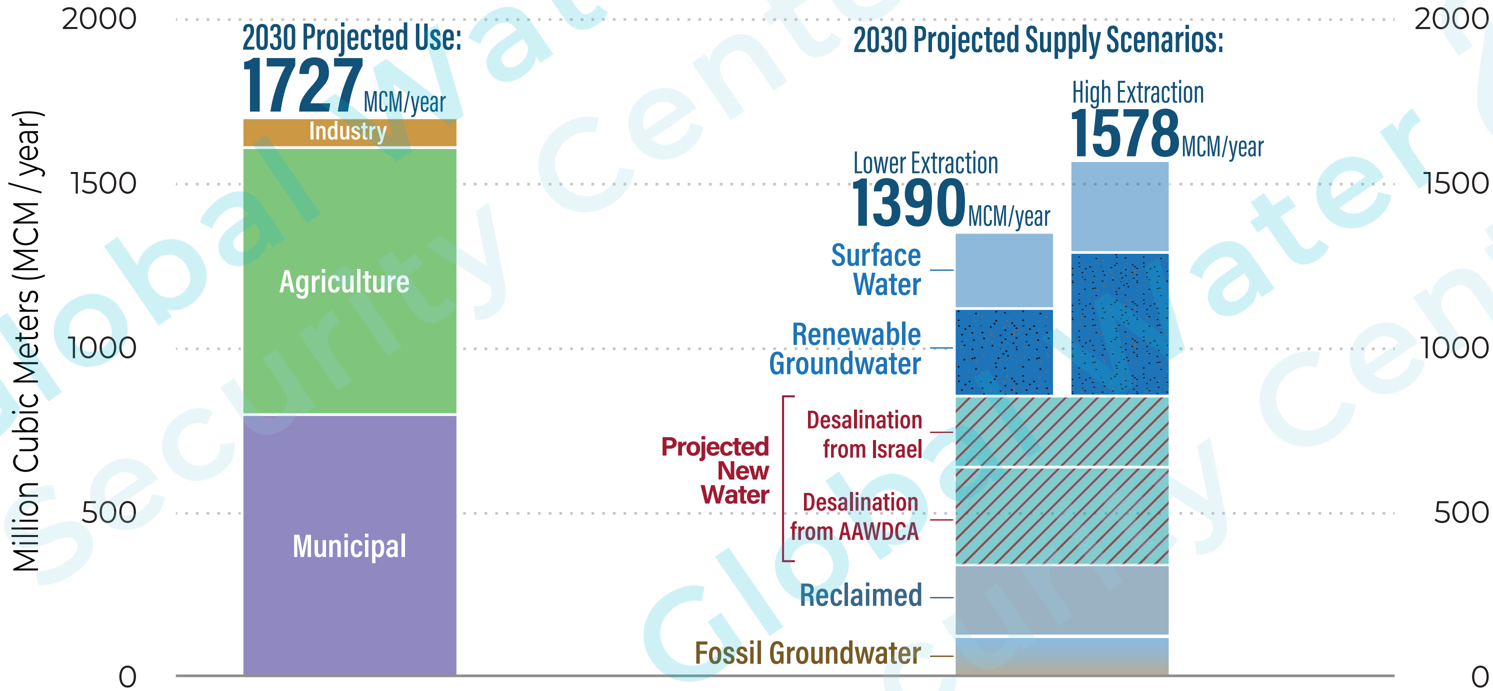
Jordan is depleting its groundwater reserves, yet the country currently does not have enough water, causing households to struggle.

Desalinated Water Will Shrink Jordan's Water Deficit; It's Still Not Enough (see page 3)

Desalination projects that increase Jordan's water budget by nearly 50% [500 million cubic meters (MCM)] are supposed to bridge the supply-demand gap from 2030-2035, but demand will still outpace supply.

Population Growth Fuels Water Scarcity, While Changing Climate Escalates Management Challenges (2035) (see page 4)

Rising population drives water scarcity in the region, but projected increases in annual rainfall variability and rising temperatures could exacerbate water management challenges.



Even with high extraction, supply is insufficient to meet demand.

Water Scarcity Hits Households Even as Jordan Over-Exploits Groundwater

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BLUF Jordan is depleting its groundwater reserves, yet the country currently does not have enough water, causing households to struggle.

BACKGROUND: Jordan, a strategic US ally in the Middle East, hosts the second most refugees per capita in the world[1]. In the context of high youth unemployment[2] and a diverse population, bad actors could leverage the unstable water situation to provoke civil unrest or lead Jordan to stop accepting refugees.

Current Water Use[3]

Agriculture uses half of Jordan's freshwater [49%, 531 million cubic meters (MCM/year)], but is mostly water efficient with 31% derived from reclaimed wastewater[5] and 80% of crops on drip irrigation[4].

- Jordan imports 70-90% of food[6,7]; the agricultural sector is only 4% of GDP.

Municipal water uses 48% of freshwater (519 MCM/year), but this volume limits household water supply to just 24-48 hours per week[8].

- In summer 2022, Amman households went up to three weeks without water[9]. People rely on tanker trucks, often of illicitly sourced well water, to bridge the gap between government-allocated water supply and minimal household water needs[10].

Industry uses 3% (35 MCM) of freshwater and provides the highest economic return per unit water, mostly for mining potash and phosphate.

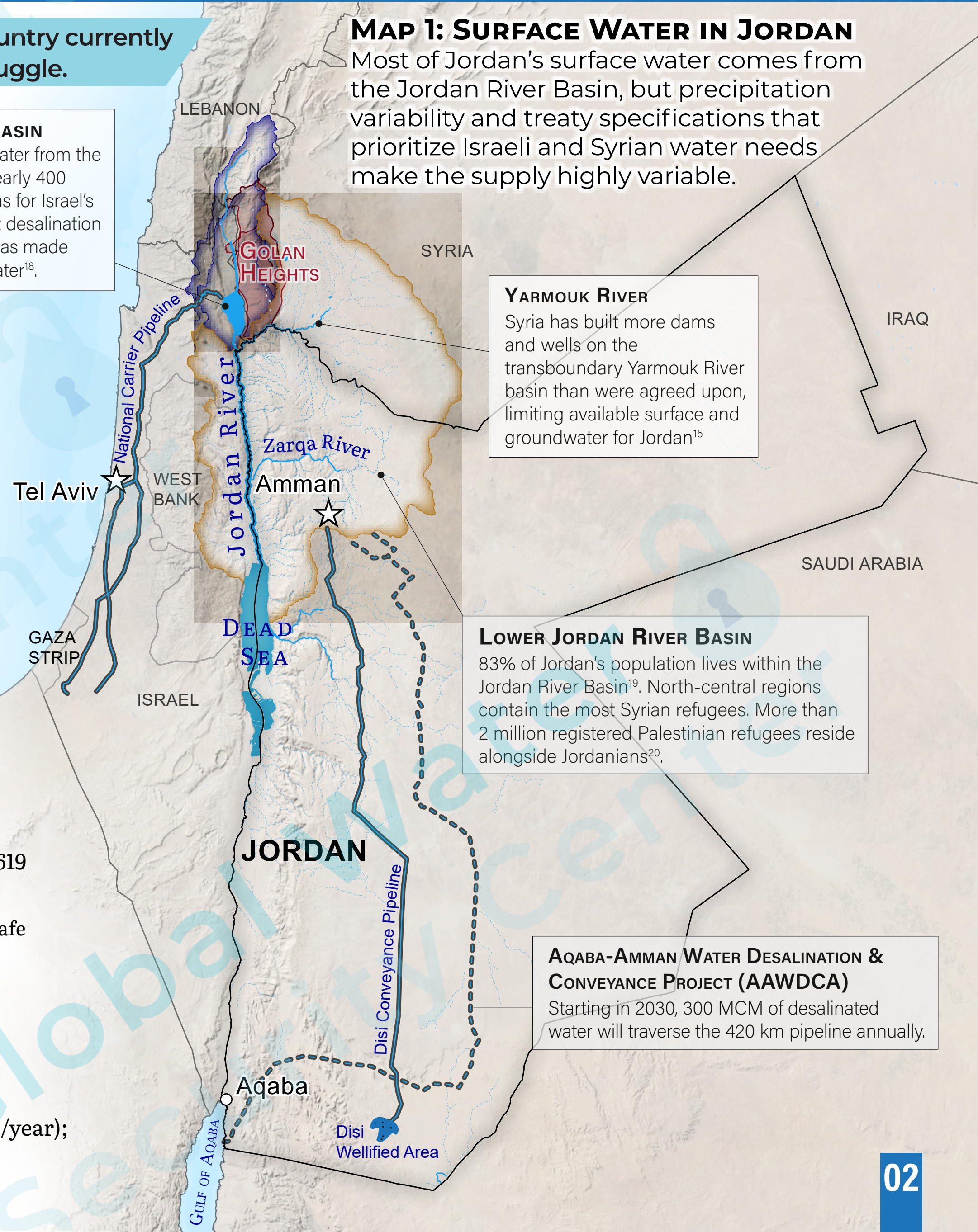
Current Water Supplies[3]

Surface water resources (Map 1) are ~28% (307 MCM/year) of freshwater supply annually but is a highly variable resource. It will continue to be limited as evaporation rates increase with rising temperatures.

As of 2021, renewable and fossil groundwater were the main source of freshwater (57%, 619 MCM/year) in Jordan.

- **Renewable groundwater is currently over-extracted by 60%**, or 170-MCM/year beyond the safe yield limits (annual recharge); in addition, illegal wells account for 100 MCM/year additional groundwater extraction, raising groundwater use to nearly 100% above recharge capacity[5].
- **The Disi Aquifer provides the bulk of fossil groundwater, 100 MCM annually** since the Disi conveyance system went online in 2013. As a fossil resource, the Disi does not recharge and may not be a reliable source for more than 20-50 years (2033 to 2064) depending on Jordanian and Saudi Arabian abstraction rates[11–13].

Jordan already treats 90% of collected wastewater, yielding 15% of freshwater (167 MCM/year); some literature suggests the water yield could be increased by 20%[14].



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Desalinated Water Will Shrink Jordan's Water Deficit; It's Still Not Enough

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BLUF Desalination projects that increase Jordan's water budget by nearly 50% (500 MCM) are supposed to bridge the supply-demand gap from 2030-2035, but demand will still outpace supply.

2030 Projected Water Use vs. Supply:

- Projected water demands for 2030 increase current use quantities by nearly 60% to account for population increases and economic growth.
- Estimated water supply, including desalinated water originating from two separate projects, could leave 9-20% (149-337 MCM/year) of water demand unmet, depending on the extraction rate of non-renewable groundwater and how much demand grows.

The Projected High-Extraction Supply is Unsustainable (Figure 1, far right):

- Continually extracting more groundwater than is renewable (from precipitation) will deplete aquifers, destabilize water supply, and make Jordan extremely vulnerable to dry years. Other risks include heightened vulnerability to sink holes and reduced groundwater storage capacity.
- Energy use to pump water will increase with dropping groundwater levels. Groundwater overextraction is already increasing the substantial amounts of energy required to withdraw water as groundwater levels are declining as much as 10 m/yr in some areas.

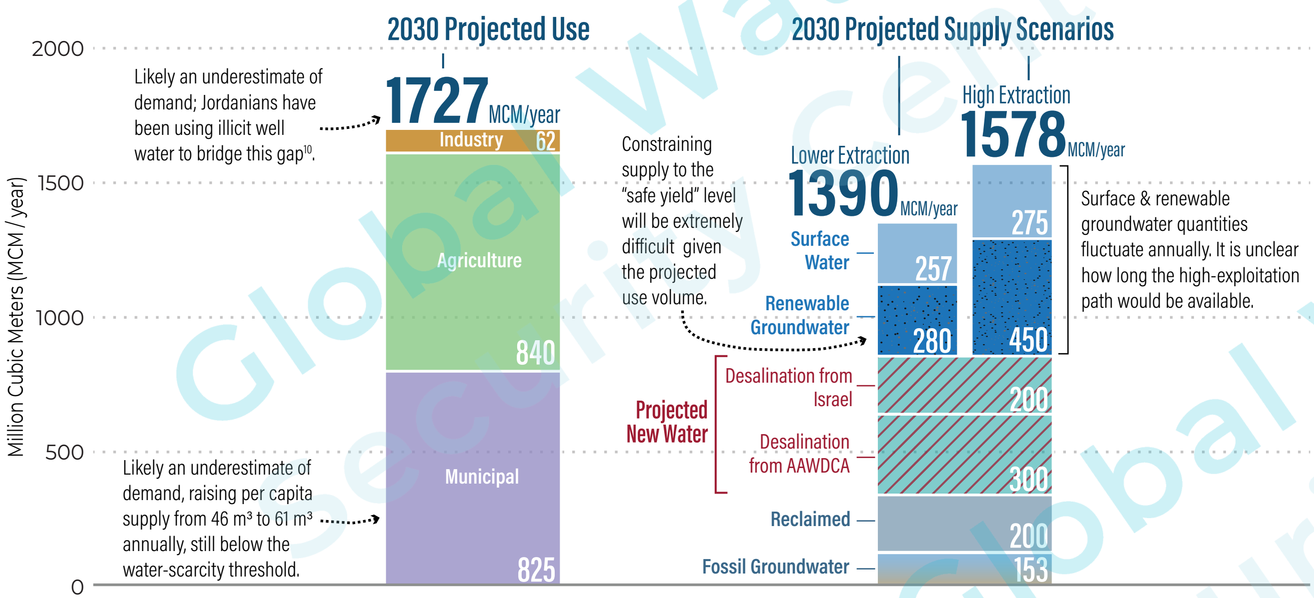

Figure 1: Even with high extraction, supply is insufficient to meet demand.
By 2030, a supply-demand gap of 9% (149 MCM) would remain. Constricting water supply to the safe yield of renewable aquifers (see the less-extractive scenario) leaves a potential supply-demand gap of 20% (337 MCM). These numbers were derived from Jordan's National Water Strategy (2023-2040). For additional details see pages 7-8 in the supplemental materials.

Possible Levers to Balance Water Supply & Demand

The water supply and demand gap will continue to grow with Jordan's rapidly increasing population, likely elevating tensions in this fragile region. While levers exist to potentially bridge the water gap, they each come with unique challenges:

Lever	Challenge
Reduce agriculture to what can be supported with available reclaimed water.	This sector is the main source of income for refugee populations.
Renegotiate transboundary water agreements.	Heightened geopolitical tensions make renegotiations increasingly difficult.
Expand desalination operations.	This path is especially expensive and energy intensive in Jordan, where most of the population lives far from the coast and relies almost exclusively on imported energy.

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Population Growth Fuels Water Scarcity, While Climate Change Escalates Management Challenges (2035)

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BLUF Rising population drives water scarcity in the region, but projected increases in annual rainfall variability and rising temperatures could exacerbate water management challenges.

BACKGROUND: The population in Jordan has nearly quadrupled since 1990 and is expected to grow from 11.3 million in 2021 to 16.8 million by 2040. This will add to water scarcity more acutely than changes in climate.

High interannual variability of precipitation in the Jordan River basin currently causes water management challenges and is projected to increase (Figure 2)

The Jordan River basin is Jordan's main surface water source. An increase in interannual variability of precipitation across the entire Jordan River basin is likely by 2035 (SSP245). More variability is projected in the upper basin (right side of Figure 2) where much of the river flow originates (Map 2), which could further stress water management in Jordan.

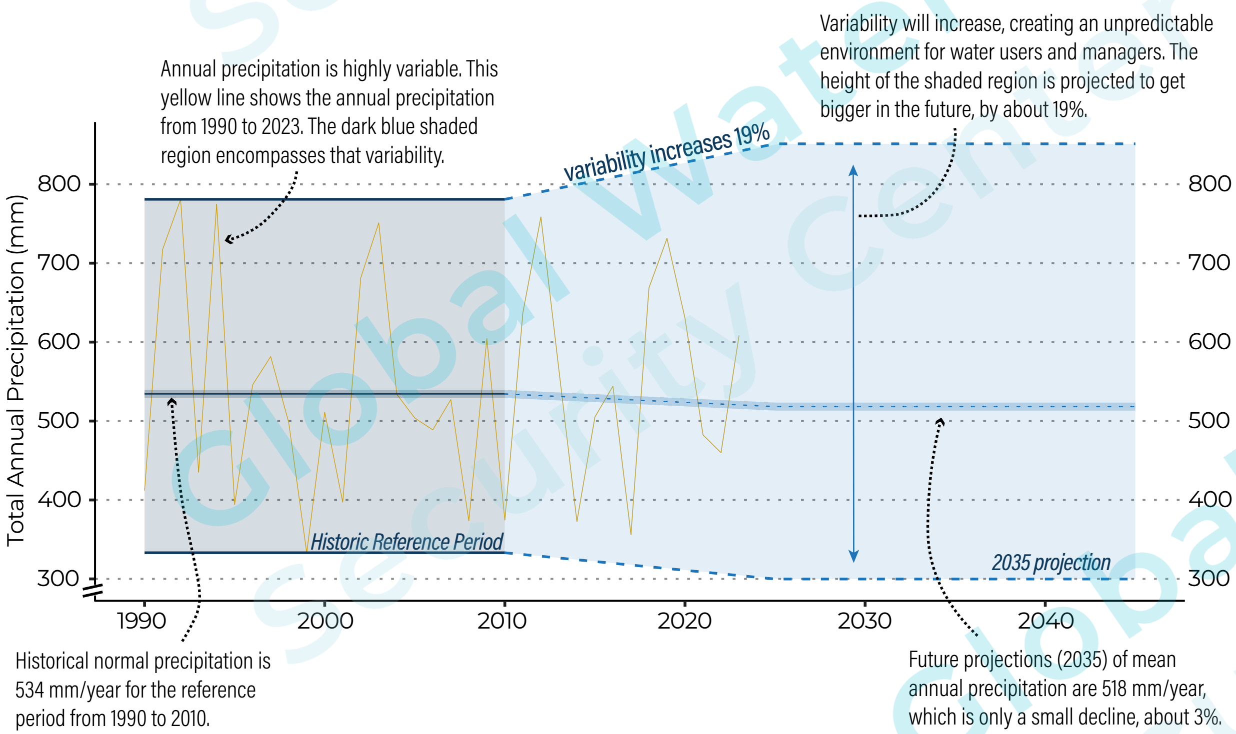
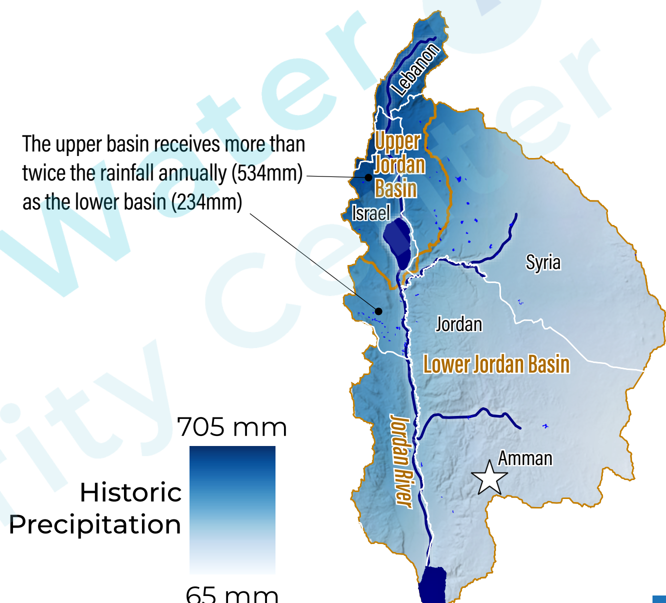


Figure 2: Annual precipitation in the Upper Jordan River basin is highly variable and is only going to get more variable.

Rising temperatures will increase evaporation of surface water, already short in supply.

Temperatures across Jordan are projected to increase on average 1.3-1.6°C by 2035 (SSP245), increasing evaporation rates over surface water and adding to an already challenging surface water problem. See page 9 in the supplemental for potential quantitative evaporation impacts on the system.

Map 2: Jordan River Watershed
The Jordan River's upper basin receives more than twice as much rain as the lower basin as shown in this map of mean annual precipitation for the historic reference period, 1990-2010. There is not a statistically significant trend (up or down) in total annual precipitation from 1990 to present.



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Map Sources:

General Basemaps:

Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap, and the GIS user community. "World Hillshade". February 10, 2022. https://services.arcgisonline.com/arcgis/rest/services/Elevation/World_Hillshade/MapServer. (May, 15, 2023).

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Supplemental Materials

Jordan's National Water Strategy 2023-2040 (NWS) was used to compile Figure 1, Jordan's projected water use vs supply infographic.

2030 Projected Water Use

Sector	Quantity (MCM)/yr	Source
Agriculture	840	p. 25 of NWS Summary
Municipal	825	
Industry	62	
Total Use*	1727	

*Illicit well use is not included in the table but is estimated to be 100 MCM/yr [p. 41 (NWS)]. This illicit water serves unmet municipal and agricultural demand.

2030 Projected Supply

Less-Extractive Scenario

Water Source	Quantity (MCM)/yr	Note	Source(s)
Surface Water	257	This figure includes: 117 MCM surface water supply for municipal in 2030 + 157 MCM for Ag. (2021 figure) + 4 MCM for Industry (2021 figure) minus 21 MCM projected water loss from evaporation (see methods section for details); 2021 supply quantities are used for Agriculture and Industry because 2030 quantities are not available. By 2040, the NWS projects more Agriculture and Industry water supply will be derived from an increase in reclaimed wastewater.	p. 30 NWS, p. 24 NWS, p. 31 NWS
Renewable Groundwater	280	The NWS states this is the annual "safe yield" level of Jordan's renewable aquifers.	p. 22 NWS
Desalination from Israel	200	*Prosperity Blue Line* desalinated water projected to be online in 2030.	p. 30 NWS
Desalination from AAWDCA	300	National conveyance project projected to be online in 2028.	p. 30 NWS
Reclaimed Wastewater	200	This figure includes 167 MCM (2021 value) + 20% increase to account for more wastewater processed and technology improvements (33 MCM).	p. 24 NWS, Qteishat, et al., 2024
Fossil Groundwater	153	The projected supply from non-renewable groundwater, including 100 MCM from Disi Aquifer.	p. 33 NWS
Total Supply	1390		
Difference from Projected Use	337	This supply figure is 20% less than projected use.	

Supplemental Materials

High-Extractive Scenario

Water Source	**Quantity (MCM)/yr**	**Note**	**Source(s)**
Surface Water	275	This figure represents an average of surface supply utilized from 2008-2021 (296 MCM), minus 21 MCM projected water loss from evaporation (see methods section for details).	p. 44 NWS
Renewable Groundwater	450	This figure is the same as 2021 renewable groundwater withdrawals and is 60% (170 MCM) more than the safe yield level. It is unclear how long this extraction rate would be viable.	p. 41 NWS
Desalination from Israel	200	*Prosperity Blue Line* desalinated water projected to be online in 2030.	p. 30 NWS
Desalination from AAWDCA	300	National conveyance project projected to be online in 2028.	p. 30 NWS
Reclaimed Wastewater	200	This figure includes 167 MCM (2021 value) + 20% increase to account for more wastewater processed and technology improvements (33 MCM).	p. 24 NWS, Qteishat, et al., 2024
Fossil Groundwater	153	The projected supply from non-renewable groundwater, including 100 MCM from Disi Aquifer.	p. 33 NWS
Total Supply	1578		
Difference from Projected Use	149	This supply figure is 9% less than projected use.	

** Future water budgets in the NWS include other "new" speculative water resources in addition to the new desalinated water in freshwater supply figures. While general quantities are incorporated in charts of the NWS, specific amounts and sources are unclear. The Strategy aims to explore new groundwater resources, enhance aquifer recharge, and use fossil groundwater where feasible. However, since these new sources are not yet identified, they were not included in supply quantities above. Other new water could refer to water retained from reducing non-revenue losses, but this is not new water in the system. The stolen water is already serving people in the system and the leaking water has been attributed to aquifer recharge[21]; in turn, water "saved" is water not going into the aquifers, likely reducing the "safe yield" amount.

Supplemental Materials

Data and Methods

Data Sets:

- ERA5 Historical Weather Data [1950-2020] - daily values for precipitation, daily average temperature, daily maximum temperature, and daily mimimum temperature.
- NASA Earth Exchange Global Daily Downscaled Projection CMIP6. SSP 245 & 585 2025-2035 & 2040-2060. Historical 1990-2010. 17 models were used: ACCESS-ESM1-5, BCC-CSM2-MR, CanESM5, CMCC-ESM2, FGOALS-g3, GISS-E2-1-G, MIROC-ES2L, MPI-ESM1-2-HR, MRI-ESM2-0, NESM3, NorESM2-MM, CNRM-ESM2-1, EC-Earth3-Veg-LR, GFDL-ESM4, INM-CM5-0, IPSL-CM6A-LR, KIOST-ESM
- North American Multi-Model Ensemble. Monthly precipitation anomaly predictions for a 12-month period beginning in October 2024. 6 models were used: CanESM5, COLA-RSMAS-CCSM4, GEM5.2-NEMO, GFDL-SPEAR, NASA-GEOSS2S, NCEP-CFSv2.

Metric Calculation:

Each metric was calculated for the ERA5 historical range (1990-2010) to get an approximate '2000' value. They were also calculated for CMIP6 historical range ('2000') and the two future time periods ('2035' & '2050'). The CMIP6 future time periods were compared to the CMIP6 historical time period to calculate the projected difference or ratio. The differences were then added back to the ERA5 historical values, and the ratios were multiplied by the ERA5 historical values to get future projections.

We grouped our results based on the pixels within each country, Koppen Zones, and the two basins of the Jordan River Watershed.

Important note: Values reported in the report are median values based on the 17 model outputs. We report the range between SSP245 and SSP585 grouped over the watershed or Koppen Zone used within this report.

Precipitation

- Yearly Total Precipitation: The summed total precipitation in mm within a given year over a defined area (by pixel or aggregated to a larger region).
- Mean Annual Precipitation: The average of the yearly total precipitation over a specified time period over a defined area (by pixel or aggregated to a larger region).
- Mean Monthly Precipitation: The summed precipitation in mm within a given month over a defined area.
- Inter-annual Precipitation Variability: We visualized between year variability as the mean over the time period and the inter-annual range over that given time period. We also quantified the coefficient of variation within a given time period and compared future to historic to get a quantitative understanding of variability.
- Consecutive Dy Days: We calculated streaks of days that were dry as a way to quantify drought. Dry days were defined as days with less than 1mm of rain. We then counted the frequency of these events occurring for three days in a row. To find the frequency of 3+ dry days, we calculated frequency of each run length of 3 or more days. The run length was then divided by 3 and floored to get how many multiples of 3 were in that particular run length (e.g., 15 = 5). The multiple of 3 was multiplied by the frequency. Thus, all of the frequencies were normalized to 3-day lengths. To calculate the frequency within a country, we took the maximum frequency of any pixel within the country for a given year, then averaged over the timespan (including years with a frequency of 0) to get a yearly frequency.
- Monthly Precipitation Anomaly: Monthly Precipitation Anomaly rate (mm/day) was converted to a total precipitation anomaly (mm) by multiplying by the number of days in each month.

Temperature

- Mean Annual Temperature: The mean of the yearly average temperature over a given time range and spatial extent.
- Mean Monthly Temperature: The monthly average temperature was defined as the average daily temperature over the month averaged over the time period and spatial extent.
- Change in Potential Evapotranspiration (PET): The change in the amount of water lost to evaporation from a surface water body between the historical reference period and the 2035 future. The PET rate was calculated using the Thornthwaite method (Thornthwaite, 1948), inputs required are monthly mean temperature and latitude. The rate of PET was then multiplied by the area of surface water in the region of interest to get a volume of water lost. The area of lakes and reservoirs greater than 1 km² was obtained from The Global Surface Water dataset. To determine river surface area, the length of a river of interest in the hydroRIVERS dataset was multiplied by the width measured from aerial imagery in several locations. The historical PET was then subtracted

Statistical Analysis:

Historic trends (1990-2023) through time were examined for mean annual temperature and total annual precipitation. For each of these metrics, we used values averaged over the country by Koppen-Geiger Zones. Linear models were applied to these metrics over time with a significance threshold of $p<0.05$.

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