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Concept Paper For Flood Warning System

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CONTENTS

1 EXECUTIVE SUMMARY---------- 1

2 FLOOD WARNING ---------- 2

2.1 introduction _____ 2

2.2 flood warning strategy _____ 2

2.3 summary of flood warning detection _____ 5

2.4 strategy for warning of a flood _____ 6

3 IMPLEMENTATION OF THE FLOOD WARNING STRATEGY ---------- 7

3.1 general _____ 7

3.2 Wadi zabid _____ 7

3.3 wadi tuban _____ 8

4 FLOOD WARNING EQUIPMENT---------- 9

4.1 general _____ 9

4.2 water level measurement stations _____ 9

4.2.1 Water level measuring instrumentation _____ 9

4.2.2 Data logging/remote telemetry unit _____ 10

4.2.3 Communications _____ 11

4.2.4 Housing and power supply _____ 12

4.3 rain gauge stations _____ 12

4.4 diversion weir structures _____ 13

4.5 control centre _____ 13

4.5.1 General _____ 13

4.5.2 Function of the control centre _____ 14

5 COST ESTIMATES AND PROCUREMENT STRATEGY----------15

5.1 procurement strategy _____ 15

5.2 Cost estimates _____ 15

Abbreviations

IIP	Irrigation Improvement Project
LCD	Liquid Crystal Display
LED	Light Emitting Diode
MIS	Management Information System
mcm	million cubic metres
NWRA	National Water Resources Administration
PC	Personnel Computer
PIU	Project Implementation Unit
PMU	Project Management unit
PSTN	Public Switched Telephone Network
RTU	Remote Telemetry Unit
SCADA	Supervisory Control and Data Acquisition
SMM	Spate Management Model
SMS	Short Message Service
TDA	Tihama Development Authority
UHF	Ultra High Frequency
UPS	Uninterruptible Power Supply
VDU	Visual Display Unit
VHF	Very High Frequency

1 EXECUTIVE SUMMARY

As the value of spate water increases and the cost of sediment control and maintenance also increase, it is considered that the advantages of a flood warning system should be evaluated more fully by the implementation of trial schemes in Wadi Zabid and Wadi Tuban.

Initial hydrological analysis of the spate volume against the peak level through the existing measuring stations shows a complex relationship between the two values. This indicates that a flood warning system based only on monitoring from existing measuring stations may not achieve the desired goals of improved water and sediment management.

The recommendation is to provide flood warning systems for each of the two wadis on a trial basis. Each of the systems should be operated from local operational control offices.

The equipment at the existing flow measuring stations at Kolah and El Dukeim will require to be replaced and will need their site rating curves to be re-calibrated. Additional measuring stations will be required upstream of the existing sites to assist in the estimation of flood volumes and to give earlier warnings.

At Wadi Tuban a further measuring station will be needed for the Wadi Billa tributary upstream of Ras Al Wadi weir. Currently no instrumentation is installed along this wadi.

In order to warn the local operators of impending floods, audible warning and visual indicators are proposed at two of the upstream weir sites on each system. In addition to this, full use should be made of the recent mobile telephone system expansion with the provision of mobile handsets to key operational and management personnel.

The hydrological analysis undertaken to date has not indicated a strong interrelationship between existing rainfall data and flood events. However where any new rain gauge stations are proposed these should be provided with communications facilities, so that the data can be gathered for further evaluation in the future.

It is also recommended that 2 or 3 observers are commissioned in each of the catchment areas to observe the local weather information and relay this back to the flood warning system management centre for cataloguing into the system.

2 FLOOD WARNING

2.1 INTRODUCTION

There is currently no flood warning system available for the Wadi Zabid and Wadi Tuban irrigation systems. Some advanced warnings have been provided by gunshots in the Wadi Zabid system and for the part of the Wadi Tuban system that is close to the road. Observations at Aqqan of a flood or likelihood of a flood are transmitted by the observer driving down the road to the operators of the diversion structures and to farmers.

As there is currently no flood warning system in place, the operational procedures are based on the traditional methods as and when the water is available. The current system is considered to lead to inefficient use of the spate water and leads to a build up of sediment with the resulting increased maintenance and, for some large spates, damage to the irrigation system.

A flood warning system would give the possibility to provide warning before a flood reaches the irrigation area, to modify the existing procedures in order to improve the efficient distribution of the water available and decrease the maintenance burden.

There is some existing hydrological monitoring equipment currently installed in both the Wadi Zabid and Wadi Tuban systems. Upgrading and or supplementation of this equipment can form the basis of a flood early warning system.

At Wadi Zabid there is a measurement station at Kolah. This is situated approximately 15 km upstream of the first diversion weir structure. It is understood that the flood takes between 30 minutes and an hour to reach the first weir from this measurement station. There are also 5 recording rain gauge stations mainly situated in the south eastern section of the catchment area. The daily data from flood measuring stations and the rain gauge stations are only collected from the sites every few months.

At Wadi Tuban there is a measuring device in operation at El Dukeim approximately 9 km upstream of the first diversion weir structure and approximately 20 km from the bifurcation weir at Ras Al Wadi. This provides a warning of approximately 30 minutes to the first diversion structure and 1 to 2 hours to Ras Al Wadi. NWRA has recently installed a level monitoring device at Aqqan which is a further 16 km upstream from El Dukeim. This is not yet in operation, but could be commissioned and form part of a flood warning system. There are also 5 recording rain gauge stations mainly situated in the southern half of the catchment area. As with Zabid, the data from measuring stations and the rain gauge stations are only collected from the sites every few months.

2.2 FLOOD WARNING STRATEGY

There is only a limited amount of data currently available on which to develop an initial flood warning strategy. At Wadi Zabid data on the level at Kolah are available for the period of 1982 to 2001. There is a rating curve for this site and using this, flood volumes have been derived. At Wadi Tuban, data on the level at El Dukeim are available for the period 2000 to 2002. There is no available rating curve for this site and so no flood volumes are available. In order to provide more reliable flood volume data it will be necessary to update and recalibrate the rating curves for both Kolah and El Dukeim.

As more data are available for Wadi Zabid, an initial analysis of the flood peak levels and corresponding flood volumes are made as shown in Figure 1. No analysis has been made for Wadi Tuban, however it is considered that a similar pattern would occur.

This chart clearly shows that there is not a direct correlation of the flood volume to the flood peak level and also after including the duration of the flood there is a wide variation.

The functions of the flood warning scheme for this project should be:

- To provide advance warning and information about potentially damaging flood peaks
- To enable improved operation and water distribution

In order to ensure that the flood warning system is respected and utilized by the operators and farmers, it has to provide warnings when appropriate and not give unnecessary warnings or false alarms, i.e. when there is not enough volume in a spate to irrigate more than a small area.

For example, for the Wadi Zabid irrigation system it has been suggested that a flood volume in excess of 1 mcm is significant enough to need operational decisions to be made. From Figure 1 it is seen that these events occur with flood peaks above 400mm. However, if a warning was given at this level then a significant flood volume would be achieved only in about 1 out of 25 warnings. If the warnings were to be delayed until the flood peak was at least 600mm then a number of significant flood volumes would not be alerted, but the number of insignificant events would be reduced.

Figure 1 does indicate that if the duration of the spate were to be known in advance, then for many of the insignificant floods no alarm would need to be raised. Figure 1 also indicates that with a few exceptions the spate duration has to be greater than 10 hours for a significant flood.

Some indication of the duration of a flood can be obtained by monitoring the recession curve of the flood after its peak has past. However, in order to obtain any meaningful indication of the shape of the recession curve, and thus the ability to make an estimate of the flood duration before it reaches the irrigation area, will require the monitoring of the flood level at locations with a flood travel time of 2, 3 or more hours from the weir structures. However, the further upstream a monitoring station is located, the greater the risk of not detecting a flood from a downstream tributary.

The current flow monitoring sites for both Wadi Zabid and Wadi Tuban will not provide this amount of warning. However, installation of additional monitoring sites about 15 km upstream of these sites should be able to provide some meaningful data regarding the recession curve of the flood before it reaches the weir structures.

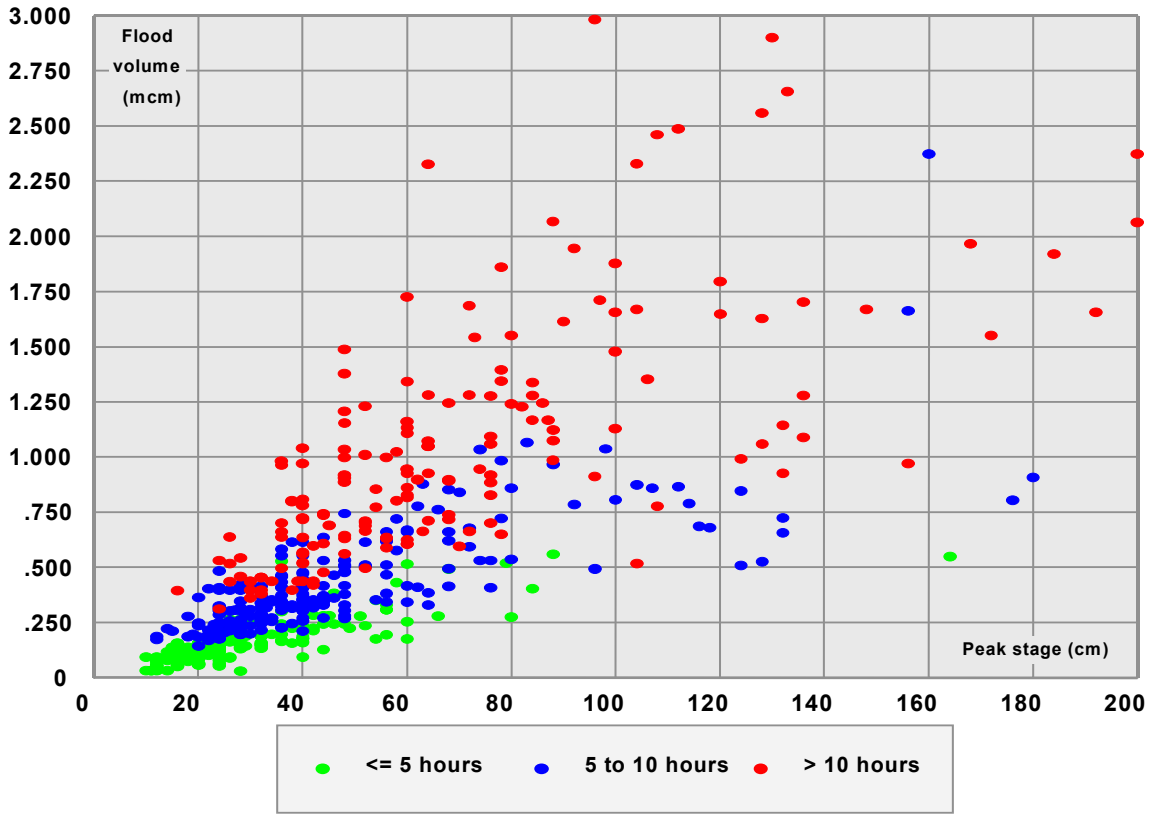
Hydrological analysis is currently being implemented within the project analysing historic rainfall and flood volume data. To date, this has been undertaken mainly for the Wadi Zabid system where there are more long-term data available than for Wadi Tuban.

Initial indications are that there is no identifiable correlation with the rainfall measurements and the spate incidence or volume. This is possibly due to the limited number of rain gauges in the catchment area and the localized nature of the rainstorms that occur. NWRA is considering supplementing these existing rain gauges with some new ones (for example 4 sites in the Tuban catchment area). It is recommended that these stations are fitted with telemetry and communications so that ‘real time’ rainfall data can be obtained. The additional data from these sites could then be used with the existing hydrological data to re-evaluate whether there is any useful relationship from this information and the flood events in the wadis.

There are several other techniques and facilities that can provide indication of the rainfall within the catchment areas which include:

- Meteorological forecasts
- Weather radar systems
- Weather satellite data
- Local observers

Figure 1: Wadi Zabid - Peak Level at Kolah Against Flow Volume



Of these techniques for weather forecasting, the cost of providing systems or of obtaining information from radar and high quality satellite systems is high and for this trial not considered cost effective. However, an overview of regional weather patterns can be obtained from the internet. Examples of such images (obtained from http://www.met-office.gov.uk/satpics/africa_IR.html) are shown on Figure 2.

The use of publicly available meteorological forecasts and the provision of observers are supported during the trial phase so that future hydrological analyses will have an enhanced database on which conclusions can be drawn.

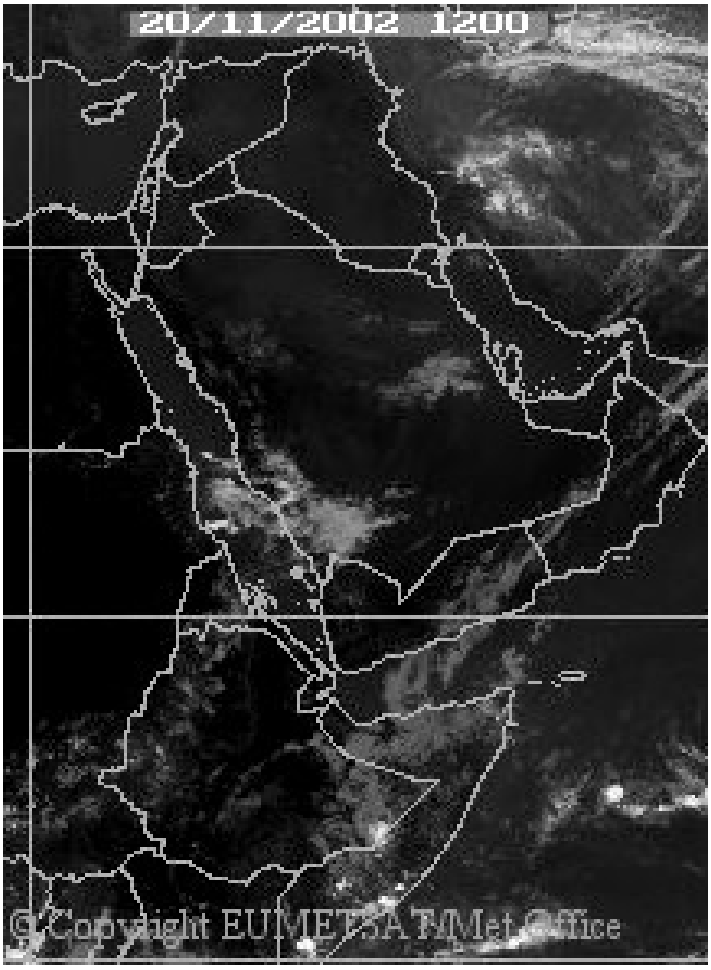


Figure 2 Regional weather patterns

2.3 SUMMARY OF FLOOD WARNING DETECTION

To detect the flood peak is relatively easy for a flood warning system, using a very basic flood warning control system. However, as has been discussed before, the estimation of flood volume from the peak level of the flood is a more complex problem.

The strategy for the flood warning system for the IIP Phase 1 irrigation areas of Wadi Zabid and Wadi Tuban should be considered to be a trial project with the following main aims:

- Provide the most useful warnings to operators and farmers based on the information currently available
- Determine the effectiveness of the flood warnings and the method of issuing the warnings
- Allow the operators to evaluate different operational strategies (in conjunction with the development of the Spate Management Model (SMM)
- Collect and correlate data so that it can be analysed to improve the effectiveness of the flood warning system and its application to other wadis during Phase 2 of the project.

In order to achieve these aims, the flood warning system implementation strategy should be to provide a flexible system. This should enable the development of techniques as more experience is gained during the trial and data that may have an effect on flood warning

prediction should be collected and archived. As new data accumulate this can be evaluated in order to improve the effectiveness of the flood warnings and use of the spate water.

2.4 STRATEGY FOR WARNING OF A FLOOD

The strategy for the warning of local operators at the diversion weirs needs to be clear and unambiguous. The following proposals provide both a wide area annunciation of a flood event in the vicinity of the weir structures and with the use of mobile phones a flexible facility to implement the appropriate management of the flood.

The measurement and monitoring stations upstream of the diversion structure will send alarms and flood profile data to a central processing system for evaluation and the subsequent issuing of flood warnings to appropriate locations and personnel.

The central processing system will be located in the flood management operation centre and in the first instance the flood management operators will be alerted that a potential flood has been detected. This alert will be achieved by initiating an audible and visual warning in the flood management control room. If this warning is not acknowledged with a certain period then a siren will sound within the management complex. Should this still not be acknowledged then the control system would automatically send voice or text messages to nominated personnel.

The flood management operators and when appropriate their supervisors will assess the possible flood incident from the data available from the measuring sites. If the incident is considered to be significant enough for the operation of the weir structures then the flood management operators will initiate the control processor to send a flood warning to the appropriate diversion weir structures.

The warning sent from the control processor will set off a siren at the weir structure to alert the local operator who is stationed on site for the duration of the flood season. This siren will also alert any farmers in the area of the imminent approach of a flood.

The flood management operators will continue to monitor the progress of the flood and its flood curve so as to try and evaluate the volume of water in the spate and determine what operational strategies and procedures to be undertaken in the irrigation area. As a simple means of transferring the information about the size of the flood to the local operators at the diversion structures it is proposed that up to 4 coloured high intensity lights are provided at the weirs with the different colours progressively representing the increase in the size of the flood.

In addition to the above visible and audible warnings at the diversion weir structures for the alerting of a flood, the flood management should make use of the mobile phone network coverage that is now available in much of the Zabid and Tuban irrigations areas. The provision of mobile phones to key operations personnel will enable dialogues to be set up between the flood management operators directing the management of any flood and the personnel on site implementing the procedures.

Currently, reception on standard mobile handsets is not reliable in the Zabid irrigation area upstream of weir 2. At these sites it is proposed to install signal boosters and antenna to provide the communications for the warning equipment. facilities will be included to enable suitable mobile phone handsets to be connected to this equipment, to enable voice communication.

3 IMPLEMENTATION OF THE FLOOD WARNING STRATEGY

3.1 GENERAL

The implementation of the flood warning strategy for the Wadi Zabid and Wadi Tuban irrigation areas should be regarded as a trial project to determine the benefits and capabilities of a flood warning system and as such should aim to be as comprehensive as possible. Thus experience will be gained and additional data collected. The experience gained will be used for the implementation of the Flood Warning Systems in the 5 additional wadis in Phase 2 of IIP if the trials during Phase I give satisfactory results.

In order to achieve this goal, each of the system components needs to be designed on a modular basis so that additional measuring or monitoring sites can be added or moved to different locations, when considered advantageous during the trial and its ongoing evaluation.

The main components of a flood warning system, to meet the strategy discussed in the preceding section (Section 2), are:

- Water level monitoring stations
- Rain gauge monitoring stations
- Central control computer
- Diversion weir flood warning stations

The detailed functionality of each of these components is provided in the following section (Section 4).

The application of these flood warning system components for each of the two irrigation areas is as follows. It is recommended for the trial that each irrigation system is controlled from its own control centre equipment which is located within that irrigation area. When the flood warning system is expanded to another further 5 wadi areas then a single centralised flood control centre should be considered. The two sets of control centre equipment provided for this phase of the project could be moved to the centralised location and configured as a main and standby redundant configuration.

3.2 WADI ZABID

The proposed configuration for the flood warning system for Wadi Zabid is as follows.

- A central control processor located in a local office in Zabid area.
- A measuring station adjacent to the existing measuring station at Kolah. It is proposed that the existing instrumentation is maintained operational through the trial period so that a comparison of measurements can be made.
- A new measuring station to be installed at a suitable location approximately 15 km upstream of the Kolah measuring station.
- Two diversion weir flood warning stations, one at weir 1 and the other at weir 3. These being the weirs most appropriate for flood control as advised by the project staff.

- The inclusion of rain gauge stations at any new locations proposed by the NWRA for the Zabid catchment area. (Note that to provide rain gauge coverage of approximately every 500 km² of the catchment area, a further 4 or 5 stations should be installed.)

3.3 WADI TUBAN

The proposed configuration for the flood warning system for Wadi Tuban is as follows.

- A central control processor located in the local office in Aden area.
- A measuring station adjacent to the existing measuring station at El Dukeim. It is proposed that the existing instrumentation is maintained operational through the trial period so that a comparison of measurements can be made.
- A new measuring station to be installed at a Aqqan approximately 15 km upstream of the El Dukeim measuring station. NWRA has recently installed a pressure probe for monitoring the level at this site and it is proposed that this instrument is incorporated into the new measuring station rather than providing a new instrument.
- A new measuring station approximately 15 – 20km upstream of Ras Al Wadi weir along the Wadi Billa. At present there is no measurement along this wadi, which joins with Wadi Tuban between Al Arais Weir and Ras Al Wadi weir.
- Two diversion weir flood warning stations, one at Al Arais weir and the other at Ras Al Wadi weir. These are the weirs considered most appropriate for flood control by the operators.
- The inclusion of rain gauge stations at any new locations proposed by the NWRA for the Tuban catchment area. (Note that to provide a rain gauge coverage of approximately every 500 km² of the catchment area, a further 4 or 5 sites should be installed.)

4 FLOOD WARNING EQUIPMENT

4.1 GENERAL

The following subsections discuss in detail the functional requirements of each of the components for the implementation of a flood warning scheme. Each of these components should be developed as a complete module, which can be provided to an installation team for installment at the most appropriate location.

4.2 WATER LEVEL MEASUREMENT STATIONS

The measurement stations are required to monitor the level of the water in the wadi. From this data the measuring station must be able to provide an alert when a flood crest develops and to download the level profile to the control centre. To achieve this there are 4 components of the measuring station:

- Water level measuring instrument
- Data logging/remote telemetry unit
- Communications
- Housing and power supply

4.2.1 WATER LEVEL MEASURING INSTRUMENTATION

There are two types of existing water level measuring instruments at the measuring stations for Wadi Zabid and Wadi Tuban. Both of these instruments have some disadvantages

Kolah has a float and wire recorder unit. This is relatively old and although working, it has a number of disadvantages:

- Scale of range and speed of chart is small, so accuracy of readings is not good
- Data is in paper format and analysis has to be done manually
- Paper and ink problems can cause loss of all data
- Needs regular maintenance to keep working

The water level measuring instrument at El Dukeim is a pressure transducer installed in a stilling well and connected to a data logger. This instrument has the following advantages:

- Robust and reliable
- Well proven for a wide range of uses in the water industry
- Relatively cheap
- Low power consumption

There are, however, some disadvantages:

- The transducer is located at the bottom of a stilling-well and could be affected by a build up of sediment thus giving erroneous readings. To help alleviate this problem the device at Dukeim is installed approximately 1 metre above the wadi floor.
- When there is no water above the transducer the instrument has a zero output. It is not always possible to determine if this means whether there is no water or that the instrument is faulty.
- The instrument is not measuring the base flow.

NWRA has recently installed a second pressure transducer and measuring station at Aqqan. This pressure transducer is installed in a pipe, which is currently located in the base flow channel. No readings have yet been taken from this instrument so its performance is unknown.

An alternative to the existing type of level measurement instruments in use at present is the ultra sonic level monitoring unit. This operates on the principle of bouncing an ultra sonic signal off a surface and measuring the time of the reflected echo. This time has a linear relationship of the distance between the ultra sonic transmitter unit and the surface below.

There are a number of advantages in applying this type of instrument for this project:

- Sealed units which are rugged and reliable
- Well proven in many different applications and environments in the water industry
- Would be mounted out of the water and therefore the reading accuracy would not be affected by sediment build up.
- Provides a reading at all times (i.e. the wadi bottom when there is no water) and so failure of the instrument is readily detectable
- Does not need a stilling-well and could be mounted using a simple bracket arrangement

Some disadvantages of the ultra sonic level monitoring unit are:

- If the units are not in a still well or similarly protected, it is possible that during a non-flood period a person or animal may stand under the detection zone, giving an erroneous reading
- The equipment needs to be located over a stable low flow channel to avoid the possibility of a shoal forming under the equipment, which would give false water levels
- Could be a target for gun practice
- Power consumption is slightly greater than for pressure transducers and therefore larger batteries and solar cells may be required

In balance it is considered that any new level instruments provided should be of this type so their performance can be evaluated against the existing instrumentation. Extension of flood warning in Phase 2 could then base its choice of instrumentation on valid experience.

4.2.2 DATA LOGGING/REMOTE TELEMETRY UNIT

The data logger at the measuring sites should include analogue and digital input capabilities for the level instrumentation and alarm indications. The functions and facilities of the data logger/RTU:

- Data storage time logging at a configurable rate between 1 minute and 1 hour;
- Data storage rate to be selectable on event detection i.e. level reading on instrument;
- Data storage capacity to be at least 10,000 time stamped records;
- System to read the instrument every 10 minutes under normal (non-flood) conditions;
- System to read and record instrument every 1 minute while level reading within a preset range;
- Data logging to be every hour under non-flood conditions;
- RTU to transmit an alarm to the control centre when the water level reaches certain preset limits;
- RTU to monitor state of battery and any solar power generator and alarm fault or battery low;
- RTU to download any current and stored data on request from the control centre;

- RTU to alarm control centre if a data download has not occurred from the control centre for more than a predetermined time;
- Equipment to be suitable for environment e.g. ranging from –10OC to +60OC
- Equipment should be housed in a cabinet to meet IP67
- Equipment to have very low power consumption
- RTU to have connection point for a laptop PC to download data and reconfigure the RTU if necessary

4.2.3 COMMUNICATIONS

General

The data logger/RTU unit shall connect to the communications equipment to enable the transmission of data and alarms to the control centre. The interface shall also include the capability of the RTU to send voice or SMS text messages to specific mobile or fixed telephones in the event of an alarm message that is not accepted by the control centre.

In order to achieve communications in the areas where the data loggers/RTU will be located, a radio based communications system will be required. There are two main radio solutions possible namely a public mobile network or a private radio communications system.

The provision of a private radio system has the advantages that, there are no ongoing revenue costs other than the cost of normal maintenance activities. A number of different radio solutions are possible in the VHF and UHF frequency bands. However, the main problems with these solutions are to obtain licences and frequency allocations, the initial cost of the equipment and the location of transmitters and antenna on high places, which would be away from the location of the monitoring equipment.

The use of the public mobile network offers a significant degree of flexibility depending on coverage of the mobile network employed. The mobile telephone equipment is very widely available and the basic cost of the equipment is relatively cheap. The main disadvantage of the normal GSM mobile networks is that coverage is not available in some of the areas within this scheme although coverage is expanding rapidly throughout Yemen. There is however a satellite based mobile network available from Thuraya through Yemen service provider Partners Company Ltd. This system would offer the same connectivity as the normal GSM mobile network but at an increased cost per call (currently US$ 0.87 per minute for outgoing calls).

Wherever possible, use will be made of the GSM mobile network rather than the satellite network. This is especially so within the irrigation area at the diversion weirs. At these sites where coverage is marginal signal booster equipment and external antenna will be employed to maintain an acceptable call quality. Facilities will be provided to enable a suitable mobile handset to be plugged into the antenna and signal booster so that voice communication can be enabled at these locations.

The use of a public mobile network allows the data to be transmitted both to other mobiles and also to the fixed national Public Switched Telephone Network (PSTN) telephones. This gives a degree of flexibility of where control centres can be located and the locations from which data could be downloaded if so required.

Method of Operation of Communication

The method of system operation using the public mobile and satellite networks would be based on a daily download from each site with event driven data transfer when an alarm situation occurs.

In normal conditions the remote measuring site would call the control centre once every day to download its accumulated data and confirm its continued operation.

Should an event occur ,e.g. a measuring station detects a possible flood or an internal fault happens, the station would immediately call the control centre and download its current data and alarm status.

The control centre would automatically process this data, and in conjunction with other station data and with supervisor/operator input as required, would output a warning to the diversion weir structure operators and farmers as necessary.

The equipment in the control centre would also be able to interrogate any station at any time for its current data and status.

Operation in the above manner gives a very flexible and reliable means of communication, which keeps the cost of the telephone calls to a minimum. With data transfer rate at 1,200 baud or greater, connection times to download the data of one day will be approximately 30 seconds. This equates to an annual call cost per station of approximately US$ 160, for stations using the more costly satellite mobile techniques, with lower costs if via local GSM phones. Line rental charges would tend to form the major part of the cost.

4.2.4 HOUSING AND POWER SUPPLY

Housing of equipment

The instrumentation and the data logger/RTU should all be packaged in housings with an IP67 rating. These units should then be housed in a protective heavy-duty metal cabinet with a heavy-duty lock.

Power supply

There is no power source available at the remote stations and therefore there are two main options for providing power to the equipment.

The simplest method is to use a battery. The equipment will have low power consumption and a battery suitable for 3 or more months operation would be readily achievable. This does have the disadvantage that the battery will require regular changing.

The alternative is to install a small photovoltaic generator on the top of the cabinet to produce enough power to run the system. A small battery is required to provide power during the night. This arrangement has the advantage that it does not rely on regular maintenance for continued operation. With this arrangement the system would still continue to operate, if a larger battery were provided giving approximately 30 days capacity for if the photo cells failed and it would provide a reasonable period to instigate the required repairs.

4.3 RAIN GAUGE STATIONS

These stations would be broadly similar to the measuring station, but would just connect to a standard tipping bucket rain gauge and count the pulses from the gauge and record the count in the data logger.

The data logger/RTU could be configured so that it produces a warning to the control centre when more than a preset level of rain falls within a specific period.

4.4 DIVERSION WEIR STRUCTURES

These RTU are installed primarily to provide the weir operators with a warning of an approaching flood with an indication of its severity and flood volume. It is proposed that a siren is sounded to warn of the flood approach and a set of high intensity flashing lights to indicate the severity/volume. The siren would be on a timer to sound for only a preset time and would also have a local reset button for the operator to silence it if so required.

These stations would have the basic functions as at the measuring stations with the following additions and exceptions:

- Alarm warnings would only be generated on equipment faults and not on any level measurements
- Upto 8 control outputs to be provided to drive lights, audible alert unit and a siren
- An LED/LCD display of at least 30 characters to display text or numerals with a scroll facility to display longer messages sent from the control centre. (Note a local audible alert unit such as a bell would be used to draw the attention of the operator that a message has been sent.)
- The battery at these stations would need to be larger and be large enough to power the siren for a period of 20 minutes and the lights for a period of 4 hours. The solar panel would then be sized to enable recharge of the batteries over a period of 3 days.
- The equipment at these sites could be housed in the operators building adjacent to the structure. The solar panels, siren and lights could be mounted on the roof.

4.5 CONTROL CENTRE

4.5.1 GENERAL

The control centre will be a standard Personnel Computer (PC) with a standard operating system. The system shall include:

- Central processing unit
- Operator interface of VDU, keyboard and mouse
- Communications controllers and modems
- Archive data storage
- Record and alarm printer
- Propriety software (and licences)
- System configuration and software specific for this project
- Dedicated Uninterruptible Power Supply (UPS)
- Desk/workstation to house all the equipment.

The data gathering and processing facilities shall be provided by the installation of a propriety SCADA software package which shall be chosen to:

- Provide all the functionality necessary to implement the flood warning scheme
- Provide a ‘User Friendly’ and intuitive operator interface
- Provide an expandable and flexible system to allow development of functions and facilities in the future
- Have a large existing user base with multiple sources available for undertaking modifications to system programming and parameter configuration

The system shall be dual language allowing the operator to select operation in either English or Arabic script.

4.5.2 FUNCTION OF THE CONTROL CENTRE

The functions of the control centre should include:

- Receive alarm warnings from measuring stations
- Include processing techniques to evaluate flood profiles in the generation of flood alarms and estimation of flood volumes
- Transmit flood alerts to the diversion weir structure location both automatically and/or with the requirement for operator confirmation
- Transmit voice and SMS text messages to mobile and fixed telephones
- Allow operator to generate a flood alert
- Allow operator to sent messages to text display units at the weir stations
- Reset warnings sent to weir locations
- Record and archive all level data and rainfall data received from monitoring sites
- Automatically request download of data from measuring and monitoring sites every 24 hours and check all stations are operating correctly
- Alarm operator when fault detected at any station
- Alarm operator when any measuring site prompts a potential flood. Alert to be initially by local buzzer, but if the alarm is not acknowledged within a predefined period, a siren should be set off in the control centre site.
- Provide schematic diagram, charts and graph of both current and archived data held on the system
- Allow operator to interrogate any measuring or monitoring station at any time to get current data
- Have the capability to generate forms for input of data from weather observers and store the data for future analysis
- Include communication modems to enable other PCs to access all current and archived data subject to security password protection. This facility should be mainly available for interfacing to MIS and SMM and for access by TDA and NWRA.
- Contain text and online help of the operational plans to assist operators to direct the correct actions to the correct parties in various flood scenarios (note that these may be developed in conjunction with the SMM)
- Include the capability of undertaking some validity checking of measurement and monitored data prior to archiving

The control centre equipment should be housed in a lockable cabinet. This cabinet should contain all flood warning system equipment including UPS and batteries. The cabinet should have an alarm panel on its front to show the status of the system to be healthy or faulty, using warning lights or a buzzer to alert an operator in the event of a change of equipment status.

5 COST ESTIMATES AND PROCUREMENT STRATEGY

5.1 PROCUREMENT STRATEGY

The main elements of equipment which form the components of a flood warning scheme will need to be procured internationally as they are not available directly within Yemen.

The design approach should be that each of the components of the flood warning scheme are designed as complete free standing units, in order to standardise and minimise the installation requirements and to facilitate future provision of additional units if required.

The system should be procured as a complete system, fully configured and tested. The individual units can then be shipped to Yemen and be installed at the appropriate location by a Yemeni installation contractor, under the responsibility of the equipment supplier.

Once installed, the equipment supplier should be required to visit the site to commission the whole system.

5.2 COST ESTIMATES

The estimates for the components of the flood warning system are as follows. The equipment costs are for supply and delivery of equipment to Yemen. The cost of support in Yemen consist of commissioning, training and installation by qualified engineers from the equipment supplier. Probably a single visit to Yemen will suffice.

The above costs do not include any local content for installation and future Operation and Maintenance activities. These costs do also not include the connection charges or the ongoing use of the mobile telephones, see table 1.

Table 1 Cost estimates

Equipment	Unit cost US$	Qty for Zabid	Cost for Zabid US$	Qty for Tuban	Cost for Tuban US$	Total Cost US$
Control centre equipment including ups and cabinet etc.	10,000	1	10,000	1	10,000	20,000
Measurement Station	5,000	2	10,000	3	15,000	25,000
Diversion Weir Station	5,000	2	10,000	2	10,000	20,000
Rain gauge station	5,000	2	10,000	2	10,000	20,000
System design, testing and documentation	25,000					25,000
System commissioning on site	10,000					10,000
Installation support	10,000					10,000
Training	10,000					10,000
Mobile Telephones	200	15	3,000	20	4,000	7,000
Spare parts	10,000					10,000
					Total cost of supply	157,000

REPUBLIC OF YEMEN

MINISTRY OF AGRICULTURE AND IRRIGATION

IRRIGATION IMPROVEMENT PROJECT

(IDA Credit No. 3412 – YEM)

Main Technical Assistance Package for IIP

WORKING PAPER 5

ANNEX

Flood Warning System
System Specification

December 2002

ARCADIS EUROCONSULT

IN ASSOCIATION WITH

Halcrow

YEMENI ENGINEERING GROUP

Contents

1 INTRODUCTION 1

1.1 Objectives of Flood Warning Scheme 1

1.2 Scope of Flood Warning Scheme 1

2 SCOPE OF WORKS 2

2.1 General 2

3 FLOOD WARNING SCHEME SYSTEM REQUIREMENTS 4

3.1 General 4

3.2 User Requirements 4

3.3 Overall System Configuration 4

4 CENTRAL CONTROL SYSTEM 6

4.1 General 6

4.2 System Facilities 6

4.3 System Hardware 7

4.3.1 Central processing unit 7

4.3.2 Operator interface 7

4.3.3 Communications controllers and modems 8

4.3.4 Archive data storage 8

4.3.5 Record and alarm printers 8

4.3.6 Site siren 9

4.4 Proprietary software (and licences) 9

4.5 System software developed for this project 9

4.5.1 Configuration 9

4.5.2 Data processing 10

4.6 Dedicated Uninterruptible Power Supply (UPS) 10

4.7 Cabinet to house equipment. 11

5 REMOTE TERMINAL UNITS 12

5.1 General 12

5.2 Level Monitoring Stations 12

5.2.1 Level transducer 12

5.2.2 Data logging/telemetry unit 13

5.2.3 Input/Output Requirements 14
5.2.4 Communications 14
5.2.5 Housing and power supply 15
5.3 Weir Alert Stations 15
5.3.1 General 15
5.3.2 Level Transducer 15
5.3.3 Data Logger/telemetry unit 16
5.3.4 Input/Output Requirements 16
5.3.5 Communications 16
5.3.6 Housing and power supply 16
5.4 Rain gauge stations 17
5.4.1 General 17
5.4.2 Rain Gauge 17
5.4.3 Data Logger/telemetry unit 17
5.4.4 Input/Output Requirements 17
5.4.5 Communications 17
5.4.6 Housing and power supply 17

6 OTHER EQUIPMENT 18
6.1 Mobile Telephone Handsets 18
6.2 Documentation 18
6.3 Spares, Test Equipment and Consumables 18
6.4 Installation Support, Training and Commissioning 18

7 BILL OF QUANTITIES 20

1 INTRODUCTION

1.1 OBJECTIVES OF FLOOD WARNING SCHEME

The traditional water rights in spate irrigation areas in Yemen are governed by the *Sharia'a law*, which embodies the principle of *Ala'ala Fala'ala*. The principle gives precedence to upstream users both between and within diversion structures and canal systems. The upstream user has the first right to full irrigation (ankle deep) before allowing the water to flow downstream. In Wadi Zabid a spate flow diversion calendar is applied between diversion structures whereas the *Ala'ala Fala'ala* principle is applied below each diversion structure.

The lower areas benefit from the excess flows that cannot be fully diverted upstream. As the high peaks have short durations often the lower farmers are not ready to utilize these flows when they arrive, as they did not have a sufficiently early warning of the incoming flows. An early flood warning system will not only result in better utilization of spate water but will also give time for undertaking protection measures for the safety of the irrigation and rural infrastructure from flood damages. The early warning information will allow better and timely coordination of activities during floods including the operation of diversion gates in a more timely and efficient manner.

Much of the sediment is transported during the higher flows, and closure of head regulator gates during such conditions can substantially reduce the entry of sediment into the canal systems. However, closure of these gates during small floods can substantially reduce the amount of water being diverted.

1.2 SCOPE OF FLOOD WARNING SCHEME

The automatic telemetry and monitoring network in this phase of IIP is being set up as a pilot for testing its operation and sustainability. This trial will be undertaken for the two irrigation areas of the Wadi Zabid and Wadi Tuban systems.

There are two basic requirements of the flood warning system:

- Monitor data from the catchment of the irrigation schemes that will be an indication of possible flood flows;
- Dissemination of the warnings within the schemes.

The Flood Warning system shall interface to the Management Information System (MIS) and the Spate Management Model (SMM).

2 SCOPE OF WORKS

2.1 GENERAL

The following outlines the Scope of Work.

The work included within the Contract is for the design, manufacture, testing, delivery to site, commissioning and setting to work of the Flood Warning control system, including, but not limited to:

1. Detailed design of the complete Flood Warning Scheme.
2. The supply of all computer hardware and peripheral devices for two Control Centres one for Wadi Zabid area and the other for Wadi Tuban area.
3. The provision of licences and back-up copies of all computer software for the implementation and continued operation of the Flood Warning Scheme.
4. The supply of power cables and interconnecting wiring to all items of equipment supplied under this Contract.
5. The supply of all communications hardware and software to enable the download of data from the Flood Warning Scheme to the following systems over a PSTN communications circuit.
    a. Management Information System (MIS)
    b. Spate Management Model (SMM)
    c. National Water Resources Authority (NWRA)
    d. Tihama Development Authority (TDA)
6. The supply of flood monitoring and flood alert control equipment and control software at the following locations:
    a. Flow monitoring station at Kolah in Zabid
    b. Wadi level station upstream of Kolah in Zabid
    c. Flow monitoring station at El-Dukeim in Tuban
    d. Wadi level station upstream of El-Dukeim in Tuban
    e. Wadi level station along Wadi Billa in Tuban
    f. Flood alert stations at Weirs 1 and 3 for Wadi Zabid
    g. Flood alert stations at El Arais and Ras al Wadi weirs for Wadi Tuban
    h. 4x Rainfall gauge stations
7. The supply of level instrumentation.

8. The supply of housing to protect all equipment for each site and provision of solar panel cells and batteries to maintain continuous operation of the site throughout the year.
9. The supply of UPS and batteries to maintain continuous operation of control centre equipment.
10. The supply of all necessary earthing and surge protection equipment.
11. Full configuration of the all components of the flood monitoring scheme.
12. Factory Acceptance Tests (FAT) of the full flood monitoring control system.
13. Commissioning of the full flood monitoring control system and instrumentation.
14. Supply of comprehensive installation, operation and maintenance manuals
15. Supply of all documentation
16. Provision of installation support and training
17. Supply of spares
18. Supply of all specialist test equipment
19. Supply of consumables for 5 years operation following system handover
20. Supply of 35 GSM mobile handsets for use by the field operators and supervisors

3 FLOOD WARNING SCHEME SYSTEM REQUIREMENTS

3.1 GENERAL

The function of the Flood Warning Scheme is to provide early warning information to allow the control of irrigation structures and gates in a more timely and efficient manner. Data is to be gathered from monitoring stations upstream of the structures and from rain gauges in the catchment areas to determine the severity of a pending spate in the wadi. The flood warning system will then transmit this information so appropriate action can be taken before the flood reaches the irrigation control structures.

3.2 USER REQUIREMENTS

The User requirement for the flood warning system can be summarised as follows.

- The existing gauging stations at Kolah and El Dukeim are replaced with automatic monitoring equipment that can transmit the data on a 'real time' basis to a flood early warning system.
- The data gathered from the gauging stations is made available to the MIS, SMM and to NWRA and TDA.
- Water levels in the wadis upstream of the irrigation structures are monitored in 'real time' in order to provide approximately 2 hours notice of a flood arriving at the structures.
- Rain gauges in the catchment areas are monitored in 'real time' in order to assist in the determination of a possible flood condition and an assessment of the severity of the flood.
- The flood warning system is to assess the severity of any possible flood.
- The flood warning system is to advise appropriate personnel of any impending flood and an indication of its severity.

3.3 OVERALL SYSTEM CONFIGURATION

The overall system configuration shall be based on a central control system communicating to a number of remote terminal units (RTUs) out in the field over the public mobile telephone network. An identical configuration shall be designed for both the Wadi Zabid and Wadi Tuban systems.

The central control system will be focus of the system. It will obtain data from RTUs in the site. This data will be processed by the control system to determine

the probability and severity of a flood condition. If a flood is predicted the central control system will output flood warnings to the RTUs at the weir sites and also be capable of sending messages to fixed or mobile telephones of appropriate personnel.

The RTUs at the remote sites will interface to the local instrumentation such as level devices or rain gauges and transmit data to the control centre on a regular basis.

Communication between the RTU and the central control unit will in general be mobile GSM radio network but in some locations where GSM mobile access cannot be achieved satellite radio systems will be employed.

The central control system will be able to display current and historical data gathered from its RTU. It will also be able to download this data to other system such as MIS, SMM, NWRA and TDA using standard communications modems over the national public switched telephone network (PSTN).

The system shall be designed to operate on a continuous basis automatically without manual operator input or supervision.

4 CENTRAL CONTROL SYSTEM

4.1 GENERAL

The central control system shall include all the equipment and software necessary to provide the flood warning functional requirements. The system shall include:

- Central processing unit
- Operator interface
- Communications controllers and modems
- Archive data storage
- Record and alarm printers
- Proprietary software (and licences)
- System software developed for this project
- Dedicated Uninterruptible Power Supply (UPS)
- Desk/workstation to house all the equipment.

Two control systems shall be supplied, one for the Zabid system and the other for the Tuban system. Each system shall operate independently with the equipment located at different sites. However the software and system configuration shall be designed such that at a date in the future the two control systems can be moved to a central site and operate in a main/standby arrangement capable of controlling both the existing areas plus an additional 5 areas as the flood warning system is expanded.

4.2 SYSTEM FACILITIES

The facilities provided by the control centre should include:

- Receive alarm warnings from measuring stations
- Include processing techniques to evaluate flood profiles, generate flood alarms and estimate flood volumes
- Transmit flood alerts to the diversion weir structure location both automatically and/or with the requirement for operator confirmation
- Transmit voice and SMS text messages to mobile and fixed telephones
- Allow operator to generate a flood alert
- Allow operator to send messages to text display units at the weir stations
- Reset warnings sent to weir locations
- Record and archive all level data and rainfall data received from monitoring sites
- Automatically receive download of data from measuring and monitoring sites every 24 hours and check all stations are operating correctly

- Alert operator when fault detected at any station
- Alert operator when a potential flood is prompted by any measuring site. Alert to be initially by local buzzer but if the alarm is not acknowledged within a predefined period set off a siren in the control centre site
- Provide schematic diagram, charts and graph of both current and archived data held on the system
- Allow operator to interrogate any measuring or monitoring station at any time to obtain current data
- Have the capability to generate forms for input of data from weather observers and store the data for future analysis
- Include communication modems to enable other PCs to access all current and archived data subject to security password protection. This facility to be mainly available for interfacing to MIS and SMM and for access by TDA and NWRA.
- Contain text fields and online help for the operational plans to assist operators to direct the correct actions to the correct parties in various flood scenarios (note the text will be input by operators/supervisors as the operational procedures develop over time).
- Include the capability of undertaking validity checking of measurement and monitored data prior to archiving.

4.3 SYSTEM HARDWARE

4.3.1 CENTRAL PROCESSING UNIT

The central computer system shall utilise a standard commercially available Personal Computer (PC), which has a clock speed and memory capacity suitable to undertake the specified functionality for the initial trial phase of two irrigation/catchment areas and be capable of being expanded to a total of seven irrigation/catchment areas in the future.

The Central Control System shall comprise a PC based system operating a SCADA type data monitoring and control package on a commercially available operating system such as Windows 2000 or Windows NT. The equipment chosen shall be designed to operate unattended and continuously at all times in a non air-conditioned office environment in the Yemen.

4.3.2 OPERATOR INTERFACE

The operator interface shall comprise a Visual Display Unit (VDU) keyboard and mouse.

The VDU shall have a screen with a minimum diagonal measurement of at least 19 inches with full colour graphics capability. The face of the VDU shall be flat and of a non-glare type with flicker free refresh. The VDU shall incorporate screen-saving technology such that the unit blanks and enters a power saving mode after a user definable period with no user input.

The keyboard shall be a standard qwerty type unit with the keys engraved with both English and Arabic lettering.

A mouse shall supplement the keyboard to enable scroll and select functions.

4.3.3 COMMUNICATIONS CONTROLLERS AND MODEMS

Communications controllers, device drivers and modems shall be supplied to support all the necessary communications interfaces for the provision of the flood warning system facilities, which shall include the following:

- Communication with the RTU at the level monitoring, flood warning and rain gauge sites. The system equipment shall include both a communications path interfaced to a standard PSTN circuit and also one connected to a GSM mobile network. Under normal circumstances the system will use the GSM for linking to RTU connected to GSM network with the fallback to PSTN if GSM connection unavailable. For the RTU connected to the satellite the system shall use the PSTN link and fallback to GSM if this fails.
- Communications to the field system operators by GSM mobile with fallback to PSTN circuit. These telephone circuits shall be separate from those used for the RTU.
- Communication access for the remote downloading data to NWRA and TDA offices and the MIS and SMM systems. This connection can use the same telephone circuits as those used for communications to field operators.
- Communication access for remote connection of a maintenance/engineers (laptop) terminal over the telephone network. This connection can use the same telephone circuits as used for communications to field operators.
- Interface to local operator interface.
- Interface to the archive data storage device.
- Interface to the report/alarm printer.

4.3.4 ARCHIVE DATA STORAGE

A redundant archive data storage system shall be provided. The system shall have the capacity to store a minimum of 10 years data collected by the system. The system shall be expandable when necessary to cater for any extension of the flood warning system in the future.

The archive system shall have the facility to produce copies of the data onto CD ROM.

4.3.5 RECORD AND ALARM PRINTERS

A high quality A3 colour printer with a throughput of a minimum of 2 pages per minute shall be provided to produce reports in both textual and graphic formats. The printer shall incorporate a power save facility such that it goes into a standby mode if the printer is not used for a user selectable time.

4.3.6 SITE SIREN

The site alarm siren shall be a self contained unit suitable for outdoor installation and have a sound output of at least 115 dBA at 1 metre with tap setting (or volume control) to enable one of at least 8 different output levels to be selected as appropriate for its chosen location.

4.4 PROPRIETARY SOFTWARE (AND LICENCES)

The flood warning control system shall run under a proprietary software operating system such as Windows 2000 or Windows NT.

The data gathering and processing facilities shall be provided by the installation of a proprietary SCADA software package, which shall be chosen to:

- Provide all the functionality necessary to implement the flood warning scheme
- Provide a 'User Friendly' and intuitive operator interface
- Provide an expandable and flexible system to allow development of functions and facilities in the future
- Have a large existing user base with multiple sources available for undertaking modifications to system programming and parameter configuration

The software packages shall be dual language allowing the operator to select operation in either English or Arabic script.

The supply shall include all necessary licences for the use of all of the proprietary software for the needs of the flood warning scheme.

4.5 SYSTEM SOFTWARE DEVELOPED FOR THIS PROJECT

The proprietary software shall be configured to meet the needs of the flood warning system for display, processing and disseminating of the data.

4.5.1 CONFIGURATION

All data inputs from the RTU shall be configured to ensure all points outstations and alarms etc are described correctly with meaningful descriptions and engineering units.

Mimic diagrams shall be drawn for the schematic representation of the scheme and instrumentation showing current and historic data in the most advantageous format. Typical mimics that shall be produced shall include:

- Log on/off of the system (incorporating user password protection giving appropriate pre-defined level of access)
- Schematic displays showing current measurements

- Text and help pages to assist operators making decisions
- Alarm and fault lists detailing all alarms and faults with their status
- Record and report displays showing current and archive information in text or graphical formats

An engineering facility shall be available for an Engineer to re-configure the system data, modify or add new mimics reports etc.

4.5.2 DATA PROCESSING

The system shall be capable of processing the raw data from the RTU undertaking logical, arithmetic and algebraic manipulation and calculations.

The system shall be capable of generating formulae to determine the probability of a flood and its approximate severity from data collected from the monitoring sites. Initially the system shall be configured to automatically raise flood alerts when the water level at monitoring sites reaches preset levels with the severity determined by the crest height of the flood. As operational experience is gained then the system shall have the capability for the supervisor/engineer to develop more complex algorithms incorporating data from other sites, rain gauges and observer reports for example.

The system shall be capable of generating a series of relationships, which identify what actions are taken for different flood alarm conditions. Each relationship shall identify which sites are to be alerted and what output to be sent, what text messages are sent to which numbers and what voice messages are output to which numbers. Initially the system shall be configured with 10 of these relationships but shall have the capacity for a minimum of 100.

The system shall be capable of allowing the comparison of current trends of a flood crest waveform with simulated or historic floods to assist the operators/supervisor in estimating the volume of a flood.

The system shall be capable of calculating a flood volume from the level measurements at the monitoring site and its appropriate rating curve. The system shall be configured to automatically calculate and archive the time, date, flood crest peak, peak volume, total volume and duration of every flood event. A flood event duration shall be defined as from the detection of a rising water level until the water level has dropped below a predefined limit (initially set at 100mm).

All data collected form the monitoring sites shall be output in Microsoft Access or Excel format for transmission to the MIS, SMM, NWRA and TDA.

4.6 DEDICATED UNINTERRUPTIBLE POWER SUPPLY (UPS)

The control centre equipment shall be powered through a UPS supply to protect the equipment from power source surges and to enable continued operation for a minimum of 48 hours in the event of the power source failure.

4.7 CABINET TO HOUSE EQUIPMENT

The control centre equipment shall be housed in a lockable cabinet as a self-contained unit. This cabinet should contain all flood warning system equipment. The cabinet should have a front mounted alarm annunciator panel to indicate system status with warning lights/buzzer to alert an operator in the event of a change of equipment status. This unit shall include any ventilation, cooling, air filters or air conditioning necessary to maintain the equipment within its operational environmental limits when installed in a non air-conditioned office in the Yemen.

The UPS and batteries shall be housed in a separate cabinet adjacent to the computer cabinet.

5 REMOTE TERMINAL UNITS

5.1 GENERAL

Three types of RTUs shall be provided for the flood warning system. These shall be:

- Level monitoring stations (initially 5 units required);
- Weir Alert Stations (initially 4 units required);
- Rain gauge stations (initially 4 units required).

Each of these types of station shall be developed as complete modules which can be provided to an installation team to install on site at the most appropriate location.

5.2 LEVEL MONITORING STATIONS

The level monitoring stations shall comprise a water level monitoring instrument connected to a data logger/telemetry unit with an associated communications link and power supply.

5.2.1 LEVEL TRANSDUCER

Level shall be monitored by means of a measuring system consisting of an ultrasonic level transducer, which shall produce an analogue output linear with level. The transducer shall comply with the following requirements:

- The transducer shall be to IP67 with a fixed waterproof connection.
- The transducer shall be supplied complete with a suitable cable of 30 metre length.

The controller/transmitter together with the transducer shall satisfy the following requirements:

- Range : 10 metres.
- Span : Site adjustable throughout range.
- Accuracy : Better than ± 0.15% of range.
- Surge Protection : To protect against voltages up to 2 KV to comply with IEC 801.
- Temperature compensation: To compensate for ambient temperature variations
- Output : 4-20 mA.
- Power Supply : 12 V DC.
- Operating Temperature : $-10^{O}C$ to $+65^{O}C$

- IP rating : IP65
- Alarm outputs : Lost Echo/Power Failure
- Commissioning : All appropriate controls and facilities shall be provided to facilitate commissioning and periodic testing, recalibration and re-ranging.

5.2.2 DATA LOGGING/TELEMETRY UNIT

The data logger/telemetry unit at the level sites should include analogue and digital input capabilities for the level instrumentation and alarm indications. The functions and facilities of the data logger/telemetry unit should include:

- Data storage time logging at a configurable rate between 1 minute and 1 hour
- Data storage rate to be selectable on event detection i.e. level reading on instrument
- Data storage capacity to be at least 10,000 time stamped records
- System to read instrument every 10 minutes under normal (non-flood) conditions
- System to read and record/log instrument reading every 1 minute while level measurement is within a preset range
- Data logging to be every hour under non-flood conditions
- Transmit an alarm to the control centre when the water level reaches certain preset limits (initially set 500mm and every 250mm above this level)
- Monitor state of battery and any solar power generator and alarm fault or battery low
- Initiate an instrument fault when current reading is outside 4 – 20ma range
- Download any current and stored data on request from the control centre
- Send text messages to specified mobile phone handsets if data has not been successfully downloaded after a predetermined number of attempts
- Send text messages to specified mobile phone handsets if transmission to control centre fails when a flood alarm warning is issued
- Equipment to be suitable for environment e.g. -10^{O}C to $+65^{O}$C
- Equipment to be housed in cabinet to meet IP67
- Equipment to be low power consumption
- Have connection point for connecting a laptop PC to download data and reconfigure the unit if necessary

5.2.3 INPUT/OUTPUT REQUIREMENTS

The remote terminal unit shall have as a minimum the following input and output facilities:

- Analogue Inputs - (4 inputs) 16 bit resolution Accuracy +/-0.1% Current 4-20ma. Voltage 0-5V, 0-10V.
- Digital Inputs - (4 inputs) Volts free contacts
- Digital outputs - (4 outputs) Volts free contacts

5.2.4 COMMUNICATIONS

General

The data logger/telemetry unit shall connect to the communications equipment to enable the transmission of data and alarms to the control centre. The interface shall also include the capability of the telemetry unit being able to send voice or SMS text messages to specific mobile or fixed telephones in the event of an alarm message not being accepted by the control centre.

In order to achieve communications in the areas where the data loggers/telemetry units will be located, a mobile radio based communications system shall be provided.

Wherever possible, use will be made of GSM mobile (operators are Spacetel or Sabafon in Yemen). As coverage may be marginal, signal booster equipment and external antenna shall be provided to ensure an acceptable call quality.

At locations where GSM mobile access is not available the system shall use the satellite based mobile network from Thuraya (service provider Partners Company Ltd in Yemen).

Facilities shall be provided to enable a suitable mobile handset to plug into the antenna and signal booster so that voice communication can be made from these locations.

Three of the Level stations shall be complete with the GSM mobile equipment and the other two shall be complete with the satellite mobile equipment.

Method of Operation of the Communications

The method of system operation using the public mobile and satellite networks shall be based on a daily download from each site with event driven data transfer when an alarm situation occurs.

In normal conditions the remote measuring site shall call the control centre once every day to download its accumulated data and confirm its continued operation. Data transfer rate shall be at 1200 baud or greater.

Should an event occur such as a level reaching an alarm limit or an internal fault occurring, the station shall immediately call the control centre, download its current data and alarm status.

The control centre shall automatically process this data and in conjunction with other station data and with supervisor/operator input as required, will output a warning to the diversion weir structure operators and farmers as necessary.

The control centre equipment shall also be able to interrogate any station at any time for its current data and status.

5.2.5 HOUSING AND POWER SUPPLY

Housing of equipment

The instrumentation and the data logger/telemetry unit shall each be packaged in housings with an IP67 rating.

The data logger/telemetry units and communication equipment shall be housed in a ventilated protective heavy-duty metal cabinet with a heavy-duty lock.

The ultrasonic detector head shall be protected by a heavy-duty hood which also acts as a sunshade.

Power supply

The Level Station equipment shall be powered by a battery which is trickle charged by a photovoltaic/solar cell fitted to the top of the equipment cabinet.

The battery shall be sized to provide continued operation, without any recharge, for 90 days based on a data-logging period of every 10 minutes. Operation during flood conditions (i.e. logging at 1 minute intervals) should be greater than 30 days.

The photovoltaic/solar cell shall be sized to maintain continued operation throughout the year.

Detection equipment shall be included to detect photovoltaic /solar cell failure and battery low voltage.

5.3 WEIR ALERT STATIONS

5.3.1 GENERAL

The weir alert stations shall be the same as the level stations with the differences as detailed below.

5.3.2 LEVEL TRANSDUCER

Provision of an ultrasonic level measuring instrument as for Level Station.

5.3.3 DATA LOGGER/TELEMETRY UNIT

These data logger/telemetry units are installed primarily to provide the weir operators with a warning of an approaching flood with an indication of its severity and flood volume. A siren shall be sounded to warn of the flood approach and a set of high intensity flashing lights to indicate the severity/volume. The siren shall be on a timer to sound for only a preset time and also have a local reset button for the operator to silence it if so required.

In addition to the primary function these locations shall also include a level measuring device to monitor the water height at the weir structure.

These stations shall have the basic functions as at the measuring stations with the following additions and exceptions:

- Alarm warnings shall only be generated on equipment faults and not on any level measurements
- Up to 8 control outputs to be provided to drive lights, audible alert unit and a siren
- An LED/LCD display of at least 30 characters to display text (in Arabic) or numerals with a scroll facility to display longer messages sent from the control centre.
- A local audible alert unit such as a bell shall be provided to draw the attention of the operator that a message had been sent on the text display.

5.3.4 INPUT/OUTPUT REQUIREMENTS

Input/outputs as Level Stations with the addition of:

- 4 Digital outputs (total 8)
- 30 character LED/LCD display

5.3.5 COMMUNICATIONS

Communications shall be as for Level Stations with 3 of the sites fitted with GSM mobile communications and 1 with satellite communications.

5.3.6 HOUSING AND POWER SUPPLY

The equipment at these sites will be housed in the operators building adjacent to the structure. It shall be housed in a lockable wall mounting cabinet, which has the LED/LCD text display mounted on the front along with the bell and siren reset buttons.

The solar panels, siren and lights shall be mounted on a bracket that can be fitted onto the roof of the operators building.

The battery at these stations shall be sized to power the data logger/telemetry equipment as for the level stations plus additional capacity to power the siren for a period of 20 minutes and the lights for a period of 4 hours. The solar panel shall be sized to enable recharge of the batteries over a period of 3 days.

5.4 RAIN GAUGE STATIONS

5.4.1 GENERAL

The rain gauge stations shall be similar to the Level Stations except that there shall be a tipping bucket rain gauge connected to the data logger/telemetry unit rather than an ultrasonic level instrument.

5.4.2 RAIN GAUGE

The rain gauge shall be a conventional tipping bucket rain gauge:

Orifice size	200mm diameter.
Resolution/bucket size	0.25mm
Output	Double output relay contacts
Levelling	Built in spirit level
Environment	IP67

5.4.3 DATA LOGGER/TELEMETRY UNIT

The data logger/telemetry unit shall have similar functions to the Level Station with the following additions and exceptions:

- Data logger shall count the operations of the tipping bucket of the rain gauge.
- Data logger shall record the number of operations of the tipping bucket for each 15 minute period
- Transmit an alarm to the control centre when the number of operations of the tipping buckets exceeds a certain preset limit over a preset time period.

5.4.4 INPUT/OUTPUT REQUIREMENTS

The input/output requirement shall be as the Level Stations with the digital inputs being used for the count inputs.

5.4.5 COMMUNICATIONS

Communications shall be as for Level Stations with all sites fitted with satellite communications.

5.4.6 HOUSING AND POWER SUPPLY

The housing and power supply for the rain stations shall be the same as for the Level Stations.

6 OTHER EQUIPMENT

6.1 MOBILE TELEPHONE HANDSETS

35 GSM mobile telephone handsets shall be provided. The handsets shall be chosen with better than average sensitivity to give the best reception in marginal signal areas. The contractor shall provide evidence to support the selection.

The telephones shall come complete with manual, mains charger and carrying pouch, which can be attached to a belt or similar.

6.2 DOCUMENTATION

A full and comprehensive set of installation instructions and O&M manuals shall be provided. 4 paper copies of the documentation shall be provided along with a CD ROM containing all the documentation in text or pdf format as appropriate.

The operator and user sections of the documentation shall be both English and Arabic whereas the technical documentation may be in English only.

All documentation shall be completed and delivered to the purchaser at the same time as the equipment.

6.3 SPARES, TEST EQUIPMENT AND CONSUMABLES

A full set of spares and consumables shall be provided for 5 years of operation of the system after handover.

One spare unit shall be provided for approximately 10% of the total units supplied. Proprietary equipment such as PC and mobile telephone handsets do not need to be included.

Any special test equipment necessary for maintenance or calibration of instruments shall be provided.

A list of all spares, test equipment and consumables offered shall be provided with the offer.

6.4 INSTALLATION SUPPORT, TRAINING AND COMMISSIONING

The provision of a suitably qualified and experienced engineer for a period of 6 weeks in the Yemen shall be provided to

- Review the installation

- Provide training on the operation and maintenance of the equipment
- Commission the system and undertake acceptance/handover tests.

7 BILL OF QUANTITIES

Item Description	Quantity	Unit Cost US$	Total Cost US$
Control Centre system	2		
Level Station with GSM mobile communication interface	3		
Level Station with satellite mobile communication interface	2		
Wadi Alert Stations with GSM mobile communication interface	3		
Wadi Alert Stations with satellite mobile communication interface	1		
Rain Gauge Stations with satellite mobile communication interface	4		
GSM mobile telephone handsets	35		
Complete installation and O&M manuals for all equipment supplied	Set		
Installation support, training and commissioning on site	6 weeks		
Set of spares, special test equipment and consumables	Set		

The costs of equipment shall include for all design, testing, carriage and import duties to a designated location in Yemen.

The costs of services in Yemen shall include all travel time and expenses.

A list shall be provided of all spares, special test equipment and consumables included in the offer.