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Kurram Tangi Dam Construction

Environmental Mitigation and Monitoring Plan
Annex VI: Instrumentation and Monitoring Plan (Final)

December 2013
This publication was produced for review by the
United States Agency for International Development.
It was prepared by MWH under contract AID-391-C-13-00002

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Map to Kurram Tangi Dam Project Documents

Shown below is the suite of documents submitted to USAID under Contract AID-391-C-13-00002 for the KTDP. This report is shaded in red in order to show its relationship to the full set of documentation.

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	VOLUME II: PROJECT ECONOMIC BENEFITS
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	SUPPLEMENTAL REPORT ON HYDROLOGY
	SUPPLEMENTAL REPORT ON CLIMATE CHANGE

All documents may be read as stand-alone documents, but the reader should be aware of the full set of documents available. Any one document may reference other documents in the suite in order to avoid duplication.

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Kurram Tangi Dam Construction

EMMP Annex VI: Instrumentation and Monitoring Plan

USAID Environmental Assessment of Kurram Tangi Dam Construction
Contract Number: AID-391-C-13-00002
From MWH Americas, Inc.
To USAID/Pakistan Energy Office
December 2013
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The author's views expressed in this publication do not necessarily reflect the views of the United States Agency for International Development or the United States Government.

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List of Acronyms

Acronym	Term
CFRD	Concrete Faced Rockfill Dam
EPP	Emergency Preparedness Plan
FATA	Federally Administered Tribal Areas
GPS	Global Positioning System
ICOLD	International Commission on Large Dams
PMF	Probable Maximum Flood
RCC	Roller Compacted Concrete
TU	Terminal Unit

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Instrumentation and Monitoring Plan

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1. INTRODUCTION

1.1 General

A monitoring program will be implemented during construction and operation of the Kurram Tangi project. This program will include systems of geotechnical, hydrological and meteorological instrumentation at the major structures, the reservoir area and along the river system. Monitoring will include visual inspections as well as water quality and environmental measurements. The planned instrumentation and monitoring plan is outlined in the following paragraphs.

The safety of existing dams and weirs can be enhanced by an engineered and implemented surveillance program. Also, the life of dams and weirs can be lengthened with appropriate remedial work that may evolve as a result of such surveillance. A key part of such a program is a visual examination of the embankment, reservoir and appurtenant facilities; however, surveillance must include more than visual observations. Surface settlement and minor deformation are expected, but the magnitude and direction of these movements generally cannot be detected by visual observations alone. Also, comparison of measured internal water levels and seepage quantities from one inspection to another and over weeks, months and years is difficult by visual observation and estimation.

Instrumentation is included to monitor the behavior, performance, and safety of the dam and weir during construction, initial reservoir filling, and during reservoir operation. The purpose of the instrumentation and monitoring plan described herein is to: (a) describe the various instrumentation types that will been installed in the dam and weir and surveillance procedures used to obtain data to evaluate whether the structure is functioning as designed; (b) provide continuing surveillance of the structure with the intent of early detection of potential problems; and (c) provide a database for the evaluation of the dams/weirs performance.

Project information may change should revisions to the design be necessary. It should be noted that seepage and deformation analysis of the dam and weir are recommended during the next phase of design. Results may have an impact of the proposed instrumentation and monitoring plan; therefore the information provided in plan is subject to change and is to be verified and updated as needed.

1.2 Project Overview

The overall Kurram Tangi project will be a multipurpose water resources development project. It will lie within the Kurram River system which consists of Kurram, Kaitu and Tocchi Rivers. This river system is in the Federally Administered Tribal Area (FATA) of Pakistan, and the river catchment spreads across the international border between Pakistan and Afghanistan.

<u>Kurram Tangi Dam</u>
The Kurram Tangi Dam site will be located on the Kurram River in North Waziristan just before it crosses the border into Bannu. Kurram Tangi Dam will be a concrete faced rockfill dam (CFRD) used for flood control and water redistribution. The proposed features of the dam are as follows:

- Dam crest elevation = 2142 ft above msl
- Riverbed elevation = 1820 ft above msl
- Dam crest width = 45 ft
- Maximum height above riverbed = 322 ft
- Dam crest length = 1,035 ft
- Slope of dam upstream and downstream face (H:V) = 1.5H: 1V

The reservoir behind Kurram Tangi Dam, at a full reservoir elevation of 2127 ft msl, will submerge a land area of about 10,940 acres. The reservoir will have a length of 8 miles and an average depth of 117 ft. The reservoir will have a total storage of:

- Live storage = 0.900 MAF

- Dead storage = 0.300 MAF
- Gross storage = 1.208 MAF

The spillway for Kurram Tangi Dam will be located on the right bank of Kurram River at River Mile 67. The spillway and its various components were designed to safely pass the Probable Maximum Flood (PMF). The spillway capacity at Kurram Tangi Dam is being fixed so that the flood surcharge due to the PMF including wave-run-up would be lower than the top of the dam. The spillway will be capable of passing the PMF, with normal flood surcharge 5.8 ft above the normal reservoir level. A gated spillway with a discharge capacity of 141,145 cfs will be provided. The spillway will be operated to maintain the reservoir level at El. 2127 ft msl. The spillway will be 200 ft wide, having four bays, and the energy will be dissipated through a 300 ft long by 200 ft wide spillway with chute blocks.

Two diversion tunnels, one 20 ft in diameter and the other 14 ft in diameter, will be located on the right bank of the Kurram River between the dam and the spillway. Following construction of Kurram Tangi Dam the 20 feet diameter tunnel will serve as a power tunnel for the main powerhouse with an installed capacity of 36 MW.

<u>Weir III</u>
Weir III, to be located about 30,000 ft downstream of Kurram Tangi Dam, will create a small reservoir for power generation. Weir III will be a roller compacted concrete (RCC) structure with a maximum height of 75 ft above the river bed level. The weir will be 1434 ft long at the crest, which will be a standard ogee. The downstream face of the weir has been provided with a cascade type of chute for dissipation of energy. The chute will terminate in a 62 ft long stilling basin. Two 12 ft dia. low level conduits, which will initially be used for river diversion, will be provided in the weir for the sluicing of sediments. These conduits will have upstream vertical gates, operated from the crest of the weir. The reservoir behind Weir III will submerge an area of approximately 730 acres, have an average depth of 57 ft, and a length of 3.5 miles. The powerhouse associated with Weir III will have an installed capacity of 16.5 MW.

1.3 Instrumentation and Monitoring for Dam and Weir Facilities

The dam and weir facilities must be monitored to ensure safe performance and to identify any problems which may arise. International Commission on Large Dams (ICOLD) (2005) outlines key parameters and monitoring facilities which are presented in . Parameters that are commonly monitored and instrument types are listed in and Table 2-2.

Table 1-1: Instruments and Measurements

Property Measured	Measurement Location	Typical Instruments
Alignment	Crest, slope or other location of interest	Surface monument, Total station, Laser, Global Positioning System (GPS), Geodimeter
Deformation or Internal Movement	All points of interest within the dam and weir, foundation, and abutments	Strain gage, Inclinometer, Settlement cell, Electro-level, Extensometers
Opening or Crack	Joints of concrete surface	Joint meter, Crack meter
Water Pressure	Within the dam and weir, foundation, and abutments	Piezometer, Observation well
Rate of Leakage Flow	Within the galleries, toe of the dam and weir and any other location of interest	Weir, Flume, Flow meter or Calibrated container
Quality of Leakage	Any location of interest	Turbidity meter
Earthquake Response	Dam and weir crest, toe of dam and weir, and abutments	Peak acceleration recorder, Strong motion accelerometer, Microseismic Station

ICOLD, "Concrete Face Rockfill Dams – Concepts for Design and Construction", July 2005

The conceptual monitoring system for the Kurram Tangi Dam and Weir III facilities will be in accordance with the guidelines presented in ICOLD (2005), USBR and other internationally recognized standards. Facility surveillance will consist of monitoring and visual inspection of the structural integrity during operation, including both qualitative and quantitative comparisons of actual facility performance to design conditions. The data collected will provide a useful tool to check design assumptions, and will be used to evaluate the following:

- Settlements within the dam to check the adequacy of camber provided and the assumed engineering properties of the rockfill.
- Surface movements of the embankment dam and concrete weirs.
- Strain measurements in the face slab of the dam.
- Joint opening in the perimetric and face slab joints of the dam.
- Seepage in the foundations and abutments of the water retaining structures.
- Ground water levels in the foundations and abutments of the dam and weir.
- Earthquake motion at the dam and weir sites.

The instrumentation and monitoring plan will comply with the World Bank guideline OP 4.37, "Safety of Dams". This document specifies that large dams (generally more than 50 ft (15 m) high) require an instrumentation plan to ensure safe operation.

OP 4.37 also includes requirements for plans related to construction supervision and quality assurance, operation and maintenance (O&M) and emergency preparedness. Details of these three plans are outside the scope of this instrumentation report. It will be necessary, however, to closely integrate the instrumentation plan with all three plans as follows.

- **Construction supervision and quality assurance**: The installation of instruments will be integrated with construction activities. Each instrument will be commissioned as it is installed. Readings will begin immediately and these will provide an ongoing database that will help monitor the effects of various construction activities.
- **Operation and maintenance (O&M):** O&M plans will incorporate procedures and criteria from the instrumentation plan. The O&M manual will include tables of all instruments together with their respective reading schedules; this is necessary to ensure that long term

monitoring of dam and weir instrumentation is performed. All instruments will have threshold level readings taken from the instrumentation plan that indicate anomalous conditions which warrant further action by plant personnel.

- **Emergency Preparedness:** The emergency preparedness plan (EPP) will refer to the monitoring activities, both instrumental and visual. The ongoing monitoring of the various structures, hydrological conditions, and meteorological activities will provide an early warning system that will help predict critical situations requiring action. It is important that personnel involved in emergency preparedness be familiar with the extent and capabilities of the monitoring system.

In accordance with OP 4.37, the monitoring program will include regular reviews by an independent panel of experts. The independent panel will consist of three or more experts, appointed by the owner and acceptable to the financing institution. The panel members will be recognized experts in hydro-technical engineering, geotechnical engineering, hydrology and environmental sciences. The panel will review and advise on technical matters related to dam design, river diversion, construction and hydrology during the next phase of design and during construction of the project. During operation of the dam and weir, the primary purpose of the panel is to review and advise on matters relative to dam safety and other critical aspects of the dam, its appurtenant structures, the catchment area, the area surrounding the reservoir, and downstream areas. The panel will contribute to the development of and review the EPP's. The panel will conduct periodic safety inspections of the dam and weir after completion and regularly review the instrumentation data and performance of critical structures. In general, the independent panel meetings will occur every six months during the construction period and every 12 months during project operation after the completion of construction and initial reservoir impoundment.

All operations personnel working at Kurram Tangi Dam and Weir III are to be involved in surveillance as a part of routine activities. On-site personnel are to maintain visual awareness of the facility and have knowledge of warning factors and procedures to follow in the event that a deviation from the planned facility performance is observed. This plan provides the procedure to be followed for monitoring and inspections.

During implementation of the plan, modifications of the procedures unique to this project may be required. Personnel will be encouraged to suggest such changes. In addition, it may be appropriate to adjust the periodic readings scheduled herein (See Section 2), based on dam and weir performance and historical readings. Any changes should be adopted only after careful consideration of the possible long-term effects and after obtaining the approval of an engineer who is thoroughly familiar with the design, construction and function of the instrumentation equipment and the structure, and appropriate regulatory agencies.

1.4 Meteorological, Hydrological and Water Quality Monitoring

Meteorological, water quality and hydrological monitoring are critical for the long term performance of the project. Hydrological and meteorological information collected is useful for reservoir operation, flood forecasting, and spillway operation. Monitoring data, together with water quality assessments, will be important to long term environmental monitoring of the impacts of reservoir impoundment and changes to the river flow regime.

Meteorological stations will be established at Kurram Tangi Dam and in the watershed catchment area. Meteorological measurements include temperature, barometric pressure, humidity, wind speed, wind direction, evaporation and precipitation. Monitoring equipment, layout and procedures will conform to World Meteorological Organization (WMO), "Guide to Meteorological Instruments and Methods of Observation". The monitoring program will also conform to prevailing local or regional government criteria. Special care must be taken with site selection. Wind measurement instruments are to be located in areas free of other obstructions that might modify wind direction and velocity. Temperature and humidity measurements must be free from direct solar radiation, or

insolation. If possible, automated measurements of temperature, wind and humidity should be installed to take measurements at least once per hour, and automated measurements of precipitation should be recorded at 15 minute intervals. If manual systems are used, observations should be taken at least once daily. Precipitation should be recorded using both manual and automated means, if possible. All manually recorded data should be converted into digital records. Instruments required for meteorological monitoring are discussed in Section 2.1.

Reservoir monitoring will have the following measurement objectives:

- Reservoir inflow and outflow.
- Reservoir sediment accumulation and sediment migration to downstream river systems.
- Water quality in the reservoir and downstream of the powerhouse.

Hydrological monitoring will encompass the reservoirs and the rivers upstream and downstream of the weir and dam. Reservoir levels will be measured at Kurram Tangi Dam and Weir III on a daily basis. Flows will be measured at the spillways, weirs, downstream of the Kurram Tangi Dam and in the inflow river at the upstream end of the reservoir. These will be measured as water levels in the field and flow rates will be computed with pre-established rating curves. A program of periodic discharge measurements will be implemented to develop and maintain up to date and accurate rating curves for the various flow rate monitoring stations. The measurements will be performed manually and all data will be entered into appropriate databases. Given that some of the catchment basis is outside Pakistan's international boundaries, it is probable that not all of the headwaters and catchment area will be monitored.

A long term program of water sampling and testing will be carried out. This program will be integrated into overall environmental monitoring works. Sampling will be carried out in the reservoirs, upstream inflow river and in the river downstream of Weir III on a regular basis. Field testing carried out during each sampling will include temperature, turbidity, dissolved oxygen, specific conductivity and pH. Samples will be tested in the laboratory for turbidity, and water chemistry. Other testing will be done as required for the assessment of various environmental parameters (refer to the Environmental Mitigation and Monitoring Plan and Supplemental Report on Water Quality).

All proposed instrumentation and monitoring programs are to be consistent with current practices in Pakistan and integrated into the national or provincial systems.

1.5 Definitions

The following terms have the meanings hereby assigned to them:

- Instrument: A geotechnical or hydraulic instrument to be installed including standpipes, readout-units and all ancillary equipment required for satisfactory performance of the unit.
- Leads: All leads, wires, cables, flexible pipes and the like required to connect that part of an Instrument with the terminal unit at which readings are taken.
- Measuring Point: That part of an instrument which is installed at the position to which the parameter measured by the instrument relates.
- Terminal Unit: The point at which instrument readings are recorded either manually or automatically.

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2. INSTRUMENTATION

2.1 General

The instrumentation system for the Kurram Tangi Dam Project will include piezometers, extensometers, settlement markers, inclinometers, 2D joint meters, 3D joint meters, seepage measurement weir(s), reservoir staff gauges, reservoir level gauges, seismometer, terminal units (TU's) and a barometer. The instruments will be installed during embankment construction. The preliminary location of instrumentation is shown on the project drawings included in Appendix A. Additional instruments may be required once drawings are prepared during the next phase of design. Also, additional instrumentation installation details may be required to ensure proper installation by the contractor.

Instrumentation to be provided at Kurram Tangi is summarized in . The quantities listed below are preliminary and final instrument quantities will be developed during the next phase of design when seepage and deformation analysis models are performed.

Table 2-1: Kurram Tangi Dam Instrumentation

Instrument	Preliminary Quantities
Settlement Markers	12
Inclinometers with magnetic settlement markers	3
Extensometers	4
Settlement Cells	10
1D Joint Meters	10
2D Joint Meters	5
3D Joint Meters	9
Electro-levels	10
Vibrating Wire Piezometers	20
Standpipe Piezometers	10
Weirs/Flumes	2
Strong Motion Accelerographs	2

Preliminary instrumentation quantities for the 75 ft high Weir III are provided in Table 2-2. This will be finalized during the next phase of design. Project drawings for Weir III are currently not available.

Table 2-2: Weir III Instrumentation

	Preliminary Quantities
Settlement Markers	6
Extensometers	3
Vibrating Wire Piezometers	3
Standpipe Piezometers	4
Strong Motion Accelerographs	1

Instrumentation required for meteorological and hydrological monitoring is shown in Table 2-3.

Table 2-3: Kurram Tangi and Weir III, Meteorological and Hydrological Monitoring

Instrument	Preliminary Quantities
Meteorological Stations (temperature, wind speed/direction, humidity, barometric pressure and precipitation measurement)	3 (1 near Kurram Tangi Dam and 2 in the upper reservoir and/or catchment area)
Reservoir staff gauge - Kurram Tangi Dam	1
Downstream staff gauge, Kurram Tangi Dam	1
Reservoir staff gauge - Weir III	1
Flow measurement station in the upper Kurram Tangi River basin (as permitted by international treaty with Afghanistan)	1

2.2 Kurram Tangi Dam

2.2.1 Embankment Instrumentation

Dam embankment instrumentation will consist of the following.

- **Settlement Markers:** Settlement markers will be installed in lines along the crest and downstream slope of the dam to monitor both vertical and horizontal movements of the embankment surface. These installations, which are survey type reference points, will be surveyed on a regular basis by high precision ground survey methods. Survey bench mark and control points will be located at a sufficient distance from the dam to ensure that they are not affected by any movements of the embankment or foundation.
- **Inclinometers:** Inclinometers measure the settlement/deflection of the dam as well as settlement beneath the slab. Three inclinometers are proposed to be installed along the dam crest. Other inclinometers will be installed into the dam foundation – one at the right abutment, one at the center, and one at the left abutment. The inclinometers will be installed at locations where maximum settlement/deflection is anticipated.
- **Invar Wire Extensometers:** Instrumented invar wire extensometers will be installed at four locations to monitor horizontal deformations. Two extensometers will be installed along the dam crest – one at the right abutment and one at the left abutment. Two extensometers are also located on the interior slope of the dam along the right abutment joint to monitor for potential displacement of the concrete face. The extensometers pass through the rockfill and tie into the foundation and/or abutments. The data obtained from the extensometers will be used to evaluate the performance of the interior rock facing during reservoir operation and provide indications of crack development, potential movement and potential slope failure.
- **Settlement Cells**: Settlement cells, both hydraulic and electric, will be used to monitor the settlements that take place within the embankment during construction, reservoir filling, and project operation. Evaluation of settlement data during construction is useful when comparing the performance of the dam to other projects with similar materials. Face deformation during reservoir filling can be estimated using empirical relationships based on analyses of settlement data.

Information and data obtained from the instrumentation will be collected, reviewed and compared with design assumptions. Periodic visual observation and documentation of conditions that develop will also be performed. The observational method will help in recognizing conditions that vary from those assumed for the design in a timely manner. Modifications to facility operation can then be made to address the observed conditions, if needed.

2.2.2 Face Slab Instrumentation

Face slab instrumentation will include the following:

- **1D Joint Meters**: One-dimensional joint meters will be used to monitor the joint opening between the concrete face slabs across vertical contraction joints.
- **2D Joint Meters:** Two-dimensional joint meters will be used to monitor the lateral and shear movement across joints. These will be embedded in the face slabs, across contraction joints.
- **3D Joint Meters**: Three-dimensional joint meters will be used in the perimeter joints to monitor the joint opening in the perpendicular, parallel and tangential directions.
- **Electro-Levels**: It should be noted that inclinometer units can be replaced or supplemented by electro-level instruments to monitor the face slab. This instrument can be used to monitor the deformation of the face slab during construction, during reservoir filling and during project operation. The electro-level consists of a glass capsule partially filled with an electrolytic fluid, commercially known as gravity sensing electrolytic potentiometers. Electro-level installations can be installed and read as soon as the concrete slab is poured. This allows early collection and evaluation of face deformation during construction.

2.2.3 Dam Piezometric, Seepage and Reservoir Level Monitoring

Seepage performance of the dam will be assessed using the instrumentation installed in the embankment, foundation, drain system, as well as on the interior slope of the embankment. The design of the dam incorporates assumptions regarding the in-situ hydraulic conductivity of the embankment and foundation materials. The design assumptions are based in part on the field tests conducted during the geotechnical site investigation and laboratory testing. These assumptions were used to estimate the pressure distribution within the embankment and dam foundation and to predict the amount of seepage expected through the system.

Piezometers provide information on real time foundation pore pressure. Readings should be monitored to watch for excessive buildup in the water pressures in the foundations, and to monitor the effectiveness of the foundation drainage systems. Piezometers will be installed in the abutments and in the foundation of the dam. In general, no monitoring of the very pervious rock fill shell material will be required. Other instrumentation will measure water flow rates and reservoir levels over time. The following instruments will be installed to measure hydrologic, seepage and piezometric uplift parameters:

- **Vibrating Wire Piezometers:** Vibrating wire piezometers will be used to monitor piezometric uplifts at the base of the concrete slab and in the adjacent bedrock foundation rock. Variations in piezometric levels in piezometers over time will be a good indicator of the performance of the grout curtain and drainage system and detect any changes in the hydrogeology of the bedrock over time.
- **Standpipe Piezometers:** Standpipe piezometers will be Casagrande type instruments installed in the abutments. Data from these instruments will supplement and expand the hydrogeologic database of the vibrating wire instruments. Water levels in these installations can be read manually with a dip type water level indicator or remotely by electronic means.
- **Flow Measurement Weir(s):** Flow-measuring weirs will be placed in strategic locations to measure leakage through the dam and through the abutments and foundation. At a minimum, a single weir will be placed at the downstream toe of the dam to measure

collected leakage in this area. It is expected that most of this leakage will flow from the pressure relief drains and the drainage blanket in the base of the embankment. Additional weirs may be needed if more than one area of visual leakage develops. Weirs can be read by manual means although automatic reading may be advantageous if critical seepage develops.

- **Reservoir and Downstream Staff Gauge(s):** Reservoir staff gauges will be installed in the reservoir upstream of the dam. Typically reservoir staff gauges are attached to a concrete structure in the reservoir, such as a concrete gate pier. A downstream staff gauge will installed downstream of the tailwater as to enable flow rates to be determined. These gauges will be read manually by visual inspection.

The data obtained from the instrumentation will be compared against the predicted seepage behavior and estimated pore pressure distribution to verify design assumptions and that the embankment is performing as expected. It should be noted that a seepage model of the dam is to be performed in the next phase of design to develop a prediction of the dam performance and to establish baseline instrument values for later verification of design assumptions and to determine whether the dam is performing as expected.

2.2.4 Earthquake Instrumentation

The dam is located in an area of high seismic activity. Strong motion seismographs should be installed to monitor earthquake activity and the response of the dam. These instruments will continuously record the seismic response of the dam and foundation to any earthquake ground motions that exceed a predetermined trigger limit. They should also be equipped with self-contained recording capability. These accelerometers can be set to monitor low seismic activity, such as that triggered by the reservoir impoundment.

Two strong motion accelerometers should be installed, one in the bedrock foundation to record base ground motions and the other at the crest of the dam to record the dam response to earthquake activity. As a general rule, ground motions at the crest of an embankment dam are more severe than the base ground motions in its foundation.

2.3 Weir III

The instrumentation system for Weir III will be developed during the next phase of design. Preliminary instrumentation for Weir III is described as follows:

- **Survey Markers:** Settlement markers should be installed in lines along the crest and on the downstream slope of the weir to monitor both vertical and horizontal movements of the weir. These installations, which are survey type reference points, will be surveyed on a regular basis by high precision ground survey methods. Final layout and locations of these points will depend upon available surface access to the weir. Installations along the crest will only be able to be read if there is no water flow over the weir and it may not be feasible to have ideal locations. Survey bench mark and control points will be located at a sufficient distance from the weir to ensure that they are not affected by any movements of the weir structure or foundation.
- **Borehole Extensometers:** Multiple point borehole extensometers will be installed at two locations to monitor horizontal deformations of the weir foundation.
- **Vibrating wire piezometers:** Vibrating wire piezometers will be used to monitor piezometric uplifts at the base of the concrete structure and in the adjacent bedrock foundation rock. Variations in piezometric levels over time will be a good indicator of the performance of the grout curtain and drainage system and detect any changes in the hydrogeology of the bedrock over time.

- **Standpipe piezometers:** Standpipe piezometers will be Casagrande type instruments installed in the abutments. Data from these instruments will supplement and expand the hydrogeologic database of the vibrating wire instruments. Water levels in these instruments can be read manually with a dip type water level indicator or remotely by electronic means.
- **Strong Motion Accelerometer:** One strong motion accelerometer will be installed in the abutment of the weir.
- **Reservoir staff gauge(s):** A reservoir staff gauge will be installed in the reservoir upstream of the weir, and a downstream staff gauge will also be installed downstream of the tailwater.

2.4 Meteorological Monitoring

Meteorological monitoring stations will be established at the project site and in the upper reservoir/catchment area. Station(s) will include instruments for measuring temperature, humidity, barometric pressure, precipitation, and wind velocity/direction. Additional monitoring of evaporation rates will be carried out as deemed necessary.

2.5 Instrumentation Controls

Instrumentation hook-ups and networking cannot be determined at this time. Fully automated network are often used in Europe and North America for similar installations however normal practice is to have a mix of manual and automatic readouts of the various instruments. It is anticipated that the Kurram Tangi Dam project will rely mostly on manual readouts of various instruments together using appropriate read-out instruments, survey methods and data loggers. The instrumentation installations will require the following equipment and installations.

Instrumentation controls for the Kurram Tangi Dam project include:

- Terminal boxes (switchboxes)
- Potable readout/logger device for readout of instruments
- Data logger
- Computer software for processing instrumentation data
- Instrument houses

The following equipment will be installed in the instrument houses:

- Piezometer distribution meters
- Piezometer terminal equipment
- Joint meters
- Transducers
- Extensometer terminal equipment
- Other equipment as required

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3. FACILITY MONITORING

3.1 General

Monitoring will be carried out by qualified site personnel. Construction/supervisory personnel will do this during the construction period. The duties will then be passed over to the owner's operations personnel during and after reservoir filling.

Instruments will be commissioned as they are installed. It is important that some monitoring be carried out, as is feasible, during the construction period, to obtain baseline data in the pre-impoundment condition. Some instruments, such as the piezometers and settlement gauges, will give background information as construction proceeds. The reservoir filling period will be a time of intense monitoring to determine the impact of the rising reservoir levels on deformations and piezometric levels in the dam and adjoining facilities. Visual inspections of the dam facilities and reservoir will be carried out at regular intervals during impoundment and operation as described in Section 4 below. The following paragraphs present various elements of the monitoring programs.

3.2 Monitoring Frequency

Measurements for each instrument are to be collected at the suggested frequencies shown in Table 3-1 (as applicable for Kurram Tangi Dam and Weir III). These frequencies are subject to modification to suit designer's criteria and operational requirements. The critical period of impoundment and the first season's operation will require the most intense monitoring and inspection activity.

Table 3-1: Summary of Reading Frequency for Instrumentation

Type of Instrument (as applicable for each structure)	Reading Frequency Interval			
	Construction	Impoundment and First Storage Period	First 24 months of Operation	After 24 months of Operation
Settlement Markers	n.a.	1 week	6 months	1 year
Reservoir Level Staff Gauge	n.a.	12 hours	1 day	1 day
Piezometers	1 week	1 day to 1 week	1 month	1 month
Inclinometers	n.a.	3 days	1 week	6 months
Extensometers	1 week	3 days	1 week	6 month
Joint Meters (1D, 2D and 3D)	n.a.	3 days	1 month	6 months
Electro levels	n.a.	3 days	1 month	6 months
Extensometers				
Weirs/flumes	1 day	1 day	1 week	2 weeks
Accelerographs	n.a.	1 week	Monthly and after each felt earthquake	6 months and after each felt earthquake.
Meteorological data	1 day	1 day	1 day	1 day
Water quality monitoring	3 months	3 months	6 months	6 months
Water sampling and laboratory analysis	3 months	3 months	6 months	6 months

3.3 Baseline Measurements

Baseline measurements will be obtained from each instrument and monitoring point after installation is completed. These initial readings and calibration data will be listed for each instrument in Appendix B following installation. Verifying/re-evaluating baseline readings will be performed before initial filling starts.

3.4 Threshold Limits and Alarm Conditions

Design and threshold limits will be set for all instrumentation and monitoring. These criteria are alarm levels that will establish the need for more frequent monitoring and/or indicate a potentially hazardous condition that requires remedial action.

Design limits are values that represent the limit for acceptable settlement, stability, seepage, etc., which together constitute the performance criteria for a dam. In general, this limit indicates the threshold of a potentially unsafe condition.

Threshold limits are warning values, set to occur before the design limits are reached, to allow for modification of the dam or its operation. Threshold limits may be revised upward or downward as the performance history is more precisely defined during dam and reservoir operation.

Monitoring criteria will be established by the project designers with input from construction personnel and operators. This requires engineering judgment in conjunction with knowledge of the specific design and past performance. Two types of threshold and design limits will trigger a monitoring alarm, namely (a) a critical variation in "rate of change" and/or (b) the detection of the predetermined "threshold" level. These alarm levels will be established in consideration of:

- Design seepage and stability analyses.
- Instrument performance during construction, initial impoundment and a short period of operation.

4. SITE INSPECTIONS

Periodic performance reviews will be made. These will consist of site inspections and assessment of instrumentation and monitoring data.

Visual field inspections are an important part of the monitoring programs. These inspections will observe the characteristics of the dam and associated facilities and equipment during reservoir filling and while in operation. Their objective will be to visually detect any potential malfunctions or unexpected behavior. Visual observation can detect indications of poor performance such as offsets, misalignment, bulges, depressions, seepage, leakage, and cracking. More importantly, visual observation can detect variations or spatial patterns of these features. Two levels of inspection are required (a) walkover inspections by construction and/or operating personnel and (b) detailed inspections by specialist personnel. These inspections are described in the following paragraphs.

4.1 Walkover Inspections by Construction and/or Operations Personnel

Frequent visual inspections will be required of the top and slopes of the dam and weir as well as major structures during late construction and throughout the period of initial reservoir filling. Routine inspections will be carried out by construction and operations personnel, and the frequency of these inspections will be:

- Once per week during the construction period.
- Twice per week during the first reservoir filling.
- Once per month during operation.

4.2 Comprehensive Inspections

Comprehensive inspections will be carried out at regular intervals and after extreme natural events (major storms, earthquakes, etc.). This work will be in addition to the regular walk-over inspections by operating personnel described in Section 4.1 above. The inspection teams will consist of personnel experienced in dam design and geotechnical engineering. These reviews will include the following assessments of the dam and related facilities:

- For Kurram Tangi Dam the following inspections will be made:
  - Upstream face slab of dam – inspect for cracking, bulging or other disturbances.
  - Crest of dam – walkover inspection to check for settlement, washout of granular fill and road toppings, and rutting of unpaved surfaces.
  - Downstream slope and toe of dam - visual observations to check for slumping, seepage (particularly in the toe area), bulging, washout, or burrowing by animals.
  - Spillway – Check the operation of mechanical components and inspect for debris blocking the channel, and condition of the concrete structures.
- Detailed weir inspections will be made during dry periods when there in minimal flow over the structures. Weir inspections will include walkover inspections of crest, and downstream toe where permitted by overflow conditions. Visual inspections will check for concrete cracking, erosion or signs of displacement. The abutments and downstream riverbed will be examined for signs of water seepage or erosion.
- Abutments of weirs and dams together with valley slopes: Inspections of slope raveling or washouts, slope movements, sinkhole development and water seepage.
- Instrumentation facilities: Check the condition of surface facilities, including instrumentation shelters, piezometer heads, survey monuments, weirs, etc.
- Reservoir Rim: Periodic check the slopes of the reservoir rim for Kurram Tangi Dam and Weir III. The primary focus of these checks will be to observe slope stability issues. Prior

to reservoir filling, the conditions of all slopes, particularly any signs of landslides or slope movements are to be documented. Repeat inspections, during and after reservoir filling will determine if any slope instability and/or washout conditions are caused by reservoir filling and by operation level fluctuations.

The comprehensive inspections will include an office assessment of all instrumentation data to determine if any anomalous patterns of readings have developed. Various concerns of the dam and weir operators will be addressed at that time.

The comprehensive inspections will be carried out every 2 months during the period of initial reservoir filling and every 6 months for the first year of operation after initial reservoir filling. In general, if no significant concerns have been identified, the detailed inspection will be carried out once per year during the life of the dam.

Inspection results will be recorded on inspection forms to be developed (a typical inspection form is provided for reference in Appendix C). Deficiencies and non-conformances in the structures and/or owners dam safety program are to be recorded on appropriate checklists to be developed. These forms checklists will be modified and tailored to suit actual site conditions once the project work is underway.

5. RECORD KEEPING

5.1 Documentation

All inspection reports and monitoring data will be archived in an orderly manner so that they can be retrieved and reviewed at any time. The archiving system and formats for retrieval of data will be described herein.

5.2 Storing Electronic Data

Based on input from the client, a method used to store data, types of data stored, data storage redundancy, standard reports, etc. will be developed during the next phase of design. The electronic data storage will depend on the level of automation included within the instrumentation system. Once the level of automation is better defined the method used to store data and provide redundancy in the system can be better defined. An electronic file/achieve storage system will be selected that meets the needs of the client and stores relevant data for later use and analysis.

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6. REFERENCES

- International Commission on Large Dams (ICOLD), Committee on Materials for Fill Dams, "Concrete Faced Rockfill Dams – Concepts for Design and Construction", July 2005.
- International Commission on Large Dams (ICOLD), "Monitoring of Dams and their Foundations", Bulletin 69, 1989.
- International Commission on Large Dams (ICOLD), "Dam Monitoring, General Considerations", Bulletin 60, 1988.
- United States Department of the Interior Bureau of Reclamation (USBR), "Concrete Dam Instrumentation Manual", October 1987.
- World Bank, Operational Policy (OP) 4.37, "Safety of Dams", 2001.
- World Meteorological Organization (WMO), "Guide to Meteorological Instruments and Methods of Observation", 2008 (updated in 2010).

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APPENDICES

Appendices supporting the information included in the report will be provided. At a minimum the following will be provided:

A. Project Drawings

B. Instrumentation Details

C. Typical Inspection Forms and Checklists

The appendices to follow are preliminary and are to be finalized as additional information becomes available.

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APPENDIX A – PROJECT DRAWINGS

The following information will be included in Appendix A as information becomes available:

- Record Drawings – at a size that is readable with a naked eye.
  - Plan Drawings – drawings that show project structures/components in relation to instrument locations.
  - Cross-Section Drawings – drawings that show project structures/components in relation to instrument locations.
- Aerial Photographs

The drawings to follow were prepared prior to the seepage and deformation analysis models and therefore are subject to change.

Drawings for Weir III are currently not available.

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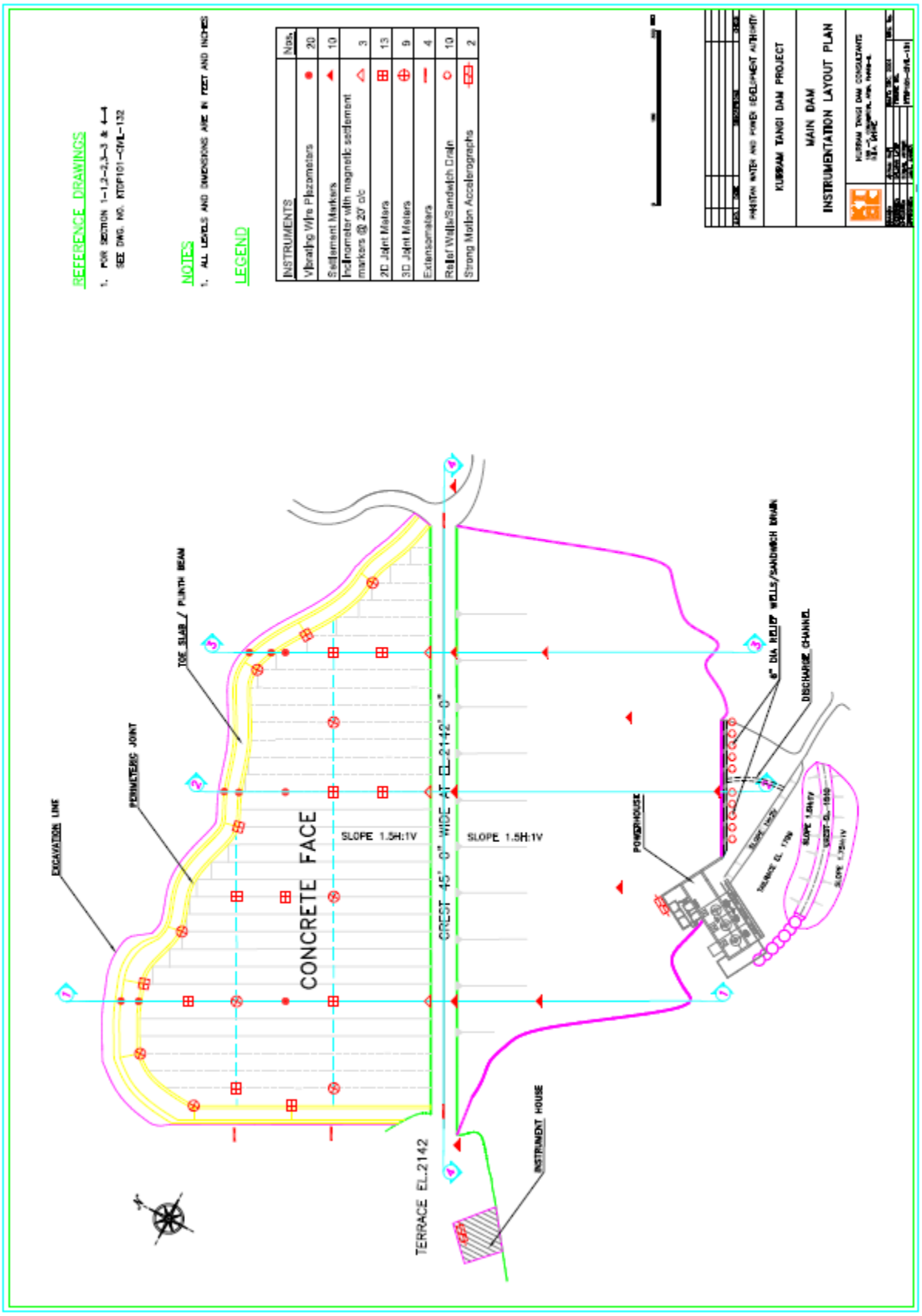
REFERENCE DRAWINGS
1. FOR SECTION 1-1,2-2,3-3 & 4-4
SEE DWG. NO. KTDP101-CIVIL-132
NOTES
1. ALL LEVELS AND DIMENSIONS ARE IN FEET AND INCHES
LEGEND
INSTRUMENTS
Nos.
Vibrating Wire Piezometers 20
Settlement Markers 10
Inclinometer with magnetic settlement markers @ 20' c/c 3
2D Joint Meters 13
3D Joint Meters 9
Extensometers 4
Relief Wells/Sandwich Drain 10
Strong Motion Accelerographs 2
KURRAM TANGI DAM PROJECT
MAIN DAM
INSTRUMENTATION LAYOUT PLAN
EXCAVATION LINE
PERIMETERIC JOINT
TOE SLAB / PLINTH BEAM
CONCRETE FACE
SLOPE 1.5H:1V
SLOPE 1.5H:1V
CREST 45' 0" WIDE AT EL.2142' 0"
TERRACE EL.2142
INSTRUMENT HOUSE
POWERHOUSE
6" DIA RELIEF WELLS/SANDWICH DRAIN
DISCHARGE CHANNEL

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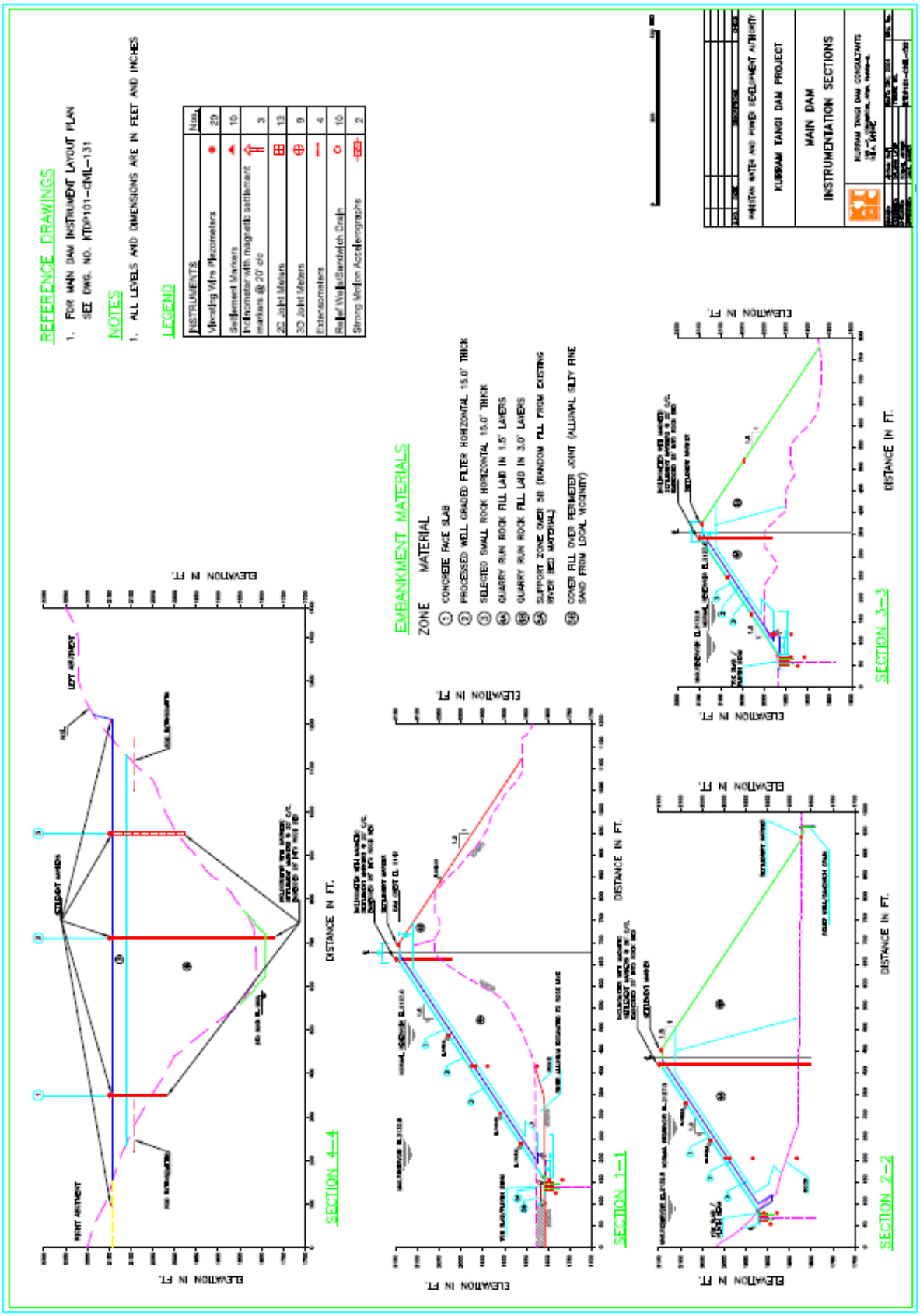
REFERENCE DRAWINGS
1. FOR MAIN DAM INSTRUMENT LAYOUT PLAN SEE DWG. NO. KTDP101-CIML-131
NOTES
1. ALL LEVELS AND DIMENSIONS ARE IN FEET AND INCHES
LEGEND
INSTRUMENTS
Nos.
Vibrating Wire Piezometers 20
Settlement Markers 10
Inclinometer with magnetic settlement markers @ 20' c/c 3
2D Joint Meters 13
3D Joint Meters 9
Extensometers 4
Relief Wells/Standpipe Drain 10
Strong Motion Accelerographs 2
EMBANKMENT MATERIALS
ZONE MATERIAL
1 CONCRETE FACE SLAB
2 PROCESSED WELL GRADED FILTER HORIZONTAL 15.0' THICK
3 SELECTED SMALL ROCK HORIZONTAL 15.0' THICK
4A QUARRY RUN ROCK FILL LAID IN 1.5' LAYERS
4B QUARRY RUN ROCK FILL LAID IN 3.0' LAYERS
5A SUPPORT ZONE OVER 5B (RANDOM FILL FROM EXISTING RIVER BED MATERIAL)
5B COVER FILL OVER PERIMETER JOINT (ALLUVIAL SILTY FINE SAND FROM LOCAL VICINITY)
SECTION 4-4
SECTION 1-1
SECTION 3-3
SECTION 2-2
ELEVATION IN FT.
DISTANCE IN FT.
MAIN DAM
INSTRUMENTATION SECTIONS
KURRAM TANGI DAM PROJECT

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APPENDIX B – INSTRUMENTATION DETAILS

The following information will be included in Appendix B as it becomes available:

- Instrumentation details that may help the reviewer understand the instrumentation and its intended use. For example: soil boring logs and installation details for a piezometer.
- Include baseline measurements for each piece of equipment.
- Include instrumentation cut sheets from the manufacturer as well as calibration factors for instruments.

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APPENDIX C – TYPICAL INSPECTION FORMS AND CHECKLISTS

This appendix will include the blank inspection forms and checklists used to document any formal inspections of project dams/weirs or facilities conducted by the licensee or blank instrumentation collection forms. Inspection forms and checklists will be developed during the next phase of design as more information becomes available

Inspection forms and checklists that contain relevant important information can be preserved in this appendix; however a complete chronology of the actual inspection forms should not be preserved in this plan.

Typical Inspection Form

Note: This inspection checklist will be updated as more information is available, and tailored to suit the dam and weir structure considered.

Date/Time:	_____	**Name of Inspector:**	_____
Name of Dam/ Weir:	**Kurram Tangi Dam / Weir III**	**Dam/ Weir Owner:**	_____
Type of Dam/Weir:	_____	**Dam/ Weir Location:**	_____
FIELD CONDITIONS OBSERVED:			
Weather:	_____	**Estimated Freeboard:**	_____
Temperature:	_____	**Reservoir Level:**	_____

Schedule:
Perform **monthly** under normal operating conditions. Perform **immediately** if the reservoir rises above El. _____, an earthquake is felt at or near the site, and/or other unusual event occurs.

Instructions:
A YES response should be given only to those question(s) below where observed conditions are different from previously observed conditions. Any observed conditions that have previously been reported and are currently unchanged should receive a NO response. For any question with a YES response provide additional information describing the situation and take photographs of the situation. A YES response indicates unexpected behavior that needs to be investigated.

Location	YES	NO	Remarks	If YES, take photograph
Crest of Dam/ Weir				
Any cracks, either transverse or longitudinal?				
Any scarps, sinkholes or areas of unusual settlement?				
Downstream Slope of the Dam/ Weir				
Any new seepage areas or wet areas?				
Any changes in conditions at existing seepage areas or wet areas?				
Any materials being transported by seepage flows at existing or new seepage areas (such as discolored seepage				

Location	YES	NO	Remarks	If YES, take photograph
water or settlement deposits)?				
Any scarps, sinkholes, sloughs, slides or areas of unusual settlement?				
Upstream Slope of the Dam/ Weir				
Any significant erosion due to wave action?				
Any scarps, sinkholes, sloughs, slides or areas of unusual settlement?				
Any whirlpools in the reservoir?				
Downstream toe area, abutments, and other areas downstream				
Any new seepage areas or wet spots?				
Any changes in conditions at existing seepage areas or wet spots?				
Any cracks, sinkholes, sloughs or areas of unusual settlement?				
Any new seepage areas along the banks of the river channel?				
Any new settlement deposits along the banks of the river channel?				
Outlet Works				
Any new or enlarged cracks or spalls in the concrete?				
Any unusual deformations or displacements?				
Any unusual flow patterns or conditions during releases?				
Any new seepage into the outlet works conduit?				
Any sediment accumulation upstream of _____?				
Spillway				
Any new cracks or enlarged cracks or spalls in the concrete?				
Any unusual deformations or displacements?				
Any unusual flow patterns or conditions during releases?				
Instrumentation				
Additional Information				