Modeling and Detecting ground and surface water in the South of Sinai. Using GIS and remote sensing techniques

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Abstract:

The current study aims to develop water resources. It is an environmental issue of world concern in light of climate change. Accordingly, the geological setting, geomorphological features, morphometric analysis, and hydrological system studied to reveal the available groundwater locations and the most providing sites of surface water that can cause injuries but on the other side can be stored for use when needed.

This field will serve many economic activities development in Southern Sinai such as irrigation, agriculture, power generation …etc. By applying on eight watersheds, which are Muqbella, Mahash El-Alaa, Dahab, Feiran, Kid, Mariekh, Aa't El-Sharqi, and Aa't El-Gharbi basin. Selected for the study according to several criteria, which are the most important that they are vulnerable valleys to flood hazards frequently. Therefore, this issue must be confronted and addressed with appropriate solutions, the most useful is constructing dams, reservoirs, and wells to reach and obstruct the flow of groundwater and store surface-water. By followed the modeling method to detect the water zones and to design dams.

The results revealed that 23.3% and 66.2% are areas with a very high and a high potential for groundwater the Southern Sinai total area, and 1.9% and 66.1% are areas with a very high and a high potential for surface water. The basins with the highest runoff are Dahab and Fieran and the least are Mahash Al-Alaa and Muqbella. Here, the construction of 15 groundwater dams and 33 surface dams was studied, and 6 of which were excluded because they weren't suitable.

Key words: South of Sinia- Water resources - flood hazard - develop - dams – wells - Modeling.

1. Introduction:

In light of the climatic changes and the fact that most of the world countries suffer from water poverty, it has become necessary to conduct many studies to provide water. Therefore, the study was applied to Southern Sinai, as it is an arid region, but torrential rains fall on it from time to time. It’s also a promising area that enjoys many natural resources, so its development will benefit the Egyptian country. A general study was applied to the region and a detailed study was conducted on eight basins which are a number of criteria were set for their selection. Which is the geographical distribution, area, exposure to flood hazard, density of structural lineaments, lithology, and geomorphology. Which will help to cover the study of the region well and comprehensively.

This study depends on six factors for detecting the groundwater potentiality zones and on nine factors for determining the surface water potentiality zones. Each factor was given a certain weight according to its effect on the availability of water. To conclude the final results by applying the weighted overlay method. Therefore, it was necessary to study the hydrological systems of the selected basins. To find out the net runoff based on calculating the difference between the total precipitation and the total water losses. Which would support the study in a more detailed and accurate way.

A number of geological, geomorphological and engineering criteria have been developed for the proposed dams. The study was provided with a database of the proposed dams, which are the length, height and type, and, the area, depth and storage capacity of the relevant artificial lakes have been estimated.

1.1. The location:

The proposed study area occupies 29.363 km^2.Which located in the southern half of the Sinai Peninsula. It has a triangle shape whose northern base is Well Taba on the Gulf of Aqaba in the east until Ras Masala on the Gulf of Suez in the west. And its sides extend along the Gulfs of Aqaba and Suez until they meet in Ras Muhammad in the south, at 27° 43̀ 23.3‶ to 29° 57̀ 46‶ N and 32° 36̀ 24‶ to 34° 55̀ 10.58‶ E. **Figure (1)** shows the location of the area and basins selected for the study.

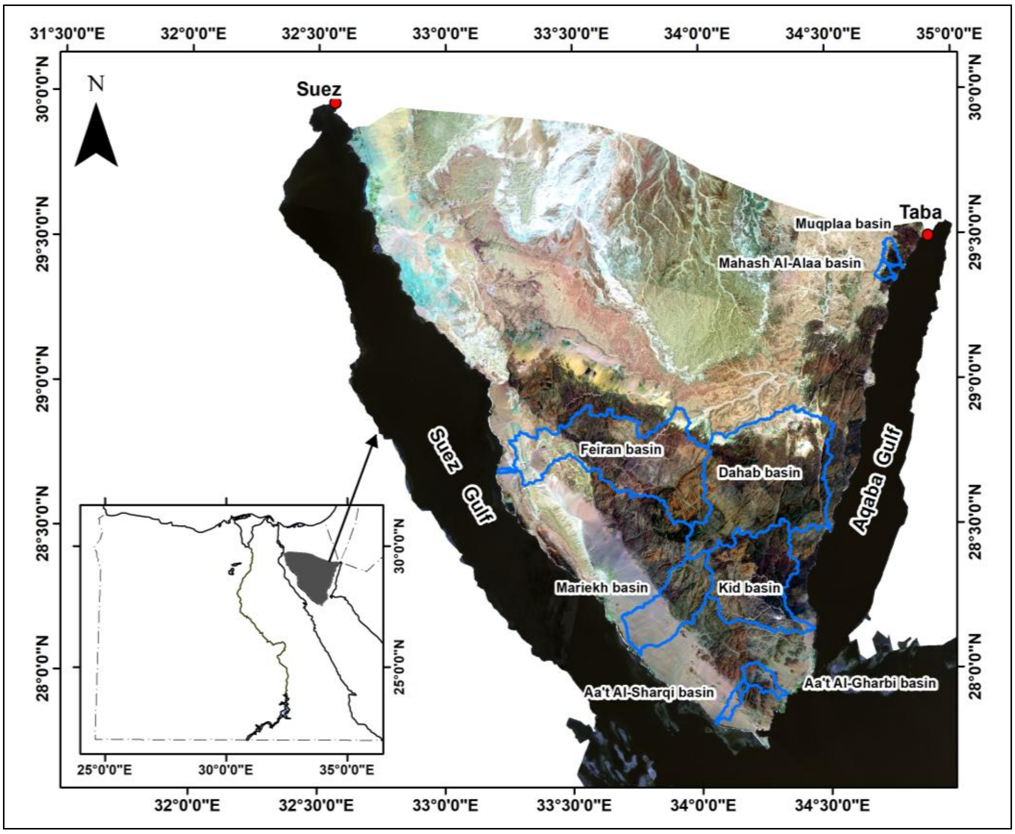

Figure (1): Location of the study area in Landsat 8 image

1.2. Geological and geomorphological setting:

The study area is composed of the basement rocks that occupy the southern part of Sinai Peninsula and is estimated 8.528 km^2. Represented in four major groups of rocks; metamorphic rocks including gneiss and metamorphosed volcanic & volcanic-sediments, ultramafic rocks, calc-alkaline rocks, and alkaline rocks, arranged from the oldest to the youngest age. These rocks take a mountainous triangle form, overlapped by a group of granitic domes and surrounding this triangle, and forming the cliffs and the terraces overlooking the eastern coast and small parts of the western coast.

The sedimentary rocks occupy 20.835 km^2 of the total region's area. Which is located at the northern border of the basement rocks. These rocks were formed in four geological ages, each of age passed through several periods. And, due to various tectonic, climatic, and biological factors from one side, and, the mechanic and chemical processes from another side, each period was characterized by distinctive rocks. *The Paleozoic age*; includes Cambrian rocks and carboniferous rocks. *The Mesozoic age*; represented in Triassic rocks. *The Tertiary age*; includes Paleocene, Eocene, Oligocene, Miocene, and Pliocene rocks. Which form large plateaus in the study area and because of the tectonic and weathering factors some buttes and mesas appear around them. Also, those rocks formed the cliffs and the terraces of the southern coast. *The Quaternary age*; which are Pleistocene and Holocene formations and deposits. These deposits are distributed in wadis that incised in the rocks, deltas, and fluvial fans in the eastern and western parts of the study area, hamada deposits located at the eastern of the southern mountainous triangle, fanglomerate and playa deposits which appear in some scattered areas of wadi Fieran and the wadis that cut through the northern plateaus.

The region is diverse in structural lineaments as faults, fractures, cracks, and dykes. Most of them, have the same directions of Suez and Aqaba gulfs. In general, their densities are high in the basement rocks and low in the sedimentary rocks. The folds' hinges and foliations are in the metamorphic rocks as mesoscopic structures that occur in the texture of rocks. And, appear as separate structural rock units in sedimentary rocks.

4. Objectives:

The present study aims for two objectives:

a) Modeling and determining the potentiality zones of groundwater in the South of Sinai, generally. And, in the eight selected basins, especially. Accordingly, to suggest constructed dams and wells to obstruct the natural flow of groundwater and stores it below the ground surface.

b) Modeling the potentiality zones of surface water in the study area. To detect the most vulnerable areas to floods and torrents. And benefit from it through the establishment of projects aimed at transforming the arid region into a green oasis. By proposing a number of dams, classifying them, and clarifying all the data related to the reservoirs attached to them.

5. material and Methods:

5.1. *The used thematic layers:*

Determining the groundwater potentiality zones depends on six factors. Namely, the annual rainfall average, elevations, slope, lithology, drainage density, and faults density. While to determine the surface-water potentiality zones it depends on nine factors. The previously mentioned factors in addition to geomorphology of earth's surface, soil types (quality and porosity), and density of vegetation. Therefore, to produce these thematic layers, many methods have been used as will be explained.

Downloaded DEMs from the website https://asf.alaska.edu/. It's ALOS PALSAR with a resolution of 12.5 m. To produce the elevation and slope maps. The area was classified into nine equal elevation classes with an interval is 300m. While it was classified into seven classes of slopes, which were graded from the low to the high slope degree.

It was based on the climatic data of average annual rainfall in the period 1999: 2021. The data was collected from 7 meteorological stations. https://www.meteoblue.com/en/climate-change; https://power.larc.nasa.gov/ Watersheds and drainage networks were extracted from the DEM, to design the morphometric analysis and drainage density of the study area .

Structural lineaments were studied from the geological maps and Landsat 8. To produce the density of faults and fractures layer.

Rock units were extracted from the geological maps 1: 250000. And, they are grouped into four categories according to their permeability where the highest helps to form and store groundwater and provides flow pathways for surface-water .

The geomorphological phenomena of the study area were classified into ten landforms. And, were arranged from the higher to the lower ability for providing surface-water.

Soil of region was classified into five classes depending on its low porosity and the inability of water leaching. In fact, drainage networks formed on the surface that prevent or decrease the opportunity of water infiltration. So, this is an indicator of the surface-water availability.

Downloaded Landsat 8 from the website https://earthexplorer.usgs.gov/. For studying the density of vegetation by applied the (NDVI). This index was studied and analyzed by the Erdas-imagine 14 program. The thematic layer was divided into two categories. Values ranging >0: 1, indicate the varying density of vegetation and therefore the availability of surface water. While the value 0 is bare rocks.

Finally, using the weighting overlay method; each thematic layer was given a certain weight according to its importance and with the help of the mathematical method “analytic hierarchy process” (AHP). And were overlayed to produce the surface and groundwater zones maps in the South of Sinai and in the eight selected basins.

5.2. Criteria of the selected basins studied:

a) Geographical distribution: two basins were selected located in the north, four in the middle, and two in the south of the study region. Four of those basins flow into the Gulf of Aqaba, and the others pour into the Gulf of Suez.

b) The area of basins: which cover a large area of the study region.

c) Exposure to flood risk: they are frequently flooded therefore they enjoy a large water budget.

d) Density of geological structures: The basins that have a high density of structural lineations were selected in order to know their impacts on the quantities of water.

e) Diversity of rocks: basins that are composed of several rock types, which is including both basement and sedimentary. To know the impact of each rock permeability on the quantities of water.

f) Geomorphology of the Earth's Surface: the basins that enjoy a variety of landforms were selected to illustrate their effects on the runoff.

- Accordingly, the study basins are Muqbella, Mahash El-Alaa, Dahab, Feiran, Kid, Mariekh, Aa't El-Sharqi, and, Aa't El-Gharbi basin.

5.3. The morphometric and hydrological system study:

It is an essential aspect that must be studied at the level of the eight basins. That helps to identify the expected amount of rainfall depending on the maximum rainfall in a day, the amount of water lost by evaporation, and the infiltration to know the net runoff. So, the hydrological study completes the surface-water study to face the flood hazard by the best ways.

Table (NO.1)

Table (1): parameters and inputs used in the analysis of the hydrological system

Basin	Area	H	Lb	LCA	Steep slope	CT(1)	Maximum rainfall in a day (2)		Average of Vapor
	Km^2	Km	Km	Km	%	--	mm	Date	mm
Muqblaa	51.9	0.986	11.60	4.802	45.02	1.4	34	Nuweibaa	12.55
Mahash	33.1	1.071	5.74	4.41	55.7	1	34	1/1/1994	12.55
Dahab	2074.7	2.534	20.9	16.87	38.63	1.4	76.2	Saint Catherine	12.95
Feiran	1863,1	2.625	75.23	48.7	30.34	1.6	76.2	8/11/1937	10.92
Kid	1074.6	2.421	19.930	22.95	64.20	0.8	48.3	Sharm El-Shiekh 7/11/1985	12.87
Mariekh	674.4	2.557	3.90	13.5	36.13	1.6	70.1	El-Tor 9/3/2002	12.54
Aa't El-Sharqi	111.8	1.392	20.26	10.277	37.40	1.6	48.3	Sharm El-Shiekh	12.87
Aa't El-Gharbi	70.8	1.011	5.20	10.20	11.30	2.2	48.3	7/11/1985	12.87

(1) Raghunath, H.M. 1991.

(2) Unpublished data from the Egyptian Meteorological Authority.

- H: the difference between minimum and maximum elevation.
- Lb: the length of the main stream.
- LCA: is the centroidal Flow path basin. That is the distance from the mouth to the center of the basin.
- Steep slope: the area percentage of the slopes ranging from 18˚ to 90˚, which is related to the total area of basin.
- Ct: Peak time coefficient related to the slope of basin. Which ranging from 0.2 to 2.2.
- The maximum rainfall in a day from 1934 to 2004. And it differs from basin to another according to the nearest meteorological station to the specific study basin.
- The average of vapor from 1934 to 2002 which was recorded in the nearest meteorological stations for each basin.

The hydrological Equations used:

Table (2): The applied hydrological Equations in the study area

Lag time formula	$TP_{(hr)} = Ct\ (Lb \times Lca)^{0.3}$
Drainage time formula	$Td = (0.305Lb)^{1.15} / [\ 7700\ (0.305H)^{0.38}]$
Expected amount of precipitation [(1)]	= Basin area × Maximum rainfall in a day
Total daily vapor	= Basin area × Vapor average in meteorological stations
Total vapor average in an hour	= Total daily vapor / 24
Total vapor in drainage time	= Total vapor in an hour × Drainage time
Infiltration in lag time	= Basin area × Lag time × o.25 mm/minute o.25 mm/minute is the infiltration average for all sediments types
Constant infiltration [(2)]	= Basin area × Drainage time × 0.0158
Water losses	= Total vapor in drainage time + Infiltration in lag time + Constant infiltration
Net runoff [(3)]	= Total precipitation - Total water losses

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٢. عمران، انتظار مهدي & عبد الرحمن، هالة محمد. ٢٠١٨
٣. سليمان، محمد فؤاد عبد العزيز. ٢٠١١.

5.4. Criteria of the suggested dams' locations:

a) In the peak flood flow areas. To protect the lands from drowning.

b) The junction points of streams. These are the areas that collect the largest amounts of water.

c) The lithology which has high resistance to weathering and erosion factors. To provide a longer lifetime of dams.

d) Low porosity of soil and low permeability of the rocks. To reduce water infiltration. غضية, أ.ر., & برقان, م.ع ٢٠١٩

e) Provide a narrow outlet as gorges. To reduce the financial cost of the constructed dams. This has been achieved through the study and examination of contour lines to select the appropriate sites.

f) Exclusion of active faults areas –long faults- because they are considered unsafe areas for dams.

g) Select a suitable basin area that allows the establishment of a reservoir lake or water channel to drainage of excess water.

h) Exclusion of the area with a large elevation difference because it is high cost and exposes the dam to failure. https://civilengineering.blog/

6. Discussion and results:

6.1. Analyzing the thematic layers:

precipitation: Average annual precipitation increases in the middle of the study area and decreases with trend towards margins. The more rainfall there is, the greater of the groundwater and surface-water amounts.

Drainage density: It plays a vital role in understanding the available water sources whether they are surface water or groundwater sources. The low drainage density indicates the possibility of groundwater availability, and on the contrary, the high drainage density indicates the availability of surface water, because the high discharge density is located above low-porous soil.

Elevation: It is an indicator of the areas of accumulation and movement of water. Lower surface elevation indicates increased groundwater volumes and surface water availability. Also, the construction of dams is more convenient in low-rise areas.

Slope: This factor affects the runoff force of surface and groundwater. A low slope indicates the high possibility of water accumulation, for both surface and groundwater.

Faults and fractures density: Structural lineaments density is an effective factor for collecting the water underground, especially the intersection areas of fractures and cracks. The high density of fractures reflects the increase of groundwater, while the low density of faults provides greater amounts of surface water. Despite the important role that faults play in directing the flow paths and thus moving and collecting surface water. However, the density of faults in a unit of km^2 determines the amounts of surface and groundwater.

Lithology: The area consists of basement rocks and some sedimentary rocks. Divided into four categories depending on their permeability; namely: sediments and Cambrian rocks, which are the highest permeability, followed by sedimentary rocks of various types, then volcanic rocks and metamorphism volcanic-sediments, and finally basement and metamorphic rocks, which are the least permeable.

Geomorphology of the Earth's Surface: The landforms play an important role in determining the quantities of surface-water availability. Which are divided into several categories that vary according to the nature of the surface of the studied basins. Where the fluvial fans, plain lands, wadis, small sedimentary landforms, sedimentary medium height landforms, rugged terrain dissected by dykes, large sedimentary plateaus, folded landforms, faulted landforms, high elevation mountains, and urban areas; respectively from the highest to the lower class. It was important to mention the urban areas, which include residential buildings and roads. Although it is a morphological factor, it indicates the intervention of humans in reshaping the earth's surface in his favor.

Soil quality and porosity: In the study area, the soil is divided into three categories; namely: liptosol (lithic), regosol (eutric), and calcisols soil. Which are generally low-fertility soils, but can be more precisely divided into typical alluvial soil, typical sandy soil, typical aridisol soil, typical calcisol soil, and rocky sandy soil. (Abd El-Wahab, Raafat.et al., 2006, 2013).

Vegetation density : The density of vegetation is an indicator of the amounts of surface water that can encourage the growth or non-growth of the natural plants and determine its density in the study area.

6.2. The weighted overlay to determine the groundwater potentiality zones in the South of Sinai:

By applying a weighted overlay to the six thematic layers. Each layer has a certain weight depending on its importance and impact on the determination of groundwater. **Table (NO.3).** According to the model builder in Figure (NO.2).

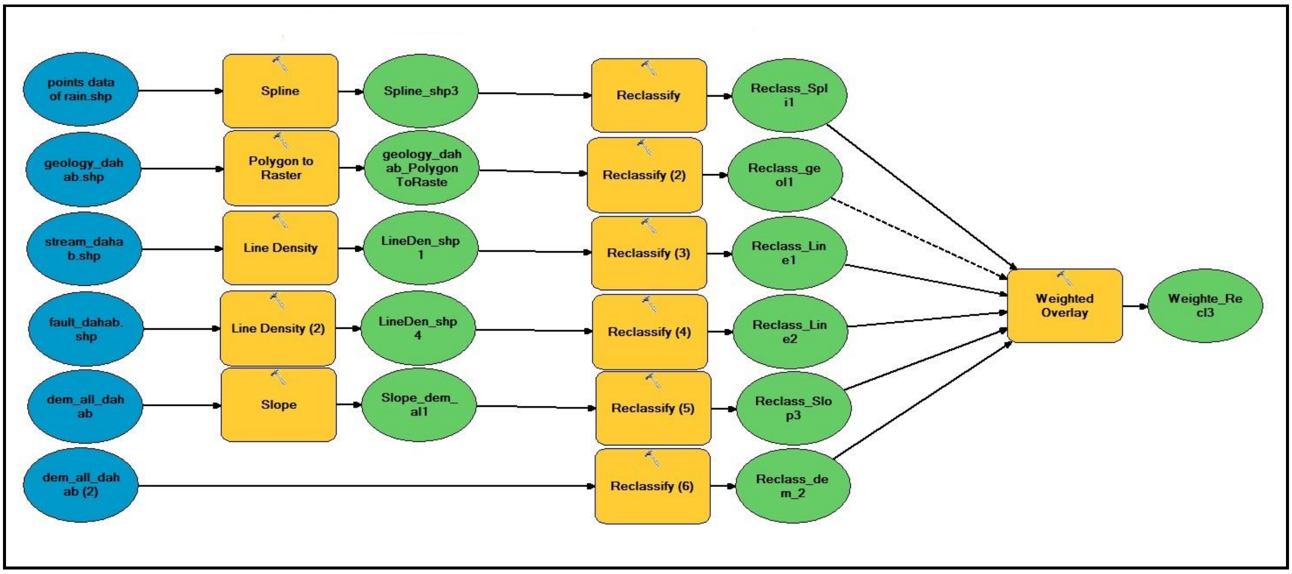


Figure (2): Model builder for determining the groundwater potentiality zones

Table (3): Groundwater potentiality zones in South of Sinai

Thematic Layer	Thematic Layer Weight	Classes	Rank
Precipitation (Mm/year)	30%	29.1: 35.1	1
		24.1: 29	2
		18.1: 24	3
		12.1: 18	4
		2.4: 12	5
Lithology	25%	Cambrian rocks and sediments	1
		Sedimentary rocks	3
		Metamorphosed volcanic and volcanic-sediments rocks	5
		Igneous and metamorphic rocks	7
Drainage density (Km/Km2)	10%	0.186: 0.804	1
		0.804: 1.423	2
		1.423: 2.040	3
		2.040: 2.659	4
		2.659: 3.275	5
Faults and fractures density (Km/Km2)	15%	0.821: 0.603	1
		0.603: 0.497	2
		0.497: 0.375	3
		0.375: 0.207	4
		0.207: 0	5
Slope (degree)	10%	0: 2	1
		2: 10	2
		10: 18	3
		18: 30	4
		30: 45	5
		45: 70	6
		70: 83.1	7
Elevations (Meter)	10%	-1: 300	1
		300: 600	2
		600: 900	3
		900: 1200	4
		1200: 1500	5
		1500: 1800	6
		1800: 2100	7
		2100: 2400	8
		2400: 2635	9

Groundwater in the South of Sinai is concentrated in the northern sedimentary plateaus, in some fluvial fans of basins which pour into Aqaba Gulf as Wadi Muqblaa, Mahash, Watier, Dahab, and Kid, and, others which pour into Suez Gulf such as Feiran and Sidri. Also, many scattered parts in the upstream and streams of those basins. The high potentiality zones in sedimentary rocks such as Eocene and Cretaceous rocks are due to the high porosity of soil and permeability of rocks. While in the southern mountainous triangle due to the density of structural lineaments **Fig (NO.3)**. The area of the groundwater potentiality zones is mentioned in the **Table (NO.4)**

Table (4): The area of the groundwater catchment land

Classes	Area		Potentiality
	Km	%	
2	7.773	23.3	Very high
3	17.517	60.2	High
4	4.047	13.9	Moderate
5	0.761	2.6	Low

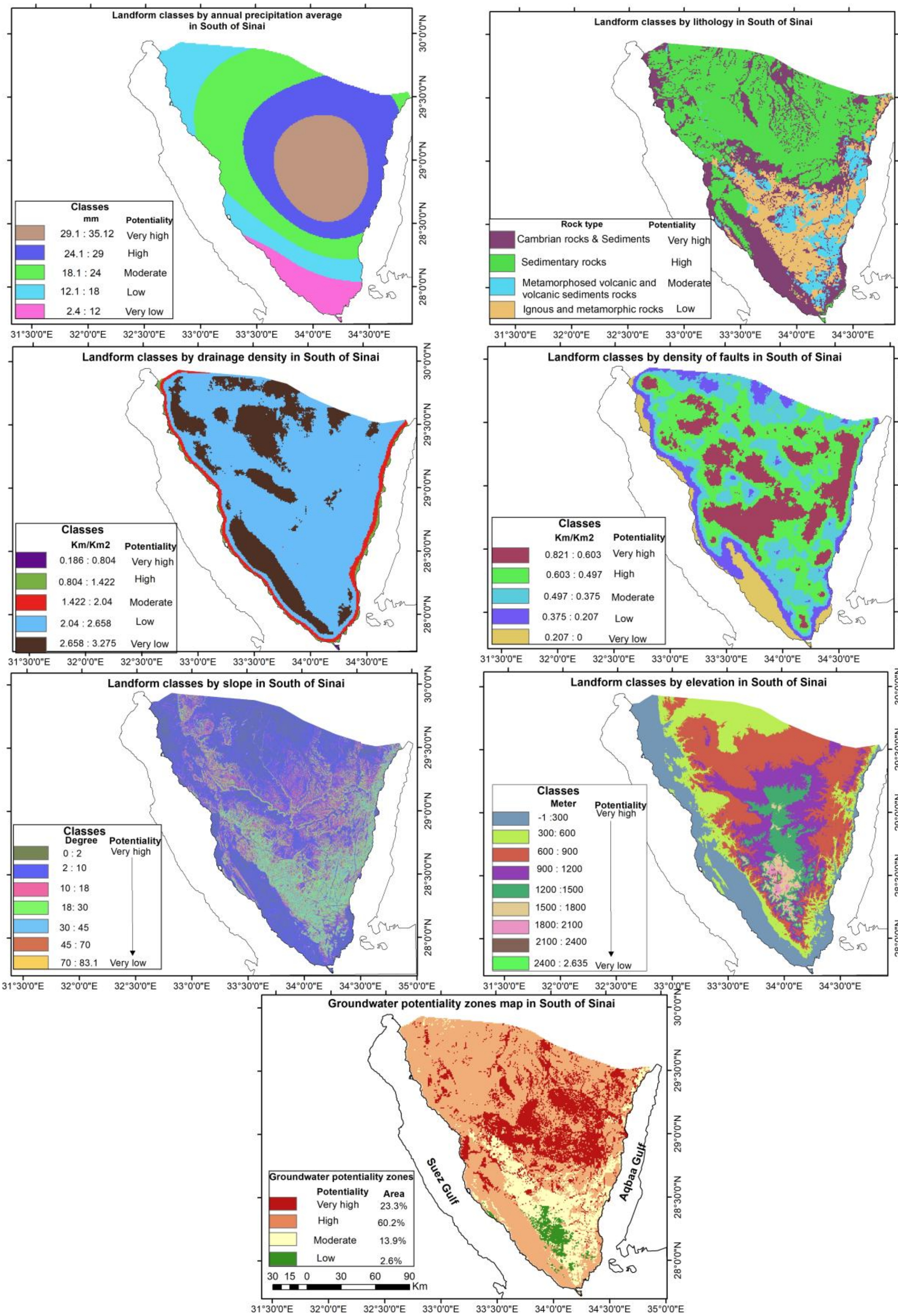


Figure (3): The groundwater potentiality zones map in the South of Sinai

6.3. The weighted overlay to determine the surface-water potentiality zones in the South of Sinai:

The weighted overlay was applied to the nine thematic layers **Fig (NO.4)**. The **Table (NO.5)** shows the used layer, their weights, classes, and ranks.

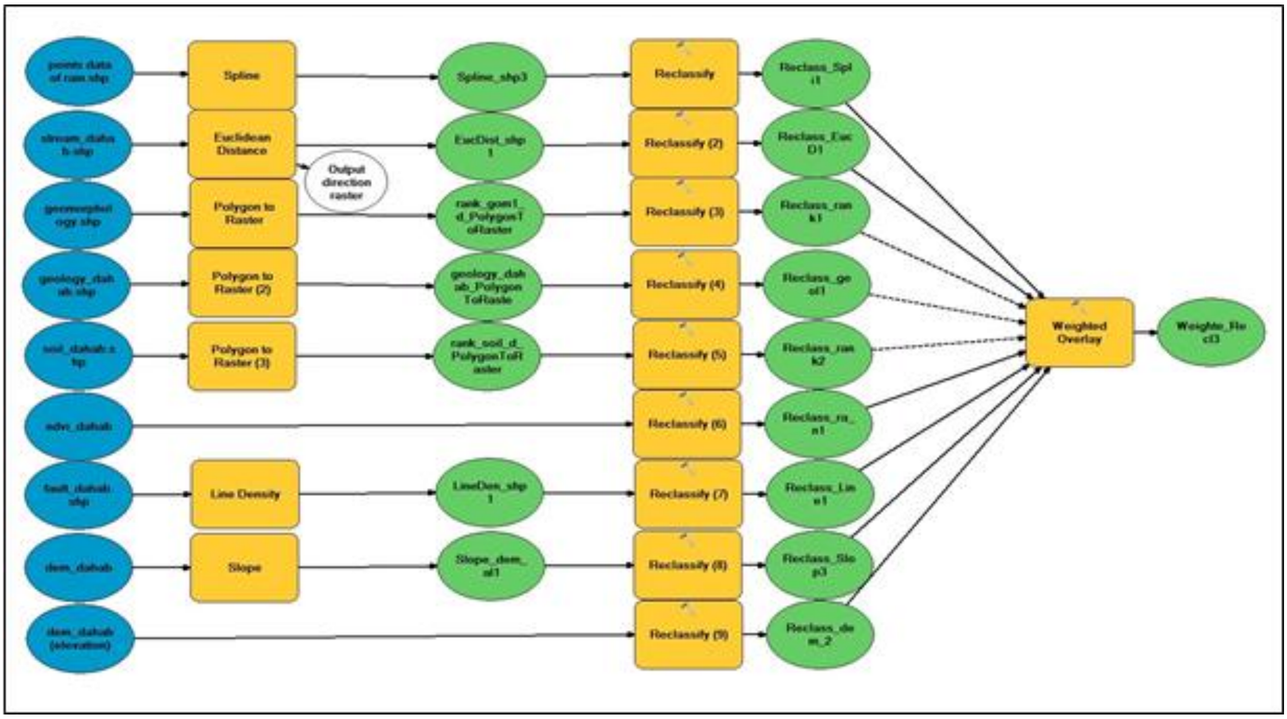


Figure (4): Model builder for determining the surface-water potentiality zones

Table (5): Surface-water potentiality zones in South of Sinai

Thematic Layer	Thematic Layer Weight	Classes	Rank
Precipitation (Mm/year)	20%	29.1: 35.1	1
		24.1: 29	2
		18.1: 24	3
		12.1: 18	4
		2.4: 12	5
Drainage density	20%	3.275: 2.659	1
		2.659: 2.040	2
		2.040: 1.423	3
		1.423: 0.804	4
		0.804: 0.186	5
Geomorphology	15%	Fluvial fans	1
		Plain lands	1
		Wadis	2

		Small sedimentary landforms		3
		Sedimentary medium height landforms		4
		Rugged terrain dissected by dykes		5
		large sedimentary plateaus		6
		Folded landforms		7
		Faulted domes and mountains		8
		High elevation mountains		9
Lithology	10%	Cambrian rocks and sediments		1
		Sedimentary rocks		3
		Metamorphosed volcanic and volcanic-sediments rocks		5
		Igneous and metamorphic rocks		7
Soil quality and porosity	10%	Typical alluvial soil		1
		Typical sandy soil		3
		Typical aridisol soil		5
		Typical calcisol soil		7
		Rocky sandy soil		9
Vegetation density	10%	Variable Vegetation density	>0: 1	1
		Barren rocks	0	7
Faults and fractures density (Km/Km2)	5%	0: 0.207		1
		0.207: 0.375		2
		0.375: 0.497		3
		0.497: 0.603		4
		0.603: 0.821		5
Slope	5%	0: 2		1
		2: 10		2
		10: 18		3
		18: 30		4
		30: 45		5
		45: 70		6
		70: 83.1		7
Elevation	5%	-1: 300		1
		300: 600		2
		600: 900		3
		900: 1200		4
		1200: 1500		5
		1500: 1800		6
		1800: 2100		7
		2100: 2400		8
		2400: 2635		9

Through the study of surface-water potentiality catchment zones after the rainfall, it has been able to determine the areas which prone to flood hazards in the South of Sinai **Fig (NO.5)**. The very high potentiality zones located in the northern sedimentary plateaus, in some northern parts of the mountainous triangle, plains areas as El-Qa'a plain, fluvial fans and upstreams of wadi

Watier, Dahab, Kid, Wardan, Gharandl, Sedri, Feiran and others basins. This is due to many of the factors previously studied, especially the high drainage density and low faults density. In addition to many areas in the basement rocks core, thanks to the low slope due to the high rate of erosion and weathering factors. The area of the surface-water zones is in **Table (NO.6).**

Table (6): The area of the surface-water catchment lands

Classes	Area		Potentiality
	Km	%	
2	0.560	1.9	Very high
3	19.2	66.1	High
4	9.3	31.9	Moderate
5	0.420	0.1	Low

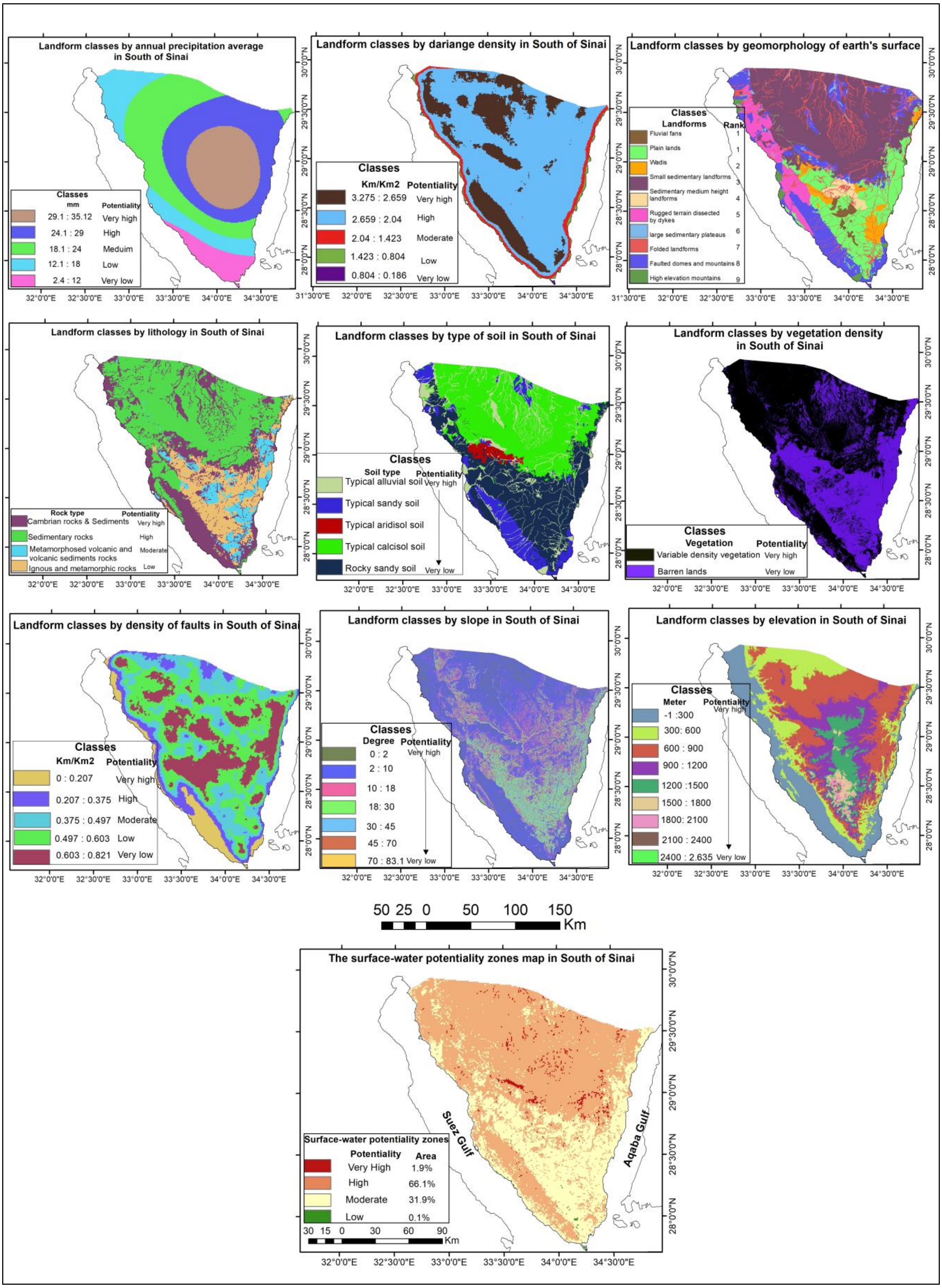

Landform classes by annual precipitation average in South of Sinai
Classes mm Potentiality
29.1 : 35.12 Very high
24.1 : 29 High
18.1 : 24 Meduim
12.1 : 18 Low
2.4 : 12 Very low
Landform classes by dariange density in South of Sinai
Classes Km/Km2 Potentiality
3.275 : 2.659 Very high
2.659 : 2.04 High
2.04 : 1.423 Moderate
1.423 : 0.804 Low
0.804 : 0.186 Very low
Landform classes by geomorphology of earth's surface
Classes Landforms Rank
Fluvial fans 1
Plain lands 1
Wadis 2
Small sedimentary landforms 3
Sedimentary medium height landforms 4
Rugged terrain dissected by dykes 5
large sedimentary plateaus 6
Folded landforms 7
Faulted domes and mountains 8
High elevation mountains 9
Landform classes by lithology in South of Sinai
Rock type Potentiality
Cambrian rocks & Sediments Very high
Sedimentary rocks High
Metamorphosed volcanic and volcanic sediments rocks Moderate
Ignous and metamorphic rocks Low
Landform classes by type of soil in South of Sinai
Classes Soil type Potentiality
Typical alluvial soil Very high
Typical sandy soil
Typical aridisol soil
Typical calcisol soil
Rocky sandy soil Very low
Landform classes by vegetation density in South of Sinai
Classes Vegetation Potentiality
Variable density vegetation Very high
Barren lands Very low
Landform classes by density of faults in South of Sinai
Classes Km/Km2 Potentiality
0 : 0.207 Very high
0.207 : 0.375 High
0.375 : 0.497 Moderate
0.497 : 0.603 Low
0.603 : 0.821 Very low
Landform classes by slope in South of Sinai
Classes Degree Potentiality
0 : 2 Very high
2 : 10
10 : 18
18: 30
30 : 45
45 : 70
70 : 83.1 Very low
Landform classes by elevation in South of Sinai
Classes Meter Potentiality
-1 :300 Very high
300: 600
600 : 900
900 : 1200
1200 :1500
1500 : 1800
1800: 2100
2100 : 2400
2400 : 2.635 Very low
50 25 0 50 100 150 Km
The surface-water potentiality zones map in South of Sinai
Suez Gulf
Aqaba Gulf
Surface-water potentiality zones
Potentiality Area
Very High 1.9%
High 66.1%
Moderate 31.9%
Low 0.1%
30 15 0 30 60 90 Km

Figure (5): The surface-water potentiality zones map in South of Sinai

6.4. *The weighted overlay of eight basins and their hydrological systems:*

The weighted overlay was applied to the eight selected basins, separately. For a more detailed and precise study. In addition to, studying the hydrological system of these basins. As shown in **Table (NO.7)**.

Table (7): The hydrological system of the basins studied

Basin	Lag time	Drainage time	Total precipitation	Total daily vapor	Vapor in hour	Vapor in drainage time	Infiltration in time lag	Constant Infiltration	Total water losses	Net runoff
	hr	hr	* 1000 m3	mm	mm	1000 m3	1000 m3	1000 m3	1000 m3	1000 m3
Muqblaa	4.68	0.45	1764.60	651.34	27.14	12.12	60.67	0.366	73.16	1691.44
Mahash	2.64	0.19	1125.40	415.40	17.31	3.34	21.82	0.101	25.26	1100.14
Dahab	8.13	0.61	158092.14	26867.36	1119.47	687.46	4218.92	20.130	4926.51	153165.63
Feiran	18.76	2.64	141986.22	20345.05	847.71	2240.36	8737.9	77.797	11056.06	130930.16
Kid	5.03	0.59	51903.18	13733.39	572.22	338.53	1350.09	10.045	1698.66	50204.52
Mariekh	5.25	0.09	47275.44	8456.98	352.37	31.28	885.93	0.946	918.16	46357.28
Aa't El-Sharqi	7.94	0.74	5399.94	1428.80	59.53	44.30	221.86	1.314	267.47	5132.47
Aa't El-Gharbi	7.24	0.18	3419.64	904.82	37.70	6.63	128.17	0.197	134.99	3284.65

***The unit of thousands was dealt with to facilitate the calculations by standardizing them**

This hydrological data is an indicator to determine the percentage ratio of storage capacity of each proposed dam project from the total expected runoff. Which helps in distinguishing and choosing between them.

6.5. *Overview of the Groundwater and Surface-water Wells and Dams' Types:*

The groundwater dams are two types, ***sub-surface*** dams and ***sandy*** dams. The subsurface or underground dam construction is designed to halt the flow of the natural aquifer, and its major role is to prevent the intrusion of salt water. Whereas a sand storage dam tends to hold and accumulate water in sediments, has an important role to store the precipitation and the infiltrate water especially in the arid regions.

The surface-water dams have many types such as gravity, arch, arch-gravity, embankment, rock fill, earth, buttress dams and others. In this study, four types were handled. A ***gravity dam*** is a building of concrete to resist the forces of water pushes. That is constructed on wide valleys and stores large amounts of water. The ***Rock Fill*** dam is built from many kinds of material as rock, concrete, metal, and clay. It's a less expensive alternative but its disadvantage is permeable but it is treated periodically. ***Arch dam*** is constructed on gorges, gullies, and narrow canyon with steep walls and have (V) shape and valleys have (U) shape. ***Arch Gravity dam*** is a mixed composition of both gravity and arch dams. (Balasubramanian, A.. 2016)

It can be distinguished between the types of dams to determine the best that appropriate with the suggested location. By applied a simple equation, if length/height of dam = ≤6; so, it's good to construct an arch dam, and if length/height of dam = >6; so, a gravity dam is more suitable. In addition to there are three types of Arch Dams, Thin Arch dam when Base (B)/Height (H) = 0.2, Medium Thick because of B/H = 0.2: 0.3, and, Thick when B/H = >0.3.. Also, surface dams can be classified into three types according to their height, small dams with a height of 30 meters, medium dams 30: 90 meters, and high dams >91 meters. In addition, the major dams range from 150 to 250m. (Bharti, Mohit. et al, 2020).

Besides, ***deep wells*** are drilled in areas where water is available but is far from the junction points of streams or there aren't narrow outlets. To utilize in irrigation, agriculture and human habitation.

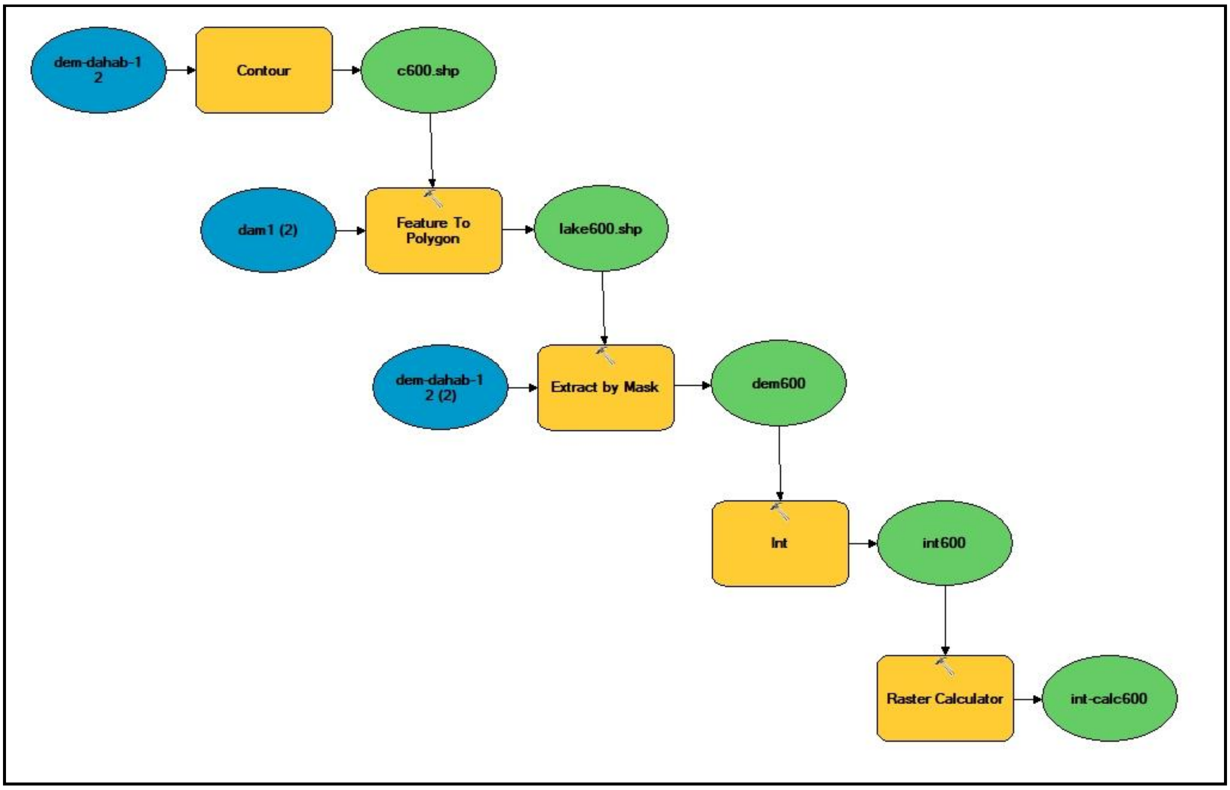


Figure (6): Model builder for determining and designing the surface-water dams and reservoirs

6.6. *Analysis of the groundwater potentiality zones and the locations of the suggested dams and wells in the selected basins*:

The figures from (NO.7) to (NO.13) show the area of groundwater potentiality zones in the studied basins, and, the suggested dams and wells.

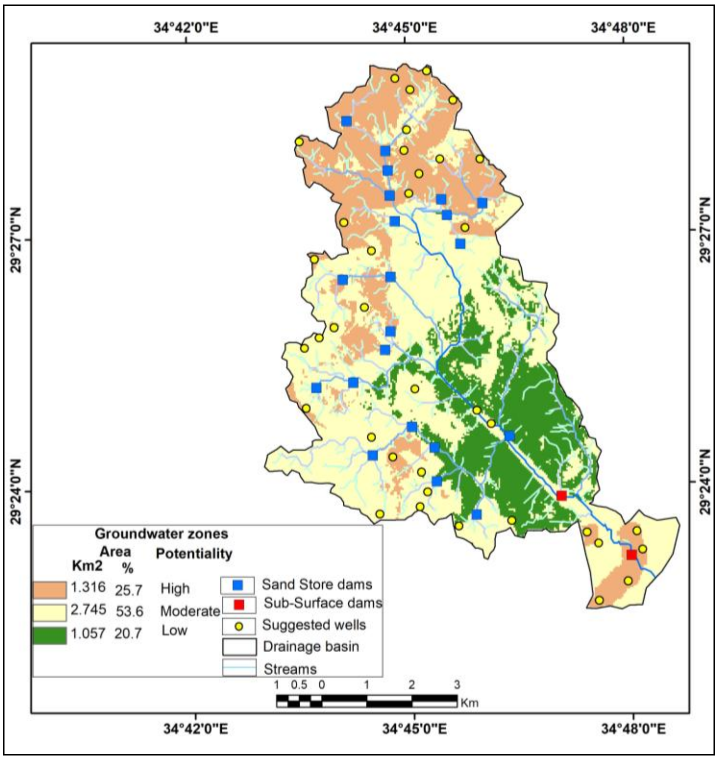


Figure (7): The suggested constructed dams and wells map to storage the groundwater in Muqblaa basin

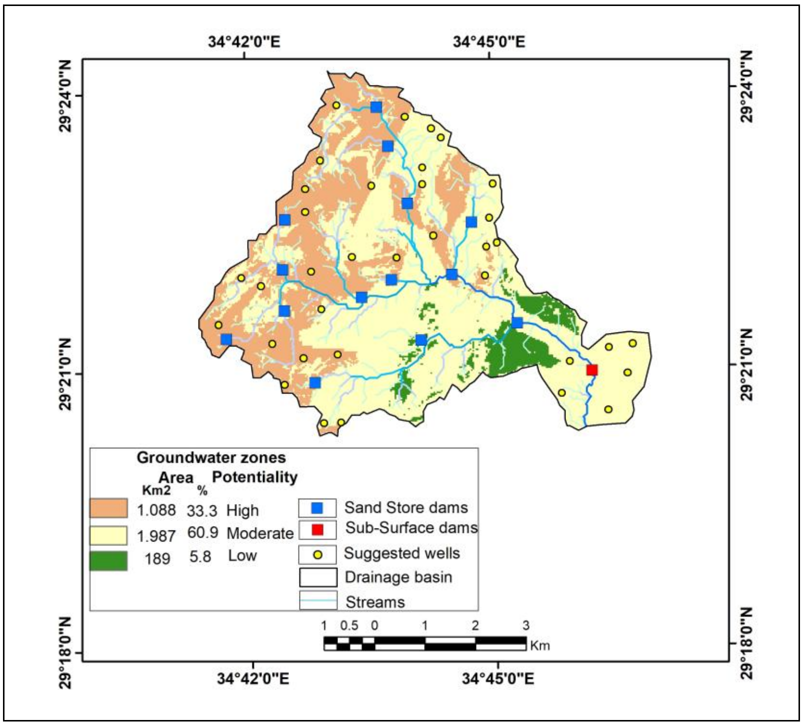


Figure (8): The suggested constructed dams and wells map to storage the groundwater in Mahash Al-Alaa basin

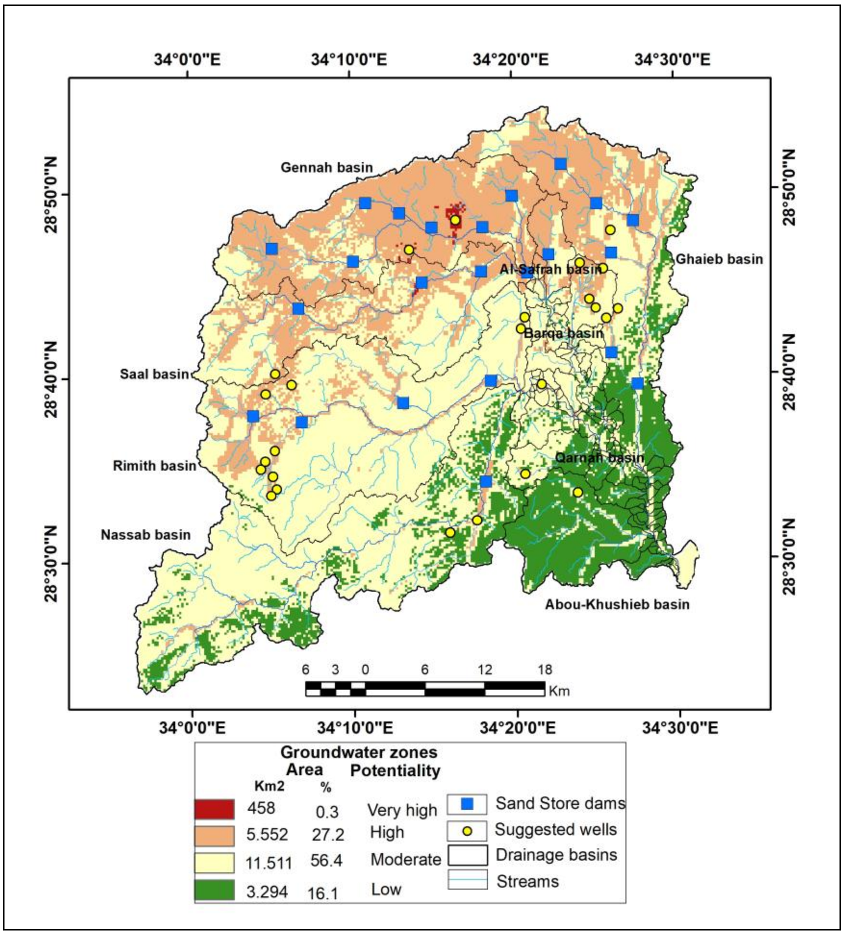


Figure (9): The suggested constructed dams and wells map to storage the groundwater in Dahab basin

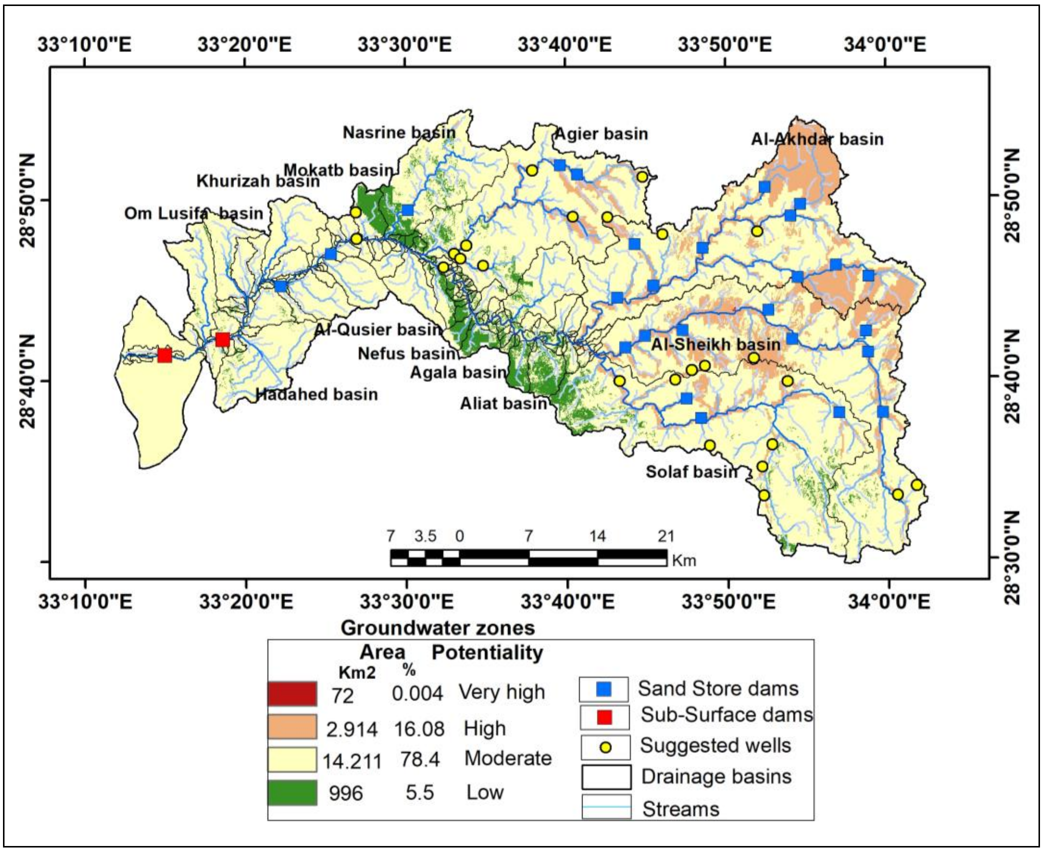


Figure (10): The suggested constructed dams and wells map to storage the groundwater in Feiran basin

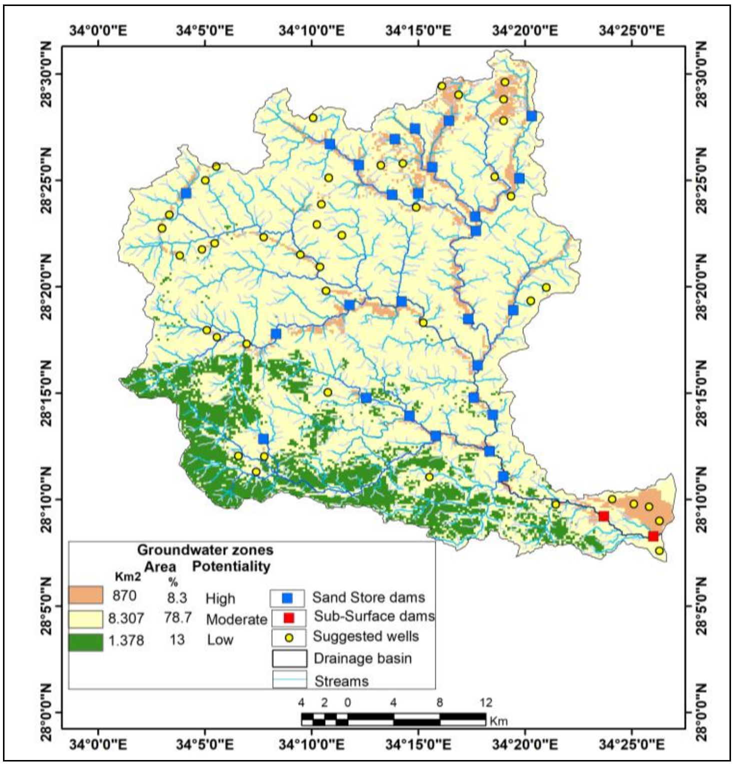


Figure (11): The suggested constructed dams and wells map to storage the groundwater in Kid basin

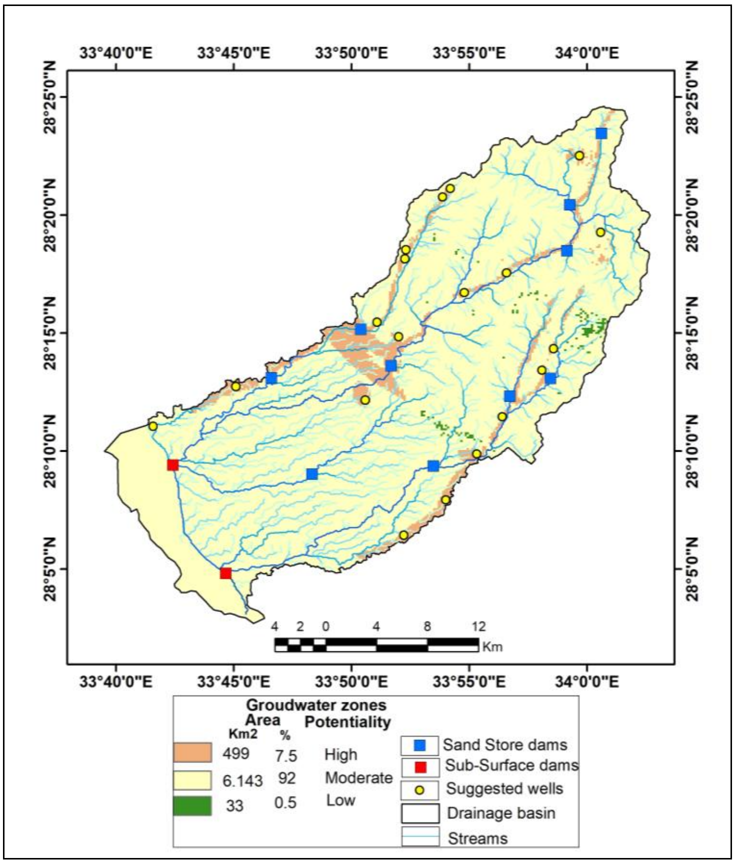


Figure (12): The suggested constructed dams and wells map to storage the groundwater in Mariekh basin

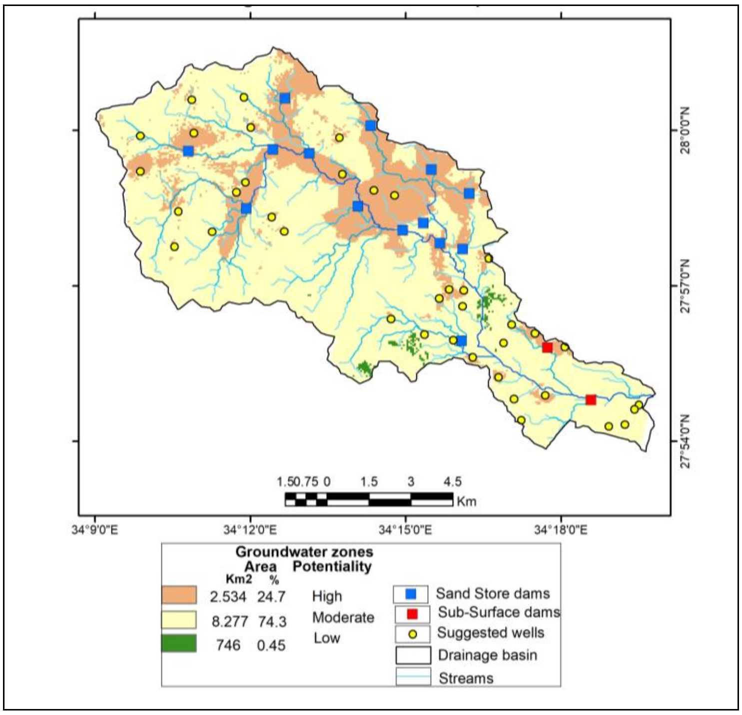


Figure (13): The suggested constructed dams and wells map to storage the groundwater in Aa't El-Sharqi basin

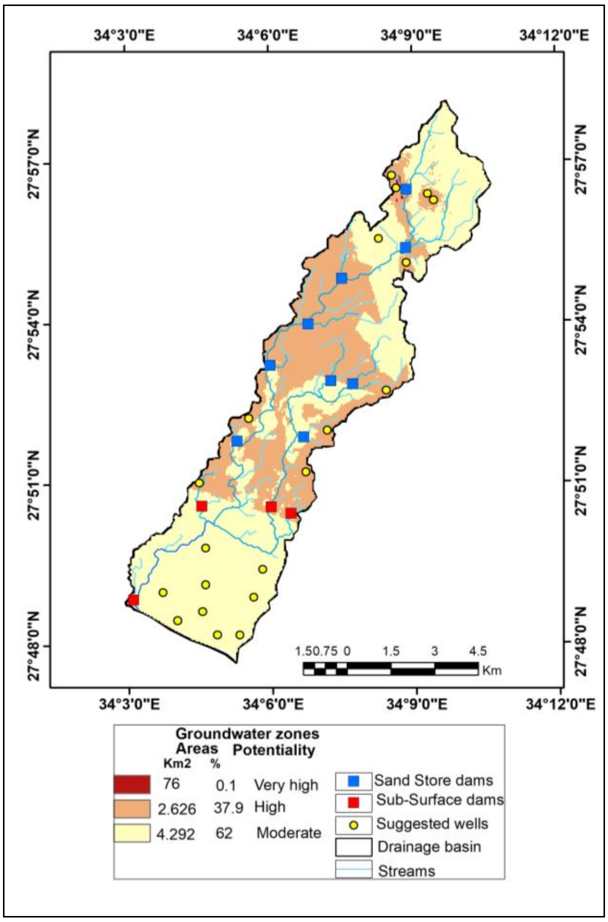


Figure (14): The suggested constructed dams and wells map to storage the groundwater in Aa't El-Gharbi basin

Generally, the high groundwater potentiality zones in the basins studied, are located in the upstream, middle streams area and some parts of fluvial fans. But the main factor of influence varies from one basin to another.

The high potentiality zone in ***Muqblaa*** and ***Mahash* Al-Alaa** is caused by the intensity of the rainfall in low-slope areas. ***Dahab***, groundwater is high in a zone that is characterized by high permeability due to the sedimentary rocks beside the high density of faults. ***Fieran***, is located in a high dissected terrain due to the swarms of dykes and faults. ***Kid***, because of high faults density which is consistent with low density drainage in the same areas. **Mariekh**, the high zone is present in the area that was affected by the faults that hit the area and led to the lifting of a large part of the upstream basin and the formation of hanging valleys. ***Aa't El-Sharqi***, the low drainage density is the main raison which due to the high porosity and permeability of Pleistocene sediments. So, this provides a great opportunity for groundwater formation. ***Aa't El-Gharbi*** is characterized by low slopes and low elevations of most territory. Therefore, this encouraged water to stay above the surface longer and infiltrate larger amounts of water.

Sub-Surface dams are preferably constructed in the downstream (estuaries) of basins, especially, Muqbla, Mahash, Kid, Aa't El-Sharqi, and Aa't El-Gharbi basins. To prevent the intrusion of the salt water of the sea and to mix with the freshwater. Whereas, the opportunity to establish ***sand store dams*** is very great in the rest areas of those basins, also, at the general level of the Feiran, Dahab, and Mariekh basins.

6.7. ***Analysis of the surface-water potentiality zones and the locations of the suggested wells and dams in the selected basins:***

6.7.1. Muqblaa basin:

The high potential zone area is 30.8% of the basin. which located in two areas, is the downstream and upstream of the Muqblaa. The first location is featured by its low porosity of the fluvial soil and the second location has intensity of rainfall on high density of drainage network**. Fig (NO.15)**

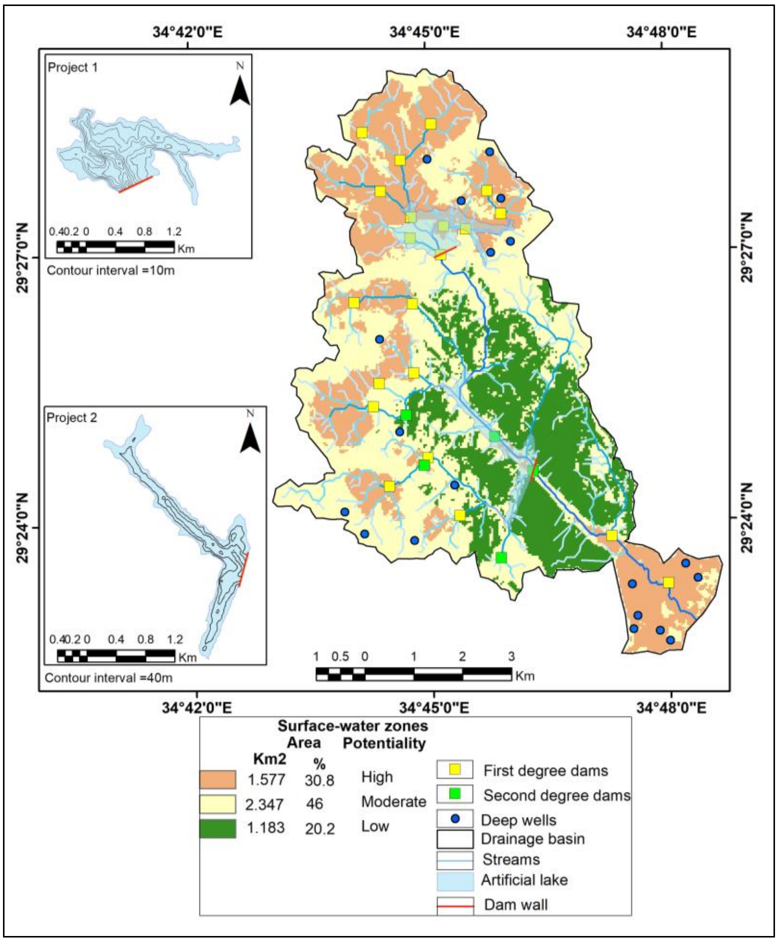


Figure (15): The suggested constructed dams and wells maps to face the flood hazard of surface-water in Muqbaa basin

The storage capacity of the two reservoirs is 0.793 Mm^3 equivalent to 46.7% of the total expected runoff. Therefore, these selected dams are very appropriate for construction. **Table (NO.8)**

The location of the first dam is best suited in the upstream area of the basin. The availability of narrow outlets of valleys at upstream is low due to several factors, including geological formation where the area consists of sedimentary rocks, lack of faults, and low slope. Although the second dam is located in an area with moderate potential, its location helps to collect the flow due to its narrow outlet. The profiles illustrated the cross-sections of the dam walls are shown in **Fig (NO.16)** and **Fig (NO.17).**

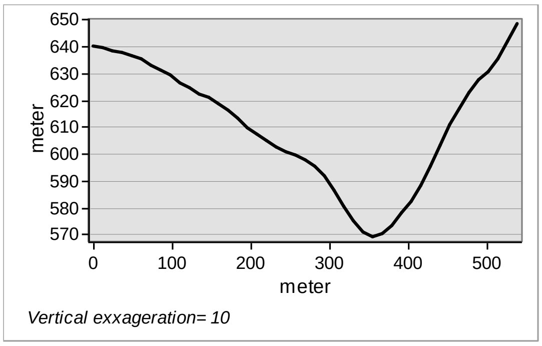


Figure (16): Cross-section of first dam wall in Muqblaa basin

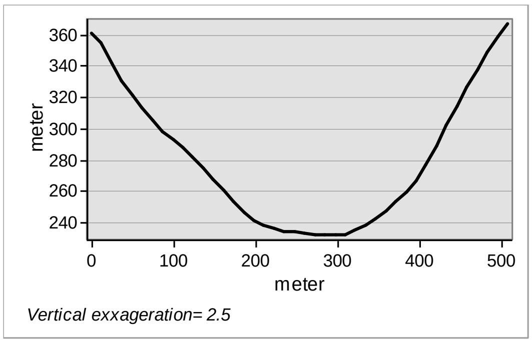


Figure (17): Cross-section of second dam wall in Muqblaa basin

Table (NO.8): The suggested dams and reservoirs in Muqblaa basin

Projects	Dams wall							Artificial lakes (Reservoir)				
	Location		*Elevation		Length	Width of dam's base	Type	Area	Depth	Crest level	Volume	Storage capacity
			Top	Base								
	x	Y	M	M	Km	M		Km^2	M	M	$*Mm^3$	%
First	34.7527	34.7527	640	567	0.538	36.5	Medium-Thin Arch	1.35	73	639	0.277	16.3
Second	34.7716	34.7716	360	232	0.510	124	High-Medium Thick Arch	1.016	128	359	0.515	30.4

*The elevation of the top of the dam relative to sea level.

*(Mm3) is million cubic meters

6.7.2. <u>Mahash Al-Alaa basin:</u>

The high potential zone area is 40.8% of the basin. Distributed in three areas. Firstly, the *basin's downstream* due to its low both elevation and slope, and soil porosity. Secondly, the *main flow path* which is formed of sediments and Cambrian rocks. Thirdly, the *upstream of the basin* because of the high density of first-order tributaries. **Fig (NO.18)**

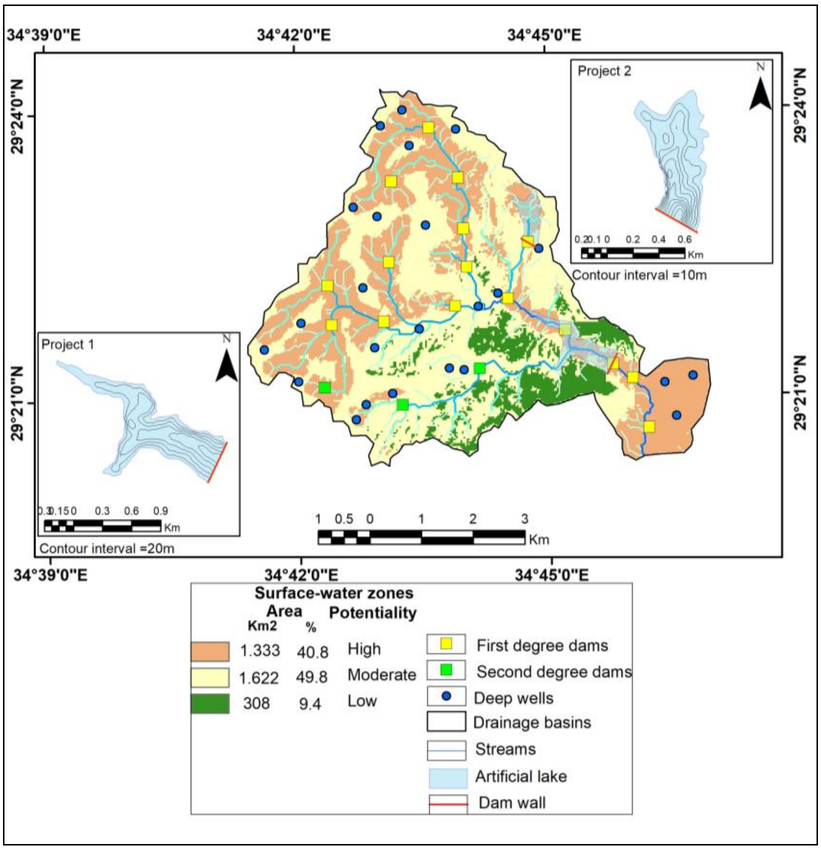
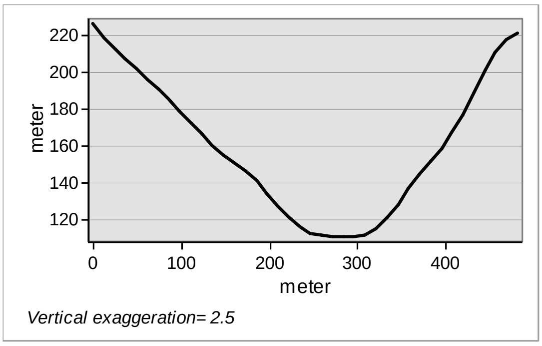
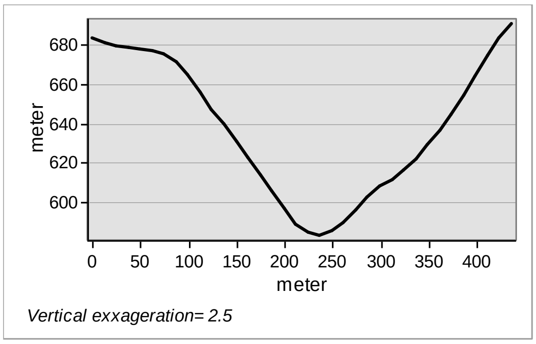


Figure (18): The suggested constructed dams and wells maps to face the flood hazard of surface-water in Mahash Al-Alaa basin





The two studied projects have capacity storage 0.333Mm^3 which is 30.1% of the total expected flow in this basin. The factors that influenced the selection of both projects' locations are the same as those that affected the previously studied basin. **Fig (NO.19), Fig (NO.20), Table (NO.9)**

Figure (19): Cross-section of first dam wall in Mahash basin

Figure (20): Cross-section of second dam wall in Mahash basin

Table (NO.9): The suggested dams and reservoirs in Mahash basin

<table>
<tr><th rowspan="3">Projects</th><th colspan="7">Dams wall</th><th colspan="5">Artificial lakes (Reservoir)</th></tr>
<tr><th colspan="2">Location</th><th colspan="2">Elevation</th><th>Length</th><th>Width of dam's base</th><th rowspan="2">Type</th><th>Area</th><th>Depth</th><th>Crest level</th><th>Volume</th><th>Storage capacity</th></tr>
<tr><th>X</th><th>Y</th><th>Top M</th><th>Base M</th><th>Km</th><th>M</th><th>Km^2</th><th>M</th><th>M</th><th>Mm^3</th><th>%</th></tr>
<tr><td>First</td><td>34.7628</td><td>29.3555</td><td>220</td><td>111</td><td>0.482</td><td>61.8</td><td>High-Thick Arch</td><td>0.621</td><td>109</td><td>219</td><td>0.254</td><td>23.1</td></tr>
<tr><td>Second</td><td>34.7462</td><td>29.3769</td><td>680</td><td>580</td><td>0.436</td><td>49.5</td><td>High-Thick Arch</td><td>0.337</td><td>100</td><td>679</td><td>0.077</td><td>7</td></tr>
</table>

6.7.3. <u>Dahab basin:</u>

The high potential zone is located in the Dahab basin at the headwaters of all its large drainage basins, especially Gennah basin, thanks to its composition of the Cambrian rocks has low resistance to water erosion process and the high density of faults, which encouraged both factors to provide paths for surface water. **Fig (NO.21)**

The dataset of the studied projects is shown in **Table (NO.10).** Which the black line shows dams that meet all standard design criteria while the red line shows excluded dams.

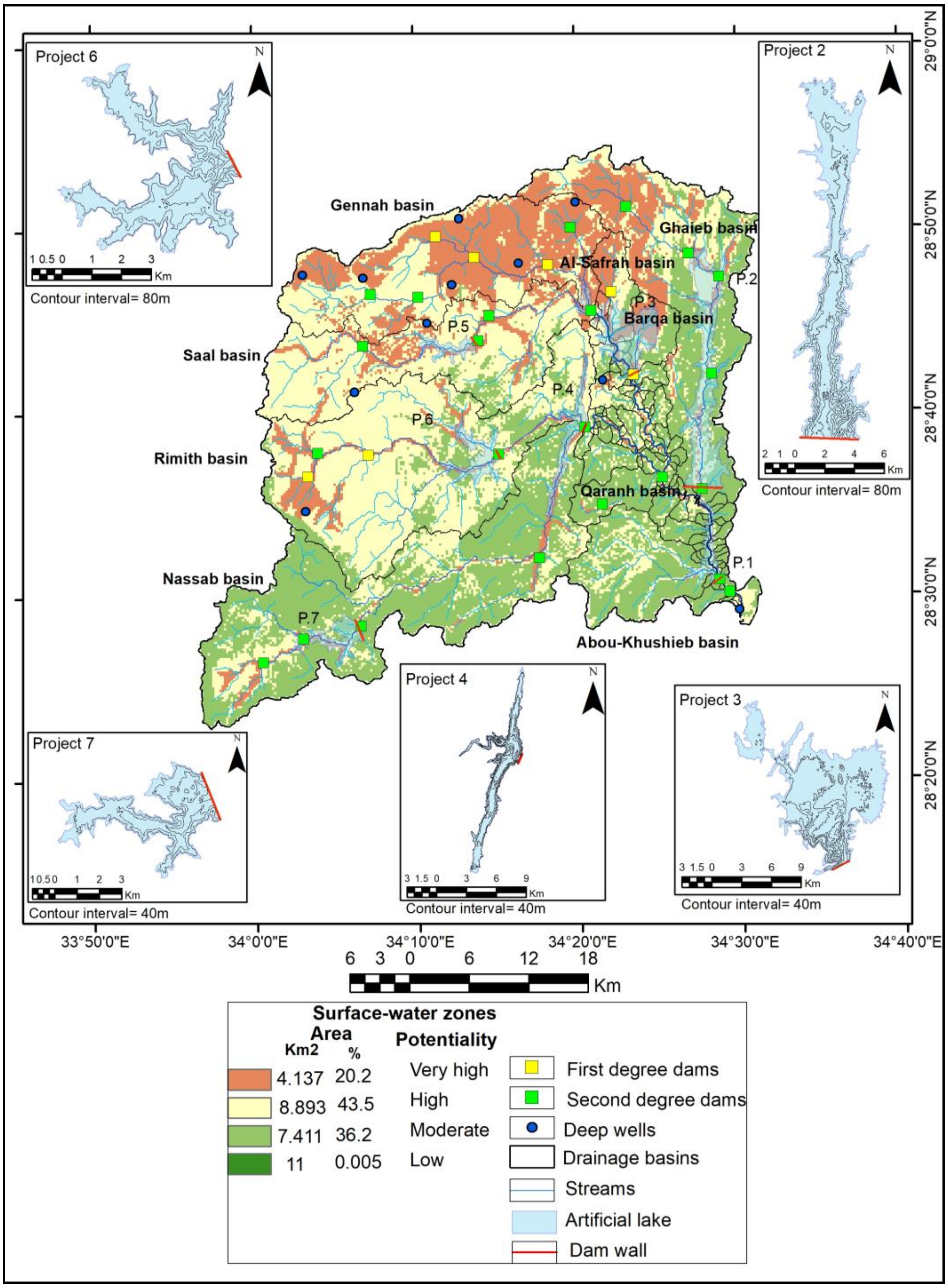


Figure (21): The suggested constructed dams and wells maps to face the flood hazard of surface-water in Dahab basin

The second dam was excluded due to its great height. the first and fifth dams can be excluded due to the low volume of the reservoirs or exploited for irrigation and cultivation of the small areas. Drilling deep wells are a good option for the upper part of the Dahab basin due to the low slope and there are no gorges and narrow outlets that permit to build dams. Generally, the low storage capacity dams are better to build as rock fill dams because of their low cost. **Fig (NO.22), Fig (NO.23), Fig (NO.24).**

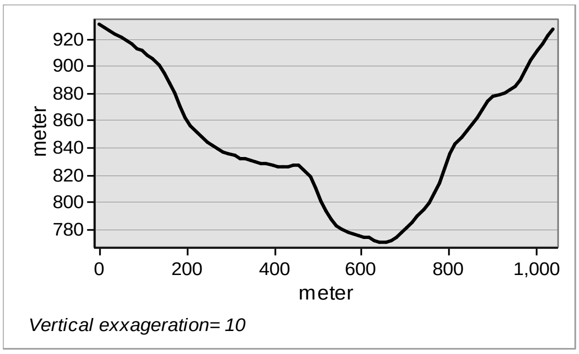


Figure (22): Cross-section of the sixth dam wall in Dahab basin

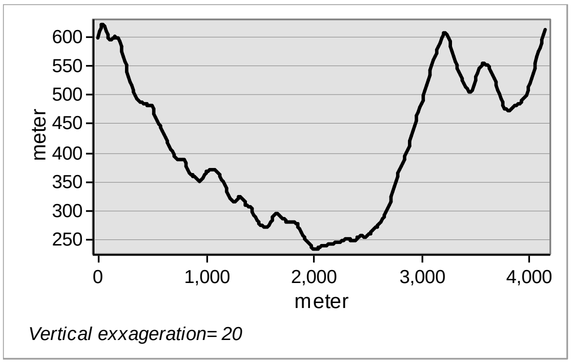


Figure (23): Cross-section of second dam wall in Dahab basin

Through the excavation and backfilling operations to reach the level of the base, an area is estimated 156,23 m^2 will be dug and what it provides 0.904 Mm^3.

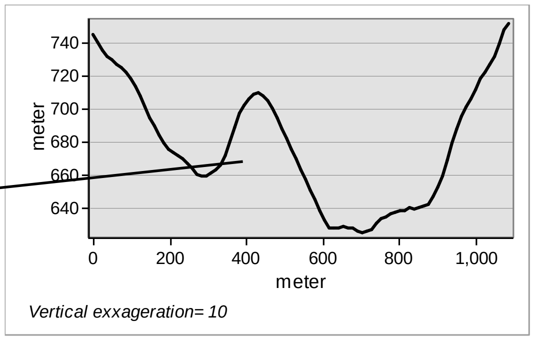


Figure (24): Cross-section of third dam wall in Dahab basin

Table (NO.10): The suggested dams and reservoirs in Dahab basin

Projects	Dams wall							Artificial lakes (Reservoir)				
	Location		Elevation		Length	Width of dam's base	Type	Area	Depth	Crest level	Volume	Storage capacity
			Top	Base								
	X	Y	M	M	Km	M		Km²	M	M	Mm³	%
First	34.45853	28.51925	210	84	1.205	359.8	High-Rock fill	8.655	126	209	3.980	2.6
Second	34.46062	28.59572	600	234	4.150	515	High-Gravity	53.4	366	599	58.9	38.4
Third	34.39119	28.70041	750	619	1.079	259.5	High-Gravity	30.9	131	749	7.517+ 0.904 (1)	5.5
Fourth	34.33577	28.65158	690	504	0.841	111.4	High-Thick Arch	14.43+ 156.23	186	689	10.30	6.70
Fifth	34.23134	28.73263	1050	937	1.222	374.2	High-Rock fill	6.956	113	1049	2.789	1.8
Sixth	34.25146	28.62933	950	773	1.039	111.3	High-Thick Arch	13.97	177	949	8.995	5.8
Seventh	34.10831	28.47404	1500	1349	1.495	611.1	High-Gravity	12.30	151	1499	6.271	4.9

(1) Shows the storage capacity plus the capacity after adjusting the levels.

6.7.4. Feiran basin:

The high potential zone is estimated 22.2% of the total basin area, and located in terrain that is composed of Phanerozoic rocks including Miocene, Pliocene, Cretaceous, and Pleistocene rocks with high drainage density. It represents two landforms, valleys, and fluvial fans. **Fig (NO.25)**

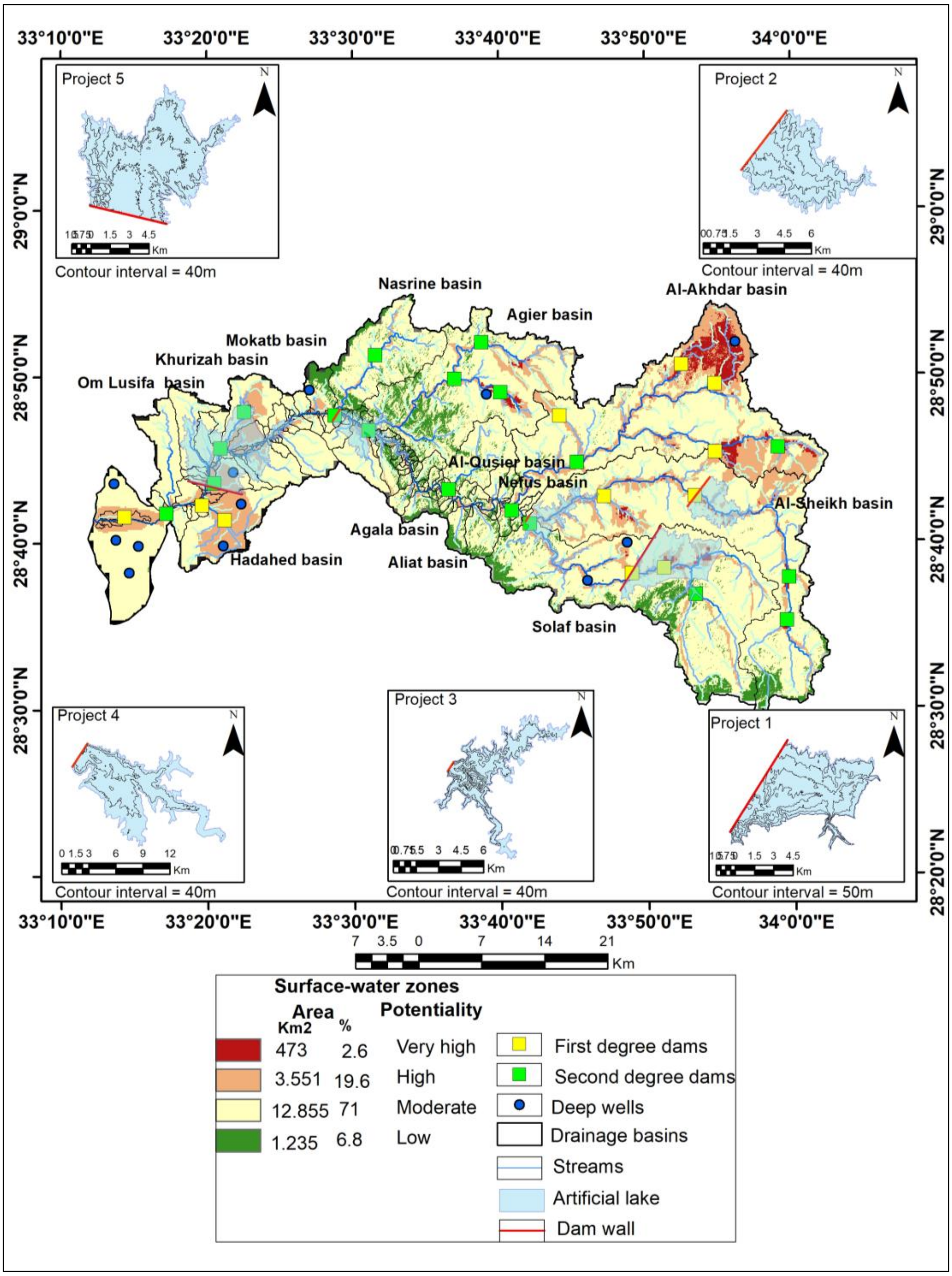


Figure (25): The suggested constructed dams and wells maps to face the flood hazard of surface-water in Feiran basin

The first dam is classified as a main dam with a height ranging from 150 to 250m. That is can store more than a third of the flow amount, but it needs a huge financial budget.

The most appropriate of the studied dams is the fifth dam. Because of its high storage capacity and the simple topographic and geological characteristics of its location. Then the other dams are very suitable to construct despite their low ability storage compared to the fifth dam. **Table (NO.11) Figure (NO.26)** and **Figure (NO.27)** show the cross-section of the walls of the first and fourth dam.

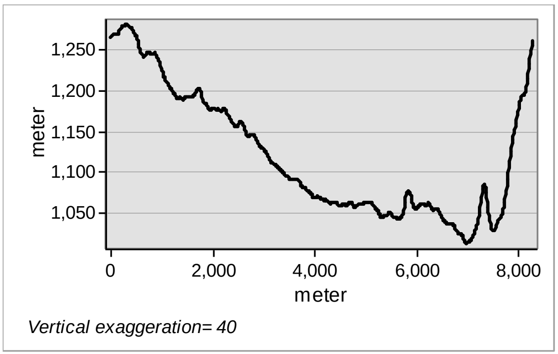


Figure (26): Cross-section of the first dam wall in Feiran basin

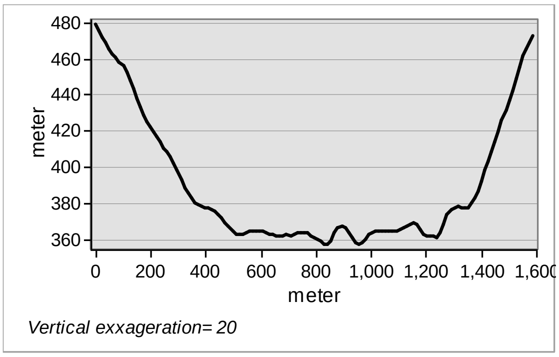


Figure (27): Cross-section of the fourth dam wall in Feiran basin

Table (NO.11): The suggested dams and reservoirs in Feiran basin

Projects	Dams wall							Artificial lakes (Reservoir)				
	Location		Elevation		Length	Width of dam's base	Type	Area	Depth	Crest level	Volume	Storage capacity
			Top	Base								
	X	Y	M	M	Km	M		Km^2	M	M	Mm^3	%
First	33.8162	28.6354	1260	1011	8.282	2.286	High-Gravity	44.9	249	1259	43.3	33.1
Second	33.8881	28.7126	1220	1.083	4.293	798.8	High-Gravity	19.53	137	1219	9.324	7.1
Third	33.7002	28.6854	900	766	0.920	224	High-Gravity	18.77	134	899	7.058 + 0.614 (1)	5.9
Fourth	33.4787	28.7945	480	344	1.589	707.6	High-Gravity	17.67	136	479	7.950	6.1
Fifth	33.3415	28.727	300	256	6.173	1.761	High-Gravity	64.9	144	299	35.02	26.7

***The black line shows dams that meet all standard design criteria while the red line shows excluded dams.**

(1) Shows the storage capacity plus the capacity after adjusting the levels.

6.7.5. Kid basin:

Part of the surface water cover is concentrated moving over Pleistocene deposits and typical river soils while the other part moves over basement rocks that have a high density of faults that provide paths for the first-order tributaries. The area of the high potentiality zone is 36.4% of the total area. **Fig (NO.28)**

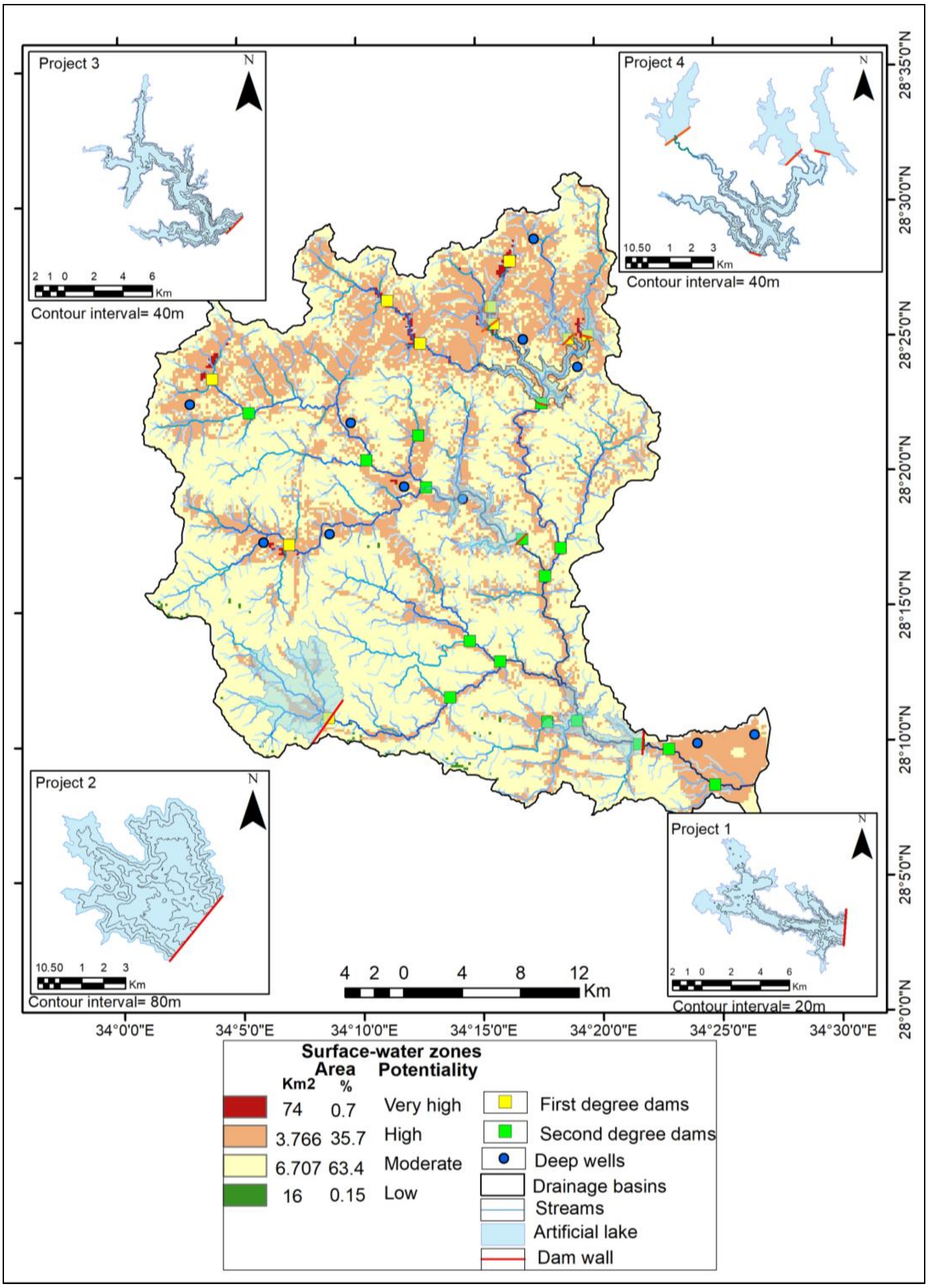


Figure (28): The suggested constructed dams and wells maps to face the flood hazard of surface-water in Kid basin

The second project was disqualified due to the large elevation variation of the dam which is very difficult to establish. Due to the high cost and the exposure of dams to crack and failure. The first dam is most suitable for construction, then the fourth dam, and finally the third dam. **Fig (NO.29), Fig (NO.30)**

The fourth project is a Gravity-Arch dam, which pushes the excess water and discharges it into the three spillways when the reservoir lake is filled with flood for the level allowed. Together, the four lakes can store 17.5% of the total expected net hydrologic budget. **Table (NO.12)**

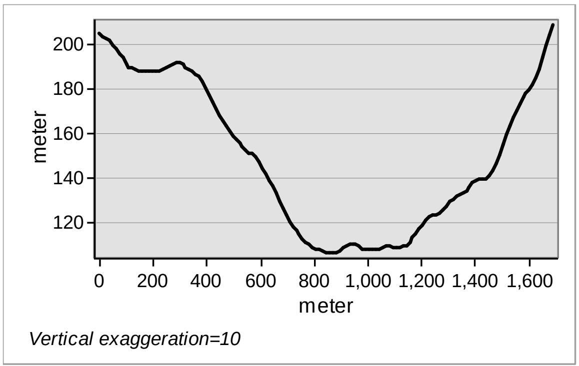


Figure (29): Cross-section of the first dam wall in Kid basin

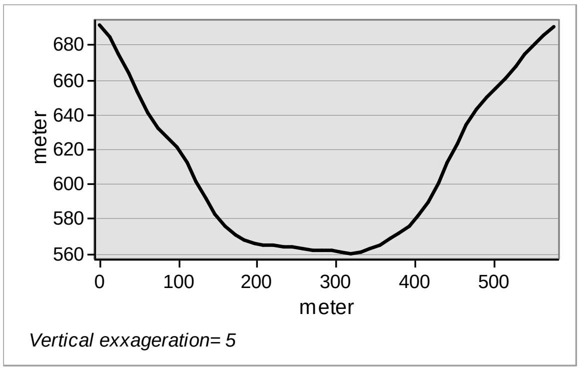


Figure (30): Cross-section of the Fourth dam wall in Kid basin

Table (NO.12): The suggested dams and reservoirs in Kid basin

Projects	Dams wall							Artificial lakes (Reservoir)				
	Location		Elevation		Length	Width of dam's base	Type	Area	Depth	Crest level	Volume	Storage capacity
			Top	Base								
	X	Y	M	M	Km	M		Km^2	M	M	Mm^3	%
First	34.3596	28.1653	200	106	1.692	323.5	High-Gravity	11.44	94	199	13.086	26.1
Second	34.1435	28.1834	1200	733	3.707	287.1	High-Gravity	44.9	467	1199	54.40	108.3
Third	34.2796	28.2928	540	352	1.123	249.8	High-Gravity	12.55	188	539	7.540	15.1
Fourth	34.2961	28.3894	690	555	0.577	135.2	High-Gravity Arch	9.31	135	689	4.456	9
Spillways attached to the fourth dam	34.327	28.4205	810	693	0.702	295.7	High-Thick Arch	2.88	117	809	1.466	2.9
	34.3061	28.4279	810	689	1.027	123.8	High-Rock Fill	3.21	121	809	1.505	3
	34.2531	28.4275	810	719	1.335	595	High-Rock Fill	3.26	91	809	1.280	2.6

6.7.6. Mariekh basin:

The concentration of surface water at the top of the valley decreases while it increases abruptly in the direction downwards of the valley due to the low slope, low height, and high drainage density due to the fault that hit the area. **Fig (NO.31)**

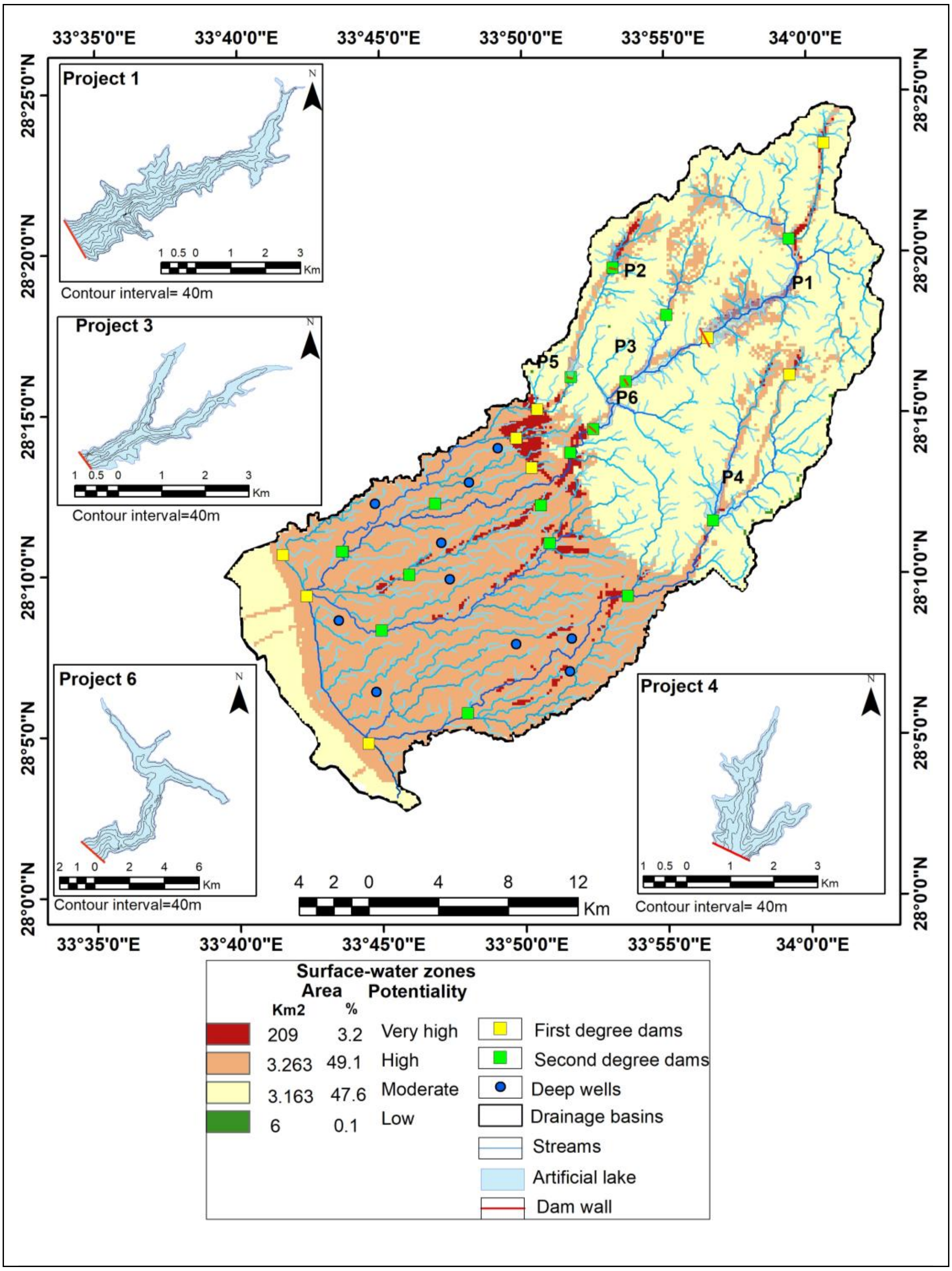


Figure (31): The suggested constructed dams and wells map to face the flood hazard of surface-water in Mariekh basin

All the suggested dams that are located in the sedimentary rocks - at the downstream of the basin – aren't appropriate to construct because there is no ability to set a dam that has a narrow outlet. This was shown by the study of the contour lines. At the same time, the studied projects have a low capacity to store large amounts of runoff. Or large elevation variations will be encountered from which it is impossible to build dams.

Therefore, there are three solutions. Construction of several low-capacity dams. Construction of a dam attached to it several spillways. Create deep-drilled wells. Here, the first dam can store more than the expected amounts of runoff, but its disadvantages are the high altitude and high cost. The other dams are appropriate to construct despite their low-capacity storage. Drilling deep wells in the lower half of the basin is a good alternative to dams. **Table (NO.13)**

The cross-section of the first and fourth dam walls in Mariekh basin is shown in **Figure (NO.32)** and **Figure (NO.33).**

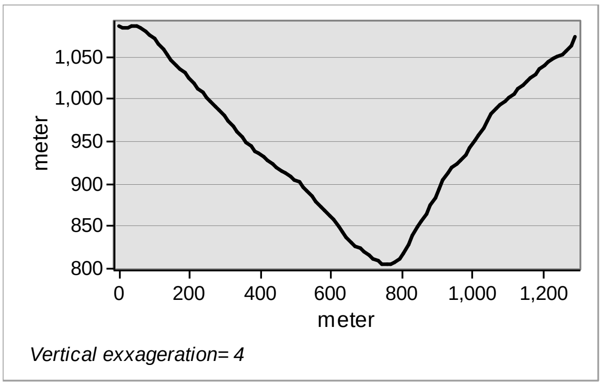


Figure (32): Cross-section of the first dam wall in Mariekh basin

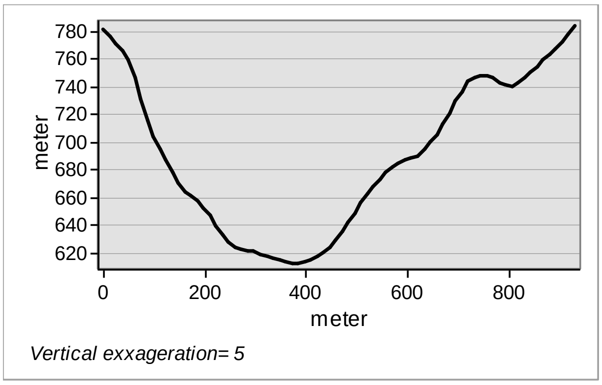


Figure (33): Cross-section of the fourth dam wall in Mariekh basin

Table (NO.13): The suggested dams and reservoirs in Mariekh basin

Projects	Dams wall							Artificial lakes (Reservoir)				
	Location		Elevation		Length	Width of dam's base	Type	Area	Depth	Crest level	Volume	Storage capacity
			Top	Base								
	X	Y	M	M	Km	M		Km^2	M	M	Mm^3	%
First	33.9415	28.2889	1090	805	1.292	62.1	High-Gravity Arch	6.36	285	1089	53.9	116.3
Second	33.8862	28.3256	1060	927	0,484	50		0.590	133	1059	0.021	0.04
Third	33.8934	28.2664	780	600	0.471	86.8	High-Thick Arch	2.22	180	779	1.072	2.2
Fourth	33.9438	28.1942	780	611	0.917	99.4		2.61	169	779	1.676	3.6
Fifth	33.9173	28.3008	650	516	0.382	24.6	High-Thin Arch	0.606	134	649	0.342	0.7
Sixth	33.8743	28.2419	610	462	0.579	37	High-Medium Thick Arch	1.43	148	609	0.702	1.5

6.7.7. Aa't El-Shargi basin:

The movement of the surface water cover is concentrated over the sedimentary formations in accordance with many factors such as low slope and altitude, which has affected the intensity of discharge in this zone. **Fig (NO.34)**

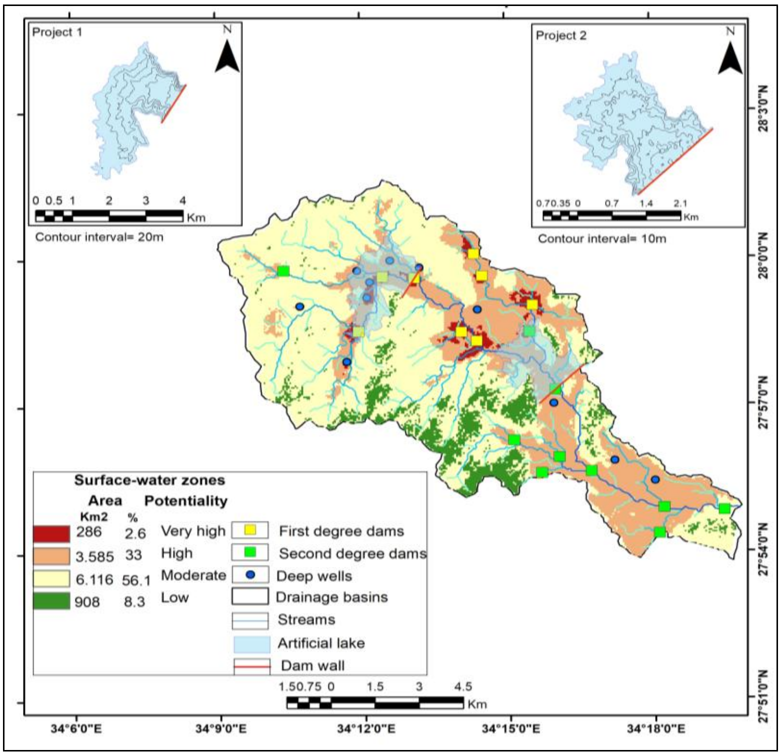


Figure (34): The suggested constructed dams and wells maps to face the flood hazard of surface-water in Aa't El-Sharqi basin

Both dams form 2.899Mm^3, which corresponds to 56.5% of the total runoff in Aa't El-Sharqi**. Table (NO.14)** One of them is a medium dam. which means that is one of the best basins studied in the construction of dams, although its share of runoff is low compared to the other basins because of its small area and low amounts of rainfall. The cross-section of the dam walls is shown in **Figure (NO.35)** and **Figure (NO.36)**

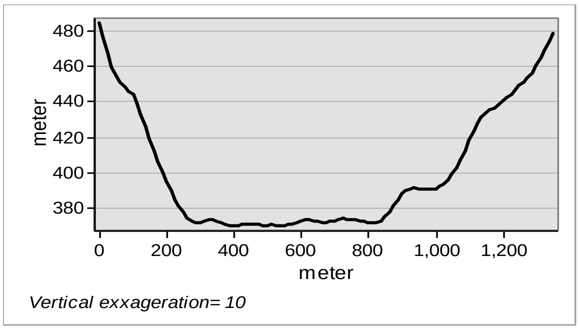


Figure (35): Cross-section of the first dam wall in Aa't El-Sharqi

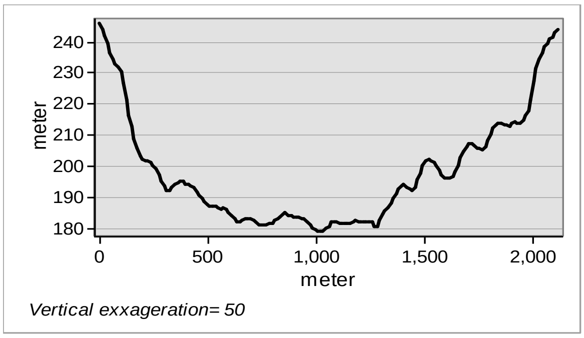


Figure (36): Cross-section the second dam wall in Aa't El-Sharqi

Table (NO.14): The suggested dams and reservoirs in Aa’t El-Sharqi basin

Projects	Dams wall							Artificial lakes (Reservoir)				
	Location		Elevation		Length	Width of dam's base	Type	Area	Depth	Crest level	Volume	Storage capacity
			Top	Base								
	X	Y	M	M	Km	M		Km^2	M	M	Mm^3	%
First	34.2181	27.9933	480	170	1.350	575	High-Gravity	5.033	110	479	1.862	36.3
Second	34.2664	27.9553	240	177	2.120	636.2	Medium-rock Fill	4.4	63	239	1.037	20.2

6.7.8. Aa't El-Gharbi basin:

These studied dams are among the best proposed dams that can be constructed in the region. Together, they make up 20.2% of the net hydrological budget. **Fig (No.37), Fig (No.38), Fig (No.39).**

Where that is impossible to build dams in more than two-thirds of the basin area. This is due to the fact that the basin does not have narrow outlets such as gorges and gullies except in the upper third area as a result of the area was exposed to fault that led to the process of lifting the basin's upstream area and the formation of the hanging wadis in it. While the rest of the basin area has become over time easy slope due to the continuous sedimentation process carried out by sediment-bearing water and dumping into this area with the direction to downstream. Therefore, it can be drilling wells to store water instead of dams. **Table (NO.15)**

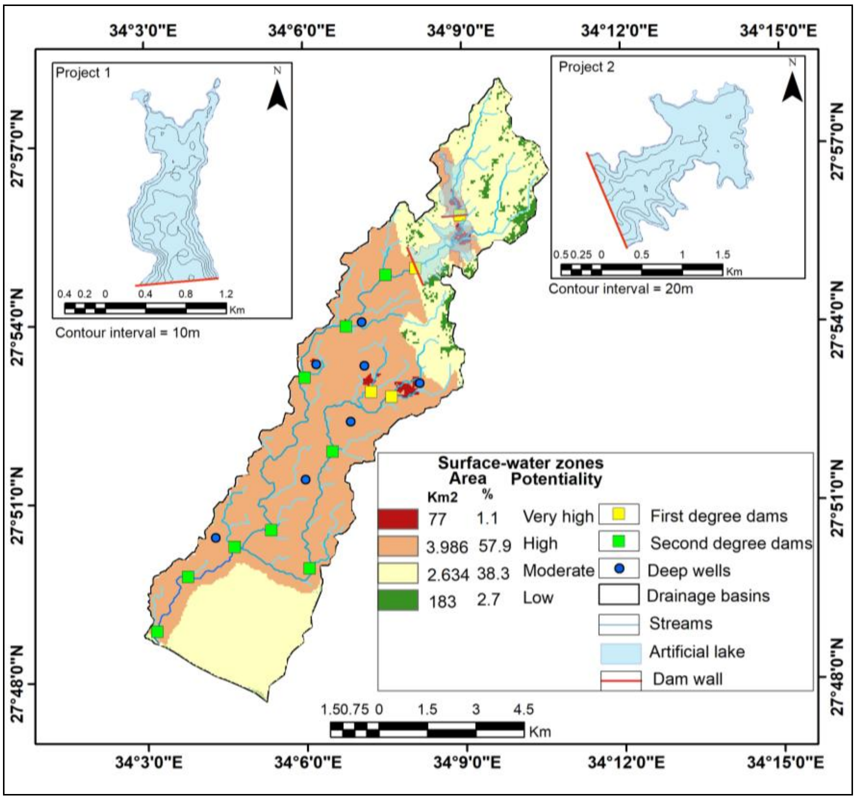


Figure (37): The suggested constructed dams and wells maps to face the flood hazard of surface-water in Aa't El-Gharbi basin

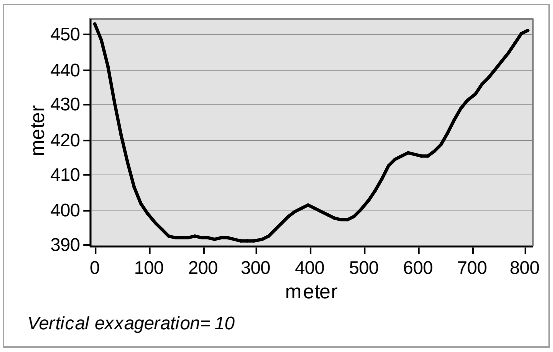


Figure (38): Cross-section the first dam wall in Aa't El-Gharbi

Figure (39): Cross-section the second dam wall in Aa't El-Gharbi

Table (NO.15): The suggested dams and reservoirs in Aa't El-Gharbi basin

Projects	Dams wall							Artificial lakes (Reservoir)				
	Location		Elevation		Length	Width of dam's base	Type	Area	Depth	Crest level	Volume	Storage capacity
			Top	Base								
	X	Y	M	M	Km	M		Km2	M	M	Mm3	%
First	34.1492	27.9303	452	389	0.805	173.3	Medium-Rock Fill	1.032	63	451	0.256	7.8
Second	34.1352	27.9156	383	305	1.278	173,7	Medium-Rock Fill	1.810	78	382	0.408	12.4

7. Conclusion:

The factor that plays a major role in the availability of groundwater is variable along the South of Sinai. Where the northern basins were affected by the high permeability rocks, the middle basins by the high-density faults and dykes, the eastern southern basins by low drainage density beside high faults density, and, the western southern basins by the retreat of rift and activity of the weathering and erosion which led to an increasing in sediments that had become a groundwater reservoir. Most of the groundwater dams are sand store type while the downstream areas of basins contain fifteen sub-surface type dams due to being near of sea.

It turns out through the study of the proposed eight basins, that the sedimentary rocks enjoy high surface-water potentiality zones. While the basement rocks are moderately zones but their potentiality increases in the high-density fault areas especially the long ones. By studying the hydrological system of the eight basins. It was noted that Dahab, Feiran, Kid, and Mariekh basins have larger amounts of the runoff despite the complexity of their geological and topographic properties in some areas. Due to this, some difficulties were encountered in choosing suitable sites for the construction of surface-water dams. While Aa't El-Sharqi, Aa't El- Gharbi, Muqbella, and Mahash Al-Alaa basins have smaller amounts of runoff, however, they have a typical surface to construct surface dams except the second basin because of the reasons studied.

Accordingly, thirty and three surface-water dams studied in the eight basins. Twelve dams are gravity, the same number is arch type, seven are rock fill and two are gravity arch. But six of them excluded because of the large variation of elevation firstly or its low storage capacity. In general, digging deep wells are a good alternative to dams in areas where surface and groundwater are available away from the paths of streams or narrow outlets are not available.

By performing a simple mathematical operation, it was concluded: the expected runoff amounts by referring to the maximum amount of rain that fell in one day are 391866 Mm^3, the storage capacity of the studied dams, reservoirs, spillways are 349054 Mm^3, and the capacity of the excluded projects is 217269 Mm^3. Therefore, the storage capacity of the standard projects is 131785 Mm^3 which represented 33.63% of the total expected runoff. All of these projects aim to develop the region and protect it from flood hazards.

8. Recommendations:

1. The projects of dams and wells that have been studied in detail be taken into consideration by specialists and decision-makers to be implemented on the ground.
2. Conduct more detailed studies of a larger number of dams and reservoirs at the level of all basins in the South of Sinai.
3. The study area needs more studying and development plans to be an attractive urban area.

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