ANNEX 3

STORM WATER HARVESTING

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Annex 3.1

Summary of Field Survey

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(1) Wadi Qilt (July 28, 2007)

- Surface of the mountain at midstream of the Wadi Qilt (Ph-Q1~Q2)
- Headrace (Ph-Q3~Q5)
- Location of the parshall flume (Ph-Q6): the site proposed for the retention dam or the underground dam.
- Geological strata around here consist from alternation of the gravel layer and the clayey layer. Thickness of the gravel layer is thicker than that of the clayey layer (Ph-Q7~Q8). Grain size of gravel is about ϕ10~500mm.
- A lot of gravel with diameter of ϕ2~5mm is observed in the Wadi riverbed (Ph-Q9).
- And fine sand is also found at all over the Wadi river bed.(Ph-Q10).
- Consequently, sand and gravel obtained from the riverbed deems to be suitable for the filter material.
- Merl begins to appear in the Wadi riverbed at upstream area of the road bridge in Jericho city (Ph-Q13~Q14).
- The road bridge of Jericho city (Ph-Q15)
- Merl at the Wadi river bed around downstream area of Jericho city has been eroded by the river flow (Ph-Q16~Q17).
- The small pond at upstream area of the garbage damping site done by JICA Grant (Ph-Q18)
- Downstream area of the garbage damping site (Ph-Q19) : proposed site for the storage facility of flood water at the area outside the Wadi riverbed.
- Running water was observed in the Wadi riverbed. Source of this water flow was not confirmed.
- Wide and flat plane consisted of Merl has been eroded by the Wadi. Height difference between surface of the plane and the Wadi riverbed is estimated at about 7 to 8m. Merl deems to be unsuitable for the impervious core material. No embankment material for the impervious core is found around here.
- Cross point between R90 and the Wadi Qilt : Vegetation around the Wadi is observed around here. So, there is a possibility of existence of the groundwater under the Wadi even though there is no river flow in the Wadi riverbed (Ph-Q20~Q21).

Ph-Q1 Surface of the mountain at midstream of the Wadi Qilt

Ph-Q2 Downstream view from midstream of the Wadi Qilt

Ph-Q3 Headrace of the spring water located on the valley surface

Ph-Q4 Headrace

Ph-Q5 Headrace

Ph-Q6 Upstream view of the Wadi from the point of the parshall flume

Ph-Q7 Geological condition beside the Wadi

Ph-Q8 - do -

Ph-Q9 Gravel in the riverbed

Ph-Q10 Sand in the riverbed

Gravel size beside the Wadi : ϕ10 ~ 500mm
Gravel size of ϕ2 ~ 5mm is found in the riverbed. And fine sand also be found in the riverbed. No material for impervious core is found around here.

Ph-Q11, Q12 On the way to the aqueduct

There is no change in the gravel layer beside the Wadi. Merl is found in the riverbed around here.
Revetment by US-AID is on going. Boulder obtained from the riverbed is used to the wire mat.

Ph-Q13 Merl located in the riverbed

Ph-Q14 Upstream area of the aqueduct

Ph-Q15 Upstream area of the road bridge

Ph-Q16 Downstream area of urban district Eroded Merl is observed in the riverbed

Ph-Q17 - do -

Ph-Q18 Small pond located at upstream area of the garbage damping site

Ph-Q19 Downstream view from the garbage damping site

River flow is observed in the Wadi.

The source of the water flow is not sure.

Ph-Q20 Upstream view from the cross point with the R90

Ph-Q21 Downstream view from the cross point with the R90

(2) Wadi 'Auja (July 29, 2007)

- A rich spring water flows in the Wadi until meet the intake weir located downstream (Ph-A1~A3). About 8 MCM/yr of annual discharge is reported.
- Intake weir (Ph-A4~A5)。
- Reddish top soil is one of the proposed impervious core material.
- After intake weir, spring water is led by the headrace (Ph-A6~A8).
- Between end of the mountain and Yitav, the land is wide and flat plane. From the viewpoint of construction condition, this area deems to be suitable for the storage facility of surplus spring water, because the headrace lies on the surface of the flat plane.

Ph-A1, A2 Upstream view around the spring

Ph-A3 Downstream view around the spring

Ph-A4 at the point of the intake weir

Ph-A5 Intake weir from downstream

Ph-A6 Headrace

Reddish top soil around here deems to be suitable as an impervious core.

Ph-A7, A8 Headrace after mountain area

Storage facility of surplus spring water deems to be able to construct at the flat plane around this area.

(3) Wadi Far'a (July 31, 2007)

- Spring water at Al Badan (Ph-F1~F3) Estimated annual discharge is around 6 MCM/yr.
- Polluted river flow and bubble due to sewage from Nablus (Ph-F4, F5).
- Proposed dam site "A" to "D" are recommended at Tubas-side upstream area of the confluence between Nablus basin and Tubas basin.
- Comments for the site A and site B are as follow : (Ph-F7~F10)
  - Steep riverbed gradient (1/20 or more)
  - Big storage pocket can not be expected.
  - From view point of dam/reservoir foundation, geological condition of these dam sites are not adequate, namely characteristics of limestone are 1) very porous and 2) remarkably cracked.
  - It's difficult to keep enough creep ratio against seepage flow pass through right bank abutment.
  - Hydraulic balance in the foundation has been kept under present condition. Additional rise of hydraulic gradient due to dam construction might be the causes to destroy the hydraulic balance.
  - In addition, decline of reservoir function due to siltation should be taken into consideration.
- Comments for the site C are as follow : (Ph-F11~F15)
  - Riverbed gradient : 1/50~1/100?
  - Height difference between top of the right bank ridge and the riverbed deems to be about 30~40m. R57 (Road) locates on the hillside of left bank, so height limit of the dame will be estimated at 15~20m.
  - Dam axis cannot be shifted to downstream side so much due to the shape of the right bank ridge.
  - From view point of geological condition, same issue as dam site A and B is pointed out.
- Impervious core material will be obtained from the area which locates about 3km far from dam site (Ph-F18~F19). Further investigation such as soil test should proceed.

Ph-F1 Al Badan spring

Ph-F2, F3 Aqueduct and Headrace

Ph-F4 Polluted water flow from Nablus and aqueduct

Ph-F5 Bubble due to polluted water

Ph-F6 Downstream bridge point located about 500m far from the point above

Ph-F7
A-site and B-site from downstream

Ph-F8
Upstream view from B-site

Ph-F9　A-site and B-site from upstream area

Ph-F10　Upstream view from A-site

Ph-F11　C-site from upstream area

Ph-F12, F13 Crack in the limestone (C-site)

Ph-F14 C-site from downstream area

Ph-F15 C-site from downstream road (R57)

Ph-F16, F17 Condition of Wadi located downstream about 3km far from C-site and utilization condition of the dry riverbed

Ph-F18, F19 Reddish top soil around here deems to be suitable as an impervious core.

Ph-F20, F21 Measurement facility of water level and pump

Annex 3.2

Study on Storage Type Dam on Wadi Far’a

Annex 3.2 Study on Storage Type Dam on Wadi Far'a

In order to assess the possibility of storm water harvesting in the study area, two types of studies were conducted: 1) site reconnaissance to Jordan and 2) study of storage type dam on Wadi Far'a.

(1) Site Reconnaissance to Jordan

JICA Study Team conducted the site reconnaissance and data/information collection from the various governmental agencies in Jordan on May 14th and 15th, 2007. The purpose of the site reconnaissance to Jordan was to obtain the data/information on procedures of water and storm water harvesting practiced in the country, which are applicable to wadis in the study area. According to the information, the following procedures/methodologies were adopted for the storm water harvesting in the country:

(i) Construction of storage type dam on wadis in the Jordan River East Bank area

(ii) Collecting and storing rainwater on roofs of houses and vinyl houses

(iii) Gathering rainwater in trench dug along same elevations at certain interval so as to grow some plants

Location of storage type dam in Jordan is listed in Table 3.2.1 and Figure 3.2.1.

Table 3.2.1 List of Dams in Jordan

No.	Name	Type*	Capacity (MCM)	Cost (M. JD)	Completion	Remarks
1	Al Wehdah	RCC	110	65	2006	
2	Wadi Arab	E	16.9	20	1986	
3	Ziglab	E	3.9	0.9	1967	
4	King Tahal	E	75	34	1977	Raised in 1987
5	Karameh	E	55	55	1997	
6	Shabiv	E	1.4	0.3	1969	
7	Kafrein	E	8.4	9.3	1967	
8	Wala	C	9.3	25	2002	
9	Mujib	C	35	46.7	2003	
10	Tannour	RCC	16.8	23.3	2001	

*Note: *RCC:Roller Compacted Concrete Dam, E:Earth Fill Dam, C:Combined Dam*

Source: Jordan Valley Authority

The Study Team visited two existing dams among the list above, namely Al Kafrein Dam and Wadi Shabiv Dam, in both of which the annual basin average rainfall is as less as 200 mm to 400 mm according to the information from the Jordan Valley Authority.

The Jordan Government has positively proceeded with the development of storage type dams on wadis of the Jordan River East Bank, even though the effective storage volume is as small as around 1 MCM.

Taking into consideration the characteristic of wadi floods like flash flood as well as their rare occurrence, it was conceived from the technical aspect that the construction of storage type dam would be the best way for the storm water harvesting, as long as there is an adequate dam site thereon for exploiting a storage type dam from the dam engineering and environmental viewpoints.

(2) Study of storage type dam on Wadi Far'a

A geological map of Wadi Far'a is shown in Figure 3.2.2. The geology of upper stream area of Wadi Far'a mainly consists of Limestone, Dolomite and Chalk. The conglomerate deposited from Miocene to Pliocene subject layer of the update world is partially distributed. Quaternary gravel layer is distributed along the valley.

The Cretaceous aquifers are widely distributed in the upstream and mid midstream of Wadi Far'a watershed. PWA is planed to construct retention dam at the upstream area in order to induce infiltration into Eocene Aquifer.

Figure 3.2.3 shows the proposed storage type dam sites in Wadi Far'a. These sites are selected to minimize the embankment volume and to obtain storage as much as possible in consideration with the topographic conditions.

- Site A Al-Far'a (Tubas area)
- Site B, C Mainstream of Wadi Far'a located downstream of confluence of Al-Far'a and Al-Badan
- Site D Nablus basin

Dam height and storage for each site is tabulated as below.

Table 3.2.2 Dam height and Storage for each site

		A	B	C	D
Dam Height	m	20	15	20	10
Storage	m^3	586,000	255,000	456,000	40,000

Note : Storage is calculated by CAD

Source: JICA Study Team

It is necessary to lower the dam height further because a part of the road on the left bank of the reservoir is flooded in the Site "B". And also in the Site "D", the dam height and gross storage of this site is extremely limited due to the same conditions as the Site "B".

[Issues to be solved]

A base rock of these dam sites consists of the limestone as shown in Figure 3.2.2 (geological condition of the proposed dam site in Wadi Far'a). The limestone in this area is very cracky and has a lot of small to large size caves due to the weathering action by the water. Therefore, it seems that the permeability of the limestone is extremely high especially near the ground surface due to weathering.

In the case storage type dam, the foundation treatment for leakage is generally treated by the grouting. However, it is very difficult to improve the permeability of the limestone by the grouting from experienced viewpoint.

On the other hand, if stored water in the reservoir returns to the original wadi through the surface of the dam foundation, it cannot function as a recharge facility.

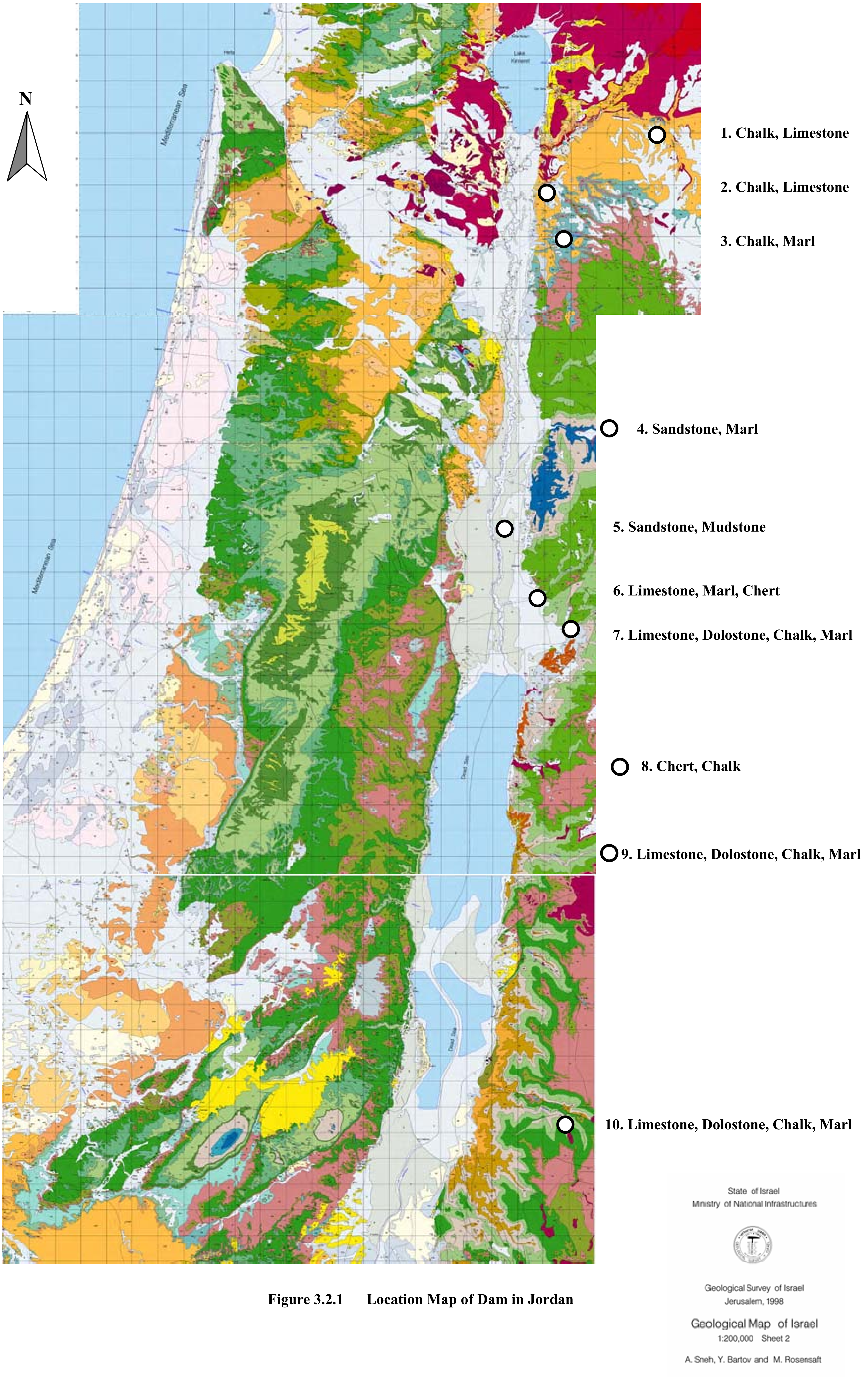
In addition, the siltation (suspended load) supplied from the catchment area of 74.2 km^2 for 100 years is calculated applying a denudation rate of 0.625 mm/year.

$$74.2(km^2) \times 0.625(mm/year) \times 100(years)/10^3 = 4.6 \text{ MCM}$$

It is obviously demerit against the gross storage mentioned above. In addition, the stream from Nablus city is contaminated with the waste water. Therefore, the electric conductivity is high by comparison spring water. This contamination issue is to be solved to realize this idea.

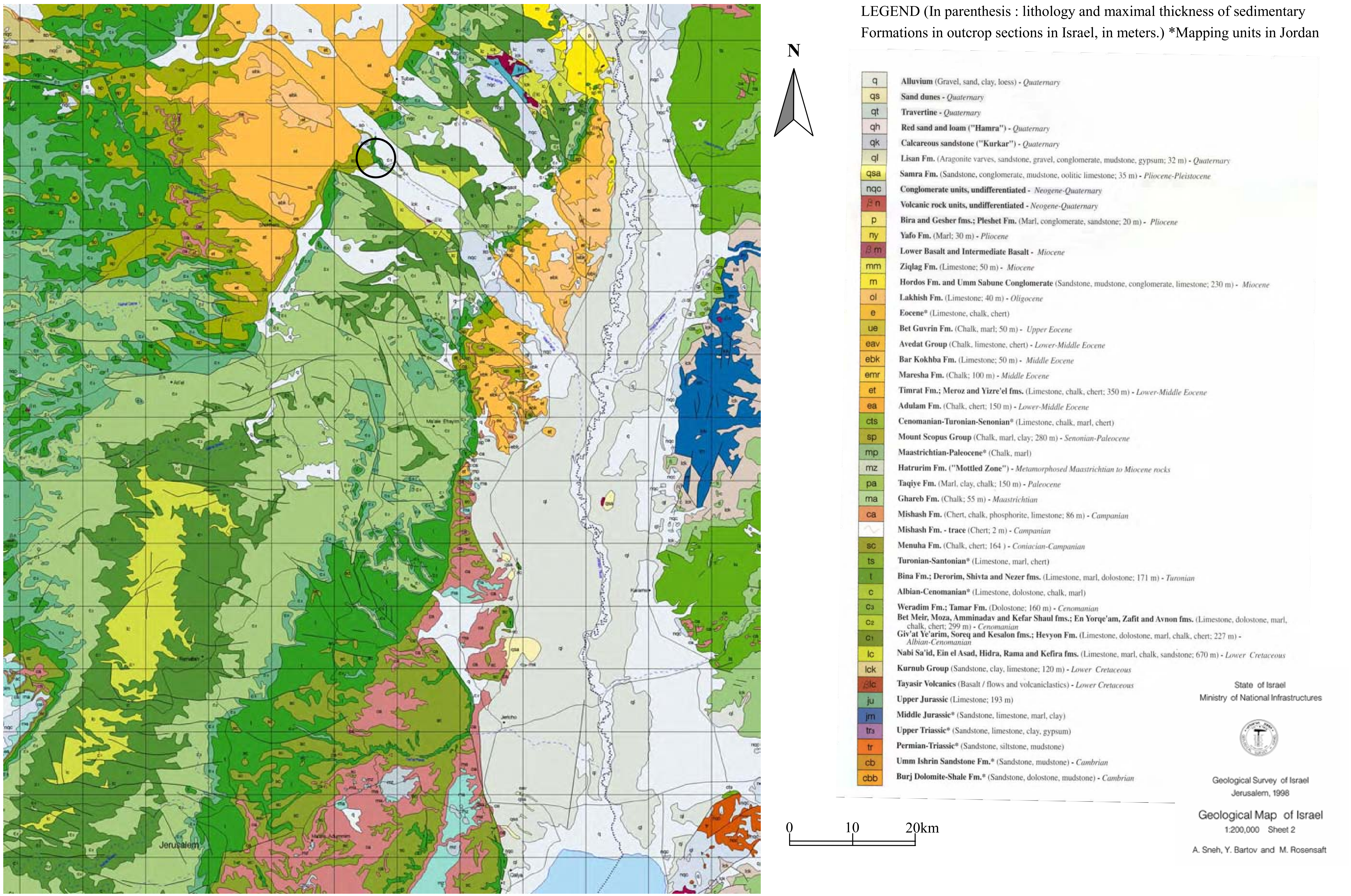
As shown in Figure 3.2.1, the dam in Jordan constructed on the base of the limestone is recognized to be few. In the case earth-fill dam especially, the hydraulic fracture such as piping phenomenon at the boundary between the dam body and the dam foundation will be serious.

As a conclusion, the storage dam in this area will not be recommended by the JICA Study Team due to serious demerits mentioned above even though the purpose of the reservoir is to recharge water to the aquifer.



Source: Ministry of National Infrastructure of Israel

Figure 3.2.1 Location Map of Dam in Jordan

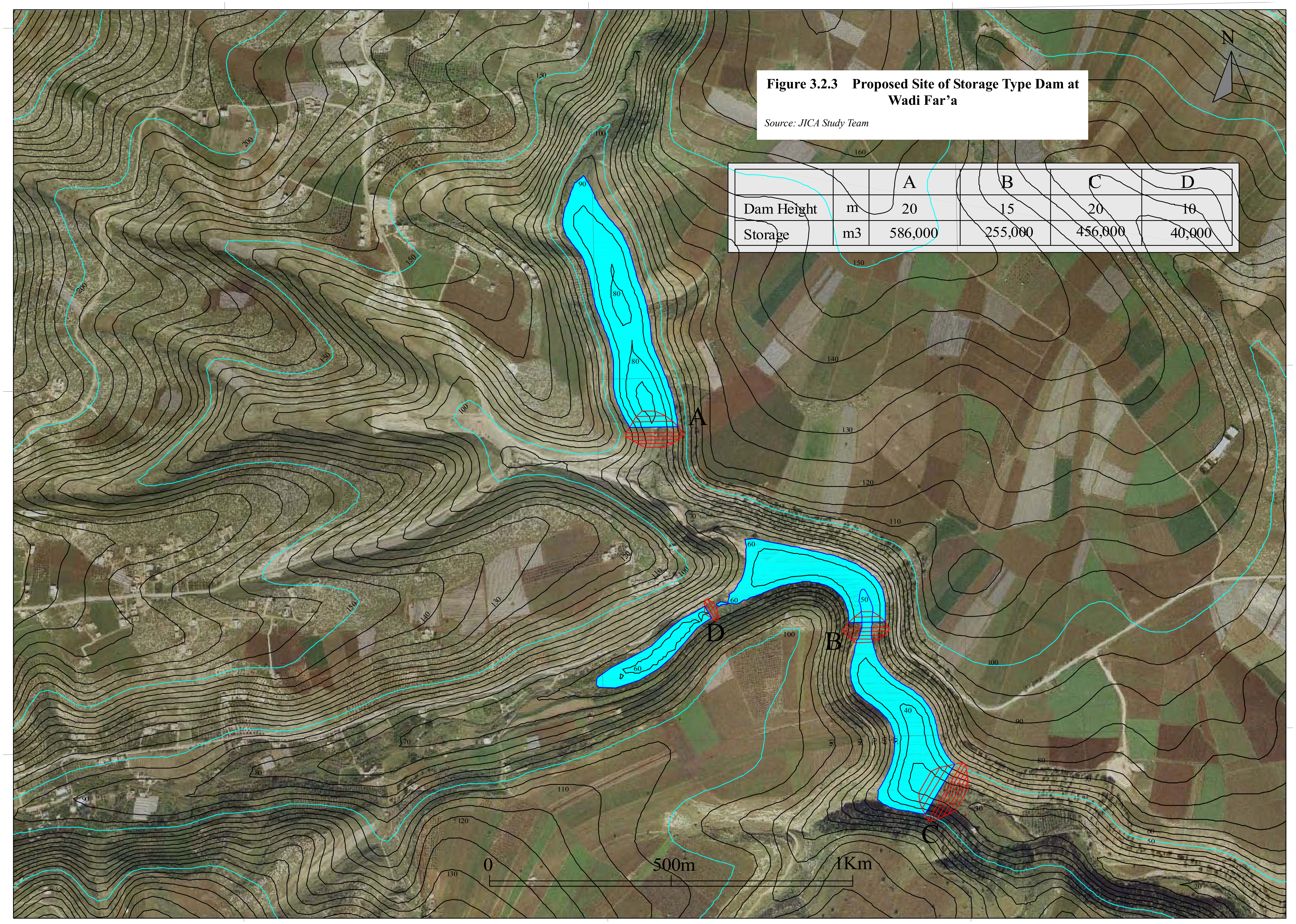


Source: Ministry of National Infrastructure of Israel

Figure 3.2.2 Geological Condition of Wadi Far'a

Figure 3.2.3 Proposed Site of Storage Type Dam at Wadi Far'a

Source: JICA Study Team



		A	B	C	D
Dam Height	m	20	15	20	10
Storage	m3	586,000	255,000	456,000	40,000

Annex 3.3

Storing Water inside Void among Cobble/Boulder

Annex 3.3 Storing Water inside Void among Cobble/Boulder

One of the ideas for preventing evaporation is introduced hereinafter. After excavation for the reservoir, cobble and boulder which has almost same size and shape are backfilled into the excavated space. Water is stored in the void between cobbles and boulders. Finally, surface of the reservoir is covered with the soil about 2m thick. High effect for preventing evaporation will be expected in this type.

Porosity (void ratio among cobbles/boulders) should be determined by laboratory test. Porosity of 20% is assumed tentatively.

Table 3.3.1 shows rough calculation result for this type. In this type, for example, excavation volume of 3,000,000m^3 is required to store 500,000m^3 of water even though this type has high effect against preventing evaporation.

In the case same size sphere, porosity under several density conditions is determined geometrically as shown in Table 3.3.2. Rock and boulder under natural condition have various shape, size and density. “Simple cubic” has the biggest porosity among them however, settlement or deformation will take place easily due to its unstable condition.

Porosity using rock and boulder will be smaller than that of the table above, even though rock and boulder with similar size and shape are used as much as possible. Details of porosity should be clarified by laboratory test prior to study stage.

Table 3.3.1 Excavation volume, Backfill volume of Rock and Storage among the Void

Target Storage (m^3)	Porosity n	Depth of Water m	B*L m	m	Excavatuin Volume (m^3)		Roughly Embankment Volume: Rock (m^3)		Filter (m^3)		Core (m^3)	
100,000	0.2	10	225	225	12*225*225=	607,500	9*225*225=	455,625	225*225*0.5*2=	50,625	2*10*225*4=	18,000
200,000	0.2	10	315	315	12*315*315=	1,190,700	9*315*315=	893,025	315*315*0.5*2=	99,225	2*10*315*4=	25,200
500,000	0.2	10	500	500	12*500*500=	3,000,000	9*500*500=	2,250,000	500*500*0.5*2=	250,000	2*10*500*4=	40,000
1,000,000	0.2	10	710	710	12*710*710=	6,049,200	9*710*710=	4,536,900	710*710*0.5*2=	504,100	2*10*710*4=	56,800

Image of underground Reservoir

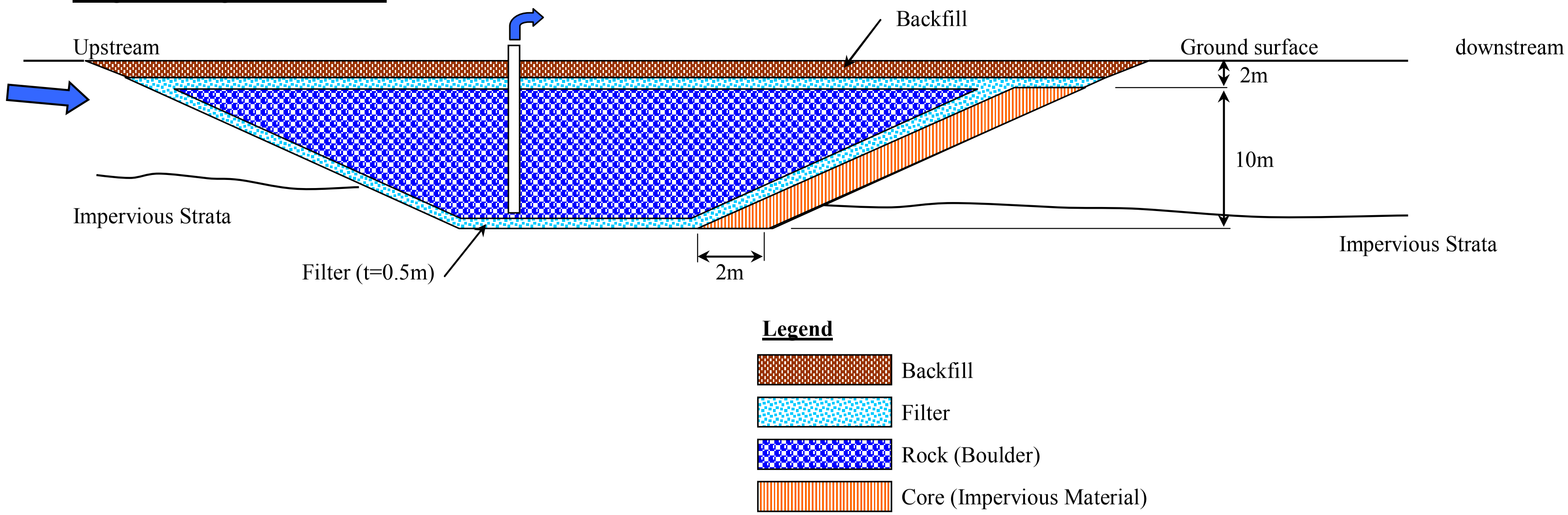
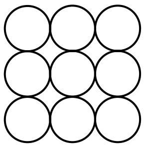
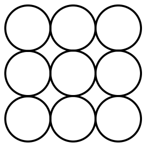
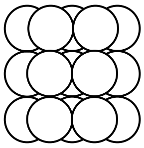
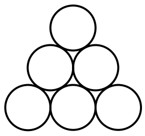
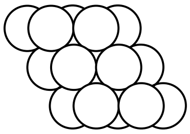
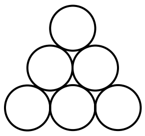
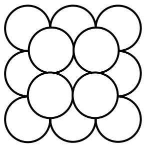
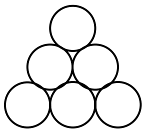
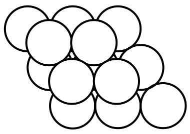


Table 3.3.2 Porosity for sphere

Packing Condition	Plan-view	Side-view	Void ratio	Porosity (%)
Simple cubic			0.9098	47.64
Cubical tetrahedral			0.6539	39.54
Tetragonal Sphenoidal			0.4324	30.19
Pyramidal			0.3504	25.95
Tetrahedral			0.3504	25.95

Source : Takeo Mogami, Soil mechanics, Gihoudou