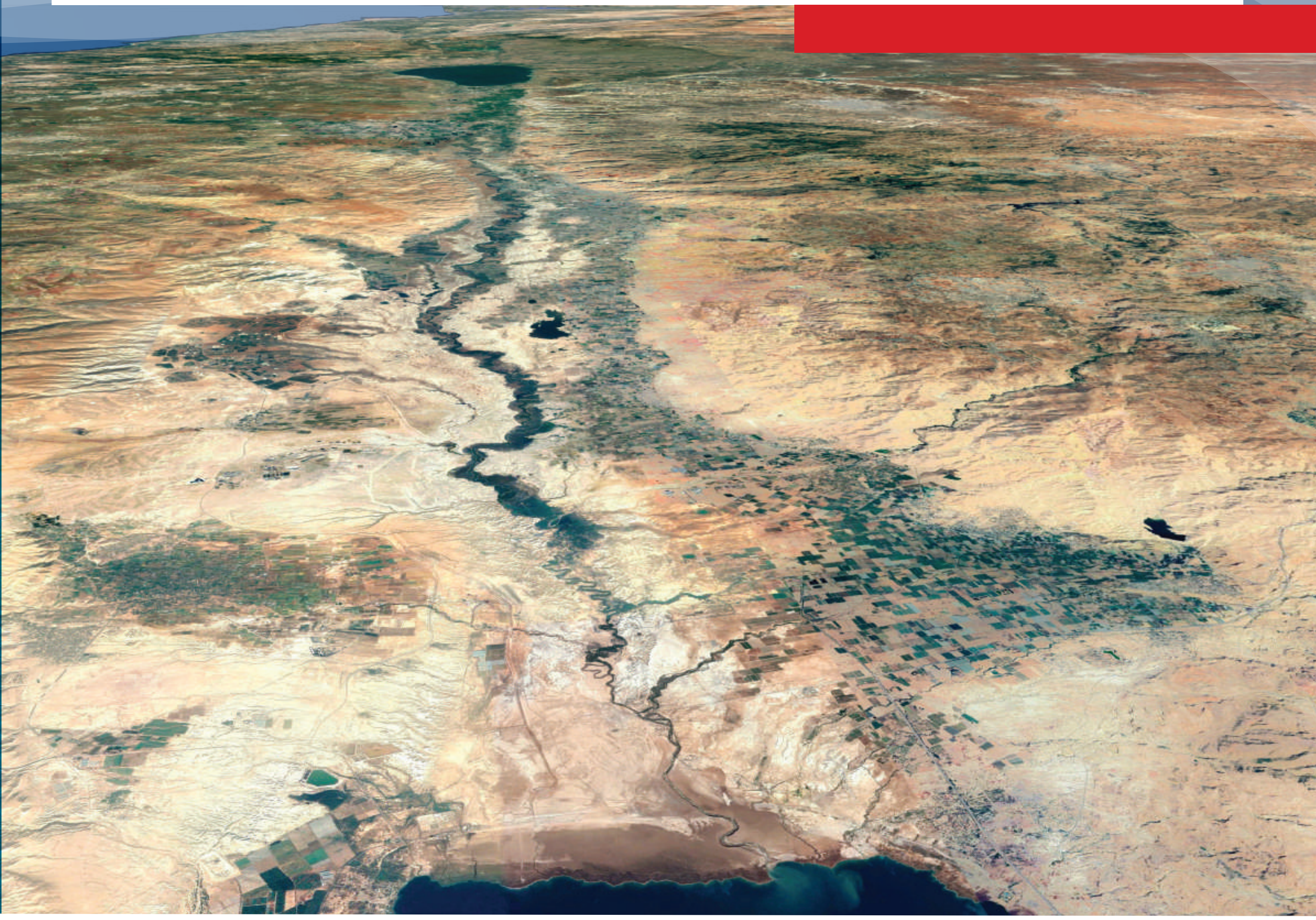
Rapid Assessment of the Consequences of Declining Resources Availability and Exploitability for the Existing Water Supply Infrastructure



Facilitated by
GIZ Management of Water Resources Project
Amman, June 2020

التعاون الألماني
DEUTSCHE ZUSAMMENARBEIT

Implemented by

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

In cooperation with

IMPRINT

PUBLISHED BY
The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH in Cooperation of the Ministry of Water and Irrigation (MWI).

CONTACT

GIZ WATER PORTFOLIO JORDAN
Management of Water Resources II Project
Mohamed Baseem Al-Khammash St.13, Sweifieh
Amman 11190, Jordan
T: +962-6-5868090
E: giz-jordanien@giz.de
I: www.giz.de

DIRECTOR OF GIZ WATER PORTFOLIO
Frauke Neumann-Silkow GIZ Jordan
frauke.neumann-silkow@giz.de

MINISTRY OF WATER AND IRRIGATION (MWI)
Strategic Planning Affairs
45 Salem Al Hendawi Street, Amman-Jordan
I: www.mwi.gov.jo

EDITORS
Dr. Armin Margane, GIZ Jordan
Eng. Mohammad Al Dwairi, MWI

MAIN AUTHORS (IN ALPHABATICAL ORDER)
Dr. Khalil Al Absi
Eng. Rami Aburwaq
Dr. Mona Dahabiyeh
Eng. Mohammed Ershaid
Eng. Mona Gharybeh
Eng. Hesham Al Hesa
Dr. Armin Margane
Mohammad Al Masri
Dr. Robert Mikovec
Eng. Mohammad Mufarih
Adel Al Obeiaat
Hala Shaheen
H.E Eng. Ahmad Uleimat

AUTHORS
The staff of MWI, WAJ and JVA contributed to this publication.

PHOTOS
Dr. Armin Margane, GIZ Jordan

DISCLAMER
This publication has been produced as a result of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH implemented project "Management of Water Resources" activities. On behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ).

The MWI has compiled all data and information required for and included in this publication.

LOCATION AND YEAR OF PUBLICATION
Jordan, June 2020






MANAGEMENT OF WATER RESOURCES PROJECT

Table of Contents

	Table of Contents	4
	Acknowledgement	12
	Abbreviations	12
	Definitions	14
1	**Executive Summary**	**16**
2	**Introduction**	**22**
3	**Water Resources**	**28**
3.1	Water Resources (Availability, Exploitability, Quality, Protection and Monitoring)	28
3.1.1	Rainfall	28
3.1.2	Water Harvesting Structures	43
3.1.3	Surface Water Resources	45
3.1.4	Groundwater Resources	56
3.1.5	Managed Aquifer Recharge (MAR)	90
3.1.6	Desalination	93
3.1.7	Treated Wastewater Reuse	103
3.1.8	Shared Water Resources	109
3.1.9	Water Imports	111
3.2	Factors Influencing Water Resources Availability and Use	113
3.2.1	Climate Change	113
3.2.2	Energy and Costs	118
3.2.3	Water Quality Impacts	120
4	**Water Demands, Uses and Allocation Gap**	**124**
4.1	Water Uses	124
4.1.1	Groundwater Use	128
4.1.2	Surface Water Use	130
4.1.3	Non-Conventional Water Resources	131
4.1.4	Municipal Water Use	131
4.1.5	Industrial Water Uses	136
4.1.6	Agricultural Water Uses	141
4.1.7	Nomadic (Livestock) Water Uses	142
4.2	Historical and Future Water Demands	142
4.2.1	Municipal Water Demand	143
4.2.2	Agricultural Demands	154
4.2.3	Industrial Demands	158
4.2.4	Nomadic (Livestock) Demands	158
4.3	Municipal Water Supply Requirements and Gaps	158
5	**Water Supply Infrastructure**	**198**
5.1	Governmental Water Infrastructure	198
5.1.1	Wellfields	198
5.1.2	Dams	203
5.1.3	King Abdullah Canal (KAC)	213
5.1.4	Current Water Supply of Main Demand Centers	213
5.1.5	Conveyance Network	249

5.1.6 Treatment and Desalination Plants 249
5.2 Infrastructure Affected by Depletion of Water Resources 250
5.3 Water Supply Infrastructure Gaps 255
5.4 Future Required Water Supply Infrastructure 270
5.4.1 Transfers to the North 270
5.4.2 Transfers to Amman and Zarqa 271
5.4.3 Transfers to Balqa Governorate 271
5.4.4 Transfers to the Southern Governorates (Aqaba, Maan, Tafilah, Karak) 271
6 Key Findings 272
7 Investment Planning 276
7.1. Review of Planned Projects 276
7.2 Project evaluation, ranking and prioritization system 282
7.3 Proposal for Modified Investment Planning 286
8 Recommendations 290
8.1 Recommendations for Water Resources Management 290
8.2 Recommendations for Wellfields 291
8.3 Recommendations for Springs 292
8.4 Recommendations for Surface Water Infrastructure 292
8.4.1 King Abdullah Canal 292
8.4.2 Dams 293
8.5 Recommendations for Water Supply Planning 293
8.6 Recommendations for Wastewater Treatment 293
8.7 Recommendations for Treated Wastewater Reuse 295
8.8 Recommendations for Update of the Capital Investment Plan and Project Planning 295
9 References by Topic 298
9.1 Water Sector general documents 298
9.2 Groundwater (Assessments, Investigations, Quality, Protection, Monitoring) 298
9.3 Surface Water (Assessments, Investigations, Quality, Protection, Monitoring), Agriculture 306
9.4 Water Supply (General, Feasibility Studies, Facility Management, Wellfield Management) 307
9.5 Wastewater (General, Guidelines, Feasibility Studies, Management) 307
9.6 Other Sectors 308
ANNEX 1: Forecasted production of wellfields 310
ANNEX 2: Factsheets for Wellfields – under preparation 311
ANNEX 3: Factsheets for Dams – under preparation 314
ANNEX 3.1 Example: Fact Sheet Mujib Dam 315
ANNEX 3.2 : Dams - General Facts 322
ANNEX 4: Facts on King Abdullah Canal 333
ANNEX 5: Water Systems 344
ANNEX 6: Water Quality Constraints 344
ANNEX 6.1: Groundwater Salinity 344
ANNEX 6.2: Areas with Elevated Heavy Metal Concentrations 347
ANNEX 7: Vulnerability of Water Supplies by Governorate 348
ANNEX 8: Procedure for Rehabilitation of Wells 360

All photos courtesy Dr. Armin Margane/GIZ

List of Figures

Figure 1: 9-year Moving Averages of Rainfall (MARGANE & ZUHDY, 1995) 30
Figure 2: Current Distribution of Weather Stations (adopted from HSSP, 2019) 31
Figure 3: Current Distribution of Rainfall Stations (adopted from HSSP, 2019) 32
Figure 4: Spatial Distribution of Telemetric Climatic Stations (98) operated by MWI 33
Figure 5: Rainfall Distribution Map for 20-years Average of Water Years 1973/74 – 1992/93 (Al ZUHDY & MARGANE, 1995) 34
Figure 6: Rainfall Distribution Map for 70-years Average of Water Years 1943/44 – 2012/13 (MWI, 2014) 35
Figure 7: Rainfall Distribution Map for 30-years Average of Water Years 1984/85 – 2013/14 (BGR, 2017) 36
Figure 8: Schematics of Ionization Technique applied in Jordan 37
Figure 9: Location of WeatherTec Emitter Stations 38
Figure 10: WeatherTec Emitter Station in Madaba 39
Figure 11: Surface Water Gauging Stations (adopted from HSSP, 2019) 47
Figure 12: Declining Provision of Water from the Yarmouk River (adopted from ZEITOUN et al., 2019) 49
Figure 13: Proposed and Existing Monitoring Network for Surface Water and Groundwater in the Lower Yarmouk catchment (MWI, 2018) 49
Figure 14: Water Exchange Mechanism for Yarmouk River and Quantities exchanged between Jordan and Israel (adopted from ZEITOUN et al., 2019) 50
Figure 15: Northern Jordan Valley Side Wadis 52
Figure 16: Southern Jordan Valley Side Wadis 52
Figure 17: Losses in the Northern Jordan Valley Distribution Network by Sections (Reaches) from North to South (left to right) 53
Figure 18: Water Balance 1995 (MARGANE et al., 2002) 58
Figure 19: Regional Distribution of Groundwater Recharge 60
Figure 20: Groundwater Contour Map of A7/B2 Aquifer for 1995 (detail; MARGANE & HOBLER, 2001) 61
Figure 21: Groundwater Contour Map of A7/B2 Aquifer for October 2013 (MARGANE et al., 2014) 62
Figure 22: Approach for Correction of Water Levels not Measured at the same Time a)for long-term trend and b) for seasonal variations to obtain values for a specific reference date 63
Figure 23: Detail of Groundwater Contour Map of A7/B2 Aquifer for 2017 (BGR, 2018) – Karak to Madaba area 64
Figure 24: Detail of Groundwater Level Differences Map for A7/B2 Aquifer 1995-2017 (BGR, 2018) 65
Figure 25: Groundwater Contour Map of A7/B2 Aquifer for Reference Date 31/10/2018 66
Figure 26: Minimum Requirements for Exploitability of an Aquifer (Exploitable Zone of Aquifer) 69
Figure 27: Shrinking Aquifer Exploitability at a Well due to Water Level Decline 70
Figure 28: Water Level Decline Rates 72
Figure 29: Tentative Groundwater Contour Map of A7/B2 Aquifer for 2040 73
Figure 30: Tentative Exploitable Zone of A7/B2 Aquifer in 2040 74
Figure 31: Tentative Distribution of Saturated Thicknesses of A7/B2 Aquifer in 2040 75
Figure 32: Tentative Distribution of Pumping Lift in A7/B2 Aquifer in 2040 76

Figure 33: Favorable Groundwater Exploitation Conditions in 2040 78
Figure 34: Areas where Heavy Metal Contents (Mo, Ni, V, U, As, etc.) are expected to rise 80
Figure 35: Current Groundwater Level Monitoring Stations in Jordan (HSSP, 2019) 83
Figure 36: Exploitation of the Disi Aquifer – Location of Wellfields 89
Figure 37: Existing MAR Facilities in Jordan (adopted from STEINEL, 2012) 92
Figure 38: Initial Planning of Aqaba Amman Water Desalination and Conveyance (AAWDC) Project 95
Figure 39: Groundwater Discharge from the Disi Aquifer into the Dead Sea (JICA, 1995) 97
Figure 40: Currently Proposal Schemes related to Reuse of Treated Wastewater in Northern Jordan Valley (WAJ, 2019) 104
Figure 41: Treated WW Reuse Distribution System in the Northern Jordan Valley (GITEC, 2004) 106
Figure 42: Expected Temperature (left) and Precipitation Changes based on First Regional Climate Change Model (KUNSTMANN et a., 2006) 114
Figure 43: Nitrate contents in the Duleil-Hallabat area (MARGANE et al., 2009) 123
Figure 44: Development of water Resources 2008-2018 (MWI Water Budget) 126
Figure 45: Water Use by Sector 2018 (MWI Water Budget) 127
Figure 46: Water Use by Resource type 2018 (MWI Water Budget) 127
Figure 47: Municipal water Use 2008-2018 (Source: MWI & WAJ 2018) 132
Figure 48: Domestic and Non-Domestic share of Municipal Water Use in 2018 133
Figure 49: Municipal Water Use and Average Per Capita share in 2018 135
Figure 50: Provision of Water for Industrial Use from Mujib River and other Dead Sea Side Wadis 140
Figure 51: Population Growth Scenarios (DOS 2015 Census) 146
Figure 52: Population Projection 2018-2040 148
Figure 53: Components of non-revenue water (INWENT, 2010) 151
Figure 54: Growth of Agricultural Production in Jordan and Lebanon (WORLD BANK, 2018) 155
Figure 55: Water Allocation Process as it theoretically should be 156
Figure 56: Water Demand and Supply Balance for Jordan Irbid Governorate 160
Figure 57: Irbid Localities and Population by Water Systems 161
Figure 58: Water Demand and Supply Balance for Irbid Governorate 163
Figure 59: Mafraq Localities, Population and Water Systems 164
Figure 60: Water Demand and Supply Balance for Mafraq Governorate 166
Figure 61: Ajloun Localities, Population and Water System 168
Figure 62: Water Demand and Supply Balance for Ajloun Governorate 170
Figure 63: Jarash Localities, Population and Water System 171
Figure 64: Water Demand and Supply Balance for Jarash Governorate 173
Figure 65: Amman Localities, Population and Water Systems 174
Figure 66: Water Demand and Supply Balance for Amman Governorate 176
Figure 67: Zarqa Localities, Population and Water Systems 178
Figure 68: Water Demand and Supply Balance for Zarqa Governorate 180
Figure 69: Balqa Localities, Population and Water Systems 181
Figure 70: Water Demand and Supply Balance for Balqa Governorate 183
Figure 71: Madaba Localities, Population and Water System 184
Figure 72: Water Demand and Supply Balance for Madaba Governorate 186
Figure 73: Karak Localities, Population and Water System 187
Figure 74: Water Demand and Supply Balance for Karak 189
Figure 75: Tafilah Localities, Population and Water Systems 190

Figure 76: Water Demand and Supply Balance for Tafilah Governorate 192
Figure 77: Maan Localities, Population and Water Systems 193
Figure 78: Water Demand and Supply Balance for Maan Governorate 195
Figure 79: Aqaba Localities, Population and Water Systems 196
Figure 80: Water Demand and Supply Balance for Aqaba 197
Figure 81: Wellfields for domestic water supply with exploited aquifer 200
Figure 82: Water Level, Inflow and Outflow of Mujib Dam in Daily Time Steps 2008-2019. incl. Minimum and Maximum used Operational Water Level 206
Figure 83: Water Level – Storage Curve of Mujib Dam based on Daily Data 2003-2019 206
Figure 84: Annual Inflow and Outflow of Mujib Dam 207
Figure 85: Average Monthly Inflow and Outflow of Mujib Dam 207
Figure 86: Main Storage Dams 210
Figure 87: Locations and Capacities of Desert Dams 211
Figure 88: Water Supply Systems of Irbid Governorate 216
Figure 89: Water Supply Systems of Mafraq Governorate 220
Figure 90: Water Supply Systems of Ajloun Governorate 222
Figure 91: Water Supply Systems of Jarash Governorate 225
Figure 92: Water Supply Systems of Amman Governorate 228
Figure 93: Water Supply Systems of Zarqa Governorate 232
Figure 94: Water Supply Systems of Balqa Governorate 235
Figure 95: Water Supply Systems of Madaba Governorate 237
Figure 96: Water Supply Systems of Karak Governorate 240
Figure 97: Water Supply Systems of Tafilah Governorate 242
Figure 98: Water Supply Systems of Maan Governorate 245
Figure 99: Water Supply Systems of Aqaba Governorate 248
Figure 100: Areas Saturated and Exploitable in 2040 in Northern Jordan (area around Irbid/Mafraq) 252
Figure 101: Areas Saturated and Exploitable in 2040 in Central Jordan (area around Qatrana) 253
Figure 102: Areas Saturated and Exploitable in 2040 in Southern Jordan (area around Maan) 254
Figure 103: Forecast of Development of Water Resources Availability, Supply Requirement and Supply Gap 2018-2040 (BAU and NRW Reduction Scenario) 260
Figure 104: Additional Needed Amounts in 2030 – BAU scenario 262
Figure 105: Additional Needed Amounts in 2040 – BAU scenario 263
Figure 106: Additional Needed Amounts in 2030 – NRW reduction scenario 264
Figure 107: Additional Needed Amounts in 2040 – NRW reduction scenario 265
Figure 108: Demand Centers proposed to be connected to the AAWDC Project – Additional needed Amounts in 2030 – BAU scenario 266
Figure 109: Demand Centers proposed to be connected to the AAWDC Project – Additional needed Amounts in 2040 267
Figure 110: Demand Centers proposed to be connected to the AAWDC Project – Additional needed Amounts in 2030 – NRW reduction scenario 268
Figure 111: Demand Centers proposed to be connected to the AAWDC Project – Additional needed Amounts in 2040 – NRW reduction scenario 269
Figure 112: Wehdah Dam – Inflow, Outflow, Water Level and Storage Curve 323
Figure 113: Wadi Al Arab Dam – Inflow, Outflow, Water Level and Storage Curve 324
Figure 114: Ziglab Dam – Inflow, Outflow, Water Level and Storage Curve 325

Figure 115: Kufrinjah Dam – Inflow, Outflow, Water Level and Storage Curve 326
Figure 116: King Talal Dam – Inflow, Outflow, Water Level and Storage Curve 327
Figure 117: Karameh Dam – Inflow, Outflow, Water Level and Storage Curve 328
Figure 118: Shuyab Dam – Inflow, Outflow, Water Level and Storage Curve 329
Figure 119: Kafrein Dam – Inflow, Outflow, Water Level and Storage Curve 330
Figure 120: Wala Dam – Inflow, Outflow, Water Level and Storage Curve 331
Figure 121: Tannour Dam – Inflow, Outflow, Water Level and Storage Curve 332
Figure 122: Schematics of Jordan Valley Irrigation Areas (adopted from TETRA TECH, 2018) 333
Figure 123: Development Areas (DA), Check Gates (CG) and Turnouts (TO) in Northern Section of KAC 336
Figure 124: Development Areas (DA), Check Gates (CG) and Turnouts (TO) in Central-Northern Section of KAC 337
Figure 125: Development Areas (DA), Check Gates (CG) and Turnouts (TO) in Central Section of KAC around Deir Allah 338
Figure 126: Development Areas (DA), Check Gates (CG) and Turnouts (TO) in Southern Section of KAC 339
Figure 127: Development Areas (DA) in South Ghor 340
Figure 128: Water Distribution System for Irrigation in Northern Jordan Valley (Northern Ghor) 341
Figure 129: Water Distribution System for Irrigation in the Central Jordan Valley (Middle Ghor) 342
Figure 130: Water Distribution System for Irrigation in the Southern Jordan Valley (South Ghor) 343
Figure 131: Extent of Brackish and Saline Groundwater Resources (modified after HOBLER et al., 2000) 345
Figure 132: Groundwater Potential Map of Northern and Central Jordan (HOBLER et al., 2000) 346
Figure 133: Molybdenum contents in Wadi Arab wellfield (average in 2017) 347

List of Tables

Table 1: Planned Volumes of the Third National Water Master Plan 24
Table 2: Work Groups for Preparation of the Third National Water Master Plan 25
Table 3: Structure of this Rapid Assessment document 26
Table 4: Jordan Valley Side Wadi Catchments and Potential Runoff 51
Table 5: Quantification of Losses in King Abdullah Canal (WMI, 2018) 53
Table 6: Assumed Groundwater Recharge (GWR) Percentages for Geological Units and overall GWR 58
Table 7: Groundwater Balance 1995 (MARGANE et al., 2002) 59
Table 8: Development of Groundwater Production from selected Public Abstraction Schemes 67
Table 9: Expected Groundwater Resources Exploitability by 2040 – only for large Wellfields in A7/B2 77
Table 10: Status of Monitoring Stations before and after HSSP Project (HSSP, 2019) 84
Table 11: Groundwater Protection Zones delineated by 2010 through BGR GWRM project 86
Table 12: Groundwater Vulnerability Maps prepared by North Jordan and GWRM Projects 87
Table 13: Wellfields Exploiting Disi Aquifer 88
Table 14: Existing MAR Facilities in Jordan (modified after STEINEL, 2012) 91
Table 15: Currently Existing Desalination Plants 99
Table 16: Wastewater Treatment Plants in North Jordan – Potential Reuse of Reclaimed Water 105
Table 17: Current Projects for Wastewater Treatment and Treated Wastewater Reuse in North Jordan 105
Table 18: Additional Water Imports from Israel 111
Table 19: Expected Precipitation and Temperature Changes based on the Second Regional Climate Change Model (UNFCCC, 2014) 116
Table 20: Consequences of Depletion of Groundwater Resources for Energy Consumption 119
Table 21: Water Use and allocation for different sectors (MWI Water Budget 2018) 126
Table 22: Groundwater Uses in 2018 129
Table 23: Groundwater Use 2008-2018 (MWI Water Budget) 130
Table 24: Surface Water Use 2008-2018 (MWI Water Budget) 131
Table 25: Municipal Water Supply for Jordan's Governorates Over 2008-2018 in MCM 132
Table 26: Domestic and Non-Domestic share for Municipal Water Use in 2018 133
Table 27: Municipal Water Use and Per Capita share in 2018 134
Table 28: Industrial Water Use by Resource Type 2008-2018 136
Table 29: Historic Industrial Water Uses [MCM] 138
Table 30: Remote-Sensing based Assessment of Groundwater Abstraction for Irrigation (WMI 2018, 2019) 141
Table 31: Estimation of Population Distributed in the Governorates 2018 (DOS Estimation 2018) 145
Table 32: Annual growth rates for all residents excluding Syrians 147
Table 33: Annual growth rates for Syrians 147
Table 34: Population Estimation and Projection by Governorates (DOS, 2018) 148
Table 35: Estimation and Projection of Syrians by Governorates (DOS) 149
Table 36: Domestic and Non-Domestic Share for 2018 (WMI 2020) 150
Table 37: Total Supply, Billed Water and NRW 2018 (WMI 2020) 152
Table 38: Historical NRW 153
Table 39: NRW reduction rate in the "Reduction in NRW" scenario 153
Table 40: Water Demand and Supply Balance for Jordan 159
Table 41: Population by Water Systems in Irbid 160

Table 42: Water Demand and Supply Balance For Irbid 162
Table 43: Population by Water Systems in Mafraq 163
Table 44: Water Demand and Supply Balance for Mafraq 166
Table 45: Population for Ajloun Water System 167
Table 46: Water Demand and Supply Balance for Ajloun 169
Table 47: Population By Water Systems in Jarash 170
Table 48: Water Demand and Supply Balance for Jarash 172
Table 49: Population by Water Systems in Amman Governorate 173
Table 50: Water Demand and Supply Balance for Amman Governorate 175
Table 51: Population by Water Systems in Zarqa Governorate 177
Table 52: Water Demand and Supply Balance for Zarqa Governorate 179
Table 53: Population by Water Systems in Balqa Governorate 180
Table 54: Water Demand and Supply Balance for Balqa Governorate 182
Table 55: Population by Water System in Madaba Governorate 183
Table 56: Water Demand and Supply Balance for Madaba Governorate 185
Table 57: Population by Water System in Karak Governorate 186
Table 58: Water Demand and Supply Balance for Karak Governorate 188
Table 59: Population by Water System in Tafilah Governorate 189
Table 60: Water Demand and Supply Balance for Tafilah Governorate 191
Table 61: Population by Water System in Maan Governorate 192
Table 62: Water Demand and Supply Balance for Maan Governorate 194
Table 63: Population by Water System in Aqaba Governorate 195
Table 64: Water Demand and Supply Balance for Aqaba 197
Table 65: Total Initial Storage Capacity and Outflow of Dams 205
Table 66: Forecast of Supply Requirement until 2040 by Governorate (part 1) – Current Supply and Development of Production 257
Table 67: Supply Requirement Forecast until 2040 by Governorate (part 2) – Business As Usual Scenario – without Transfers/with Transfers 258
Table 68: Supply Requirement Forecast until 2040 by Governorate (part 3) – NRW Reduction Scenario – without Transfers/with Transfers 259
Table 69: Forecast of Development of Water Resources Availability, Supply Requirement and Supply Gap 2018-2040 261
Table 70: Investments by Category planned in the Capital Investment Plan (MWI, 2016) 279
Table 71: Planned Dam Projects – Feasibility and Long-Term Sustainability 280
Table 72: General Information for Project Evaluation, Ranking and Prioritization System 283
Table 73: Ranking Matrix of Project Evaluation, Ranking and Prioritization System 284
Table 74: Rating Scheme of Project Evaluation, Ranking and Prioritization System 286
Table 75: List of Priority Investments (in order of declining priority) 286
Table 76: Production Forecast for Important Wellfields 310
Table 77: Wellfields - General Facts 312
Table 78: Dams - General Facts 322
Table 79: Inflows to Jordan Valley (adopted from WORLD BANK, 2016) 334
Table 80: Water Uses in the Jordan Valley (adopted from WORLD BANK, 2016) 335

Acknowledgement

This document was jointly prepared, with support of GIZ, by the water sector institutions of Jordan, MWI, WAJ and JVA. About 130 persons contributed to its preparation, as part of nine Work Groups. We thank H.E. the Minister of Water and Irrigation, Raed Abu Soud, and the SG of WAJ/MWI and JVA, H.E. Eng. Ali Subah for their support during preparation.

Abbreviations

AAWDC	Aqaba Amman Water Desalination and Conveyance project
As	Arsenic
AWC	Aqaba Water Company
BGR	Bundesanstalt für Geowissenschaft und Rohstoffe, Federal Institute for Geosciences and Natural Resources, Hannover/Germany
BOT	Build-operate-transfer
CCTV	Closed-circuit television
CIP	Capital Investment Plan
COP	Method for groundwater vulnerability map preparation, C-concentration of flow, O-overlying layers, P-precipitation
DIWACO	Disi Water Company
DWL	Dynamic water level
EC	Electric conductivity
EIA	Environmental impact assessment
ESCWA	Economic and Social Commission of Western Asia, Beirut/Lebanon
GIZ	Gesellschaft für Internationale Zusammenarbeit, Eschborn/Germany
GLA	Geologische Landesanstalten, German geological surveys of the states
GLOWA	Global Change and the Hydrological Cycle, research project funded by German ministry BMBF (2001-2013)
GW	Groundwater
GWR	Groundwater recharge
HSSP	Hydrometeorological System Support Project, implemented by KfW & MWI
I-GWRM	Integrated Groundwater Resources Management, project implemented by BGR and MWI
ISSP	Institutional Strengthening and Support Program, USAID funded project
JICA	Japan International Cooperation Agency, Tokyo/Japan
JMD	Jordan Meteorological Department
JSMO	Jordan Standards and Metrology Organization

KAC	King Abdullah Canal
KEMAPCO	Arab Fertilizers & Chemicals Industries Ltd., owned by Arab Potash company
KfW	Kreditanstalt für Wiederaufbau, KfW Development Bank, Frankfurt/Germany
MAR	Managed aquifer recharge
MCM	Million cubic meters
Mo	Molybdenum
MoA	Ministry of Agriculture
MoLA	Ministry of Local Administration (previously Municipal Affairs)
Ni	Nickel
NRA	Natural Resources Authority (of Jordan), now part of Ministry of Energy and Mineral Resources (MEMR)
NRW	Non-revenue water
NWIS	National Water Information System, database of MWI
NWMP	National Water Master Plan
RCM	Regional climate model
RCP	Representative Concentration Pathway, term used in climate change modelling
RICCAR	Regional Initiative for the Assessment of Climate Change Impacts on Water, Beirut/ Lebanon (ESCWA)
RWH	Rainwater harvesting
SCADA	Supervisory control and data acquisition
SMART	Sustainable Management of Available Water Resources with Innovative Technologies, research project funded by German ministry BMBF (2005-2019)
SW	Surface water
SWL	Static water level
TD	Total depth
TDS	Total dissolved solids
TO	Turnout (in King Abdullah Canal)
UFW	Unaccounted-for water
UNFCCC	United Nations Framework Convention on Climate Change, UN Climate Change Secretariat, Bonn/Germany
UNICEF	United Nations Children's Fund, New York/USA
UNDP	United Nations Development Program, New York/USA
USBR	United States Bureau of Reclamation, Denver/USA
USAID	United States Agency for International Development, Washington/USA

V	Vanadium
WL	Water level
WMI	Water Management Initiative, USAID funded project
WMIS	Water Management Information System, software used by JVA in the Deir Allah Control Center
WUA	Water User Association
WW	Wastewater
WWTP	Wastewater treatment plant
YWC	Yarmouk Water Company

Definitions

Allocation	Water allocation is the process of distributing water from different water sources to different points of use in a society. Decisions regarding the amount of water that is distributed to which user and for which purpose require an in-depth knowledge of the entity responsible for water allocation, the total amounts that will be available to be distributed, and what the quality at each point of the network will be.
Consumption	The volume withdrawn that is not returned to the water system (is evaporated, transpired, incorporated into products, plants, or animals) and is no longer available for use.
Conventional water resources	Surface and groundwater resources
Demand	Water demand describes the amount of water needed at the customer side. Demand must be predicted to schedule water allocations and to design the necessary transmission and distribution lines, pumping systems, and storage facilities. As many water operations are intermittent, pressure must not exceed critical limits at any point in the network and regular hydraulic network analyses are required to assess network pressure when demand or designs change. Expected average day, maximum day, and peak hour water demand must therefore be determined for any proposed developments. Demand varies over the year depending on climatic influences, socioeconomic influences, the condition of the distribution system, and the conservation practices in use. Domestic demand depends on social criteria such as income or ability to pay, and the number of persons per household connection. Economic status (income) and residential population densities are sometimes used as proxies for these values. Industrial water demand is very dependent on the specific quantity and quality of water needed for each process, and the degree of recycling techniques that are in use. Agricultural water demand depends on the crops being grown, the cropping pattern (how many seasons and which crops are grown where) and the irrigation techniques being used.
Domestic demand	Is the water consumed through household activities for indoor and outdoor purposes, including toilet flushing, bathing, laundry, dishwashing, cooking, drinking, and the less frequent outdoor use for gardening and car washing, etc.

Downward leakage	The vertical percolation of water through an aquitard
Municipal water	Is the water supplied through the water supply network owned and managed by public organization which is WAJ and the water utilities for Jordan.
conventional water resources	All water resources which are generated for direct use but are not part of conventional water resources (surface and groundwater), i.e. treated wastewater, desalinated water, harvested water.
Non-domestic demand	Is the water used for industrial, commercial uses (tourism, shops, private offices, schools, universities, hospitals, airports, etc.), public uses (governmental offices, schools, universities, and hospitals) and for irrigation of public spaces occasionally delivered from primary water supply systems.
Non-revenue water (NRW)	Non-revenue water reflects the difference between the amount of water supplied through the water distribution system and the amount billed to customers. NRW includes physical losses, and apparent losses such as illegal connections and meter inaccuracies. It also includes unbilled authorized consumption. In order to assess NRW, district metered areas (DMAs) with calibrated flow meters are required.
Supply requirement	The amount of water that has to be produced and transferred to the supply network to meet demand. The supply requirement is based on the average water demand for municipal water adding the physical losses.
Unaccounted-for water (UFW)	The term UFW is similar to NRW, but excludes authorized unbilled consumption. Unaccounted-for water is the difference between the volume of water delivered in a network and legitimate consumption, both metered and unmetered.
Use	Water that is withdrawn for a specific purpose, such as for public supply, domestic use, irrigation, thermoelectric-power cooling, or industrial processing
Water system	A water network structure, which has defined internal supply sources or a known quantity supplied from outside to a clearly defined demand center (often a city, a district or a governorate). Water distributed from (demand requirements), used from (billed consumption) and lost from (physical and administrative losses) a water system can be clearly determined. Water system boundaries and administrative boundaries may be significantly different. A water system can serve a demand center with several localities (villages) with different administrative boundaries within a governorate. A water system may not match with administrative boundaries and one locality may be contained in more than one water system.

1 EXECUTIVE SUMMARY

This document was elaborated within the framework of GIZ support, funded by BMZ, for the preparation of the Third National Water Master Plan (NWMP-3), which started in February 2019. The new Water Master Plan is entirely prepared by the water sector institutions themselves, will take about five years to be compiled and will describe the status of water resources, current supply and gaps for all sectors, and required actions over a 20-year planning horizon, from 2020 to 2040.

The objective of a Water Master Plan is to ensure future water supply security. The status of all water resources is first described in terms of long-term availability and exploitability, quality, and protection, along with existing infrastructure, allocation mechanisms for their use, and the actual and future demands from all sectors. Requirements for additional resources and infrastructure can then be obtained and proposals made for reallocating and optimizing water resources use. Future investments in a) water sector governance, b) provision of additional water resources, c) water supply infrastructure and d) wastewater infrastructure are then planned in as much detail as possible, using a set of standard parameters and methods for future projections. The projects being planned are ultimately ranked by strategic priority and social, economic and ecological criteria, based on an agreed standard ranking system.

Previous planning assumed a constant or even increased availability of renewable water resources, although it was known that groundwater resources are highly overexploited, while surface water resources are nearly fully exploited. As this future reduced availability poses a major constraint to development, an update of the Capital Investment Plan is urgently required.

In May 2019, it was decided to first prepare a Rapid Assessment of the situation. This would take one year, be based solely on existing data, and answer the most important questions, namely:

- → How will the availability, quality and exploitability of groundwater resources change between now and 2040?
- → Which water supply infrastructure will become invalid?
- → How does the depletion of water resources affect domestic water supply and water security?
- → Which domestic water supply investments are most urgently needed?

Due to the nature of the existing data, the proposed planning is preliminary. The reason is that many data of importance are not collected regularly, and are thus not available or are only very rough estimations with high uncertainties. Wherever possible, therefore the level of uncertainty is mentioned in this document. Important missing data are for instance:

- → the current long-term available surface water runoff;
- → the expected impact of Climate Change on groundwater recharge and the expected impact of Climate Change on groundwater recharge and on surface water runoff.

The project is currently working to improve the knowledge base for these topics. In parallel to the Third National Water Master Plan, the USAID-funded project Water Management Initiative (WMI) was tasked to carry out an Update of the Water Infrastructure Master Plan, based on the previous USAID ISSP project (Water and Wastewater Infrastructure Master Plans published in 2015). In order to avoid duplication of work or any major differences in the outcome, a comprehensive coordination and information exchange mechanism with the WMI project was introduced and the WMI project was invited by GIZ and MWI to all activities of the NWMP-3.

Summary of results

How will groundwater resources availability, quality and exploitability change until 2040 ?

Both, **surface and groundwater resources availability are impacted by climate change**. Based on UNFCCC (2014), rainfall in Jordan is expected to decrease by 13.6% or 12.9 mm/yr by 2035 (countrywide average 95 mm/yr), and temperature to increase by 1.6°C. On a countrywide scale, this would mean **a decline in long-term groundwater recharge of about 15% from 280 MCM/yr to approx. 240 MCM/yr by 2040**. Long-term **surface water runoff** would also **decrease by about 15% from around 400 MCM/yr to around 340 MCM/yr over the same period**. As a result, **the internal long-term conventional water resources availability will decrease even further from current levels of 65 m^3/ca/yr to 46 m^3/ca/yr.**

The project is currently preparing a countrywide hydrological model and a climate change impact model in order to better quantify these amounts. This will be included in the final Water Master Plan documents (NWMP-3).

Groundwater production will continue to decline, mainly due to overabstraction. **Currently total groundwater abstraction is about three times the amount of natural groundwater recharge**. An updated groundwater contour map for the main used A7/B2 aquifer (reference date 31 October 2018) and a map of currently observed groundwater level declines were prepared. Based on these, a forecast for the groundwater contour in 2040 was established. For this, a linear water level decline was applied until 2040, although decline is expected to increase due to the geometry of the aquifer, i.e. expected decline assumption are therefore likely to be highly conservative. In 2040, **average loss in saturated thickness will be at least approx. 100 m by 2040. This means that pumping water will require much more energy (approx. 40% more). The areas where aquifers will be saturated, and groundwater be exploitable will continuously shrink. Therefore, many of the wells currently being exploited will be dry.**

An analysis was produced of how much water could be abstracted in 2040, based on the water wells currently in use, the given geometry of the aquifer, and the depth of each well. Various different assumptions were made for aquifers where less or no impact is expected, e.g. due to artificial recharge, such as the Hidan wells. Production was also assumed to remain constant from the Dubaidib wellfield (Disi), where the operator has to provide a constant amount of 100 MCM/yr, and from other wells which exploit the Disi aquifer, since the permeability and porosity of that aquifer are much higher than of others. **Production from surface water resources was reduced by 15%, based on expected climate change impact**. For groundwater abstractions, climate change impact was currently not taken into account, considering that a noticeable effect might take more time because flow velocities are much less in groundwater, compared to surface water.

In summary, **production for domestic water supply from renewable groundwater resources (both governmental and private) is expected to decline from 251 MCM in 2018 to 73 MCM in 2040 or to 29% of the present amount.**

At the same time, **groundwater quality will deteriorate due to an increased movement of brackish water resources** from the eastern part of the country towards the western, exploited areas. It must therefore be expected that, even though some wellfields along the desert highway might still be exploitable, they would require desalination by 2040 or earlier. Also, **heavy metal contents (Mo, Ni, V, U, As, etc.) will increase**, resulting from downward leakage from the B3 oilshale unit, in all areas where the A7/B2 aquifer is overlain by the B3 (currently mainly known from the area around Irbid). This problem is expected to spread and not only to affect domestic water supply but also agricultural products, irrigated with such water. The project aims to provide further insight into this problem in the final Water Master Plan.

Which water supply infrastructure will be negatively affected ?

Wellfields, dams and King Abdullah Canal will all be affected by water resources decline.

Groundwater

The main **wellfields affected** are :

→ in the north: Wadi Al Arab, Kufr Assad, Aqeb, Corridor, Zaatari, Somaya, Samer As Sarhan, Hakama (i.e. Irbid, Mafraq, Ajloun, Jerash water supply);

→ in the central part: Hallabat, Siwaqa, Qatrana, Lajjun, Sultani (i.e. Karak and Amman water supply);

→ in the south: Tahouneh, Samna, Jitheh (i.e. Maan water supply).

Surface water

→ Wadi **Mujib dam** is likely to be filled up with sediment and cannot be raised.

→ **Wala dam**, which is currently being raised, will likely be filled up with sediment again by 2040. There is no possibility to raise the dam another time.

→ **KAC**: it is expected that less water will be available from the Yarmouk catchment, a) due to climate change (-15%), and b) the probability that the situation in Syria will normalize, which will lead to higher water use there.

How does water resources depletion affect domestic water supply and water security?

The rapid decline of conventional water resources highlights the urgency to **enforce prioritization** of their use **for domestic water supply** and to seriously address the **phasing out of conventional water use for irrigation**. In the future, the share of treated wastewater used for irrigation should therefore be significantly increased.

Conventional water resources depletion will most severely affect the northwestern part of the country, i.e. Irbid and Mafraq governorates. In these areas, only around 15% of current production will remain in 2040, while **total supply requirement (domestic water demand plus physical loss) will increase by around 31% from 618 to 811 MCM. Transfers of at least approximately 167 MCM/yr to Irbid and Mafraq will be required in 2040.**

Because water resources will become scarce in many areas simultaneously, there will be increased competition over their use. It will thus become increasingly important to take decisions concerning allocation and transfers jointly among all related stakeholders. It is recommended to establish a **Water Resources Allocation Committee** that meets monthly.

Which investments into domestic water supply are most urgently needed ?

811 MCM will be needed for municipal water supply in 2040. Resources available from groundwater and surface water will decrease to 280 MCM in 2040. The total **additional amount of water needed in 2040 (supply gap) will be around 531 MCM/yr**, only **for domestic water supply. Based on current planning, up to 297 MCM could be provided through new projects. In this case, the supply gap would be only around 234 MCM. However, implementation and timing of these projects depend on availability of related funding.**

As the exploitation of conventional water resources cannot be expanded, **most of this demand will need to be covered by desalination.** Brackish water desalination can cover a certain share (up to approx. 100 MCM/yr) but **additional large-scale seawater desalination schemes will be needed**. In all likelihood, the Aqaba-Amman-Water Desalination and Conveyance (AAWDC) project will not be enough to bridge the increasing gap between demand and supply. All desalination plants should be built as DBOT projects. In view of the immense investment sums required, investments in other sectors will need to be decreased. Only 3% of the water supply augmentation targeted in the CIP 2016-25 are implemented thus far. Therefore, there is an urgent need to change the investment planning towards more additional water supply projects, less wastewater projects and more water governance projects.

The approx. share of investments per category should be:

- Governance (water resources assessments/management/monitoring/planning/exploration wells/capacity building) (20%)
- Augmentation of water supply (desalination, surface water, groundwater, including maintenance and feasibility studies) (50%)
- Sanitation and reuse (including maintenance and feasibility studies) (20%)
- Reducing NRW (10%)

Abandoned Brackish Water Well In Wadi Hisban

2 INTRODUCTION

Water supply security in Jordan is in a critical situation. Groundwater extraction has increased at an unprecedented pace over the past decade. The current annual groundwater deficit is almost 600 MCM, and **groundwater abstraction is 3 times higher than groundwater recharge** (280 MCM/yr). Recent studies have shown that this extreme overabstraction has led to average **groundwater level declines** of up to 10 m/yr in some areas and **4-5 m/yr in most wellfield areas.** Electricity consumption for water operations was 14.5% of total consumption in Jordan (including agricultural abstractions; NEPCO, 2018) and constitutes around 50% of the costs for domestic water supply. Due to falling water levels, this share is going to further increase. For many sources the **costs of water delivery have therefore surged to almost 3 JOD/m³** (YWC), and this without any major investment into required upgrades or repairs, which have been neglected for far too long.

The current water tariff does not fully cover the operational costs. The increasing costs of the water sector will be more and more a burden for the Jordanian government. Therefore, tariff restructuring needs to be considered.

The German Government had supported the preparation of two previous Water Master Plans (published in 1977 and in 2004). This Rapid Assessment is part of the Third National Water Master Plan (NWMP-3), again supported by the German Government. The purpose of a Water Master Plan is to provide the basis for a sound planning of investments over a defined planning horizon, commonly 20 years; in this case: 2020-2040. As such, it has to give answers to the following questions:

- → How much water is available and reasonably extractable, and how will resources availability and extractability change over time (e.g. due to climate change and other factors, e.g. water quality or extraction (energy) costs) ?
- → How will demand of the population for all uses (drinking, irrigatstrial, etc.) develop and what are potential growth areas ? and finally.
- → How can the Jordanian Government meet future demand ? From where can additional resources be brought to the demand centers and what investments into the water supply and sanitation infrastructure are required in order to be able to meet this demand ?

The areas where groundwater can be extracted in the future are shrinking significantly and therefore parts of the currently existing water supply infrastructure will become obsolete. Moreover, with growing demand and shrinking resources availability, water must come increasingly from other sources. These could be desalination of brackish groundwater or seawater, or the purchase of water from neighboring countries. Although cost-intensive water-loss reduction programs have been implemented over the course of the past three decades, they have failed to achieve their aim. **Non-revenue water has constantly remained at almost the same level**. They also will not be able to achieve this aim because the network is continuously expanding, thus

creating more possibilities for losses. Another reason is that the transfers and flow paths in the distribution network have increased. A major shortcoming for the calculation of non-revenue water is that it is anyway only considered for the distribution part of the supply infrastructure and not for the abstraction part, i.e. not from the wells to the major distribution points (reservoirs). Therefore, NRW number might be even higher than currently considered. In order to monitor NRW reduction properly related monitoring station must be continuously measured and a related database needs to be available.

The possibility to increase abstraction from fossil groundwater resources is limited and done at the expense of future generations. Although principally the Disi aquifer is a huge resource, with partly more than 1,000 m thickness and a porosity of ~20%, and present in all of Jordan, optimal extraction conditions are given mainly in the Disi area. Also, the presence of elements detrimental to human health, such as radium in the Disi aquifer and molybdenum in the A7/B2 aquifer, put limits to their use.

The most recent planning of the future water supply and sanitation infrastructure had been undertaken in 2015, when the Capital Investment Plan (CIP) was developed. However, at the time **current and future water resources availability and extractability had not been considered correctly in investment planning** and had not even been available. Therefore, **many parts of the CIP have to urgently reviewed**. Moreover, previously there was little coordination between the individual sectors concerning project planning. Each sector prepared its own list of projects, without considering the implications for the other sectors. To avoid such internal competition over projects, a **joint and coordinated planning is needed**. With this aim, the **Joint Planning Committee** was established in December 2019, supported and facilitated by GIZ activities.

This Rapid Assessment was requested by the Jordanian Government in order to have quick answers as to which investments should be undertaken with highest priority. It can, however, not incorporate aspects which the project is still working on, in particular:

→ How much groundwater recharge and surface water resources availability (runoff) will decrease due to impacts of climate change (results of new study expected by end of 2020) ?
→ What impact will changes in water quality, particularly increasing salinity, have on the exploitability of water resources, transfer, and future required treatment (results of new study expected by beginning of 2021) ?
→ How will energy demand, and thus costs, increase due to declining water levels and the increasing necessity to desalinate brackish groundwater and seawater ?

The Rapid Assessment only covers domestic water supply, other sectors will be covered in the main documents of the **Third National Water Master Plan**, which **will have 8 volumes**. The NWMP-3 will comprise the following volumes: (light green: to be completed by June 2021):

Table 1: Planned Volumes of the Third National Water Master Plan

A. Background and approach, Institutional and legal framework (enabling environment)
B. Water resources (conventional/non-conventional) (a) Availability, exploitability, quality, protection (b) Factors influencing water resources availability and use
C. Water demands, uses and allocation gaps
D. Planning and decision-support system tools
E. Water supply infrastructure
F. Wastewater and related infrastructure
G. Synthesis, findings and recommendations for investment planning
H. Summary volume

Current planning foresees that the volumes of the Water Master Plan marked in light green color in Table 1 should be completed by June 2021. All volumes will probably be completed within 5 years, given the resources of the project (start: 03/2019).

Work on the NWMP-3 is done through **9 Work Groups**, each comprising of 10-20 members from MWI, WAJ and JVA, meeting regularly to provide the required contributions to the NWMP-3:

Table 2: Work Groups for Preparation of the Third National Water Master Plan

Work Group	Tasks
1. Institutional and legal framework	Laws, agreements, by-laws, institutions, reform, strategies and policies, planning, KPI, SDG, tariff, data exchange, project factsheets
2. Conventional water resources availability and exploitability: rainfall, surface water, groundwater	Rainfall, induced rainfall, surface water, renewable groundwater, fossil groundwater, managed aquifer recharge, surface water
3. Unconventional water resources availability and exploitability: Desalination, treated WW reuse, shared water resources, imported water	desalination, treated wastewater reuse, shared water resources, imported water
4. Factors influencing water resources availability and use	Climate change, energy and costs, water quality impacts
5. Water demands and uses	Domestic, touristic, industrial, agricultural, nomadic demands and uses, uses by type of water, allocation gaps
6. Planning and Decision-Support System tools (WEAP)	Water balance, planning of projects, WEAP
7. Water supply infrastructure	Wellfields, dams, canals, imports, conveyance network, treatment plants, private water infrastructure, gaps, future infrastructure
8. Wastewater and related infrastructure	Centralized systems, decentralized systems, collection, treatment, treated wastewater reuse, sludge reuse/disposal
9. GIS and data management	Harmonize GIS data use; make information available

This document is structured into 9 Chapters (Table 3).

Table 3: Structure of this Rapid Assessment document

Chapter 1	Gives a summary of the main results and findings.
Chapter 2	Provides an introduction as to why and how the Third National Water Master Plan was prepared.
Chapter 3	Presents an overview on how much conventional and non-conventional water resources are available and can be exploited in the future.
Chapter 4	Shows the current and future water demand for all uses considered under domestic water supply.
Chapter 5	Summarizes the domestic water supply schemes in place, both, governmental and private infrastructure. Moreover, it presents which infrastructure will become obsolete due to water resources depletion, which gaps in water supply there will be, and which infrastructure is required to bridge these gaps.
Chapter 6	Summarizes the main findings of this assessment.
Chapter 7	Reviews the previously planned projects: is there a potential funding ? What is their implementation status ? What are the commonly used planning parameters and criteria ?
Chapter 8	Presents all recommendations for improving water supply security.
Chapter 9	Provides important references for all topics covered.

Ancient Archaeological Site Of Pella With Spring (Tabaqat Fahel) Formerly Producing 8 Million Cubic Meters Per Year

3 WATER RESOURCES

3.1 Water Resources(Availability, Exploitability, Quality,Protection and Monitoring)

3.1.1 Rainfall

Facts

Rainfall is the source of all water resources used in Jordan, both surface and groundwater. Due to natural conditions, rainfall in Jordan is highly variable in space and time. Climate change will have a high impact on future rainfall and temperature distribution in the Middle East region. The monitoring and assessment of rainfall (and other climatic parameters) provide the basis for the assessment of long-term available quantities of water resources. Therefore, rainfall monitoring is essential for investment planning in the water sector. It is essential to consider climate change in all related planning. Current internal long-term conventional water resources availability is 65 m^3/ca/yr. Due to climate change and population increase, availability would decrease to 46 m^3/ca/yr.

3.1.1.1 Natural Rainfall

Countrywide rainfall measurements are done in Jordan since the late 1930s. The oldest rainfall records in Jordan, dating back to 1922, are available for rainfall station Amman Airport (at Marka). While an optimal coverage of measurements was reached in the early 1990s, monitoring efforts and in particular the number of stations has significantly decreased since then. With support from the KfW HSSP project (final report presented in 2019), 32 new weather stations (Figure 2) and 39 rainfall stations (Figure 3) were established and equipped with telemetry between 2015-18. In 2017, Jordan had a total of 154 stations for precipitation measurement (MWI yearbook 2016/17), of which 74 also monitored temperature and evaporation. However, many evaporation stations are not operational as water to the class A pans needs to be added manually, and there is no staff available to do so on a regular basis.

Nowadays, MWI operates 98 telemetric climatic stations (Figure 4), while 36 climatic stations are operated by the Jordan Meteorological Department (JMD) and 10 stations by Ministry of Agriculture. In addition, MWI has 22 rainfall totalizers in remote areas, from which it collects data once a year.

MWI, together with foreign donors, has prepared several rainfall distribution maps over the course of the past few decades. In the framework of the support by BGR (North Jordan Groundwater Resources Assessment project), an assessment of the rainfall monitoring network was conducted (MARGANE & ZUHDY, 1995). At that time there were 80 stations equipped with automatic rainfall recorders, 240 stations equipped with standard precipitation gauges (manual daily measurements), and 40 stations equipped with precipitation totalizers (annual rainfall measurements) in operation throughout the country. Figure 5 shows the rainfall distribution map that was developed, based on the data available for the 20-years time period of water years 1973/74 – 1992/93. In the document all records between water years 1937/38 to 1993/94 were considered; long-term average for the time period 1973/74 – 1992/93 was 8,449 MCM/yr (countrywide average: 95 mm). This time period is close to the reference period used by IPCC for climate change impact consideration (1960-90),

and it is therefore important to be considered in the NWMP-3. Annual variations can be 30-300 % of the long-term average (MARGANE & ZUHDY, 1995).

In 2014, MWI prepared a rainfall distribution map showing the 70-years average of water years 1943/44–2012/13 (Figure 6). However, there is no related documentation to show how the map was prepared, and which data were used. Total rainfall during this period was 6,890 MCM/yr (countrywide average: 77.1 mm.

In 2017, BGR produced another 30-years average distribution map for the period covering water years 1984/85 – 2013/14 (Figure 7). Total rainfall during this period was 5,940 MCM/yr (countrywide average: 66.5 mm). However, this map and the one developed by MWI are already impacted by climate change since 1990. MARGANE & ZUHDY (1995) show that long-term rainfall averages changed significantly between 1937/38 and 1993/94 (Figure 1).

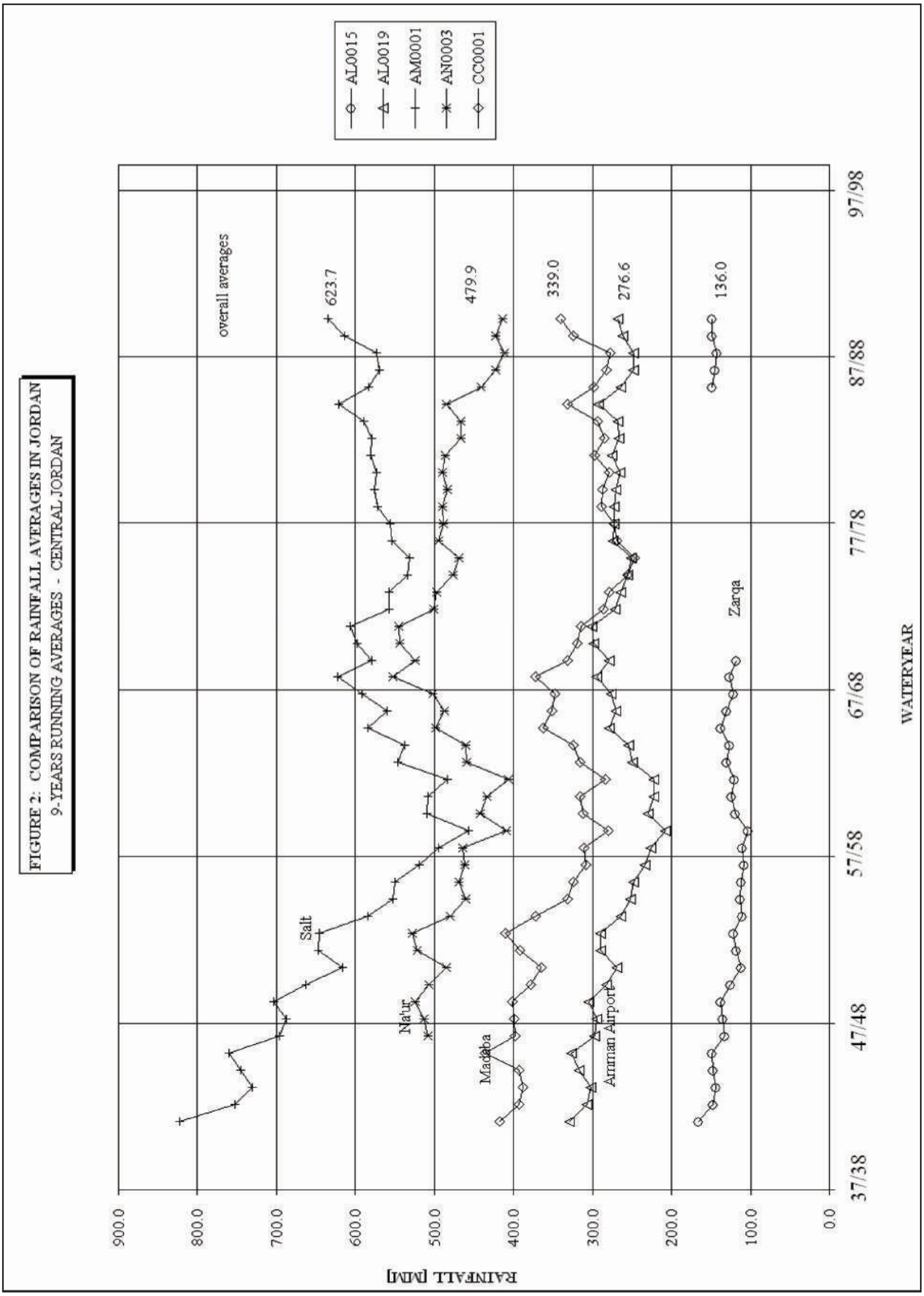


Figure 1 :9-year Moving Averages of Rainfall (MARGANE & ZUHDY, 1995)

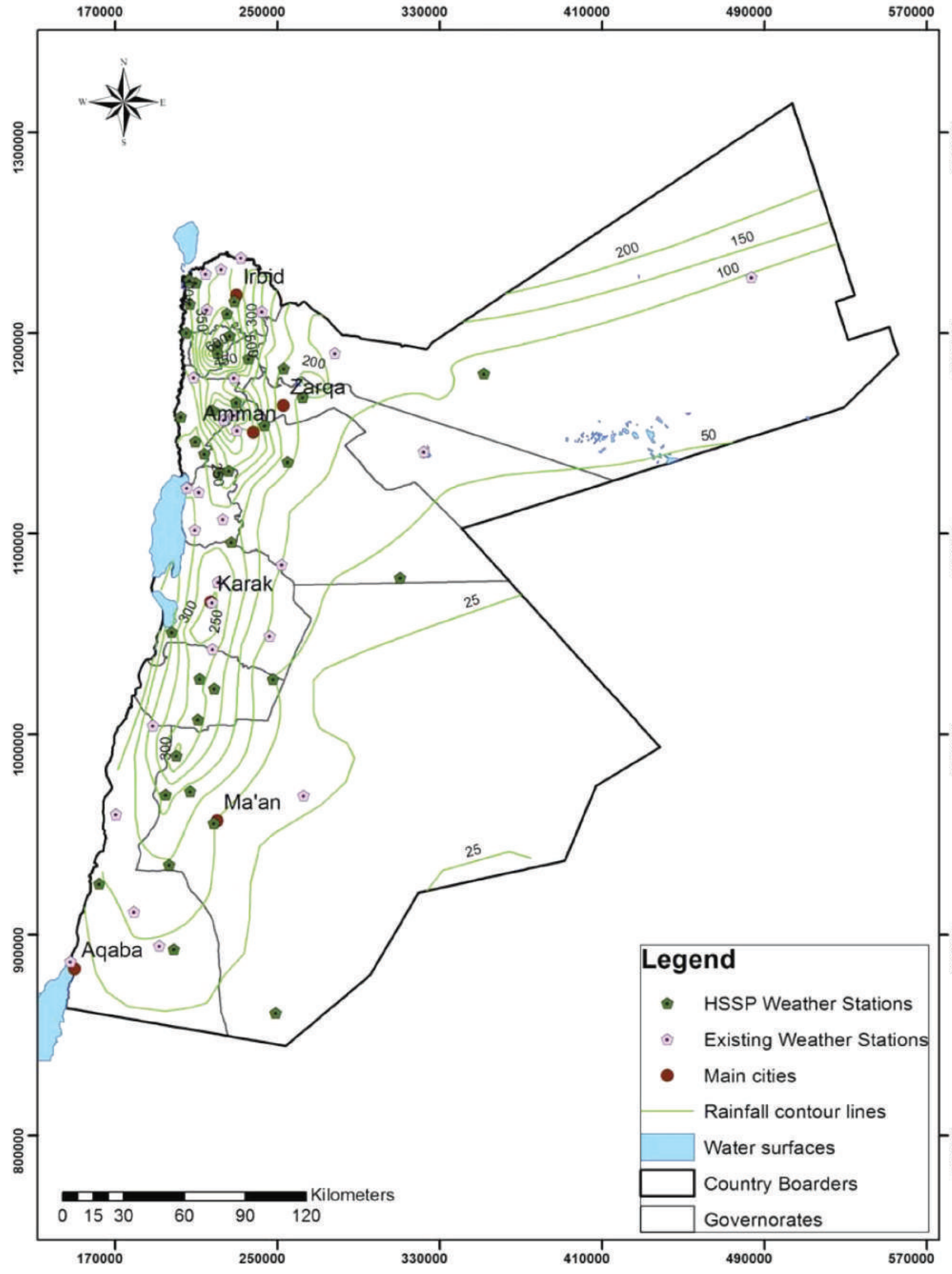


Figure 2: Current Distribution of Weather Stations (adopted from HSSP, 2019)

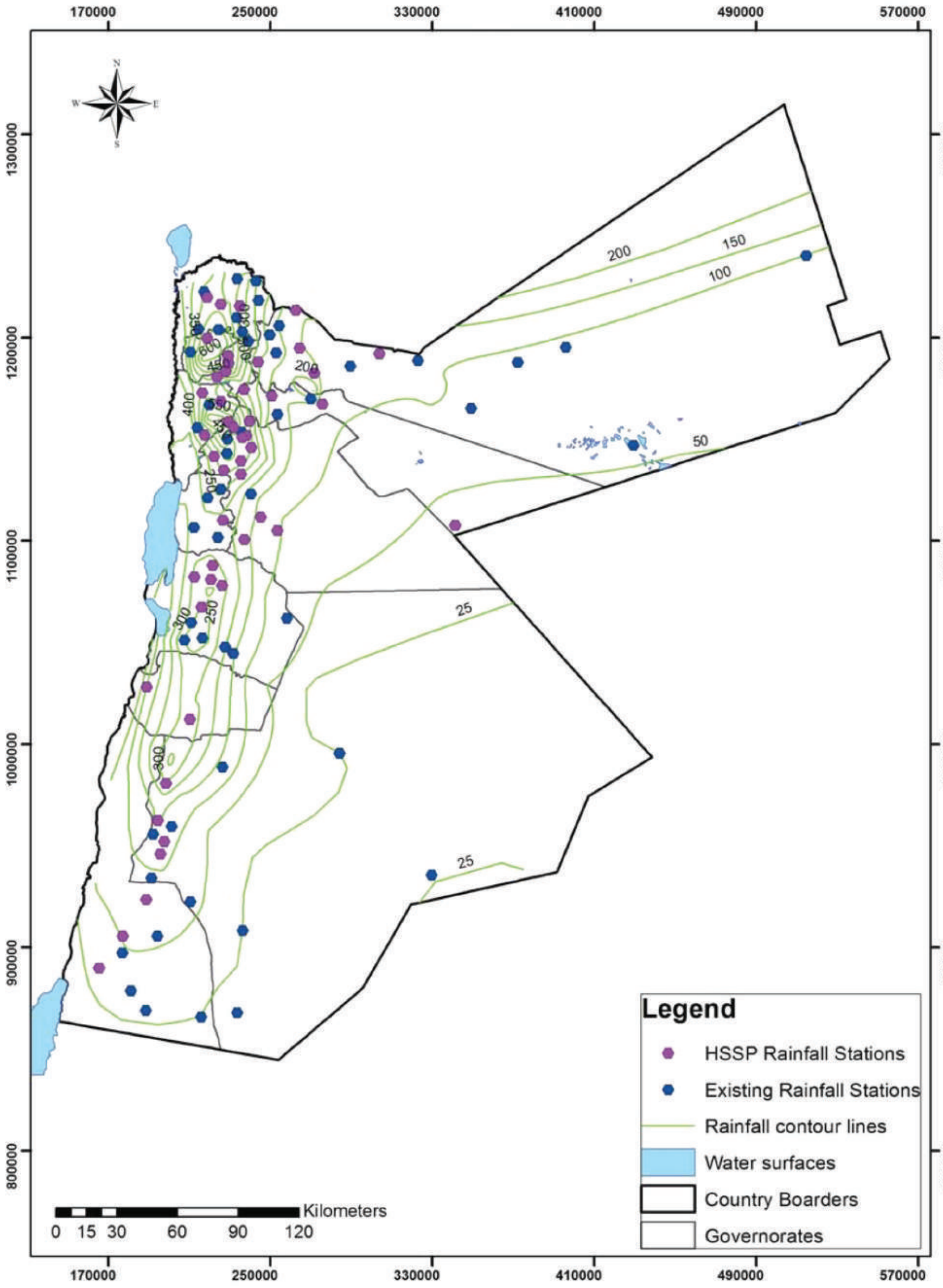


Figure 3: Current Distribution of Rainfall Stations (adopted from HSSP, 2019)

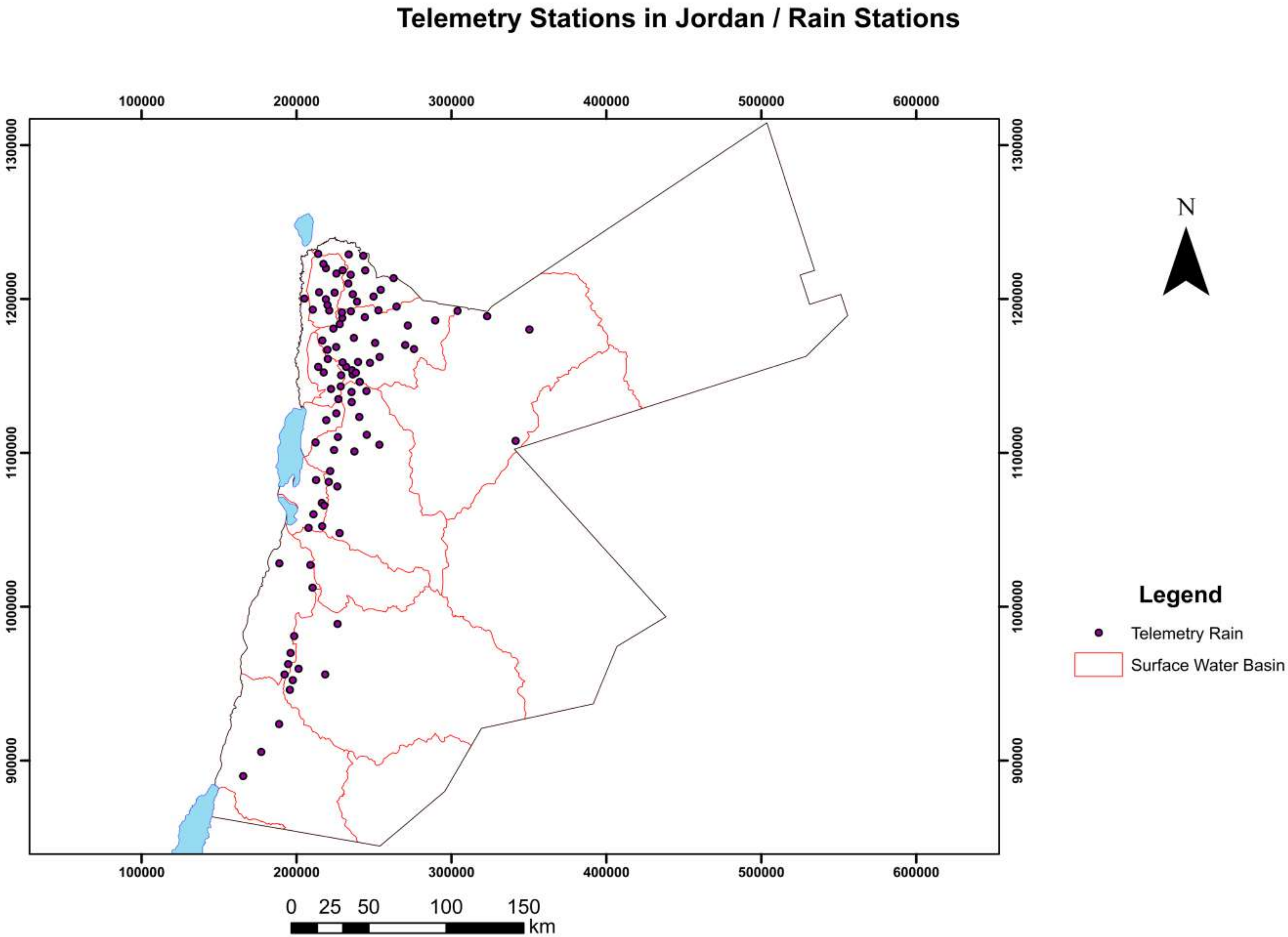


Figure 4: Spatial Distribution of Telemetric Climatic Stations (98) operated by MWI

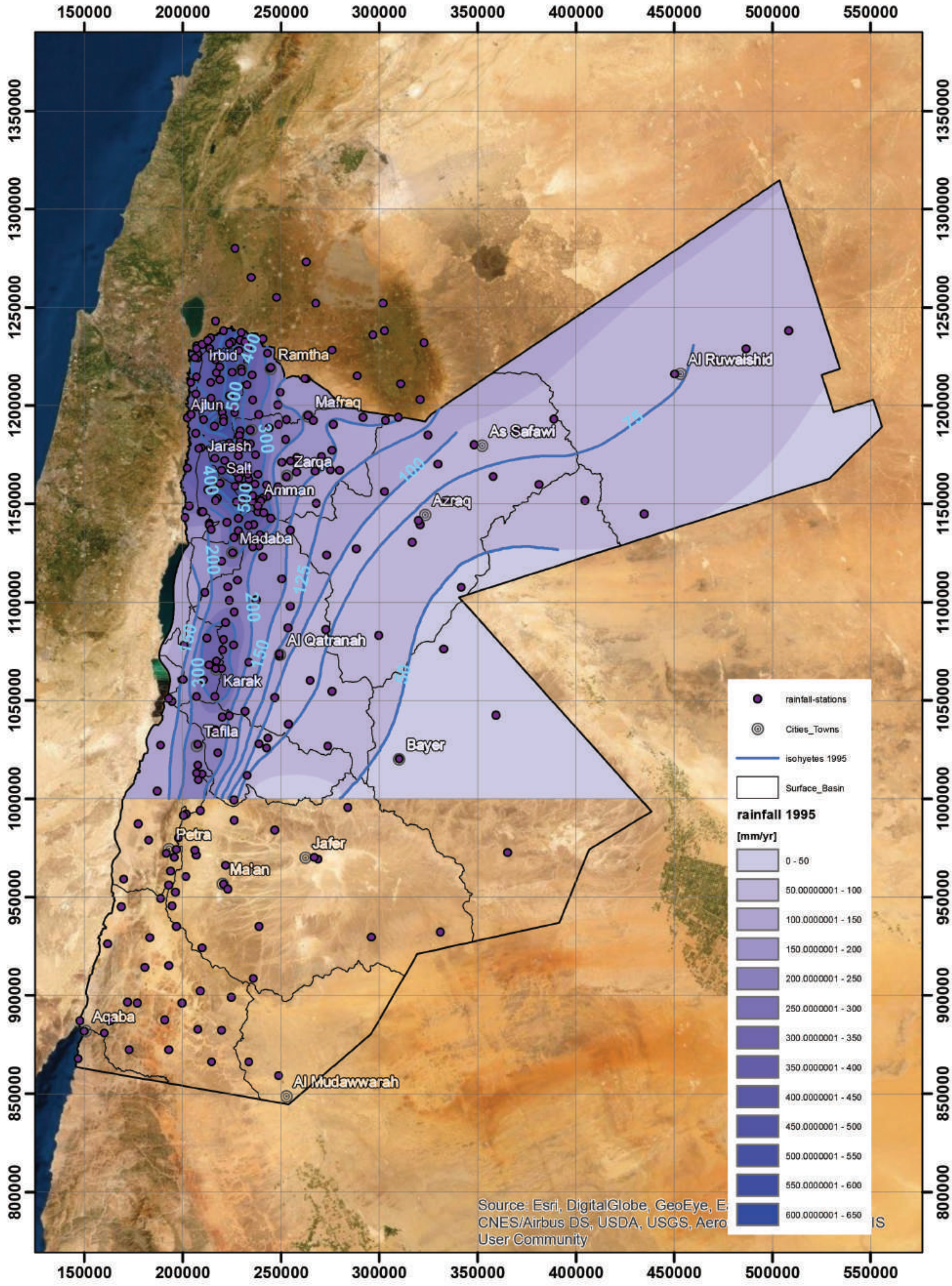


Figure 5: Rainfall Distribution Map for 20-years Average of Water Years 1973/74 – 1992/93 (Al ZUHDY&MARGANE, 1995)

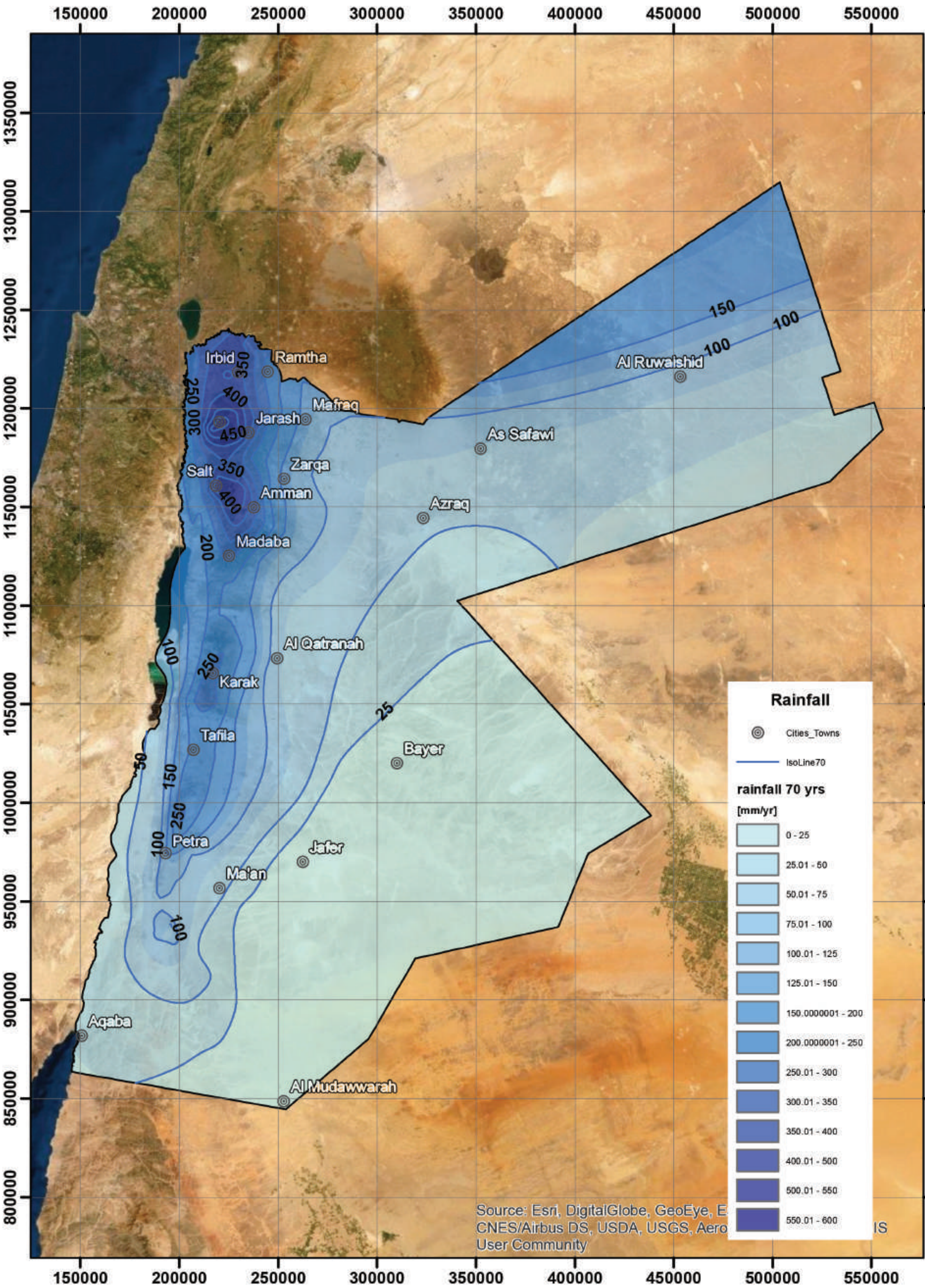


Figure 6: Rainfall Distribution Map for 70-years Average of Water Years 1943/44 – 2012/13 (MWI, 2014)

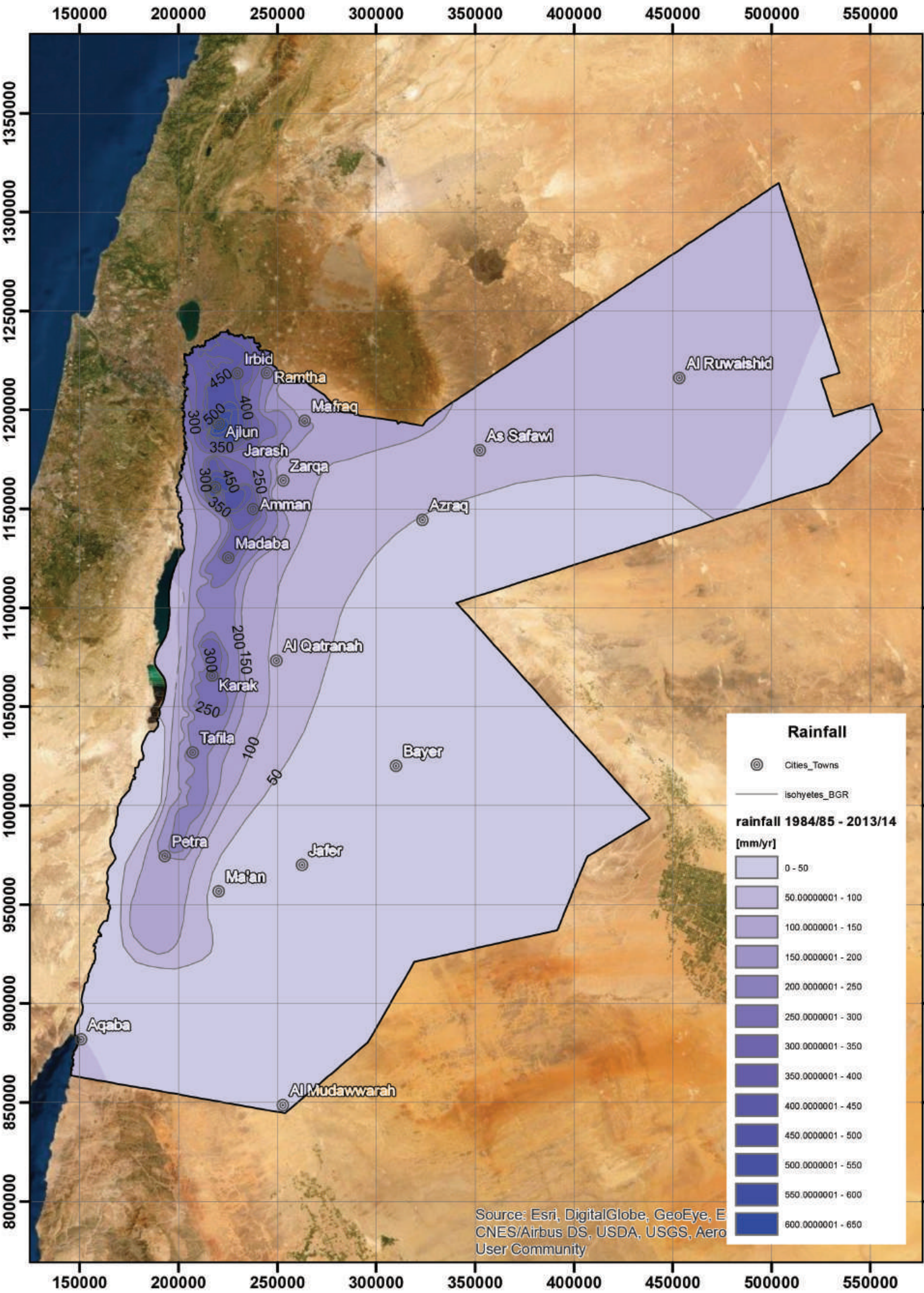


Figure 7: Rainfall Distribution Map for 30-years Average of Water Years 1984/85 – 2013/14 (BGR, 2017)

3.1.1.2 Induced Rainfall Measures

Facts

Rainfall can be increased by chemical (cloud-seeding) or physical (ionization) means. This requires advanced monitoring of potential rainfall events that could be targeted. Although the success of such measures often cannot be verified, such methods are useful for increasing rainfall at low costs.

Ionization Beams

Natural rainfall can be increased by ionization (Figure 8). A related system has been in place in Jordan since 2016. Ionization increases natural precipitation by mimicking the sun's ionization. The technology is based on negatively charging particles in the atmosphere through emitting high voltage beams. As a consequence, enhanced clouds are developed, and rainfall occurs over large areas. WeatherTec, the company that has and still is applying this technology in Jordan, claims that this system has no negative environmental effects, and that it does not decrease precipitation over neighboring regions or countries.

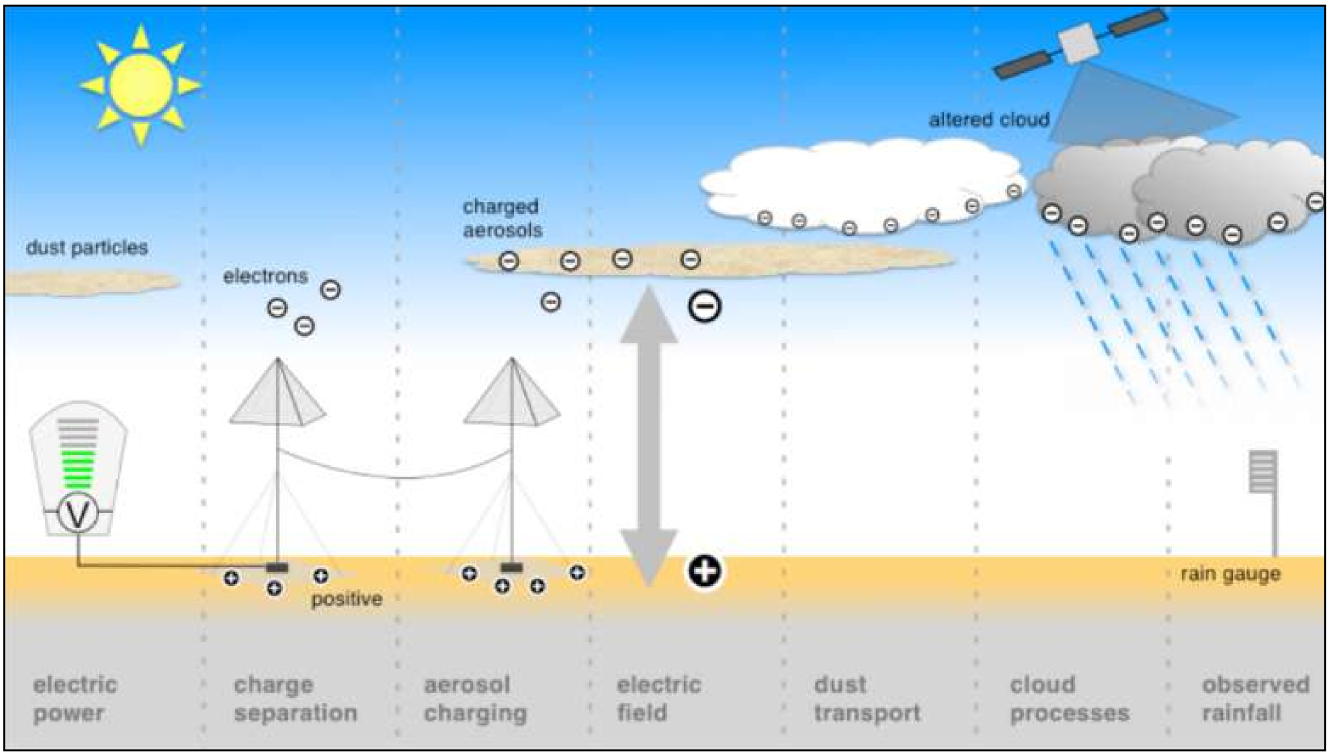


Figure 8: Schematics of Ionization Technique applied in Jordan

In May 2016, Jordan (Jordan Meteorological Department) contracted WeatherTec Services GmbH, Germany, to use ionization. Four (4) stations have since then been operating in the northwestern part of the Kingdom, covering an area of approximately 10,000 km^2 between Irbid and the Dead Sea over a distance of 100 km (Figure 9).

Locations of Emitter Stations:

WT1 Deir Abu Said	32°30’40.55“N 35°39’14.84“E
WT2 Kufranjeh	32°17‘12.12“N 35°42‘22.88“E
WT3 Salt	32° 4‘52.34“N 35°42‘43.95“E
WT4 Madaba	31°47’28.42“N 35°45’51.76“E

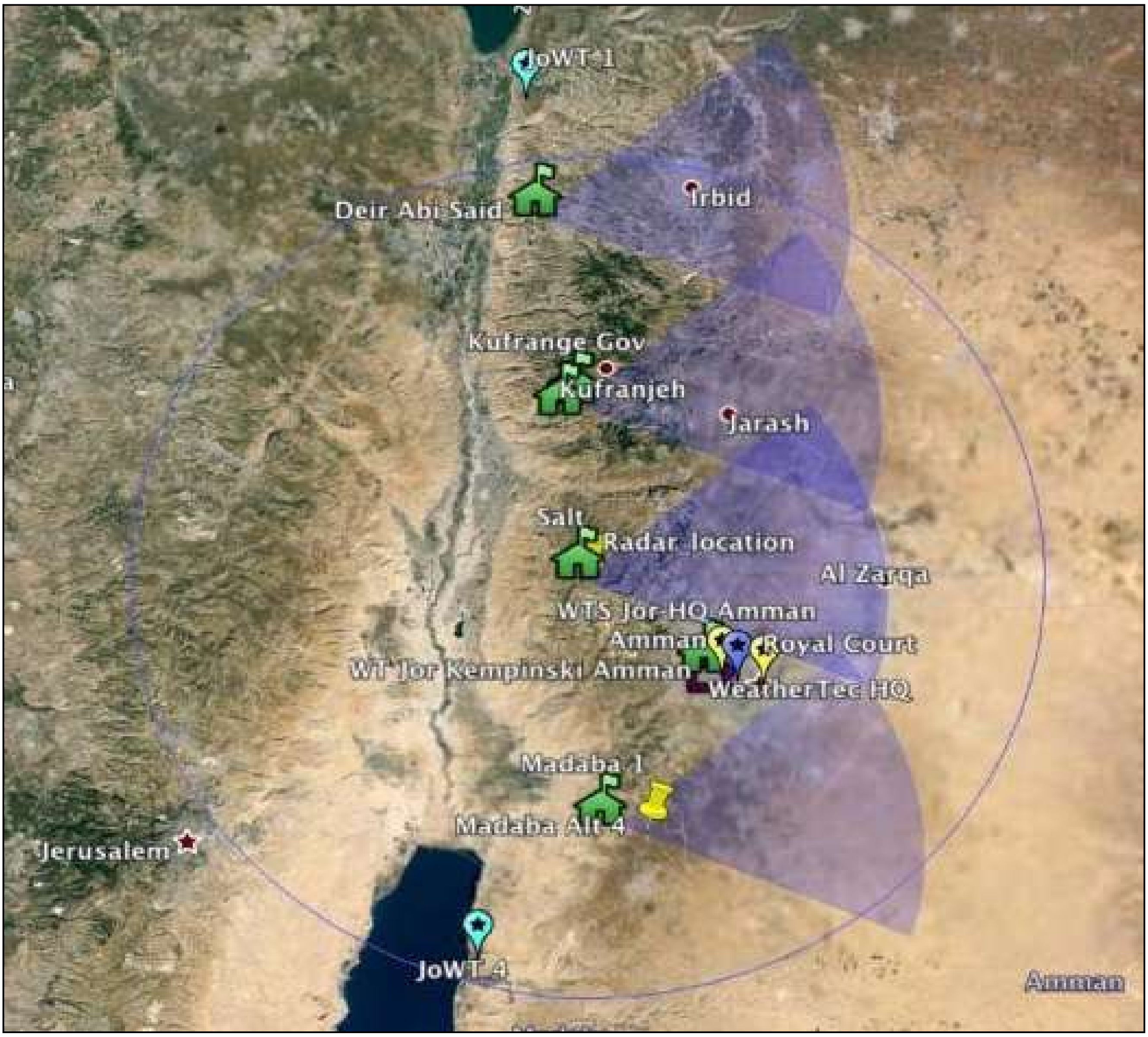


Figure 9: Location of WeatherTec Emitter Stations

Each station has 3 or 4 emitters (Figure 10), and each site is equipped with its own weather station to measure temperature, humidity, rainfall, wind speed and direction.

Due to the nature of operations, the positive effect of ionization is difficult to prove and quantify.

Figure 10: WeatherTec Emitter Station in Madaba

Ancient Water Harvesting Structure at Qasr Qatrana


Rainwater Harvesting (RWH) Structure in Northwest Jordan

3.1.2 Water Harvesting Structures

Facts

Rainwater harvesting can provide limited additional amounts of water for agriculture, households or use in remote areas.
It requires additional infrastructure for collection and distribution.
Installation of related infrastructure is favorable in areas with a high annual precipitation (>300 mm).

Rainwater harvesting (RWH) can provide additional amounts of water for use in:

→ Agriculture, through a system of surface water collection and storage cisterns. Favorable areas are those where rainfall exceeding 300 mm/yr. Sediment must be removed before storage, and cisterns cleaned regularly;
→ Households for toilets or gardening in cities/villages, based on rooftop harvesting. This requires costly infrastructure for collection and distribution, but conditions are favorable at all public buildings with large rooftops (schools, municipalities, barracks);
→ Rural areas for pasture, based on check dams and desert dams.

The following rainwater harvesting structures exist in Jordan:

- Harvesting perimeters and cisterns for agriculture (several hundred; no statistics available);
- Rooftop and courtyard harvesting in buildings (no statistics available);
- Desert dams (or check dams) (considered in this document under Managed Aquifer Recharge).

A recent amendment to the building code requests anyone constructing a building to establish an infrastructure to harvest rooftop rainwater. However, there is no related enforcement yet. For the Amman area this is regulated by the Amman city building code, number 21, latest amendment published on 25 March 2019 (by-law no. 2 of 2018; Building Code: amendments to by-law no. 136 of 2016). As for the rest of the country, MWI has asked the Ministry of Local Administration (MoLA) to amend the article related to rainwater harvesting by making it mandatory (and to remove the payment of fines).

In 2018, the USAID project WMI prepared a guideline for rooftop rainwater harvesting with details on how these systems should be designed (TETRA TECH, 2018b, 2020). GTZ also implemented the Participatory Watershed Management project (WSMP), which promoted the construction of cisterns in rural communities (GTZ, 2000, 2003).

Acomprehensive guideline on RWH is given in MEKDASCHI STUDER & LINIGER (2013).

The overall amount that can be gained through rainwater harvesting from rooftops is fairly low, and not everyone can make use of the water stored to enable their consumption of drinking water to be reduced. Rainwater harvesting is largely practiced in northern Jordan, mainly in the Ajloun region and collected quantities can cover water supply shortages in the summer. A map of potential favorable areas is included in the WMI (2018) publication. A list of 284 sites used for rainfall harvesting in irrigation and registered with MoA is included in the GTZ (2003) report.

Chapter 13 of the 3rd GLOWA Jordan report (GLOWA 2013) contains some examples of rainwater harvesting from the region. The authors estimate Jordan's potential for RWH at 13 MCM in normal years and <1 MCM in dry years. However, the document does not contain any reference as to how these figures were estimated.

Mujib Dam

3.1.3 Surface Water Resources

Facts

Surface water potential follows the distribution of rainfall and is thus highest in the northwestern highlands. The large surface water catchments of Yarmouk, Zarqa and Mujib accumulate the biggest amounts of runoff. Dams have been constructed in all major catchments since the 1970s. However, runoff also brings significant amounts of fine sediments to the dams, slowly filling them up. This siltation can be avoided through intelligent dam management. Most dams cannot be raised, and, in most cases, no alternative dam locations are available.

The vast majority of surface water resources intercepted through dams is used for agriculture. For many years, the government has intended to allocate reclaimed water to agricultural uses so that precious freshwater resources can be used for domestic water supplies.

Data of production from and use of surface water resources (dams, KAC) are subject to high levels of uncertainty

The planning of infrastructure making use of surface water resources can only be based on proper measurements of surface water runoff. An appropriate hydrological monitoring network existed until the late 1980s. It disappeared with the construction of dams in all major wadis. Today, most runoff stations are located at the wrong places, are not operational, are not maintained, or are not calibrated. Moreover, measurements of surface water runoff are not representative since they are frequently influenced by wastewater effluents, inflows from leaky water supply networks, irrigation return flows, and abstractions. The most recent dams were therefore planned on the basis of estimations rather than on actual and representative surface water runoff data.

Aside from largely lacking surface water monitoring data, there is also still no hydrological model for the entire country and thus, the average amount of runoff generated in Jordan is still unknown. The first Water Master Plan (NRA & GIZ, 1977), which was largely based on a theoretical approach for runoff factors, assumed that average runoff is around 880 MCM/yr. While the report mentions that a large share of approx. 400 MCM/yr originates from catchments in Syria (Yarmouk), its estimations of both the amount generated on Jordanian territory (480 MCM/yr) and the long-term surface water resources availability in the Yarmouk catchment area (ZEITOUN et al., 2018: 200 MCM/yr) appear to be too high.

In the second National Water Master Plan (MWI & GIZ, 2004), a simple hydrological model was established that used a modification of the outdated USBR curve-number method (using a standard set of runoff curves for a set of hydrological soil type, land use and climatic zone conditions). The model uses a 2 km * 2 km grid, and daily data had to be generated artificially for it to run. It remains unclear how the model was calibrated. The document mentions an amount of 236 MCM/yr as mean floodflow and 218 MCM as baseflow, so that overall runoff was assumed to be around 450 MCM/yr, but by then the data necessary to calculate this, particularly that pertaining to surface water runoff measurements, hardly existed. More importantly, although the report states that groundwater recharge was based on this runoff model, it does not mention how it was calculated. In general, the USBR curve-number method is not suitable for predicting groundwater recharge under the conditions prevailing in Jordan.

A countrywide hydrological model is currently being built as part of the NWMP-3. A **long-term available amount of 400 MCM/yr of surface water** will be used until this model is finalized.

At the time of the Groundwater Assessment of North Jordan project (BGR, 1992-96) there were 54 surface water runoff stations providing data. However, many of them only did so sporadically, and often merely for flood flow. Only a few stations such as Adassiyeh (AD0033) had continuous runoff data. However, this station doesn't provide accurate data since it is only 1.4 m high and cannot measure flow that exceeds this level. Many stations were not being maintained or rehabilitated at that time.

Despite the importance of surface water resources, there have been no major efforts to prepare a concept for measuring surface water runoff since the 1980s, although that was when the major dams started to be planned and constructed. While this is very much needed, a recent project only covered a minimal upgrading of the surface water monitoring network, particularly regarding the upgrading of the national water resources monitoring system (KfW/HSSP project). The large overall volume of investment needed for surface water stations meant that only 6 stations were rehabilitated and equipped with telemetric data transfer (Figure 11).

Currently, there are 57 runoff gauging stations, out of which 24 are still active and only 12 provide continuous records (MWI yearbook 2016/17). However, in recent years the number of active stations became less.

Production from dams during 2014-18, reported by JVA is listed in ANNEX 3.

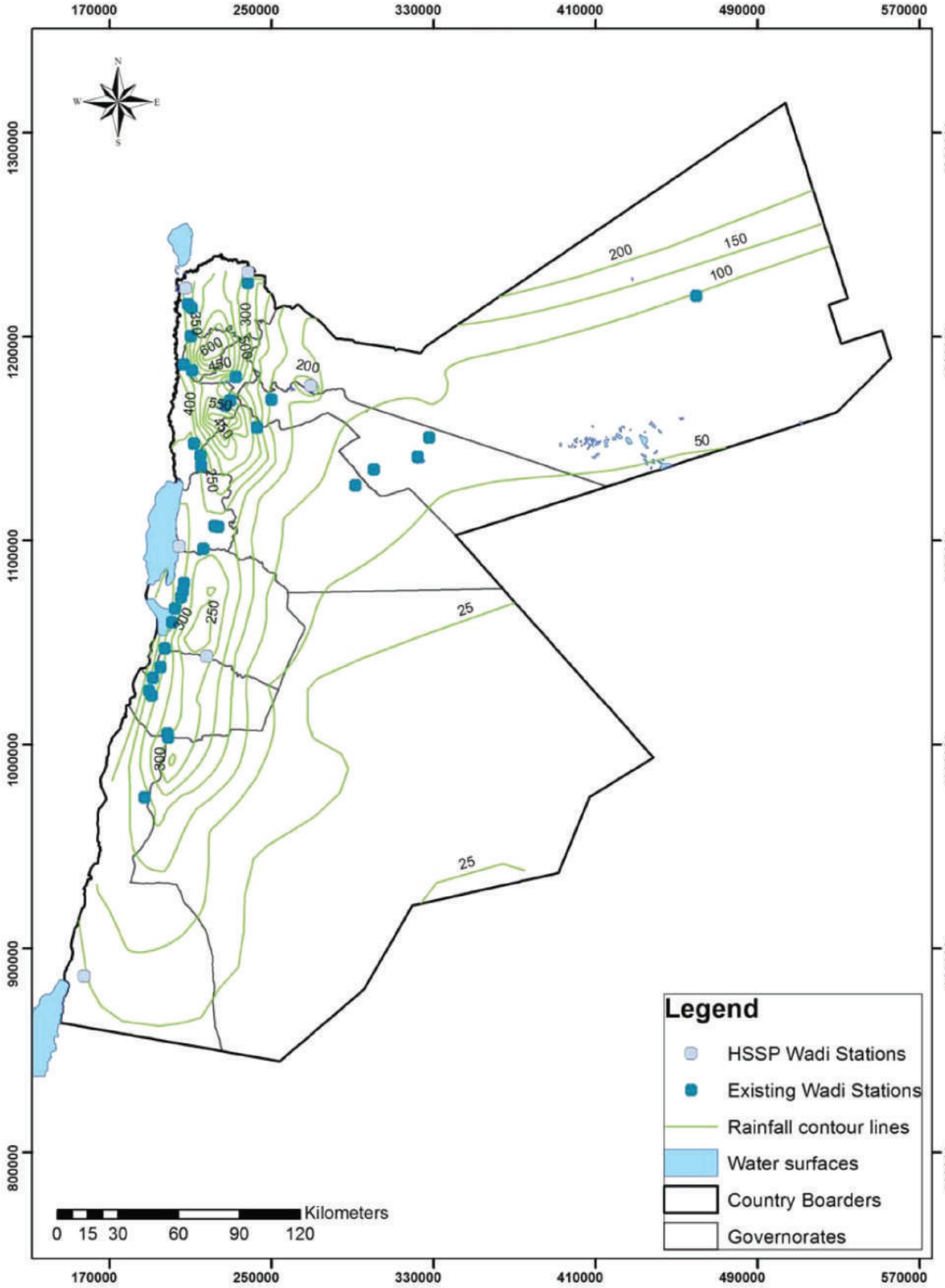


Figure 11: Surface Water Gauging Stations (adopted from HSSP, 2019)

Use of Surface Water from the Yarmouk Catchment

The most important surface water resource for Jordan's drinking water supply is the Yarmouk River, from where water is made available through the King Abdullah Canal (KAC) for use in Amman and Balqa, and in the future (probably as of July 2020) also to Irbid. The second most important surface water resource is the Mujib dam. Details for both systems are shown in Figure 14, Chapter 5.1.2.1 and ANNEX 3.1.

The total flow of the Yarmouk River is strongly affected by landuse in Syria, which controls around 80% of the Yarmouk catchment. Syria uses both surface and groundwater excessively, has more dams (32) than is permitted in the bilateral agreement (25), and also has in excess of 4,000 wells that are over-abstracting groundwater for irrigation in one of the country's most fertile areas (ZEITOUN et al., 2018; long-term water resources availability in Yarmouk catchment: surface water 200 MCM/yr; groundwater 250 MCM/yr).

The result of overuse in Syria is that much less water than is allocated to Jordan arrives at Wehdah dam and ultimately at the King Abdullah Canal and can be used by Jordan (Figure 12). One effect of the civil war in Syria was that the amount of water stored at the Wehdah dam increased. It is very likely that, once the civil war in Syria ceases, water use for agriculture will increase dramatically there. By then, unless there is some form of control, the number of illegal wells in Syria will most likely have doubled. It is therefore probable that the availability of surface water resources to Jordan from the Yarmouk catchment will decrease in the long term.

The following components determine flow in the Yarmouk River at Adassiyeh:

- Wehdah dam (max. storage capacity: 110 MCM) with its five tributaries, of which one is in Jordan: Wadi Shallalah, and the rest is in Syria: Wadi Allan, Wadi Hareer, Wadi Thahab, Wadi Zeidi;
- Discharge from the unnamed spring created when Wahdeh dam was built (artesian discharge from A7/B2 aquifer; flow not monitored);
- Mukheibeh wells (uncontrolled discharge into the Yarmouk River; not quantified, because partly artesian; currently ~20 MCM; A7/B2 aquifer);
- Surface runoff from Wadi Raqqad (northern tributary; flow not monitored);
- Himmeh/Hamat Gader springs (A7/B2 aquifer) (flow not monitored); flow estimated in the 1960s at ~60 MCM/yr (Himmeh and Mukheiba springs/Jordan: 80 MCM/yr, of which Mukheiba springs: 20 MCM/yr) (WAJ files; HADDADIN, 2002).

The above illustrates that flows in the Lower Yarmouk River are not well monitored. To monitor flows better, it is recommended to establish runoff gauging stations in this area. In view of the complicated situation with regards to surface water and groundwater flow and use, the establishment of a monitoring network for both was proposed in 2018 (Figure 13), if possible under international supervision.

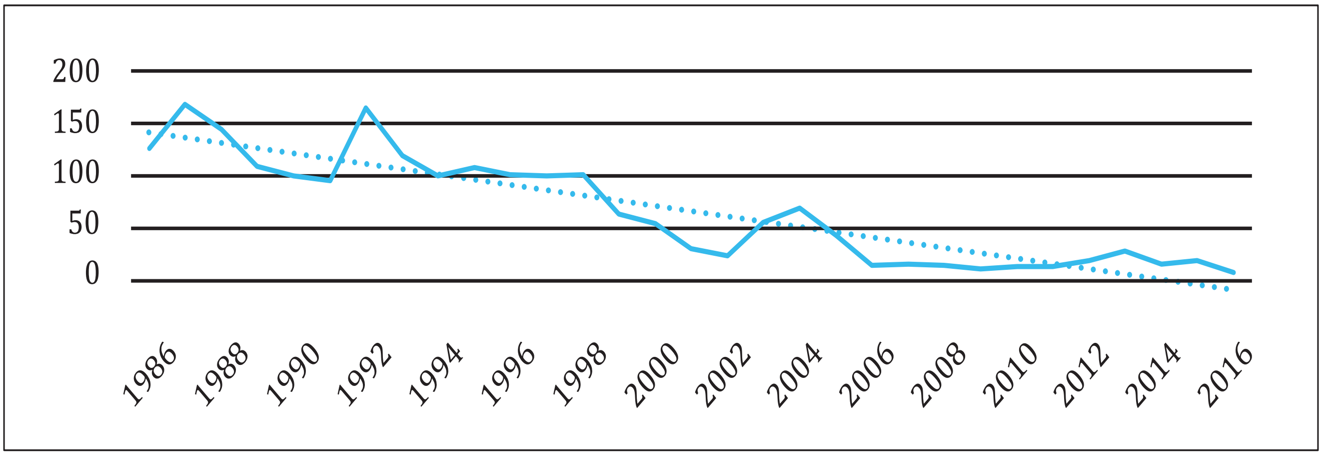


Figure 12: Declining Provision of Water from the Yarmouk River (adopted from ZEITOUN et al., 2019)

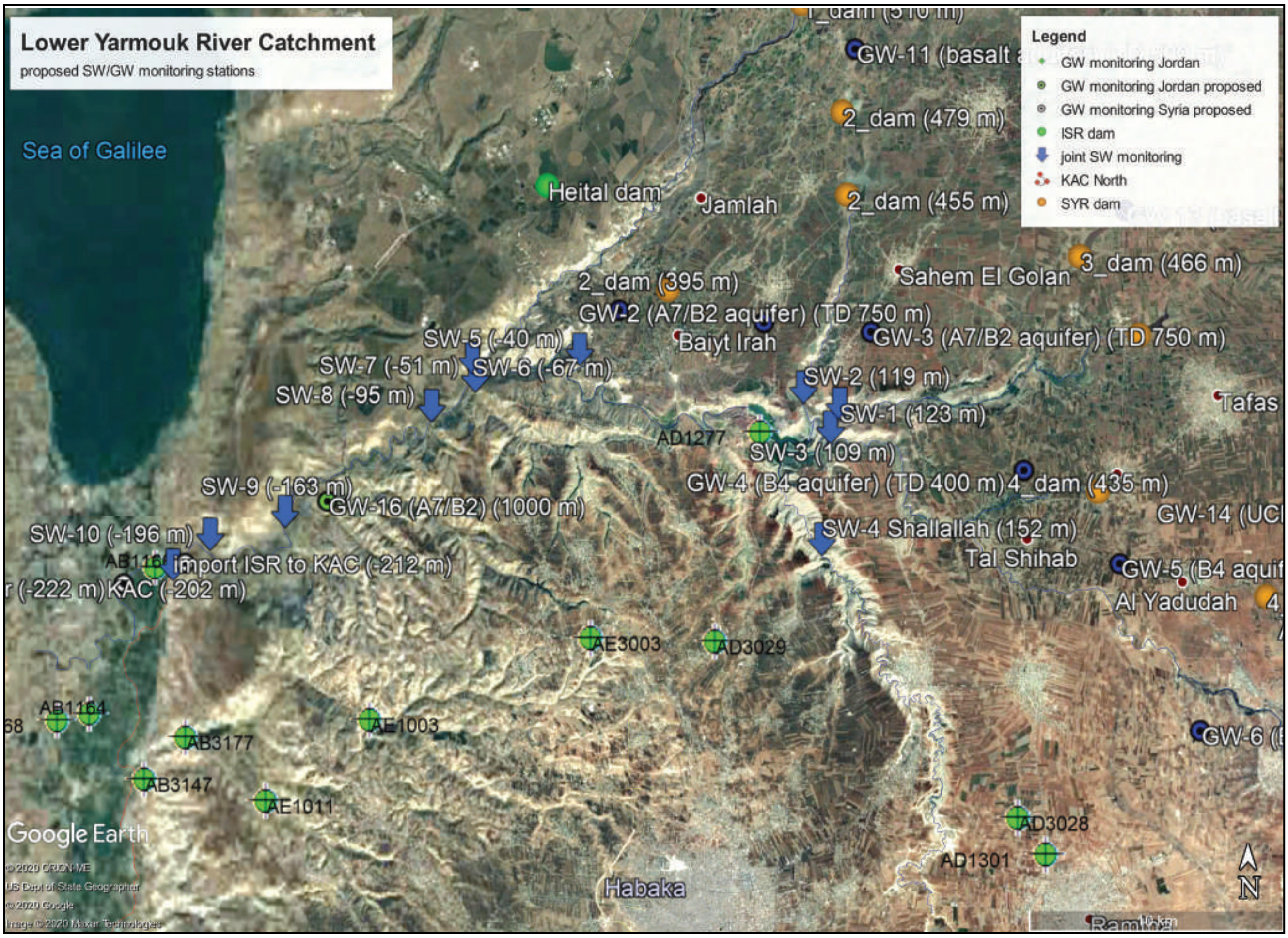


Figure 13: Proposed and Existing Monitoring Network for Surface Water and Groundwater in the Lower Yarmouk catchment (MWI, 2018)

The exchange of water resources between Jordan and Israel is regulated in the 1994 peace accord, and between Jordan and Syria in the agreements from 1953 and 1987. The current exchange mechanism in the Lower Yarmouk River area was analyzed by ZEITOUN et al. (2018, 2019) and is shown in Figure 14. A weak point is that Adassiyeh weir is only 1.4 m high so that any flow exceeding this level cannot be measured on the Jordanian side. Also, storage in Adassiyeh dam is too little. Instead, Jordan uses measurements from the Israeli side for its internal calculations. From the Jordanian perspective, there is a high uncertainty with regards to flow to Israel. Also, water quantity and quality of flow returning to Jordan from Lake Tiberias is not measured on the Jordanian side but only on the Israeli side.

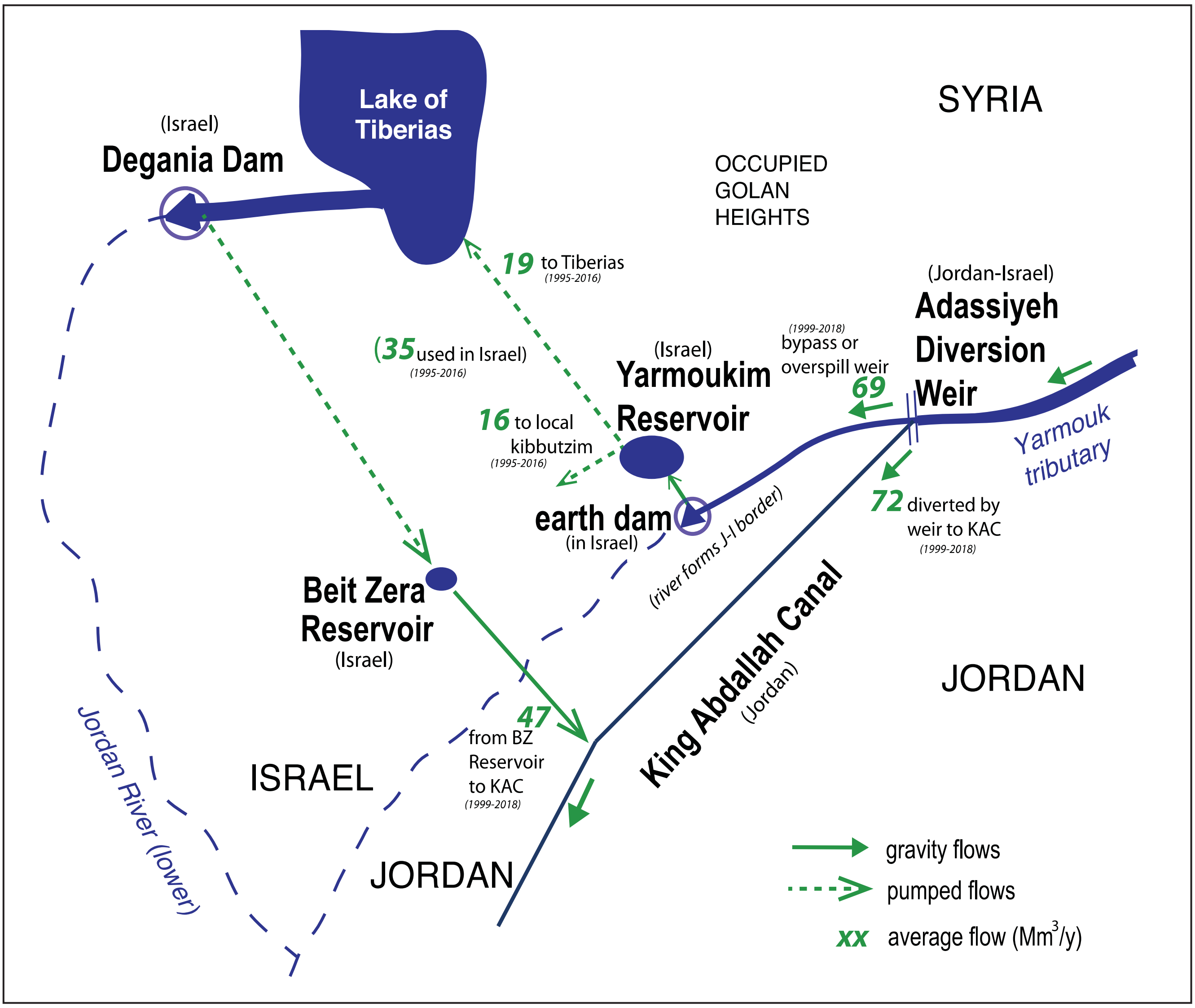


Figure 14: Water Exchange Mechanism for Yarmouk River and Quantities exchanged between Jordan and Israel (adopted from ZEITOUN et al., 2019)

The King Abdullah Canal (KAC)

The King Abdallah Canal (KAC) was built between 1961 and 1987. It is 110 km long, of which 65 km constitutes the northern and middle sections, or Upper KAC, between Adassiyeh and Deir Allah, while 45 km constitutes the southern part or Lower KAC. Water flows entirely by gravity in a concrete-lined open canal and crosses wadis and rivers by means of syphons and bridges. A SCADA system in the canal, which comprises 27 stations at 37 so-called check gates, measures water levels, but does not measure flow velocities. Also, many of the stations are not operational due to malfunctions, and flow-level rating curves at these stations were not properly calibrated (WMI, 2018). Flow in the KAC is visualized (WMIS) at the JVA Deir Allah Control Center, which was established in 1995.

While there is an exchange in flows between the Jordan Valley side wadis and the King Abdullah Canal (see Figures 15-16), many of these are not implemented in practice. The Wadi Arab dam acts as a buffer and receives water from the KAC when there is excess water, particularly in winter. Water from the Wadi Arab dam should return to KAC during summer, but this has not been the case since 2018, due to contamination of the Wadi Arab dam by wastewater.

Further details about water distribution in the Jordan Valley are given in ANNEX 4. The following rivers/wadis cross the King Abdullah canal and are fully used for irrigation (north to south; Figure 15, Figure 16); amounts used in irrigation from these wadis can only be estimated roughly, as there are no continuous flow measurements for most of them (Table 4):

Table 4: Jordan Valley Side Wadi Catchments and Potential Runoff

Code	Name	Catchment size [km²]	Average precipitation in catchment [mm/yr]	Precipitation volume [MCM/yr]	Runoff estimated (15%) [MCM/yr]	Runoff estimated by JVA (Seder) 1990-99(average)
AD	Yarmouk (in Jordan)	1391.5	265	368.7	55.3	
AE	Wadi Arab (Wadi Arab dam)	265.9	412	109.6	16.4	measured downstream
AC	Wadi Tayyiba	56.7	439	24.9	3.7	-
AF	Wadi Ziglab	100.1	467	46.7	7.0	7.2
AG	Wadi Jurum	21.2	409	8.7	1.3	6.3
AH	Wadi Yabis	116.6	500	58.3	8.7	3.8
AJ	Wadi Kufrinja	111.6	521	58.1	8.7	7.1
AK	Wadi Rajib	82.4	480	39.6	5.9	5.9
AL	Zarqa River	3,590.1	192	689.3	103.4	98.0
AM	Wadi Shuayb (Shuayb dam)	179.2	373	66.8	10.0	8.8
AN	Wadi Kafrein (Kafrein dam)	158.8	320	50.8	7.6	15.3
Sum / average		6074.1	398.0	1521.6	228.2	152.4

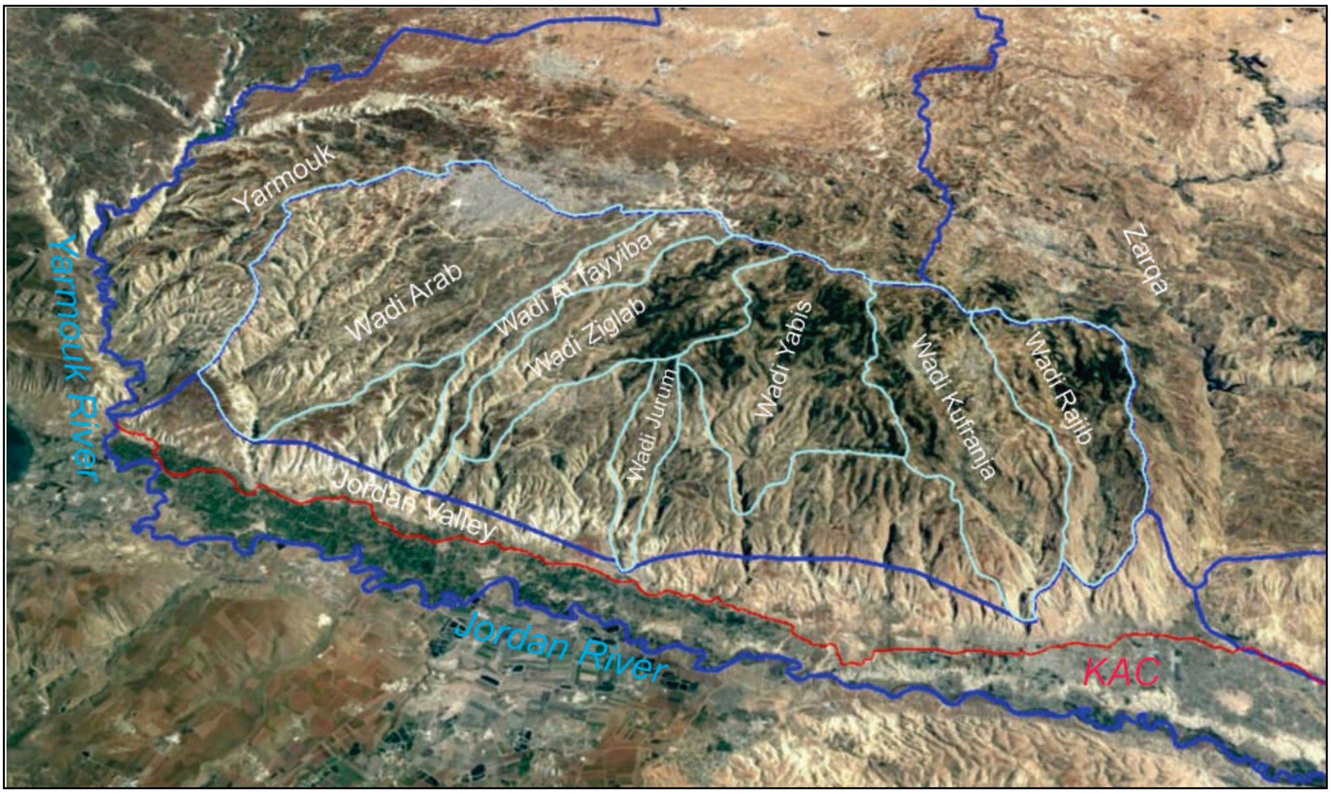


Figure 15: Northern Jordan Valley Side Wadis
Dark blue – main SW catchments; light blue – sub-catchments

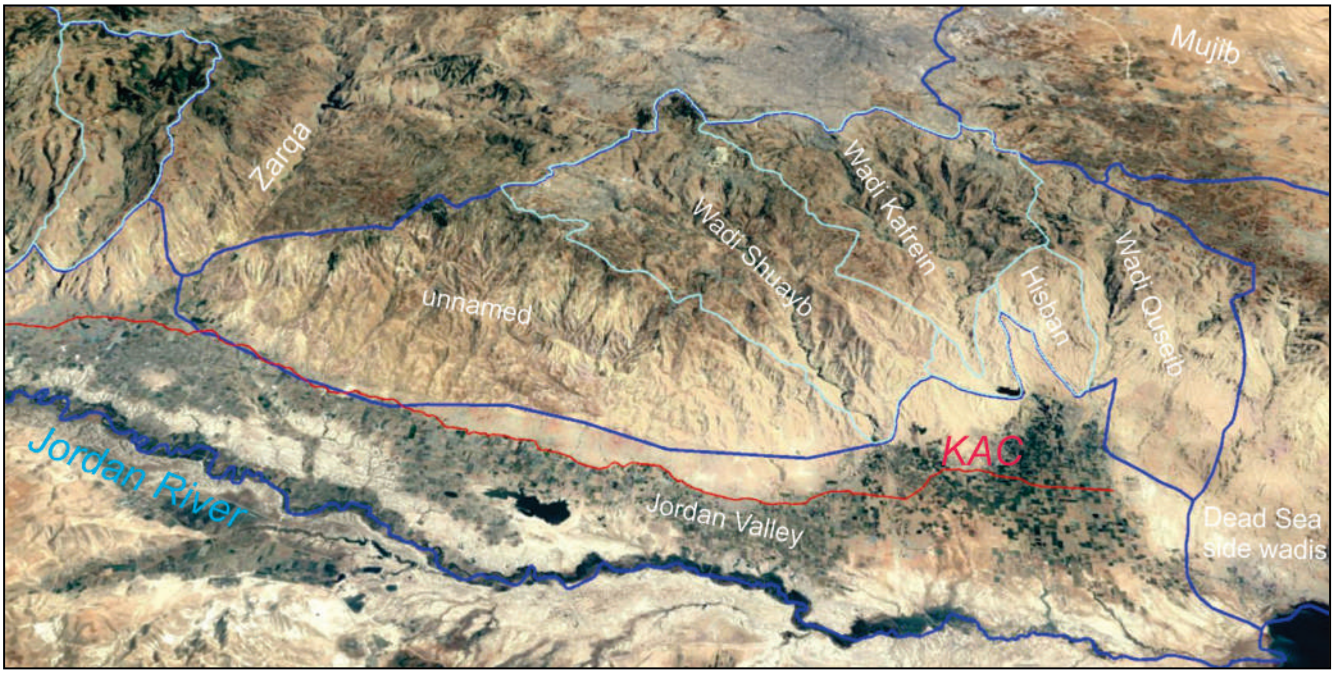


Figure 16: Southern Jordan Valley Side Wadis
Dark blue – main SW catchments; light blue – sub-catchments

The monitoring of surface water allocation for irrigation in the Jordan Valley is inadequate, and does not allow for a quantification of amounts being used in agriculture and those left for domestic purposes. This is because flow to irrigation command areas (the so-called development areas) from the 28 KAC turnouts (TO) is not measured, and flow to farm units is only estimated (for billing purposes). Moreover, the KAC has hundreds of unmonitored abstractions, including from water tankers, and leakage losses from the KAC are not regularly quantified through flow measurements. In 2017 (between July and October), the USAID project WMI (WMI, 2018) quantified losses, thefts and evaporation through one-time spot measurements at ~25.4% or ~40 MCM/yr (Table 5, Figure 17). Losses in the distribution network are even more significant.

Improvements in the water flow and quality monitoring system in the Jordan Valley and the KAC, and the outflow to irrigation command areas, are urgently required. The Control Center also needs to be upgraded with more recent software. A maintenance budget should be established to ensure that all elements of the system are functional for the foreseeable future.

Table 5: Quantification of Losses in King Abdullah Canal (WMI, 2018)

Year	Total Delivered to KAC (MCM)	Total Released from KAC (MCM)	Losses in KAC (MCM)	% Losses in KAC
2010	109.65	95.29	14.36	13.10%
2011	100.27	82.84	17.43	17.38%
2012	119.47	98.67	20.8	17.41%
2013	148.05	122.89	25.16	16.99%
2014	131.4	108.64	22.76	17.32%
2015	143.94	115.75	28.19	19.58%
2016	158.51	124.59	33.92	21.40%

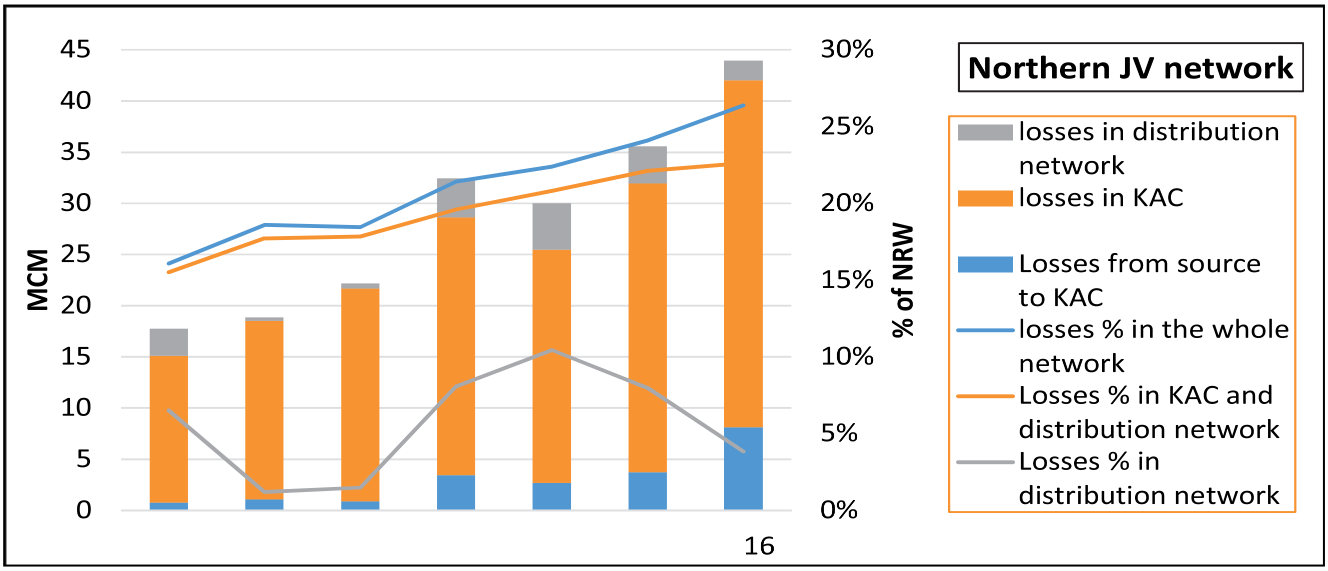


Figure 17: Losses in the Northern Jordan Valley Distribution Network by Sections (Reaches) from North to South (left to right)

Use of Surface Water from Dead Sea Side Wadis Catchments

Drinking water is also provided from the northern Dead Sea side wadis to Amman and, to a lesser extent, some villages north of Karak. This part of Amman water supply is based on surface and groundwater from the following sources:

- Mujib dam (flowing by gravity to the Dead Sea collector and from there diverted to the north, i.e. the Zara Main desalination plant and to the south, i.e. the industrial complex (potash, bromine, and magnesium companies) but recently also for irrigation
- Surface water in Mujib catchment below Mujib dam
- Groundwater discharge from Disi aquifer in Mujib and Wala catchments below Mujib and Wala dams
- Surface water in Mujib catchment below Wala dam
- Surface water and groundwater from Disi aquifer in Wadi Abu Khusheiba, and received by Dead Sea collector
- Surface water and groundwater from Disi aquifer in Wadi Zarqa Main, and received by Dead Sea collector
- Groundwater from Disi aquifer discharged at Zara Main springs, and received by Dead Sea collector

There is also inadequate monitoring of amounts and water quality from these sources. Basically, only the amount received is known. The system is highly vulnerable due to active tectonic activities near the Dead Sea and could easily be compromised. The collector is partly built on stilts, and some of these have already been affected by underground vertical displacements. Precautionary measures should therefore be taken to avoid the temporary loss of this important resource.

Actions required:

- Improvement of flow measurements at dams (inflow, outflow, evaporation, abstraction, seepage)
- Improvement of measurements of sediment accumulation in dams (siltation)
- Improvement of flow measurements at King Abdullah Canal (inflow, outflow)
- Regular cleaning of King Abdullah Canal (sediment removal twice per year; more frequent removal of garbage)
- Annual leakage loss detection measurement at King Abdullah Canal
- Repair of concrete slabs and lining at King Abdullah Canal or reconstruction as piped conveyance system
- Conduct regular technical meetings with Israeli side and Syrian side in order to achieve a just implementation of the bilateral agreements as for amount and quality of surface water received.

Lajjun Deep Well (Disi Aquifer)

3.1.4 Groundwater Resources

3.1.4.1 Renewable Groundwater Resources

Facts

Groundwater resources have been overexploited since the 1980s, i.e. more groundwater is being abstracted than is recharged to the aquifers. Climate change is causing a reduction in groundwater recharge. Water levels are rapidly declining, in some areas by up to 10 m per year and more. Exploitation costs are therefore increasing rapidly. Large areas where the aquifers were previously exploited will become dry by 2040. With increasing depletion of the aquifers, production from groundwater will significantly decrease. Large parts of the current infrastructure for groundwater abstraction and conveyance will become obsolete. The only option to ensure water supply security in the future is the desalination of sea or brackish groundwater.
The overabstraction in many areas is also causing a change in groundwater flow. In the future, higher treatment costs will be required because brackish groundwater will increasingly move from the eastern part of the country towards the western part, which is currently the most exploited.

In the past, the term Groundwater Basin was widely used. This term comes from the 1960s and referred to the then known groundwater flow in the uppermost mainly used aquifer, mostly the A7/B2. Since then the groundwater flow and exploitation has entirely change. More importantly the understanding about the entire aquifer system has much improved. The use of this term is not useful anymore, because a) all aquifers are interconnected, and leakage takes place across aquifers and b) the flow pattern has fully changed. In Jordan there is only one Groundwater Basin because all groundwater flows towards the lowest point, the Dead Sea. Also, at international level this term is not used since many decades.

3.1.4.1.1 Available Groundwater Resources

The first Water Master Plan (NRA & GTZ, 1977) assumed an average annual groundwater recharge of 580 MCM/yr. It stated that 220 MCM/yr should be a reasonable amount of exploitation (~40%). However, this amount was not based on accurate hydrogeological information as such was not available at the time. The first thorough assessment of the geological structure, which formed the basis for the Second Water Master Plan (MWI & GTZ, 2004), was done in the framework of the groundwater resources assessments, with support from BGR (Groundwater Resources Assessment South Jordan: 1986-1990; Groundwater Resources Assessment North Jordan: 1992-1996).

This assessment estimated groundwater recharge at 280 MCM/yr, based on the analysis of early development springflow and baseflow data (MARGANE et al., 2002). This is approx. equivalent to the amount that was introduced in the mid-1980s by WAJ as the "safe yield" (277 MCM/yr). However, already in the early 1990s, groundwater abstraction was at around 500 MCM/yr and the groundwater deficit in Jordan had already reached approx. 230 MCM/yr in 1995 (MARGANE et al., 2002; Table 7; Figure 18). At that time abstraction from private wells was estimated rather than measured, based on the initial yield of licensed wells and assumed average pumping hours. Farmers were not forced to allow flow meters to be installed until 1994.

A new attempt to assess (the depletion of) groundwater resources had been done again with support of BGR between 2015 and 2018 (I-GWRM and GWRM projects). However, it must be stated that hydrogeological and operational data availability have significantly decreased since the early 1990s, so that this assessment is more based on estimations, compared to the previous one. Although huge efforts have been made since around 2006 to modernize the monitoring network, the data situation has actually deteriorated since less and less effort is being made to measure and record static and dynamic water levels, discharge of springs and wells, water flows, and electricity consumption. This hinders any evaluation of the status (decline) of water resources, and has negative consequences for future exploitability. The recent evaluation of groundwater levels has shown that there has been a drop of 50-170m in the most exploited part of the main aquifer, the A7/B2, between 1995 and 2017 (BGR assessment 2018 and subsequent GIZ assessment, presented in this report). Monitoring wells show that the drop in the water level has gotten worse over the past 5-10 years. In many areas the dynamic water level is already below 350 m bgl, and so exploitation has largely become uneconomical.

On the other hand, groundwater exploitation for public water supply is not optimally organized. Most wellfields are not located in areas with low depths to groundwater (low pumping lift) and low drilling depths. The provision of water supply infrastructure is rarely planned properly and is usually in reaction to shortfall of supply or dried up wells. Hydrogeological and operational conditions are often not taken into consideration. The hydrogeological planning of the water supply must therefore be given more priority.

Estimations of groundwater abstraction from private wells, based on remote sensing data and comparisons with observed storage losses in the aquifer in recent years, show that groundwater abstraction is actually much higher than previously reported. According to the Water Strategy (MWI, 2016), total groundwater discharge in 2014 was about 860 MCM. In this assessment groundwater abstraction was 225 MCM/yr more than in the conventional assumption from the WAJ Groundwater Basin Directorate. This means that in total **about three times as much groundwater is abstracted as is being recharged**. This high overabstraction explains the strong decline in water levels in recent years in the aquifers. USAID conducted several remote sensing assessments in the framework of the ISSP and WMI projects between 2014 and 2019. This update will be scaled up to the entire country with the support of GIZ in the NWMP-3.

3.1.4.1.2 Groundwater Recharge (GWR)

A first estimation of groundwater recharge in Jordan was developed by the Investigation of the Sandstone Aquifers of East Jordan project (UNDP, 1966), which indicated a GWR of around 336 MCM/yr. However, at the time, the groundwater system was poorly understood.

In the framework of the BGR project Groundwater Resources of Northern Jordan, MARGANE et al. (2002) quantified recharge as **280 MCM/yr**. This assessment was based on the analysis of baseflow and springflow data, focusing on the pre-development period before 1970. Based on geology (infiltration capacity) and rainfall a map of spatial distribution of groundwater recharge was prepared (modified after KUISI et al., 2014; Figure 19). It is based on observed percentages of recharge in the different geological units and selected catchments (MARGANE & HOBLER, 2001) In the current study, this method was applied across the whole of Jordan using observed approximate infiltration rates, as listed in Table 6. From previous assessments in defined catchments/areas, groundwater recharge is known to be relatively high in basalt, due to high porosity, and in A7/B2, which is predominantly fractured limestone (porosity ~ 4-5%). Infiltration was assumed to be less in B4 limestone, due to lower degree of fracturation and in A1/6 due to the mix of limestones and marls; similarly, GWR is lower in the Kurnub sandstone. Recharge in all areas receiving rainfall of less than 75 mm/yr was set to zero. Total groundwater recharge is 277 MCM/yr, using the 30-years average rainfall of water years 1984/85 – 2013/14 (BGR, 2017). The resulting map is the first attempt to transfer the previous findings into a spatial distribution (Figure 19).

Table 6: Assumed Groundwater Recharge (GWR) Percentages for Geological Units and overall GWR

Geological Unit at Outcrop	Percentage of Rainfall	Area [km]	GWR
Alluvium	0	2518	
Basalt	10	11679	42
B4	5	37552	17
B3	0	10652	
A7/B2	10	12264	180
A1/6	5	2234	28
Kurnub	5	2987	10
Zarqa	0	128	
Khreim	0	2922	
Rum	0	3430	
Basement Complex	0	2171	
Total			**277**

Figure 18 shows the water balance established in 1995 (MARGANE et al., 2002).

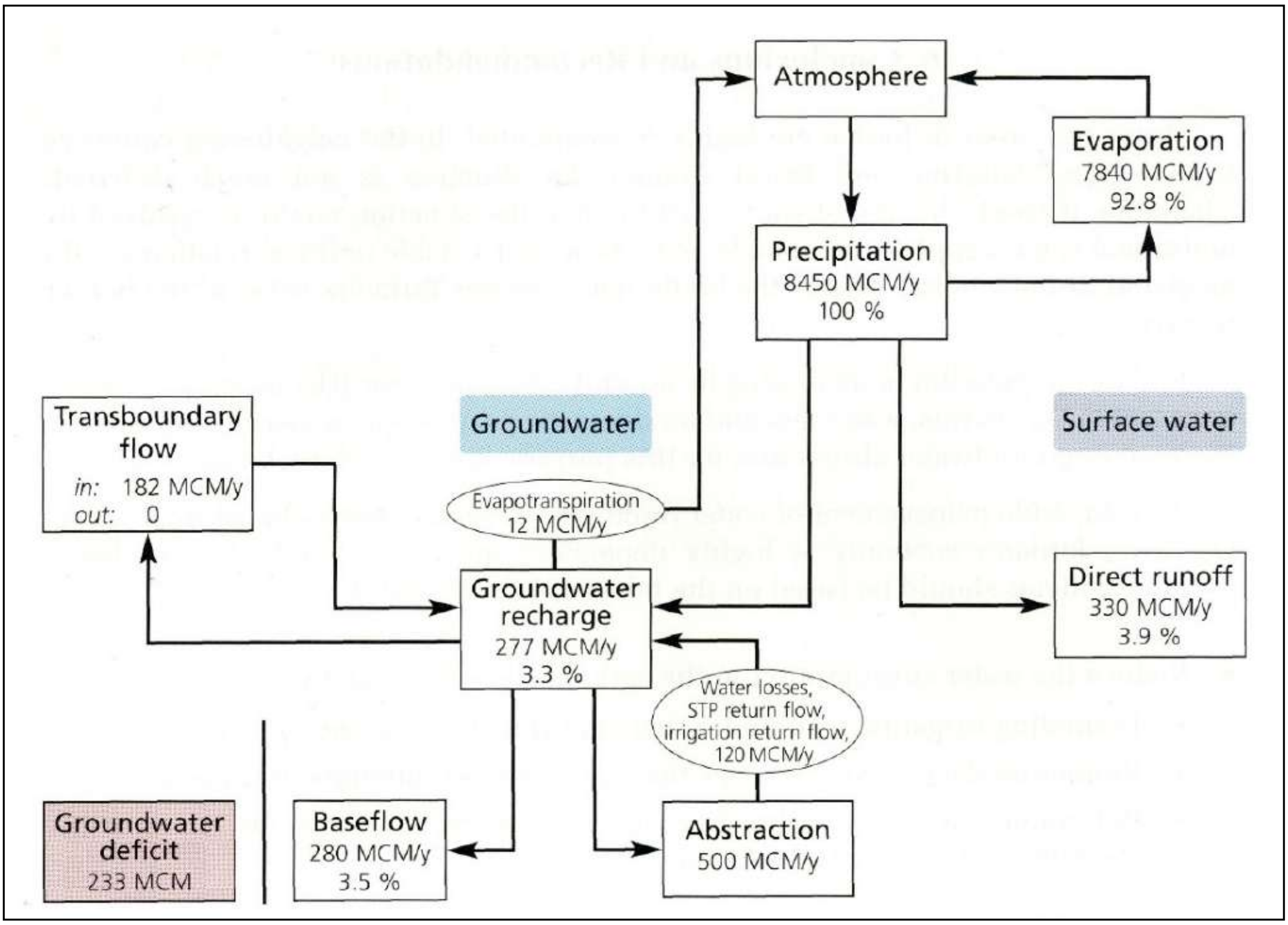


Figure 18: Water Balance 1995 (MARGANE et al., 2002)

Table 7: Groundwater Balance 1995 (MARGANE et al., 2002)

Balance component	Amount (MCM)
Groundwater abstraction	500
Spring abstraction	20
Baseflow	280
Trans-boundary flow (out)	-
Evapotranspiration (mostly Azarq)	12
Totale (out)	812
Groundwater recharge	277
Trans- boundary flow (in) (from Syria and Saudi Arabia)	182
Inflow from irrigation return flow,water losses and return flow from STPs	120
Total (in)	579
Balance (deficit)	**-233**

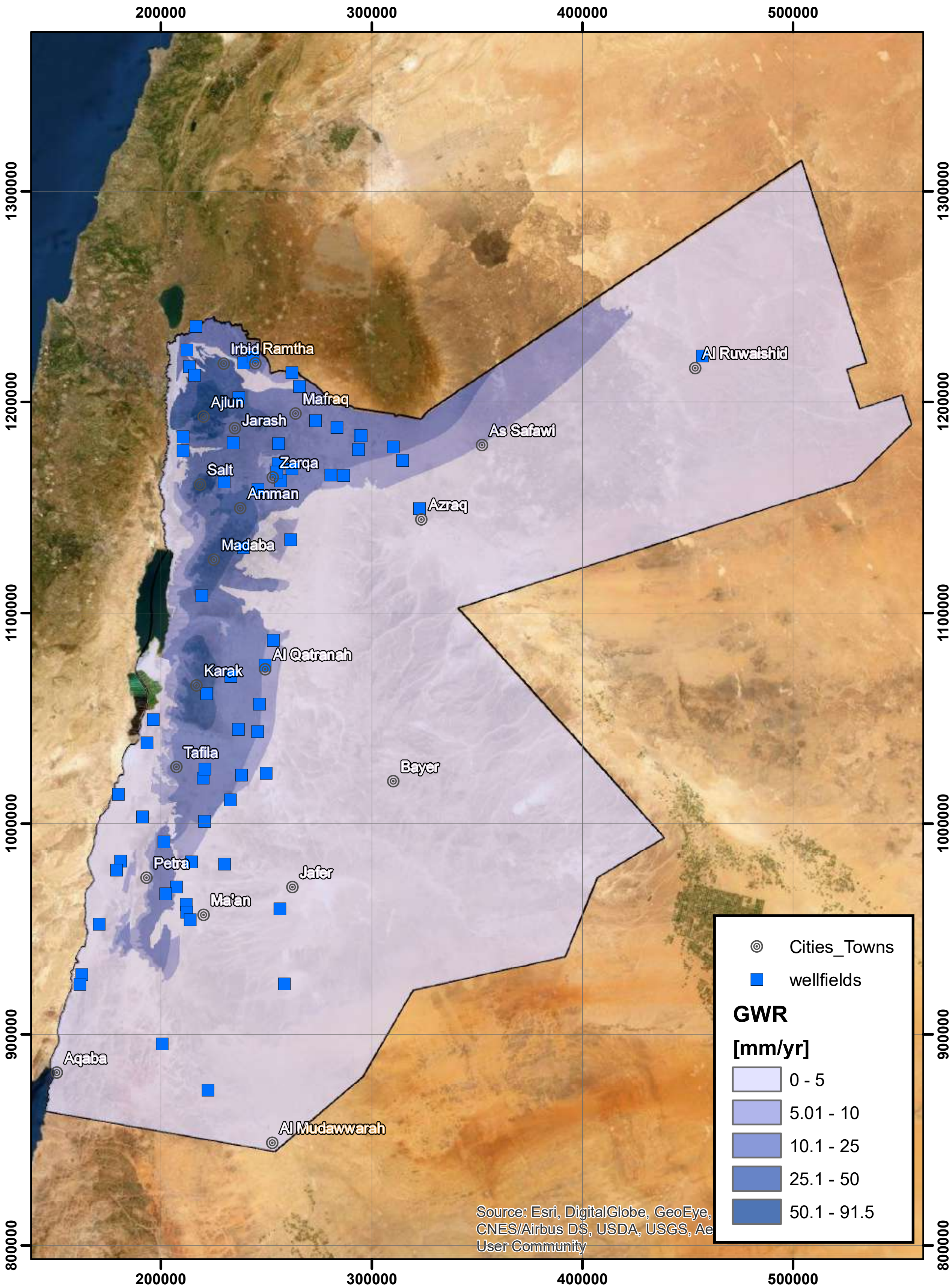


Figure 19: Regional Distribution of Groundwater Recharge

3.1.4.1.3 Groundwater Flow

Groundwater flow in 1995 was evaluated by the project Groundwater Resources of Northern Jordan (MARGANE & HOBLER, 2001; Figure 20).

Due to high overabstraction (approx. 3 times the amount of recharge) a dramatic water level decline has been observed over the past 20 years. This was first noticed in the most heavily exploited part of the A7/B2 aquifer E of Mafraq (MARGANE et al., 2014). In this area the direction of groundwater flow had dramatically changed as the water levels, in particular in the western part had strongly declined (Figure 21). During the wellfield management activities (BGR I-GWRM project 2015-2018), it was noticed that in Wadi Al Arab wellfield dynamic water levels had declined since around 2009 by ~10 m/yr (QADI et al, 2017).

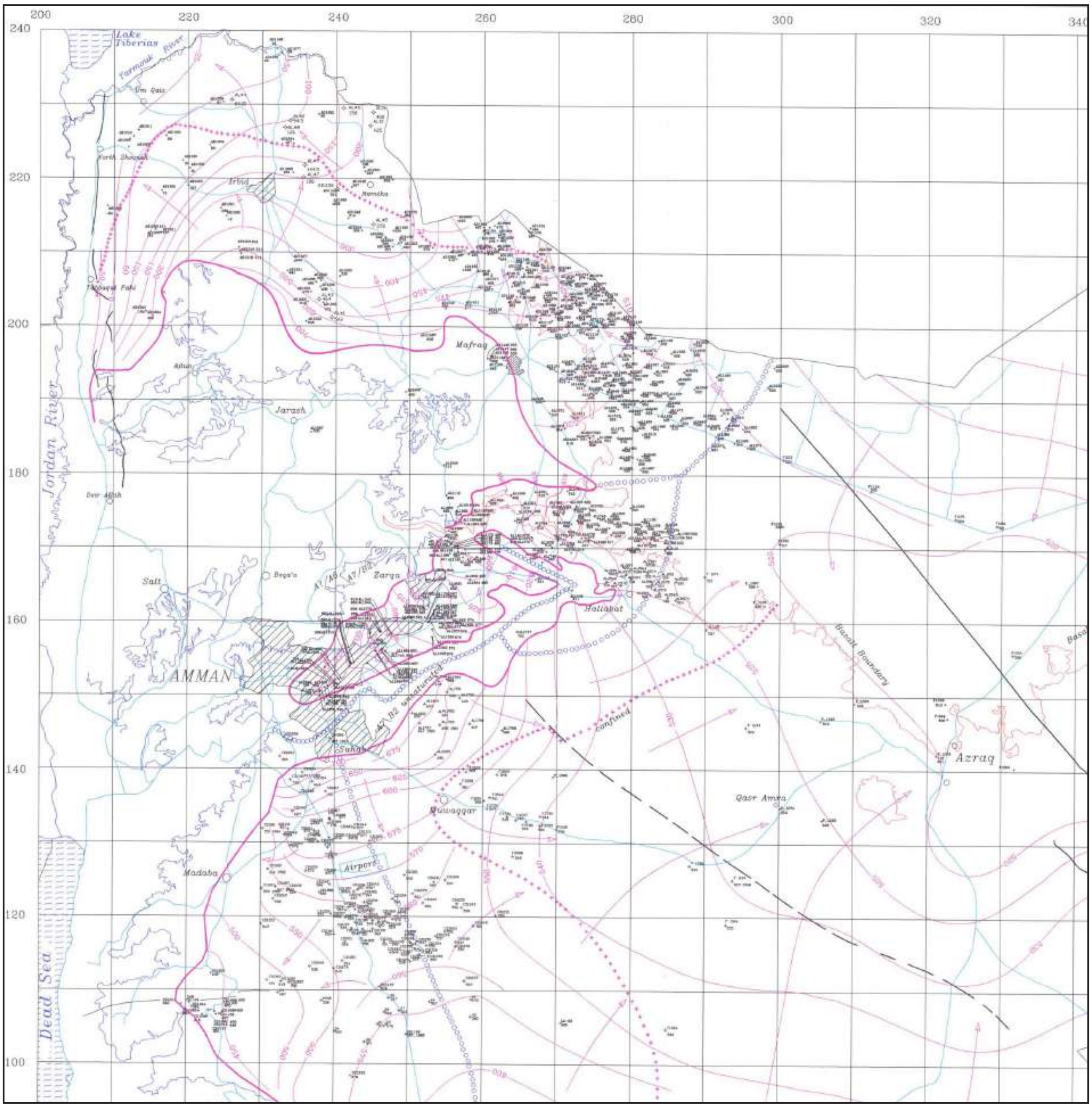


Figure 20: Groundwater Contour Map of A7/B2 Aquifer for 1995 (detail; MARGANE & HOBLER, 2001)

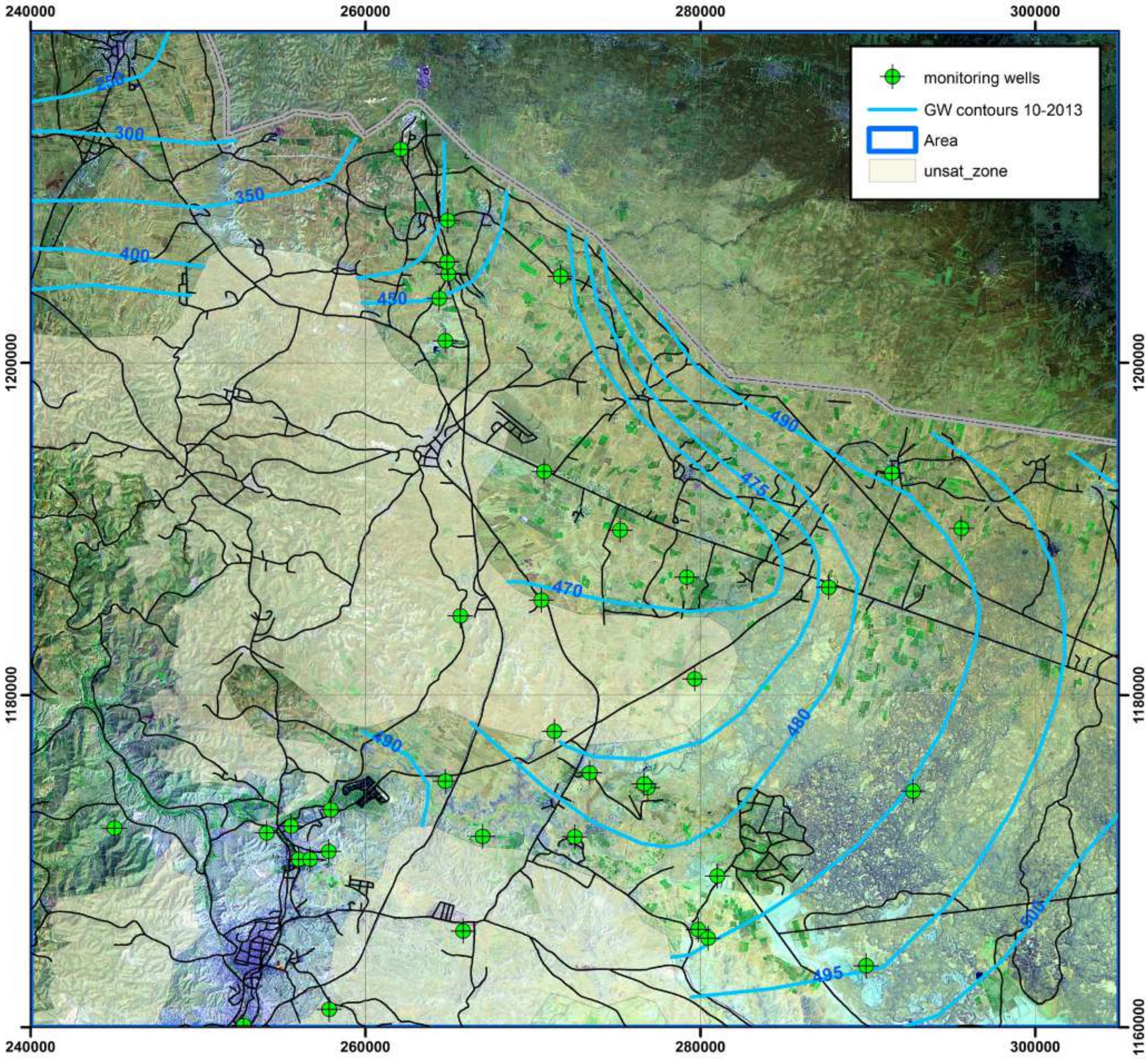


Figure 21: Groundwater Contour Map of A7/B2 Aquifer for October 2013 (MARGANE et al., 2014)
Note previous drainage to Zarqa River in Figure 20, now all water drained to Yarmouk River

BGR (2018) later prepared an updated groundwater contour map of the A7/B2 aquifer (and others) for the entire country in the framework of the Groundwater Resources Management-2 project, which was slightly modified in 2019. However, this was based on insufficient water level data between 2012 and 2017 (229), and lacked the necessary corrections for a) local long-term trends to a specific reference date and b) seasonal fluctuations, as were calculated by MARGANE et al. (2014) (Figure 22). Instead of using a specific reference date, the BGR (2018) used all water levels obtained between 2012 and 2017 without corrections. Therefore, for this Rapid Assessment, the A7/B2 groundwater contour map was reassessed and referenced to a specific reference date, namely 31 October 2018 (Figure 25), adding actual water levels from CCTV scans and private well rehabilitations, pumping tests, new wells drilled, etc. (in total 514 points or more than double those used by BGR).

The BGR map is also problematic for many other reasons. For example, it shows water in areas where the aquifer is dry (Figure 23, area between Karak and Madaba), and suggests that in some places the water level is above land surface (Wadi Mujib, Wadi Hasa). Near Tafila, the groundwater contour passes through an unsaturated area. The aquifer is shown as saturated in places where there can be no groundwater (e.g. around Madaba). The contour lines are very unevenly spaced so that gradients would have extreme changes over short distances (e.g. Maan area), which seems highly unlikely. The new map uses the geological structure updated in 2017, while the BGR map uses the old (1995) geological structure.

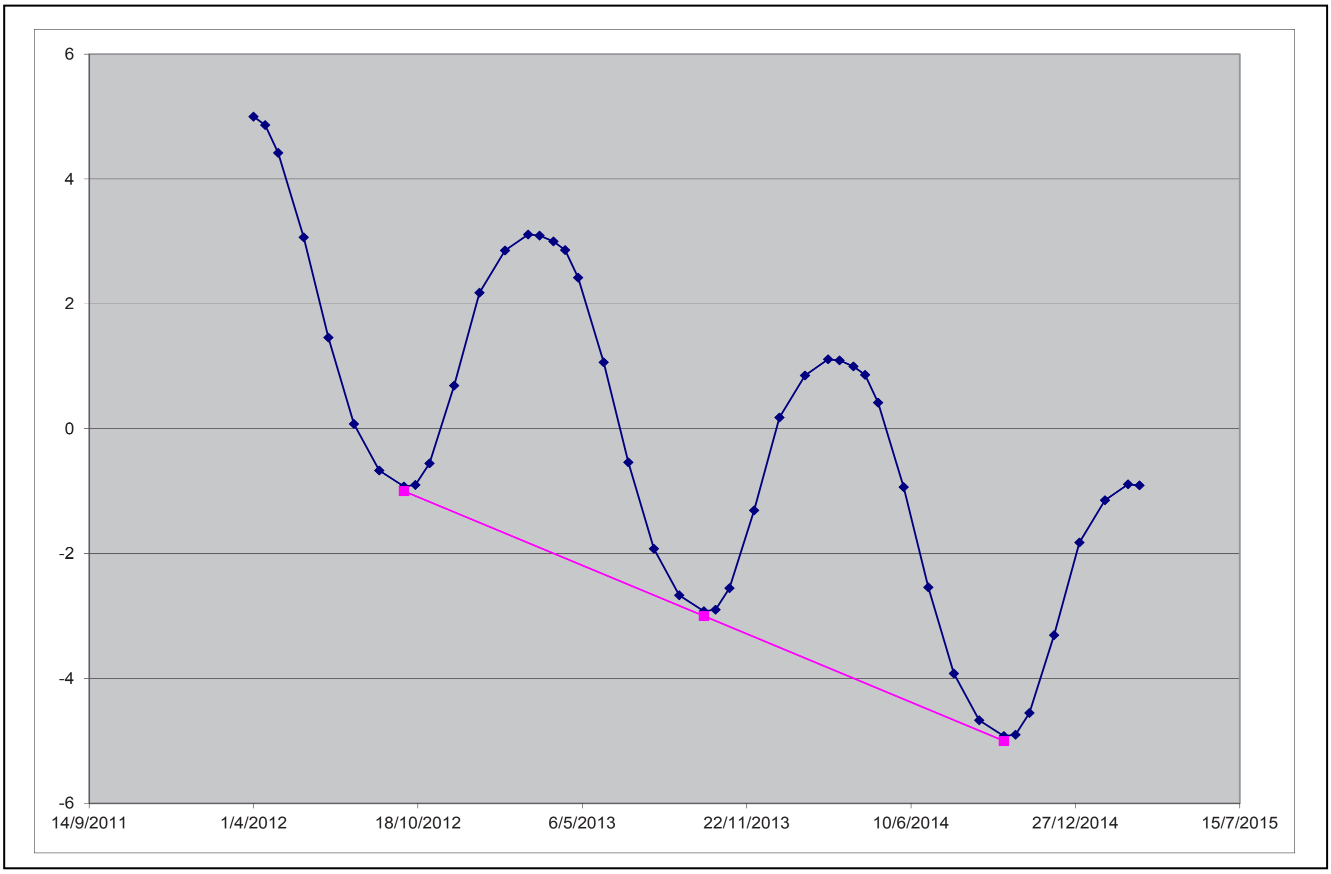


Figure 22: Approach for Correction of Water Levels not Measured at the same Time a) for long-term trend and b) for seasonal variations to obtain values for a specific reference date

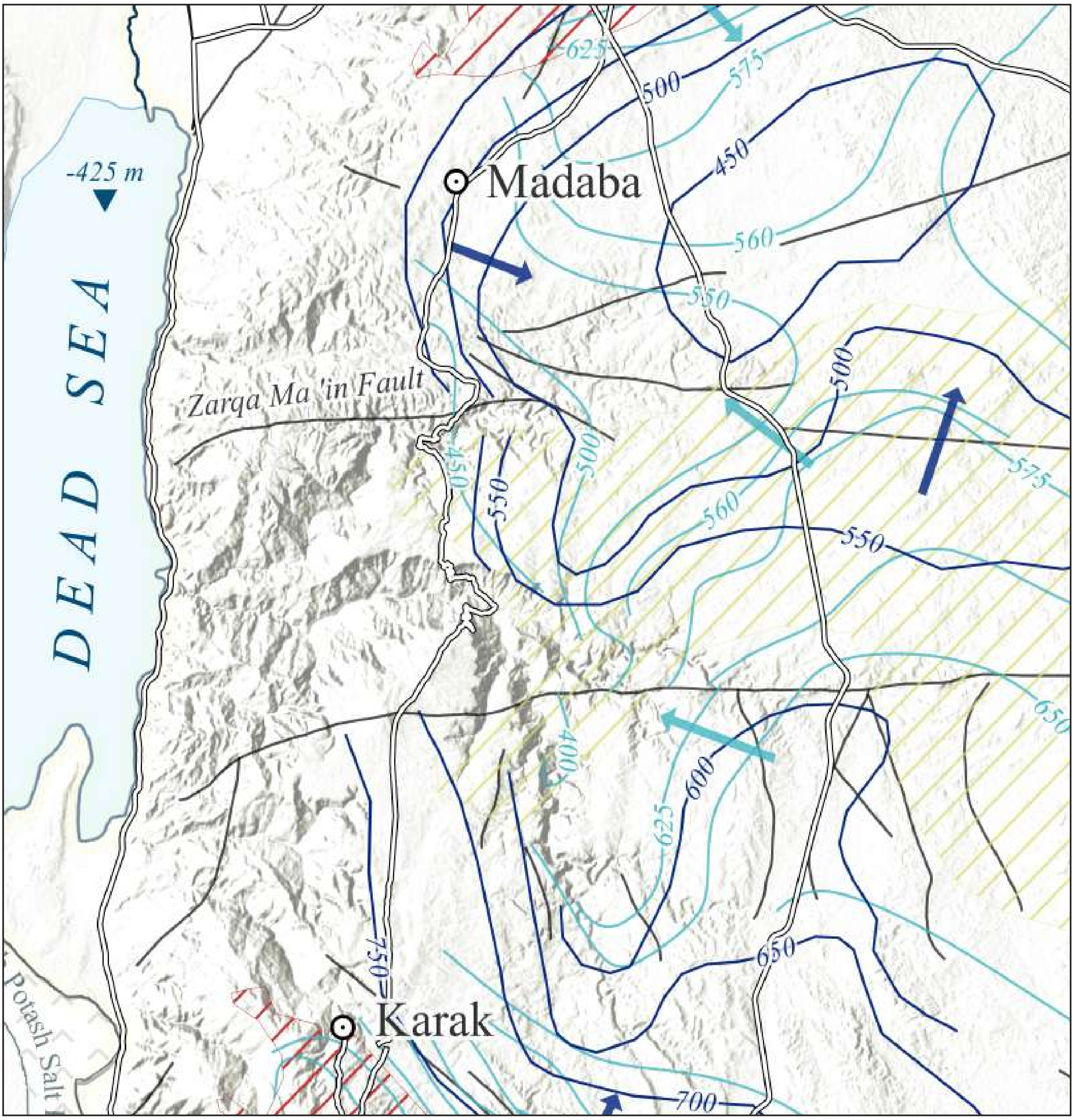


Figure 23: Detail of Groundwater Contour Map of A7/B2 Aquifer for 2017 (BGR, 2019) – Karak to Madaba area (dark blue: GW contour 2017; light blue: GW contour 1995)

The map of differences in groundwater level between the assessment in 1995 (MARGANE et al., 2001, 2002) and 2017 (BGR, 2018) shows high water level declines in particular in the northwestern part of Jordan, where water level decline over this 22-years time period reaches more than 170 m (Figure 24).

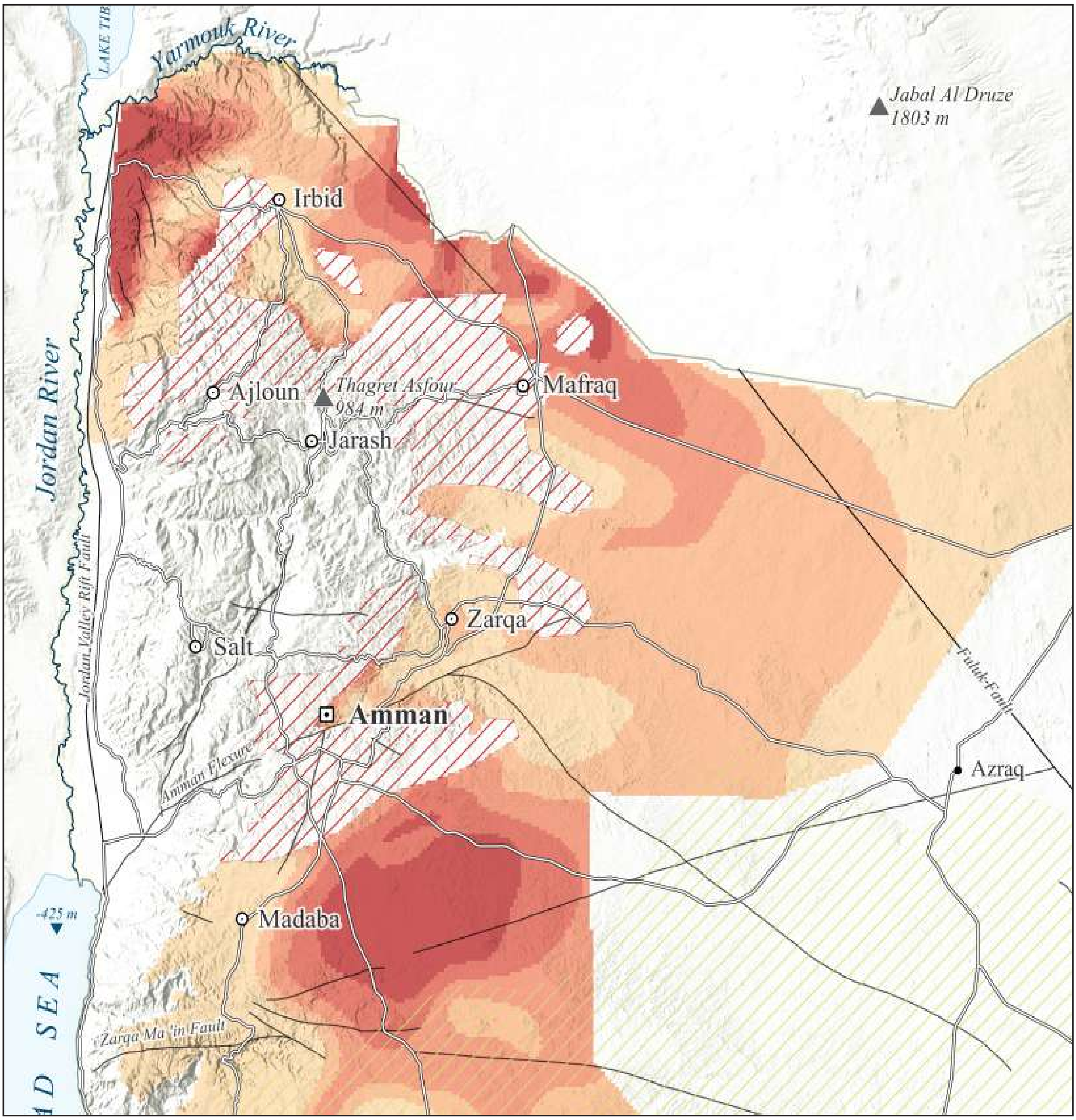


Figure 24: Detail of Groundwater Level Differences Map for A7/B2 Aquifer 1995-2017 (BGR, 2018)
(brown hatched area: unsaturated; light green hatched area: high salinity area, adopted from HOBLER et al. (2000))

The resulting groundwater level map for the A7/B2 at reference date 31/10/2018 is shown in Figure 25.

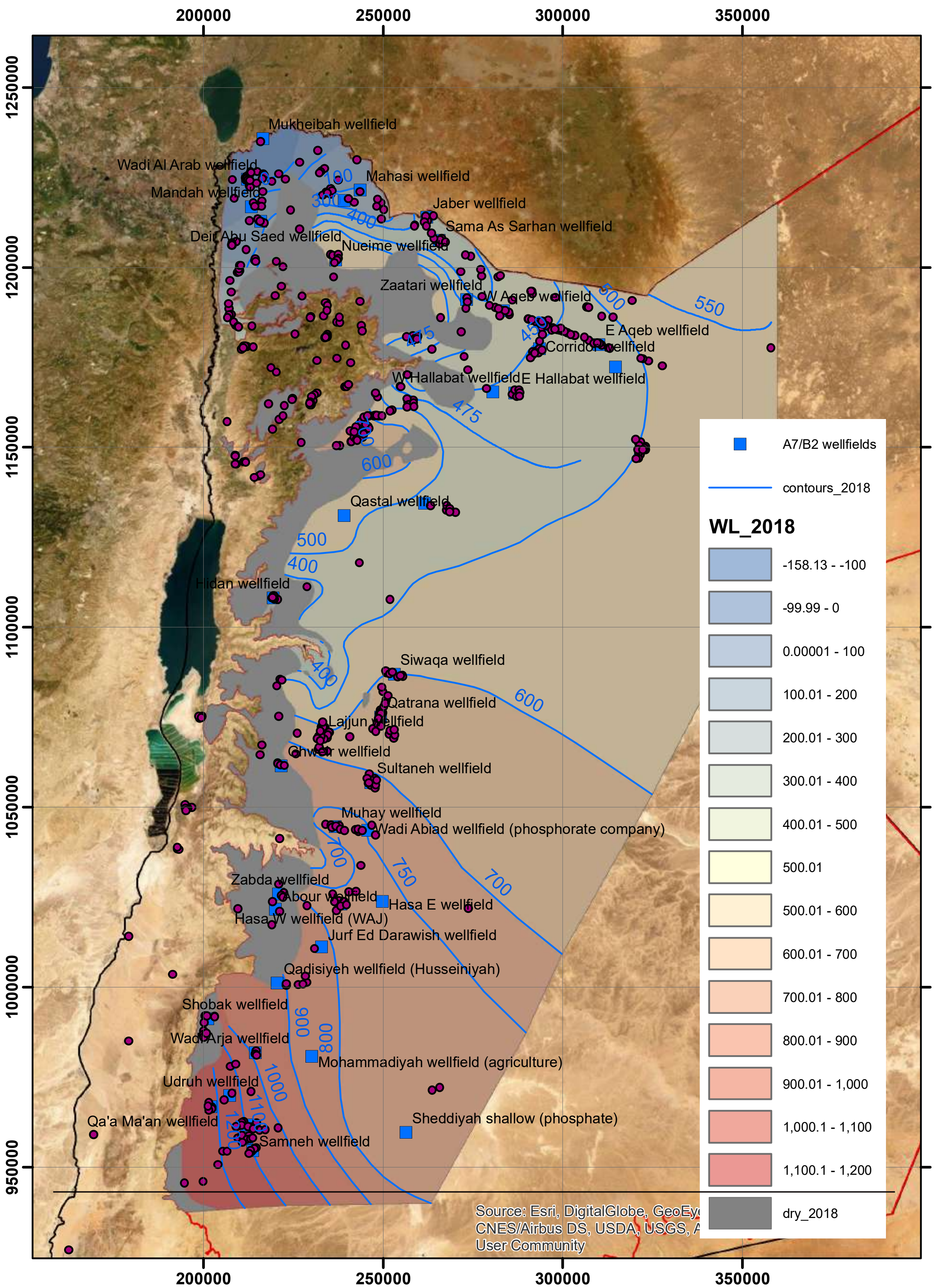


Figure 25: Groundwater Contour Map of A7/B2 Aquifer for Reference Date 31/10/2018

Actions required:

- Updates of the groundwater contour map of the A7/B2 aquifer and the Disi aquifer should be compiled every 5 years.

3.1.4.1.4 Historic Groundwater Abstraction

In 2018 **groundwater abstraction for public water supply** was: **253 MCM** from 631 governmental wells and springs. Historic abstraction from large wellfields is shown in Table 8. This does not include **groundwater abstraction** from the Disi aquifer conveyed to Amman, separately reported by DIWACO. Abstraction in 2018 from the **Dubaidib wellfield** was: **100 MCM**, as per BOT contract. From Disi water supply, no water was given to other demand centers such as Madaba, Karak, Tafila and Maan in 2019. In 2019, total water supply by DIWACO was 100 MCM, of which 12 MCM were exported to Zarqa and another 3.06 MCM to Irbid.

In 2018, the government bought 17.0 MCM for 10.0 M JOD (IMF, 2019) for domestic water supply from owners of renewable private wells, and AWC bought about 4.0 MCM from the Non-renewable wells of Rum farms.

Private groundwater abstraction for industrial use, not provided through public water supply, was: **26.7 MCM** from 192 wells.

Private groundwater abstraction for agricultural use not provided through public water supply is still in process of being reviewed through the NWMP-3 activities.

Table 8: Development of Groundwater Production [MCM] from selected Public Abstraction Schemes

Wellfield	2014	2015	2016	2017	2018
Aqeb	13.95	16.3	16.5	14.3	19.2
Wadi Al Arab	15.5	18.6	17.5	19.0	17.2
Azraq AWSA	15.9	15.8	17.9	15.6	17.1
Lajjun	5.1	5.6	5.9	5.2	5.2
Siwaqa	4.0	3.9	3.9	4.02	3.8
Qatrana	3.5	4.2	4.1	3.9	5.7
Hidan	9.4	8.9	8.7	11.1	11.0

Based on figures provided by WAJ Operations Directorate

The groundwater abstractions for different uses are further discussed in Chapter 4.1.1.

3.1.4.1.5 Exploitability of Groundwater Resources

Facts

The recent assessment of renewable groundwater resources suggests that we will lose approximately 65% of current production by 2040. The exploitable areas will shrink significantly. Future exploitation will continuously move further east. Favorable exploitation conditions will only be present in the area west and north of Azraq.

Groundwater can be exploited if conditions are favorable in terms of overall costs for abstraction, conveyance to the demand center and treatment. Costs for abstraction depend on drilling depth, pumping lift and yield. These costs are increasing due to the declining water levels.

General criteria are defined to justify the exploitation of groundwater. These pertain to the quantity and quality provided in relation to the costs of abstraction per m³. However, such criteria are not yet defined for Jordan. WAJ/MMI used the following criteria to justify the expense of rehabilitating wells (e.g. in the EEP2 KfW project):

Pumping lift should not exceed 350 m and well yield should remain above 20 m³/h for seven years after rehabilitation**, while all water quality standards must be met.**

These criteria should be used for all operational considerations to reduce energy consumption, plus stipulations that **combined pump and motor efficiency of the well should not be less than 60%** (which would require pump efficiency to be assessed at regular intervals and pumps exchanged with more suitable pumps when efficiency falls below 60%, which in many areas is around every 2-3 years, neither of which are currently happening), and that **well efficiency should be > 70%** (which can be achieved by using well screens with an open area not less than 2%; currently only 1%).

Combined pump and motor efficiency of most wells is currently about 50% (optimal efficiency is 75%). In other words, **at least 50% of energy is currently lost.**

In addition, the efficiency of most wells is currently about 50% (I-GWRM project; wellfield management plans). **This creates an average additional drawdown in the well of approximately 15m (equivalent to ~5% energy loss).**

Not all parts of an aquifer can actually be exploited. A schematic example in Figure 26. shows the exploitability of the aquifers and the exploitability through existing wells.

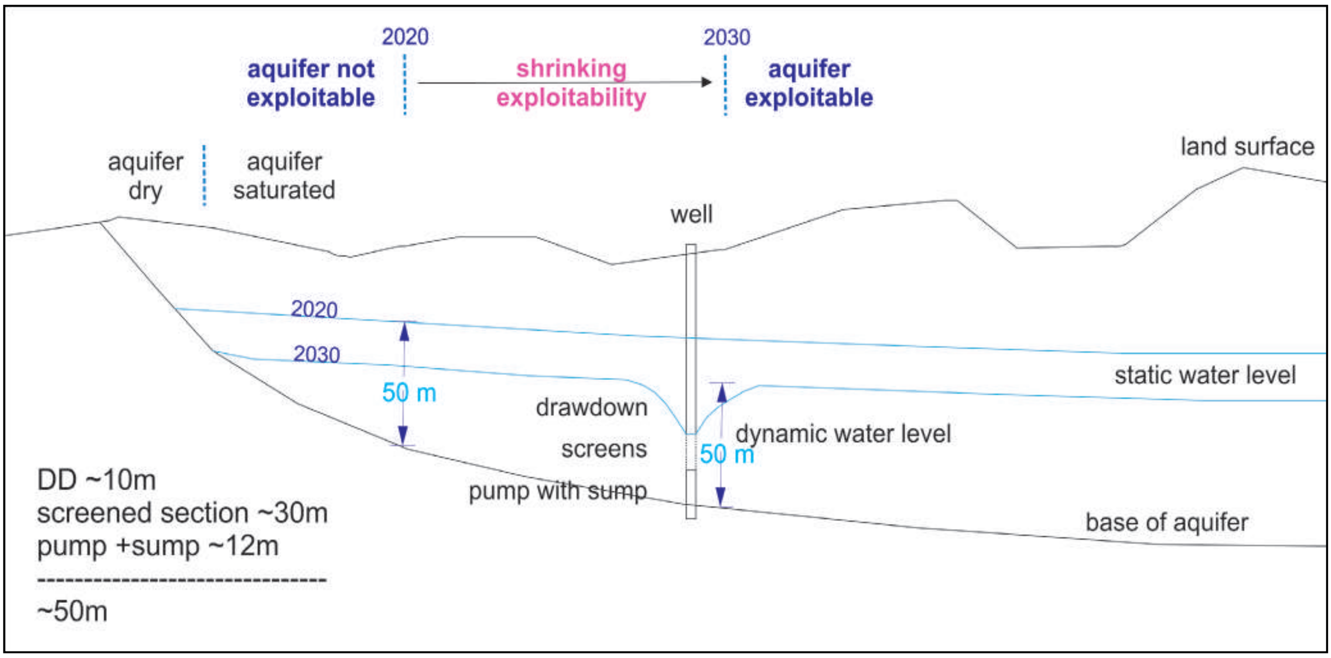


Figure 26: Minimum Requirements for Exploitability of an Aquifer (Exploitable Zone of Aquifer)

Although the A7/B2 formation is present in many parts of the country at subcrop, a large part of it is actually dry. This dry part is expanding due to drastically declining water levels. The geological units forming the A7/B2 aquifer have a thickness of up to 400 m. But groundwater in this aquifer can only be exploited where it has a minimum saturated thickness of around 50 m. This because drawdown at the well and the required length of pump and pump sump reduce the available saturated thickness. Furthermore, in order to obtain the mentioned minimum yield of 20 m^3/h, a certain screened section is required. The pump must be above this screened section because it would be damaged otherwise. It is noted that the pump should be in a plain section of the casing so that the pump would not overheat. In the absence of the required detailed data, and to allow for a harmonized approach over all the country, a length of 50 m is thus subtracted from the available base of the aquifer, as shown in Figure 26. The figure also shows the lengths used for drawdown, pump, pump sump and minimum screened section. This method was used to approximate the **exploitable zones in an aquifer** during the planning horizon 2020-2040, e.g. of the main used A7/B2 aquifer (see Figure 30, Figure 31, Figure 32).

However, most wells do, unfortunately, not reach the base of the aquifer. Therefore, many wells in the exploitable zone are actually not exploitable.

In reality, however, more than 90% of wells do not fully penetrate the aquifer, as they should. The majority only taps the upper < 100 m. Therefore, not only the extent of the exploitable zone of the aquifer (Figure 30) is of interest but also it must be evaluated which wells would become dry during the planning horizon. **Exploitability of wells** depends of the total depth in relation of the top/base of the aquifer, the pump setting and the screened sections. Furthermore, over time, in most wells actual total depth is much less than initial total depth because of pumps that have fallen into the wells, often several times, broken casings, collapsed parts of wells, etc.

Since many of these factors, such as pump settings or the length of riser pipes, are not even known at the Water Utility level (QADI et al., 2018), a more general approach had to be used. The same requirements as mentioned above are valid: a well must have a yield of at least 20 m^3/h and a saturated thickness of at least 30 m to be exploitable. A minimum drawdown of 10 m and a minimum depth of 12 m for pump and sump are assumed, i.e. it must be at least ~50 m below the static water level. Subtracting this from the known total depth of each well in the exploitable zone yields the number of wells that would still be exploitable (Figure 27).

To estimate which wells can be used until what time, and approximately how much they would produce, 50 m was deducted from their initial total depth. The corrected groundwater contour map for reference date 31/10/2018 was used to estimate both the exploitable zones of the aquifer and the actual exploitability through wells. This method was used to estimate the exploitability of wells and well yields during the planning horizon 2020-2040.

Figure 27 shows this further reduced exploitability of the aquifer through wells.

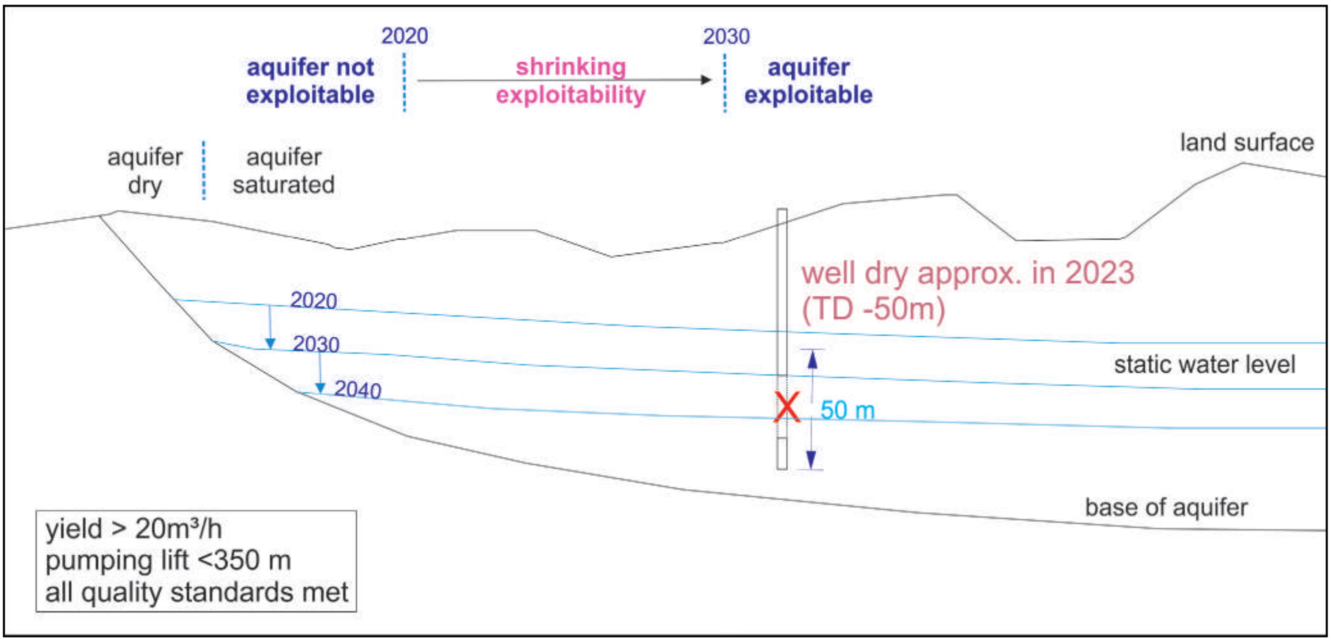


Figure 27: Shrinking Aquifer Exploitability at a Well due to Water Level Decline

What has to be borne in mind for such assessments is that all groundwater resources assessments require the continuous monitoring of a large amount of data, in particular from operation (SWL, DWL, yield, electricity consumption). In reality, only a small amount of such data is available.

In order to assess where and how much water can be extracted over the planning horizon, i.e. until 2040, it also needs to be known how the water levels will decline. Unfortunately, the current groundwater model cannot be used for this assessment, mainly because the modelled water levels do not reflect the reality. Water levels in the model are up to 60 m higher than those actually observed. Part of the problem might be that vertical permeabilities were set extremely low (e.g. 2E-8 to 2E-11 in A1/6) in the model, and it cannot reflect the true water levels at any well using the current grid spacing (2 km * 2 km).

Moreover, the dynamic water level is important for the long-term exploitability of the aquifer, not the static water level.

In order to overcome these difficulties, the following approach was used:

- The A7/B2 groundwater contour map (static water level) was updated for 31 October 2018, based on an additional 250 points of water level data (i.e. approx. double of what was used before, derived from various sources (GREEN SAHARA, 2019).
- The observed local water level decline rates were used to estimate the water levels over the planning horizon, i.e. in 2025, 2030, 2035 and 2040. This considered the dynamic water levels (10 m), a minimum saturated and screened section of the aquifer (30 m) above the pump and a required distance from the base of aquifer for the pump setting (12 m) in the plain casing in order to allow for an abstraction of at least 20 m^3/h. Overall a minimum thickness of ~50 m of the saturated aquifer is required (based on static water level) in order to be able to exploit it.

Actions required

- Pump and well efficiencies could be increased with comparatively little effort, which could save 50% of the current energy consumption of groundwater abstraction.
- The operators need to collect static and dynamic water level measurements at least once a year for the required pump specifications to be determined.
- Well designs should be changed so that wells fully penetrate the aquifer and screens have at least a 2% open area.

3.1.4.1.6 Water Level Decline Rates and Future Exploitability of the A7/B2 Aquifer

Although large investments were made to upgrade the groundwater level monitoring network through a related KfW project (HSSP, 2019), which was implemented by Dornier between 2014-19, the status of the network is worse than ever. Data from many stations are doubtful, especially since only few manual measurements have been made since this upgrade. For the A7/B2 aquifer, these data could therefore not be used. Instead, the declines from the groundwater difference map of BGR (2018), i.e. the difference between water levels in 1995 and 2017, was used as a minimum decline rate. The decline rates shown in Figure 28 were applied as linear declines over time. However, this might not be the case, since water level declines should principally increase with increasing aquifer depletion. In the absence of a functioning groundwater model that might have been used for such a purpose, this was the only reliable means. This decline map focuses on wellfields where water level declines are better known. Wells with multiple water level observations over time were used to correct the decline map.

Based on these declines, the approximated groundwater contour map of 2040 is shown in Figure 29. Although this map is tentative, it is currently the best means for approximation. **The map shows that the dried-up zone will have drastically increased by 2040. The actually exploitable zone will be even much smaller** (Figure 30). At the same time, **the saturated thickness will drastically decrease** (Figure 31) and the **pumping lift will increase, by on average 100 m** (Figure 32). In many areas it will result in pumping from more than 350-400 m and thus be principally uneconomic.

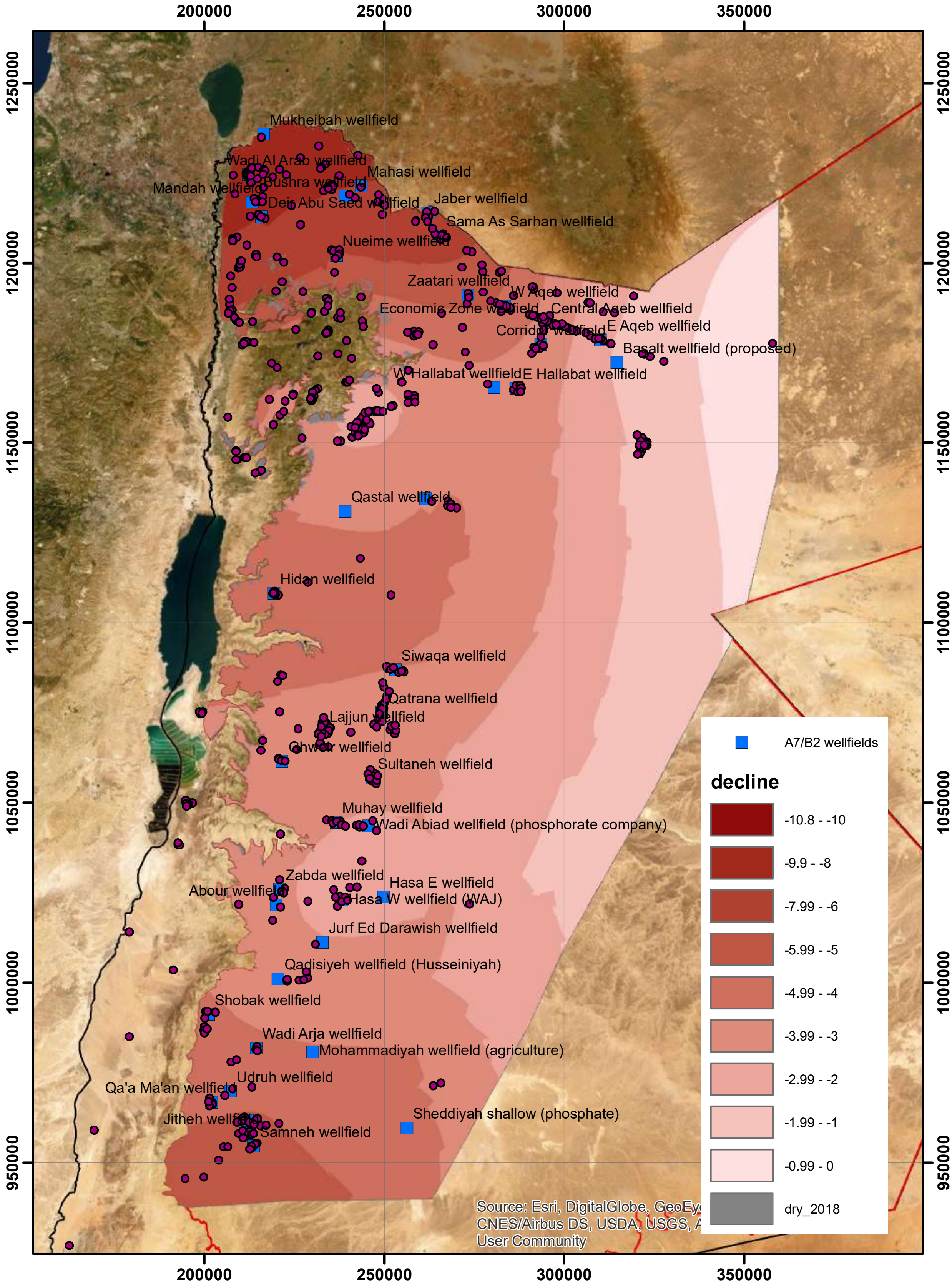


Figure 28: Water Level Decline Rates

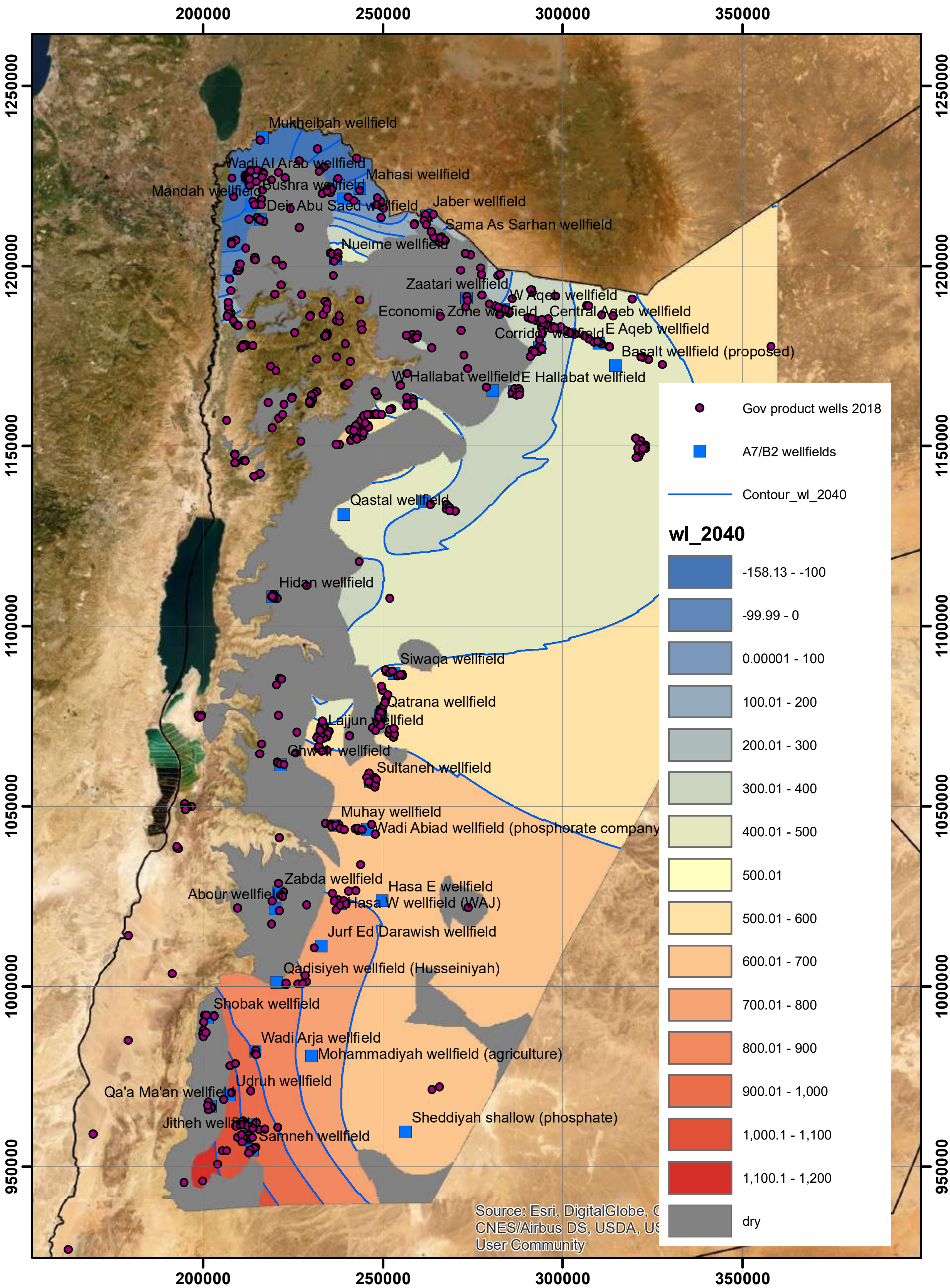


Figure 29: Tentative Groundwater Contour Map of A7/B2 Aquifer for 2040

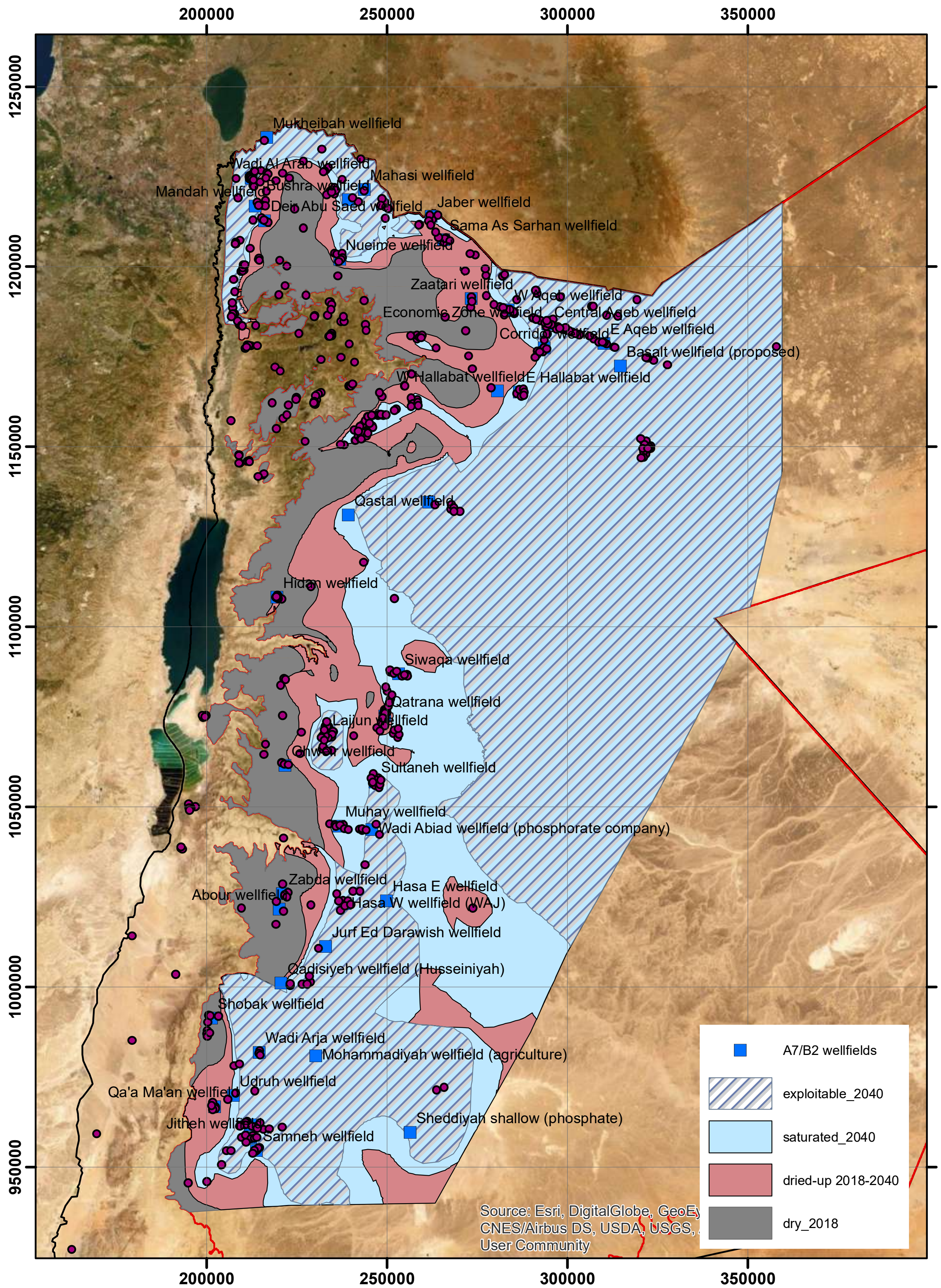


Figure 30: Tentative Exploitable Zone of A7/B2 Aquifer in 2040

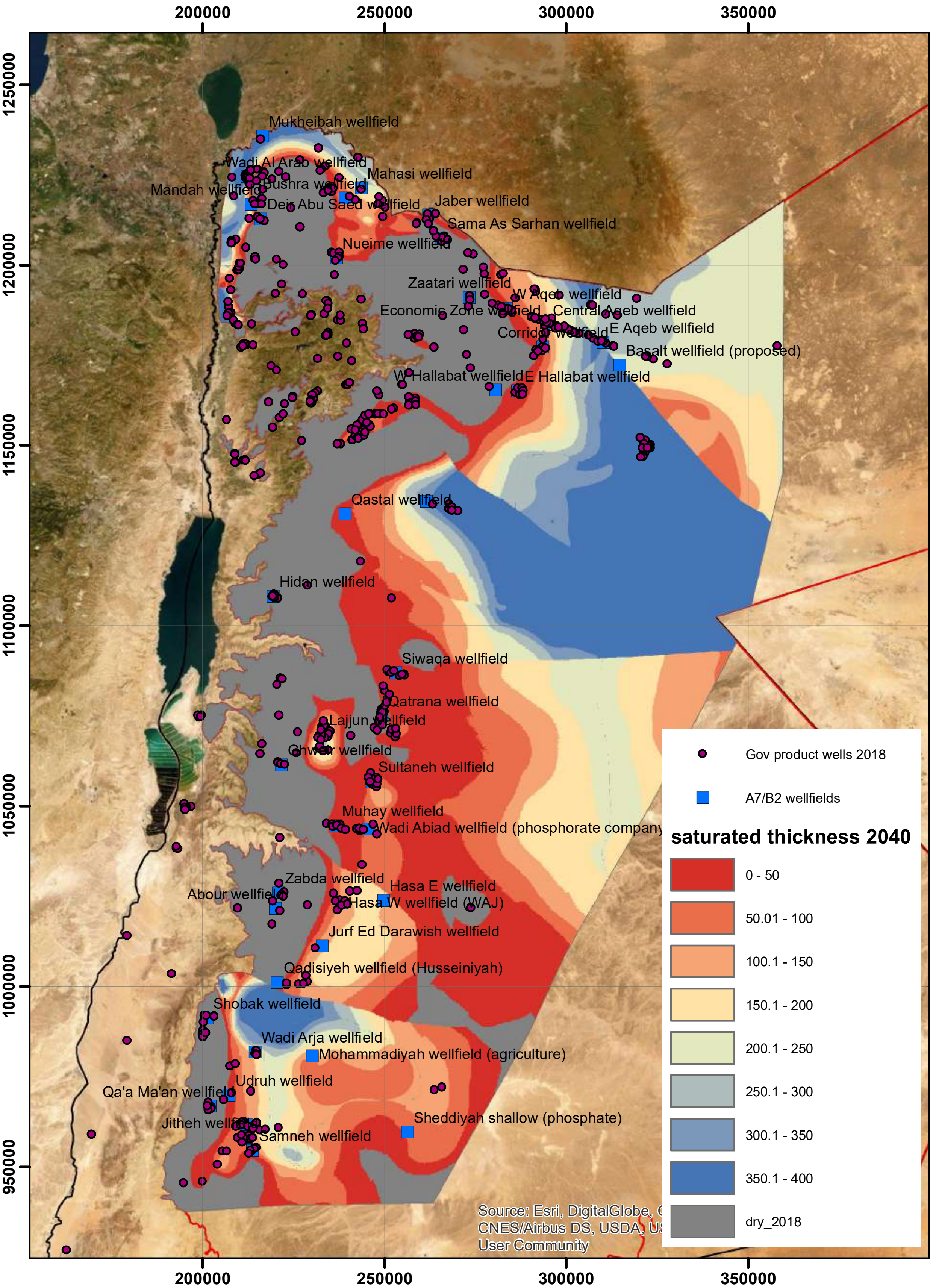


Figure 31: Tentative Distribution of Saturated Thicknesses of A7/B2 Aquifer in 2040

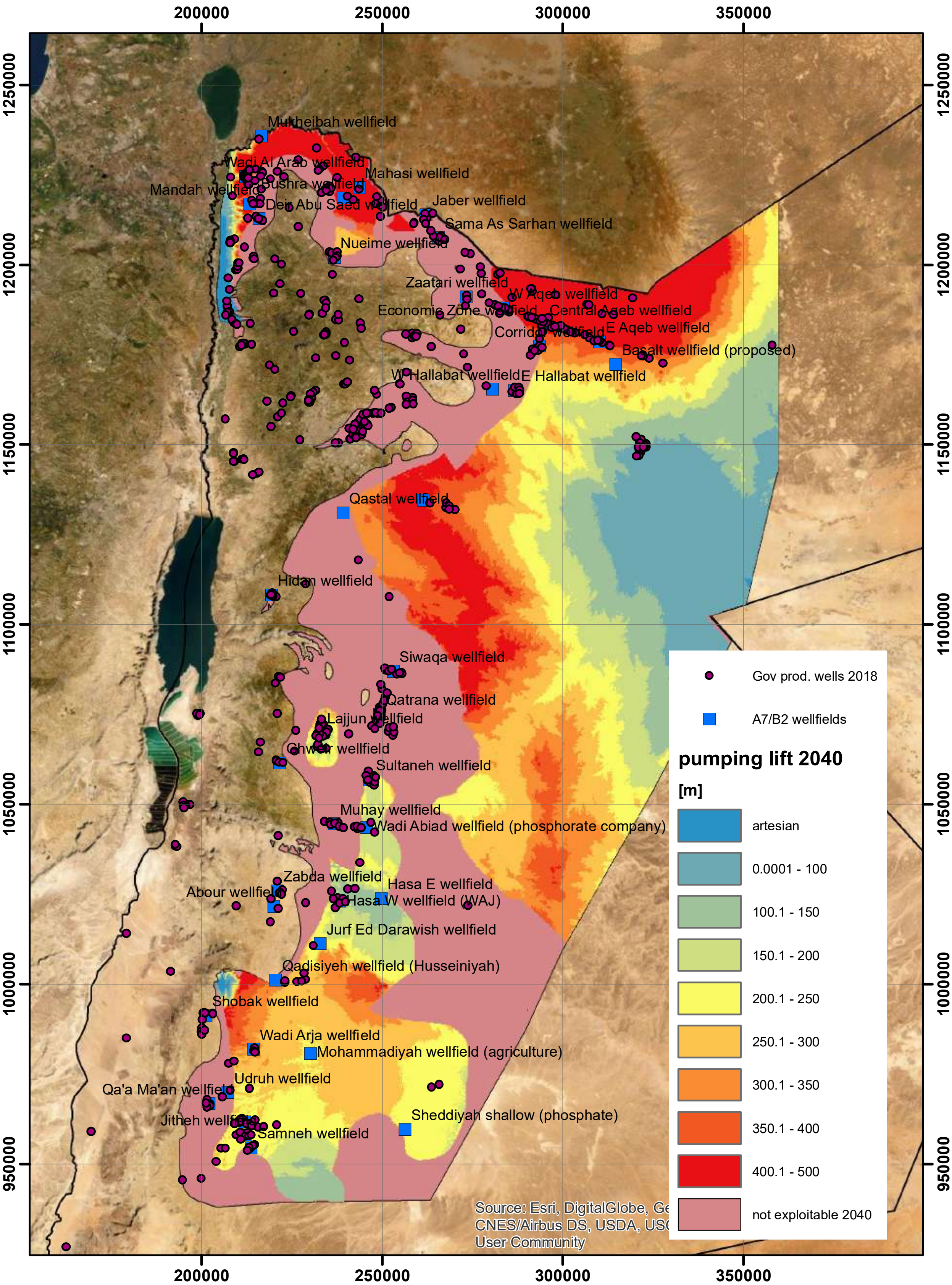


Figure 32: Tentative Distribution of Pumping Lift in A7/B2 Aquifer in 2040

3.1.4.1.7 Estimated Future Groundwater Abstraction

In 2040, about 43% of wells, currently exploiting the A7/B2 aquifer, will be in the non-exploitable zone. Many wells in the exploitable zone will be dry before. Although there is a possibility that some of these can be deepened, the cost will be high, as drilling depths will also increase. Furthermore, with decreasing saturated thickness, the yields will decline below yields justifying abstraction (>20 m^3/h). It is estimated that this will affect at least another 30% of wells. **Production from the A7/B2 would decrease from around 163 MCM in 2018 to around 24 MCM in 2040.**

The approximations of water level decline and exploitability were also applied to other aquifers.

Another factor is the cost of exploitation, i.e. the pumping lift. Due to the significant water level declines, the pumping lift increases; on average by about 100 m. In all Aqeb wells pumping lift will be exceeding 400 m by 2040 (Figure 32).

Based on the aforementioned facts, **about 65% of current domestic production from groundwater (254 MCM) will be lost** (all aquifers except Disi), **i.e. only 35% of current production can be maintained (89 MCM).** As an example, estimations for the most heavily affected wellfields are given below (Table 9):

Table 9: Expected Groundwater Resources Exploitability by 2040 – only for large Wellfields in A7/B2

Wellfield	Supply area	2018	2040	Lost
Wadi Al Arab	Irbid	18.1 MCM	(2.1 MCM) *	16.0 MCM
Aqeb	Irbid/Mafraq	16.6 MCM	2.4 MCM	14.2 MCM
Economic Zone	Irbid/Mafraq	3.2 MCM	0.5 MCM	2.7 MCM
Corridor	Irbid/Mafraq/Zarqa	5.4 MCM	0.1 MCM	5.3 MCM
Hallabat	Zarqa	3.6 MCM	0 MCM	3.6 MCM
Siwaqa	Amman	3.8 MCM	0.3 MCM	3.5 MCM
Qatrana	Karak	5.7 MCM	0.6 MCM	5.1 MCM
Lajjun	Karak	5.5 MCM	2.8 MCM	2.7 MCM
Sultaneh	Karak	3.4 MCM	0.5 MCM	2.9 MCM
Mhay	Karak	3.9 MCM	0.3 MCM	3.6 MCM
Hasa	Hasa	5.4 MCM	0.4 MCM	5.0 MCM
Zabda+Shobak+Udruh+Qaa	Rural Maan	3.5 MCM	0.0 MCM	3.5 MCM
Tahoune+Jitheh+Samnah	Maan	6.6 MCM	0.1 MCM	6.5 MCM
Total		**58 MCM**	**15 MCM**	**41 MCM**

* already significantly affected by heavy metal contamination; usable only if Molybdenum removal is applied

This reduced availability and exploitability of the A7/B2 aquifer will in particular affect water supply in the North (Irbid, Mafraq, Ajloun and Jerash), but also in Karak, Tafilah and Maan.

Favorable exploitation conditions (pumping lift <350 m, saturated thickness > 200 m) will mainly be given in the north (Figure 33).

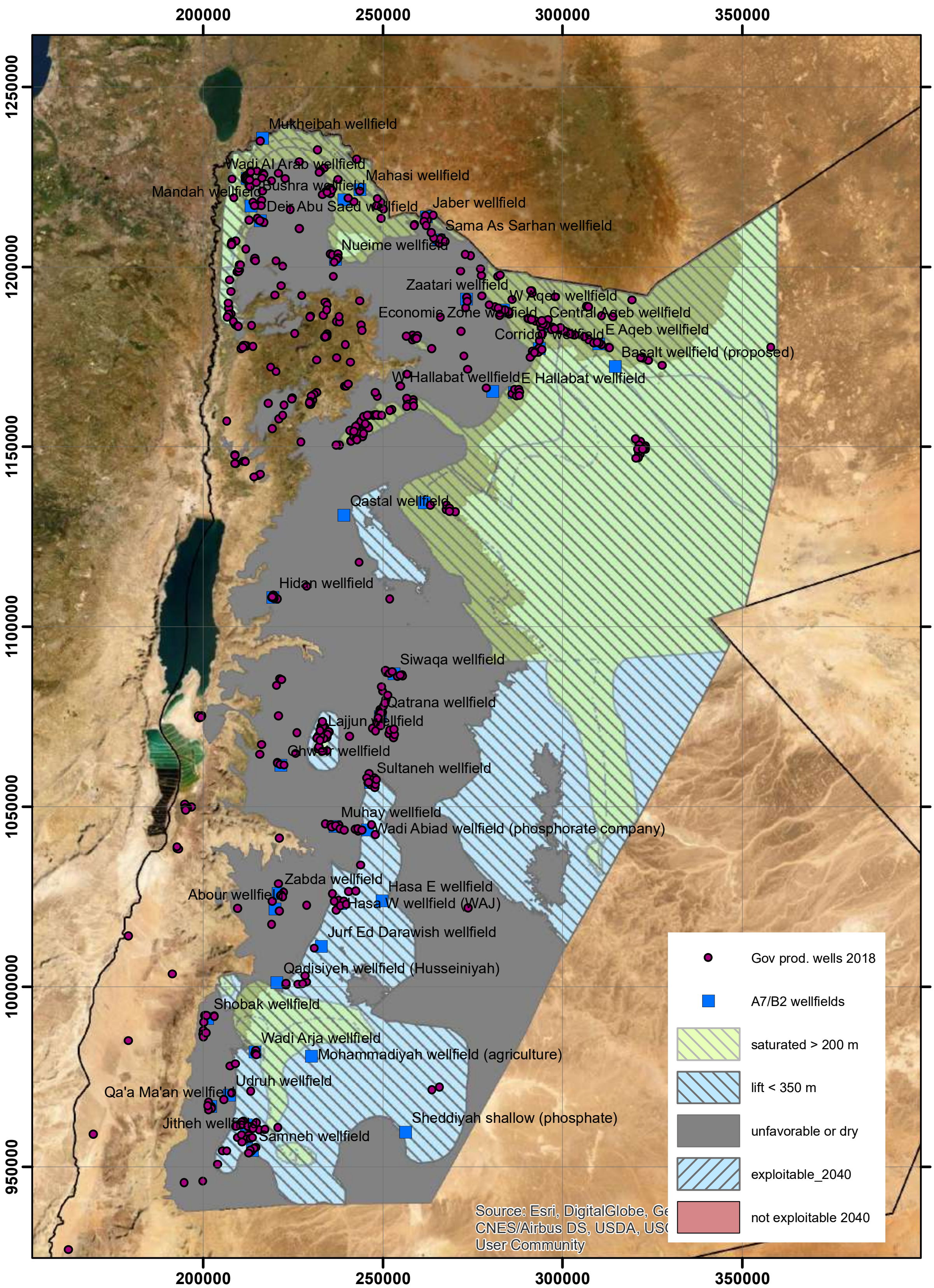


Figure 33: Favorable Groundwater Exploitation Conditions in 2040

3.1.4.1.8 Groundwater Quality

Facts

The overuse of groundwater causes changes in groundwater quality for various reasons and with various impacts. Expected impacts are: rising salinities and heavy metal contents.
Changes in water quality will make it necessary to treat more water in the future. It is important to map the areas affected and estimate their future extent to prepare the necessary investment.

Groundwater quality is monitored in irregular intervals by WAJ laboratory. Drinking water should comply with standard JS286/2015. However, over the past years, the budget for water quality monitoring was significantly reduced. The required assessments of the results are, therefore, currently not available.

The following changes should be analyzed:

- → **Increasing salinities** in the A7/B2 aquifer through
    - brackish groundwater mobilization
    - irrigation return flow
    - discharge (injection into wells) of brine from desalination in some places
- → **Increase in heavy metal contents** from natural sources (e.g. as a result of downward leakage from the B3 into the A7/B2 aquifer, resulting in elevated contents of Mo, Ni, U, V, As, etc.)
- → Widespread contaminations as a result of human activities (e.g. mining of oilshale; same elements as above)
- → Major local contaminations resulting from human activities
- → Unsafe **disposal of brine**, filters, sand, etc. from desalination plants

Further results are provided in ANNEX 6.

Figure 34 shows where downward leakage from the B3 could be problematic, also for food production.

It is intended to conduct a more detailed analysis for the development of volume B of the NWMP-3. Further details on how water quality changes will impact the future use of water resources are contained in chapter 3.2.3 of this document.

The expected changes in water quality affect public health not only through the drinking water and food produced in areas where contaminated irrigation is used, possibly without knowing, but also through infrastructure integrity.

Required Actions:

- ➢ Map the current distribution of salinity (as TDS or EC) and heavy metal contents detrimental to human health
- ➢ Estimate their future extent and level
- ➢ Propose investments related to treatment/removal

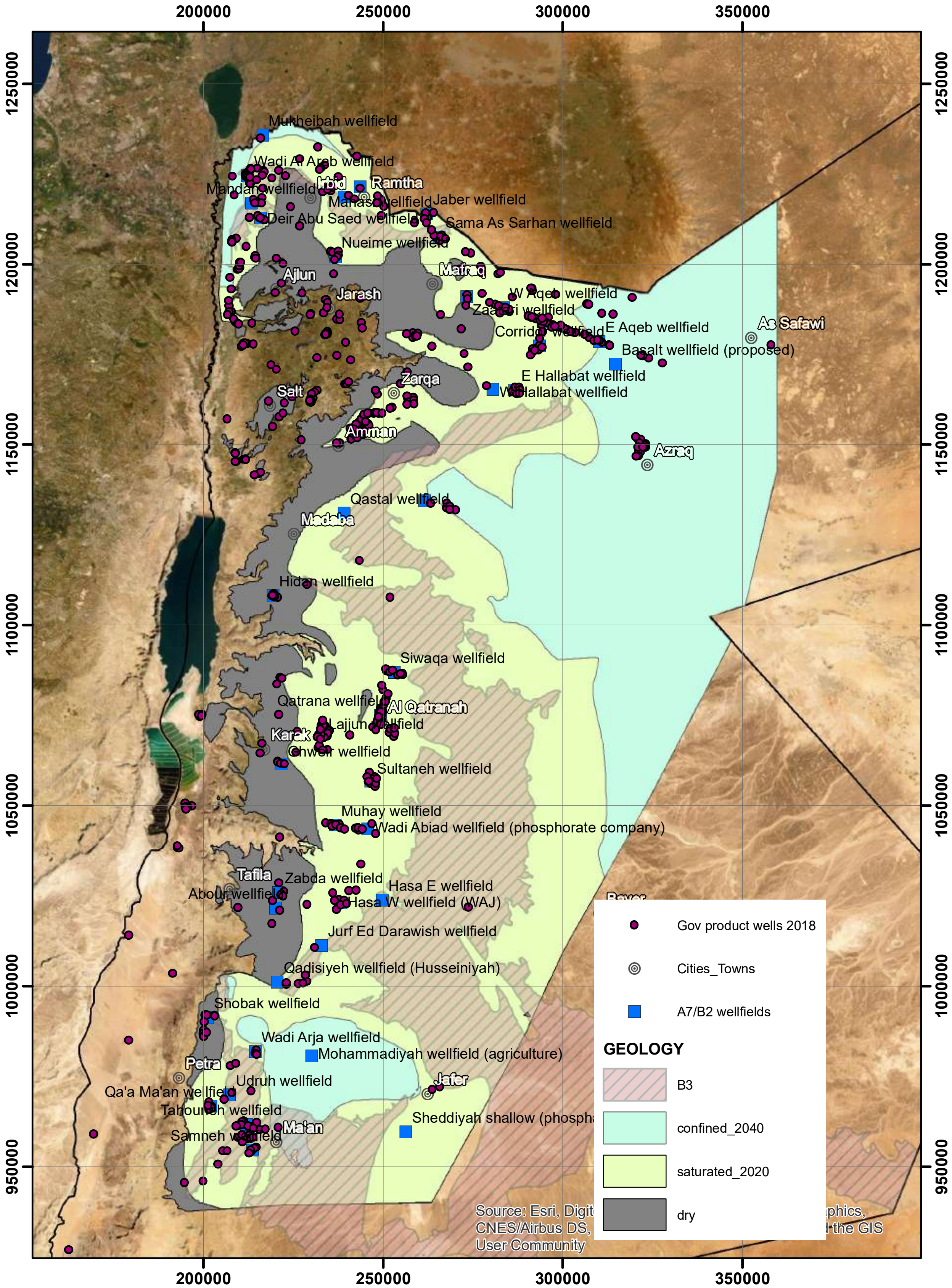


Figure 34: Areas where Heavy Metal Contents (Mo, Ni, V, U, As, etc.) are expected to rise

Groundwater Monitoring Well in Hallabat Area

3.1.4.1.9 Groundwater Monitoring

Facts

In the 1990s water level decline was still at an average of 2 m/yr.
With increasing overabstraction, groundwater level decline rates have increased notably during the past two decades. In the Northwest of the country water level decline rate has reached 10 m and more; in many parts of the country the average decline is 4-5 m/yr.

A comprehensive assessment of groundwater level monitoring was done within the framework of the BGR project Groundwater Resources Assessment of Northern Jordan (MARGANE et al., 1995). At that time there were 92 groundwater level monitoring stations, mostly automatic recorders (58) with floats and drum charts (Stevens), and only 7 wells were equipped with pressure transducers and data loggers. In the mid-2000s work started on converting manual stations and automatic recorders to pressure transducers with loggers and often telemetric data transfer. There are currently 147 groundwater level monitoring stations (Figure 35), of which 56 were recently installed and equipped with telemetry through the KfW HSSP project, and 22 groundwater wells were newly drilled for water level monitoring. However, as Table 10 shows, many of the sites have since stopped being operational, often after only short time, including the majority of the newly installed HSSP sites.

Required Actions:

Well operators are not collecting groundwater level data from domestic water supply wells correctly (SWL, DWL). Decisions for both the operation and maintenance of wells and investment planning can only be sound if they are based on adequate groundwater level data.

- All water well operators should collect and submit actual static and dynamic water levels from each well they operate to the NWIS database at least once per year.

A comprehensive review (ex-post analysis) of the consequences of the recently implemented HSSP project is required. Many of the newly installed groundwater monitoring stations are not operating correctly.

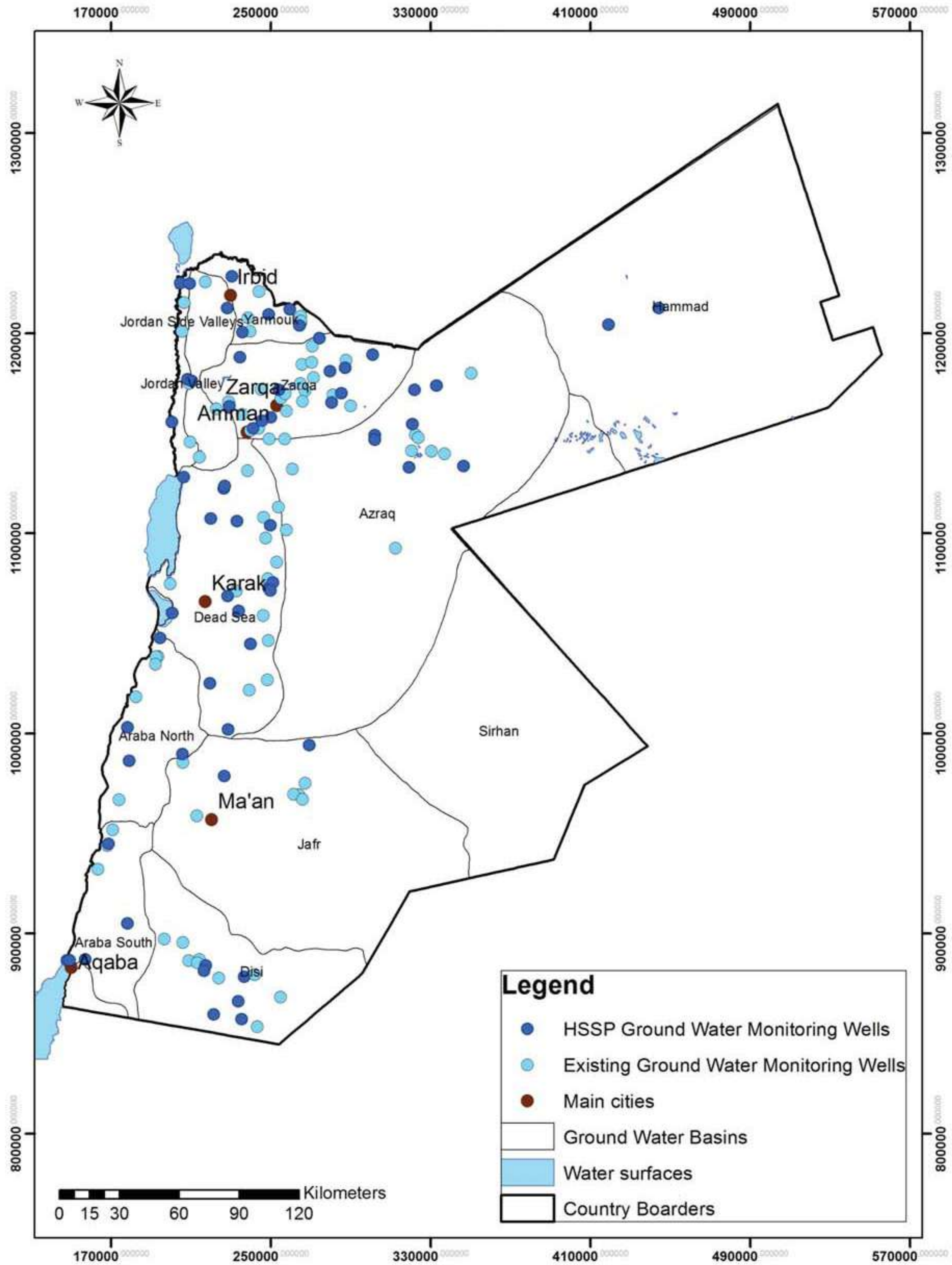


Figure 35: Current Groundwater Level Monitoring Stations in Jordan (HSSP, 2019)

Table 10: Status of Monitoring Stations before and after HSSP Project (HSSP, 2019)

Previous Telemetric Projects																		
	PPP		TeWaRON1		TeWaRON2		TeWaRON3		TeWaRON4		TeWaRON5		USAID		TOTAL	HSSP		TOTAL
Type/ststus	Operating	not operating	Operat-ing	not operating	Operating	not operating	Operating	not operating	Operating	not operating	Operating	not operating	Operating	not operating		Operating	not operating	
Weather	0	2	3	3	4	1	5	0	0	0	0	0	1		19	2	30	32
Rain	0	1	0	0	13	1	9	1	10	0	23	0			58	10	29	39
Groundwater	4	3	4	4	7	7	10	6	6	9	8	7			75	5	51	56
Wadi	0	1	0	0	0	0	0	0	0	0	0	0			1	2	5	7
Dam	0	0	0	0	0	0	0	0	0	0	0	0			0	2	6	8
Total Operating															107			21
Total Not Operating															46			121
SUM	4	7	7	7	24	9	24	7	16	9	31	7	1	0	153	21	121	142

Protection Zone Rahoub Spring

3.1.4.1.10 Groundwater Protection

Protection zones for groundwater wells and springs were introduced in 1999, first for the Tabaqat Fahel spring (Pella; MARGANE et al., 1999). In the Groundwater Resources Management (GWRM) project, guidelines were developed for groundwater (MARGANE & SUNNA, 2002; later updated as ACSAD groundwater guideline no. 5 (MARGANE, 2003b) and surface water (MARGANE & SUBAH, 2006) and a high number of protection zones were later delineated, particularly through that project. By 2010, 31% of all domestic water supply was protected through protection zones (Table 11):

Table 11: Groundwater Protection Zones delineated by 2010 through BGR GWRM project

Groundwater Protection Zones, Date, Reference	Amount supplied
Pella Spring (Tabaqat Fahel, Jordan Valley; MARGANE et al., 1999)	8 MCM
Qunayyah Spring (E of Jarash; HOBLER et al., 2004)	2.9 MCM
Wadi al Arab wellfield (W of Irbid; HOBLER et al., 2006)	11.2 MCM
Rahoub Spring (NE of Irbid; MARGANE et al., 2007)	0.2 MCM
Corridor wellfield (E of Mafraq; BORGSTEDT et al., 2007)	8.1 MCM
Hallabat wellfield (NE of Zarqa; MARGANE et al., 2009)	4 MCM
Wadi Shuayb springs (S and E of Salt; MARGANE et al., 2010)	8 MCM
Lajjun/Qatrana/Ghweir/Sultani wellfields (E of Karak; MARGANE et al., 2010)	20 MCM
Sub-Total	62.4 MCM
Surface Water Protection Zones	**Amount supplied**
Wadi Mujib Dam (N of Karak; MARGANE et al., 2008)	16.6 MCM
Wadi Wala Dam (S of Madaba; MARGANE et al., 2009)	9.3 MCM
Sub-Total	25.9 MCM
Total	88.3 MCM
Water Supply (2007)	284 MCM
Drinking water sources protected	**31%**

The BGR project Water Aspects in Landuse Planning (WALUP) continued to delineate protection zones for the Azraq (GASSEN, 2013), Hidan (GASSEN et al., 2013) , and Siwaqa wellfields (BRÜCKNER et al, 2015a) as well as Tannour and Rassoun springs (BRÜCKNER et al, 2015b). Through USAID projects, the Quairawan spring (CDM, 2004) and Wadi As Sir spring (WAJ, 2008) protection zones were delineated.

Although the delineation of protection zones provided a significant step forward with regards to safeguarding drinking water supplies, implementation of local proposed measures, such as wastewater collection and treatment, often through decentralized systems, is lagging behind.

Groundwater vulnerability maps similarly aim to provide protection of water resources through integrated landuse planning. A guideline for the preparation of such maps, including a comparison of internationally used methods, had been prepared in 2002 (MARGANE, 2002; later updated as ACSAD groundwater guideline no. 4 (MARGANE, 2003a)). Starting in 1995, the following groundwater vulnerability maps were prepared, using the GLA method (modified German state method, described in MARGANE, 2002), also largely through the Groundwater Resources of North Jordan and GWRM projects (Table 12):

Table 12: Groundwater Vulnerability Maps prepared by North Jordan and GWRM Projects

Area, Date, Reference
Greater Irbid area (MARGANE et al., 1996)
South Amman (SUBAH et al., 1999)
Qunayyah spring area (BROSIG, K., 2005)
Karak - Lajjun area (MARGANE et al., 2005)
Corridor wellfield area (BORSTEDT et al., 2007)
Hallabat wellfield area (MARGANE et al., 2009)

In 2017, a groundwater vulnerability map, which used the COP method, before tested in Lebanon (MARGANE & SCHULER, 2013) has been prepared, covering almost the entire country (BRÜCKNER et al., 2017).

Actions required:

- Protection zones of wells need to be updated because groundwater flow directions and groundwater gradients have changed.
- The actions recommended in the delineation reports are not sufficiently implemented and there is no follow-up on enforcement of landuse restrictions. In particular the actions required with regards to wastewater collection and treatment must be implemented.
- It is suggested to evaluate all resources used for domestic purposes whether a protection zone 1 is present, and which are the needed actions at the utility level.
- Protection in zones 2 and 3 can be improved through consideration in landuse licensing committees, wastewater collection and treatment projects, etc.

3.1.4.2 Fossil Groundwater Resources

Facts

A large amount of fossil groundwater resources is stored underground within the territory of Jordan. This water was recharged during the past 40,000 years. Exploiting it constitutes mining of resources, as there is no present-day recharge. The Disi aquifer is present underground almost throughout the entire country. However, in most areas it is located so deep, or has such an unfavorable chemical composition, that it is not economically feasible to exploit it.

The Disi aquifer is considered a fossil aquifer. Groundwater recharge to this aquifer occurred during the last ice age (pluvial period); since then there has been practically no recharge (MARGANE, 1990). The aquifer has a thickness of up to and exceeding 1,000 m. In many areas it has not yet been explored. Groundwater flow is directed from Saudi Arabia, the main outcrop area, towards the Dead Sea. A good overview on the aquifer characteristics is given in BGR & ESCWA (2013; Chapter 10).

The Disi aquifer was first investigated through the Investigation of the Sandstone Aquifers of East Jordan project (UNDP, 1966). A dedicated drilling program was implemented between 1989-95 in the framework of the UK funded Study of the Rum Aquifer of South Jordan (HAISTE & SCOTT WILSON KIRKPATRICK, 1995), during which 24 boreholes were drilled. Based on the related exploitation proposal a BOT project was implemented between 2010-13, during which 55 exploitation wells and 9 monitoring wells were drilled. The Dubaidib wellfield is operated since July 2013 by the company DIWACO and shall provide 100 MCM/yr over a time period of currently 25 years (until 2039) (Figure 36). The concession may be extended until 2065.

About 30 deep wells have been drilled to the Disi aquifer in other areas, mostly between Disi and the Dead Sea but also E of Azraq, where a geological structural high provides favorable exploitation conditions. Most of these exploration wells are not in use. The Disi aquifer is also exploited at the Phosphate Company site of Sheddiyya, but the amount exploited there is much less than originally planned (7 MCM). A major constraint on the use of the Disi aquifer is the high temperature, iron content, corrosivity and elevated radioactivity (radium). Exploiting this aquifer therefore requires high costs for well construction, operation, treatment and maintenance.

The Disi aquifer is currently being exploited or will soon be exploited at the following locations (Table 13):

Table 13: Wellfields Exploiting Disi Aquifer

Wellfield	Amount/yr	Wells
Dubaidib wellfield (DIWACO) (2010-13)	100-112	55 abstraction wells, 9 monitoring wells
Aqaba Water Company wells (Qa'a Disi wells)	14.8 MCM (2018)	2018: 20 wells operational
Shediyyah phosphate mine (private wellfield) (2011-12)	1.8 MCM (2014) [shallow aq.: 6.3 MCM]	6 deep wells
Lajjun deep wells (KD) (1999-2003)	10 MCM (2004) Rapid decline thereafter due to corrosion 2 MCM (2019)	16 deep wells 2020: 5 wells operational
Khan Az Zabib wellfield (Hasa-Sheddiyah Lot 4) (2019-~2021)	Proposed: 20 MCM	20 wells (proposed) Phase 1: 7 wells Phase 2: 13 wells

<u>Example Lajjun Wellfield</u>

The Lajjun wellfield was drilled by NRA (Natural Resources Authority) in the early 1980s. It consists of 21 shallow wells tapping the A7/B2 aquifer, most of which have in the meantime been abandoned. Only 5 wells are currently still producing (~1.0 MCM/yr). Between 1999 and 2003, 16 deep wells (named KD) have been drilled to tap the Disi aquifer. Most of them were lost over time due to heavy corrosion and wrong selection of material (pumps and riser lines have fallen into wells). In February 2020, 5 deep wells were still operational, yielding about 2 MCM/yr. Also between 1999 and 2003, 11 more shallow wells were drilled into A7/B2 aquifer, 7 of which are still operational currently, producing about 1.3 MCM/yr.

Actions required:

- The depletion and limited exploitability of groundwater resources must be taken into consideration for all project planning processes
- It must become obligatory for water utilities and WAJ to measure water levels of all production wells at least once per year

Figure 36: Exploitation of the Disi Aquifer – Location of Wellfields

3.1.5 Managed Aquifer Recharge (MAR)

Facts

Although managed aquifer recharge has been attempted in Jordan since the early-1960s, most of the recharge dams that have been constructed have failed to reach their objective of infiltrating significant amounts of surface water into the underground, at reasonable costs, and contributing to groundwater recharge in areas where this groundwater can be used downstream for domestic water supply. A countrywide analysis showed that the potential for managed groundwater recharge is low in Jordan.

Artificial groundwater recharge by means of infiltrating surface water resources has been implemented in Jordan since the early 1960s, and the Qatrana, Siwaqa, Shuayb and Wala dams were built for this purpose. However, many of these efforts were largely unsuccessful. At Qatrana and Siwaqa dams, there was no good understanding of the hydrogeological conditions and there is even no infrastructure to abstract infiltrated groundwater in the downstream area. Due to the topographic conditions most of the water impounded by these dams evaporates and does not infiltrate, as mentioned by STEINEL (2012).

Although a research study on MAR was conducted in Wadi Madone, supported by the Dutch government through IHE/Delft (DE LAAT & NONNER, 2011), its purpose was purely academic and there was no later follow-up from the water sector institutions. The Madone site consists of four small dams, constructed in 2007 as recharge release dams.

A study conducted on MAR by BGR (STEINEL, 2012; Figure 37, Table 14) found that **the potential in Jordan for artificial groundwater recharge is low** because few favorable locations exist, and facilities would be difficult to build because of preexisting landuse.

There is no proof that recharged water from the Wala dam actually flows towards the Hidan wellfield. A related tracer test conducted by the BGR in 2014 did not prove a hydrological connection between the two sites exists.

As pointed out by STEINEL (2012), a sufficient MAR potential is given only in areas with rainfall >200 mm/yr. The recommendation from this report was that for semi-arid regions with high sediment loads in wadi runoff, such as in Jordan, recharge release dams are more effective than recharge dams and low-cost surface infiltration is preferred over infiltration or injection wells. Moreover, the study suggested to improve monitoring of existing sites to prove their effectiveness before entering into the construction of new MAR facilities.

Table 14: Existing MAR Facilities in Jordan (modified after STEINEL, 2012)

Name	Year put in operation	Initial storage capacity (MCM)	Use	Type/functionality
Sultani	1962	1.2	-	Filled up with sediment
Qatrana	1964	4	-	Filled up with sediment
Wadi Shuayb	1968	2.5	-	Filled up with sediment
Wadi Kafrein	1968	8.5	Agriculture	
Wadi Rajil	1992	3.5	-	Filled up with sediment
Siwaqa	1993	2.5	-	Filled up with sediment
Wala	2002	9.3	Hidan wellfield; planned direct withdrawal, treatment and conveyance to Madaba	Filled up with sediment; raising ongoing, 15 MCM; no proof of hydrogeological connection with Hidan wellfield
Wadi Madone	2003	0.09	-	4 small dams; Research project
Wadi Butum	2011	0.47	Pastoral	3 small dams; Research project

Desert dams are listed in Chapter 5.1.2.4.

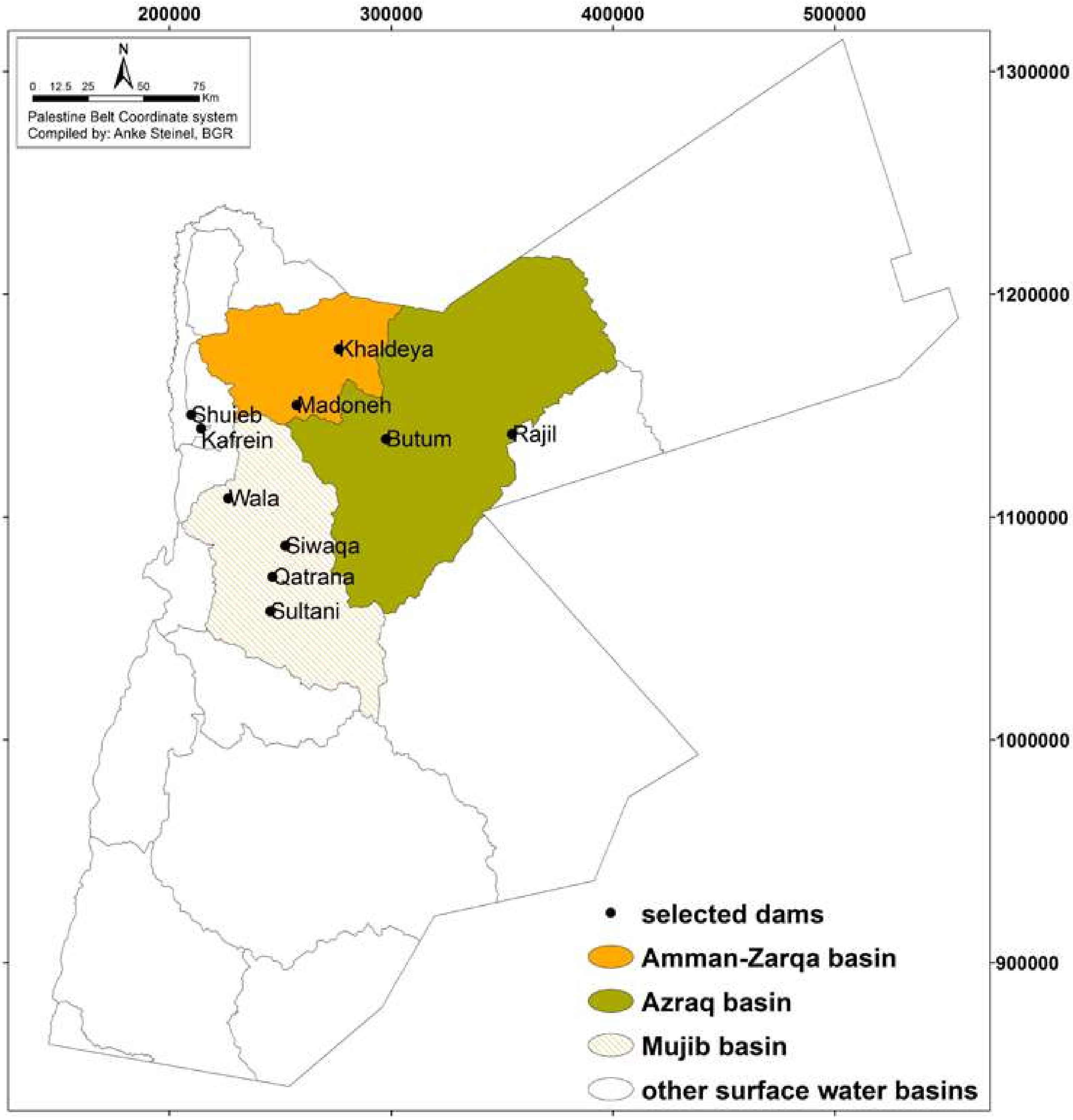


Figure 37: Existing MAR Facilities in Jordan (adopted from STEINEL, 2012)

Actions required:

- more efforts should be undertaken at small-scale level, e.g. through the construction of check dams in wadis and related maintenance
- re-evaluated all available MAR projects
- remove sediments from desert dams to improve infiltration

3.1.6 Desalination

Facts

Due to the depletion of conventional water resources, desalination constitutes the last resort for Jordan. **Capacities to desalinate water must be rapidly increased to secure water supply.** Brackish water resources have the advantage of being located close to the main demand areas, while discharging brine into the Dead Sea does not pose any major environmental problems. Although the cost of brackish water desalination would be relatively low, their potential is limited. The focus should therefore be on the desalination of seawater to provide the amount of water that is needed.

3.1.6.1 Desalination from Seawater

Planning for desalination currently falls under the MWI for seawater, and the WAJ for brackish groundwater. The focus is on seawater desalination due to the larger amounts that can be made available.

The only operational seawater desalination plant is located south of Aqaba at an industrial complex near the Saudi border operated by AquaTreat and owned by KEMAPCO, a company belonging to the Potash Company. Intake and outfall are both in the new Aqaba harbor, and the company has had a license for cooling water for about 20 years. Although it can produce up to 500 m^3/h (5 MCM/yr), it currently only produces around 3.5 MCM. 150 m^3/h are needed for operations at the Potash Company facilities, while the remainder is sold to Aqaba Water Company (AWC) at a cost of 0.745 JOD/m^3.

In 2005, Jordan, Israel and Palestine agreed to prepare a feasibility study for a desalination project from Red Sea water. In 2009 the World Bank commissioned the study of the Red Sea-Dead Sea Water Conveyance Project that was finalized in 2012. In August 2013, the Jordanian government announced that it would move ahead with the first phase of a project and funding was committed by several donors. In December 2013, an agreement to build the pipeline was signed by Israel, Jordan and Palestine. In November 2016, the Jordanian government announced that it is shortlisting five consortiums out of 17 bids to implement the project. Since 2018, however, the project is on hold due to political differences. A feasibility study has since been prepared for the “National Conveyor” project or Aqaba Amman Water Desalination and Conveyance (AAWDC) project (DAR AL HANDASAH, 2018). The initial plan was for the conveyance of an additional amount of 150 MCM/yr to Amman, which would be made available in two phases (50 MCM by groundwater abstraction from the Disi aquifer and 100 MCM from reverse osmosis (RO)). In September 2020, this plan was changed to:

- → Phase 1: total delivery 150 MCM/yr > build RO plant to deliver 100 MCM/yr desalinated water, (targeted operational year: 2026);
- → Phase 2a: total delivery 200 MCM/yr > expand desalination to delivery of 200 MCM/yr (targeted operational year: 2031).
- → Phase 2b: total delivery 250 MCM/yr > expand desalination to delivery of 250 MCM/yr (targeted operational year: 2036 for 25 years).

The documents for a related BOT project are currently being prepared by CDM (Figure 38). The construction costs (scenario 2, 50 MCM from wells), previously assumed in the DAR AL HANDASAH (2018) report were 1.53 B USD, of which 859 M USD for the wells, component (1), and 659 M USD for the desalination, component (2).

Operational costs (scenario 2) would be (assuming a 25-year deal with 4 years construction) :

→ 1.84 USD/m^3 (with Disi water use, excluding contingencies)
→ 2.06 USD/ m^3 (including contingencies)
→ 2.81 USD/ m^3 (wells not in operation)

The operational costs would be almost the same for conventional construction, instead of BOT. Operational cost could be significantly reduced through solar power use. However, the proposal only includes solar IPP (independent power producer) for the wells, component (1) and not for desalination, component (2). As, based on current agreement, NEPCO would be the sole power provider, the concept of an independent power provider would not be relevant.

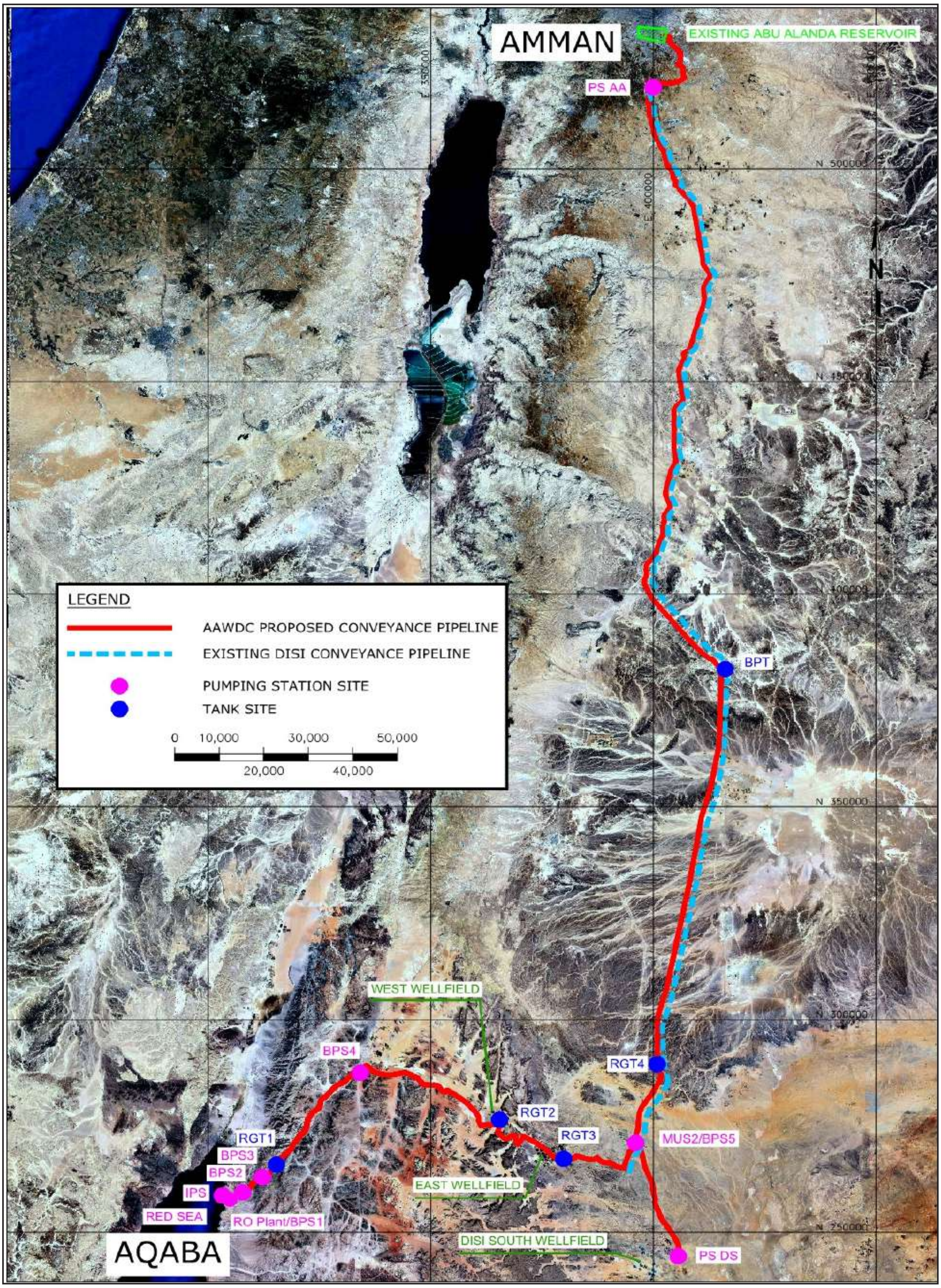


Figure 38: Initial Planning of Aqaba Amman Water Desalination and Conveyance (AAWDC) Project

Desalination of Brackish Groundwater at Abu Zighan (near Deir Allah/Jordan Valley)

3.1.6.2 Desalination from Brackish Water

Resources

The main potential for brackish groundwater desalination in Jordan lies in areas where the source is close to the brine discharge area. As brine discharge in most areas would impact on groundwater, the only options for brine discharge are the Dead Sea or Red Sea. **There are large brackish groundwater resources close to the Dead Sea**, where it would be easy to discharge the brine without causing a negative environmental impact. Brackish water can be desalinated for about 0.3 JOD/m³ under favorable conditions with conventional energy. These brackish water resources are associated with the geological units between Jurassic (Zarqa Group) and Cambrian/Ordovician (Ram Group). The Jurassic Abu Ruwais Formation contains evaporites, including rock salt. These are dissolved by the uprising water in the Disi aquifer (Ram Group) in the area between Deir Allah and South Shooneh.

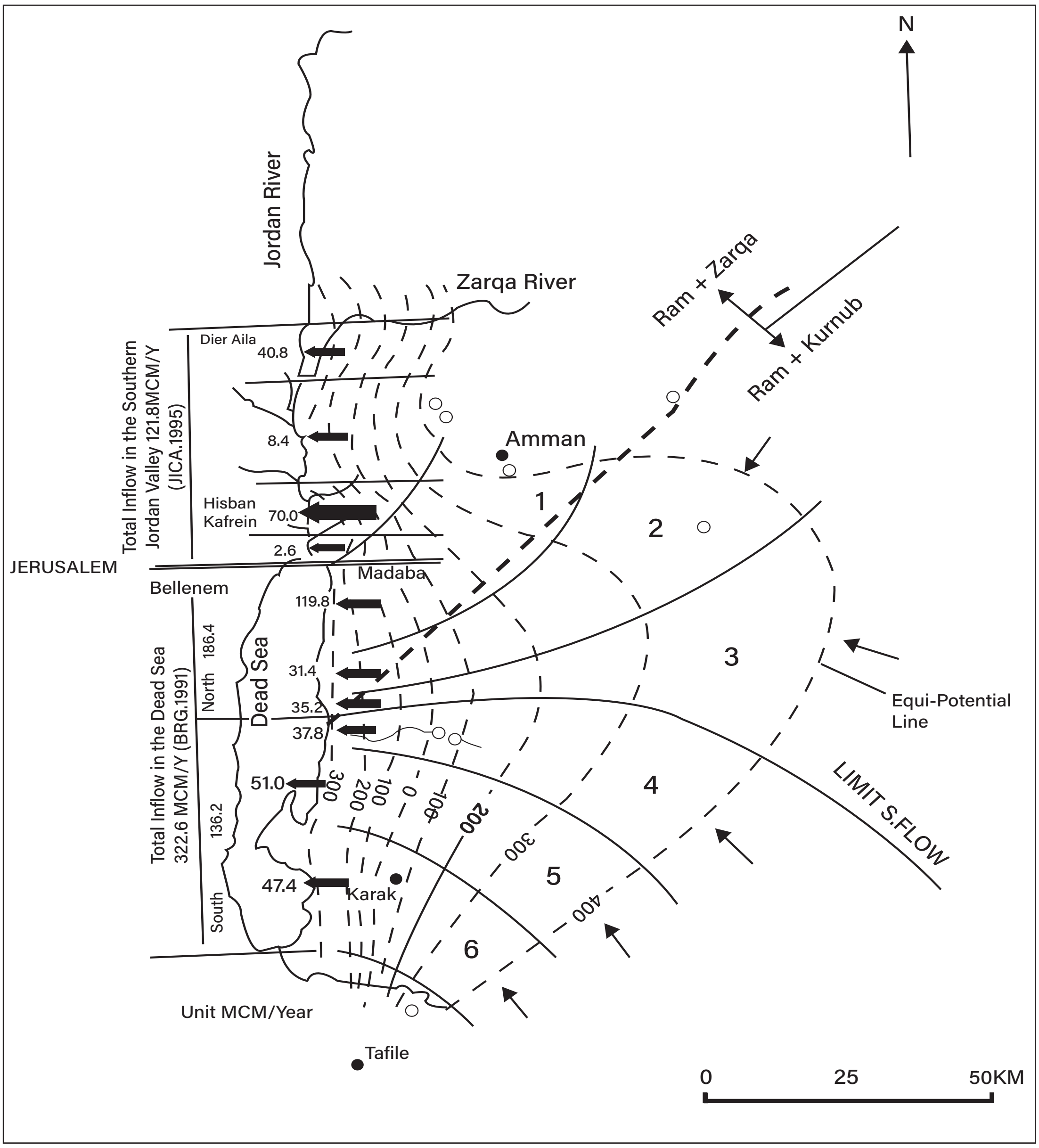


Figure 39: Groundwater Discharge from the Disi Aquifer into the Dead Sea (JICA, 1995)

Brackish groundwater resources had been investigated by the project The Study on Brackish Groundwater Desalination in Jordan (JICA, 1995). At that time, the resource capacity in the Lower Jordan Valley was tentatively quantified at around 75 MCM/yr, while the total groundwater inflow from Zarqa Group was estimated at around 122 MCM/yr (Figure 39). As main exploitation areas the Deir Allah and Hisban areas were identified, based on 6 wells and electrical resistivity soundings/electromagnetic soundings. However, through the latter only the shallow part of the aquifer system can be investigated. Due to the large extent of the area, this study can give only a rough estimate of the exploitation potential. A more comprehensive investigation is therefore needed.

The Deir Allah resource was later exploited through the Abu Zighan wellfield, where wells were drilled first in 2002. The Abu Zighan desalination plant was built in 2003 and first operated by the Amman Water Utility (Lyonnaise des Eaux), now Miyahuna (since 2007). Responsibility was recently returned to the WAJ and water is now used for the Deir Allah area rather than for the Amman water supply.

In parallel with the JICA study, MARGANE et al. (1996) proposed the drilling of wells in the Hisban area to exploit the Disi aquifer, although not specifically as brackish groundwater (the upper section was to be sealed off). It was anticipated that salinity would be around 2 g/l if only the deeper section (Disi aquifer) were tapped. Well locations were proposed at elevations where water would not be under artesian pressure, so that wells could be more easily drilled and cemented. In 2009, Miyahuna drilled 5 wells close to this proposed area, however, further downstream and screened in Zarqa and Disi units (wells tap Disi aquifer only for max. 100 m). The wells could not be used due to high iron and ammonium contents. Also, water was under artesian pressure and is flowing freely since then. Most of these wells are now heavily corroded. CDM carried out investigations into these wells in 2011 and 2013. A draft plan was prepared (MARGANE, 2019) to exploit the brackish groundwater at Wadi Hisban through 10 wells (10 MCM in the first phase). It was also suggested to install monitoring wells upstream of the proposed exploitation area in order to observe the response of the aquifer to exploitation.

Current Exploitation of Brackish Groundwater

There are currently 26 desalination plants operated by the WAJ or Water Utilities in Jordan (Table 15), many of them through EPC contracts (engineering, procurement, and construction). While the current desalination capacity is around 88 MCM/yr, the actual amount desalinated is much lower. Due to the reporting mechanism, this amount and the actual costs per cubic meter are not currently known. The joint GIZ-MWI Technical Cooperation project “Desalination of Sea and Brackish Water” will be working on improving such data in the future.

Apart from that, there are also several hundred privately operated, mostly small, desalination plants, most of which are located in the Jordan Valley. However, the number of desalination plants is growing in other agricultural areas (e.g. between Ramtha and Mafraq), and this is of concern for domestic water supplies. As these do not require operational licenses or EIAs, their numbers can only be estimated. It is assumed that many of these privately-operated desalination facilities inject the generated brine into old abandoned wells, thus contaminating the main aquifers in use.

Table 15: Currently Existing Desalination Plants

Desalination plants in Jordan					
Ref#	**Plant Name**	**Construction Date**	**Type of project**	**Production Capacity (MCM/Yr)**	**CAPEX (JOD)**
1	Ruwaished Wells(1,4) (after expansi on)	2000	EPC	1.06	242,960
2	Deir Alla	2001	EPC	0.44	120,000
3	Zarqa	2002	EPC	5.26	750,000
4	Al Reasha	2002	EPC	0.31	120,000
5	Al Safawi	2003	EPC	0.48	194,000
6	Abu Zeighan	2003	EPC	15.77	2,500,00
7	Mudawara containerized	2003	EPC	0.31	89,500
8	Ghor Al Mazraa	2003	EPC	0.13	87,500
9	Shouna (5) Containerized	2003	EPC	0.13	87,500
10	Qatar	2003	Grant	0.03	Grant
11	Ghor Al Safi (after expansi on)	2005	EPC	0.79	178,000
12	Ain Sara (c1ftcr expansion)	2005	EPC	0.96	124,000
13	Ghwaibeh	2006	EPC	0.13	50,000
14	Zara Main	2006	EPC	47	87,500,000
15	Ghor Fifa	2007	EPC	0.26	99,000
16	Kraymeh	2007	BOT	0.88	1,000,000
17	Karama Dam/Thahret Al Ramel	2009	BOT	0.88	3,000,000
18	Znaiya	2008	EPC	0.79	133,300
19	Omari	2008	EPC	0.04	85,000
20	Mashtal Faisal (After expan-sion)	2010	BOT	3.73	2,250,000
21	Karama(2)	2013	Grant SMART Project	0.04	Grant SMART Project
22	Dabaan	2014	EPC	0.07	58,000
23	Mahasi	2014	EPC	1.05	256,000
24	Kufranja (Tabaget Fahel)	2014	EPC	1.54	700,000
25	Kemapaco sea water Ro	2017	EPC	5	6,500,000
26	Hadalat	2017	EPC	0.5	204,895
Total				**87.94**	**106,329,655**

Effluent Discharge from Khirbet As Samra WWTP

Zarqa River and Abu Zighan Canal – Infrastructure for Treated Wastewater Reuse in Southern Jordan Valley and Discharge of Brine into Zarqa River from Abu Zighan Desalination Plant

3.1.7 Treated Wastewater Reuse

Facts

Large amounts of treated wastewater are available and could be used in agriculture where there is a huge demand for water. At the same time, there is a need to replace the precious freshwater used in irrigation with reclaimed water. The concepts have existed for more than 20 years, but so far there is little implementation. Large investments have been made in anticipation of treated wastewater reuse. However, in North Jordan, most reclaimed water is still flowing unused into the Jordan River because the JVA and/or farmers refuse to use it due to claims over water quality. Thus, while the amounts available for reuse are relatively high, the amount actually reused should be increased.

Currently 33 WWTPs are in operation, from which in 2018 the amount of 167 MCM was released as treated effluent. Although plans for a more extensive reuse of treated WW were developed more than two decades ago, acceptance for reuse in agriculture is still problematic.

There is currently no map showing the infrastructure in place for treated WW reuse. The main current reuse area is the southern part of the Jordan Valley (JV), where freshwater is scarce. Here, farmers have successfully adapted to the use of reclaimed water. Effluent water from Khirbet As Samra WWTP is used for irrigation in the southern JV through the Abu Zighan canal, while Zarqa Carrier 3 (delivery to stage office 2, SO2), operational since 2010, shall convey treated WW to the northern and central JV and Zarqa Carriers 1 and 2 (delivery to stage offices 4, 5, and 8; SO4, SO5, SO8) shall distribute treated WW in the area around Deir Allah.

In the northern part of Jordan, all treated WW in the Irbid region, from the Doghara (also called Wadi Arab), Irbid Central, Wadi Shallalah and Ramtha WWTPs shall now, according to WAJ plans, be diverted to a final treatment plant, which will be built downstream of Wadi Al Arab dam (KACHEL, 2018) (Figure 40, Table 16, Table 17). The plan is to distribute treated WW from there to the northern part of the Jordan Valley. According to current planning, treated wastewater could be reused as of approx. 2023. However, since the separate distribution infrastructure that is necessary in the northern Jordan Valley area has not yet been built, treated WW is currently discharged unused into Jordan River. Moreover, the JVA and local farmers are concerned about the quality of treated wastewater, specifically that it will have a high TDS (> 1,000 mg/l), which would cause damage to the predominantly citrus cultivations in this area. Therefore, the JVA and/or farmers refuse to use reclaimed water. Also, the amounts available and their level of treatment are uncertain. The overall quantity of treated wastewater that could be made available for reuse in Northern Jordan was 11.7 MCM in 2017. However, WAJ plans to connect further villages around Irbid to the existing WWTPs, so that the treated wastewater effluent amount could increase to ~45 MCM by 2045 (DORSCH, 2019; CDM, 2019). Making sure that the treated wastewater that is made available is actually used in agriculture would require a proper concept for monitoring water quality by both WAJ and JVA, based on the relevant standard. WAJ and KfW had initially proposed a Final Treatment Plant, where all treated wastewater arriving near Wadi Arab dam would be treated again to be ready for reuse. However, it is unclear whether this plan is still being pursued. Furthermore, KfW proposed introducing a blending process, but it is also unclear whether and how this proposal is being or could be applied.

Part of treated WW from the two treatment plants South Amman and Jiza, located just 1 km from each other, is locally reused for fodder production.

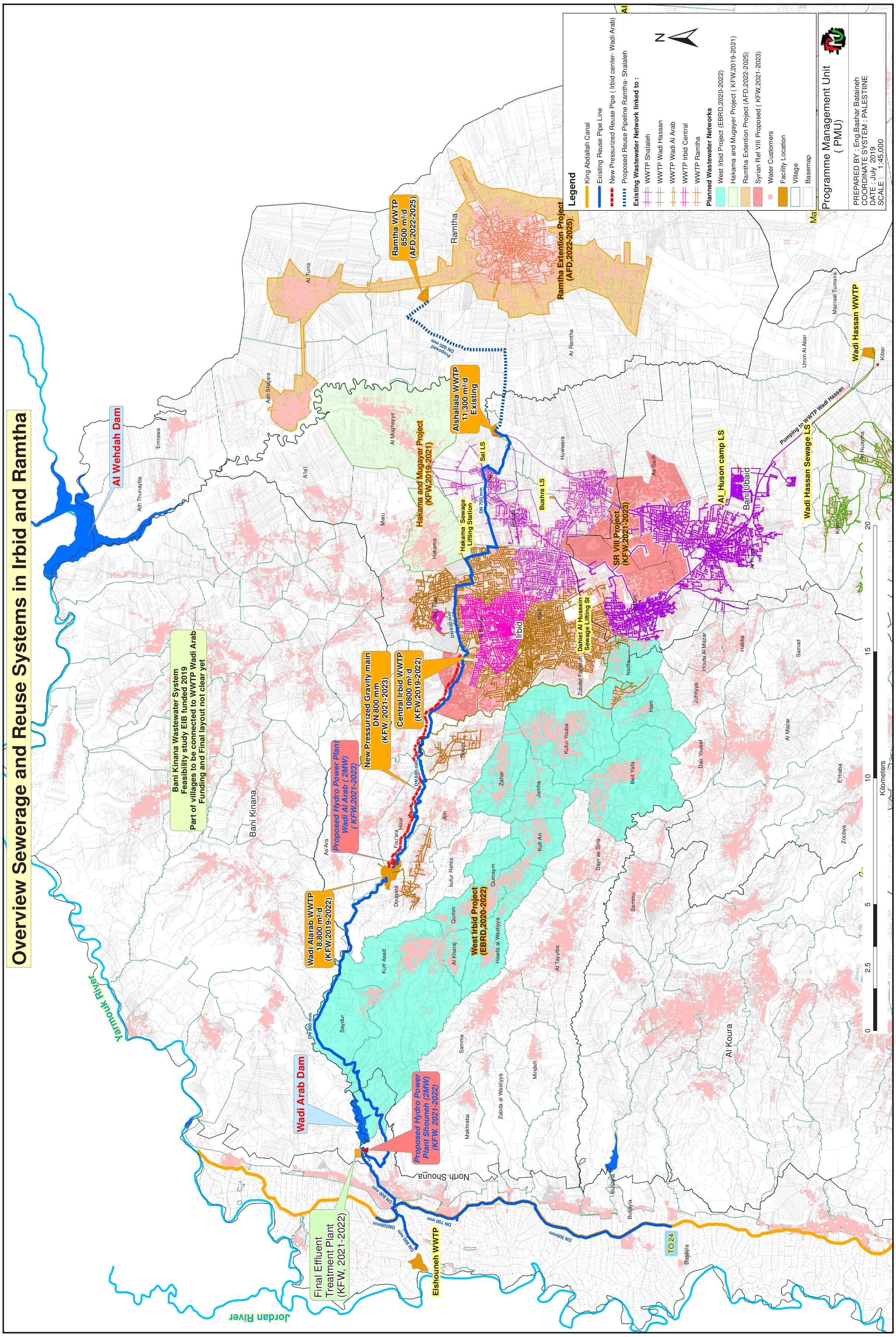


Figure 40: Currently Proposal Schemes related to Reuse of Treated Wastewater in Northern Jordan Valley (WAJ, 2019)

Table 16: Wastewater Treatment Plants in North Jordan – Potential Reuse of Reclaimed Water

Existing WWTPs								
Operator	Name WWTP	Year Operational/ Upgraded	Design Capacity (Max Dai)	Amount inflow (m^3 / d) (2017)	Amount outflow (m^3 / d) (2017)	Quality (BOD-5 design)	Quality (BOD-5 in/out)	Treament Method
YWC	Wadi Arab (Doghara)	1999 (2017)	18,800	12,680	12,306	580		activated sludge/ tertiar
YWC	West Irbid / Irbid Central	1987 (2017)	13,350	8,270	7,817	800		activated sludge
YWC	Wadi Shallalah	2014	13,750	8,421	8,015	760		activated sludge
YWC	Ramtha	1987 (2004)	8,500	4,270	3,957	1000		activated sludge
YWC	Mafraq	2017	5,500	3,730	3,694	825		aeration ponds
YWC	Wadi Hassan/ Nueime	2001	1,600	1,260	1,181	800		activated sludge
YWC	North shouneh	2015	1,200	655	635	1200		natural ponds

Table 17: Current Projects for Wastewater Treatment and Treated Wastewater Reuse in North Jordan

Capital Investment Plan 2016 With Modifications						
Funding	Project	Amount	Year operational	Cost	Design Capacity	BOD-5 design
Kfw	Expansion of Wadi Al Arab WWTP	25 MCM	2017-20 (2019-22)	4.8 M JOD	27,000 m^3/d	770 mg/l
Kfw	Expansion of Central WWTP	5 MCM	2022-25 (2019-22)	2.2 M JOD	13,000 m^3/d	940 mg/l
AFD	Expansion of Ramtha WWTP : phase 1+2	8 MCM	2022-24 (2022-25)	50-70 M USD	22,000 m^3/d	
Kfw /SR-8	Expansion of WWTP Wadi Hassan : phase 2	1.9 MCM	2019-22 (2021-23)	1.1 M JOD		
?	Jordan valley wase water Project	5 MCM	2017-19	42M JOD		

Proposed distribution system for North Jordan

KfW, through their consultant GITEC, proposed the following treated WW reuse system for northern Jordan (Figure 41) in 2004 (conveyance and distribution from Shalallah, Central Irbid and Doghara/Wadi Arab WWTPs) (unfortunately no newer document based on actual planning was made available):

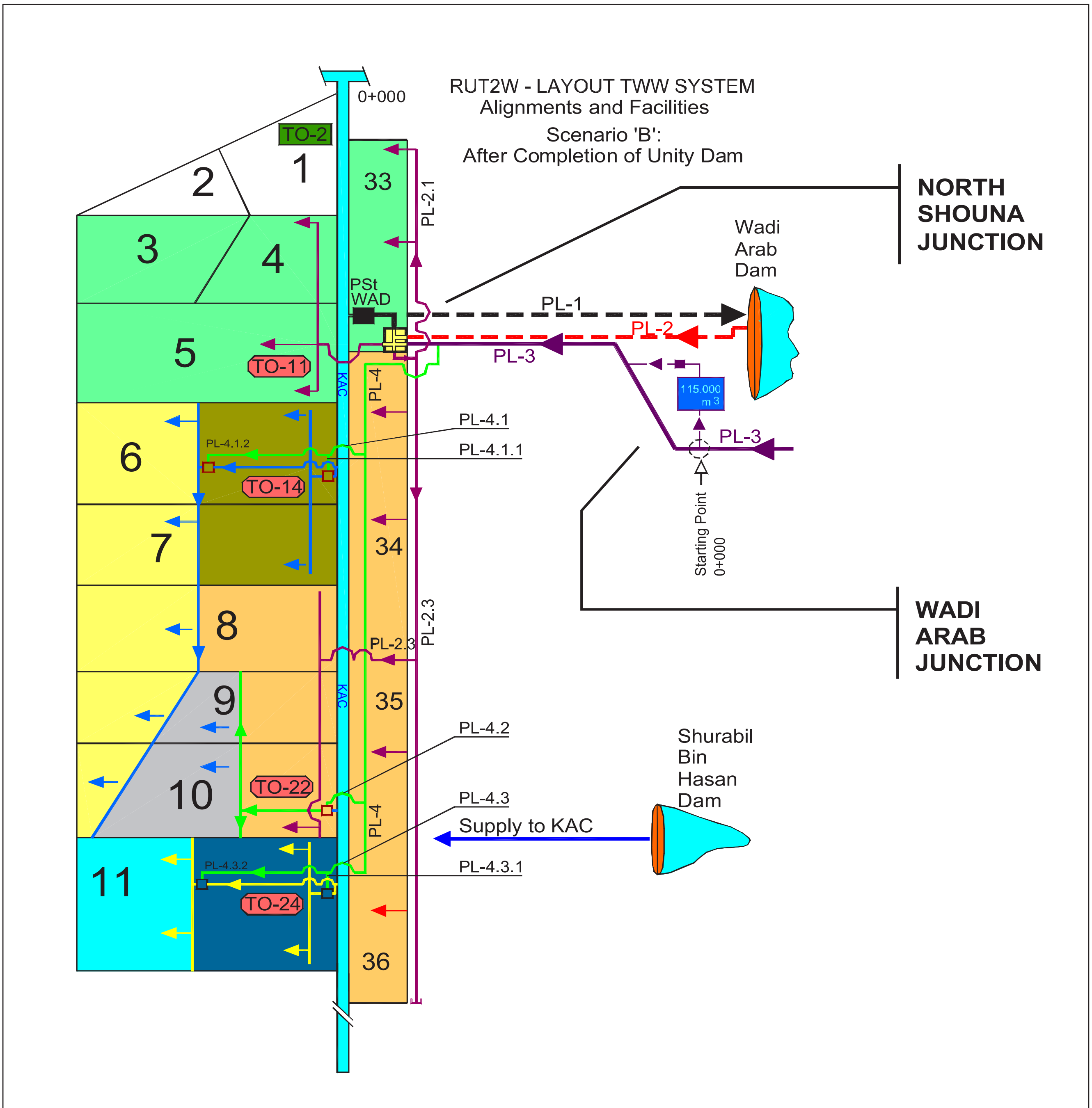


Figure 41: Treated WW Reuse Distribution System in the Northern Jordan Valley (GITEC, 2004)

Purple lines: intended use of reclaimed water

The available updated concepts for the Jordan Valley were unfortunately not communicated by JVA.

Required actions:

- Regularly verify the validity of assumptions of projects for WWTP upgrades;
- Improve coordination among investment projects in wastewater treatment;
- Improve coordination between WAJ and JVA;
- Prepare a GIS map showing water distribution network of JVA in the Jordan Valley, including the infrastructure in place for treated WW reuse;
- Fully implement the monitoring of effluent water quality at the handover point to convince JVA and farmers that the reuse of treated wastewater is in the farmer's interest; document and publish results;
- Implement and control blending process.

Wehdah Dam in Yarmouk River

3.1.8 Shared Water Resources

Groundwater

Groundwater resources are shared in the

- → North (Yarmouk, Badia, Ruqban) with Syria;
- → Southeast (Sirhan) with Saudi Arabia;
- → South (Disi) with Saudi Arabia; and
- → Wadi Araba with Israel.

In the area E of Mafraq, groundwater from the basalt aquifer (and underlying aquifers) flows from Syria towards Jordan, previously to the Azraq depression, but now, due to the overabstraction of the A7/B2 aquifers E of Mafraq, back to the Yarmouk region (MARGANE et al., 2015). Flow into Jordan was quantified in the framework of the Basalt Aquifer Study (ESCWA & BGR, 1996) as 50 MCM, however this estimation is based only on a simple flow-through calculation.

Groundwater in the B4 aquifer enters Jordan in the northeastern border with Syria in the Ruqban area. This amount was quantified as 2 MCM/yr (GITEC &HSI, 1995).

Small amounts of groundwater probably leave Jordan towards Saudi Arabia in the Sirhan area, but this is difficult to quantify based on existing data (GITEC &HIS, 1995).

In the Disi area, groundwater in the Rum Group sandstone aquifer (the so-called Disi aquifer), which partly attains a thickness of over 1,000 m, flows largely from Saudi Arabia into Jordan. This flow was quantified in the framework of the Qaa Disi Aquifer Study (HAISTE & SCOTT WILSON KIRKPATRICK, 1995) as 160-230 MCM/yr. This roughly matches the amount of water that is now being extracted since July 2013 on the Jordanian side at Dubaidib and other wellfields (West Rum Co., East Rum Co., AWC).

The aquifer system and flow conditions in the Wadi Araba aquifer system, which is shared with Israel, are not well understood, so no statement can be made about shared groundwater resources in this area. There has been no comprehensive groundwater investigation on the Jordanian side of this area. Israel has developed some medium sized wellfields to cultivate land at Idan, Marzava, Tzofar, Paran, Ya’alon. In 1994, when the border was changed, responsibility for operation of the Tsofar, Paran and Ya’alon wells remained with Israel, although these wells are now on Jordanian territory.

Surface Water

Water from the Yarmouk River is shared with Syria and Israel. 80% of the Yarmouk catchment area is located in Syria and 20% in Jordan. Average rainfall is higher on the Syrian side.

Agreement on Water Use with Israel

The current agreement between Jordan and Israel from 1994, foresees that:

1. As for the Yarmouk River, Israel pumps 12 MCM and Jordan gets the rest of the flow, during the summer period (15 May to 15 October). During the winter period (16 October to 14 May) Israel pumps 13 MCM and Jordan is entitled to the rest of the flow from Yarmouk River.

2. As for the Jordan River, in return for the additional water that Jordan concedes to Israel in winter Israel concedes to transfer to Jordan in the summer period 20 MCM from the Jordan River directly upstream from Deganya gates. Jordan shall pay the operation and maintenance cost of such transfer through existing systems (not including capital cost) and shall bear the total cost of any new transmission system. During the winter period, Jordan is entitled to store for its use a minimum average of 20 MCM of the floods in the Jordan River south of its confluence with the Yarmouk. Excess floods that are not usable and that will otherwise be wasted can be utilized for the benefit of the two parties including pumped storage off the course of the river.

3. Jordan is entitled to an annual quantity of 10 MCM of desalinated water from the desalination of about 20 MCM of saline springs now diverted to the Jordan River. Until the desalination facilities are operational Israel will supply Jordan 10 MCM of Jordan River water, outside the summer period and during dates Jordan selects, subject to the maximum capacity of transmission.

4.) Israel and Jordan shall cooperate in finding sources for the supply to Jordan of an additional quantity of 50 MCM/yr of water of drinkable standards.

<u>Agreement on Water Use with Syria</u>

In 1953 Jordan and Syria signed an agreement to jointly construct a dam, originally called Bunger dam or Maqarin dam, now Wehdah dam, at their common border. This was based on the Bunger Plan, which foresaw the joint utilization of the waters of the Yarmouk. Syria retained the right to use the water from springs that emerge in its territories at an elevation of more than 250 meters above sea level, would benefit from 75% of the power generated at the dam, and would pay 5% of the construction costs (HADDADIN, 2002).

An amended agreement between Jordan and Syria was signed in 1987 (a translated version is contained in volume 3 of the second Water Master Plan (MWI & GIZ, 2004). This agreement was also meant to prepare the Wehdah dam project and states that:

→ Syria reserves the right to use the water from all springs discharging in its lands within the Yarmouk River Basin and its tributaries, with the exception of those springs discharging upstream of the dam below the 250 m contour. Syria also reserves the right to utilize the waters discharging into the River and its tributaries downstream of the dam, to irrigate its lands situated along the course of the River.
→ Jordan has the right to use the water released from the dam.
→ Electricity generated from the Al Wehdah Dam will be divided between Jordan and Syria in the ratio of 25 percent to Jordan and 75 percent to Syria.
→ A Jordanian-Syrian commission shall be formed to supervise the implementation of the agreement.

<u>Planned Agreement on the Water Swap</u>

In the framework of the Red Sea Dead Sea (RSDS) project, it was planned that 30 MCM of water desalinated in Aqaba would be transferred to Israel, while the same amount would be transferred to Jordan from Lake Tiberius. The water supplied to Jordan in the North would mainly be needed in Irbid. In anticipation of this agreement, an intake station at KAC and transfer station to Irbid have already been built at Manshieh. The pipeline to Irbid was built and can currently convey 30 MCM (could be expanded to 45 MCM at a later stage). However, if this amount was conveyed to Irbid from the KAC, it would be missing for water supply of Amman. Jordan plans to start conveyance of 5 MCM to Irbid in July 2020 and increase this amount by 5 MCM each year until is reaches 30 MCM.

3.1.9 Water Imports

Jordan currently imports amounts from Israel in addition to those agreed in the bilateral agreement of 1994, for which it pays an agreed amount of between 0.3 and 0.33 JOD/m^3, depending on electricity prices in Israel. The following amounts were imported over the past 6 years (Table 18):

Table 18: Additional Water Imports from Israel

Year	Water imports [MCM]
2014	15
2015	10
2016	10
2017	10
2018	14
2019	0

Currently Jordan does not control the quality of water received from Israel. A related monitoring station should be installed to allow for such measurements (continuous EC and pH monitoring, monthly analysis of all relevant parameters).


Wadi Hasa

3.2 Factors Influencing Water Resources Availability and Use

How much water will be available in the future, and where and under which conditions it can be exploited, will depend on three main factors:

→ Climate change will lead to lower precipitation and higher temperatures, which will result in decreased surface water runoff and groundwater recharge. The deficit between natural resources availability and exploitation will therefore increase more than it would otherwise. The consequences of climate change therefore need to be taken into consideration for all planning processes, not just in the water sector.

→ Energy consumption will increase significantly for three reasons:

- Declining groundwater levels require higher energy consumption for pumping, while at the same time the yield of the wells is decreasing.
- Water transfers have continuously increased over time, and are going to increase even further because desalinated water can mainly be produced near the sea, while water demand is highest in the northern and central regions. Although it is important to implement energy efficiency measures, this cannot lead to lower energy consumption.
- The only possibility to generate the amounts of water that will be needed in the future is through the desalination of seawater. With current technologies, this requires more energy than the production of surface or groundwater.

→ Water quality will deteriorate due to the impacts of natural processes and of human activities. This will increasingly constrain the use of water for domestic purposes and agriculture. Salinities and heavy metal contents and the frequency and extent of microbiological contamination events will rise. This will require more and complex treatment solutions.

3.2.1 Climate Change

Facts

All current studies agree that Climate Change will significantly affect Jordan. There were, however, no current estimations on the degree to which water resources availability would be decreased. This is currently under preparation by the NWMP-3 team and will later be integrated into the Water Master Plan. At this stage the estimation is based on the UNFCCC (2014) document. The predictions of precipitation and temperatures changes mean that both, surface and groundwater resources availability would be reduced by 15% each until 2040. Adaptation measures to Climate Change are therefore urgently needed.

Jordan addressed climate change issues in the following key documents governing the water sector:

- The National Climate Change Policy of Hashemite Kingdom of Jordan 2013-2020 (MoE, 2013);
- the Jordan Intended Nationally Determined Contributions (INDC, 2015);
- the National Water Strategy 2016-2025 (MWI, 2016);
- the Climate Change Policy for a Resilient Water Sector (MWI, 2016); and
- the Adaptation to Climate Change to Sustain Jordan's MDG Achievements 2009-2013.

The vision of these legislative and regulatory frameworks and strategies is to achieve a more resilient water sector through an Integrated Water Resources Management approach in order to ensure water security in the long term. The Ministry of Water and Irrigation tries to implement adaptation measures through a Directorate of Climate Change.

In this document the existing three climate change models are considered that look into expected climate in the future:

a) Climate Change Model of KIT/Germany (2006), based on IPCC AR3 (2001)
b) Climate Change Model of UNFCCC (2014), based on IPCC AR4 (2007)
c) Climate Change Model of RICCAR/ESCWA (2018), based on AR5 (2014)

For the Rapid Assessment document, the temperature and precipitation forecast of the UNFCCC model are used, as it provides related data that can be used for an impact estimation.

1) First Climate Change Model prepared by KIT (KUNSTMANN et al., 2006):
downscaled ECHAM4 regional climate change model (RCM) for Jordan, Israel, Lebanon and SW-Syria, resolution: 18 km

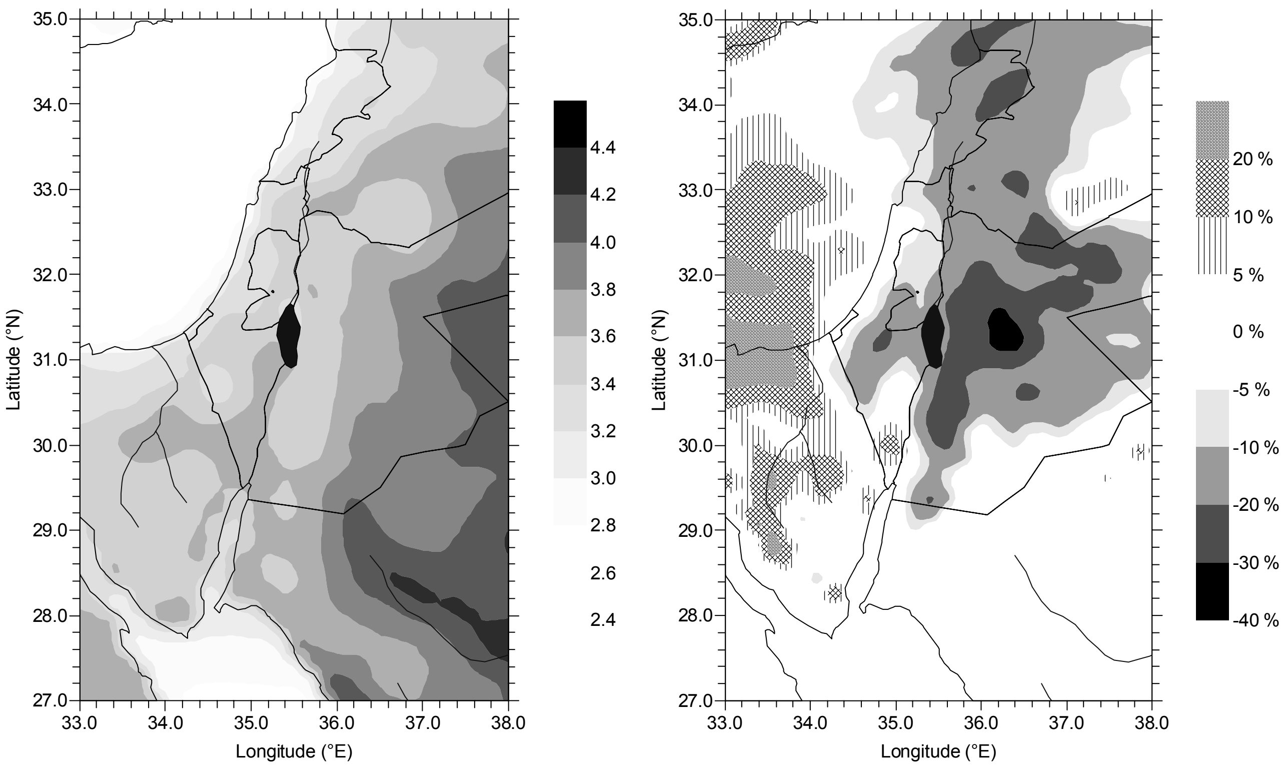


Figure 42: Expected Temperature (left) and Precipitation Changes based on First Regional Climate Change Model (KUNSTMANN et a., 2006)

Global warming is predicted to result in temperature rises of up to 7° C in Jordan in summer and around 2° C in winter in the time period 2070-99 (KUNSTMANN et al. 2006; Figure 42; average annual temperatures would be around 3.5° C higher than in the time period 1961-90). According to the climate model, this would result in a decrease in precipitation in the northwestern part of Jordan of around 25%. Since this part of the country presently receives most of the regional rainfall, i.e. up to 500 mm in the area south of Irbid, it is likely that groundwater recharge will also decline considerably.

In the past, snow melt was a major contributor to groundwater recharge in the northern and central highlands of Jordan, resulting in groundwater recharge rates of up to 30 % in years with extensive snow fall (Margane et al., 2002). With rising temperatures, snow fall will be much rarer than at present, so groundwater recharge from snow melt will possibly disappear. Presently, groundwater recharge in areas receiving less than 200 mm/a rainfall is almost negligible. Since these areas will become more extended, the area where groundwater recharge can possibly take place in the future will be limited to a very small part of the country in the northern and central highlands. If this climate change scenario proves to be correct, the effect on groundwater recharge might therefore be that total groundwater recharge will actually decrease much more than 25 %. Moreover, with higher temperatures, especially during the summer months, evaporation from surface water resources will also increase dramatically. This would affect the King Abdullah Canal (KAC) and, more importantly, the dams. Thus, a reduction of the total water resources availability to around 550 MCM/a (i.e. 2/3rds of the present value) is a likely scenario.

2) Second Climate Change Model prepared by UNFCCC (2014); regional climate model (RCM) prepared for the so-called Third National Communication

Results refer to the average value for Jordan. Thus, in the most likely result of a business as usual scenario, rainfall would be 12.9% lower and mean temperatures would be 1.6°C higher than during the reference period 1961-1990 (Table 19). These data are available in raster format and will be used at a later stage for calculation of the impact on the runoff and on groundwater recharge. It is currently estimated that in 2035 both surface water resources availability and groundwater recharge will be about 15% less than during the reference period. This would mean that GW recharge will no longer be 280 MCM/yr but only ~240 MCM/yr, while surface water resources availability will decrease from ~400 MCM/yr to ~340 MCM/yr. The climate models point to a hotter and drier climate in Jordan. There is no indication of an increase in rainfall intensity while the number of consecutive dry days are likely to increase.

Table 19: Expected Precipitation and Temperature Changes based on the Second Regional Climate Change Model (UNFCCC, 2014)

business as usual

	RCP 4.5					RCP				
	Year	Minimum	Medium	Maximum	Reference	Year	Minimum	Medium	Maximum	Reference
Precipitation (mm)	2035	-15.9	-8.2	9.2	-3.0	2035	-20.4	-12.9	-0.5	-12.9
	2055	-24.2	-15.4	0.7	-15.4	2055	-26.5	-15.0	-7.0	-12.9
	2085	-22.5	-13.6	-5.7	-12.0	2085	-38.0	-21.9	-10.9	-14.8
Mean Temperature	2035	0.9	1.2	1.8	1.2	2035	1.3	1.6	2.2	1.6
	2055	1.6	1.7	2.5	1.8	2055	2.1	2.6	3.4	2.6
	2085	1.8	2.1	2.8	2.5	2085	3.8	4.0	5.1	4.0
Maximum Temperature	2035	1.0	1.1	1.8	1.1	2035	1.3	1.5	2.3	1.5
	2055	1.6	1.7	2.5	1.7	2055	2.2	2.6	3.5	2.5
	2085	1.7	2.1	2.8	2.5	2085	3.8	4.1	5.0	3.9
Minimum Temperature	2035	0.9	1.1	1.7	1.3	2035	1.2	1.6	2.1	1.7
	2055	1.5	1.7	2.4	1.8	2055	2.0	2.5	3.3	2.7
	2085	1.7	2.0	2.8	2.5	2085	3.7	4.0	5.1	4.0

Years refer to the midpoint of moving averages over 30 years; reference model: SMHI – NCC-NorESM-LR (Norwegian Climate Centre)

The authors suggest high to very high vulnerability with regards to the water resources availability and quality impact on Jordan.

2) Third Climate Change Model prepared by RICCAR (2018) for UNESCWA; considers 9 different regional climate models (RCM)

The Arab Climate Change Assessment Report (ACCAR) came out of the Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR), which was launched jointly in 2017 by the United Nations organizations and the League of Arab States. The report is the first attempt to comprehensively assess the impact of climate change on water resources in the Arab region, and to examine the implications these impacts will have on social, economic and environmental vulnerability in the region. The assessment uses projections from regional climate modelling (RCM) and regional hydrological modelling (RHM) until the year 2100, which are in turn based on climate scenarios of the Intergovernmental Panel on Climate Change (IPCC) in its Fifth Assessment Report (AR5). The findings in this report are based on a common and uniform methodological framework that is applied across the Arab region, which is crucial for the regional dialogue and exchange among the Arab States. The integrated assessment methodology also provides a regional baseline which can be used to inform and prepare assessments at sub-regional, national, and local levels.

In this context, the RICCAR report provides a comprehensive and scientific basis for examining climate change issues in the assessment of the Third National Water Master Plan (NWMP-3) and helps to understand what the global and regional processes and threats of climate change mean for the exploitation of water resources and usability of existing infrastructures in Jordan in the future. In doing so, the RICCAR assessment results are used in the NWMP-3 for the climate change modelling and hydrological modelling projections in Jordan until the year 2040. In particular, the results are used to calculate the impact on generated runoff and on groundwater recharge. In this way, extreme vulnerable regions and infrastructures are identified to prioritize coordinated actions on climate change adaptation.

The findings of the climate change projections over the Arab region are averaged for mid-century (2046-2065) and end-century (2081-2100), compared to the reference period (1986-2005). It must be remembered that the period covered by the NWMP-3 is only until 2040, which is in the near future and therefore more subject to climate variability than to climate change. Climate change projections in the RICCAR assessment are based on two representative concentration pathways (RCPs), which describe the moderate emission scenario (RCP4.5) and the high emission or 'business as usual' (BAU) scenario (RCP8.5). The time periods and scenarios mentioned were chosen to facilitate comparisons with climate modelling projections at global, regional, and national levels.

Currently, tiles are 50 km * 50 km large, but it is intended to downscale the model to a 8 km * 8 km grid.

The average mean temperature is expected to increase for RCP4.5 around 0,8° C and for RCP8.5 around 1.1° C between 2020 and 2040. The projected changes in temperature become even more evident for the two scenarios after 2040. Average mean temperature in the Arab region for RCP4.5 is expected to increase by around 1.6° C, at mid-century and by 1.9° C, at end-century. The RCP8.5 shows an increase of around 2.2° C from mid-century and 4° C towards end-century. When focusing on seasonal changes, the findings show that the temperature increase is more or less evenly distributed over all seasons.

Precipitation changes until 2040 are variable, but show decreasing trends at the end of the century. In the Arab region, rainfall is projected to decrease 7% for RCP4.5 and 13% for RCP8.5 by 2100. In the summer season, precipitation is projected to decrease by 22% for RCP8.5 at end-century. However, the average change in precipitation between 2020 and 2040 is an increase of 13.2 mm/year for RCP4.5 and a decrease of 0.2 mm/year for RCP8.5, compared to the reference period.

The findings of the RHM show a wide range for the mean change in runoff over time for both the RCP4.5 and RCP8.5 projections. Therefore, runoff projections are variable, and do not indicate a consistent trend. Changes in runoff between 2020 and 2040 are projected to generally increase for RCP4.5 and remain stable for RCP8.5, compared to the reference period. The average increase in runoff for RCP4.5 is around 1.6 mm/ year for the 20-years period, compared to the reference period.

Since the evaluation of the impact based on RICCAR data is not yet finalized, impact assessments are currently based on data from UNFCCC (2014). UNFCCC (2014) assumed that rainfall will fall by 12.9 mm/yr (countrywide average 95 mm/yr) or 13.6 % by 2035, and temperature will increase by 1.6°C. On a countrywide scale, this would mean a **decline in long-term groundwater recharge of about 15% by 2040 from 280 MCM/yr to approx. 240 MCM/yr.** Long-term **surface water runoff** would also **decrease by about 15% from around 400 MCM/yr to around 340 MCM/yr by 2040**. This would mean that **the internal long-term conventional water resources availability will decrease even further from the current level of 65 m^3/ca/yr to 46 m^3/ca/yr**.

Actions required:

- Integrate expected impacts of Climate Change on water resources into investment planning.
- Use expected reduced water resources availability for all project planning.
- Coordinate with other sectors on how to respond to future challenges, e.g. changed water resources allocation for agriculture, or flood protection.

3.2.2 Energy and Costs

Facts

Energy currently constitutes about 50% of costs in the water sector, and about 15% of national energy consumption is spent on water abstractions and transfers (including energy consumption for water use in agriculture). Energy consumption for water operations, and thus both percentages, are going to increase, even if energy efficiency measures are introduced. With declining water levels, more energy will be needed for abstractions in the future. Because water is not available where it is needed, transfers will increase, which will also require more energy. The desalination of seawater requires more energy than abstracting conventional water resources.

It was originally planned to include a chapter on energy and costs in this document, specifying:

- → Energy Policy
- → Cost of Water
- → Electricity Cost analysis for water resources
- → Action Plan for energy efficiency
- → Energy Projects
- → NRW
- → Hydropower in KTD and the Pumped-storage proposal at Mujib
- → Renewable energy systems water sector institutions

It was also intended to forecast future energy consumption. However, the way that energy consumption data is currently collected is very much incomplete and does not allow such a forecast.Unfortunately, therefore, no text can be provided for these topics at this point.

Energy for water supply operations is provided by the national power companies and, until now, the water sector institutions have not been allowed to operate on-grid solutions for generating and feeding in renewable energy that exceeds 1 MW. This limits what the water sector institutions can do to save energy mainly to energy efficiency measures.

Energy consumption and costs have been a focus of management decisions for the past decade, and many projects have been implemented to improve energy efficiency. However, not nearly enough is done to save energy. Moreover, the depletion of conventional water resources and the need for more water from non-conventional resources, particularly desalination, will dictate what will happen in the future, and this will inevitably mean more and more energy will be needed.

The following general facts will have an impact on energy consumption (based on I-GWRM project/BGR, related to wellfield management) (Table 20):

- → <u>Well efficiencies</u> are mostly only around 50%, mainly because of the low open area in the screens (commonly only ~1%), which results in a higher drawdown (or pumping lift) than necessary. A simple solution would be to increase the open area to around that of the porosity (~3-6%). About 5% of the energy is lost due to this factor.
- → <u>Pump efficiencies</u> (combined pump and motor efficiency) are equally low, mostly also around 50%. If the right pump were installed, there would normally be efficiencies of 70%. About 20% of the energy is lost due to this factor.

→ The optimal location of wells and other water supply infrastructure, based on energy consumption (topographic) considerations, is often not considered in the planning process. Much energy could be saved by choosing the optimal places for well galleries and pumping stations. More than 10% of energy is lost due to this factor.

The following additional impacts due to the declining groundwater resources are expected:

→ Average combined pump and motor efficiency is already low at ~50%. The increased decline of groundwater levels will result in pumps needing to be changed more often. As this is not expected to happen, pump efficiencies will decrease by even more than 50%.

→ An average increase in pumping lift of around 5 m/yr means that an additional lift of more than 50 m must be expected over the next 10 years, in which case average pumping lifts will be about 350 m. Energy consumption at the existing wells will therefore increase by at least 40% by 2040. Due to this increase in pumping lift, the cost of exchanging pumps and the time needed to do so will also increase. With more time needed for repairs, pumps will be operational for less time and will therefore deliver less water.

→ While increased pumping levels would lead to a rise in friction losses, since well yield would also decrease, the overall friction loss might not increase by very much.

→ With saturated thickness at wells decreasing by ~50 m (>25%) over the next 10 years, well yields will decrease (see related chapter).

→ Theoretically, well efficiencies would increase due to lower yield; however, as water levels will also decline, well efficiencies might remain at around the current level.

Table 20: Consequences of Depletion of Groundwater Resources for Energy Consumption

Factor	Trend	Energy use trend	Relative contribution to increased consumption
Wells			
Pumping efficiency (pump+motor) (50%)	↓	↑	50%
Pumping lift (+5 m/yr)	↑	↑	35%
Friction loss in pipes	↑	↑	15%
Yield (saturated thickness) (-10%/yr; -5 m /yr)	↓	↔	0
Well efficiency (50%) (additional DD)	↑	↔	0

Actions required:

- Pumps need to be adjusted more frequently (~every 2 years) with increasing pumping lifts /decreasing yields, currently mostly < 50%; they need to consider current Q/H conditions (H / DWL not sufficiently monitored)
- Extended riser pipes have more friction loss
- Well efficiency: with decreasing yields, efficiency will increase but additional drawdown will remain high due to increasing overall pumping lift and lower screened/saturated interval

3.2.3 Water Quality Impacts

The future use of water resources also largely depends on water quality development. Water quality is more and more impacted by human activities. Although the occurrence, extent and level of elements appearing that are detrimental to human health is alarming, they are still not systematically mapped. Treatment possibilities are currently limited, and were not designed to deal with such impairments in water quality. The observed water quality changes will impact on the usability of groundwater and surface water resources, and will require more and more dedicated and complex treatment solutions. Finding out which areas and what infrastructure that is currently in use are affected by which process is therefore essential, since the future supply of safe water depends on such an analysis. Some previously established facts concerning water quality impacts are summarized below and in ANNEX 6.

The following effects of water quality deterioration have been observed:

1) Groundwater gradients and flow directions are changing; salinities are increasing in many parts of the A7/B2 aquifer that are currently exploited due to the mobilization of brackish groundwater from the eastern parts of the country towards the western part.
2) In areas of high exploitation, there is less and less water in the water system. Irrigation return flows therefore have an increasing impact and salinities, particularly in the A7/B2 aquifer, will constantly rise. In some areas that are extensively cultivated, nitrate and other contaminants have reached levels where the use of water resources for domestic water supply is no longer possible.
3) The unsafe disposals of brine, sand, membranes, etc. from governmental desalination plants (radioactivity problem) is having an environmental impact in downstream areas.
4) Salinities in the A7/B2 and other aquifers are increasing locally due to the discharge of brine from small/mobile private desalination plants (injection into wells; discharge into rivers).
5) Heavy metal contents are increasing due to downward leakage from the B3 aquifer (oilshale) caused by declining hydraulic pressure in the A7/B2 aquifer.
6) Contaminations (other than microbiological) are becoming more widespread and more frequent as a result of human activities (e.g. due to mining; uranium, sulphate).
7) Microbiological contaminations are becoming more widespread and more frequent as a result of human activities (mainly wastewater).

While most water quality impact trends show a significant increase over the past decade, insufficient monitoring of these effects often makes it difficult to forecast the extent and level of future impacts at the moment.

1. brackish groundwater mobilization in the A7/B2 aquifer:

In the past, GW flow closely followed dips in the geological strata; i.e. in many areas it was directed towards the east, and then only flowed towards the main wadis draining towards the west in areas where the structure permitted it, namely the Hasa, Mujib, Zarqa and Yarmouk. This flow pattern has changed significantly and, with declining water levels, is going to change even further. Most groundwater flows will then be diverted to Yarmouk River as a natural outlet due to its low structural position.

Groundwater salinity previously increased along the flow path towards the east, so that all groundwater in the A7/B2 aquifer in the east of Jordan is brackish. Groundwater gradients in the western part have already partly inverted due to abstraction, causing a mobilization of the brackish groundwater towards the west. This inversion of the gradient was first noticed in the area between Azraq and Muwwaqqar, but is likely to affect all areas with high abstraction in the A7/B2 in the west, such as the Jiza-Zumayla, Siwaqa, Qatrana, Lajjun, Hasa and Maan areas.

Groundwater salinity has so far only roughly been characterized and presented in the groundwater potential maps that were prepared in the groundwater resources assessments of South Jordan (BGR, 1986-90) and Northern and Central Jordan (BGR, 1992-96; MARGANE et al., 2002). ANNEX 6.1

2. widespread contaminations related to agricultural landuse:

Some areas have been in use for agriculture since the mid-1960s, like the Dhuleil-Hallabat area. Nitrate contents in these areas have increased drastically and reached levels well beyond the acceptable limit for drinking purposes (MARGANE et al., 2009; Figure 43).

3. discharge of brine and other contaminants from governmental desalination plants:

None of the 26 official desalination plants in Jordan currently has an environmental impact assessment (EIA). The generated brine is discharged into nearby wadis, creating environmental problems in the downstream area. If surface water is used directly, this would have higher salinity. Salinity would increase in places where surface water infiltrates into groundwater.

Environmental problems also relate to the discharge of processed water that contains other elements including radioactive ones, particularly radium and uranium which are naturally contained in the raw water, and chemicals that are added to prevent the biofouling of membranes. In some cases, radium is retained from the produced water through ceramic filters. Backwashing of these leads to discharge to wadis, and thus contaminations. Related procedures must be improved to avoid these. This is also valid for the disposal of radioactive contaminated membranes.

4. discharge of brine from private desalination plants:

Apart from the official ones, there are an unknown (but high) number of privately operated, sometimes mobile desalination plants used for irrigation. These do not require a license for operation, or an EIA for brine discharge. Private desalination plants are widespread in the Jordan Valley and in the North (Mafraq-Ramtha-Jaber area), where farmers have drilled (illegally) to the deeper aquifers (A4, A1/2, Kurnub) which have a higher salinity (1-5 g/l). Impacts have been reported on downstream drinking water wells in the A7/B2 aquifer, and it appears that brine is often injected into old dry wells in the A7/B2.

5. heavy metal contaminations from the B3 (oilshale):

The B3 aquitard, which overlies the A7/B2 aquifer in many locations where groundwater is abstracted, contains high concentrations of heavy metals. Molybdenum (Mo), nickel (Ni), vanadium (V), uranium (U) and arsenic (As) are particularly problematic for human health. Related problems were first investigated in the Wadi Al Arab wellfield, where Mo concentrations have reached several mg/l in some wells (the limit in drinking water is 0.09 mg/l; extended limit: 0.27 mg/l, in case no alternative water source exists and use is approved by the Jordanian Ministry of Health (MoH)). ANNEX 6.2 contains a related map of molybdenum contents in the Wadi Al Arab wellfield area, as observed in 2017. However, while the problem is much more widespread, a comprehensive analysis is so far lacking. Based on observed facts, the problem occurs mainly where the A7/B2 aquifer had previously been confined but due to overabstraction water levels in the A7/B2 aquifer have strongly declined so that downward leakage has significantly increased.

6. widespread contaminations as a result of human activities:

Industrial or mining activities have led to large contaminations. Examples are the sulphate mining in the Mujib dam area or the phosphate mining in the Abiad and Hasa mines. The impact of the none of these is properly monitored.

7. local contaminations as a result of human activities (mainly wastewater)

Many springs and wells are affected by microbiological contamination. Although such effects are observed in many areas, there is still no compilation at the national level of related events. Related groundwater protection zones were established, hoping that this would result in an improved catchment management. It must however be observed that related proposed protection measures are often not implemented. Wells and springs where microbiological contamination had frequently been observed are:

- Pella spring (protection zone delineated in 1999, discharge ~8 MCM/yr)
- Rahoub spring (protection zone delineated in 2006, discharge ~0.3 MCM/yr)
- Wadi Shuayb springs: Hazzir, Azraq, Shreyah, Baqqouriah (protection zone delineated in 2010, discharge ~8 MCM/yr)
- Qunayyah spring (protection zone delineated in 2004, discharge ~2.9 MCM/yr)
- Quairawan spring (protection zone delineated in 2004)
- Wadi As Sir spring (Water Safety Plan by WAJ in 2008; updated in 2017)

Actions required:

- ➢ Monitoring of water resources quality needs to be improved in all mentioned areas
- ➢ Dedicated reports with maps on all mentioned phenomena should be compiled in order to inform decision-makers

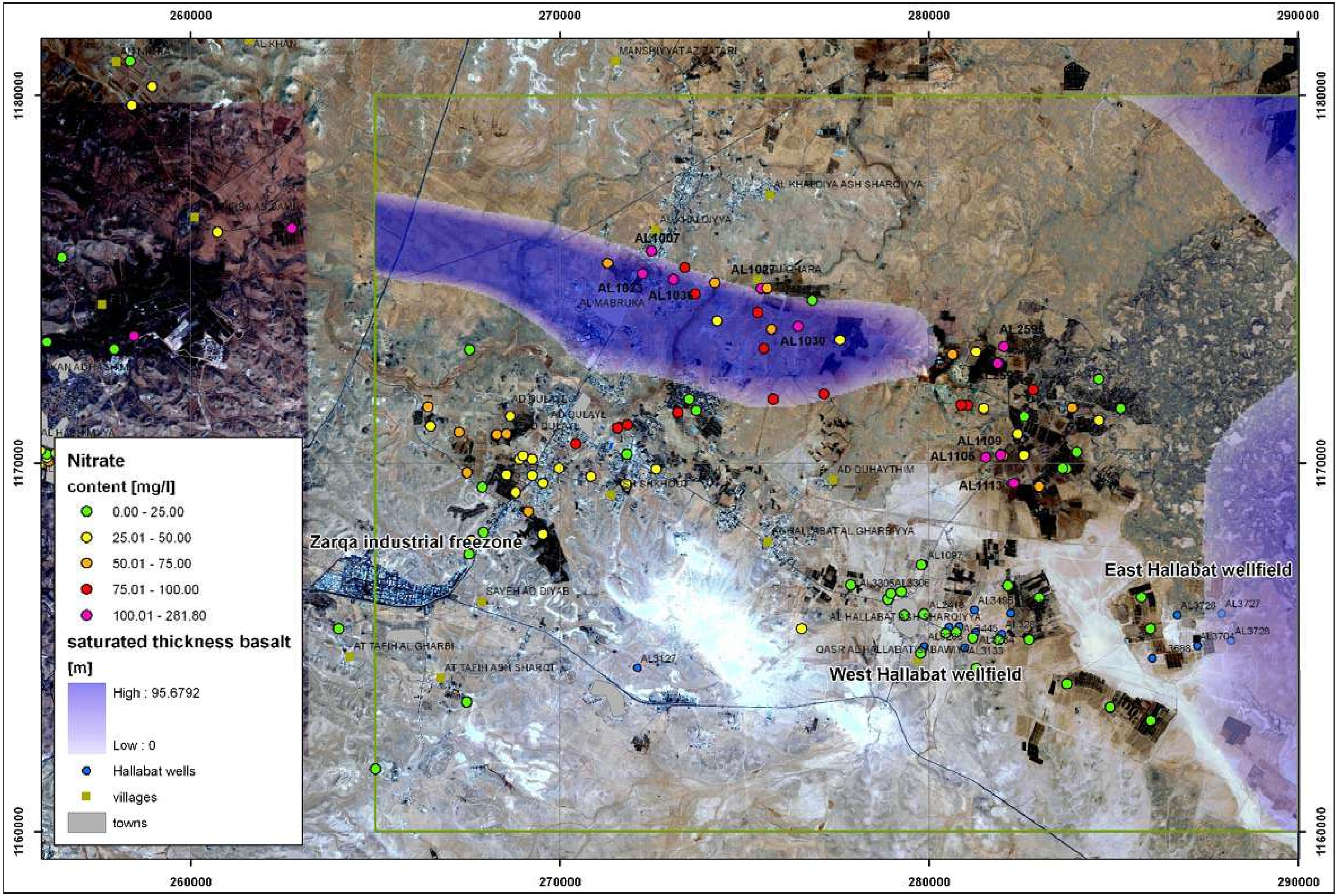
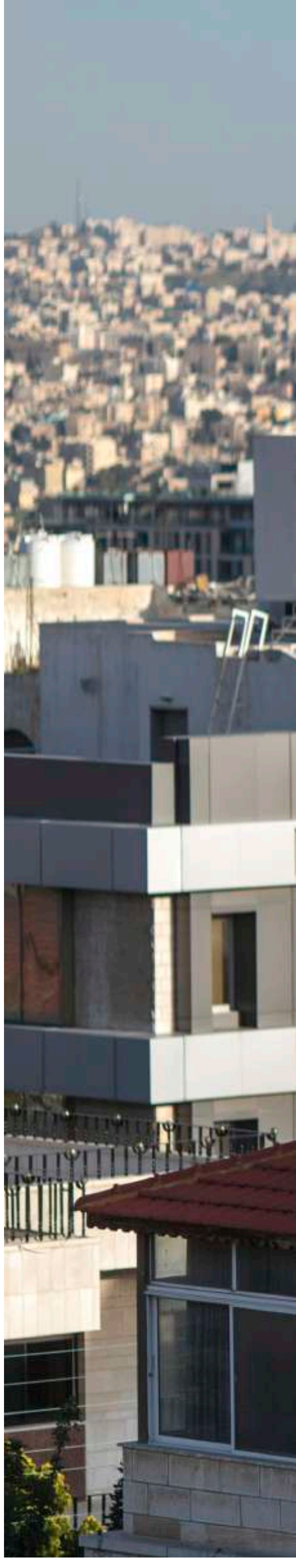


Figure 43: Nitrate contents in the Duleil-Hallabat area (MARGANE et al., 2009)

4 WATER DEMANDS,USES AND ALLOCATION GAPS



Terms used in this Chapter are explained under Definitions in the front matter.

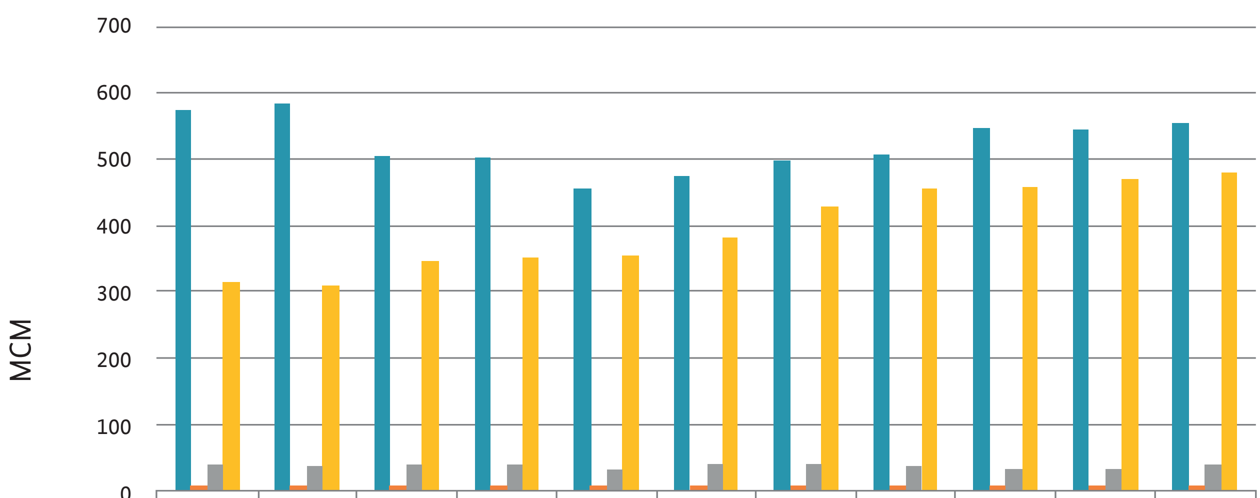
4.1 Water Uses

The internal conventional water resources availability is 65 m3/ca/yr (280 MCM GW, 400 MCM SW, 10.3 million inhabitants in 2018). The gap between water demand and supply is projected to continue widening. With a municipal water demand of 810 MCM only 34% of available supply, through the remaining production of around 280 MCM, can be covered by 2040 (in the BAU scenario, Chapter 4.3), due to sharp population increase, climate change and economic development in Jordan. However, the gap is more extensive with a consideration of the demand of other sectors (industrial, agriculture, etc.). It is not well known and difficult to predict how water demand for these sectors will develop. The possibilities for an economic development more and more depend also on a reliable estimation of future industrial water demand and this projection is therefore is crucial for water resources planning.

Water supplies have been tailored to meet the demands of all sectors (agriculture, municipal, industry, and others). Competition for water allocation is continually growing due to increasing scarcity, and in the face of this growing demand the National Water Strategy has emphasized the priority of water supply for the domestic sector over others. While this Rapid Assessment focuses on municipal water demand, it is essential to present a quick overview of the other sectors which are competing for these limited water resources, and are largely responsible for the extreme groundwater level declines over the past two decades.

Total water use in 2018 shows an increase of 15% since 2008. Water use varies per sector; the agricultural sector has always been the main water consumer, ranging from highs of over 61% of total use in 2008 to about 51% in 2015 (this is based on WAJ metering data of groundwater abstraction for irrigation and estimated surface water use in Jordan Valley; however, GW abstraction data based on remote sensing indicate that the share of water use in agriculture was still much higher. The second largest consumer is the municipal sector (domestic and non-domestic), which has increased significantly by more than 50% since 2008. The industrial sector (mainly mining industries) accounts for an average of 4%. Less than 1% is continuously allocated for livestock uses.


Amman



	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Irrigation	573.8	584.2	504.7	501.3	454.7	474.8	497.5	506.8	547.0	544.7	555.8
Livestock	7.6	7.9	7.1	7.3	7.1	7.1	7.1	7.2	7.7	7.1	7.1
Industrial	39.4	37.2	40.3	40.5	33.4	39.1	39.0	37.2	32.5	32.7	40.9
Municipal	315.1	308.5	346.7	351.7	353.7	380.6	428.2	456.0	457.0	469.7	479.6

Figure 44: Development of Water Usage 2008-2018 (MWI Water Budget)

In 2018, the total water use for all sectors was 1082.9 MCM. Figure 45 presents the share of water uses for the four main sectors. Most of this consumption, 51%, went to the agricultural sector, which produces 4% of the Gross Domestic Product (GDP). The municipal sector accounted for 44% of total uses, while industrial uses accounted for 4%, and livestock uses for 1%.

Table 21: Water Use and Allocation for different Sectors (MWI Water Budget 2018) [MCM]

Resource/Sector	Municipal	Industrial	Irrigation	Livestock	Total Uses
Surface Water	125.8*	10.4	147.3	5	288.5
Groundwater	351.1	26.7	261.1***	2.1	641
Treated Wastewater	0	2.5	146.9	0	149.4
Desalination (Sea Water)	2.7	1.3	0	0	4
Total	**479.6****	**40.90**	**555.3**	**7.1**	**1082.9**

*Including stprings

**including water from private wells provide tankers (not supplied through the municipal network)

***including 16.5 MCM from Mukheiba wells ; MWI Water Budget considers Mukheiba wells as part of surface water, as they deliver water to KAC

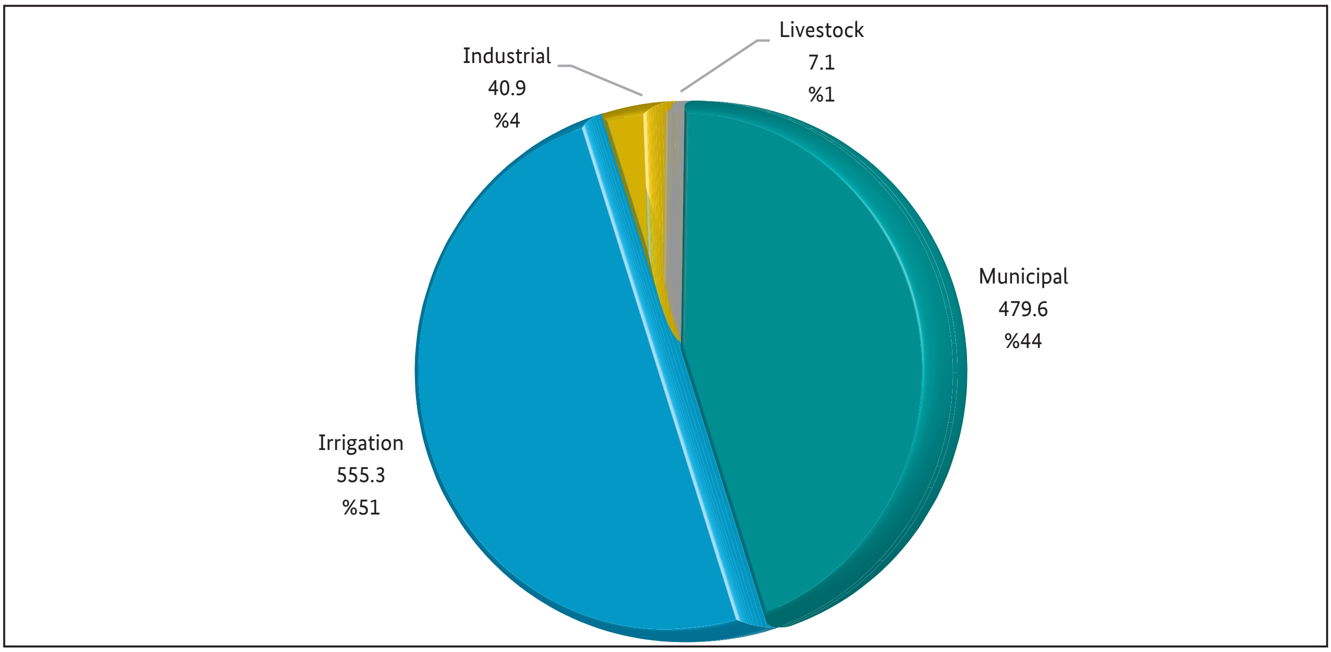


Figure 45: Water Use [in MCM and percentage of total] by Sector 2018 (MWI Water Budget)

Water Use by Resource Type

In 2018, about 58% of the water supplied came from groundwater (641 MCM), while surface water provided 26.6% (288.5 MCM, including water from springs), and the remainder was from non-conventional water resources, treated wastewater (13.8% or 149.4 MCM), and a limited amount from desalination of seawater (4 MCM or 0.4%). Competition for the limited resources between the agricultural, municipal and industrial sectors is intense and constantly growing. This section presents the water use by resource type.

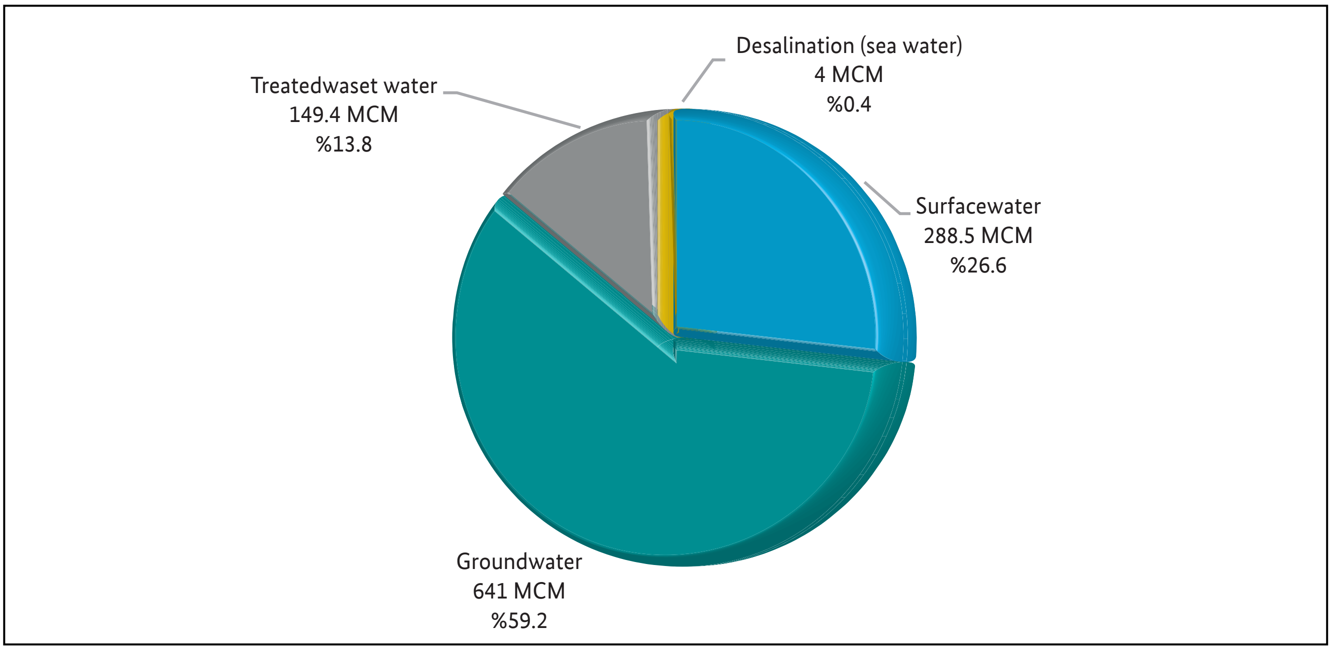


Figure 46: Water Use by Resource type 2018 (MWI Water Budget)

4.1.1 Groundwater Use

Springs should be principally considered as groundwater, since they emerge from groundwater and are thus part of the groundwater budget. Unfortunately, this is not currently the case. The consumption of groundwater production has been increased by 25 % during the last decade. In 2018, the total use of groundwater was estimated at 641 MCM. Domestic use of groundwater allocation is given priority. The municipal and agricultural sectors utilize more than 93% of abstracted groundwater. In 2008, both sectors were sharing the groundwater production almost equally, with municipalities taking 46% (228 MCM) and agriculture 47% (236 MCM). The municipal share of groundwater increased to 55% (351 MCM) in 2018, while the agriculture share fell to 41% (261 MCM), eventually due to a reduction in illegal wells and the contribution of treated wastewater for irrigation in the Jordan Valley and through the development of fossil groundwater resources for domestic uses (Disi), which replaced a part of renewable groundwater use. The remaining 5% is consumed by the industrial sector (4 %; 26.7 MCM) and livestock husbandry (<0.5%; 2.1 MCM).

Still, the agriculture sector consumes a significant part of the water budget in the country; groundwater remains the main water source exploited for agriculture, accounting for 47% of all water used in this sector in 2018. Non-documented, illegal and unlicensed wells have further worsened the deterioration of groundwater resources. The remote sensing studies indicate higher amounts of groundwater pumped for irrigation in spots areas of the highlands; the estimated groundwater abstraction is 290 MCM in 2018, accounted for an additional 83.7 MCM of overabstraction and unbilled water used for agriculture, which could otherwise be used for domestic supply. Details are given in section 4.4.

Groundwater uses in 2018 by uses are shown in Table 22 (MWI Water Budget 2018).

Table 22: Groundwater Uses [MCM] in 2018

Basin/Uses (MCM)	Domestic (private wells)		Domestic (Gov.wells)		Agiculture (Private wells)		Agiculture (Gov.wells)		Industry		Rural and Livestock		Tourism		Total Withdrawi	Total Wells
	Withdrawl	No.of wells	Withdrawl	No.of wells	Withdrawl	No.of wells	Withdrawl	No.of wells	Withdrawl	No.of wells	Withdrawl	No.of wells	Withdrawl	No.of wells		
Amman Zarqa	4.09	73	86.13	197	81.35	637	0.29	2	4.92	79	1.03	20	0	0	177.81	1008
Azraq	1.52	15	19.72	28	39.91	555	0	0	0.89	18	0.49	8	0	0	62.53	624
Dead Sea	2.22	32	42.55	137	26.55	228	4.01	15	7.2	51	0.51	13	0.09	4	83.13	480
Disi	0	0	115.36	76	26.94	32	1.72	4	0	0	0	0	0	0	144.02	112
Hamad	0.03	1	1.22	4	0.09	3	0	0	0.01	1	0	0	0	0	1.35	9
Jafer	0.3	4	11.79	53	17.23	142	0.39	1	11.9	26	0.01	1	0		41.62	227
Jordan Valley	0.48	9	10.61	21	15.72	357	0	0	0.13	4	0.02	2	0	0	26.96	393
Rift Side Wadis	0.59	6	39.25	85	2.4	47	0	4	0.12	0	0	0	0	0	42.36	142
Serhan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
North Wadi Araba	0	0	1.28	10	3.24	18	0.36	3	1.4	5	0	1	0	0	6.28	37
South Wadi Araba	0.01	0	0	0	10.45	52	1.81	6	0.11	2	0	0	0.03	1	12.41	61
Yarmouk	0.35	20	13.43	48	19.63	149	9.41	7	0.07	2	0.01	2	0	0	42.9	228
Total	**9.6**	**160**	**341.34**	**659**	**243.51**	**2220**	**17.98**	**42**	**26.74**	**188**	**2.06**	**47**	**0.13**	**5**	**641.36**	**3321**

Source: MWI Water Budget

Table 23 presents the annual supply from groundwater for different uses. Consumption in the municipal sector, which is the biggest consumer of total groundwater, increased by 54% (351 MCM) between 2008 and 2018 as a result of population growth and urbanization. Agriculture production has only increased by 4% since 2008. Consumption in the industrial sector, which relies on the groundwater supply, was relatively stable between 2008 and 2018. Although the livestock sector only consumes 2 MCM from groundwater, this consumption has almost doubled since 2008.

Table 23: Groundwater Use [MCM] 2008-2018 (MWI Water Budget)

Sector	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Municipal	228.2	214.6	232.1	231.69	231.4	257.4	325	332	333.2	338.4	351.1
Irrigation	236	245.7	252.4	245	250.6	249.8	231.2	237	257.8	251.1	261.1
Industrial	34.3	32.9	32.3	33.9	26.5	32.5	32.2	31	27.4	27.2	26.7
Livestock	0.55	0.9	0.07	0.31	0.1	0.1	0.1	0.2	0.7	2.1	2.1
Total Uses	**499.1**	**494.1**	**516.9**	**510.9**	**508.6**	**539.8**	**588.5**	**600.2**	**619.1**	**618.8**	**641**

4.1.2 Surface Water Use

The consumption of fresh surface water resources has decreased by 14 % during the last decade, due to increase in the utilization of groundwater resources and other resources.

Most fresh surface water is also used by the agriculture and municipal sectors. Table 24 presents the annual utilization of surface water by different users. During the last ten years, these two sectors have accounted for 95% of the surface water available. Agricultural production was originally more dominant at over 70% in 2008, while municipal use accounted for 26%. However, as demand from the domestic sector has significantly increased, the need to prioritize the allocation of surface water to the domestic sector has become more evident. It reached 41% in 2010 and, with some annual fluctuations, has stabilized at 44% in 2018, while the agricultural use of surface water has reduced, recently averaging 51%.

Use in the industrial sector has recently increased to 10.4 MCM (4%) from available fresh surface water resources, while the remainder is utilized by livestock (2-3%; 5-7 MCM).

In 2018, municipal supply consumed 44% (125.8 MCM) of fresh surface water while agricultural production consumed 51% (147.3 MCM) of fresh surface water resources and more than 98% of treated wastewater. The agricultural sector therefore used 69% of surface water (fresh and treated).

A relatively limited amount of surface water resources was allocated for the industrial sector, mainly from the wadis and the Mujib dam for the Potash company. Desert dams that supply livestock in remote areas accounted for a very limited amount of the available surface water (MCM in water budget 2018). However, there is no accurate quantification of water uses from desert dams.

Table 24: Surface Water Use 2008-2018 in MCM (MWI Water Budget)

Sector	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Municipal	86.9	93.9	114.6	120	122.3	123.2	103.2	124	123.8	131.3	125.8
Irrigation	238	237.3	151.1	154.8	104.2	117.6	143	139	155	149.4	147.3
Industrial	3.9	3.1	6.4	5.1	5.5	4.9	4.8	4	3	2.4	10.4
Livestock	7	7	7	7	7	7	7	7	7	5	5
Total Uses	**335.8**	**341.3**	**279.2**	**286.8**	**239**	**252.7**	**258**	**274**	**288.8**	**288.1**	**288.5**

4.1.3 Non-Conventional Water Resources

Treated wastewater is considered a main element of the water budget. While there are ongoing efforts to maximize the efficient use of all possible water resources, almost 90 % of all treated wastewater is currently used for irrigation in the Jordan Valley. According to the Water budget, 166.5 MCM of treated effluent were released, of which 149.4 MCM were used (146.9 MCM for irrigation and 2.5 MCM for industrial purposes).

This resource has been developed as a byproduct from wastewater treatment plants. The main plant is the As Samra WWTP, which provides 88% of the treated wastewater in Jordan. Use from this source, which accounted for 100 MCM in 2008, has increased by 47% over the last decade to reach 147 MCM in 2018 following expansion of the As Samra WWTP. Agriculture production utilizes 98% of the treated wastewater for irrigation in the Jordan Valley. A marginal amount of 2.5 MCM is used by the industrial sector (the Aqaba Fertilizer Company).

The recent development of a small-scale desalination scheme in Aqaba has secured an additional 4 MCM for the Aqaba governorate, which is shared between the industrial (1.3 MCM) and municipal (2.7 MCM) sectors.

4.1.4 Municipal Water Use

All activities which are primarily supplied through the municipal water supply network are considered municipal users. They are classified into domestic and non-domestic users. Domestic use is the water consumed through household activities, while non-domestic comprises a variety of commercial and public uses, tourism, light industries, and the occasional irrigation of public spaces from the main water supply network.

Municipal water consumption has increased by more than 50% in the last ten years due to population growth, economic developments, and the influx of refugees from neighboring countries. Table 25 shows the annual water supply for each governorate between 2008 and 2018. These are the total amounts of water produced from the sources and transferred through municipal water networks before any losses (physical leaks and administrative losses).

The actual consumption by users is therefore less than this due to losses, mainly physical leakages. Although the Water Authority of Jordan has taken several measures to reduce water losses from the water distribution network and main transmission line, the average percentage of water loss is actually increasing, and exceeding 50% during the last 5 years. Further improvements are therefore needed to reduce this figure.

Table 25: Municipal Water Supply for Jordan's Governorates Over 2008-2018 [MCM]

Governorate	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Amman	128.7	129.0	134.2	132.2	135.8	151.8	179.2	183.3	189.9	195.8	195.99
Zarqa	44.8	46.7	48.3	50.1	47.3	54.1	66.6	62.7	62.5	63.5	64.06
Mafraq	18.6	20.3	20.5	20.4	21.4	20.1	24.7	25.2	27.3	27.6	28.66
Jarash	4.6	4.6	4.7	5.2	5.9	6.2	6.7	7.2	4.7	8.0	8.39
Ajloun	3.8	3.9	3.9	3.6	4.4	4.7	4.9	4.9	7.9	5.2	5.74
Balqa	21.4	23.1	25.6	26.1	29.2	30.1	35.7	35.2	42.4	42.5	42.39
Irbid	39.2	37.0	37.9	41.0	40.5	42.1	45.2	46.9	47.5	50.3	54
Tafilah	4.6	4.9	4.9	3.5	4.3	4.2	5.5	5.9	6.1	6.1	6.82
Karak	13.7	14.6	15.4	15.2	15.8	18.9	22.2	21.7	22.6	21.1	25.41
Ma'an	9.3	9.1	10.4	10.5	11.9	11.5	14.2	14.2	14.1	14.4	15.65
Aqaba	14.3	12.4	14.5	15.3	15.7	16.3	22.6	23.7	15.9	22.1	24.48
Madaba	7.4	7.8	7.5	6.7	7.3	8.9	8.9	8.8	8.7	9.8	10.54
Total	**310.4**	**313.4**	**327.8**	**329.8**	**339.5**	**368.9**	**436.4**	**439.8**	**449.6**	**466.2**	**482.1***

Source: ISSP-WAJ
*including 5.5 MCM for irrigation through the municipal water supply system

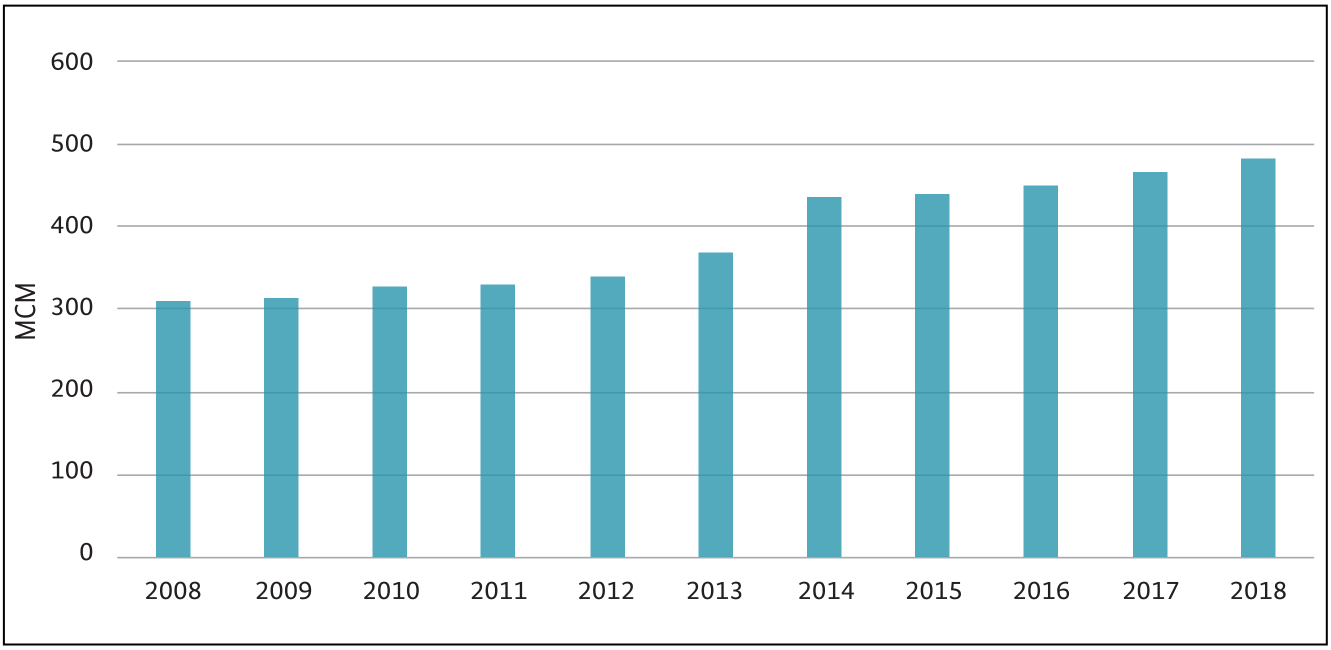


Figure 47: Municipal Water Use 2008-2018 (Source: MWI & WAJ 2018) [MCM]

The priority for water supply is domestic use, with a target of delivering 120 l/c/d for Amman, 100 l/c/d for all other cities, and 80 l/c/d for rural areas. Estimations of non-domestic share are based on the categories of each subscriber in the billing data, namely the commercial, tourism, and public sectors, and some industry. Accordingly, the share between the domestic and non-domestic use of municipal water supplies is analyzed for all governorates based on 2018 as presented in Table 26. Projected estimates of non-domestic demand in the demand section are based on these shares.

Nationwide, domestic use accounts for an average of 85% (88% without usage in Aqaba, where it falls to 35% due to the high number of hotels, industries and related commercial activities there). Total domestic use was about 410.8 MCM in 2018, while non-domestic use was 71.3 MCM, or 15% of total municipal use.

Table 26: Domestic and Non-Domestic share for Municipal Water Use in 2018

Governorate	Supply 2018 (MCM)	Domestic Consumption Ratio (%)	Non-Domestic Ratio (%)	Domestic Use (MCM)	Non-Domestic Use (MCM)
Irbid	54.0	87.9	12.1	48.95	5.05
Mafraq	28.66	91.05	8.95	23.97	4.68
Ajloun	5.74	81.07	18.93	5.09	0.65
Jarash	8.39	85.41	14.59	7.95	0.44
Amman	195.99	82.06	17.94	172.28	23.71
Zarqa	64.06	90.5	9.5	58.32	5.73
Balqa	42.39	93.2	6.8	34.36	8.02
Madaba	10.54	83.66	16.34	9.83	0.72
Karak	25.41	90.65	9.35	21.7	3.71
Tafilah	6.82	88.69	11.31	5.6	1.22
Ma'an	15.65	94.77	5.23	14.16	1.49
Aqaba	24.48	35	65	8.57	15.91
Total	**482.1**	**85.2**	**14.8**	**410.79**	**71.34**

Source: WMI estimation based on billing data obtained from WAJ, Miyahuna, YWC and AWC for 2018

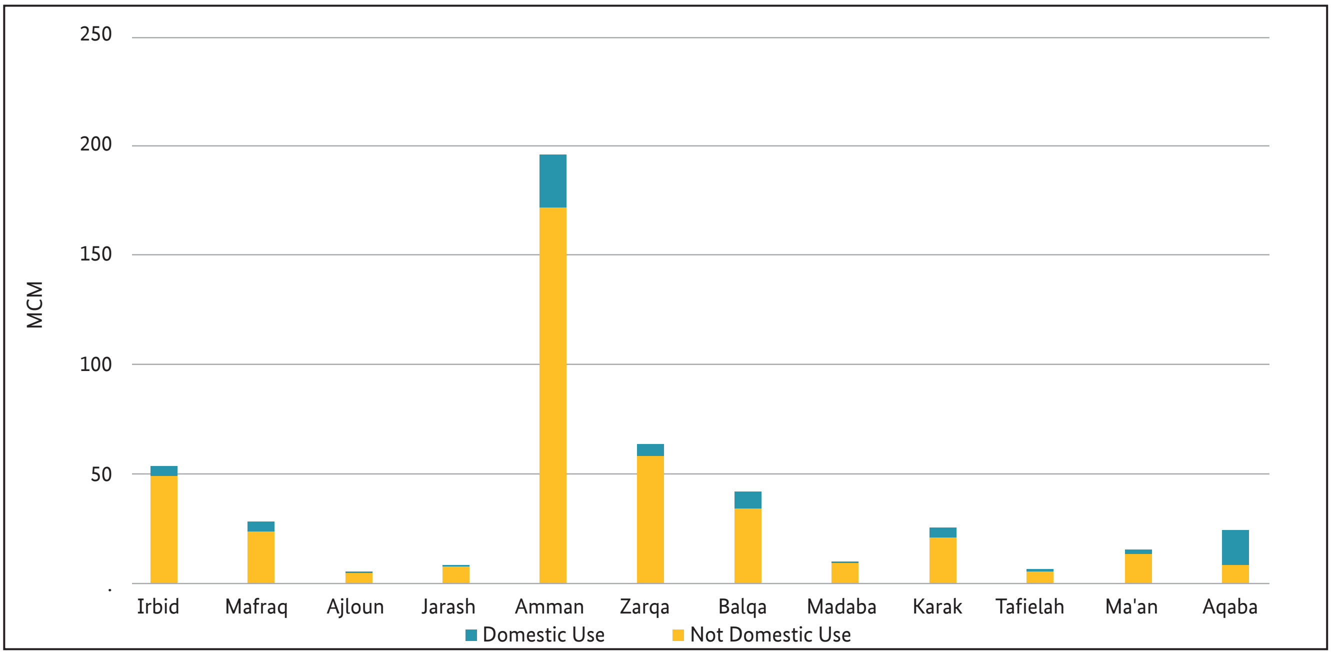


Figure 48: Domestic and Non-Domestic share of Municipal Water Use in 2018

Municipal water consumption was 476.6 MCM in 2018 (excluding water for irrigation), which is equivalent to 127 l/c/d (liters per capita per day). The minimum share was 77 l/c/d for Irbid, and the maximum 330 l/c/d for Aqaba, due to high touristic activities. When the per capita share for domestic use (excluding non-domestic use) is calculated for each governorate, based on the domestic share of the municipal supply as discussed in this section, the lowest share is 70 l/c/d for Irbid and the highest 211 l/c/d for Maan, with an average of 108 l/c/d across all governorates. These figures reflect a vast deviation from the national target and an inequality of water distribution and allocation for domestic water between governorates, which also report more losses and do not include the use of drinking water for other activities (i.e., irrigation and livestock).

Additional private wells, not connected with the municipal water network, are supplying the domestic and non-domestic activities in some areas. In 2018, around 9.6 MCM were pumped from 160 wells; that also has a slight increase of the per capita consumption. However, the Rapid Assessment excluded these wells through the analysis.

Moreover, due to the high percentage of water losses (53.3%; adopted from WMI project), the actual share is much lower than the shares presented in Table 27. When administrative losses are counted as water that is consumed by users but not billed, the average consumption share dropped significantly to around 80 l/c/d for all governorates. A detailed analysis of water losses (Non-Revenue Water-NRW) is given below in Chapter 4.2.

Table 27: Municipal Water Use and Per Capita share in 2018

Governorates	Total Supply for Municipal use 2018	Population 2018	Average Consumption of total Supply l/c/d	Average Consumption for domestic use l/c/d	Average Consumption Including Admin. Losses consumed by domestic use l/c/d
Irbid	53.77	1,911,600	77	70	52
Mafraq	28.65	550,275*	143	119	75
Ajloun	5.74	190,200	83	73	61
Jarash	8.25	256,000	88	84	68
Amman	195.99	4,337,839	124	109	84
Zarqa	63.37	1,457,402**	119	108	75
Balqa	42.39	531,000	219	177	112
Madaba	9.89	204,300	133	124	95
Karak	22.74	341,900	182	156	102
Al Tafilah	6.81	104,000	179	147	103
Ma'an	14.54	171,100	233	211	132
Aqaba	24.48	203,200	330	116	99
Kingdom	476.61*	10,258,816	127	108	80

*excluding water used for irrigation through municipal supply system

**Excluding Syrians living in the Refugees camps supplied through private wells

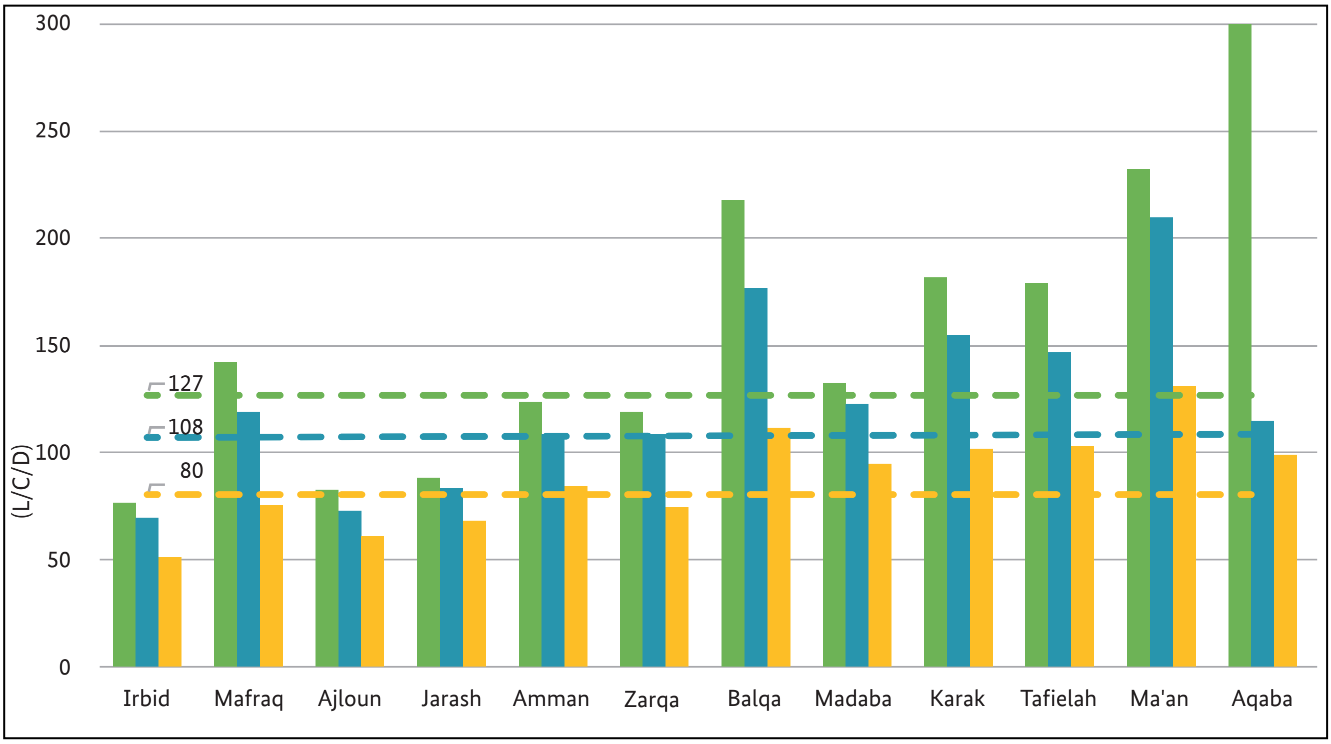


Figure 49: Municipal Water Use and Average Per Capita share in 2018

4.1.5 Industrial Water Uses

Industrial water consumption refers to the amount of water consumed by industries that exploit water produced locally, mainly from deep wells, with the exception of two major industries in Aqaba, the Thermal Power Station and Jordan Fertilizer Industry Company that are currently receiving their water from the public network.

Other light industries that are supplied through the municipal network across the Kingdom are considered within the commercial categories of non-domestic use. There are currently 16 Industrial Development and Free Zones under control of the Jordan Investment Commission (JIC). Most of these depend on water supplies from the government, and do not have their own water supply.

Industrial development has increased in Jordan over the past decade, with industrial activities contributing 28% to GDP in 2018 (World Bank, Jordan Country Profile). The major industries are mining and manufacturing, with phosphate and potash mining, cement production, petroleum refining and fertilizer production utilizing the biggest share of industrial water consumption.

Although industrial activity has been increasing, recent records only show a slight increase in water consumption. That stability is attributed to the development of in-site treatment and reuse technologies. Table 28 presents the industrial sector's annual consumption. The average total amount of water used by industry is estimated at 37 MCM/yr.

These big industries rely heavily on groundwater resources. In 2018, 68% of the sector needs have been covered by the groundwater abstraction estimated by 27.8 MCM; surface water contributes by 25% (10.4 MCM), the utilization of treated wastewater in industrial activities implemented only in Aqaba by 2.5 MCM for Aqaba fertilizer Company, and recent development of desalination in Aqaba contribute to industrial use by 1.3 MCM.

Table 28: Industrial Water Use [MCM] by Resource Type 2008-2018

Water Type / Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Surface Water	3.91	3.1	6.36	5.054	5.5	4.86	4.8	4	3	2.97	10.4
Groundwater	34.3	32.9	32.3	33.9	26.5	32.5	32.2	31	27.4	27.2	27.8
Treated Wastewater	1.2	1.2	1.6	1.5	1.4	1.7	2	2.2	2.1	2.5	2.5
Desalination (seawater)	0	0	0	0	0	0	0	0	0	0	1.3
Total	**39.41**	**37.2**	**40.26**	**40.454**	**33.4**	**39.06**	**39**	**37.2**	**32.5**	**32.67**	**40.9**

Water supply to the industrial complex at the southern end of the Dead Sea is provided from a combination of surface and groundwater resources (Figure 49):

- → Mujib/Wala groundwater (GW) (Disi)
- → Mujib surface water (SW) Mujib dam
- → Mujib SW downstream Mujib dam
- → Wala SW downstream Wala dam
- → Wadi Ibn Hammad dam (under construction, mainly from Disi aquifer)
- → Wadi Ibn Hammad spring (CA0502; Disi aquifer)

Major industrial uses are those for exploiting and processing mineral resources, such as

- **Phosphate** by the Jordan Phosphate Mines Company (JPMC). Current exploitation and processing is at Abiad mine (which will be phased out), Hasa mine, Sheddiyya mine, and the DAP plant at Aqaba new port;
  Nippon Jordan Fertilizers Company, established in 1992 and owned by APC, Jordan Phosphate Mines Company (JPMC), ZEN-NOH, Mitsubishi Kasei, Asahi and Mitsubishi Corporations, produces NPK (nitrogen, phosphorus, and potassium) and DAP (diammonium phosphate) fertilizers from phosphate in Aqaba new port;
- **Potash** by the Arab Potash Company (APC). This is currently exploited at the southern end of the Dead Sea and processing plants at the Dead Sea and at Aqaba new port (KEMAPCO). APC holds a 100-year concession (1958-2058) for the evaporation of 250-300 MCM of Dead Sea water per year, which is processed into KCl (production ~ 450,00 t/yr). KEMAPCO produces potassium nitrate fertilizer;
  APC also owns the Numeira Mixed Salts and Mud Company for production of cosmetics products at the Dead Sea.
- **Oilshale** Jordan has huge reserves of ~31 B tons in several areas, and the following agreements/licenses exist:
  * The joint venture Jordan Oil Shale Energy Company (foreign partner: Eesti Energia) exploits oilshale in the Attarat area. The company presented a plan to establish a shale oil plant with the capacity to produce 36,000 barrels per day in 2008, and has had a concession for this exploitation and plant since 2010. A separate concession agreement was signed in 2008 between the Ministry of Energy and Mineral Resources, the National Electricity Power Company of Jordan, and Eesti Energia for operating the Attarat Power Plant, which is expected to be in operation by mid-2020 and will be operated by Attarat Power Company (APCO);
  * the Brazilian company Petrobras signed an MoU in 2007 for exploitation of oilshale in the Attarat Umm Ghudran area;
  * Royal Dutch Shell company signed an MoU in 2006 for in-situ conversion processing in the Azraq and Al-Jafr blocks of central Jordan. Exploitation by Shell's subsidiary Jordan Oil Shale Company will start in 2022;
  * Karak International Oil, a subsidiary of Jordan Energy and Mining, has held a concession license since 2011 for producing 15,000 barrels per day in the Lajjun area from a related shale oil plant. Production was supposed to start in 2015;
  * Saudi Arabian International Corporation for Oil Shale Investment (INCOSIN) has held a license since 2013 to investigate the El Lajjun deposit and Attarat Umm Ghudran resources. The company is cooperating with Russian Atomenergoprojekt to build a shale oil plant that will produce 30,000 barrels per day;
  *An MoU was signed in 2009 with the Russian company Inter RAO UES and Aqaba Petroleum Company;
- **Bromine** by the Jordan Bromine Company (JBC), established in 1999, at the Dead Sea (private free zone). Water supply to this company is considered as a part of that supplied to the Potash subsidiary company;
- **Magnesia**: Manaseer Magnesia Company owns and operates a factory at the Dead Sea producing caustic calcined magnesia (CCM) (previously the Jordan Magnesia Company).

In 2015, the Jordan Atomic Energy Commission (JAEC) signed an agreement with Russia's Rosatom Overseas to build two nuclear reactors near Qasr Amra. However, after initial investigations, the plan was dropped in June 2018. Cooling at the power plants would have consumed ~130 MCM/yr. Jordan is currently pursuing a plan to build small modular reactors (SMRs), but no concrete plans have yet been presented.

In 2017, it was announced that the new capital of Jordan would be built ~80 km E of Amman. Currently there is no further related planning, although initial plans were drafted for a water supply.
Collection of surface water consumption data is incomplete and needs to be improved.

Table 29: Historic Industrial Water Uses [MCM]

Company	Source/license	2017	2018	2019
Jordan Phosphate Mines Company (JPMC) – all sites	Groundwater/own abstraction license	7.2	13.2	13.14
Arab Potash Company (APC) – all sites/with subsidiary companies	Surface water from Mujib catchment (from diversion of 8 MCM/yr to Ghor area) (Listed in table: groundwater abstraction from own wells)	6.5	8.3	7.48
Oilshale - Jordan Oil Shale Energy Company (Attarat)	Processing: Groundwater	NA	NA	NA
Attarat Power Company (APCO)	Cooling: Groundwater	0.08	0.15	0.4
Jordan Bromine Company (JBC)	Surface water from Mujib catchment (from diversion of 8 MCM/yr to Ghor area)	Considered under Potash Company	Considered under Potash Company	Considered under Potash Company
Manaseer Magnesia Company	Surface water from Mujib catchment (from diversion of 8 MCM/yr to Ghor area)	NA	NA	NA

NA – not available
Individual surface water quantities received by companies are not reported by JVA

Water abstractions from groundwater for other industrial purposes in 2018 were: 27.8 MCM from 192 private wells. In 2018, 8.3 MCM were provided from surface water (for Potash, Magnesia and Bromine companies) and 2.5 MCM from treated wastewater (for a fertilizers factory in Aqaba that belongs to the Phosphate mines company).

In 2018, the use of water resources in the South Dead Sea area was (different from year to year, as evaluated by JVA):

2018		
Wadi	**Destination**	**quantity (MCM)**
Wadi Hasa	Potash	3.853
Wadi Fifa	0	0
Wadi Khnaizereh		0
Wadi Ibn Hammad	Potash	0.0689
Wadi Karak		0
Wadi Dera		0
Wadi Essal		0
Wadi Numaira	Potash	0.33
Mujib Carrier	Potash	1.067
Mujib Carrier	Bromine	1.094
Mujib Carrier	Magnesia	0

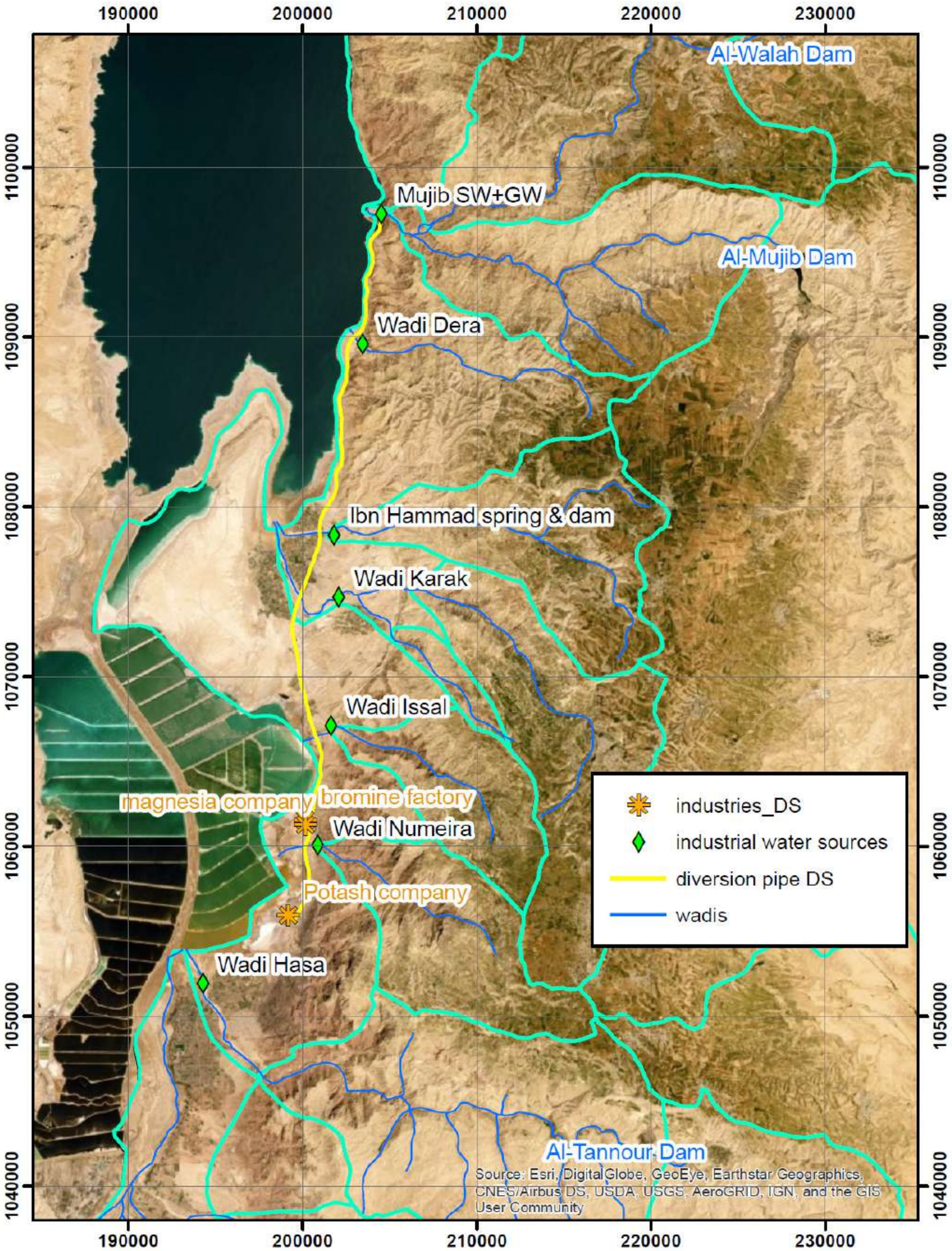


Figure 50: Provision of Water for Industrial Use from Mujib River and other Dead Sea Side Wadis

4.1.6 Agricultural Water Uses

Facts

Agricultural water uses still constitute the most significant share of all water uses. Despite many efforts the quantification of agricultural uses still poses a major problem. For both, surface water and groundwater uses in agriculture, there is no proper metering in place.

Agricultural development started in the mid-1960s in the Dhuleil-Hallabat area, and spread to the Madaba, Mafraq, Azraq and north Badia areas by the mid-1980s. However, since most of these areas receive < 200 mm/yr rainfall, it was soon recognized that permitting agriculture to expand would inevitably lead to overexploitation of the available resources. A ban on private wells was introduced in the late-1980s, but this has only led to the number of private wells, most of them now illegal, skyrocketing.

Until metering was introduced for groundwater abstraction for agricultural uses in 1993, abstraction estimates were based on a well's yield when it was built and a standard number of hours' production per day for all wells (12h/d). By 1993, groundwater abstraction from private wells had already reached 279 MCM (60% of the total groundwater abstraction of 464 MCM) (MARGANE et al., 2002). Since the mid-1980s the groundwater balance has been negative, i.e. more groundwater has been abstracted than recharged. Metering soon proved problematic, as farmers proved very inventive in finding ways to hide their real abstraction. As a result, metering actually led to a nominal decrease in abstraction, which of course was not the case. It was therefore recognized that metering would not lead to obtaining proper results for agricultural abstractions. Although remote sensing techniques have been used worldwide to estimate groundwater abstraction, e.g. in Saudi Arabia since the early-1990s, this method only started to be used in Jordan in 2014. Although groundwater abstraction for irrigation is being estimated with support from FAO, GIZ and, most recently, USAID, no countrywide assessment has yet been available. Such an assessment is now underway in the framework of the Third National Water Master Plan, NWMP-3.

The most recent assessments of groundwater abstraction for irrigation using remote sensing were made by Prof. Jawad Bakri (University Jordan) for the WMI project (USAID) for the years 2017 and 2018. These were done for five areas (called groundwater basins in the documents, despite the fact that no such groundwater basins exist), and show the following estimated groundwater abstraction (Table 30):

Table 30: Remote-Sensing based Assessment of Groundwater Abstraction for Irrigation (WMI 2018, 2019)

Year	2017 (MCM)	2018 (MCM)
Irrigation water requirement	287	290
Recorded abstraction	207	206.3
Difference	80	83.7

This assessment only covers the Azraq, Amman-Zarqa, Yarmouk, Dead Sea and Jafr basins. The missing areas, namely the Jordan Valley side wadis, the Jordan Valley, the Dead Sea side wadis, and the South Ghor, Wadi Araba, Disi, Sirhan and Hamad areas, will be added through the NWMP-3 project activities. A historical overview of the increase in cultivated areas and on agricultural production would also be useful. The above numbers are less than those in the 2018 water budget (also because these were not established for the entire country).

Water use in the Jordan Valley is difficult to quantify, because surface and groundwater resources are used in conjunction. Groundwater abstraction in Jordan Valley is largely not metered and thus unknown. The highest groundwater use is in the South Shooneh region where it is estimated that there are more than 1,000 wells, most of which are illegal.

Knowledge about surface water use is not much better, as allocated amounts are also largely estimated rather than metered. Based on the available resources and allocation practices, WORLD BANK (2016) estimated that surface water resources availability averaged 237 MCM/yr between 2001 and 2011, of which 133 MCM were allocated to irrigation and 46 MCM to domestic water supply (ANNEX 4). During the same period, an average of 83 MCM of reclaimed water was available for agriculture (estimation based on 75% of the 110 MCM from Khirbet As Samra), so that total water use between 2001 and 2011 was around 220 MCM. About 60% of the irrigated area is cultivated by vegetables and 35% by trees (mainly citrus). The WORLD BANK (2016) noted that, between 1994 and 2010, the area under cultivation in the Jordan Valley grew by 22 percent and agricultural production doubled, while the production of vegetables tripled. Average actual irrigation efficiency in the Jordan Valley is estimated at less than 60%.

4.1.7 Nomadic (Livestock) Water Uses

Nomadic uses, also called livestock or pastoral uses, are mainly met by providing water to nomads from dedicated wells and desert dams (compare Chapter 5.1.2.3). Many of these desert dams are located in remote areas, in particular the Hamad area around Ruwaished. However, it must be noted that most of the water collected in such dams evaporates due to the shallow topography, so this costly infrastructure mostly goes unused.

In 2018, groundwater use for nomadic purposes and related livestock production was 2.1 MCM. Surface water use for nomadic purposes cannot be quantified, however estimated annually by 5 MCM as reported in MWI water budget.

4.2 Historical and Future Water Demands

This section evaluates the demand estimation and projections for the municipal water use as well as their consequences for planning. The method of projections is based on the reallocation policy (MWI, 2016) using the WEAP model currently deployed at the Ministry of Water and Irrigation. Furthermore, the section discusses the identified water supply gaps in each governorate.

A countrywide WEAP model, developed for Jordan, creates a comprehensive and integrated picture of municipal, industrial, and agricultural water use and respective supply sources. The model simulates water demand and future water supplies based on water supply preference rules, population growth trends, as well as water sector allocation and priorities criteria. It is useful to systematically identify all uses and supply sources by quantity, and in space and time; to forecast future demand; to compare supply and demand and identify potential shortages; to examine supplies and uses under different scenarios.

Recently, the model has been updated to reflect the water systems that were defined and agreed on in cooperation with WMI project and presented in Chapter 5.1.4. Water system boundaries and administrative boundaries may be significantly different. A water system can serve a demand center with several localities (villages) across different administrative boundaries of the governorates. Now the WEAP model can be applied for both, governorate administrative boundaries and water system boundaries.

The model determined the demand and demand projections for each water system using 2018 population data and growth rates, obtained from the Department of Statistics. The localities were attributed to the water system boundaries and the population data were compiled for each system.

The following sections provide more details about the input parameters and methodology considered for water demand estimation until the year 2040.

Additional water demands for the new capital, proposed in 2017 (~80 km E of Amman), are currently not considered. If this proposal was implemented, it would lead to an increased municipal water demand, partly because the area is much more desertic (~70 mm rainfall) compared to Amman (much higher potential evaporation) and would require more water for office and personal use, cleaning and urban landscaping and parks.

4.2.1 Municipal Water Demand

As indicated in earlier sections, municipal water comprises the domestic and non-domestic users. Water demand is calculated based on the Water Allocation Policy. The policy is addressing domestic demand through the target of delivering 120, 100, 80 l/c/d to Amman, other cities, and rural areas, respectively. Rural areas and villages are defined as those localities with population size under 5,000 inhabitants.

Water demand and the projection along the planning horizon 2040 is analyzed in this section. Population data for 2018, provided by DOS, is used as a baseline. Annual growth rate is calculated based on DOS projection. Water demand is calculated for each water system defined in this Rapid Assessment, as presented in Chapter 5.

Non-domestic demand is calculated based on the share between the domestic and non-domestic use obtained from the billing data obtained from WAJ, Miyahuna, YWC and AWC for 2018.

In theory, water demand coincides with water consumption. However, physical losses must be included to meet demand. Thus, the water supplied to the network or supply requirements adds the physical losses in the network.

4.2.1.1 Population

Population estimation is essential in reflecting the current situation and assessing the future water demand under different social, economic, and political challenges confronting Jordan. Population projections and censuses are the main sources of statistical data that countries seek to make available because they constitute the basis for the planning and policy-making process in the economic, social, health and educational fields.

Due to the regional political unrest, Jordan has been experiencing rapid population fluctuations as refugees from neighboring countries flee ongoing conflicts. As a result, the population of Jordan has increased from 4.2 million in 1994 to 9.5 million in 2015, despite an overall decline in the national population growth rate from 3.7% to 1.9% over the same period.

In 2015, a general Population and Housing Census was conducted by the Department of Statistics (DOS). The census counted all residents of Jordan from all nationalities and addressed several demographic issues. Jordan`s population figures were determined for each governorate within different categories which are, the Jordanians, Syrians Refugees, other refugees and foreign workers. Overall population of Jordan was estimated at 9,531,712, of which Jordanians represent 69.4%, Syrian refugees comprise 13.3%, and other residents comprise 17.3%.

Beside the census, the Department of Statistics (DOS) estimates, annually, the population number for each governorate, district and locality, based on different criteria, specific surveys, and latest information. In 2018, DOS estimated the total population at 10,258,816 habitants, which is 3.2% higher than the projection figures from the census 2015 (9,938,179 habitants). Table 31 indicates the distribution of the population and of the Syrians among each governorate.

The population estimation for 2018, based on the latter estimation (Table 31), forms the basis for calculating the domestic water demand in the Rapid Assessment and the NWMP-3. The annual population growth along the planning horizon 2020-2040 is obtained from the population projection of the latest census 2015.

The Syrian refugees are living in Jordan within two types of settlements: refugees residing within urban and rural areas of the host communities, and Syrians living in three designated refugee camps: Zaatari in Mafraq, Azraq and EJC (Murijib Al Fohoud) in Zarqa.

Table 31: Estimation of Population Distributed in the Governorates 2018 (DOS Estimation 2018)

Governorate	Total Population 2018 (DOS estimation)	Syrians Refugees in Host Communities (DOS) **	Syrians in Refugee Camps (UNHCR)	All Syrians	% Syrians
Amman	4,337,839	485,226		485,226	11.2%
Zarqa	1,457,402	141,124	47,576*	188,700	12.9%
Balqa	531,000	31,171		31,171	5.9%
Madaba	204,300	16,341		16,341	8.0%
Irbid	1,911,600	382,630		382,630	20.0%
Mafraq	550,275	109,448	78,527	187,975	34.2%
Ajloun	190,200	16,148		16,148	8.5%
Jarash	256,000	12,107		12,107	4.7%
Karak	341,900	19,023		19,023	5.6%
Tafilah	104,000	2,153		2,153	2.1%
Maan	171,100	9,413		9,413	5.5%
Aqaba	203,200	8,688		8,688	4.3%
Jordan	10,258,816	1,233,474	126,103	1,359,577	13.3%

*Azraq; 40,650+ EJC 6,926 (UNHCR 2018)

** Syrians distribution among governorates were calculated based on 2015 census

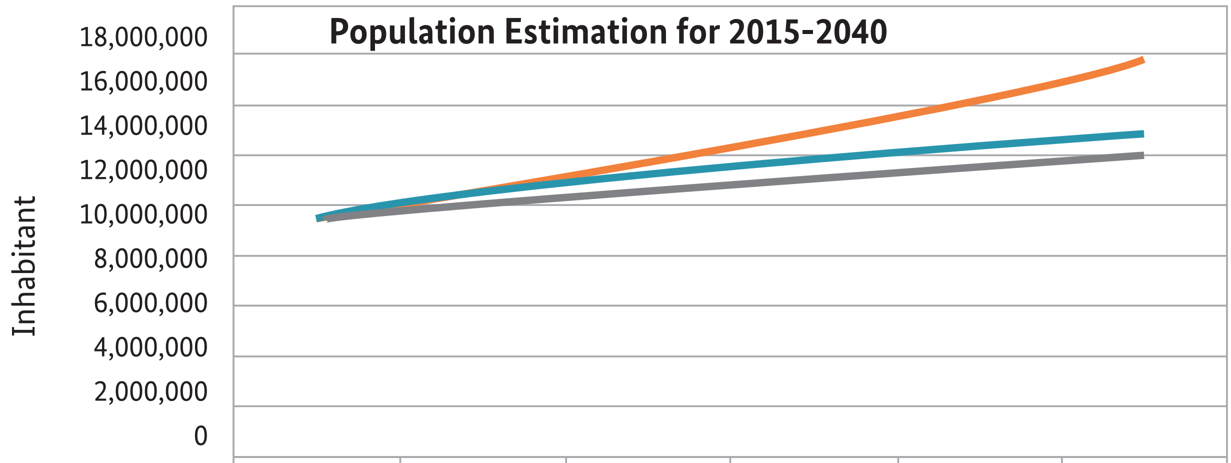
It should be mentioned that DOS estimated the Syrians living in the camps at 176,287 based on 2015 census and a designated projection methodology; MWI recommended to use the UNHCR numbers who is responsible for managing these camps.

4.2.1.1.1 Population Projection for the Planning Horizon

Population growth is the major parameter influencing future water demand development. Population growth is estimated using distinctive growth rates. The growth rates are influenced by "reproduction, mortality and net migration", which in turn affect and are affected by many demographic, economic and social factors. These factors are the main components of future population projections, demographic and economic changes in population conditions.

In order to project the future number of Jordanians and non-Jordanians in the Kingdom, DOS has evaluated the population growth elements under different assumptions of birth, death and immigration, including Syrians refugees. Three scenarios for population projections were concluded, based on the latest Census (2015). These scenarios are a high-basic scenario, which is considered as a continuation of the current situation, a medium scenario, and a low scenario. Figure 51 shows the population projection for the three suggested scenarios. In 2040, the projected population would be 15.74 million for the high scenario, 12.86 million for the medium scenario, and 12.06 million for the low scenario. Comparing the three projections to 2040, the medium scenario is only 5.8% higher than the low scenario; however, the high scenario is 23% higher than the medium scenario.

The annual estimation of 2018 indicates a higher population compared with the projection along 2016-2018, based on the 2015 census; however, DOS recommended the medium growth scenario for medium to long-term planning as it is implemented by all institutions and for the development of projects. MWI adopts the medium growth scenario in the entire planning activities as well. Accordingly, the medium population growth scenario is applied in calculating the water demand through developing the Rapid Assessment and the NWMP-3 documents.



	2015	2020	2025	2030	2035	2040
Medium Scenario	9,531,712	10,294,911	11,188,353	11,995,549	12,394,488	12,778,164
High Scenario	9,531,712	10,466,345	11,641,209	12,919,279	14,275,995	15,727,857
Low Scenario	9,531,712	10,044,153	10,644,336	11,145,040	11,614,924	12,077,487

Figure 51: Population Growth Scenarios (DOS 2015 Census)

Based on the above projection figures, the annual population growth rate for the years 2020, 2025, 2030, 2035 and 2040 is calculated for all population and detailed further for each governorate. MWI suggests distinguishing the population growth of Syrians refugees from that of all others in order to address specific needs and decisions required for planning and allocating the limited water resources along the areas impacted by the current uncertain political situations.

Therefore, two sets of growth rates are considered in this analysis, a combined growth rate for all residents excluding Syrians, and a designated growth rate for Syrians. The annual growth rates for each governorate were calculated based on population projection figures of 2015 census provided by DOS and applied on the 2018 estimation for all districts and localities within the governorate. Therefore, the projection was adjusted to account for the baseline year 2018 adopted in this Rapid Assessment. As the baseline year (2018) has a higher estimation of population, compared with the initial DOS projection, the adjusted projection has, consequently, 3% higher population than the projections, (i.e. 2040 DOS projection 12,866,275 inhabitants, adjusted projection 13,273,123 inhabitants).

Combined growth rates for all other residents (Jordanians and others) are presented in Table 32 for each governorate.

Table 32: Annual Growth Rates for all Residents excluding Syrians

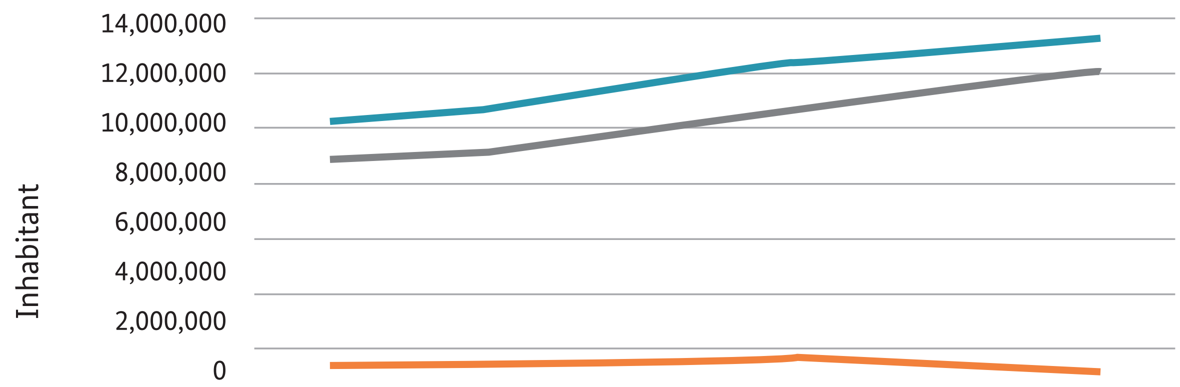
Governorate	2018-2020	2021-2025	2026-2030	2031-2035	2036-2040
Irbid	2.03%	1.89%	1.65%	1.49%	1.40%
Balqa	2.02%	1.88%	1.66%	1.52%	1.46%
Zarqa	1.93%	1.82%	1.55%	1.33%	1.23%
Tafilah	2.14%	1.93%	1.64%	1.49%	1.43%
Amman	1.45%	1.34%	1.12%	0.94%	0.86%
Aqaba	1.69%	1.59%	1.42%	1.30%	1.23%
Karak	1.82%	1.71%	1.56%	1.45%	1.35%
Mafraq	2.29%	2.12%	1.88%	1.76%	1.70%
Jarash	2.42%	2.22%	1.87%	1.67%	1.65%
Ajloun	2.34%	2.17%	1.92%	1.77%	1.69%
Madaba	1.82%	1.67%	1.46%	1.33%	1.24%
Maan	2.23%	2.01%	1.68%	1.51%	1.46%

The medium growth scenario suggests that Syrians growth will be stable with annual growth rate of 1.9% during 2015-2025 and will decrease to 1.4% during 2025-2030, where return of Syrians will start after 2030 in regular numbers (assuming return of Syrians after 17 years) so that their number at the end of the projection period becomes half of their number in 2015. Accordingly, a generalized growth rate for Syrians is considered for all governorates as presented in Table 33.

Table 33: Annual Growth Rates for Syrians

Period	Growth Rate
2018-2025	1.9%
2026-2030	1.4%
2031-2035	-3.3%
2036-2040	-3.9%

Table 34 indicates the projected population for each governorate along 2018-2040. Detailed distribution at districts, subdistricts and localities level is presented in Chapter 4.3.



	2018	2020	2025	2030	2035	2040
Total Population	10,258,816	10,630,034	11,557,371	12,402,781	12,837,520	13,273,123
Residents(W/O Syrians)	8,899,239	9,218,163	10,006,179	10,739,922	11,431,512	12,120,719
Syrians	1,359,577	1,411,871	1,551,193	1,662,860	1,406,008	1,152,404

Figure 52: Population Projection 2018-2040

Table 34: Population Estimation and Projection by Governorates (DOS, 2018)

Gov.	2018 (DOS estimation)	2020	2025	2030	2035	2040
Irbid	1,911,600	1,989,252	2,184,629	2,365,429	2,438,930	2,514,492
Mafraq	550,275*	574,307	635,454	692,016	698,563	707,879
Jarash	1,457,402	1,514,116	1,657,624	1,788,764	1,859,862	1,929,423
Ajloun	104,000	108,494	119,352	129,427	138,784	148,402
Amman	4,337,839	4,468,900	4,791,999	5,075,249	5,198,479	5,313,458
Zarqa	1,457,402*	1,514,116	1,657,624	1,788,764	1,859,862	1,929,423
Balqa	341,900	354,477	386,102	417,038	442,900	468,748
Madaba	550,275	574,307	635,454	692,016	698,563	707,879
Karak	256,000	268,429	299,413	328,164	352,871	379,569
Tafeleh	190,200	199,078	221,391	242,912	260,264	278,574
Maan	204,300	211,818	230,339	247,623	260,022	272,457
Aqaba	171,100	178,388	196,953	213,912	228,035	242,834
Total	**10,258,816**	**10,630,034**	**11,557,371**	**12,402,781**	**12,837,520**	**13,273,123**

*including 126,103 Syrians refugees living in camps (UNCHR 2018)

Table 35: Estimation and Projection of Syrians by Governorates (DOS)

Gov.	2018 (DOS estimation)	2020	2025	2030	2035	2040
Irbid	382,630	397,449	436,669	468,104	395,799	324,408
Balqa	31,171	32,379	35,574	38,135	32,244	26,428
Zarqa	188,700*	196,009	215,350	230,853	195,195	159,987
Tafeleh	2,153	2,237	2,457	2,634	2,227	1,826
Amman	485,226	504,020	553,756	593,620	501,927	411,394
Aqaba	8,688	9,024	9,915	10,629	8,987	7,366
Karak	19,023	19,760	21,710	23,273	19,678	16,129
Mafraq	187,975*	195,256	214,524	229,967	194,445	159,373
Jarash	12,107	12,576	13,817	14,811	12,523	10,265
Ajloun	16,148	16,774	18,429	19,756	16,704	13,691
Madaba	16,341	16,974	18,649	19,991	16,903	13,855
Maan	9,413	9,413	10,342	11,087	9,374	7,683
Total	**1,359,577**	**1,411,871**	**1,551,193**	**1,662,860**	**1,406,008**	**1,152,404**

*including 126,103 Syrians refugees living in camps (UNCHR 2018)

4.2.1.2 Per Capita Water Demand

As previously described, municipal water supply comprises domestic and non-domestic users. All activities supplied primarily through the municipal water supply network is considered as municipal water use. Domestic use is the water consumed through household activities, while non-domestic use comprises a variety of commercial and public uses, tourism, light industries, and irrigation of public spaces occasionally delivered from main water supply network.

In 2004, the National Water Master Plan (NWMP) set a goal of delivering 150 l/c/d for urban areas and 132 l/c/d for rural areas. This target has been adjusted several times, in 2009 the Water for Life: Jordan's Water Strategy 2008-2022, suggested a target of delivering at least 100 l/c/d to all residents. The "Jordan 2025, A National Vision and Strategy" introduced a goal of increasing domestic water consumption to 115 l/c/d.

In 2015, the Water Reallocation Policy suggested specific water demands of 120 l/c/d for Amman city, 100 l/c/d for other cities, and 80 l/c/d for rural areas and villages. Localities with population less than 5,000 people are considered rural areas. These domestic water allocation figures are essential parameters currently used by WAJ, donors and respective consultants for developing water supply projects and related design documents. Based on these criteria, the average water demand is calculated for each locality as presented in the following paragraphs.

For the non-domestic component, subscribers supplied through the water supply systems are specified in the billing data under pre-defined category numbers. Based on this, the share between domestic and non-domestic water demand is determined for each governorate and ratios of non- domestic to domestic water demand are estimated for calculating the non-domestic water demand. Table 36 presents the water shares and ratios of non-domestic to domestic water demand for 2018.

Non-domestic water demand is calculated by multiplying the domestic demand with the obtained ratio for the related governorate. This ratio is influenced by the type and size of commercial activities within the governorates. Aqaba possess the highest ratio of (186 %) as it has large touristic and commercial activities that increase the non-domestic share, while Jarash has the lowest ratio of (5.5%) due to its low commercial activities.

Table 36: Domestic and Non-Domestic Share for 2018 (WMI 2020)

Governorate	Domestic Consumption Ratio (%)	Non-Domestic Ratio (%)	Ratio of Non-domestic over domestic share (%)
Amman	87.9	12.1	13.8
Zarqa	91.05	8.95	9.8
Balqa	81.07	18.93	23.4
Karak	85.41	14.59	17.1
Tafilah	82.06	17.94	21.9
Maan	90.5	9.5	10.5
Madaba	93.2	6.8	7.3
Mafraq	83.66	16.34	19.5
Irbid	90.65	9.35	10.3
Ajloun	88.69	11.31	12.8
Jarash	94.77	5.23	5.5
Aqaba	35	65	186

4.2.1.3 Non-Revenue Water (NRW)

Non-revenue water (NRW) refers to water produced and transferred into the water distribution systems but not generating revenue, thus considered as water losses. It is one of the major issues affecting the supply of water and impacting the demand as well. Non-Revenue Water (NRW) has two major components: real losses (physical/technical) and apparent losses, also known as administrative/commercial losses. The real losses occur when water is lost through leakages and damages of the water distribution system. The apparent or commercial losses encompass incorrect or missing meter readings, billing inaccuracies, inaccurate customer information, or illegal connections.

The International Water Association (IWA) has defined the components of NRW shown in Figure 53. In principal, the Water Utilities (Miyahuna, YWC and AWC) are adopting IWA approaches in dealing with NRW issues. However, the utilities are not yet able to accurately quantify each component of NRW, partially due to the widespread intermittent supply system in Jordan, and partly due to lack of flow measurements in the network system. Metering of water use at the level of production (wells, bulk water supply), at key points in the distribution network and for consumers is essential to estimate levels of NRW. Thus far, NRW is considering only the losses between the main reservoirs where water is received from the production sources and the consumer. Therefore, NRW consideration currently leaves out a major loss component, those generated on the way from the production point (well, spring, dam, desalination plant) to the main reservoir or other handover point between water utility and bulk water supplier.

System Input Volume	Authorized Consumption	Billed Authorized Consumption	Billed Metered Consumption	Revenue Water
			Billed Unmetered Consumption	
		Unbilled Authorized Consumption	Unbilled Metered Consumption	Non-Revenue Water
			Unbilled Unmetered Consumption	
	Water Losses	Commercial Losses	Unauthorized Consumption	
			Metering Inaccuracies and Data Handling Errors	
		Physical Losses	Leakage on Transmission & Distribution Mains	
			Leakage and Overflows at Storage Tanks	
			Leakage on Service Connections up to Point of Customer Metering	

Figure 53: Components of non-revenue water (INWENT, 2010)

Based on the above balance, NRW is the difference between system input volumes and billed authorized consumption. The volume of water “lost” is put in relation to the total amount of water produced. Accordingly, the following formula is adopted by the sector to calculate the NRW ratio:

$$\mathbf{NRW=}\ \frac{\textbf{(Produced + Imported) – (Billed + Exported)}}{\textbf{Produced + Imported}}$$

The input parameters for calculating the NRW for 2018 is presented in Table 37. Total NRW estimated in 2018 was around 53.3%, which is considered high. When considering the NRW across the governorates, they can be grouped into two categories:

→ Governorates with a particularly high NRW (between 50% and 75%), in descending order Ma’an, Mafraq, Al-Balqa, Karak, Tafilah, Zarqa, and Irbid.
→ Governorates with lower NRW (between 50% and 28%) – these include, again in descending order, Madaba, Amman, Ajloun, Jarash and Aqaba.

Table 37: Total Supply, Billed Water and NRW 2018 (WMI 2020)

Governorate	Water Supply (MCM)	Billed water (MCM)	NRW (MCM)	NRW (%)
Irbid	53.767	25.747	28.020	52.1
Mafraq	28.654	7.577	21.077	73.6
Jarash	8.248	5.563	2.685	32.6
Ajloun	5.741	3.635	2.106	36.7
Amman	195.990	107.762	88.228	45.0
Zarqa	63.369	24.478	38.891	61.4
Balqa	42.387	11.236	31.151	73.5
Madaba	9.893	5.371	4.522	45.7
Karak	22.736	7.056	15.680	69.0
Tafilah	6.807	2.730	4.078	59.9
Maan	14.540	3.625	10.915	75.1
Aqaba	24.483**	17.6	6.883	28.1%
Kingdom	476.615	222.38	254.235	53.3%

* Excluding water used for irrigation from the supply network ~5.5 MCM

Despite the constant efforts and major investments in the last decade that WAJ and the utilities have made to reduce NRW with the assistance of international donors, the historical figures of high NRW is a continuing problem. Various measures were implemented to reduce water losses, especially those related to the rehabilitation of networks, main transmission links, in addition to analyzing the components of water supply systems, however only minor (localized and short term) improvements were achieved. In general, physical water losses still remained high, as also the network grew considerably.

Due to lack of concrete data, the water sector has divided the water losses equally between the physical and administrative losses (National Water Strategy 2015-2025 and Water Reallocation Policy 2015) and commonly uses 50% as the general countrywide NRW.

4.2.1.4 NRW Reduction Plan

The gross municipal demand projections are also crucially affected by the assumptions about future NRW levels and physical losses in the public water distribution systems. The NWMP 2004 optimistically assumed that NRW would be reduced to 15% by 2020, while the actual NRW is still at around 50%. MWI has made a policy commitment that average NRW will be reduced to 25% by 2025 (MWI 2016; National Water Strategy 2016-25). Historical performance indicates that these targets are not achievable. Accordingly, there is a need to set strict but realistic NRW targets for all governorates supported with the required measures and action plans.

The Rapid Assessment presents the demand projection for the municipal sector based on 2018 data as the baseline. In 2018 overall NRW was 53.3%, with the assumption of continuing NRW at the same level. In order to meet policy aspirations, another scenario implies the reduction of NRW along the planning horizon, is suggested and analyzed in this report.

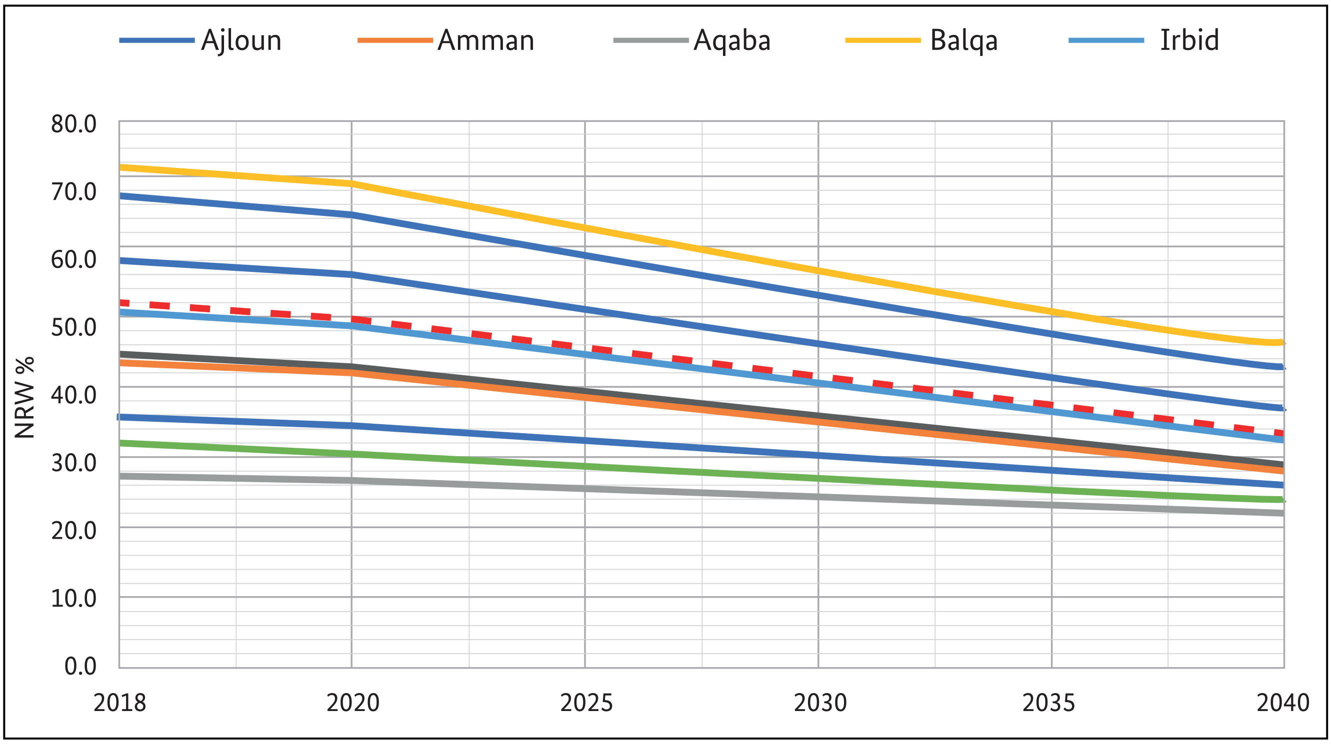
The scenario for reduction of NRW includes the percentage of reduction in NRW for different levels as suggested in Table 38 to reach rather near to 46%, which is the targeted average NRW for the whole Kingdom by the year 2025 (MWI Water Strategy). Table 39 presents the reduced value that can be attained if the NRW reduction plan is implemented.

Table 38: NRW reduction rate in the “Reduction in NRW” scenario

Current Level of NRW	Annual NRW reduction as % from previous year
> 30	2
20-30	1
< 20	0.5

Table 39: NRW% Projected Reduced Values up to 2040 based new/adjusted reduction plan

Gov.	2018	2020	2025	2030	2035	2040
Ajloun	36.7	35	32	29	28	27
Amman	45.0	43	39	35	32	29
Aqaba	28.1	28	26	25	24	23
Balqa	73.5	71	64	58	52	47
Irbid	52.1	50	45	41	37	33
Jerash	32.6	31	29	27	26	25
Karak	69.0	66	60	54	49	44
Maan	75.1	72	65	59	53	48
Madaba	45.7	44	40	36	32	30
Mafraq	73.6	71	64	58	52	47
Tafilah	59.9	58	52	47	42	38
Zarqa	61.4	59	53	48	44	39
Jordan	53.3	51	46	42	38	35



4.2.1.5 Water Supply Requirement

Water consumption (targeted or actual) and physical losses are the two components to determine the supply requirement, i.e. the overall amount that needs to be produced and transferred. For monitoring of consumption, WAJ and the utilities rely on the customer water meters. These also have inherent inaccuracies, in particular if not frequently replaced or calibrated.

Administrative losses are the supplied amount that is used by the customers but not billed (e.g. through illegal connections) or where no fee is collected (e.g. due to incomplete customer records).
Supply requirement is calculated as:

$$\text{Supply Requirement} = \frac{\text{Water Demand}}{100\% - \text{Physical Losses (\%)}}$$

A difference between supply requirement and actual total supply occurs due to facts beyond reach of the planners (e.g. delays in projects or that not all water planned to be allocated could actually be allocated). This allocation gap or coverage of domestic water demand, is an indicator for the service level with regards of meeting customers' needs or policy expectations, expressed as:

$$\text{Coverage of Water Demand} = \frac{\text{Supply Delivered}}{\text{Supply Requirement}}$$

Through the WEAP model, the water demand and the supply requirements are calculated for each governorate and at water systems level. Deficits in water supply for the baseline year 2018 and along the planning horizon 2020-2040 are discussed in Chapter 4.3 as well, taking into consideration the decrease in water resources discussed in Chapter 3.1.4.

4.2.2 Agricultural Demands

The process of water allocation to agriculture is not properly documented or even regulated (GIZ, 2018). The process as it should be implemented is shown in Figure 55. However, in practice much of the required data are not collected (any longer). According to WORLD BANK (2018) livestock and crop production indices have increased by 84 and 71 percent, respectively, in Jordan between 1995 and 2014 (Figure 54), which means that water consumption has also increased significantly during this time period. With regards to GDP contribution, the agricultural sector has significantly increased over the past years to 4.5% in 2018 (FIGUEROA et al., 2018). Between 2000-2014, cultivated land has increased by 24%. The use of fertilizers has increased to around 1t per ha, more than three times that of neighboring countries.

This comes at a heavy price, with regards to water consumption in the agricultural sector (WORLD BANK, 2016). Furthermore, water in the Jordan Valley is not adequately priced (0.008 JOD/m^3 for monthly consumption up to 2,500 m^3, most common block) and requires a reform.

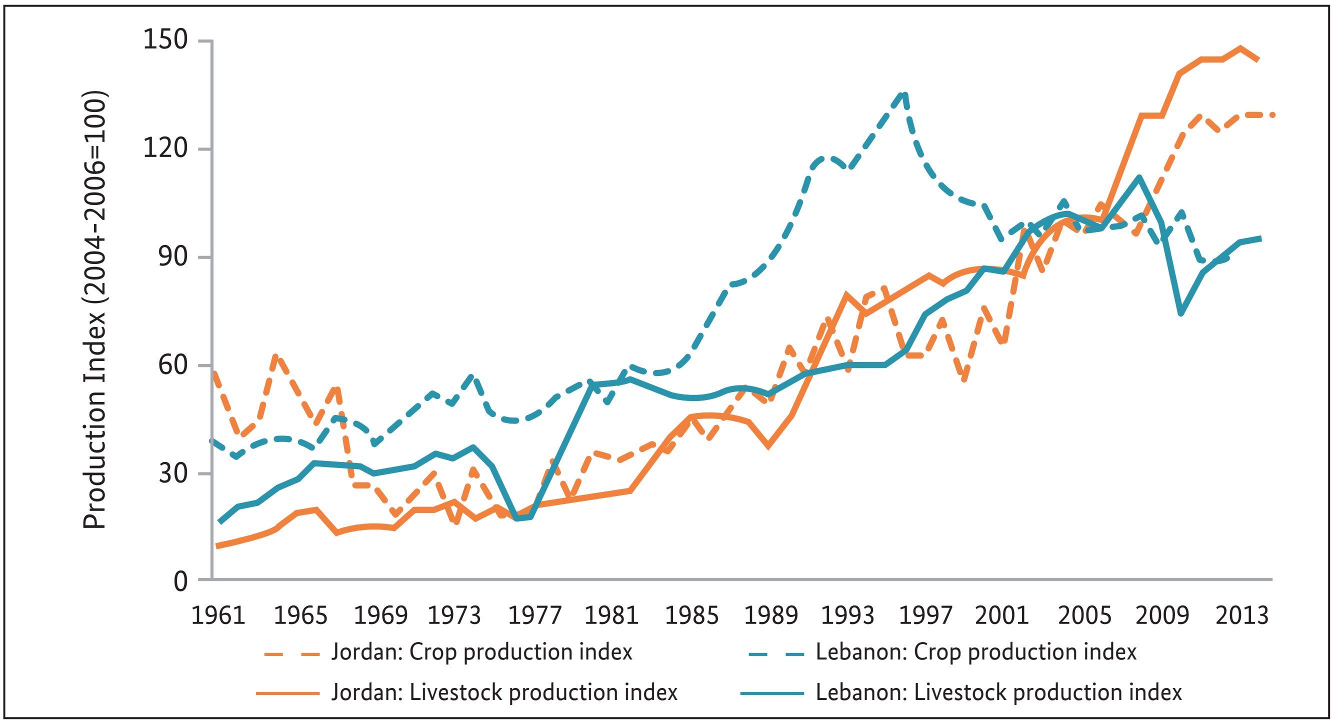


Figure 54: Growth of Agricultural Production in Jordan and Lebanon (WORLD BANK, 2018)

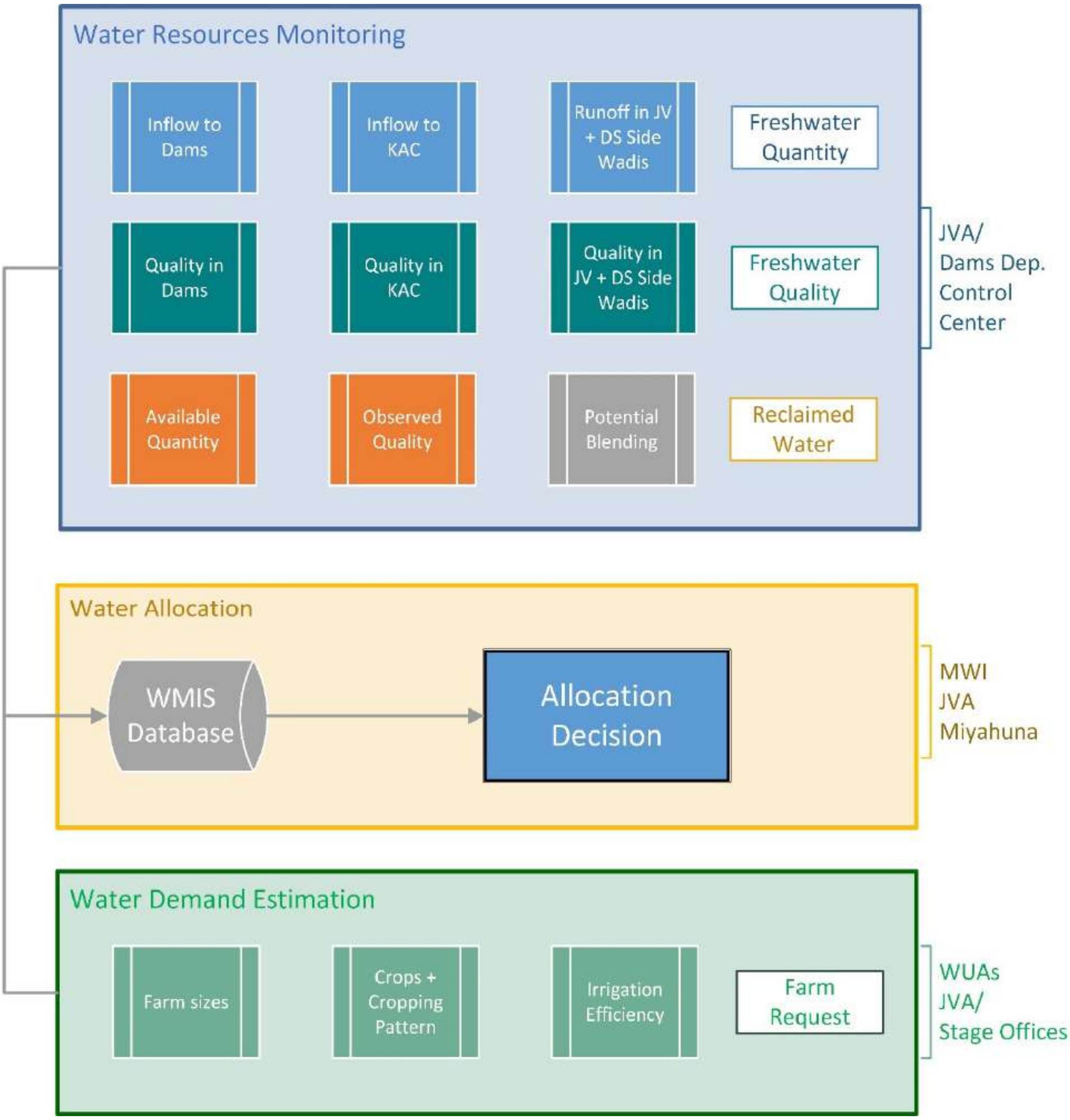


Figure 55: Water Allocation Process as it theoretically should be

Water Tanker for Nomadic (Livestock) Water Supply

4.2.3 Industrial Demands

Current industrial water uses are about 41 MCM (2018). There are, however, many plans for industrial development, which would increase water consumption, among them (by order of magnitude):

→ Nuclear power generation (currently on halt)
→ Mining and processing of oilshale (increasing trend, not yet fully implemented)
→ Mining and processing of phosphate (expanding)
→ Mining and processing of Dead Sea minerals (expanding)
→ Food processing

4.2.4 Nomadic (Livestock) Demands

The water demand for livestock will be covered in volume C of the NWMP-3.

4.3 Municipal Water Supply Requirements and Gaps

Water supply requirement is evaluated against the water supplied in 2018 and the future projected production of water resources allocated to all governorates along the planning horizon 2020-2040.

The following key parameters are used for calculation of the supply requirement:

- population estimation and projection (DOS)
- per capita demand (Water Reallocation policy)
- Commercial demand based on ratio of non-domestic to domestic use 2018
- Physical Losses accounts for 50% of NRW 2018

Two scenarios were examined, “BAU” considering a continuation of the current level of NRW, and “NRW reduction scenario” that implies reduction plan in NRW by applying the criteria proposed in the previous section.

Jordan Overall Requirements

The total municipal water demand (supply requirements) were estimated at 618 MCM for all governorates in 2018 (Figure 103). The projected demand will increase by 31% reaching to 811 MCM in 2040. This increase is attributed to population growth only, assuming that NRW will remain at the current level of 53.3 %. The estimated water demand and projected water production is presented in and Figure 56.

Water supply of 476.6 MCM in 2018 has satisfied 77 % of the required demand, excluding water used for irrigation through the network (around 5.5 MCM). However, the gap between the remaining water production and the required demand is widening due to an increase in demand and the expected substantial decrease of production from conventional water resources. By 2040, the available production of water resources will satisfy only 34% of the required demand as the remaining production will drop to around 279.6 MCM.

The increase in the additional needed amount during the planning horizon 2020-2040 is indicated in Figure 56. Currently, only 460.5 MCM can be produced from the existing governmental water resources, an additional 219 MCM is required to meet the demand of 2020, the deficit will increase to 531.5 MCM by 2040. This gap urgently needs to be addressed through planning of projects for water augmentation.

The impact of reduction in NRW compared with the current situation revealed 4% of recovery for demand coverage. This would amount to 90 MCM in water savings if successfully implemented.

Table 40: Water Demand and Supply Balance for Jordan

Municipal Water Balance of Jordan (M^3)	2018	2020	2025	2030	2035	2040
Supply Requirement_ (BAU)	618,012,489	641,856,067	696,473,098	749,553,984	779,681,947	811,116,853
Supply Requirement_ (NRW Reduction)	618,012,489	632,955,214	665,377,770	696,555,242	707,202,315	720,673,314
Total Supply	476,614,045					
Production	460,536,157	423,079,767	363,511,213	323,697,836	298,406,106	279,634,646
Additional needed amount_(BAU)	157,476,332	218,776,299	332,961,885	425,856,149	481,275,841	531,482,207
Additional needed amount_ (NRW Reduction)	157,476,332	209,875,446	301,866,557	372,857,406	408,796,209	441,038,668
Production Coverage of Required Demand (%)	75%	66%	52%	43%	38%	34%
Production Coverage of Required Demand (%)_(NRW RP)	75%	67%	55%	46%	42%	39%
Total Supply coverage (2018)	**77%**					

*Excluding water used for irrigation from the supply network ~5.5 MCM and 2.3 MCM for Brine/Filter wash

*Including 17 MCM from private wells, 4 MCM from Rum Farms, and 3 MCM from Sea desalination

** Production before any distribution/uses

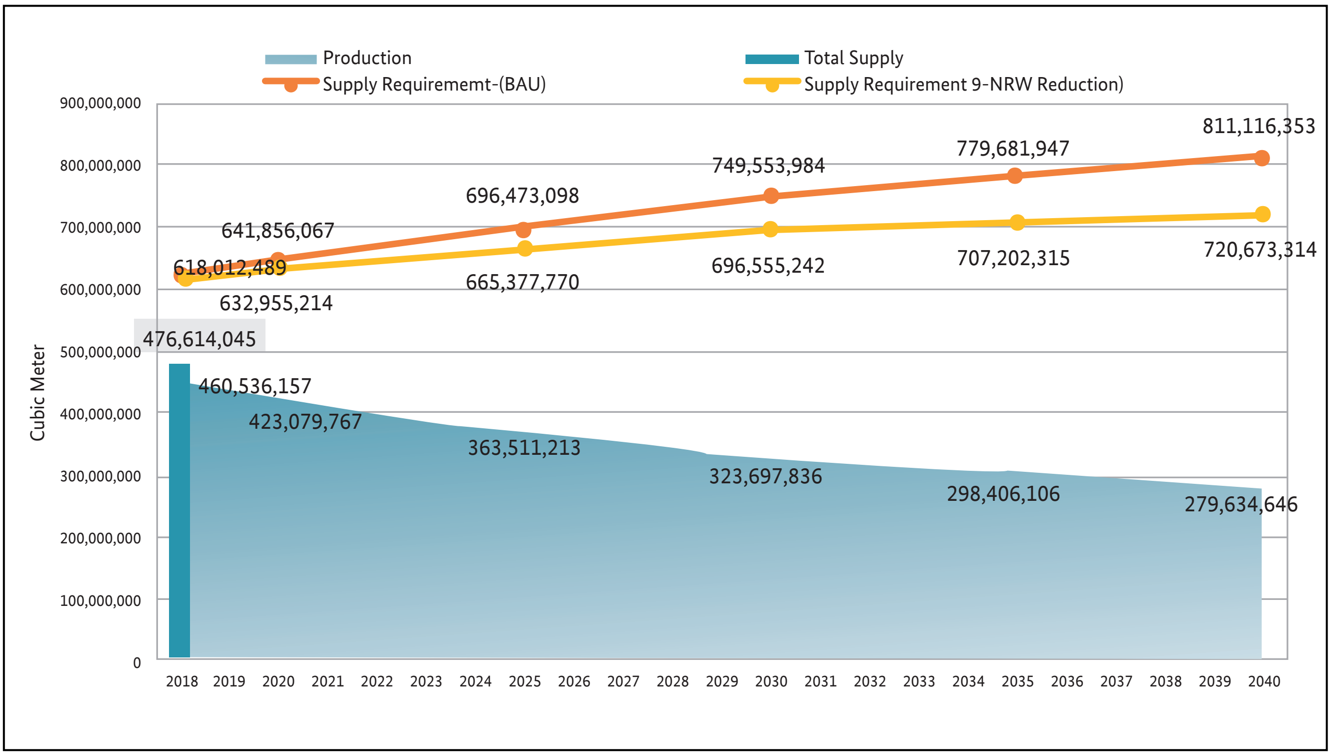


Figure 56: Water Demand and Supply Balance for Jordan

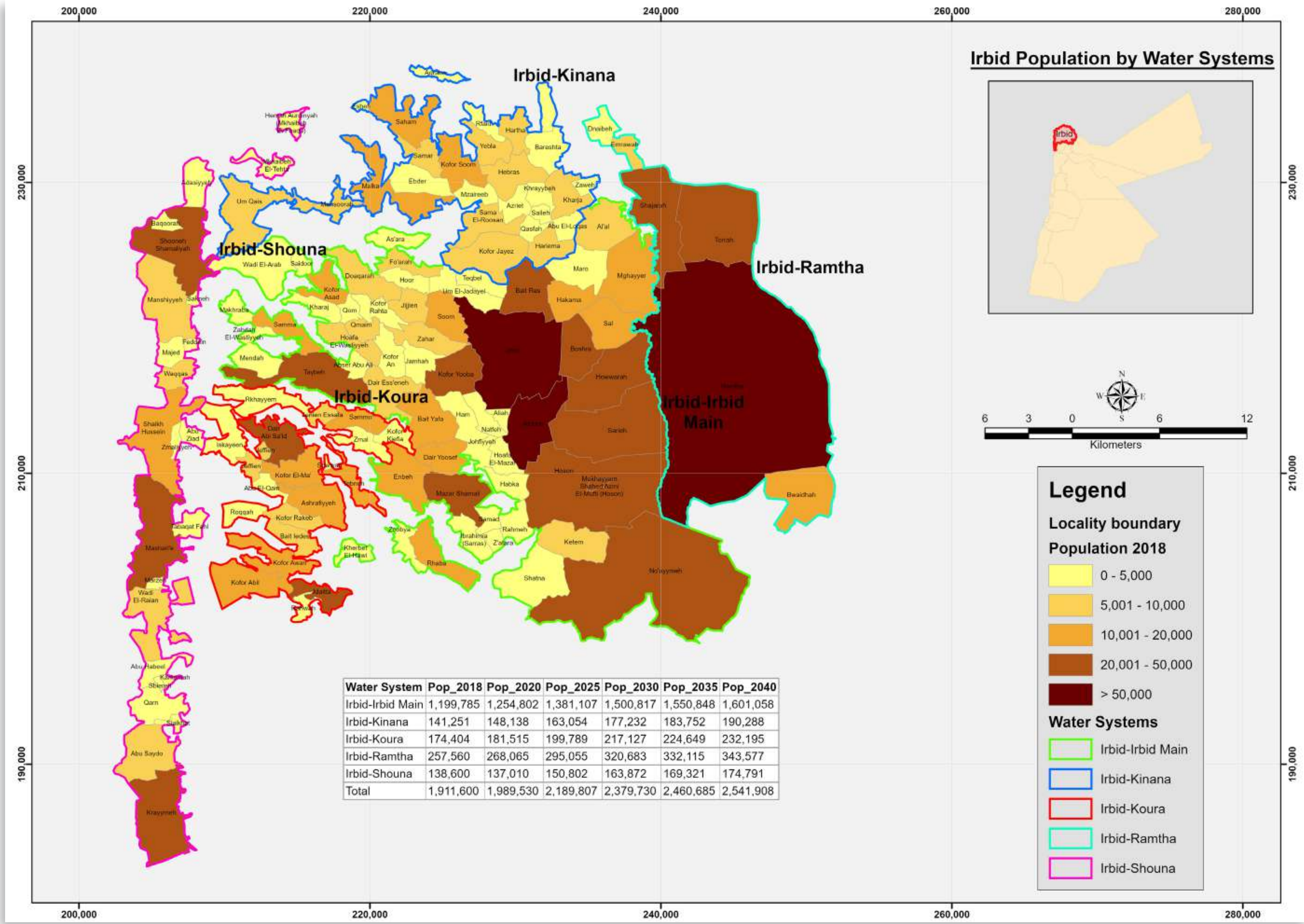
Irbid Governorate

Administratively, Irbid governorate is divided into 10 districts, with a total of 137 localities. Most of these localities (93%) are classified as urban areas. Figure 57 shows the location of localities in Irbid and the boundary of water systems serving the localities. In 2018, the estimated population for Irbid governorate was 1,911,600 capita. Syrians living in the host communities accounted for 20% (382,630) of the total population of Irbid.

The population projection for Irbid is presented in Table 41. By 2040, the projected population will increase by 33% reaching to 2,541,908 capita.

Table 41: Population by Water Systems in Irbid

Water System	2018	Urban (%)	2020	2025	2030	2035	2040
Irbid_Main	1,205,661	94.2%	1,254,802	1,381,107	1,500,817	1,550,848	1,601,058
Irbid_Kinana	142,330	75.3%	148,138	163,054	177,232	183,752	190,288
Irbid_Koura	174,404	95.3%	181,515	199,789	217,127	224,649	232,195
Irbid_Ramtha	257,560	98.4%	268,065	295,055	320,683	332,115	343,577
Irbid_Shouna	131,645	85.8%	137,010	150,802	163,872	169,321	174,791
Total Irbid	**1,911,600**	**92.9%**	**1,989,530**	**2,189,807**	**2,379,730**	**2,460,685**	**2,541,908**



Water System	Pop_2018	Pop_2020	Pop_2025	Pop_2030	Pop_2035	Pop_2040
Irbid-Irbid Main	1,199,785	1,254,802	1,381,107	1,500,817	1,550,848	1,601,058
Irbid-Kinana	141,251	148,138	163,054	177,232	183,752	190,288
Irbid-Koura	174,404	181,515	199,789	217,127	224,649	232,195
Irbid-Ramtha	257,560	268,065	295,055	320,683	332,115	343,577
Irbid-Shouna	138,600	137,010	150,802	163,872	169,321	174,791
Total	1,911,600	1,989,530	2,189,807	2,379,730	2,460,685	2,541,908

Figure 57: Irbid Localities and Population by Water Systems

Water Allocation Gaps (Water Balance)

The average water system demand (supply requirement), estimated at 102.6 MCM in 2018, is projected to increase by 32%, and will reach about 136.8 MCM by 2040. The estimated water demand and projected water production is presented in Table 42 and Figure 58.

The total production of around 46.4 MCM in 2018, has satisfied 45% of the required supply for all systems in Irbid governorate. With the additional 7 MCM imported to Irbid, the coverage has been improved to 52%, which still reflects a low service level and coverage. By 2040, this coverage will drop to 5% as the remaining production will drop to around 6.2 MCM.

Along 2020-2040, the additional needed amount is very significant. Currently, only around 36.9 MCM can be produced from the existing water resources, an additional 70.2 MCM is required to meet the full supply requirement of 2020 and will increase to 130.5 MCM by 2040.

Table 42: Water Demand and Supply Balance For Irbid

Irbid Gov. Demand_ Supply Balance (M^3)	2018	2020	2025	2030	2035	2040
Supply Requirement_ (BAU)	102,588,551	107,062,391	117,517,891	127,710,243	132,054,326	136,786,517
Supply Requirement _ (NRW Reduction)	102,588,551	105,589,450	112,300,975	118,707,825	119,788,490	121,436,568
Total Supply	53,767,101					
Production	46,389,473	36,866,869	20,376,145	13,307,277	9,339,947	6,239,164
Additional needed amount_(BAU)	56,199,078	70,195,522	97,141,746	114,402,966	122,714,379	130,547,353
Additional needed amount_ (NRW Reduction)	56,199,078	68,722,581	91,924,830	105,400,548	110,448,543	115,197,404
Production Coverage of Required Demand (%)_(BAU)	45%	34%	17%	10%	7%	5%
Production Coverage of Required Demand (%)_(NRW RP)	45%	35%	18%	11%	8%	5%
Total Supply coverage (2018)	**52%**					

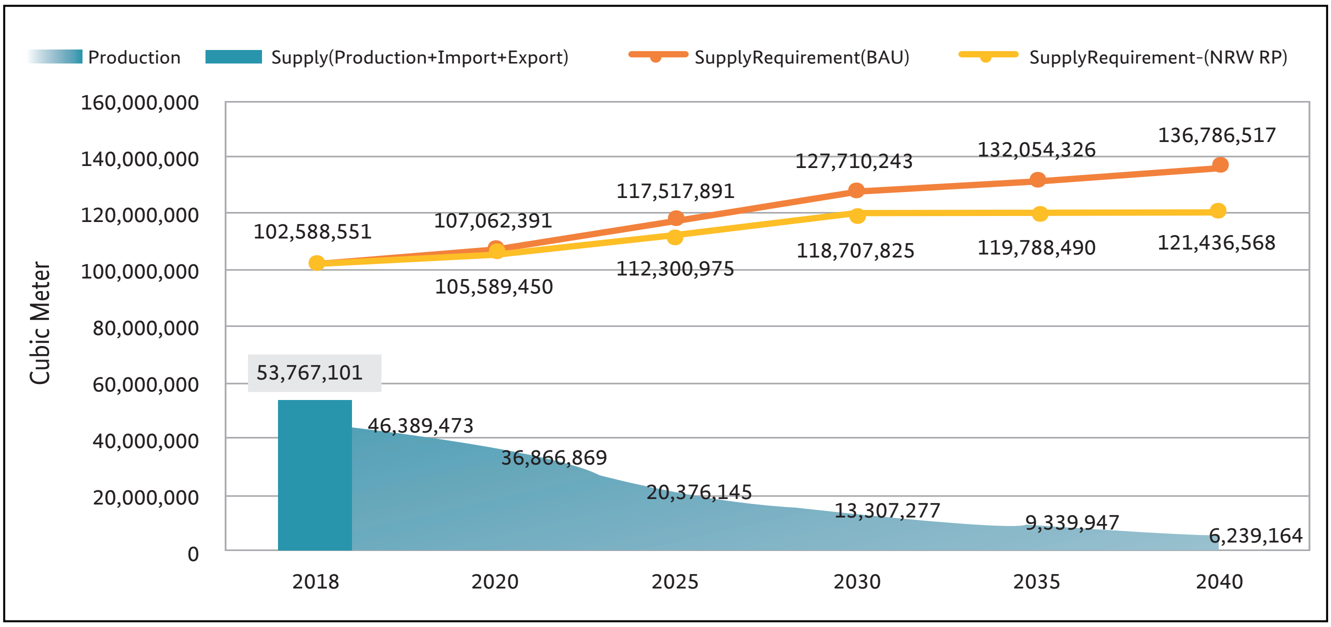


Figure 58: Water Demand and Supply Balance for Irbid Governorate

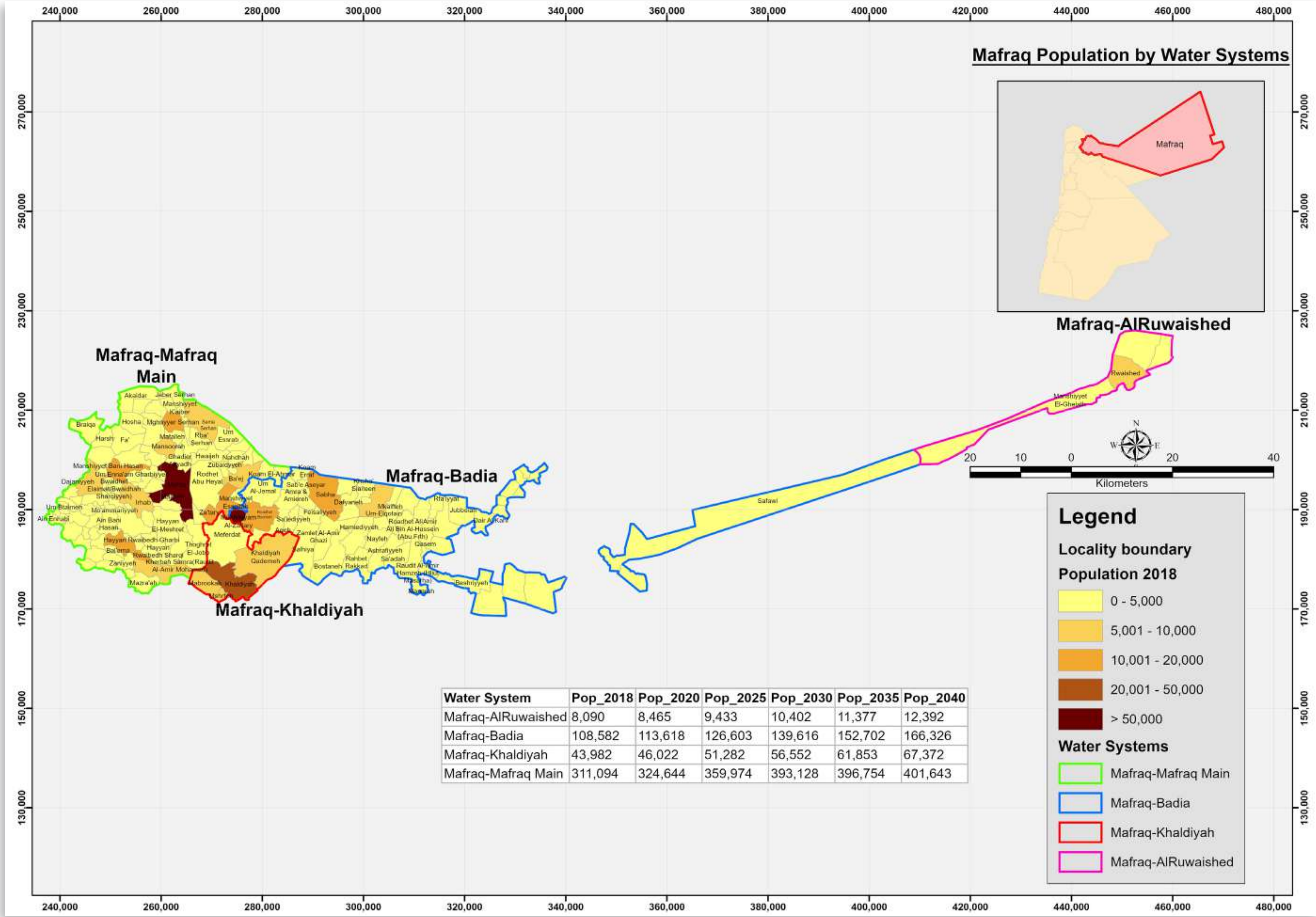
Mafraq Governorate

Population

Mafraq governorate is divided into 4 districts and 14 sub-districts with a total of 161 localities. Around 63 % of the localities are categorized as urban, excluding Zaatari Camp. Figure 59 shows the distribution of localities in Mafraq and the boundary of the water systems serving designated localities. The estimated population for Mafraq governorate in 2018 was 550,275 capita. Syrians refugees in Mafraq present 39% of the governorate population (231,600 capita, including 78,527 in Zaatari camp). Population projection for Mafraq is presented in Table 43. By 2040, the projected population will increase by 26 %, reaching to 751,261.

Table 43: Population by Water Systems in Mafraq

Water System	2018	Urban (%)	2020	2025	2030	2035	2040
Mafraq_Badia	108,582	31%	113,618	126,603	139,616	152,702	166,326
Mafraq_Khaldiyah	43,982	97%	46,022	51,282	56,552	61,853	67,372
Mafraq_Main	311,094	69%	324,644	359,974	393,128	396,754	401,643
Mafraq_Rwashed	8,090	77%	8,465	9,433	10,402	11,377	12,392
Mafraq_RC_Zaatari\Private wells	78,527	Refugee Camp	81,539	89,586	96,035	81,201	66,554
Total	**550,275**	**63%**	**574,288**	**636,878**	**695,733**	**703,887**	**714,287**



Water System	Pop_2018	Pop_2020	Pop_2025	Pop_2030	Pop_2035	Pop_2040
Mafraq-AlRuwaished	8,090	8,465	9,433	10,402	11,377	12,392
Mafraq-Badia	108,582	113,618	126,603	139,616	152,702	166,326
Mafraq-Khaldiyah	43,982	46,022	51,282	56,552	61,853	67,372
Mafraq-Mafraq Main	311,094	324,644	359,974	393,128	396,754	401,643

Figure 59: Mafraq Localities, Population and Water Systems

Water Allocation Gaps (Water Balance)

Supply requirement for Mafraq municipal water was estimated by 30.1 MCM in 2018, projected to increase by 37 % reaching to about 41.4 MCM in 2040. Estimated water demand and projected water production is presented in Table 44 and Figure 60.

Zaatari refugee camp is supplied by 3 private wells operated by UNICEF, not through municipal water systems. Water demand estimation based on 35 l/c/d was around 1.0 MCM in 2018, which is expected to decrease to around 0.850 MCM by 2040 as a result of Syrians` return.

The production of water resources in Mafraq has exceeded the required supply in 2018 by 4.3 MCM that can satisfy 100% of Mafraq demand. To improve the supply in other governorates, 5.7 MCM where exported from Mafraq resources. Accordingly, remaining supply of 28.6 MCM covered 90% of the required demand, which is a very good level of coverage.

However, these resources will be dramatically decreased by 2040, with remaining production of 24 MCM in 2020 so that the level of coverage will drop to 72% in 2020 and further decrease to 12% in 2040 as only 4.9 MCM can be produced. Eventually, that will adversely affect Irbid, Ajloun and Jarash, importing water from Mafraq.

As Mafraq possess a very high NRW level of 73.6%, there is an urgent need to reduce these losses. Figure 60 shows the impact of reduction in NRW compared with the current situation which showed some improvements for covering the required demand of 14% instead.

The additional needed amount along 2020-2040 is very significant. Currently, only around 24 MCM can be produced from the existing water resources. An additional amount of 6.9 MCM is required to meet the demand in 2020 and will be reaching to 36.5 MCM by 2040 if NRW remains high.

Table 44: Water Demand and Supply Balance for Mafraq

Mafraq Gov. Demand_ Supply Balance (M^3)	2018	2020	2025	2030	2035	2040
Supply Requirement_ (BAU)	30,145,040	31,572,536	34,970,102	38,315,574	39,757,186	41,443,360
Supply Requirement _ (NRW Reduction)	30,145,040	30,860,938	32,476,321	34,047,550	34,002,132	34,280,782
Total Supply	28,653,675					
Production	34,415,531	23,993,559	15,569,821	9,625,934	6,604,400	4,899,229
Additional needed amount_(BAU)	-4,270,491	7,578,977	19,400,281	28,689,640	33,152,786	36,544,131
Additional needed amount_ (NRW Reduction)	-4,270,491	6,867,379	16,906,500	24,421,616	27,397,732	29,381,553
Production Coverage of Required Demand (BAU)	114%	76%	45%	25%	17%	12%
Production Coverage of Required Demand (NRW Reduction)	114%	78%	48%	28%	19%	14%
Total Supply coverage (2018)	**95%**					

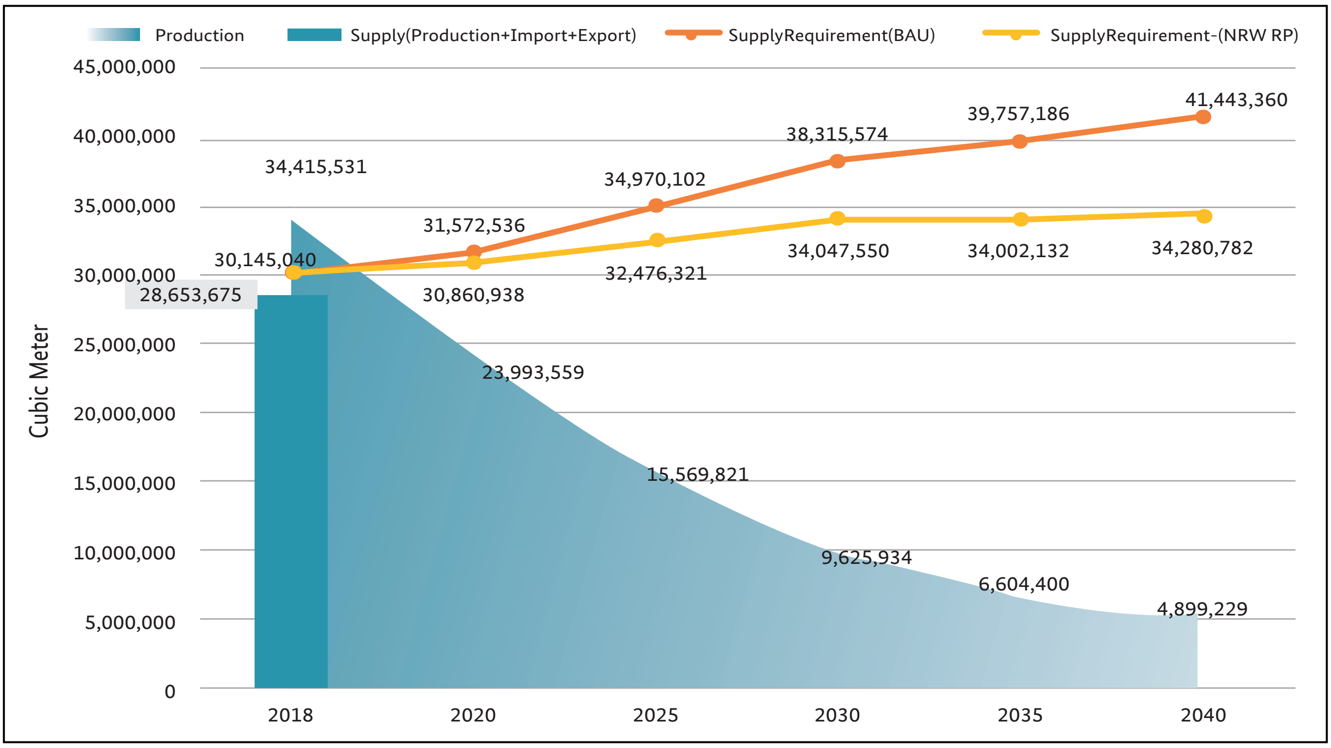


Figure 60: Water Demand and Supply Balance for Mafraq Governorate

Ajloun Governorate

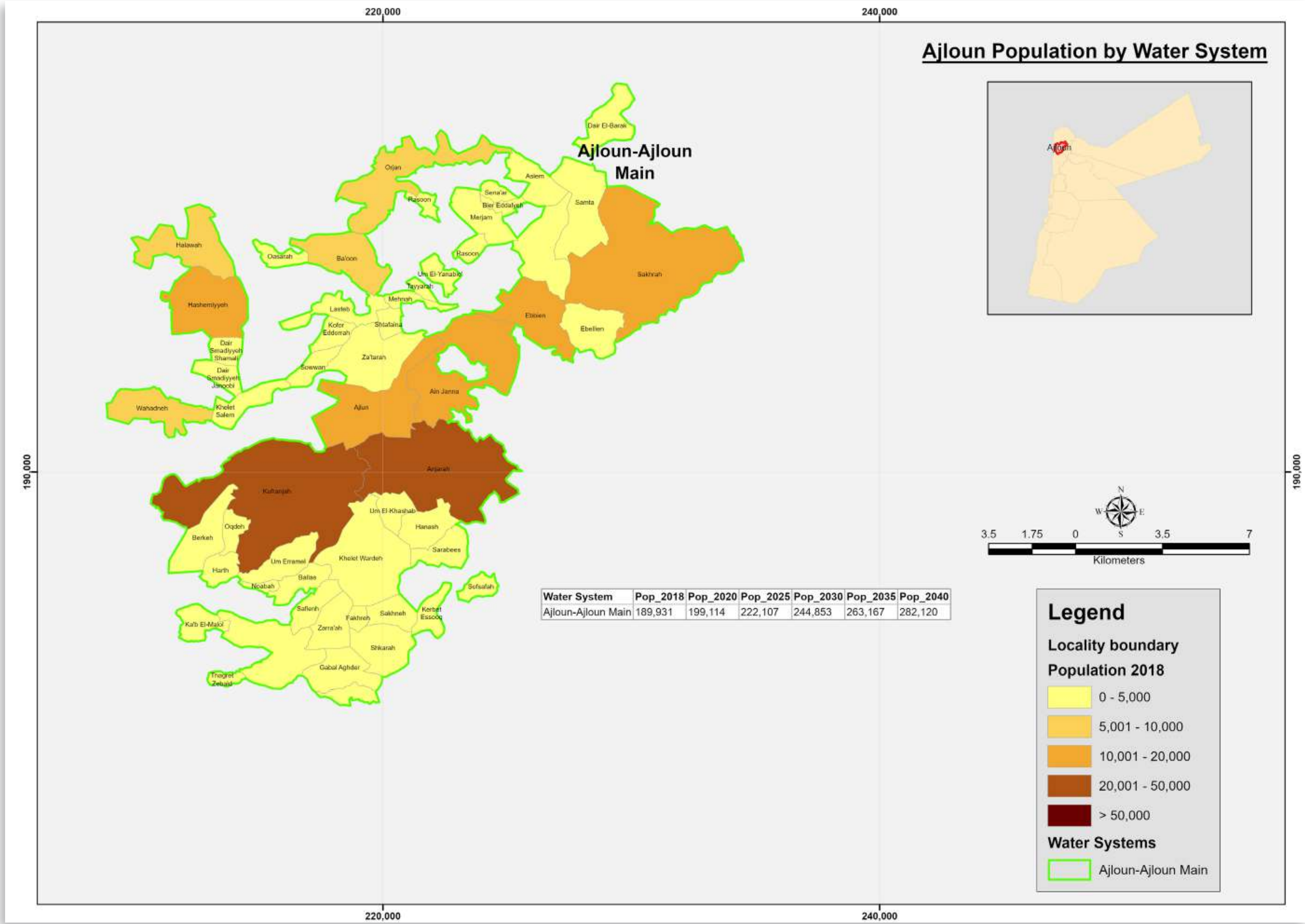
Population

Total population of Ajloun was estimated at 282,120 capita in 2018. The governorate is divided into two main districts and four subdistricts, comprising of 52 localities, 84% of which are classified as urban. Figure 61 shows the localities within Ajloun and the boundary of the water system serving all localities in the governorate. Syrians living in Ajloun are around 8% (16,148 capita) of the governorate population.

Population projection for Ajloun is presented in Table 45. It is estimated that population will increase by 48% reaching to 282,120 capita in 2040.

Table 45: Population for Ajloun Water System

Water System	2018 (DOS estimation)	Urban (%)	Population Projection				
			2020	2025	2030	2035	2040
Ajloun_Main	190,200	81%	199,114	222,107	244,853	263,167	282,120



Water System	Pop_2018	Pop_2020	Pop_2025	Pop_2030	Pop_2035	Pop_2040
Ajloun-Ajloun Main	189,931	199,114	222,107	244,853	263,167	282,120

Figure 61: Ajloun Localities, Population and Water System

Water Allocation Gaps (Water Balance)

The average water system demand (supply requirement) of 9.3 MCM in 2018 is projected to increase to around 14 MCM (49%) by 2040. Estimated water demand and projected water production is presented in Table 46 and Figure 62.

In 2018, the total production of around 3.3 MCM has satisfied only 36% of the required supply for all Ajloun governorate. Ajloun relies on importing additional 2.4 MCM from Irbid, which has significantly improved coverage to 63%. By 2040, it is expected that this level of coverage will drastically drop to 19%, while the remaining production will be 2.6 MCM. Additionally, the imported amount will be also impacted and will not be secured as currently allocated. Figure 62 also shows the impact of reduction in NRW compared with the current situation, revealing a marginal improvement in covering the required demand.

The additional needed amount along 2020-2040 is very significant for Ajloun as presented. Around 9.7 MCM are required to meet the demand in 2020. Current production can secure 3.3 MCM and the remaining amount of 7.7 MCM is required by this year, while reaching 11.1 MCM by 2040.

Table 46: Water Demand and Supply Balance for Ajloun

Ajloun Gov. Demand_ Supply Balance (M^3)	2018	2020	2025	2030	2035	2040
Supply Requirement_ (BAU)	9,282,007	9,743,837	10,839,327	11,949,391	12,843,175	13,805,832
Supply Requirement _ (NRW Reduction)	9,282,007	9,657,885	10,527,324	11,437,393	12,189,966	13,000,160
Total Supply	5,740,627					
Production	3,353,682	3,287,948	3,124,468	2,960,872	2,797,244	2,633,833
Additional needed amount_(BAU)	5,928,325	6,455,889	7,714,859	8,988,519	10,045,930	11,171,999
Additional needed amount_ (NRW Reduction)	5,928,325	6,369,937	7,402,856	8,476,522	9,392,722	10,366,327
Production Coverage of Required Demand (%)_(BAU)	36%	34%	29%	25%	22%	19%
Production Coverage of Required Demand (%)_(NRW Reduction)	36%	34%	30%	26%	23%	20%
Total Supply coverage (2018)	**62%**					

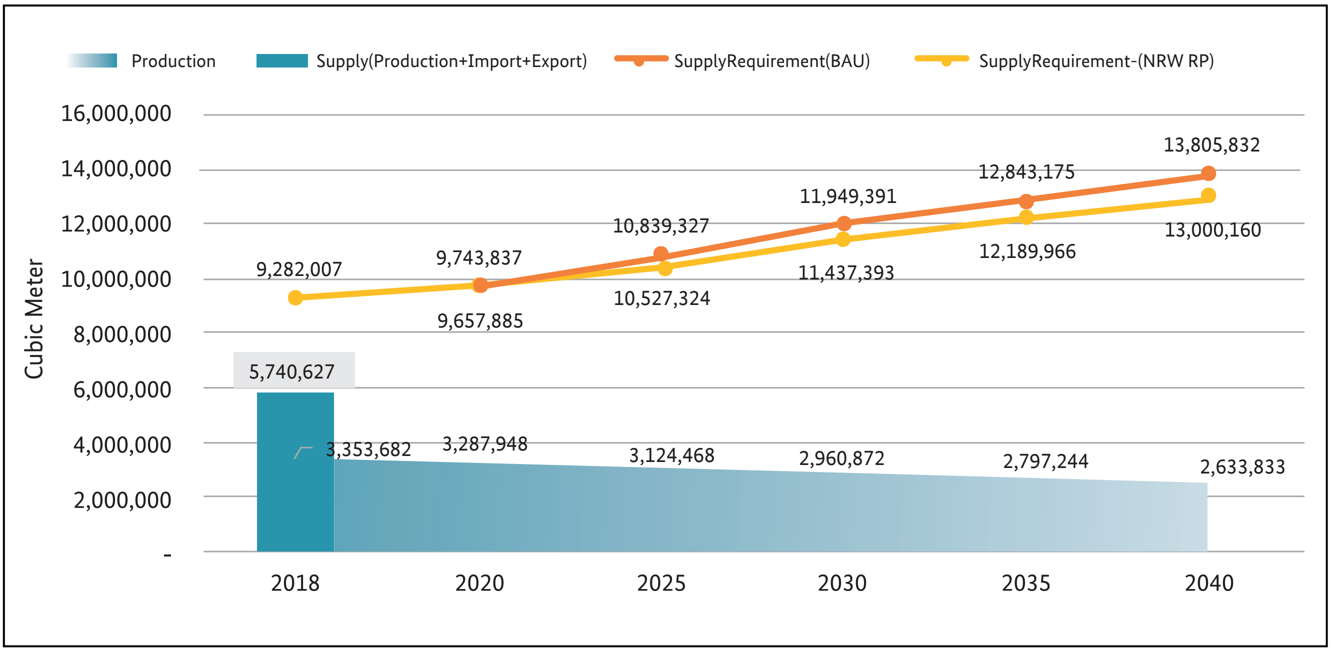


Figure 62: Water Demand and Supply Balance for Ajloun Governorate

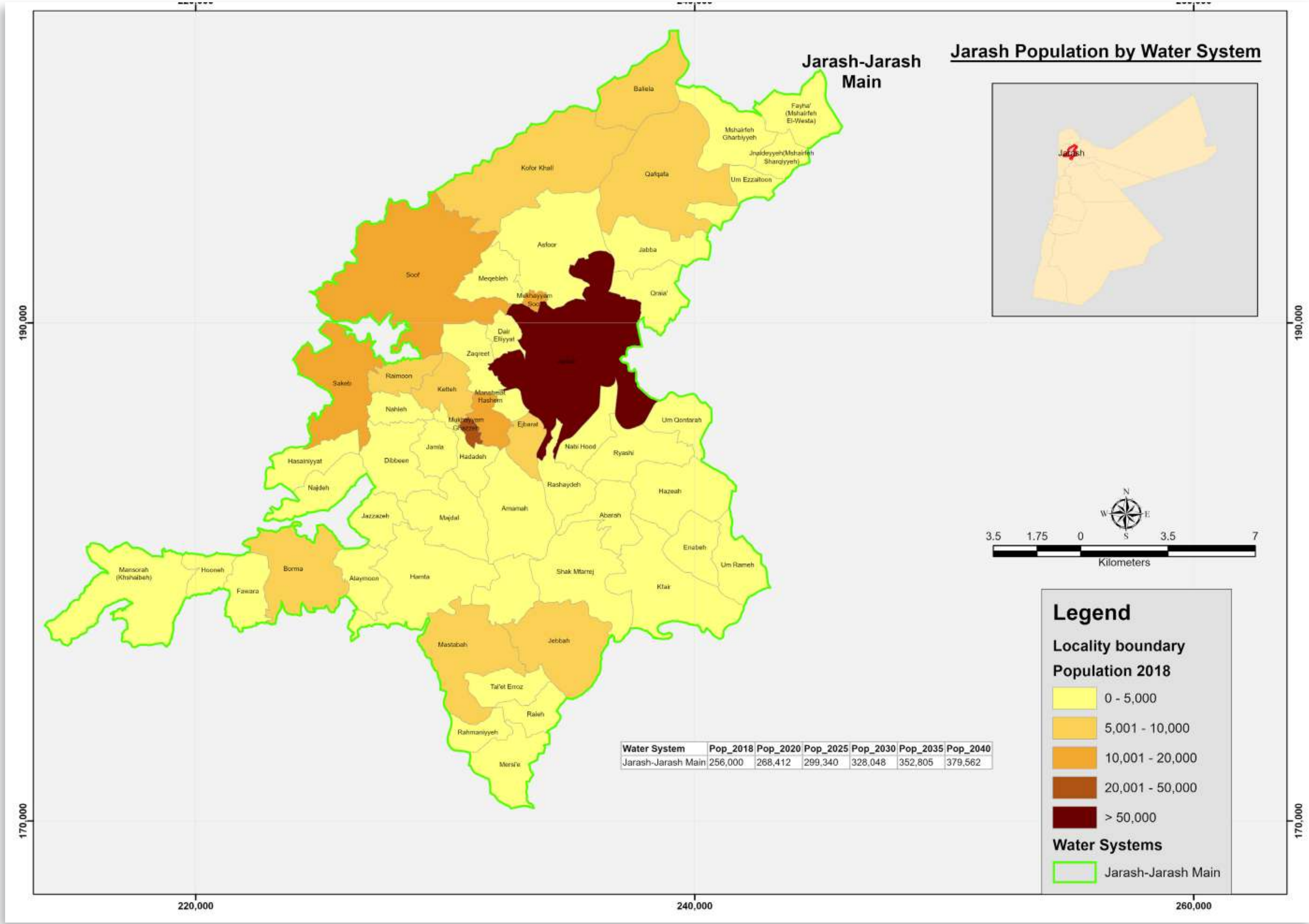
Jarash Governorate

Total population of Jarash was estimated at 256,000 capita in 2018. Jarash Qasabah is the only district boundary of the governorate, however, with three sub-districts and 53 localities. 81% of these localities are classified as urban. Figure 63 shows the localities within Jarash and the boundary of the water system serving all localities in the governorate. Syrians living in Jarash are less than 5% (12,107 capita) of the governorate population.

Population projection for Jarash is presented in Table 47. It is estimated that the population will increase by 51% reaching 385,328 capita in 2040.

Table 47: Population By Water Systems in Jarash

Water System	2018 (DOS estimation)	Urban (%)	Population Projection				
			2020	2025	2030	2035	2040
Jarash_Main	256,000	81%	268,512	300,570	331,565	357,982	385,328



Water System	Pop_2018	Pop_2020	Pop_2025	Pop_2030	Pop_2035	Pop_2040
Jarash-Jarash Main	256,000	268,412	299,340	328,048	352,805	379,562

Figure 63: Jarash Localities, Population and Water System

Water Allocation Gaps (Water Balance)

The average water system demand (supply requirement) of 11.3 MCM in 2018 is projected to increase by 51% and will reach 17.1 MCM by 2040. Estimated water demand and projected water production is presented in Table 48 and Figure 64.

In 2018, the total production of around 5.6 MCM, has satisfied 50% of the required supply for Jarash governorate. By importing an additional 2.6 MCM, the coverage has been improved to 73% which is a relatively good coverage, compared with Irbid. By 2040, it is expected that this level of coverage will drop to 13%, as the remaining production will be only 2.2 MCM. Jarash governorate has a low level of NRW (32.6%), the impact of reduction in physical losses is very limited, but should not be neglected.

The additional needed amount along 2020-2040 is very significant for Jarash. Around 11.9 MCM is required to meet the demand of 2020. Current production can secure 5.3 MCM. An additional amount of 6.6 MCM is required by this year and will reach 14.9 MCM by 2040.

Table 48: Water Demand and Supply Balance for Jarash

Jarash Gov.Demand_ Supply Balance (M^3)	2018	2020	2025	2030	2035	2040
Supply Requirement_(BAU)	11,330,130	11,916,432	13,302,745	14,674,524	15,843,666	17,100,688
Supply Requirement _ (NRW Reduction)	11,330,130	11,825,237	13,013,662	14,237,856	15,253,203	16,343,059
Total Supply	8,248,006					
Production	5,644,683	5,333,483	4,550,870	3,770,886	2,990,998	2,209,377
Additional needed amount_(BAU)	5,685,447	6,582,949	8,751,875	10,903,638	12,852,668	14,891,311
Additional needed amount_ (NRW Reduction)	5,685,447	6,491,754	8,462,792	10,466,970	12,262,205	14,133,682
Production Coverage of Required Demand (%)_(BAU)	50%	45%	34%	26%	19%	13%
Production Coverage of Required Demand (%)_(NRW Reduction)	50%	45%	35%	26%	20%	14%
Total Supply coverage (2018)	**73%**					

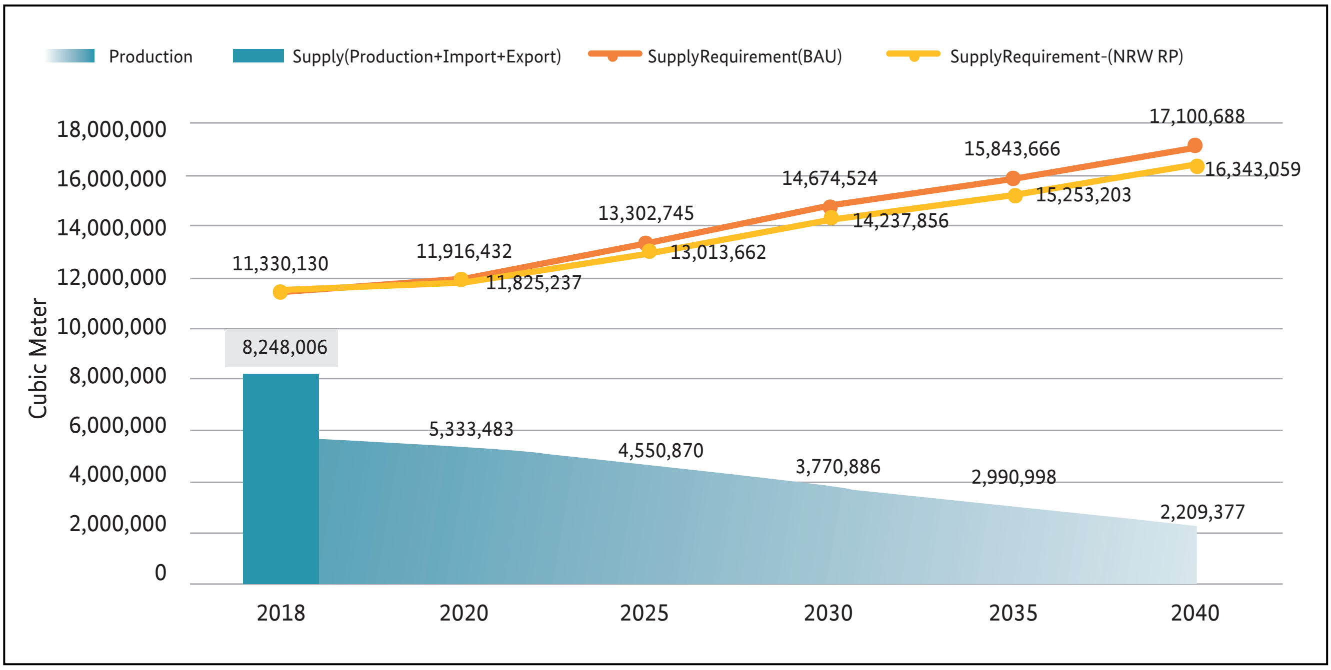


Figure 64: Water Demand and Supply Balance for Jarash Governorate

Amman Governorate

Population

The capital Amman has around 42% of Jordan population. In 2018, DOS estimated the population of Amman at 4,337,839. Syrians refugees in Amman present 11% (485,226 capita) of the governorate population.

Amman is divided into 9 districts and 13 sub-districts with 113 localities. More than 97 % of localities are categorized as urban. Figure 65 shows the distribution of localities in Amman and the boundary of the water systems serving designated localities.

Population projection for Amman is presented in Table 49. By 2040, the projected population will increase by 25 %, reaching 5,369,497 capita.

Table 49: Population by Water Systems in Amman Governorate

Water System	2018	Urban (%)	2020	2025	2030	2035	2040
Amman_Main	4,077,073	99%	4,200,606	4,513,319	4,798,182	4,923,632	5,033,896
Amman_Deep South	260,766	75%	268,383	287,476	305,264	321,026	335,602
Total	**4,337,839**	**97%**	**4,468,989**	**4,800,795**	**5,103,447**	**5,244,658**	**5,369,497**

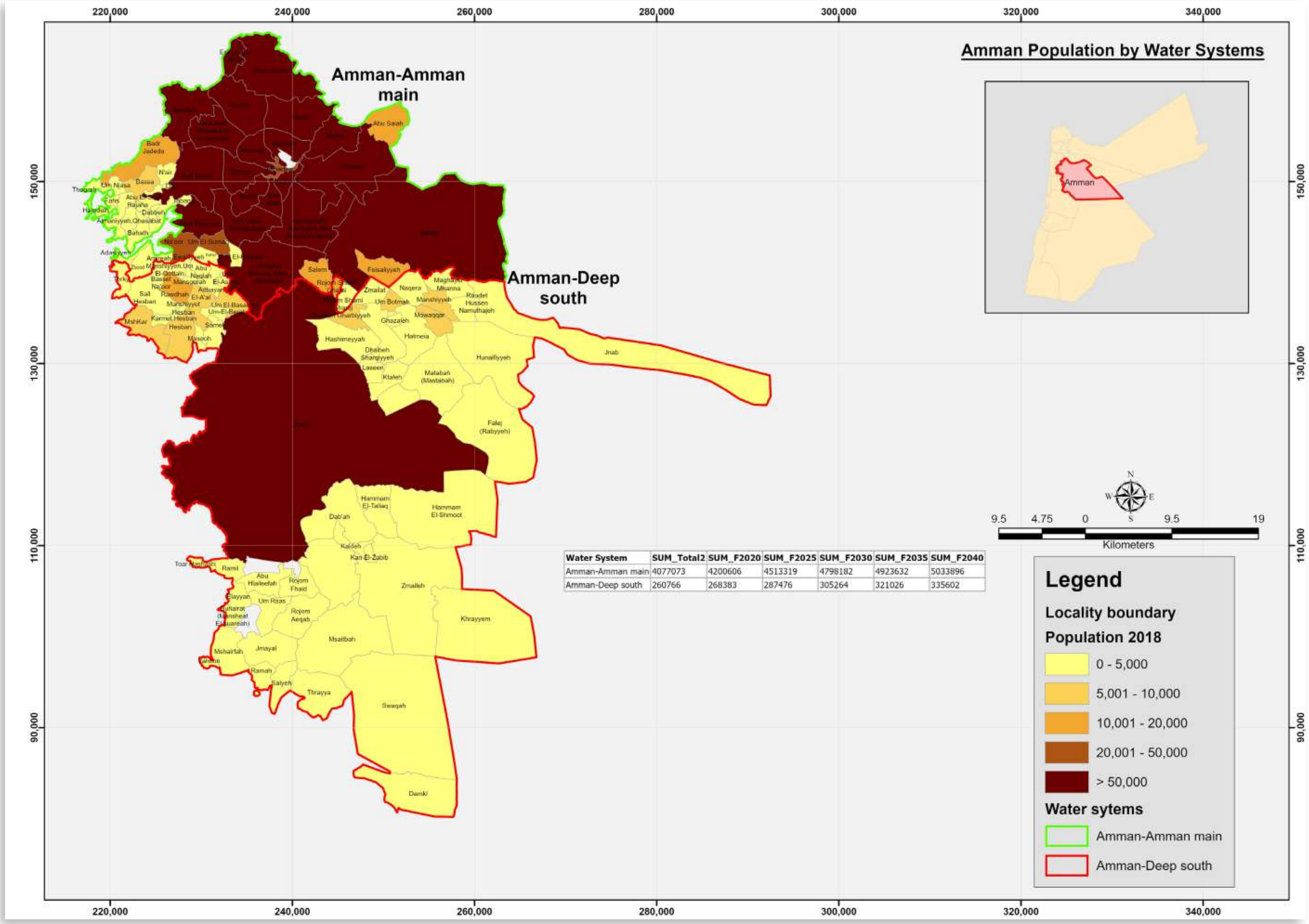


Figure 65: Amman Localities, Population and Water Systems

Water Allocation Gaps (Water Balance)

The average water system demand (supply requirement) estimated for Amman was 276.2 MCM in 2018, and is projected to increase by 24% reaching to about 342.4 MCM by 2040. Estimated water demand and projected water production is presented in Table 50 and Figure 66.

The total production of around 236.8 MCM in 2018 including Disi water, would have satisfied 86% of the required demand for Amman. However, around 40.8 MCM of this production were exported to other governorates. By 2040, this coverage will drop significantly to 59%, as the remaining production will be around 203.7 MCM including Disi, constantly supplying 100 MCM.

Along 2020-2040, the additional needed amount is very significant. Currently, 236.8 MCM is produced from the existing water resources, an additional 39.6 MCM is required to meet the demand of 2020. However, the gap between supply and demand will be significantly widened by time, with an additional required amount of 138.8 to meet the high demand of Amman in 2040. A considerable water saving can be attained if NRW reduction was implemented successfully.

Table 50: Water Demand and Supply Balance for Amman Governorate

Amman Gov.Demand_ Supply Balance (M^3)	2018	2020	2025	2030	2035	2040
Supply Requirement_ (BAU)	276,181,159	285,285,730	305,579,567	324,793,772	333,653,465	342,410,131
Supply Requirement- (NRW Reduction)	276,181,159	282,053,033	294,343,597	305,738,974	307,755,277	310,719,696
Total Supply	195,990,060					
Production	236,824,199	233,224,626	224,408,032	216,454,380	209,710,456	203,650,344
Additional needed amount_(BAU)	39,356,960	52,061,104	81,171,535	108,339,392	123,943,009	138,759,787
Additional needed amount_ (NRW Reduction)	39,356,960	48,828,407	69,935,565	89,284,594	98,044,821	107,069,352
Production Coverage of Required Demand (%)_(BAU)	86%	82%	73%	67%	63%	59%
Production Coverage of Required Demand (%)_(NRW Reduction)	86%	83%	76%	71%	68%	66%
Total Supply coverage (2018)	**71%**					

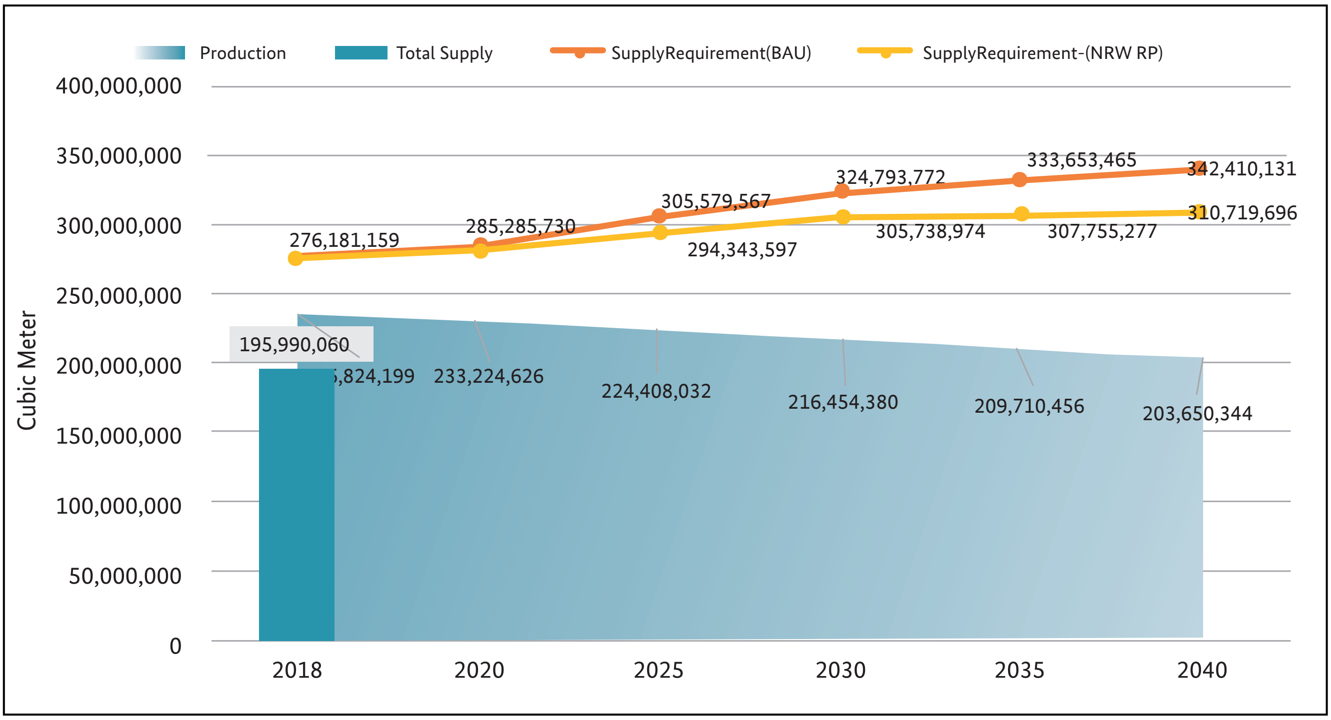


Figure 66: Water Demand and Supply Balance for Amman Governorate

Zarqa Governorate

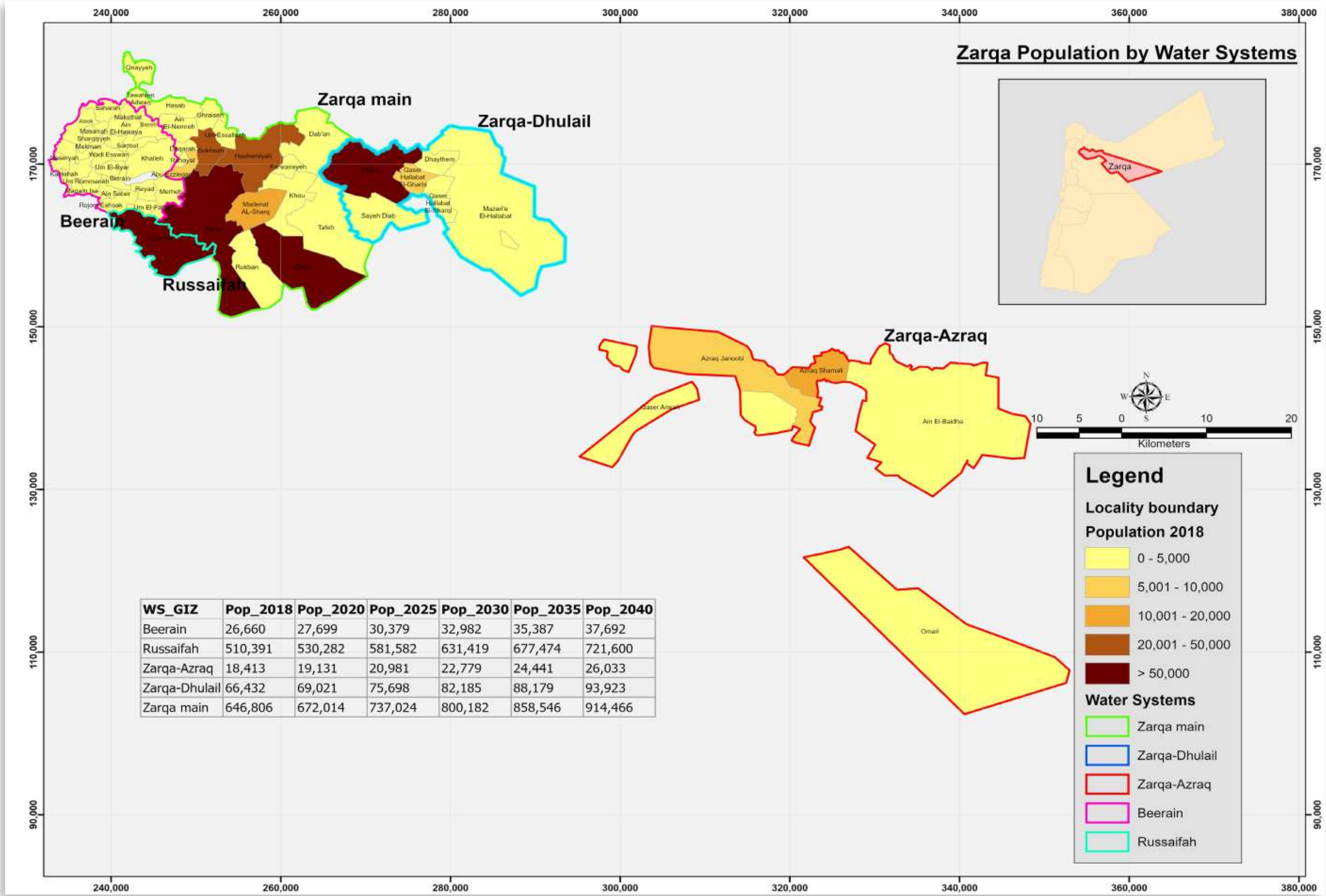
Population

DOS estimated the total population of Zarqa at 1,457,402 in 2018. Syrian refugees present 10% of Zarqa host communities, excluding refugee camps. Additional 47,576 Syrians are living in Azraq and EJC camps. Zarqa is divided into 3 main districts and 6 sub-districts with 55 localities. More than 97 % of localities are categorized as urban. Figure 67 shows the distribution of localities in Zarqa and the boundaries of the water systems serving designated localities.

Population projection for Zarqa is presented in Table 51. By 2040, the projected population will increase by 36 %, reaching 1,953,568.

Table 51: Population by Water Systems in Zarqa Governorate

Water System	2018	Urban %	% population of total	2020	2025	2030	2035	2040
Zarqa_Azraq	18,413	%92	19,131	20,981	22,779	24,441	26,033	26,033
Zarqa_Beerain	26,660	0	27,699	30,379	32,982	35,387	37,692	37,692
Zarqa_Dhlail	66,432	%91	69,021	75,698	82,185	88,179	93,923	93,923
Zarqa_Main	787,930	%98	818,551	898,022	972,770	1,004,475	1,034,074	1,034,074
Zarqa_Russeifa	510,391	%100	530,282	581,582	631,419	677,474	721,600	721,600
Total on Municipal WS	1,409,826		1,464,684	1,606,662	1,742,135	1,829,956	1,913,322	1,913,322
Zarqa_RC_Azraq\ Private Wells	40,650	RC	42,209	46,375	49,713	42,034	34,452	31,983
Zarqa_RC_EJC\ Private Wells	6,926	RC	7,192	7,901	8,470	7,162	5,870	13,898
Total Refugees in Camps	47,576		49,401	54,276	58,183	49,196	40,322	45,881
Total Zarqa	**1,457,402**		**1,514,085**	**1,660,938**	**1,800,318**	**1,879,152**	**1,953,644**	**1,959,203**



WS_GIZ	Pop_2018	Pop_2020	Pop_2025	Pop_2030	Pop_2035	Pop_2040
Beerain	26,660	27,699	30,379	32,982	35,387	37,692
Russaifah	510,391	530,282	581,582	631,419	677,474	721,600
Zarqa-Azraq	18,413	19,131	20,981	22,779	24,441	26,033
Zarqa-Dhulail	66,432	69,021	75,698	82,185	88,179	93,923
Zarqa main	646,806	672,014	737,024	800,182	858,546	914,466

Figure 67: Zarqa Localities, Population and Water Systems

Water Allocation Gaps (Water Balance)

The average water system demand (supply requirement) is estimated at 90 MCM in 2018 for all municipal water systems of Zarqa. An increase of 24 % is expected until 2040, when supply requirement will reach 110.2 MCM. Estimated water demand and projected water production is presented in Table 52 and Figure 68.

Refugees camps are supplied by private wells, not through municipal water systems. Water demand estimation, based on 35 l/c/d, was around 0.6 MCM in 2018, and is subjected to a slight decrease to around 0.5 MCM by 2040 as a result of the anticipated return of Syrians.

Total production of around 41.5 MCM in 2018 has satisfied 51% of the required supply for Zarqa. With the additional amount of 21.8 MCM that was imported, the coverage was raised to 78%. By 2040, however, coverage will drop drastically to 13%, as the remaining production will be around 14 MCM.

Along 2020-2040, the additional needed amount is very significant. Currently, only around 37 MCM can be produced from the existing water resources, and an additional 47.4 MCM is required to meet the demand of 2020. The additional needed amount will increase to 96 MCM by 2040. Considerable water saving can be attained if NRW reduction was implemented successfully.

Table 52: Water Demand and Supply Balance for Zarqa Governorate

Zarqa Gov. Demand_ Supply Balance (M^3)	2018	2020	2025	2030	2035	2040
Supply Requirement_ (BAU)	80,974,918	84,356,221	92,280,409	100,061,080	105,097,861	110,179,849
Supply Requirement _ (NRW Reduction)	80,974,918	82,901,885	87,186,900	91,349,048	93,108,233	95,067,706
Total Supply	63,368,685					
Production	41,519,756	36,957,465	28,157,790	19,992,149	16,512,696	14,090,628
Additional needed amount_(BAU)	39,455,162	47,398,756	64,122,619	80,068,931	88,585,165	96,089,221
Additional needed amount_ (NRW Reduction)	39,455,162	45,944,420	59,029,110	71,356,899	76,595,537	80,977,078
Production Coverage of Required Demand (%)_(BAU)	51%	44%	31%	20%	16%	13%
Production Coverage of Required Demand (%)_(NRW Reduction)	51%	45%	32%	22%	18%	15%
Total Supply coverage (2018)	**78%**					

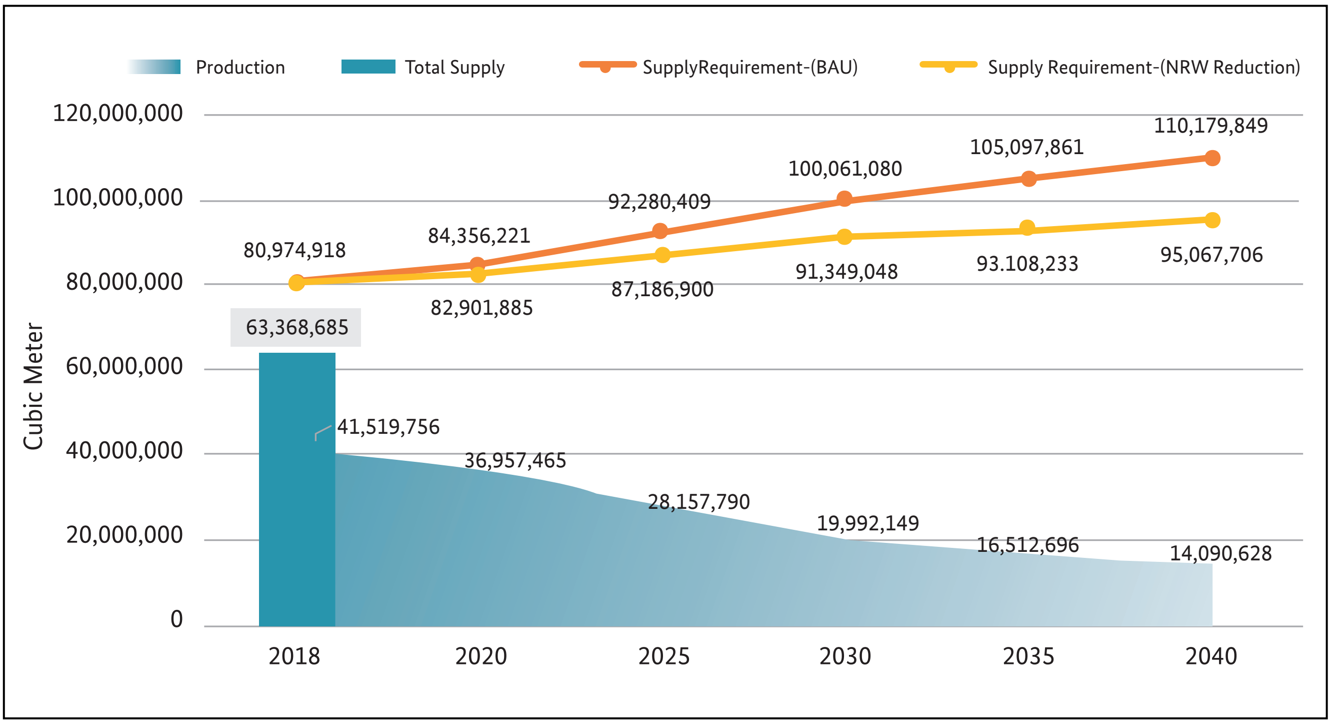


Figure 68: Water Demand and Supply Balance for Zarqa Governorate

Balqa Governorate

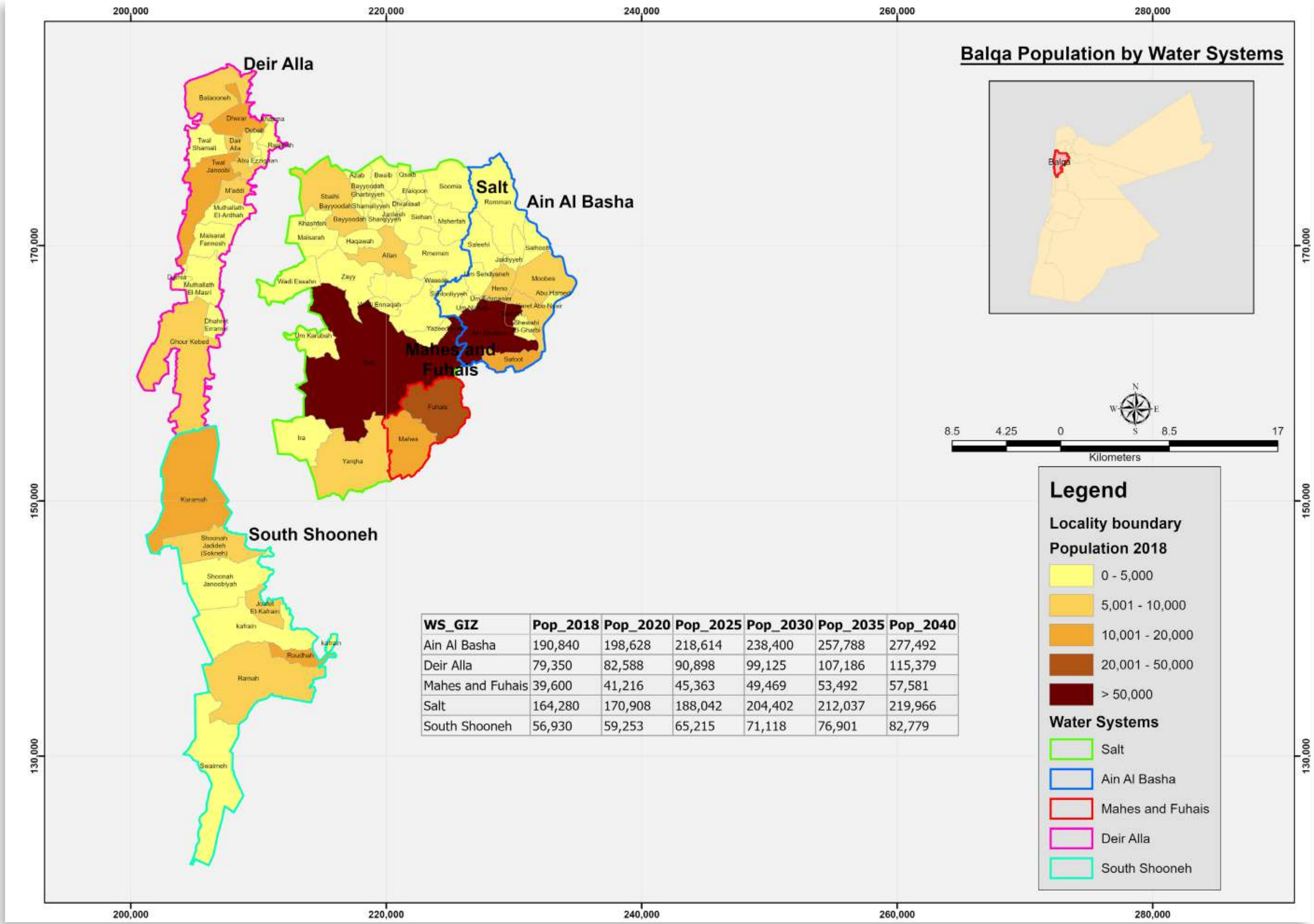
Population

Balqa governorate is divided into 5 districts and 8 sub-districts with a total of 71 localities. Around 84 % of the localities are categorized as urban. Figure 69 shows the distribution of localities in Balqa and the boundary of the water systems serving designated localities. The estimated population for Balqa governorate in 2018 was 531,000 capita. Syrians refugees in Balqa present 6% of the governorate population (31,171 capita).

Population projection for Balqa is presented in Table 53. By 2040, the projected population will increase by 42 %, reaching 753,197.

Table 53: Population by Water Systems in Balqa Governorate

Water System	2018	Urban %	2020	2025	2030	2035	2040
Balqa_AinAlBasha	190,840	92%	198,628	218,614	238,400	257,788	277,492
Balqa_DairAlla	79,350	67%	82,588	90,898	99,125	107,186	115,379
Balqa_FuhaisMahis	39,600	100%	41,216	45,363	49,469	53,492	57,581
Balqa_Salt	164,280	80%	170,908	188,042	204,402	212,037	219,966
Balqa_Shouneh	56,930	83%	59,253	65,215	71,118	76,901	82,779
Total	**531,000**		**552,593**	**608,132**	**662,515**	**707,404**	**753,197**



WS_GIZ	Pop_2018	Pop_2020	Pop_2025	Pop_2030	Pop_2035	Pop_2040
Ain Al Basha	190,840	198,628	218,614	238,400	257,788	277,492
Deir Alla	79,350	82,588	90,898	99,125	107,186	115,379
Mahes and Fuhais	39,600	41,216	45,363	49,469	53,492	57,581
Salt	164,280	170,908	188,042	204,402	212,037	219,966
South Shooneh	56,930	59,253	65,215	71,118	76,901	82,779

Figure 69: Balqa Localities, Population and Water Systems

Water Allocation Gaps (Water Balance)

The average water system demand (supply requirement) is estimated at 36.6 MCM in 2018 for all municipal water systems of Balqa. An increase of 42% is expected by 2040, then reaching 52 MCM. Estimated water demand and projected water production is presented in Table 54 and Figure 70.

In 2018, the total production of around 15.4 MCM, has satisfied only 42% of the required demand for Balqa. An additional amount of 26.9 MCM was imported to improve water supply in Balqa, however, with this amount the coverage reached 116%, i.e. oversupply. By 2040, the remaining production of 8.4 MCM will satisfy only 16% of the required demand.

Balqa has a very high NRW level of 73.5%, therefore there is an urgent need to reduce these losses. Reduction in physical losses implies significant improvement by gradual water savings of 3 MCM in 2025, increasing to 9 MCM in 2040, that would lead to a better service level of 20% coverage.

The additional needed amount along 2020-2040 is very significant. Currently, only around 14.8 MCM can be produced from the existing water resources. An additional amount of 23.4 MCM will be required to meet the demand in 2020 and the additional needed amount will reach 43.6 MCM by 2040, if NRW remain high. Considerable water savings can be attained if the NRW reduction is implemented successfully.

Table 54: Water Demand and Supply Balance for Balqa Governorate

Balqa Gov. Demand_ Supply Balance (M^3)	2018	2020	2025	2030	2035	2040
Supply Requirement_(BAU)	36,605,161	38,198,102	41,922,471	45,671,819	48,772,027	52,076,809
Supply Requirement _ (NRW Reduction)	36,605,161	37,338,981	38,938,869	40,594,085	41,725,003	43,092,470
Total Supply	42,387,078					
Production	15,445,397	14,764,854	13,099,229	11,432,026	9,763,668	8,441,245
Additional needed amount_(BAU)	21,159,764	23,433,248	28,823,242	34,239,793	39,008,359	43,635,564
Additional needed amount_ (NRW Reduction)	21,159,764	22,574,127	25,839,640	29,162,059	31,961,335	34,651,225
Production Coverage of Required Demand (%)-(BAU)	42%	39%	31%	25%	20%	16%
Production Coverage of Required Demand (%)_(NRW Reduction)	42%	40%	34%	28%	23%	20%
Total Supply coverage (2018)	**116%**					

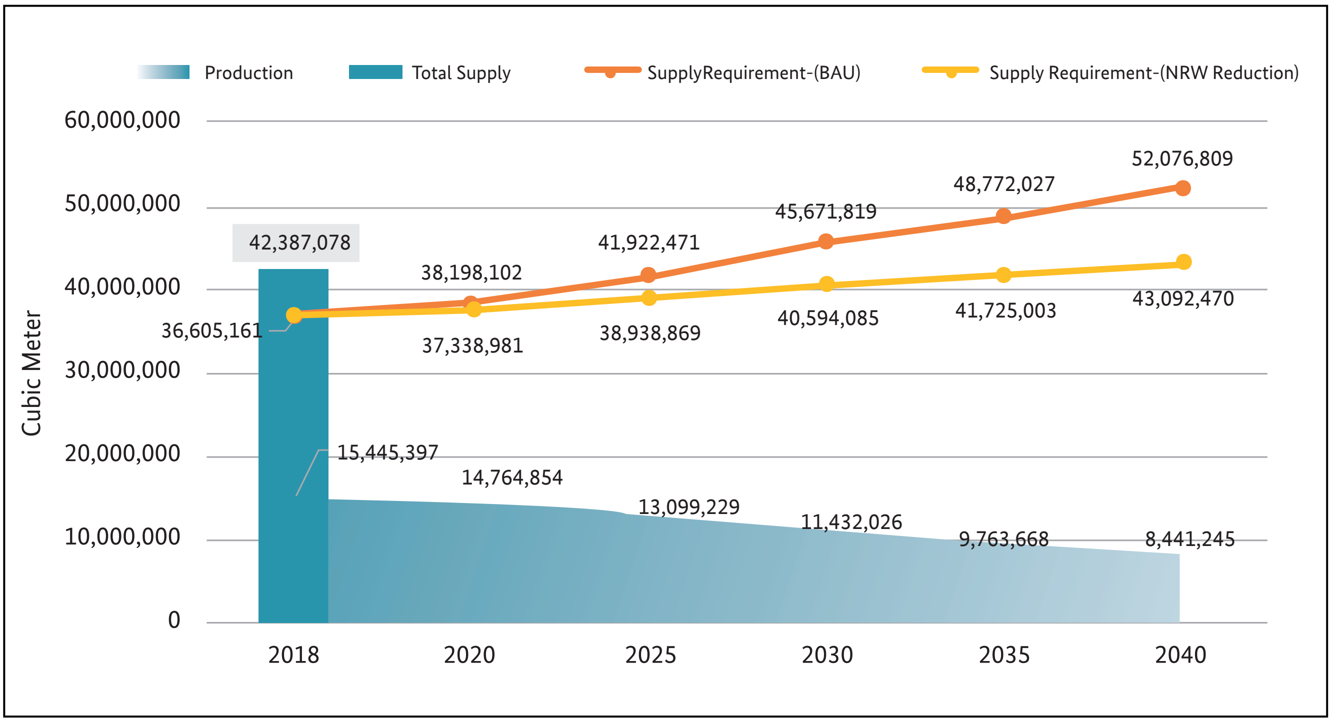


Figure 70: Water Demand and Supply Balance for Balqa Governorate

Madaba Governorate

Population

Madaba governorate is divided into 2 districts and 7 sub-districts with a total of 73 localities. Around 81% of the localities are categorized as urban. Figure 71 shows the distribution of localities in Madaba and the boundary of the water systems serving designated localities. The estimated population was 593,900 capita in 2018. Syrians refugees were estimated at 16,341 capita, representing 8% of the governorate population.

Population projection for Madaba is presented in Table 55. By 2040, the projected population will increase by 32 %, reaching 269,369.

Table 55: Population by Water System in Madaba Governorate

Water System	2018	Urban (%)	2020	2025	2030	2035	2040
Madaba_Main	204,300	81%	211,400	228,556	244,809	256,863	269,369

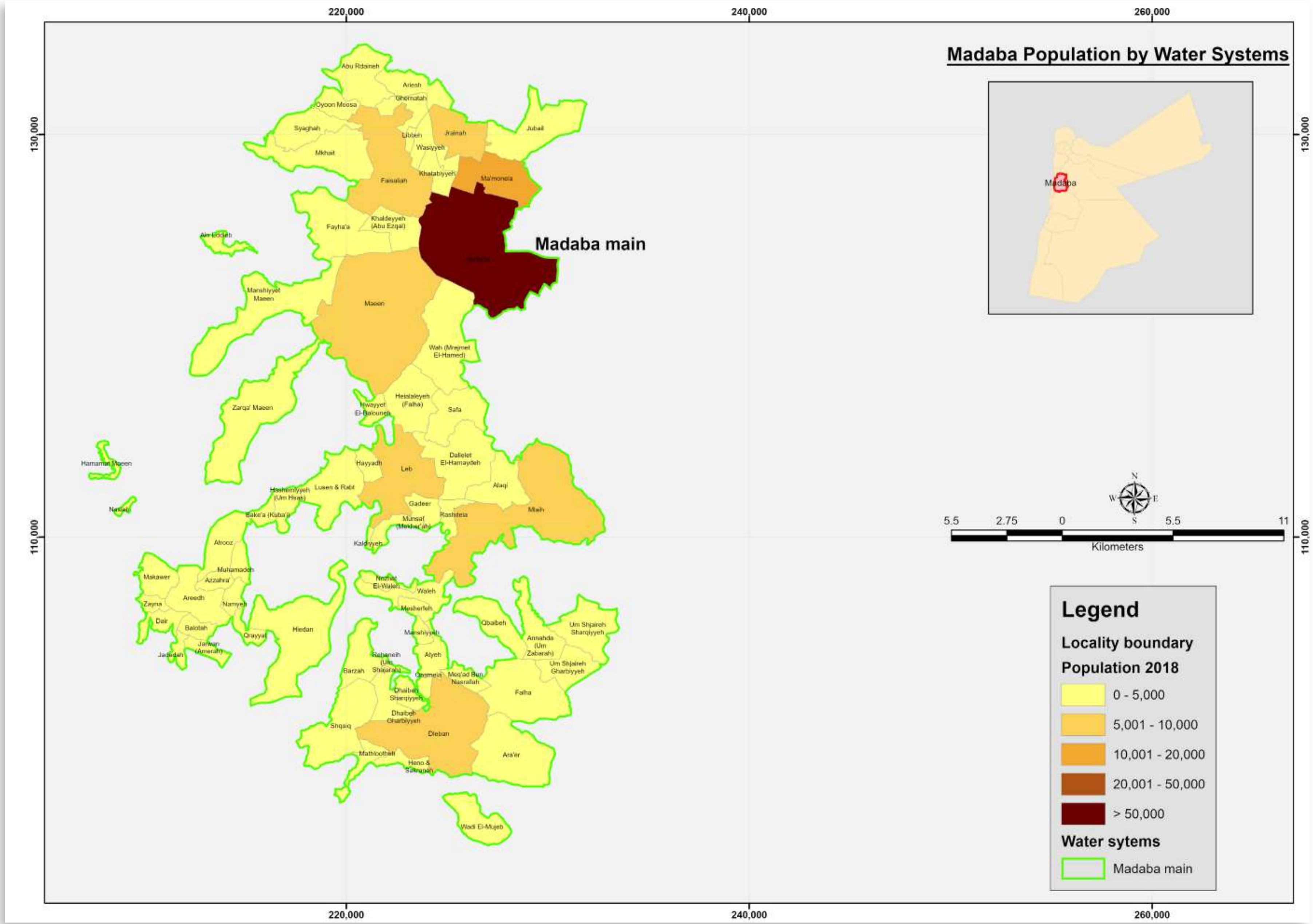


Figure 71: Madaba Localities, Population and Water System

Water Allocation Gaps (Water Balance)

Supply requirement for Madaba was estimated at around 10 MCM in 2018, and is projected to increase by 32 %, reaching about 13.2 MCM in 2040. Estimated water demand and projected water production is presented in Table 56 and Figure 72.

The production of water resources in Madaba has exceeded the required supply in 2018 by 1.1 MCM. Due to supply arrangements, Madaba exchanged around 1.9 MCM with Amman. However, total supply of 9.9 MCM has almost satisfied Madaba municipal water demand.

Water resources in Madaba will be subjected to only 4% decrease by 2040. Current production of 10.5 MCM still exceeds the required demand by 5%. Remaining production in 2040 is estimated at 10.5 MCM and will satisfy 80% of the required demand. Reduction in physical losses would maintain coverage at 88%.

Table 56: Water Demand and Supply Balance for Madaba Governorate

Madaba Gov.Demand_ Supply Balance (M^3)	2018	2020	2025	2030	2035	2040
Supply Requirement (BAU)	9,970,780	10,345,580	11,154,563	11,947,805	12,536,085	13,182,465
Supply Requirement _ (NRW Reduction)	9,970,780	10,225,648	10,735,264	11,231,655	11,542,379	11,936,974
Total Supply	9,892,607					
Production	11,003,747	10,892,976	10,617,310	10,536,357	10,536,357	10,536,357
Additional needed amount (BAU)	-1,032,967	-547,396	537,253	1,411,448	1,999,728	2,646,108
Additional needed amount_ (NRW Reduction)	-1,032,967	-667,328	117,954	695,298	1,006,022	1,400,617
Coverage of Required Demand (%)_(BAU)	110%	105%	95%	88%	84%	80%
Coverage of Required Demand (%)_(NRW Reduction)	110%	107%	99%	94%	91%	88%
Total Supply coverage (2018)	**99%**					

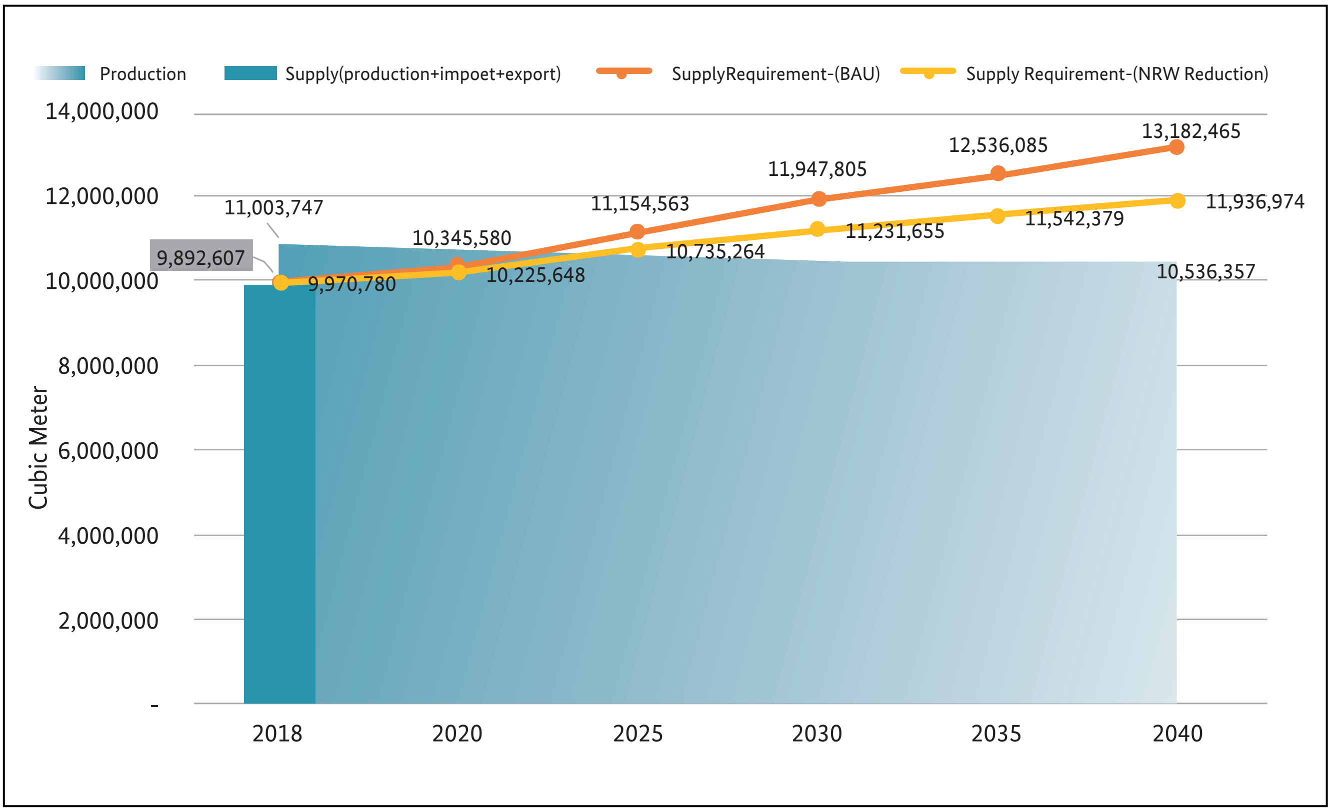


Figure 72: Water Demand and Supply Balance for Madaba Governorate

Karak Governorate

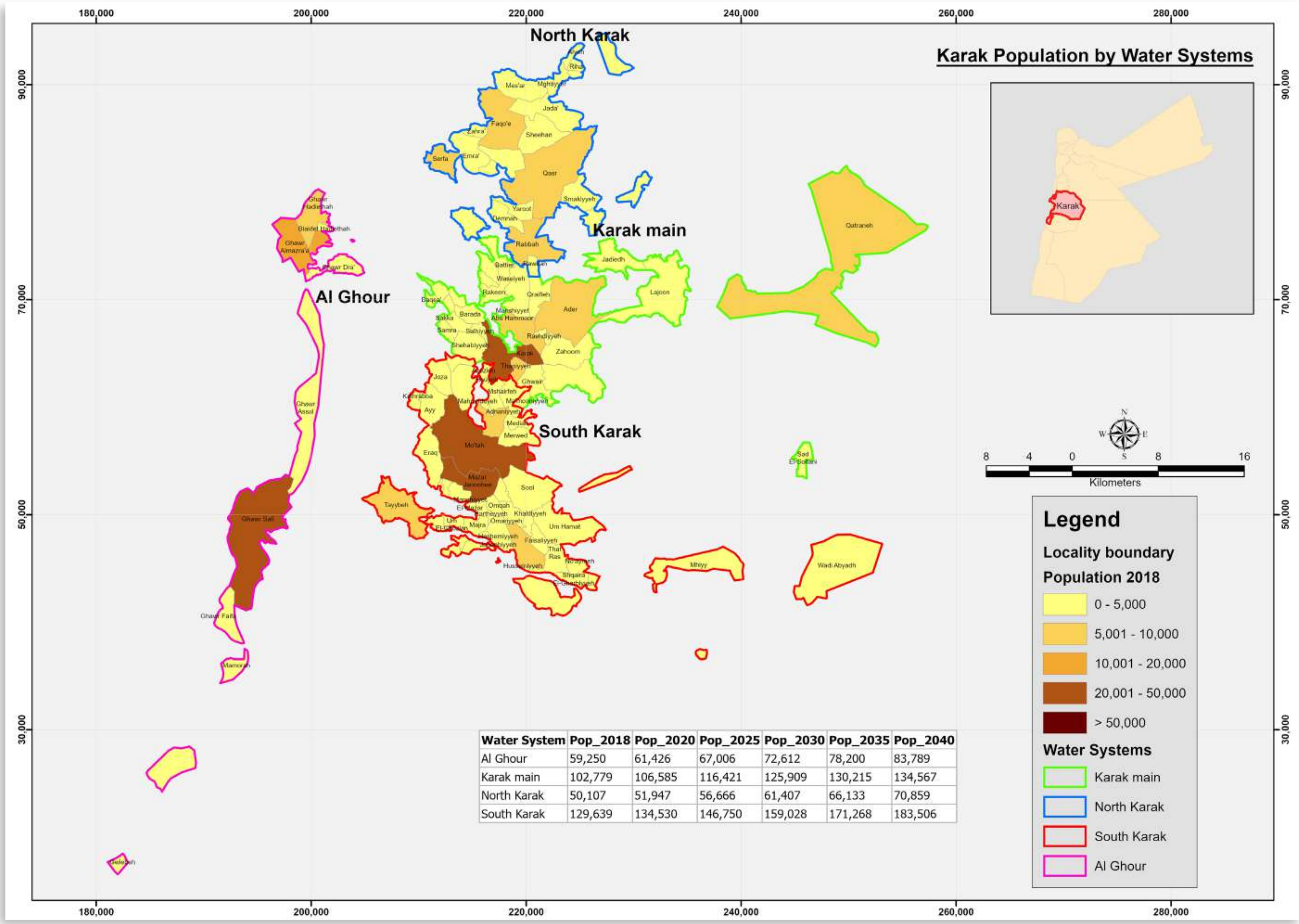
Population

Karak governorate is divided into 7 districts and 10sub-districts with a total of 112 localities. Around 61% of the localities are categorized as urban. Figure 73 shows the distribution of localities in Karak and the boundary of the water systems serving designated localities. The estimated population was 341,900 capita in 2018. Syrian refugees are estimated at 19,023 capita living in Karak, representing 4% of the governorate population.

Population projection is presented in Table 57. By 2040, the projected population will increase by 38 %, reaching to 472,720.

Table 57: Population by Water System in Karak Governorate

Water System	2018	Urban (%)	2020	2025	2030	2035	2040
Karak_AlGhawr	59,250	82%	61,426	67,006	72,612	78,200	83,789
Karak_Main	102,779	62%	106,585	116,421	125,909	130,215	134,567
Karak_North	50,107	55%	51,947	56,666	61,407	66,133	70,859
Karak_South	129,764	53%	134,530	146,750	159,028	171,268	183,506
Total	**341,900**		**354,489**	**386,843**	**418,955**	**445,816**	**472,720**



Water System	Pop_2018	Pop_2020	Pop_2025	Pop_2030	Pop_2035	Pop_2040
Al Ghour	59,250	61,426	67,006	72,612	78,200	83,789
Karak main	102,779	106,585	116,421	125,909	130,215	134,567
North Karak	50,107	51,947	56,666	61,407	66,133	70,859
South Karak	129,639	134,530	146,750	159,028	171,268	183,506

Figure 73: Karak Localities, Population and Water System

Water Allocation Gaps (Water Balance)

Supply requirement for Karak was estimated at 20.6 MCM in 2018, and is projected to increase by 39 %, reaching about 28.5 MCM in 2040. Estimated water demand and projected water production is presented in Table 58 and Figure 74.

The production of water resources in Karak has exceeded the required supply in 2018 by 5.1 MCM. Around 2.9 MCM is exported, however the remaining is still beyond the requirement, with 111% coverage.

Current production of 25.7 MCM exceeds the required demand of 2020. Water resources will be subjected to a drastic decrease of 68% until 2040. By 2025, Karak will lack resources, and additional resources will be required to cover the deficit of 5.3 MCM, which will reach 20.4 MCM in 2040. Remaining production is estimated at 8.1 MCM and will cover only 28% of the required demand. Implementing NRW reduction measures could increase demand coverage to 34%, however large investments into NRW reduction would be required as the network is fairly old. In order to ensure that NRW is sustainably reduced a long-term monitoring system and related database needs to be in place.

Table 58: Water Demand and Supply Balance for Karak Governorate

Karak Gov.Demand_ Supply Balance (M^3)	2018	2020	2025	2030	2035	2040
Supply Requirement (BAU)	20,555,273	21,370,550	23,257,299	25,187,893	26,802,142	28,496,831
Supply Requirement _ (NRW Reduction)	20,555,273	20,933,911	21,746,756	22,622,634	23,243,446	23,967,023
Total Supply	22,736,064					
Production	25,667,941	23,381,428	17,963,075	13,622,221	10,383,496	8,108,783
Additional needed amount (BAU)	-5,112,668	-2,010,878	5,294,224	11,565,672	16,418,646	20,388,048
Additional needed amount_ (NRW Reduction)	-5,112,668	-2,447,517	3,783,681	9,000,413	12,859,950	15,858,240
Coverage of Required Demand (%)_(BAU)	125%	109%	77%	54%	39%	28%
Coverage of Required Demand (%)_(NRW Reduction)	125%	112%	83%	60%	45%	34%
Total Supply coverage (2018)	**111%**					

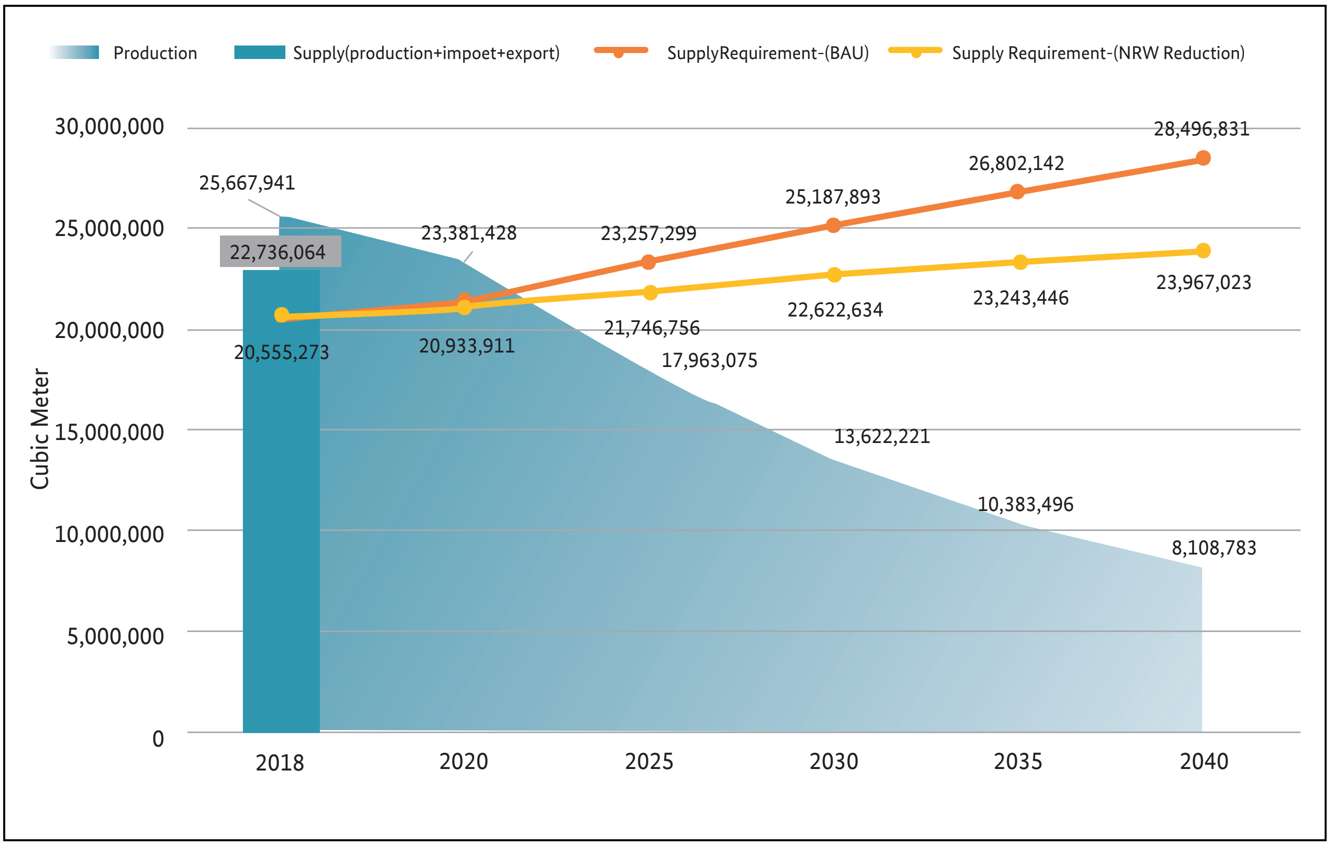


Figure 74: Water Demand and Supply Balance for Kara

Tafilah Governorate

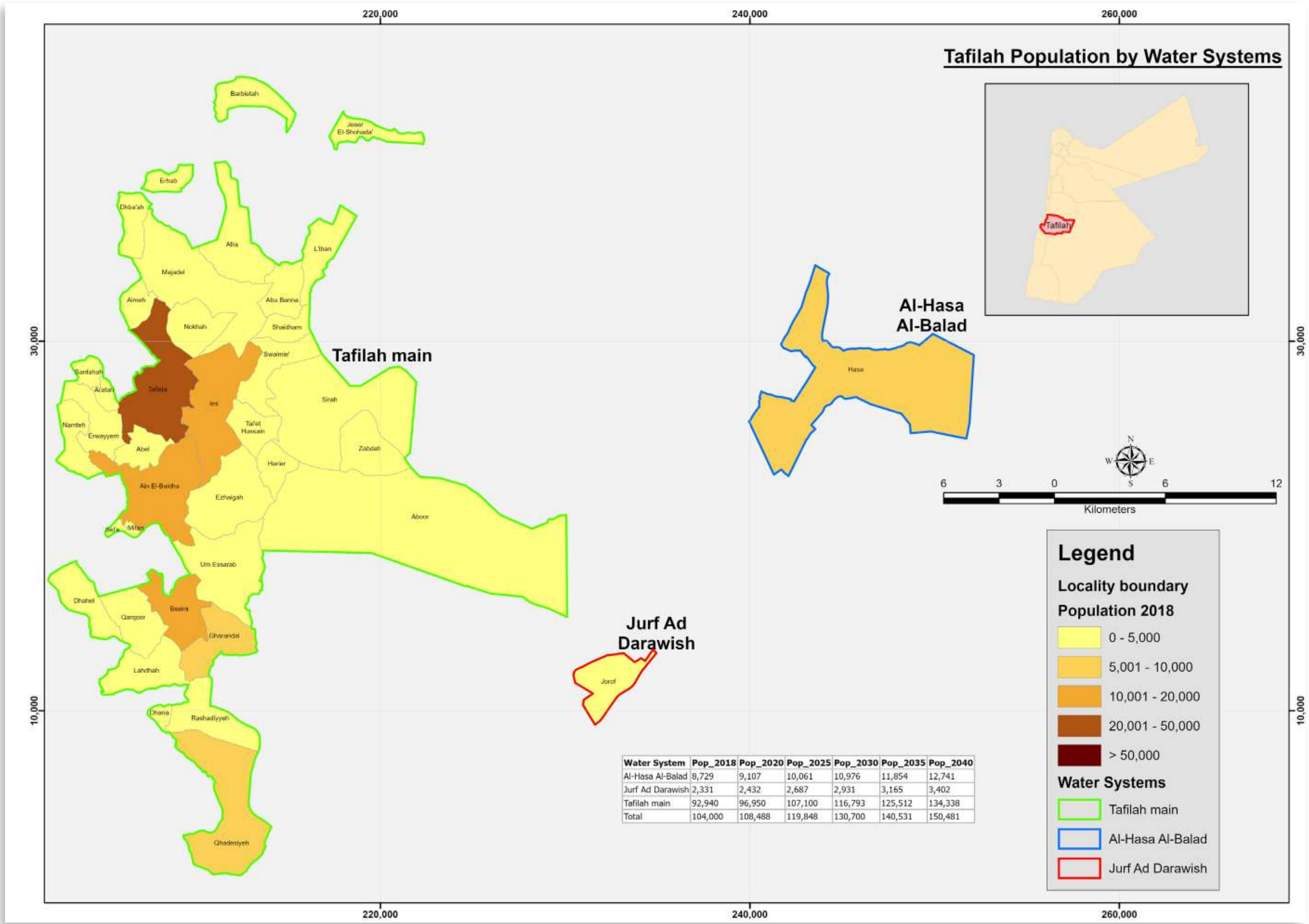
Population

Tafilah governorate is divided into 3 districts and sub-districts with a total of 37 localities. Around 83% of the localities are categorized as urban. Figure 75 shows the distribution of localities in Tafilah and the boundary of the water systems serving designated localities. The estimated population was 104,000 capita in 2018. Syrian refugees are estimated at 2,153 capita, representing 2% of the governorate population.

Population projection for Tafilah is presented in Table 59. By 2040, the projected population will increase by 45 %, reaching 150,481.

Table 59: Population by Water System in Tafilah Governorate

Water System	2018	Urban (%)	2020	2025	2030	2035	2040
Tafilah_AlHasa AlBalad	8,729	100%	9,107	10,061	10,976	11,854	12,741
Tafilah_JurfAdDarawish	2,331	0	2,432	2,687	2,931	3,165	3,402
Tafilah_Main	92,940	83%	96,950	107,100	116,793	125,512	134,338
Total	**104,000**		**108,488**	**119,848**	**130,700**	**140,531**	**150,481**



Water System	Pop_2018	Pop_2020	Pop_2025	Pop_2030	Pop_2035	Pop_2040
Al-Hasa Al-Balad	8,729	9,107	10,061	10,976	11,854	12,741
Jurf Ad Darawish	2,331	2,432	2,687	2,931	3,165	3,402
Tafilah main	92,940	96,950	107,100	116,793	125,512	134,338
Total	104,000	108,488	119,848	130,700	140,531	150,481

Figure 75: Tafilah Localities, Population and Water Systems

Water Allocation Gaps (Water Balance)

Supply requirement for Tafilah was estimated at 6.4 MCM in 2018, and are projected to increase by 45 %, reaching about 9.2 MCM in 2040. Estimated water demand and projected water production is presented in Table 60 and Figure 76Figure 1.

Water resources in Tafilah are also subjected to a drastic reduction of 95% by 2040. Current production of 5.6 MCM can satisfy 84% of 2020 demand and will drop significantly to 4% with less than 0.5 MCM remaining production in 2040.

There is an urgent need for allocating of new resources for Tafilah. An additional amount of 4.2 MCM is required to meet the demand by 2025 and of 9 MCM by 2040.

Table 60: Water Demand and Supply Balance for Tafilah Governorate

Tafilah Gov.Demand_ Supply Balance (M^3)	2018	2020	2025	2030	2035	2040
Supply Requirement (BAU)	6,378,964	6,672,489	7,351,030	8,016,649	8,619,604	9,255,142
Supply Requirement _ (NRW Reduction)	6,378,964	6,561,398	6,958,678	7,340,953	7,666,777	8,024,099
Total Supply	6,807,213					
Production	6,821,491	5,604,970	3,190,783	1,637,361	717,055	355,646
Additional needed amount (BAU)	-442,527	1,067,519	4,160,247	6,379,288	7,902,549	8,899,496
Additional needed amount_ (NRW Reduction)	-442,527	956,428	3,767,895	5,703,592	6,949,722	7,668,453
Coverage of Required Demand (%)_(BAU)	107%	84%	43%	20%	8%	4%
Coverage of Required Demand (%)_(NRW Reduction)	107%	85%	46%	22%	9%	4%
Total Supply coverage (2018)	**107%**					

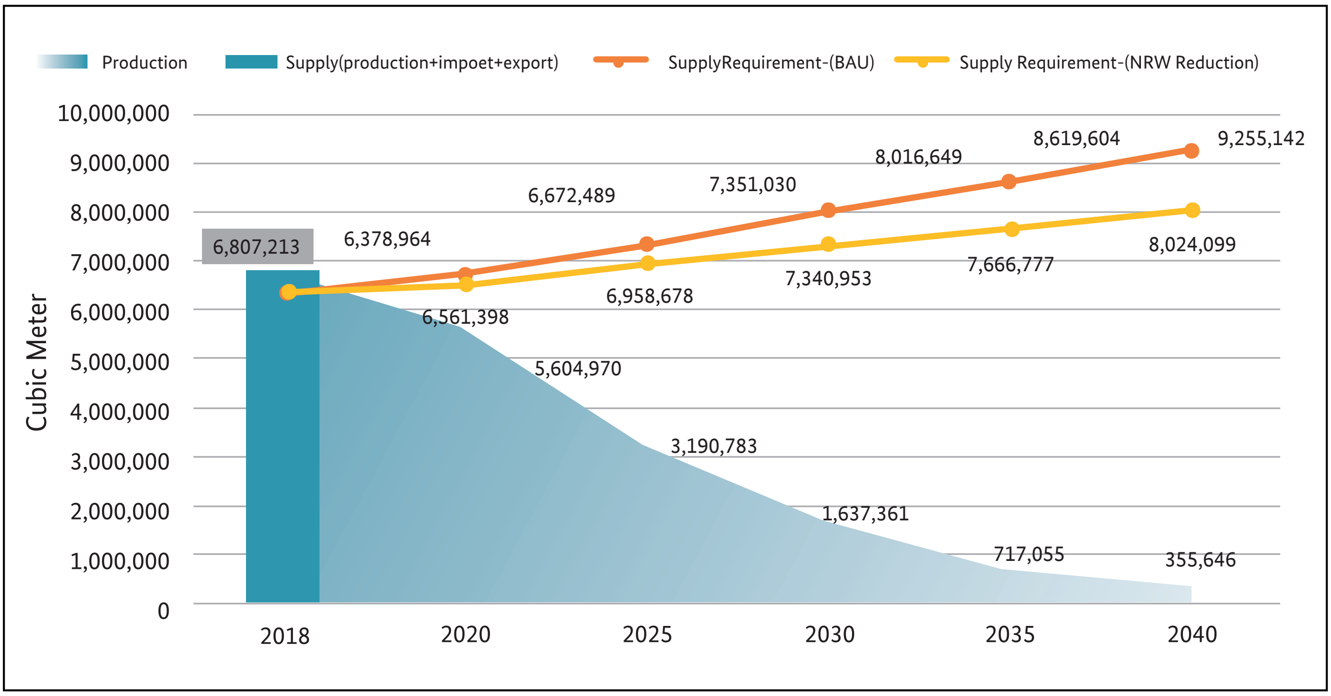


Figure 76: Water Demand and Supply Balance for Tafilah Governorate

Maan Governorate

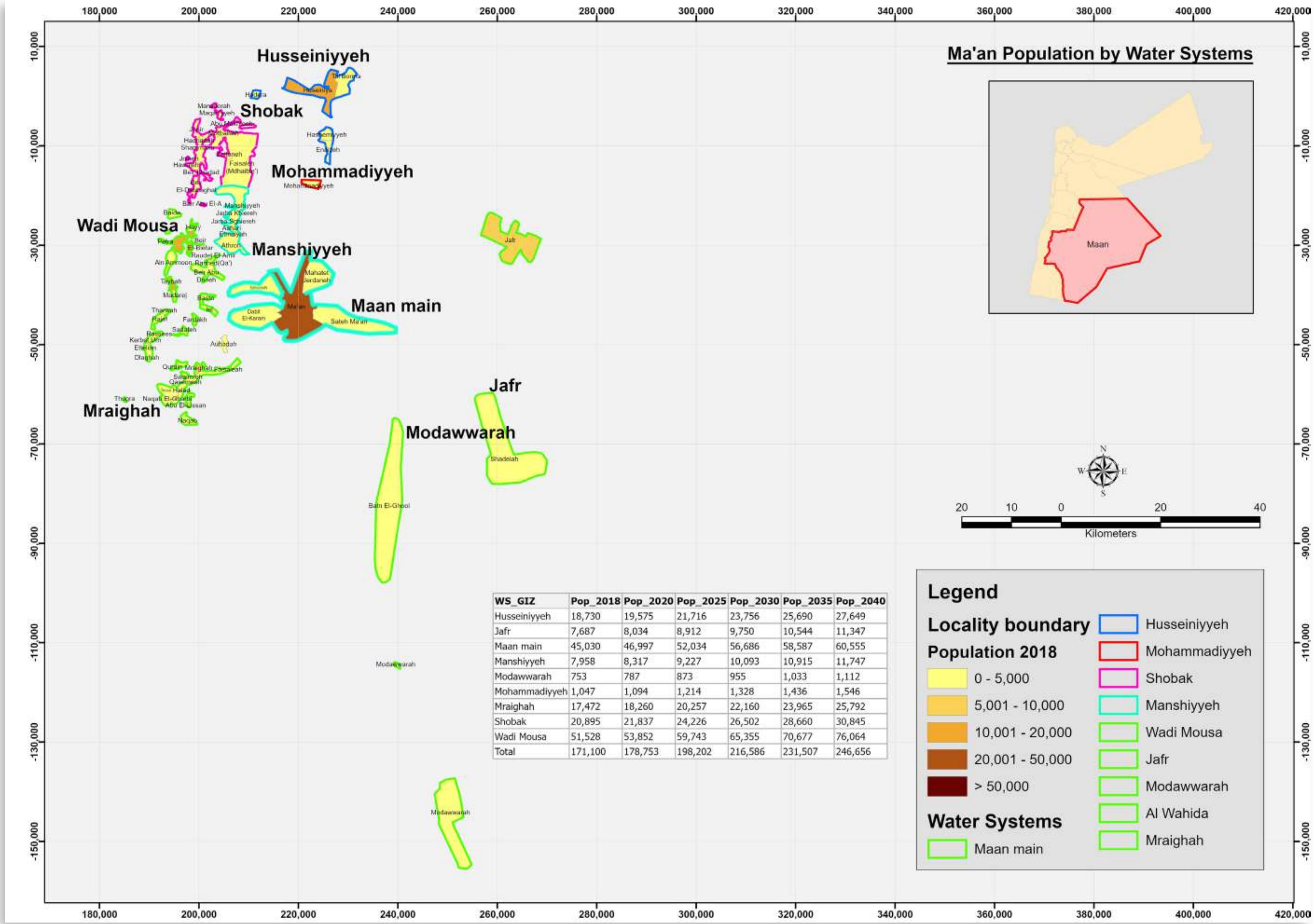
Population

Maan governorate is divided into 4 districts and 9 sub-districts with 66 localities. Around 55% of the localities are categorized as urban. Figure 77 shows the distribution of localities and the boundary of the water systems serving designated localities. The estimated population was 171,000 in 2018. Syrian refugees are estimated at 9,413 capita, representing 6% of the governorate population.

Population projection for Maan is presented in Table 61. By 2040, the projected population will increase by 44 %, reaching 246,656.

Table 61: Population by Water System in Maan Governorate

Water System	2018	Urban (%)	2020	2025	2030	2035	2040
Maan_AlHusayniyyah	18,730	%73	19,575	21,716	23,756	25,690	27,649
Maan_AlJafr	7,687	%90	8,034	8,912	9,750	10,544	11,347
Maan_AlMudawwara	753	0	787	873	955	1,033	1,112
Maan_AlMuhammadiyyah	1,047	0	1,094	1,214	1,328	1,436	1,546
Maan_AlMurayghaAlWahaida	17,472	32%	18,260	20,257	22,160	23,965	25,792
Maan_Main	45,030	99%	46,997	52,034	56,686	58,587	60,555
Maan_Manshiyya	7,958	0	8,317	9,227	10,093	10,915	11,747
Maan_Shoubak	20,895	0	21,837	24,226	26,502	28,660	30,845
Maan_WadiMousa	51,528	45%	53,852	59,743	65,355	70,677	76,064
Total	**171,100**		**178,753**	**198,202**	**216,586**	**231,507**	**246,656**



WS_GIZ	Pop_2018	Pop_2020	Pop_2025	Pop_2030	Pop_2035	Pop_2040
Husseiniyyeh	18,730	19,575	21,716	23,756	25,690	27,649
Jafr	7,687	8,034	8,912	9,750	10,544	11,347
Maan main	45,030	46,997	52,034	56,686	58,587	60,555
Manshiyyeh	7,958	8,317	9,227	10,093	10,915	11,747
Modawwarah	753	787	873	955	1,033	1,112
Mohammadiyyeh	1,047	1,094	1,214	1,328	1,436	1,546
Mraighah	17,472	18,260	20,257	22,160	23,965	25,792
Shobak	20,895	21,837	24,226	26,502	28,660	30,845
Wadi Mousa	51,528	53,852	59,743	65,355	70,677	76,064
Total	171,100	178,753	198,202	216,586	231,507	246,656

Figure 77: Maan Localities, Population and Water Systems

Water Allocation Gaps (Water Balance)

Supply requirement for Maan was estimated at around 10 MCM in 2018, and is projected to increase by 44 %, reaching about 14.5 MCM in 2040. Estimated water demand and projected water production is presented in Table 62 and Figure 78.

The production of 15.6 MCM has exceeded the required supply in 2018 by 5.6 MCM. Although WAJ reported that 1.1 MCM is used for irrigation in Maan, still significant part of the actual supply 14.5 MCM is also used for irrigation and livestock purposes but cannot be quantified. The export from Maan is limited to 20,000 m3 to Aqaba.

Production of 10.5 MCM in 2020 can still satisfy 105% of the required demand. With the significant drop of water resources, Maan will lose 94 % of its resources. By 2040 the production will drop to less than 1 MCM that would cover only 6% of the demand. In 2025, the additional needed amount is estimated at 6.6 MCM and will further increase to 13.6 MCM by 2040.

Maan has the highest NRW level of Jordan, estimated at 75.1%, so that there is an urgent need to reduce these losses, to protect the remaining resources and any future allocate resources.

Table 62: Water Demand and Supply Balance for Maan Governorate

Maan Gov.Demand_ Supply Balance (M^3)	2018	2020	2025	2030	2035	2040
Supply Requirement (BAU)	10,053,574	10,531,654	11,645,085	12,723,854	13,585,060	14,499,319
Supply Requirement _ (NRW Reduction)	10,053,574	10,286,720	10,789,544	11,265,574	11,563,925	11,926,163
Total Supply	14,539,621					
Production	15,671,049	11,021,790	4,777,246	2,755,238	1,483,450	906,395
Additional needed amount (BAU)	-5,617,475	-490,136	6,867,839	9,968,616	12,101,610	13,592,924
Additional needed amount_ (NRW Reduction)	-5,617,475	-735,070	6,012,298	8,510,336	10,080,475	11,019,768
Coverage of Required Demand (%)_(BAU)	156%	105%	41%	22%	11%	6%
Coverage of Required Demand (%)_(NRW Reduction)	156%	107%	44%	24%	13%	8%
Total Supply coverage (2018)	**145%**					

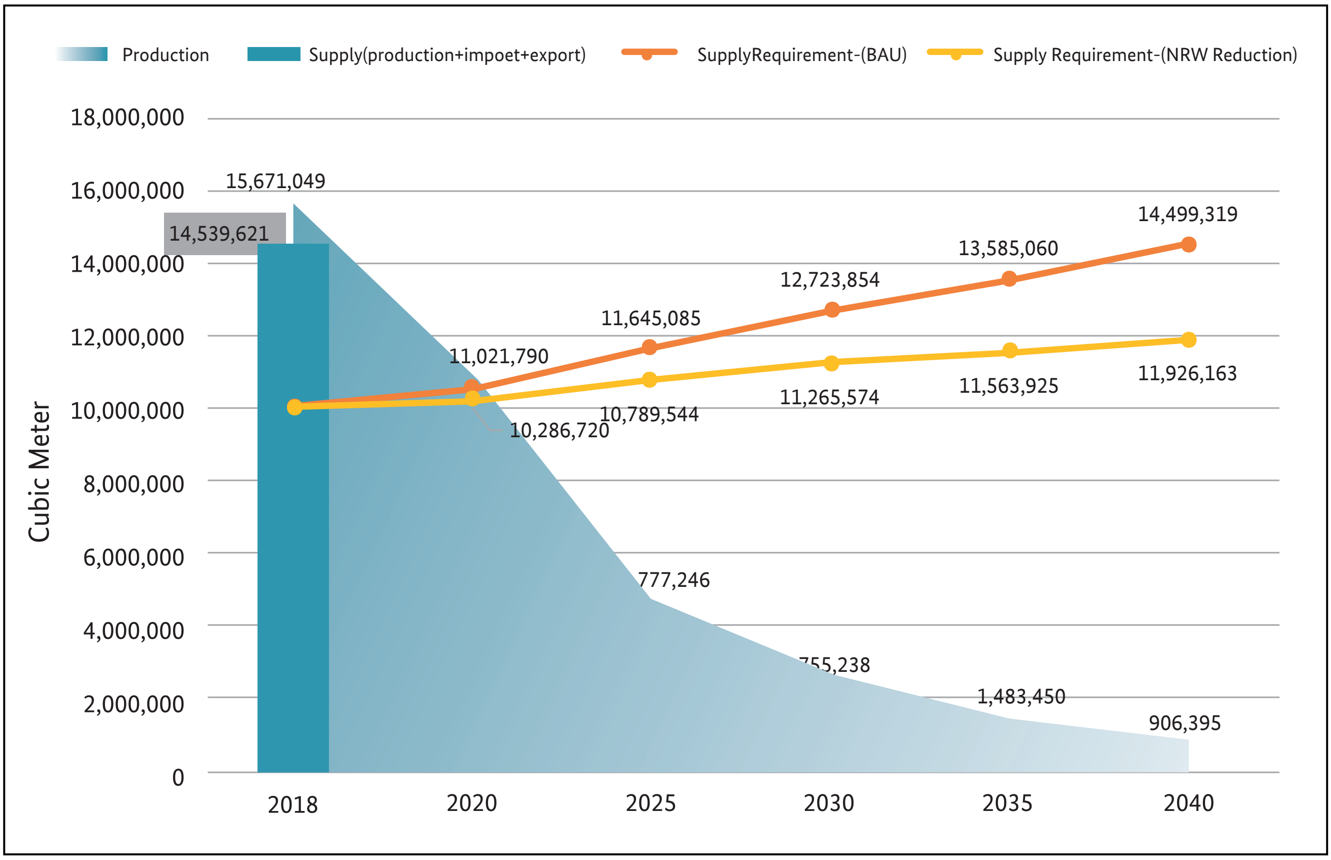


Figure 78: Water Demand and Supply Balance for Maan Governorate

Aqaba Governorate

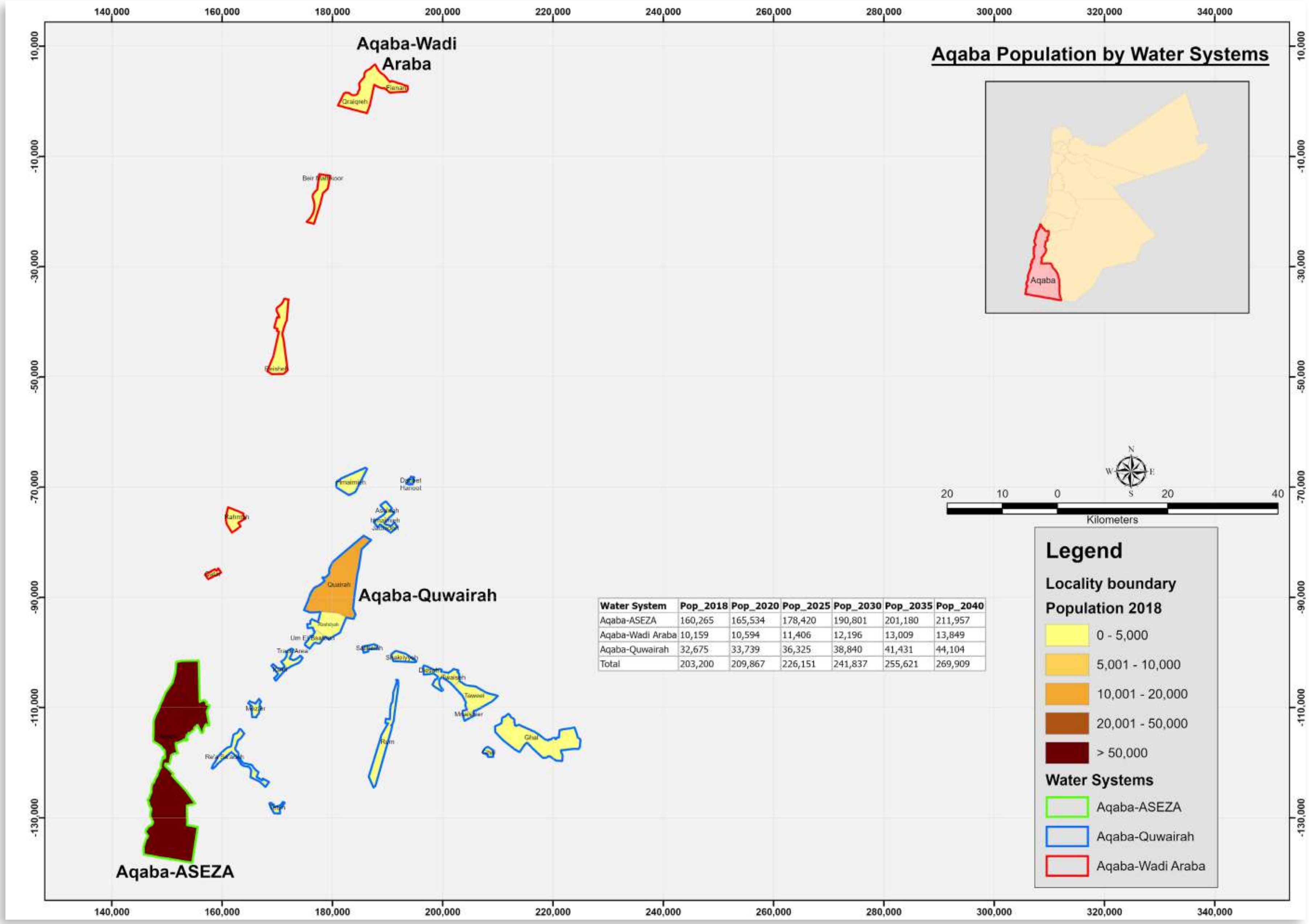
Population

Aqaba governorate is divided into 2 districts and 4 sub-districts with a total of 28 localities. Around 85% of the localities are categorized as urban. Figure 79 shows the distribution of localities in Aqaba and the boundary of the water systems serving designated localities. The estimated population was 203,200 capita in 2018. Syrians refugees estimated at 8,680 capita living in Aqaba presents 4% of the governorate population.

The population projection for Aqaba is presented in Table 63. By 2040, the projected population will increase by 33 %, reaching to 269,909.

Table 63: Population by Water System in Aqaba Governorate

Water System	2018	Urban (%)	2020	2025	2030	2035	2040
Aqaba_Main	160,265	100%	165,534	178,420	190,801	201,180	211,957
Aqaba_Quwaira	32,675	39%	33,739	36,325	38,840	41,431	44,104
Aqaba_WadiAraba	10,260	0	10,594	11,406	12,196	13,009	13,849
Total	**203,200**		**209,867**	**226,151**	**241,837**	**255,621**	**269,909**



Water System	Pop_2018	Pop_2020	Pop_2025	Pop_2030	Pop_2035	Pop_2040
Aqaba-ASEZA	160,265	165,534	178,420	190,801	201,180	211,957
Aqaba-Wadi Araba	10,159	10,594	11,406	12,196	13,009	13,849
Aqaba-Quwairah	32,675	33,739	36,325	38,840	41,431	44,104
Total	203,200	209,867	226,151	241,837	255,621	269,909

Figure 79: Aqaba Localities, Population and Water Systems

Water Allocation Gaps (Water Balance)

Supply requirement for Aqaba was estimated at 23.9 MCM in 2018, and is projected to increase by 33 %, reaching about 31.9 MCM in 2040. Estimated water demand and projected water production is presented in Table 64 and Figure 80.

For the municipal water systems, the total production of around 17.8 MCM in 2018 has satisfied 74% of the required supply for Aqaba. Additional 6.7 MCM has improved the demand coverage by 102 % through private resources (Desalination and Rum Farms). With the slight reduction of the water resources, the remaining production will decrease by 1% to 17.6 MCM, which will provide a coverage of 55% by 2040.

Table 64: Water Demand and Supply Balance for Aqaba

Aqaba Gov.Demand_ Supply Balance (M^3)	2018	2020	2025	2030	2035	2040
Supply Requirement (BAU)	23,946,931	24,800,542	26,652,609	28,501,380	30,117,351	31,879,910
Supply Requirement _ (NRW Reduction)	23,946,931	24,720,128	26,359,880	27,981,694	29,363,484	30,878,613
Total Supply	24,483,309					
Production	17,779,208	17,749,799	17,676,444	17,603,135	17,566,339	17,563,645
Additional needed amount (BAU)	6,167,723	7,050,743	8,976,165	10,898,245	12,551,012	14,316,265
Additional needed amount_ (NRW Reduction)	6,167,723	6,970,329	8,683,436	10,378,559	11,797,145	13,314,968
Coverage of Required Demand (%)_(BAU)	74%	72%	66%	62%	58%	55%
Coverage of Required Demand (%)_(NRW Reduction)	74%	72%	67%	63%	60%	57%
Total Supply coverage (2018)	**102%**					

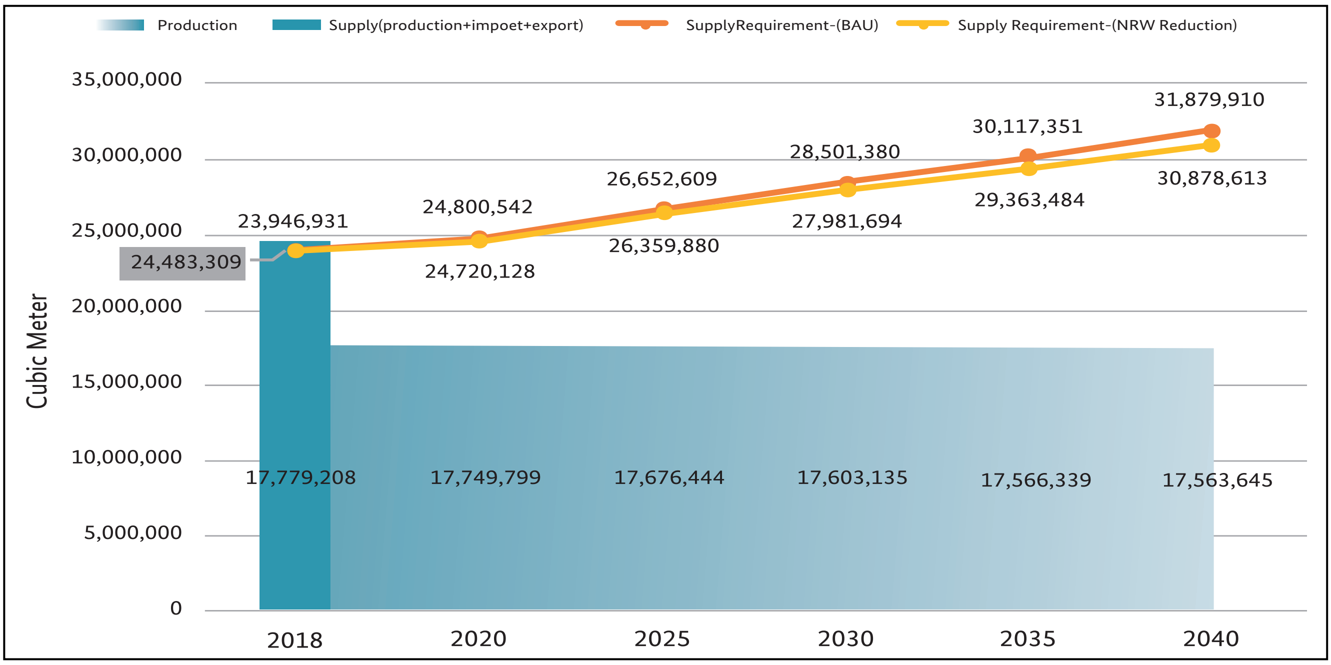


Figure 80: Water Demand and Supply Balance for Aqaba

5 WATER SUPPLY INFRASTRUCTURE

5.1 Governmental Water Infrastructure

5.1.1 Wellfields

5.1.1.1 Overview

Most public water supply is currently secured through 67 large wellfields (Figure 81), 43 of which exploit the A7/B2 aquifer. Many of these wellfields are decades old and have not had any major rehabilitation. The analysis of the status of 3 major wellfields in northern Jordan through the BGR project Improved Groundwater Resources Management (I-GWRM) between 2015-2018 revealed major operational problems and maintenance deficits, and is representative for the status of wellfields throughout the country:

- The corrugated steel casings most commonly used in exploitation wells are often highly corroded or broken. Sediments have accumulated at the bottom of the wells and never been removed (e.g. through airlifting), causing a reduction of the exploitable section.
  * recommendation: uPVC casings/screens could be installed in many cases.
  * recommendation: selection of material should be based on corrosivity of water.
- Corrosion of riser pipes has caused (often several) pumps to fall into wells (see below), thereby reducing the exploitable section even further.
- Well screens are mostly self-slotted by torching (4 slits per round, each 1 m long, leaving the next m blank). The open area of screens is therefore mostly only around 1%, i.e. much smaller than rock (or fracture) porosity. This causes high friction losses at entry into the well and thus low well efficiency (mostly around 50%), which in turn causes additional drawdown in the well and therefore energy losses of up to 20%. On average, this unnecessary additional energy loss constitutes around 5% of energy demand for pumping lift.
  * recommendation: increase open area of screens to at least 2%.
- Most of the pumps installed are not suitable for the given Q/H conditions, and any available pump is usually installed when damaged pumps are replaced. The average pump efficiency is therefore only 50%, while under optimal conditions this can reach more than 75%. This causes 50% of energy demand for water lifting to be lost.
- Static and operational water levels are mostly not measured. Therefore, pumps cannot be properly configured based on Q/H conditions.
  * recommendation: regularly measure water levels (SWL, DWL), determine optimal pump specifications, and replace pumps.
- Flows (yield) are often not measured. Electricity consumption is sometimes used as a proxy to estimate flow. Therefore, holes in riser pipes or pumps are not discovered in time.
  * recommendation: regularly measure yields and electricity consumption.

Corroded Riser Pipe in well Wadi Arab4

– Wells rarely tap the entire aquifer. Most wells were only drilled up to 50-100 m below current water levels, to save costs. Designs mostly do not allow for wells to be deepened at a later time. With current water level decline rates, replacement wells have to be drilled every few years. Instead of drilling at more favorable locations from a hydrogeological perspective, replacement wells are drilled at the same location.
 * recommendation: allow experienced hydrogeologists at MWI to develop well designs using the structure contour maps developed in 2017 (BGR I-GWRM project), rather than civil engineers.

A list of all wellfields in Jordan with related exploited aquifers is presented in ANNEX 2.

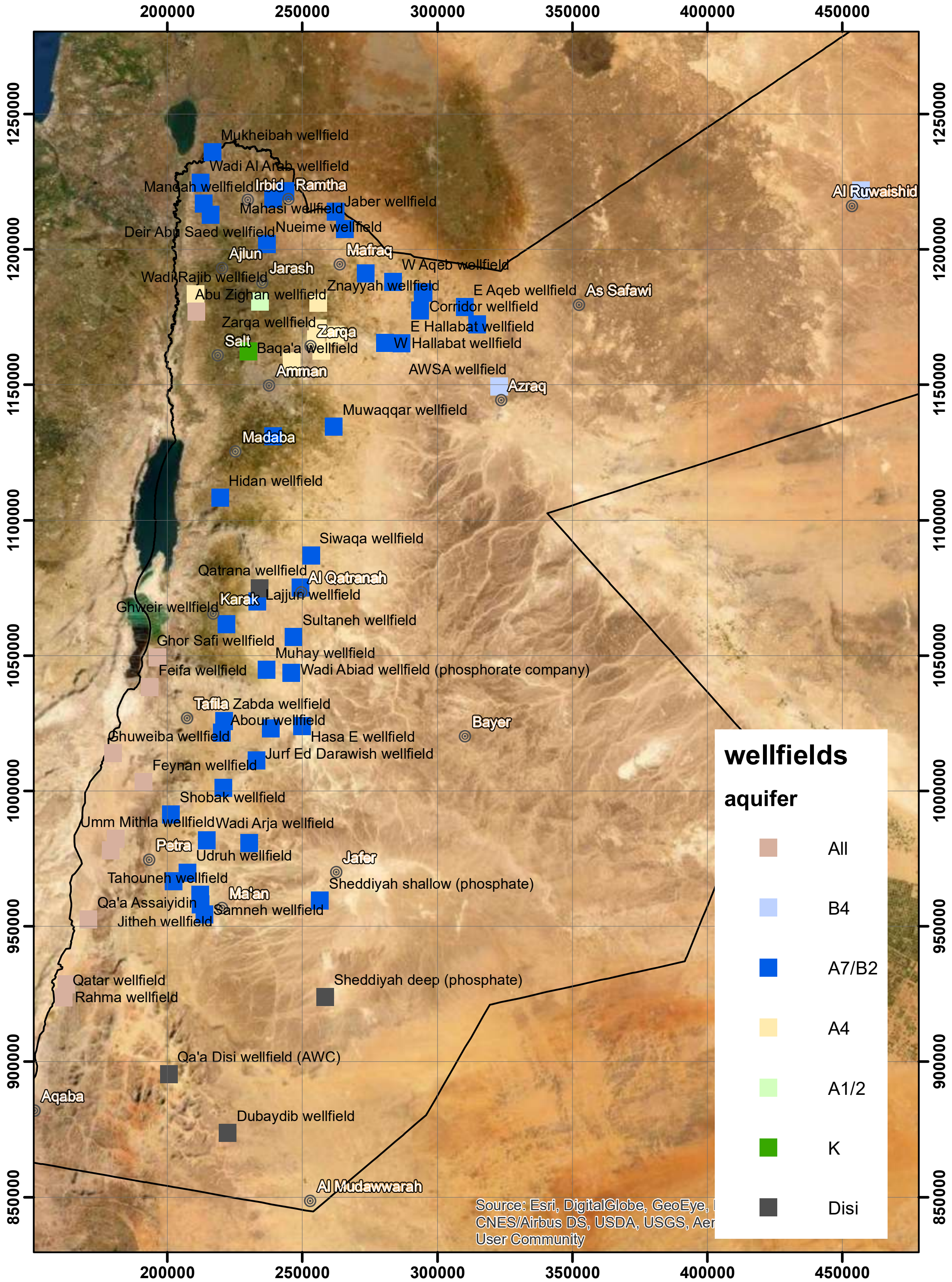


Figure 81: Wellfields for domestic water supply with exploited aquifer

5.1.1.2 Wellfield Management

Facts

A systematic wellfield management would improve water supply security and reduce costs. However, wellfield management has never been introduced in Jordan and there is no systematic monitoring that would allow the status of wells to be determined. Recently, SCADA systems were installed in some wells, however often without water level monitoring. In many cases SIM cards were removed after handover to the Water Utilities.

There is no systematic wellfield management that would include frequent static and dynamic water level measurements, production recording, and electricity consumption monitoring. More importantly, there are even no wellfield managers, responsible for operation and maintenance of wells. Lengths of riser pipes and even pump specifications are mostly unknown and there is no related database for all these data which would be up to date and could be used in case of failures. The corrosivity of water is not determined, so that casings riser pipes in many cases last only a few years. There are no maps showing which infrastructure is installed where and what is the status of wells. Due to all this, wells frequently fail and only then maintenance is done. This kind of management significantly contributes to the low water supply security.

The type of operational problems that are frequently encountered are (lessons-learnt from wellfield management component of I-GWRM project:

- Riser pipes corroded, in particular at pump > pumps and riser pipes fall into well (often several pumps are accumulated at the bottom of wells).
- Riser pipes have holes (mostly near the pump) > water is pumped without lifting water to the land surface.
- Pumps burnt because the dynamic water level reached pump (pumps switch on/off all the time).
- Pumps operate at efficiencies <50% due to wrong pump selection.
- Casings corroded and broken, wells collapse.
- Cables and control panels stolen.
- No 1-inch pipe for water level measurement installed or 1-inch pipe broken.
- No valve for water quality testing.
- Wellhead not properly covered and/or located and/or well base not high enough > flooding of well. Sediment accumulation > 10 m and thus reduced production > conduct airlifting/surging.

Actions required:

- Introduce systematic wellfield management with proactive maintenance measures; a related institutional capacity has to be created.
- Introduce managers for wellfields, responsible for planning and conducting all maintenance measures.
- Introduce professional maintenance of pumps.
- Measure water levels in every well at least once per year and report to MWI.
- Record production and energy consumption at each well and report energy consumption in kW/m³.
- Determine lengths of riser pipes and pump specifications for each well.
- Enter all data into an operations database > establish alert system (when to deepen wells, extend riser pipes, change pumps, close wells).
- Determine corrosivity for each well (every 5 years).

5.1.1.3 Optimal Yields of wellfields

Yield in most wellfields is severely declining due to overabstraction in competition with agriculture. The safe yield is exceeded in all wellfields. Under such conditions it is difficult to develop a target for optimal yield (the amount that can safely be abstracted without exceeding a set target level, e.g. of annual water level decline) that will eventually be respected by Water Authority and the Water Utilities. Also, the tools to determine optimal yields do not currently exist, as the groundwater model in its current state would not be useful for this purpose. Therefore, no proposal of optimal yield of wellfields has currently been developed. A production forecast is included in chapter 3.1.4.1.7.

5.1.1.4 Maintenance Requirements

There is no systematic preventive maintenance, except through donor funded projects. Maintenance of wells is only done when wells are not operational, but the previously produced amount is needed, and the problem can be solved through repair. Maintenance covers the following aspects:

- Replacing and/or repairing pumps
- Extending riser pipes
- Maintaining control rooms (panel) (frequent vandalism)
- Replacing cables (frequent vandalism)
- Maintaining SCADA systems
- Deepening wells
- Closing wells (backfilled/cemented)
- Fishing for lost pumps/riser pipes

WAJ is doing maintenance through the WAJ Workshop in Zarqa for all wells in: Karak, Tafilah, Maan, Balqa. They have 6 maintenance crews.

Yarmouk Water Company (YWC) has the highest number of domestic water supply wells (~240) and is thus covering the highest costs for wells maintenance. However, there is no dedicated budget for maintenance. YWC does all maintenance through sub-contractors.

In 2018, Miyahuna only had 44 wells and 3 springs in operation. These are maintained by WAJ Workshop, through a service agreement.

Two large KfW financed projects, focusing on maintenance, were implemented between 2013 and 2018 to maintain wells, mainly in the North (YWC). Based on these, MARGANE (2018) had proposed a modified concept for wells rehabilitation (summarized in ANNEX 8). The main lessons learnt are:

- Better feasibility studies are required, taking into account hydrogeological aspects and actual well conditions (which wells can successfully be rehabilitated ?).
- The main criteria used to justify rehabilitation must be future water resources availability and water quality (> 20 m^3/h, pumping lift < 350 m, no water quality problems until 7 years after rehabilitation).
- Energy efficiency is not equal to pump efficiency (well efficiency not considered).
- Replacement wells at the same site are mostly problematic.
- Better coordination is needed between the MWI, WAJ, and Water Utilities.
- Better data exchange and more frequent meetings between all parties are needed (WUs were not

adequately involved, but they will be the ultimate beneficiary.

- Technical concepts must be improved (acquisition of SWL/DWL data in the beginning; 5-step step tests).
- Monitoring and reporting of rehabilitation success.

5.1.1.5 Costs of Groundwater Abstraction

There is no systematic monitoring of capital, operational and maintenance costs for wells; thus, production costs are unknown. As wells are often drilled through projects and then handed over to the Water Utilities, such costs are not considered by either the projects or the Water Utilities.

Water Utilities have no dedicated maintenance budget and thus maintenance is only done when wells fail to operate.

Currently average groundwater abstraction requires approx. 1.4 kW/m³. Due to water level decline this will increase to an average of approx. 2 kW/m³, about 40% more than currently.

Actions required:

- Establish a database at Water Utility level for monitoring the costs of
  - well maintenance
  - water abstraction (energy consumption per m³ water production)

5.1.2 Dams

Jordan is using all of the available surface water through dams. Apart from the last Water Master Plan (MWI & GIZ, 2004), there is unfortunately no recent document available summarizing the facts about dams. Therefore, the NWMP-3 aims to establish factsheets for dams, which give an overview on the existing infrastructure and their contribution to water supply. Apart from technical facts like commissioning date, capital and operational cost, use it will also give the main operational data, like the annual production over the past 10 years, the status (leakage, siltation, operational problems, last maintenance, required maintenance, and geo-risks and water quality concerns (sulfate content, algae bloom, reduced conditions, etc.). Most of dams are used for the irrigation and domestic demand. Some of the dams are used for the groundwater recharge.

Many components of flow are only estimated or cannot be measured correctly due to lack of equipment. The current volume in the reservoir is computed mainly from the water-level-storage relation. Based on the changes of the water level storage between current and previous day, the inflow is computed using the balance method, including evaporation (if assessed), seepage (if assessed) and outflow (mostly only measured through inaccurate flow measurements by propeller in undefined segments). The missing measured inflow influences the efficient operation in some dams; annual flood events are not fully retained because of relatively high remaining water level in reservoirs at the beginning of the winter seasons. Consequently, part of the flood event volume flows over the emergency spillway and cannot be used (almost every year at Mujib dam). This means that **the stored volume can sometimes not be used efficiently in the summer season.**

Considering the water level, outflow and inflow in Figure 82, the frequent overflow through the spillway of Mujib Dam can be recognized. The minimum water level of 170 m asl can also be seen in Figure 82. Below this level, the storage of 5 MCM is most likely silted up and cannot be used anymore to store water, as can be seen in the water level – storage curve depicted in Figure 83. It can be expected that the storage will continue to be filled up with silt and to further lose its operational capacity.

The annual (assessed) inflow and outflow of Mujib Dam are depicted in Figure 84. A very high variation of inflow was identified over the period under consideration (2003-2018), between 2.5 MCM in dry years and 35 MCM in wet years. The variation of outflow is between 2.5 and 25 MCM per year, respectively. Both variables reveal significant increasing trends. It is uncertain whether this trend is a true reflection of the natural hydro-meteorological conditions or is caused by uncertain measured and evaluated data. An average year (2008-2018) in monthly interval is depicted in Figure 85. It is a crucial characteristic of all dams, coupled with the inflow and outflow distribution over the average year.

Measurements of all components of inflow and outflow should be improved. JVA is lacking adequate equipment for this purpose (ultrasonic flowmeters; hydraulic profiles for inflow/outflow; evaporation measurements).

Siltation has been measured by different means. However, **it is strongly recommended to quantify the loss of storage of all reservoirs due to siltation annually.**

5.1.2.1 Storage Dams

Currently there are 14 large dams used for storage and partly for recharge, shown in Figure 86 with related storage capacity. While total capacity is nominally around 336 MCM, loss in storage capacity through siltation is not measured comprehensively. GIZ will assist JVA on related measurements. The theoretical amount produced is shown in Table 65. The experience of the Wadi Mujib dam (MARGANE, 2008) shows that this loss can be significant. Moreover, as built volume models are also not always available, except in the form of related tables, i.e. loss cannot easily be quantified. It is assumed that storage loss is around 20% or around 70 MCM, which means that current actual storage capacity may be only around 260 MCM.

It is even more difficult to monitor the flow and water balance components. These are:

- Inflow (measured only at 5 dams: Kafrein, Shuayb, Wahdeh, Kufrinjah, King Talal; monthly) > GIZ will assist JVA in the assessment where additional stations are needed
- Outflow (only in Wehdah dam measured through ultrasonic flowmeter; some dams have propeller measurements but no dedicated sections; measured in other dams through portable ultrasonic flowmeters) > additional ultrasonic flowmeters are needed
- Evaporation (some major dams have climate stations; 6 new class A pans have been purchased) > GIZ will assist JVA in the assessment where additional stations are needed
- Seepage through dams (not determined in all dams; tunnels in: Wahdeh, Mujib, Talal, Kufrinjah, W. Arab, Tannour, Karak, Wala)
- Seepage through side flow in adjacent geological units (not measured in any dam)
- Seepage through underflow in underlying geological units (not measured in any dam)
- Direct abstraction from dams, either for irrigation (illegal) or domestic water supply (only rough estimations at Mujib dam)

Table 65: Total Initial Storage Capacity and Outflow of Dams

Dam	Capacity (MCM)	Outflow 2012	Outflow 2013	Outflow 2014	Outflow 2015	Outflow 2016	Outflow 2017	Outflow 2018	Outflow 2019
Wahdeh (Unity)	110	20.9	44.8	46.9	58.9	84.5	93.7	80.4	45.3
Wadi Arab	16.8	12.4	16.0	14.5	14.6	13.0	11.3	10.0	9.0
Wadi Ziqlab (Sharhabil)	4	1.8	3.8	1.8	1.9	1.1	0.6	0.8	0.6
Kufrinjah	7.8	0	0	0	0	0	1.2	1.2	7.6
King Talal**	75	114	115.5	123	133.6	132.4	141.8	130.0	120.2
Wadi Shuayb	1.7	6.2	7.6	6.2	9	7	7.3	7.3	9.8
Karameh	55	9.4	1.2	1.1	1.2	1.4	6.2	0.8	1.5
Kafrein	8.5	9.9	11.9	10.1	14.1	12.2	10.9	9.9	13.6
Mujib**	29.8	11.6	14.4	11.1	16.9	23.3	20.7	22.7	20.6
Wala	8.2	4.7	17.4	13.6	14.6	7.2	6.3	9.2	19.4
Tannour	14.7	5.8	5.1	5.5	7.5	7.7	5.9	6.8	3.2
Zarqa Main*	2.0								
Lajjun*	1.0								
Karak*	2.0								
Total	**336.5**	**196.7**	**237.7**	**233.8**	**272.3**	**289.8**	**305.9**	**279.1**	**250.1**

*) groundwater recharge dam

**) storage capacity changed in 2017 after siltation measurements

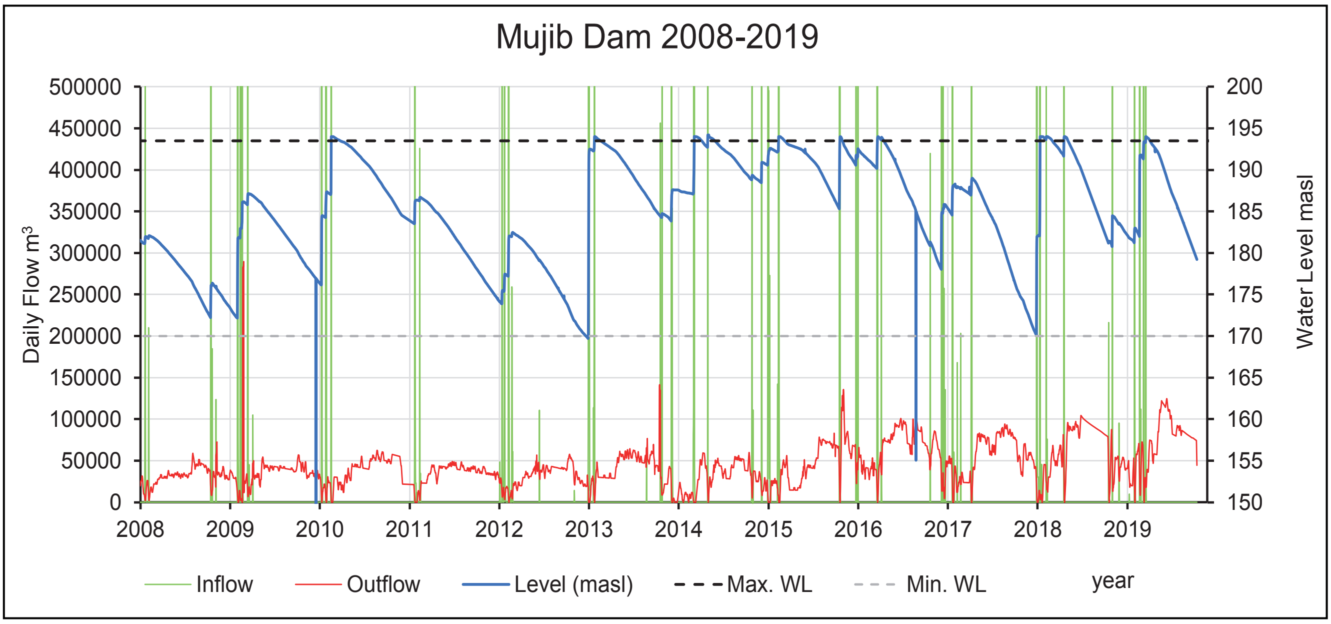


Figure 82: Water Level, Inflow and Outflow of Mujib Dam in Daily Time Steps 2008-2019. incl. Minimum and Maximum used Operational Water Level

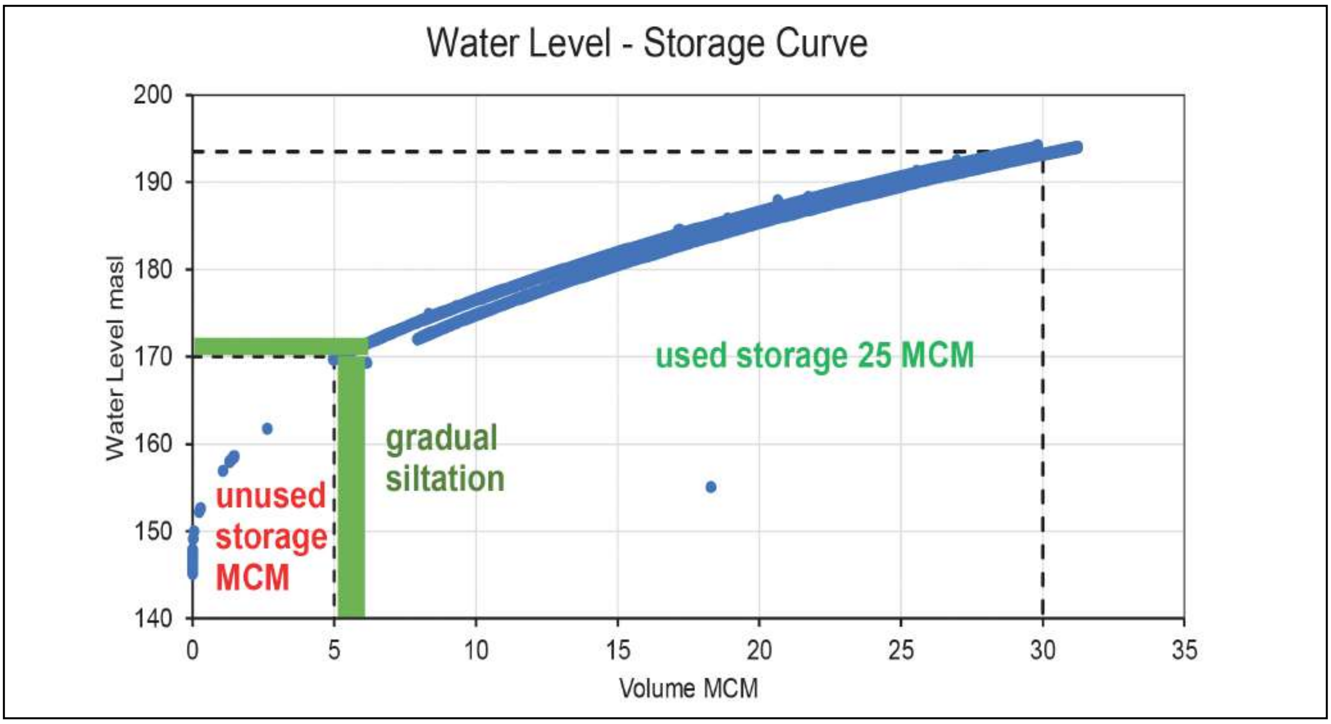


Figure 83: Water Level – Storage Curve of Mujib Dam based on Daily Data 2003-2019

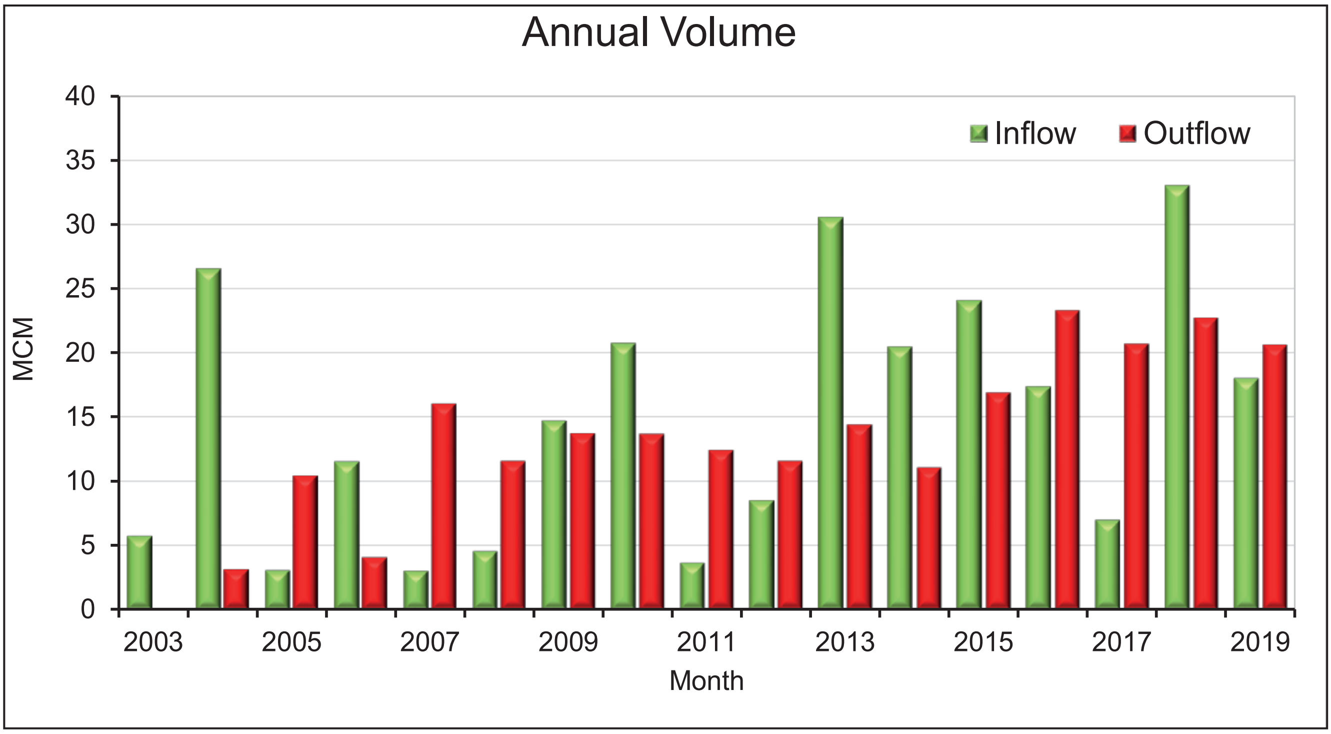


Figure 84: Annual Inflow and Outflow of Mujib Dam

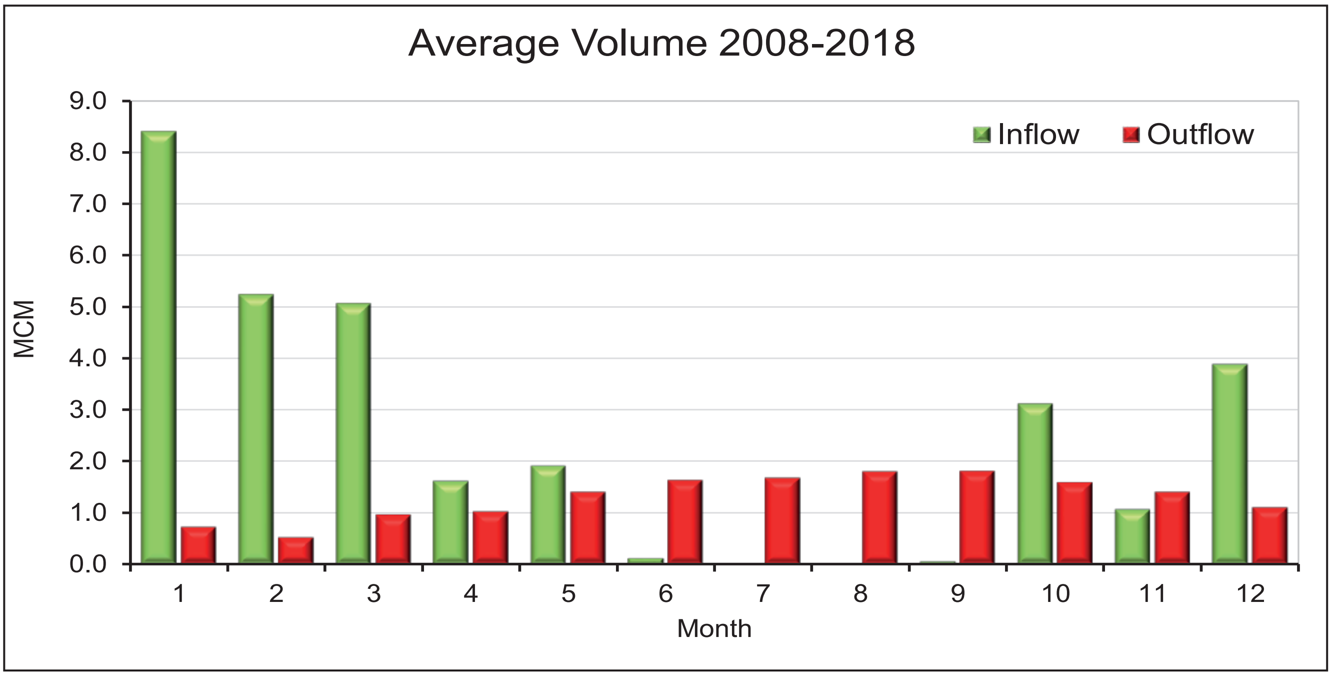


Figure 85: Average Monthly Inflow and Outflow of Mujib Dam

5.1.2.2 Recharge Dams

Many recharge dams are classified by JVA as desert dams, and are therefore contained in Figure 87. Some dams listed under storage dams are actually recharge dams (Shuayb, Zarqa Main, Lajjun, Karak).

Dams with recharge function are listed in the related Chapter on Managed Aquifer Recharge (3.1.5).

5.1.2.3 Flood Protection Dams

One effect of climate change will be an increased number of extreme rainfall events which will increase the risk of flooding, for example in densely built up low-lying areas with a lack of sufficiently dimensioned stormwater drainage such as downtown Amman, or the Petra archaeological site. There are no dedicated flood protection dams or stormwater retention structures in place yet. Related measures are currently under investigation through SDC.

5.1.2.4 Desert Dams

Some 64 dams are classified as desert dams (Figure 87). Most of them are on average 10 m high and were built as earthfill dams. They are mostly used exclusively for livestock ranging, but sometimes also for irrigation. While total storage capacity is around 97 MCM, many receive little or irregular water. The highest storage capacity (65% of total) is in the area around Ruwaished.

Desert Dam at Jawa – Early Bronze Age Settlement

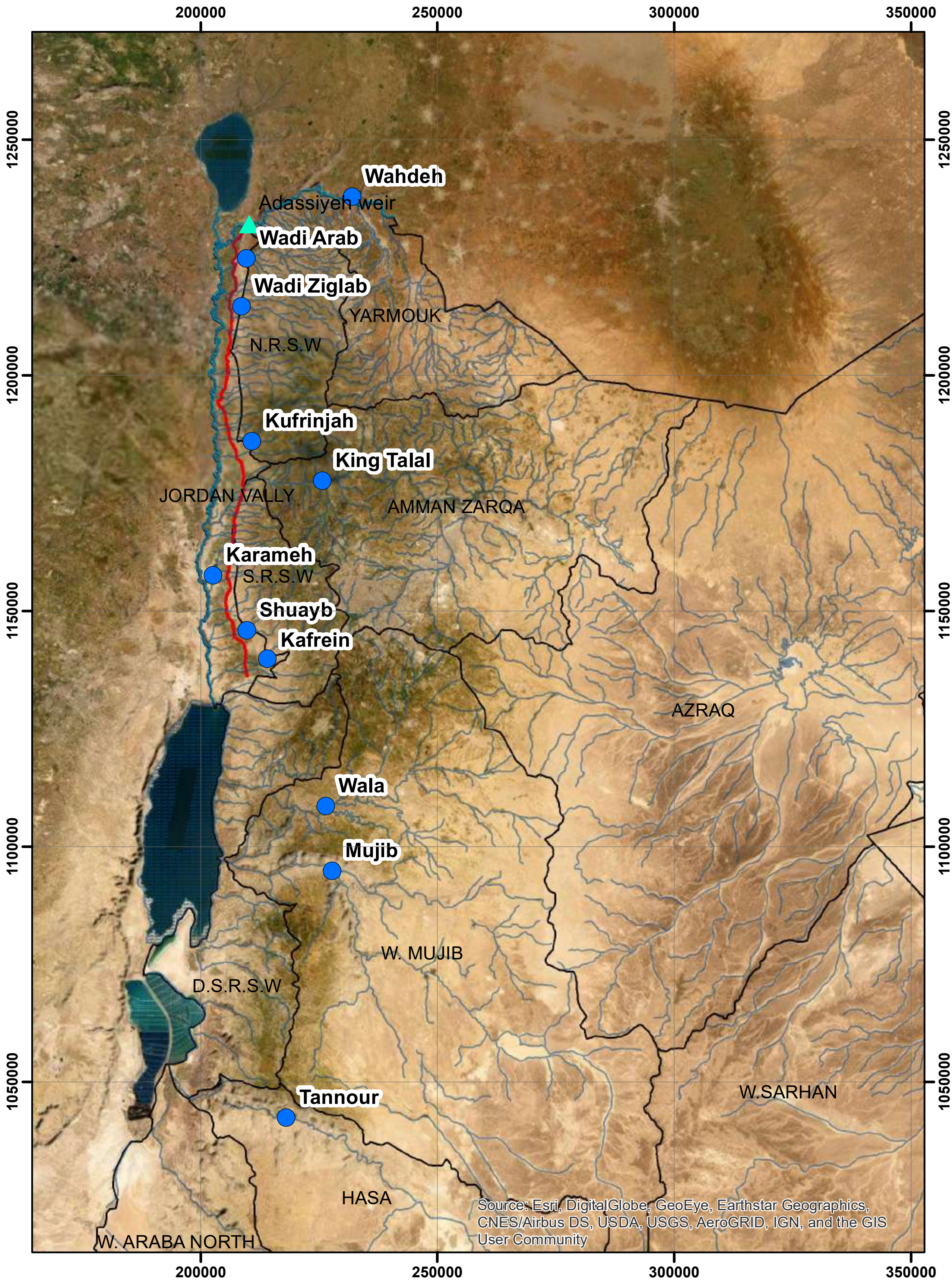


Figure 86: Main Storage Dams

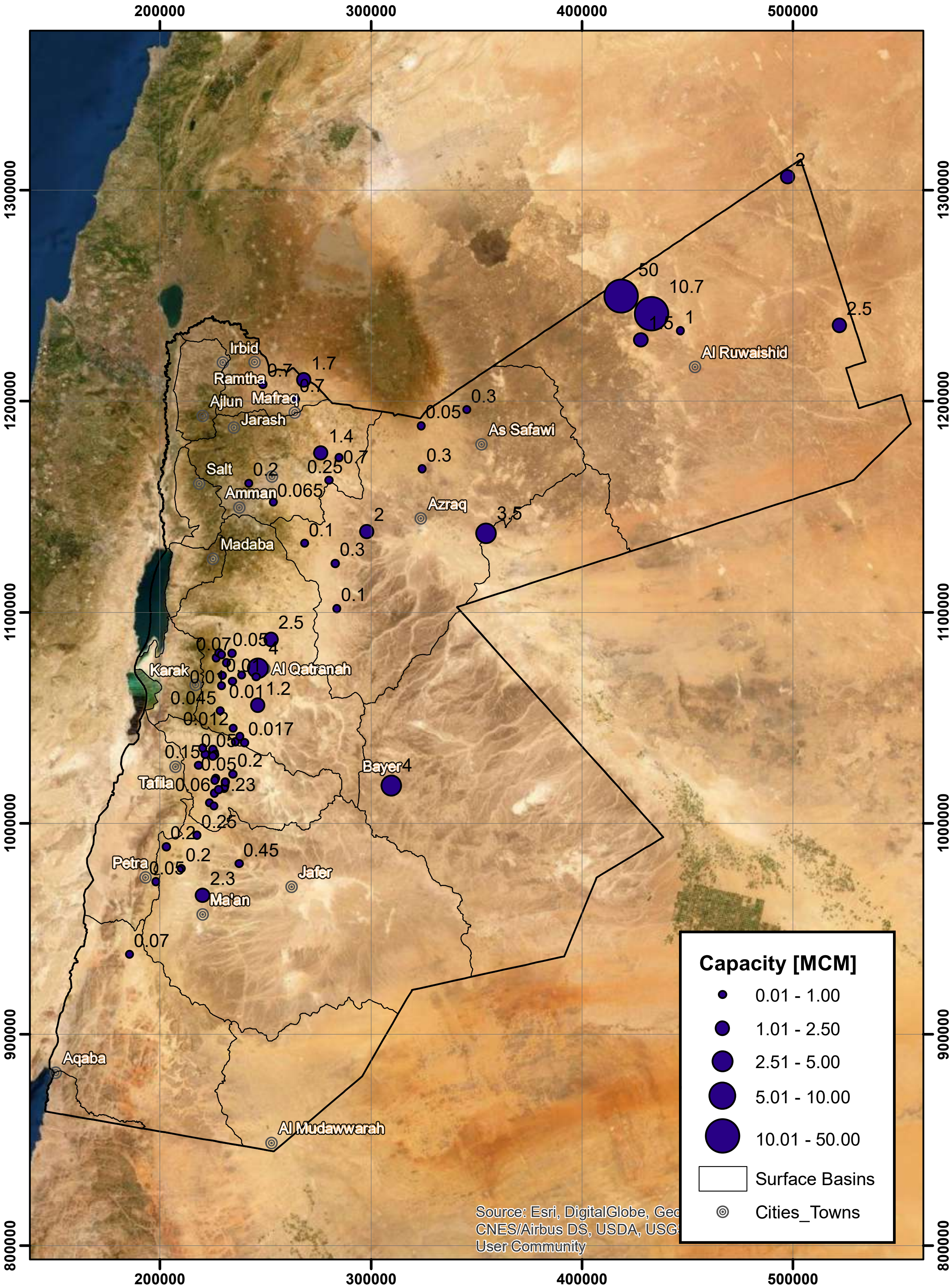


Figure 87: Locations and Capacities of Desert Dams

King Abdullah Canal Sediment Removal

5.1.3 King Abdullah Canal (KAC)

An overview with the related conveyance network and development areas is presented in ANNEX 4. There is no adequate documentation on where and how much treated wastewater is used, and how and where it is mixed. It is difficult to obtain correct numbers on operational data (annual production), as much of the flow is not measured but only estimated. The status of the KAC is summarized in TETRA TECH (2018), which analyzed the losses and reported on leakage, sediment accumulation, operational problems, and required maintenance. However, even in this document there is no good presentation on the monitoring stations, the siphons and bridges, and the water used in agriculture from the canal.

The water allocation committee (JVA, Miyahuna) meets once a year in springtime to agree on global amounts to be allocated to water supply of Amman and to the farmers in the Jordan Valley. Implementation of this allocation plan is organized from the Control Center in Deir Allah in coordination with the Stage Offices. Farmers request irrigation water based on the size of their plot of land and the crops grown. The control center decides on this request and staff from the stage offices opens the gates at the farm units based on the agreed schedule. This flow is commonly not metered but estimated, and bills are issued based on these estimated amounts.

In many cases, flows from side wadis in the Jordan Valley and South Ghor contribute to irrigation (see ANNEX 4). However, most of the related gauging stations are not operational and/or are often only measured manually (monthly) by JVA staff. Therefore, the flow amounts reported by the JVA are generally only rough estimations.

The KAC suffers severely from contamination (MARGANE & SUNNA, 2006) and contamination events occur frequently, which puts domestic use at risk. Conveyance through a closed pipe would therefore lead to better protection and reduce costs for maintenance (repair of damaged concrete slabs, mud removal).

5.1.4 Current Water Supply of Main Demand Centers

5.1.4.1 Water Supply of Irbid

Water Systems

Irbid governorate is served by five water systems according to its resources and distribution networks. Irbid's water supply is managed by Yarmouk company, which is the responsible company for water management and distribution for the northern governorates (Irbid, Mafraq, Ajloun, and Jarash).

The five water systems serving Irbid governorate are:

- → Irbid main water system: serving the districts Qasabet Irbid, Wastiyyah, Tayybeh, Mazar Shamali, Bani Obaid and one locality from Koura district (Khirbet El-Hawi).
- → Irbid- Kinana water system: serving Bani Kinana district, and one locality from Irbid district (Kufr Jayez).
- → Irbid-Koura water system: serving Koura district.
- → Irbid-Ramtha water system: serving Ramtha district.
- → Irbid-Shouna water system: serving North Shouna district and two localities from Bani Kinana district (Mukheibeh El-Tehta and Hemah Aurdinyah (Mukheibeh El-Foaqa).

For each of the above water systems the available water facilities as detailed in the table below:

Water System	No. of Pumping Stations	No. of Reservoirs	Desalination/ Treatment
Irbid Main	22	5	1
Irbid-Kinana	4	2	0
Irbid-Koura	7	1	0
Irbid-Ramtha	5	4	0
Irbid-Shouna	5	8	2

Production

In 2018, The total internal water production for Irbid was 46,389,473 m3. These quantities were produced from the following sources according to WAJ official 2018 production and supply figures:

Source	Amount (MCM)	Received at	Distributed to
Wadi Al Arab (18 wells)	16.592312	Wadi Al Arab PSs	Irbid Main water system
Hakama (6 wells)	1.799327	Hakama PS and Bushra PS	Irbid Main water system
Na'ymeh (6 wells)	1.490599	Na'ymeh PSs	Irbid Main water system
Mandah (4 wells)	2.028812	Mandah PSs	Irbid Main water system
Tabqet Fahl-Irbid (4 wells)	3.654470	Wadi Al Arab PS0	Irbid Main water system
Juhfiyya (2 wells)	1.781190	Mandah PSs	Irbid Main water system
Kufr Assad-Irbid (2 wells)	0.445782	Kufr Assad PS1	Irbid Main water system
Al Manshyah Well	0.116924	Network	Irbid Main water system
Al Tayybeh well	0.075964	Network	Irbid Main water system
As'ara well	0.116740	As'ara PS	Irbid Main water system
Dougara well	0.311551	Dougara PS	Irbid Main water system
Fo'ara well	0.066814	Fo'ara PS	Irbid Main water system
Kufr Youba well	0.211739	Kufr Youba PS	Irbid Main water system
Rahoub Spring	0.176564	Rahoub PS	Irbid Main water system
Tuqbul well	0.145922	Fo'ara PS	Irbid Main water system
Kufr Assad-Kinana (5 wells)	2.331472	Kufr Asad PS6	Irbid-Kinana water system
Harima (4 wells)	1.270765	Harima PS	Irbid-Kinana water system
Quilba well	0.478689	Quilba PS	Irbid-Kinana water system
Oyoun Al Hammam (5 wells)	2.626920	Oyoun Al Hammam PS	Irbid-Koura water system
Jdaita (3 wells)	1.440835	Jdaita PS	Irbid-Koura water system
Beit Eidis well	0.365265	Jdaita PS	Irbid-Koura water system
Jaber (6 wells)	1.686413	Jaber PS	Irbid-Ramtha water system
Abu Al Basal (3 wells)	0.649387	Abu Al Basal PS	Irbid-Ramtha water system
As Sleikhat (5 wells)	1.039669	Al Mkeemnat PS	Irbid-Shouna water system
Al Kraymeh (4 wells)	1.278305	Al Kraymeh PS	Irbid-Shouna water system
Tabqet Fahl-Shouna (3 wells)	1.710305	Tabqet Fahl PS	Irbid-Shouna water system
Al Mukheibeh well	0.999909	Al Mukhaiba PS	Irbid-Shouna water system
Wadi Al Arab Well 6	1.496829	Mouath Res	Irbid-Shouna water system
Total	**46.389473**		

Export & Import

Irbid water Imported the amount of 11,663,097m3 from Mafraq water in 2018 to increase the supply for some areas.

Furthermore, in 2018 Irbid water exchanged quantities of water with other governorates as detailed in the below tables:

Export to	Quantity m^3
Ajloun (from Samad PS)	2,386,945
Jarash (from Samad PS)	1,665,480
Total Exported	**4,052,425**

Supply

Irbid water also provided in 2018 233,045 m^3 for irrigation, these quantities provided are half the production of the wells (AB3007 Sbeireh well and AG3008 Tabqet Fahl well 1).

The total domestic supply quantity for Irbid governorate according to 2018 official figures for production, export & import was 53,767,101 m^3.

Total Supply = (46,389,473 + 11,663,097) – 4,052,425 – 233,045 = **53,767,101 m^3**

The map in Figure 88 shows an overview of Irbid water supply systems.

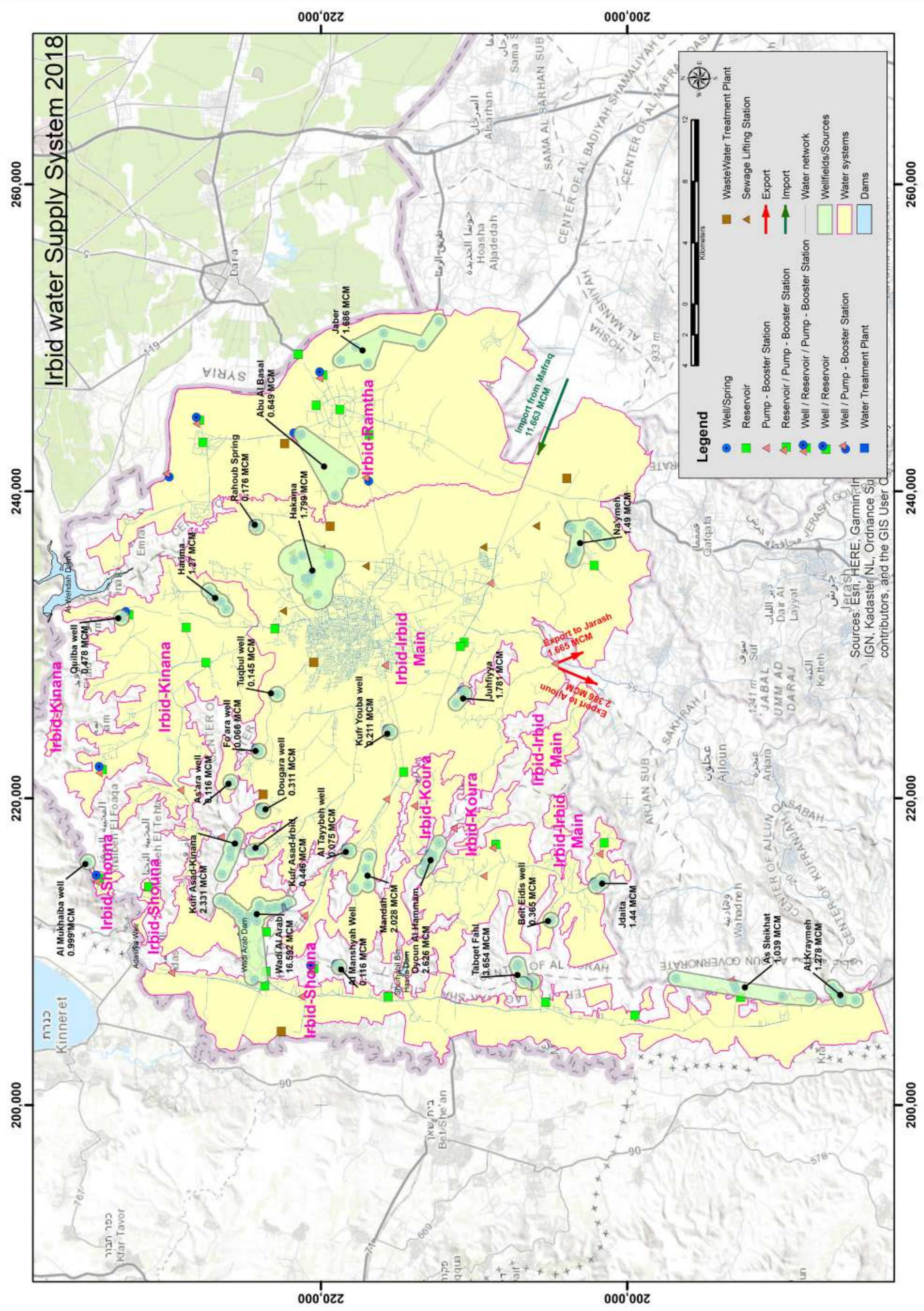


Figure 88: Water Supply Systems of Irbid Governorate

5.1.4.2 Water Supply of Mafraq

Water Systems

Mafraq governorate is served by four water systems according to its resources and distribution networks. Mafraq's water supply is managed by Yarmouk company which is the responsible company for water management and distribution for the northern governorates (Irbid, Mafraq, Ajloun, and Jarash).

The four water systems serving Mafraq governorate are:

- → Mafraq main water system: serving the Qasabet Al-Mafraq district, Badiah Shamaliyyeh Gharbiyyeh district except Khaldiyah sub-district, and 3 localities from Badiah Shamaliyyeh district.
- → Mafraq-Badia: water system serving Badiah Shamaliyyeh district
- → Mafraq-Khaldiyah water system: serving Khaldiyah sub-district from Badiah Shamaliyyeh Gharbiyyeh district
- → Mafraq-Al Ruwaished water system: serving Al Ruwaished district.

For each of the above water systems the available water facilities as detailed in the table below:

Water System	No. of Pumping Stations	No. of Reservoirs	Desalination/ Treatment
Mafraq main	19	13	1
Mafraq-Badia	20	4	1
Mafraq-Khaldiyah	3	0	0
Mafraq-Al Ruwaished	6	1	0

Production

In 2018, the total internal water production for Mafraq was 34,557,255 m^3. These quantities were produced from the following sources according to WAJ official 2018 production and supply figures:

Source	Amount (MCM)	Received at	Distributed to
Aqeb-Mafraq (35 wells)	15.403275	Za'atari WTP	Mafraq Main water system
Coridor-Mafraq (8 wells)	2.802391	Zumleh Res	Mafraq Main water system
Znaya (6 wells)	1.452155	Znaya PS	Mafraq Main water system
Sumaya (4 wells)	1.121938	Sumaya PS2	Mafraq Main water system
Jaber-Hudud (4 wells)	0.909929	Jaber PS	Mafraq Main water system
Za'atari (4 wells)	0.623642	Za'atari WTP	Mafraq Main water system
AL Kum Al Ahmer (2 wells)	0.418255	AL Kum Al Ahmer PS	Mafraq Main water system
Baej (2 wells)	0.603008	Baej PS	Mafraq Main water system
Muogaer sarhan (2 wells)	0.418302	Sumaya PS2	Mafraq Main water system
Suwelmeh (2 wells)	0.161745	Suwelmeh PS	Mafraq Main water system
Um Es Sarb (2 wells)	0.321498	Um Es Sarb PS	Mafraq Main water system
Daba`an Well	0.040491	Daba`an PS	Mafraq Main water system
Daqmaseh Well	0.055508	Daqmaseh PS	Mafraq Main water system
Harfusheh Well	0.304849	Network	Mafraq Main water system
Hosha Well	0.101462	Hosha PS	Mafraq Main water system
Qnayyah Deep Well	0.912094	Qnayyah PS	Mafraq Main water system
Thaghret Al Jub Well	0.041573	Network	Mafraq Main water system
AL Zubaideyeh Well	0.233134	AL Zubaideyeh PS	Mafraq Main water system
Economic zone (6 wells)	3.233765	Zumleh Res	Mafraq-Badia water system
Aqeb-Badia (4 wells)	1.177722	Zumleh Res	Mafraq-Badia water system
Mukefteh (3 wells)	0.750806	Mukefteh PS	Mafraq-Badia water system
Sabha (2 wells)	0.585796	Sabha PS	Mafraq-Badia water system
Abu Alfarth Well	0.252697	Abu Alfarth PS	Mafraq-Badia water system
Abu Qardi Well	0.003434	Abu Qardi PS	Mafraq-Badia water system
Al Faisaliyeh Well	0.080706	Al Faisaliyeh PS	Mafraq-Badia water system
Al Rafayyat Well	0.141810	Al Rafayyat PS	Mafraq-Badia water system
AlBustaneh Well	0.081443	AlBustaneh PS	Mafraq-Badia water system
Amra Wa Umaira Well	0.346880	Amra PS	Mafraq-Badia water system
Dafyaneh Well	0.084526	Dafyaneh PS	Mafraq-Badia water system
Jubbiyeh Well	0.240193	Jubbiyeh PS	Mafraq-Badia water system
Khaldiyeh Well	0.205567	Khaldiyeh PS	Mafraq-Khaldiyah water system
Al-Mofradat Well	0.089180	Khaldiyeh PS	Mafraq-Khaldiyah water system
Al Ruwaished	1.215757	AlRuwaished PS	Mafraq-AlRuwaished
Total	**34.557255**		

Export & Import

Mafraq imported the amount of 3,418,934 m^3 in 2018 to increase the supply for some areas. Furthermore, in 2018 Mafraq water exported the amount of 13,495,835 m^3 to other neighboring governorates.

Export and import quantities in Mafraq are detailed in the below tables:

Import from	Quantity m^3
Zarqa (from Qnayyah spring)	525,600
Zarqa (to Khaldiyah water system)	1,371,554
Zarqa private wells (to Khaldiyah water system)	188,270
Amman-DISI	1,333,510
Total Imported	**3,418,934**

Also, Mafraq water imported 4,560,692 m^3 from the local private wells inside the different water systems areas.

Export to	Quantity m^3
Irbid	11,663,097
Jarash	920,644
Zarqa (to Qnayyah)	912,094
Total Exported	**13,495,835**

Supply

For the other uses, the amount of 387,371 m^3 was used for irrigation, livestock, and filters washout in Mafraq in 2018. The total domestic supply quantity for Mafraq governorate according to 2018 official figures for production, export & import was 28,653,675 m^3.

Total Supply = (34,557,255 + 4,560,692 + 3,418,934) – 13,495,835– 387,371 = **28,653,675 m^3**

Syrian Refugee Camps

Mafraq governorate contains the biggest refugee camp for the Syrians affected by the Syrian crisis. Which is in Zaatari district and it is named Zaatari Refugee Camp. and according to DOS estimations in 2018, about 78,527 people are living in this camp.

Refugees camps are supplied by private wells, not through municipal water systems. Water demand estimation, based on 35 l/c/d, was around 0.6 MCM in 2018, and is subjected to a slight decrease to around 0.5 MCM by 2040 as a result of the anticipated return of Syrians.

The wells that supply water to Zaatari camp are:

ID	Name	Total production in 2018
AL4068	UNICEF/Zaatari 1	405,815
AL4067	UNICEF/Zaatari 2	311,348
F 4384	UNICEF/Zaatari 3	212,520
Total		**929,683**

The map in Figure 89 shows an overview of Irbid water supply systems.

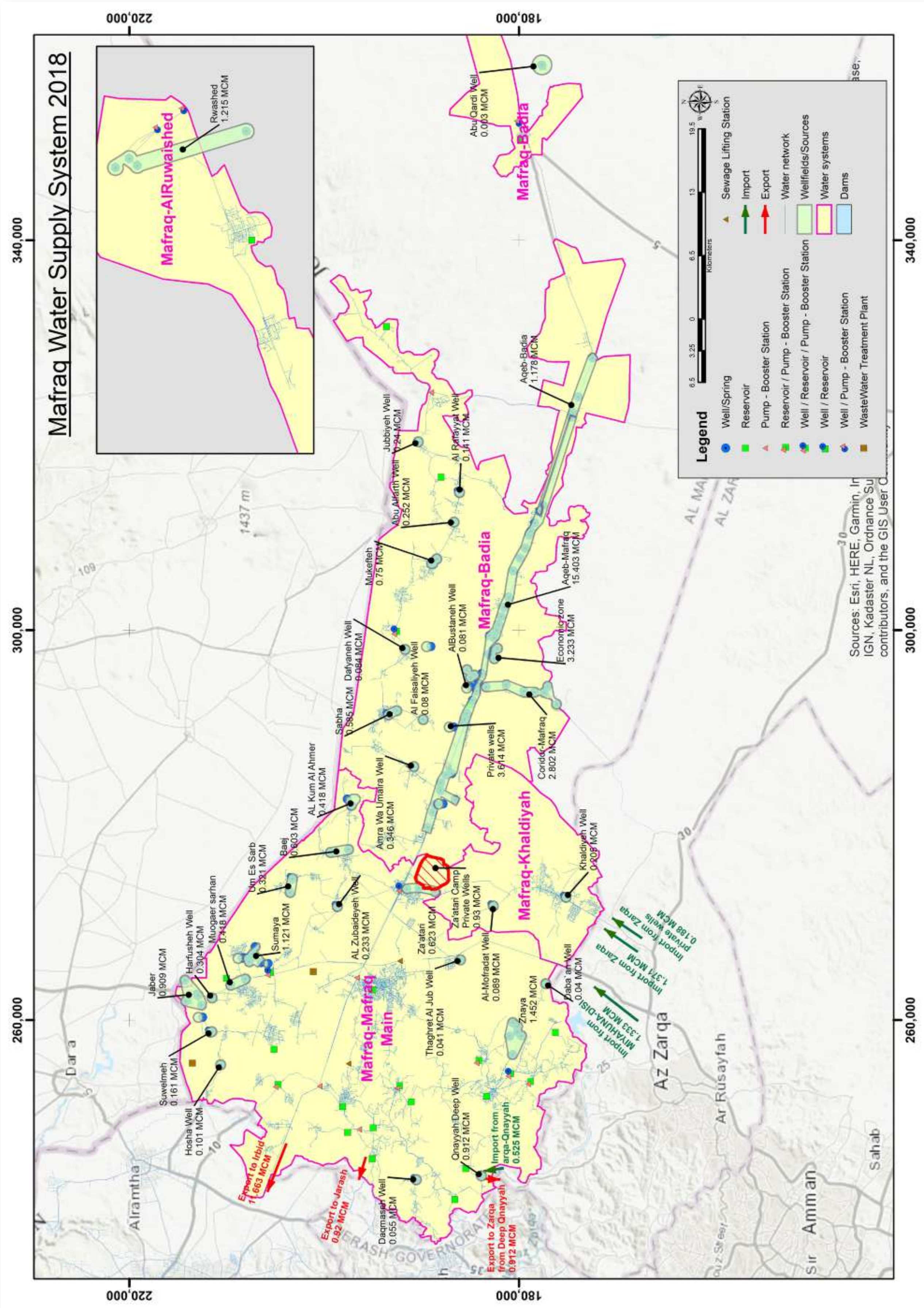


Figure 89: Water Supply Systems of Mafraq Governorate

5.1.4.3 Water Supply of Ajloun

Water Systems

Ajloun governorate is served by one water system (Ajloun Main water system) according to its resources and distribution networks. Ajloun's water supply is managed by Yarmouk Water Company, which is the responsible company for water management and distribution for the northern governorates (Irbid, Mafraq, Ajloun, and Jarash).

Water System	No. of Pumping Stations	No. of Reservoirs	Desalination/ Treatment
Ajloun Main Water System	17	12	1

Production

In 2018, The total internal water production for Ajloun was 3,353,682 m^3, these quantities were produced from the following sources according to WAJ official 2018 production and supply figures:

Source	Amount (MCM)	Received at	Distributed to
Zuqaiq wells (6 wells)	1.087484	Zuqaiq PS	Ajloun Main Water System
Rasoun Spring Station	0.114807	Rasoun PS	Ajloun Main Water System
Ain Tanour Station	0.975303	Arjan PS	Ajloun Main Water System
Ain Qantarah	0.408296	Ajloun Res.	Ajloun Main Water System
Ain Jannah Spring Station	0.050683	Ain Jannah PS	Ajloun Main Water System
Ain Um Qasem Station	0.073909	Rajeb Res.	Ajloun Main Water System
From Kufranja Dam	0.643200	Kufranja Res.	Ajloun Main Water System
Total	**3.353682**		Ajloun Main Water System

Export & Import

Ajloun water Imported the amount of 2,386,945 m^3 from Irbid through Samad PS in 2018 to increase the supply.

Import from	Quantity m^3
Samad PS	2,386,945
Total Imported	**2,386,945**

Supply

The total supply quantity for Ajloun governorate according to 2018 official figures for production, export & import was 5,740627 m^3.

Total Supply = 3,353,682 + 2,386,945 = **5,740,627 m^3**

The map in Figure 90 shows an overview of Ajloun water supply systems.

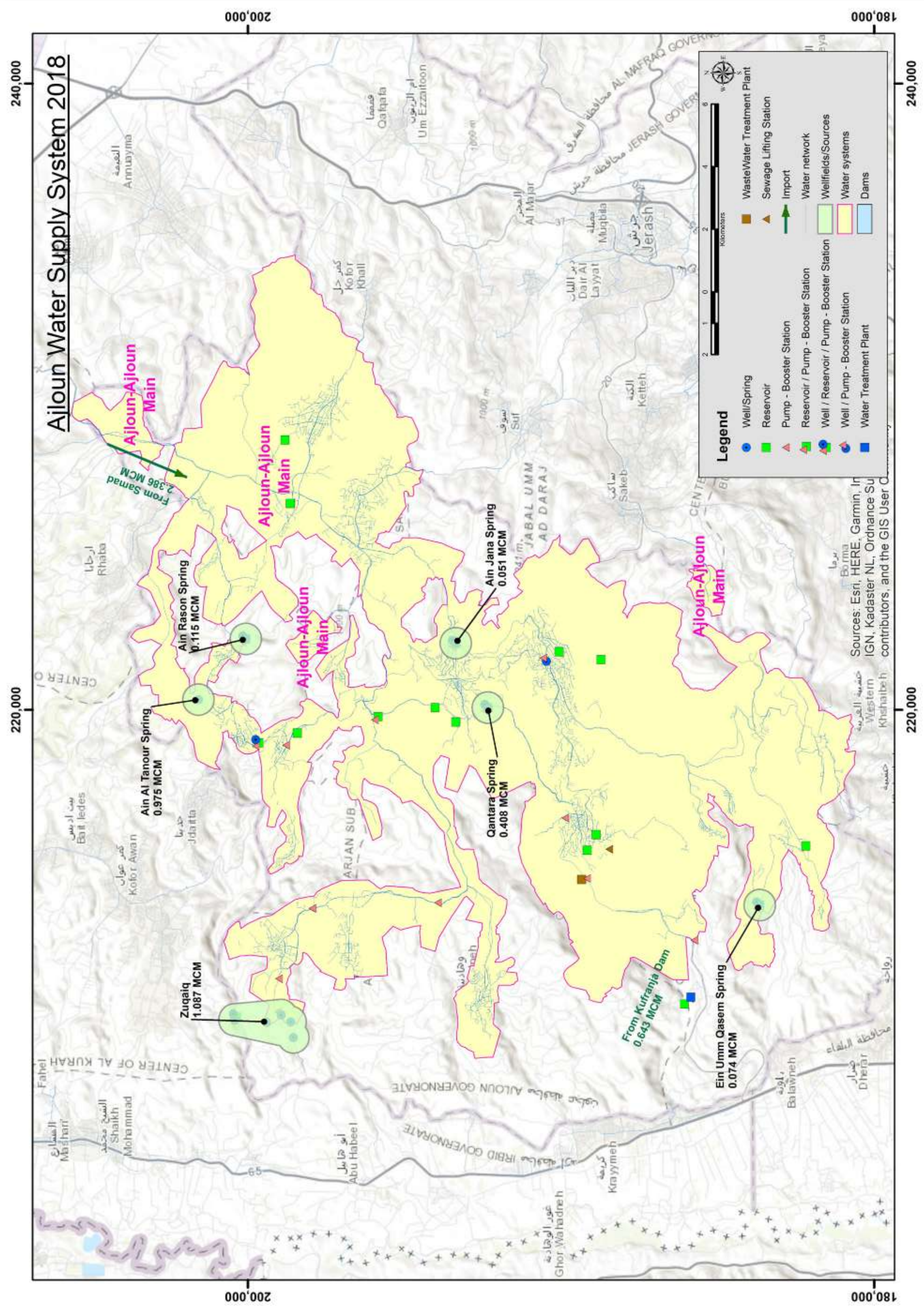


Figure 90: Water Supply Systems of Ajloun Governorate

5.1.4.4 Water Supply of Jarash

Water Systems

One water system is serving Jarash governorate, Jarash main water system. this water system is managed by Yarmouk Water Company, which is the responsible company for water management and distribution for the northern governorates (Irbid, Mafraq, Ajloun, and Jarash).

Each of the above water systems the available water facilities as detailed in the table below:

Water System	No. of Pumping Stations	No. of Reservoirs	Desalination/ Treatment
Jarash Main Water System	11	25	0

Production

In 2018, The total internal water production for Jarash was 5,644,683 m^3, these quantities were produced from the following sources according to WAJ official 2018 production and supply figures:

Source	Amount (MCM)	Received at	Distributed to
Bab Amman Well	0.020450	Network	Jarash Main Water System
Kufr Khal Well	0.0315	Network	Jarash Main Water System
Burma Well	0.096	Burma Res.	Jarash Main Water System
Um Qantara Well	0.143048	Network	Jarash Main Water System
Wadi Ed Dear Well	0.267646	Network	Jarash Main Water System
Al Qairawan well	0.290762	Al Qairawan PS	Jarash Main Water System
Souf Wells	0.108097	Souf Res.	Jarash Main Water System
AL Shawahed Wells	1.214989	Al Shawahed Res.	Jarash Main Water System
Rayashi Wells	0.392481	Rayashi PS	Jarash Main Water System
Mashtal Faysal Wells	3.098312	Mashtal Faysal PS	Jarash Main Water System
Al Deek & Al Teis springs	0.703209	Al Deek PS	Jarash Main Water System
Total	**5.644683**		

Export & Import

To increase the supply, Jarash imported in 2018 the amount of 2,747,404 m^3 from Irbid through Samad PS, and from Mafraq through Um Elolo PS, and from Zarqa through Um Rummanah PS.

Import from	Quantity m^3
Samad PS	1,665,480
Um Elolo PS	920,644
Um Rummaneh PS	161,280
Total Imported	**2,747,404**

Supply

The total supply for Jarash governorate is calculated after subtracting the amount of 144,081 m^3 Which is used for irrigation and filter washing.

Total Supply = (5,644,683 – 144,081) + 2,747,404 **= 8,248,006 m^3**

The map in Figure 91 shows an overview of Jarash water supply system.

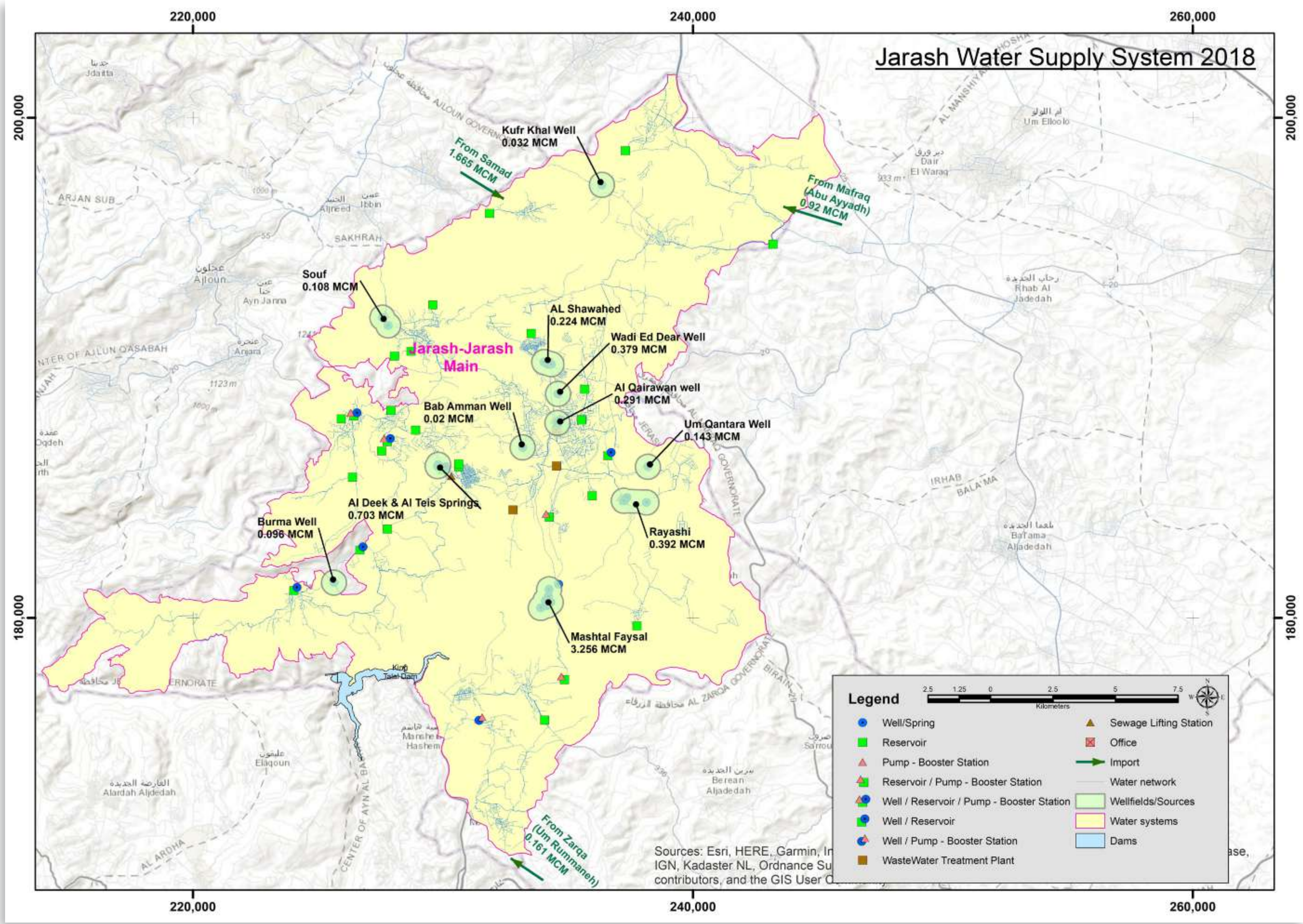


Figure 91: Water Supply Systems of Jarash Governorate

5.1.4.5 Water Supply of Amman

Water Systems

Amman water is managed by MIYAHUNA water company, which responsible for the water production and distribution for Amman, Madaba, and Zarqa governorates.

Amman governorate is served by two main water systems according to its resources and distribution networks setup.

The two water systems serving Amman governorate are:

- → Amman main water system: serving greater Amman municipality areas. Which includes East Amman, West Amman, North Amman, and South Amman areas.
- → Amman Deep south water system: serving the remaining areas outside greater Amman municipality in the southern areas of Amman.

For each of the above water systems the available water facilities as detailed in the table below:

Water System	No. of Pumping Stations	No. of Reservoirs	Desalination/ Treatment
Amman main	44	71 Res. & 12 towers	3
Amman Deep South	10	10	

Production

In 2018, the total water production for Amman was 30,795,035 m^3 from internal ground resources, and 106,029,164 m^3 from surface water resources, so the total internal production in 2018 was 136,824,199 m^3. these quantities were produced from the following sources according to WAJ official 2018 production and supply figures:

Source/Wellfield	Amount (MCM)	Received at	Distributed to
Taj (14 wells)	8.592358	Abu Alanda Res.	Amman main water system
Ain Ghazal (9 wells)	4.709686	Abu Alanda Res.	Amman main water system
Muhajrin-M Well	2.927342	Abu Alanda Res.	Amman main water system
Ras El Ain Spring	5.431660	Abu Alanda Res.	Amman main water system
Wadi Essir Spring	4.415905	Wadi Essir WTP	Amman main water system
Swaqa (14 wells)	3.812278	Swaqa Res.	Amman Deep South water system
Mwaqar (6 wells)	0.806044	Mwaqar PS	Amman Deep South water system
Irainbe well	0.099762	Irainbe PS	Amman Deep South water system
Zai intake (Surface water)	73.901110	Dabouq Res.	Amman main water system
Zara-Main	32.128054	Montaza Res.	Amman main water system
Total	**136.824199**		

Export & Import

In 2018 Amman water company (MIYAHUNA) exchanged quantities of water with other governorates as detailed in the below tables:

Export to	Quantity m^3
Balqa-Balqa connections from Zai line	20,463,521
Balqa-Royal Palaces	392,326
Balqa-Abu Nusair village	183,505
Balqa-Shouneh from Zara-Ma'in	1,356,816
Zarqa-Rusaifah from Amman-Rusaifah wells	3,358,315
Zarqa-Rusaifah from Dabouq line	2,688,434
Zarqa from Abu Alanda line	10,338,263
Zarqa-Um Rummaneh from Shafa Badran	1,144,540
Madaba	673,950
North-Yarmouk	1,333,510
Total Exported	**41,933,180**

Import from	Quantity m^3
DISI company	99,997,680
Zarqa-Khaw line	318,536
Balqa-to Um Ena'aj	30,000
Balqa (Fuhais)-to Dabouq area	13,956
(Madaba (Al Wala	1,206,659
Total Imported	**101,566,831**

Supply

The total supply quantity for Amman governorate according to 2018 official figures for production, export & import was **195,990,060** m^3 after subtracting the Amount of **467,790** m3 for Zai Brine water.

Total Supply = (136,824,199 + 101,566,831) - 41,933,180 - 467,790 = **195,990,060 m^3**

The map in Figure 92 shows an overview of Amman water supply systems.

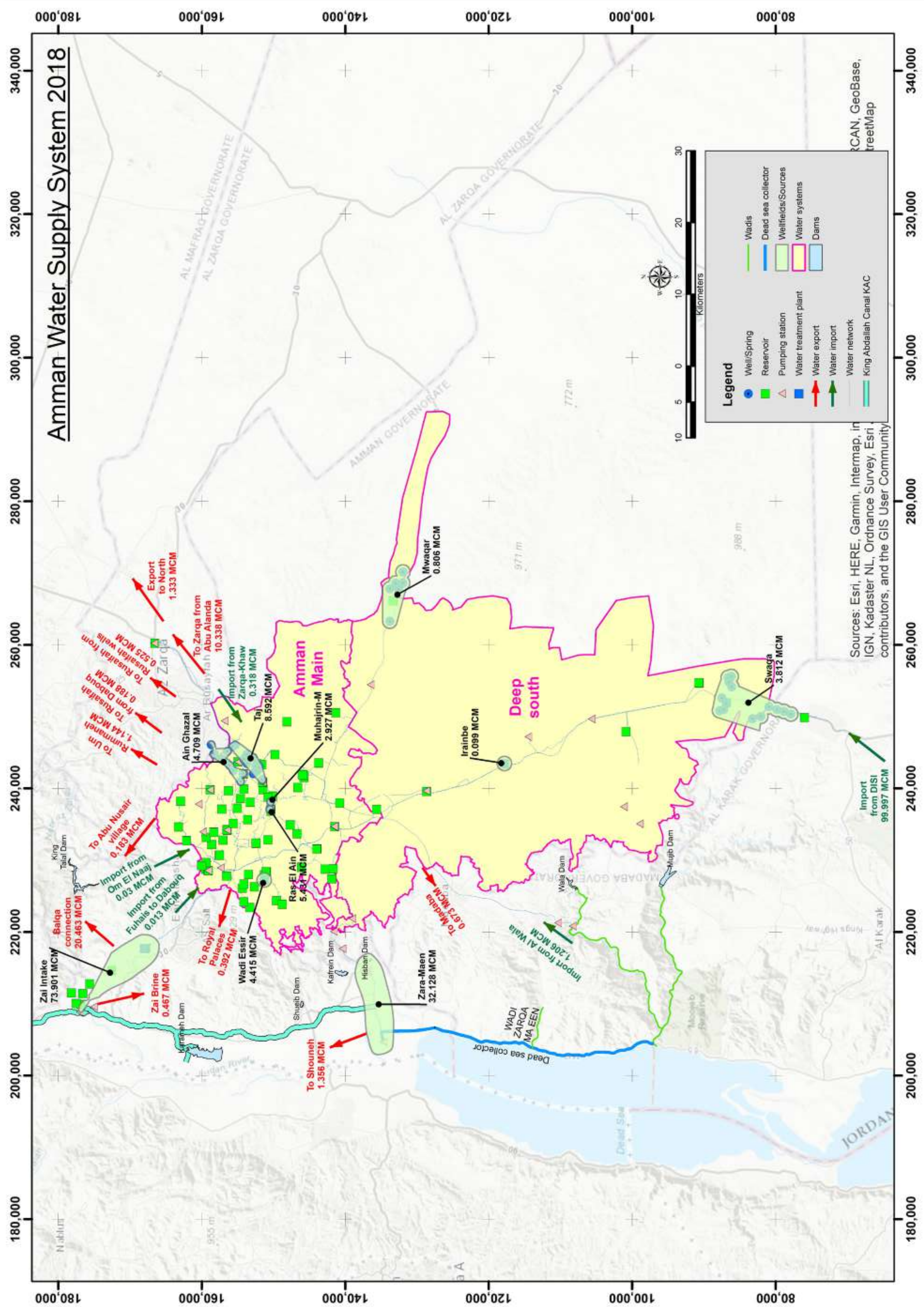


Figure 92: Water Supply Systems of Amman Governorate

5.1.4.6 Water Supply of Zarqa

Water Systems

Zarqa water is managed by MIYAHUNA water company, which responsible for the water production and distribution for Amman, Madaba, and Zarqa governorates.

Zarqa governorate is divided into five water systems according to the water resources and distribution networks.

The water systems are:

- → Zarqa Main: The largest and most complex system is Zarqa main water system which serves Zarqa Qasabah district, as well as Al-Hashemiyah district.
- → Rusaifah water system: serving Rusaifah district.
- → Bierain water system: serving Bierain sub-district
- → Dhulail water system: serving Dhulail sub-district
- → Azraq water system: serving Azraq sub-district

For each of the above water systems the available water facilities as detailed in the table below:

Water System	No. of Pumping Stations	No. of Reservoirs	Desalination/ Treatment
Zarqa Main Water System	8	1	1
Zarqa - Dhlail Water Sub-System	2	1	
Zarqa - Azraq Water Sub-System	1	3	
Bierain Water System	3	4	
Hashemiyah Water System	3	3	
Russeifa Water system	1	3	

Production

In 2018, The total internal water production for Zarqa was 41,378,032 m^3, these quantities were produced from the following sources according to WAJ official 2018 production and supply figures:

Source/Wellfield	Amount (MCM)	Received at	Distributed to
Azraq wells (17)	17.149113	Azraq Res then to Khaw Res.	Zarqa Main water system/Azraq water system
Coridor wells (5)	2.459336	Khaw Res.	Zarqa Main water system
Zarqa wells (3)	4.297182	Zarqa Res.	Zarqa Main Water System
Tamween wells (7)	1.823160	Tamween PS	Zarqa Main water system
Awajan wells (2)	3.46358	Awajan Res.	Zarqa Main water system
Hashimiyyah Wells (2)	1.383227	Hashimiyyah Res.	Zarqa Main water system
Qnayyah Spring	0.45554	Qnayyah Res.	Zarqa Main water system
Alouk Spring	0.06258	Alouk Res.	Bierain Water System
Sarout Spring	0.096238	Sarout Res.	Bierain Water System
Bierain wells (3)	0.717407	Beerain Res.	Bierain Water system
Merheb wells (4)	0.788768	Mrheb PS.	Bierain Water system
Hallabat wells (7)	3.620377	Hallabat Res./Khaw Res.	Zarqa water system/Dhulail water system
Rusaifah wells (9)	5.061524	Rasheed Res.	Rusaifah water system
Total	**41.378032**		

Export & Import

Zarqa water utility Imported the amount of 7,694,059 m3 from 9 private wells in 2018 to increase the supply for some areas.

Furthermore, in 2018 Zarqa water utility exchanged quantities of water with other governorates as detailed in the below tables:

Export to	Quantity m^3
Amman	318,536
Jarash (from Um Rummaneh)	161,280
Balqa (from Um Rummaneh)	74,880
Mafraq villages (from Qnayyah)	525,600
Khaldiyah-Mafraq	1,371,554
Khaldiyah (from private wells)	188,270
Total Exported	**2,640,120**

Import from	Quantity m^3
Rusaifah wells (Amman)	3,358,315
From Dabouq to Rusaifah	2,688,434
(Abu Alanda (DISI	10,338,263
(Um Rummaneh (from Shafa Badran	1,144,540
(Qnayyah Well (From Mafraq	912,094
Total Imported	**18,441,646**

Supply

The total supply quantity for Zarqa governorate according to 2018 official figures for production, export & import was 63,368,685 m3 after subtracting the Amount of 1,504,932 m3 which is given to Azraq Natural reserve for irrigation (688,850m3) and the brine from Zarqa desalination plant (816,082m3).

Total Supply = (41,378,032 + 18,441,646 +7,694,059) - 2,640,120 - 1,504,932 = **63,368,685 m^3**

Syrian Refugee Camps

Zarqa governorate contains two camps for the Syrian refugees affected by the Syrian crisis, The two camps are in Dhulail and Azraq districts:

Azraq Syrian Refugee Camp (Mkhaizen Camp):

The Azraq refugee camp is in Azraq district and according to DOS estimation in 2018, about 40,650 people are living in this camp. For domestic water supply for the camp, the camp is supplied by two private wells owned and operated by UNICEF, not through municipal water systems.

The wells that supply water to Azraq camp are:

ID	Name	Total production in 2018
F 4352	UNICEF/Mkhaizen refugee camp 1	429,275
F 1417	UNICEF/Mkhaizen refugee camp 2	234,377
Total		**663,652**

The total supply for Azraq refugee camp was 663,652 m^3 in 2018.

Emirati Syrian Refugee Camp (Mraijeeb Al Fhoud Camp):

This camp is in Dhulail district and according to DOS estimation in 2018, about 6,926 people are living in this camp. For domestic supply for the camp, the camp is supplied by a private well (AL4096-Mraijeeb Al Fhoud Camp) owned and operated by the General Command of the Armed Forces of Jordan. Municipal water utilities are not providing the camp with domestic water for drinking.

Refugees camps are supplied by private wells, not through municipal water systems. Water demand estimation, based on 35 l/c/d, was around 0.6 MCM in 2018, and is subjected to a slight decrease to around 0.5 MCM by 2040 as a result of the anticipated return of Syrians.

The map in Figure 93 shows an overview of Zarqa water supply systems.

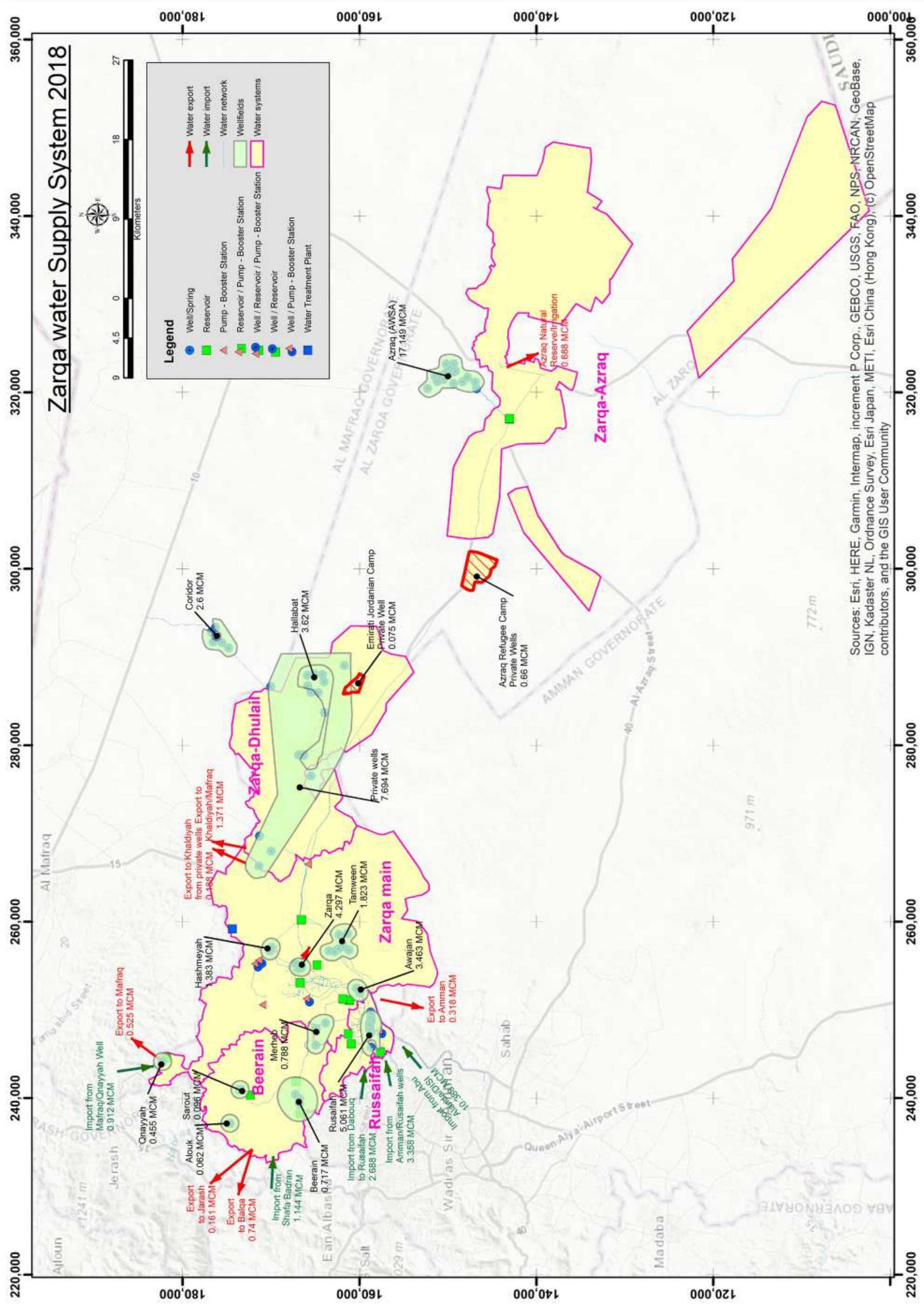


Figure 93: Water Supply Systems of Zarqa Governorate

5.1.4.7 Water Supply of Balqa

Water Systems

Balqa water administration is one of the water administrations managed by WAJ. It is operated through the following water systems:

- → Balqa-Salt water system: serving Salt district
- → Balqa-Ain Basha water system: serving Ain Basha district
- → Balqa-Mahes and Fuhais water system: serving Mahes and Fuhais districts
- → Balqa-Deir Alla water system: serving Deir-Alla district
- → Balqa-South Shouneh water system: serving South Shouneh district.

For each of the above water systems the available water facilities as detailed in the table below:

Water System	No. of Pumping Stations	No. of Reservoirs	Desalination/ Treatment
Balqa-Salt	9	21 Res. & 1 Tower	1
Balqa-Ain Basha	4	7	1
Balqa-Mahes & Fuhais	2	3	
Balqa-Deir Alla	7	7	1
Balqa-South Shouneh	4	9	2

Production

In 2018, The total internal water production for Balqa was 15,445,397 m^3, these quantities were produced from the following sources according to WAJ official 2018 production and supply figures:

Source/Wellfield	Amount (MCM)	Received at	Distributed to
Al Yazeediyya wells (3)	1.046580	Al Yazeediyya PS	Balqa-Salt water system
Al Buqouriyya - Spring	2.655131	As Shrei'a WTP	Balqa-Salt water system
As Shrei'a Spring	1.20153	As Shrei'a WTP	Balqa-Salt water system
Um Attiyya well	0.34272	Network	Balqa-Salt water system
Alan Well	0.16632	Network	Balqa-Salt water system
As Subeihi - Well	0.15042	Network	Balqa-Salt water system
Baqa'a wells (11)	1.544019	Baqa'a Res./Abu Nusair 2 Res.	Balqa-Ain Basha water system
Al Rumman Well	0.065779	Network	Balqa-Ain Basha water system
Azraq Spring	1.080143	Azraq PS	Balqa-Mahes & Fuhais water system
Abu ElZeeghan wells	3.213150	Abu ElZeeghan Res.	Balqa-Deir Alla water system
As Samahiyyat wells (2)	0.874360	Wadi Rajib Res.	Balqa-Deir Alla water system
Wadi Rajib wells (3)	0.63316	Wadi Rajib Res.	Balqa-Deir Alla water system
Al Kafrain wells (3)	1.47854	Al Kafrain Res.	Balqa-South Shouneh water system
Juraiaa wells (3)	0.76035	Juraiaa Res.	Balqa-South Shouneh water system
Sukneh wells (2)	0.217805	Network	Balqa-South Shouneh water system
South Shouna 2 Well	0.01539	Network	Balqa-South Shouneh water system
Total	**15.445397**		

Export & Import

In 2018 Balqa water administration exchanged quantities of water with other governorates as detailed in the below tables:

Export to	Quantity m^3
Um Ena'aj	30,000
From Fuhais to Dabouq area	13,956
Total Exported	**43,956**

Import from	Quantity m^3
Zai line to Balqa connections	20,463,521
Balqa-Royal Palaces	392,326
Balqa-Abu Nusair village	183,505
From Zara-Ma'in to Balqa-Shouneh	1,356,816
From Um Rummaneh	74,880
Total Imported	**22,471,048**

Also, Balqa governorate imported in 2018 the amount of 4,616,967 m^3 from private wells distributed in the water systems.

Supply

The total supply quantity for Balqa governorate according to 2018 official figures for production, export & import was 42,387,078 m^3 after subtracting the Amount of 102,378 m^3 which is used for Brine and filter washout.

Total Supply = (15,445,397 + 22,471,048 + 4,616,967) - 43,956 - 102,378 = **42,387,078 m^3**

The map in Figure 94 shows an overview of Balqa water supply systems.

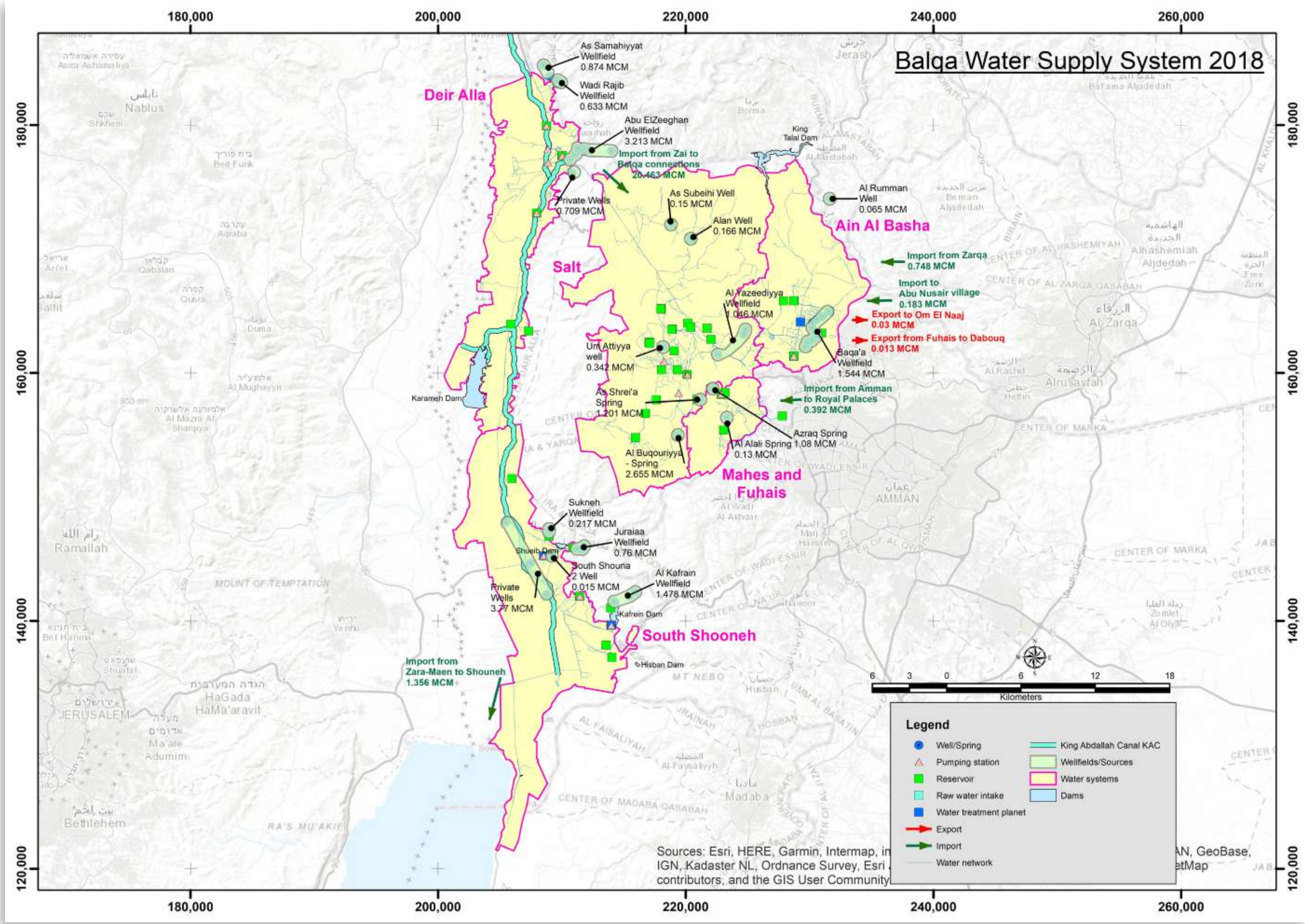


Figure 94: Water Supply Systems of Balqa Governorate

5.1.4.8 Water Supply of Madaba

Water Systems

Madaba water is managed by MIYAHUNA water company, it has one main water system serving the below listed districts:

- → Madaba district
- → Dhiban district
- → Mlaih and al Areedh areas.

Each of the above water systems the available water facilities as detailed in the table below:

Water System	No. of Pumping Stations	No. of Reservoirs	Desalination/ Treatment
Madaba main water system	6	7 res. & 3 water towers	

Production

Total production of Madaba resources in 2018 was 11,003,747 m^3. These quantities were produced from the following sources according to WAJ official 2018 production and supply figures:

Source	Amount (MCM)	Received at	Distributed to
Heedan wells (15 wells) and Wala No.9 well	10.536357	Wala PS	Madaba Main Water System
Wala 5 Well	0. 425503	Wala PS	Madaba Main Water System
Mlaih Well	0.0 41887	Network	Madaba Main Water System
Total	**11.003747**		

Export & Import

Due to supply needs in 2018, Madaba exchanged the following water quantities with Amman according to the table below:

Water Exchange	Quantity m^3
To Amman	1,206,659
From Amman	673,950

Supply

Madaba production in 2018 was reduced by the amount of 537,274 m^3 to be used for irrigation, and the amount of 114,657 m^3 for the pumping on the washouts, the total supply for Madaba in 2018 was as follows:

Total Supply = (11003747+ 673,950) – (114,657- 537,274 - 1,206,659) = **9,892,607 m^3**

The map in Figure 95 shows an overview of Madaba Water supply system.

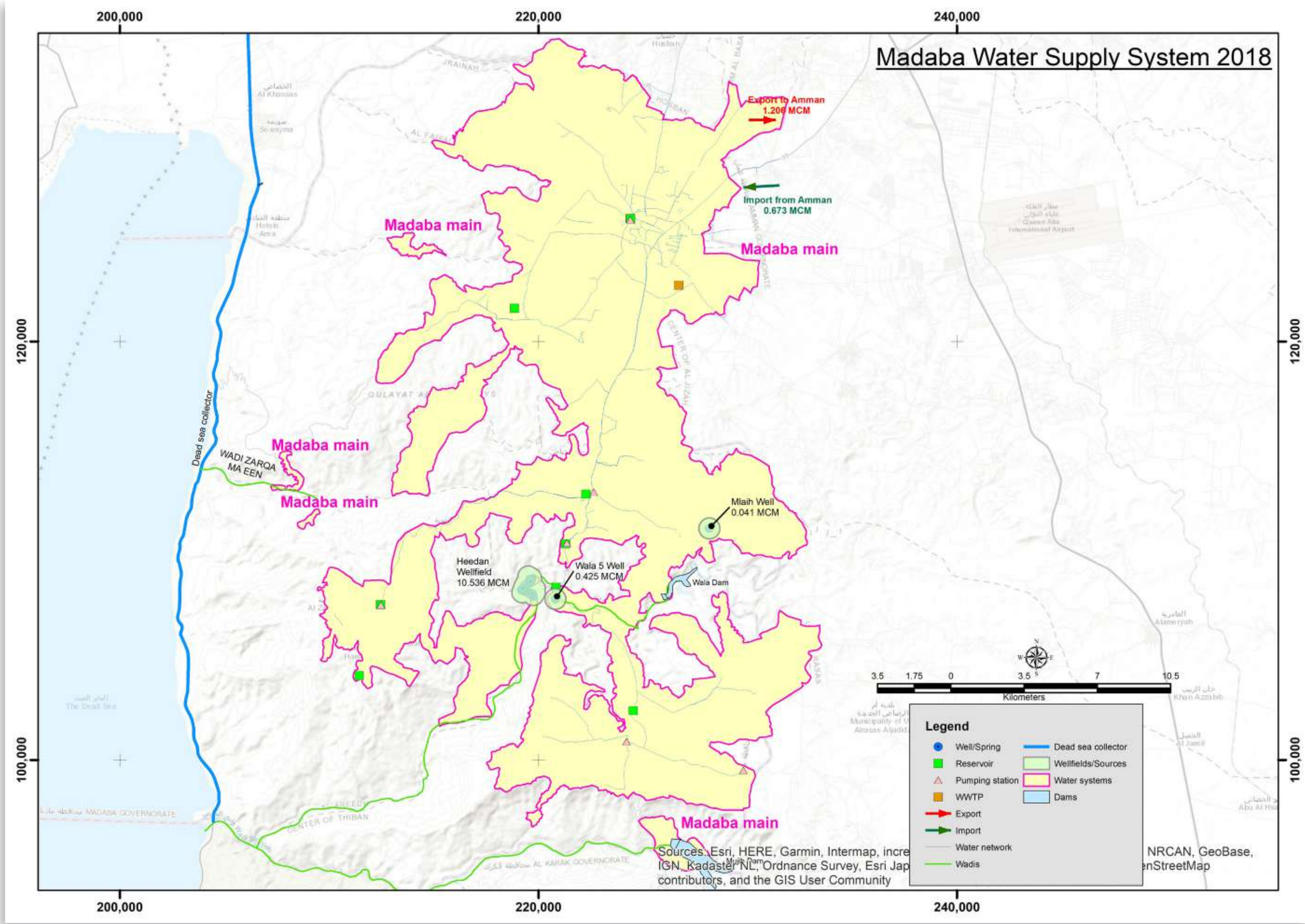


Figure 95: Water Supply Systems of Madaba Governorate

5.1.4.9 Water Supply of Karak

Water Systems

Karak water administration is one of the southern water administrations managed by WAJ. It is operated through the following water systems:

- → Karak Main Water System: serving Karak city and surrounding villages.
- → North karak Water System: serving al Qasr area and the northern parts of Karak
- → South Karak Water System: Qatraneh Water System: serving the southern villages of KArak and Wadi Abyadh village
- → Al Ghawr Water System: serving Jordan valley-GHAWR localities that include:

- o Ghawr Safi
- o Ghawr Faifa
- o Ghawr Almazra'a
- o Ghawr Hadiethah
- o Blaidet Almazra'a
- o Blaidet Hadiethah
- o Mamorah
- o Gwiebeh

For each of the above water systems, the available water facilities are detailed in the table below:

Water System	No. of Pumping Stations	No. of Reservoirs	Desalination/ Treatment
Karak Main Water System	7	9 Res. & 3 Water Towers	0
North Karak Water System	3	3 Res. & 1 Water Tower	0
South Karak Water System	4	6	0
Al Ghawr water system	4	3	0

Production

Total Well production of Karak resources in 2018 was 24,047,162 m^3, and with adding the quantities received from Mujib Dam, which is about 1,620,779 m^3 to it, the Total production in 2018 was 25,667,941 m^3 according to WAJ official 2018 production and supply figures:

Source	Amount (MCM)	Received at	Distributed to
Jad'ah wells (2 Wells) and Sheehan Well and Rabbah Agricultural well	0.783334	Sheehan PS	North Karak Water System
Sad El Sultani Wells (13 wells)	3.390936	Sad El Sultani PS	Karak Main Water System
Qatraneh Wells (23 wells)	5.690167	Qanraneh PS	Karak Main Water System
Lajoun Wells (28 Wells)	5.518499	Lajoun PS	Karak Main Water System
Al Ghwair Wells (4 Wells)	1.039259	Al Ghwair PS	Karak Main Water System
Ain Sarah Spring	0.490033	Ain Sara Res.	Karak Main Water System
Ash Shehabiyyah Spring	0.118269	Ash Shehabiyyeh Res.	Karak Main Water System
Ader Well	0.205228	Network	Karak Main Water System
Mhiyy Wells (11 Wells)	3.200973	Mhiyy PS	South Karak Water System
WADI AL ABYAD NO 1	0.410266	Network	South Karak Water System
WADI SAKHRIYYA NO 2 (S 119)	0.280467	Network	South Karak Water System
Al Ghawr Wells (17 wells)	2.744521	Al Ghawr PSs	Al Ghawr Water system
Total	**24.047162**		

Export & Import

Karak water administration imported in 2018 a small amount of water from the Potash company private well (146,454 m^3).

Supply

The total supply for Karak governorate is calculated after subtracting the amount of 5,821,268 m^3 Which is used for irrigation and filter washing.

Total Supply = (24,047,162 – 3,078,331) + 1,620,779 + 146,454 **= 22,736,064 m^3**

The map in Figure 96 shows an overview of Karak water supply systems.

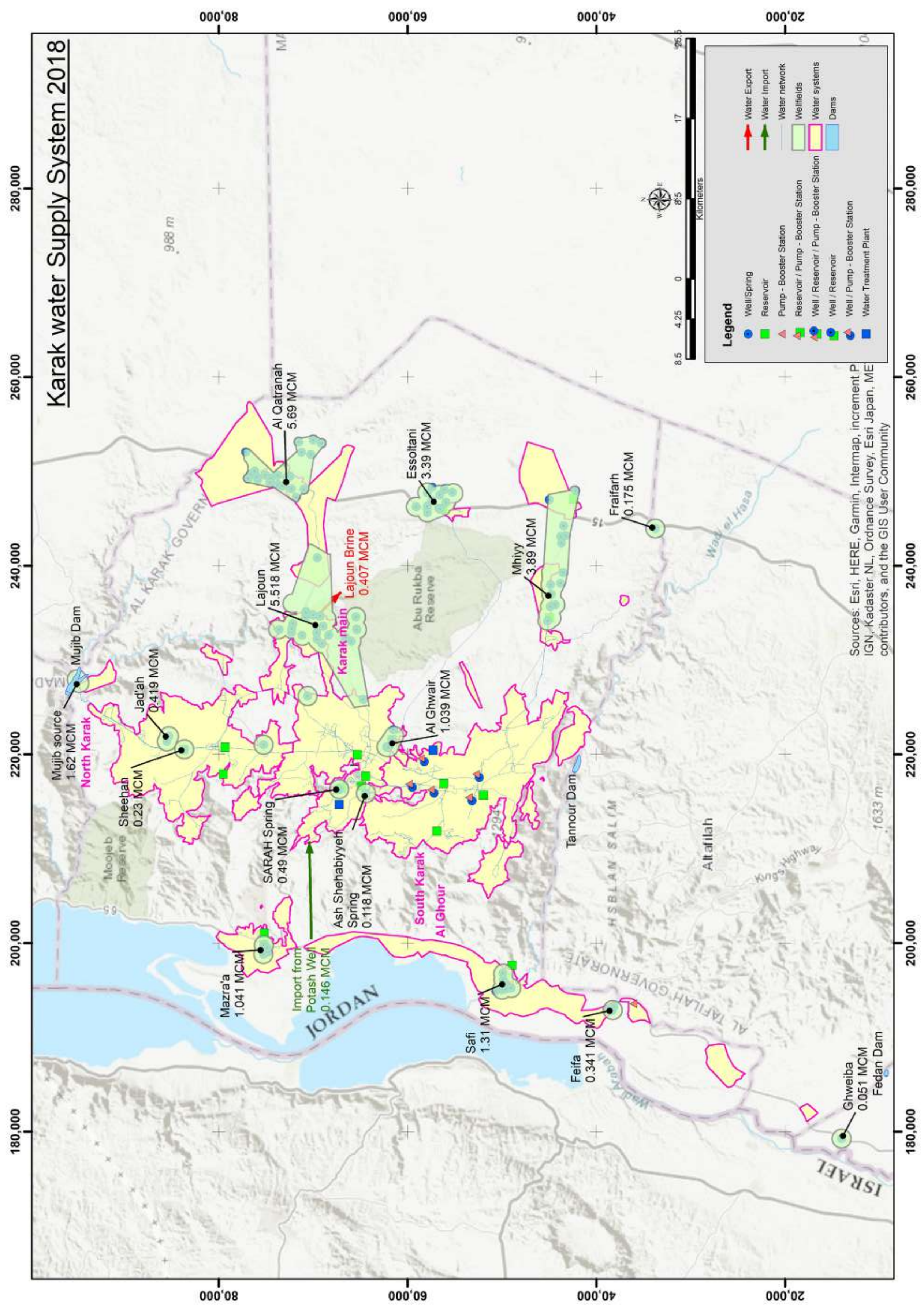


Figure 96: Water Supply Systems of Karak Governorate

5.1.4.10 Water Supply of Tafilah

Water Systems

Tafilah water administration is one of WAJ's water utilities in the southern part of Jordan, it is divided to 3 water systems according to its resources and distribution networks.

- → Tafilah main water system: serving Tafilah city and other nearby villages
- → Jurf Ad Darawish water system: serving Jurf Ad Darawish village
- → Hasa Al Balad water system: Serving al Hasa village

For each of the above water systems the available water facilities as detailed in the table below:

Water System	No. of Pumping Stations	No. of Reservoirs	Desalination/ Treatment
Tafilah Main Water System	5	15	1
Jurf Ad Darawish water system	1	2	0
Hasa Al Balad water system	0	2	0

Production

The total water production for Tafilah in 2018 was 6,821,491 m^3, the operating water resources in tafilah are as follows:

Source	Amount (MCM)	Received at	Distributed to
Al Hasa wells (9)	5.438516	Al Hasa PSs	Tafilah Main Water System
Zabda wells (6)	0.462902	Zabda PS	Tafilah Main Water System
Al Hasa Al Balad Wells (2)	0.655361	Al Hasa Old & New Res.s	Al Hasa Al Balad Water system
Jurf Ad Darawish Well	0.261712	Jurf Ad Darawish Res.	Jurf Ad Darawish Water System
Twana Well No 1	0.000480	Network	Tafilah Main Water System
Hasa El Tanour Deep 1	0.002099	Network	Tafilah Main Water System
E'laqa	0.000421	Network	Tafilah Main Water System
Total	**6.821491**		

Export & Import

Tafilah has no water exporting or importing within its water systems.

Supply

From the total production amount, the amount of 14,278 m^3 is going to livestock and tankers for irrigation use, the total supply for drinking in Tafilah is then:

Total Supply = (6,821,491 – 14,278 = **6,807,213 m^3**

The map in Figure 97 shows an overview of Tafilah Water supply systems.

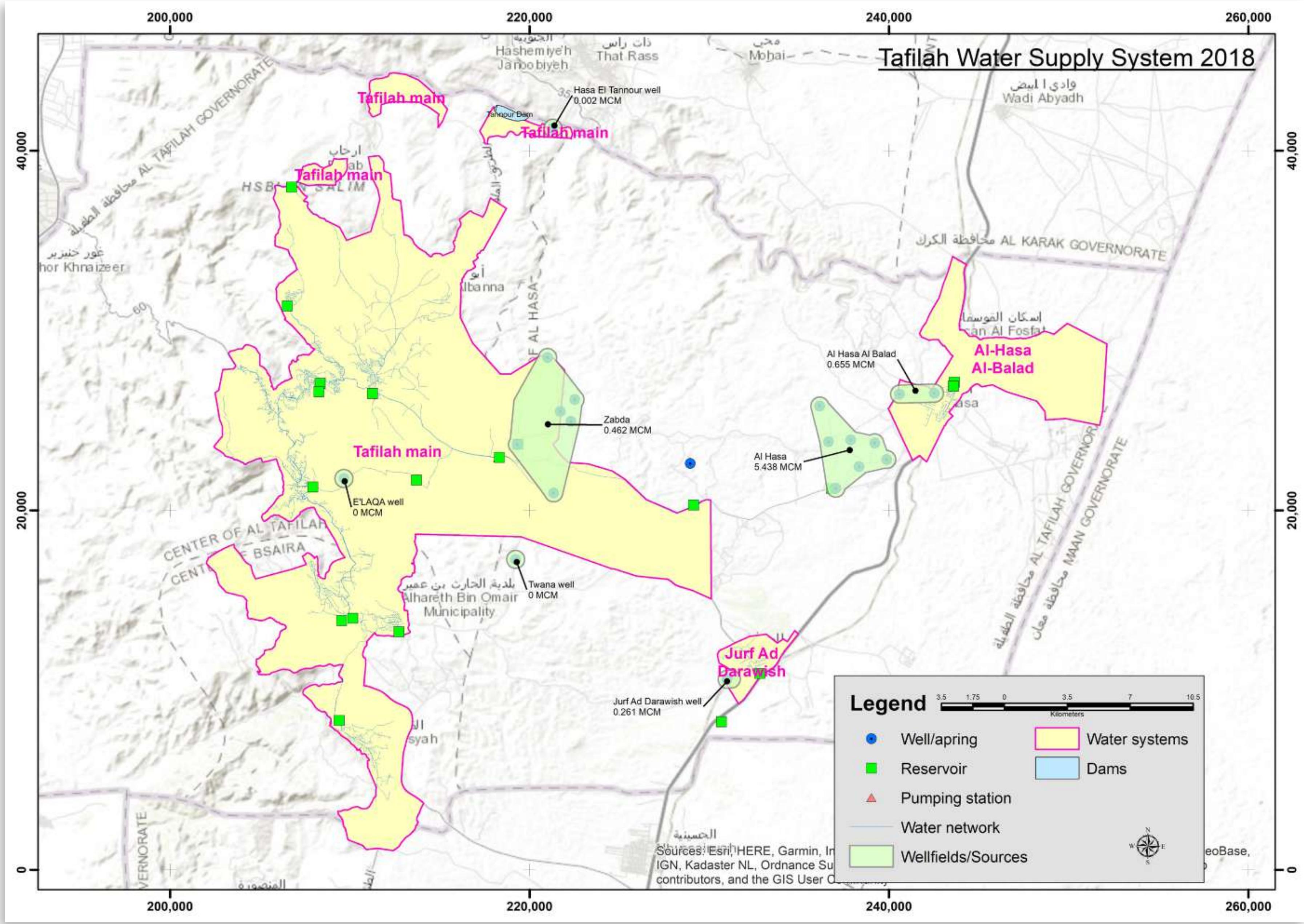


Figure 97: Water Supply Systems of Tafilah Governorate

5.1.4.11 Water Supply of Maan

Water Systems

Maan water administration is one of the southern water administrations managed by WAJ, It is operated through the following water systems:

- → Maan main water system: serving Qasabet Maan district
- → Husseiniyyeh water system: serving Husseiniyyeh district
- → Mohammadiyyeh: Serving Mohammadiyyah locality from Adroh Sub-district
- → Shobak water system: serving Shobak district and fjaij locality from Husseiniyyeh sub-district and Bair Abu El-Alaq from Adroh sub-district
- → Wadi Mousa water system: serving Petra district and Iel sub-district from Qasabet Maan district
- → Manshiyyeh water system: serving Adroh sub-district from Qasabet Maan district
- → Mraighah water system: serving Mraighah sub-district from Qasabet Maan district
- → Al Wahida water system: serving Al Wahida from Iel sub-district
- → Jafr water system: serving Jafr locality from Qasabet Ma'an district
- → Modawwarah water system: serving Modawwarah locality from Qasabet Maan district

For each of the above water systems the available water Facilities as detailed in the table below:

Water System	No. of Pumping Stations	No. of Reservoirs	Desalination/ Treatment
Maan Main	3	3	1
Husseiniyyeh	1	1	0
Mohammadiyyeh	0	1	0
Shobak	3	4	0
Wadi Mousa	4	6	0
Manshiyyeh	1	1	0
Mraighah	1	2	0
Al Wahida	0	1	0
Jafr	1	1	0
Modawwarah	0	1	0

Production

The total water production for Maan in 2018 was 15,671,049 m^3, the operating water resources in Ma'an are as follows:

Source/Wellfield	Amount (MCM)	Received at	Distributed to
Tahounah (13 wells)	2.590950	Tahouneh Res.	Maan Main Water System
Samna (8 wells)	2.124153	Samna PS.	Maan Main Water System
Sath Maan well	0.128550	Sath Ma'an Res.	Maan Main Water system
Taqatqa Well	0.009319	Network	Maan Main Water system
Husseiniyyeh (2 wells)	0.905738	Husseiniyyeh PS	Husseiniyyeh Water System
Tell Burma (2 wells)	1.016035	Network	Husseiniyyeh Water System
Wadi Arja (3 wells)	0.710626	Network	Mohammadiyyeh Water System
Shoubak (9 wells)	1.229415	Nijl PS	Shoubak water system
Fjaij (2 wells)	0.743960	Network	Husseiniyyeh water system
Jitheh (9 wells)	1.895982	Jitheh PS	Wadi Mousa water system
Qa'a (5 wells)	1.176127	Iel PS	Wadi Mousa water system
Adhroh (2 wells)	0.619639	Adroh PS	Manshiyyeh Water System
Manshiyyah (2 wells)	0.281186	Manshiyyah PS	Manshiyyeh Water System
MREIGHA well	0.172799	Network	Mraighah water system
QREIN NO 4 well	0.235505	Network	Mraighah water system
Wheida no 2 well	0.472778	Network	Al Wahida water system
Jafer (4 wells)	1.038773	Jafr PS	Jafr water system
Al-Mudawwara 1 well	0.167529	Al-Mudawwara PS	Modawwarah water system
HALET A'MMAR well	0.151985	Network	Modawwarah water system
Total	**15.671049**		

Export & Import

Maan water do not have any external import of water. Nevertheless, Maan water exported the amount of 20,000 m^3 to Dabet Hanout area in Aqaba governorate.

Supply

From the total production amount, the amount of 1,111,428 m^3 is going for irrigation use, the total supply for drinking in Maan is then:

Total Supply = (15,671,049 – (20,000 + 1,111,428) = **14,539,621 m^3**

The map in Figure 98 shows an overview of Maan Water supply systems.

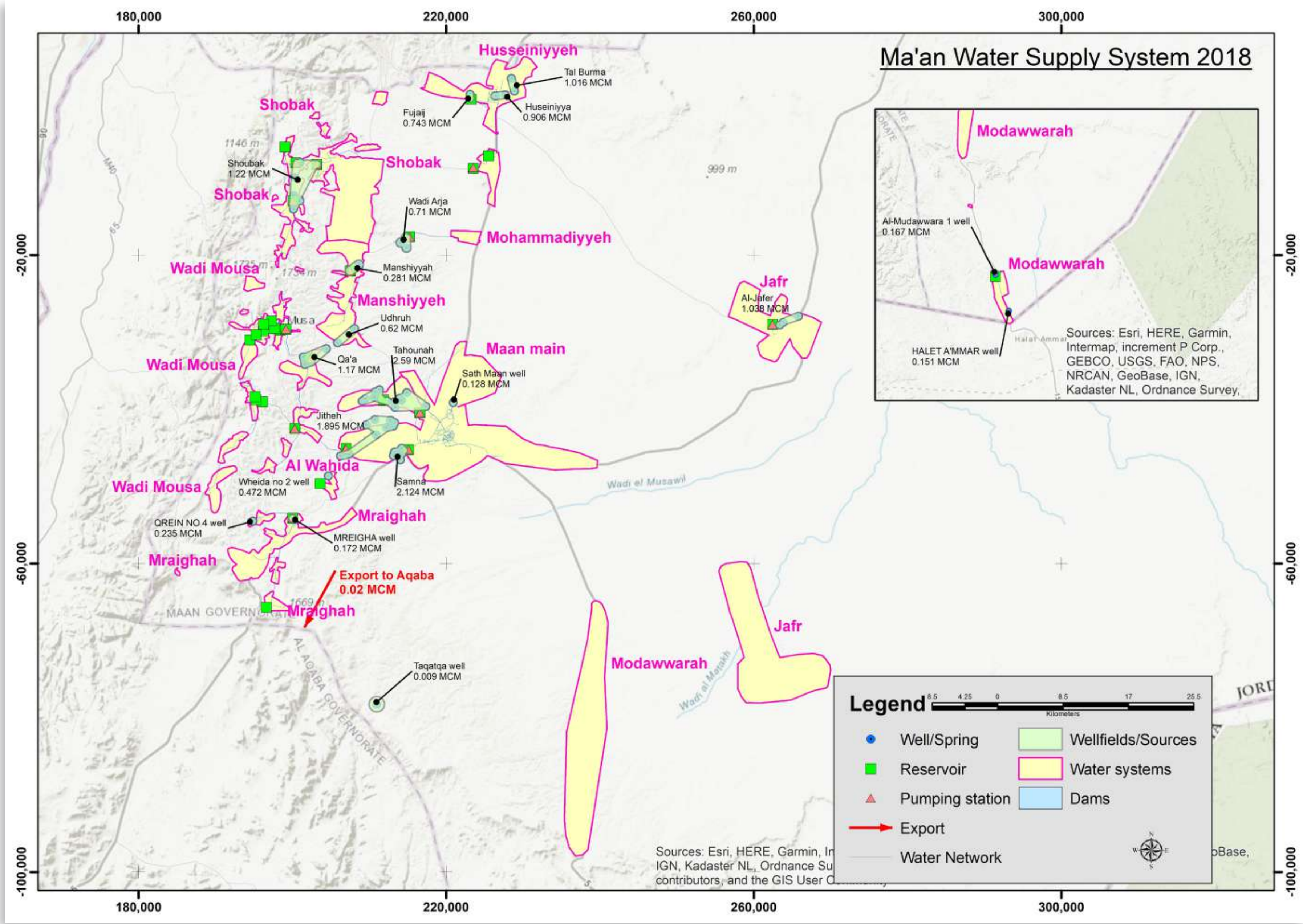


Figure 98: Water Supply Systems of Maan Governorate

5.1.4.12 Water Supply of Aqaba

Water Systems

Aqaba water services in managed by Aqaba Water Company (AWC), which is responsible for the water services for ASEZA and the local agricultural areas in the governorate.

From the water resources and water distribution networks, Aqaba is divided to three water systems as follows:

- → Aqaba Main water system: serving ASEZA service area.
- → Aqaba-Quwairah and Aqaba villages water system: serving Quwairah district and the local agricultural localities along the main DISI transmission line to ASEZA.
- → Aqaba-Wadi Araba: serving the local agricultural localities in Wadi Araba sub-district.

For each of the above water systems the available water facilities as detailed in the table below:

Water System	No. of Pumping Stations	No. of Reservoirs	Desalination/ Treatment
Aqaba Main	0	13	1
Aqaba-Quwairah	4	2	0
Aqaba-Wadi Araba	0	0	0

Production

The total water production for Aqaba in 2018 was 19,089,742 m^3, the operating water resources in Aqaba are:

Source/Wellfield	Amount (MCM)	Received at	Distributed to
Qa'a Disi (26 wells)	17.363949	Collection Res.	Aqaba Main Water System/Aqaba-Quwairah water system
Quwairah (3 wells)	0.930697	Local network	Aqaba-Quwairah water system
Rahma well	0.288520	Local network	Aqaba-Wadi Araba water system
Um Mithla Well-Beer Mathkour	0.172060	Local network	Aqaba-Wadi Araba water system
Risheh Well	0.154284	Local network	Aqaba-Wadi Araba water system
Feenan Well	0.145942	Local network	Aqaba-Wadi Araba water system
Qatar Well	0.034290	Local network	Aqaba-Wadi Araba water system

Aqaba also received in 2018 the amount of 2,682,491 m^3 desalinated sea water from the KEMAPCO desalination plant.

Furthermore, the amount of 3,981,610 m3 is bought from Rum Company (Rum Agriculture) to Aqaba water and was added to its supply quantities.

Export & Import

In 2018, Aqaba imported the amount of 20,000 m3 from Ma'an governorate to the area of Dabet Hanout. This import source was stopped in Arpil.2018.

Supply

According to AW official figures the 2018 well production was 17,779,208 m3. Therefore, the total domestic water supply for Aqaba governorate in 2018 was as follows:

Total Supply to Aqaba governorate = 17,779,208 + 2,682,491 + 3,981,610 + 20,000 **= 24,483,309 m3**

Total water supplied to Aqaba City =17,596,780 m3

Total water supplied to other areas in Aqaba governorate = 6,886,529 m3

The map in Figure 99 shows an overview of Aqaba water supply systems.

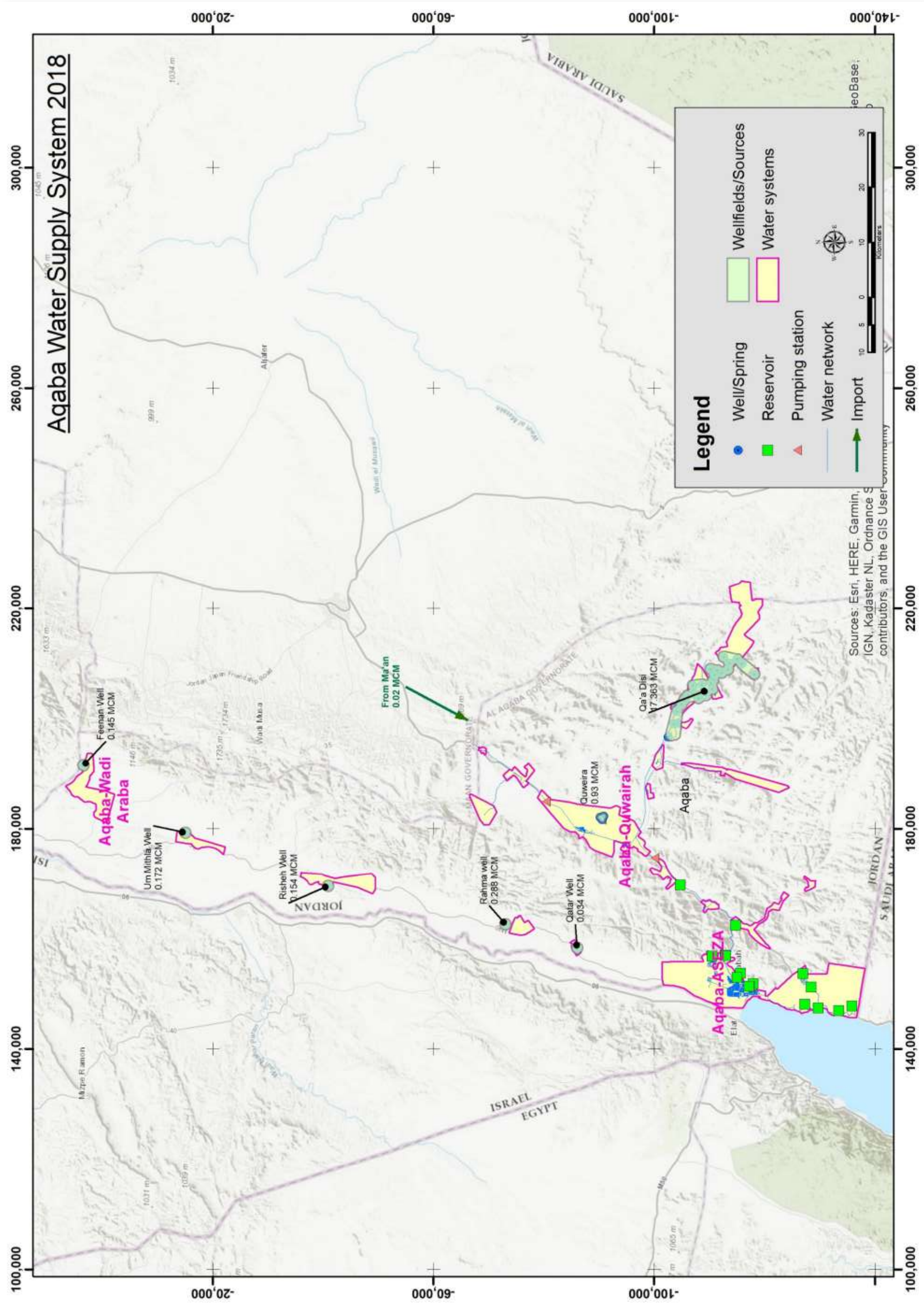


Figure 99: Water Supply Systems of Aqaba Governorate

5.1.5 Conveyance Network

Originally it was planned to include a chapter on the existing conveyance networks, the frequency of water supply, water supply security and contingency planning. However, no text was provided. As this is an important issue, it will be tried to add this in the NWMP-3 document Volume E.

5.1.6 Treatment and Desalination Plants

Treatment plants are installed to produce potable water from water resources that does not fall within the Jordanian drinking water standards. These plants can be grouped into two categories:

- desalination plants that are used to reduce salinity in brackish ground water resources which have salinity higher than 1,300 mg/l;
- treatment plants which are used to remove other contaminants from freshwater resources either surface or ground water.

5.1.6.1 Plants for Treatment of Raw Water

<u>Surface Water Treatment Plants</u>

Altogether there are 45 treatment plants, some for only individual wells, springs or surface water supplies, some for wellfields.

Only two plants have been installed for surface water: Zai and Mujib dam water treatment plants (WTP). Typical conventional treatment has been selected for Zai WTP in 1970. The plant faced operational problems that impacted the finished water quality supplied to customers. In 2000 the plant has been upgraded to address taste and odor issues. In 2019 UV systems have been installed as additional barrier for giardia, cryptosporidium, and viruses. Overall, the plant performance is good after these updates. However, there are still some limitations to the existing facility as such as the operation is modified to meet water quality standards under certain raw water quality events.

Mujib Dam WTP has more advanced treatment units where ultrafiltration has been used. Since the plant started production in 2015, several operational problems were faced that have caused shutdowns for long periods due to unforeseen events. During the design there was not enough historical and representative water quality data for the dam, both spatially and in depth. Nutrients are released during lake stratification in the lower layer (hypolimnion) and accumulate in the lake by time that cause development of severe seasonal algal blooms and as a result caused continuous degradation in water quality. Raw water can be extracted from the lake by two ways; either from the upper layer through a floating pump where this layer suffers from high algae and its products, or from the bottom layer through the dam gates which have anaerobic conditions with high concentrations of ammonia hydrogen sulfide, and heavy metals (mainly iron). The operator changes between the two intakes according to water quality. In addition to the raw water quality, the operator might stop the plant due to low level of water in the dam lake.

WAJ developed some measures to improve water quality in the dam which include opening the dam’s bottom gate during flash floods and keeping open the lower gate at level 175 m asl to improve aeration in the bottom layers. Nevertheless, WAJ found these tools are not enough and believe it should invest in other tools

Groundwater treatment

Treatment schemes in these plants depend on the water quality parameters of the specific water resource. The Jordanian Standard - Drinking Water No. 286 and its respective updates has been used as guidance for finished water quality after treatment. The current and future groundwater quality problems have been described in Chapter 3.1.4.1.8. They are mainly related to salinity, heavy metals, and radioactivity.

5.1.6.2 Desalination Plants

There are 26 desalination plants that have been installed by the water sector entities, scattered all over the kingdom. The list of currently existing desalination plants is contained in Chapter 3.1.6.2 (Table 15).

It can be noticed from the figure that most of the plants are located in the Jordan Valley where brackish water is abundant, and brine can be easily disposed off to the Dead Sea.

Brackish water reverse osmosis (BWRO) technology has been used in all desalination plants to reduce salinity with average design recovery of 75%. Table 15 shows that total design production capacity of the BWRO plants is about 90 MCM. However, the real production of each plant is less, either for source limitations or due to low performance of the plant.

The largest BWRO plant installed in Jordan is Zara-Main BWRO desalination plant with a design capacity of 47 MCM/ year and an overall recovery rate of 85%. Figure no. (location map). Although the plant is operated very efficiently and close to the design recovery, the actual annual production is about 20% less than the designed capacity. The plant is designed to receive 55 MCMY from an estimated available 60 MCMY raw water from three sources:

- Mujib Dam (30 MCM/yr),
- Zara (7 MCM/yr), and
- Zarqa Maen (23 MCM/yr) springs.

However, the annual raw water produced by the three sources and transferred to Zara Main is much less. There is no direct measurement for the received quantities from each source.

The first desalination plant has been installed in 2001 in Ruwaished and, apart from salinity, removes hardness and fluoride.

5.2 Infrastructure Affected by Depletion of Water Resources

Major changes in water resources availability will occur until 2040. The main changes in the aquifer exploitability and how wells are affected is shown below. It is also mentioned where reduced surface water availability will affect water supplies.

Northern Jordan

Since the gradient in the geological structure (dip) is relatively high, the extent of the area which will become dry by 2040 is less than in areas with lower gradients. However, the annual decline is so high that many wellfields in this area which currently provide water to Irbid or Mafraq will be dry by 2040. Although the Wadi Arab wells will still be in the exploitable zone, yields will decline significantly compared to now.
The wellfields most severely affected will be (Figure 100):

- Wadi Al Arab wellfield (Irbid water supply) > high loss of production
- Kufr Assad wellfield (Bani Kenana water supply) > high loss of production
- Mandah wellfield (Koura water supply)
- Deir Abu Said wellfield (Koura water supply)
- Hakama wellfield (Irbid water supply) > dry
- Nueime wellfield (local water supply)
- Sama As Sarhan, Somaya, Mughayer As Sarhan wellfield (local water supply)
- Zaatari wellfield (Irbid/Mafraq water supply) > dry
- Aqeb wellfield (Irbid/Mafraq water supply) > high loss of production
- Corridor wellfield (Irbid/Mafraq and Zarqa water supply) > high loss of production

The ability to use surface water resources from the Yarmouk River via the Manshieh intake in the KAC, highly depends on the future situation in Syria and the climate change impact. It must be anticipated that much less water will be available from this source, and this should be taken into account in all related planning. In any case, water from Yarmouk River that would be used for water supply of the northern governorates would not be available further downstream for water supply of Amman.

Central Jordan

Vast areas will be affected by water level decline due to the low gradient in the geological structure. Many wellfields in this area which currently provide water to Karak or Tafileh will be dry. The most severely affected wellfields will be (Figure 101):

- Siwaqa wellfield (Amman water supply) > high loss of production
- Qatrana wellfield (Karak water supply) > high loss of production
- Ghweir wellfield (Karak water supply) > high loss of production
- Mhay wellfield (Karak water supply) > high loss of production
- Zabda wellfield (Tafilah water supply) > dry

This means that most of the currently existing small to mid-size wellfields along the desert highway would be more or less out of use by 2040.

Water supply of Amman and Balqa depend on use of Yarmouk River water via KAC. As mentioned above, future reduced availability must be considered in any related planning.

Southern Jordan

Due to the relatively high gradient in the geological structure, smaller areas will become dry because of water level decline. Some wellfields in this area which currently provide water locally or to Maan will be dry. The most severely affected wellfields will be (Figure 102):

- Qaa Maan wellfield (local water supply) > high loss of production
- Shobak wellfield (local water supply) > high loss of production

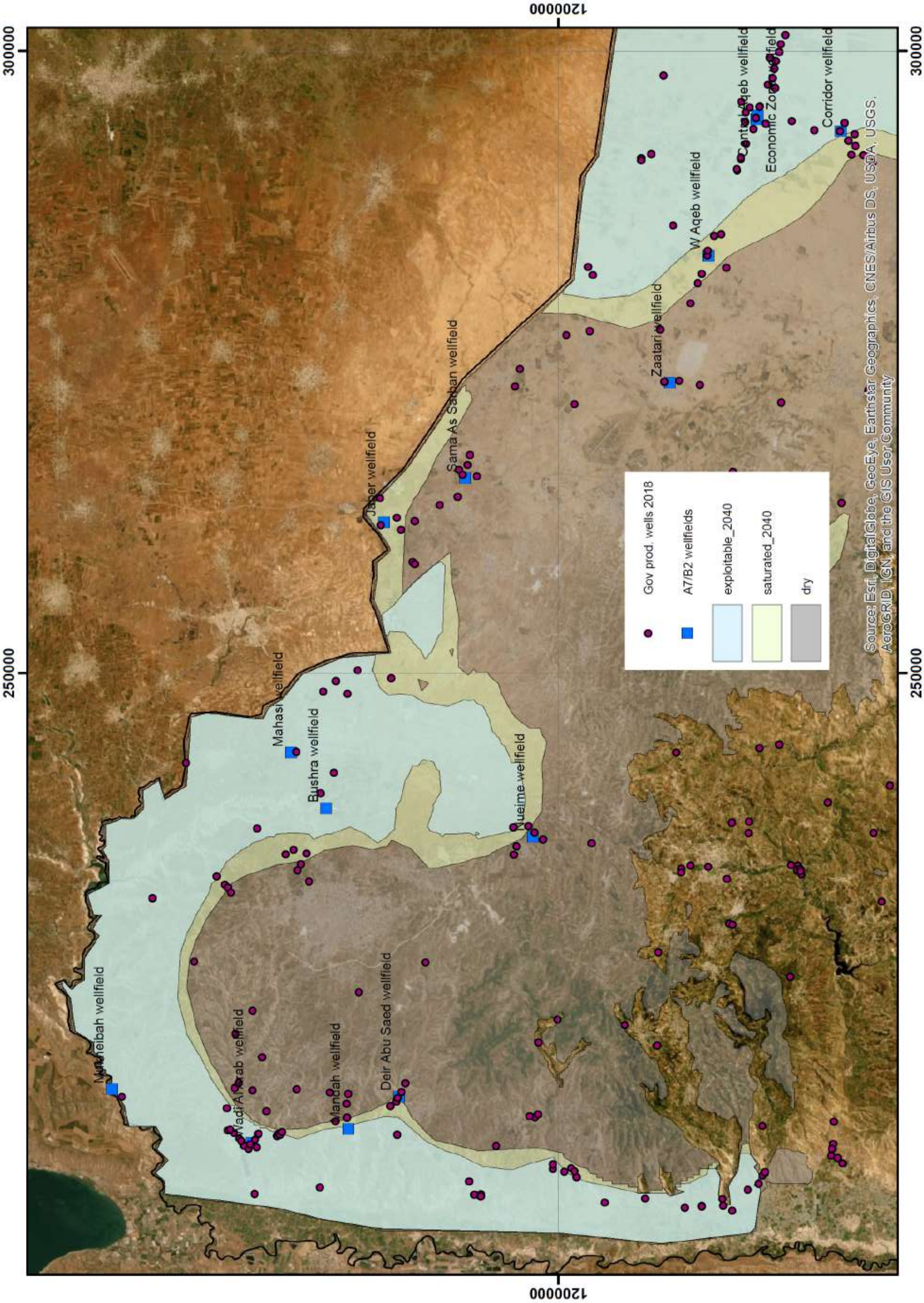


Figure 100: Areas Saturated and Exploitable in 2040 in Northern Jordan (area around Irbid/Mafraq)

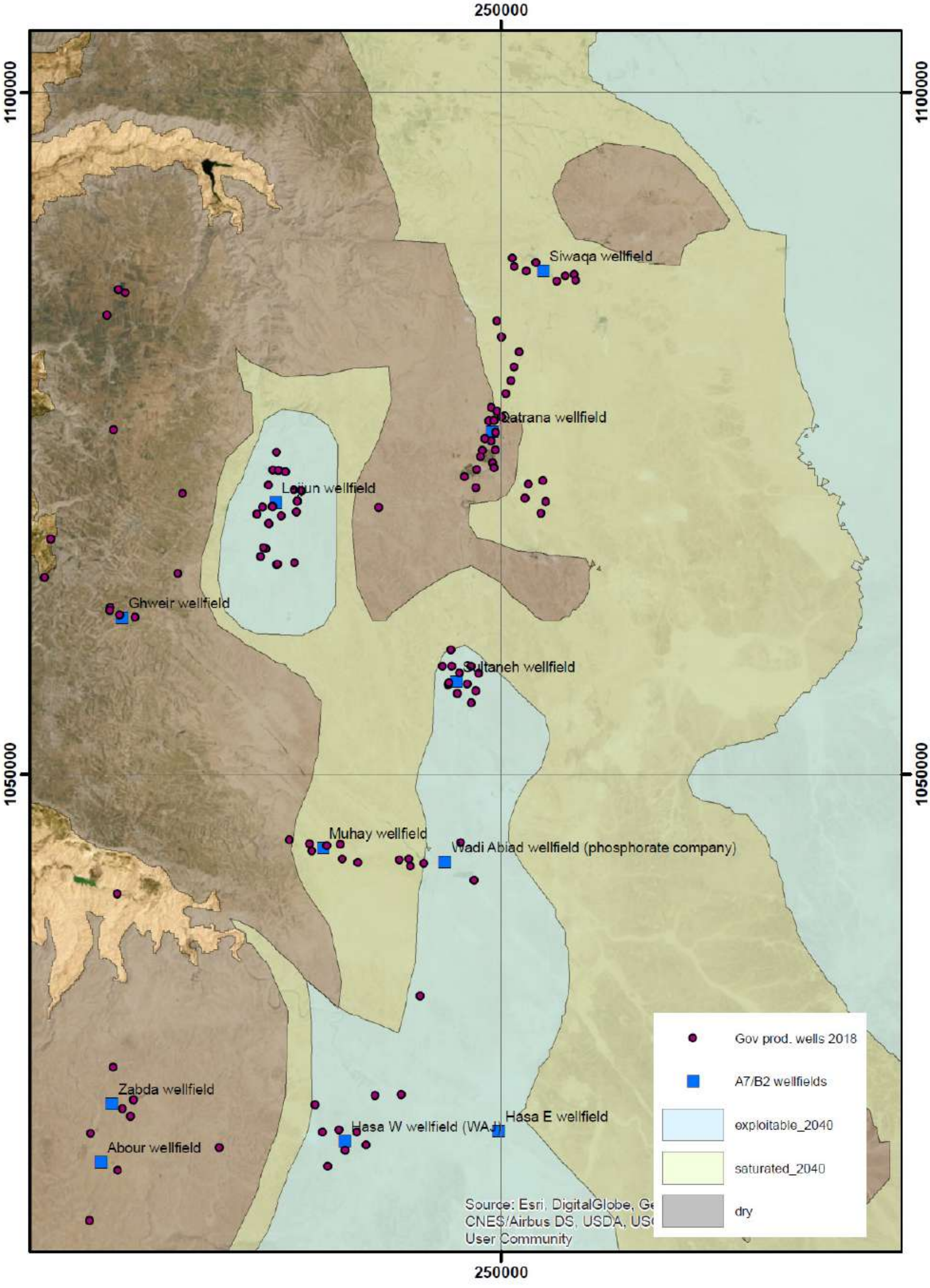


Figure 101: Areas Saturated and Exploitable in 2040 in Central Jordan (area around Qatrana)

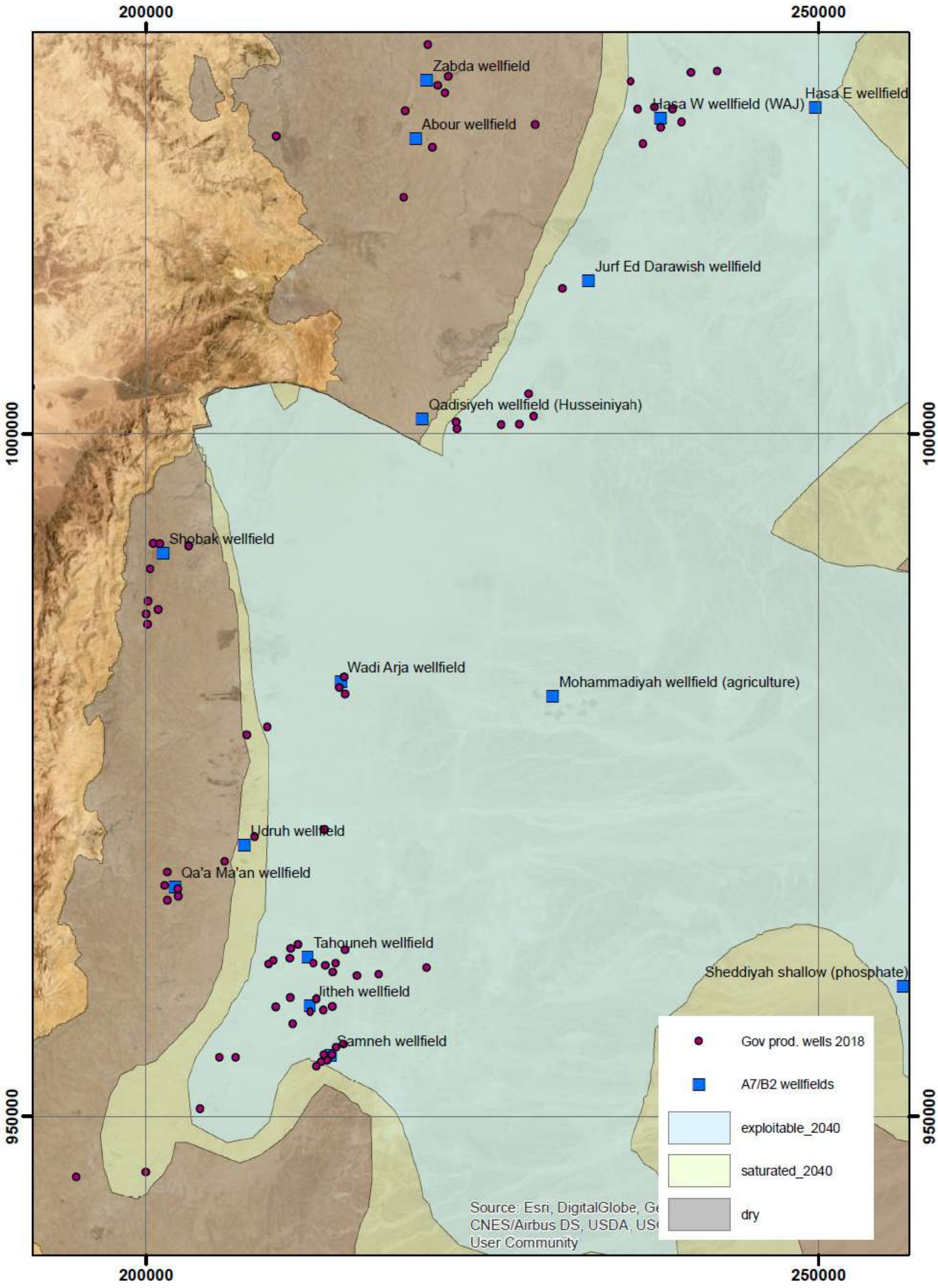


Figure 102: Areas Saturated and Exploitable in 2040 in Southern Jordan (area around Maan)

5.3 Water Supply Infrastructure Gaps

In Chapter 4.3 the municipal water supply requirements were analyzed.

Based on these, **the forecast of the amounts additionally needed by 2040 is shown below in Figure 103 as well as in Table 66, Table 67, and Table 68.** Two scenarios are used:

- <u>Business as usual</u> (BAU) – more likely (Table 67);
- <u>NRW reduction</u> (0.5%, 1%, 2%) – less likely (Table 68).

In the BAU scenario, 811 MCM would be needed for municipal water supply in 2040. Resources available from groundwater and surface water will decrease to 280 MCM in 2040, which means that the supply gap will be around 531 MCM. Based on current planning, up to 297 MCM could be provided through new projects. In this case, the supply gap would be only around 234 MCM. However, implementation and timing of these projects depend on availability of related funding.

The water augmentation projects considered are:

- AAWDC phase 1: 150 MCM (2026), phase 2a: 200 MCM (2031), phase 2b: 250 MCM (2036)
- Basalt Wellfield: 15 MCM (2023)
- Hasa Sheddiyyah, Lot 4 (Khan Az Zabib), phase 1: 7 MCM (2023), phase 2: 20 MCM (2028)
- Hisban wellfield and desalination plant (BOT): 10 MCM (2023)
- Azraq Deep Aquifer: 10 MCM (2028)
- Hasa Sheddiyyah, Lot 3: 20 MCM (2034)

Total: up to 297 MCM as of 2034.

Historically seen, NRW has remained constant at around 50% over the past 30 years. Even if NRW measures were implemented, it is unlikely that a lasting reduction could be achieved; mainly as a consequence of future required network expansions and lacking proper pressure management. This component should, however, not be neglected.

The forecast also contains a scenario without transfers and one with transfers (remaining constant); however, this is also highly unlikely, as competition over the scarce resources will rather increase.

The resources availability and supply requirement forecasts are shown in Figure 103 and Table 69.

The resources availability and supply requirement forecasts are shown in Figure 103 and Table 69.

In order to show the deficits by region, the <u>future needed amounts</u> in the years 2030 and 2040 are presented in the form of maps for the 2 scenarios (<u>Figure 104 to Figure 107</u>).

In view of the development of resources and supply requirements, it is of utmost importance to commence setting up a proper allocation mechanism, by which water allocation decisions are coordinated regularly (at least once a month) among all relevant parties. To this end, it is recommended to establish an <u>Allocation Committee</u>.

The decline in water resources availability and population growth will have the following effects on the governorates. Two scenarios are considered here, a business-as-usual scenario (BAU) (Table 66) with no reduction in NRW (as was the case throughout the past decades) and a NRW-reduction scenario (Table 68), which is, however, less likely. The related chart is shown in Figure 103.

The vulnerability of individual supplies is summarized in the graphics in Annex 7, where the depletion of local water supply sources is shown in connection with the entire supply network.

Another factor which will affect future demand is residential growth areas. Since these have not yet been confirmed with the Greater Amman Municipality (GAM) and the Ministry of Local Administration (MoLA), no statement can yet be made on the upgrades and extensions of the network that will be needed. This could possibly be included in the WMI Infrastructure Master Plan, and then included in the NWMP-3 document volume E, Water Supply Infrastructure.

Many areas already are undersupplied due to reduced conventional resources availability, and this is likely to get worse. These are:

- Irbid governorate
- Mafraq governorate
- Karak governorate
- Tafilah governorate
- Maan governorate

It is suggested to link these regions to water supply from the Aqaba-Amman Water Desalination and Conveyance (AAWDC) project, also called National Conveyor.

Many areas depend on only one source of water supply, and are not linked to other sources. Since water quality impacts may compromise this single source, contingency planning must be considered in the future. This is particularly the case in:

- Ajloun governorate (high dependency on external sources conveyed from Irbid/Houfa).
- Jarash governorate (high dependency on external sources conveyed from Irbid/Houfa).
- Madaba governorate (high dependency on water from Hidan wellfield; frequently compromised due to high turbidity).
- Salt governorate (high dependency on water from local springs; frequently compromised due to microbiological contamination).

It is suggested to link these to water supplies from alternative sources.

Table 66: Forecast of Supply Requirement until 2040 by Governorate (part 1) – Current Supply and Development of Production

Governorate	Current total production [2018] * **	Future expected remaining production [2020]	Future expected remaining production [2025]	Future expected remaining production [2030]	Future expected remaining production [2035]	Future expected remaining production [2040]	Net Water from Transfers	Current total supply received [2018]*	Current supply requirement [2018]
Irbid	46,389,473	36,866,869	20,376,145	13,307,277	9,339,947	6,239,164	7,377,628	53,767,101	102,588,551
Mafraq	34,415,531	23,993,559	15,569,821	9,625,934	6,604,400	4,899,229	-5,761,856	28,653,675	30,145,040
Ajloun	3,353,682	3,287,948	3,124,468	2,960,872	2,797,244	2,633,833	2,386,945	5,740,627	9,282,007
Jerash	5,644,683	5,333,483	4,550,870	3,770,886	2,990,998	2,209,377	2,603,323	8,248,006	11,330,130
Amman	236,824,199	233,224,626	224,408,032	216,454,380	209,710,456	203,650,344	-40,834,139	195,990,060	276,181,159
Zarqa	41,519,756	36,957,465	28,157,790	19,992,149	16,512,696	14,090,628	21,848,929	63,368,685	80,974,918
Balqa	15,445,397	14,764,854	13,099,229	11,432,026	9,763,668	8,441,245	26,941,681	42,387,078	36,605,161
Madaba	11,003,747	10,892,976	10,617,310	10,536,357	10,536,357	10,536,357	-1,111,140	9,892,607	9,970,780
Karak	25,667,941	23,381,428	17,963,075	13,622,221	10,383,496	8,108,783	-2,931,877	22,736,064	20,555,273
Tafileh	6,821,491	5,604,970	3,190,783	1,637,361	717,055	355,646	-14,278	6,807,213	6,378,964
Maan	15,671,049	11,021,790	4,777,246	2,755,238	1,483,450	906,395	-1,131,428	14,539,621	10,053,574
Aqaba	17,779,208	17,749,799	17,676,444	17,603,135	17,566,339	17,563,645	6,704,101	24,483,309	23,946,931
Total	**460,536,157**	**423,079,767**	**363,511,213**	**323,697,836**	**298,406,106**	**279,634,646**	**16,077,888**	**476,614,045**	**618,012,489**

* Supply in 2018 included 17 MCM from private wells; MWI intends to phase out from this kind of supply; amounts are therefore not considered in future years

** brine rejection and treatment losses constituted about 2.3 MCM in 2018; these are considered in future years

Table 67: Supply Requirement Forecast until 2040 by Governorate (part 2) – Business As Usual Scenario – without Transfers/with Transfers

Governorate	Future expected supply requirements [2020] -BAU	Future expected supply requirements [2025] -BAU	Future expected supply requirements [2030] -BAU	Future expected supply requirements [2035] -BAU	Future expected supply requirements [2040] -BAU	Future additional needed amount [2030]-BAU ***	Future additional needed amount [2040]-BAU ***	Future additional needed amount [2030]-BAU ****	Future additional needed amount [2040]-BAU ****
Irbid	107,062,391	117,517,891	127,710,243	132,054,326	136,786,517	114,402,966	130,547,353	107,025,339	123,169,725
Mafraq	31,572,536	34,970,102	38,315,574	39,757,186	41,443,360	28,689,640	36,544,131	34,451,496	42,305,987
Ajloun	9,743,837	10,839,327	11,949,391	12,843,175	13,805,832	8,988,519	11,171,999	6,601,574	8,785,054
Jerash	11,916,432	13,302,745	14,674,524	15,843,666	17,100,688	10,903,638	14,891,311	8,300,315	12,287,988
Amman	285,285,730	305,579,567	324,793,772	333,653,465	342,410,131	108,339,392	138,759,787	149,173,531	179,593,926
Zarqa	84,356,221	92,280,409	100,061,080	105,097,861	110,179,849	80,068,931	96,089,221	58,220,002	74,240,292
Balqa	38,198,102	41,922,471	45,671,819	48,772,027	52,076,809	34,239,793	43,635,564	7,298,112	16,693,883
Madaba	10,345,580	11,154,563	11,947,805	12,536,085	13,182,465	1,411,448	2,646,108	2,522,588	3,757,248
Karak	21,370,550	23,257,299	25,187,893	26,802,142	28,496,831	11,565,672	20,388,048	14,497,550	23,319,925
Tafileh	6,672,489	7,351,030	8,016,649	8,619,604	9,255,142	6,379,288	8,899,496	6,393,566	8,913,774
Maan	10,531,654	11,645,085	12,723,854	13,585,060	14,499,319	9,968,616	13,592,924	11,100,044	14,724,352
Aqaba	24,800,542	26,652,609	28,501,380	30,117,351	31,879,910	10,898,245	14,316,265	4,194,144	7,612,164
Total	**641,856,067**	**696,473,098**	**749,553,984**	**779,681,947**	**811,116,853**	**425,856,149**	**531,482,207**	**409,778,261**	**515,404,319**

*** not considering transfers.

**** considering transfers as constant (highly unlikely).

Table 68: Supply Requirement Forecast until 2040 by Governorate (part 3) – NRW Reduction Scenario – without Transfers/with Transfers

Governorate	Future expected supply requirements [2020] -NRW Reduction	Future expected supply requirements [2025] -NRW Reduction	Future expected supply requirements [2030] -NRW Reduction	Future expected supply requirements [2035] -NRW Reduction	Future expected supply requirements [2040] -NRW Reduction	Future additional needed amount [2030]-BAU ***	Future additional needed amount [2040]-NRW Reduction Plan ***	Future additional needed amount [2030]-NRW Reduction Plan ****	Future additional needed amount [2040]-NRW Reduction Plan ****
Irbid	105,589,450	112,300,975	118,707,825	119,788,490	121,436,568	105,400,548	115,197,404	98,022,920	107,819,777
Mafraq	30,860,938	32,476,321	34,047,550	34,002,132	34,280,782	24,421,616	29,381,553	30,183,472	35,143,409
Ajloun	9,657,885	10,527,324	11,437,393	12,189,966	13,000,160	8,476,522	10,366,327	6,089,577	7,979,382
Jerash	11,825,237	13,013,662	14,237,856	15,253,203	16,343,059	10,466,970	14,133,682	7,863,647	11,530,359
Amman	282,053,033	294,343,597	305,738,974	307,755,277	310,719,696	89,284,594	107,069,352	130,118,733	147,903,491
Zarqa	82,901,885	87,186,900	91,349,048	93,108,233	95,067,706	71,356,899	80,977,078	49,507,970	59,128,149
Balqa	37,338,981	38,938,869	40,594,085	41,725,003	43,092,470	29,162,059	34,651,225	2,220,378	7,709,544
Madaba	10,225,648	10,735,264	11,231,655	11,542,379	11,936,974	695,298	1,400,617	1,806,438	2,511,757
Karak	20,933,911	21,746,756	22,622,634	23,243,446	23,967,023	9,000,413	15,858,240	11,932,290	18,790,117
Tafileh	6,561,398	6,958,678	7,340,953	7,666,777	8,024,099	5,703,592	7,668,453	5,717,870	7,682,731
Maan	10,286,720	10,789,544	11,265,574	11,563,925	11,926,163	8,510,336	11,019,768	9,641,764	12,151,196
Aqaba	24,720,128	26,359,880	27,981,694	29,363,484	30,878,613	10,378,559	13,314,968	3,674,458	6,610,867
Total	**632,955,214**	**665,377,770**	**696,555,242**	**707,202,315**	**720,673,314**	**372,857,406**	**441,038,668**	**356,779,518**	**424,960,780**

NRW reduction: 0.5%/1%/2% depending on actual NRW class
*** not considering transfers
*** considering transfers as constant (highly unlikely)

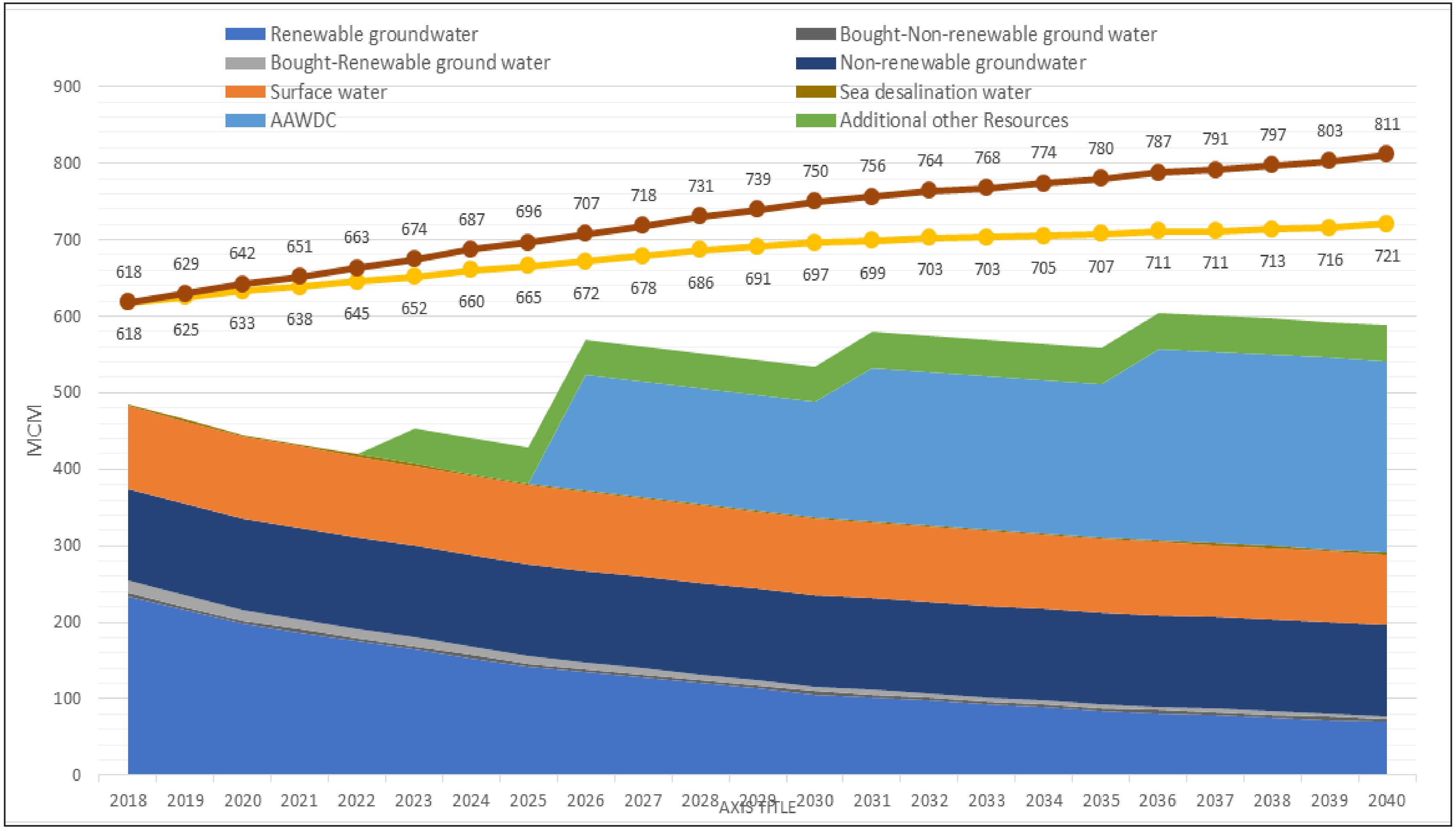


Figure 103: Forecast of Development of Water Resources Availability, Supply Requirement and Supply Gap 2018-2040 (BAU and NRW Reduction Scenario)

Table 69: Forecast of Development of Water Resources Availability, Supply Requirement and Supply Gap 2018-2040

Resources Development						
Year	**2018**	**2020**	**2025**	**2030**	**2035**	**2040**
Renewable groundwater	234	198	142	106	85	69
Non-renewable groundwater	119	119	119	119	119	119
Surface water	108	107	103	99	96	92
Bought-renewable groundwater	17	14	10	6	5	4
Bought-non-renewable groundwater	4	4	4	4	4	4
Desalinated seawater	3	3	3	3	3	3
AAWDC	0	0	0	150	200	250
Additional other resources	0	0	47	47	47	47
Total Resources	**486**	445	428	535	558	**588**
Supply Requirement (BAU scenario)	**618**	642	696	750	780	**811**
Supply Requirement _(NRW reduction Scenario)	618	633	665	697	707	721
Deficit in MCM/a _BAU	**132**	197	268	215	221	**223**
Deficit in MCM/a _NRW reduction	132	188	237	162	149	132

* There are about 1.3 MCM difference between Aqaba total production and supply in 2018 to be clarified in next reports.

- Springs forecasted quantities are part of the groundwater forecasting with 15% decline.
- Bought renewable groundwater quantities (Private wells) are included in the forecasting assumptions.
- Non-renewable groundwater resources (governmental and bought) are considered with constant production until 2040.
- Surface water resources are decreased by 15% until 2040.
- Sea desalination water quantities are considered constant until 2040.

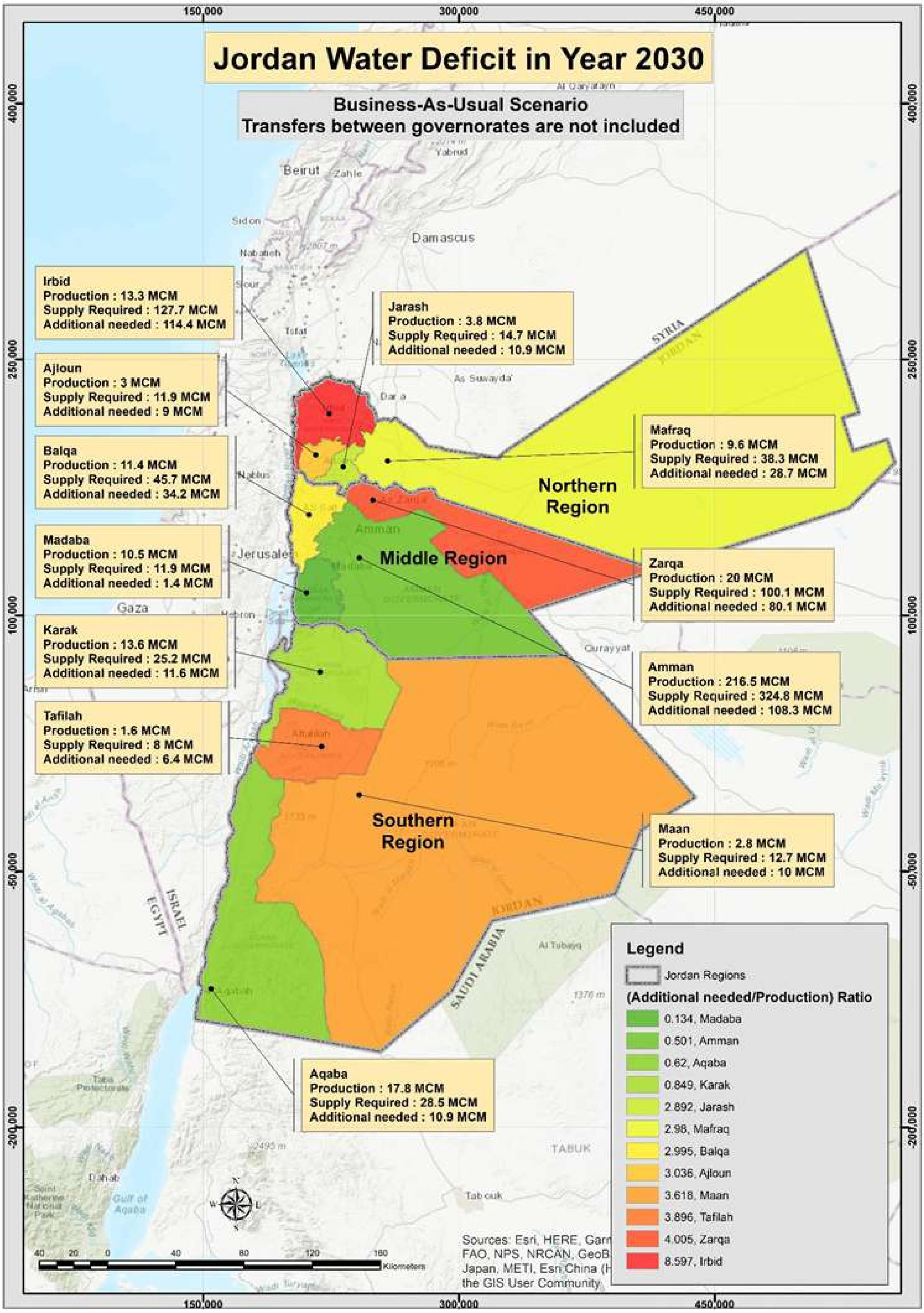


Figure 104: Additional Needed Amounts in 2030 – BAU scenario

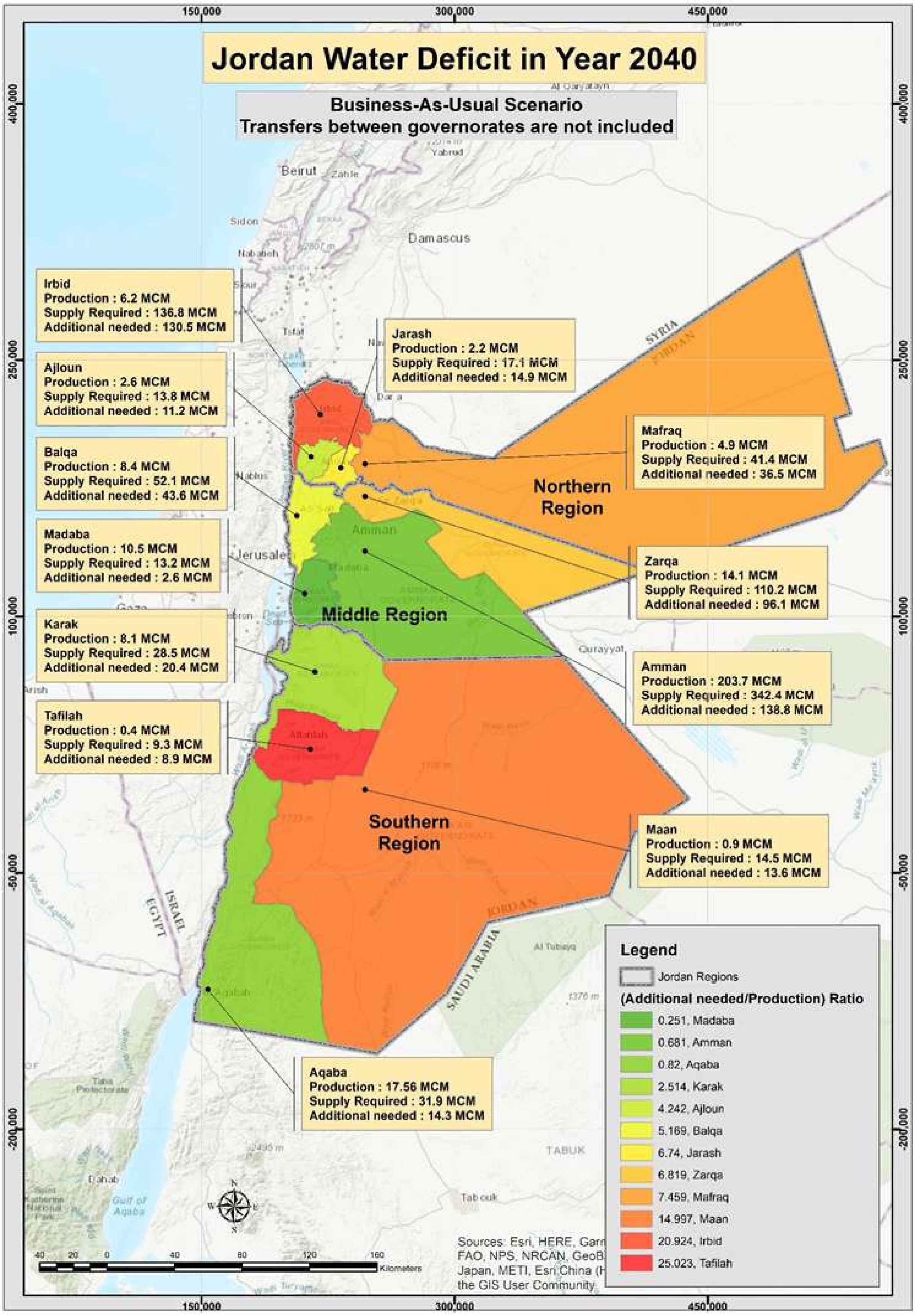


Figure 105: Additional Needed Amounts in 2040 – BAU scenar

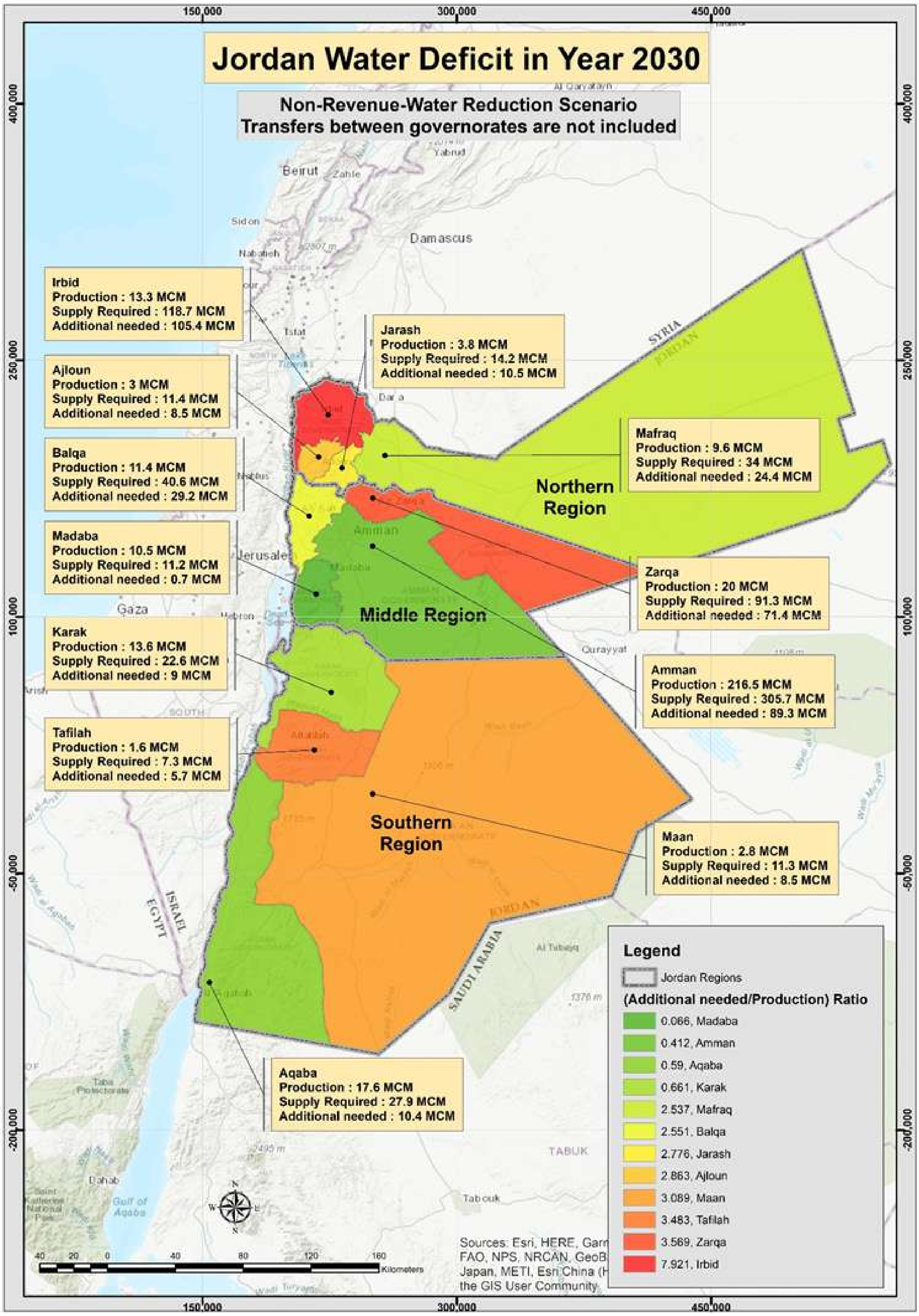


Figure 106: Additional Needed Amounts in 2030 – NRW reduction scenario

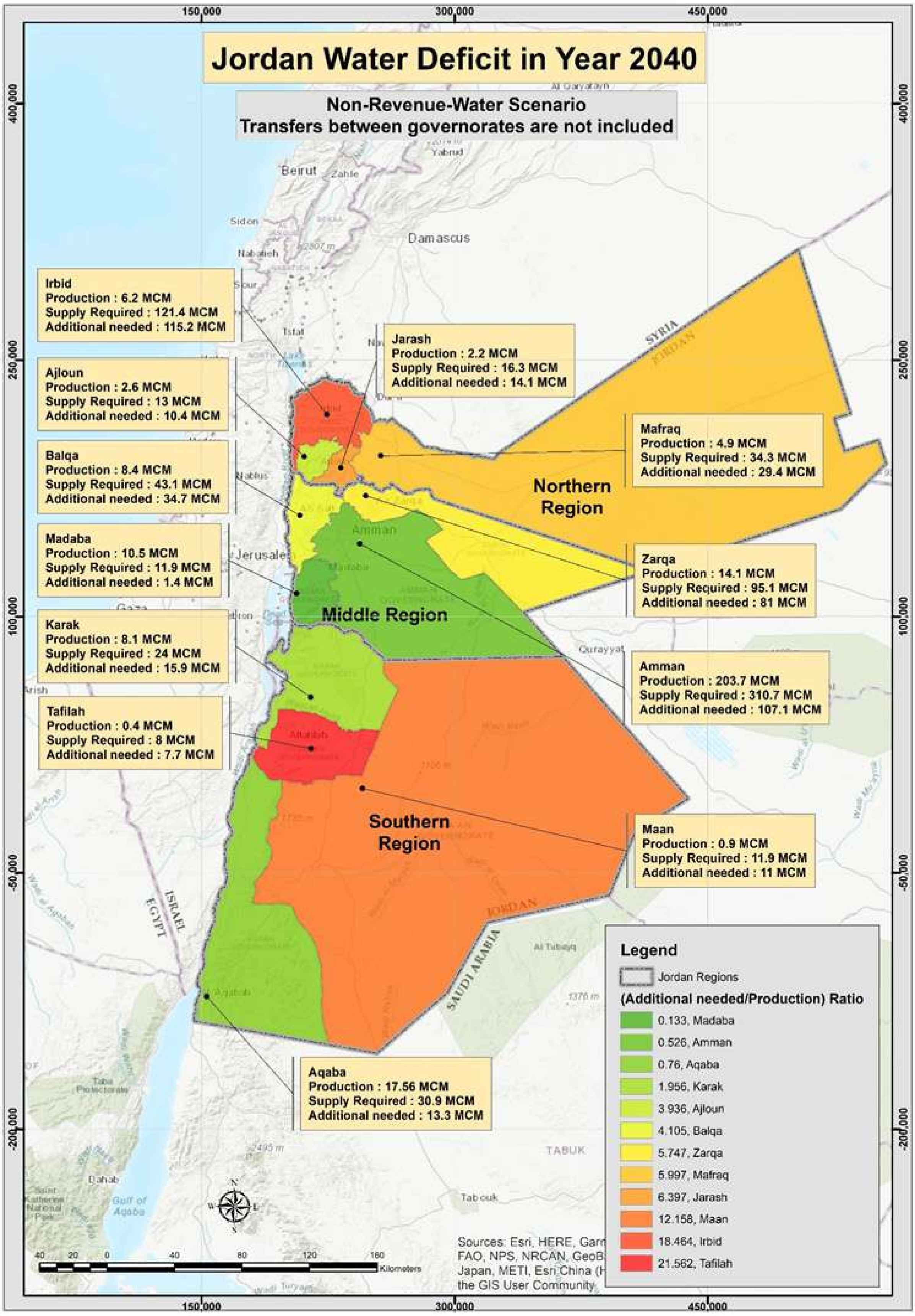


Figure 107: Additional Needed Amounts in 2040 – NRW reduction scenario

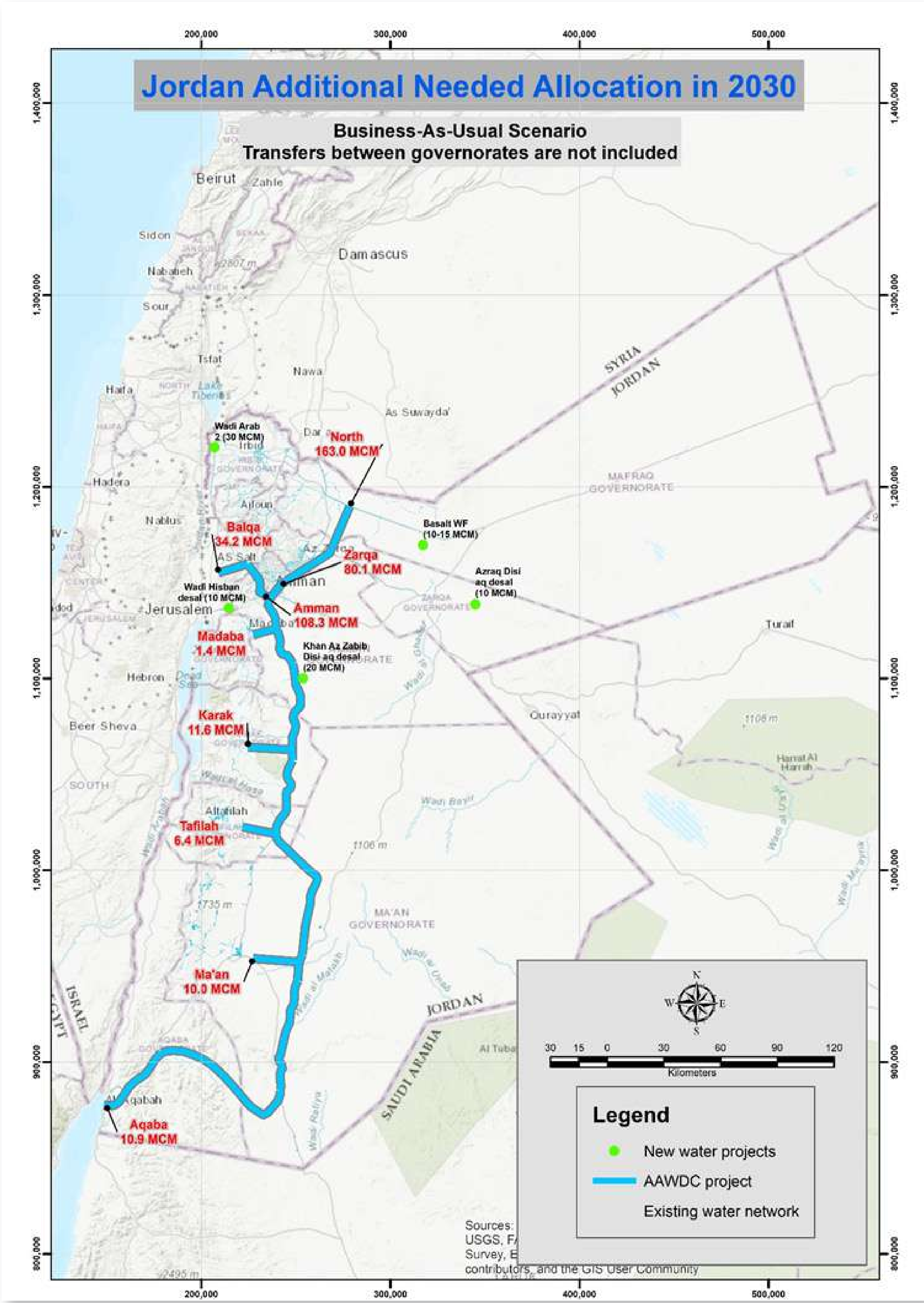


Figure 108: Demand Centers proposed to be connected to the AAWDC Project – Additional needed Amounts in 2030 – BAU scenario

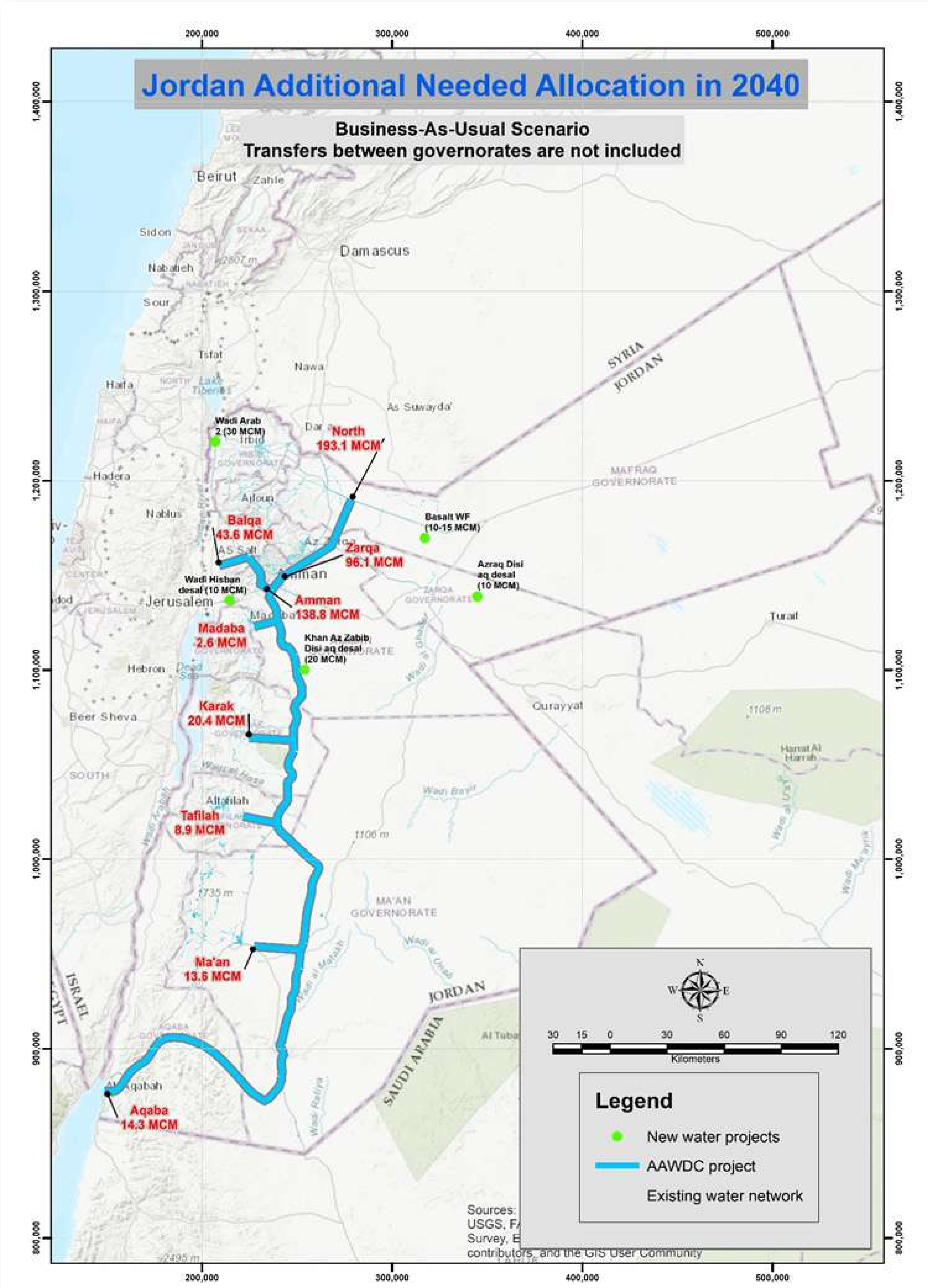


Figure 109: Demand Centers proposed to be connected to the AAWDC Project – Additional needed Amounts in 2040

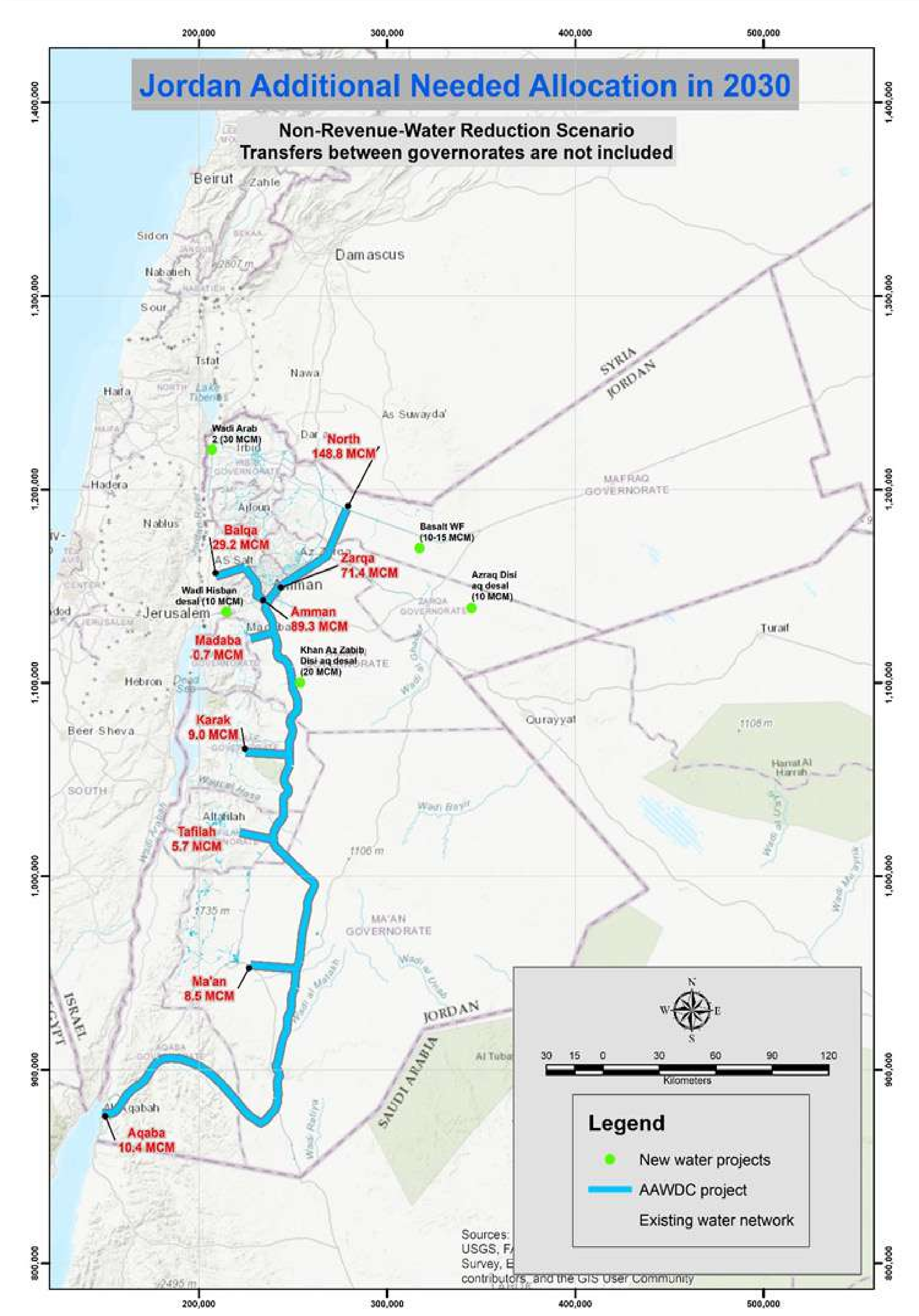


Figure 110: Demand Centers proposed to be connected to the AAWDC Project – Additional needed Amounts in 2030 – NRW reduction scenario

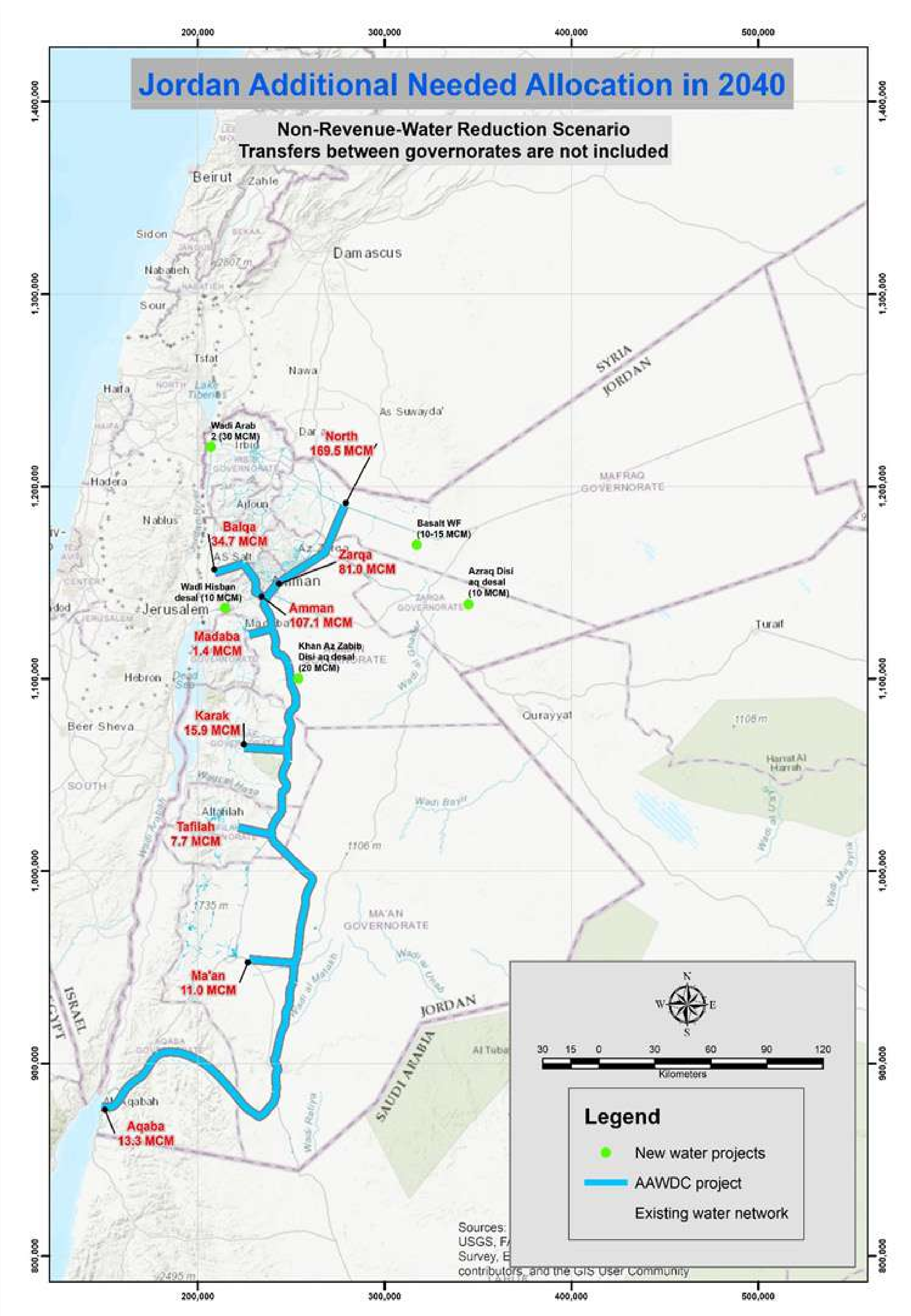


Figure 111: Demand Centers proposed to be connected to the AAWDC Project – Additional needed Amounts in 2040 – NRW reduction scenario

Required actions:

- ➢ Urgent decisions on projects for water supply augmentation are needed. To make related funds available, the share of water versus wastewater projects must be changed; i.e. wastewater must be deprioritized.
- ➢ The large supply gaps expected until 2040 can only be bridged by large-scale desalination projects.
- ➢ With decreasing available amounts and increasing demands, water allocation from the existing sources will become problematic. Allocation rules must be jointly established by all parties, and not by only a few persons as in the past.
- ➢ The prioritization of projects must be based on agreed national criteria.

5.4 Future Required Water Supply Infrastructure

Facts

Most water systems lack a proper a proper hydraulic network analysis. The future required transfers need to be based on such an analysis. This not only to permit transfer but also to save energy.

This chapter is intended to provide answers to the following questions:

- What infrastructure will be needed to meet future needs? (while this document particularly looks at municipal water demands, additional water demands for industrial development or mineral resources extraction (e.g. the mining of oilshale and phosphate) will be examined for the NWMP-3 at a later stage
- How should the Capital Investment Plan be adapted to meet changing conditions?

The projects proposed in the Capital Investment Plan (MWI, 2016) are reviewed in Chapter 7. While a number of projects related to water supply augmentation are useful, **many of the CIP projects are too expensive (cost-benefit), do not have an adequate justification or would not truly augment water supply**.

5.4.1 Transfers to the North

The amounts of water needed for municipal water supply in Irbid, Mafraq, Ajloun and Jarash are in the order of 190 MCM in 2040. Water could be brought from the Basalt Wellfield: 15 MCM.

The currently existing transfer systems are:

- Transfer from Khaw PS to Zaatari PS: 800 mm, design capacity 10 MCM/yr > transfer from Zaatari PS to Houfa reservoir/S Irbid:
    - o 1000 mm pipeline from Zaatari PS to Mafraq Water Administation.
    - o 900 mm from Mafraq Water Adsministration to Um Elolu PS.
    - o 700 mm from Um Elolu PS to Hofa PS.
- ➢ Pipeline diameter and design capacity (currently 35 MCM/yr) need to be considerably increased to allow transfer of ~160 MCM.
- Transfer from Manshiyeh intake station/KAC to Zabda reservoir/W Irbid: : 1200 mm, design capacity 30 MCM/yr.

  maximum intended diversion from KAC: 30 MCM.

5.4.2 Transfers to Amman and Zarqa

The additional amounts needed in Amman and Zarqa are around 139 MCM and 97 MCM, respectively (combined: ~336 MCM). Minor amounts of water could be brought from the following four projects:

- Hasa-Sheddiyyah project, Lot 4: 20 MCM
- Hasa-Sheddiyyah project, Lot 3: 20 MCM
- Hisban Brackish Groundwater Desalination: 10 MCM
- Azraq Disi Aquifer: 10 MCM

(note 1: the modification of the AWSA wellfield described in the Azraq Aquifer Action Plan will not bring any additional amounts of water).

(note 2: the increasing exploitation of radioactive water from the Disi aquifer requires a treatment station for removal of radium as soon as possible).

However, the main amount can only be brought from seawater desalination, i.e. from the AAWDC project. If water from this project is diverted to the southern governorates and the northern governorates, AAWDC phase 2a (200 MCM/yr) should be operational in 2031.

5.4.3 Transfers to Balqa Governorate

The amount needed in Balqa, around 44 MCM, can be generated from local brackish water desalination in the Southern Jordan Valley, currently under investigation.

5.4.4 Transfers to the Southern Governorates (Aqaba, Maan, Tafilah, Karak)

The amount of 14.3 MCM need in Aqaba can be directly diverted from the AAWDC desalination plant.

- ➢ A related pipeline with PS to transfer this amount is needed.

The amounts of 13.6 MCM needed in Maan, 8.9 MCM needed in Tafilah, and 20.4 MCM needed in Karak can be directly diverted from the AAWDC pipeline (a diversion from the Disi pipeline would require a modification of the BOT contract).

The additional needed amount of 2.6 MCM in Madaba could be provided from the raised Wala dam.

6 KEY FINDINGS

This Rapid Assessment was conducted between May 2019 and May 2020. It addresses domestic water supply only and is based on existing data/information. The aim was to provide a relatively quick compilation of facts concerning :

→ the development of long-term water resources availability and exploitability.
→ a forecast of future water demand.
→ an evaluation of which existing infrastructure would still be needed/in operation, due to depletion of resources, i.e. which infrastructure needs to be maintained until 2040.
→ what projects are required to maintain water supply security.

These facts would then allow investment planning until 2040 to be updated.

Both surface and groundwater resources will lose 15% of their potential by 2040, due to **climate change**. This means that the potential for groundwater exploitation will decline from 280 to around 240 MCM/yr, and the potential for surface water exploitation will decrease from around 400 MCM/yr to around 340 MCM/yr. Climate Change impacts must therefore be considered in the planning processes.

Due to decades of overabstraction and little prospect that this will significantly change, **exploitability of groundwater resources will drastically decrease** between now and 2040. Large parts of the main exploited aquifers will run dry and no longer be exploitable. Only 35% of current production will be available, and in the northern parts only around 15%.

Therefore, the way we currently use groundwater for domestic water supply will drastically change. **Major wellfields** in the north (e.g. Wadi Al Arab, Aqeb) **will either provide almost no water, be affected by water quality deterioration, or extraction will become too expensive** (because water levels will be extremely deep) compared to other resources. The same is true for all the major wellfields along or near desert highway (Siwaqa, Qatrana, Lajjun, Sultani, Hasa, and all wellfields in Maan).

In 2040, 811 MCM will be needed for municipal water supply. Resources available from groundwater and surface water will decrease to 280 MCM in 2040 (35%), which means that the supply gap will be around 531 MCM (65%). Based on current planning, up to 297 MCM could be provided through new projects. In this case, the supply gap would be only around 234 MCM (29%). However, implementation and timing of these projects depend on availability of related funding.

The only long-term alternative is desalination from brackish and seawater. In term of budget allocation, **the water sector should focus on projects that provide large additional amounts of water for domestic water supply**. Unless negotiations with neighboring countries are successful in bringing significant amounts of water to the north, **increased water transfers to the north will be needed**. This will require changes in the setup of the **national water conveyance system, with much higher transfer capacities** towards the governorates of Irbid and Mafraq.


Dead Sea Gypsum

7 INVESTMENT PLANNING

A coordinated planning of projects is still the exception. Most projects do not have a proper description of areas, boundaries, goals, indicators, beneficiaries, planning criteria, etc. All projects should have a project brief containing all related information, in addition to what is the current status of the investigation or proposal, what is the suggested funding and most importantly what is the justification. Many projects are planned without looking at the effects on other plans or processes or downstream impacts. A Joint Planning Committee was set up and will hopefully continue to update the list of planned water sector investment projects. This Chapter contains a proposal of a modification of the CIP, based on the meetings conducted until now and a proposed Project Evaluation, Ranking and Prioritization System.

7.1. Review of Planned Projects

The Capital Investment Plan of 2016 asked for an investment volume of 3.5 B JOD for water projects and 1.9 B JOD for wastewater projects. Including energy projects, the total requested investment was around 6 B JOD. While some of these projects were implemented, in reality the CIP was hardly used for project implementation since most of the proposals were only vague concepts with very little information on what they would do, and no realistic evaluations of the costs and facts through feasibility studies. This did not convince donors to invest in such proposals.

Regarding water supply, the CIP's focus was on improving the distribution system and reducing water losses. It aimed at reaching an average water supply of 105 l/c/d, and reducing NRW to 30%. Five years into the CIP 2016-26, we are still more or less at the starting point with no reduction in NRW and no increase in average water supply. On the contrary, water supply security and supply frequency has decreased in many areas, particularly the North.

Regarding wastewater, projects were adopted from the CIP for the 2014 ISSP Wastewater Master Plan. This called for all localities with over 5,000 inhabitants (at that time 173) to be served by WWTPs by 2035. This plan is highly unrealistic and would result in extremely high additional operational costs, which could not be covered by the Water Utilities. Future operational costs are not addressed in either projects planning or the CIP. The CIP also aimed to increase the amount of treated wastewater by around 94 MCM, but this plan was based on a demand of 80/100/120 l/c/d and an assumption of a 20% loss at household level, unlike in projects planning, where actual consumptions are used instead. Losses in the wastewater collection network, which normally constitute around 15% under the conditions prevailing in Jordan, were also not considered, as was the fact that many households do not connect to the sewer network as this costs money. As a result, the capacities of WWTPs are often oversized.

King Abdullah Canal – Bridge Crossing
Northern Jordan Valley Side Wadi

The CIP suggested the following projects and amounts; Table 70:

- → Projects for water supply: 3.5 B JOD, of which:
  - o 740 M JOD were planned for improvements in the domestic water supply network, meters replacements, water loss reduction etc.
  - o 2.37 B JOD were planned for water supply augmentation projects
    - ▪ of this, 650 (phase 1) and 1,312 M JOD (phase 2) (total ~2 B JOD) for the Red Sea Dead Sea Water Conveyance Project
    - ▪ of this, 292.4 M JOD was for 13 new dams, four in Wadi Araba/Aqaba area where variation in flow is extreme and evaporation and siltation are extremely high (meaning that these investments do not seem justified)

        - of this 60 M JOD for the Wadi Araba Integrated Development Project (for irrigation; not enough water to support the planned irrigation sites; no studies available)
    - 231 M JOD were planned for projects of water supply in remote areas (nomadic)
    - 208 M JOD for feasibility studies, detailed design studies and supervision of implementation, as "technical assistance" component
- → Projects for wastewater treatment and treated wastewater reuse: 1.9 B JOD, of which:
    - 424 M JOD for projects in Amman;
    - 313 M JOD for projects in Zarqa;
    - 397 M JOD for projects in Irbid and Mafraq;
    - 321 M JOD for projects in Balqa;
    - 151 M JOD for projects in Karak.

Most proposed dam projects have no reasonable sustainability perspective, inflow amounts are not properly assessed, the national benefit is unclear, and costs do not justify the investment, in particular as and the use purpose mostly is irrigation (Table 71).

Despite being listed in the CIP, many of the projects do not provide any additional amounts of water, and many of the project briefs can be misinterpreted in this sense: e.g. neither the Amman Customers Meters Replacement project (page 90) nor the Improvement of Amman Governorate Water Network - Phase Two project provide the additional 80 MCM or 45 MCM of water that they claim (the same is true for Abu Zighan, Wadi Arab II, etc.).

Looking at what has been achieved over the past 5 years, it becomes obvious that the main issue that must be addressed with highest priority is the augmentation of water supply. Only 3% of the targeted supply amount has been reached, and many of the related projects show little progress (Table 70).

The CIP does not explain the strategic objectives and national benefit anticipated for the high expenses that are planned in remote areas. Much of the amount "allocated" by the related measures is actually lost through evaporation within a short time, and so is hardly justified.

Projects in the Jordan Valley and elsewhere for treated wastewater reuse are not directly linked to projects for wastewater treatment. In the future, there should be a direct link between such projects to ensure that treated WW is not generated without being reused. The projects list must directly specify which projects are linked.

Most wastewater projects do not give a specific justification for why they are needed (which would generally be to protect the health of water resources). In many cases this general justification does not actually apply, particularly in places where the exploited groundwater resources cannot be contaminated because they are naturally protected through an aquitard (e.g. Bani Kenana or Ramtha projects). Describing geology and groundwater vulnerability (BGR, 2017) must be made obligatory in all related documents, which is currently the exception rather than the rule.

These are just a few facts to illustrate the fact that planning for the listed projects was not done in a coordinated manner to fulfil common objectives, but rather each entity planned towards its own ends. To avoid this in the next CIP, the Joint Planning Committee was founded in December 2019 and is facilitated by the GIZ Master Plan activity. The aim is to jointly agree on investment planning for the entire sector through discussions about the relevance and benefit of each project.

Although **projects related to water sector governance were totally neglected in the CIP 2016**, they are urgently needed to manage, monitor, and protect water resources correctly. It is suggested that such projects should be added to the updated list on the following:

Water Governance Projects (MWI, WAJ, JVA):

- **Water resources assessments** (every 5 years), including updated groundwater contour maps;
- **Monitoring** of groundwater abstraction, production from dams, groundwater level, groundwater quality, spring flow, surface water runoff, electricity consumption for water operations;
- **Groundwater protection** measures, including protection zone delineation studies and constructive measures (maintenance and upgrade of spring/well/dam protection perimeters);
- **Annual remote sensing analysis** of groundwater abstraction for irrigation;
- **Upgrade and maintenance** of national water information system (database);
- **Alert system for water scarcity**;
- Upgrade of monitoring and control center in Jordan Valley;
- **Groundwater exploration** (siting and drilling of wells);
- **Capacity building**; and
- **Awareness raising**.

Table 70: Investments by Category planned in the Capital Investment Plan (MWI, 2016)

Category	Planned projects	Additional amount water/treated wastewater	Planned investment volume	Currently implemented projects providing additional water (operational)	Actual Water /wastewater Supplied	Target reached (amount of water)
Governance	-		-	-		-
Improvement of Water Supply	76	422.5 MCM/yr	2.37 B JOD	6	18.5 MCM/yr	**3%**
Marginal Water Resources in Remote Areas	12	36.4 MCM/yr	231 M JOD	1	15 MCM/yr	40%
Collection and Treatment of Wastewater	88	94 MCM/yr	1.9 B JOD	1	35 MCM/yr	37%
Overall		553 MCM/yr			68.5 MCM/yr	**12%**

Table 71: Planned Dam Projects – Feasibility and Long-Term Sustainability

Dams Projects CIP 2016		Additional Water (CIP) (MCM/Yr)	Actual Assumed Amount for Irrigation	Actual Assumed Amount for Domestic Supply	Cost (CIP) (M JOD)	CAPEX/m³ (CIP)	Operational (cip)	Concept or Feasibility Study	Comments	Long-Term Sustainability
5	Kofranjih dam	3	2	1	10	3.3	2020	concept	largely not used due to contamination by wastwater effluent	failed investrnent
6	Mojib dam water treatment,conveyance to Karak	3		0	6	2.0	2019	concept	not operated any longer due to algae and siltation in Mujib dam	failed investrnent
7	Tannour dam water treatment,conveyance to Karak and Tafilah	3		0	10	3.3	2019	concept	will have same problem as ccorvyance to Karak	not given
8	Malaqy dam	10		10	40	4.0	2025	concept	difficult site conditions due to extreme geo-risks high follow -up costs to safeguard installation	
9	Tumout king Talal dam	0		0	2		2020	concept	concept unclear ?	
10	Wadi Hisban dam	5	5		15	3.0	2023	concept	high salinity of source,not justified,uncertain amount ,use for irrigation	not given
11	Wadi Issal dam	2	1		11	5.5	2021	concept	not justified, use for irrigation, uncertain a mount, high anticipated siltation rate	not given
12	Wadi Meddain dam	1.5	1		6	4.0	2021	concept	not justified, use for irrigation, uncertain a mount, high anticipated siltation rate	not given
13	Wadi Tlah dam	0.2	0		3.5	17.5	2021	concept	not justified, use for irrigation and industry,uncertain a mount, high anticipated siltation rate	not given
14	Wadi AL Yutum dam	20	3		100	5.0	2021	concept	not justified, use for irrigation, uncertain a mount, high anticipated siltation rate	not given
15	Wadat dam	0.4	0		5	12.5	2025	concept	not justified, use for irrigation, uncertain a mount, high anticipated siltation rate	not given
16	Sharhabeel dam	0	0		0.4	#DIV/O!	2019	concept	dam has no water, requires sealing of dam structure	

	Dams Projects CIP 2016	Additional Water (CIP) (MCM/Yr)	Actual Assumed Amount for Irrigation	Actual Assumed Amount for Domestic Supply	Cost (CIP) (M JOD)	CAPEX/m^3 (CIP)	Operational (cip)	Concept or Feasibility Study	Comments	Long-Term Sustainability
17	Wadi Rahma dam	0.65	0		3.5	5.4	2022	concept	not justified, use for irrigation, uncertain a mount, high anticipated siltation rate	not given
18	Wadi Moussa dam	2.5	1		8	3.2	2022	concept	not justified, use for irrigation, uncertain a mount, high anticipated siltation rate	not given
19	Wadi Fidan dam	4.4	1		20	4.5	2024	concept	not justified, use for irrigation, uncertain a mount, high anticipated siltation rate	not given
20	Tal Dhahab dam	4	2		25	6.3	2018	concept	no additional water not justified use for irrigation, uncertain a mount, high anticipated siltation rate	
21	150 ponds and desert dams	15	5		20	1.3		concept	no proper cost estimation,no locations	
22	Raising Wadi Shuayb dam	1	1		1	1.0	2021	concept		
26	Raising Wala dam	5.7		0	4	0.7	2022	concept	not additional capacity,Wala dam filled with sediments,will last only afew years,due to high siltation rate,uncertain inflow amount	not given
27	Wala dam water conveyance	2.6				8.0	2025			
	Sum	83.95	22	11	290.4	8.8				
	Outside CIP									
xx	Wadi Karak dam		0				completed 2018		no water stored since completion	not given

7.2 Project evaluation, ranking and prioritization system

Since the Capital Investment Plan (2016) does not attach priorities to projects, there are questions at donor level regarding what the sector's actual priorities are.

For future Capital Investment Planning, it is therefore highly recommended that a ranking of projects based on national priorities is produced. This should be based on clear and transparent criteria (general, social, economic, ecological). The best format for this would be a point-score matrix with a rating scheme and a weighting of criteria.

This requires a proper description of each project's objective and a formulation of its expected:

- Outcomes
- Number of beneficiaries
- Justification
- Future operator
- Capital cost
- Future operational costs (in a standard year)
- Future maintenance costs (in a standard year)

As many projects on the CIP (2016) list are often not even comprehensive concepts, these data will have to be generated by the water sector institutions.

It is proposed to group the Rating Matrix into 4 categories, with separate criteria for each of them:

→ Governance projects
→ Water supply projects
→ Wastewater projects
→ Irrigation and Reuse projects

Cross-cutting issues would be considered for all of them.

The results from the rating matrix (Table 72, Table 73, and Table 74) regarding the extent to which they meet the strategic objectives would be multiplied by weighting factors for these objectives to achieve an overall ranking. This system can be easily modified, once filled with life.

Table 72: General Information for Project Evaluation, Ranking and Prioritization System

Project evaluation, ranking and prioritization system	Status: date	Remark
project name		
project description	enter project description	
area	describe project area (district, villages)	
sector		
status		select from: - concept - feasibility - funding agreement signed - detailed design
goal-1		
goal-2		
indicator-1		only verifiable and achievable indicators
indicator-2		
indicator-3		
capital cost		
annual operational cost 2030		
annual maintenace cost 2030		
number of beneficiaries		

Table 73: Ranking Matrix of Project Evaluation, Ranking and Prioritization System

Ranking	Rating (-2 - +5)	Weighting		Additional information
estimated for 2030	significant adverse effects (high)	weighting factor (0-10)	points	justification
	(-2)			
Governance				
improved understanding of national groundwater system		5	0	
improved understanding of local groundwater system			0	
improved monitoring of water re-sources			0	
improved database			0	
improved well licensing			0	
improved planning			0	
improved allocation			0	
improved GW protection			0	
improved human capacity			0	
improved awareness			0	
overall score			**0**	
Water Supply			**0**	
improved water security (supply as percentage of peak load)		10	0	
improved reliability of water supply (frequency)		8	0	
contingency planning		6	0	
improved water supply service		6	0	
improved water quality (as percentage of average TDS deviation; -50% - + 200%)		6	0	
overall score			**0**	
Sanitation			**0**	
reduced health risk (water related cases)		6	0	
improved protection of exploited water resources (surface and groundwater)			0	
improved sanitation service		6	0	
overall score			**0**	

Ranking	Rating (-2 - +5)	Weighting		Additional information
Irrigation and Reuse			**0**	
improved use of treated wastewater			0	
improved irrigation efficiency			0	
overall score			**0**	
Cross-cutting				
reduced social vulnerability		6	0	
reduced operational cost (cost per m^3)		10	0	
improved revenue		10	0	
affordability (cost per customer)		8	0	
affordability (cost per m^3)		8	0	
reduced energy consumption (kW/ m^3)		10	0	
improved energy efficiency (-20% - +40%)			0	
environmental impacts on water resources)			0	
environmental impacts (noise, air pollution, odor)			0	
standard project description available			0	
recent feasibility study of good quality available			0	
EIA available and accepted			0	
recent detailed design study of good quality available			0	
funding committed			0	
adverse effects if project is not implemented		10	0	
overall score			**0**	
overall project relevance			**0**	

Table 74: Rating Scheme of Project Evaluation, Ranking and Prioritization System

Rating (-2-+5)						
	negative impact	no impact	positive impact			w
significant adverse effects (high)	adverse effects (low)	no relevance	low relevance	moderate relevance	high relevance	very high relevance
-2	(-1)	(0)	(1)	(2)	(3)	(4)

7.3 Proposal for Modified Investment Planning

In view of the development of water resources availability it is highly recommended to shift the focus of investments towards projects that make more water available for domestic water supply. A related proposal is included in Table 75.

Table 75: List of Priority Investments (in order of declining priority)

Priority	Project name/category/objective/ status	Details/source of information	Approx. Capital Cost Date
1	Aqaba Amman Water Desalination and Conveyance (AAWDC) Provision of additional amounts of water for domestic water supply Updated feasibility required due to changed concept	**150/200/250 MCM** (phases 1/2a/2b) With water transfers to: Maan, Tafilah, Karak, Amman, Zarqa, Irbid, Mafraq [MWI & USAID Stakeholders Consultation Workshop; February[2020] [not in CIP 2016]	~1.2 B JOD (phase 1) Phase 1 operational in 2026 > timeline for phase 2 should be pushed to be operational in 2032
2	Basalt Wellfield Provision of additional amounts of water for domestic water supply Feasibility status	20 boreholes, **15 MCM** (2-3 phases) (A7/B2 aquifer) to be allocated to Irbid, Ajloun, Jarash governorates [I-GWRM project, proposed concepts, December 2014 - July 2018] [in CIP 2016]	~20 M JOD Should be operational in 2023
3	Hasa Sheddiyyah, Lot 4 (Khan Az Zabib) Provision of additional amounts of water for domestic water supply Updated feasibility required after end of phase 1	Currently 7 boreholes with max. 7 MCM/yr (phase 1) (Disi aquifer) Complete Lot 4 of total 20 boreholes with **20 MCM** (phase 2) Treatment plant with removal of radioactivity to be allocated to Amman and Zarqa [in CIP 2016]	~13 M JOD (phase 1) ~80 M JOD (phase 2) (13 wells, pre-treatment/Ra removal/desalination/ pipes) Should be operational in 2023
4	Hisban wellfield and desalination plant Provision of additional amounts of water for domestic water supply Feasibility status	14 boreholes, **10 MCM desalinated water**,4 existing boreholes may be used [modified GIZ proposals NWMP-3, May 2019 – February 2020] [in CIP 2016]	~15 M JOD Should be operational in 2023

Priority	Project name/category/objective/ status	Details/source of information	Approx. Capital Cost Date
5	Azraq Aquifer Action Plan **Maintain** domestic water supply/ Provision of additional amounts of water for domestic water supply Detailed design study required	Problem: saltwater intrusion from Azraq oasis (B4 aquifer) Shift AWSA wellfield to NW, (build gallery of defense wells, desalination) Option A: 19.5 – 24 MCM/yr Option B: 17 – 25 MCM/yr (current supply (2018): 17.1 MCM/yr) **0-8 MCM additional water** for Zarqa [I-GWRM project ASD-22 report; October 2017]	Option A: ~57 M JOD **Option B: ~27 M JOD** Should be implemented ASAP
6	Azraq Deep Aquifer Provision of additional amounts of water for domestic water supply Detailed design study required	10 boreholes, **10 MCM** (2 phases) (Disi aquifer) to be allocated to Amman/Zarqa [I-GWRM project, proposed concept February 2018] [not in CIP 2016]	~25 M JOD Should be implemented ASAP
7	Hasa Sheddiyyah, Lot 3 Provision of additional amounts of water for domestic water supply Feasibility study required	20 boreholes, **20 MCM** (2 phases) (Disi aquifer) (near Qatrana) to be allocated to Amman/Zarqa [original proposal: ORIENT (2014): Hydrogeological Assessment of Deep Aquifers Complex in South – Central Jordan; modified by I-GWRM project, 2018] [in CIP 2016]	~100 M JOD Should be implemented ASAP
8	Abiad wellfield Provision of additional amounts of water for domestic water supply Detailed design study required	Conversion of existing wells, used for Abiad mine, to domestic water supply wells, and drilling of additional wells 20 boreholes, **5-8 MCM** (2 phases) [I-GWRM project, proposed concept September 2018] [not in CIP 2016]	~9 M JOD Should be implemented ASAP
9a	Development of Agreed and Harmonized Concept of Wastewater Treatment and Treated Wastewater Reuse in North Jordan (Irbid/Mafgraq) Detailed design study required	Currently not existing, project planning insufficiently harmonized	2 M JOD
9b	Upgrade WWTPs in North Jordan (partially already ongoing) Modified detailed design study required	Only to capacities actually required; Problem: overcapacity; while high BOD load in influent and high TDS in effluent	200 M JOD
9c	Upgrade wastewater collection network in North Jordan (partially already ongoing) Modified detailed design study required	Collection and treatment only where necessary (groundwater vulnerability) and economically feasible (operational costs)	200 M JOD
9d	Final Treatment Plant Northern Jordan Valley with monitoring by WAJ and JVA (handover point to JVA) Detailed design study required		
9e	Freshwater/Reclaimed Water Blending Station & Upgrade Treated Wastewater Distribution Network in Northern and Middle Jordan Valley Detailed design study required		

Priority	Project name/category/objective/ status	Details/source of information	Approx. Capital Cost Date
10	Piped Freshwater Conveyance System in King Abdullah Canal Detailed design study required	From Adassiyeh to Sawalha intake	
11	Upgrade of Monitoring System in Jordan Valley (flows and water quality) Detailed design study required		
12	Upgrade of Monitoring System for all Major Dams (flows, silt accumulation, and water quality) Detailed design study required		
13a	Development of Agreed and Harmonized Concept of Wastewater Treatment and Treated Wastewater Reuse in Central Jordan (Amman/Zarqa/Madaba) Detailed design study required		
13b	Upgrade Khirbet As Samra WWTP (already ongoing)		
13c	Upgrade and combine WWTPs South Amman/Jiza Detailed design study required		
13d	Upgrade wastewater collection network in South Amman Detailed design study required		
13e	Establish Local Treated Wastewater Distribution Network (Madaba) Detailed design study required		
14a	Development of Agreed and Harmonized Concept of Wastewater Treatment and Treated Wastewater Reuse in South Jordan (Karak/Tafilah/Maan) Detailed design study required		
14b	Upgrade WWTPs in Karak/Tafilah/Maan Detailed design study required		
14c	Upgrade wastewater collection network in South Jordan (partially already ongoing) Modified detailed design study required		
14d	Establish Local Treated Wastewater Distribution Network (where feasible regarding groundwater vulnerability) Detailed design study required		


Adassiyeh Weir

8 RECOMNENDATIONS

The following actions should be undertaken to ensure that adequate data is available to make informed decisions.

8.1 Recommendations for Water Resources Management

The preparation of the Annual Water Budget is hindered by lack of cooperation among the involved parties and timely provision of the large amount of required data by all related entities. Templates for all data to be compiled need to be prepared and filled. Data flow processes need to be visualized and deadlines for provision of data must be set. More staff is needed to establish the Annual Water Budget. The same is valid for the next update of the Water Master Plan. Also here, processes are not established and the required staff is not available and trained.

With water resources becoming more scarce, conflicts about water allocation shares will increase. A Water Resources Allocation Committee is needed, which brings together all stakeholders, meets on a monthly basis and decides about the required allocation of water for all sectors.

WEAP has been used since 2008 in the water sector as a tool for water resources budgeting, forecasting and planning of allocation. Integration of WEAP analysis and scenarios in the decision-making process is needed for resources management and investments planning.

Establish a sector-wide GIS unit responsible for collecting, updating and providing GIS data and maps to all water sector institutions and consultants.

Establish a sector-wide digital data and document repository (archive), where all reports prepared by implementing agencies and consultants are stored.

Water resources assessments need to be carried out more often (at least every 10 years) in order to have better information about the status of groundwater and surface water resources.

Planning of water supply and sanitation infrastructure requires a better coordination.

Many groundwater and surface water protection zones have been established over the past 2 decades. However, the proposed actions were not always implemented, and enforcement of protection measures is lacking. More efforts need to be undertaken to protect water resources.

Monitoring of water levels is important for a proper description of the status of groundwater resources. However, most of the essential data, such as water levels, electricity consumption, and production, are either not collected appropriately by water utilities or not passed on the supervising authorities (WAJ, MWI). The mechanism of reporting by the water utilities must be improved.

Monitoring of water quality needs to be improved as water quality changes are expected to impact water resources usability and will require more treatment.

8.2 Recommendations for Wellfields

Wellfields are an important part of the water supply infrastructure. Their maintenance requires a good knowledge of their status. Unfortunately, many of the most basic facts are unknown and there is no “wellfield manager” who would be able to take related decisions for maintenance. Moreover, since Water Utilities do not have a dedicated budget for wells maintenance, most well infrastructure is in a poor condition.

The wells infrastructure has been largely neglected. With few exceptions, there have been no major maintenance measures during the past 30 years. Although many wells are arranged in wellfields, there are still no wellfield managers who would be responsible for their operation, monitoring and maintenance. Wellfield managers should be nominated and given powers to conduct and implement the above-mentioned tasks. **The deterioration of wells infrastructure contributes to the accelerated production decline detailed above.**

8.3 Recommendations for Springs

Little is known and documented about the amounts available from and the quality of springs. Improved monitoring of both is required. In many cases springs are used by water user groups (GTZ, 2005).

8.4 Recommendations for Surface Water Infrastructure

Annual reports should be prepared by JVA, documenting the production and allocation of water from all dams. A separate report should be prepared by JVA, documenting the water resources availability and allocation of water in the Jordan Valley, including the amounts of treated wastewater being made available and those actually used.

8.4.1 King Abdullah Canal

Option 1: conveyance through closed pipe from Adassiyeh until km 65 (Sawalha station/Deir Allah)
Advantages:

→ Reduced leakage loss and theft, no evaporation;
→ All treated wastewater could be distributed through existing canal;
→ No sediment inflow;
→ No wastewater and trash compromising water quality;
→ Improved possibility to monitor flows (requires measurement of flow at all turnouts).

Actions required:

→ New intake station with full sediment removal
→ Construct new pipe
→ Blending station for reuse of treated wastewater
→ New turnouts with flow measurements (all equipped with flow meters)

Option 2: keep infrastructure as is
Disadvantages:

→ High repair and maintenance costs;
→ Repair difficult while in operation;
→ Remaining sediment inflow;
→ Remaining water quality problem through discharge of waste and wastewater into canal.

Actions required:

→ Repair of entire canal to reduce leakage loss;
→ Implement anti-theft program (canal surveillance);
→ Improvement of monitoring of all inflows and abstractions (upgrading all existing stations, install new stations, regular surveys by police unit);

→ Improvement of monitoring of all water quality;
→ Implement and enforce anti-pollution program;
→ Regularly perform routine cleaning of canal sediments and trash;
→ Systematically remove vegetation from the canal;
→ Decrease trash load in the canal (awareness, waste collection).

8.4.2 Dams

The validity of the concept of a dam should be verified before any existing dams are raised or new dams constructed. The sediment accumulation in dams has never been analyzed and must be assumed to already be fairly high (at least 30%). Current analyses of long-term surface water resources availability indicate that their storage potential is already almost fully exploited. While the current dams are located at the most favorable positions, previous construction only permits dams to be raised in a few cases (such as Wala dam).

Since flows are not currently measured, production from the dams is uncertain.
Actions required:

→ Measurement of sediment accumulation in all major dams (entire impoundment area);
→ Reactivation of flow measurements at all major dams.

8.5 Recommendations for Water Supply Planning

Non-revenue water (NRW) constitutes a considerable share. It means on the one hand that a large amount of water is being physically lost before reaching the customer. On the other hand, it means that a large amount of money is not being collected. Reducing NRW should therefore be addressed from the central level, i.e. MWI/WAJ. The past experience shows that that neither measuring success nor long-term sustainability of NRW reduction were provided by the implemented measures.
The related investments must be more targeted to reach

- A continuous and nationwide monitoring of NRW covering all elements from source to customer (currently only part of these components are measured randomly).
- Such monitoring should not be dependent of projects, i.e. foreign donor financing, but rather be implemented from the central level.

Asset management must also be a central process to follow from the central level. Asset management should comprise a central register of all water supply components, i.e. the abstraction, conveyance and distribution network of: wells, pumps, pipes, pumping stations, reservoirs, treatment facilities, meters, their specifications, age and expected lifetime. Based on these a plan of replacement could be established and constantly revised. This would require a new unit at MWI/WAJ.

8.6 Recommendations for Wastewater Treatment

The Water Utilities are unable to carry the enormous cost of upgrading, operating and maintaining the 33 current WWTPs. This suggests that, rather than increase the number of WWTPs, the capacity of the existing ones should be increased, and additional collected wastewater conveyed to them. This is possible in most cases. The Water Utilities only handle the operation and maintenance for the asset, meaning that the development of the current and new asset is a central process through MWI. This central process of asset management is currently missing and must be added to the responsibility of MWI/WAJ.

Concerning capital investments, from the current perspective, the collection and treatment of additional amounts of wastewater has a low priority, as the highest priority must be given to water supply and governance.

In general, wastewater needs to be collected and treated **if there is an imminent health concern or a groundwater contamination risk** for exploited resources. The latter is not always given, and often the main used aquifer is naturally protected. It should therefore be obligatory for feasibility studies to present the **hydrogeological conditions**, and in particular **groundwater vulnerability**. This is largely not the case at present.

Other facts that should be included in the planning process for wastewater projects but are often neglected are:

- → **Topography** (**avoid pumping if possible**; high maintenance requirements; high potential contamination risks) > e.g. the Bani Kenana project is not justified (groundwater vulnerability: very low)
- → Spacing between built-up areas and estimation of households to be connected (topo/pumping)(cost-benefit analysis) > served/unserved area
- → Estimated water consumption development (population forecast, commercial share)
  > the actual water consumption and predicted demand numbers are often not used
- → Estimated loss at household & development levels (~20%)
- → Estimated **loss in the conveyance system** (~15%; depending on age and maintenance of WW network)
  > currently not considered
- → A realistic consideration of the willingness of subscribers who will be connected to the new system to cover costs (conversion at household level from drainage to cesspit to drainage to sewer pipe)
  > often households are not connected because of associated costs
- → Estimated inflow quality &development > seasonality/peak flows > stable treatment process
- → Land availability/costs /including for future required expansions
- → **Realistic consideration of reuse possibilities** (acceptance at farmers level)
- → **Stormwater in WW network > overload/bypass** > increased contamination risk
  > stormwater **retention tanks** are often not large enough
- → How to divide areas between several projects (**project boundaries?**)
- → It is very important from a hydrogeological and environmental impact perspective to **select appropriate sites for WWTP** facilities and collector lines (groundwater protection needs and vulnerability must be considered)
- → **Effluent discharge locations** should not have a negative impact on groundwater resources (karst)
- → **Geo-risks along collector lines and at WWTP** > guideline for EIAs of wastewater facilities
- → Treatment plants should be at lowest elevation of the area serviced (often not feasible due to land availability)
  > follow catchment approach, not district
- → The following must be planned for:

- o **monitoring of operational parameters** (flow/quality/sludge/energy)
- o **monitoring of effluent quality** (by independent agency)
- o **monitoring of operation & maintenance costs** (by independent agency)
- o **sludge disposal/reuse**

Useful guidance documents on WW planning are contained in MARGANE (2011), MARGANE & ABI RIZK (2011), and STEINEL & MARGANE (2011).

8.7 Recommendations for Treated Wastewater Reuse

Jordan's exploited renewable aquifers are almost exclusively limestone aquifers, which are moderately fractured and karstified. Fracturation is high in places close to larger tectonic elements, in particular the Dead Sea Transform (DST) (which the Jordan Rift Valley and Wadi Araba are part of), the Amman Flexure, Siwaqa Fault, etc. The level of karstification depends on fracturation and rainfall, and is thus highest in the northwestern part of the country, i.e. around Ajloun, Jarash and Salt.

The higher the level of karstification, the higher the rate of infiltration. Karstification creates pathways for contamination. Contamination risks are therefore highest in these areas.

The main criteria for making decisions on which areas to apply treated wastewater reuse must always be the related contamination risk, which is determined through groundwater vulnerability. Reuse must not be permitted if there is a risk of contaminating water resources used for domestic water supply.

A Useful guidance document on treated WW reuse planning is contained in MARGANE & STEINEL (2011).

Other regulations also apply, such as those set by the WHO or the JS 893/2006 (reclaimed water specifications).

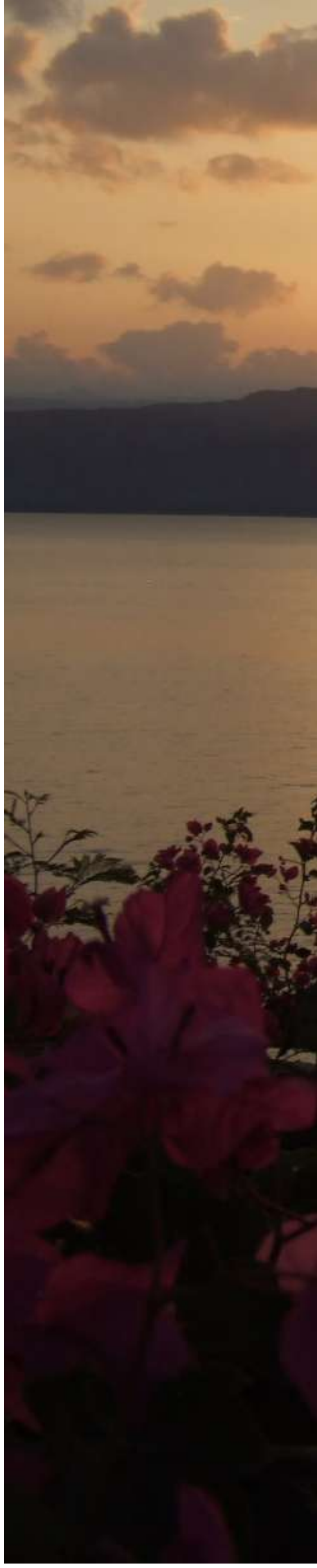
8.8 Recommendations for Update of the Capital Investment Plan and Project Planning

Investment planning and project planning must be more closely coordinated by all involved parties. Often investment decisions are taken by one unit only without coordination with all other units. Effects on other sectors are not considered (e.g. wastewater on water supply, or wastewater on treated wastewater reuse. Often justifications are used which do not apply.

The Joint Planning Committee, established and facilitated with support of GIZ, must be the major basis for decision making.

As mentioned above, governance projects are not considered at all in the previous CIP. However, all governance measures (water resources monitoring, production and energy consumption monitoring, Master Plans, project planning, etc.) forms the basis for investment planning. Therefore, adequate input is required for these measures.


Dead Sea Sinkholes



9 REFERENCES BY TOPIC

(only documents of significance for this report)

9.1 Water Sector general documents

HADDADIN, M. & SHAMIR, U. (2003): Jordan Case Study. – UNESCO IHP Technical Documents in Hydrology, 15, 21 p; Paris.

9.2 Groundwater (Assessments, Investigations, Quality, Protection, Monitoring)

ACSAD (1982): Water Resources of the Hamad area. - Unpubl. Rep. prepared by GTZ and BGR; Frankfurt, Hannover, Amman.

AL KUISI, M., ALJAZZAR, T., RÜDE, T.R., MARGANE, A. (2008): Impact of the Use of Reclaimed Water on the Quality of Groundwater Resources in the Jordan Valley, Jordan. – Clean - Soil, Air, Water, 36 (12), 1001-1014.

AL KUISI, M., MASHAL, K., AL-QINNA, M., ABU HAMAD, A., MARGANE, A. (2014): Groundwater Vulnerability and Hazard Mapping in an Arid Region: Case Study, Amman-Zarqa Basin (AZB)-Jordan. – J. Water Resource Protection, 2014, 6, 297-318.

ALMOMANI, M. & ABU MAIZER, M. (1989): Isotopic and Hydrochemical Study in the Yarmouk River Basin and Northern Rift Side Wadies of Jordan. - Unpubl. Report of the Water Authority of Jordan, IAEA Workshop, Amman.

AL-MOMANI, M., (1994): Environmental Isotope and Hydrochemical Study of the Shallow and Deep Ground Water in the Azraq Basin, Jordan. - Amman.

BARBER, W. & CARR, D. P., (1973): Digital Model of the Shallow Aquifer Complex of the Azraq Basin, East Jordan. – Unpubl. Rep. Raikes & Partners, FAO, SF: JOR/71/525; Rome, Amman.

BENDER, F. (1974): Geology of Jordan. Contributions to the Regional Geology of the Earth: Supplementary Edition of Vol. 7, 196 p., 160 fig., 14 tables, 5 charts, 1 geol. map scale 1 : 250,000; BerlinStuttgart (Gebrhder Borntr@ger).

BENDER, H. & DÜRBAUM, H.J. (1969): Groundwater Exploration and Exploitation for the Irrigation Project Arja-Uweina in Southern Jordan. – Technical report BGR, 44 p; Hannover.

BENDER, H., GIESEL, W., HUESER, M., KLINGE, H., KNOP, R.-M., RASHDAN, J. & SCHELKES, K. (1987): Possibilities of and Constraints to Groundwater Development for the Water Supply of the Envisaged Oilshale Processing Plant. – Jordanian-German Technical Cooperation Project El Lajjun Oilshale Feasibility Study Phase I, prepared for Central Water Authority, BGR archive no. 101584, 128 p; Hannover.

BGR & ESCWA (2013): Inventory of Shared Water Resources in Western Asia. – 606 p; Beirut.

BORGSTEDT, A., MARGANE, A., SUBAH, A., HAJALI, Z., ALMOMANI, T., KHALIFA, N., JABER, A. & HAMDAN, I. (2007): Delineation of Groundwater Protection Zones for the Corridor Wellfield. – Technical Cooperation Project 'Groundwater Resources Management', Technical Report No. 8, prepared by BGR & MWI, BGR archive no. 012xxxxx, 191 p.; Amman.

BRÜCKNER, F., AL HYARI, M., TOLL, M., JABER, A., BANI KHALAF, R., OBAIAT, A. & HANBALI, B. (2015a): Delineation of Groundwater Protection Zones for Siwaqa Well Field. - Unpubl. Rep. Fed. Inst. For Geosc. And Nat. Res. (BGR), Water Aspects in Landuse Planning project, 127 p; Amman.

BRÜCKNER, F., AL HYARI, M., HIASAT, T., JABER, A., OBAIAT, A., QADI, M., TOLL, M. & BANI-MUSTAFA, B. (2015b): Delineation of Groundwater Protection Zones for Tanoor and Rasoon Springs. - Unpubl.

Rep. Fed. Inst. For Geosc. And Nat. Res. (BGR), Water Aspects in Landuse Planning project, 83 p; Amman.

BRUNKE, H.-P. (1997): Groundwater Resources of Northern Jordan - Vol. 5, Part 1: Three-dimensional groundwater flow model of Northern Jordan. - Unpublished report prepared by Federal Institute for Geosciences and Natural Resources (BGR) and Water Authority of Jordan (WAJ), Technical Cooperation Project 'Groundwater Resources of Northern Jordan', BGR-archive no. 118705; Amman and Hannover.

CDM (2004): Jordan Watershed/Water Quality Management Project–Phase 2 Task 1 - Qairawan Watershed Management Plan. – Unpubl. Report prepared for USAID, MWI and WAJ, 128 p; Amman.

CONSULTING ENGINEERS SALZGITTER (CES) & ARABTECH (1994): Ground Water Investigation in the Azraq Basin - Final Report. - Unpubl. Rep., Vol.I-III, prepared for the Water Authority of Jordan; Amman.

DRURY, D. (1993): Hydrogeology of the Azraq Basin. – MSc, University College London, 79 p; London.

EL-NASER, H. (1991): Groundwater Resources of the Deep Aquifer Systems in NW – Jordan: Hydrogeological and Hydrochemical quasi Three-dimensional Modelling. – Hydrogeologie und Umwelt, Heft 3, Wuerzburg.

ESCWA & BGR (1996): Investigation of the Regional Basalt Aquifer System in Jordan and the Syrian Arab Republic. – 178 p; Amman.

GASSEN, N. (2013): Delineation of Groundwater Protection Zones for AWSA Well Field. - Unpubl. Rep. Fed. Inst. For Geosc. And Nat. Res. (BGR), Water Aspects in Landuse Planning project, 98 p; Amman.

GASSEN, N., AL HYARI, M., HANBALI, B., OBAIAT, A., KIRSCH, H., TOLL, M. & XANKE, J. (2013): Delineation of Groundwater Protection Zones for Hidan Well Field. - Unpubl. Rep. Fed. Inst. For Geosc. And Nat. Res. (BGR), Water Aspects in Landuse Planning project, 96 p; Amman.

GEYH, M.A., WAGNER, W. (1996): Report on hydrogeological study of the Basalt Aquifer System in Syria and Jordan, 29.05.-09.06.1996 in ESCWA, Jordan. - Unpubl. Report, prepared by Federal Institute for Geosciences and Natural Resources (BGR) and ESCWA, BGR Archive-no. 115189. Hannover.

GIBBS, B. (1993): Hydrogeology of the Azraq Basin. – MSc, University College London, 196 p; London.

GITEC & HSI (1995): Groundwater Investigations in the Hammad and Sirhan Basins. – Technical Report, Volume 1, 165 p; Amman.

GLOWA (2006): Vulnerability and Water Resources in Eastern Mediterranean Ecosystems. – Final report first phase of BMBF funded GLOWA Jordan River project (Global Change and the Hydrological Cycle), 255 p.

GLOWA (2008): An integrated approach to sustainable management of water resources under global change. – Final report second phase of BMBF funded GLOWA Jordan River project, 357 p.

GLOWA (2013): An integrated approach to sustainable management of water resources under global change. –

Final report third phase of BMBF funded GLOWA Jordan River project, 255 p.

GTZ (2000): Participatory Watershed Management in Wadi Rajib Catchment – a report on the approach, project experiences and prospects in the future. - Unpublished technical report prepared by GTZ Watershed Management Project (WSMP), 66 p; Amman.

GTZ (2003): Participatory Watershed Management – cistern construction and water harvesting measures in rural communities in Jordan. - Unpublished technical report prepared by GTZ Watershed Management Project (WSMP), 44 p; Amman.

GTZ (2005): Rural Communities Sharing Surface Runoff – a survey of experience in irrigated agriculture in Jordan. – Unpublished technical report prepared by GTZ Water Resource Management in Irrigated Agriculture (WMIA) project, 109 p; Amman.

HAISTE & SCOTT WILSON KIRKPATRICK (1995) Qa'a Disi Aquifer Study. – Unpublished report prepared for WAJ; Amman.

HOBLER, M., BENDER, H., RASHDAN, J. & SCHMIDT, G. (1991): Groundwater Resources of Southern Jordan, Vol. 1-5. – Unpubl. Rep. Fed. Inst. For Geosc. And Nat. Res. (BGR), Project No. 86.2068.4 and No. 88.2180.3, Report No. 108652 and 107375; Hannover.

HOBLER, M., MARGANE, A., ALMOMANI, M. & SUBAH, A. (2001): Groundwater Resources of Northern Jordan, Vol.4: Hydrogeological Features of Northern Jordan. – Technical Cooperation Project 'Advisory Services to the Water Authority of Jordan', BGR & WAJ, BGR archive no. 112708:5, 84 p.; Amman.

HOBLER, M., SUBAH, A. & MARGANE, A. (1999): Map of Groundwater Resources Potential of Northern Jordan. – Technical Cooperation Project 'Advisory Services to the Water Authority of Jordan', BGR & WAJ; Amman.

HOWARD HUMPHREYS CONSULTING ENGINEERS (1983): Monitoring and Evaluation of the Amman-Zerqa Aquifers. – Unpubl. Rep. prepared for Amman Water and Sewerage Authority; Amman.

HSSP (2019): Consulting Services for Conceptual and Final Design Including Tender Documents, Assistance in Tendering, Contracting and Site Supervision. – Unpublished report prepared by Dornier for MWI and KfW, Hydrometeorological System Support Project, Final Report, 92 p.

JICA (1995) The Study on Brackish Groundwater Desalination in Jordan. – Unpublished report prepared by Yachiyo Engineering Co. Ltd. & Mitsui Mineral Development Engineering Co. Ltd.; Tokyo.

JOUSMA, G., ATTANAYAKE, P., CHILTON, J., MARGANE, A., NAVARRETE, C.M., MELO, M.T., GUERRERO, P.N.L., POLEMIO, M., ROELOFSEN, F., SHARMA, S.K., STREETLY, M., SUBAH, A. & AL-YAQOUBI, A. (2006): Guideline on Groundwater Monitoring for General Reference Purposes. – IGRAC/UNESCO, 165 p.; Utrecht.

LERNER, D., ISSAR, A.S. & SIMMERS, I. (1990): Groundwater Recharge. – IAH International Contributions to Hydrogeology, 8, 345 p; Hannover.

LLOYD, J.W.: (1969): Investigation of the Sandstone Aquifers of East Jordan. – Unpubl. Rep. UNDP/FAO, LA:SF/JOR 9; Rome, Amman.

MARGANE, A. (1990): Paleoclimate and Groundwater Recharge in the past 30,000 Years Before Present in Jordan. – Technical Report, BGR archive no. 107712, 37 p; Hannover. [in English and German]

MARGANE, A. (1995): Groundwater Resources of Northern Jordan, Vol.2, Part 2: Monitoring of Groundwater Levels in Northern Jordan. – Technical Cooperation Project 'Advisory Services to the Water Authority of Jordan', BGR & WAJ, BGR archive no. 118701:2, 71 p., 3 app., 3 maps; Amman.

MARGANE, A. (1999): Mapping of Groundwater Vulnerabilty and Hazards to Groundwater in Developping Countries. – Proc. 29th IAH-Congress 6-10 Sep 1999, 87-92; Bratislava.

MARGANE, A. (2002): Criteria for the Preparation of Groundwater Vulnerability Maps. – Technical Cooperation Project 'Groundwater Resources Management', Technical Report No. 2, prepared by BGR & MWI, BGR archive no. 0125646, 118 p.; Amman.

MARGANE, A. (2003): Guideline for Sustainable Groundwater Resources Management. – Technical Cooperation Project 'Management, Protection and Sustainable Use of Groundwater and Soil Resources in the Arab Region', Technical Reports Vol. 6, prepared by BGR & ACSAD, BGR archive no. 122917:6, 235 p., 1 CD; Damascus.

MARGANE, A. (2003): Guideline for the Delineation of Groundwater Protection Zones. – Technical Cooperation Project 'Management, Protection and Sustainable Use of Groundwater and Soil Resources in the Arab Region', Technical Reports Vol. 5, prepared by BGR & ACSAD, BGR archive no. 122917:5, 329 p., 1 CD; Damascus.

MARGANE, A. (2003): Guideline for Groundwater Vulnerability Mapping and Risk Assessment for the Susceptibility of Groundwater Resources to Contamination. – Technical Cooperation Project 'Management, Protection and Sustainable Use of Groundwater and Soil Resources in the Arab Region', Technical Reports Vol. 4, prepared by BGR & ACSAD, BGR archive no. 122917:4, 177 p., 1 CD; Damascus.

MARGANE, A. (2004): Guideline for Groundwater Monitoring. – Technical Cooperation Project 'Management, Protection and Sustainable Use of Groundwater and Soil Resources in the Arab Region', Technical Reports Vol. 7, prepared by BGR & ACSAD, BGR archive no. 122917:7, 318 p., 1 CD; Damascus.

MARGANE, A. & ALMOMANY, M. (1995): Groundwater Resources of Northern Jordan, Vol.2, Part 1: Groundwater Abstraction in Northern Jordan. – Technical Cooperation Project 'Advisory Services to the Water Authority of Jordan', BGR & WAJ, BGR archive no. 118701:1, 35 p., 1 app., 1 map; Amman.

MARGANE, A. & ALMOMANI, M. [Edts.] (2002): Preliminary Draft – National Water Master Plan, Vol. IV – Groundwater Resources. – Technical Cooperation Project 'Groundwater Resources Management', Technical Report No. 3, prepared by BGR & MWI, BGR archive no. 125647: 4, 68 p.; Amman.

MARGANE, A. & AL ZUHDY, Z. (1996): Groundwater Resources of Northern Jordan, Vol.1, Part 2: Spring Discharge in Northern Jordan. – Technical Cooperation Project 'Advisory Services to the Water Authority of Jordan', BGR & WAJ, BGR archive no. 112708:2 and 3, 12 p., 5 app., 3 maps; Amman.

MARGANE, A. & AL ZUHDY, Z. (1995): Groundwater Resources of Northern Jordan, Vol.1, Part 1: Rainfall in Jordan. – Technical Cooperation Project 'Advisory Services to the Water Authority of Jordan', BGR & WAJ, BGR archive no. 112708:1, 12 p., 3 app., 1 map; Amman.

MARGANE, A., BORGSTEDT, A., HAMDAN, I., SUBAH, A. & HAJALI, Z. (2009): Delineation of Surface Water Protection Zones for the Wala Dam. – Technical Cooperation Project 'Groundwater Resources Management', Technical Report No. 12, prepared by BGR & MWI, BGR archive no. 012xxxxx, 126 p.; Amman.

MARGANE, A., BORGSTEDT, A. & SUBAH, A. (2007): Training Course on Groundwater Protection Zone Delineation. – Technical Report No. 9, prepared by BGR & MWI, BGR archive no. 0127704, 168 p., 1 CD; Hannover and Amman.

MARGANE, A., BORGSTEDT, A. & SUBAH, A. (2008): Delineation and Implementation of Groundwater and Surface Water Protection Zones in Jordan – Practical Experiences. – The Fourth Environmental Symposium of German - Arab Scientific Forum for Environmental Studies, October 7-8, 2008, Conference Proceedings, pp. 92-95; Fez, Morocco.

MARGANE, A., BORGSTEDT, A. & SUBAH, A. (2008): Water Resources Protection Efforts in Jordan and their Contribution to a Sustainable Water Resources Management. – pp 325-345; In: ZEREINI, F. & HOELZL, H.: Climatic Changes and Water Resources in the Middle East and in North Africa, 552 p.; Heidelberg (Springer).

MARGANE, A., BORGSTEDT, A., SUBAH, A., HAJALI, Z., ALMOMANI, T. (2006): Delineation of Groundwater Protection Zones for the Rahoub Spring. – Technical Cooperation Project 'Groundwater Resources Management', Technical Report No. 7, prepared by BGR & MWI, BGR archive no. 0126944, 97 p.; Amman.

MARGANE, A. & HOBLER, M. (1994): Groundwater Resources of Northern Jordan, Vol.3: Structural Features of the Main Hydrogeological Units in Northern Jordan. – Technical Cooperation Project 'Advisory Services to the Water Authority of Jordan', BGR & WAJ, BGR archive no. 118702:1-3, 57 p., 30 app., 38 ann.; Amman.

MARGANE, A., HOBLER, M., ALMOMANI, M. & SUBAH, A. (2002): Contributions to the Groundwater Resources of Northern and Central Jordan. – Geol.Jb., C. 68, 52 p.; Hannover.

MARGANE, A., HOBLER, M., DROUBI, A., SUBAH, A. & KHATER, A.R. (2004): Groundwater Vulnerability Mapping in the Arab Region. – In: ZEREINI, F. & JAESCHKE, W.: Water in the Middle East and North Africa – Resources, Protection and Management, 145-155; Heidelberg (Springer).

MARGANE, A., HOBLER, M. & HAMMOUDEH, A. (1996): Groundwater Resources of Northern Jordan, Special Report No. 2: Proposal for an exploration Drilling Program of the Ram Group Aquifer in the Dead Sea – Amman Area. – Technical Cooperation Project 'Advisory Services to the Water Authority of Jordan', BGR & WAJ, BGR archive no. 118707, 35 p., 6 ann.; Amman.

MARGANE, A., HOBLER, M., OURAN, S. & AL ZUHDY, A. (1999) Groundwater Resources of Northern Jordan – Special Report No. 5: Hydrogeological Proposal for the Delineation of a Groundwater Protection Area for the Tabaqat Fahl (Pella) Spring. – Technical Cooperation Project 'Groundwater Resources of Northern Jordan', BGR & WAJ, BGR-archive no. 119256; Amman and Hannover.

MARGANE, A., HOBLER, M. & SUBAH, A. (1999): Mapping of Groundwater Vulnerability and Hazards to Groundwater in the Irbid Area, N-Jordan. – Zeitschr.Angew.Geol., 45, 4, 175-187; Hannover.

MARGANE, A., HOBLER, M. & SUBAH, A. (1997): Groundwater Resources of Northern Jordan, Special Report No. 3: Mapping of Groundwater Vulnerability and Hazards to Groundwater in the Irbid Area. – Technical Cooperation Project 'Advisory Services to the Water Authority of Jordan', BGR archive no. 118708, 50 p., 10 app., 4 ann.; Amman.

MARGANE, A., HOBLER, M. & SUBAH, A. (2006): Case Study: Groundwater Vulnerability Mapping in the Irbid Area in Northern Jordan. – pp 209-212 in: SCHMOLL, O., HOWARD, G., CHILTON, J. & CHORUS, I.: Protecting Groundwater for Health – Managing the Quality of Drinking-water Sources. – WHO, 678 p.; London & Seattle (IWA publishing).

MARGANE, A., QADI, M. & KURDI, O. (2014): Updating the Groundwater Contour Map of the A7/B2 Aquifer in North Jordan. – Technical Cooperation Project 'Syrian Refugee Response', Technical Report prepared by BGR, BGR archive no. 0132576, 115 p., data CD; Amman.

MARGANE, A. & RAYYAN, M. (1995): Groundwater Resources of Northern Jordan, Special Report No. 1:

Upgrading of the Borehole Filing System of the Water Resources Studies Directorate. – Technical Cooperation Project 'Advisory Services to the Water Authority of Jordan', BGR & WAJ, BGR archive no. 118706, 4 p., 1 app.; Amman.

MARGANE, A. & SCHULER, P. (2013): Groundwater Vulnerability in the Groundwater Catchment of Jeita Spring and Delineation of Groundwater Protection Zones using the COP Method. – Technical Cooperation Project 'Protection of Jeita Spring', Technical Report No. 7, prepared by BGR, BGR archive no. 0131739, 117 p.; Raifoun.

MARGANE, A. & SUBAH, A. (2007): Guideline for the Delineation of Surface Water Protection Areas. – Technical Cooperation Project 'Groundwater Resources Management', Technical Report No. 6, prepared by BGR & MWI, BGR archive no. 0126943, 117 p., 1 CD; Amman.

MARGANE, A., SUBAH, A., KHALIFA, N. & ALMOMANI, T. (2005): Groundwater Vulnerability Mapping in the Karak – Lajjun Area. – Proceedings of UNESCO-IHP Jordan Workshop on Aquifer Vulnerability, 11 p.; Zarqa (Hashemiyya University).

MARGANE, A., SUBAH, A., HAMDAN, I., ALMOMANI, T., HAJALI, Z., MA'MOUN, I., AL-HASSANI, I. & SMADI, H. (2010): Delineation of Groundwater Protection Zones for the Lajjun, Qatrana, Sultani and Ghweir Wellfields. – Technical Cooperation Project 'Groundwater Resources Management', Technical Report No. 9, prepared by BGR & MWI, BGR archive no. 012xxxxx, 292 p.; Amman.

MARGANE, A., SUBAH, A., HAMDAN, I., HAJALI, Z. & ALMOMANI, T. (2010): Delineation of Groundwater Protection Zones for the Springs in Wadi Shuayb. – Technical Cooperation Project 'Groundwater Resources Management', Technical Report No. 14, prepared by BGR & MWI, BGR archive no. 012xxxxx, 98 p.; Amman.

MARGANE, A., SUBAH, A., HAMDAN, I., BORGSTEDT, A., ALMOMANI, T., AL-HASSANI, I., HAJALI, Z., JABER, A., SMADI, H. & MA'MOUN, I. (2009): Delineation of Groundwater Protection Zones for the Hallabat Wellfield. – Technical Cooperation Project 'Groundwater Resources Management', Technical Report No. 13, prepared by BGR & MWI, BGR archive no. 012xxxxx, 182 p.; Amman.

MARGANE, A., SUBAH, A., HAJALI, Z., ALMOMANI, T., KOZ, A. (2008): Delineation of Surface Water Protection Zones for the Mujib Dam. – Technical Cooperation Project 'Groundwater Resources Management', Technical Report No. 10, prepared by BGR & MWI, BGR archive no. 012xxxxx, 132 p.; Amman.

MARGANE, A., SUBAH, S., KHALIFA, N., ALMOMANI, T., OURAN, S., HAJALI, Z., OURAN, S., JABER, A., ATRASH, M., HIJAZI, H. & TARAWNEH, R. (2005): Mapping of Groundwater Vulnerability and Hazards to Groundwater in the Karak – Lajjun Area. – Technical Cooperation Project 'Groundwater Resources Management', Technical Report No. 5, prepared by BGR & MWI, BGR archive no. 0126002, 138 p., 1 map; Amman.

MARGANE, A. & SUNNA, N. (2002): Proposal for a National Guideline for the Delineation of Groundwater Protection Zones. – Technical Cooperation Project 'Groundwater Resources Management', Technical Report No. 1, prepared by BGR & MWI, BGR archive no. 0125645, 161 p.; Amman.

MEKDASCHI STUDER, R. & LINIGER, H. (2013): Water Harvesting: Guidelines to Good Practice. Centre for Development and Environment (CDE), Bern; Rainwater Harvesting Implementation Network (RAIN), Amsterdam; MetaMeta, Wageningen; The International Fund for Agricultural Development (IFAD), 72 p; Rome.

MWI (2013): Jordan Water Sector – Facts and Figures. – 29 p; Amman.

MWI & GTZ (2004): Digital National Water Master Plan of Jordan. – Unpubl. Rep., 9 volumes; Hannover, Frankfurt, Amman.

NOBLE, P. (1994): Quantification of Recharge to the Azraq Basin. – MSc, University College London, 89 p; London.

NRA & GTZ (1977): National Water Master Plan of Jordan. – Unpubl. Rep. Vol. I-IV; Hannover, Frankfurt, Amman.

PARKER, D. H. (1969): Investigation of the Sandstone Aquifers of East Jordan The Hydrogeology of the MesozoicCainozoic Aquifers of the Western Highlands and Plateau of East Jordan. – UNDP/FAO 212 Techn. Rep. 2 (AGL:SF/JOR 9), 4 Vols.; Rome.

SCHELKES, K., MARGANE, A., SCHMIDT, G., KHALIFAH, N. & SUBAH, A. (2006): Contributions to the Protection of Water Resources in Jordan. – IAH-BGR conference, „Interaction between Groundwater and Surface Water", p. 18; Berlin.

SEDER, N. & VALENTIN, A. (2006): Irrigation Water Quality Guideline. – GTZ Water Program, 24 p; Amman.

SIMMERS, I. (2003): Understanding Water in a Dry Environment. – IAH International Contributions to Hydrogeology, 23, 341 p; Lisse/Netherlands.

SMART (2011): Integrated Water Resources Management in the Lower Jordan Rift Valley. – Final report of first phase of BMBF IWRM R&D Programme SMART – IWRM (Sustainable Management of Available Water Resources with Innovative Technologies), 266 p.

SMART (2015): Integrated Water Resources Management in the Lower Jordan Rift Valley. – Final report of second phase of BMBF IWRM R&D Programme SMART – IWRM (Sustainable Management of Available Water Resources with Innovative Technologies), 448 p.

SMART (2019): Integrated Water Resources Management in the Lower Jordan Rift Valley. – Final report of third phase of BMBF IWRM R&D Programme SMART – MOVE (Sustainable Management of Available Water Resources with Innovative Technologies - Management Of highly variable Water rEsources in semi-arid Regions), 148 p.

STEINEL, A. (2012): Guideline for assessment and implementation of Managed Aquifer Recharge (MAR) in (semi-)arid regions - Pre-feasibility study for infiltration of floodwater in the Amman-Zarqa and Azraq basins, Jordan. - Unpubl. report prepared by BGR, 220 p; Hannover.

SUBAH, A., BORGSTEDT, A. & MARGANE, A. (2008): Delineation and Implementation of Water Resources Protection Zones in Jordan Practical Experiences. – World Water Week 2008, MENA Seminar, Innovations in Groundwater Governance in the Mena Region, Paper 14, p. 22.

SUBAH, A, HOBLER, M., RAYYAN, M. &. HIJAZI, H. (1999): Mapping of Groundwater Vulnerability and Hazards to Groundwater in the Area South of Amman. - Unpubl. report prepared by Technical Cooperation Project BMZ No. 89.2105.8, BGR-Archive No. 112708, 62 p.; Amman.

TETRA TECH (2018a): Remote Sensing for crop mapping and assessment for groundwater abstraction (during 2017) – Azraq Basin Report. – Water Management Initiative project (USAID), 53 p; Amman.

TETRA TECH (2018b): Remote Sensing for crop mapping and assessment for groundwater abstraction (during 2017) – Yarmouk Basin Report. – Water Management Initiative project (USAID), 44 p; Amman.

TETRA TECH (2018c): Remote Sensing for crop mapping and assessment for groundwater abstraction during

2018 – Amman-Zarqa Basin Report. – Water Management Initiative project (USAID), 22 p; Amman.

TETRA TECH (2018d): Remote Sensing for crop mapping and assessment for groundwater abstraction (during 2017) – Dead Sea Basin Report. – Water Management Initiative project (USAID), 39 p; Amman.

TETRA TECH (2018e): Remote Sensing for crop mapping and assessment for groundwater abstraction (during 2017) – Jafr Basin Report. – Water Management Initiative project (USAID), 41 p; Amman.

TETRA TECH (2019a): Remote Sensing for crop mapping and assessment for groundwater abstraction (during 2017) – Azraq Basin Report. – Water Management Initiative project (USAID), 41 p; Amman.

TETRA TECH (2019b): Remote Sensing for crop mapping and assessment for groundwater abstraction during 2018 – Yarmouk Basin Report. – Water Management Initiative project (USAID), 19 p; Amman.

TETRA TECH (2019c): Remote Sensing for crop mapping and assessment for groundwater abstraction during 2018 – Amman-Zarqa Basin Report. – Water Management Initiative project (USAID), 22 p; Amman.

TETRA TECH (2019d): Remote Sensing for crop mapping and assessment for groundwater abstraction during 2018 – Dead Sea Basin Report. – Water Management Initiative project (USAID), 20 p; Amman.

TETRA TECH (2019e): Remote Sensing for crop mapping and assessment for groundwater abstraction during 2018 – Jafr Basin Report. – Water Management Initiative project (USAID), 21 p; Amman.

WADDINGHAM, J. (1994): Water Demand in the North-East Badia, Jordan. – MSc thesis, Univ. Newcastle upon Tyne, 46 p.; Newcastle upon Tyne.

WATER AUTHORITY OF JORDAN (1989a): Yarmouk Basin Water Resources Study, Final Report. – Unpubl. Rep. North Jordan Water Resources Investigation Project; Amman.

WATER AUTHORITY OF JORDAN (1989b): Azraq Basin Water Resources Study. – Unpubl. Rep. North Jordan Water Resources Investigation Project; Amman.

WATER AUTHORITY OF JORDAN (1989c): Amman Zarqa Basin Water Resources Study, – Unpubl. Rep. North Jordan Water Resources Investigation Project; Amman.

WATER AUTHORITY OF JORDAN (2008): Wadi Es-sir Watershed Management Plan. - Unpubl. Report prepared for USAID project Pollution Prevention for Environmental Health Protection (P2EHP), 76 p; Amman.

9.3 Surface Water (Assessments, Investigations, Quality, Protection, Monitoring), Agriculture

FIGUEROA, J.L., MAHMOUD, M. & BREISINGER, C. (2018: The Role of Agriculture and Agro-processing for Development in Jordan. – IFPRI Regional Program Working Paper, 5, 23 p; Cairo.

HADDADIN, M. (2002): Diplomacy on the Jordan - International Conflict and Negotiated Resolution. – Natural resource management and policy, 21, 535 p; Amsterdam. [Kluwer Academic Publishers]

TETRA TECH (2018a): Determination of KAC Water Losses and Recommended Solutions for Improvements – Upper KAC. – Water Management Initiative project (USAID), 63 p; Amman.

TETRA TECH (2018b): Rainwater Harvesting for Households Guide. – Water Management Initiative project (USAID), 16 p; Amman. [in English and Arabic]

TETRA TECH (2020): Rainwater Harvesting for Households Guide. – Water Management Initiative project (USAID), 44 p; Amman.

WORLD BANK (2016): The Cost of Irrigation Water in the Jordan Valley. – 99 p; Washington.

WORLD BANK (2018): The role of food and agriculture for job creation and poverty reduction in Jordan and Lebanon - Agricultural Sector Note. – 22 p.; Washington.

9.4 Water Supply (General, Feasibility Studies, Facility Management, Wellfield Management)

DORSCH, T., QADI, M., HAMDAN, I., HIASAT, T., MARGANE, A. (2017): Wellfield Management Assessment Wadi Al Arab. – Technical Cooperation Project 'Improved Groundwater Resources Management in Response to the Syrian Refugee Crisis', Technical Report No. 1, prepared by BGR, 101 p.; Amman.

HAMDAN, I., MARGANE, A., SUBAH, A., QADI, M., HIASAT, T., KURDI, O., TAHA, W., KHARASNEH, B., SELAWI, G. (2017): Management of Aqeb Wellfield – Part 4 – Wellfield Management Plan – Zero Draft. – Technical Cooperation Project 'Improved Groundwater Resources Management in Response to the Syrian Refugee Crisis', Technical Report No. 8, prepared by BGR, 505 p.; Amman.

HIASAT, T., MARGANE, A., SUBAH, A., QADI, M., HAMDAN, I., KURDI, O., TAHA, W., KHARASNEH, B., SELAWI, G. (2017): Management of Corridor Wellfield – Part 4 – Wellfield Management Plan – Zero Draft. - Technical Cooperation Project 'Improved Groundwater Resources Management in Response to the Syrian Refugee Crisis', Technical Report No. 12, prepared by BGR, 247 p.; Amman.

MARGANE, A. (2018): Proposed Procedure for Rehabilitation of Wells. – Technical Cooperation Project 'Improved Groundwater Resources Management in Response to the Syrian Refugee Crisis', Advisory Service Document 23

MARGANE, A., SUBAH, A., HAMDAN, I. & ALOBAIAAT, A. (2017): Azraq Aquifer Action Plan. – Technical Cooperation Project 'Improved Groundwater Resources Management in Response to the Syrian Refugee Crisis', Advisory Service Document No. 22, prepared by BGR, 48 p.; Amman.

QADI, M., MARGANE, A., HAMDAN, I. (2018): Management of Wadi Al Arab Wellfield – Part 4 – Wellfield Management Plan – Version 2. - Technical Cooperation Project 'Improved Groundwater Resources Management in Response to the Syrian Refugee Crisis', Technical Report No. 4, prepared by BGR, 243 p.; Amman.

9.5 Wastewater (General, Guidelines, Feasibility Studies, Management)

DORSCH (2019): Rehabilitation and Upgrade of Irbid Central and Wadi Arab WWTPs. - Detailed Design Draft – Vol I, report prepared for KfW & WAJ, Climate Change Mitigation Measures, 255 p; Amman.

MARGANE, A. (2011): Site Selection for Wastewater Facilities in the Nahr el Kalb Catchment – General Recommendations from the Perspective of Groundwater Resources Protection. – Technical Cooperation Project 'Protection of Jeita Spring', Technical Report No. 1, prepared by BGR, BGR archive no. 0131746, 155 p.; Ballouneh.

MARGANE, A. & ABI RIZK, J. (2011): Guideline for Environmental Impact Assessments for Wastewater Facilities in Lebanon. – Technical Cooperation Project 'Protection of Jeita Spring', Technical Report No. 3, prepared by BGR, BGR archive no. 0131736, 27 p.; Ballouneh.

MARGANE, A. & STEINEL, A. (2011): Proposed National Standard for Treated Domestic Wastewater Reuse for Irrigation. – Technical Cooperation Project 'Protection of Jeita Spring', Special Report No. 4, prepared by BGR, BGR archive no. 0131754, 42 p.; Ballouneh.

STEINEL, A. & MARGANE, A. (2011): Best Management Practice Guideline for Wastewater Facilities in Karstic Areas of Lebanon – with special respect to the protection of ground- and surface waters. – Technical Cooperation Project 'Protection of Jeita Spring', Technical Report No. 2, prepared by BGR, BGR archive no. 0132589, 147 p.; Ballouneh.

9.6 Other Sectors

NEPCO (2018): Annual Report 2018. – 95 p; Amman.

Petra – Ad Deir

ANNEX 1: Forecasted production of wellfields

Table 76: Production Forecast for Important Wellfields

(production in 2018, only wellfields > 3 MCM)

Wellfield	Production_2018	Production_2020	Production_2025	Production_2030	Production_2035	Production_2040	wells
Wadi Al Arab	18,089,141	15,441,067	9,775,502	6,235,065	4,053,112	2,117,221	19
Aqeb	16,580,997	10,087,704	6,705,812	4,414,538	3,140,372	2,417,509	39
Azraq	17,149,113	16,620,840	15,299,595	13,978,486	12,657,226	11,404,478	17
Hallabat	3,620,377	3,021,988	1,527,319	485,398	106,735	0	7
Economic Zone	3,233,765	2,661,531	1,810,459	1,291,286	916,556	541,828	6
Majdal Faisal	3,255,705	3,047,340	2,523,198	2,000,897	1,478,663	955,215	9
Ruseifa	5,061,524	3,569,606	2,723,222	1,877,634	1,434,108	1,185,170	9
Taj	8,592,358	7,650,822	5,293,637	2,971,466	1,618,377	561,174	14
Hidan*	10,536,357	10,536,357	10,536,357	10,536,357	10,536,357	10,536,357	16
Siwaqa	3,812,278	3,151,638	1,678,625	990,905	527,413	254,549	14
Qatraneh	5,690,167	4,968,449	3,160,639	1,653,127	947,185	593,190	23
Lajjun	5,518,499	5,203,379	4,527,294	3,933,236	3,339,235	2,789,945	28
Mhay	3,891,706	3,524,699	2,610,099	1,695,266	872,899	327,271	13
Sultaneh	3,390,936	2,815,577	1,563,262	1,007,554	619,523	464,131	13
Hasa	5,438,516	4,650,543	2,951,694	1,560,901	716,952	355,646	9
Qaa Disi (AWC) **	17,363,949	17,363,949	17,363,949	17,363,949	17,363,949	17,363,949	26

* due to artificial groundwater recharge from Wala dam

** decline of yield currently not considered due to high porosity of aquifer

ANNEX 2: Factsheets for Wellfields – under preparation

Wellfields are an important part of the water supply infrastructure, and their maintenance requires a good knowledge of their status. Unfortunately, many of the most basic facts are unknown and there is no "wellfield manager" who could take related maintenance decisions. Moreover, the Water Utilities do not have a dedicated budget for wells maintenance. Most well infrastructure is therefore in a poor condition. This deterioration of infrastructure contributes to the accelerated production decline detailed above.

Within the I-GWRM project (2015-20), BGR has addressed "Wellfield Management" as an important topic and suggested dedicated maintenance measures for three important wellfields in the North: the Wadi Al Arab, Aqeb and Corridor wellfields (QADI et al., 2018, HAMDAN et al., 2017, HIASAT et al., 2017).

The NWMP-3 intends to prepare factsheets for wellfields to support wells maintenance.

Table 77: Wellfields - General Facts

Wellfield	Production 2018	No. of wells active in 2018	Used for water supply of	Aquifer	Responsible entity	SWL annual decline (m)
Wadi Al Arab	17.8 MCM	14	Irbid	A7/B2	YWC	10
Kufr Assad	2.8	7	Bani Kenana district	A7/B2	YWC	9
Mukheiba	?		Amman	A7/B2	JVA	9
Mandah	2.0	4	Local	A7/B2	YWC	8
Deir Abu Said (Oyoon Al Hammam)	2.6	5	Local	A7/B2	YWC	8
Bushra/Hakama	1.8	6	Local	A7/B2	YWC	8
Neime	1.5	6	Local	A4+(A1/2)	YWC	6
Jaber	2.6	10	Local	A7/B2	YWC	7
Sama As Sarhan/Somaya/ Mughayer Sarhan	1.5	7	Local	A7/B2	YWC	7
Zaatari	0.6	4	Irbid	A4 (+ A7/B2)	YWC	5
Aqeb	16.6	39	Irbid	A7/B2	YWC	W: 5 E: 2
Wellfield	Production 2018	No. of wells active in 2018	Used for water supply of	Aquifer	Responsible entity	SWL annual decline (m)
Economic zone	3.2	6	Irbid	A7/B2	YWC	4
Corridor (North) Corridor (South)	2.8 2.6	8 5	North: Irbid South: Zarqa	A7/B2	YWC/ Miyahuna	4
Birein	0.7	3	Local	A4	YWC	4
Znayya	1.5	6	Local	A4	YWC	4
Majdal Faisal & desalination plant	3.3	9	Jarash	A1/2	YWC	
Wadi Rajib	0.6	3	Deir Allah, Central Jordan Valley	A4+(A1/2?)	YWC	
Baqa'a	1.5	11	Local	K	WAJ	
Supply/Tamween	1.8	7	Zarqa	A4+(A1/2?)	Miyahuna	3
Hashemiyya	1.4	2	Zarqa	A4+(A1/2?)	Miyahuna	3
Rusaifa	5.1	9	Zarqa	A7/B2	Miyahuna	0

Wellfield	Production 2018	No. of wells active in 2018	Used for water supply of	Aquifer	Responsible entity	SWL annual decline (m)
Wadi Al Arab	17.8 MCM	14	Irbid	A7/B2	YWC	10
Kufr Assad	2.8	7	Bani Kenana district	A7/B2	YWC	9
Mukheiba	?		Amman	A7/B2	JVA	9
Awajan	3.5	2	Zarqa	A7/B2	Miyahuna	0
Hallabat W/E	3.6	7	Zarqa	A7/B2	Miyahuna	4
Wellfield	Production 2018	No. of wells active in 2018	Used for water supply of	Aquifer	Responsible entity	SWL annual decline (m)
Azraq	17.1	17	Zarqa	B4	Miyahuna	2
Abu Zighan	1.0	6	Deir Allah	Alluvium+Z	WAJ	
Muwaqqar	0.8	6	Amman	A7/B2	Miyahuna	5
Siwaqa	3.8	14	Amman	A7/B2	Miyahuna	4
Qatrana	4.0	17	Amman	A7/B2	Miyahuna	4
Wadi Hidan	10.5	16	Madaba	A4	WAJ?	5
Lajjun	5.5	28	Karak	A7/B2+Disi	WAJ	4
Ghweir	1.0	4	Karak	A7/B2	WAJ	4
Sultani	3.4	13	Karak	A7/B2	WAJ	3
Muhaj	3.2	11	Local	A7/B2	WAJ	3
Abiad			not yet converted	A7/B2	WAJ	3
Hasa	6.1	11	Phosphate mine	A7/B2	WAJ	3
Jafr			Local	A7/B2+(B4)	WAJ	4
Shobak	1.2	9	Shobak	A7/B2	WAJ	4
Udruh	0.3	2	Wadi Mousa	A7/B2	WAJ	5
Wadi Arja	0.7	3	Local	A7/B2	WAJ	4
Wellfield	Production 2018	No. of wells active in 2018	Used for water supply of	Aquifer	Responsible entity	SWL annual decline (m)
Qaa Maan	1.2	5	Local	A7/B2	WAJ	5
Tahouneh	2.6	13	Maan	A7/B2	WAJ	5
Jiteh	1.9	9	Maan	A7/B2	WAJ	5
Samneh	2.1	8	Maan	A7/B2	WAJ	5
Fifa	0.3	3	Local	All	WAJ/JVA	

Wellfield	Production 2018	No. of wells active in 2018	Used for water supply of	Aquifer	Responsible entity	SWL annual decline (m)
Wadi Al Arab	17.8 MCM	14	Irbid	A7/B2	YWC	10
Kufr Assad	2.8	7	Bani Kenana district	A7/B2	YWC	9
Mukheiba	?		Amman	A7/B2	JVA	9
Dubaidib (GAMA) (Disi)/	112	55	Amman, Karak, Zarqa, Irbid, Ajlun, Jarash	Disi	WAJ-BOT	4
Aqaba wellfield / Sabieh Al Masri farm (selling water to AWC)	14.8	20	Aqaba	Disi	AWC	4

ANNEX 3: Factsheets for Dams – under preparation

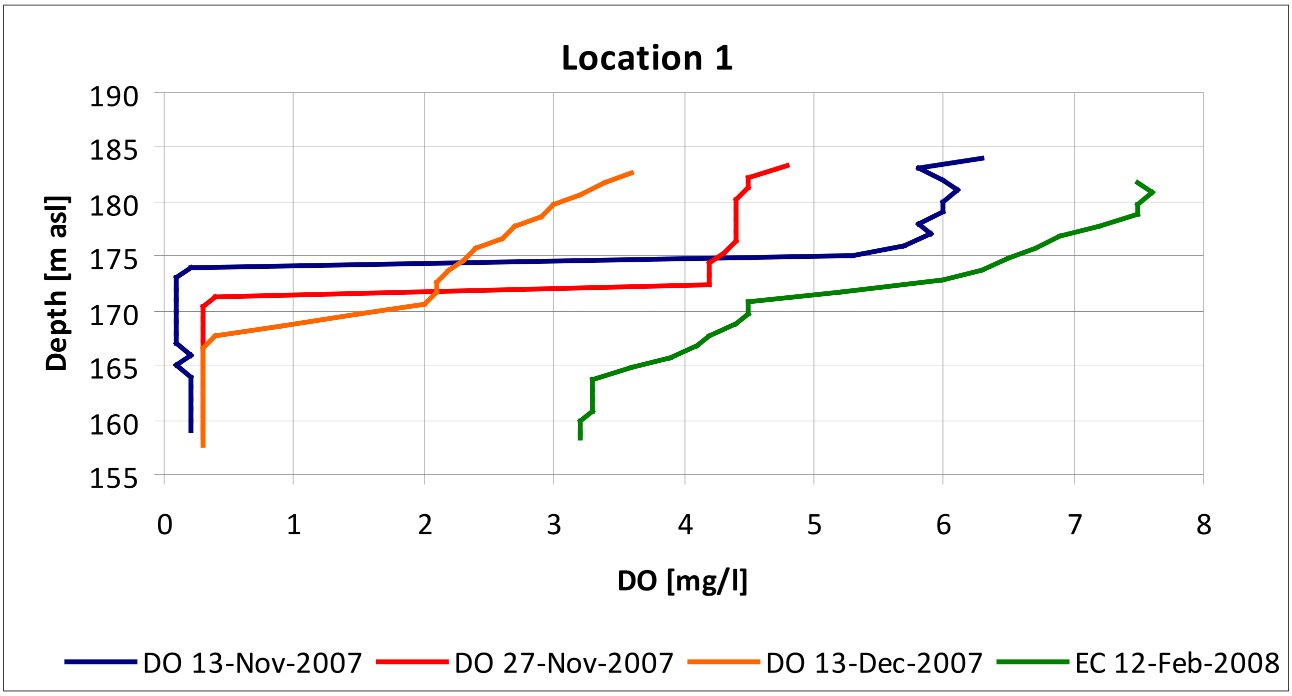
→ Wehdah dam
→ Wadi Al Arab dam
→ Ziglab dam
→ Kufrinjah
→ King Talal dam
→ Karameh dam
→ Shuayb dam
→ Kafrein dam
→ Wala dam
→ Mujib dam
→ Tannour dam

ANNEX 3.1 Example: Fact Sheet Mujib Dam

MWI & JVA Dams Department & GIZ	
Dam manager (name/phone)	AL Mujib Dam Eng.Ahmad Al Khawalda
Location/Coordinates (geographic/Palestine belt)	PGE 227619.1470 PGN 94792.1752
Elevation Height dam crest (m above ground/ m asl)	62 m agl Same as spillover
Height spillover (m above ground/ m asl)	194 m asl (spillway: 300 m width)
Date completed	27/9/2006; water impoundment started in November 2002 Water release to Dead Sea conveyor: 04/2007
Project phase (implemented expansions)	-
Maximum live storage capacity (MCM)	27.5 MCM
Dead storage (MCM)	1.4 MCM (at completion)
Annual safe yield	16.6 MCM
Dam type	RCC for the central section &zoned earth fill with U/S & D/S rock faces for the abutments.
Seepage measurements (yes/no, amount/yr)	641,500 m^3/yr
Seismic measurements (yes/no)	Yes
Maximum observed seismic hazard (Richter scale)	No info (MEMR)
Siltation measurements; yes/no; last record	1.4 MCM (xx/201x)
Outlet(s); types and dimensions	500 mm
Type of flow measurements inflow	
Type of flow measurements outflow	No flowmeter; current meter measurements in wadi when flow changes; percentage open pipe
Power generation quantity	None
Water production (MCM/yr)	
Years with spillover events	
Peak flow recorded (m^3/s)	
Maximum annual flow recorded (MCM/yr)	
Used for (domestic water supply/irrigation/industrial water supply) with shares (MCM/yr)	Domestic, agricultural, and industrial water supply
Point of Delivery (reservoir, irrigation site)	
Protection zone yes/no	No
Flood protection yes/no/area	33,040,085
Surface water catchment size (km^2)	4380
Notes	

Average flow was expected to be around 42 MCM/a, collected by the Mujib diversion weir at the mouth of Wadi Mujib. The intention was to convey 30 MCM/a from Wadi Mujib to Amman and the hotel area at the Dead Sea and another 12 MCM/a to the Southern Ghor (the total volume of water collected by the diversion weirs at all Dead Sea side wadis from Wadi Mujib to the north was expected to be around 53 MCM/a).

A formation of thermal and physico-chemical layers (epilimnion/hypolimnion) is observed every year between around July and December; decomposition of algae (algae blooms during summer) lead to generation H_2S and reduced conditions (zero oxygen in hypolimnion):

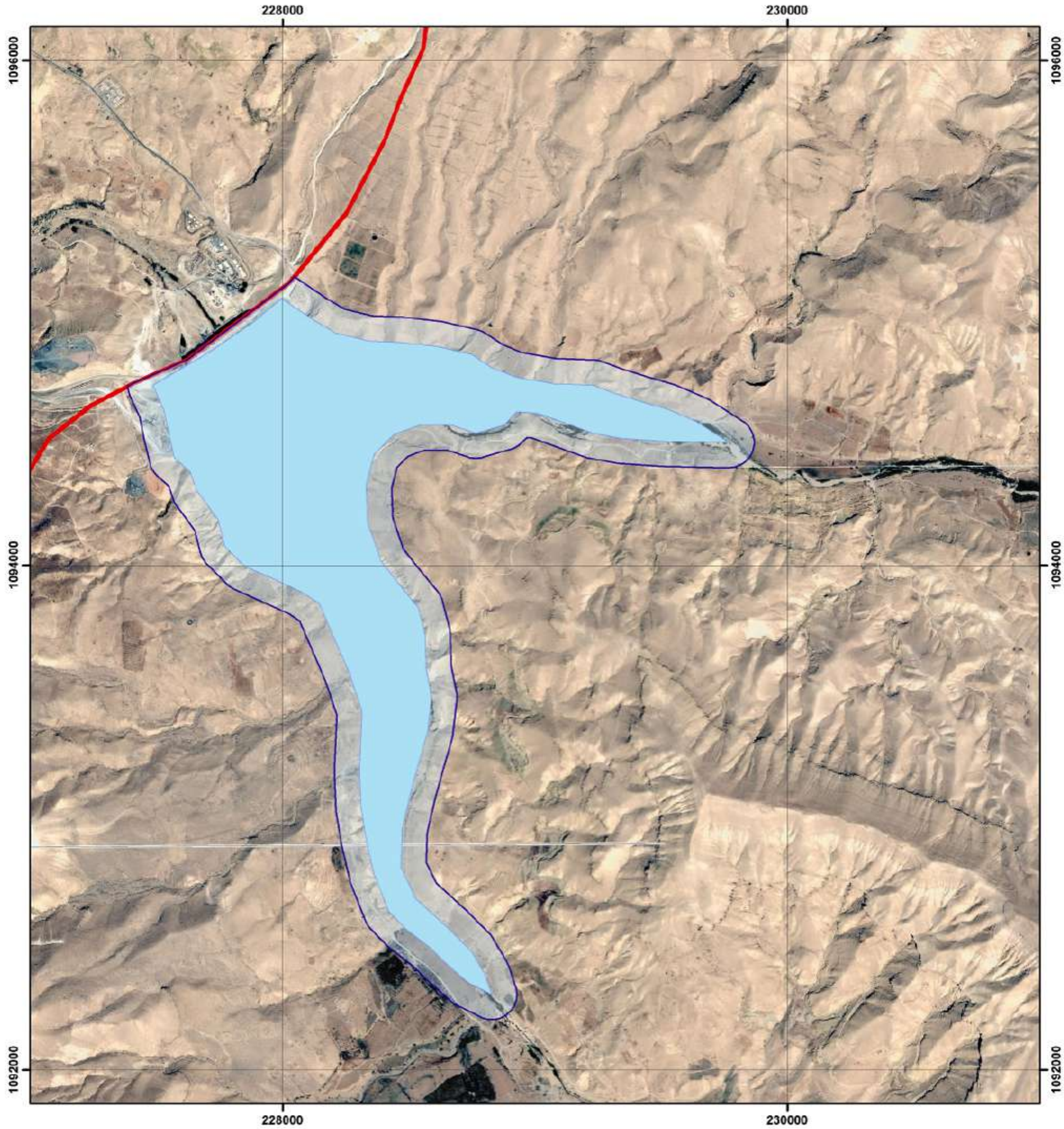


[MARGANE et al., 2008: Delineation of Surface Water Protection Zones for the Mujib Dam]

Maps of catchment with protection zones

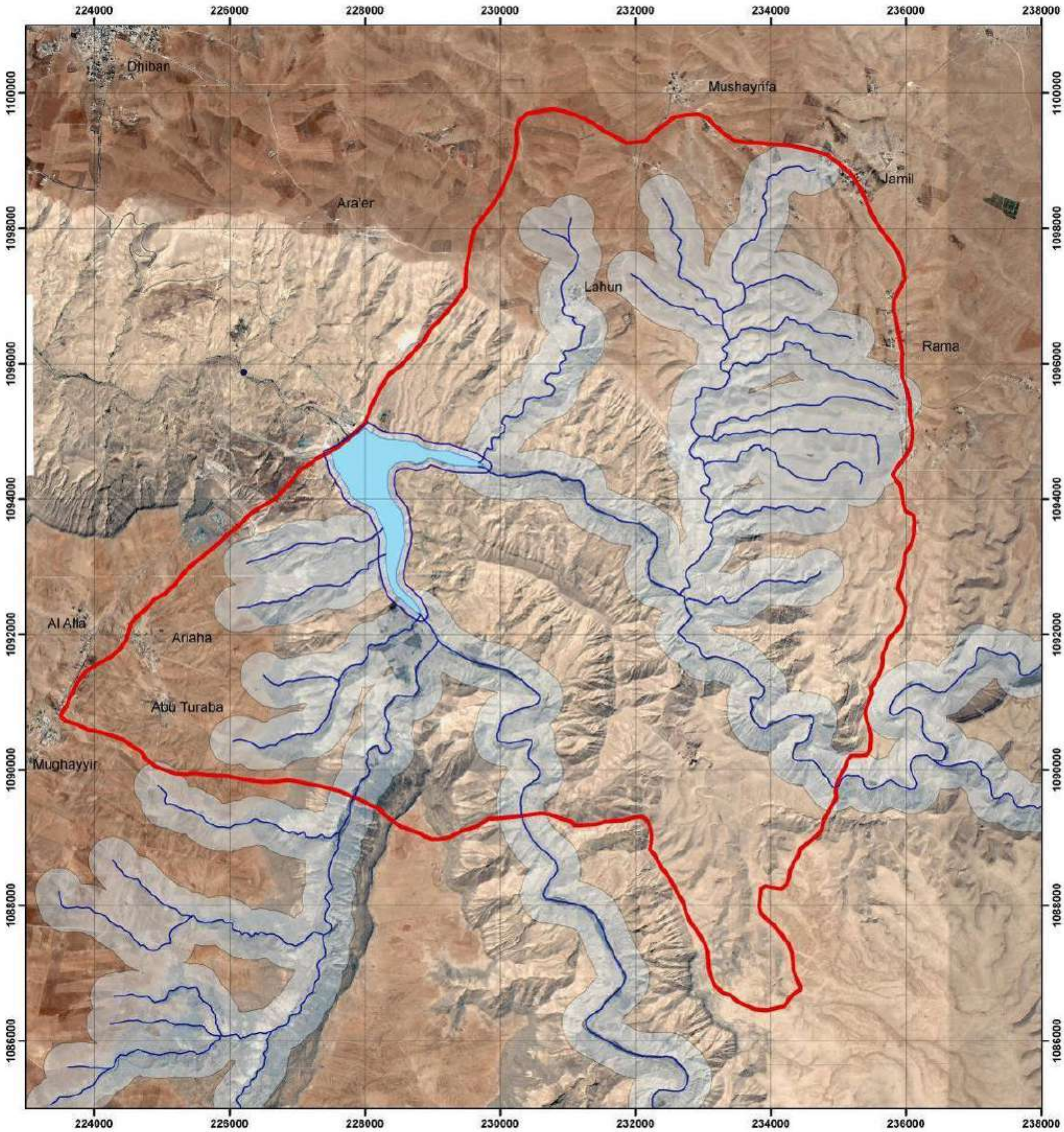
[MARGANE et al., 2008: Delineation of Surface Water Protection Zones for the Mujib Dam]

Protection zone 1 (100 m from high water level)



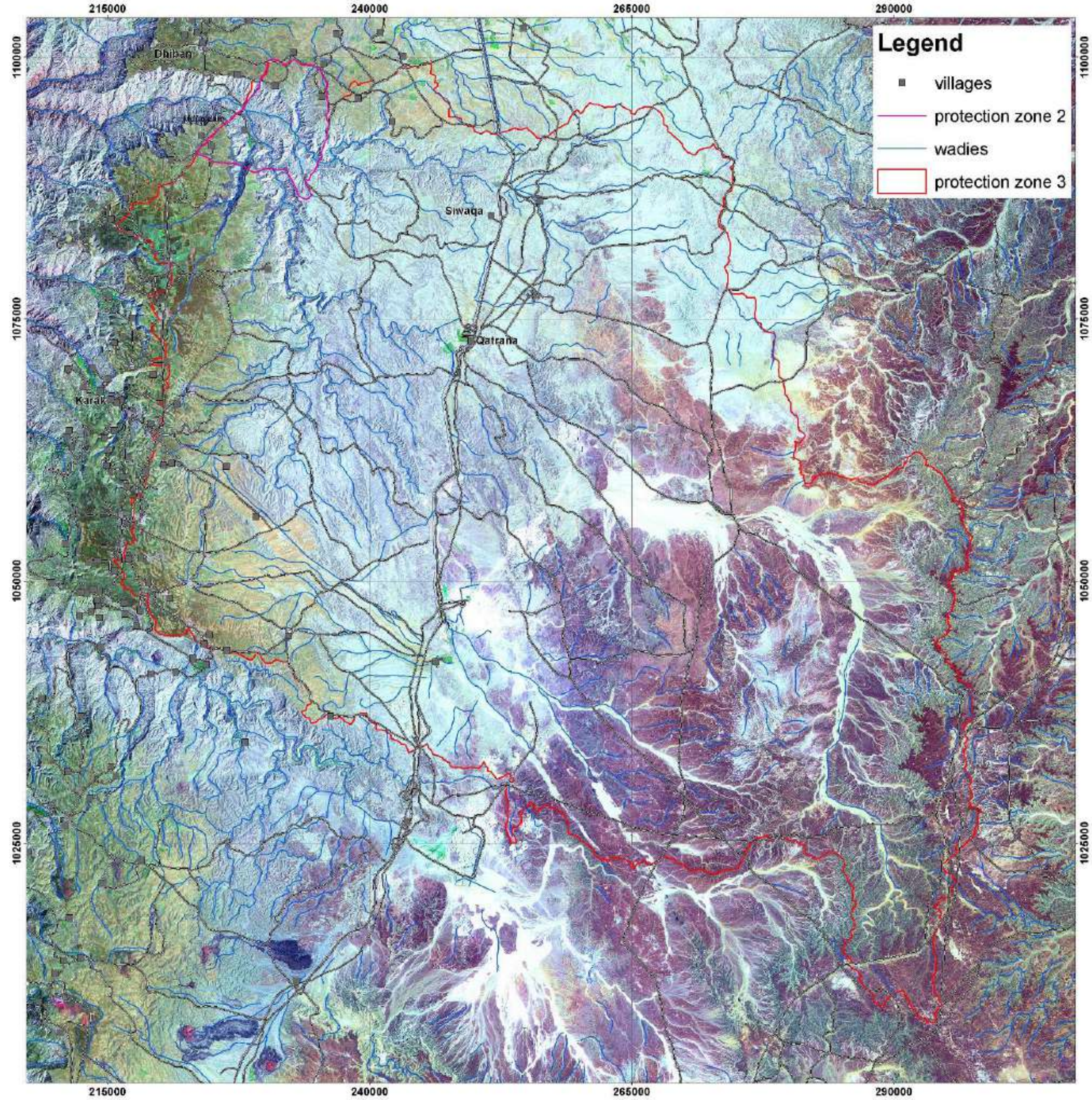
Protection Zone 2

(zone 2 extends at least to 500 m around zone 1, measured from the highest possible water level, if slope within this zone is below 2°. If the slope exceeds 2° at a distance of 500 m, zone 2 will reach to the point where the slope angle becomes less than 2°)

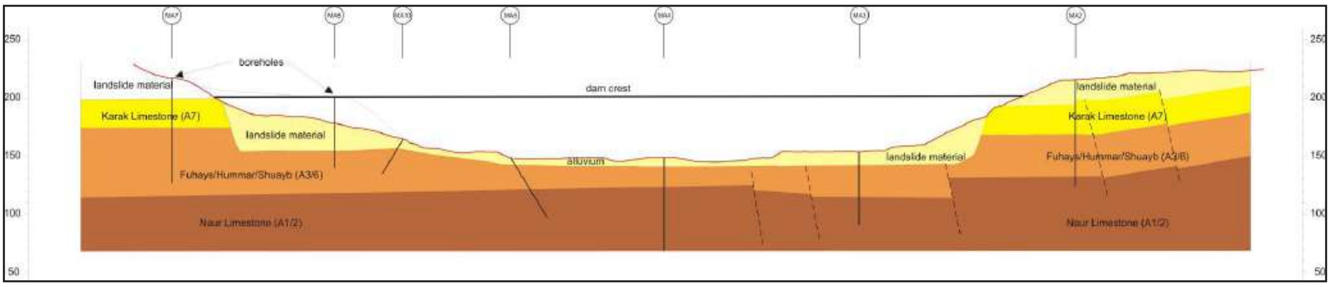


Protection Zone 3

(entire surface water catchment)



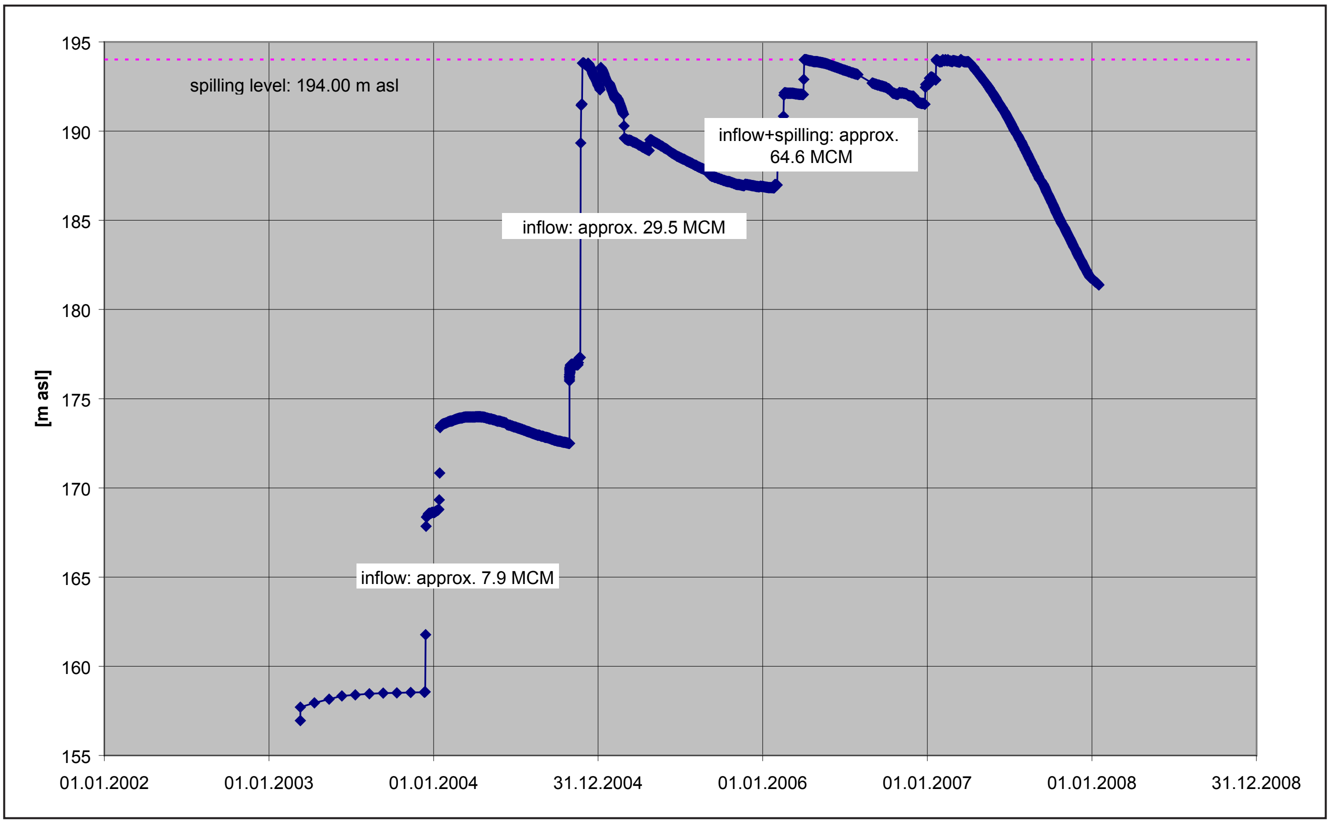
Profile with elevations



HOWARD HUMPHREYS et al. (1992)
Dam at completion

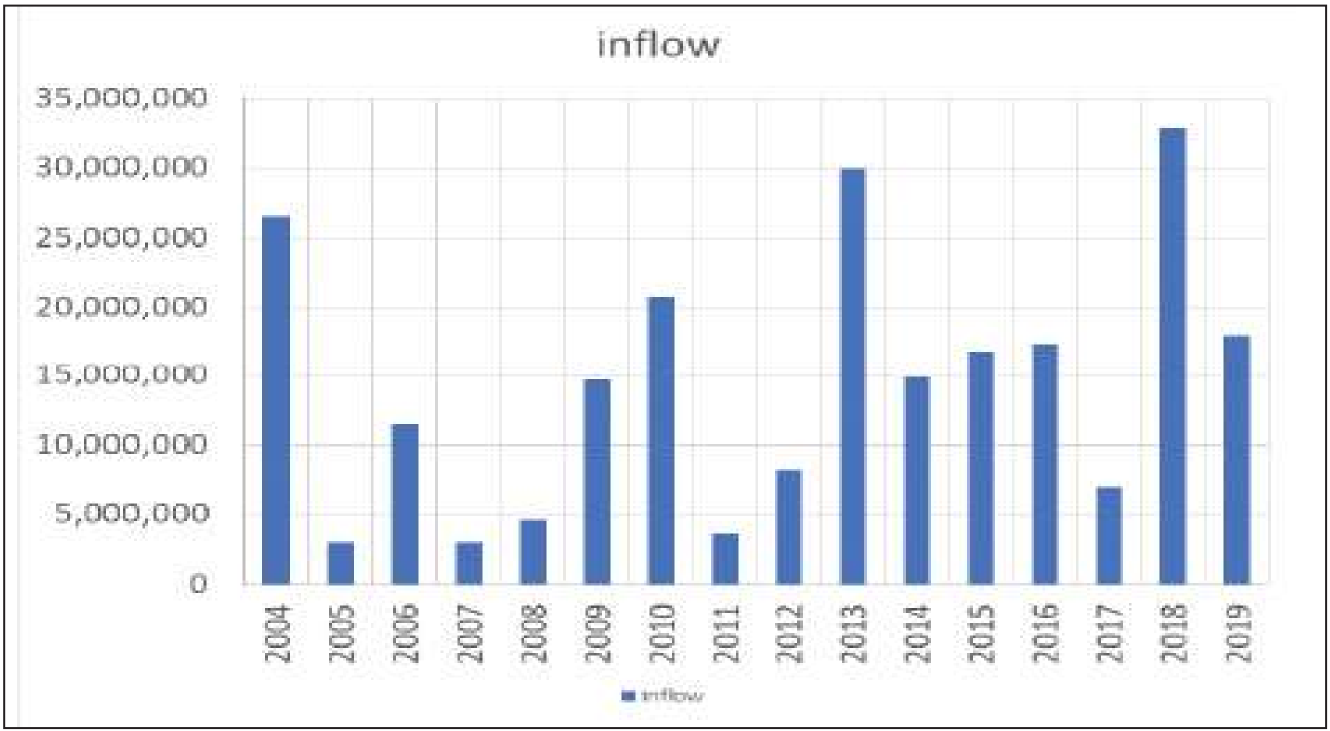
Bottom gate (sluice gate) @ 145 m asl
Draw-off pipes @ 165 m asl, 175 m asl, 185 m asl

Flow charts



At beginning of impoundment spilling events occurred in 12/2003, 03/2006 and 01-03/2007

Inflow (OCT/2019)



Status: 6-Aug-20

ANNEX 3.2 Dams - General Facts

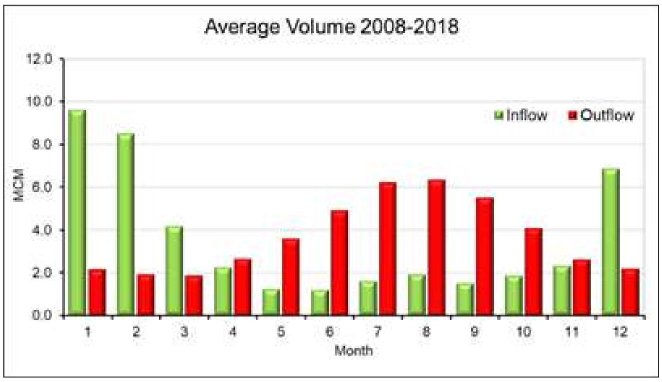
Table 78: Dams - General Facts

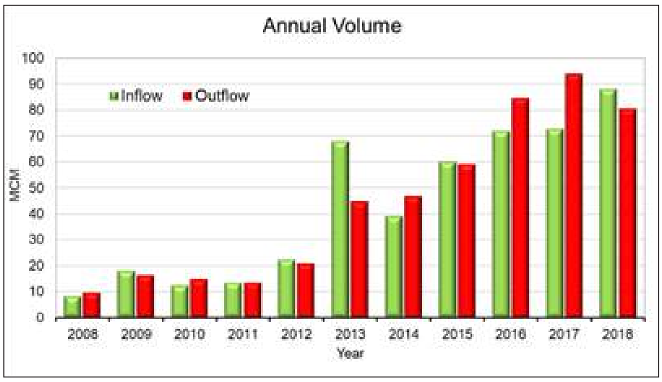
Dam	Storage capacity (MCM)	Production 2014 (MCM)	Production 2015 (MCM)	Production 2016 (MCM)	Production 2017 (MCM)	Production 2018 (MCM)	Used for water supply of
Wehdah dam	110.0	39.2	60.2	72.1	93.7	80.4	Irrigation, domestic water for Amman via KAC
Wadi Al Arab dam	16.8	16.9	13.2	12.4	11.3	10.0	Irrigation, domestic water for Amman via KAC
Ziglab dam	4.0	1.8	1.6	1.1	0.4	0.8	Irrigation N Jordan Valley
Kufrinjah	7.8	-	-	-	1.2	2.0	Irrigation N Jordan Valley
King Talal dam	75.0	123.0	133.6	140.0	141.8	130.0	Irrigation S Jordan Valley
Karameh dam	55.0	3.6	2.4	3.8	6.2	0.8	Not used, TDS 20 g/l
Shuayb dam	1.7	6.2	9.0	7.0	7.3	7.2	MAR (Irrigation S Jordan Valley)
Kafrein dam	8.5	10.1	15.4	12.2	10.9	9.9	Irrigation S Jordan Valley
Wala dam	8.2	14.0	13.7	9.5	7.9	9.2	domestic water for Mad-aba, Amman > MAR for Hidan wellfield
Mujib dam	29.8	21.8	24.0	17.4	6.3	22.7	domestic water for Amman via Zara Main desalination plant; industrial and irrigation water use in Ghor Safi area
Zarqa Main dam	2.0						Irrigation, GW recharge
Lajjoun dam	1.0						Irrigation, GW recharge
Karak dam	2.0						Irrigation
Tannour dam	14.7	9.5	7.9	2.1	20.7	6.8	irrigation Ghor Safi
Total	**336.5**	**246.1**	**281.0**	**277.6**	**307.7**	**270.6**	

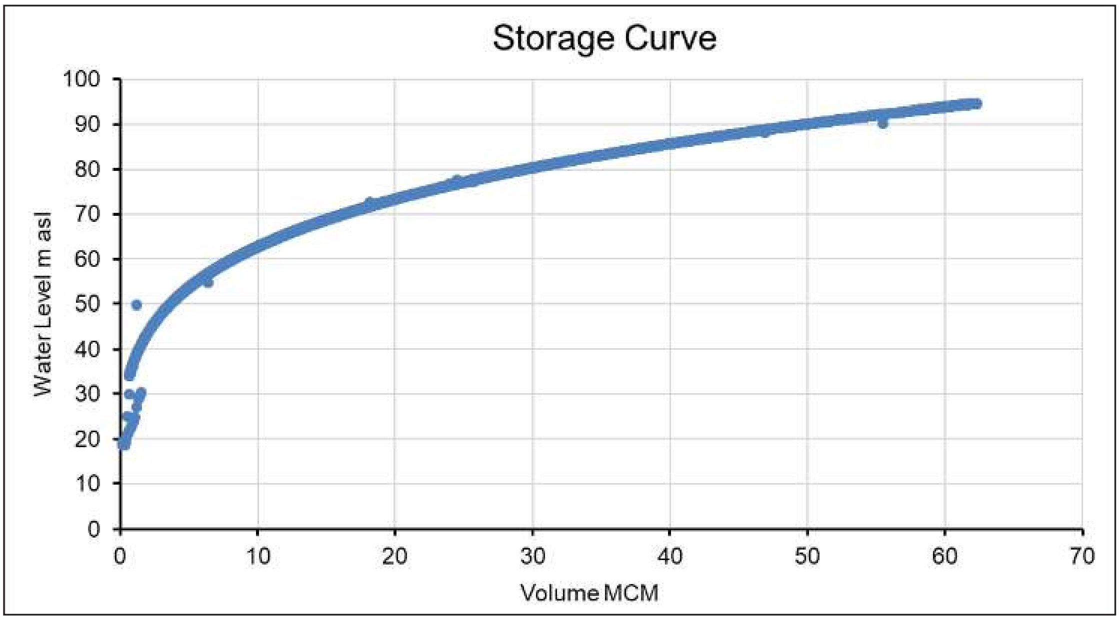
* siltation is not considered in any of the dams (>20%)

** outflow (production) is measured through: mobile flow meter or current meter for discharge measurements (mechanical or electromagnetic) Total drinking water supply in 2018 ~15 MCM (from Mujib dam)

Total supply for irrigation in 2018 ~200 MCM (from all other dams)







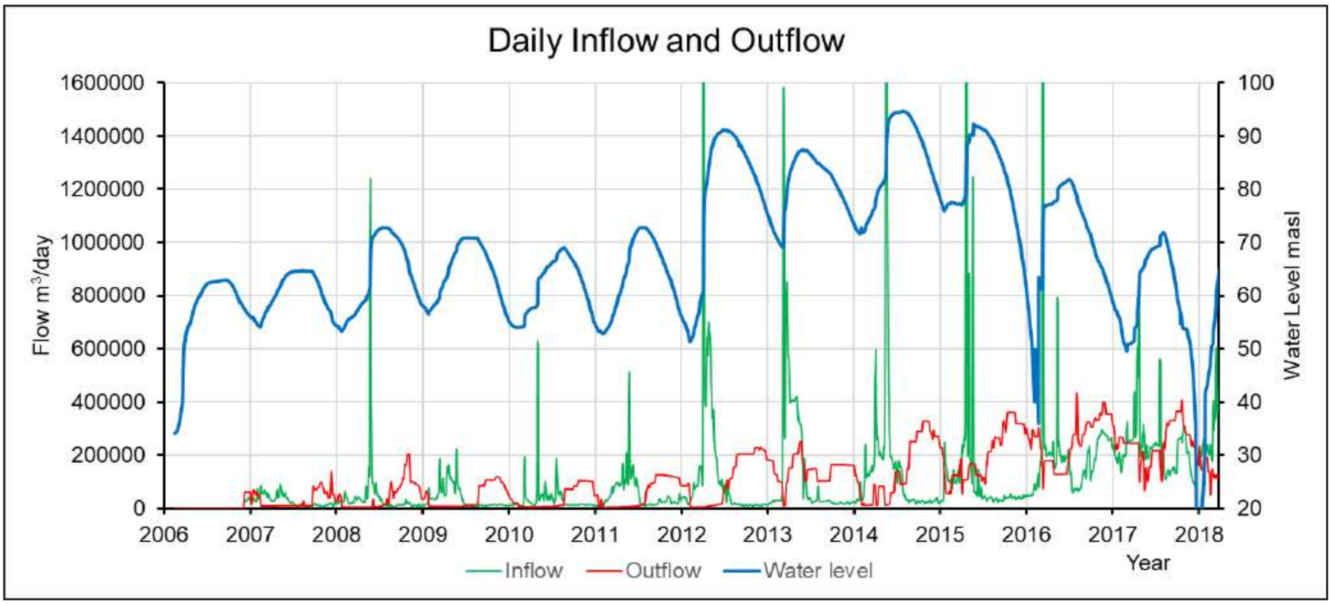


Figure 112: Wehdah Dam – Inflow, Outflow, Water Level and Storage Curve

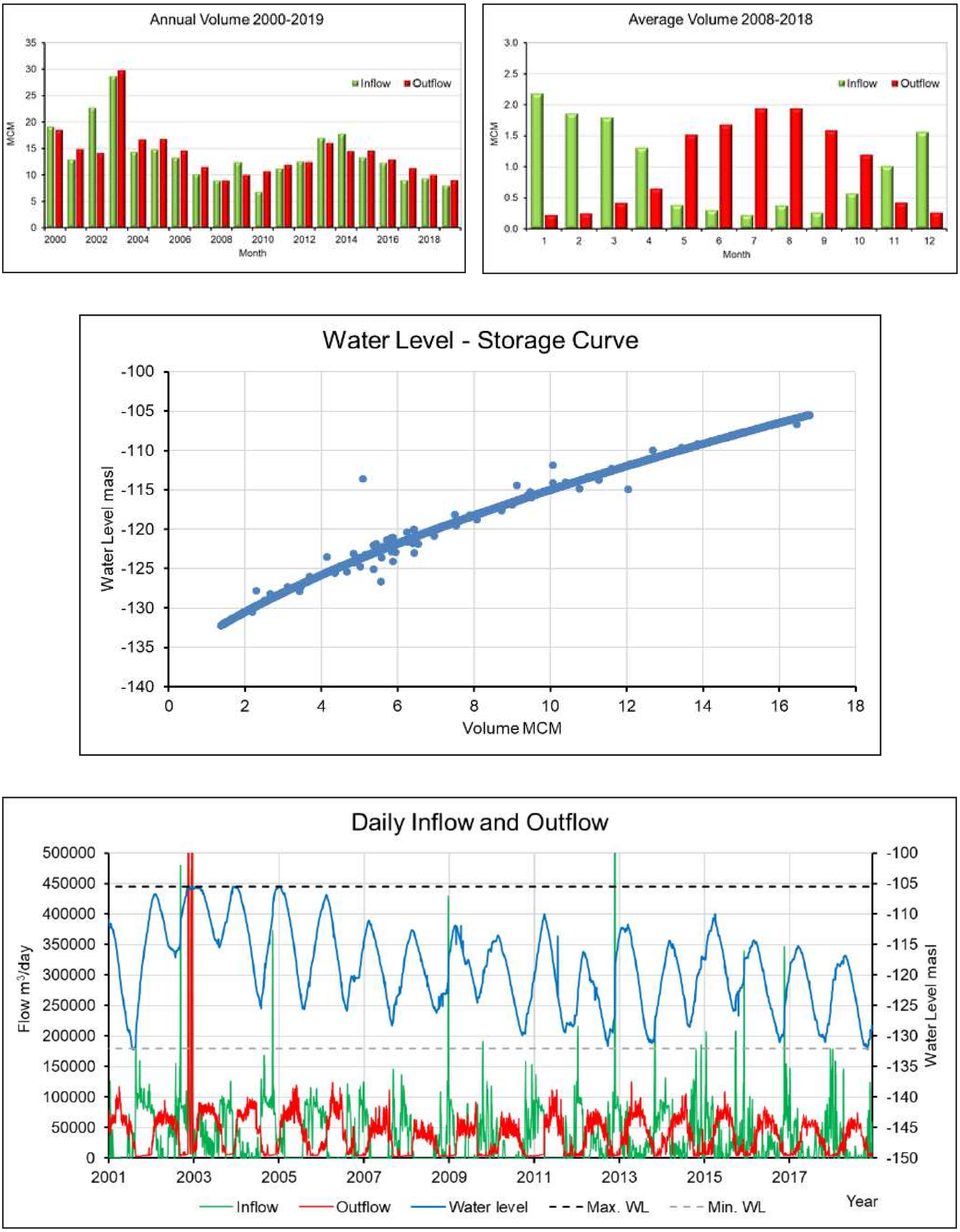
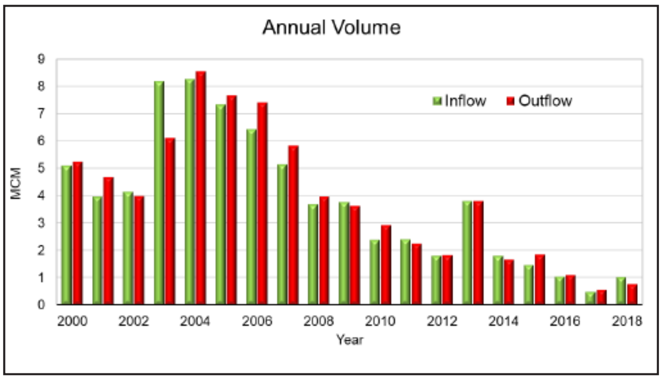
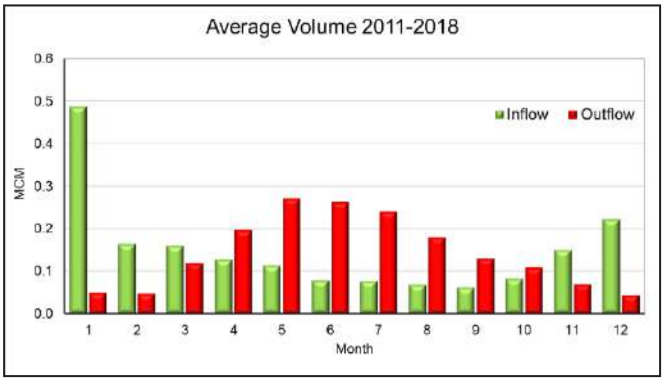
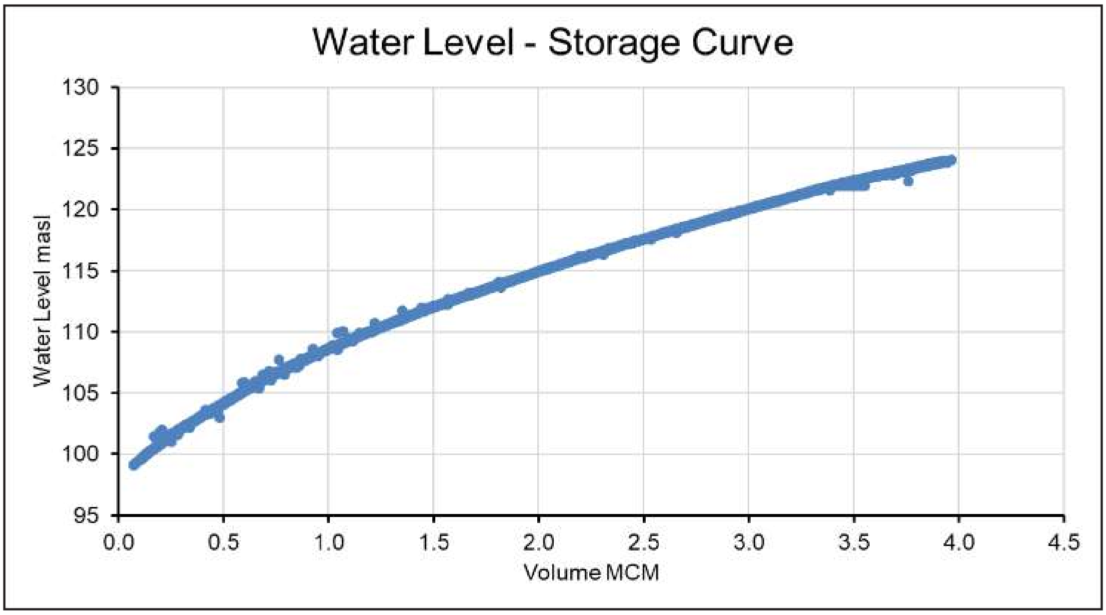


Figure 113: Wadi Al Arab Dam – Inflow, Outflow, Water Level and Storage Curve







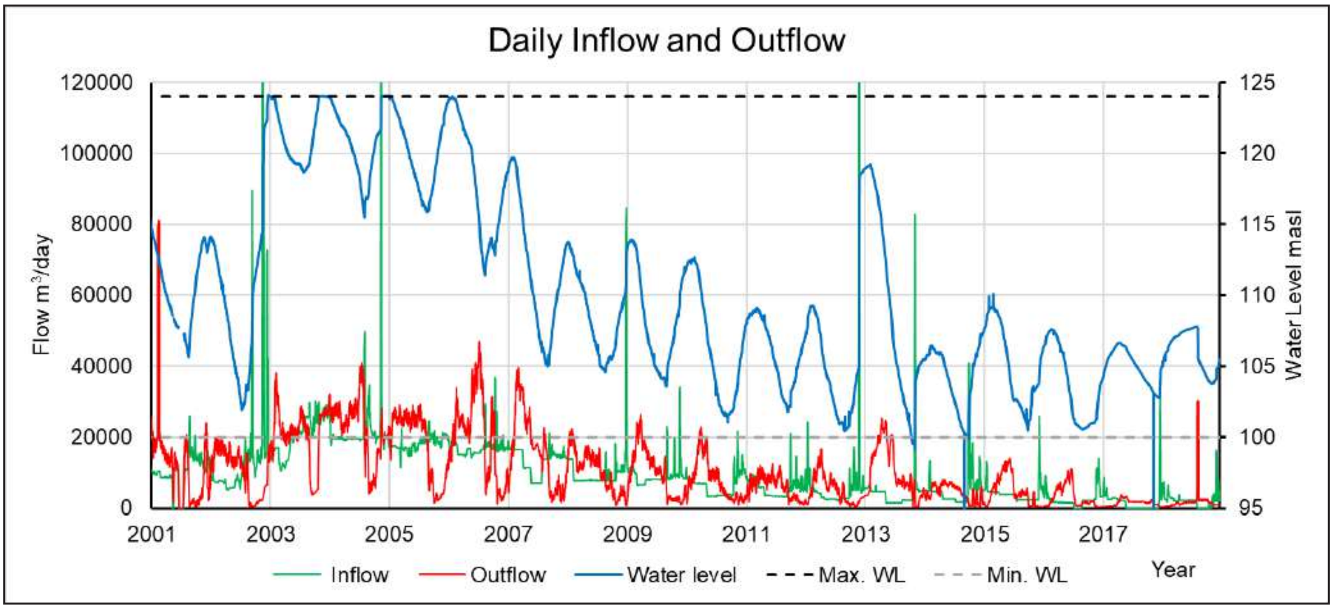
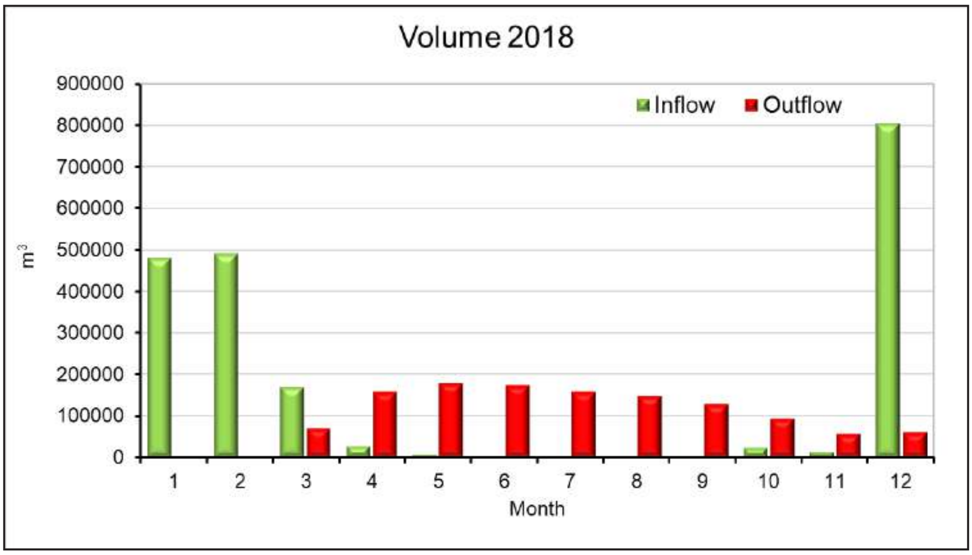
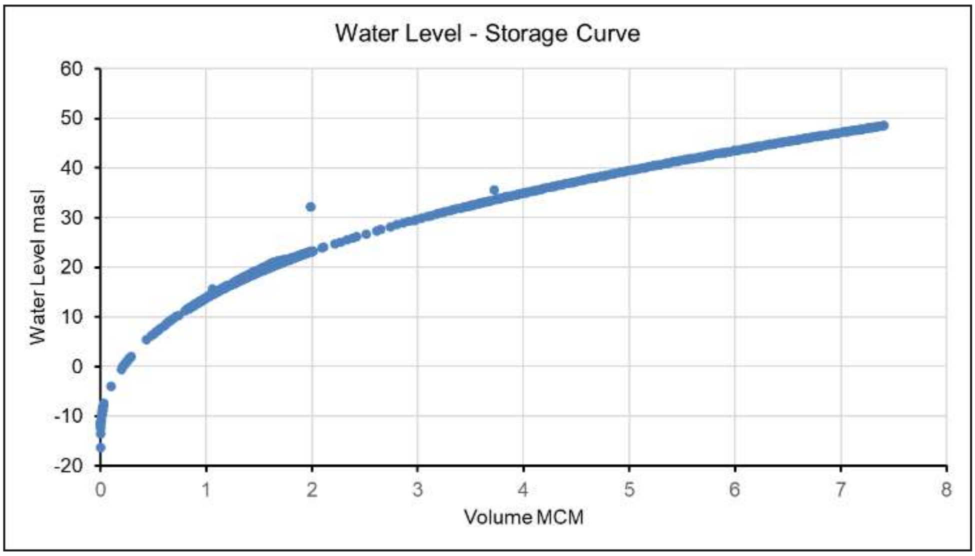


Figure 114: Ziglab Dam – Inflow, Outflow, Water Level and Storage Curve





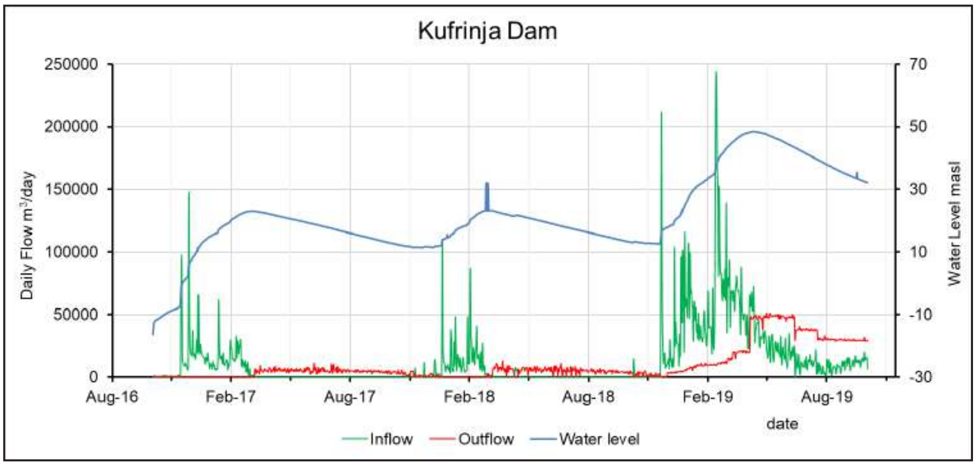
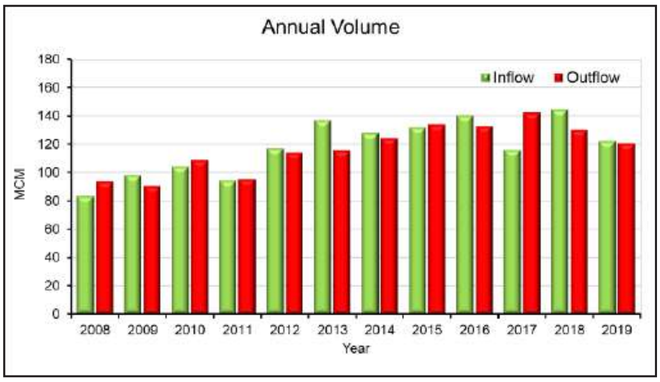
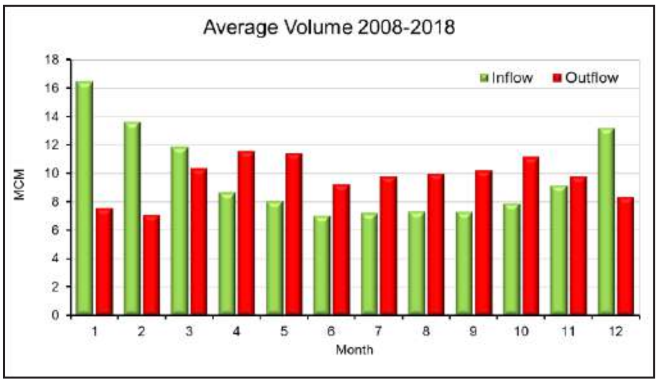
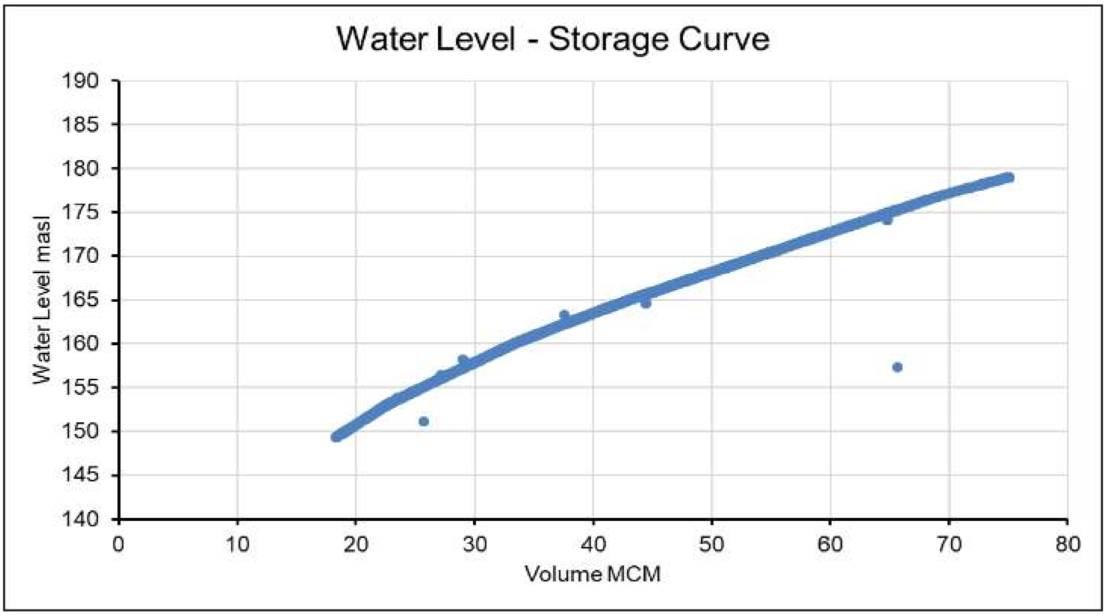


Figure 115: Kufrinjah Dam – Inflow, Outflow, Water Level and Storage Curve







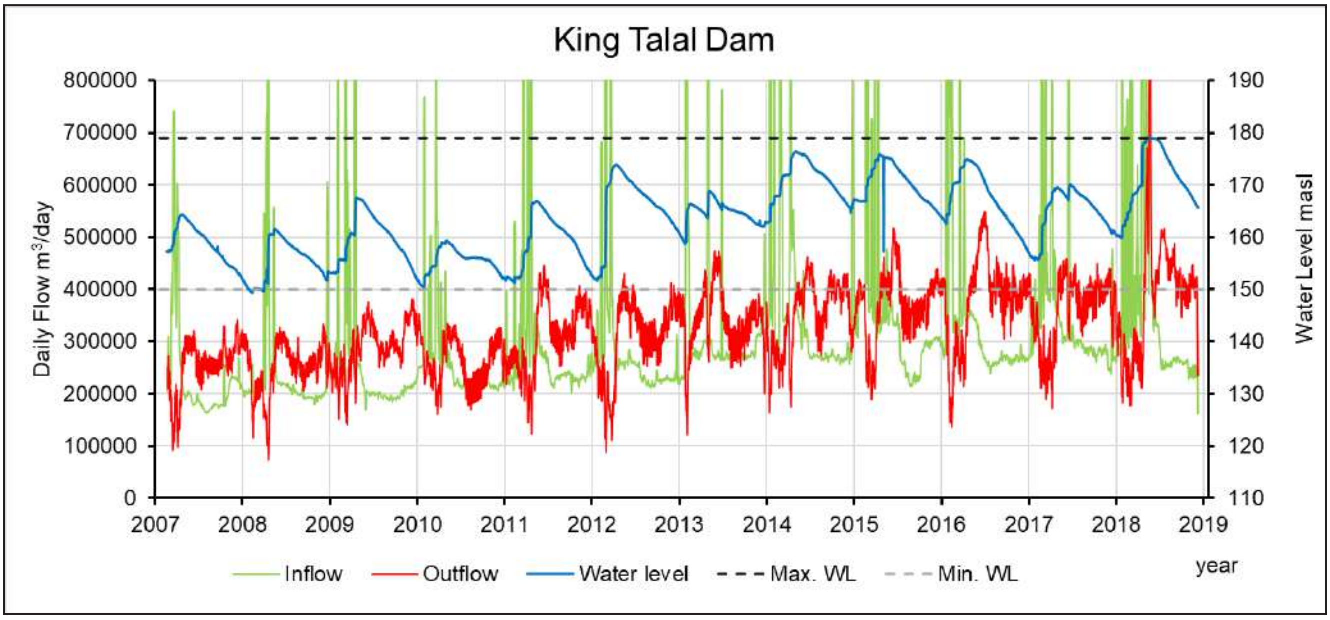
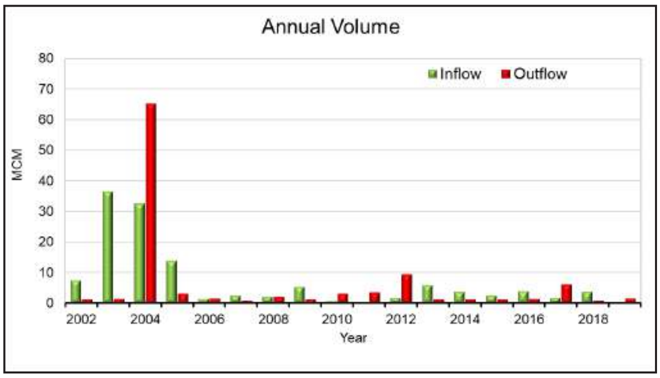
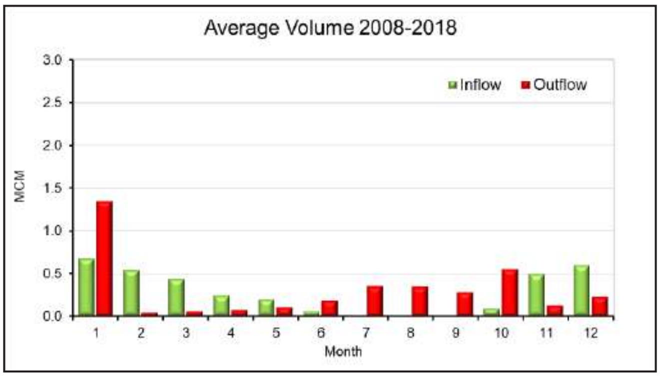
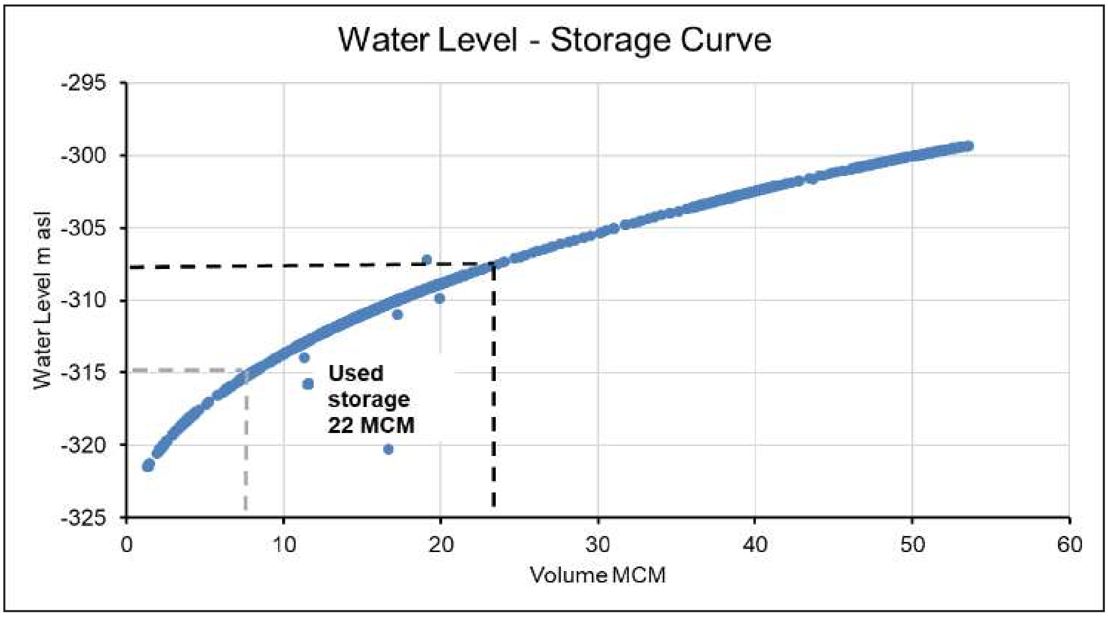


Figure 116: King Talal Dam – Inflow, Outflow, Water Level and Storage Curve







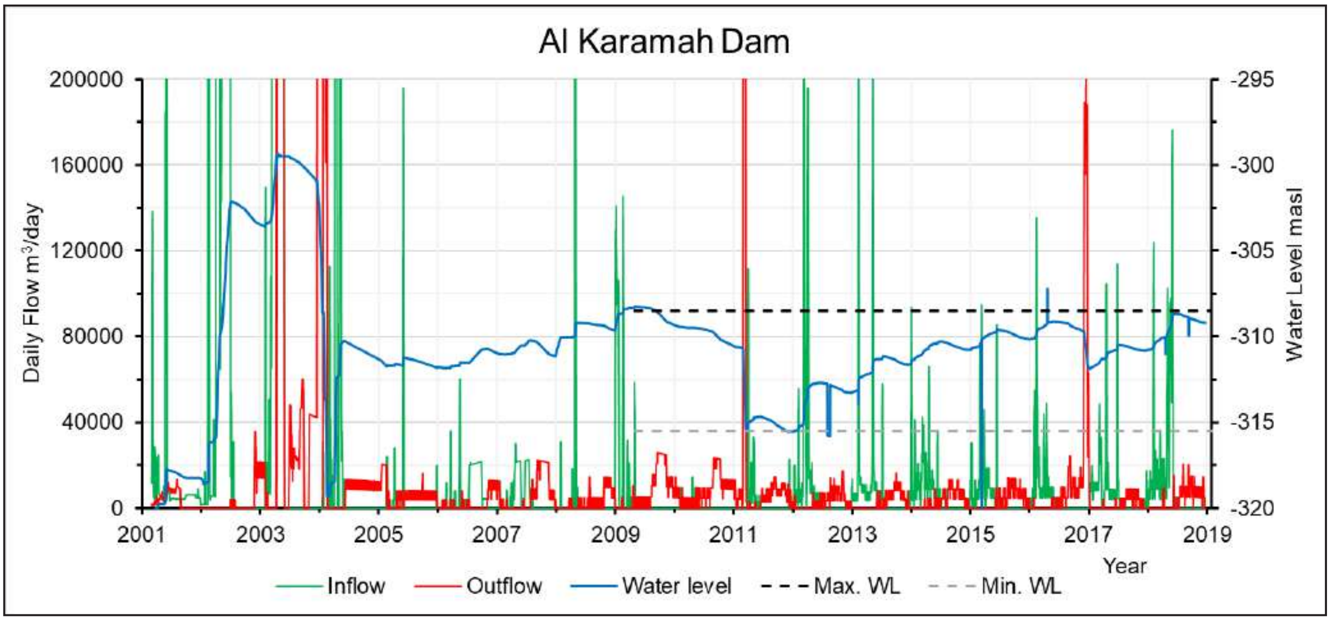


Figure 117: Karameh Dam – Inflow, Outflow, Water Level and Storage Curve

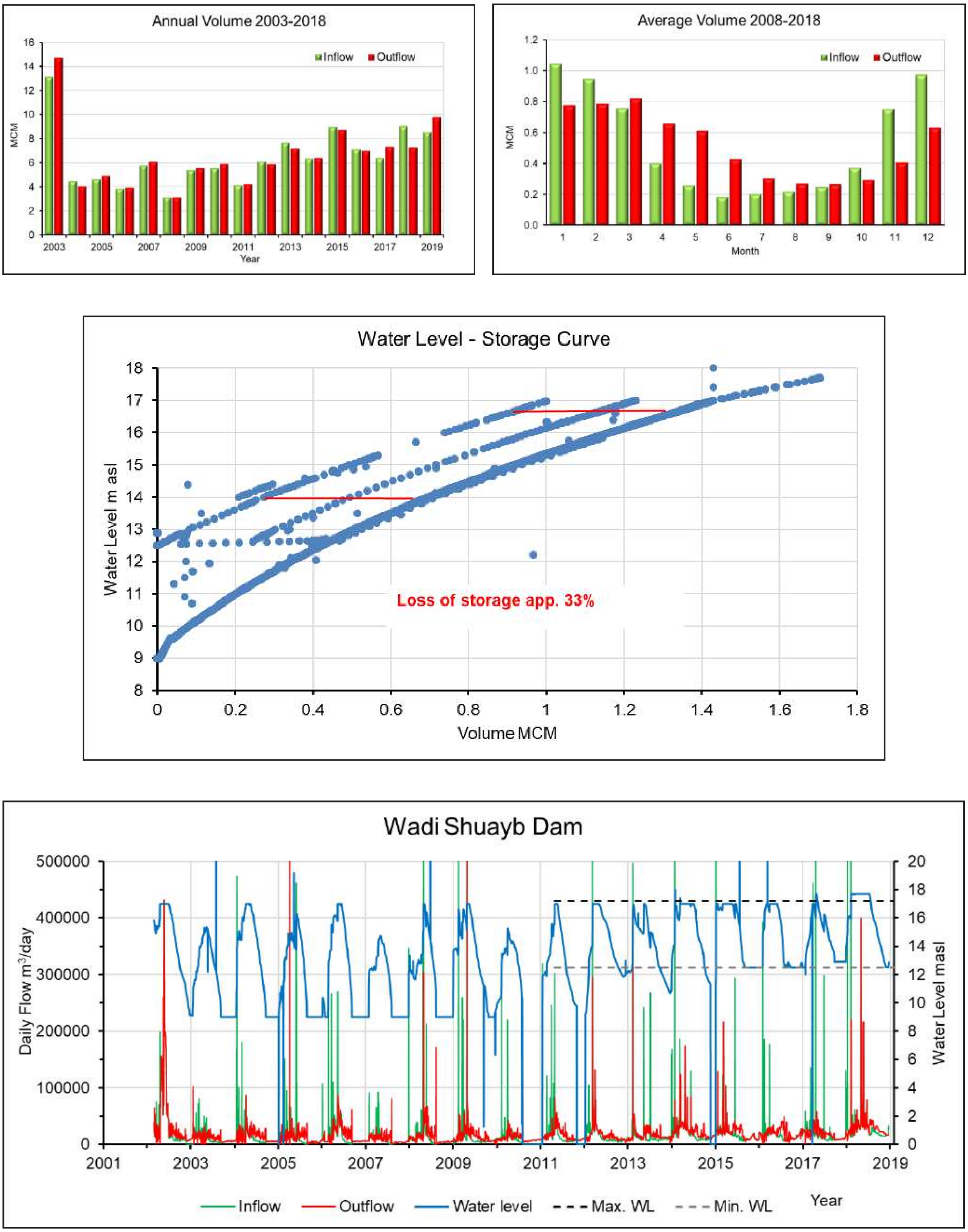
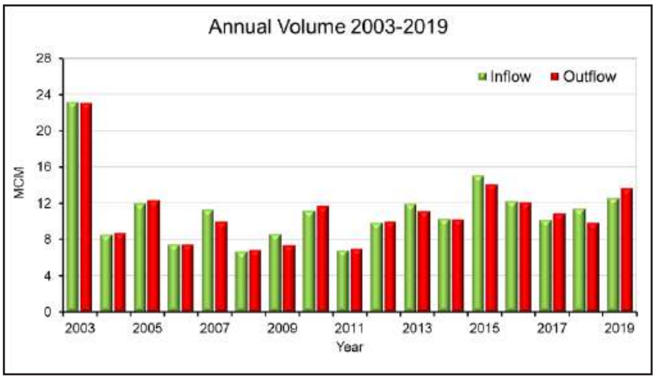
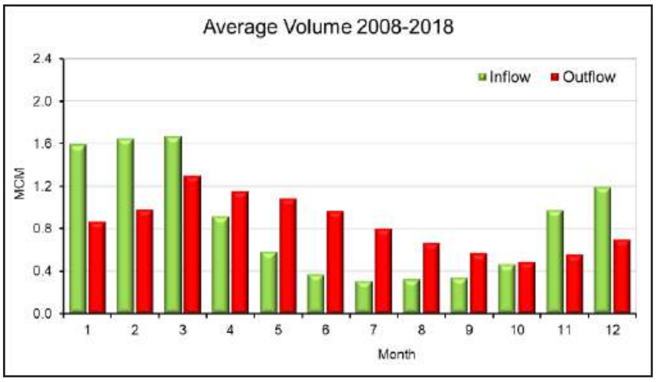
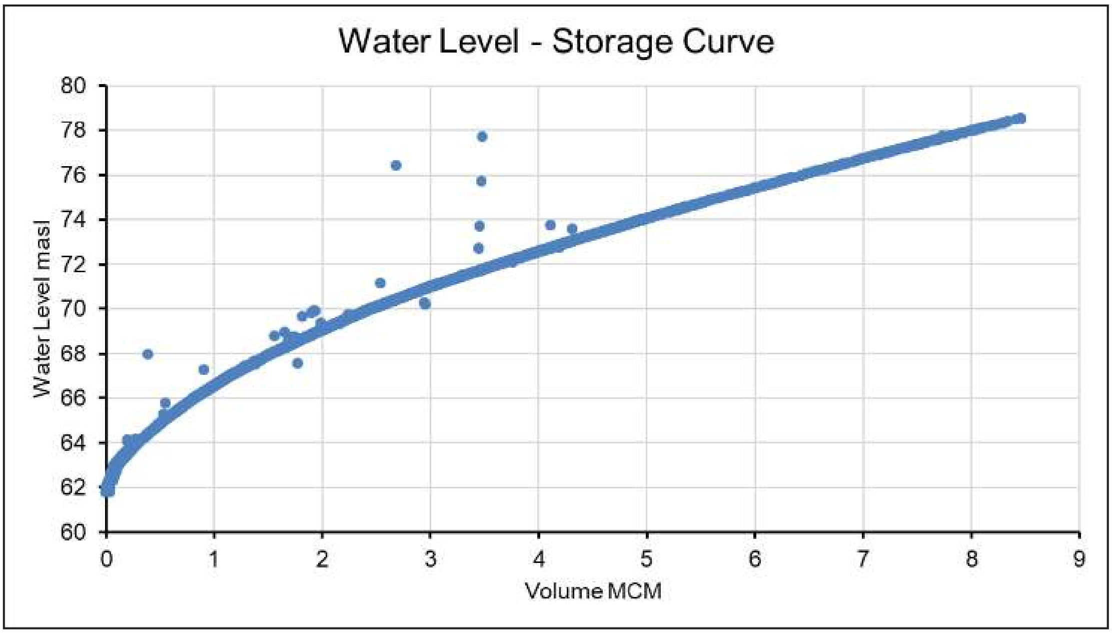


Figure 118: Shuyab Dam – Inflow, Outflow, Water Level and Storage Curve







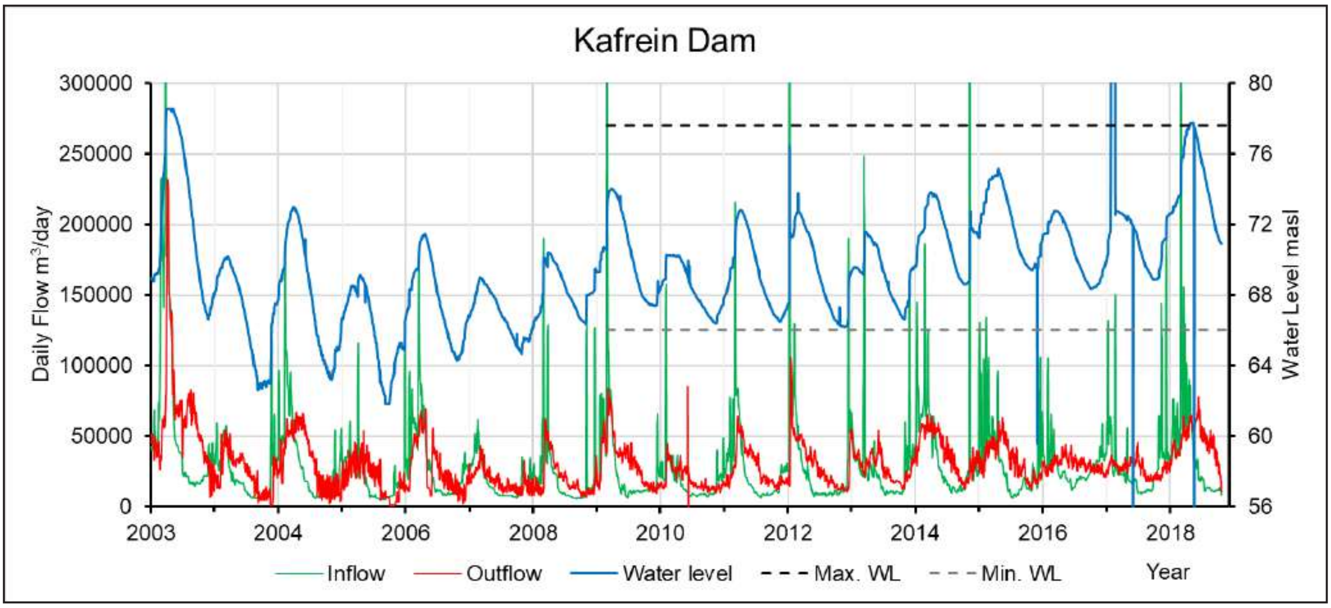


Figure 119: Kafrein Dam – Inflow, Outflow, Water Level and Storage Curve

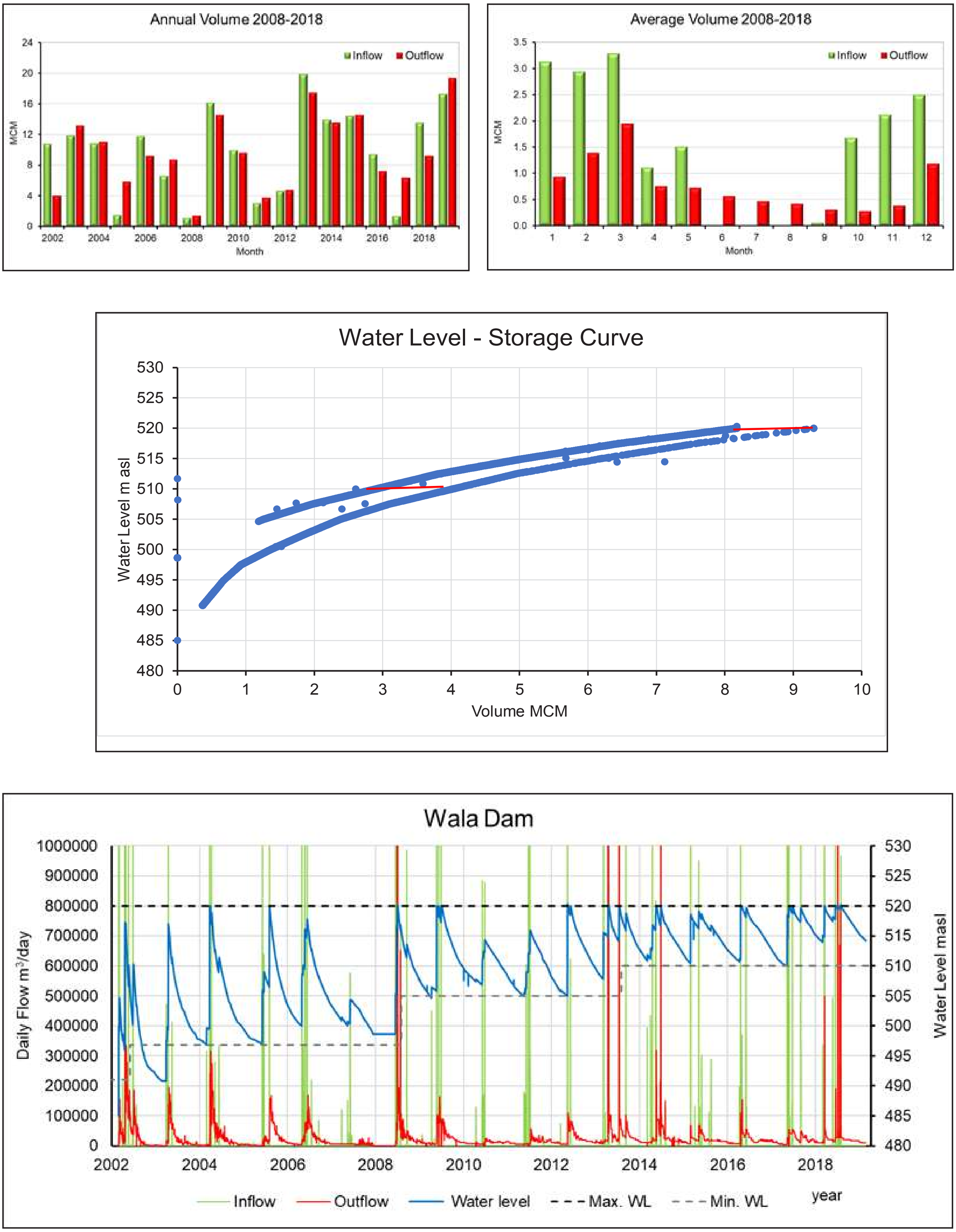


Figure 120: Wala Dam – Inflow, Outflow, Water Level and Storage Curve

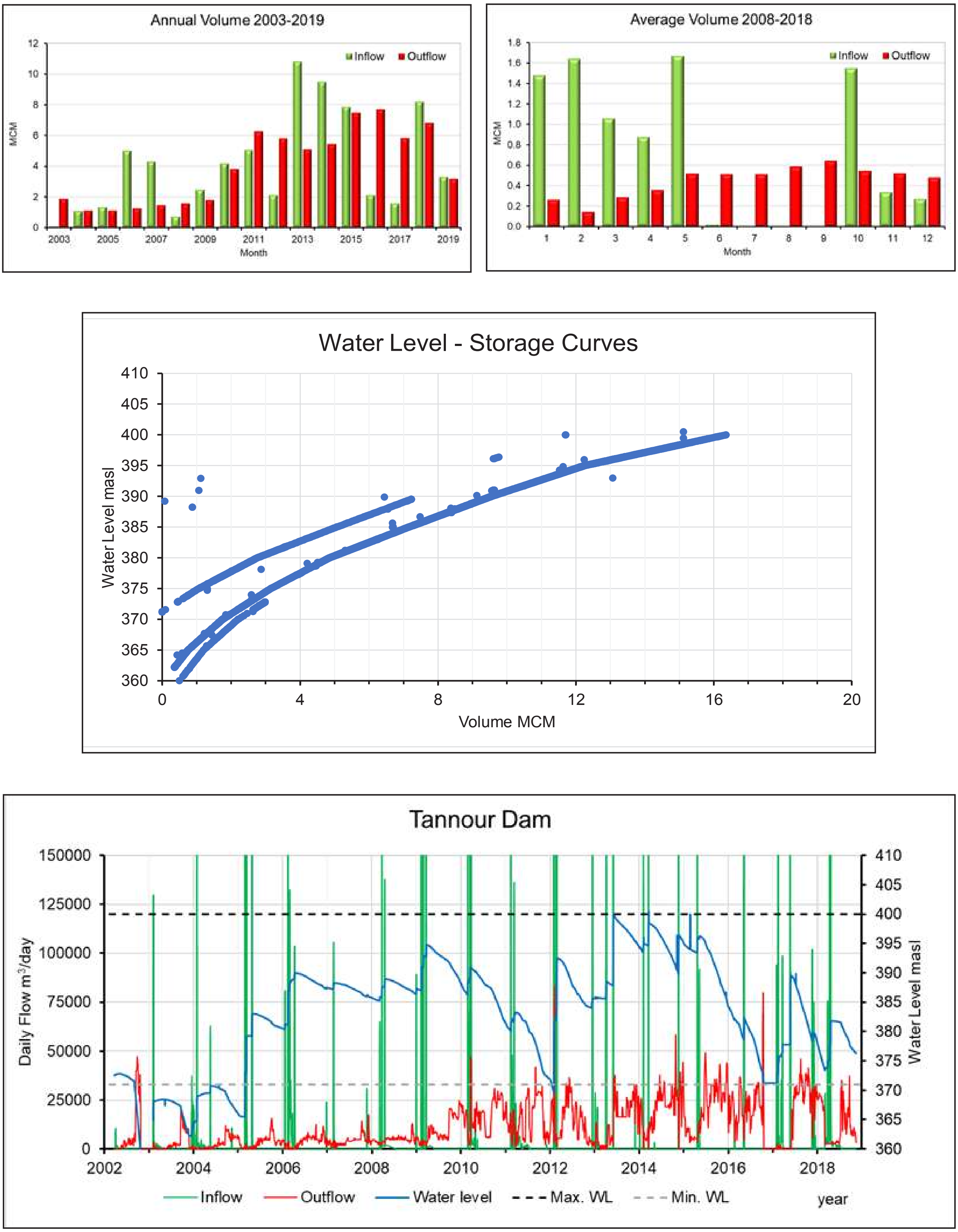


Figure 121: Tannour Dam – Inflow, Outflow, Water Level and Storage Curve

ANNEX 4: Facts on King Abdullah Canal

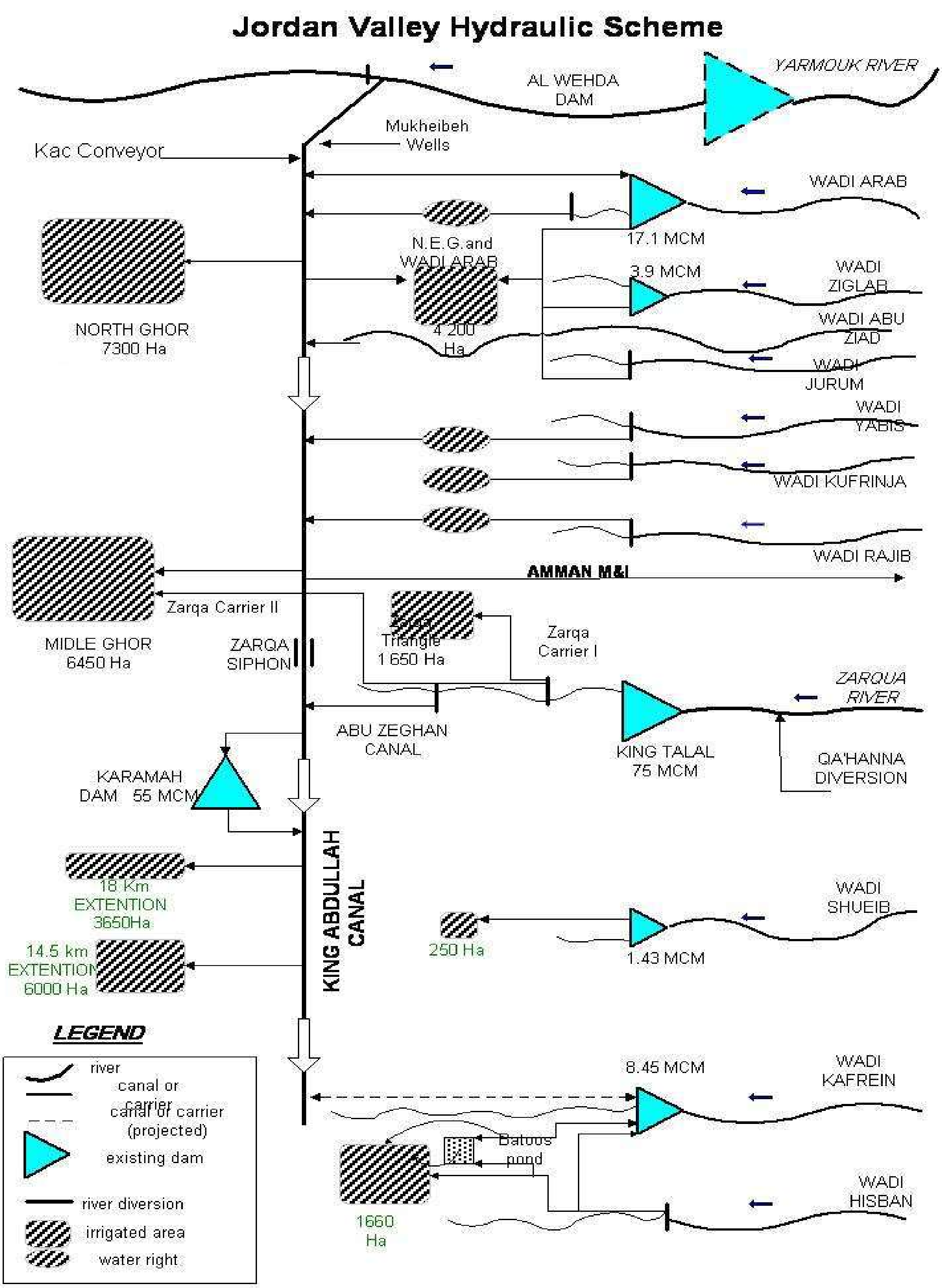


Figure 1: Jordan Valley Hydraulic Scheme

Figure 122: Schematics of Jordan Valley Irrigation Areas (adopted from TETRA TECH, 2018)

Table 79: Inflows to Jordan Valley (adopted from WORLD BANK, 2016)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	\2010	2011
Yamouk	54.616	30.414	22.953	54.748	68.610	42.550	14.249	31.765	23.496	28.500	26.203	26.407
Mukhaibah Wells	17.865	19.871	30.880	24.410	28.753	32.121	34.665	31.830	30.199	28.529	27.698	25.557
Ziqlab	5.111	4.393	4.150	8.158	8.235	7.284	6.429	5.136	3.896	3.752	2.384	2.374
Jarem	4.518	2.771	2.502	3.662	4.041	3.225	3.304	3.278	2.672	2.406	2.249	1.877
Kufranja	5.043	2.727	3.657	17.320	4.180	6.518	4.147	4.280	2.204	2.694	2.371	2.460
Rajib	3.535	1.712	2.639	11.775	2.792	3.124	2.337	2.596	1.596	1.629	0.106	0.022
Zarqa River	77.287	72.774	87.514	117.477	82.466	89.098	76.293	82.110	79.341	98.717	104.228	95.414
Shieb	4.674	4.398	7.812	13.911	4.468	4.698	3.933	6.142	3.071	6.155	5.549	4.006
Kafreen	8.028	6.558	14.592	23.137	8.518	11.615	7.393	10.855	6.938	8.435	11.257	6.746
Hasban	1.498	1.375	3.296	4.074	2.782	3.186	2.173	0.909	1.031	3.031	3.091	3.080
N. Conveyor	54.485	45.360	51.138	53.392	50.206	46.989	53.121	43.480	42.137	42.219	45.525	43.628
Small Wadis	1.000	0.319	0.337	15.308	2.329	4.811	2.527	1.762	1.653	1.578	0.046	0.050
Total	**237.760**	**192.672**	**231.470**	**347.372**	**267.380**	**255.220**	**210.571**	**224.144**	**198.234**	**227.407**	**230.706**	**211.622**

Table 80: Water Uses in the Jordan Valley (adopted from WORLD BANK, 2016)

Year	Estimated inflow (MCM)	Discharged for irrigation (MCM)	Drinking water (MCM)	Total water for all uses (MCM)	Water for all uses as a percentage of total water inflows	Three-year trend average of water uses as a percentage of total water inflows	Drinking water as a percentage of total water uses
2001	192.67	102.07	39.94	142.01	74%	n.a.	28%
2002	231.47	158.39	36.75	195.13	84%	73%	19%
2003	343.37	169.53	38.50	208.02	60%	77%	19%
2004	267.38	183.75	50.60	234.35	88%	77%	22%
2005	255.22	162.49	53.53	216.02	85%	86%	25%
2006	210.57	128.83	52.68	181.51	88%	83%	29%
2007	214.14	136.92	40.61	177.52	79%	84%	23%
2008	198.23	125.10	43.79	168.89	85%	81%	26%
2009	227.41	132.33	49.43	181.76	80%	83%	27%
2010	230.71	138.21	53.00	191.21	83%	82%	28%
2011	211.62	123.72	53.54	177.29	84%	83%	30%
Average	236.87	133.36	46.48	179.85	76	76%	26%
Hasban	1.498	1.375	3.296	4.074	2.782		3.186
N. Conveyor	54.485	45.360	51.138	53.392	50.206		46.989
Small Wadis	1.000	0.319	0.337	15.308	2.329		4.811
Total	**237.760**	**192.672**	**231.470**	**347.372**	**267.380**		**255.220**

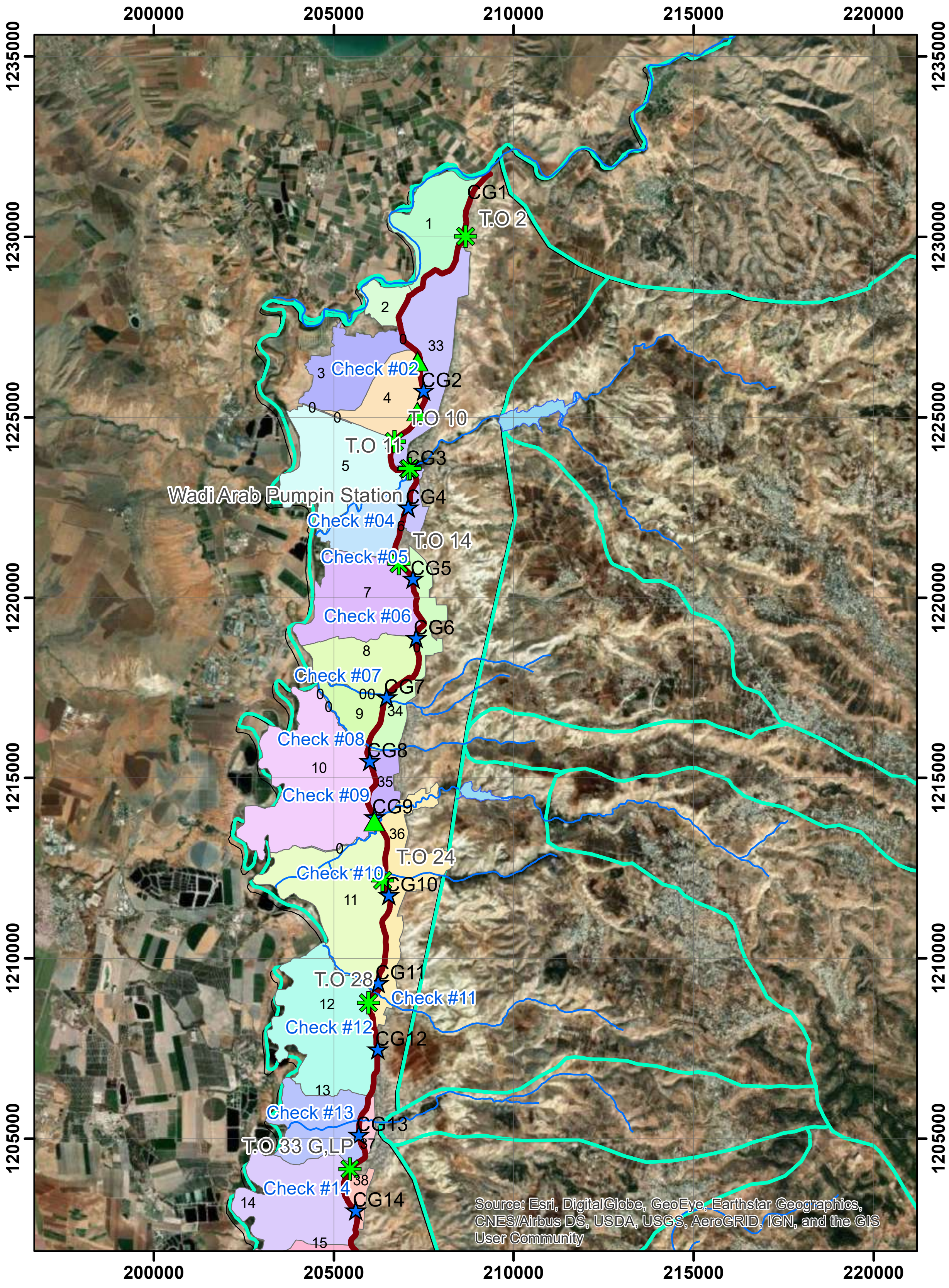


Figure 123: Development Areas (DA), Check Gates (CG) and Turnouts (TO) in Northern Section of KAC

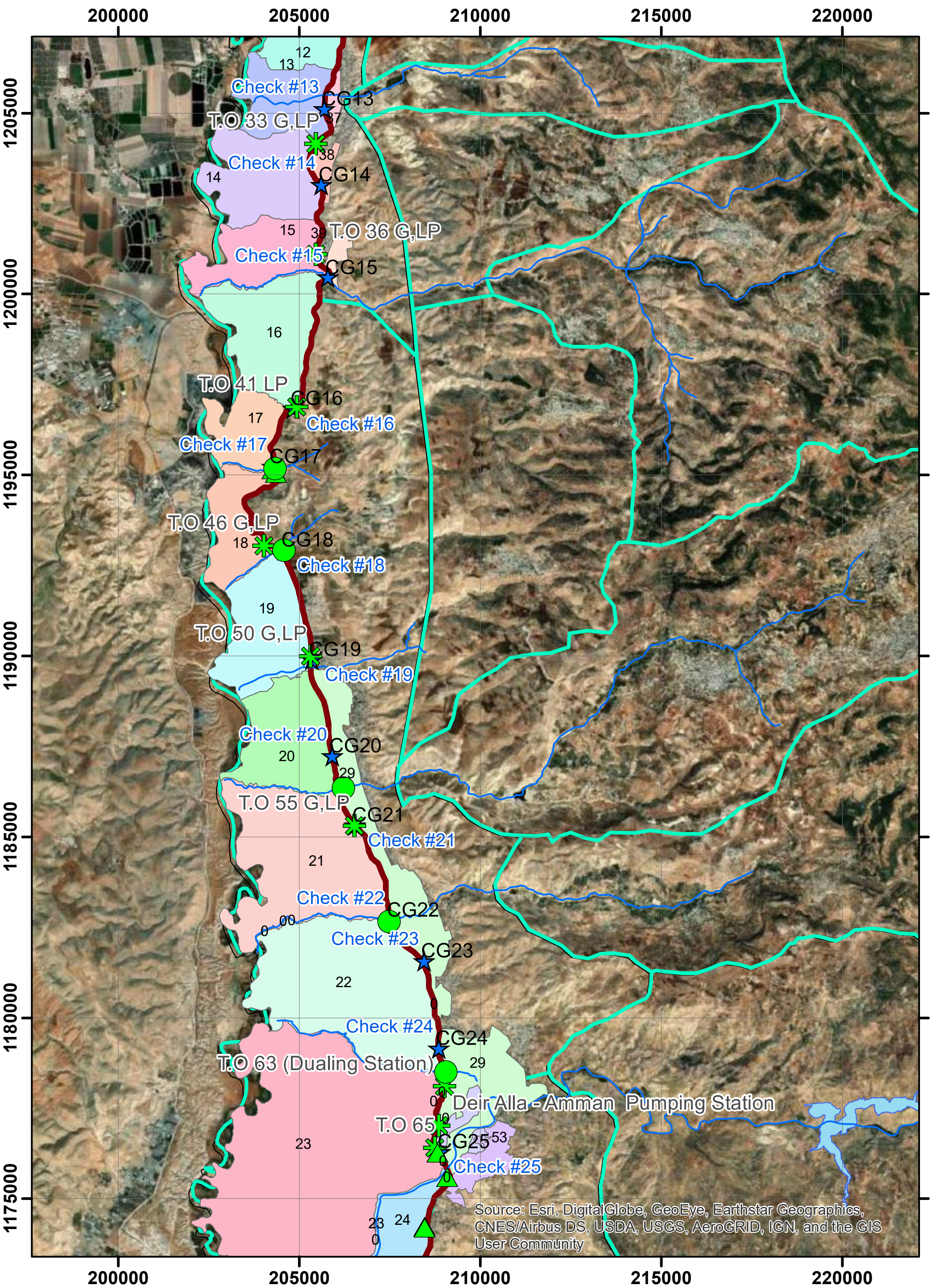


Figure 124: Development Areas (DA), Check Gates (CG) and Turnouts (TO) in Central-Northern Section of KAC

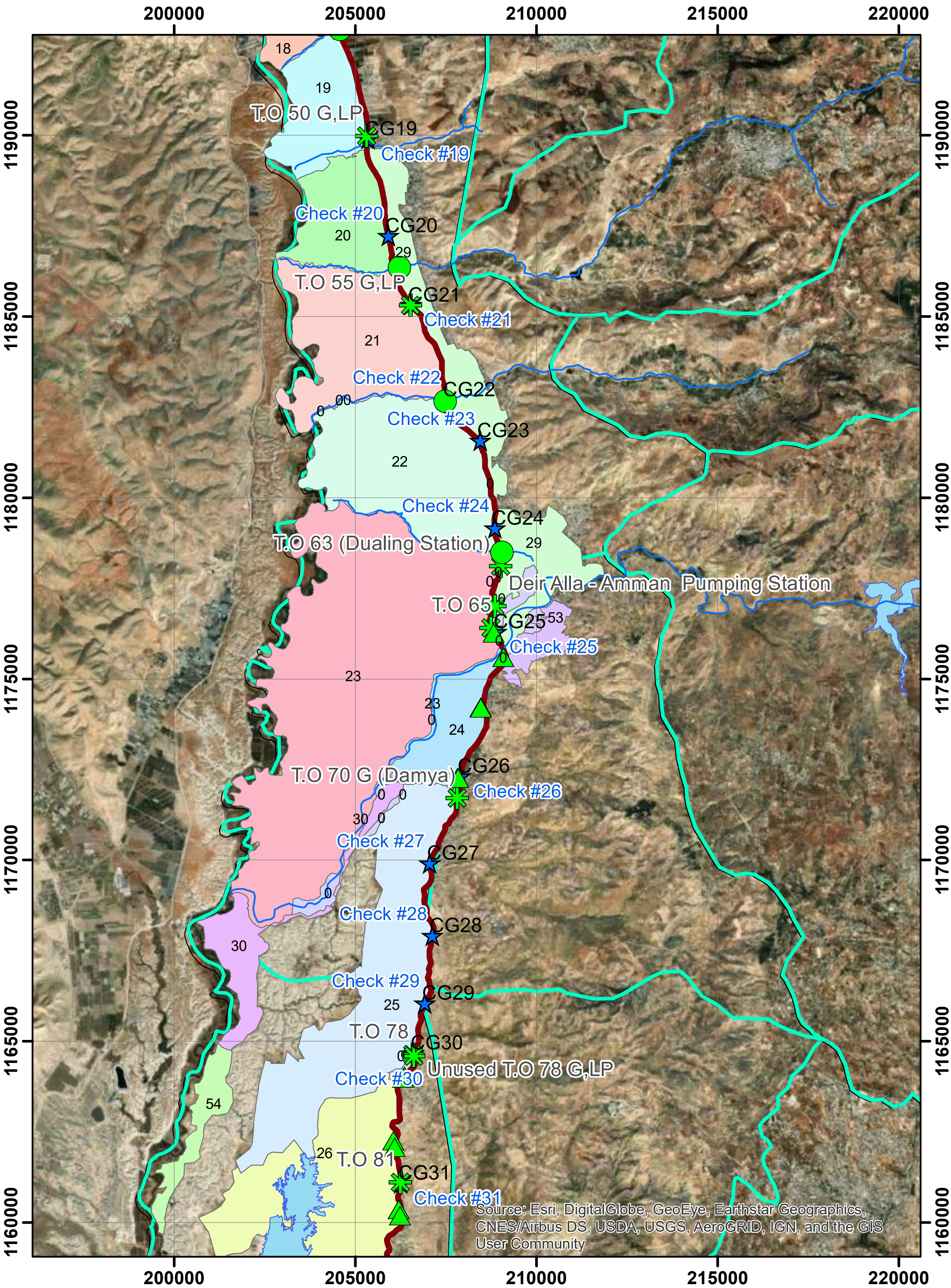


Figure 125: Development Areas (DA), Check Gates (CG) and Turnouts (TO) in Central Section of KAC around Deir Allah

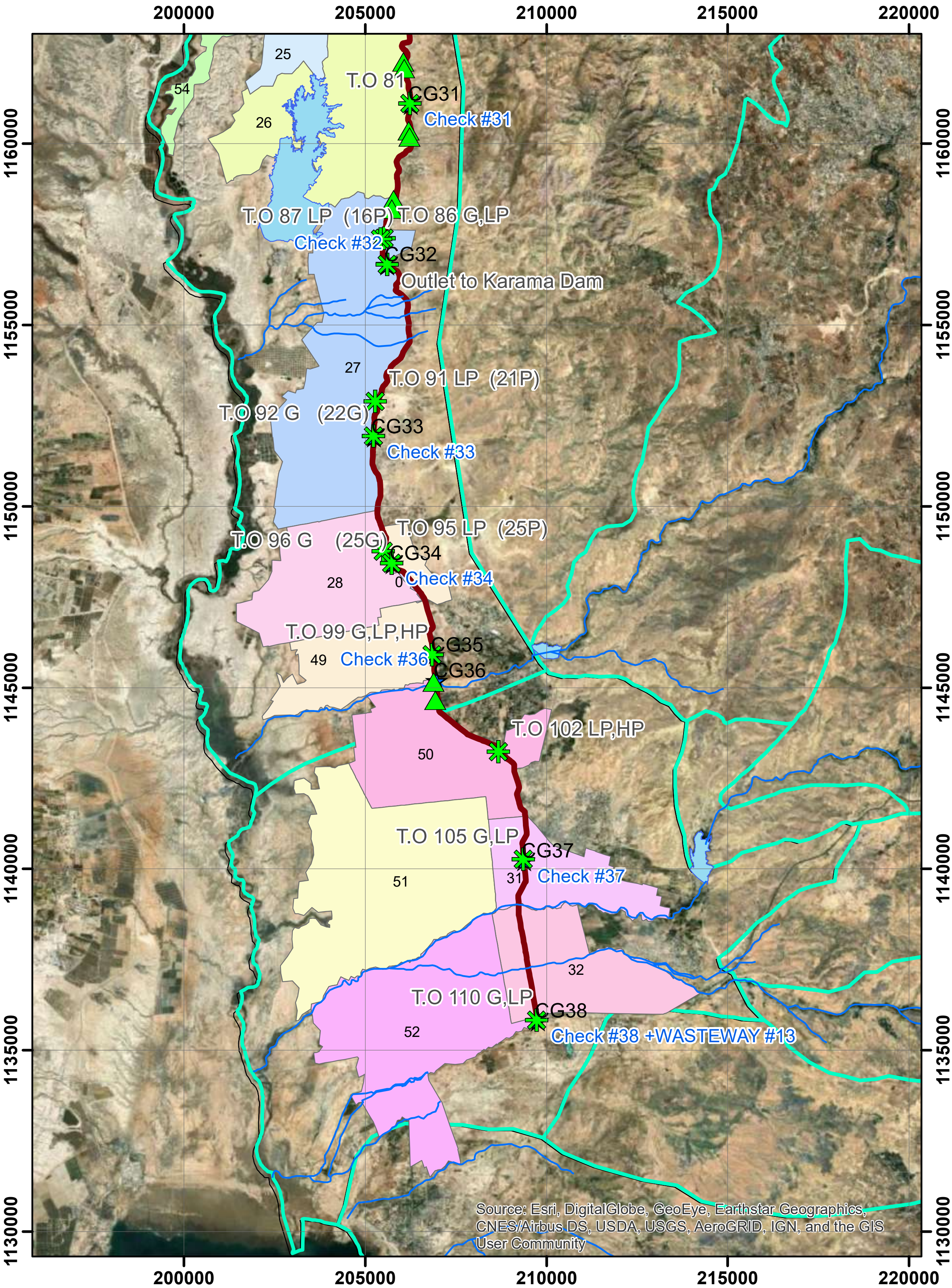


Figure 126: Development Areas (DA), Check Gates (CG) and Turnouts (TO) in Southern Section of KAC

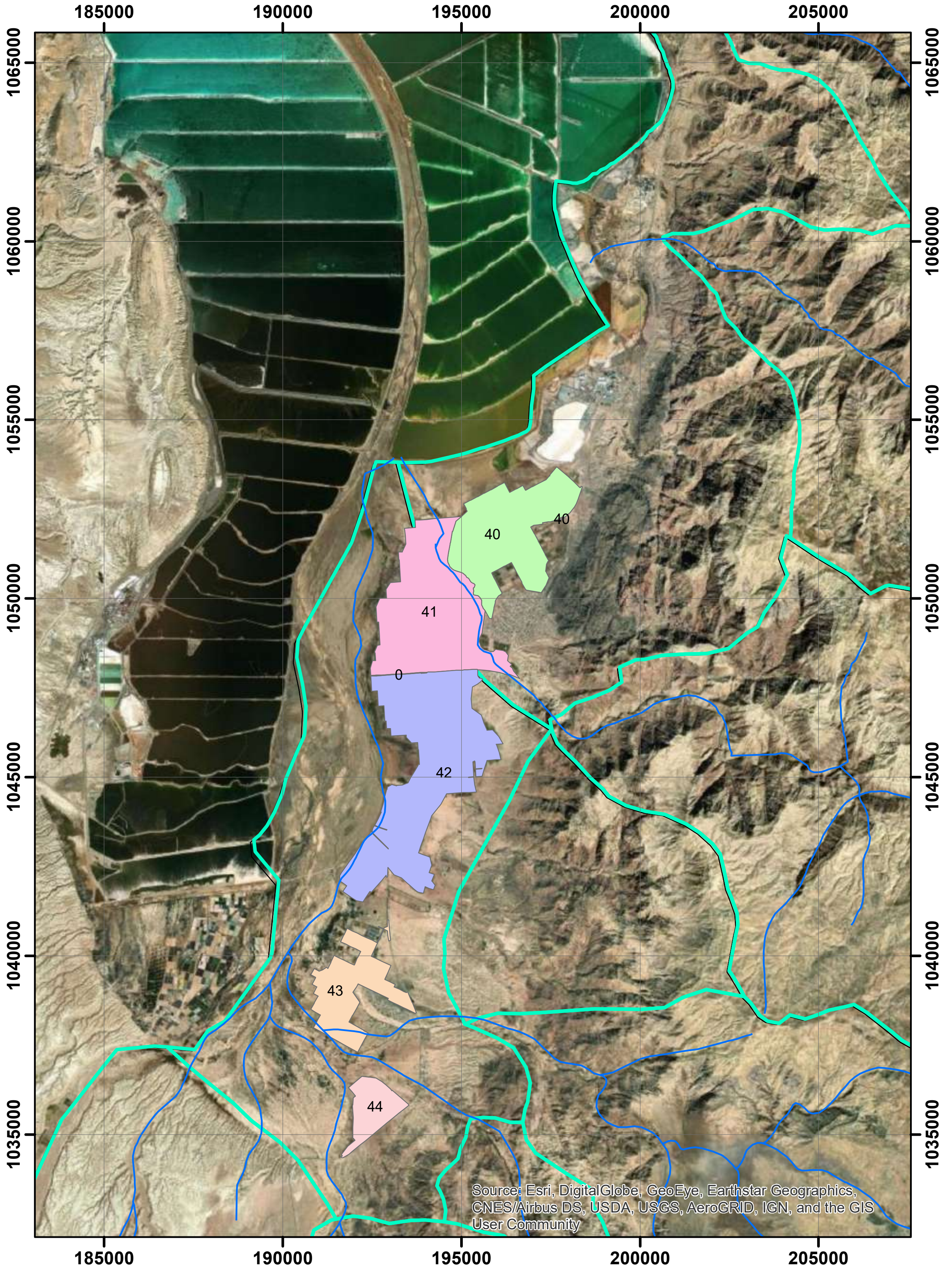


Figure 127: Development Areas (DA) in South Ghor

Surface water and treated wastewater distribution in the Jordan Valley is arranged in three sections:

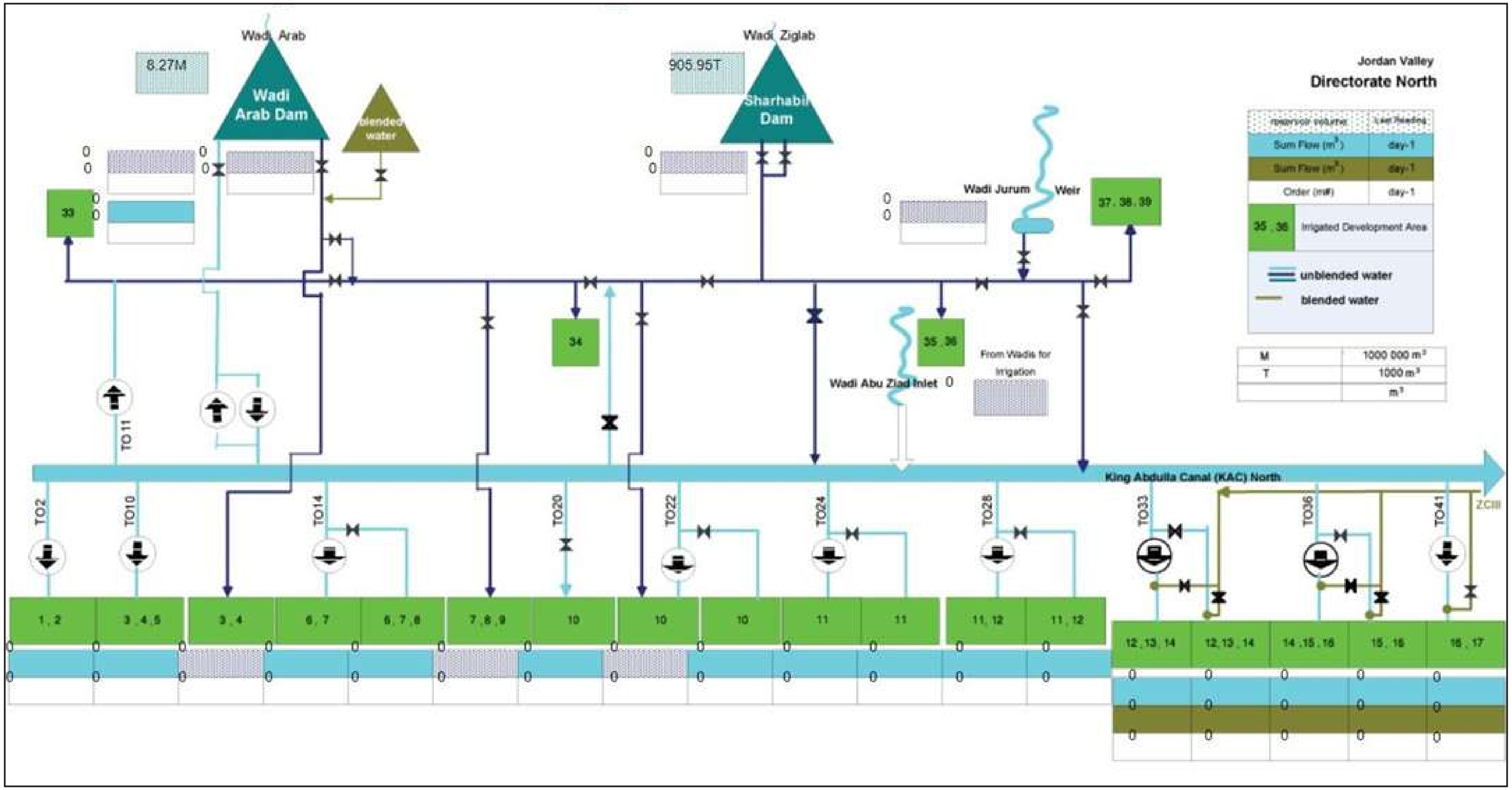


Figure 128: Water Distribution System for Irrigation in Northern Jordan Valley (Northern Ghor)

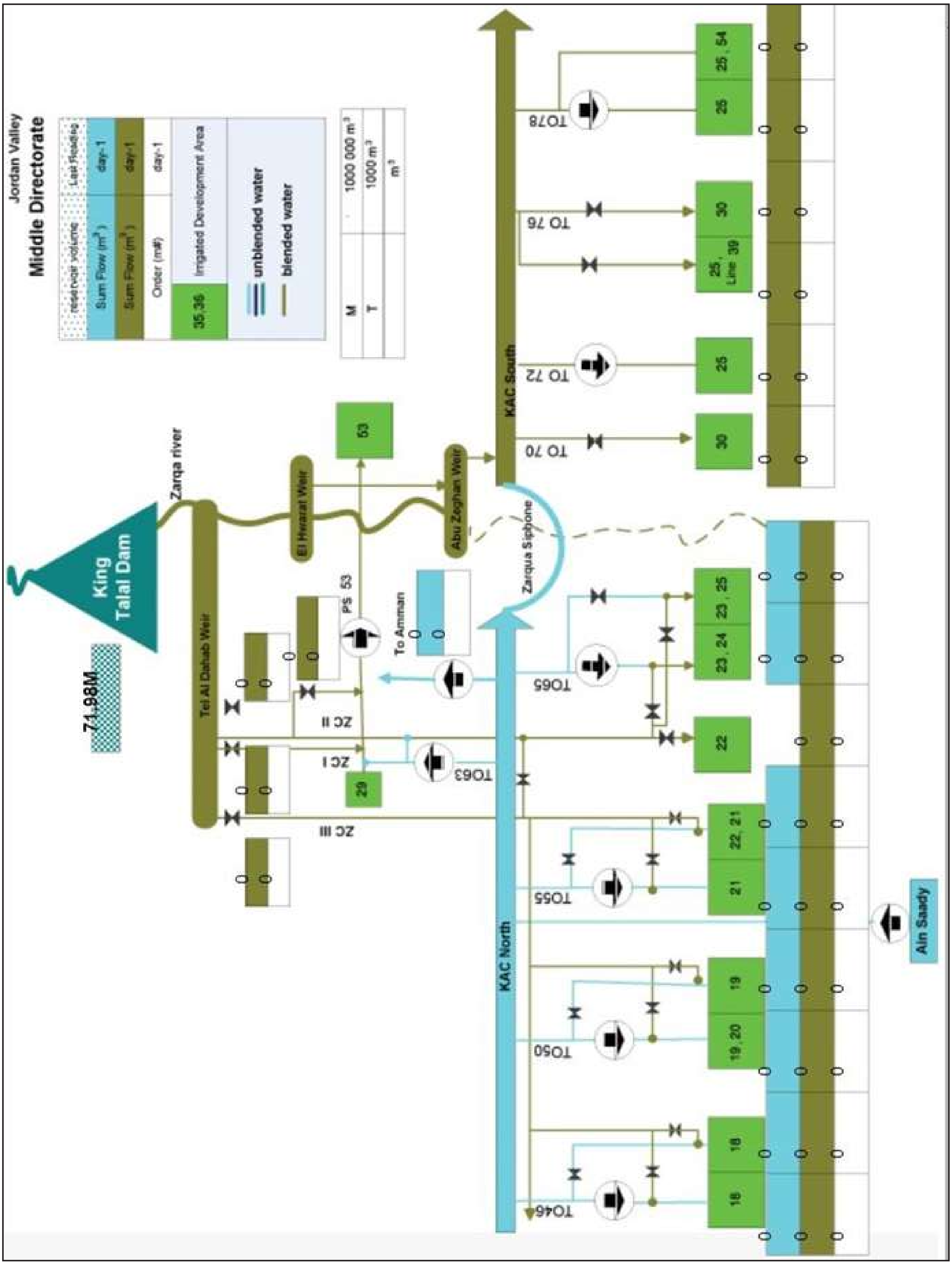


Figure 129: Water Distribution System for Irrigation in the Central Jordan Valley (Middle Ghor)

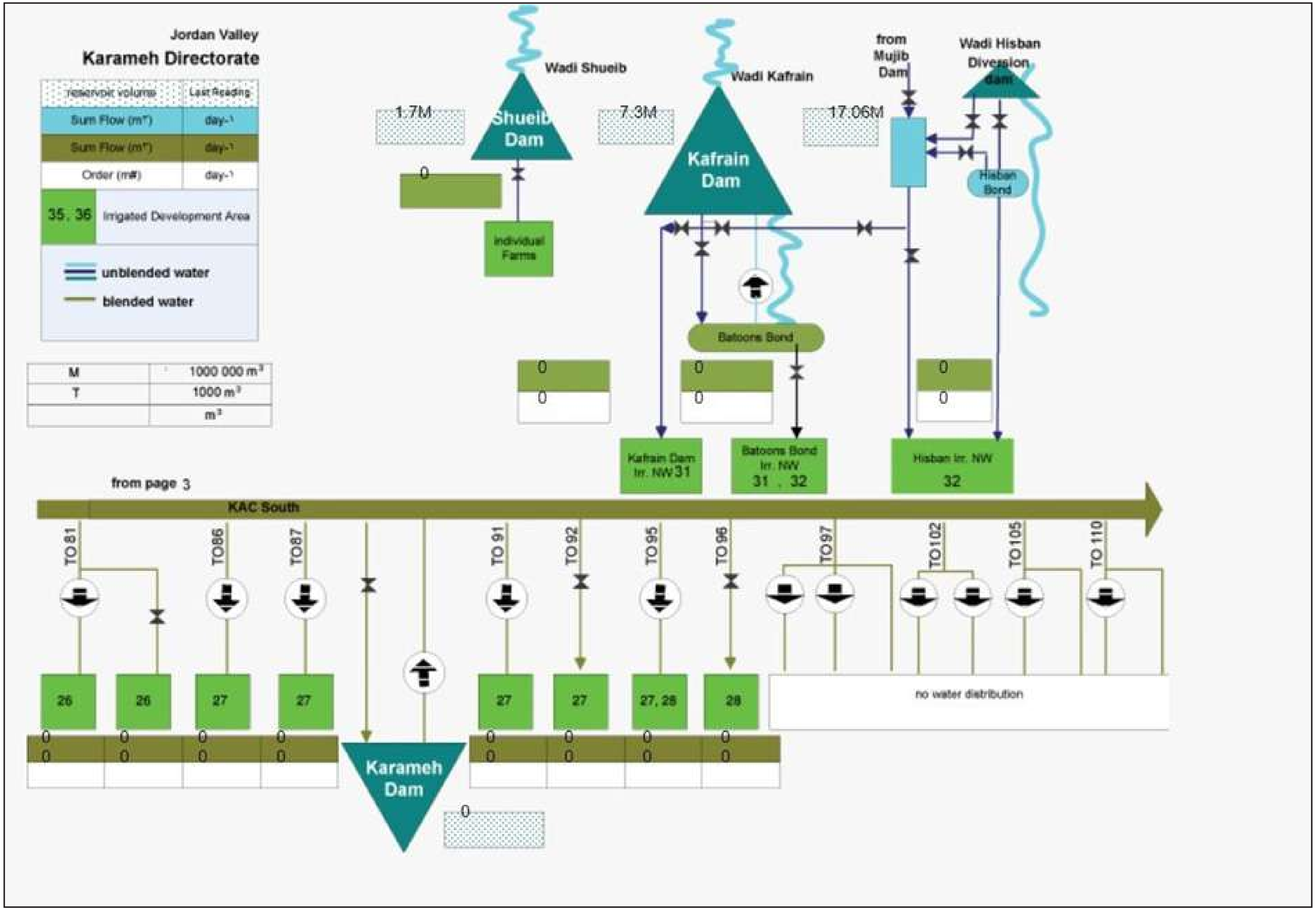


Figure 130: Water Distribution System for Irrigation in the Southern Jordan Valley (South Ghor)

ANNEX 5: Water Systems

This Annex might present the Water Systems that are used in this document. Until now, however, WMI project did not permit to include these here. The Water Systems were defined and agreed on in cooperation with the WMI project, and are listed by governorates from North to South. Drawings were prepared and adopted from the WMI project. Depending on the interconnection among systems, Water Systems are divided into many (such as Irbid) or not subdivided at all (such as Zarqa)

ANNEX 6: Water Quality Constraints

This Annex refers to Chapter 3.2.3, where expected water quality changes are described. The Annex documents some maps from investigations related to this issue.

ANNEX 6.1: Groundwater Salinity

A map of the groundwater resources potential of Northern Jordan was prepared in the framework of the Groundwater Resources Assessment of Northern Jordan (BGR, 1992-2001; Figure 131). This map contained the known extent of brackish and saline groundwater resources (Figure 132). However, since there were an inadequate number and distribution of points for this map, the distribution only constitutes a rough estimation.

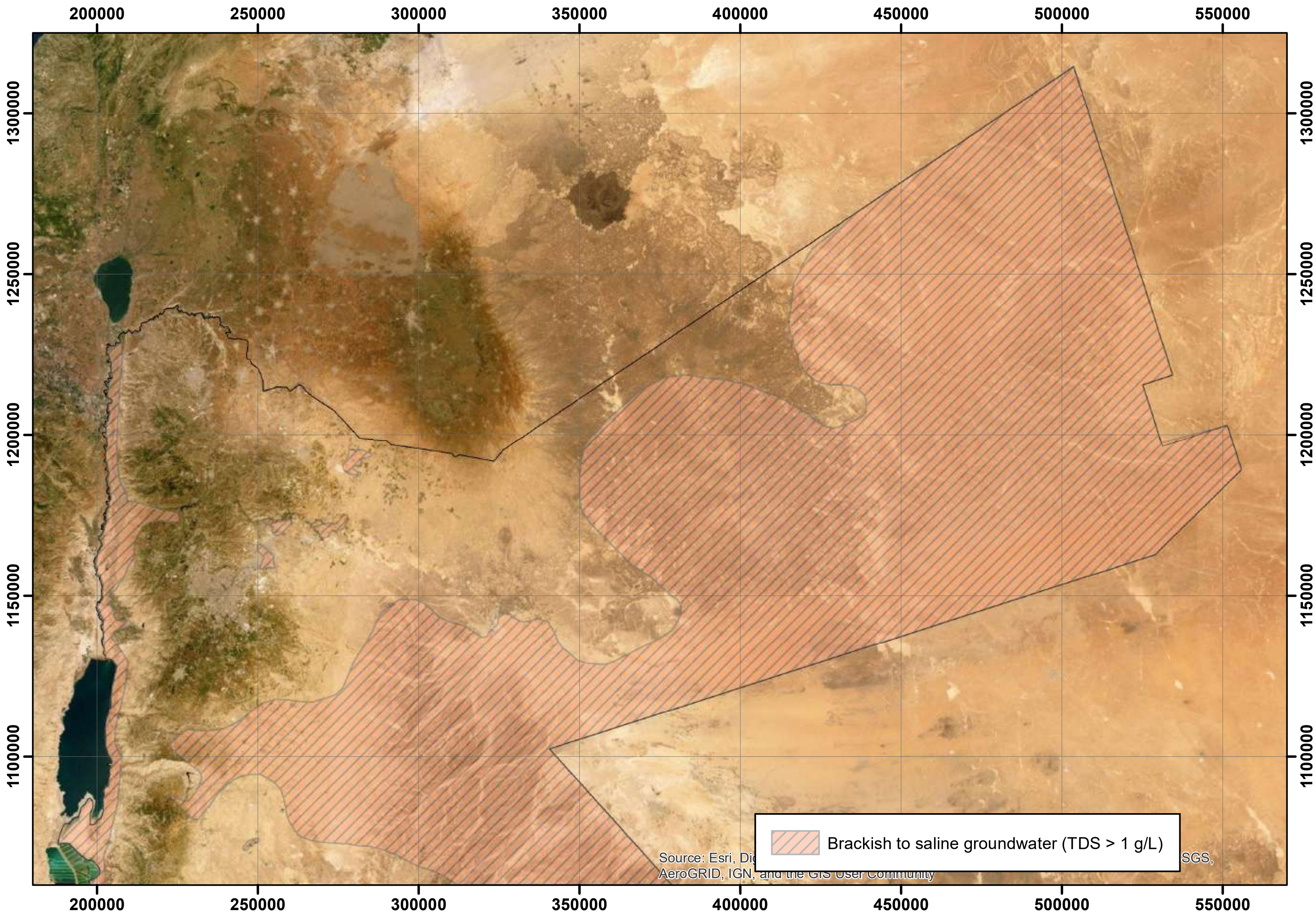


Figure 131: Extent of Brackish and Saline Groundwater Resources (modified after HOBLER et al., 2000)

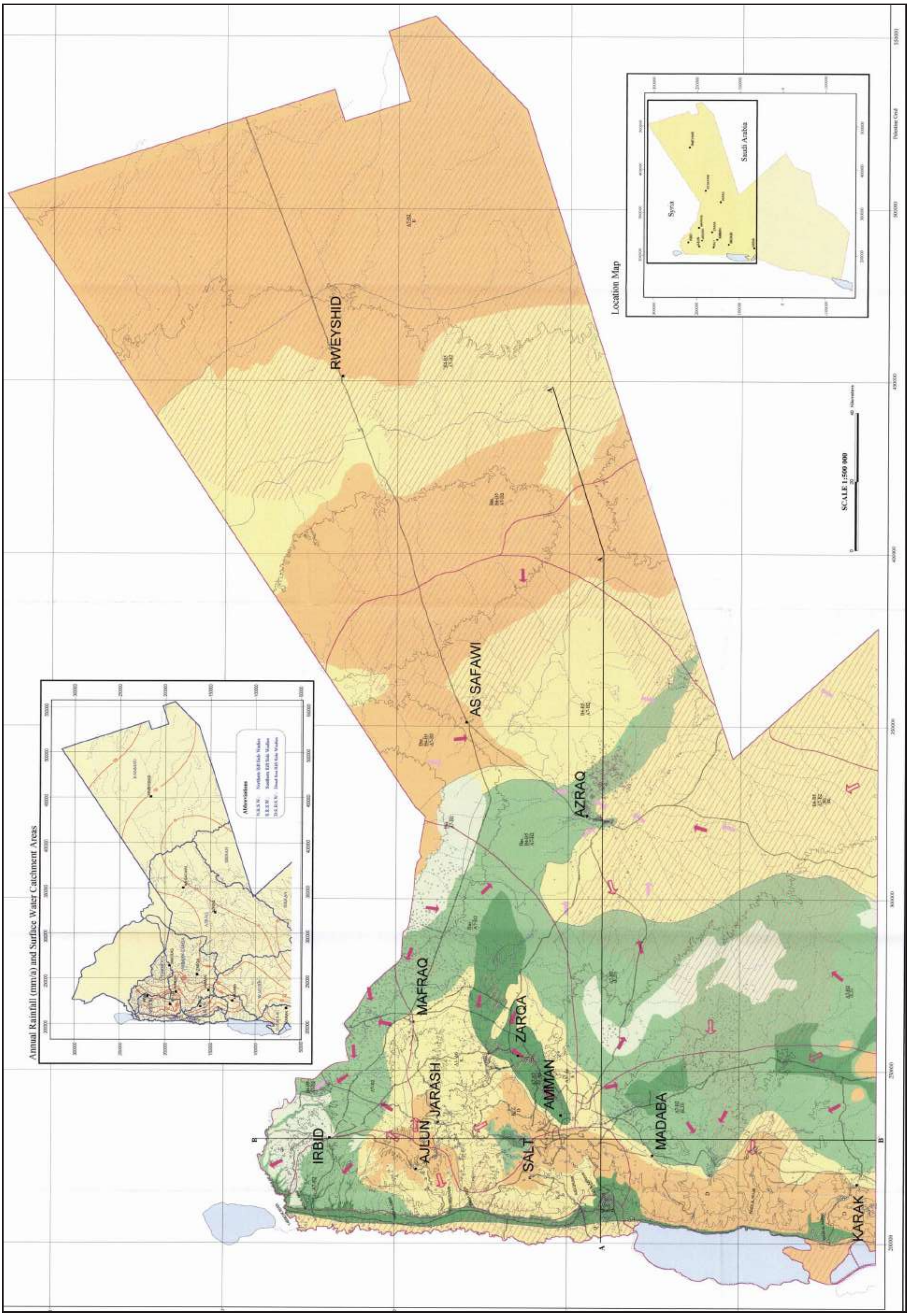


Figure 132: Groundwater Potential Map of Northern and Central Jordan (HOBLER et al., 2000)

ANNEX 6.2: Areas with Elevated Heavy Metal Concentrations

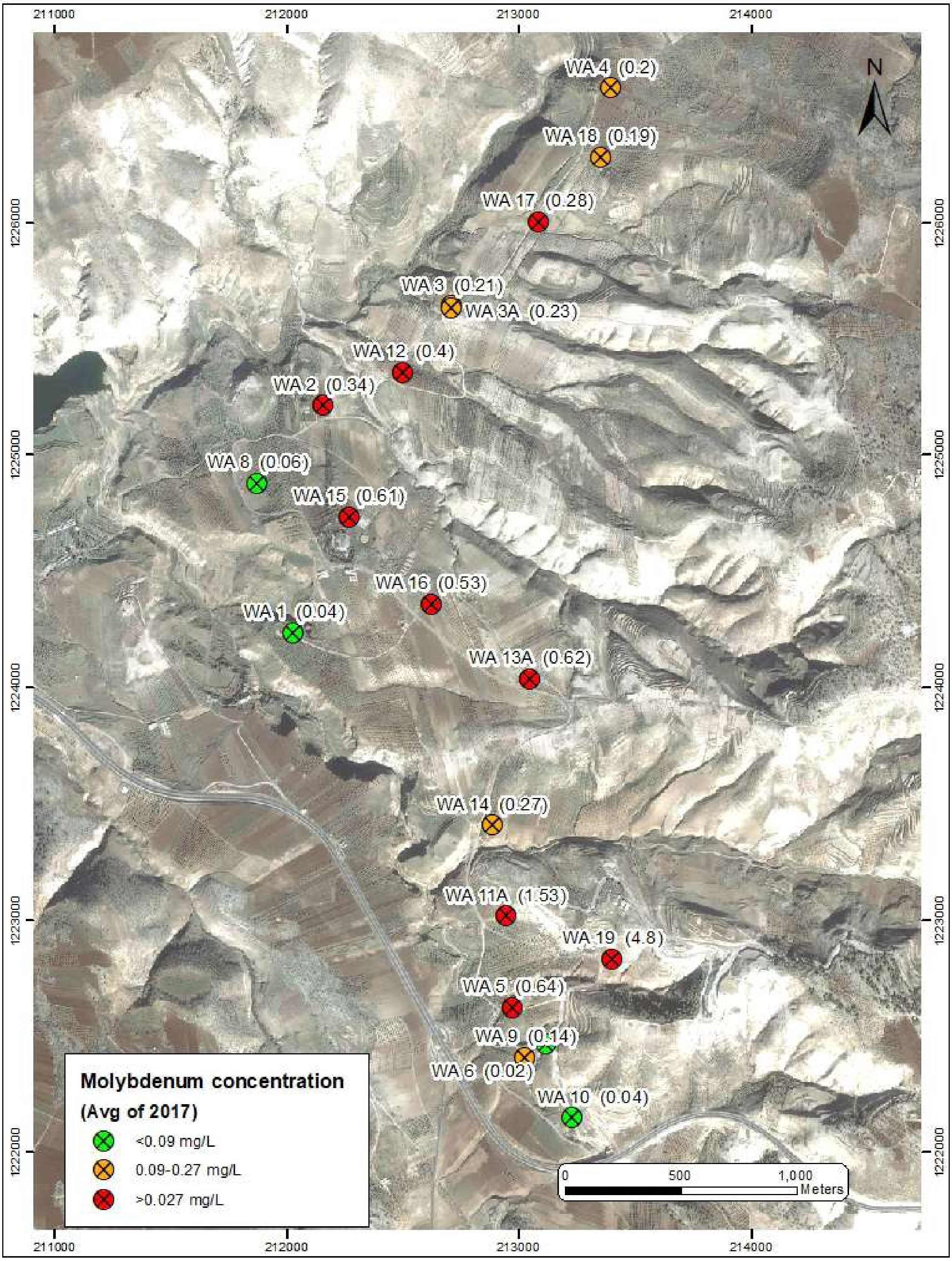
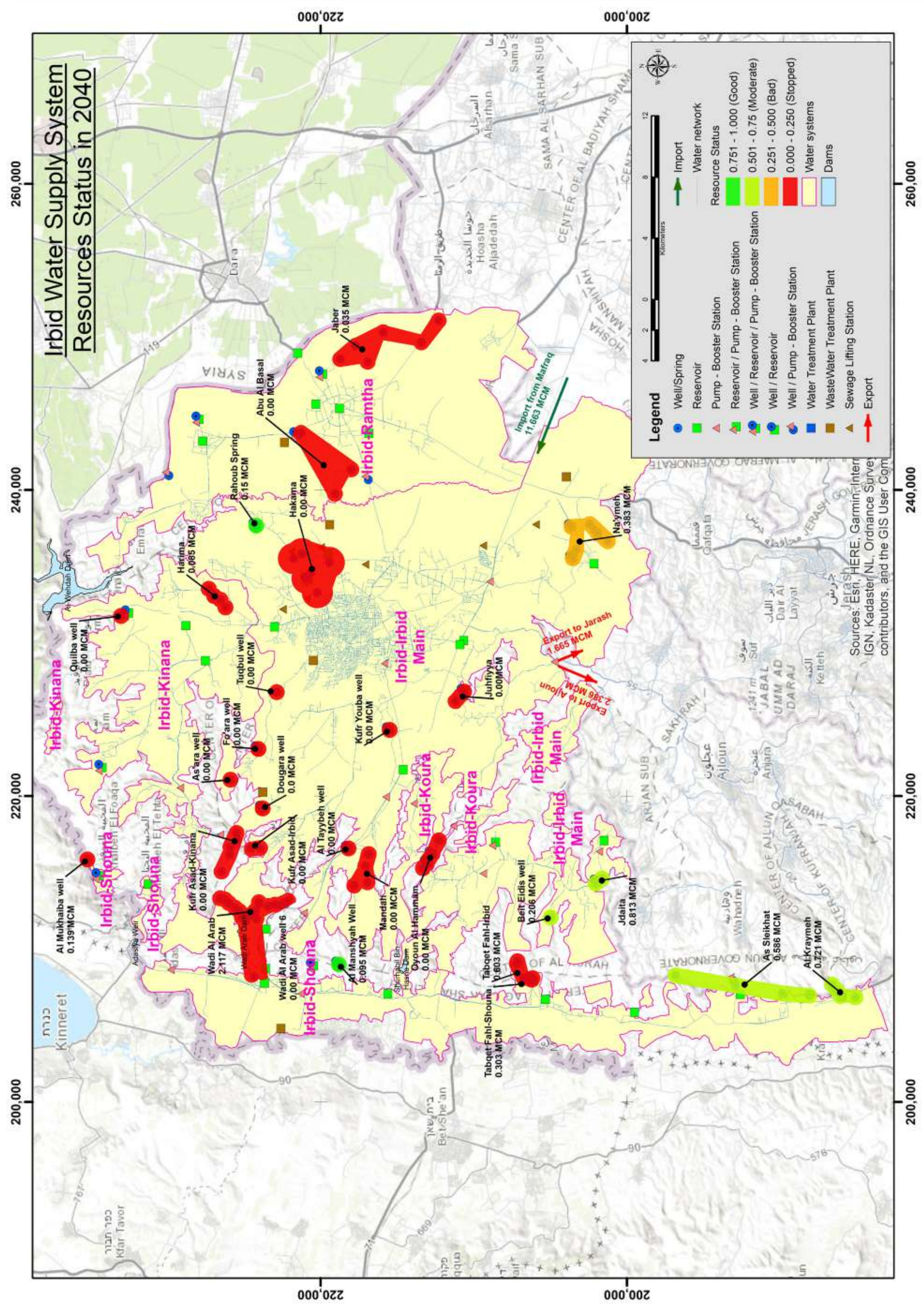
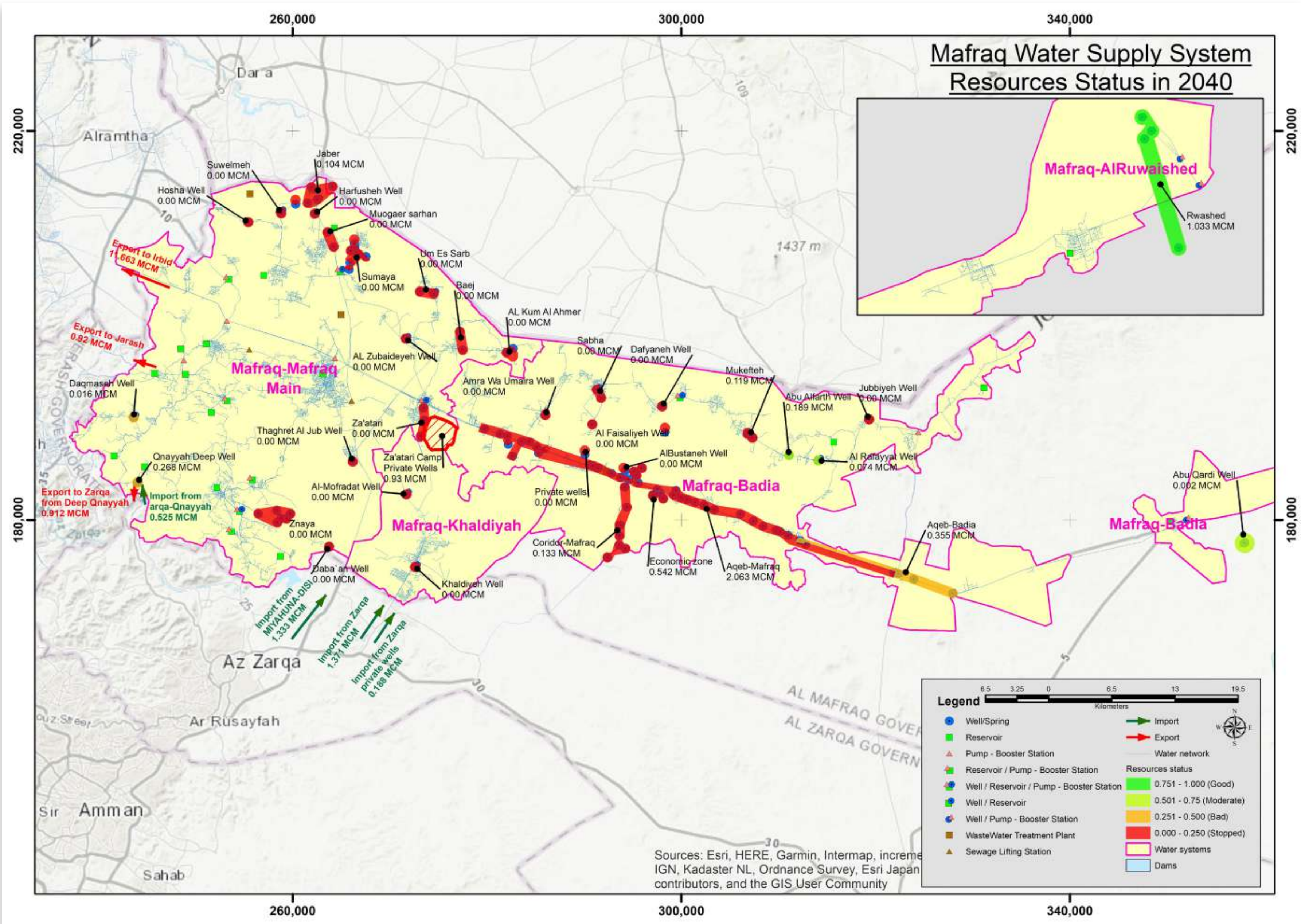
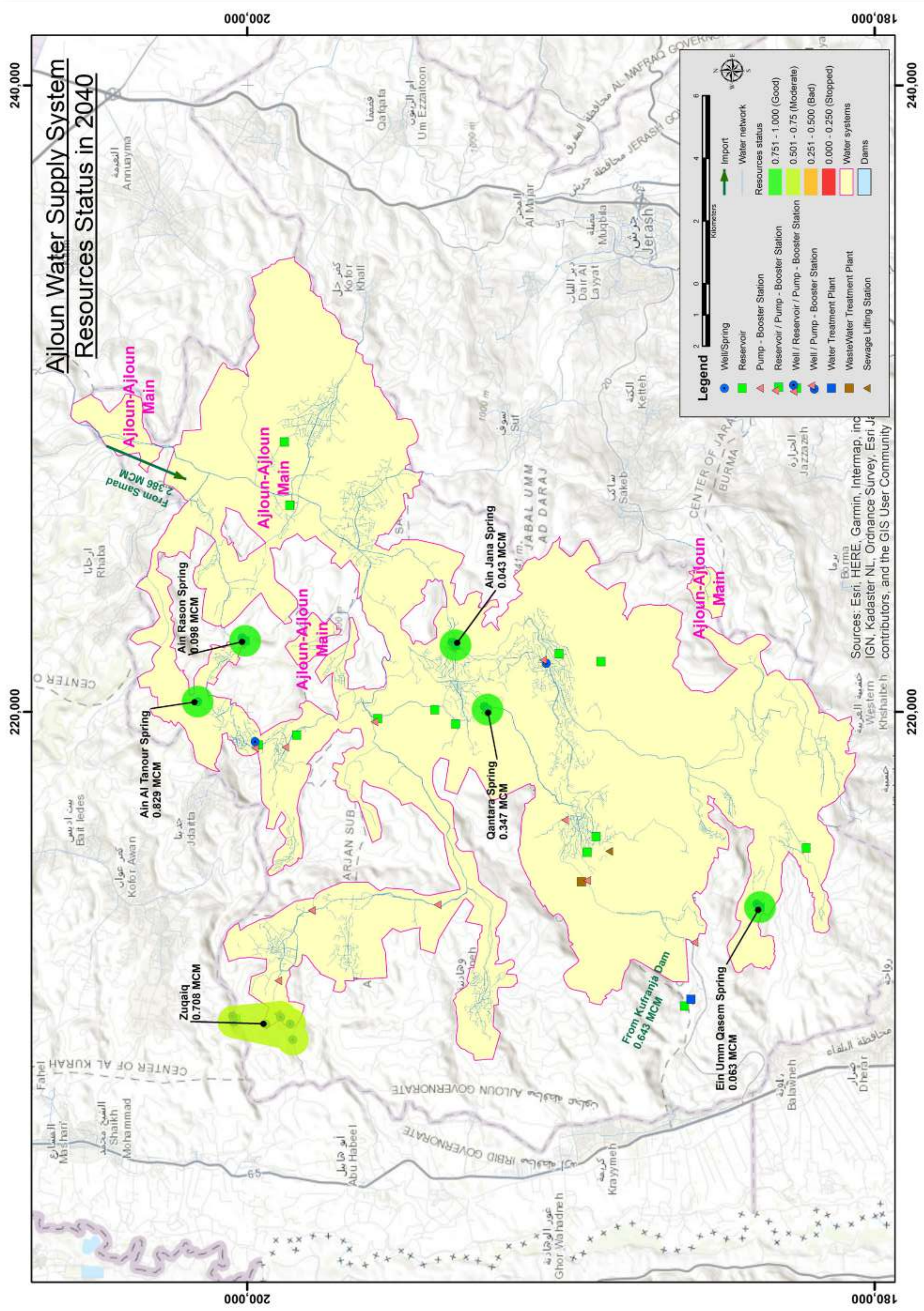


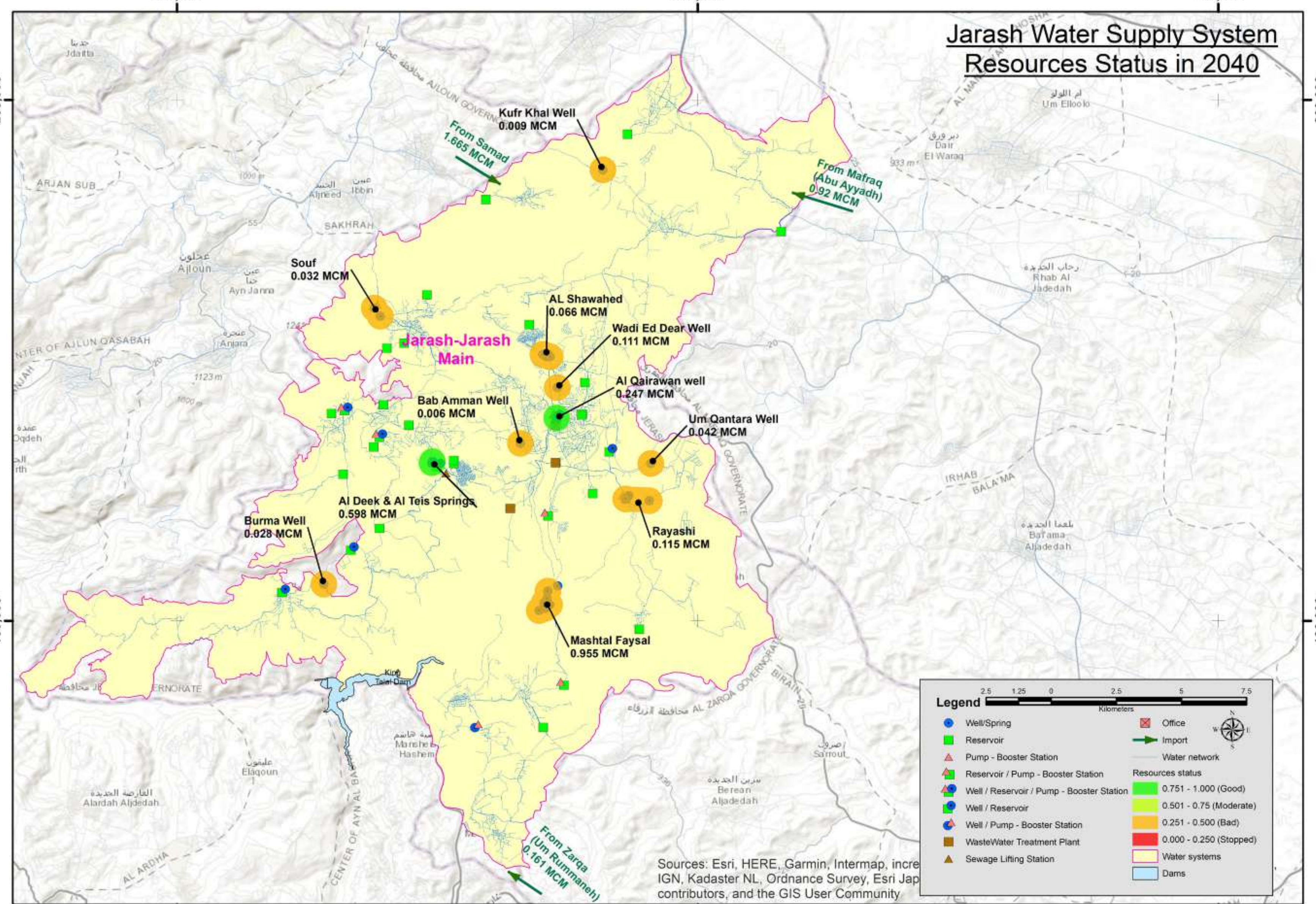
Figure 133: Molybdenum contents in Wadi Arab wellfield (average in 2017)

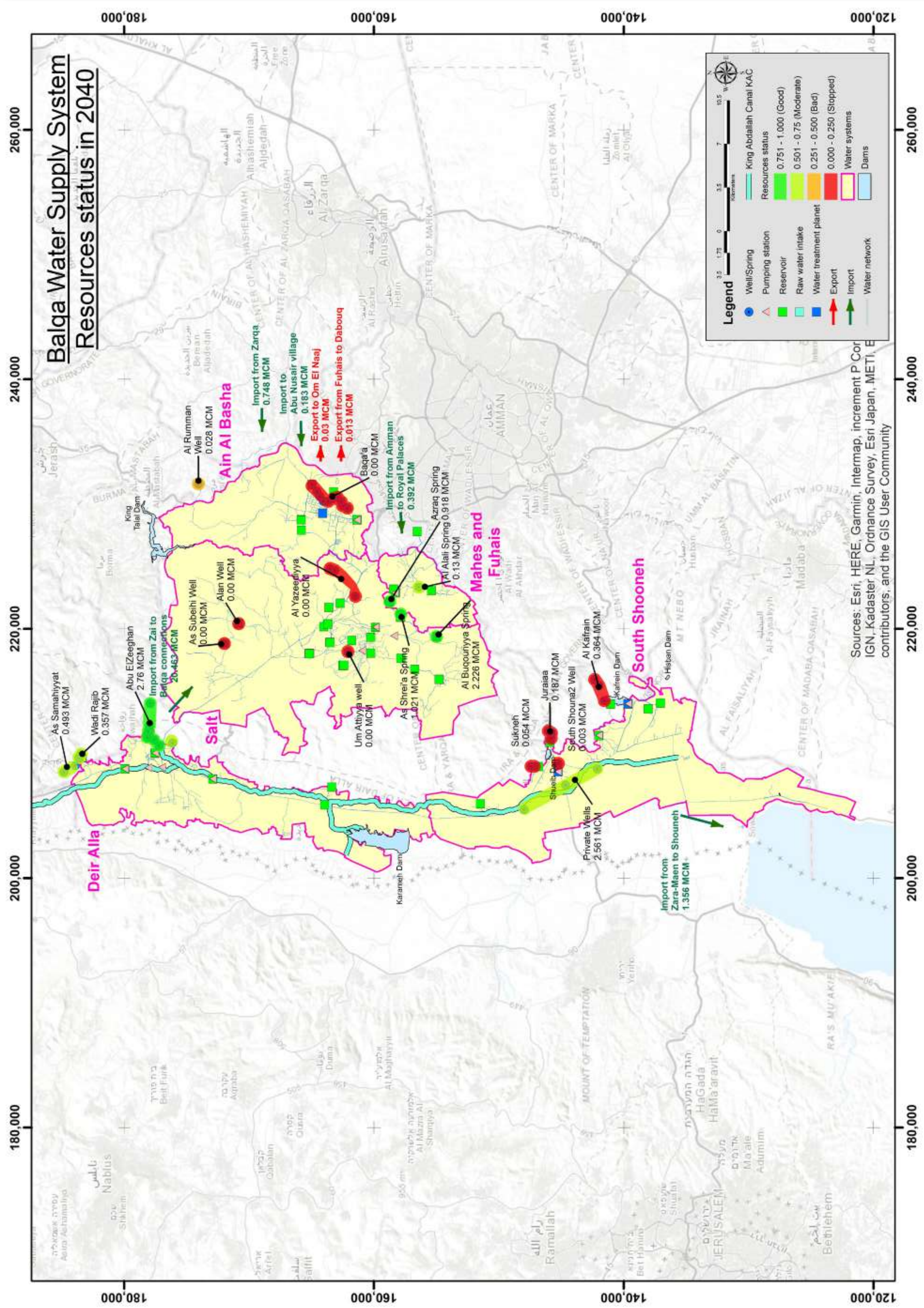
ANNEX 7: Vulnerability of Water Supplies by Governorate

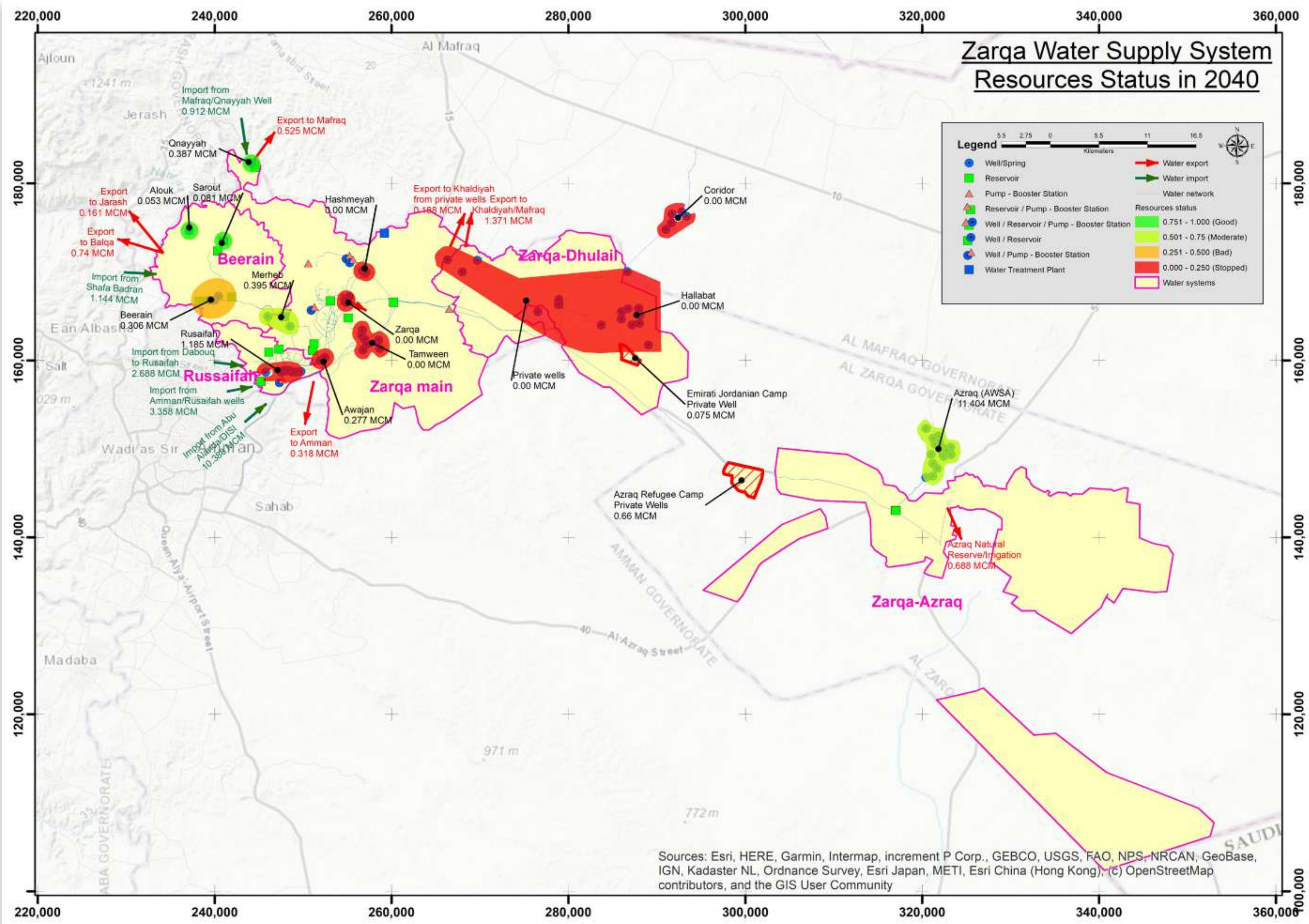



Mafraq Water Supply System
Resources Status in 2040
260,000
300,000
340,000
220,000
180,000
Mafraq-AlRuwaished
Rwashed
1.033 MCM
Mafraq-Mafraq Main
Mafraq-Khaldiyah
Mafraq-Badia
Jaber
0.104 MCM
Suwelmeh
0.00 MCM
Hosha Well
0.00 MCM
Harfusheh Well
0.00 MCM
Muogaer sarhan
0.00 MCM
Um Es Sarb
0.00 MCM
Sumaya
0.00 MCM
Baej
0.00 MCM
AL Kum Al Ahmer
0.00 MCM
AL Zubaideyeh Well
0.00 MCM
Sabha
0.00 MCM
Dafyaneh Well
0.00 MCM
Amra Wa Umaira Well
0.00 MCM
Mukefteh
0.119 MCM
Abu Alfarth Well
0.189 MCM
Jubbiyeh Well
0.00 MCM
Al Rafayyat Well
0.074 MCM
Al Faisaliyeh Well
0.00 MCM
AlBustaneh Well
0.00 MCM
Private wells
0.00 MCM
Corridor-Mafraq
0.133 MCM
Economic zone
0.542 MCM
Aqeb-Mafraq
2.063 MCM
Aqeb-Badia
0.355 MCM
Abu Qardi Well
0.002 MCM
Za'atari
0.00 MCM
Za'atari Camp
Private Wells
0.93 MCM
Thaghret Al Jub Well
0.00 MCM
Al-Mofradat Well
0.00 MCM
Znaya
0.00 MCM
Daba'an Well
0.00 MCM
Khaldiyeh Well
0.00 MCM
Daqmaseh Well
0.016 MCM
Qnayyah Deep Well
0.268 MCM
Export to Irbid
11.663 MCM
Export to Jarash
0.92 MCM
Export to Zarqa
from Deep Qnayyah
0.912 MCM
Import from
arqa-Qnayyah
0.525 MCM
Import from
MIYAHUNA-DISI
1.333 MCM
Import from Zarqa
1.371 MCM
Import from Zarqa
private wells
0.188 MCM
Dar'a
Alramtha
Az Zarqa
Ar Rusayfah
Amman
Sahab
AL MAFRAQ GOVER
AL ZARQA GOVERN
1437 m
Legend
6.5 3.25 0 6.5 13 19.5
Kilometers
Well/Spring
Reservoir
Pump - Booster Station
Reservoir / Pump - Booster Station
Well / Reservoir / Pump - Booster Station
Well / Reservoir
Well / Pump - Booster Station
WasteWater Treatment Plant
Sewage Lifting Station
Import
Export
Water network
Resources status
0.751 - 1.000 (Good)
0.501 - 0.75 (Moderate)
0.251 - 0.500 (Bad)
0.000 - 0.250 (Stopped)
Water systems
Dams
Sources: Esri, HERE, Garmin, Intermap, increme
IGN, Kadaster NL, Ordnance Survey, Esri Japan
contributors, and the GIS User Community

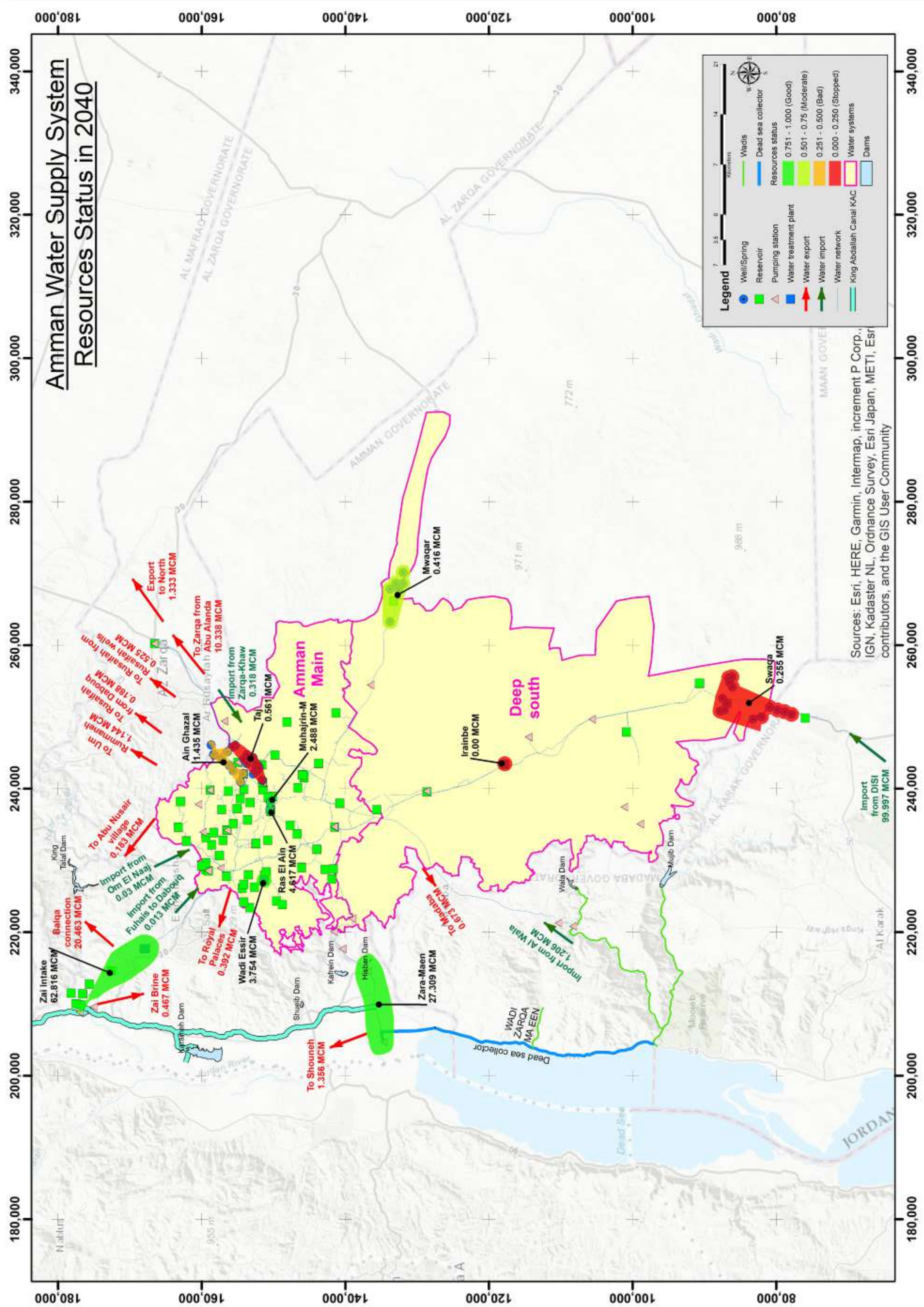

Ajloun Water Supply System
Resources Status in 2040
Ain Al Tanour Spring 0.829 MCM
Ain Rason Spring 0.098 MCM
Ain Jana Spring 0.043 MCM
Qantara Spring 0.347 MCM
Zuqaiq 0.708 MCM
Ein Umm Qasem Spring 0.063 MCM
From Kufranja Dam 0.643 MCM
From Samad 2.386 MCM
Ajloun-Ajloun Main
Legend
Well/Spring
Reservoir
Pump - Booster Station
Reservoir / Pump - Booster Station
Well / Reservoir / Pump - Booster Station
Well / Pump - Booster Station
Water Treatment Plant
WasteWater Treatment Plant
Sewage Lifting Station
Import
Water network
Resources status
0.751 - 1.000 (Good)
0.501 - 0.75 (Moderate)
0.251 - 0.500 (Bad)
0.000 - 0.250 (Stopped)
Water systems
Dams
Kilometers
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase,
IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap
contributors, and the GIS User Community
200,000
220,000
240,000
180,000

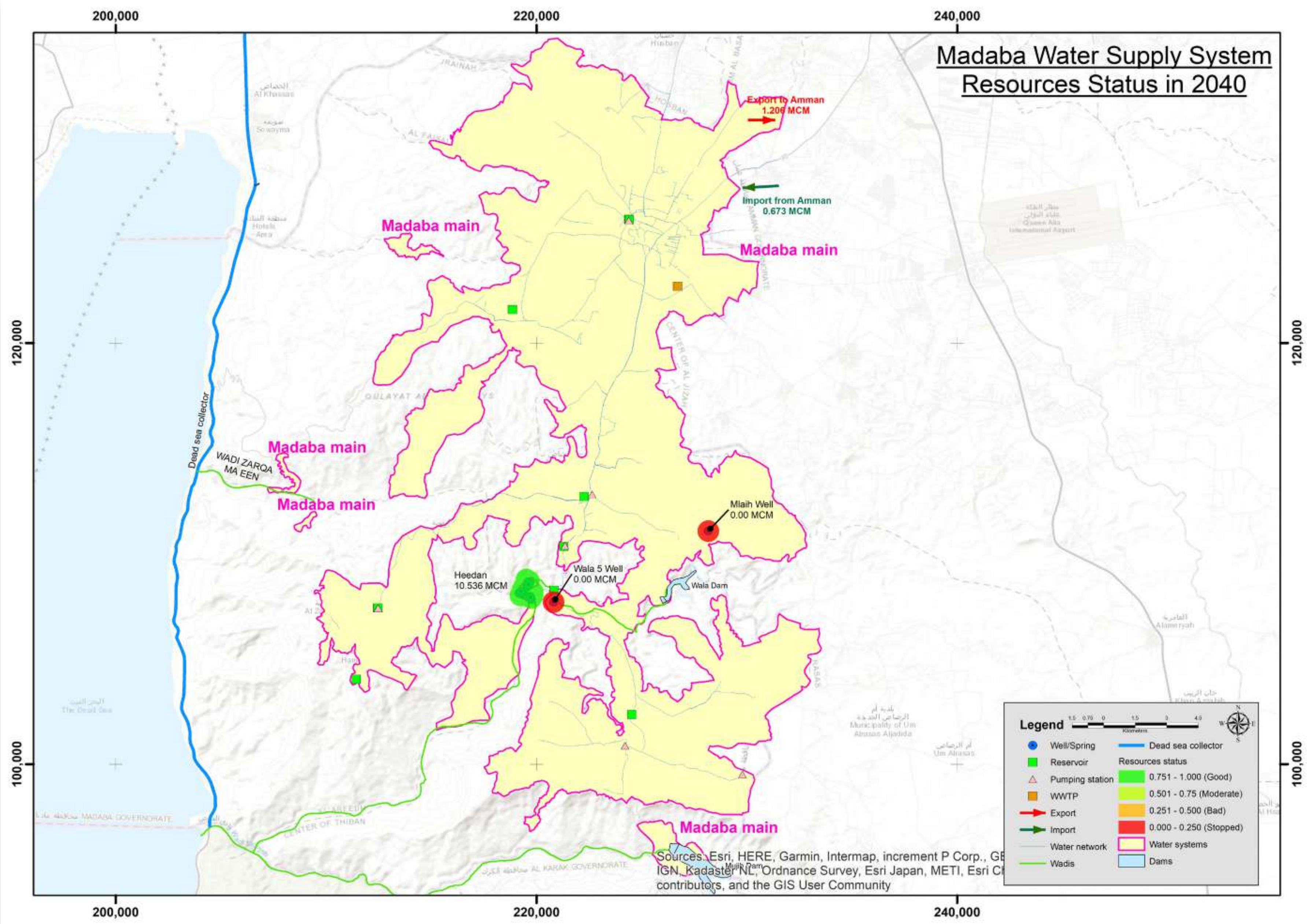

Jarash Water Supply System
Resources Status in 2040
Jarash-Jarash Main
Kufr Khal Well 0.009 MCM
From Samad 1.665 MCM
From Mafraq (Abu Ayyadh) 0.92 MCM
Souf 0.032 MCM
AL Shawahed 0.066 MCM
Wadi Ed Dear Well 0.111 MCM
Al Qairawan well 0.247 MCM
Bab Amman Well 0.006 MCM
Um Qantara Well 0.042 MCM
Al Deek & Al Teis Springs 0.598 MCM
Burma Well 0.028 MCM
Rayashi 0.115 MCM
Mashtal Faysal 0.955 MCM
From Zarqa (Um Rummaneh) 0.161 MCM
Legend
Well/Spring
Reservoir
Pump - Booster Station
Reservoir / Pump - Booster Station
Well / Reservoir / Pump - Booster Station
Well / Reservoir
Well / Pump - Booster Station
WasteWater Treatment Plant
Sewage Lifting Station
Office
Import
Water network
Resources status
0.751 - 1.000 (Good)
0.501 - 0.75 (Moderate)
0.251 - 0.500 (Bad)
0.000 - 0.250 (Stopped)
Water systems
Dams
Kilometers
220,000
240,000
260,000
200,000
180,000
Sources: Esri, HERE, Garmin, Intermap, incre
IGN, Kadaster NL, Ordnance Survey, Esri Jap
contributors, and the GIS User Community

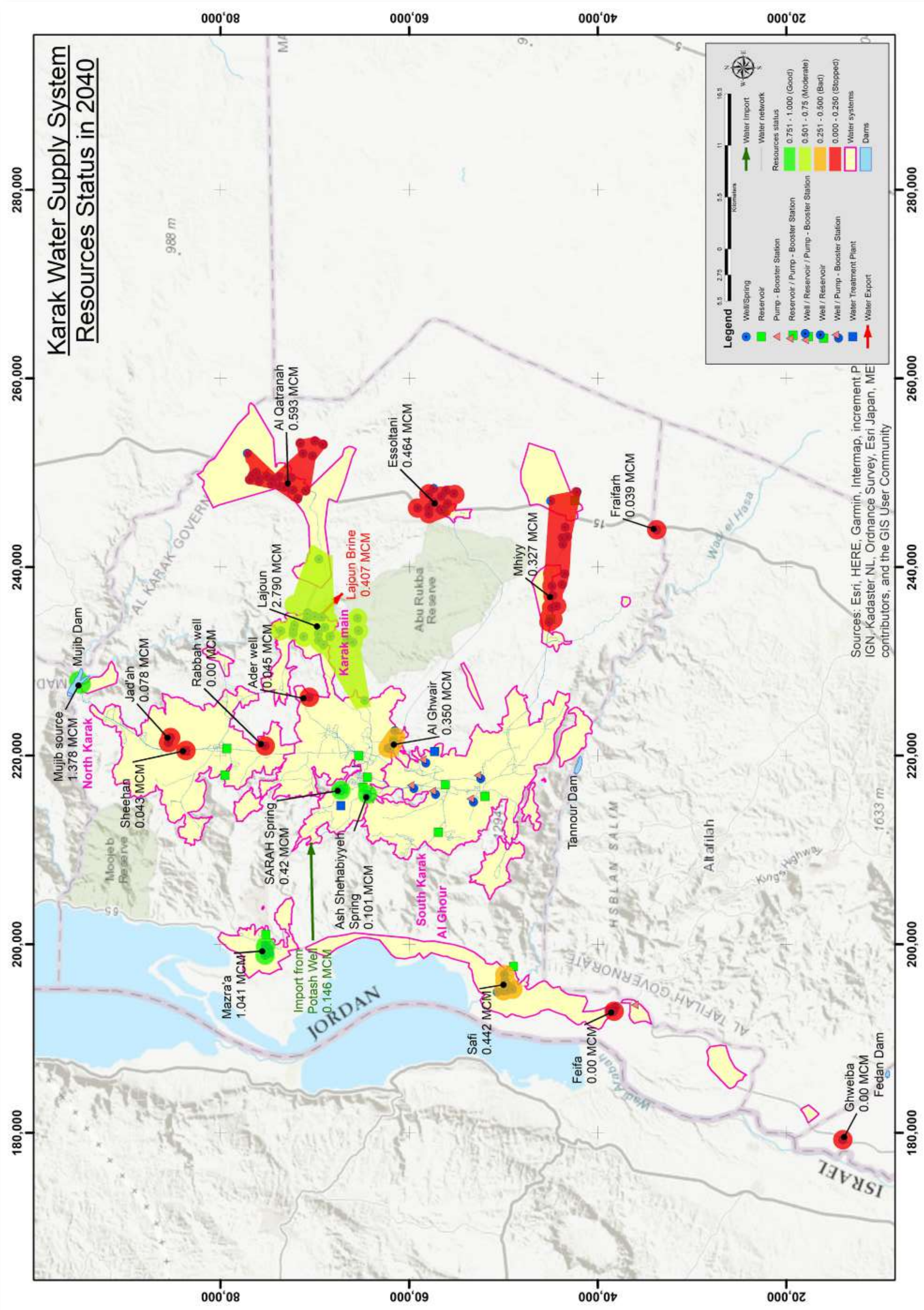

Balqa Water Supply System
Resources status in 2040
Deir Alla
Salt
Ain Al Basha
Mahes and Fuhais
South Shooneh
As Samahiyyat 0.493 MCM
Wadi Rajib 0.357 MCM
Abu ElZeeghan 2.76 MCM
Import from Zai to Balqa connections 20.463 MCM
As Subeihi Well 0.00 MCM
Alan Well 0.00 MCM
Al Rumman Well 0.028 MCM
Import from Zarqa 0.748 MCM
Import to Abu Nusair village 0.183 MCM
Export to Om El Naaj 0.03 MCM
Export from Fuhais to Dabouq 0.013 MCM
Baqa'a 0.00 MCM
Al Yazeediyya 0.00 MCM
Um Attiyya well 0.00 MCM
As Shrei'a Spring 1.021 MCM
Import from Amman to Royal Palaces 0.392 MCM
Azraq Spring 0.918 MCM
Al Alali Spring 0.13 MCM
Al Bucouriyya Spring 2.226 MCM
Sukneh 0.054 MCM
Juraiaa 0.187 MCM
South Shouna2 Well 0.003 MCM
Al Kafrain 0.364 MCM
Private Wells 2.561 MCM
Import from Zara-Maen to Shouneh 1.356 MCM
King Talal Dam
Karameh Dam
Shueib Dam
Kafrein Dam
Hisban Dam
Legend
Well/Spring
Pumping station
Reservoir
Raw water intake
Water treatment planet
Export
Import
Water network
King Abdallah Canal KAC
Resources status
0.751 - 1.000 (Good)
0.501 - 0.75 (Moderate)
0.251 - 0.500 (Bad)
0.000 - 0.250 (Stopped)
Water systems
Dams
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

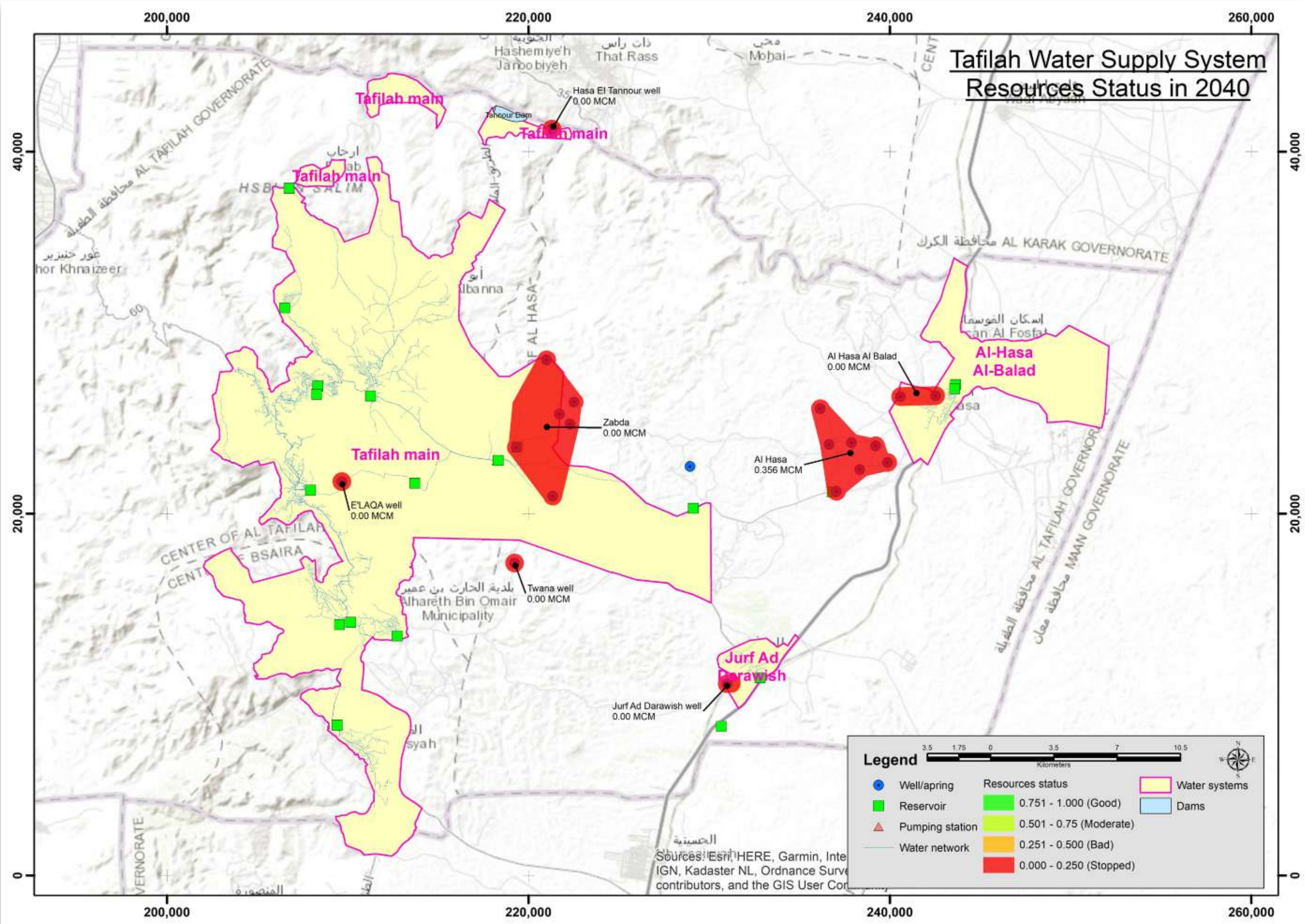


Zarqa Water Supply System
Resources Status in 2040
Legend
Kilometers
Well/Spring
Reservoir
Pump - Booster Station
Reservoir / Pump - Booster Station
Well / Reservoir / Pump - Booster Station
Well / Reservoir
Well / Pump - Booster Station
Water Treatment Plant
Water export
Water import
Water network
Resources status
0.751 - 1.000 (Good)
0.501 - 0.75 (Moderate)
0.251 - 0.500 (Bad)
0.000 - 0.250 (Stopped)
Water systems
Import from Mafraq/Qnayyah Well 0.912 MCM
Export to Mafraq 0.525 MCM
Qnayyah 0.387 MCM
Alouk 0.053 MCM
Sarout 0.081 MCM
Export to Jarash 0.161 MCM
Export to Balqa 0.74 MCM
Import from Shafa Badran 1.144 MCM
Beerain
Beerain 0.306 MCM
Merheb 0.395 MCM
Hashmeyah 0.00 MCM
Export to Khaldiyah from private wells 0.188 MCM
Export to Khaldiyah/Mafraq 1.371 MCM
Zarqa-Dhulail
Coridor 0.00 MCM
Hallabat 0.00 MCM
Zarqa 0.00 MCM
Tamween 0.00 MCM
Rusaifah 1.185 MCM
Import from Dabouq to Rusaifah 2.688 MCM
Russaifah
Import from Amman/Rusaifah wells 3.358 MCM
Import from Abu Alanda/DISI 10.388 MCM
Awajan 0.277 MCM
Export to Amman 0.318 MCM
Zarqa main
Private wells 0.00 MCM
Emirati Jordanian Camp Private Well 0.075 MCM
Azraq (AWSA) 11.404 MCM
Azraq Refugee Camp Private Wells 0.66 MCM
Azraq Natural Reserve/Irrigation 0.688 MCM
Zarqa-Azraq
Al Mafraq
Ajloun
Jerash
Ean Albasha
Salt
Wadi as Sir
Sahab
Madaba
AL MAFRAQ GOVERNORATE
AL ZARQA GOVERNORATE
AMMAN GOVERNORATE
Al-Azraq Street
Queen Alya'-Airport Street
971 m
772 m
1241 m
220,000
240,000
260,000
280,000
300,000
320,000
340,000
360,000
180,000
160,000
140,000
120,000
100,000
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

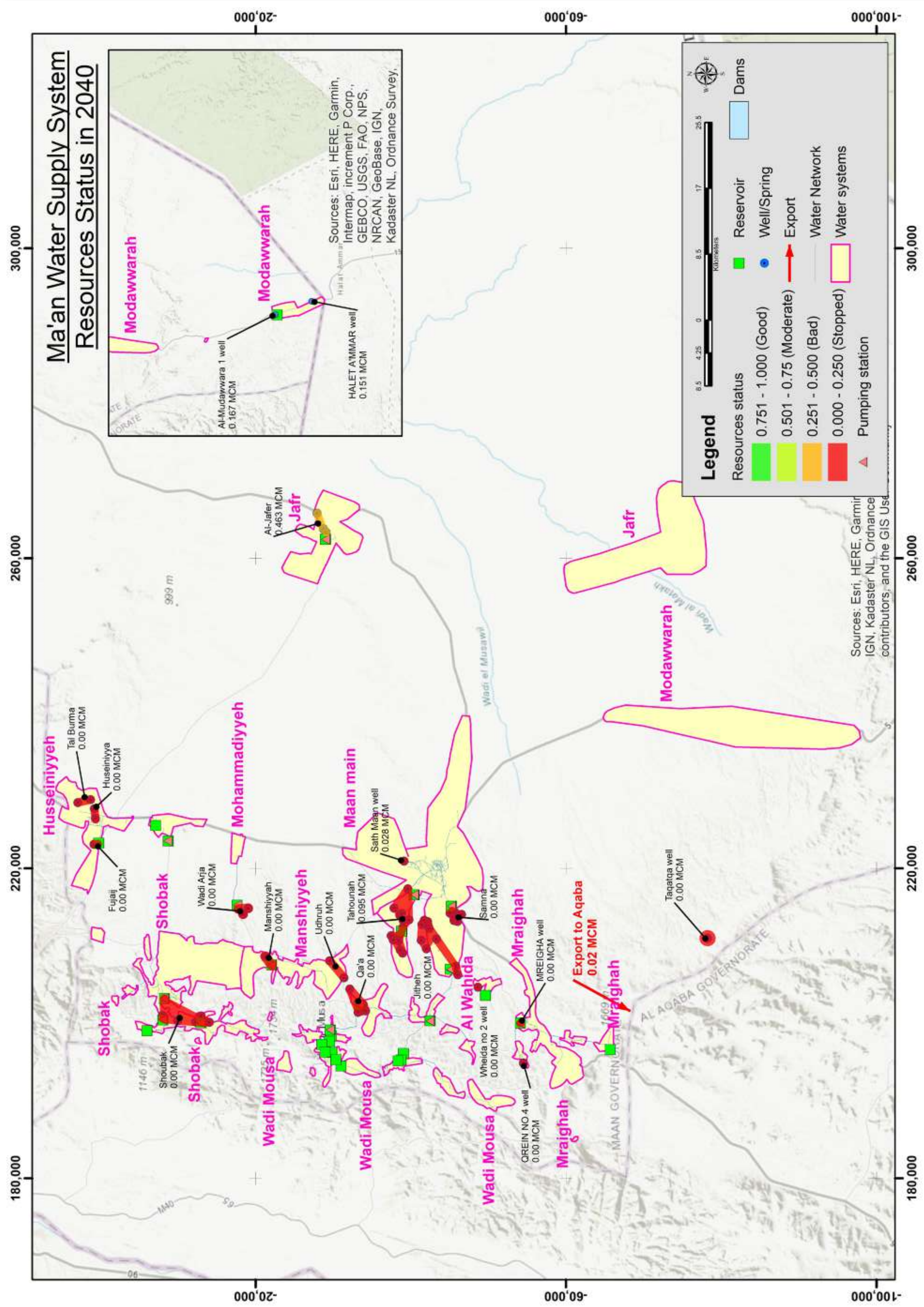

Amman Water Supply System
Resources Status in 2040
Legend
Well/Spring
Reservoir
Pumping station
Water treatment plant
Water export
Water import
Water network
King Abdallah Canal KAC
Wadis
Dead sea collector
Resources status
0.751 - 1.000 (Good)
0.501 - 0.75 (Moderate)
0.251 - 0.500 (Bad)
0.000 - 0.250 (Stopped)
Water systems
Dams
Amman Main
Deep south
Zai Intake 62.816 MCM
Balqa connection 20.463 MCM
Zai Brine 0.467 MCM
Wadi Essir 3.754 MCM
Ras El Ain 4.617 MCM
Muhajrin-M 2.488 MCM
Ain Ghazal 1.435 MCM
Taj 0.561 MCM
Zara-Maen 27.309 MCM
Mwaqar 0.416 MCM
Iraínbe 0.00 MCM
Swaqa 0.255 MCM
Import from DISI 99.997 MCM
Import from Al Wala 1.206 MCM
To Madaba 0.673 MCM
To Shouneh 1.356 MCM
To Royal Palaces 0.392 MCM
Import from Fuhais to Dabouq 0.013 MCM
Import from Om El Naaj 0.03 MCM
To Abu Nusair village 0.183 MCM
To Um Rummaneh 1.144 MCM
To Rusaifah from Dabouq 0.188 MCM
To Rusaifah from Rusaifah wells 0.525 MCM
Import from Zarqa-Khaw 0.318 MCM
To Zarqa from Abu Alanda 10.338 MCM
Export to North 1.333 MCM
Dead sea collector
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

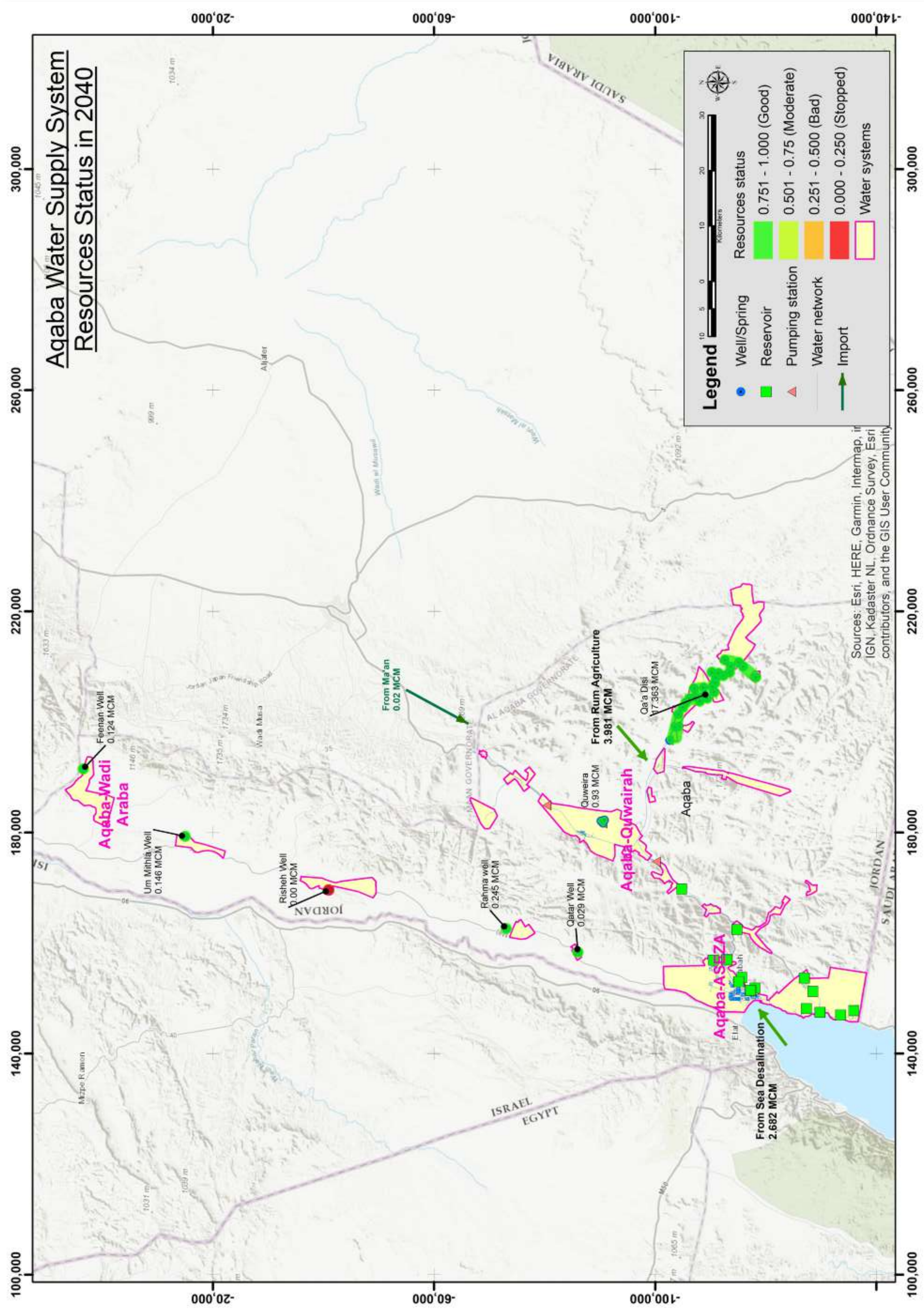

Madaba Water Supply System
Resources Status in 2040
Export to Amman
1.206 MCM
Import from Amman
0.673 MCM
Madaba main
Madaba main
Madaba main
Madaba main
Madaba main
WADI ZARQA
MA EEN
Dead sea collector
Mlaih Well
0.00 MCM
Wala 5 Well
0.00 MCM
Heedan
10.536 MCM
Wala Dam
200,000
220,000
240,000
120,000
100,000
Legend
Well/Spring
Reservoir
Pumping station
WWTP
Export
Import
Water network
Wadis
Dead sea collector
Resources status
0.751 - 1.000 (Good)
0.501 - 0.75 (Moderate)
0.251 - 0.500 (Bad)
0.000 - 0.250 (Stopped)
Water systems
Dams
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GE
IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri Ch
contributors, and the GIS User Community


Karak Water Supply System
Resources Status in 2040
Legend
Well/Spring
Reservoir
Pump - Booster Station
Reservoir / Pump - Booster Station
Well / Reservoir / Pump - Booster Station
Well / Reservoir
Well / Pump - Booster Station
Water Treatment Plant
Water Export
Water Import
Water network
Resources status
0.751 - 1.000 (Good)
0.501 - 0.75 (Moderate)
0.251 - 0.500 (Bad)
0.000 - 0.250 (Stopped)
Water systems
Dams
Mujib Dam
Mujib source 1.378 MCM
North Karak
Jad'ah 0.078 MCM
Sheehan 0.043 MCM
Rabbah well 0.00 MCM
Ader well 0.045 MCM
Lajoun 2.790 MCM
Lajoun Brine 0.407 MCM
Karak main
Al Qatranah 0.593 MCM
Essoltani 0.464 MCM
Al Ghwair 0.350 MCM
Mhiyy 0.327 MCM
Fraifarh 0.039 MCM
SARAH Spring 0.42 MCM
Ash Shehabiyyeh Spring 0.101 MCM
South Karak
Al Ghour
Tannour Dam
Mazra'a 1.041 MCM
Import from Potash Well 0.146 MCM
Safi 0.442 MCM
Feifa 0.00 MCM
Ghweiba 0.00 MCM
Fedan Dam
Abu Rukba Reserve
Mojeb Reserve
JORDAN
ISRAEL
AL TAFILAH GOVERNORATE
AL KARAK GOVERN
Wadi el Hasa
Sources: Esri, HERE, Garmin, Intermap, increment P, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, contributors, and the GIS User Community



Tafilah Water Supply System
Resources Status in 2040
Tafilah main
Tafilah main
Tafilah main
Tafilah main
Hasa El Tannour well
0.00 MCM
Tannour Dam
Zabda
0.00 MCM
E'LAQA well
0.00 MCM
Twana well
0.00 MCM
Al Hasa
0.356 MCM
Al Hasa Al Balad
0.00 MCM
Al-Hasa
Al-Balad
Jurf Ad
Darawish
Jurf Ad Darawish well
0.00 MCM
AL KARAK GOVERNORATE
AL TAFILAH GOVERNORATE
MAAN GOVERNORATE
Legend
Well/apring
Reservoir
Pumping station
Water network
Resources status
0.751 - 1.000 (Good)
0.501 - 0.75 (Moderate)
0.251 - 0.500 (Bad)
0.000 - 0.250 (Stopped)
Water systems
Dams
Kilometers
200,000
220,000
240,000
260,000
0
20,000
40,000


Ma'an Water Supply System
Resources Status in 2040
Legend
Resources status
0.751 - 1.000 (Good)
0.501 - 0.75 (Moderate)
0.251 - 0.500 (Bad)
0.000 - 0.250 (Stopped)
Pumping station
Reservoir
Well/Spring
Export
Water Network
Water systems
Dams
Export to Aqaba
0.02 MCM


Aqaba Water Supply System
Resources Status in 2040
Legend
Well/Spring
Reservoir
Pumping station
Water network
Import
Resources status
0.751 - 1.000 (Good)
0.501 - 0.75 (Moderate)
0.251 - 0.500 (Bad)
0.000 - 0.250 (Stopped)
Water systems
Kilometers
Aqaba-Wadi Araba
Aqaba-Quwairah
Aqaba-ASEZA
Feenan Well 0.124 MCM
Um Mithla Well 0.146 MCM
Risheh Well 0.00 MCM
Rahma well 0.245 MCM
Qatar Well 0.029 MCM
Quweira 0.93 MCM
Qa'a Disi 17.363 MCM
From Ma'an 0.02 MCM
From Rum Agriculture 3.981 MCM
From Sea Desalination 2.682 MCM
Aqaba
JORDAN
ISRAEL
EGYPT
SAUDI ARABIA
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community
100,000
140,000
180,000
220,000
260,000
300,000
-20,000
-60,000
-100,000
-140,000

ANNEX 8: Procedure for Rehabilitation of Wells

(summarized from MARGANE (2018): Advisory Service Document 23: Proposed Procedure for Rehabilitation of Wells)

The proposal is based on the lessons-learnt from two KfW-funded projects:

- → Immediate Measures for Improvement of Water Supply in Northern Jordan directed to Syrian Refugees (IMWS): implemented by Dorsch Consult in 2014-15 in 2 phases;
  Initially this project covered more than 100 wells. Based on a related baseline survey, it was found that many wells were dysfunctional and rehabilitation would not be justified. Due to that, in the end 27 wells were drilled as replacement wells.
- → Energy Efficiency Project (EEP2): implemented by Fichtner Consult in 2016-17;
  In the beginning it comprised of 105 wells, which were later reduced to 79, then 53 wells, even before the rehabilitation process started. The declared aim of the EEP2 project was to increase energy efficiency by at least 15%. During the implementation of the project it turned out that this aim could not be achieved in most wells. Ultimately, rehabilitation was done only for 34 wells, mainly due to the poor status of wells and the hydrogeological situation (exhausted groundwater resources).

Summary of previous rehabilitation works

The results of previous projects show that the process needs to be improved:

Problems

- → EEP2 Project was from the beginning too much focused on pump efficiency while this is not the only issue (the main problems are often rather: the exhausted aquifer/declining water levels and the well design/construction)
- → Priority lists were not coordinated between PMU – WAJ – MWI: based on which criteria ? Not: future water resources availability and water quality!
- → Unclear which well was selected (due to use of different ID numbers), unclear which base data used (because not referring to WIS IDNs)
- → Overall rehabilitation concept wrong: mostly no SWL/DWL data available, not acquired in the beginning (as requested by BGR) > it remained unclear what is the reason for low production
- → Unclear decisions: why is rehabilitation continued if the result (no success) is already clear ?
- → Why question of potential well deepening / well replacement / drilling of new wells was not addressed in the beginning ? while it was clear that this would become an issue due to high age of wells
- → Step tests are needed to assess well efficiency: consultant wanted only pump efficiency, which is often not the main reason for high energy consumption (but rather the overall low well efficiency of <50%); 5 steps needed because often no straight-line correlation
- → Unclear data: water levels (SWL, DWL), total depth, actual depth > current saturated thickness
- → Data exchange not well organized

Lessons Learnt

- → Better feasibility study required taking into account hydrogeological aspects and actual well conditions
- → Future water resources availability and water quality must be the main criteria to justify rehabilitation
- → Energy efficiency is not equal to pump efficiency
- → Replacement wells at the same site is mostly problematic
- → Better coordination is required
- → Better data exchange and more frequent meetings with all parties are required
- → Technical concept must be improved (acquisition of SWL/DWL data in the beginning; 5-step step tests)

Proposed New Rehabilitation Procedure

1. Selection Process

Future lists of wells to be rehabilitated should be agreed upon among all stakeholders (committee) using valid criteria, such as:

- **Age of wells and borehole design:** the wells are not older than 20 years and was drilled in a way that the currently remaining saturated thickness of the aquifer in the well is adequate to support an operation over the next 7 years after rehabilitation considering current regional water level decline rates; casing diameter is large enough to install a suitable pump at the currently assumed pump setting depth after rehabilitation;
- **Initial data compilation/assessment:** all basic data of the well are known and have been compiled and assessed (WIS ID number, location, TD, yield, historic and current water levels SWL/DWL, historic and current water quality);
- **Current yield:** the current yield decrease is not due to known mistakes in borehole design or borehole collapse
- a **site survey** needs to be conducted to confirm that the information of the initial data compilation/assessment step was correct, that potential problems (flooding risk,) were ruled out or can be addressed through constructional measures, that there cannot be any confusion as to the location and WIS IDN;

<u>Criteria to be used for success (justification of investment)</u>

7 years after rehabilitation

- the yield of the well should be > 20 m^3/h
- the quality should be acceptable for human consumption without major treatment processes, except chlorination
- the pumping lift should not exceed 350 m.
- a pump of reasonable cost could be installed; the overall rehabilitation costs could be justified by the amounts to be produced over the next 7 years

2. Procedure of Well Rehabilitation

Decision 1 is taken <u>after the Site Survey</u> and includes the following criteria for stopping the process at this point:

- sites requested not to be rehabilitated by the client PMU or WAJ or the water utilities or MWI

- sites where the existing flooding risk cannot be mitigated
- sites where there are already now considerable water quality problems (for major water quality constraints according to the maximum allowable limits of the Jordanian Drinking Water Standard
- sites where it can already now, without having current water level data available, be assumed that wells would not have enough water 7 years after rehabilitation and would provide a yield of < 20 m³/h, due to regional water level decline
- sites where the pumping lift would exceed 350 m 7 years after rehabilitation

Decision 2 follows after/during the Baseline 1 Survey
Baseline 1 survey must provide at least the following data:

- Current SWL
- Current DWL
- Current yield
- Current total depth
- Current (not older than 2 years) water quality, including major quality constraints (such as: Mo, Ra, U; this may require water quality sampling/analysis)
- CCTV logs providing: blank/slotted casing depths/intervals, status of casing

A 5-6 steps step test should be conducted during Baseline 1, to be able to assess the current well efficiency/head losses (energy loss due to well construction). However, if a camera scan can be conducted over the full depth of the borehole, a step test at this point may not necessarily required. The optimal yield and pump specifications and well efficiency/head losses can be determined after rehabilitation and would thus reflect the improved conditions. If there is no step test during Baseline 1, the assessment of well efficiency will only be a very rough estimate. Without a step test during Baseline 1, it would be difficult to compare the current and improved conditions, thus the effect of rehabilitation.

Decision 2 is based on the following criteria for stopping the process at this point:

- All criteria as applied to decision 1, and
- Well casing is not intact (broken) and wall thickness is too thin
- Total depth of well is inadequate (e.g. because of pumps fallen into the well or inadequate penetration of the aquifer)
- Section(s) of slotted casings are inadequate (potentially low transmissivity and thus yield)
- Pump cannot be lowered to a blank casing section of adequate depth
- Well efficiency is assumed (because no step test) to be too low, causing low well efficiency, turbulent flow and significant head losses

Decision 3, whether and where to drill a replacement well (if that was planned), will be taken a) after the Baseline 1 Survey or b) if rehabilitation was not successful.
Criteria are:

- WAJ/water utilities have the need to provide water supply for a certain area and related wells sites in this program could not be rehabilitated successfully, and
- MWI, using hydrogeological criteria and from the perspective of sustainable management of groundwater resources agrees to drill a replacement well because there would be water in the long-term, i.e. at least for the next 7 years (yield > 20 m³/h, etc., see above).

The decision where and if to drill a replacement well must be based solely on:

- the long-term availability of groundwater
- regional water level decline rates
- regional transmissivity

In areas where the A7-B2 aquifer is exploited, deeper aquifers (A4, A1/2, Kurnub, etc.) should not be penetrated and are in many areas not allowed to be exploited.

Decision 4, optimal yield to use for a the new pump, will be taken after conducting at each well:

- a 5-6 steps step test and
- a long duration test

Step tests in new wells are done following adequate development, i.e. until DD and indicative physic-chemical water quality parameters (pH, EC, turbidity, temperature) are stable and turbidity is below 2 NTU. For step and long duration tests, dedicated pumps have to be used, not the existing pump in the well.

During step tests and long duration test water levels must be continuously measured in the pumped borehole and in other not pumped boreholes in the vicinity (distance < 300 m), if feasible.

During step tests yield measurements must be done every 30 minutes, during long duration tests every 2 hours. Each step should last 4 hours. At the end of long duration tests, recovery of the water level must be measured for 24 h.

General considerations for pumping tests apply, as e.g. detailed in KRUSEMAN & de RIDDER (1991).

Decision 5, at which depth to install the new pump must be taken subsequently and is based on the following criteria

- pump setting will not need to be adjusted (due to regional water level decline) for the next 3 years after rehabilitation with pump efficiency remaining >70%

3. Monitoring of Results

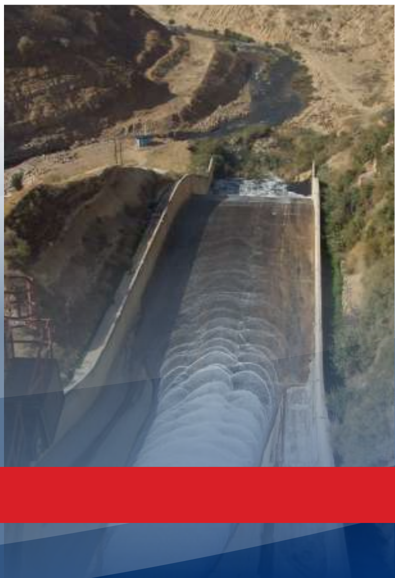
The times and results of all activities must be monitored and documented. This documentation of results is the precondition for decisions at the different steps during the process to be taken (see above).
The contractor is responsible for this documentation. It will be supervised by the consultant and client.

4. Assessment of Success

At different Stages the success of each previous step has to be assessed. At the end the overall success needs to be reported. Typical objectives of related projects are:

- energy efficiency was increased by x%
- water supply security for xyz area was increased by x%


Mujib Dam



Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn

Friedrich-Ebert-Allee 32+36
53113 Bonn, Germany
T+49 228 44 60-0
F+49 228 44 60-17 66

Dag-Hammarskjöld-Weg 1 - 5
65760 Eschborn, Germany
T + 49 61 96 79-0
F + 49 61 96 79-11 15

E info@giz.de
I www.giz.de