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PHASE II

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IMPLEMENTATION AND OPERATION OF PILOT HYDRAULIC MONITORING PROJECT

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EXECUTIVE SUMMARY

This report defines the procedure for the implementation and operation of a pilot hydraulic monitoring project. The project will be initiated in selected irrigation canal circles in each province. The selected circles are:

Punjab

Upper Chenab Canal Circle, Lahore
Lower Jhelum Canal Circle, Sargodha
Lower Chenab Canal East Circle, Faisalabad
Muzaffargarh Canal Circle, Multan
Bahawalpur Canal Circle, Bahawalpur

Sindh

Pinyari Canal Circle, Hyderabad
Bagari Sindh Feeder Circle, Sukkur
Rohri Canal Circle, Hyderabad
Nara Canal Circle, Hyderabad

Balochistan

Irrigation Circle, Quetta
Pat Feeder and Sibi Circle, Mardan

Northwest Frontier

Northern Irrigation Circle, Mardan
Southern Circle, Bannu

"Hydraulic Monitoring" is defined as the monitoring of the operation and performance of the irrigation and drainage systems of the provincial irrigation departments by collecting and evaluating the hydraulic, sediment and morphological data. The evaluation of the data will provide necessary information to judge the "reliability" and "equity" of the irrigation system.

Hydraulic monitoring will essentially involve:

- Data collection and preparation of performance history of irrigation system.
- Routine hydraulic measurements including installation of staff gages and recorders, stage and flow measurements, sediment sampling and determination of stage-discharge relationships

- Cross sectional and longitudinal bed profiles survey
- Laboratory analysis of sediment data
- Office analysis and data evaluation

Superintending engineers, in charge of the circles, will be primarily responsible for the implementation and operation of the pilot projects. The regional chief engineers will check the progress of the projects and will take the overall responsibility.

Executive engineers, in charge of divisions, will be responsible to execute the project. Preparation of performance history, including collection of data for this purpose, hydraulic measurements, sediment sampling and profile surveys will be done by the sub-engineers and assistant engineers under their control. They also will prepare evaluation reports for selected sub-systems which are not functioning properly and plan for remedial measures.

The sediment analysis will be done by a special unit established in each circle. The unit will consist of two research assistants and one office assistant. The unit will keep a liaison between the executive engineers and the superintending engineer. All hydraulic and sediment data collected in the divisions will be compiled and computerized by this unit.

The sub-engineers and assistant engineers in the divisions and special units in the circles will be trained by a hydraulic/sediment monitoring specialist from the Technical Assistance team. The training will involve:

- Class room lectures to define monitoring needs and methodology
- Field training
- Laboratory analysis
- Office procedures

FOREWORD

This report is a continuation of a previous report entitled, "Assessment of Hydraulic Monitoring Equipment Needs of Provincial Irrigation Departments," submitted to the United States Agency for International Development (USAID) by Harza Engineering Company in October 1991, in compliance with the requirements of the Irrigation Systems Management Project, Phase II (ISM II). The need for this report was realized based on the review comments and discussion on the previous report. The report has been prepared by Khalid Jawed, senior Hydrologist, Harza Engineering Company, Chicago. The concept and some ideas provided by Mr. J.C. Ringenoldus, Chief of Party, and Mr. Jim Wolf, Monitoring and Evaluation (M&E) specialist, for the preparation of this report are highly appreciated.

OBJECTIVE AND SCOPE

The ISM-II project is designed to increase agricultural production of Pakistan by improving the reliability of water delivery and the equity of water distribution throughout the irrigation systems in each province. The project inputs and the efforts of the Technical Assistance (TA) team are directed to the following major activities:

- Rehabilitation planning and design
- Physical improvements to selected systems
- Equipment management and utilization
- Monitoring and evaluation of irrigation systems
- Computerization
- Training

Under "Monitoring and Evaluation", a number of monitoring activities such as canal breaches, status of canal berms, conditions of control structures and silt excluders, hydraulic parameters, sediment characteristics, water quality, etc., can be included. Some of these parameters are either currently being monitored by the provincial irrigation departments (PIDs) or will be monitored in the future. This report provides guidelines and details for the implementation and operation of a pilot "Hydraulic Monitoring" project. "Hydraulic Monitoring" is defined as "the monitoring of the operation and performance of the irrigation and drainage systems by collecting, and evaluating hydraulic, sediment and morphological data."

This report defines the responsibilities, institutional arrangement, and procedures for the implementation and operation of the pilot project by the PIDs. The report covers the following major tasks.

- Need for hydraulic monitoring
- Project definition
- Project responsibility
- Hydraulic/sediment monitoring equipment
- Field monitoring procedures
- Sediment laboratory analyses
- Office analyses
- Training program
- Periodic review of project operation
- Future extension

NEED FOR HYDRAULIC MONITORING

According to general irrigation practices in Pakistan, the field divisions of the PIDs are required to maintain a performance history of irrigation systems (main canal, distributaries and minors) under their administrative control. Staff gages are supposed to be functioning at the heads, tails, and at important intermediate locations of main canals, branches, distributaries, and minors. Periodic current meter or velocity-rod measurements are required to check the discharges derived from the previously established stage-discharge relationships at the gage locations. Longitudinal and cross-sectional profiles of canals distributaries also are required to monitor the extent of and deposition/scour in the system. Generally, these profiles should be surveyed during the closure periods.

Over the past years, the above practices have been discontinued in all provinces. Due to lack of monitoring and poor maintenance, the systems have deteriorated resulting in frequent breaches and shortages of water at the tail outlets.

To ensure "reliability" and "equity" of an irrigation system, hydraulic monitoring is necessary to check these parameters. Reliability is defined as "average percent of days that a planned water supply was available to the tail outlets". Equity is considered as a relationship between water delivery to the farmers near the head versus the farmers near the tail. This is analyzed by comparing the ratio of delivered discharge to design discharge in the head reach versus tail reach outlets.

The "reliability" and "equity" of an irrigation system changes over a period of time. This is because modifications in channel cross sections and bed levels occur due to weed growth along banks, channel sedimentation or scour, and bank damage by animals. These modifications change water levels for a given discharge in the system. Because the delivery to distributaries, minors, and outlets (moghas), is based on the relationship of water level to discharge, the actual delivery may be significantly higher or lower depending upon the type of modification.

Long-term changes in the water levels also occur because of changes in the quantity and quality of sediment introduced into the system at a diversion. Each year additional sediment may be deposited in a sub-system resulting in a general rise of channel bed. This also will affect the "reliability" and "equity" of the system.

Hydraulic monitoring will essentially involve periodic updating of the history of the irrigation systems/sub-

systems, installation of water level monitoring staff gages and recorders at key locations on the system, establishment or revision of stage-discharge relationships (or empirical relationships) used to determine canal/outlet delivery through periodic current meter flow measurements, collection and analyses of limited numbers of suspended and bed material samples, and survey of cross sectional and longitudinal profiles of the systems/sub-systems during closure periods. The monitoring will essentially identify any flow changes corresponding to indicated water levels on a seasonal or a long-term basis.

PILOT PROJECT PROGRAM

The ISM-II project is to help the PIDs develop the capabilities for monitoring the operation and performance of their irrigation and drainage systems through collection and evaluation of the hydraulic, sediment, and morphological data. The type of data required should include:

1. History of performance:

- Sedimentation in channel bed
- Excessive silt movement through outlets
- Continuous shortages at the outlets at tail
- Overgrowth on berms
- Frequent canal breaches.

2. Routine hydraulic measurements:

- Installation of water-level-monitoring staff gages and recorders
- Periodic discharge measurements to establish or update stage-discharge relationships at key locations in the system (at head, tail, or intermediate reaches, outlets, and regulating structures)
- Periodic sampling of suspended sediment
- Periodic boil sampling at regulators
- Survey of cross sectional and longitudinal profiles for selected reaches during closures.

3. Detailed hydraulic survey for selected reaches:

- Measurement of water surface profiles
- Survey of cross sectional profile at about four locations
- Measurement of flow
- Sampling of suspended sediment at 3 to 10 verticals (depth integration method), depending upon the width of channel, at the cross section where discharge was measured
- Sampling of bed material at three verticals (1/6, 1/2 and 5/6 of width)
- Survey of longitudinal and cross sectional profiles using echo sounders and during closure periods.

4. Laboratory and office analyses:

- Analysis of sediment samples
- Cataloguing and computerization of data.

Hydraulic equipment needs of the PIDs for the collection and evaluation of the above data were assessed as discussed in a previous report entitled, "Assessment of Hydraulic Monitoring Equipment Needs of Provincial Irrigation Departments". The cost of equipment for full operation was quite high. Also, during discussions with the Provincial Advisors and Provincial Coordinators of the respective PIDs, it was realized that there had been a lack of interest among the engineering staff of the PIDs for monitoring the operation and performance of the canal system, or the staff was inexperienced. Practically, there is no hydraulic/sediment monitoring equipment with the field divisions.

Because of little experience of the field staff in hydraulic monitoring and also some lack of interest, an enhanced flow monitoring program, as discussed above, was not considered feasible. A pilot project approach would be most viable because this will reduce the cost of equipment and also provide an opportunity to judge the response and enthusiasm of the PIDs to the monitoring efforts, the willingness of engineers and sub-engineers to monitor the canal systems under their control along with their routine duties, and to check the difficulties faced by the PIDs to employ research staff for sediment analysis and office work.

Under the pilot project in each province, the work tasks will include preparation of the history of performance, routine hydraulic measurements, and laboratory and office analyses as defined above. The project will be initiated in the irrigation circles of the PIDs listed in Tables 1 to 4. The selection of these circles was made in consultation with the Provincial Advisors of the TA team. The underlying idea was to select at least one circle from each zone (regional chief engineer) and from different geographic locations so that the training is spread throughout a province. This would help the future training of the staff in the nearby circles/divisions, which would not receive formal training through ISM-II, by the local staff of the selected circles.

PROJECT IMPLEMENTATION AND OPERATION

Major responsibility for the implementation and operation of the project will rest with the superintending engineer in charge of a circle. The regional chief engineer should check the progress and project operation periodically.

Performance history and hydraulic measurements including sediment sampling will be done at divisional levels under the control of executive engineers. The executive engineers will also document the data in an orderly manner, evaluate the data and identify any problem with the system such as:

- Canal cannot pass the design discharge
- Freeboard has been significantly reduced
- Stage-discharge relationships at control points need to be revised
- Silt clearance is required
- Frequent breaches occur
- Berms are overgrown
- Heavy silt passes through outlets
- Shortages occur at the tail outlets.

The executive engineers should identify the reasons for the above problems and prepare a report for the review of the superintending engineer.

The sediment analysis will be done by a special unit established in a circle. The results of the analysis should be sent to the respective executive engineers for review and evaluation. The unit will consist of two research assistants and one office assistant. The unit also will be responsible for computerizing all hydraulic and sediment data and documentation of evaluation reports by executive engineers and decisions on remedial measures taken any respective superintending engineer and chief engineer.

Details of the responsibilities of a chief engineer, superintending engineer and executive engineer are given below:

Regional Level

Regional chief engineers will have overall responsibility to ensure that the objective of the pilot hydraulic monitoring project is being achieved and would plan to extend the hydraulic monitoring efforts to other circles/divisions under their administrative control.

Circle Level

Superintending engineers in charge of the circles will have the major responsibility for the successful implementation and operation of the project. With the help of a special unit, the following tasks will be performed:

1. Operate a sediment analysis laboratory and provide results of total concentration and particle size distribution of suspended sediment samples and particle size distribution of bed material samples to the respective executive engineers;

2. Review the performance history of the irrigation systems prepared by the executive engineers;

3. Review the special reports prepared by the executive engineers, identify the canals with poor performance, and determine remedial measures in consultation with chief engineer and the executive engineer;

4. Review the field data collection procedures periodically and provide technical guidance;

5. Properly computerize and/or file the data for future use.

Divisional Level

The executive engineers and subdivisional officers of the divisions under the pilot project will have primary responsibility for carrying out the field work and analysis of hydraulic monitoring. The following tasks will be performed at the division levels:

1. Update the performance history of canals after every five years in respect of silting, scouring shortages at tail outlets, breaches, encroachments of freeboard, berm growth, etc;

2. Install staff gages at selected locations on the canals to develop stage-discharge relationships which can be used to monitor the flow using the staff gage readings;

3. Make current meter discharge measurements on headworks, and other control structures in the system three or four times (preferably in different cropping seasons) during a year to check the discharge tables and/or empirical discharge relationships;

4. Establish stage-discharge relationships at sites with no control structure, by initially making current meter measurements at least four times each cropping season (at different discharge rates); later reducing the measurements to two each cropping season with the timing of the measurement selected to best represent the true flow conditions of the channel);

5. Measure watercourse discharges at different flow rates in the canals using pygmy current meters or standardized flumes or other equipment, (pygmy current meters are provided for the project, flumes or other equipment, if needed, should be provided by the PIDs);

6. Compare the measured watercourse discharge with the outlet discharge estimated from empirical relationships;

7. Collect suspended sediment and bed material samples at selected locations and send to the sediment laboratory in the circle office for analysis;

8. Check the reliability and equity of a canal system using the flow data;

9. Prepare longitudinal and cross sectional profiles of the canals, distributaries, and minors during the closure periods;

10. Evaluate the data and identify the channels which indicate poor performance;

11. Define remedial measures to upgrade the performance of the problematic canals in consultation with the superintending engineer and chief engineer;

12. Properly document the basic data and evaluation results for submission to the circle office.

MONITORING EQUIPMENT

The types and specifications of the hydraulic monitoring equipment were selected based on the hydraulic parameters and sediment characteristics required for monitoring the operation and performance of the canals. The recommended equipment is suitable for measuring canals and drains but not the large rivers. It includes hydraulic equipment for discharge and stage measurements, sediment sampling (by wading), and laboratory equipment for particle size distribution analysis of suspended and bed material samples and total suspended sediment concentration analysis.

The recommended equipment does not include vehicles, computers, and other office accessories. Also, small portable flumes may be required in some divisions for measurements of small flows from outlets (moghas). These should be manufactured locally for site-specific conditions.

Tables 1 to 4 show the total number of each equipment item for the four provinces. Table 5 shows the specifications of each item, unit price of each item, and representative supplier. Tables 6 and 7 summarize the equipment recommended for each circle, identifying which is available in Pakistan and which is to be imported from USA.

Equipment requirements of a circle are estimated based on providing one piece of each item of equipment for the circle for sediment analysis, and one piece of each item of equipment for each division for hydraulic monitoring, except that two pieces are provided for the items that will be subjected to frequent wear and tear. Spares are provided for about two years of operation.

FIELD MONITORING

Field monitoring will essentially involve:

1. Collection of data for updating the performance history of canals,
2. Daily stage measurements to determine flow in the system using stage-discharge relationships,
3. Periodic current meter measurements on canals/distributaries,
4. Periodic measurements of flow through outlets,
5. Suspended sediment and bed material sampling,
6. Survey of longitudinal and cross sectional profiles during closure periods.

Performance History

Field data for the preparation of the performance history mainly will be derived from the evaluation of the hydraulic data except that freeboard measurements using a survey level should be made at selected locations along the canal to check any encroachment on freeboard. Also visual inspection will be required periodically to assess the extent of overgrowth on the banks.

Hydraulic Monitoring

As discussed in the previous sections, the hydraulic monitoring will involve installation of staff gages and water level recorders, periodic measurements of flow and sediment characteristics, and survey of longitudinal and cross sectional profiles of the channel. Brief descriptions of general precautions and procedures for the monitoring are discussed below.

General Precautions.

All hydraulic measurements have uncertainties either because of random error or systematic error. The random errors are introduced due to measuring procedures or field conditions. To minimize random error, it is always advisable to make a set of measurements and use the average value as the acceptable value.

Systematic errors are caused due to non-calibration of the instruments, malfunctioning, or poor installations. These

are repetitive in nature or error by the some amount. These should be avoided by periodic inspections of the installation, periodic replacement of replaceable parts, and reasonably frequent calibration of the measuring instruments.

Canal Water Level Measurements

Canal water levels will be measured by a staff gage or water level recorder housed over a stilling well (18 inches diameter galvanized corrugated iron or plastic pipe). A staff gage will also be installed along with the recorder to provide a check on the recorder. The datum of the gage should be set to Standard Pakistan Datum. Two or three bench marks should be established near a gage at locations unlikely to be disturbed. The following precautions should be exercised in the installation of gages.

1. The canal reaches selected for gaging should be uniform (no erosion of banks) and straight, at least for a distance of 4 to 5 times the width of the canal. They should be away from obstructions in the channel such as bridges, etc.;

2. To cover the complete range of the water levels, the gage should be installed in steps;

3. There should be no backwater effect on the gage from downstream structures or other sources;

4. At regulating structures where the gage is installed upstream of the structure, it should be away from the drawdown effect at the structure (a general rule is to install the gage a distance of about three to four times the width of the channel upstream from the structure);

5. A tail gage at a regulating structure should be installed at a distance sufficiently downstream to avoid turbulence effect on the gage;

6. Datum of the gage should be checked periodically with respect to the bench marks available near the gage.

A water level recorder will provide a continuous record of the water levels. The staff gages should be read once a day if no changes in flow occur during a day or more often, depending upon the changes in flow.

The locations of the gages should be finalized with the guidance of the superintending engineer in charge of a circle. Ideally, a gage should be established at the head,

at the points where bifurcations in flow occur, and at the tail.

Flow Measurements

The canal reach selected for the installation of the gage, if properly selected, should be adequate to select a cross section for the flow measurements. The selected section should have uniform velocity distribution across the width of the canal, no evidence of secondary currents, and no bank erosion. When measuring flow downstream from a regulating structure with a fall or high velocity, the measuring section should be away from the turbulence, where the velocity has become uniform. In alluvial canals, bed sand movement occurs with high velocities. Depth and velocity at such locations are significantly changing with the movement of the bed sand.

The most common method for determining the flow in a canal is the velocity-area method. In this method, discharge measurement is computed as the summation of the products of partial areas of the flow cross section and their respective average velocities for each of these sections as:

$$Q = \Sigma\ (av) = \Sigma\ (a_i \times v_i) = \Sigma\ (d_i, w_i, v_i)$$

In each partial sections "i", the flow is computed by mid-section method as (see Exhibit 1).

$$q_i = v_i\ [(b_i - b_{i-1})/2 + (b_{i+1} - b_i)/2]\ d_i$$

$$= v_i\ (b_{i+1} - b_{i-1})/2\ d_i$$

in which

q_i = discharge through partial section "i"
v_i = mean velocity at location "i"
d_i = depth at location "i"
b_i = distance from initial reference point to location "i"
b_{i-1} = distance from initial reference point to preceding location
b_{i+1} = distance from initial reference point to next location.

In this method, a small sub-area of flow at either end may be neglected. It is customary to estimate the velocity in these sub-areas as a percentage of the velocity at the next or previous section and area as the area of a triangle.

To guarantee accuracy and reliability of the measurements, it is necessary to have at least 25 to 30 sections across the canal width. However, the minimum width of section should not be less than one foot for a Price AA type current meter and 0.5 foot for a pygmy current meter.

Current meter flow measurement on the canal systems will be made by wading or using a boat outfit. The limit of wading is set by safety considerations. The amount of water which can be waded safely varies slightly with each individual. However, a "rule-of-thumb" sets this limit at a discharge of about 12-13 cfs/ft of width. The total canal width, spacing of sections for depth soundings and velocity measurements, and width of the partial sections are measured by a tagline stretched perpendicular to the direction of flow. Depth soundings are made with a wading rod. The Price type AA or pygmy current meter is used for velocity measurement by two-point or one-point method depending upon the depth of flow. For the Price type AA current meter, the depth of flow for 0.2-and 0.8-depth velocities should be 1.5 feet or more. The 0.6-depth method should be used for depths between 0.75 to 1.5 feet. The pygmy meter should be used for average velocity less 2.5 feet per second. The two-point method should be used where depths, are between 1.0 and 1.5 feet and one-point method for depths between 0.6 and 1.0 feet. For smaller depths 0.5-depth or surface velocity can be measured to compute average velocity after multiplying with an appropriate correction factor.

If for some unavoidable reasons, the direction of flow is not at right angles to the tagline stretched across the canal, the velocity vector normal to the cross section (tagline) should be calculated. The velocity measured by the current meter, multiplied by the cosine of the horizontal angle will give the velocity component normal to the measuring cross section.

In the boat measurement, a heavy duty tagline is stretched across the cross section, perpendicular to the direction of flow. The distance from the initial point and the widths of the partial sections are measured by this tagline. The boat is held perpendicular to the flow by a boom and crosspiece affixed to the boat and the tagline. The depth is measured by a sounding reel with a counter. A sounding weight is attached to a double conductor sounding cable through a connector and a hanger bar. The current meter is fixed on the hanger bar either at 0.55 feet or 0.9 feet above the bottom of the 50 pound weight. If the meter is at 0.55 feet, the minimum depths for 0.6 depth, and 0.2 and 0.8, depth velocity methods are 1.4 and 2.8 feet respectively. If the meter is at 0.9 feet, the corresponding minimum depths are 2.2 and 4.5 feet.

Flow measurements in the watercourses or small channels may be made by standard portable flumes. These flumes are not provided under this pilot project. It is expected that the PIDs will obtain particular type of flues depending on the site-specific conditions from their own resources. A type of flume should be selected carefully and consideration should be given to such factors as amount of sediment necessary to

be passed, expected range of discharge, shape of the channel cross section compared to the flume, and construction cost. Volumetric method may be used for measuring discharge from an irrigation outlet or to calibrate small flumes. The method consists either of observing the time required to fill a container of known capacity or of determining the rate at which a calibrated tank will fill.

Stage-Discharge Relationship

Stage-discharge relationships at the gaged locations are developed from simultaneous measurements of canal stage and discharge. For the canals, these relationships should be simple. However, the relationship developed at one location in time will not be permanent and will not represent long-term conditions. Changes in the canal such as scour or deposition, changes in channel roughness, aquatic growth and debris, all result in changes in the stage-discharge relationship. Therefore, periodic discharge measurements with corresponding stages should be continued to define reasonably accurate shape and/or changes in the stage-discharge relationships. Periodic discharge measurements also should be made to check the empirical stage-discharge relationships at control structures.

Sediment Sampling

Both suspended sediment samples and bed material samples will be collected periodically from the canals. The suspended sediment samples will be analyzed to define the concentration and particle size distribution of suspended sediment at a given location and instant in time with respect to the discharge rates. The bed material samples will be analyzed for particle size distribution. The purpose of these periodic measurements will be to determine the quantity and quality of the sediment corresponding to various flow rates through the canal at different times. Based on these data, approximate causes of scouring and sedimentation in the irrigation system will be determined.

For the pilot project, US DH-48 (depth-integrating suspended sediment hand-type sampler) and US BMH-53 (bed material hand-type samplers) samplers are provided. These samples can be used where the flow depth is shallow and the canal can be waded. For deeper canals, it may be advisable to extend the suspension rods of the samplers depending upon the site-specific conditions.

The US DH-48 sampler is used with a hand-held rod and is designed to be used in a sampling procedure called depth integration. The sample container and intake nozzle are mounted as one integrated unit with short conduit connecting

the two. The sampler has an air exhaust port. The sample is taken by lowering and raising the sampler at a uniform rate throughout the depth (or a portion of depth in special cases). The nozzle of sampler should be pointing upstream parallel to the flow. The size of the nozzle should be such that about 450 cc volume can be collected with a reasonable transit rate.

The suspended sediment samples can be taken using either by the equal-discharge-increment (EDI) method or equal-width-increment (EWI)/equal-transit rate (ETR) method. In the EDI method, the cross sectional area is divided laterally into three or five subsections, each of which conveys nearly the same water discharge. Depth integration is carried out at a vertical in each sub-section where approximately half the sub-section discharge is on one side and half on the other side. In each sub-section, the vertical transit rate should be such that will provide a sample volume for the vertical which is equal to the sample volume for every other vertical. This procedure provides a group of sub-samples that are nearly of the same size and that represent the same proportion of the total water discharge. These sub-samples can be combined to provide a single composite sample and then analyzed, or alternatively, if the sub-sample volumes are different, the concentrations of all sub-samples can be averaged to give concentration representative of the flow rate.

In the EWI/(ETR) method, depth integration is performed at equally spaced verticals across the cross section and the same transit rate is used at each vertical. The sub samples are composited even though they are of different volumes.

The suspended sediment samples should be taken at the time of discharge measurements. Therefore, the EDI method should be used because the flows in various sub-section are available prior to sampling.

The BMH-53 sampler is a piston-type, manually operated core sampler designed for use in shallow streams. The sampler consists of a 51-mm diameter by 203-mm long cylinder fitted with a rod-mounted piston. As the cylinder is pressed into the stream bed, the piston retracts and holds the sample in the cylinder by means of a partial vacuum. The piston is also used to eject the sample.

The bed material samples may be taken at the same locations at which the suspended sediment samples are collected. However, if the bed material indicate significant variation in size distribution cross the channel, more samples may be collected. Each sample should be analyzed separately.

Downstream from the diversion and regulating structures, the flow is turbulent and the sediment including bed load

(coarse sediment normally moving near the bed) is in suspension. The samples taken in a channel reach where total sediment being transported by a canal is in suspension are called "boil samples." The "boil samples" should be collected periodically to investigate the characteristics of the sediment being transported. Also these characteristics should be compared with those of the suspended sediment and bed material samples taken at the gage sites.

Canal Profiles

A number of cross sections should be selected to be surveyed periodically during the closures of the canals. A longitudinal profile should also be surveyed. The frequency of survey should be determined based on site-specific conditions of silting and scouring in a channel reach. Survey levels and staffs are provided to perform these surveys.

LABORATORY ANALYSIS

Accepted laboratory methods and procedures will be used for determining the sediment concentration and particle size distribution of the suspended sediment samples, and particle size distribution of the bed material samples. A sediment laboratory will be established in each circle as discussed previously. The equipment for a laboratory is listed in Tables 5 to 8 for each province.

Total Concentration

The common unit for expressing suspended sediment concentration is milligrams per liter (mg/l) and is computed as one million times the ratio of the dry weight of sediment in grams to the volume of water-sediment mixtures in cubic centimeters or parts per million (ppm) defined as one million times the ratio between weight of dry sediment and weight of water-sediment mixture.

Evaporation and filtration are the two most frequently used methods for determining sediment concentration. The evaporation method is usually best for high concentrations of sediment. The method also may be used for low concentrations, but a correction for dissolved solids is required.

The filtration method is suitable for low concentrations and eliminates the need for separate determination of dissolved-solids concentration. The simplest method of filtration is to place a filter paper in a glass funnel and allow gravity to force filtration. To obtain a satisfactory filtration, all fine particles as well as coarse particles should be retained.

Particle Size Distribution

For suspended sediment, separation of the fine material from the sands at .062 mm is frequently required to assist in the particle size analysis of the sediment. The selection of particle-size classes or grades to be determined may be made with the help of the following table (published be American Geophysical Union).

SCALE OF PARTICLE SIZES OF SEDIMENT

Class Name	Millimeters	Class Name	Millimeters
Gravel	64.0-2.0	Medium Silt	.031-.016
Very Coarse Sand	2.0-1.0	Fine Silt	.016-.008
Coarse Sand	1.0-0.5	Very Fine Silt	.008-.004
Medium Sand	.50-.25	Coarse Clay	.004-.002
Fine Sand	.25-.125	Medium Clay	.002-.001
Very Fine Sand	.125-.062	Fine Clay	<.001
Coarse Silt	.062-.031		

The methods of particle size analysis are generally sieving, pipette, bottom-withdrawal tube, and visual-accumulation tube. The laboratory equipment provided in this project is adequate to perform the particle size distribution analyses using sieving, pipette, and bottom-withdrawal (BH) tube methods.

Generally, more than one method of particle size analysis is used on a given sample. The particles larger than 0.062 mm are analyzed by sieving and the finer particles by pipette or bottom withdrawal methods. Recommended quantities of sediment and desirable range of concentration for the various methods are given below:

Method	Size (mm)	Concent. (mg/l)	Sediment (mg)
Sieve	.062-32	-	-
Pipette	.002-.062	2,000-5,000	1,000-5,000
B.W. tube	.002-.062	1,000-3,000	500-1,800

The pipette method is probably the most accurate and routinely used method in fluvial sediment analysis. The BW method is more accurate for low concentrations of fine sediment than the pipette method but it is more time consuming. Detailed instructions for both methods are provided with the equipment.

Both wet and dry sieving methods are used to separate sand particles. In wet sieving, material finer than the sieve opening is washed through, preferably while the sample and sieve screen are submerged in water. Dry sieving requires a sample that is completely dry. Generally, 3-inch (or 76-mm) diameter sieves are used.

OFFICE ANALYSIS

This analysis will be performed partly at divisional levels and partly at circle levels as discussed under "Project Implementation and Operation." At divisional levels, all the field data will be reviewed, interpreted, and documented for transmission to the circle offices. Canal profile data will be used to determine the extent of silting or scouring in the selected reaches. The executive engineers also will prepare the evaluation reports about the performance of the canals under their control.

At circle levels, the data submitted by the divisions will be computerized for future use. Remedial measures to improve the performance of the canals will be designed in consultation with the regional chief engineers.

PROPOSED TRAINING PROGRAM

The PIDs have been involved in discharge measurements at the headworks, diversion structures and at selected locations on the canals. The discharge measurements are generally made using floats or velocity-rods. The current meter measurements are limited to some of the major headworks. However, this data collection effort is perfunctory and frequently either the data are not observed at all or their accuracy is questionable. The primary reasons for this are lack of interest of the field staff for monitoring the operation and performance of the canal system, inexperienced staff, and practically no hydraulic/sediment monitoring equipment.

Concept

Well planned and accurately performed hydraulic monitoring is required to provide information and data to enable an assessments of the quality of irrigation service, to check performance of the system, and to make decisions about remedial measures. For this purpose, the field staff should be properly trained both for field data collection and to analyse and maintain the record. Some training was provided by the Alluvial Channels Observation Project (ACOP), WAPDA, to selected groups of sub-engineers, assistant engineers, executive engineers, and research staff. This training was designed to introduce general procedures of stream gaging, sediment sampling, and laboratory analysis of sediment samples.

A training program limited to the procedures suitable for monitoring of the operation and performance of the canals is needed. This should provide step-by-step instructions to conduct routine hydraulic monitoring; to survey the cross sectional and longitudinal profiles of canals; to perform laboratory analysis, and to interpret, evaluate, and analyse the data.

Implementation

The training program will be initiated at the time of delivery of the equipment to the selected circles in each province. The training will be provided by ACOP with the assistance of a hydraulic/sediment monitoring specialist of the TA team.

The Field training program will be limited to the methods of discharge measurement by wading and boat, suspended sediment sampling using US DH-48 depth-integrading sampler, bed material sampling using US BMH-53 sampler, and morphological

survey during closure of the canals using a level. Instruction for installation and monitoring of staff gages and water level recorders will be given. Methods of measuring flow at calibrated control structures (regulators, weirs, broad-crested weirs, and outlets) will be demonstrated.

Laboratory analysis procedures will be demonstrated by actual analysis of suspended sediment and bed material samples. The PIDs are expected to provide necessary facilities and furniture to establish the laboratories.

Attention of the trainees will be drawn to the field precautions to be exercised to obtain accurate and reliable data, particularity during selection of sites for staff gages/water level recorders and for discharge measuring sites, during measurement of flow and canal levels, and during survey of cross sectional and bed profiles. Also potential errors in velocity and depth observations of canal, measurement of outlets and water course discharges and sediment sampling will be pointed out.

The training will also include lectures prior to field measurements to introduce the trainees to the importance of hydraulic monitoring and provide an overall view of hydraulic monitoring methods. The methods of data interpretation, evaluation, and compilation; and evaluation of reliability of water delivery and equity of water distribution system will be explained.

Tables 1 to 4 show the number of circles selected in the four provinces. The five circles in the Punjab province are located at Lahore, Sargodha, Faisalabad, Multan, and Bahawalpur. One-week training programs will be planned for each circle. In the Sindh province three circles are located at Hyderabad and one at Sukkur. A two-week training program for Hyderabad and a one-week program at Sukkur will be planned.

In the provinces of NWFP and Balochistan, the two circles selected in each province are at different locations. A one-week training program will be conducted in each circle.

Training Document

A training document will be prepared to educate the trainees with the field and office procedures. This document will include details of field monitoring, office procedures, and evaluation method. A brief description of field monitoring and office procedures is provided in this report.

The training document will include the following major topics:

1. Need for Hydraulic/sediment monitoring

2. Monitoring Parameters
    - Performance History
    - Canal Stage
    - Canal Discharge
    - Suspended Sediment
    - Bed Material
    - Cross Sectional Profile
    - Bed Profile

3. General Methodology
    - Instrumentation
    - Methodology
    - Precautions
    - Potential Errors

4. Data Collection for Performance History

5. Measurements of Stage
    - Staff Gage
    - Recording Gage
    - Gage Datum
    - Daily Observations
    - Measurement During Survey
    - Gage Data Reduction

6. Measurement of Discharge
    - Main Canal
    - Wading Method
    - Boat Method
    - Calibrated Control Structures
    - Water Course
    - Wading Method
    - Portable Flumes
    - Outlet Geometry
    - Measurement of Width
    - Measurement of Depth
    - Computation of Flow Area
    - Measurement of Velocity
    - Methods of Mean Velocity Determination
    - Discharge Computations

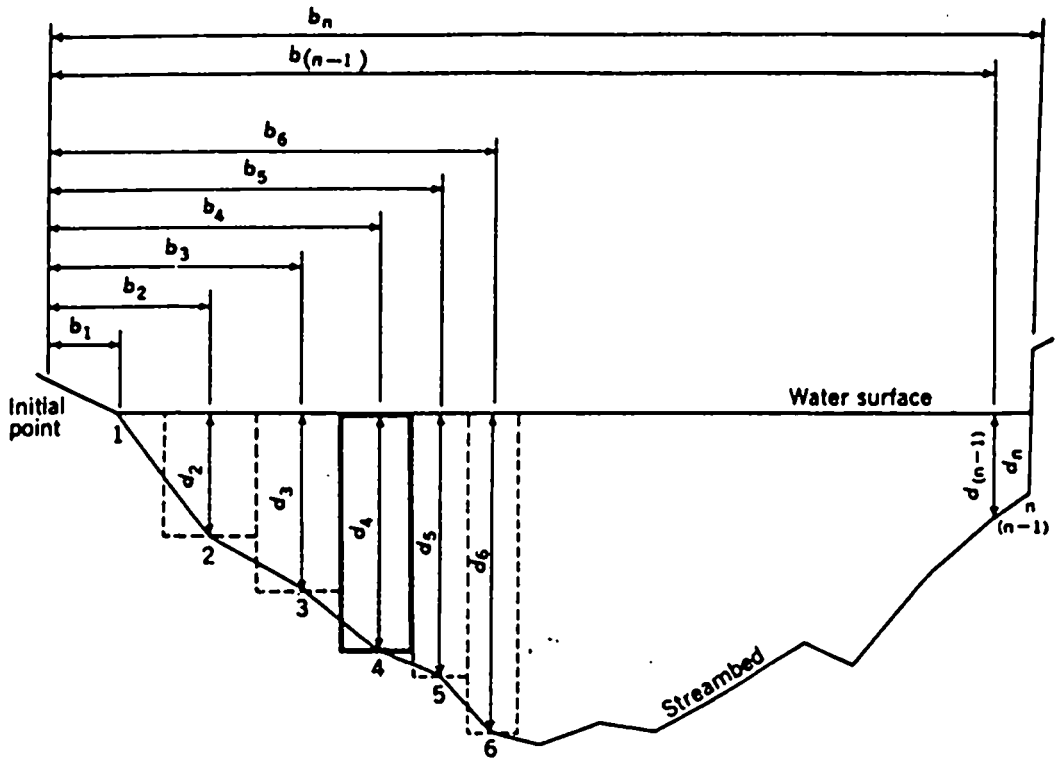
7. Development of Stage-Discharge Relationship
    - Canal Reach
    - Control Structure

8. Sediment Sampling
    - Suspended Sediment
    - Bed Material

9. Laboratory Analysis
    - Total Concentration
    - Particle Size Distribution

10. Canal Survey
    - Cross Sectional Profile
    - Bed Profile

11. Office Procedures
    - Preparation and Evaluation of Performance History
    - Data Reduction, Interpretation, Evaluation and Compilation
    - Evaluation of Reliability and Equity of Irrigation System.



EXPLANATION

1, 2, 3, ... n	Observation points
$b_1, b_2, b_3, \ldots\ldots b_n$	Distance, in feet, from the initial point to the observation point
$d_1, d_2, d_3, \ldots\ldots d_n$	Depth of water, in feet, at the observation point
Dashed lines	Boundary of partial sections; one heavily outlined discussed in text

Definition sketch of midsection method of computing cross-section area for discharge measurements.

HYDRAULIC AND SEDIMENT MONITORING EQUIPMENT FOR PUNJAB PROVINCE

A: Selected Circles/ Divisions

1. Lahore Zone (Chief Engineer, Lahore)
   - Upper Chenab Canal Circle, Lahore
     - Gujranwala Division, Gujranwala
     - Sheikhupura Division, Sheikhupura
     - Marala Headworks Division, Marala

2. Sargodha Zone (Chief Engineer, Sargodha)
   - Lower Jhelum Canal Circle, Sargodha
     - Rasul Headworks Division, Rasul
     - Kirana Division, Sargodha
     - Shahpur Division, Sargodha
     - Sargodha Division, Sargodha

3. Faisalabad Zone (Chief Engineer, Faisalabad)
   - Lower Chenab Canal East Circle, Faisalabad
     - Upper Gugera Division, Sheikhupura
     - Burala Division, Faisalabad
     - Lower Gugera Division, Faisalabad

4. Multan Zone (Chief Engineer, Multan)
   - Muzaffargarh Canal Circle, Multan
     - Kot Adu Division, Kot Adu
     - Muzaffargarh Division, Muzaffargarh
     - Taunsa Barrage Division, Kot Adu

5. Bahawalpur Zone (Chief Engineer, Bahawalpur)
   - Bahawalpur Canal Circle, Bahawalpur
     - Bahawalpur Division, Bahawalpur
     - Ahmedpur Division, Bahawalpur
     - Panjnad Headworks Division, Panjnad

b: Equipment (based on five circles and 16 divisions)

1.	Current Meter Price AA	32 Nos.
2.	Pygmy Current Meter	32 Nos.
3.	Standard Wading Rods Set	32 Sets
4.	Light Duty Tagline	32 Nos.
5.	Heavy Duty Tagline	16 Nos.
6.	Headset	32 Nos.
7.	Electronic Watch	16 Nos.
8.	Spares for Current Meters	- L S
9.	Rubber Chest Wader	16 Nos.
10.	Hip Boots	16 Pairs
11.	Boat Improvizement Set	16 Sets
12.	Sounding Reel	16 Nos.
13.	Sounding Weight, 50 Pounds	16 Nos.
14.	Hanger Bar with Pin	32 Nos.

15.	Spare Cable Connector	10 Nos.
16.	Spare Sounding Cable	1,600 Feet
17.	Life Jacket	32 Nos.
18.	Flat Bottom Fibre Glass Boat	16 Nos.
19.	Metallic 100-Foot Measuring Tape	16 Nos.
20.	Level with Tripod	16 Nos.
21.	Levelling Staff	16 Nos.
22.	Y-rod for Measuring Geometry of Outlets	16 Nos.
23.	Water Level Recorder with Spares	16 Nos.
24.	Staff Gage, four 3.33-Foot Section at each Site, 100 Sites	400 Sections
25.	US DH-48 Suspended Sediment Sampler	16 Nos.
26.	US BMH53 Bed Material Sampler	16 Nos.
27.	Pint Glass bottles, 24 per box	16 Nos.
28.	Sample Label	16 Packets
29.	Bottom Withdrawal Tube	10 Nos.
30.	Analytical Balance	05 Nos.
31.	Electric Oven	05 Nos.
32.	Sieve. 3-inch Diameter, 12 Sieves Set	05 Sets
33.	Sieve, 8-inch Diameter, 6 Sieves Set	05 Sets
34.	Sieve Brush	10 Nos.
35.	Sieve Lid	05 Nos.
36.	Sieve Pan	05 Nos.
37.	Sieve Shaker	05 Nos.
38.	Stop Watch	05 Nos.
39.	Pipette	10 Nos.
40.	Vacuum Pump	05 Nos.
41.	Beaker	30 Nos.
42.	Cylinder	40 Nos.
43.	Evaporating Dish	100 Nos.
44.	Desiccator	05 Nos.
45.	Wash Bottle	05 Nos.
46.	Filtering Funnel	10 Nos.
47.	Filter Circle	10 Nos.
48.	Stirring Rod	10 Nos.
49.	Thermometer	10 Nos.
50.	3-way Stop Cock	10 Nos.
51.	French Curve Set	05 Sets

HYDRAULIC AND SEDIMENT MONITORING EQUIPMENT FOR SINDH PROVINCE

A: Selected Circles/ Divisions

1. Kotri Zone (Chief Engineer, Kotri)
   - Pinyari Canal Circle, Hydrabad
     - Upper Pinyari Canal Division, Hydarabad
     - Lower Pinyari Canal Division, Sujawal

2. Guddu Zone (Chief Engineer, Sukkur)
   - Bagari Sindh Feeder Circle, Sukkur
     - Begari Canal Division, Jacobabad
     - Begari Sindh Feeder, Kashmore

3. Sukkur Zone (Chief Engineer, Sukkur)
   - Rohri Canal Circle, Hydarabad
     - Rohri Canal Division, Maro
     - Nasrat Canal Division, Nawabshah
     - Dad Canal Nawabshah
     - Nasir Canal, Hydarabad
     - Hala Canal, Hydarabad
   - Nara Canal Circle, Hydarabad
     - Thar Canal Division, Mirpur Khas
     - Mithrao Canal Division, Mirpur Khas
     - Jamrod Canal Division, Mirpur Khas

b: Equipment (based on four circles and 12 divisions)

1.	Current Meter Price AA	24 Nos.
2.	Pygmy Current Meter	24 Nos.
3.	Standard Wading Rods Set	24 Sets
4.	Light Duty Tagline	24 Nos.
5.	Heavy Duty Tagline	12 Nos.
6.	Headset	24 Nos.
7.	Electronic Watch	12 Nos.
8.	Spares for Current Meters	- L S
9.	Rubber Chest Wader	12 Nos.
10.	Hip Boots	12 Pairs
11.	Boat Improvizement Set	12 Sets
12.	Sounding Reel	12 Nos.
13.	Sounding Weight, 50 Pounds	12 Nos.
14.	Hanger Bar with Pin	24 Nos.
15.	Spare Cable Connector	10 Nos.
16.	Spare Sounding Cable	1,200 Feet
17.	Life Jacket	24 Nos.
18.	Flat Bottom Fibre Glass Boat	12 Nos.
19.	Metallic 100-Foot Measuring Tape	12 Nos.
20.	Level with Tripod	12 Nos.
21.	Levelling Staff	12 Nos.
22.	Y-rod for Measuring Geometry of Outlets	12 Nos.
23.	Water Level Recorder with Spares	12 Nos.

24.	Staff Gage, four 3.33-Foot Section at each Site, 72 Sites	288 Sections
25.	US DH-48 Suspended Sediment Sampler	12 Nos.
26.	US BMH53 Bed Material Sampler	12 Nos.
27.	Pint Glass bottles, 24 per box	12 Nos.
28.	Sample Label	12 Packets
29.	Bottom Withdrawal Tube	08 Nos.
30.	Analytical Balance	04 Nos.
31.	Electric Oven	04 Nos.
32.	Sieve, 3-inch Diameter, 12 Sieves Set	04 Sets
33.	Sieve, 8-inch Diameter, 6 Sieves Set	04 Sets
34.	Sieve Brush	08 Nos.
35.	Sieve Lid	04 Nos.
36.	Sieve Pan	04 Nos.
37.	Sieve Shaker	04 Nos.
38.	Stop Watch	04 Nos.
39.	Pipette	08 Nos.
40.	Vacuum Pump	04 Nos.
41.	Beaker	24 Nos.
42.	Cylinder	32 Nos.
43.	Evaporating Dish	80 Nos.
44.	Desiccator	04 Nos.
45.	Wash Bottle	04 Nos.
46.	Filtering Funnel	08 Nos.
47.	Filter Circle	08 Nos.
48.	Stirring Rod	08 Nos.
49.	Thermometer	08 Nos.
50.	3-way Stop Cock	08 Nos.
51.	French Curve Set	04 Sets

HYDRAULIC AND SEDIMENT MONITORING EQUIPMENT FOR BALOCHISTAN PROVINCE

A: **Selected Circles/ Divisions**

1. Irrigation Circle. Quetta
   - Quetta Division, Quetta
   - Pishin Division, Pishin
   - Hydrology Division, Quetta

2. Pat Feeder and Sibi Circle, Dera Murad Jamali (DMJ)
   - Kachhi Canal Division, Kachhi
   - Kirter Canal Division, DMJ
   - Pat Feeder Division, DMJ
   - Dera Bughti Division, Dera Bughti
   - Sibi Canal Division, Sibi

b: **Equipment (based on two circles and eight divisions, assumed three divisions will need boats for flow measurements).**

1.	Current Meter Price AA	16 Nos.
2.	Pygmy Current Meter	16 Nos.
3.	Standard Wading Rods Set	16 Sets
4.	Light Duty Tagline	16 Nos.
5.	Heavy Duty Tagline	03 Nos.
6.	Headset	16 Nos.
7.	Electronic Watch	08 Nos.
8.	Spares for Current Meters	- L S
9.	Rubber Chest Wader	08 Nos.
10.	Hip Boots	08 Pairs
11.	Boat Improvizement Set	03 Sets
12.	Sounding Reel	03 Nos.
13.	Sounding Weight, 50 Pounds	03 Nos.
14.	Hanger Bar with Pin	06 Nos.
15.	Spare Cable Connector	03 Nos.
16.	Spare Sounding Cable	300 Feet
17.	Life Jacket	09 Nos.
18.	Flat Bottom Fibre Glass Boat	03 Nos.
19.	Metallic 100-Foot Measuring Tape	08 Nos.
20.	Level with Tripod	08 Nos.
21.	Levelling Staff	08 Nos.
22.	Y-rod for Measuring Geometry of Outlets	03 Nos.
23.	Water Level Recorder with Spares	08 Nos.
24.	Staff Gage, four-3.33 Foot Section at each Site, 40 Sites	160 Sections
25.	US DH-48 Suspended Sediment Sampler	08 Nos.
26.	US BMH53 Bed Material Sampler	08 Nos.
27.	Pint Glass bottles, 24 per box	08 Nos.
28.	Sample Label	08 Packets
29.	Bottom Withdrawal Tube	04 Nos.
30.	Analytical Balance	02 Nos.
31.	Electric Oven	02 Nos.

32.	Sieve, 3-inch Diameter, 12 Sieves Set	02 Sets
33.	Sieve, 8-inch Diameter, 6 Sieves Set	02 Sets
34.	Sieve Brush	04 Nos.
35.	Sieve Lid	02 Nos.
36.	Sieve Pan	02 Nos.
37.	Sieve Shaker	02 Nos.
38.	Stop Watch	02 Nos.
39.	Pipette	04 Nos.
40.	Vacuum Pump	02 Nos.
41.	Beaker	12 Nos.
42.	Cylinder	16 Nos.
43.	Evaporating Dish	40 Nos.
44.	Desiccator	02 Nos.
45.	Wash Bottle	02 Nos.
46.	Filtering Funnel	04 Nos.
47.	Filter Circle	04 Nos.
48.	Stirring Rod	04 Nos.
49.	Thermometer	04 Nos.
50.	3-way Stop Cock	04 Nos.
51.	French Curve Set	02 Sets

HYDRAULIC AND SEDIMENT MONITORING EQUIPMENT FOR NWFP

A: **Selected Circles/ Divisions**

1. Northern Irrigation Circle, Mardan
   - Swabi Division, Swabi
   - Malakand Division, Malakand
   - Mardan Division, Mardan

2. Southern Circles, Bannu
   - Marvat Canal Division, Bannu
   - Bannu Canal Division, Bannu
   - Paharpur Canal Division, D.I. Khan

b: **Equipment (based on two circles and six divisions, assumed four divisions will need boats for flow measurements).**

1.	Current Meter Price AA	12 Nos.
2.	Pygmy Current Meter	12 Nos.
3.	Standard Wading Rods Set	12 Sets
4.	Light Duty Tagline	12 Nos.
5.	Heavy Duty Tagline	04 Nos.
6.	Headset	12 Nos.
7.	Electronic Watch	06 Nos.
8.	Spares for Current Meters	- L S
9.	Rubber Chest Wader	06 Nos.
10.	Hip Boots	06 Pairs
11.	Boat Improvizement Set	04 Sets
12.	Sounding Reel	04 Nos.
13.	Sounding Weight, 50 Pounds	04 Nos.
14.	Hanger Bar with Pin	08 Nos.
15.	Spare Cable Connector	04 Nos.
16.	Spare Sounding Cable	400 Feet
17.	Life Jacket	12 Nos.
18.	Flat Bottom Fibre Glass Boat	04 Nos.
19.	Metallic 100-Foot Measuring Tape	06 Nos.
20.	Level with Tripod	06 Nos.
21.	Levelling Staff	06 Nos.
22.	Y-rod for Measuring Geometry of Outlets	06 Nos.
23.	Water Level Recorder with Spares	06 Nos.
24.	Staff Gage, four 3.33-Foot Section at each Site, 30 Sites	120 Sections
25.	US DH-48 Suspended Sediment Sampler	06 Nos.
26.	US BMH53 Bed Material Sampler	06 Nos.
27.	Pint Glass bottles, 24 per box	06 Nos.
28.	Sample Label	06 Packets
29.	Bottom Withdrawal Tube	04 Nos.
30.	Analytical Balance	02 Nos.
31.	Electric Oven	02 Nos.
32.	Sieve, 3-inch Diameter, 12 Sieves Set	02 Sets

33.	Sieve, 8-inch Diameter, 6 Sieves Set	02 Sets
34.	Sieve Brush	04 Nos.
35.	Sieve Lid	02 Nos.
36.	Sieve Pan	02 Nos.
37.	Sieve Shaker	02 Nos.
38.	Stop Watch	02 Nos.
39.	Pipette	04 Nos.
40.	Vacuum Pump	02 Nos.
41.	Beaker	12 Nos.
42.	Cylinder	16 Nos.
43.	Evaporating Dish	40 Nos.
44.	Desiccator	02 Nos.
45.	Wash Bottle	02 Nos.
46.	Filtering Funnel	04 Nos.
47.	Filter Circle	04 Nos.
48.	Stirring Rod	04 Nos.
49.	Thermometer	04 Nos.
50.	3-way Stop Cock	04 Nos.
51.	French Curve Set	02 Sets

TABLE 5
SPECIFICATIONS FOR
HYDRAULIC AND SEDIMENT MONITORING EQUIPMENT FOR PILOT PROJECT

S.#	ITEM	SPECIFICATIONS	UNIT COST Local Rs.	UNIT COST Dollar US$	SUPPLIER
(1)	(2)	(3)	(4)	(5)	(6)
Hydraulic Equipment					
1.	Current Meter	Price Type AA (vertical axis, horizontal bucket wheel); chrome plated stainless steel; minimum velocity = 0.1 fps and maximum velocity = 20.0 fps; single and penta contacts; furnished complete in a foam cushioned carrying case, along with a rating chart, tail fin assembly, screw driver, assorted spare parts, and special lubricant, both for rod and cable suspension.	-	790	Scientific Investments Inc. 518 West Cherry Milwauke, Wi 53212-3822 USA (414)263-1600 FAX (414)263-5506
2.	Mini Current Meter (Pygmy)	Vertical axis, horizontal bucket wheel; chrome plated stainless steel; minimum velocity: .05 fps and maximum velocity = 3.0 fps; furnished complete in a foam cushioned carrying case with assorted spare parts, a rating chart and lubricant; for rod suspension only.	-	630	Scientific Instruments Inc.
3.	Standard Wading Rods	Four 2-foot graduated rods in 0.1 foot increment, bottom rod with base plate; an adjustable sliding support capable of holding price Type AA and Pygmy current meters; a flexible two-conductor wire with one end having two-pole conductor for head set and the other end suitable for connecting to current meter and rods. Base plate and slider made from corrosion resistant material; complete set in heavy duty canvas carrying case.	2,100	-	Ahmad Enterprises 1-McLeod Road Lahore
4.	Light Duty Tagline	About 300 feet long of 0.04 inch diameter stainless steel with a hook at one end, wound on a heavy plastic reel and mounted on a hardwood stake; brass beads every 2 feet for the first 50 feet, every 5 feet from 50 to 200 feet and every 10 feet from 200 to 300 feet.	-	525	Scientific Instruments Inc.

(Table 5 Continued)

5. Heavy Duty Lee Au Type Tagline	About 500 feet long 1/16 inch diameter open reel with handles; marked with brass beads every 2 feet for the first 50 feet, every 5 feet from 50 to 200 feet, every 10 feet from 200 to 300 feet and every 50 feet from 300 to 500 feet; heavy duty hooks on both ends for attaching to trees or other sturdy objects.	-	580	Scientific Instruments Inc.
6. Headset	Flexible headband, built in compartment for dry cell battery, including flexible wire with two pole connector for connecting to two-conductor wire from current meter on wading rod or from sounding reel.	-	65	Scientific Instruments Inc.
7. Electronic Watch	Electronic, digital reading to 0.01 second, with a neck cord and having easy to use finger tip control buttons.	-	70	Scientific Instruments Inc.
8. Spares for Current Meters	Compatible to the selected current meters; should should include: pivot assembly, hanger screw, binding post assembly; extra screws for price AA and Pygmy meters; instrument oil, cleaning cloth, two-pole connector (male and female); bucket wheel assembly.	-	-	Scientific Instruments Inc.
9. Rubber Chest Wader	1. Medium Size 2. Large Size	- -	160 210	Rickly Hydrologic Company 2710 Joyce Ave Columbus, Ohio 43211 USA
10. Hip boots	1. Medium Size 2. Large Size	- -	75 105	
11. Boat Improvizement Set	Boom and cross arm, USGS standard.	5,300	-	Ahmad Enterprises Lahore
12. Sounding Reel	USGS A-type light duty, with a maximum load capacity of 100 pounds; two-position handle for leverage, scale reading 0.1 foot; complete with 0.1 inch double conductor cable, "B" type connector and flexible two-conductor wire for connecting reel to headset.	-	1,460	Scientific Instruments Inc.
13. Sounding Weight	USGS Columbus (C) type 50 pounds.	1,300	-	M. Ahmad & Sons I-Brandreth Rd, Lahore
14. Hanger Bar with Pin	USGS type for 30 and 50 pounds Columbus type weights, one foot long	260	-	M. Ahmad & Sons
15. Cable Connector	USGS Type B.	-	27	Scientific Instruments Inc.
16. Sounding Cable	Elsworth double conductor (inner core), 0.1 inch diameter, per foot	-	6	Scientific Instruments Inc.
17. Life Jacket	USGS approved model A2 Adult universal, general purpose type-II.	-	100	ERO Industries Inc. Harzlehurst, GA 31539, USA

(Table 5 Continued)

18. Flat Bottom Fibre Glass Boat	16 feet long and 6 feet wide.	30,000	-	Zaarock Company Multan Rd., Lahore
19. Metalic Measuring Tape	Length 100 feet, marked in 0.1 foot increments or in inches; housed in a case.	210	-	Sibtain Brothers Karachi
20. Level with Tripod	Topcon (Japan) automatic levelling, magnification 20 X with standard accessories.	21,000	-	Sibtain Brothers
21. Levelling Staff	Japanese stave pole standard, 15 ft long.	1,260	-	Sibtain Brothers
22. Y - Rod	Standard, for measuring geometry of outlets.	2,500	-	Kotri Gaging Sub-division Hydrology Directorate Hyderabad
23. Water Level Recorder	Stevens A-71; English units with 1:6 gage scale; chart speed 2.4 inches per day; chart 10 inches wide and 25 yard long; 4.5 - month negator spring driven clock; 18 inch circumference pulley for perforated tape; stainless steel graduated, perforated tape 50 feet long with set end hooks and index bracket; 8-inch diameter float with counter weight, reversal indicator.	-	3,100	Leupold & Stevens, Inc. P.O. Box 688 Beaverton, Or 97075 USA
24. Spares for Water Level Recorder	1. Recorder chart	-	21	Leupold & Stevens
	2. Pen, ink	-	9	
	3. Capillary pen with lucite reservoir	-	52	
	4. Pen Cleaner, packet	-	9	
25. Staff Gage	Special porclain enamel coated, four inches wide in in 3.30-foot sections; graduated to .01 foot and marked every foot, 0.1 and .02 foot.			Kotri Gaging Sub-division Hydrology Directorate Hyderabad
	Range: 0-3.33 ft	500	-	Ahmad Enterprises Lahore
	3.33-6.66 ft	500	-	
	6.66-9.99 ft	500	-	
	9.99-13.33 ft	500	-	

Sediment Sampling Equipment

1. Wading Type, Depth Integrating Suspended Sediment Hand Sampler	US DH-48 with wading rod including three sets of spare gaskets, and nozzles of 1/8, 3/16 and 1/4 inch openings, aluminum casting.	2,100	-	Ahmad Enterprises Lahore
2. Piston Type Bed Material Hand Sampler	US BMH 53	-	420	Minnesota Fabricators 2515 Highway 61 North St. Paul, MN 55109 USA
3. Pint Glass Bottles	For use with DH-48, 24 per box	-	75	Minnesota Fabricators

Table 5 (Continued)

4. Sample Label	For use on all bottles or jars, self adhesive, packet.	-	25	Minnesota Fabricators

Laboratory Equipment For Sediment Analysis

1. Bottom Withdrawal Tube	Standard by St. Anthony Falls Hydraulic Laboratories, including rubber tape and pinch clamp.	-	220	Federal Interagency Sedimentation Project St. Anthony Falls Hydraulic Laboratory 2-3rd Avenue South-East Minneapolis, MN 55414 USA
2. Analytical Balance	Capacity of 200 grams with weight box and .001 gram sensitivity, beam -.05 to +.05 gram in 200 graduated divisions; two concave stainless steel pans, front and back sliding glass doors case.	-	1,800	Soiltest 66 Albrecht Dr. P.O. Box 8004 Lake Bluff, IL 6044-9902 USA
3. Electric Oven	Fan-Forced air circulation, temperature range upto 110C, two doors, pilot light, adjustable shelf, welded steel exterior, overall diameter 30"x25"x24".	-	1,100	Soiltest
4. Sieve set (Fine)	USA standard sieves, 3-inch diameter brass sieve, fine series.			Soiltest
	No. / Openings			
	5 / 4.00 mm	-	38	
	10 / 2.00 mm	-	38	
	18 / 1.00 mm	-	38	
	25 / .710 mm	-	38	
	35 / .500 mm	-	38	
	45 / .355 mm	-	38	
	60 / .250 mm	-	38	
	80 / .180 mm	-	38	
	120 / .125 mm	-	38	
	170 / .090 mm	-	45	
	230 / .063 mm	-	55	
	325 / .045 mm	-	60	
5. Sieve set (Coarse)	USA standard sieve; 8 - inch diameter, brass sieve.			Soiltest
	Sieve size			
	5.6 mm	-	38	
	8.0 mm	-	38	
	16.0 mm	-	38	
	31.5 mm	-	38	
	63 mm	-	38	
	100 mm	-	38	
6. Sieve Brush	Fine hair bristles, wooden handle.	-	8	Soiltest
7. Sieve Lid	For US Standard 3-inch sieves	-	16	Soiltest

Table 5 (Continued)

8. Sieve Pan	For US Standard 3-inch sieves	-	16	Soiltest
9. Sieve Shaker (Hand operated)	Head-operated shaker; capacity seven sieves, 8-inch diameter.	-	350	Soiltest
10. Stop Watch	Reading to one second, Swiss/China	100	-	Ahmad Enterprises, Lahore
11. Pipette	Pyrex glass;			Fisher Scientific
	1. 25 ml capacity; tolerance + 0.06 ml	-	100	W.Glenlake Ave Itasca, IL 60143 USA
	2. 50 ml capacity; tolerance + 0.10 ml	-	130	
12. Vacuum Pump	Two series-connected electric pumps, 0.3 mm ultimate pressure in leak proof system, 1/4 HP motor, 240 volts 50 Hz.	-	850	Soiltest
13. Beaker	Pyrex glass; safe temperature limit 500C;			Soiltest
	1. 100 ml	-	3	
	2. 250 ml	-	3	
	3. 600 ml	-	4	
14. Cylinder	Pyrex glass graduated			Soiltest
	1. 100 ml	-	12	
	2. 250 ml	-	18	
	3. 500 ml	-	22	
	4. 1000 ml	-	32	
15. Evaporating Dish	Poreclain, glazed inside, partially glazed outside.			Soiltest
	1. 90 mm diameter 120 ml capacity	-	9	
	2. 115 mm diameter 250 ml capacity	-	13	
16. Desiccator	For cooling samples in moisture-free environment, glass construction, 125 mm inside diameter and 75 mm depth to plate.	-	65	Soiltest
17. Wash Bottle	Borosilicate Florence flask with special molded rubber grip containing valve system, one litre capacity.	-	78	Soiltest
18. Filtering Funnel	Pyrex glass, 60 angle bowl, beaded to reduce chipping, top diameter 127 mm, stem length 100 mm.	-	80	Fisher Scientific
19. Filter Circle	Whatman, ashless filter paper, fine porosity, particle retention .0025 mm, diameter 12.5 cm packet.	-	25	Fisher Scientific

Table 5 (Continued)

20. Stirring Rod	Glass, 5 mm diameter, 30 cm long	-	2	Fisher Scientific
21. Thermometer	Range - 20 to 110C, minimum graduation one degree, length 300 mm.	-	32	Fisher Scientific
22. 3-Way Stop Cock	Glass construction.	-	12	Fisher Scientific
23. French Curve Set	Plastic.	-	100	Common Item.

EQUIPMENT TO BE PURCHASED LOCALLY

TABLE -6
SHEET 1/1

(1)		QUANTITY													TOTAL
		PUNJAB					SINDH				BALOCHISTAN		NWFP		
		1/ UCC (2)	2/ LJC (3)	3/ LCC (4)	4/ MC (5)	5/ BC (6)	6/ Piny. (7)	7/ Beg. (8)	8/ RC (9)	9/ NC (10)	10/ Quetta (11)	11/ Sibi (12)	2/ N C (13)	3/ S C (14)	(15)
HYDRAULIC EQUIPMENT															
1. Standard Wading Rods Set	(sets)	6	8	6	6	6	4	4	10	6	6	10	6	6	84
2. Boat Improvizement Set	(sets)	3	4	3	3	3	2	2	5	3	–	3	2	2	35
3. Sounding Weight 50 Pounds	(nos)	3	4	3	3	3	2	2	5	3	–	3	2	2	35
4. Hanger Bar With Pins	(nos)	6	8	6	6	6	4	4	10	6	–	3	4	4	67
5. Flat Bottom Fibre Glass Boat	(nos)	3	4	3	3	3	2	2	5	3	–	3	2	2	35
6. Y-rod	(nos)	3	4	3	3	3	2	2	5	3	1	3	2	3	37
7. Staff Gages															
0 – 3.33 ft		20	20	20	20	20	12	12	30	18	20	20	12	18	242
3.33 – 6.66 ft		20	20	20	20	20	12	12	30	18	20	20	12	18	242
6.66 – 9.99 ft		20	20	20	20	20	12	12	30	18	20	20	12	18	242
9.99 – 13.33 ft		20	20	20	20	20	12	12	30	18	20	20	12	18	242
8. U.S. DH 48 Sampler	(nos)	3	4	3	3	3	2	2	5	3	3	5	3	3	42
9. Stop Watch	(nos)	1	1	1	1	1	1	1	1	1	1	1	1	1	13
SURVEY EQUIPMENT															
1. 100-Foot Metallic Measuring Tape	(nos)	3	4	3	3	3	2	2	5	3	3	5	3	3	42
2. Level with Tripod	(nos)	3	4	3	3	3	2	2	5	3	3	5	3	3	42
3. Levelling Staff	(nos)	3	4	3	3	3	2	2	5	3	3	5	3	3	42

Notes: Delivery in Pakistan at the following locations:

1/ Supt. Engineer, Upper Chenab Canal Circle, Lahore
2/ Supt. Engineer, Lower Jhelum Canal Circle, Sargodha
3/ Supt. Engineer, Lower Chenab Canal East Circle, Faisalabad
4/ Supt. Engineer, Muzaffargarh Canal Circle, Multan
5/ Supt. Engineer, Bahawalpur Canal Circle, Bahawalpur
6/ Supt. Engineer, Pinyari Canal Circle, Hydrabad
7/ Supt. Engineer, Begari Sindh Feeder Circle, Sukkur
8/ Supt. Engineer, Rohri Canal Circle, Hydarabad
9/ Supt. Engineer, Nara Canal Circle, Hydarabad
10/ Supt. Engineer, Irrigation Circle, Quetta
11/ Supt. Engineer, Pat Feeder and Sibi Circle, Dera Murad Hamali (Balochistan)
12/ Supt. Engineer, Northern Irrigation Circle, Mardan
13/ Supt. Engineer, Southern Irrigation Circle, Bannu

EQUIPMENT TO BE PURCHASED FROM USA

TABLE -7
SHEET 1/4

(1)		QUANTITY													TOTAL
		PUNJAB					SINDH				BALOCHISTAN		NWFP		
		1/ UCC (2)	2/ LJC (3)	3/ LCC (4)	4/ MC (5)	5/ BC (6)	6/ Piny. (7)	7/ Beg. (8)	8/ RC (9)	9/ NC (10)	10/ Quetta (11)	11/ Sibi (12)	2/ N C (13)	3/ S C (14)	(15)
HYDRAULIC EQUIPMENT															
1. Current Meter AA	(nos)	6	8	6	6	6	4	4	10	6	6	10	6	6	84
2. Pygmy Current Meter	(nos)	6	8	6	6	6	4	4	10	6	6	10	6	6	84
3. Light Duty Tagline	(nos)	6	8	6	6	6	4	4	10	6	6	10	6	6	84
4. Heavy Duty Tagline	(nos)	3	4	3	3	3	2	2	5	3	–	3	2	2	35
5. Headset	(nos)	6	8	6	6	6	4	4	10	6	6	10	6	6	84
6. Electronic Stop Watch	(nos)	3	4	3	3	3	2	2	5	3	3	5	3	3	42
7. Spares for Current Meters	(nos)														
Pivot Assembly		1	1	1	1	1	1	1	2	1	1	2	1	1	15
Hanger Screw		1	1	1	1	1	1	1	2	1	1	2	1	1	15
Binding Post Assembly		1	1	1	1	1	1	1	2	1	1	2	1	1	15
Two-pole Connector		1	1	1	1	1	1	1	2	1	1	2	1	1	15
Extra Screws		2	2	2	2	2	2	2	4	2	2	4	1	1	28
8. Rubber Chest Wader	(nos)														
Medium Size		2	3	2	2	2	1	1	4	2	2	4	2	2	29
Large Size		1	1	1	1	1	1	1	1	1	1	1	1	1	13
9. Hip Boats	(pair)														
Medium Size		2	3	2	2	2	1	1	4	2	2	4	2	2	29
Large Size		1	1	1	1	1	1	1	1	1	1	1	1	1	13
10. Sounding Reel	(nos)	3	4	3	3	3	2	2	5	3	–	3	2	2	35
11. Spare Cable Connector	(nos)	2	2	2	2	2	2	2	4	2	–	3	2	2	27
12. Spare Sounding Cables	(ft)	300	400	300	300	300	200	200	500	300	–	300	200	200	3500
13. Life Jacket	(nos)	6	8	6	6	6	4	4	10	6	–	9	6	6	77
14. Water Level Recorder	(nos)	3	4	3	3	3	2	2	5	3	3	5	3	3	42

TABLE -7
SHEET 2/4

(1)		QUANTITY													TOTAL
		PUNJAB					SINDH				BALOCHISTAN		NWFP		
		1/ UCC (2)	2/ LJC (3)	3/ LCC (4)	4/ MC (5)	5/ BC (6)	6/ Piny. (7)	7/ Beg. (8)	8/ RC (9)	9/ NC (10)	10/ Quetta (11)	11/ Sibi (12)	2/ N C (13)	3/ S C (14)	(15)
15. Spares for W.L Recorder															
Recorder Chart		3	4	3	3	3	2	2	5	3	3	5	3	3	42
Pen Ink		3	4	3	3	3	2	2	5	3	3	5	3	3	42
Capillary Pen		3	4	3	3	3	2	2	5	3	3	5	3	3	42
Pen Cleaner		3	4	3	3	3	2	2	5	3	3	5	3	3	42
16. US BMH53 Sampler	(nos)	3	4	3	3	3	2	2	5	3	3	5	3	3	42
17. Pint Glass Bottels, 24 per Box	(boxs)	3	4	3	3	3	2	2	5	3	3	5	3	3	42
18. Sample Label	(packet)	3	4	3	3	3	2	2	5	3	3	5	3	3	42
SEDIMENT LABORATORY EQUIPMENT															
1. Bottom Withdrawal Tube	(nos)	2	2	2	2	2	2	2	2	2	2	2	2	2	26
2. Analytical Balance	(nos)	1	1	1	1	1	1	1	1	1	1	1	1	1	13
3. Electric Oven	(nos)	1	1	1	1	1	1	1	1	1	1	1	1	1	13
4. 3-inches Diameter 12 Sieves, Nos. 5, 10, 18, 25, 35, 45, 60, 80, 120, 170, 230, 325	(Sets)	1	1	1	1	1	1	1	1	1	1	1	1	1	13
5. 8-inch Diameter 6 Sieves, Size 5.6; 8.0; 16.0; 31.5; 63; 100 mm	(Sets)	1	1	1	1	1	1	1	1	1	1	1	1	1	13
6. Sieve Brush		2	2	2	2	2	2	2	2	2	2	2	2	2	26
7. 8-inch Dia Sieve Lid	(nos)	1	1	1	1	1	1	1	1	1	1	1	1	1	13
8. 8-inch Dia Sieve Pan	(nos)	1	1	1	1	1	1	1	1	1	1	1	1	1	13
9. 8-inch Dia Sieve Shaker	(nos)	1	1	1	1	1	1	1	1	1	1	1	1	1	13
10. Pipette	(nos)														
25 ml		1	1	1	1	1	1	1	1	1	1	1	1	1	13
50 ml		1	1	1	1	1	1	1	1	1	1	1	1	1	13

TABLE -7
SHEET 3/4

(1)		QUANTITY													TOTAL
		PUNJAB					SINDH				BALOCHISTAN		NWFP		
		1/ UCC (2)	2/ LJC (3)	3/ LCC (4)	4/ MC (5)	5/ BC (6)	6/ Piny. (7)	7/ Beg. (8)	8/ RC (9)	9/ NC (10)	10/ Quetta (11)	11/ Sibi (12)	2/ N C (13)	3/ S C (14)	(15)
11. Vacuum Pump	(nos)	1	1	1	1	1	1	1	1	1	1	1	1	1	13
12. Beaker	(nos)														
100 ml		2	2	2	2	2	2	2	2	2	2	2	2	2	26
250 ml		2	2	2	2	2	2	2	2	2	2	2	2	2	26
600 ml		2	2	2	2	2	2	2	2	2	2	2	2	2	26
13. Cylinder	(nos)														
100 ml		2	2	2	2	2	2	2	2	2	2	2	2	2	26
250 ml		2	2	2	2	2	2	2	2	2	2	2	2	2	26
500 ml		2	2	2	2	2	2	2	2	2	2	2	2	2	26
1000 ml		2	2	2	2	2	2	2	2	2	2	2	2	2	26
14. Evaporating Dish	(nos)														
120 ml		10	10	10	10	10	10	10	10	10	10	10	10	10	130
250 ml		10	10	10	10	10	10	10	10	10	10	10	10	10	130
15. Desiccator	(nos)	1	1	1	1	1	1	1	1	1	1	1	1	1	13
16. Wash Bottle	(nos)	1	1	1	1	1	1	1	1	1	1	1	1	1	13
17. Filtering Tunnel	(nos)	2	2	2	2	2	2	2	2	2	2	2	2	2	26
18. Filter Circle	(packet)	2	2	2	2	2	2	2	2	2	2	2	2	2	26
19. Stirring Rod	(nos)	2	2	2	2	2	2	2	2	2	2	2	2	2	26
20. Thermometer	(nos)	2	2	2	2	2	2	2	2	2	2	2	2	2	26
21. 3-way Stop Cock	(nos)	2	2	2	2	2	2	2	2	2	2	2	2	2	26
22. French Curve Set	(sets)	1	1	1	1	1	1	1	1	1	1	1	1	1	13

Notes: Delivery in Pakistan at the following locations:

1_/ Superintending Engineer, Upper Chenab Canal Circle, Lahore
2_/ Superintending Engineer, Lower Jhelum Canal Circle, Sargodha
3_/ Superintending Engineer, Lower Chenab Canal East Circle, Faisalabad
4_/ Superintending Engineer, Muzaffargarh Canal Circle, Multan
5_/ Superintending Engineer, Bahawalpur Canal Circle, Bahawalpur
6_/ Superintending Engineer, Pinyari Canal Circle, Hydrabad
7_/ Superintending Engineer, Begari Sindh Feeder Circle, Sukkur
8_/ Superintending Engineer, Rohri Canal Circle, Hydarabad
9_/ Superintending Engineer, Nara Canal Circle, Hydarabad
10_/ Superintending Engineer, Irrigation Circle, Quetta
11_/ Superintending Engineer, Pat Feeder and Sibi Circle, Dera Murad Hamali (Balochistan)
12_/ Superintending Engineer, Northern Irrigation Circle, Mardan
13_/ Superintending Engineer, Southern Irrigation Circle, Bannu