MINISTRY OF AGRICULTURE AND IRRIGATION
SANA'A

REPUBLIC OF YEMEN

IRRIGATION IMPROVEMENT PROJECT

WATER RESOURCES ASSESSMENT AND DETAIL DESIGN OF DIFFERENT COMPONENTS OF WADI AHWAR- ABYAN

MAIN REPORT

VOLUME ONE

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In association with IdRC

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1. INTODUCTION

1.1 Project Background

The government of Yemen has obtained a development credit from the International Development Association (IDA) of the World Bank for the Irrigation Improvement Project. The purpose of the project is to improve agricultural productivity and sustainability through sustainable water resources management. This is expected to lead to the improved efficiency of use and distribution of spate irrigation water.

The objective is to be reached by introducing important changes in the spate irrigation system of about seven main schemes. The changes involve the decentralisation and increased participation of the users in management and ownership of the system, rehabilitation of the water distribution infrastructure, and the provision of improved management tools in the form of spate warning and management systems and an Information management system. The credits are available in an Adaptable Programme lending package, which allows the adaptation of the subsequent funding of a programme according to the results of experience with earlier phases of the project. Therefore, the IIP package is divided into two phases:

Phase I, is presently being implemented covering two spate irrigation schemes: Wadi Zabid and Wadi Tuban, with a total command area of about 26 000 ha, for a cost of Mill.US$ 25.6 approximately.

The second phase (2006 - 2010) will cover some of the selected Wadis out of five Wadis: Bana, Ahwar, Mawr, Rima and Siham. It will profit from the experience gained with the first phase.

Wadi Ahwar was selected to be included in IIP as a new component to be implemented during IIP follow up bridging Phase (July, 2007 to December, 2008) .IDA and Govt of Yemen (GOY) agreed to engage a consultant to carry out major works in wadi Ahwar and accordingly Hydrosult consult has been selected to carry out the consultancy work for period of six months.

1.2 Wadi Ahwar: Physical set up

Wadi Ahwar is located in the eastern part of Abyan Governorate at a distance of about 240 km east of Aden. The Wadi is formed by joining two tributaries: Wadi Saba and Wadi Jahir. The total catchments of the Wadi are estimated at 6352 km2 and are considered generally as under arid and tropical hot climate.

The Wadi is 160 km long and originates from the high mountains where it receives around 220 mm of annual rainfall. The Wadi ends up in an alluvial plain which is the main agricultural area of Ahwar delta.

Rainfall in the catchments occurs in two periods: March-May and July-September. The Wadi is not equipped with a rain gauge and hydrometric station. No runoff data are available after 1989. Average annual runoff is estimated at 70.9 million m^3.

Groundwater is available in Ahwar delta and it occurs in three interrelated aquifers. Based on well monitoring survey carried out by Hydrosult within the framework of the present project, actual total groundwater abstraction is estimated at around 17.0 million m^3, which is approximately equal to the safe yield estimated at 18 million m^3. Total groundwater storage is estimated at 1099 million m^3. However, groundwater aquifers in the delta are suffering from sea salt-water intrusion.

Two main irrigation schemes exist in Wadi Ahwar: Fuad Diversion Weir and Hand Diversion Weir, Figure 1.1. They are constructed in 1971-1973 by the Yemeni- Soviet Projects. The discharge capacity of each system is 3660 m≥/sec, which was found to be inadequate. Fuad Weir was reconstructed in 1986 for a maximum discharge of 6630 m≥/sec and has been recently rehabilitated.

Irrigation systems in both weirs are suffering from lack of proper operation and maintenance system and are in general in very bad operational conditions:

- Main canals have been filled by trees of Porosities species;
- Most control structures have been impaired by salutation from upstream watersheds; and
- Secondary and tertiary canal systems are malfunctioning.

According to Hydrosult survey, the Wadi contains around 450 wells, which are mainly located in delta area of the wadi. Groundwater irrigation covers about 1930 ha.

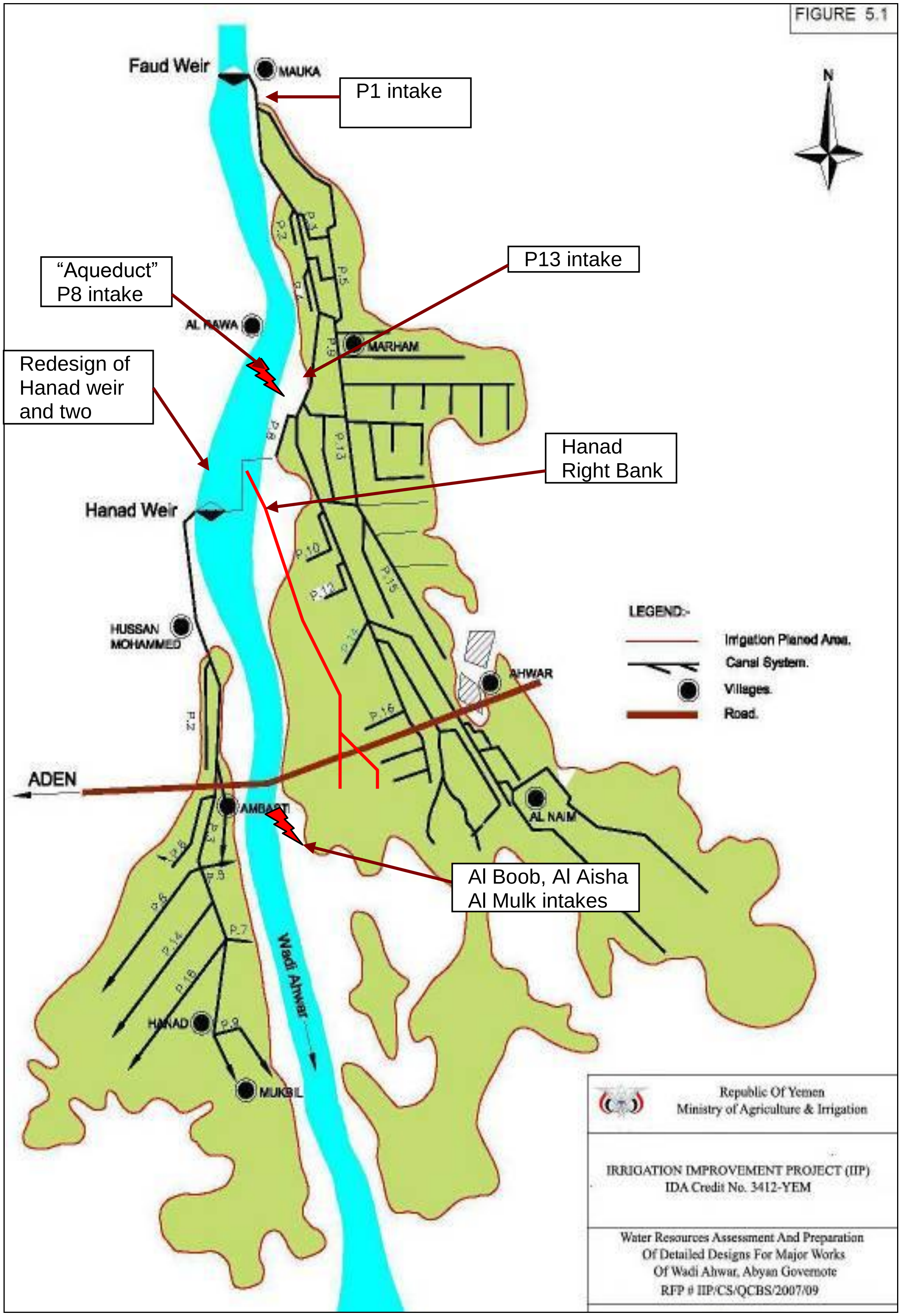


Figure 1, Location Map of IIP Wadi Ahwar

2. WATER RESOURCES ASSESSMENT

2.1 Wadi Ahwar Catchment

Wadi Ahwar catchment is located in Abyan Governorate. It lies within coordinates of 14^{o}14' - 14^{o}21' North and 45^{o}45' - 47^{o}10' East. Wadi Ahwar originates at mountainous area and flows in a general southerly direction towards the deltaic area and terminates at Gulf of Aden. Two major tributaries forms Wadi Ahwar, Wadi Sabah and Wadi Jahir; Wadi Jahir has another major tributary, Wadi Seiga. Wadi Ahwar has a total catchment area of 6980 km^2 upto Fuad dam site according to the newly delineated area using GIS techniques. The catchment area including the Delta is 7311 km^2. Figure 2.1 shows the catchment area of Wadi Ahwar

Wadi Sabah is a right side tributary which originates at about 2250 meters above sea level (masl). The upper catchment of Wadi Sabah consists of mountain ridges and flat foot slopes. The foot slopes are well irrigated from the floods of the mountains. The mountains are rocky with little soil cover and vegetation. They are flood producing areas and their waters are effectively held by a series of irrigation basins. Wadi Sabah joins Wadi Jahir at about 150 masl and together form Wadi Ahwar basin. The catchment area of Wadi Sabah is about 2932 km^2. Mudia town which is located at about 830 masl is in this catchment and had been a rainfall recording station before. It is important to re instate the raingauge station within this project. The flows of the Wadis are captured for irrigation purposes in this inter mountainous area. During low flow normal floods and only hogh floods reach Fuad weir.

Wadi Jahir occupy the central catchment of Wadi Ahwar it origins at an elevation of about 2245 masl.At the beginning it is a confluence of wadi dashin and wadi Ray. It is draining a rocky mountainous area with bare soil cover and no vegetation. The shape of the valley is trapezoidal with wide Wadi floor. It receives its larger tributary, Wadi Seiga, at about 200 masl. The two catchments together have 3760 km^2. Wadi Jahir without Wadi Seiga has a catchment area of 1430 km^2. It will be very important to establish a rainfall station at Al Ahmar village in Wadi Jahir to represent the upper catchment of Wadi Ahwar sub basin. Wadi flow gauge also need to be established with automatic water level recorder and staff gauge at the bridge crossing of Wadi Jahir.

Wadi Seiga is a major tributary draining the left side of Wadi Ahwar catchment. Wadi Seiga originates at about 2275 masl and is formed by three tributories;Kafa, Ragba,and Hamda. The form of the wadi is Vshaped and width ranges from 100 to 1 km.The channels consists of sand gravel andpebbles.Bed slope vaies from 10%to 100%. It drains mountainous area through different tributaries the area is bare rock with little soil cover and vegetation. The catchment area of Wadi Seiga at its confluence, at about 200 masl, with Wadi Jahir is 2330 km^2. Wadi Ahwar finally terminates at Gulf of Aden.

A little downstream of the confluence of Wadi Sabah and Wadi Jahir the Wadi Ahwar Delta begins. The Ahwar delta constitutes the concerned irrigation development of this project and an existing system of irrigation through Fuad Dam/Weir. Downstream of the Fuad diversion dam is the location of the old Hanad dam/weir which is badly damaged by the tremendous 1982and 1983 flood. The redesign and rehabilitation of Hanad weir is the major objective of this project.

The Consultant has prepared a digitised map of Wadi Ahwar watershed. The map indicated the physiograhical and drainage system of the watershed.

2.2 Flood discharge and volume

Flood discharges of various recurrence intervals (return periods) for the design of Hanad weir and flood volumes was determined in two ways. Rainfall runoff modelling using the rainfall data of MOQEIFIA'A station. Due to rainfall data limitation (9 years) only upto 20 year return period flood was determined from rainfall runoff modelling. The 100 year design flood of Hanad weir is determined from statistical analysis of measured flow data.

Rainfall Runoff modelling

The SCS-CN method of rainfall as built- in HEC-HMS software was used for the analysis. Flood Discharge at Fuad and Hanad weir site are considered the same as there is no tributary between them.
The peak discharge determined as 20 year return period at Fuad dam is 4130 m^3/sec.The hydrograph is shown in Figure 2.2

The biggest deficiency in the determination of the peak flood is the rainfall data. The representativeness of the Moqeifia'a station in data quality, quantity and overall representativeness for such big catchments. Therefore rainfall runoff modelling is limited to determine low return period floods and mean annual flows. Design discharge for Hanad weir is determined from statistical analysis of flow data.

Figure 2.1 Catchment Area of Wadi Ahwar

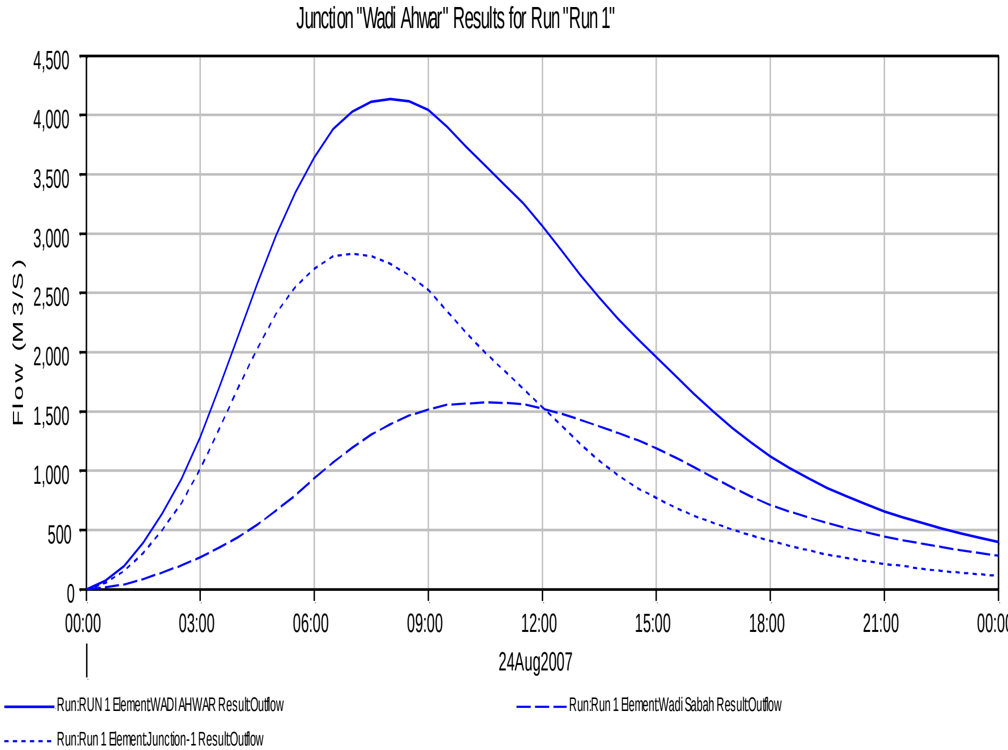


Figure 2.2 The 20 year flood from rainfall runoff modelling

2.3 Design Flood

The design flood discharge for Hanad Weir/Dam was being determined from the available hydrological data. There is no adequate rainfall data for rainfall runoff modelling to determine design flood at 100 year return period. Therefore, the best available is the annual maximum flow data measured for 19 years at Fuad gauging station. The available discharge data were analysed by several distribution method. The summary is given below:

Table 2.1 Summary of Wadi Ahwar flood according to several distributions

Return Period (years)	Gumbel (EVI)	GEV	Log Pearson III (Bulletin 17B)
5-years	2856	1837	2224
10-years	4028	2823	3894
25-years	5509	4102	5860
50-years	6609	6419	8784
100-years	7699	8839	11159

As the results shows estimating the 100 year design flood from the available 19 years data is very difficult. The results are varying from method to method. The 1982 flood has about 25 year event according to the frequency analysis. The 100 year event can be overly estimated from the short coming of the data. However, the best thing is still to use the data instead of resorting to unreliable empirical methods. The recommended peak discharges, from GEV upto 25 year return period and Gumbel for 50 and 100 years are shown in Table 2.2

Table 2.2 Recommended Flood Discharge for Hanad Weir Design

Return Period (Years)	Peak Discharge (m3/sec)
5-years	1837
10-years	2823
25-years	4102
50-years	6609
100-years	7699

2.4 Water Availability (Runoff Volume)

Water availability in the Ahwar wadi at the delta was estimated using the Moqeifia'a daily rainfall data. Flood runoff volumes from daily rainfall are computed by HEC-HMS software. The effective catchment area of Ahwar Wadi at Fuad weir is 4680 km^2. The CN value is 90 for average flood condition but depending on the antecedent moisture condition based on the 5 day prior rainfall a wet value of CN 96 considered in some cases. An aerial reduction factor of 0.55 is applied.

The mean annual runoff in the Ahwar Wadi according to the above results is 65.8 Mm^3 and at 75% probability (3 out of four years exceeded) the annual runoff volume will be 31.2 Mm^3. Due to limited data availability the probability curve falls sharply and the 80% probable (4 out of five years exceeded) volume will be 18 Mm3. In line to the data availability the 75% probable volume of 31.2 Mm^3 of water is considered as dependable runoff volume of Ahwar Wadi. It is this amount of dependable runoff on which the Fuad and Hanad irrigation projects will share for spate irrigation. The mean value is high because it is skewed to the high rainfalls in some years. Figure 2.3 shows the probability of annual runoff occurrence in the Ahwar Wadi. The Russian study results with a mean annual runoff of 70.4 Mm3 with a range of 51.8 - 89.0 Mm3. Though the methodology and data used are completely different the results are comparable.

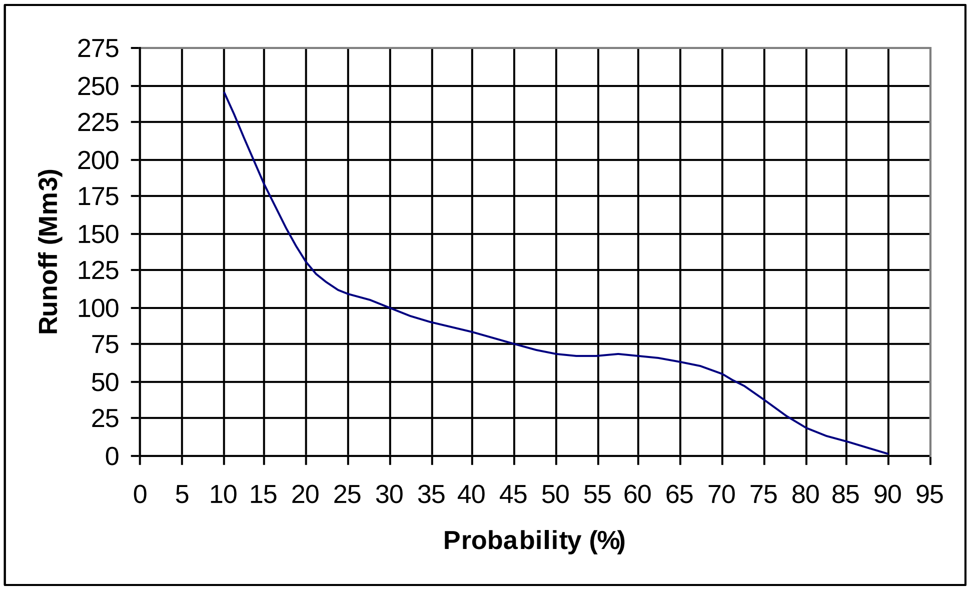


Figure 2.3 Probability of Annual Runoff Occurrence in Ahwar Wadi (Fuad Dam)

2.5 Water Balance

Water balance method is used to determine water availability at Hanad dam. The distance between Fuad and Hanad dams is about 7.0 km and when completely inundated the area will be about 16 km^2 (SELKHOZPROMEXPORT, 1990). Average evaporation at Ahwar delta is about 8.3 mm/day. The daily evaporation loss between Fuad and Hanad dams is therefore about 0.134 Mm^3. Considering 0.5% water losses by evaporation between Fuad and Hanad dam is reasonable with the above argument.

The other important parameter is channel loss to the ground water, the Ground Water Development Consultants (GDC, 1981) provide a channel loss curve for Wadi Tuban delta which is reproduced and used by SELKHOZPROMEXPORT. A constant percentage of 0.75% is provided for discharge value of above 80 m^3/sec per 1 km of channel length. That is about 5% channel loss for 7 km distance between Fuad and Hanad.

Channel precipitation at the delta is insignificant and ignored in this analysis.

Water diversion to Fuad and Hanad weir depends on runoff hydrograph characteristics including runoff discharge and duration. Based on exiting reports (Dar AlHandassa,1972; Yemeni-Soviet project, 1983; and Kazgiprovodkhoz, 1990) and on local information from local people, duration of runoff flow in wadi Ahwar varies between 4 hours to more than 24 hours for large flood, during which runoff volume varies between less than 1-5 Mm^3 to more than 50 Mm^3.

The Fuad dam main canal capacity is about 50 m^3/sec, therefore, therefore volume of diverted water depends on runoff duration with a maximum of 4.3 Mm^3 of water will be diverted in 24 hours period. After subtracting the losses and diversion at Fuad dam the remaining water is assumed to be available at Hanad dam site. Capacity of Hanad weir main canals is about 70 m^3/sec with a maximum of 6.05 Mm^{3}of water will be diverted in 24 hours period. The capacity of the three obars downstream Hanad weir is estimated at 1.5 Mm^3 .

Details of runoff water balance assessment is provided in Table 6.1 of the Hydrology Report. The following are the main results:

- The average volume of runoff water, which reaches the sea is 16.3 Mm^3 (or 25% of the average runoff volume). It varies from 0.00 to 73.7 Mm^3 depending on the runoff value.
- The groundwater recharge from the wadi bed averages 7.4 Mm^3/yr.
- Spate irrigation water average 42.1 Mm^3 (or 65% of annual runoff flow).

2.6 Groundwater Assessment

After understanding the groundwater flow pattern in AHWAR area, water balance could be calculated taking in account all identified groundwater sources, water balance could be one of the tools required for water resources management from the different components and their interactions as the impact of human interference. AHWAR Delta consists of the flood plain of Wadi Ahwar. The plain consists for the most part of alluvial fan areas, which are mainly developed for groundwater agriculture, near the foothills in the east rain fed agriculture and some hills runoff agriculture take place. Spate irrigation can be found along upper streambed of the Wadi, groundwater irrigation mainly concentrated at the center of AHWAR Plain.

Except for some runoff from hill slopes in the foothills, no runoff is generated in AHWAR Delta. The Delta is considered a runoff absorbing area. The flow seeps down to the wadi courses in AHWAR area causing direct recharge to the aquifer, the annual average wadi flow of (65.8 Mm3) causing direct recharge to the delta aquifer system. The estimated amount of annual recharge through wadi flow is presented in the runoff water balance sheet. Despite of upstream spate irrigation, large surface flow is still available at wadi Ahwar delta. While groundwater natural inflows to the basin are increasing gradually with groundwater slope and the slope increases together with drawdown and /or abstraction from the basin, the inflows then were calculated as percentages from the actual abstraction, more abstraction means more irrigation and more return flow. The total abstraction was calculated to 24 Mm^3 according to the conducted surveys, The annual rainfall in the area varies between 60 mm along the coast and 100 mm at the edge of the foothills.

The average rainfall is in the order of 80mm. The direct recharge from rainfall was estimated to 5% of the average rainfall or 0.6 MCM of direct recharge over the study area. This amount was not considered in the water budget.

The groundwater loss by evaporation is considered equal to 9.7 Mm3. This is based on Kazgiprovodkhoz Institute (1990) evaluation.

Irrigation return flow coefficients, is the ratio between the quantity of water returned from the cultivated area to the groundwater system and the amount of abstraction is considered equal to 25% of the total amount of irrigation water diverted through spate irrigation.

Groundwater level elevations in AHWAR area has been dropped down in many places composing depleted cones. The groundwater flow pattern has been changed and lateral flow has been occurred and even from the depleted cones to recover the new status of groundwater depletion, this lateral flow was calculated to 3 % of the total annual abstraction this figure was driven from Darcy law relaying on groundwater approximate gradient and aquifer permeability to about 6m/d from the pumping tests assuming the average saturated thickness of the aquifer to 30m at North and to only 15m at the south .

The detailed groundwater budget for the period 1999 to 2007 is provided in the table below.

Table 2.3 Groundwater budget Wadi Ahwar *)

Year	Runoff	Irrigation	from Irrigation to ground water	Wadi loss to ground water	Lateral inflow	Total in (4+5+6)	Abstraction	Evaporation	Total Out (8+9)	Yearly balance (7-10)
1	2	3	4	5	6	7	8	9	10	11
1999	101.12	56.01	14.00	11.79	0.72	26.51	24.00	9.70	33.70	-7.19
2000	50.50	39.54	9.88	5.54	0.72	16.14	24.00	9.70	33.70	-17.56
2001	76.97	58.82	14.71	8.36	0.72	23.79	24.00	9.70	33.70	-9.91
2002	53.57	38.10	9.53	5.87	0.72	16.11	24.00	9.70	33.70	-17.59
2003	1.16	1.10	0.28	0.06	0.72	1.05	24.00	9.70	33.70	-32.65
2004	14.29	10.46	2.62	1.49	0.72	4.83	24.00	9.70	33.70	-28.87
2005	41.72	36.30	9.08	4.30	0.72	14.10	24.00	9.70	33.70	-19.60
2006	188.15	90.74	22.69	22.40	0.72	45.81	24.00	9.70	33.70	12.11
2007	64.65	47.78	11.95	6.98	0.72	19.64	24.00	9.70	33.70	-14.06
averages			10.52	7.42		18.66			33.70	-15.04

*) values in columns 2 - 11 in Million Cubic Meters (MCM) data on column 2, 3 and 5 are form table 6.1 in Hydrology Report

The ground water yearly deficit is about 15 Mm^3 annually, the deficit is accumulated yearly , increasing water abstraction will led to more groundwater depletion and will allow to seawater intrusion.

The safe yield of the groundwater system is estimated at 18.66 Mm^3

2.7 Integrated Monitoring System

2.7.1 Surface Water Monitoring

Hydrological monitoring is essential in Ahwar catchment for effective utilization of the water resources for spate irrigation and flood warning. Practically there is no flow gauging station or rainfall station inside the catchment since 1989. Both flow (water level) measuring stations and rainfall stations are recommended to be implemented and operated inside the catchment.

Wadi Flow Gauging Stations

Based on our assessment on the Wadi Ahwar, two wadi flow gauging stations are recommended. The best location to install the automatic water level station is the location of the previous station about 1.15 km upstream Fuad dam. The exact location is on the left bank of the wadi at the rocky abutment. The coordinate is 0681770 N and 1505118 E. Both automatic water level recorder and staff gauge need to be established.

The second wadi flow gauging station is upstream in the Jahir catchment near Al Ahmar village at the road bridge crossing. Staff gauge and automatic water level recorder has to put at the second pier downstream from the left abutment. The site coordinate at the bridge is 0657142 N and 1545688 E.

Ott, Stevensen, or SEBA type automatic water level recorders are very suitable for wadi flows gauging.

Rainfall stations
One meteo station at Ahwar delta and several rainfall stations are recommended to be installed and operated on continuous basis in the Ahwar catchment. The following equipments are familiar to NWRA, therefore, it is beneficial to adopt the same for Ahwar for efficient operational purposes.

Meteo Station
Two types of equipments are used by NWRA to record various climatic parameters. OMNIDATA and DATALOGGER 900 type. The instruments are equipped with several sensors through which parameters variations are detected and stored in the system as raw data using internal memory DSR and/or removable external memory DSP.

In addition, we recommend to install evaporation pan of " Colorado class A" type. The meteo station at Ahwar should have office for data processing and telemetry system for receiving data from rainfall and wadi flow gauging stations. The operators at the other rainfall stations should be equipped with radio or mobile telephone to report data daily and as necessary for flood warning downstream.

The most important thing to note is that operation and maintenance of hydro-meteorological stations is equally important to their establishment. It is reported that weather station was established in Ahwar before but abandoned due to lack of operational facilities including manpower and financial resources.

The new locations of weather station have been selected in the same compound of the Equipment yard in the old equipment rental station of Ahwar. There is sufficient land for weather station and equipment yard. The location is very near to the present PIU office.
Automatic Rainfall station

NWRA has good experience in maintaining and operating the following type of rainfall recorders: DATAPOD 101 and DPX-RG type or DPX2C type. (more information on the specifications are provided in the Hydrology report, Volume 2)

Location of Rainfall Sites
In arid watersheds, the number and locations of rainfall stations are determined by the availability of human settlements such as khorbats, small villages, villages and towns. Due to difficulty of access in the mountainous catchment for operation and maintenance of rainfall stations the following sites are selected as minimum network of rain gauges in Wadi Ahwar catchment. The best locations for the catchment are the towns along the road from Mudiya-Al Ahmar-Mukala. Both Automatic (recording) type and manual (non recording) rain gauges are recommended at each site.

Table 2.3 Recommended locations of Rain gauge and Meteo stations

	Station	Type
1	Ahwar	Meteo station
2	Rawad	Rainfall
3	Mudiya	Rainfall
4	Al Ahmar	Rainfall
5	Mabar	Rainfall
6	Sawda	Rainfall
7	Al Hag	Rainfall

Therefore, a total of 7 manual rain gauges, 6 automatic (recording) rain gauges, 1-complete meteo station, and 1 Evaporation pan are required for this minimum network in Ahwar catchment.

The consultant could select the location of two rain gauge station: Ahwar gauge station will be situated in the present Equipment Rental station near to PIU office another will be situated in the Rowad school compound in Rowad village. The other five stations will be located during the installation with the help of Administrative director of the respective district.

Installation of a network of telemeter stations both for water level and rainfall measurement is very important for flood warning system. This network would operate continually, providing reliable data for water resources planning in addition to its role as part of the flood warning system. Until a fully fledged telemetric system is setup telephone communication using mobile phones will be effective. All gauge operators need to be equipped with mobile phones so that they can transmit message at the project office in Ahwar where easily can be communicated with gate operators during high rainfall or flow at upstream catchments.

2.7.2 Ground Water Monitoring

Monitoring approach

The monitoring network for the delta groundwater management unit consists of a number of observation bores/one observation well/50km^2, with a proposed bi-annual to monthly monitoring frequency and includes two automatic data loggers.

A number of observation bores within the delta should be specifically constructed to locate the fresh/salt water interface and monitor the movement of the saltwater wedge. These particular observation bores have continuously slotted casing which enables monitoring to consist of conductivity readings recorded at 1 m intervals from the water level to the base of the bore. The groundwater monitoring network within the Delta should be adequate for the detection of seawater intrusion or a marked rise in the water table, and observation bores should continue to be measured for water level, major ions, pH, and conductivity and salinity movements.

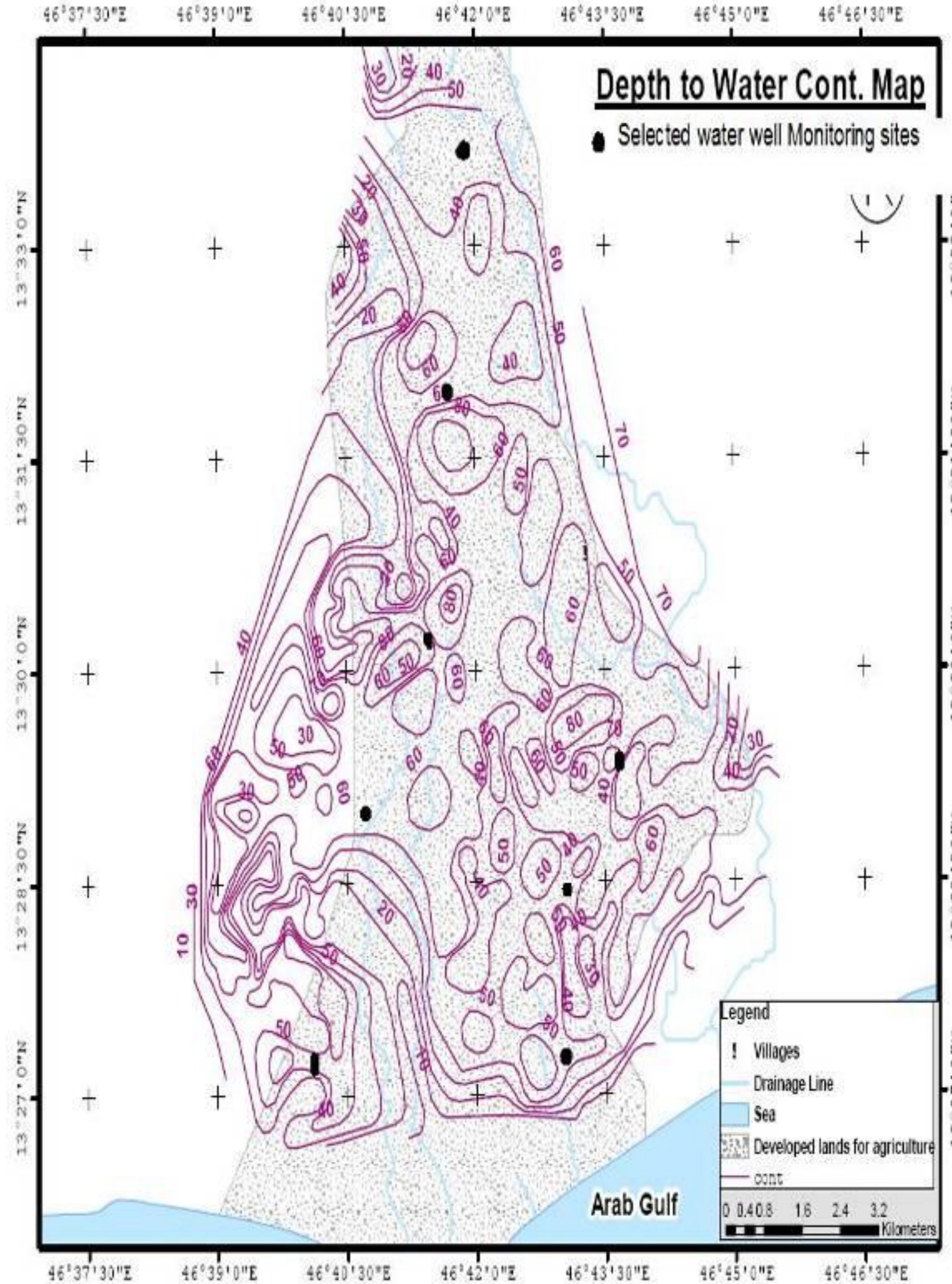
Monitoring of water levels and complete water quality (including nutrients) is essential to the management facilitating integration between surface water and groundwater resources, and enabling swift management response to changes in water quality.

Groundwater monitoring network

In the absence of monitoring network and the increasing importance of water level and water quality monitoring network in Ahwar delta jump to the scene due to water quality deterioration and groundwater levels decline, decisions still rely on one campaign direct measurements and subjective judgments in setting water monitoring stations. This study proposes an effective water monitoring network in Ahwar Delta. In order to develop a design scheme, planning objectives were identified for water level-quality monitoring networks

Eight monitoring well sites were selected to reflect the actual groundwater movement, abstraction and water quality variations, 5well were selected along the groundwater path from the Delta recharging point in the north to the discharging point in the south to represent the actual ground water conditions, two wells were selected to be close to the coast to track the water quality variation and the possible seawater intrusion.

Other two wells were selected in the eastern part of the Delta to monitor the groundwater depletion between the pumping wells.


Depth to Water Cont. Map
Selected water well Monitoring sites
Legend
Villages
Drainage Line
Sea
Developed lands for agriculture
cont
Arab Gulf
0 0.40.8 1.6 2.4 3.2
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46°45'0"E
46°46'30"E
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13°27'0"N

3 DETAIL DESIGN OF DIFFERENT COMPONENTS OF HANAD WEIR

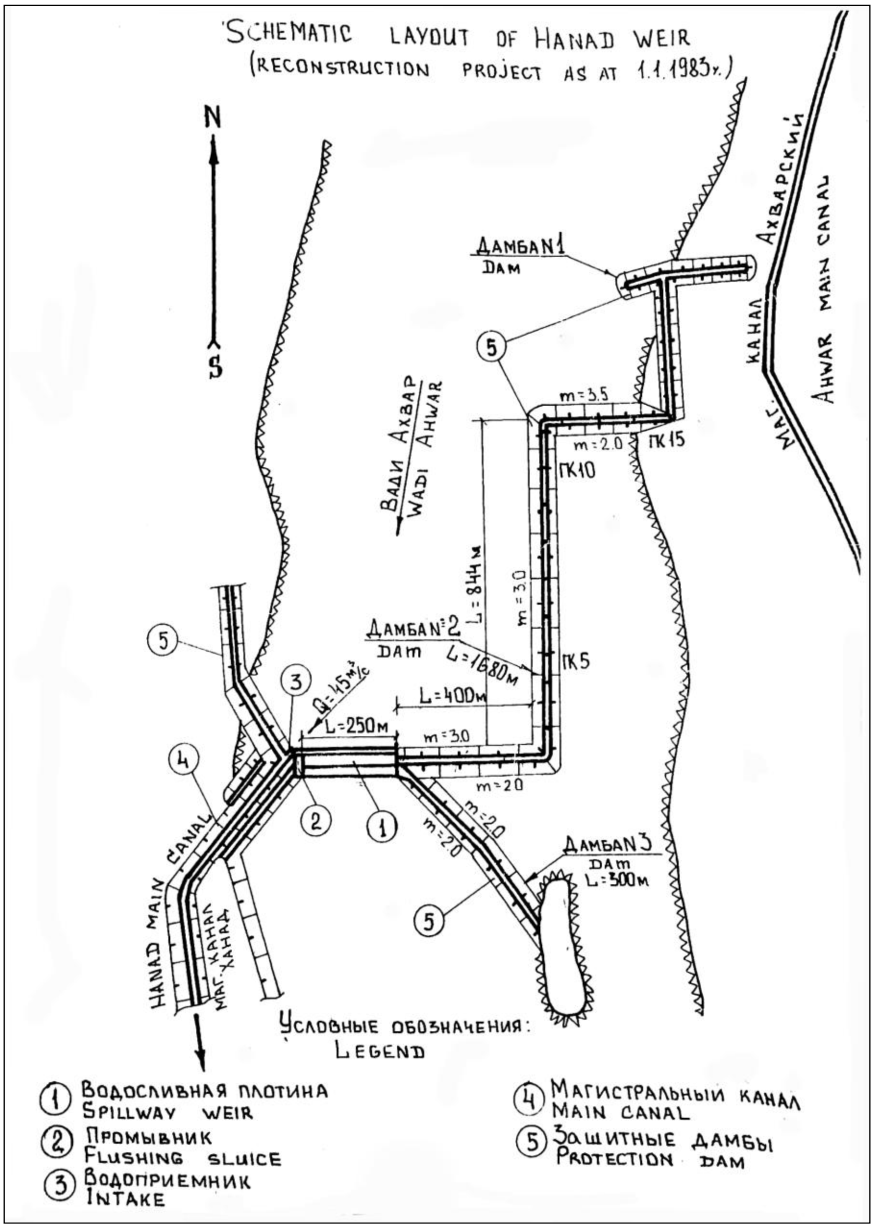
3.1 Design of Hanad Weir

Objectives

To provide a new diversion structure to supply irrigation water to canals on the left and right banks to irrigate an area of up to 3500ha.

Design Requirements

The RFP indicates the canal flows are 35m³/s. However, it would be prudent to design some additional capacity into the head works. The original head regulators were designed to pass 45m³/s.



Assessment of Original and Modified Designs

The original design of the Al Hanad weir used a weir crest length of 250m. This arrangement involved a substantial constriction in the natural wadi channel which was about 650m wide prior to the construction of the weir. The weir was constructed in about 1973 and functioned satisfactorily until the major flood of 1982 which bypassed the weir on the left side, damaged the weir and associated works and also washed out about 180ha of farmland. The layout of the intake structures appears to be satisfactory for flow diversion and sediment exclusion.

After the 1983 flood the weir was repaired but the left bank head regulator was closed off and an embankment constructed to connect the left weir abutment to the new left side of the wadi at a location about 1.5km upstream. The closing bunds were aligned either parallel or perpendicular to the flow. In 1989 (flood of 4800m³/s in SELKHOZPROMEXPORT, 1990) the left side embankments were again breached. The layout of the embankments must have increased their vulnerability since they did not smoothly guide the flood flow towards the weir. The weir itself was also damaged with about 50m of weir near to the right head regulator destroyed and part of the head regulator structure damaged. Investigations in 2008 have also revealed that the downstream apron is missing over much of the weir length.

Options for the New Diversion Structure

The Inception Report identified two options for the rehabilitation of Al Hanad weir:
(i). Restoration of the present structure including the right head regulator and sand sluice system with the weir extended towards the left wadi bank where a new intake for the left canal would be constructed. An armoured embankment would be constructed to connect the left abutment with the existing protection works about 1.5km upstream. The right bank of the left main canal would be protected downstream of the intake.
(ii). The existing weir and left intake would be abandoned and the right bank intake rehabilitated. A new left bank intake would be constructed near the left bank. An armoured embankment would be constructed to connect the left abutment with the existing protection works about 1.5km upstream. Instead of a conventional weir, a low guide wall or bed bar would guide water towards the intakes.

Additional options and sub-options have now been identified.
(iii) The inclusion of a breaching section in the weir structure to pass the extreme floods. The breaching section would be designed to be overtopped and washed out during floods greater than the 1 in 10 year (10%) probability, events. This will reduce the discharge passing over the remaining structure.

(iv) Provision of a completely new structure that either does not use the existing right bank intake structure or reconstructs it with a lower sill level. The sill level of the existing right bank intake structure is 39.5m which is 1.5m higher than the adjacent wadi bed and is more than the minimum 0.5m head difference needed for flushing. The weir crest level is intake sill level + intake flow depth = 39.5 + ~1.5 = 41.0m, or 3m above the wadi bed. To create opportunity for a lower height (and less expensive diversion structure) the alternatives are to either use a lower intake sill level or move the diversion structure upstream.

Flood Hydrology

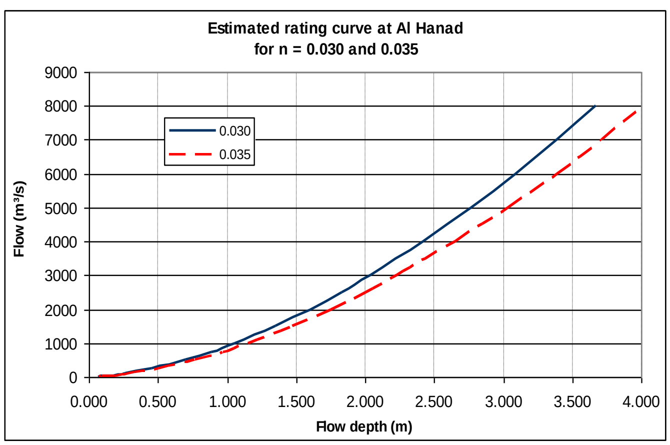
Perhaps the most important parameter for the design of spate diversion structures is the design flood. The summary of the flood frequency results is shown below:

Return Period (years)	Recommended Design Flood (m^3/s)
5	1837
10	2823
25	4102
50	6609
100	7699

Flood Attenuation

It is envisaged that a breaching bund will form part of the proposed works. It is normal practice to design a breaching bund to be overtopped about once per ten years. Problems have been encountered with breaching bunds provided for spate irrigation systems in Eritrea and Pakistan. The problem locations are at or close to the mountains with intense short duration rainfall on the nearby catchment generating floods with peak flows exceeding the design 10% probability flood determined using runoff from the whole catchment.

The observed and estimated flood data for Wadi Ahwar is at Fuad weir, where the wadi is confined with little potential for attenuation of the flood peaks. Therefore consideration has been given to the potential for attenuation of short duration floods in the 7.5km of wider channel between Fuad and Al Hanad weirs where the wadi expands from about 250m width to up to 1km. The total wadi area between the two weirs is about $4.9Mm^2$.



The storage volume up to 0.5m depth would be 2.45 Mm^3 which is larger than the volume of water in a flood peak of $1000m^3/s$ for 30 minutes duration. This suggests there is potential for attenuation of short duration flood peaks and therefore the breaching bund will only be breached by the floods with longer duration. However, in the absence of flood hydrograph data, the design will assume that the flood peaks at Al Hanad weir are the same as at Fuad weir.

Wadi Rating Curve: Assuming that:

- the wadi width is 700m
- the bed slope is 3m/km (0.003)
- the wadi roughness is 0.03
- the wadi channel is trapezoidal

Gives this rating curve which indicates an average wadi flow depth of about 3.5m for the 1% probability flood.

Overall Design Assumptions

The overall width of the diversion structure should be similar to the wadi width before the construction of Al Hanad Weir. The original location plan shows this is 650 to 700m. The vegetation on the Google Earth imagery (2003) indicates that 700m east of the existing right bank intake is just clear of the current main wadi channel. The Lacey width, defined as 4.83 $\sqrt{Q}$, is 423m for the 1% flood event (7699m³/s), which is narrower than the natural width of the channel but about 70% wider than the original weir. Given the uncertainty about the design flood, it would be prudent it minimise reduction of the natural channel width.

The proposed head regulator flows are 35m³/s with water at weir crest level to match the canal flows. The Russian design provided head regulator capacity of 45m³/s with the additional water assumed to be used by the sediment sluice provided in the canal head reach.

The required command level will be that needed to supply the irrigation system and have sufficient head for flushing of sediment at the head regulator.

One option for the proposed new structure is to include a breaching bund. The initial assumption will be that it has sufficient capacity to pass the incremental flow between the 10% and 1% probability (ie 1 in 10 year and 1 in 100 year) floods (ie 4876m³/s). This will mean that the upstream water level for the two events should be similar. However, an intermediate flood event will have a lower upstream water level so a check will be needed that this does not leave the canal intakes without water. If this proves to be a potential problem then the breaching bund could be divided into sections with additional divide walls. This type of diversion structure, with an intake at each end, suffers from the weakness that there is no technical solution to ensure that the incoming flow will pass to both intakes. It is quite likely that the approach flow will favour one side of the wadi. Measures to help ensure that the flow will reach both intakes include (i) flushing of the intake approaches to each intake during medium (>100m³/s) and large floods; and (ii) bulldozer work upstream of the weir to ensure that there is a shallow low flow channel towards each intake combined with a low inverted V-shaped embankment to divert the flows to each side.

The proposed structures will be designed to resist scour. However, the normal Lacey scour formulae may not be appropriate for conditions with high sediment loads and the likelihood of the larger transported sediment acting as armouring of scour holes. Extensive should is not considered to be a risk upstream of weirs. 1.5 x Lacey scour depth is used on the downstream and adjacent to the breaching bund. The structures will not be designed to prevent seepage under the structures (which can result in problems of uplift pressures) but will be provided with filters / drainage to ensure easy passage of seepage water.

The topographic survey indicates an average bed level at the weir centreline of 38.5m.

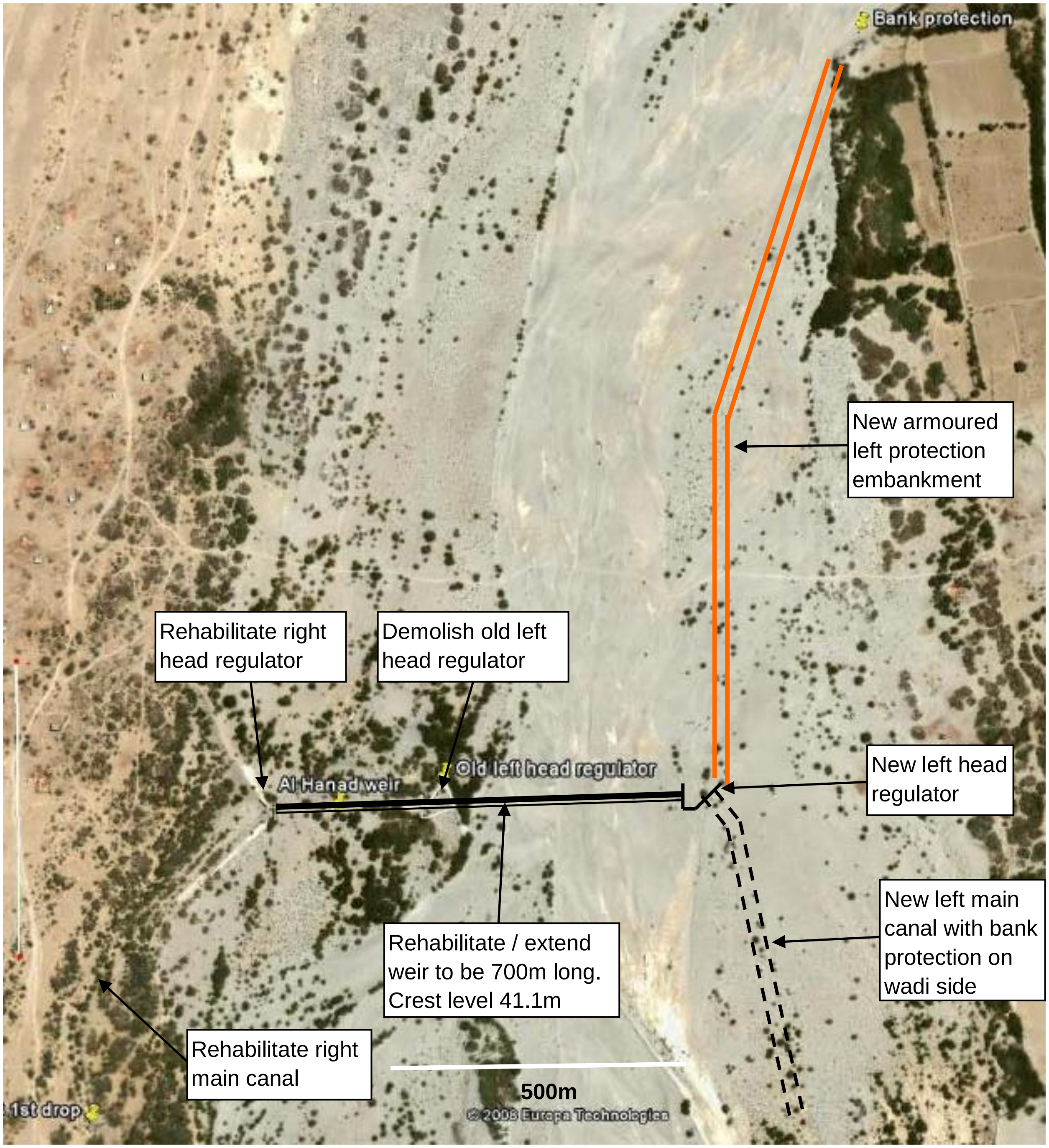
Required Command Level

The original weir had a crest level of 41.1m and head regulator sill levels of 39.5m with a design water level of 41.32m downstream of the canal head regulators (at a design maximum flow of 45m³/s). However, there are substantial drops at the first check structures on the original canal drawings. The original design water levels are 39.7 (left) and 38.6m (right) downstream of the first check structures. The reasons for the higher command level in the original design are not completely certain but may be (i) the inclusion of sediment ejectors in the canal head reaches and (ii) command of some high land from the first check structure on the left main canal. The current design for the Al Hanad left main canal has a required FSL of 39.63m at the start of head reach. This approximates to a required water level of 40.0m on the upstream side of the head regulator and means the design weir crest level can be lower than the original design (provided that the head reach of the right main canal is also lowered).

There are other options for commanding any area of high land on the left bank including: (i) taking water from the Ahwar main canal; (ii) irrigating the land from wells; and (iii) lowering the land down to a commandable level. Option (iii) is attractive since it provides a source of fill for the canal embankment crossing the current wadi channel.

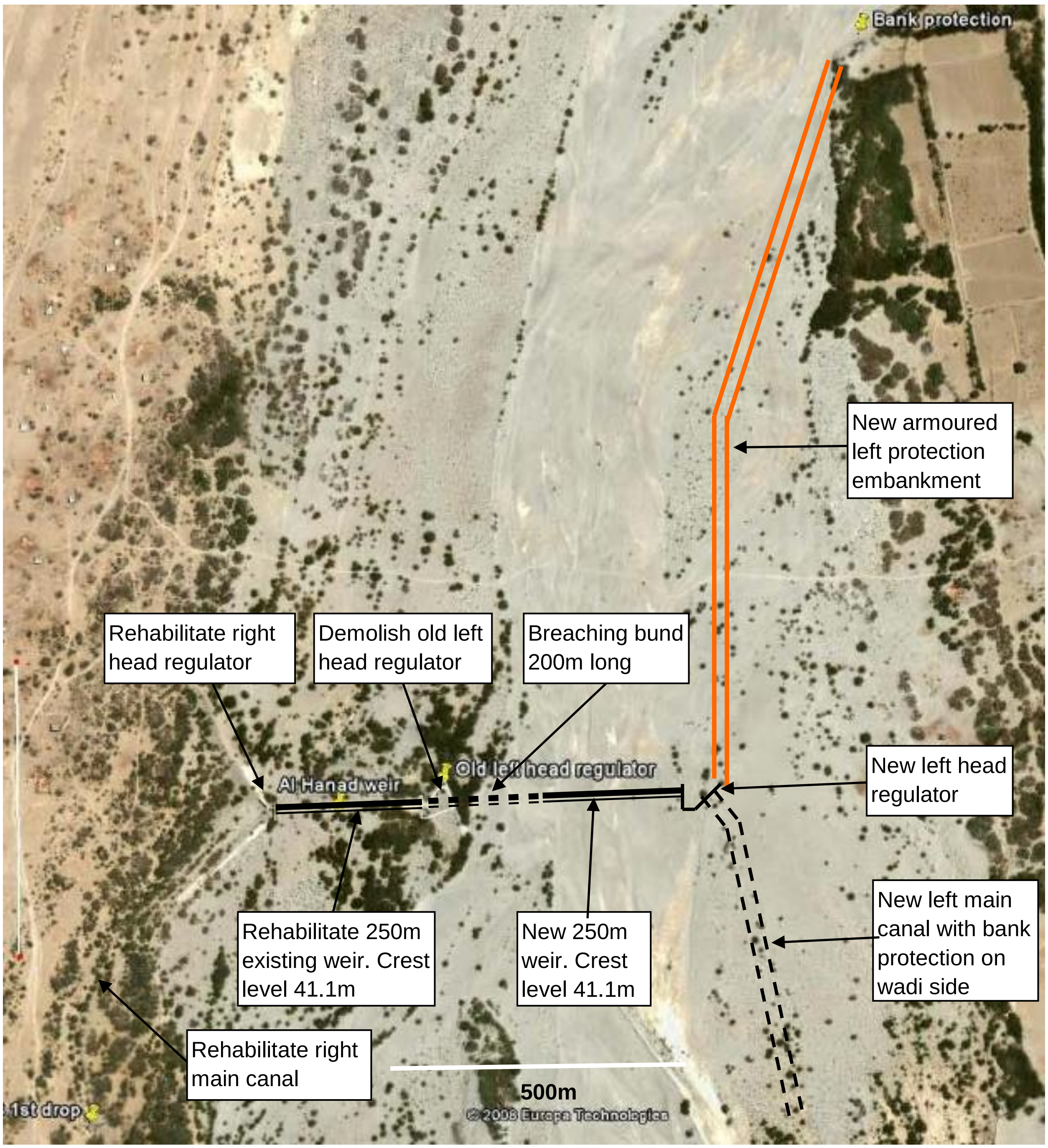
Option 1 Restoration of the present structure including the right head regulator and sand sluice system with the weir extended to 700m total length towards the left wadi bank where a new intake for the left canal would be constructed. The previous weir crest level of 41.1m will be required to command the right canal head regulator.

The estimated water level for the 1 in 10 year flood (~2800m³/s) would be 42.7m and for the 1 in 100 year flood 44.25m. This is a reduction of 0.95m relative to the original design flood level of 45.2m for a smaller maximum unit discharge because of the longer crest length.

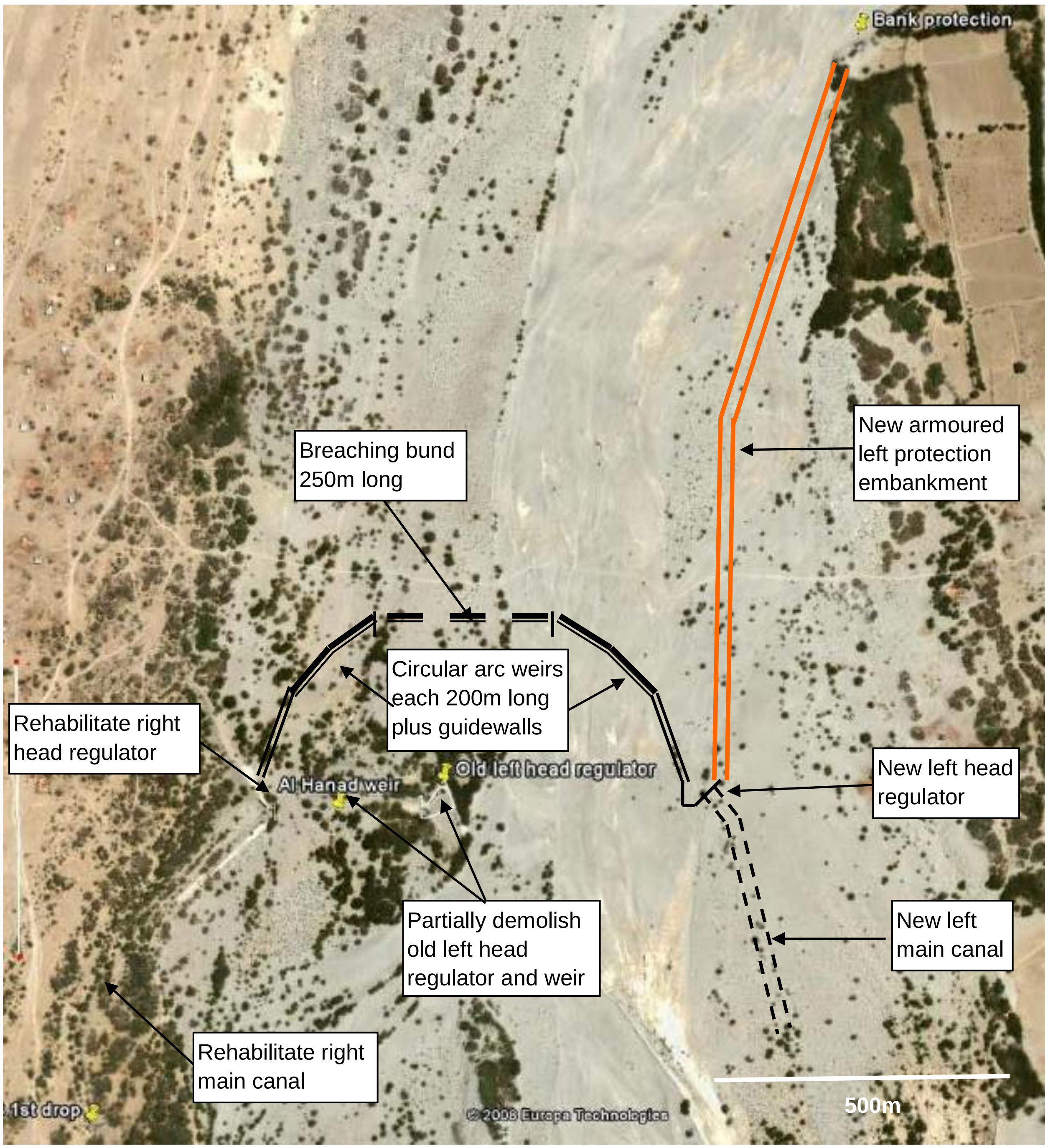

Bank protection
New armoured left protection embankment
Rehabilitate right head regulator
Demolish old left head regulator
Al Hanad weir
Old left head regulator
New left head regulator
New left main canal with bank protection on wadi side
Rehabilitate / extend weir to be 700m long. Crest level 41.1m
Rehabilitate right main canal
1st drop
500m
© 2008 Europa Technologies

Option 2 Restoration of the present structure including the right head regulator and sand sluice system with the weir, including a breaching centre section, extended towards the left wadi bank where a new intake for the left canal would be constructed. The previous weir crest level of 41.1m will be required to command the right canal head regulator. The breaching bund would be relatively short in this configuration.

The estimated water level for the 1 in 10 year flood (~2800m³/s) would be 43.05m. The flow through a 200m wide breach, with an upstream water level of about 43.05m (based on channel flow through the breach using Manning's equation for the wadi bed slope is approximately the difference (4876m³/s) between the 1% and 10% probability floods. The highest water level, for a short duration, would be just before the bund breaches.

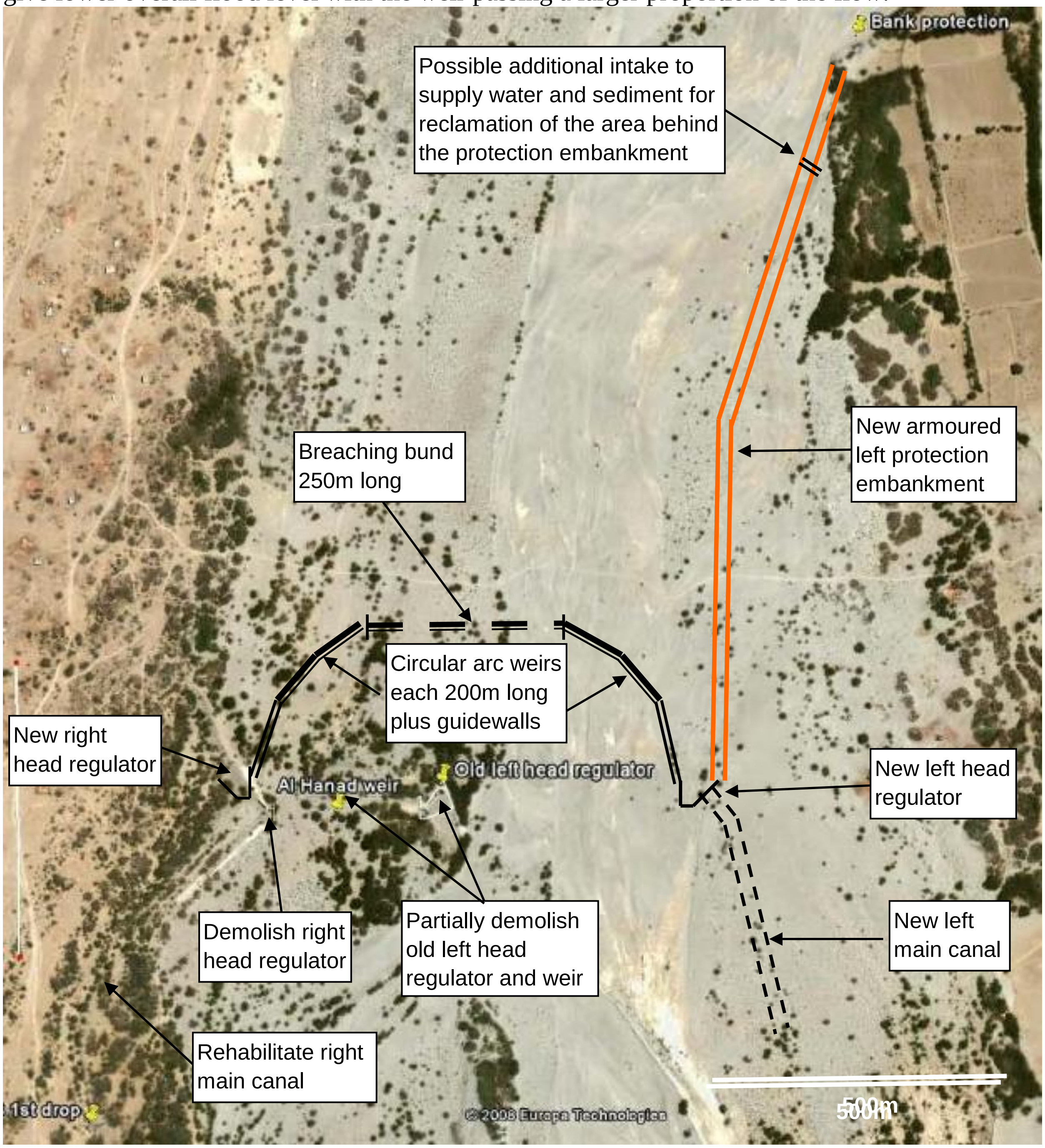


Option 3 New circular arc weirs and a central breaching bund would be provided upstream of the existing structure. The existing weir and left intake would be abandoned and demolished down to wadi bed level. The right bank intake rehabilitated. This configuration provides space for a longer breaching bund. However, the previous weir crest level of 41.1m will be required to command the right canal head regulator.
The estimated water level for the 1 in 10 year flood (~2800m³/s) would be 43.45m. When the breaching bund has breached then the maximum water levels will drop, with an upstream water level of about 43.1m based on channel flow through the breach using Manning's equation for the wadi bed slope (the hydraulic slope will be greater but offset by turbulence losses). The longer breach opening offset the higher bed level relative to option 2.

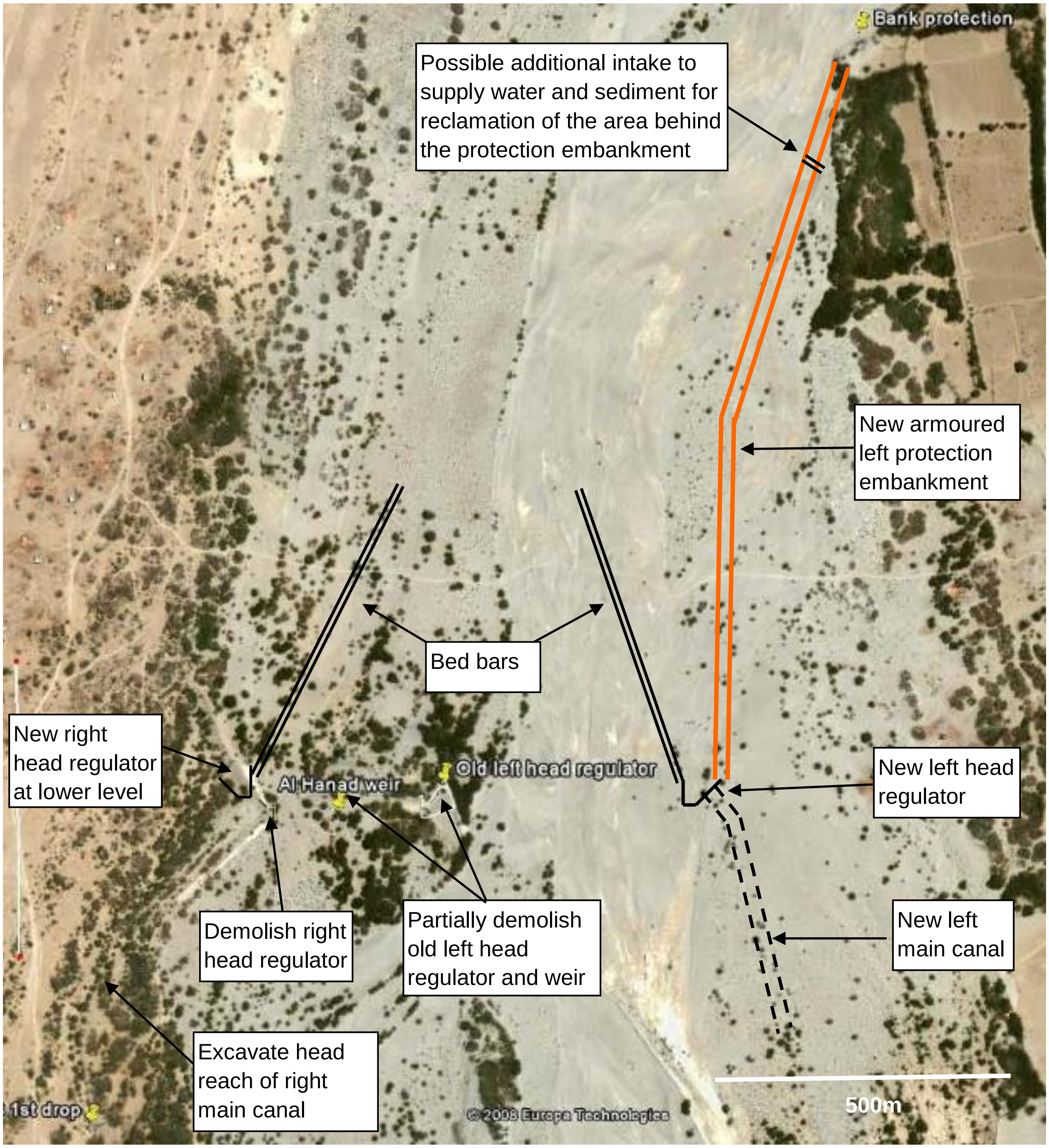


Option 4 The existing weir and both intakes would be abandoned and demolished down to wadi bed level. This will enable use of a lower design weir crest level (40.0m) which is sufficient to enable flushing at the head regulators and command the canals. New diagonal weirs and a central breaching bund would be provided. A new right canal head regulator would be constructed slightly west of the current structure.

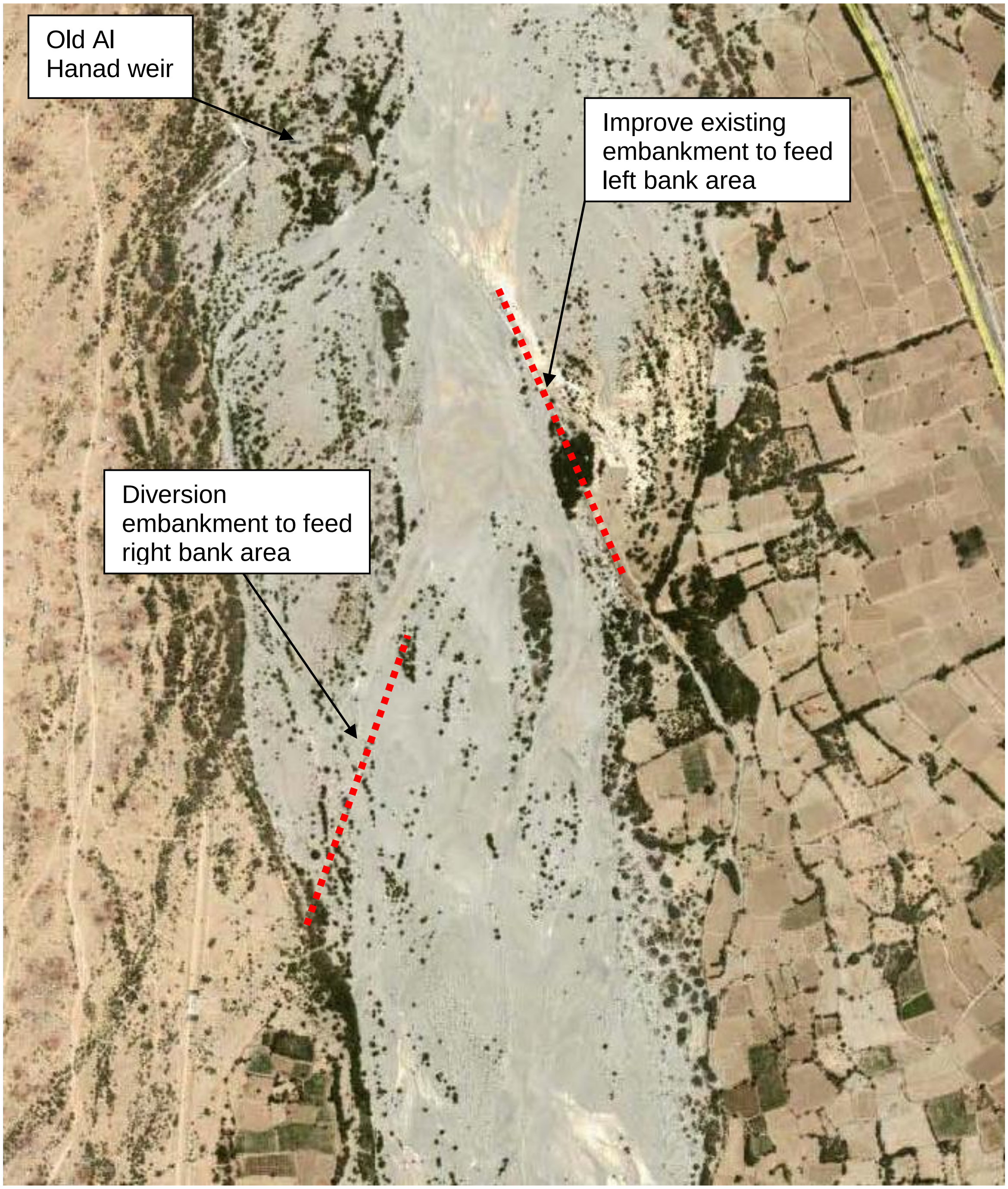
The estimated water level for the 1 in 10 year flood (~2800m³/s) would be 42.4m. The estimated water level for the 1 in 100 year flood would be about 42.5m based on channel flow through the breach using Manning's equation for the wadi bed slope (the hydraulic slope will be greater but offset by turbulence losses). The lower weir crest level relative to option 3 will give lower overall flood level with the weir passing a larger proportion of the flow.



Option 5 This option would comprise separate bed bars to divert water towards each intake. However, for this to work the intakes would need to be (re)constructed at a lower level. The main uncertainty of this layout would be the sharing of the flow between the two intakes. It is likely that regular temporary earthworks would be required to direct the water towards the intakes and maintain a satisfactory sharing of the flow. The flow management would be easier if the intakes were staggered, with the right bank intake further downstream. However, this would inherently give the left bank priority, which may not be acceptable to the farmers on the right bank. This option is unlikely to meet the beneficiaries' expectations and has not been studied further.



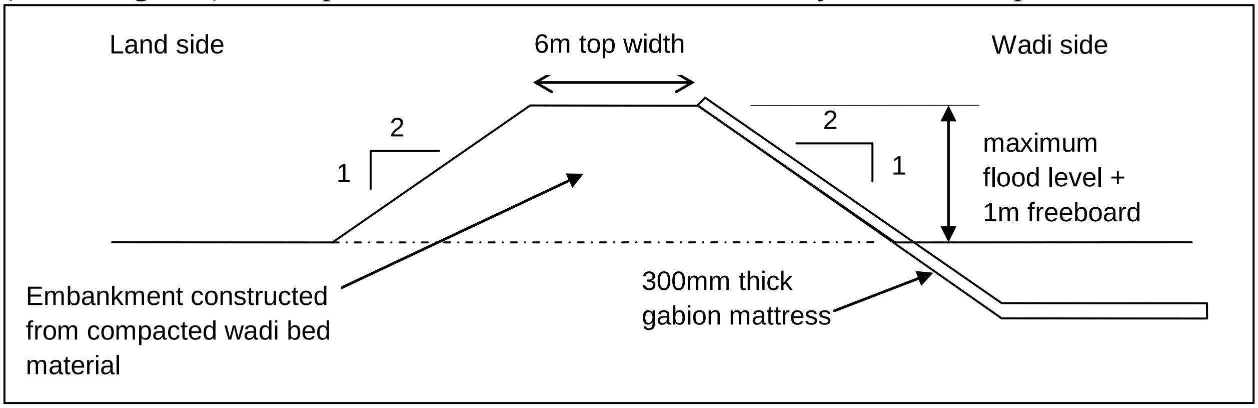
Option 6 This option involves no new engineered infrastructure and would rely on temporary embankments created by bulldozer to divert the flows. The investment cost would be much lower than with an engineered solution, but the efficiency in diverting floods would also be reduced. Large volume long duration floods would tend to break through the embankments and pass downstream. Also, any floods with a peak large enough to breach the embankments will result in loss of water until the embankments are reinstated.If the water reaches the sea then it is no longer available for either irrigation or grounwater recharge. This is why the farmers see a more robust, engineered, solution.



The Left Bank Protection Embankment

The left bank protection embankment is common to all options although the length may vary according to the location of the left head regulator. This embankment will need to be sufficiently large and well protected to avoid the risk of breaching in the future. A minimum freeboard of 1m above the estimated 1% flood level is proposed.

It is proposed that the embankment is constructed from compacted excavated wadi bed material (sand and gravel). The top width will be sufficient to enable easy access for inspection.



The embankment will need to be protected against scour. Spurs are the least expensive form of protection. However, spurs may adversely affect the approach flow conditions for the weir and are therefore not recommended so revetment is the alternative. It is recommended to provide gabion mattress protection for the whole length of the embankment. The toe of the protection should be buried within the wadi bed so that it needs to bend less in response to scour.

Provision is made for five ungated culverts 1m x 1m through the upstream part of the embankment to pass flood flows into the area behind the embankment to (i) deposit sediment for gradual conversion to productive land and (ii) provide recharge to groundwater.

Summary of Levels

	Option 1	**Option 2**	**Option 3**	**Option 4**
Design weir crest level	41.1m	41.1m	41.1m	40m
1 in 10 year flood level	42.7m	43.05m	43.45m	42.4m
1 in 100 year flood level	44.25m	43.05m	43.1m	42.5m
Design embankment level (d/s end)	45.25m	44.05m	43.45m	43.5m

Technical Comparison of Options

Options 1 and 2 reuse the existing weir and right bank head regulator. The design weir crest level will be the same as existing but the flood water level will be lower because of the longer weir crest / breaching section and therefore energy dissipation requirements will be less onerous than for the original design. Option 1 would reduce the maximum flood level (1 in 100 year event) from 45.2m for the original design to 44.25m while passing a larger design flood. However, substantial repairs will be required to the original weir structure. About 55m adjacent to the right bank head regulator has been washed out completed and the intermediate basin and downstream protection is missing over most of the weir except for about 50m adjacent to the left abutment.

Option 3 proposes a new weir located upstream. The proposed layout provides more space for the weirs and a long breaching section while moving upstream which will slightly reduce the height of the weir relative to the wadi bed level. The overall concept layout is based on the Al Afiyah - Al Fakih weir on Wadi Tuban which has performed satisfactorily.

Al Afiyah - Al Fakih weir

Option 4 takes advantage of the lower canal command levels made possible by the updated design for the new left main canal. The head reach of the right main canal can also be lowered without affecting the command of the irrigated area although the first check structure will need to be rebuilt. Lower canal command levels enables the weir crest to be lower enabling lower structure cost, reduced energy dissipation and lower maximum flood levels (and therefore lower left protection embankment).

However, it will be no longer feasible to use the (rehabilitated) right main canal head regulator without modification. There are two options for the right head regulator: (i) Break out the floor of the existing structure and construct a new floor at a lower level; and (ii) to build a new structure to the west of the existing structure. The former can enable retention of the existing revetment and intake geometry and possibly the right head regulator abutment (reduced to a lower height). It should also be possible to re-use foundations and some walls. The overall structure layout is hydraulically satisfactory. The latter would use a new site, but it will be necessary to demolish the existing structure down to the foundation level to avoid any disturbance to the flow. Re-use of the existing structure is therefore considered preferable.

Hydraulic Design

Options 1 and 2 would adopt the existing weir design so that the existing structure can be reused where possible. The longer weir length will reduce the unit discharge and reduce the risk of future damage during major floods.

Other configurations were considered for layout of the weirs for options 3 and 4. Straight oblique weirs were initially considered but may cause flow disturbance where there are changes in direction. Therefore, it is proposed to provide weirs which are circular arcs in plan. These offer the advantage of more gradual changes in flow conditions with higher discharge coefficients near the centre of the wadi and lower discharge coefficients near the sides so more of the diverted water will flow towards the intakes while the main wadi flow will be concentrated towards the centre of the channel.

Options 3 and 4 use a simple stilling basin with baffle blocks to shorten the length, based on the ARS stilling basin design. However, the overall hydraulic situation means that the lower weir height of option 4 does not result in a corresponding reduction in stilling basin length and structure cost. In addition, to the weir for options 3 and 4 has been provided with an innovative crest configuration to increase turbulence and energy dissipation.
Sluiceway Structures

Larger sluiceways facilitate more effective flushing during larger floods, not only to clear sediment from in front of the canal intake but also to help form an approach channel to the intake. It is proposed to provide flow capacity of at least 50% of the head regulator capacity. The left bank sluiceway will be new construction while the right bank sluiceway requires reconstruction since the divide wall between the weir and the sluiceway is partly collapsed.

It is proposed that there will be no breast walls on the sluiceways. This will enable weir flow over the gates if the gates are closed, and will substantially increase the flow capacity during high floods when the gates are open. The risk of blockage by trash will be substantially reduced.

Structural Design

Options 1 and 2 re-use most of the existing weir. It is therefore proposed that the additional weir will be of similar construction with plain concrete and some masonry. Use of reinforced concrete for the new construction would substantially increase the cost of the weir while the reused section of old weir would remain as the original, potentially weaker, design. The length of the downstream protection would be increased relative to the original design.

The proposed weir design for options 3 and 4 would use a reinforced concrete base slab with a masonry weir and masonry lining to the basin. Reinforced concrete baffle blocks will be provided with steel angle protection of all exposed edges.

Demolition Requirements

As a minimum the following demolition works should be undertaken to reduce the impact of the existing structures on the wadi flood flows:
Remove the weir structure down to the level of 37m
Remove the left bank intake down to the level of 37m
Demolish the existing sluiceway of the right bank intake
Demolish the upstream apron of the existing right bank intake

Stone arising from the demolition can be reused and broken concrete can be used to supplement the scour protection.

Quantities and Costs

Preliminary estimates of quantities and costs have been prepared for each option. The most accurate estimate is for option 3 with adjustments made for the different scope of works of the other options.

		Amount (USD)			
Bill No.	Description	Option 1	Option 2	Option 3	Option 4
A	Preliminary and General Items	74,000	74,000	74,000	74,000
B	Weir	2,302,800	1,838,050	2,681,520	2,574,270
C	Divide Walls and Breaching Bund	N/A	341,140	341,140	341,140
D	Left Canal Head Regulator	928,350	883,750	859,600	859,600
E	Right Canal Head Regulator	346,420	339,370	339,370	749,150
F	Left Protection Embankment	1,653,674	1,442,133	1,449,099	1,212,756
G	Day works	79,310	79,310	79,310	79,310
	Contingencies and minor items (10% of Bills B - F)	523,124	484,444	567,072	573,691
	Total (US$)	**5,907,679**	**5,482,197**	**6,391,112**	**6,463,917**

The basis for the cost adjustments is:

- (i) Preliminary and General items is the same for all options
- (ii) The weir for options 1 and 2 is calculated based on the original design and the estimated extent of reconstruction. The cost for option 4 is slightly reduced from option 3 because of the lower weir crest.
- (iii) The cost of divide walls and breaching bund (and associated protection) is the same for all options except option 1, where it is not provided.
- (iv) The left head regulator is the same for options 3 and 4 but costs increase for options 1 because of the higher design flood level.
- (v) The works at the right head regulator are the same for options 2 and 3. Option 1 is slightly more expensive because of the higher design flood level and option 4 is substantially more expensive because of the reconstruction to a lower canal invert level.
- (vi) The volumes for the left protection embankment are calculated assuming the same top level at the upstream end but with the downstream top level 1m above the estimate maximum flood level (highest for option 1 which has no breaching bund).

Evaluation of Options

It can be seen that the least cost option is option 2. However, this option has two technical weaknesses: (i) It re-uses part of the existing weir which is already over 30 years old; and (ii) significant temporary earthworks may be required to split the upstream flow between the two intakes (a weakness shared with option 1).

Options 3 and 4 use a new weir with a reinforced concrete base and should prove to be more durable. The layout will facilitate sharing of the flow. While option 4 provides a significant saving on the left protection embankment and a small reduction in weir cost, these savings are more than offset by the cost of modifying the right bank intake to have a lower sill level and also lowering of the head reach of the right main canal. **Option 3** is therefore recommended as the preferred option.

Cost Estimate for Option 3:

	Grand Summary				
Bill No.	**Description**			**Page**	**Amount (USD)**
A	Preliminary and General Items				74,000
B	Reconstruction of Al Hanad Weir				2,681,520
C	Divide Walls and Breaching Bund				341,140
D	Left Canal Head Regulator				859,600
E	Right Canal Head Regulator				339,370
F	Left Protection Embankment				1,449,099
G	Day works				79,310
	Total				**5,824,039**

Bill A: Preliminary and General Items

<table>
<tr><th rowspan="2">Item No.</th><th rowspan="2">Description</th><th rowspan="3">Unit</th><th rowspan="3">Qty</th><th colspan="2">US$</th></tr>
<tr><th rowspan="2">Rate</th><th rowspan="2">Amount</th></tr>
<tr><td></td><td>Contractor's Requirements</td></tr>
<tr><td>1</td><td>Performance Bond</td><td colspan="4" rowspan="13">These items are deemed to be included in the Contractor's unit prices</td></tr>
<tr><td>2</td><td>Advance Payment Guarantee</td></tr>
<tr><td>3</td><td>Insurances</td></tr>
<tr><td>3.1</td><td>Loss or damage to Works, Plant and Materials</td></tr>
<tr><td>3.2</td><td>Loss or damage to equipment</td></tr>
<tr><td>3.3</td><td>Loss or damage to property in connection with the Contract</td></tr>
<tr><td>3.4</td><td>Personal injury or death</td></tr>
<tr><td>4</td><td>Mobilization of plant, staff and equipment</td></tr>
<tr><td>5</td><td>Contractor's camp</td></tr>
<tr><td>5.1</td><td>Camp establishment (Offices, messes, workshops, stores and all other facilities for the Contractor), maintenance and removal</td></tr>
<tr><td>6</td><td>Demobilization of plant, staff and equipment</td></tr>
<tr><td>7</td><td>Signboards</td></tr>
<tr style="display:none"></tr>
<tr><td></td><td>Project Manager's Requirements</td><td></td><td></td><td></td><td></td></tr>
<tr><td>8</td><td>Provide office and furniture for Project Manager as per specification</td><td>month</td><td>18</td><td>1000</td><td>18000</td></tr>
<tr><td>9</td><td>Hand over office and equipment upon completion of contract</td><td>sum</td><td>1</td><td>20000</td><td>20000</td></tr>
<tr><td>10</td><td>Provide, operate and maintain vehicle for Project Manager as per specification</td><td>month</td><td>18</td><td>1500</td><td>27000</td></tr>
<tr><td>11</td><td>Provide services for Project Manager's Office</td><td>month</td><td>18</td><td>500</td><td>9000</td></tr>
<tr><td></td><td colspan="4">Total for Bill A</td><td>74,000.00</td></tr>
</table>

Bill B New Al Hanad Weir

Item No.	Description	Unit	Qty	US$	
				Rate	Amount
B.1	Site clearance and removal of top soil to maximum depth of 15 cm and disposal for haul distance within 500m.	m²	30000	0.9	27,000
B.2	Demolish existing masonry and remove materials to stockpile or disposal within haul distance of 500m	m³	1000	13	13,000
B.3	Break out unreinforced concrete and disposal for haul distance within 500m	m³	5000	27	135,000
B.4	Break out reinforced concrete and disposal for haul distance within 500m	m³	200	46	9,200
B.5	Filling with selected material from borrow pits within haul distance 500m, including compaction	m³	2000	4.6	9,200
B.6	Excavation in wadi bed and bank and disposal for haul distance within 500 m.	m³	18000	3.4	61,200
B.7	Provide and place blinding concrete of grade 7.5/20	m³	700	80	56,000
B.8	Provide and place reinforced concrete of grade 30/20	m³	4000	335	1,340,000
B.9	Provide and place squared rubble coursed masonry	m³	3500	80	280,000
B.10	Provide and place random rubble uncoursed masonry	m³	2000	61	122,000
B.11	Provide and place plum concrete of grade 20/40	m³	800	85	68,000
B.12	Supply, weld and fix 50 x 50 x 5 steel angle protection to blocks	m.l	6000	5.6	33,600
B.13	Provide and place granular filter material	m³	250	16	4,000
B.14	Provide and place weep hole pipes	m.l	300	13	3,900
B.15	Provide and install geotextile fabric (filter cloth)	m²	6600	3.7	24,420
B16	Provide and install linked concrete slabs 1 x 1 x 0.25 m grade 20/40	No.	6600	75	495,000
	Total for Bill B				**2,681,520**

Bill C: Divide Walls and Breaching Bund

Item No.	Description	Unit	Qty	US$	
				Rate	Amount
C.1	Site clearance and removal of top soil to maximum depth of 15 cm and disposal for haul distance within 500m.	m²	4000	0.9	3,600
C.2	Excavation in wadi bed and bank and disposal for haul distance within 500 m.	m³	12000	3.4	40,800
C.3	Filling with selected material from borrow pits or stockpile within haul distance 500m, without compaction	m³	2000	3.5	7,000
C.4	Provide and place plain concrete of grade 20/40	m³	260	110	28,600
C.5	Provide and place plum concrete of grade 20/40	m³	800	85	68,000
C.6	Provide and place squared rubble coursed masonry	m³	250	80	20,000
C.7	Provide and install geotextile fabric (filter cloth)	m²	2200	3.7	8,140
C.8	Provide and install linked concrete slabs 1 x 1 x 0.25 m grade 20/40	No.	2200	75	165,000
	Total for Bill C				**341,140**

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Bill D: Left Canal Head Regulator

Item No.	Description	Unit	Qty	US$	
				Rate	Amount
D.1	Site clearance and removal of top soil to maximum depth of 15 cm and disposal for haul distance within 500m.	m²	1500	0.9	1,350
D2	Excavation in wadi bed and bank and disposal for haul distance within 500 m.	m³	1000	3.4	3,400
D.3	Filling with selected material from borrow pitswithinhauldistance500m,include compact	m³	5000	4.6	23,000
D.4	Demolish existing masonry and remove materials to stockpile or disposal within haul distance of 500m	m³	1700	13	22,100
D.5	Break out unreinforced concrete and disposal for haul distance within 500m	m³	800	27	21,600
D.6	Break out reinforced concrete and disposal for haul distance within 500m	m³	350	46	16,100
D.7	Provide and place blinding concrete of grade 7.5/20	m³	100	80	8,000
D.8	Provide and place plain concrete of grade 20/40	m³	650	110	71,500
D.9	Provide and place reinforced concrete of grade 30/20	m³	300	335	100,500
D.10	Provide and place squared rubble coursed masonry	m³	750	80	60,000
D.11	Provide and place random rubble uncoursed masonry	m³	750	61	45,750
D.12	Provide and install linked concrete slabs 1 x 1 x 0.25 m grade 20/40	No.	1500	75	112,500
D.13	Hand placed grouted stone pitching	m³	400	40	16,000
D.14	Provide and install geotextile fabric (filter cloth)	m²	10000	3.7	37,000
D.15	Provide and install gabion mattress(0.3m thick) filled with stones	m³	3000	58	174,000
D.16	Steel handrails, complete	m.l	100	28	2,800
D.17	Supply and install radial gate 3m wide x 1.5m high	No.	9	10000	90,000
D18	Supply and install complete lifting gear for radial gate	No.	9	6000	54,000
	Total for Bill D				**859,600**

Bill E: Right Canal Head Regulator

Item No.	Description	Unit	Qty	US$	
				Rate	Amount
E.1	Demolish existing masonry and remove materials to stockpile or disposal within haul distance of 500m	m³	500	13	6,500
E.2	Break out un reinforced concrete and disposal for haul distance within 500m	m³	350	27	9,450
E.3	Break out reinforced concrete and disposal for haul distance within 500m	m³	120	46	5,520
E.4	Excavation in wadi bed and bank and disposal for haul distance within 500 m.	m³	500	3.4	1,700
E.5	Filling with selected material from borrow pits within haul distance 500m, including compaction	m³	1000	4.6	4,600
E.6	Provide and place plain concrete of grade 20/40	m³	250	110	27,500
E.7	Provide and place reinforced concrete of grade 30/20	m³	100	335	33,500
E.8	Provide and place squared rubble coursed masonry	m³	300	80	24,000
E.9	Provide and place random rubble un coursed masonry	m³	300	61	18,300
E.10	Hand placed grouted stone pitching	m³	250	40	10,000
E.11	Supply, weld and fix 50 x 50 x 5 steel angle protection to blocks	m^3	500	5.6	2,800
E.12	Provide and install geotextile fabric (filter cloth)	m²	1000	3.7	3,700
E.13	Provide and install linked concrete slabs 1 x 1 x 0.25 m grade 20/40	No.	1000	75	75,000
E.14	Steel handrails, complete	m.l	100	28	2,800
E.15	Supply and install radial gate 3m wide x 1.5m high	No.	3	10000	30,000
E.16	Repair and reuse radial gate 3m wide x 1.5m high	No.	6	5000	30,000
E17	Supply and install complete lifting gear for radial gate	No.	9	6000	54,000
	Total for Bill E				**339,370**

Bill F: Left Protection Embankment

Item No.	Description	Unit	Qty	US$	
				Rate	Amount
F.1	Site clearance and removal of top soil to maximum depth of 15 cm and disposal for haul distance within 500m.	m^2	42,977	0.9	38,679
F.2	Filling with selected material from borrow pits within haul distance 500m, including compaction	m^3	134,214	4.6	617,383
F.3	Excavation in wadi bed and bank and disposal for haul distance within 500 m.	m^3	17,500	3.4	59,500
F.4	Provide and install geotextile fabric (filter cloth)	m^2	31,687	3.7	117,240
F.5	Provide and install gabion mattress (0.3m thick) filled with stones	m^3	9,506	58	551,347
F.6	Provide and place plain concrete of grade 20/40	m^3	120	110	13,200
F.7	Provide and place squared rubble coursed masonry	m^3	270	80	21,600
F.8	Provide and place reinforced concrete of grade 30/20	m^3	90	335	30,150
	Total for Bill F				**1,449,099**

Bill G: Dayworks

Item No.	Description	Unit	Qty	US$	
				Rate	Amount
G.1					
G.1.1	Unskilled worker	Day	100	6.6	660
G.1.2	Skilled mason	Day	200	15	3000
G.1.3	Skilled concrete mixer	Day	100	14	1400
G.1.4	Skilled block layer	Day	50	14	700
G.1.5	Skilled reinforcement fixer	Day	50	14	700
G.1.6	Skilled carpenter	Day	50	14	700
G.1.7	Skilled welder	Day	50	17	850
G.1.8	Skilled mechanic	Day	50	17	850
G.1.9	Driver	Day	50	14	700
G.1.10	Operator for excavator, loader, etc	Day	100	18	1800
G.1.11	Operator for tractor, crane	Day	100	18	1800
G.1.12	Operator for roller, dumper	Day	50	18	900
	Total for Bill No. G 1.1				**14,060.00**

Bill G: Day works

Item No.	Description	Unit	Qty	US$	
				Rate	Amount
G.2	**Schedule of Rates – 2: Materials**				
G.2.1	Ordinary Portland cement in bags of 50 kg weight	Ton	20	159	3180
G.2.2	Sulfate resistant cement in bags of 50 kg weight	Ton	10	207	2070
G.2.3	Sand	m^3	100	11	1100
G.2.4	Aggregate	m^3	100	13	1300
G.2.5	High yield steel reinforcement bars 20mm	Ton	5	1000	5000
G.2.6	Bituminous paint	Kg	50	4.1	205
G.2.7	Stones from Quarries	m^3	200	20	4000
G.2.8	Gabion crates (1.0 m depth)	M^3	200	28	5600
G.2.9	Gabion mattress (0.3m thick)	M^3	200	46	9200
G.2.10	Gabion mattress (0.5m thick)	M^3	100	37	3700
G.2.11	Filter cloth (Geotextile Fabric)	M^2	1000	2.8	2800
G.2.12	Mild steel reinforcement bars 12mm dia	Ton	5	954	4770
	Total for Bill No. G 1.2				**42,925.00**

Bill G: Day works

Item No.	Description	Unit	Quantity	US$	
				Rate	Amount
G.3.	**Schedule of Rates- 3. Construction Plant**				
G.3.1	Four wheel drive double-cab pickup	hr	100	8.3	830
G.3.2	Flatbed truck (3 tons)	hr	50	11	550
G.3.3	Tipper truck (7 tons)	hr	100	17	1700
G.3.4	15 tons crane	hr	100	28	2800
G.3.5	Tractor	hr	50	21	1050
G.3.6	Front-End loader	hr	100	25	2500
G.3.7	Back-Hoe loader	hr	50	34	1700
G.3.8	10T vibrating roller	hr	100	28	2800
G.3.9	Dumper	hr	50	11	550
G.3.10	Welding Machine	hr	100	3.4	340
G.3.11	Vibrator	hr	50	4.1	205
G.3.12	Water tanker (10 tons)	hr	100	17	1700
G.3.13	Air compressor	hr	50	28	1400
G.3.14	Grader	hr	50	28	1400
G.3.14	Bulldozer, minimum 180HP	hr	100	28	2800
	Total for Bill No. G 1.3				**22,325.00**

3.2 Design of Hanad Left Bank Main canal

The upper reach of the canal and two check structures were constructed during the construction of the main Hanad weir by Russians. During the flood of 1983 the river outflanked the weir through the left bank and destroyed the upper reach of the canal including check structure no one. Check no 2 is still present. No structure exists downstream of check 2, though canal exists in some reaches. The alignment and location of proposed new canal check structures and intake details were fixed by PIU and the Ambasti Water User Group.

Canal structures

All off-take structures on the canal are provided with box culvert type to allow O&M traffic over the canal banks. No distributory canals are required. The water will be directly going to the farmers land and they will manage the conveyance to indivijual plots.

Out of the 12 /Control/check structures in the main canal, three are provided with road crossing. The three structures will be combined with a vehicle bridge. The remaining check structures are provided with footbridges.

The table below presents the location of check structures and name, location & size of off-take structures.

Hanad left main canal-List of off take structure

Check structure No	Off-take name	Location on embankment bank	Command Area(feddan)	Design Discharge (m³/sec)	Off take size(m)
check no1 at +550	Ali binsayeed	Rightch0+50	30	1.5	1x1.5x1
	Salem Tami	Left ch o+50	60	2.5	1x1.5x1
Check no 2 at1+400	Ba fawas	Rightch1+33	40	2	1x1.5x1
	Bure sayani	Leftach1+33	90	4	2x1.5x1
Check no 3 at1+675	Asssadi	Rightach1+63	30	1.5	1x1.5x1
	Shahabi	Leftach1+63	280	12	4x1.5x1
Check no 4 at 2+275	Arafa	Right ch2+23	15	1	1x1.5x1
	Saediat	Leftch2+23	180	7.5	3x1.5x1
Check no 5 at2+600	Alarefa	Left ch2+55	140	6	3x1.5x1
Check no6 at 3+200	Almahalla	Rightch3+150	30	1.5	1x1.5x1
	Ambasti Branch canal	Rightch 3+160	180	7.5	3x1.5x1
Check no 7 at 3+700	Delserab	Leftch3+65	150	6	3x1.5x1
	Masab	Right	60	2.5	1x1.5x1
Check no8 at 4+350	Al junaid	Leftch 4+30	130	6	3x1.5x1
Check no 9 at 4700	Almasabi	Leftch4+65	250	10	4x1.5x1
Check no 10 at 5+425	Bakumasi	Right5+33	130	6	3x1.5x1
	Gaimah	Right5+38	250	10	4x1.5x1
Check no11 at 6+050	Alwazari	Leftch 5+95	120	5	2x1.5x1
	Alwazari	Rightch 5+95	120	5	2x1.5x1
	Kazemah	Left6+00	60	2.5	1x1.5x1
	Kazemah	Rightch 6+00	60	2.5	1x1.5x1
Check no12 ch 6+700	Bart al Awazi	Right ch6+65	60	2.5	1x1.5x1
	Ba Haroon	Left ch6+65	160	7	3x1.5x1
Check1(+200) Ambosti branch canal	Al rawhwi	Rightch+150	70	3	2x1.5x1
	Al rawhwi	Leftch+150	70	3	2x1.5x1
Check2(+900) Ambasti branch canal	Al rawhwi	Rightch0+850	20	1	1x1.5x1
	Al rawhwi	Left+850	20	1	1x1.5x1

The design details of the canal, the check and off-take structures are shown in the Album of Drawings no.

IIP/A/1201, 1202, 1203, 1204, 1205, 1206, 1207, 1208, 1209, 1210, 1300, 1301, 1302, 1303, 1304, 1305, 1306, 1307, 1308, 1309, 1310, 1311, 1312, 1400, 1401, 1402, 1403,1404,1405,1406,1407,1408.

3.3 Rehabilitation of Hanad right bank main canal system

Hanad right bank canal were eroded in the upstream reach during flood of 1989 and were reconstructed during 1990 with two new check structures. But the work could not be completed and the new main canal could not be connected to the old main canal as the donor Russians ceased to work. Thus the two new main checks need rehabilitation. Further downstream of Ahwar Aden road, there are 4 check structures on the old main canal which need rehabilitation.

A 500m length of canal needs to be constructed to connect the new main canal with the old main canal for the operation of this canal system. The section of the canal should be the same of the existing canal section at the start off the proposed connecting canal.

As per the list supplied by PIU Ahwar and Water User Groups the design of the rehabilitation woks for the following structures has been completed. The list and detail information/cut off statement of structures of this System were not available with PIU Ahwar or in Aden office.

Rehabilitation of check 1 and 2

Check no 1 needs three gates: 2 on the main check and one on the intake on left bank.

Check no 2 needs two gates on the main check and two gates on the existing off-take on the left bank.

On the right bank, the box type off-take was not completed, only the foundation was done. The required reinforced concrete works have been provided in the cost to complete the box off-take and to provide two gates on them. The details are shown in the Album of Drawings.

Rehabilitation of Control Structures/drops

The rehabilitation of 4 drop structures downstream of Aden road on the old reach of main canal have been provided in the Album of Drawings. The detailed information of the structures to be rehabilitated and drawing numbers are given in the following table:

Hanad Right Main canal (HRMC) Rehabilitation of Structures

Name of canal	Name & location of structure	Existing condition	Required rehabilitation	Justification for rehabilitation	Drawing no
HRMC	Control structure no1	Concrete structure in good condition	Gates on check & left offtake required	Gates required for proper operation of the structure	IIP/A/1504, 1505
HRMC	Control structure no2	Concrete structure in good condition	Gates on check, left & right offtake required	Gates required for proper operation of the structure	IIP/A/1504, 1505
HRMC	Control structure no3/drop	Piers broken no gates exist	Piers and gate provided	Without gate farmer put earthen bund	IIP/A/1501, 1502, 1503
HRMC	Control structure no4/drop	Piers broken no gates exist	Piers, slab and gates provided	Without gate farmer put earthen/tree bund	IIP/A/1501, 1502, 1503
	Control structure no5/drop	No gates exist for operation	Piers, slab and gates provided	Without gate farmer put earthen/tree bund	IIP/A/1501, 1502, 1503
HRMC	Control structure no5/drop	No gates exist for operation	Piers, slab and gates provided	Without gate farmer put earthen/tree bund	IIP/A/1501, 1502, 1503

4. DETAIL DESIGN OF DIFFERENT COMPONENTS OF FUAD WEIR IRRIGARION SYTEM

4.1 Design of off take of secondary canal P1 and P13

As per the requirement of TOR, two head regulators to be designed at the off-take of secondary canal P1 and P13. The two structures exist but farmers complain that they don't get water in the canal.

The existing P1 structure is a 2-box intake with radial gates (2x1.5m size). The intake walls and junction with the box have broken and the gate fixing has been loosened as its major components constructed of mass concrete. The structure is not in operational condition.

A three-vent RCC box (1.5mx1.5m) intake structure have been provided with about the same opening area as was provided by the existing structure. The structure will be constructed at upstream side of the existing structure. This was agreed with the Water Users Group. The Group proposes that the bottom sill to be raised. The secondary canal is being cleared of sediment under IIP programme and rehabilitated.

Regarding P13 off take, farmers want straight intake in line with the canal in front of the check structure no 4 of Fuad system. At present, there is a bend in the canal and takes off 100 m ahead of the check.

A two-vent (1.5x 1m) box type off-take has been provided. It is to be located 15m upstream of the drop/check structure no 4 on left bank of Fuad main canal.

The details are shown in the Album of Drawings no.IIP/A/2201,2202,2203,2204.

4.2 Intake structure at the aqueduct of secondary canal P8

There is an existing aqueduct under P8 secondary canal on the right bank of Fuad main canal. This was constructed to get additional water from the wadi during spate in the wadi to supplement the flow of Fuad main canal down stream of check no 4. The structure was abandoned as the wadi bank shifted westward after construction of the concrete groyne upstream of the aqueduct. But the farmers demand still remains of additional water downstream of check no4. Thus a gated intake structure with diversion weir/bed bar has been designed to divert water from the wadi. The intake structure will be connected to the aqueduct by excavating 700m of earthen canal up the aqueduct. The present aqueduct is a two box opening size (1.7mx1.7m). This to be cleaned and minor repair of concrete elements to be done and the inlet channel to be protected by lined concrete. The out let to the Fuad main canal needs to be cleaned of the soil deposit.

The details are shown in the Album of Drawings noIIP/A/2101,2102,2103,210421052106.

4.3 Rehabilitation of other structure in Fuad canal system

Fuad canal system is getting water by Fuad weir. About 50 m^3/sec of water is diverted by Fuad weir in a normal spate season through this system to irrigate about 2450 ha of land. The canal network includes secondary and tertiary system.The list of Deatil information/ cut off statement of all the structures of the System were not available with PIU Ahwar or in Aden office.

As per the list supplied by PIU and Water User Groups the design of the rehabilitation woks for the following structures has been completed:

Rehabilitation of Fuad drops

There are 7 un-gated check structures. Farmers demand gates on the check for better control water flow. At present they put erath/tree bund to close the checks for diversionof water. The piers are on lower level than the bank top. Thus, it has been recommended by PIU Ahwar to increase the pier abutment width to 1.4 m and raise the slab up to top of embankment so that they can operate the gates during rotational flow in the canal. The present pier shall have to be integrated with the new pier. Drop no 2 to 6 on Fuad main canal have been designed for rehabilitation. In addition, there is an un-gated check structure at Bahar Al Nil on the Fuad left branch canal. This structure also has been included in the rehabilitation plan.

Off-take at Bamazahem and Bahar Al Nil ,P4,P10,Muzalia

One new off-take by the side of present Bamazahem off-take and one new off-take at Bahar Al Nil have been designed. At Bamazahem they complain of insufficient capacity of present off take. So additional structure provided at the side of the present one. At Bahar Alnil they cut embankment for taking water, so new structure has been provided.

Further there have been a demand for three new intakes in place of two existing damaged structure at the offtake of Secondary P4 andP10 on the right bank and one at new location at Muzalia of size (1.5x1 m) box size on Fuad right bank. A typical structure for this three location has been designed.

Redesign of P1 canal:

The P1 canal has been provided with a new intake of 3-box as present intake damaged . But the canal size and dimension is not adequate to convey the intake discharge. So as per suggestion of PIU and farmers, the Consultant has reviewed and redesigned the P1 canal for carrying the intake discharge volume of this canal with 4 new check structures on the P1 branch canal. The existing canal was designed for 4m3/sec for a command area of 100ha. The new canal has been designed for 10m3/sec considering rotational flow management. It is expected that, once the canal is cleared of sediment and re-excavated according to new design and the new intake constructed farmers will receive water.

Redesign of others structure:

The following structures have been designed as per the list of PIU and requirement of farmers: These structures have partly broken and not performing now.

- Two Intakes on secondary canal P7 from Fuad left branch canal.
- One check structure on secondary P7 on Fuad left branch canal.

Design of farm turnout:

There are great demands by farmers for farm turn out structure. Farmers complained that they do not receive water through existing structures for levels and other reasons. Thus new structure of typical design has been provided for 23 no turnouts on different canals. The detail designs are shown in Album of Drawings noIIP/A/2401, 2402, 2403.

The detail information for the structures proposed for rehabilitation in addition to those mentioned in the TOR is given in the following table:

Fuad Main canal (FMC)
Rehabilitation of structures

Name of canal	Name &location of structure	Existing condition	Required rehabilitation	Justification for rehabilitation	Drawing no
FMC	Control structure no2/Drop	Piers &abutment in good condition	Piers, slab and gates provided	Without gate farmer put earthen/tree bund	IIP/A/2301,2302, 2303
FMC	Control structure no3/Drop	Piers &abutment in good condition	Piers, slab and gates provided	Without gate farmer put earthen/tree bund	IIP/A/2301,2302, 2303
FMC	Control structure no4/Drop	Piers &abutment in good condition	Piers, slab and gate provided	Without gate farmer put earthen/tree bund	IIP/A/2301,2302, 2303
FMC	Control structure no5/Drop	Piers broken	Piers, slab and gates provided	Without gate farmer put earthen/tree bund	IIP/A/2301,2302, 2303
FMC	Control structure no6/Drop	Piers &abutment in good condition	Piers, slab and gates provided	Without gate farmer put earthen/tree bund	IIP/A/2301,2302, 2303
Fuad left branch canal (FLBC)	Control structure/ Drop At Bahar Alnil	No piers exist for operation	Piers, slab and gates provided	Without gate farmer put earthen/tree bund	IIP/A/2301,2302, 2303
FLBC	Offtake Bamazahe, Baharalnil	Bamazahem insufficient capacity, Bahar new construction	New offtakes	Farmer cut embankment to take additional water	IIP/A/2310,2311
FMC	Offtake P4, P10,Muzalia	Existing offtake broken at p4, p10, Muzalia new reqd.	New construction	Existing structure damaged/under size	IIP/A/2308,2309
FMC	Redesign canal P1	Canal silted& abandoned Scarcity of water in the canal	Canal extension &new Control structure	Irrigation suffers for canal size& of structure	IIP/A/2304,2305, 2306, 2307
FLBC	Re design of checks & offtake on P7	The existing structure damaged	Reconstructio n after demolishing the existing structure	It is required for supply of irrigation water to the field	IIP/A/2404, 2405, 2406, 2407, 2408, 2409.

Different Secondary, Tertiary Canals	Given on the Drawings noIIP/A/2401	The structures to be constructed new	The structures to be constructed new	It will bring additional land under irrigation	IIP/A/2401,2402, 2403

5. IMPROVEMENT OF TRADITIONAL OBARS

There are three traditional canal taking water from left bank of Wadi Ahwar by diversion with embankment in the wadi. These canals are located downstream of the Aden road near Ambasti village. The two canals Alboob and Alaisha runs parallel. Al Mulk canal runs bit away.

The existing canal sections were measured: average bed width of Al Boob is= 12m and Al Aisha= 10m. with side slope of 1:1.5 and water depth of 1.5m in the canal with long slope of 0.002. The maximum discharge in Alboob is calculated as 29m^3/sec and that in Al Aisha is 25m^3 /sec and in Al Mulk is 10 m^3 /sec from the existing canal section.
Thus the structure will have to be designed for a maximum discharge of 64 m^3 /sec.

During meeting with the farmers, they indicated that the irrigation command area to be about 1600 haincluding unused fallow area and additional command of AlMulk of208ha, though the TOR indicates 600ha. As per our judgement an area of 1000ha will be potential /command/befitted area of this structure. However if we accept Water Users figures then a discharge of 48 m^3/sec is needed at a rate of 30 litre/sec/ha which is normally followed in the design of Fuad and Hanad main canal. However the off-takes of these structures were designed for a discharge of 64m^3/sec estimating the flood discharge from the existing canal section.

The three canal Alboob, Al Aisha andAl Mulk runs side by side to different command Area.Three gated intakes have been designed separately according to the demand of the Water Users Group for the three canals to avoid future conflict among the farmers.

Wadi side embankment of the Al Mulk will be protected for about 300 m. The left bank of the wadi will be connected to the structure by embankment and will be protected by gabion boxes. Water will be diverted from the wadi by low height diversion weir or bed bar. The top of the bed bar is fixed at 0.9 meter above the wadi bed to divert at average flow level in the wadi.

The details are shown in the Album of Drawings noIIP/A/3101,3102,31033104.

6. PROTECTION OF WELLS IN WADI ELBEREK AND BIN SAAD

In the upper catchment of Wadi Ahwar there are some settlements in Wadi Elberak and Binsaad. Rural water supply authority have constructed dug wells for water supply to the community and one water conservation pond for water supply to the villagers .These wells are situated on the wadi bed and are subject to erosion during spate in the wadi.

Protection work with gabion box has been provided for existing water conservation pond and 8 wells.

Another new conservation pond have been included in the programme as per demand of the people of the wadi Hafia to facilitate conservation of water in wadi hafia for use of the people.

The details are shown in the Album of Drawings no.IIP/A/3301,3302,3304,3305,3306

The list of the pond and wells is given below

No.	Name	Location	Embankment
1.	Protection of Water conservation pond At Elbarek	E0705879 N15322968	60m
2.	Protection of wells at Yarek	E0709996 N1531313	40 m
3.	Protection of wells at Al-Zaya	E0709869 N1531313	20meter
4.	Protection of wells at Al-Bakah	E0710675 N1535988	20 meter
5.	Protection of wells at Al-sakah	E0710976 N1537373	38 meter
6.	Protection of wells at Al-Lahya	E0705587 N1537625	40 meter
7.	Protection of well at Arar	E6098834 N1523522	60meter
8.	Protection of well at Madawab	E0690677 N1529368	35meter
9.	Protection of well at Asra	E0693379 N1522830	38meter
10.	Construction of Water conservation pond at wadi Hafia, Distributory of Elbarek	E0704018 N1522384	100mx40m

7. PROJECT COST

7.1 Unit Rate

Background

A detailed unit rate analysis was prepared for IIP in 2003 and has been used as the basis for estimation of unit rates for Wadi Ahwar. The key factors causing changes in the costs have been identified and applied where appropriate. Construction costs have changed over the intervening five years for several reasons including:

General price inflation

Specific increases in costs of certain items such as fuel, cement and steel

Changes in exchange rates

In addition, Ahwar is 240km from Aden so haulage is a significant cost for materials which are not sourced locally. The local facilities are limited, remoteness also increases logistical problems and staff may expect extra incentives to work there.

US$ is the normal currency used for major contracts in Yemen. In 2003 one US$ bought about 180 YER. The exchange rate is about now about US$1 = 200 YER. However, the value of the US$ has weakened against most international currencies so there will have been overall devaluation of the Yemeni Rial. The depreciation of the US$ will be automatically reflected in the increase of US$ cost of imported items originally purchased with other currencies.

There has been a recent substantial global increase in oil costs. This will have affected the costs of materials which have a high energy input or those, such as geotextiles, which are use oil as the raw material. The costs of manufactured materials have also increased in response to the higher costs of oil and other raw materials and increased demand in the global market, which may now be reducing due to general economic slowdown.

Specific checks in September 2008 on material costs at Ahwar revealed a cement price of 1500 YER per 50kg bag (equivalent to US$150/tonne) and a steel reinforcement price of 2700 YER for 12m of 12mm steel bar (equivalent to US$1300/tonne) compared to US$100/tonne and US$450/tonne, respectively, in 2003. These new prices will include transport to Ahwar. However, it is understood that the cost of reinforcing bar has now dropped to below $1000/tonne in Aden, perhaps as a result of reduced international demand. The cost of concrete, particularly reinforced concrete, will have increased by much more than the average. Labour rates have also increased by about 25% in response to the higher cost of living.

Ahwar is 240km from the nearest major city so transport will be a significant cost for some heavy or bulky items and will increase further if the price of diesel fuel in Yemen is increased to nearer the black market rate. Any increase in the cost of fuel will also increase the operation cost of construction equipment. The current cost estimates do not include provision for an increase in the price of diesel. Contractors may assume an increase in the cost of fuel if contracts do not include any separate cost escalation provision.

7.2 Price Adjustment Methodology

The updating process combined the application of general factors for price uplift with specific checks using other recent unit rates for similar work and build-ups to check the rates for a few items.

The general uplift factors are:

Uplifts for different categories		
Material / work	Effects	Uplift
Cement	Material cost increase	50%
Reinforcing bar	Material cost increase	100%
Plain concrete	Cement + general increase	50%
Reinforced concrete	Cement + steel + general increase	75%
Filled gabions	Gabion materials (steel) + general increase	75%
Steel products	Steel + general increase	75%
Plastic materials	Materials + general increase	75%
General increase (used for all remaining items)		**30%**

In addition, a further factor of between 2 and 6% has been applied to each rate to reflect the remoteness of Wadi Ahwar. This factor can be different for each item to reflect the extent to which remoteness will affect the cost. For example, stone masonry would have a small factor since the remoteness will increase the haulage cost of cement which reinforced concrete will have a bigger uplift because cement, reinforcement, formwork, skilled labour and equipment may all have to be brought to Ahwar.

Remoteness factor		
Category	**Condition**	**Rate uplift**
1	Few materials or skills need to be brought to Ahwar	2%
2	Some materials or skills need to be brought to Ahwar	4%
3	Considerable materials or skills need to be brought to Ahwar	6%

7.3 Other Recent Unit Rates

EU-funded projects in the Tihama

Current rates for a few items have been obtained for EU-funded spate irrigation improvements being implemented in the Tihama. The Tihama is near a port city and remoteness would not apply.

Description	**Unit**	**Price (EUR)**	**Price (US$)**
Earthworks			
Excavation according to the length profile and cross sections	m³	1.8	2.6
Compacted fill according to the length profile and cross sections with material from excavation	m³	2	2.8
Gravel and Stone works	m³		0.0
Gabion works according to project designs with thickness 100 cm	m³	35	49.6
Gabion works according to project designs with thickness 50 cm	m³	37	52.4
Gabion works according to project designs with thickness 30 cm	m³	40	56.7
200 mm thick graded filter with textile	m²	4	5.7
Note: Assumes €1 = US$1.42 (as at September 2008)			

7.4 Project Cost Estimate

The estimated cost of the Project components is presented in the Table 7.1 below

Bill No.	Description	Page	Amount (USD)
1	Preliminary and General items		162,000.00
2	Reconstruction of Al Hanad Weir and Associated Works		5,556,584.76
3	Hanad Left Main Canal & Left Ambosti Branch Canal		2,726,261.71
4	Rehabilitation of Hanad Right Bank Main Canal		181,390.54
5	Intake for Aqueduct at P8 for Fuad Main Canal		429,110.
6	New Head Regulators for P1 & P13		73,865.80
7	Rehabilitation of Fuad Main Canal System		725,876.99
8	Traditional Canals Al Boob, Al Aisha and Al Mulk Intake		1,363,355.84
9	Construction of water Conservation Pond & protection of wells in Wadi Al Bereak and Bin Saad		143,482.30
10	Day works		213,635.00
11	Water Supply System for Al Naim Village		75,600.00
12	Two pilot farms set up and running for 3 years		240,000.00
13	Training to Farmers and PIU staff		30,000.00
14	Feasibility assessment of new interventions		100,000.00
	Sub-total		12,021,162.94
15	O&M cost for 5 years@1.0% per year		601058.15
16	**Total**		**12,622,221.09**
	a) Physical Contingencies, 10% of Subtotal		1,202,116.29
	b) Financial contingencies, 5% of subtotall		601,058.15
	C)Supervision and Implementation management,5%of Subtotal		601,058.15
			15,026,453.68

8.0 NAIM VILLAGE WATER SUPPLY SYSTEM

8.1 Background

Al-Naim village is an agricultural village of 148 people and a growth rate of 3.9%, according to that last census of 2004. The people of Al Naim do not reside at one location, rather than they reside close to their agricultural lands forming two clusters of homes of approximately 10 to 15 houses at each cluster. One group of houses is approximately 1 km to the south of Ahwar, while the other one is approximately 5 km further to the south. The only connection between the two groups is a non-paved road that passes by an agricultural canal. The upper village is supplied by a 2 inch pipeline that supplies the village on intermittent basis from brackish water well. The village has wastewater network made of 4 in polyethylene pipes. The wastewater is discarded to a nearby area forming an open lagoon.

GARWSP (General Authority for Rural Water Supply Project) as well as local officials agreed on the following planning for Al naim village:

- Construct a new line that connects Ahwar Tank with the upper group of houses for Al-Naim.This will connect to the existing system.
- Propose a low tech solution for the wastewater accumulation that is occurring near by the upper group of houses for Al-Naim village.

8.2 Water supply System

8.2.1 Design Criteria for Water Supply System

Design Period

The Water supply system facilities will be designed for a period of 30 years to satisfy number of residents of 150 as of 2004 census. In the year 2034, Naim population is expected to be 421 people.

Water Requirements

The water requirements for the rural areas according to WHO standards are 35 l/c/d as a basic need requirement. However, the design will be based on 70 l/c/d considering the increase in per capita need in 2034 and other needs.

Uncounted for water (U F W)

The issue of the UFW is important for the design requirement. For a normally operated water utility, UFW should not exceed the 15%. However, in Yemen, UFW can go as high of 50%. Common experience tells that rural areas usually have higher UFW percentages. The design will consider 100% for UFW.

8.2.2 Component of the water supply system

The water supply system will be composed from the following components:

- Water supply network. The network will consist of 3" polyethylene pipe connected to the existing elevated water tank at Ahwar village.
- Communal tap with 4 facets at Naim village (consisting of concrete wall of 4x1.5 x 0.2m)

Details of the design is provided in the report No 4 of volume 2.

8.3 Waste water treatment

The following options for waste water treatment have been studied:

- Water proof septic tank
- Vegetated leach field/ subsurface flow wet land
- Vegetated leach field/ surface flow wetland
- Communal septic tank

The last option has been retained as it is the least cost option and requires simple maintenance.

Details of the design are provided in the report No 4 of volume 2.

8.4 Estimated Cost

The estimated cost of both systems is provided below:

Work Description	Unit	Qty	Estimated Cost (US$)
3" Polyethylene pipe of high density and can resist 16 Bar pressure according to DIN8074-ISO4427 Black Colour with all accessories.	m.l	740	45,000
Valve (No return Valve)		2	2,000
Regular Valve		2	1,600
Earth works for a depth of 100 cm and width of 50 cm including filling material and compaction	m^3	210	3,000
Communal tap with accessories (galvanized pipes and facets)	lump sum	1	4,000
Septic tank	lump sum	1	20,000
Sub-total			**75600**
Contingencies 10%			7560
Total Estimated Cost		**370**	**83160**

9. PILOT FARMS

9.1 Pilot Farm with Well Irrigation

9.1.1 Pilot Farm Location

PIU identified a location in Hanad command area for installing Pilot Farm of around 4 feddan for demonstration activities. The area of the identified farm is around 12 feddan and is equipped with well in which the depth of the water level is around 15 m.

9.1.2 Objectives of Demonstration Activities

The demonstration activities will aim at improving the technical capacity of the farmers in subjects related to water saving techniques and farming practices. The activities may include:
Introducing of drip irrigation as a water saving technique.

- Irrigation management including irrigation water application and scheduling.
- Salinity control through using appropriate leaching coeffiecient, applying pre-plant irrigation and salt-tolerant crops.
- Irrigation and fertilizer management.
- Pest control and management and use of bio-agriculture.
- Test different type and varieties of crops.

9.1.3 Components of the Pilot Farm

The Pilot Farm will consist of:

i. Drip irrigation system consisting of:
   - Well motor pump.
   - Concrete ground reservoir of 4 m^3.
   - Irrigation pump along with filter and fertilizer tanks with accessories.
   - The drip irrigation network.

ii. Small building consisting of 1 office of 3.5 x 6 m and a warehouse (3.5 x 6 m).

iii. Network of internal road of 2 m width

In addition to the above equipment and facilities, it is proposed to provide 6 sets of tension-meters (40, 60 and 80 cm length) and 20 gypsum blocks. These equipment will be needed to assess soil moisture depletion and scheduling irrigation according to crop water requirement.

9.1.4 Layout of the Network

The area of the pilot farm is divided to 6 main plots of around 2500 m^2 each. Each plot can be used for one specific treatment and demonstration. The plot can be divided to sub-plots if needed.
The general layout of the pilot farm and drip irrigation network is provided in the Annex B of the Agriculture Report.

9.1.5 Preliminary Works to be done before installing the Pilot Farm

The following activities should be performed before the installation of the Pilot Fram:

- Detailed soils physical and chemical analysis and a soil classification map.
- Detailed well water quality analysis (mainly for EC).
- Well pumping test to assess the capacity of the well.

- A clear contract with the farm owner defining the responsibilities and rights of PIU and the owner in addition to the contract duration.

9.1.6 Technical Specification of the Drip Network

Technical specifications and bill of quantities of the network components are provided in Annex B of the Agriculture Report.

It is important that all the materials and equipment should be imported and be fabricated according to acceptable universal standards.
Engineering drawing of the ground reservoir is provided in Annex B.

9.1.7 The Agriculture Program

Priority in the selection of crops will be for those which have high value and giving high remunerations and benefit. High value cash crops propose are (i) fruit trees (orchard), (ii) export value leafy vegetables like Amaranthus sp., lettuce, (ii) chillies, (iv) onion, (v) tomato, (vi) water melon, (vii) cucurbits, okra egg plant etc. (viii) groundnut, cowpea, pigeon pea and (ix) Alfa Alfa (fodder) in addition to different species of orchards. These crops will be suitably rotated taking care that there is no residual effect of insect pest and diseases. It will be ensured that soil fertility does not deteriorate and all the three (a) physical, (b) biological and (c) chemical conditions are maintained.

It is proposed to plant one row the Neemtree or Parkinsomia tree as a fence surrounding the pilot farm. Trees will be planted at close spacing of 2 meter. After full growth within 2-3 years, this row will act as windbreak..

9.1.8 Cost Estimates

The total cost of installing the Pilot Farm is estimated at $US 56100. Summary of the cost is provided in the Agriculture Report.

9.1.9 Running Cost

Running cost is estimated at $US 24000/yr and it covers the required agriculture inputs, irrigation (power), and maintenance of the network and demonstration activities. Detail of the cost is provided in the Agriculture report.

9.2 Pilot Farm for Spate Irrigation

9.2.1 Pilot Farm Location

PIU identified a farm of 7 feddan located in Fuad scheme for installing Plot Farm of around 4 feddan.

9.2.2 Objectives of Demonstration Activities

The demonstration activities will aim at improving the technical capacity of farmers in subjects related to water saving techniques and farming practices. The activities may include:

- Introducing land levelling concept as a mean for a proper distribution of spate water over the irrigation plot.
- Proper management of surface and ground water as described below.
- Use of farm pond as described below.

- Irrigation and fertilizer management.
- Pest control and management and use of bio-agriculture.
- Test different type and varieties of crops.

9.2.3 Proposed Demonstration Alternatives

The Pilot Farm will be equally divided to two parts to assess and demonstrate the following activities:

- *Conjunctive use of surface and ground water.*

This activity aims to demonstrate the proper management of surface and groundwater for satisfying crops water requirement and achieving optimum crop yield.
This activity requires drilling a well in the Pilot Farm equipped with all the pumping accessories. In addition a network of ground pipe of 3 inches to convey the water to 4 irrigation plots.

Groundwater will be used to supplement spate or runoff water and for pre-plant irrigation. The amount of groundwater application should fill the gaps between crop water requirement (as defined in Section 3.4 of the Agriculture Report) and the amount provided by spate irrigation.

The agriculture program for this activity is similar to one proposed for well irrigation pilot farm.

- *Use of farm pond*

Under spate irrigation condition the time and quality of water likely to be made available is unpredictable as well as uncertain. A ground earth reservoir of 20mx15mx 2m having a capacity of 500 m^3 water has been proposed to be excavated. This quantity of water is sufficient to irrigate a depth of 5cm to an area of 2 Fedans. Whenever spate water comes first of all the entire farm area will be irrigated and farm pond also filled up with water which can be used for one irrigation application. The reservoir lateral side and bottom will be covered with plastic sheet and be equipped with small pumps. A plastic pipe network of 3 inches will be provided to convert the water to around 4 irrigation plots.

Drought tolerant and low water requiring crops like sorghum, sesame, and cotton and water melon have been proposed. With sufficient water and inputs these crops will give high returns.
Both demonstrations will be equipped with internal roads of 2 m wide.

9.2.4 General Layout

The general layout of the Pilot Farm along with the details farm pond is provided in Annex B of Agriculture Report (Report 2).

9.2.5 Preliminary Works to be done before installing the Pilot Farm

The following activities should be performed before the installation of the Pilot Farm:

- Detailed soils physical and chemical analysis and a soil classification map.
- Detailed well water quality analysis (mainly for EC).
- Detailed topographic survey for land levelling works.
- Well pumping test.

A clear contract with the farm owner defining the responsibilities and obligations of PIU and the owner in addition to the contract duration.

9.2.6 Cost Estimates

The total cost of installing the Pilot Farm is estimated at $ US 49500. Summary of the cost is provided in the Agriculture Report.

9.2.7 Running Cost

Running cost is estimated at $US 24000/yr and it covers the required agriculture inputs, irrigation (power), and maintenance of the network and demonstration activities. Detail of the cost is provided in the Agriculture report.

10.0 INTEGRATED WATER RESOURCES MANAGEMENT

10.1 Existing Water Resources Management System

Runoff water is the main water sources in the wadi to satisfy irrigation, domestic and some limited commercial water supply needs, ground water recharge and the emerging needs to control salinity in the delta. Irrigation is the main water consuming sector.

At present, irrigated area in the wadi is estimated at around 7170 ha of which 5240 ha are using runoff water (spate irrigation). Spate irrigation is mainly concentrated around Fuad and Hanad and some obars. The area under irrigation is estimated at 2450 ha in Fuad scheme, 2490 ha in Hanad scheme and around 600 ha from obars. Hanad weir was completely destroyed in 1982 flood and no runoff water is diverted to this scheme. With the implementation of the present project, Hanad weir will be operational and an additional amount of around 500 ha will be irrigated from obars.

According to the well monitoring activity carried out by Hydrosult within the framework of this project, the irrigated area in the delta is estimated at 1930 ha. Around 16,975 Mm^3 of water are annually abstracted from groundwater, through 453 wells, to satisfy irrigation needs of this area and water supply demand of Ahwar villages. This is around three times the volume of water abstracted in 1988 (Kaziprovodkhoz, 1990) estimated at 5.80 Mm^3.

Irrigated agriculture in the delta is suffering from the joined effect of soil and ground water salinity. As a result, cultivated land is gradually deteriorating by soil salt accumulation process. Groundwater abstraction and well digging is not controlled in wadi Ahwar. The number of wells during the period 1990 to date has increased from around 150 to 453 wells. The extensive abstraction of ground water generates seawater intrusion which, gradually increase groundwater salinity. Thus, an important water consuming sector is emerging in the wadi related to groundwater recharge to reduce groundwater mining and control sea water intrusion.

Under present situation, there is no physical means for the wadi runoff water management. Water 'naturally' allocated to irrigation, depends on runoff characteristics and the physical configuration and hydraulic capacity of the irrigation intakes. The remaining runoff water flows downstream of Fuad and Hanad weir toward the sea. Some of this water contributes in groundwater recharge in the delta area. Other source of groundwater recharge is return flow for the irrigation system and runoff water infiltration through the alluvial bed of the wadi.

Runoff water abstraction from the wadi intake by Fuad and Hanad weir depends on runoff flow characteristics mainly its hydrogram (discharge and duration). During runoff event, the amount of wadi discharge determines the hydraulic head over the intake and thus the intake flow discharge, which is limited by the capacity of the main canal (50 m^3/sec for Fuad weir and 70 m^3/sec for Hanad weir). Duration of the runoff determines the volume of the water abstracted by the intake during runoff event. Percentage of runoff water abstracted by each of the two intakes depends on runoff volume and it varies between 50 % for small runoff to 5% for large runoff.

Irrigation water needs in the wadi is estimated at 93.9 Mm^3. This volume is estimated based on the assumptions of cropping intensity of 100% in area under spate irrigation and of 200% for groundwater irrigation. The volume of spate water used for irrigation averages 42 Mm^3 which is around 50% of the irrigation water requirement estimated above. This indicates that the diverted spate flows to the irrigation schemes (Fuad and Hanad weirs and different obars) cover in average 50% of the irrigated area. This figure has variable degree of probability.

The only mean for controlling water management are the intake gates at Fuad and Hanad weirs. These gates are only used in the case of high flood event. In general, under normal runoff event, these gates are opened and wadi water flows freely through the intake. Runoff water management over the wadi is regulated by the traditional water rights which gives priority to upstream users.

Water balance of Wadi Ahwar developed by Hydrosult indicates that out of an estimated average annual runoff of 65.8 Mm3 (for the period 1999-2007), around 16 Mm^3 (25% of annual water runoff) reaches the sea. During this period, this amount has varied between 0.00 to 73.7 Mm^3. Study of Kazgiprovodkhoz Insitiute (1990) indicates that an average of 37.4 Mm^3, or 59% of the estimated annual runoff of 63.5 Mm^3 are lost to the sea. However the information collected from the PIU and number of local communities in the wadi are more close to Hydrosult estimation.

The above results indicate the need for developing some alternatives for better runoff water management in the wadi.

10.2 Storage Reservoir

A dam of approximately 120 Mm^3 capacity can be considered upstream of Fuad weir. This volume is based on the consideration of the mean annual runoff flow, maximum flood estimated discharge and the expected volume of silt deposition during the service life (30 years) of the dam. The live storage is estimated at 50 million m3.

The Kazgiprovodkhoz Institute (1990) proposes the construction of a dam 6 km upstream of Fuad weir at the junction of wadi Saba and Dzhakhir. The proposed site seems to be the most suitable from hydrological and geomorphological point of view.

The proposed dam will have the following roles:

- Flood control to protect the area downstream of the dam.
- Regulating the highly variable spate flows of awdi Ahwar.
- Runoff water control and mangement. Allocation of water for irrigation and groundwater recharge in the wadi and delta will be controlled from the reservoir through planned water release.

- Groundwater recharge. This role will largely depend on the geological characteristics of the reservoir banks. The water recharge capacity of the reservoir will be decreased with the accumulation of silt deposit in the reservoir.

The storage reservoir will have the following benefits:

- Increasing spate irrigation area.
- Improved spate irrigation management. Water release from the reservoir would correspond to the variation of crops water needs. This will result in higher crop yield.
- Reducing ground water salinity.

However, the implementation of the dam will face the following issues:

- High sediment yield of the Ahwar cachment. We expect that the sediment yield of the catchment will average 4 ton/ha/yr. (Data from Hassan Al Dakhil dam in Morocco, which is located in a catchment with similar hydrological and agro-meteorological characteristics of wadi Ahwar). This will represent around 2 million ton/year or around 4% of the live reservoir storage.
- High evaporation losses from the reservoir. Evaporation rate at Ahwar is estimated at 3033 mm/year or 8.5 mm/day.

The decision about the construction of dam should be based on a solid study and investigations and on a detailed economic analysis to justify the investment cost. However, it is expected that the investment cost per ha will be relatively high due to the required large storage and the relatively limited extent of the command area. This is the general case of the South-West Arabian peninsula wadis (Proceeding of Spate Irrigation Conference, 1987, Aden).

The implementation of the storage reservoir will change the nature of the irrigation system: from spate to perennial water supply system. This will imply a change in the exiting traditional rules of water management and right.

10.3 Enhancing Groundwater Recharge

Based on the groundwater budget study (Groundwater Report) the average annual groundwater deficit is estimated at 15 Mm^3. The excess of runoff water balance can be used to re-establish groundwater deficit. This could be an alternative for dam construction upstream Fuad weir. Enhancing groundwater recharge offers the following benefits:

- Control sea water intrusion;
- Reduce groundwater salinity; and
- Replenish groundwater reservoir and increase the volume of groundwater which can be safely abstracted.

Groundwater recharge enhancement can be done using different techniques: construction of small check dykes across the wadi, water spreading and sub-surface dams.

Water spreading is the most appropriate method for ground water recharge in Wadi Ahwar. High solid discharge (in form of suspended solid and bed boulder or stone transport) limits the use of small check dykes. In addition, the large thickness of the alluvial layer (as indicated from the well inventory survey) renders the use of sub-surface dam very costly.

The design of traditional diversion weirs (obars) at Aisha, Al Bob and Al Mulk, which covers an area of 800 ha, is an appropriate combined technique for irrigation and water spreading. However, we consider in the project budget an amount of 100 000 USD for the assessment of the feasibility of the above techniques in addition to interventions upstream Fuad weir.

10.4 Inventory of Basin characteristic and present water management practices in the upper catchment of wadi Ahwar

Consultant conducted survey and investigation mainly from secondary sources in the upper catchment of wadi Ahwar to have first hand knowledge of existing water storage and management practice in view of possible storage potential as a part of integrated water resources practices.

Catchments description of wadi Ahwar

The upper catchment of Wadi Ahwar consists of mountain ridges and flat foot slopes.
The mountains are rocky with little soil cover and vegetation. The foot slopes are agriculture areas and irrigated from the floods of the mountains, while there are agricultural activities in the mountainous area especially in the western part of the catchment.

The Ahwar basin divided into four parts Wadi Sabah, Wadi Jahir, Wadi Seiga and Wadi Ahwar proper. Wadi Sabah joins Wadi Jahir at about 111 metre above sea level (masl) at the coordinates of13^{o}39' North and 46^{o}38' East. and together form Wadi Ahwar basin.

The catchment area of Wadi Sabah is about 2932 km2. Mudia town is located at about 830 masl is in this catchment ,Wadi Jahir occupy the central catchment of Wadi Ahwar it origins at an elevation of about 2245 masl. It is draining a rocky mountainous area with bare soil cover and no vegetation. The shape of the valley is trapezoidal with wide Wadi bed. It receives its larger tributary, Wadi Seiga, at about 200 masl. The two catchments together have 3760 km2. Wadi Jahir without Wadi Seiga has a catchment area of 1430 km2.

Wadi Seiga is a major tributary draining the left side of Wadi Ahwar catchment. Wadi Seiga originates at about 2275 masl; It drains mountainous area through different tributaries, the area is bare rock with little soil cover and vegetation. The catchment area of Wadi Seiga at its confluence, at about 200 masl, with Wadi Jahir is 2330 km2.

The upper watershed has the following characteristics;

Gently sloping mountainous (foothills zone) terrain at low elevations bounded from the higher rugged and highly dissected mountains that reach elevations about 2500 meters.

- The largest stream length and gradient are 80 km and 0.005 m/m, respectively.
- Seventy-two percent of the catchment area is mountainous terrain with shallow soil depths varying from 1.5 to 3 m. The rest is a rugged terrain and plain with minor vegetations.

From the inventory, it is seen that in the upper catchment in the upstream of Fuad weirs, there are little agriculture activities, major activities of the local people (Bedouin) are livestock grazing and beekeeping. Some scattered agricultural area around 20 – 30 Fedan in the major wadi in the upstream of Fuad weirs are irrigated by traditional method using Obar . The traditional ober break the first flow reaching the Obar and, a few minutes later the peak flood joins the detained water.

Mudia town is the biggest town in far upstream in the north west of the catchment with around 40,000 inhabitants. In the upper catchment especially in the western part around Mudia town there are plain land under agriculture development. This area is consist of about 5 % of the total catchment of Wadi Ahwar .

The main agriculture practice in this area is by spate irrigation and also by groundwater . The farmers divert the flood from the main wadi to agricultural lands by traditional spate techniques name Obar. It is used to irrigate small area. The obar is washed out during high floods.
In some area located in the mountains edge especially in northern and eastern part of the catchment, the water harvesting techniques is a common method. The local people harvest the runoff after the rain in the pond and big cistern and are used for domestic use and livestock.
Several crops are grown in this area which include cereal, fruits and vegetables. The most common crops depending on the spate irrigation are grain sorghum, water melon and sweet melon.

Storage Dam: There are few storage dam in Mudia and Lawder Area. one big storage dam has been constructed in Lawder .The following table shows the list of major dams and cisterns in the upper catchment.

Names of Dams & cistern	**location**	**Capacity(M3)**	**Purpose**
Mehlia dam	Lawder	900,000	Irrigation
Al Rughab dam	Mudia	450,000	Irrigation
Azzan Dam	Lawder	230,000	Irrigation
Marran Dam(under construction)	Mudia	185,000	Irrigation
Hathath Cistern	Mahfad	18700	Domestic purpose
Rasras	US of Ahwar	4300	Drinking water purpose
Rawad	US of Ahwar	4300	Drinking water purpose

The cistern and ponds are were built by local people and also by government through program known as social fund for development(SFD).

Field visit has been conducted to the location of the proposed storage dam upstream of Fuad weir. The location of the storage dam is around 6 km upstream of Fuad weirs where the Wadi Sabah joins Wadi Jahir at the coordinates of $13^0$39' North and $46^0$38' East with elevation is 111 m.a.s.l.

The proposed dam when constructed will have the following role as indicated above in this article:

- flood control
- regulation of high spate
- runoff control and management
- recharge control through planned water release from the reservoir
- groundwater recharge

Disadvantages of the storage dam

Construction of the storage dam at the foothill have the following disadvantages:

- large quantity of the sediment deposition
- High loss of water due to the high evaporation
- Environmental impact of surface reservoirs may often be highly undesirable for human health, flooding of inhabited, or good agricultural land,
- Released water (small floods) from the storage dam to the weirs DS will suffer from high transmission losses making little water available for surface irrigation.

Recommendation

Detail Hydrological , geological and environmental study and the human perspective of a Storage dam on wadi Ahahwar is recommended after detail survey.

11. ENVIRONMENTAL IMPACT ASSESSMENT

11.1 Introduction

The purpose of this section of the report is to give a description of the anticipated environmental impacts resulting from the Wadi Ahwar project and identifying the mitigative measures and the required environmental management planning activities in order to minimize and/or eliminate any environmental impacts. The report presents some background information on the project, at and a description of the methodology that was followed in the assessment process including the data collection and the relevant environmental information.

11.2 Methodology

A number of steps have been undertaken in order to collate and analyze information on the project environmental aspects. In order to gain first- hand knowledge of existing environmental conditions and also to put the proposed engineering works into their physical and social context, an environmental expert carried out detailed site reconnaissance visit.
In addition to field visits, formal meetings and discussions with the local authorities were held to obtain all the relevant information regarding the existing facilities in addition to the proposed future plans.

Sources from other team members such as the survey team that conducted the field-reconnaissance-level survey of the surrounding areas and the edges of the Study area were also utilized. This included a survey of agricultural land to determine future urban growth potentials and significant agricultural land. The survey also included the identification of main zoning ordinances, municipal services and facilities. Te results of the soil investigation that was carried out to identify the different soil classification and distribution around the site was also referred to.

11.3 Policy, legal and Administrative framework

Before 1995, the primary responsibility for environmental matters in Yemen resided with the State Ministry of Environmental Affairs, although an Environmental Protection Council (EPC) was established in 1990 under Prime Ministerial Decree 94. This council was reformed by the Prime Minister's decree 28 of 1995. In 2001 the EPC was transformed to Environmental Protection Authority (EPA).
The Ministry of Water and Environment was established for the first time in Yemen in 2003. The new ministry is expected to be responsible for all governmental institutions working in the field of water and environment.

Notwithstanding the fact that the EPA is established and given the nature of the EIA process, it is inevitable during this transitional phase that many of the key environmental responsibilities in Yemen still reside under other competent authorities.

EIA in Yemen is enabled by the environmental Protection Law No 26 of 1995 (EPL). The provision of this framework law, including these for EIA, are implemented through Executive Regulations (BY-law 148 of 2000), issued by a decree of the council of Ministers. The following are key relevant highlights of the law:

Chapter 2 of Part I sets out the objectives and general basis for the law, and establish a number of fundamental principles including:
Official authorities, public and private institutions and individuals shall be responsible for protection of the environmental and its natural resources (Article 4.3).
Official authorities, public and private institutions and individuals shall…. Give priority and preference to the principle of protection of the environment from pollution and not just to the removal of damages after its occurrence or to compensate for it (Article 4.5).

The official authorities "shall ensure that environmental planning is an essential part of comprehensive development planning" To avoid the negative effects to the environmental (Article 4.5).

The official authorities and its public, private and co-operative institution, especially those authorized to issue licenses for new or existing projects shall take into consideration the principle of environmental assessment of project (Article 4.7)

It shall not be permissible to issue a license for new project and establishments that damage or pollute the environment or cause its degradation (Article 4.8.1).

Anyone who damages the environment shall be responsible for all the costs and expenses arising out of removing the damage, in addition to the compensation for it (Article 4.9 with further expansion in (Article 79).

Various aspects relating to environmental impact assessment are covered in outline in Part 3, Chapter 3 of the Environment Impact Assessment Report, and make provision for the cabinet to issue a decree setting out standards, criteria, conditions etc. relating to environmental protection and the environmental assessment process, as well as requiring to competent body (EPC) responsible for evaluation of environmental assessments, to determine applications within a period of months after the date of submission.

Main environmental Issues Related to the Proposed Project and Proposed Mitigation Measures.
Environmental issues related to irrigation projects in general can be divided to issues related to the construction phase and issues related to the operational phase. The various relevant issues are summarized in the following sub-sections.

11.4 Design and Construction Phase

Environmental issues related the construction of agriculture and irrigation facilities include construction site waste generation, soil erosion and sediment control of materials – sourcing areas and site preparation activities, fugitive dust and other emersions, noise from heavy equipment and truck traffic, and potential for hazardous materials and oil spills associated with heavy equipment operation and fuelling activities.
The project area is large enough to allow for heavy equipment operations and to allow for waste management and material storage in a comfortable and easy way. The following are the key risks during the construction phase:

- Construction Site Access
- Contractor’s areas
- Storage
- Safety
- Waste Management Generation
- Construction Activities
- Pollution Control

Uncovered Hauling of Dirt Observed During Field Visit

11.5 Operational Phase

The key relevant environmental issues associated with the project at hand as a typical irrigation project during operations include the following:

- Hydrology
- Water and Air Quality
- Soil Properties
- Erosion and Sedimentation
- Socioeconomic Impacts
- Ecological Imbalance
- Human and Public Health

Hydrology

The consumptive nature of irrigation means that some change to the local hydrological regime will occur when new schemes are constructed and, to a lesser extent, when old schemes are rehabilitated. The ecology and uses of a river will have developed as a consequence of the existing regime and may not be able to adapt easily to major changes. It is also important to recognize the interrelationship between river flows and the water table. During high flow periods, recharge tends to occur through the river bed whereas groundwater often contributes to low flows.

Water and Air Quality

In general the purer the water, the more valuable and useful it is for riverine ecology and for abstractions to meet human demands such as irrigation, drinking and industry. Conversely, the more polluted the water, the more expensive it is to treat to satisfactory levels. As soil salinity levels rise above plant tolerance levels, both crops and natural vegetation are affected. This leads to disruption of natural food chains and the loss of agricultural production. The critical problem of salinity is covered in the section Soil properties and salinity effects.

Soil Properties and Safety Erects

On-going comprehensive soil studies are essential to the successful management of irrigated areas. A wide range of activities associated with an increased intensity of production can contribute to reduced soil fertility. Soil salinity is probably the most important issue although mono-cropping, without a fallow period, rapidly depletes the soil fertility. A reduction in organic content will contribute to a soil's erodability. The increased use of agro-chemicals, needed to retain productivity under intensification, can introduce toxic elements that occur in fertilizers and pesticides.

Arable land is continuously going out of production at approximately 5 to 7 million hectares per year (approx 0.5%) due to soil degradation (FAO, 1992). On irrigated lands salinization is the major cause of land being lost to production and is one of the most prolific adverse environmental impacts associated with irrigation. Saline conditions severely limit the choice of crop, adversely affect crop germination and yields, and can make soils difficult to work. Careful management can reduce the rate of salinity build up and minimize the effects on crops. Management strategies include: leaching; altering irrigation methods and schedules; installing sub-surface drainage; changing tillage techniques; adjusting crop patterns; and, incorporating soil ameliorates. All such actions, which may be very costly, would require careful study to determine their local suitability.

It is important that all evaluation regarding irrigation water quality is linked to the evaluation of the soils to be irrigated. Low quality irrigation waters might be hazardous on heavy, clayey soils, while the same water could be used satisfactorily on sandy and/or permeable soils.

Erosion and Sedimentation

Upstream erosion may result in the delivery of fertile sediments to delta areas. However, this gain is a measure of the loss of fertility of upstream eroded lands. A major negative impact of erosion and the associated transport of soil particles is the sedimentation of reservoirs and abstraction points downstream, such as irrigation intakes and pumping stations. Desilting intakes and irrigation canals is often the major annual maintenance cost on irrigation schemes. The increased sediment load is likely to change the river morphology which, together with the increased turbidity, will effect the downstream ecology.

Excessive Siltation and Sediment Transport in Ahwar Due to Loss of Ground Cover

Soil erosion rates are greatest when vegetative cover is reduced and can be 10 to 100 times higher under agriculture compared with other land uses. However, there are a wide range of management and design techniques available to minimize and control erosion. For erosion to take place, soil particles need to be first dislodged and then transported by either wind or water. Both actions can be prevented by erosion control techniques which disperse erosive energy and avoid concentrating it. For example, providing good vegetative cover will disperse the energy of rain drops and contour drainage will slow down surface runoff.

Biological and Ecological Change

This section focuses on the ecological changes brought about by the project. The most obvious ones are a consequence of the change of land use and water use in the project area but effects on the land around the project and on aquatic ecosystems that share the catchment are likely. Biological diversity, areas of special scientific interest, animal migration and natural industry are important study areas. The overall habitat as well as individual groups (mammals, birds, fish, reptiles, insects etc.) and species need to be considered. Rare and endangered species are often highly adapted to habitats with very narrow ranges of environmental gradients. Such habitats may not be of obvious economic value to man, eg arid areas, and therefore current knowledge of the biota may be poor and a special study may be required. Local knowledge is particularly important as the range of species may be very local.

Bird Nesting Activity Observed During Field Visit

Thienemann's rules are useful in thinking about the ecology of the effected areas:

The greater the diversity of conditions in a locality, the larger the number of species in a biological community.

The more conditions in a locality deviate from the normal, and thus from the optimum for most species, the smaller the number of species and the greater the biomass of each.

The longer a locality has been in a stable condition, the richer its biological community.

Socio-Economic Impacts

The major purpose of irrigated agriculture is to increase agricultural production and consequently improve the economic and social well-being of the area of the project. Although irrigation schemes usually achieve this objective, they could often have been more successful in developing countries if more attention had been paid to the social and economic structure of the project area.

Changing land-use patterns are a common cause of problems. Small plots, communal land-use rights, and conflicting traditional and legal land rights all create difficulties when land is converted to irrigated agriculture. Land tenure/ownership patterns are almost certain to be disrupted by major rehabilitation work as well as a new irrigation project. Access

improvements and changes to the infrastructure are likely to require some field layout changes and a loss of some cultivated land. The 'losers' will need tailored compensation best designed with local participation. Similar problems arise as a result of changes to rights to water.
User participation at the planning and design stages of both new schemes and the rehabilitation of existing schemes, as well as the provision of extension, marketing and credit services, can minimize negative impacts and maximize positive ones.

Ecological Imbalances

Without appropriate management measures, irrigated agriculture has the potential to create serious ecological imbalances both at the project site and in adjacent areas. Excessive clearance of natural vegetation cover in the command area, for example, can affect the microclimate and expose the soil to erosion, leading to a loss of top soil and nutrient leaching. The removal of roots and vegetation disrupts the water cycle, increasing the rate at which water enters rivers and streams, thereby changing flow regimes and increasing siltation in the downstream zone. This is often to the detriment of fisheries and aquaculture activities. The destruction of natural habitats in this manner and the creation of agricultural monocultures also impacts on the local flora and fauna reducing biodiversity. The introduction of exotic species of plant or animal may oust indigenous species or introduce disease agents which may affect plants, animals and/or man. Fertilizers and pesticides are widely applied to correct imbalances. These can percolate through the soil and/or be carried away in the drainage water polluting both groundwater and surface waters especially in the downstream zone. The nutrients in fertilizers may give rise to eutrophication of surface water bodies and promote the growth of aquatic weeds. Pesticide residues are hazardous to the health of both man and animals.

The above examples serve to illustrate, together with the range of biological and ecological changes described in the section *Biological and ecological change*, the wide variety of potential impacts which may arise. Many may be of relatively minor significance in their own right but they often interact to produce a cumulative effect over a prolonged period of time which can result in very significant long term changes to the local ecology. This cumulative effect may impair the long-term viability of both the project and economic activities in the surrounding area.

Human Health

This section concentrates on human health issues associated with irrigation and drainage. Relevant characteristics of diseases, whose transmission potential is a function of ecological parameters affected by irrigation development, are summarized for non-expert readership; health risks mentioned in connection with the environmental and socioeconomic changes are discussed with possible preventive and mitigating measures; and, opportunities to promote human health in an integrated approach to irrigation development are presented. Health is a complex subject and specialist expertise will be required when preparing an EIA. Only brief introductory comments are made here. Human health considerations may warrant a separate Health Impact Assessment.
Irrigated agriculture contributes substantially to conditions that favor good health: food security, an improved infrastructure allowing better access to and by health services and economic progress which permits rural households a greater purchasing power for drugs and health services. On the other hand there can be significant negative impacts and two conditions need to be met to successfully deal with the potential negative impacts on human health in the context of an EIA. Firstly, relevant departments in the Ministry of Health and other appropriate health sector institutions should be involved and consulted at the earliest stages of any project.

11.6 Mitigation Measures

As the world's population continues to grow, dams, aqueducts and other kinds of infrastructure will still have to be built, particularly in developing countries where basic human needs have not been met. But such projects must be built to higher standards and with more accountability to local people and their environment than in the past. And even in regions where new projects seem warranted we must find ways to meet demands with fewer resources, minimum ecological disruption and less money.

FAO has estimated that the potential exists, based on physiography and soil conditions, for an eventual total of 400 million hectares of irrigated land, three-quarters of which would be in the developing countries. Irrigated areas are 2.5 times more productive than rain-fed agricultural land, and there is a strong presumption that their extent (some 300 million hectares at present) will increase. However, expansion beyond present levels is constrained by the shortage of suitable land, limited water supplies and the high cost of installing large-scale irrigation schemes. In many cases it is more effective to improve the management and production efficiency of existing irrigated areas than to open up new irrigation schemes.

The largest single consumer of water is agriculture, and this use is largely inefficient. Water is lost as it is distributed to farmers and applied to crops. Consequently, as much as half of all water diverted for agriculture never yields any food. Thus, even modest improvements in agricultural efficiency could free up large quantities of water. Growing tomatoes with traditional irrigation systems may require 40 percent more water than growing tomatoes with drip systems. Even our diets have an effect on our overall water needs. Growing a pound of corn can take between 100 and 250 gallons of water, depending on soil and climate conditions and irrigation methods. But growing the grain to produce a pound of beef can require between 2,000 and 8,500 gallons.

Shifting where people use water can also lead to tremendous gains in efficiency. Ultimately these disparities will lead to more and more pressure to transfer water from agricultural uses to other economic sectors. Unless the agricultural community embraces water conservation efforts, conflicts between farmers and urban water users will worsen.

New approaches to meeting water needs will not be easy to implement: economic and institutional structures still encourage the wasting of water and the destruction of ecosystems. Among the barriers to better water planning and use are inappropriately low water prices, inadequate information on new efficiency technologies, inequitable water allocations, and government subsidies for growing water-intensive crops in arid regions or building dams.

Several types of interventions aimed at preventing, mitigating, or reversing soil and water degradation at various levels within irrigated agriculture are possible. Some are applicable at field or farm level, others at system, regional, or sub regional level. Examples of possible interventions are given below, categorized as policy, engineering, system management, and irrigation/agronomic practice interventions.

Construction Aspect	Mitigative Practices
Construction Site Access	Locate and identify all underground services and servitudes before construction commences. Choosing of access routes based on minimum disturbance to neighbouring residents and land uses All roads for construction access must be planned and approved ahead of construction activities and must not be created on an ad hoc basis
Contractor's areas	Provision of potable water and acceptable waste disposal facilities (e.g., portable WCs) An adequate number of waste receptacles must be available at strategic locations for gathering all domestic refuse, and to minimize littering. Recycling and the provision of separate waste receptacles for different types of waste must be encouraged. Fenced area must be allocated for waste sorting and disposal
Storage	Choice of location for storage areas must take into account prevailing winds, distance from water bodies and general on-site topography. All fuel required on site is to be stored within an adequately sized bund wall that has an impermeable base. The capacity of the bund wall is adequate to cope with a spill / leak of the fuel storage container. A designated working area must be made available and must be underlain by an impermeable surface (e.g. a concrete slab or plastic lining). All handling of potentially toxic or hazardous material, and the repair, maintenance and storage of vehicles and equipment must be undertaken on the impermeable working surface in accordance with the Materials Safety standards Fire prevention facilities must be present and easily accessible at all storage facilities.
Safety	Material stockpiles must be stable and well secured to avoid collapse and possible injuries Flammable materials should be stored as far as possible from any sensitive receptors. Fire fighting equipment is to be present on site at all times No materials are to be stored in unsuitable or high-risk areas Hazardous storage and re-fuelling areas must be bonded with an impermeable liner to protect groundwater Storage areas containing hazardous substances / materials must be clearly signed. Staff handling hazardous substances must be aware of their potential impacts and follow safety measures.
Waste Management Generation	All wastewater and contaminated runoff from the storage and working areas of the site must be channelled into existing wastewater management system Contaminated liquids and sediments from the wastewater management system must be disposed of at an appropriate permitted disposal site. Identification of disposal sites for the various categories of waste likely to be generated on site The general cleanliness of the site and compliance with the waste disposal requirements Where possible, waste must be collected for recycling programmes provided that the original contents of the containers were not hazardous. Scrap metal (components, sheet metal, nails, tins) must be stored in a designated scrap metal container (e.g. a skip) When the scrap metal container is full, the metal must either be collected or transferred to an appropriate disposal site. Hazardous substance containers, contaminated substrates and materials used in the

	clean-up of spillages must be stored in a designated, impermeable container (e.g. a skip) The hazardous substance containers, contaminated soil, clean-up materials, etc. must be transferred to an appropriate disposal site on a regular basis. On completion of construction, all leftover construction materials are to be removed from the working area.
Construction Activities	Concrete mixing is to be undertaken on a hard surface covered in plastic sheeting so that concrete waste and runoff can be contained. All concrete waste is to be collected, recycled if possible, and removed from the site for disposal at an appropriate disposal site To prevent the contamination of water by materials used during construction, ensure the following: Materials are prepared and stored away from watercourses; Implement measures to prevent seepage of liquid materials into ground where it could contaminate groundwater; Ensure prompt cleaning up of accidental spillages To prevent the contamination of hydrological features by diesel, grease, oil, etc. derived from the working area ensure that: The machinery / equipment is maintained in a good operating condition; Specially designated areas for vehicle maintenance are created; Accidental spillages are cleaned up promptly
Pollution Control	Dust Control Excavation, handling and transport of materials must be avoided under high wind conditions or when a visible dust plume is present. During high wind conditions, dust suppression measures will be required. Soils stockpiles are to be located in sheltered areas where they will not be exposed to the erosive effects of the wind. Appropriate dust suppression measures must be used when dust generation is unavoidable (dampening with water). Noise Disturbance of the residents in the vicinity of the construction areas will have to be taken into account during the construction period. The sitting of areas for delivery of equipment and materials must take into account the noise generated by the vehicle as well as noise generated by off-loading equipment. Jackhammers and their associated compressors exhibit continuous noise that could impact on nearby residents. Acoustic treatment of the jackhammers must include silencers on the exhausts. Concrete mixers must be sited to minimize the impact on nearby residents. All vehicles and equipment must be properly maintained to reduce unnecessary noise. Factors to take into account are; arriving and departing traffic, loading and unloading of equipment and materials; and day-to-day operations Hazardous Substances The handling and storage of hazardous materials must be in accordance with the international best practices and must be restricted to designated areas. If additional areas / sites are required for the storage or handling of hazardous substances, they must be assessed. An inventory of all fuels and hazardous substances to be used and stored on the site, and must ensure that they know the effects of these substances on their staff and the environment. Quantities of fuels and chemicals stored on site must be appropriately stored and handled so as to minimize the risk of spills.

	All fuels and chemicals must be confined to specific and secured areas Chemicals must be stored in a bunded area with an impermeable base (e.g. concrete or plastic lining). Spills of Hazardous Substances The accidental or negligent spillage of any fuels or potentially hazardous substances must be cleaned up immediately using the most appropriate methodologies, equipment and materials. Necessary materials and equipment and chemicals must be available on the site to deal with spills of any of the hazardous materials present Contaminated Water and Soils All soil that is contaminated must be removed and stored in a skip until it can be disposed of at an appropriate disposal site. All wastewater and polluted runoff from contaminated areas must be channelled into appropriately sized, designed and located collection sump. Fuel Tanks All liquid fuels (e.g. diesel and petrol) which are stored in tanks or drums must have a bund wall around the tanks to prevent liquids from escaping in the event of a spill or leak. The volume of the bund must be 110% of the volume of the storage tanks. Any person delivering fuels or other chemicals to the site must be aware of the appropriate storage / drop-off locations and the environmental controls that apply Equipment / Machinery All equipment that may leak on an impermeable surface should be stored with watertight drip trays to catch any pollutants. The drip trays must be cleaned regularly, and must not be allowed to overflow. Chemicals collected in the drip trays must be collected and disposed of in an appropriate manner

12. INSITUTIONAL SUPPORT

12.1 Establishment of local PIU equipped with Heavy equipments

12.1.1 PIU Mandate and Functions Mandate

The PIU will work under PMU within the following mandate:

- Responsible before PMU on project implementation.
- Management project implementation as stated in its functions in order to ensure that the Project is completed according to the planned schedule and within the approved budget
- Reporting to the PMU.

Functions

The main functions of PIU are listed below:

- Planning (in close coordination with PMU) the implementation of the project activities and preparation of the semi-annual and annual plans including the construction, capacity building on O&M and disbursement plans.
- Preparation of progress reports (monthly, quarterly, semi-annual and yearly progress reports and any other reports related to issues on project progress) to the PMU, recommend on remedial measures to solve any implementation issue. The semi-annual and annual progress reports should cover the physical and financial aspects.
- Coordinate the activities of different contractors.
- Construction management including:
- Follow up the progress of works and ensuring that the facilities are constructed on time and within the budget;
- Assessment of the quality control of the works executed by the contractors.
- Assessment the proper implementation of the environmental measures
- Preparation by the contractor of as-built drawings
- Participate with PMU and beneficiaries representatives in commissioning of the works including planning commissioning activity.
- Ensuring the participatory approach in project implementation including organizing workshops and seminars for the concerned stakeholders to explain project objectives, implementation procedures and discuss issues.
- Develop and implement a Monitoring and Evaluation (M&E) system.
- Preparation (PMU) of the final report of the project including recommendations and lessons learned.

12.1.2 PIU Personnel

The PIU Ahwar will consist of the following key staff:

- PIU Director.
- Civil/Irrigation Engineer.
- Institutional/WUA sp.
- Agronomist.
- Mechanical engineer.
- Accountant
- In addition to the above key personnel, the following support staff will be needed:
- Secretary.
- Civil engineering technicians (2).

12.1.3 Tasks and Qualifications of Key Staff

(i). PIU Director

Tasks

The PIU director will report directly to PMU director in Sana'a.
He will be responsible for:

- Overall implementation of the project activities including monitoring work progress and preparation of annual work plan as indicate in PIU functions.
- Overall management of PIU-Ahwar including the administration and financial aspects.
- Monitoring the works of Project's consultant and contractors engaged by PMU.
- Coordinating project activities.
- Verification and certification of contractors' invoices.
- Preparation of annual plan including project disbursement plan.
- Providing advice to PMU Director on any issue related to the well progress of the project.
- Preparation of progress reports including quarterly and annual reports and any report which may be requested by PMU director.
- In close cooperation with the other PIU staff including mainly the institutional sp., the agronomist and the civil/irrigation engineer, prepare the Monitoring and Evaluation reports.
- Liaise with local authorities.

Qualifications

The PIU director should possess the following qualifications:

- B.Sc. in any of the following disciplines: civil, irrigation or water resources engineering.
- At least ten years experience in managing similar projects.
- Good experience in IT.
- Fluent in Arabic and English (speaking and writing).

(ii). Civil/irrigation engineer

Tasks

The civil/irrigation engineer will report directly to PIU director. He will assume the following tasks:

- Participate with the consultant in selecting the design criteria and alternatives.
- Monitor the progress of the construction works and ensure that they are in accordance with the agreed schedule and plan.
- Ensure that environmental considerations as per national and World Bank guidelines are respected in the design and during construction.
- Monitor the quality of construction works.
- Review and certify contractor's bill.
- Plan and organize the commissioning of the civil works.
- Participate with PIU director, WUAs and concerned agencies in the preparation of annual O&M plan including O&M follow-up programme.
- Install the agreed hydrological monitoring equipment.
- Collect the hydrological data measured by the equipment installed as part of IIP.

- Monitor the implementation of the agreed maintenance programmes, assess the performance of the O&M system and participate in the preparation of the Monitoring and Evaluation report.
- In close collaboration with the local extension services agency, participate with the Institutional specialist in developing and implementing the farmers and WUGs/WUAs training programmes on irrigation water management under the spate irrigation system.
- Participate with the PIU director in the preparation of the project annual works plan including project disbursement plan.
- Prepare (to the PIU director) quarterly and annual progress reports on the consultant and contractors activities, and any report which may be requested by PIU director.

Qualifications
The civil/irrigation engineer should possess the following qualifications:

- B.Sc. in any of the following disciplines : civil, irrigation or water resources engineering.
- At least seven years experience in designing or construction management of irrigation projects.
- Good experience in IT.
- Fluent in Arabic and English (speaking and writing).

(iii). Institutional specialist
Tasks
The mechanical engineer will directly report to PIU director and will assume the following tasks:

- Assess the social-institutional-economical and technical profile of the existing communities and farmers groups including Water Users Groups.
- Participate with the PIU director in the establishment of WUGs and WUAs.
- Develop and implement awareness campaign on IIP-Ahwar Project objectives and activities and on Participatory Irrigation Management principles and process.
- Develop and implement, in close cooperation with the agronomist and the civil/irrigation engineer, the capacity building activities for WUGs and WUAs covering the managerial and the technical aspects of WUAs management.
- Organize training activities to concerned stakeholders including seminars and workshops on PIM.
- Assess the performance of WUGs and WUAs and participate in the preparation of the Monitoring and Evaluation report.
- Report periodically (through quarterly and annual reports) to PIU director on WUGs and WUAs establishment, capacity building and performance.

Qualifications
The institutional sp. should possess the following qualifications:

- B.Sc. in any of the following disciplines: sociology, agriculture/extensions or community development.
- At least seven years experience in PIM and WUAs development.
- Good experience in IT.
- Fluent in Arabic and English (speaking and writing).

(iv). Agronomist

Tasks

The agronomist will directly report to PIU director and will assume the following tasks:

- Assess the existing cropping system and farming practices and recommend on alternatives for improvement.
- In close collaboration with the local extension services agency, participate with the Institutional specialist in developing and implementing the farmers and WUGs/WUAs training programmes on new farming practices under the spate irrigation system.
- Participate with the institutional specialist and the civil and irrigation engineer in preparing and implementing the O&M programmes.
- Monitor the performance of the rehabilitated and upgraded spate irrigation system including assessing crops yield in spate irrigation schemes.
- Report periodically to the PIU director on the above activities.

Qualifications

The agronomist should possess the following qualifications:

- B.Sc in agronomy.
- At least seven years experience in agriculture development projects.
- Good experience in IT.
- Fluent in Arabic (speaking and writing) and working knowledge in English.

(v). Mechanical Engineer.

Tasks

The mechanical engineer will directly report to PIU director and will assume the following tasks:

- Assess PIU needs for maintenance equipment including mobile and stationary equipment.
- Participate with the PMU in contracting the suppliers of maintenance equipment including preparation of the specifications, evaluation of the tenders and bids, selection the best offered equipment and contracting the suppliers.
- Prepare and implement the O&M plan of the maintenance equipments including preventive maintenance (both daily and scheduled maintenance).
- Manage the mechanical workshop.
- Verify and approve the repair and overhaul needs of equipment.
- Participate with the institutional sp. in preparing the lending and renting programmes of the equipments to farmers.

Qualifications

The mechanical engineer should possess the following qualifications:

- B.Sc. in mechanical engineering.
- At least seven years experience in mechanical works.
- Good experience in IT.
- Fluent in Arabic (speaking and writing) and working knowledge in English.

(vi). Accountant

Tasks

The accountant will directly report to PIU director and will assume the following tasks:

- Manage the PIU financial affairs and accounts.

- Follow-up local procurement of goods.
- Financial verification and approval of contractors invoices.
- Participate with the PIU director in preparing the annual disbursement plan.
- Prepare monthly, quarterly and annual financial reports.

Qualifications

The accountant should possess the following qualifications:

- B.Sc. in accountancy.
- At least five years experience in accountancy.
- Good experience in IT.
- Fluent in Arabic (speaking and writing) and working knowledge in English.

Support staff

(i). Secretary

Tasks

Responsible for general secretariat support including managing the filing and record systems, typing, schedule appointments and tracking communications.

Qualifications

- Graduate degree.
- Five years experience in secretariat works.
- Good experience in word processing, spreadsheets application.
- Excellent typing skill in Arabic and English.
- Good knowledge in English

(ii). Civil engineering technicians (2)

Tasks

Provide field support to the civil engineer in quality control of the construction works.
Field assessment of the quantity of works executed by the contractors.

Qualifications

- Graduate degree in professional engineering school.
- Five years experience in monitoring or executing construction works preferably irrigation works.
- Good experience in topographic survey

12.1.4 Logistics

PIU office (of around 140 m^2) will be located at Al-Ahwar village and needs to be equipped with the following:

- 2 field cars (as in the table of section 4.1).
- Office equipment: computers (6), 2 printers (BW/Colour) and 2 photocopiers.
- Communication equipment.
- AC units (one in each room).
- Stand-by electrical generator.

12.1.5 Maintenance Equipment Needs

Two basic types of equipment are required for the maintenance of irrigation structures in the wadi :

- Mobile equipment which includes motor vehicle and heavy equipment; and
- stationary equipment which includes machinery to maintain the mobile equipment, structures and equipment of stationary installations.

Mobile equipment

The table below provides an assessment of the mobile equipment required for the maintenance of irrigation works in the wadi. This assessment is done in close collaboration with PIU director.

Sr. No.	Name of equipment	Nos.
1	Loader	2
2	Excavator	2
3	Tipping trucks	2
4	Mobile water tank	1
5	Mobile crane	1
6	Motor cycle	3
7	Land cruiser	2
8	Concrete mixture machine	1
9	Bulldozer D6	2

Stationary equipment and maintenance workshop

Stationary equipment

Main stationary equipment includes:

- Battery charger (600 A), and battery load tester and engine starter.
- Engine cranes and stands (1500 kg foldable engine cranes).
- Oil flasks and oil changer.
- Truck dual wheel dolly.
- Lubrification tools.
- Hydraulic bottle jacks, pair (2 t)
- Hydraulic bottle jacks, pair (10 t).
- Hydraulic floor jack (2 t)
- Hydraulic floor jack (5 t)
- Air hydraulic pump.
- Pneumatic and air tools accessories including air compressor with tank (20 l), engine cleaning gun, air dust gun, air filter regulator with gauge, air hose (15 m).
- Welder and welding masks.
- 5 t air lift truck/hydraulic lifting system.
- Hydraulic body repair kits
- Various hand tools (hammer, screw driver, trimming and scraping knives, flaring and tubing tools).

Maintenance workshop

Location for equipment yard and maintenance workshop has been selected at the existing (unused) Rental Machinery station, Ahwar with the help of PIU and local administration. The existing station cover around 10 feddan land and possesses office and equipment shed earlier used for renting equipment.

The maintenance workshop staff includes:

- One senior technician with at least ten years experience in the maintenance of heavy mobile equipment such as bulldozer, loader, excavator and trucks. He will be the director of the workshop and in charge of managing the mechanical parts store.
- Three junior technicians with at least five years experience in the general maintenance works of mechanical equipment

13 ESTABLISHMENT OF MONITORING AND EVALUATION UNIT

13.1 Definition

Monitoring

Monitoring is the continuous assessment of project implementation in relation to agreed schedules and of use of services, infrastructure by project beneficiaries. Its main objectives are to provide continuous feedback on implementation and to identify actual or potential successes and problems as early as possible to facilitate timely adjustments to project operation.

Evaluation

Evaluation is the periodic assessment of the performance, efficiency and impact of the project in relation to stated objectives. There are essentially three types:

Interim evaluation

Interim evaluation is undertaken by project management during implementation as a first review of progress of the project. It is intended to identify project design problems, and is essentially an internal activity undertaken by project, management.

Terminal evaluation is a similar process undertaken at the end of the project. It is required for the project completion report (PCR). It includes an assessment of the project's effects and their potential sustainability.

A third type is *impact evaluation*. It is usually undertaken several years after final disbursement and measures changes attributable to the project.

13.2 M&E System Components

A M&E system includes the following phases and components:

- Preparation of baseline data.
- Development of performance (benefit or impact) monitoring indicators (Specific, Measurable, Affordable, Realistic, and Time-bound, SMART)).
- Interim Project Evaluation and End-of-Project Evaluation.

13.2.1 Monitor Project Progress

This activity is a five-step process:

- Computerize performance check-list;
- Establish replicable, practical, and politically acceptable data collection procedures for PMU, community groups and/or NGO's;
- Review proposed instrument and indicators and procedures with PMU, community groups and/or NGO's);
- Develop data collection program and arrange for timely data collection; and
- Collate and analyze raw survey data, summarize, compare to baseline data, and disseminate periodic progress reports.

13.2.2 Establish a set of objectively verifiable performance indicators

It is necessary to establish a set of SMART performance indicator (Specific, Measurable, Affordable, Realistic, and Time-bound) objectively verifiable indicators (with the participation of stakeholders) for project evaluation related to the main components of the Project with respect to:

- Rehabilitation of irrigation system and improving O&M and water use;
- Participatory Irrigation Management (PIM) and establishing and strengthening WUAs;
- Improving agricultural system; and
- Integrated Water Resources Management (IWRM).

Examples of some SMART indicators are presented in Table 1. For each project objectives (i.e. row) and each performance area (i.e. column), two or three SMART, simple, and replicable indicators must be developed.

Table13. 1 SMART Indicators

SMART Indicators		OIIAWMIP Project Components			
		a) PIM/WUAS Capacity building	b) Irrigation development/ water use	c) Agriculture	d) IWRM
i)	Economic performance				
ii)	Social performance				
iii)	Poverty indicators				
iv)	Institutional performance				
v)	Technical performance				

For each project component (i.e. column) and each performance area (i.e. row), two or three SMART, simple, and replicable indicators must be developed. These will be developed before design of the baseline survey instrument to secure both consistency and utility.

SMART economic performance indicators include such things as production levels, crop yields, farm costs, relative costs-of-production, farm revenue, gross farm margins, specific marketing costs (by function), input supply margins, product marketing margins, and farm shares.

SMART social performance indicators include such things as range of personal incomes, extent of personal income disparities (group shares and Gini coefficient), access to basic amenities, and access to supporting social and physical infrastructure, community cohesion, community vitality, and indigenous social initiative.

SMART poverty measures are typically measures which relate to a pre-determined poverty line, e.g. percentage above or below a pre-determined subsistence income level.

All monitoring and evaluation must be done in accordance with the World Bank guidelines on its project performance management system.

A final review and revision of the proposed indicators will be conducted with stakeholders, NGO's, and related agencies to ensure that they are not only SMART but also politically acceptable. It is also necessary to fully consider how easily these indicators can continue to be estimated after completion of the present TA.

It is necessary to establish a set of SMART performance indicator (Specific, Measurable, after completion of the present TA.

13.2.3 Conduct interim and end-of-project evaluation

A basic three-step process is also required in order to successfully conduct an interim and end-of-project evaluation:
Design instrument including performance indicators;
pre-test, review instrument(s) with PMU, community groups and/or NGO's, and arrange for timely data collection; and
Collate and analyze raw survey data, summarize, compare to baseline data, establish a consensus regarding the lessons learned, make recommendations (also with stakeholder input), and disseminate end-of-project evaluation report.

This primary data collection process will include questions which directly ask stakeholders what they think are the lessons learned from this project. A workshop will be organized at the end of these evaluation activities to disseminate the TA findings and recommendations.

13.2.4 Institutional arrangement

A monitoring and evaluation (M&E) unit should be established within the PMU (Sana'a) to actually implement the M&E system and to monitor and evaluate the progress of the project and to disseminate the M&E results. The M&E unit should have at least two staff members:

- An agro-economist with at least ten years experience in projects M&E system; and
- A Management Information System specialist with at least five years experience.

The two specialists will work on an on-going basis with the PIUs in different sub-projects.

The director of PIU office in each project will be in charge of implementing the M&E system including monitoring project progress and collecting the related information.

Three PIU staff members will closely works with the PIU director to collect the needed data. These staff members are: the irrigation engineer, the institutional/WUA specialist and the agronomist.

The M&E units need to be supported by a Consultant, who will have the following tasks:

- Design of data collection system including preparation of the questionnaires;
- Design a Management Information System (MIS);
- Data collating and analysis;
- In close participation with PMU and beneficiaries, preparation of the performance indicators ;
- Preparation of interim M&E report;
- Preparation of final M&E report;

- In close participation with PMU, preparation of lessons learned and recommendations and;
- Training M&E unit staff of PMU and PIU staff M&E system and process.

Data could be collected by NGOs or by Consultant's staff.

13.2.5 Management Information system (MIS)

The development and implementation of the above Monitoring and Evaluation system requires to be based on a solid and reliable information system.

The MIS system will include all relevant technical and financial information of the program and for individual projects and sub-projects.

The MIS system will be based on a computerized database. The Database is to be set-up in a professional way, with all data being entered by the related works in one, unified database, allowing multiple analyzing and reporting.

14. FINANCIAL AND ECONOMIC ANALYSIS

14.1 Financial Analysis

As requirement of scope of this project consultant conducted agroeconomic study to check the economic viability of the project.An area of around 4300 ha will be directly benefitted from the project; 2490 ha out of this area are in Hanad area; 808 ha in Fuad weir area, and 1000 ha will benefit from the development of traditional irrigation system (obars).

14.1.1 Investment Cost and Cash Flow

The estimated service life of the project is 25 years. The details of the project cost estimated by the consultant are as follows:

- Total cost is US$ 14.6 million.
- Construction cost irrigation infrastructure is US$ 12.016 million
- Contigencies and supervision and other cost are US$ 2.403 million
- Opeartion & maintenace cost for 5 years are US$ 0.600million
- Project implementation duration is 2 years. The total investment cost is distributed in construction period as follows:
  - ❖ First year: 40% (US$ 5,84 million)
  - ❖ Second year: 60% (US$ 8,76 million)
- Starting from the third year, an amount of US$ 120,160.0 will be required for project maintenance purposes; this amount is estimated on the basis of 1% of construction cost.
- Exchange rate estimated as 200 YR per U$$.
- Discount rate estimated as 7% to calculate the present value of cash flows.

14.1.2 Return Flow:

The benefits from the project are estimated on the basis of with and without project scenarios according to the following:

- The total cultivated area which benefit from project is 4300 ha.
- The cropping pattern in this area is explained in table (14.1). Tomato and onion excluded because of its high sensitivity to drought. The water melon and sweet melon area was decreased in comparison with ground water irrigation system.

Table (14.1) Cropping pattern in Financial and Economic Analysis

	Crop	Sufficient Spate %	Insufficient Spate %
Kharif season	Water melon	35	20
	Cotton	15	10
	Sorghum & Millet	40	60
	Sesame	10	10
	Total	**100**	**100**
Summer season	Sorghum & Millet	**65**	**70**
	Sesame	**20**	**15**
	Sweet melon	**15**	**15**
	Total	**100**	**100**

- The data from the water assessment study showed that the average size of the spate water is about 68 M.CM per year, the study also showed from the available data, that the mean annual runoff in ahwar Wadi at 75% probability (3 out of four years) is 31.2M.cm, and that runoff will be less than this average in one year out of four. The study took this situation into account and assumed that in one of each four years the cropping area will decrease by 50% in insufficient spate (1040 ha), then the total revenue will contain three quarters from ordinary year and one quarter from insufficient spate year.
- Agro Economic study showed that the crop rotation within about 70% from farmers imply cultivating one half of the land in the season (cropping intensity is 100%), the other 30% which most of them are small holders cultivating all their land in the two seasons (cropping intensity is 200%).

To take this situation into account, the study calculated the area in the normal years as following:

1. Kharif season = 3010/2 + 1290 =2795 ha
2. Summer season = 3010/2 + 1290 =2795 ha

Then the Crop intensity is (2795 + 2795)/4300 = 1.3

And in the insufficient spate year as:

1- Kharif season =2795/2 =1397.5 ha
2-Summer season =2795/2 =1397.5 ha

Then the Crop intensity is (1397.5 +1397.5)/4300 = 0.65

The productivity under Spate irrigation estimation is as follows:

Table (14.2) Productivity under Spate irrigation (kg/ha)

Crops	Water melon	Cotton	Sorghum, Millet	Sesame	Sweet melon
Productivity (Kg/ha)	**13000**	**1500**	**1250**	**1000**	**8000**

Table (14.3) Cropping area Details for Financial Analysis

	Sufficient Spate			Insufficient Spate		
	Kharif			Kharif		
	Area%	**Total area**	**Cropping Area**	**Area%**	**Total area**	**Cropping Area**
Water melon	35	2795	978.25	20	1397.5	279.5
Cotton	15	2795	419.25	10	1397.5	139.75
Sorghum, Millet	40	2795	1118	60	1397.5	838.5
Sesame	10	2795	279.5	10	1397.5	139.75
Sub Total	100		2795	100		1397.5
	Summer			**Summer**		
Sorghum, Millet	0.65	2795	1816.75	70	1397.5	978.25
Sesame	0.2	2795	559	15	1397.5	209.625
Sweet melon	0.15	2795	419.25	15	1397.5	209.625
Sub Total			2795			1397.5
	Total(Khareef+ Summer)			**Total(Khareef+ Summer)**		
Water melon			978.25			279.5
Cotton			419.25			139.75
Sorghum & Millet			2934.75			1816.75
Sesame			838.5			349.375
Sweet melon			419.25			209.625
Total			5590			2795
		Cropping Intensity	1.3			0.65

- The benefits in the first year is zero
- The benefits in the second year estimated by 50%.
- The other years gives the total net return.

Table (16) illustrates the total net returns per ha and for total area. The total net return is 880,420,808YR in ordinary year, in insufficient spate year the total net revenue is 393,236,236YR.

According to the assumption of 3 sufficient spate years and one un-sufficient, the average of net annual return is as:

Annual net return = {(880,420,808*3) +(393,236,236*1)}/4 =758,624,665 YR

Table (14.4) Total net return per ha for financial analysis

	Net Return Yr/ha	Cropping area	Gross revenue
Sufficient Flood			
Water melon	296760	978.25	290305470
Cotton	60640	419.25	25423320
Sorghum & Millet	94070	2934.75	276071933
Sesame	191690	838.5	160732065
Sweet melon	305040	419.25	127888020
Total		5590	880420808
Insufficient Flood			
Water melon	296760	279.5	82944420
Cotton	60640	139.75	8474440
Sorghum & Millet	94070	1816.75	170901673
Sesame	191690	349.375	66971693.8
Sweet melon	305040	209.625	63944010
Total		2795	393236236

14.1.3 Financial analysis findings

Table (14.4) above showing the return per ha and the gross revenue. The estimated value of the financial analysis is as following:

1. Internal Rate of Return (IRR) = 25.72 %
2. Benefit Cost Ratio (B/C ratio) = 273 %
3. Net Present value (N.P.v) =4,064,712,312.92 YR

The Value shows a high profitability for the project.

14.1.4 Sensitivity Analysis:

The project cost and benefits may change during the project life which is estimated at 25 years. Sensitivity analysis deals with the effects of these changes in costs and benefits on the profitability of the project. The analysis Involved in these four cases is as follows:

- **10% increase in project cost:**

When the project cost increases by 10%, IRR Still high at 23.3%.

- **10% decrease in project benefit:**

When the projects benefit decreases by 10%, IRR is still high at 22.94%.

- **50% increase in project cost:**

When the project cost increases by 50%, IRR is 16.34%. This value means that the project can withstand financial risks.

- **50% decrease in project benefit:**

When the projects benefit decreases by 50%, IRR 1s 11.4 %. This value means that the project is more sensitive with respect to benefit than to cost, but also that IRR value at 11.4% is satisfactory (acceptable) in the long run.

14.2 Economic Analysis:

The Economic analysis is different from financial in the way that cost and benefit determination and estimation is calculated. Economic analysis is from the social point of view, while the financial is from project investment point of view.
In this study, the Economic analysis was conducted under the follwing assumptions:

14.2.1 Benefit and Cost

According to social view point, the benefits from the project contain the additional production and employment, sustainability of ground water; in addition there are benefits from more exports. In the cost side, labour cost was adopted to reflect the social cost with high unemployment.

14.2.2 Assumptions

- Market prices were used for evaluating inputs and outputs.
- Social value of Labour cost estimated as 50% of the Actual, this difference is because of the high unemployment in Yemen.
- Benefits included the value of the irrigation water that the project provide to the area, the value determined by 50%of the cost of fuel required to irrigate one haktar from ground water

According to these assumptions, the Economic Analysis Criteria are as following:

1. Internal Rate of Return (IRR) =34%
2. Benefit Cost Ratio (B/C ratio) = 351%
3. Net Present value (N.P.v) =7,189,395,634YR

These criteria show high profitability for the project.