Use of Remote Sensing to Improve Water Management in Saudi Arabia

Chair of the Prince Sultan Bin Abdulaziz International Prize for Water

COPUOS – Vienna, February 2010

Prince Sultan Bin Abdulaziz International Prize for Water

The recognition and success achieved by the **Prince Sultan Bin Abdulaziz International Prize for Water** provided the incentive to establish a research chair in its name to focus research efforts on rainwater and runoff water harvesting and storage, with particular emphasis on the use of GIS and remote sensing technologies.

The **Prize Chair** promotes research excellence and the application of advanced technology to realize the best, most economically viable solutions for maximizing benefit from available water resources.

Vision of the Prize Chair

The Chair's vision is to develop and institute techniques and programs that will provide the maximum possible benefit from rainfall and runoff water in order to alleviate serious water deficiencies and narrow the gap between water availability and demand. The Chair will realize this vision by initiating and supporting original and exceptional scientific research related to the harvesting and storage of rainfall and runoff water, by applying GIS and remote sensing technologies to these efforts, and by conducting studies to evaluate and develop these methods to optimise them for the particular needs of arid regions.

Mission Statement

The Chair of the Prince Sultan Bin Abdulaziz International Prize for Water seeks to play a leading role in increasing scientific knowledge and awareness about the harvesting and storage of rainfall and runoff water. The Chair will accomplish this by conducting advanced research and by developing methods that can be instituted on the national level.

The looming threat of climate change makes these efforts all the more urgent. The methods and technologies pursued by the Chair will also provide a nucleus for training a cadre of researchers and produce a body of research of a quality commensurate with those of other research centres around the world.

Goals

1. To conduct advanced and specialized research related to the storage and harvesting of rainfall and runoff water and the effects that climate change has on these activities.
2. To attract qualified and distinguished scholars of international repute to conduct research into the problems of harvesting and storing rainfall and runoff water in Saudi Arabia and suggest appropriate solutions for those problems.
3. To promote and inculcate a culture of innovation and originality, to further scientific research that serves development and the economy, and to support means for cooperation and the sharing of expertise between the University and other organizations concerned with water.
4. To exchange knowledge with other specialized research centres.
5. To increase awareness of the importance of water by achieving the maximum possible benefit from rainfall and runoff water in addition to managing water demand.
6. To strengthen to position of the Prince Sultan Research Center for Environment, Water, and Desert so it will play a leading role in research related to the harvesting and storage of rainfall and runoff water on the national, regional, and global level.
7. To publish the results of the Chair's research in top-ranking scientific journals.

Activities

The Prize Chair:

1. Engages in pioneering scientific research into various aspects of harvesting and storing rainfall and runoff water as well as the effects of climate change.
2. Holds a variety of activities related to the Chair's research areas, including seminars, workshops, and conferences.
3. Supervises masters-level and doctoral research in cooperation with the relevant departments of King Saud University.
4. Establishes and equips an advanced laboratory to serve the Chair's various research needs.
5. Designs physical and computer models that effectively communicate the Chair's research output.

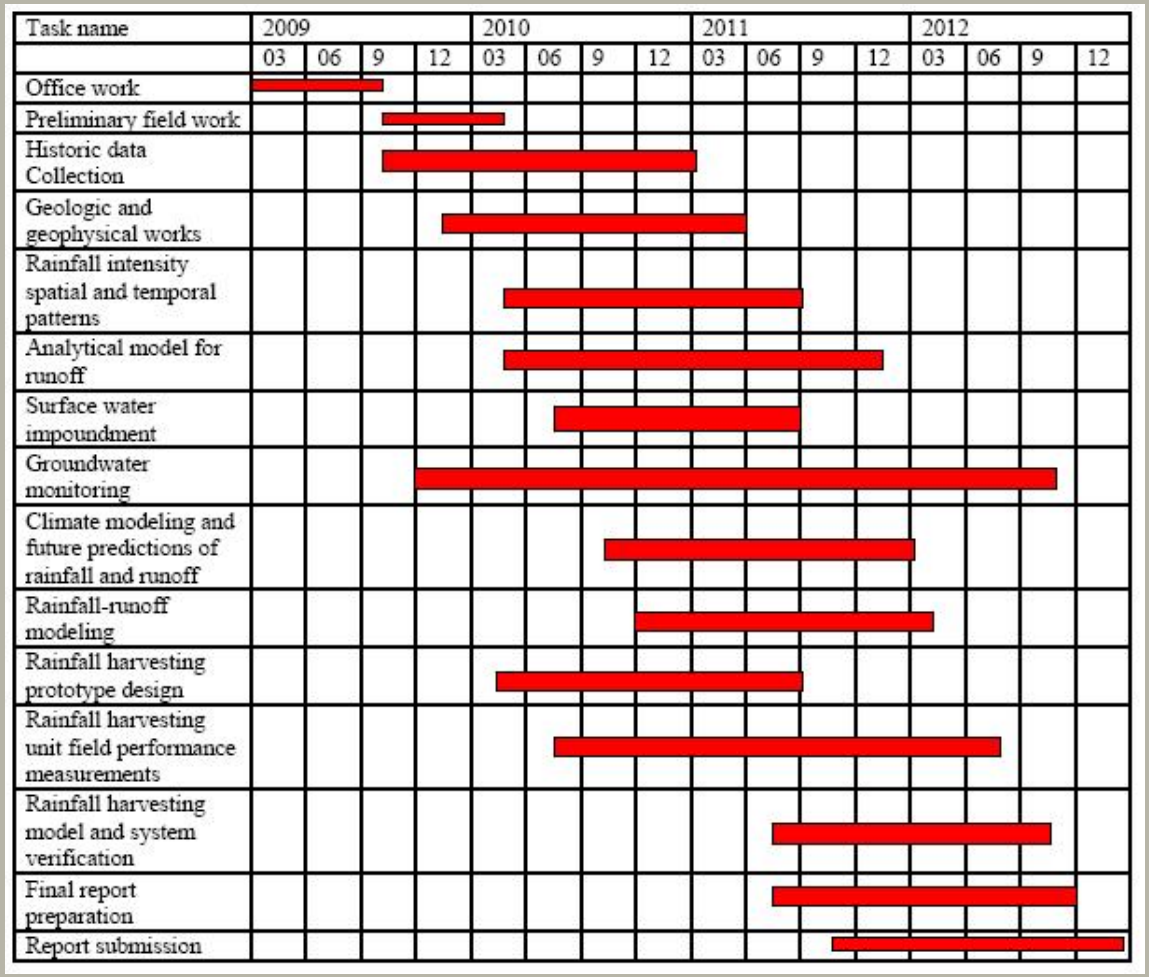
Inauguration

The charter for the Chair was ratified on 19 July 2008 and was inaugurated on 1 November 2008 during a formal ceremony held under the patronage of His Royal Highness Prince Khalid Bin Sultan Bin Abdulaziz, Assistant Defence Minister for Military Affairs and Chairman of the Prize Council for the Prince Sultan Bin Abdulaziz International Prize for Water.

Research Program

The main objective of the project is to propose methodologies, mathematical models, and field application design procedures for enhancing the yields from rainwater harvesting methods, including groundwater recharge, in convenient locations within wadi courses. A particular emphasis is given to the application of GIS and remote sensing technologies towards realizing these goals.

Timetable of Primary Research Program



Professor of the Chair

Professor Zekai Şen

- Professor Zekai Şen was born in 1947 in Turkey.
- He won the Nobel Peace Prize in 2007 along with the other members of the research team working on the United Nations Intergovernmental Panel on Climate Change (IPCC).
- He has been awarded numerous other medals and scientific prizes, both locally and internationally.
- He is the president of the Turkish Water Foundation.
- Professor Zekai Şen holds a Ph.D. in Stochastic Hydrology form Imperial College, University of London (1974)
- He is currently a professor at the Civil Engineering Faculty of the Technical University of Istanbul, Department of Hydraulics and Water Power.

The research of the Chair supports the efforts of

King Fahd's Project for Rainwater and Runoff Harvesting and Recharge in Saudi Arabia

Project Chairman:
Dr. Abdulmalek Al Al-Shaikh
Director of the Prince Sultan Research Center
for Environment, Water and Desert
King Saud University- -Riyadh- Saudi Arabia

The project was approved and supported by

HRH Crown Prince Sultan bin Abdul-Aziz

Starting Date: 30-1-2005

The project was designed and executed by:

The Prince Sultan Research Center
for Environment, Water and Desert
at King Saud University
Riyadh, Saudi Arabia
psrcewd@ksu.edu.sa
www.psrcewd.edu.sa

Project Objectives

To apply rainwater and runoff harvesting and recharge techniques in the Kingdom of Saudi Arabia in order to:

1. **Guarantee water for the inhabitants of villages, hamlets, and desert areas as well as for their livestock and agricultural production.**
2. **Minimize the migration from hamlets and villages, due to water scarcity and low agricultural production, to the already overcrowded cities.**

3. Restore sustainability in the traditional agricultural areas found along the rims of wadis. These areas suffer now from water scarcity due to the excess groundwater consumption for irrigation. These areas are still viable for agriculture due to its deep soil and the presence of renewable water resources.
4. Minimize water evaporation from the dam's lakes by storing water in the deep aquifers.
5. Ensure the availability of surplus water for strategic storage.

Project Stages

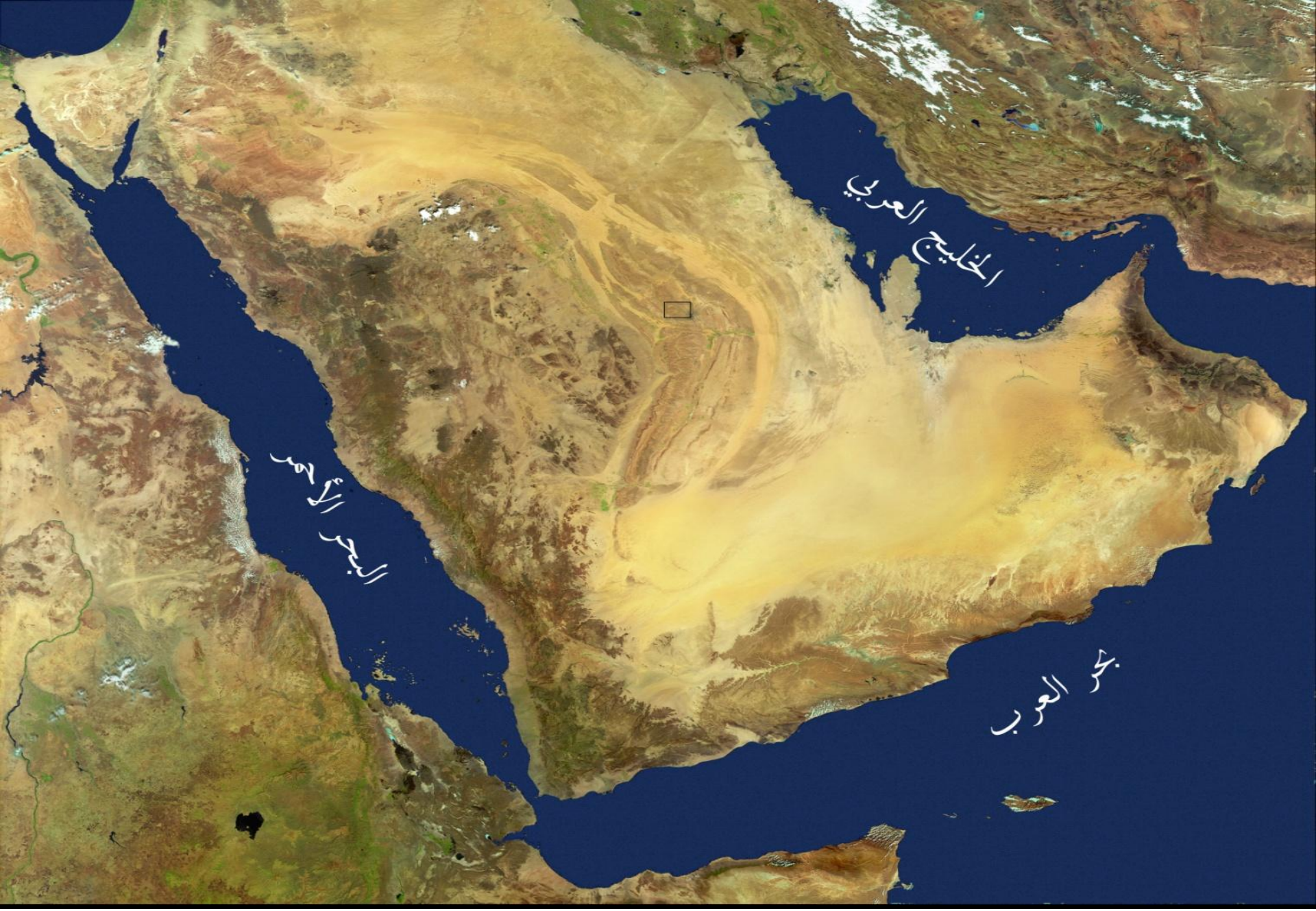
Preliminary experimental Stage

1- Artificial Groundwater Recharge (6 Locations)

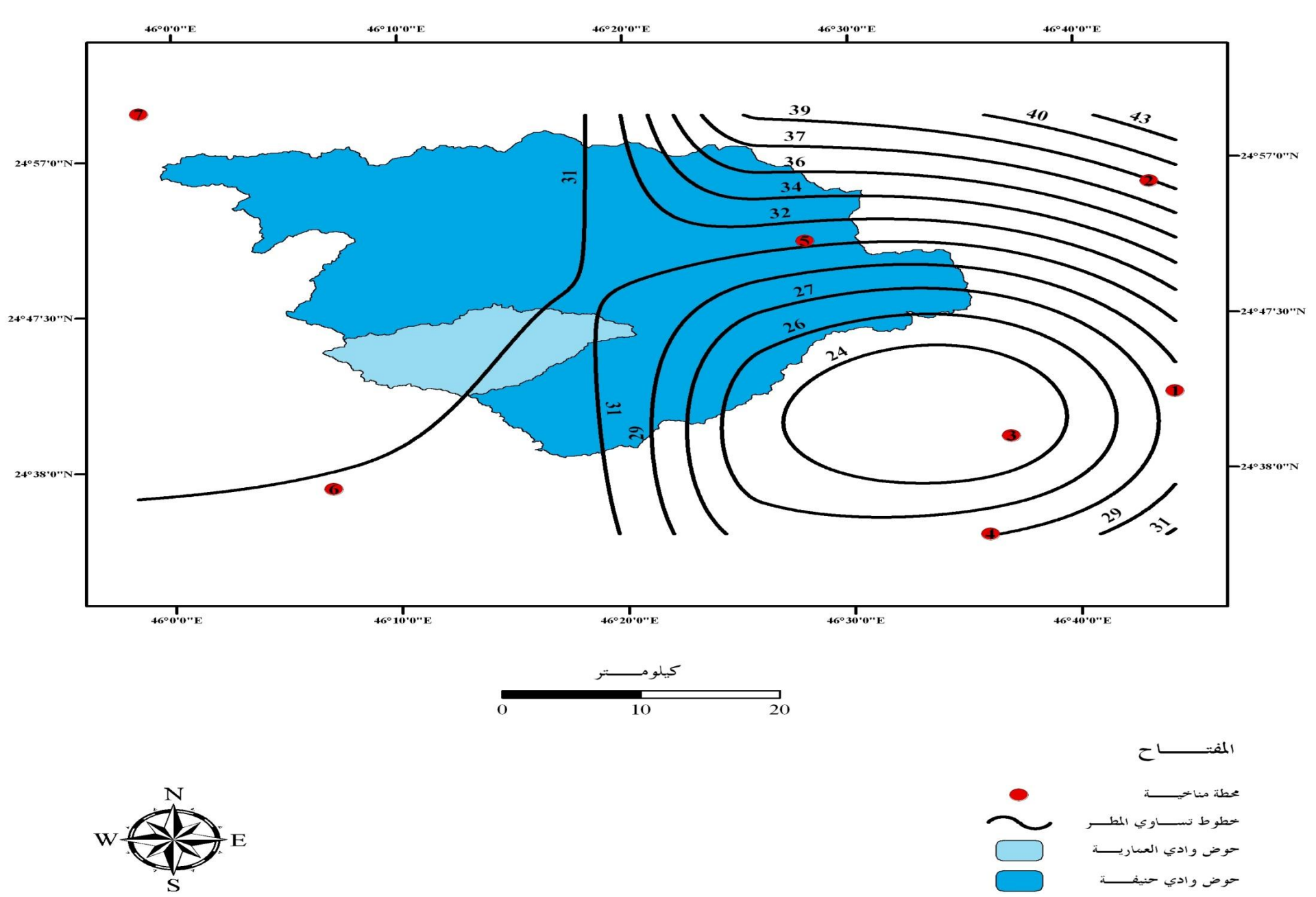
2- Artificial Ponds (2 Locations)

Final Stage

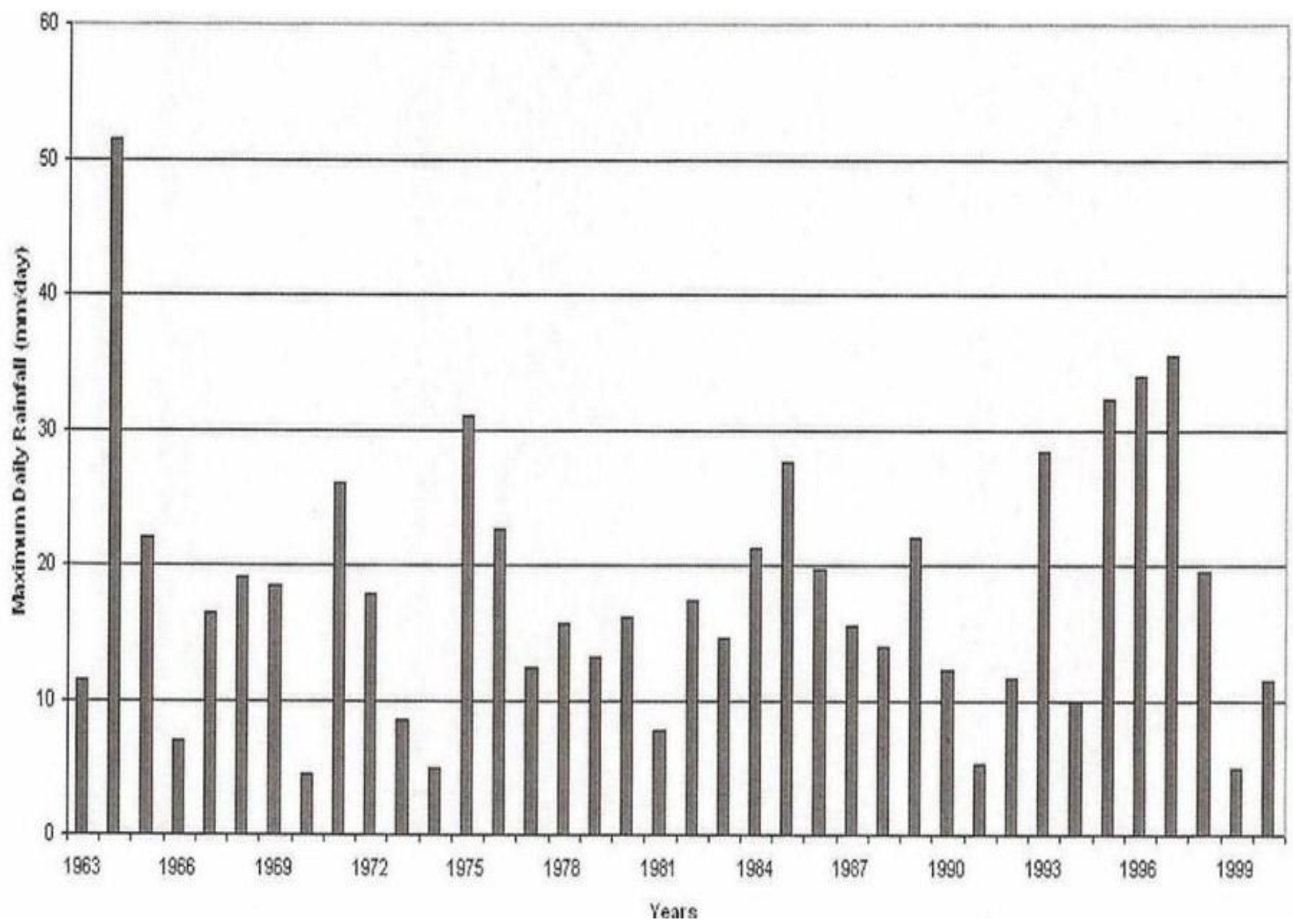
Utilization of both techniques throughout the Kingdom.



The selected sites



Rainfall Pattern in Riyadh area



Maximum Daily Rainfall mm/day in Riyadh area

The 1st Technique:

Artificial Groundwater Recharge

Methodology

- Using remote sensing satellite imagery and DEM to identify the best sites for implementing rainwater harvesting and recharge techniques.
- Collecting information and carrying out geophysical and ground survey and performing morphometric studies in the selected sites.
- Choosing the locations and establishment of the recharge wells.
- Water level and quality monitoring through observation wells.
- Data analysis.

Al Alab Dam

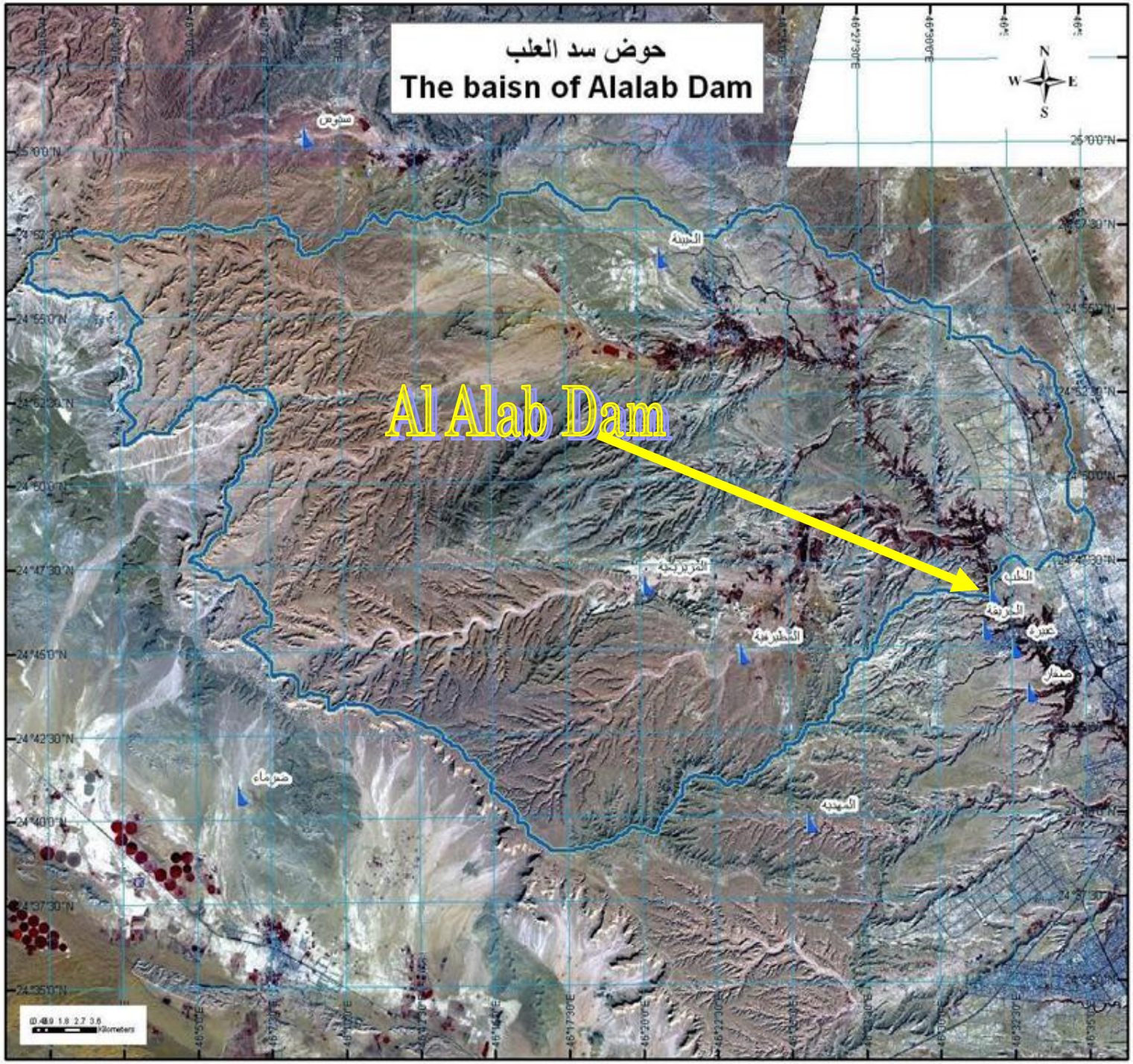
اسم السد : العلب
Dam Name : Alalab
نوع السد : خرساني
Dam Type : Concrete

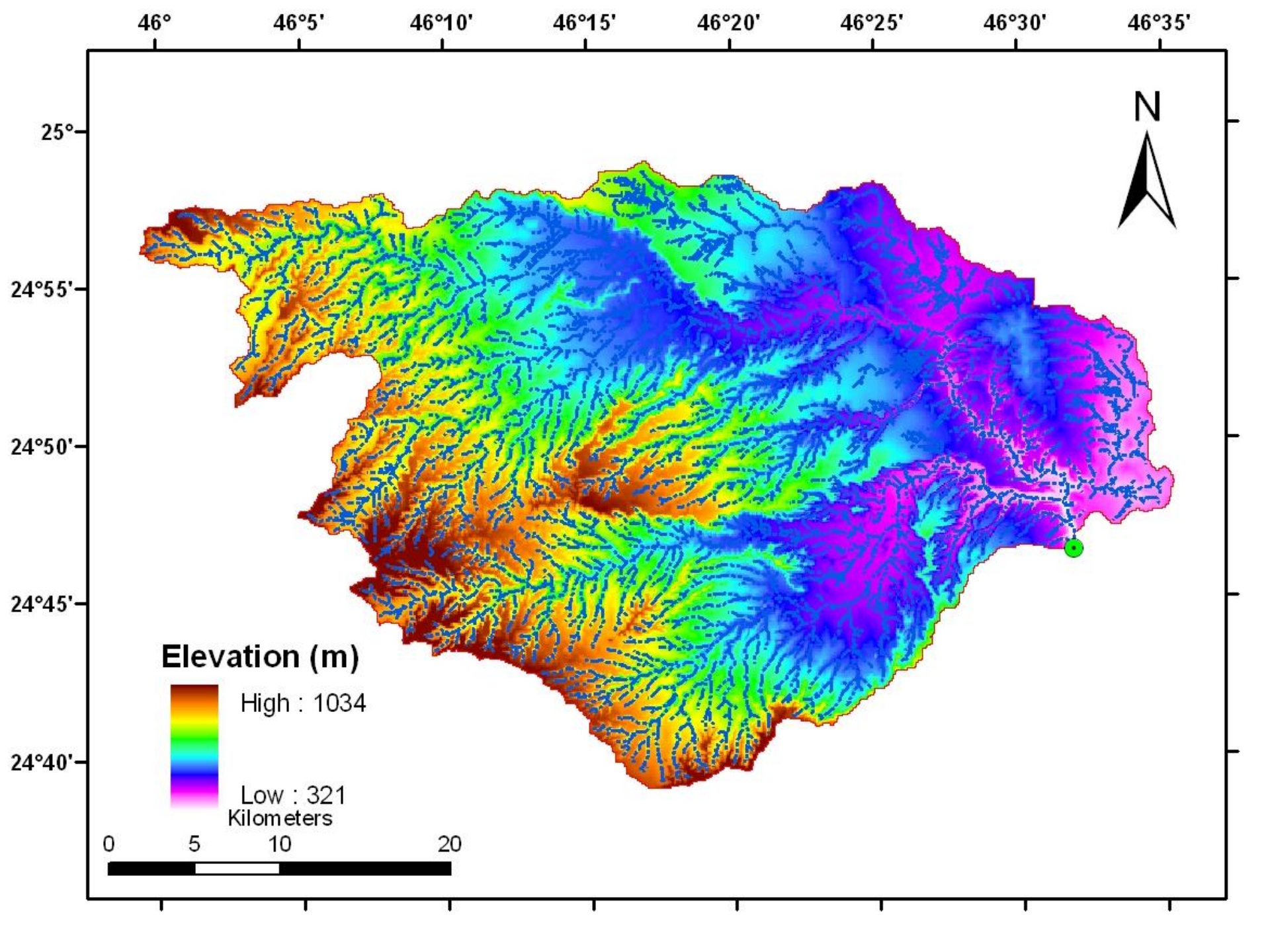
Location الموقع

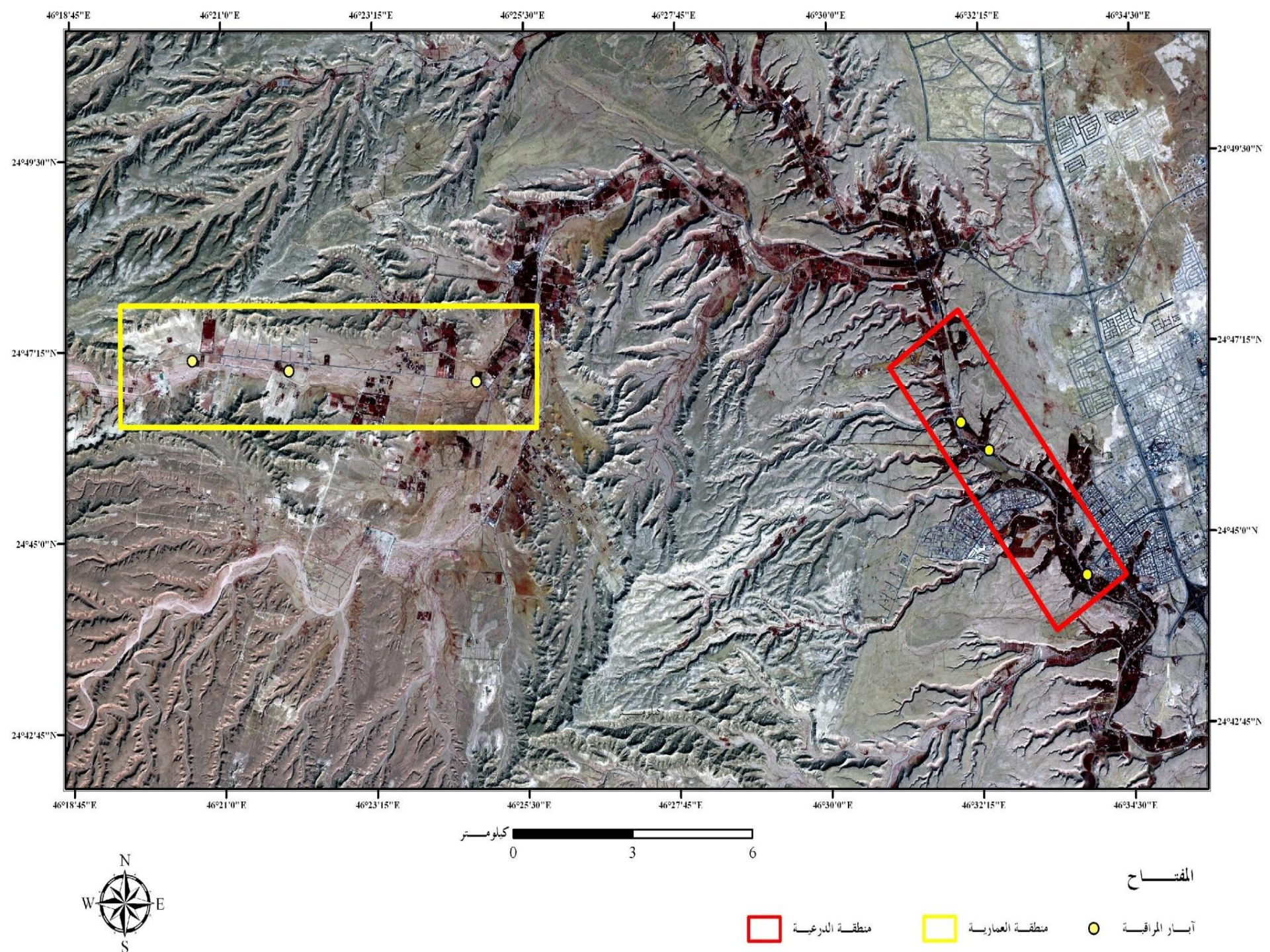
46°31'50.956"E
24°46'26.984"N

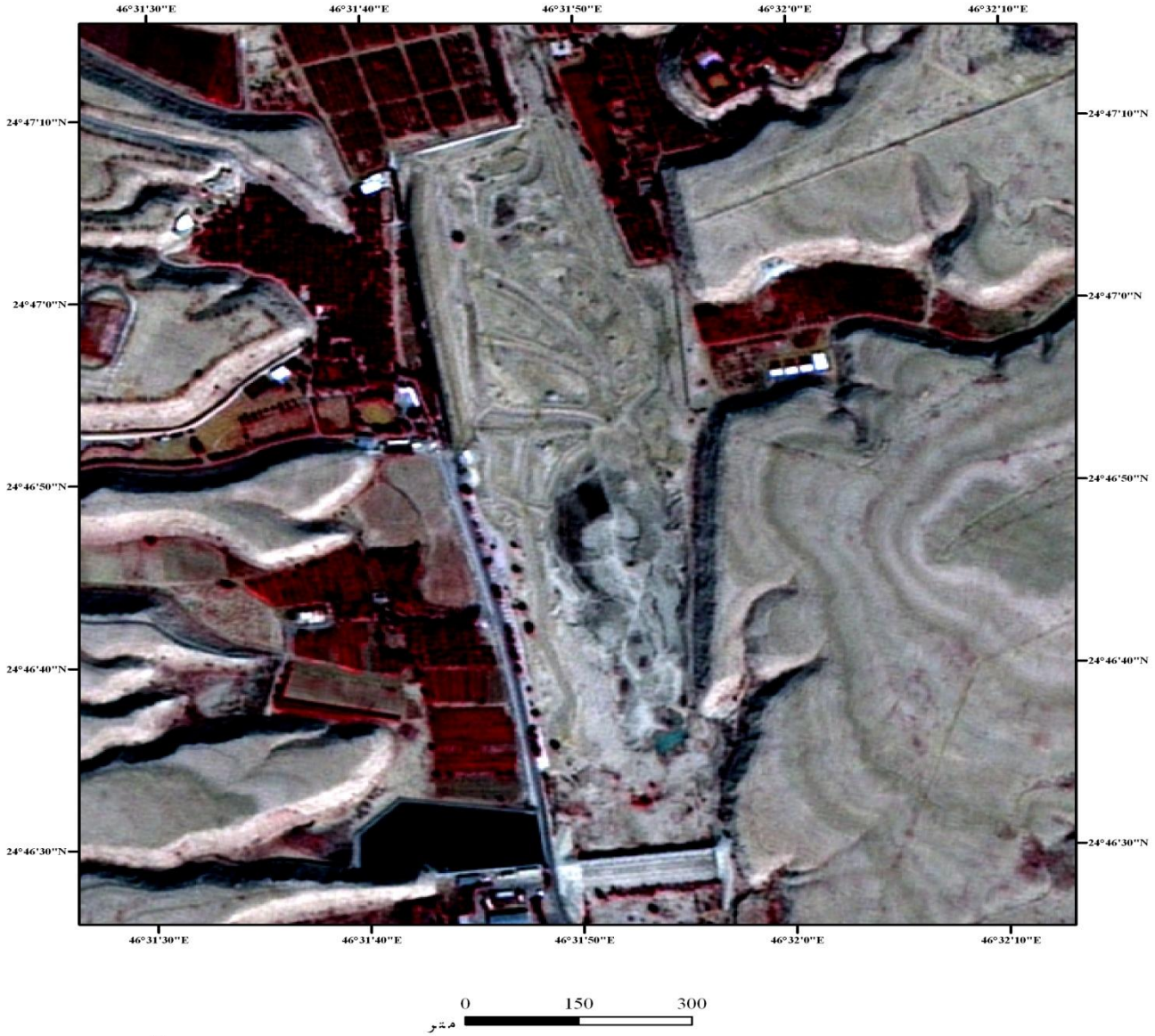
Dam Location

Basin



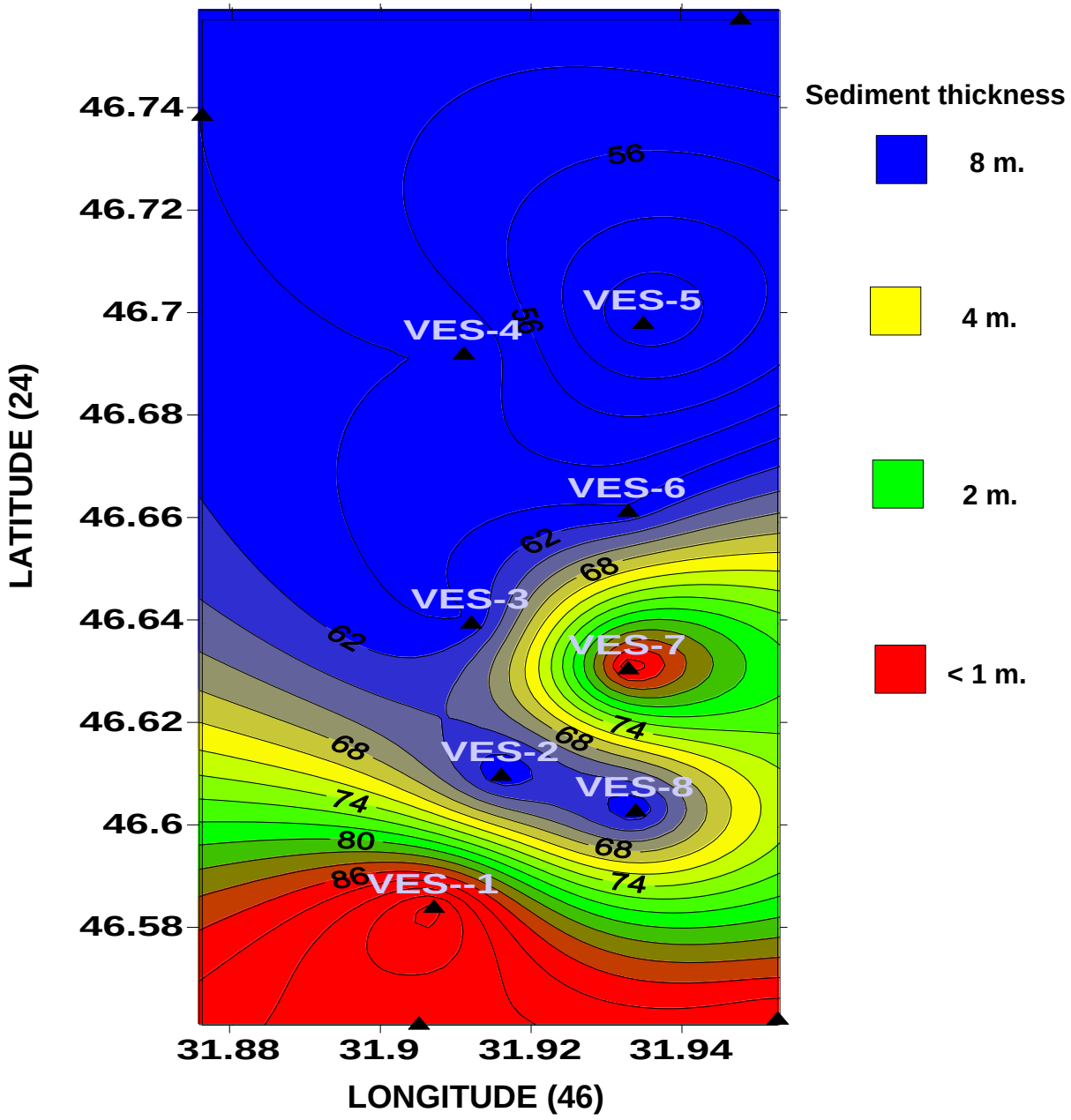

46°
46°5'
46°10'
46°15'
46°20'
46°25'
46°30'
46°35'
25°
24°55'
24°50'
24°45'
24°40'
N
Elevation (m)
High : 1034
Low : 321
Kilometers
0
5
10
20


46°18'45"E
46°21'0"E
46°23'15"E
46°25'30"E
46°27'45"E
46°30'0"E
46°32'15"E
46°34'30"E
24°49'30"N
24°47'15"N
24°45'0"N
24°42'45"N
كيلومـــتر
0
3
6
N
W
E
S
المفتـــاح
آبـــار المراقبـــة
منطقـــة العماريـــة
منطقـــة الدرعيـــة



SPOT 5 image, Bands 1, 2, 3 of Al Alab dam

RESISTIVITY MAP SHOWING SEDIMENTS THICKNESS



morphometric parameters	Abbr.	Unit	113Jalajil
Basin Area	A	Km^2	1291
Total Stream Length (km)	Ct	km	2515
Basin Slope	BS	m/m	0.07587
Maximum Flow Distance	MFD	m	75874
Maximum Flow Slope	MFS	m/m	0.00393
Centroid Stream Distance	CSD	m	38660
Centroid Stream Slope	CSS	m/m	0.00410
South Aspect ratio	%SF	%	0.42078
North Aspect ratio	%NF	%	0.57922
Maximum Stream Length	MSL	m	75477
Maximum Stream Slope	MSS	m/m	0.003595
Basin Length	L	m	57549
Shape Factor (Circularity)	Shape	mi^2/mi^2	2.5662
Sinuosity Factor	Sin	msl/l	1.3115
Perimeter	P	m	253371
Elevation	AVEL	m	823
Basin Centroid X		m	631821
Basin Centroid Y		m	2747430
Average Stream Slope	ASS	m/m	0.02143
Drainage Density	D_d	Km^{-1}	1.948
Relief	H_b	m	950
Relief Ratio	R		0.0165
Elongation	E		0.624

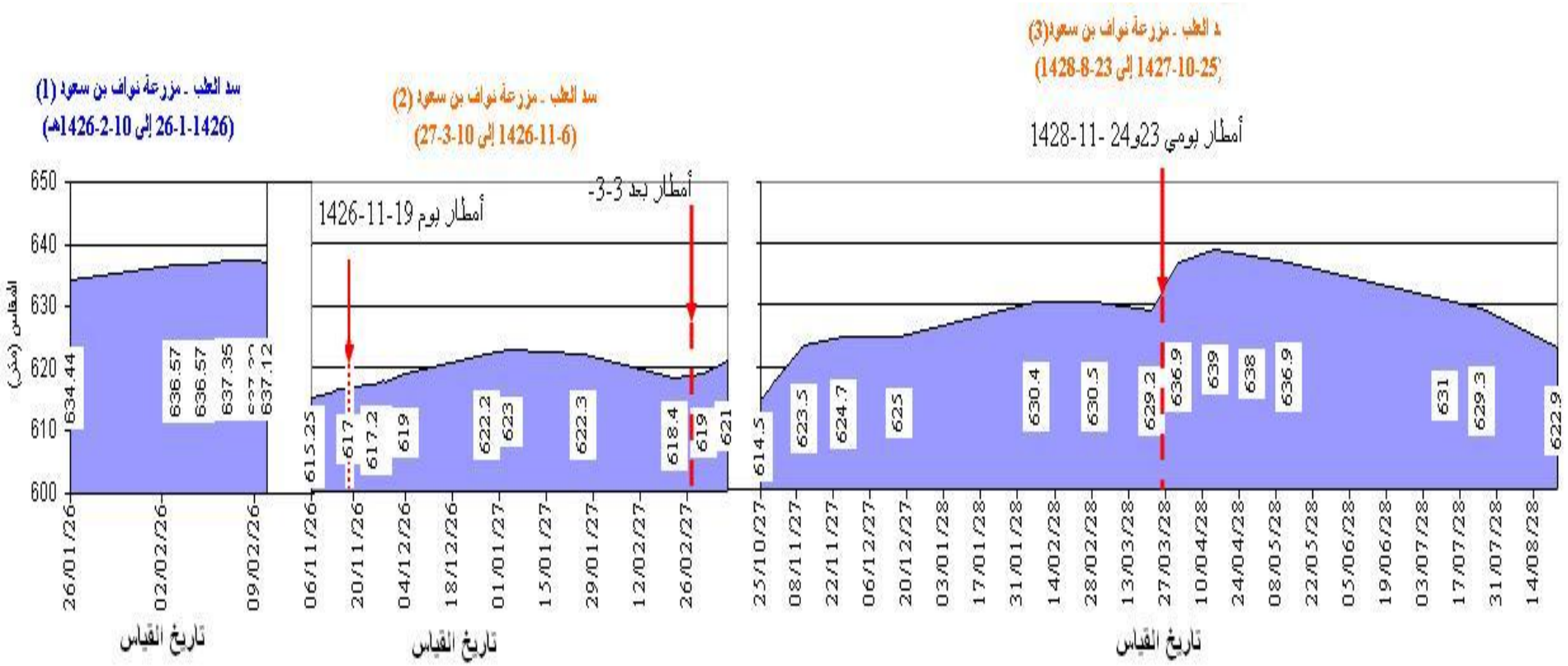
Groundwater level measurement downstream (before and after recharge)


سد العلب
Al Alab Dam
24 46 26.984N , 46 31 50.956E
سد العلب
329.64 km
م نواف بن سعد-العلب
Nawaf Saad Farm
© 2008 Europa Technologies
Image © 2009 DigitalGlobe
493 ft
Google
24°46'23.51" N 46°31'51.36" E elev 2177 ft Apr 2, 2007 Eye alt 3999 ft

Date	measurement	Mean sea level
26/01/1426	36.56	634.44
03/02/1426	34.43	636.57
05/02/1426	34.43	636.57
07/02/1426	33.65	637.35
09/02/1426	33.68	637.32
10/02/1426	33.88	637.12
06/11/1426	55.75	615.25
19/11/1426	54	617
26/11/1426	53.8	617.2
04/12/1426	52	619
28/12/1426	48.8	622.2
04/01/1427	48	623
26/01/1427	48.7	622.3
22/02/1427	52.6	618.4
03/03/1427	52	619
10/03/1427	50	621

Date	measurement	Mean sea level
25/10/1427	56.5	614.5
11/11/1427	47.5	623.5
26/11/1427	46.3	624.7
17/12/1427	46	625
07/02/1428	40.6	630.4
29/02/1428	40.5	630.5
22/03/1428	41.8	629.2
01/04/1428	34.1	636.9
15/04/1428	32	639
29/04/1428	33	638
13/05/1428	34.1	636.9
11/07/1428	40	631
25/07/1428	41.7	629.3
23/08/1428	48.1	622.9
08/11/1429	32.4	638.6
26/11/1429	29.3	641.7

Nawaf Saad Farm- Water level


سد الطب ـ مزرعة نواف بن سعود (1)
(26-1-1426 إلى 10-2-1426هـ)
سد الطب ـ مزرعة نواف بن سعود (2)
(6-11-1426 إلى 27-3-10)
سد الطب ـ مزرعة نواف بن سعود(3)
(25-10-1427 إلى 23-8-1428)
أمطار يوم 19-11-1426
أمطار بعد 3-3-
أمطار يومي 23و24 -11-1428
المقاس (متر)
650
640
630
620
610
600
634.44
636.57
636.57
637.35
637.12
615.25
617
617.2
619
622.2
623
622.3
618.4
619
621
614.5
623.5
624.7
625
630.4
630.5
629.2
636.9
639
638
636.9
631
629.3
622.9
26/01/26
02/02/26
09/02/26
06/11/26
20/11/26
04/12/26
18/12/26
01/01/27
15/01/27
29/01/27
12/02/27
26/02/27
25/10/27
08/11/27
22/11/27
06/12/27
20/12/27
03/01/28
17/01/28
31/01/28
14/02/28
28/02/28
13/03/28
27/03/28
10/04/28
24/04/28
08/05/28
22/05/28
05/06/28
19/06/28
03/07/28
17/07/28
31/07/28
14/08/28
تاريخ القياس
تاريخ القياس
تاريخ القياس

Results

- After 14 days of the rainfall event, more than 65% of the lake's water were recharged.
- Groundwater level increased by 8.85 m during the first two days.
- Total rise in groundwater level in the observation wells was about 15 meters.
- Water quality has been improved after the recharge (lower salinity).

Al Muzaira Dam

اسم السد : المزيريعية
Dam Name : Amezyryah
نوع السد : خرساني
Dam Type : Concrete

Location الموقع

46°20'14.103"E
24°46'52.453"N

Dam Location

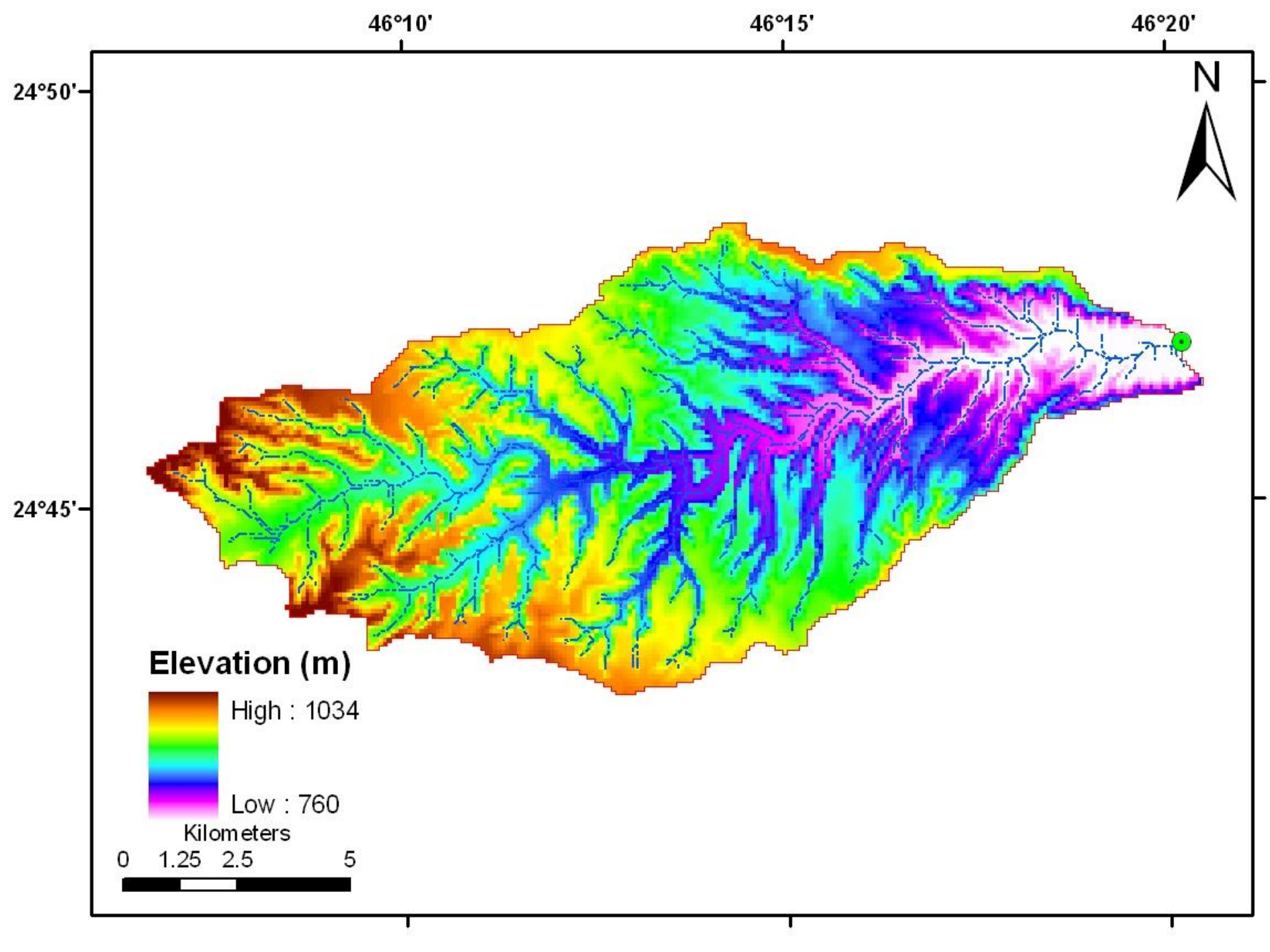
Basin

حوض سد المزيريعية
The baisn of Amezyryah Dam

N
W E
S

24°50'0"N
24°47'30"N
24°45'0"N
24°42'30"N
46°12'30"E
46°15'0"E
46°17'30"E

0 0.5 1 2 3 4 Kilometers


46°10'
46°15'
46°20'
24°50'
24°45'
N
Elevation (m)
High : 1034
Low : 760
Kilometers
0 1.25 2.5 5


3
2
1

Al Hareeq Dam

اسم السد : الحريق
Dam Name : Alhariq
نوع السد : ترابي
Dam Type : Earthen

Location الموقع

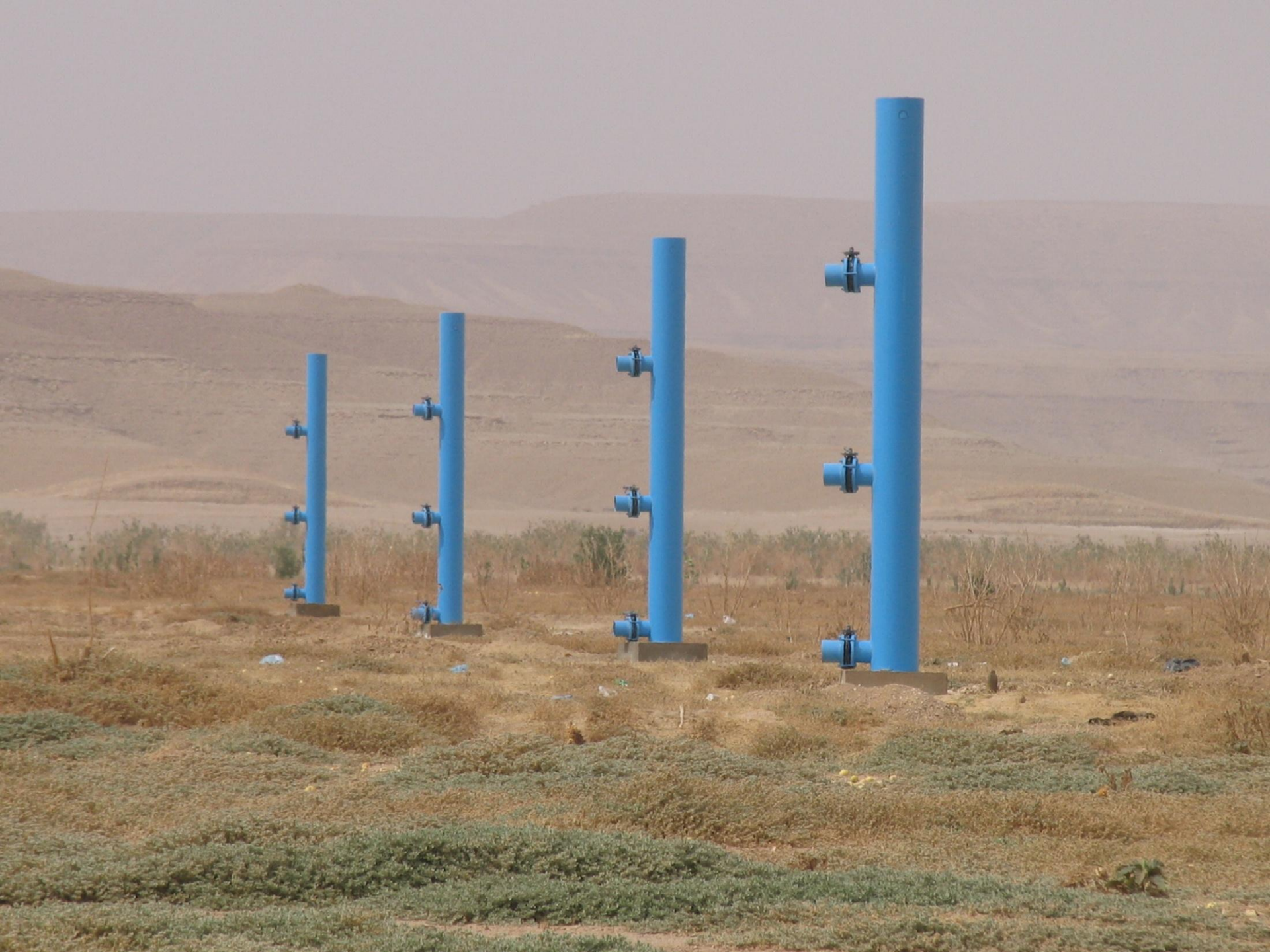
46°25'39.675"E
23°40'14.143"N

Dam Location

حوض سد الحريق
The baisn of Alhariq Dam

N
W E
S

الحريق



Dhruma Dam

اسم السد : ضرماء
Dam Name : Dhorma
نوع السد : ترابي
Dam Type : Earthen

Location الموقع

46°6'29.703"E
24°40'44.191"N

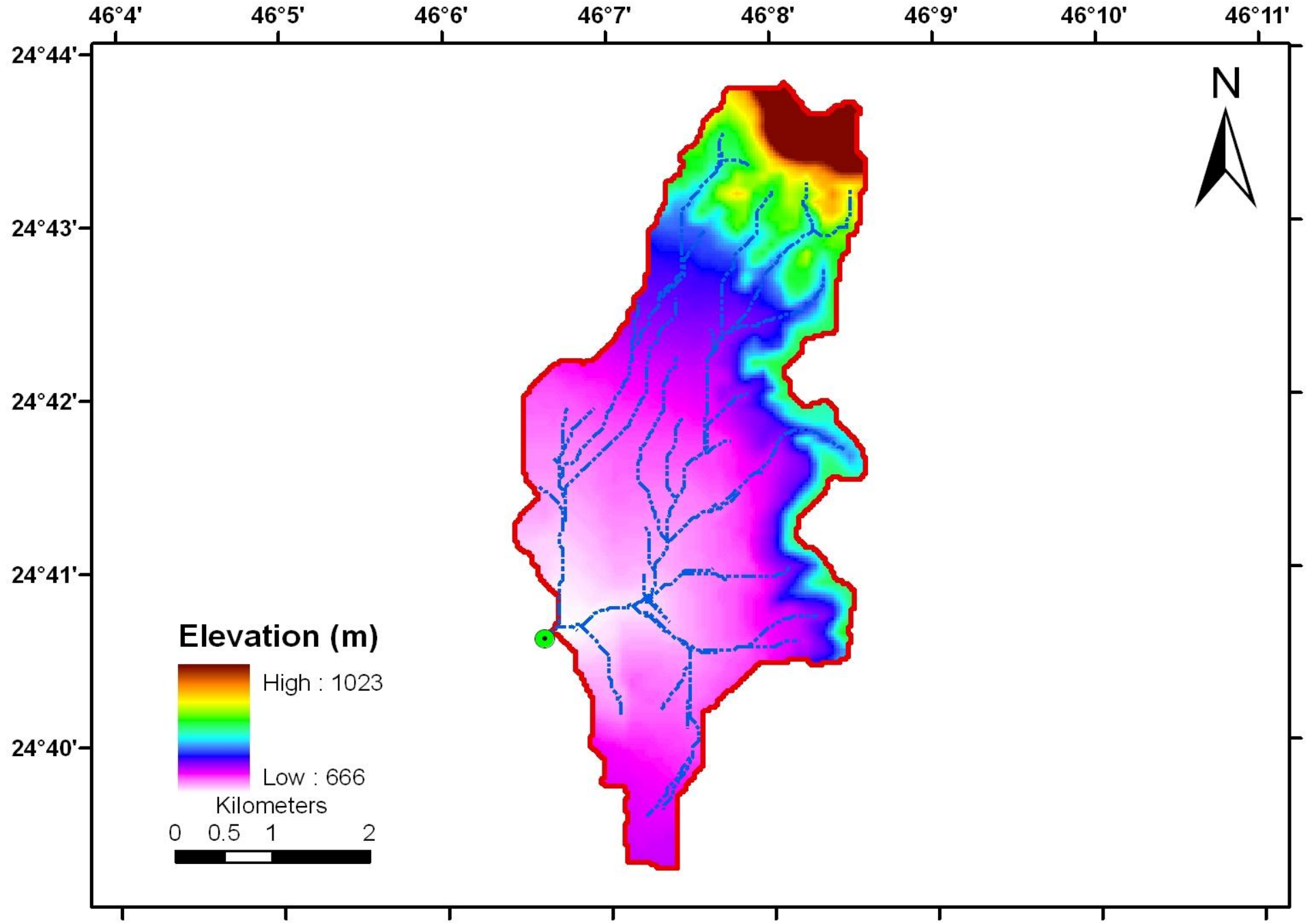
Dam Location

Basin

حوض سد ضرماء
The baisn of Dhorma Dam

N
W E
S

24°42'30"N
24°40'0"N
46°5'0"E
46°7'0"E
46°10'0"E


46°4'
46°5'
46°6'
46°7'
46°8'
46°9'
46°10'
46°11'
24°44'
24°43'
24°42'
24°41'
24°40'
N
Elevation (m)
High : 1023
Low : 666
Kilometers
0 0.5 1 2

morphometric parameters	Abbr.	Unit	Dhorma 131
Basin Area	A	Km^2	17.3
Total Stream Length (km)	Ct	km	42
Basin Slope	BS	m/m	0.0586
Maximum Flow Distance	MFD	m	7771
Maximum Flow Slope	MFS	m/m	0.04585
Centroid Stream Distance	CSD	m	3052
Centroid Stream Slope	CSS	m/m	0.0059
South Aspect ratio	%SF	%	0.69743
North Aspect ratio	%NF	%	0.30257
Maximum Stream Length	MSL	m	6784
Maximum Stream Slope	MSS	m/m	0.0154
Basin Length	L	m	6527
Shape Factor (Circularity)	Shape	mi^2/mi^2	2.4584
Sinuosity Factor	Sin	msl/l	1.0394
Perimeter	P	m	28729
Elevation	AVEL	m	708
Basin Centroid X		m	613919
Basin Centroid Y		m	2731609
Average Stream Slope	ASS	m/m	0.0115
Drainage Density	D_d	Km^{-1}	2.4[3]
Relief	H_b	m	1020
Relief Ratio	R		0.156[3]
Elongation	E		0.637[3]

Al Ghad Dam

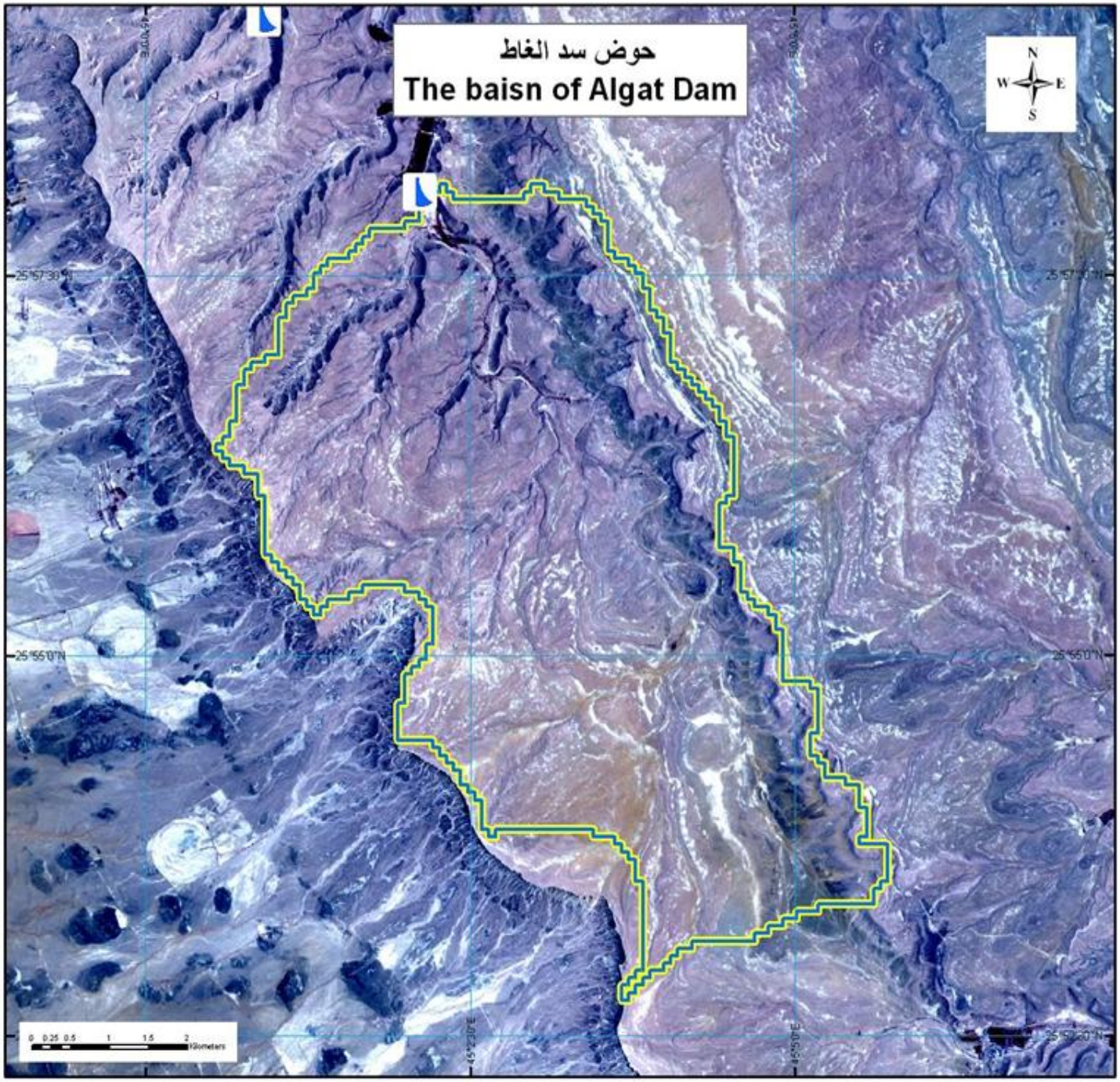
اسم السد : الغاط
Dam Name : Algat
نوع السد : ترابي
Dam Type : Earthen

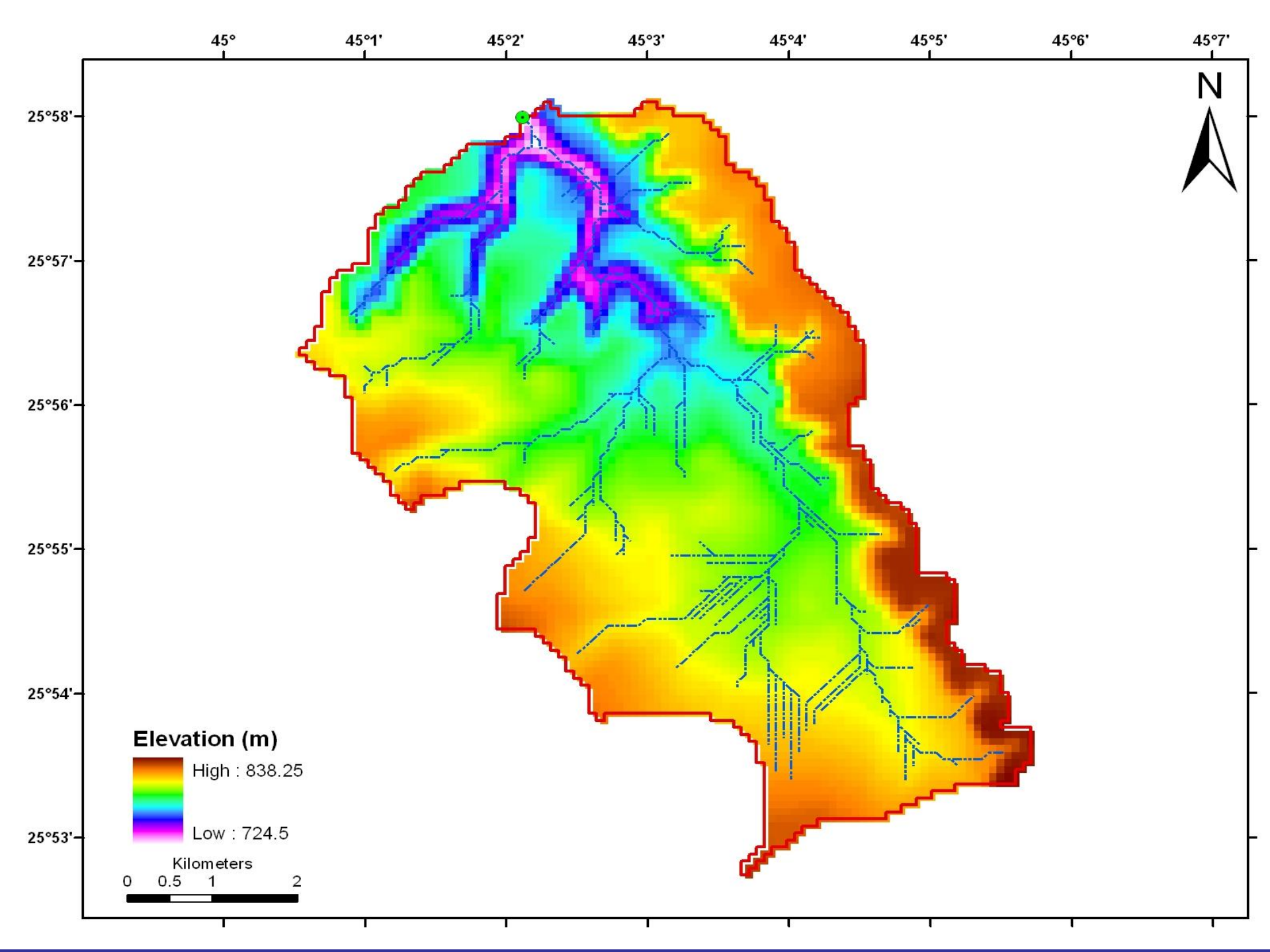
Location الموقع

45°2'6.554"E
25°58'2.187"N

Dam Location

Basin




45°
45°1'
45°2'
45°3'
45°4'
45°5'
45°6'
45°7'
25°58'
25°57'
25°56'
25°55'
25°54'
25°53'
N
Elevation (m)
High : 838.25
Low : 724.5
Kilometers
0 0.5 1 2

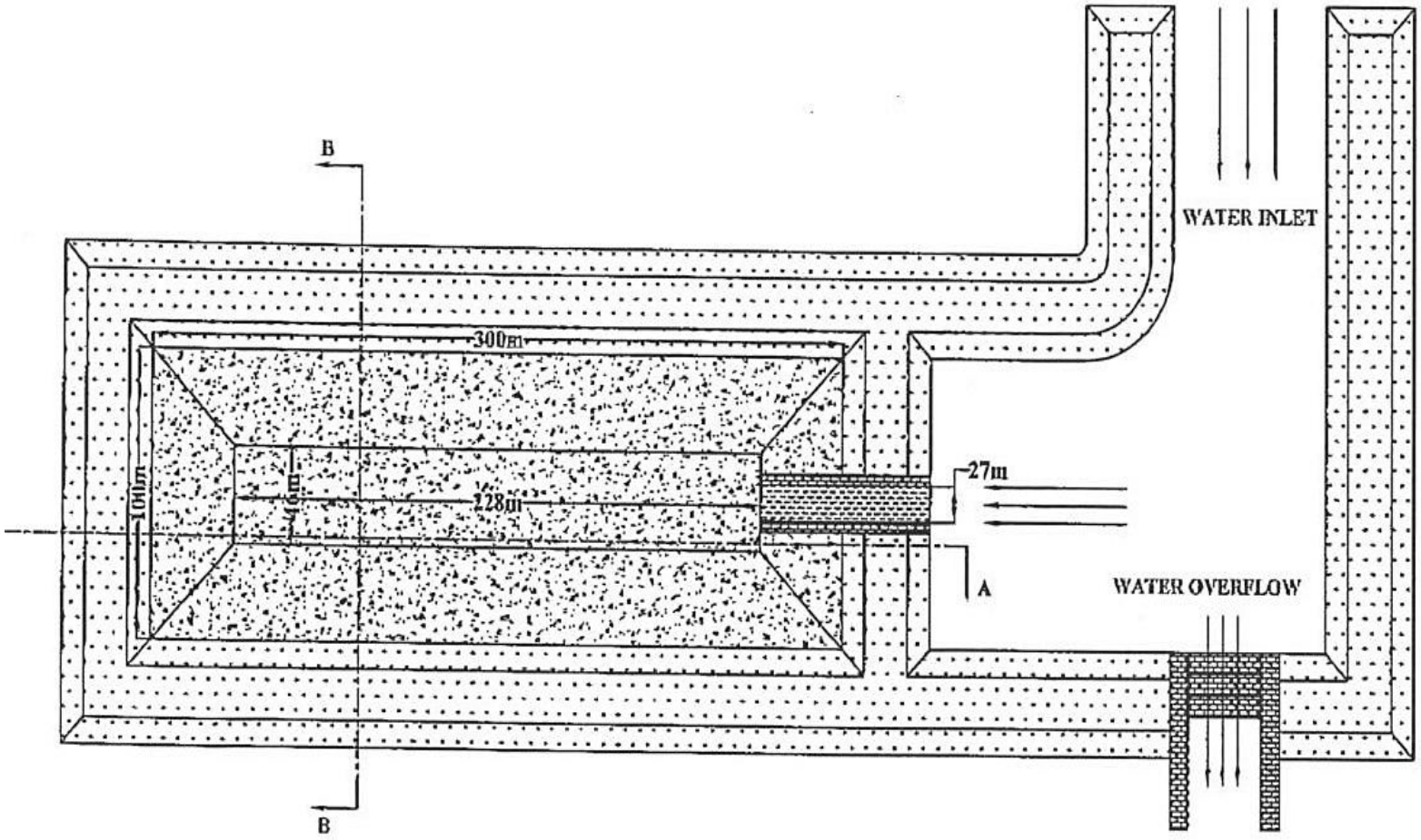
morphometric parameters	Abbr.	Unit	Algat 115
Basin Area	A	Km^2	42.8
Total Stream Length (km)	Ct	km	81.8
Basin Slope	BS	m/m	0.03882
Maximum Flow Distance	MFD	m	12233
Maximum Flow Slope	MFS	m/m	0.00909
Centroid Stream Distance	CSD	m	5631
Centroid Stream Slope	CSS	m/m	0.01251
South Aspect ratio	%SF	%	0.31370
North Aspect ratio	%NF	%	0.68630
Maximum Stream Length	MSL	m	11805
Maximum Stream Slope	MSS	m/m	0.00883
Basin Length	L	m	10235
Shape Factor (Circularity)	Shape	mi^2/mi^2	2.44971
Sinuosity Factor	Sin	msl/l	1.15345
Perimeter	P	m	40491
Elevation	AVEL	m	798
Basin Centroid X		m	505236
Basin Centroid Y		m	2867657
Average Stream Slope	ASS	m/m	0.01921
Drainage Density	D_d	Km^{-1}	1.9130775
Relief	H_b	m	840
Relief Ratio	R		0.08207519
Elongation	E		0.63891486

The 2nd Technique:

Artificial Ponds

Design and Methodology

- Dimensions: 300 m length, 100 m width and 9 m depth – soil removed used as mounds.
- Construction of a small dam to divert floodwater toward the pond.
- Pipes placed for conveying stored water to points of use.



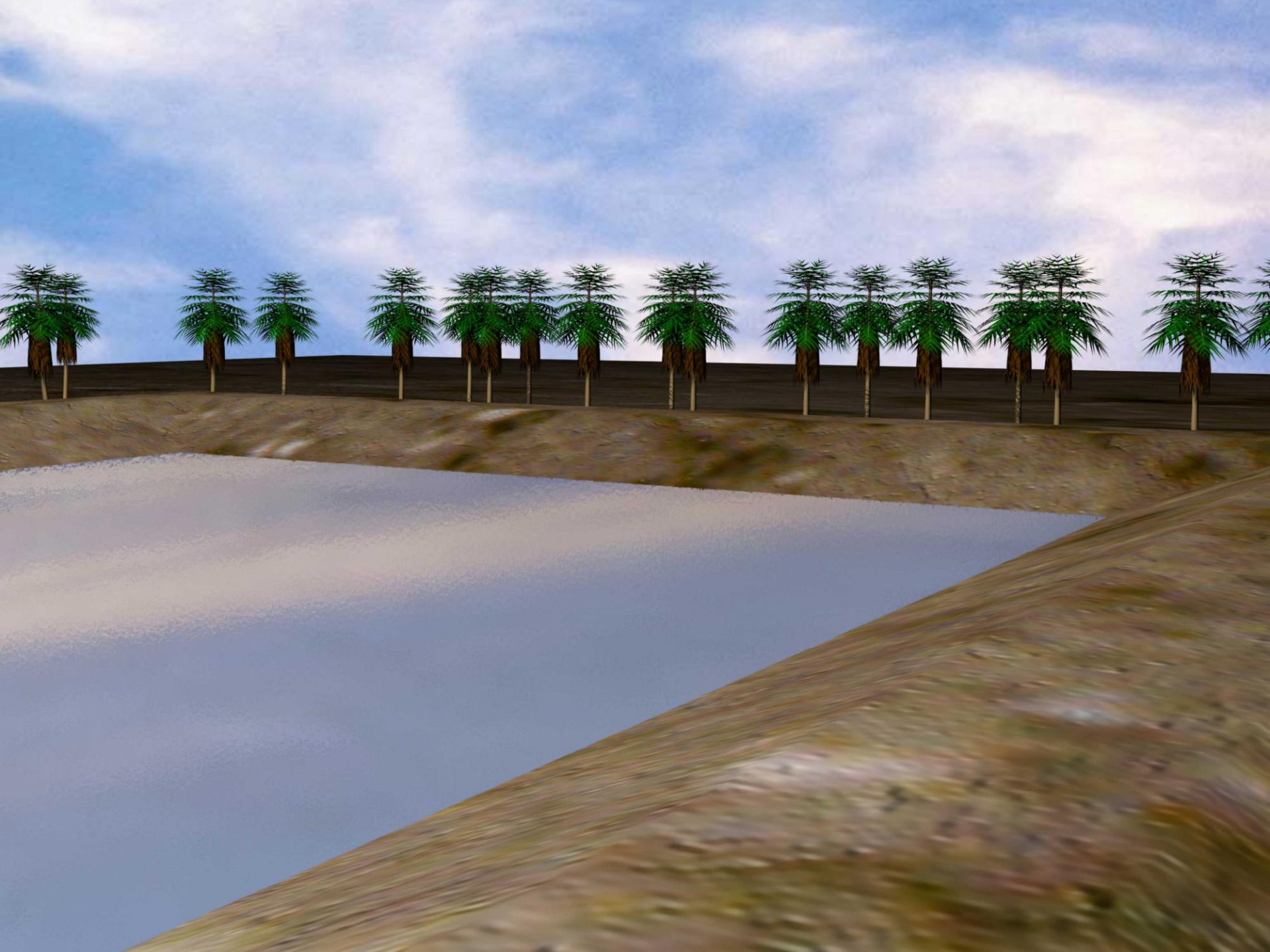
SECTION A-A

STONE

SAND

COCRETE

CLAY



First Artificial Pond at Dhruma

اسم السد : ضرماء
Dam Name : Dhorma
نوع السد : ترابي
Dam Type : Earthen

Location الموقع

46°6'29.703"E
24°40'44.191"N

Dam Location

Basin

حوض سد ضرماء
The baisn of Dhorma Dam

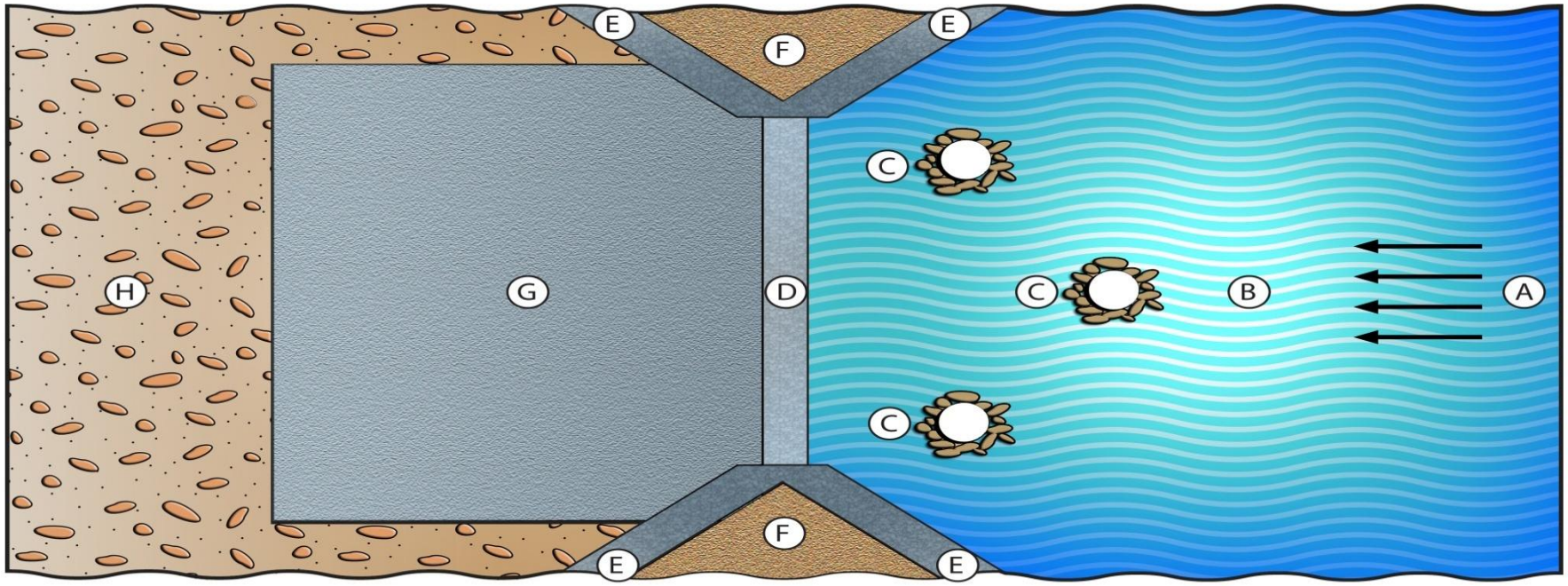
N
W E
S

24°42'30"N
24°40'0"N
46°5'0"E
46°7'0"E
46°10'0"E

Artificial Pond in Dhruma after rainstorm December 2006

3rd Technique :

Construction of small, low-cost dams along the water washes close to old settlements and villages to store water and achieve sustainable agriculture and development in the area



A. Water flow channel between 10 & 50m wide

B. Excavated & leveled area for water storage at a proposed length of double the width of (A). For example, if (A) is 12 m, then B will be 24m.

C. Recharge well with double-valve pipe built over it, not to exceed the dam in height. The number of wells in (B) will range from 2-4, depending on the width of (A).

D. Concrete dam 1 m in height, 1/2m thick, whose length = 2/3 the width of (A).

E. Support walls of equal thickness to the dam and with a height 1m higher than the dam.

F. Excavated soil from Area (B).

G. Primary overflow area covered by 15cm-thick layer of concrete extending away from the dam to half its length with a width exceeding the length of the dam by 2m.

H. Secondary overflow area covered with gravel.

Conclusions

1- Water harvesting and recharge techniques have proven to be successful in increasing groundwater level and improving its quality.

2- Water recharge through pipes eliminates the evaporation process from the dam's lake and reduces the negative impacts of dams in the arid regions.

3- Water harvesting and recharge projects are cost effective in terms of the benefits that they yield.

4- Stored and recharged water behind dams close to cities can be utilized in emergency situation.

5- Water harvesting and recharge techniques can be implemented to control flood and minimize its damage.

6- Remote sensing technology has improved the water harvesting and storage design, implementation and management.

Thank you