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Kurram Tangi Dam Construction

Supplemental Report on Geology
Final Report

December 2013
This publication was produced for review by the
United States Agency for International Development.
It was prepared by MWH under contract number 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.

ENVIRONMENTAL ASSESSMENT	
	VOLUME I: MAIN REPORT
	VOLUME II: PROJECT ECONOMIC BENEFITS
	VOLUME III: MAPS
ENVIRONMENTAL MITIGATION AND MONITORING PLAN	
	MAIN REPORT
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	ANNEX II: WATERSHED MANAGEMENT PLAN
	ANNEX III: WASTE MANAGEMENT PLAN
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	ANNEX VI: INSTRUMENTATION AND MONITORING PLAN
LAND ACQUISITION AND RESETTLEMENT	
	RESETTLEMENT POLICY FRAMEWORK
	RESETTLEMENT ACTION PLAN (COMPONENT I)
CULTURAL HERITAGE PRESERVATION PLAN	
VULNERABLE TRIBES PLAN	
GENDER PLAN	
KEY SUPPORTING TECHNICAL REPORTS	
	SUPPLEMENTAL REPORT ON GEOLOGY
	SUPPLEMENTAL REPORT ON GEOTECHNICAL ASPECTS
	SUPPLEMENTAL REPORT ON SEISMIC HAZARD
	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
Supplemental Report on Geology

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
Author: MWH Americas, Inc.

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 Acronym

Acronym	Term
ABGM	Angular Boulder Gravel in Silt
BHP	Broken Hill Proprietary Company Limited
CFRD	Concrete Faced Rockfill Dam
DDR	Detailed Design Report
GSP	Geological Survey of Pakistan
JV	Joint Venture
KTDC	Kurram Tangi Dam Consultants
KTDP	Kurram Tangi Dam Project
MPa	Mega Pascal
NWFP	North West Frontier Province
RBGM	Rounded Boulder Gravel in Silt
RMR	Rock Mass Rating
TOR	Terms of Reference
WAPDA	Water and Power Development Authority

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Unit Conversion Tables

Length				
3.28	ft	=	1	m
5,280	ft	=	1	mile
1	km	=	0.62	miles
1	yard	=	0.91	m
1	inch	=	25.4	mm

Area				
1	acre	=	43,560	ft^2
1	acre	=	0.405	Hectares
1	ft^2	=	0.09	m^2

Pressure				
1	MPa	=	145.038	psi
1	GPa	=	1000	MPa
1	Kg/cm2	=	0.098	MPa

Volume				
1	acre-ft	=	43,560	ft^3
27	ft^3	=	1	yd^3
35.3	ft^3	=	1	m^3

Others				
1	cusecs	=	1	cfs
1	ton (US)	=	2,000	lbs (US)
1	Lugeon	=	1	Liter/minute/m at 10 kg/cm^2 pressure

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Geology
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1 INTRODUCTION

The Kurram Tangi geology has been reviewed as part of the Kurram Tangi Environmental Assessment Project. This review follows up the earlier Scoping Statement which was finalized in March 2013. The Scoping Statement reviewed of the geological aspects of the proposed Kurram Tangi Dam Project (KTDP). It included the preliminary review of available geological data from the Project Feasibility Report, Detail Design Report and the other related documents. These documents were studied to assess whether sufficient site characterizations, in support of the design of the project and the tender documents, were carried out. The preliminary review comments were outlined in the scoping statement under significant scoping issues, additional data required, fatal flaws, etc.

Further studies of the available documents were carried to further assess the significant scoping issues as required by the Terms of Reference (TOR) requirements entitled "Baseline data, Geological Assessment and Evaluation their impacts on the project and at the end their Mitigation and Recommendations". These studies are presented in this technical report.

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2 DOCUMENTS REVIEWED

The data sources available for the KTDP are listed in Table 2-1below.

Table 2-1: Data Sources for Kurram Tangi Dam Project

Sr. No.	Document	Chapter Reference	Remarks
1	KTDP Feasibility Report (2004)	Annexure to the Main Report. Annexure - 1	Feasibility report comprises of a Main Report, Annexure and Appendices. The findings of feasibility studies are given in the main report while details of the studies and analyses are provided in the Annexure and Appendices.
2	KTDP Detail Engineering Design Report (2011)	Volume - 1	The Detailed Engineering Design Report consists of Volume – 1, Main Report
3	KTDP Detail Engineering Design Report (2011)	Volume - 2	The Detailed Engineering Design Report consists of Volume – 2, KTD Drawings
4	Tender Documents (2011)	Volume 3 – C Tender Drawings, Geology	Tender Documents consists of 7 volumes. Volume 3 – c related to drawings. General Drawings contain Geologic Map and Sections
5	KTDP PC - 1	All	Available
6	Rapid Assessment KTDC, Final Report (2012)	All	Available
7	KTDP Initial Review of Reports, June 2012	Chapter – 3 Geotechnical Aspects	Available

The Feasibility and Detail Engineering Design Report was prepared by Kurram Tangi Dam Consultants (KTDC), a Joint Venture (JV) of local consulting firms. The reports were prepared in two stages during 2004 and 2011.

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3 REGIONAL GEOLOGY

3.1 General

The regional geology assessment of the KTDP area is based on available literature and the previous field studies.

Regional geology maps covering the project area include the following:

- Geological Map of Pakistan by Geological Survey of Pakistan
- Geological Map of North West Frontier Project (NWFP), Pakistan by Geological Survey of Pakistan
- Geological Map of Northern Pakistan prepared by BHP, Shell Pakistan and AMOCO
- Tectonic Map of Pakistan by Geological Survey of Pakistan

3.1.1 Regional Geology

The exposed formations in the catchments and command areas are studied and briefly discussed here. Ages of the formations range from Eocene to recent. The stratigraphy of Pakistan is summarized in Table 3-1. Most of the description is based on "Geological map of Pakistan", published by Geological Survey of Pakistan.

Table 3-1: Stratigraphy of Pakistan

Sr. No	Symbol	Age	Formation	Lithologic Description
1.	Q	Recent	Unconsolidated Surficial Deposits of Silt, Sand, Gravel and Boulder.	ABGM (Angular Boulders Gravels in Silty matrix) on hill slopes. RBGM (Rounded Boulders Gravels in Silty matrix) along stream beds.
2.	Tnl	Neogene	Litra Formation	Grey sandstone with red brown siltstone (shale), and intra-formational conglomerate.
3.	Tmn	Early Pliocene	Nagri Formation (Siwalik group)	Dominantly grey, massive, thick sandstone forming laterally extensive ridges, with subordinate silt (shale) and conglomerate.
4.	Tmc	Late Miocene	Chinji Formation (Siwalik group)	Red brown mudstone (siltstone and shale) with grey sandstone units; sandstone more frequently and thicker in the upper part.
5.	Tmk	Mid to late Miocene	Kamlial Formation (Rawalpindi group)	Grey and Red purple sandstone with subordinate purple and red shale, minor intra-formational conglomerate.
6.	Kk	Cretaceous	Kurramfacies	Tectonic emplaced bodies, variegated colour, lithographic light grey limestone and brown sandstone.
7.	K	Cretaceous	Cretaceous Rocks (Undifferentiated)	Formations laterally are of variable thickness and

				intergrade into each other, thus all the components, formation are not developed in every area. These rocks include Pab formation, Fortmunro formation, Mughalkot formation, Parh formation, Sember formation.
8.	J	Jurassic	Jurassic rocks(Undifferentiated); Samanasuk formation Shirinab formation, Datta formation	Limestone + Shale with subordinate Sandstone.

The area within100 km of site, which includes the catchment area of the Kurram Tangi Dam and the Kaitu Weir, is underlain by both sedimentary and metamorphic rocks. The sedimentary rocks are fluvial to marine in nature. These include sandstone, siltstone, shale, limestone, and marl. These range in age from upper Paleozoic to Recent. The metamorphic rocks belong to lower Paleozoic era and are exposed in the northern area of the region. The detail of the lithological units of the Regional Stratigraphy of the area is given on Figure A (Source: Geological Map of Pakistan, 2006, GSP). Descriptions and distributions of all the rock units are also shown on Figure A.

The project area under study is a part of Kohat Plateau and is located on the western limb of Bannu Basin. The area is underlain by stratified sedimentary formations of marine and fluviatile origin of Eocene to Pliocene age. The marine facies are mostly comprised of the Eocene age Panobashales and Kohat limestone formations. The fluviatile facies consist of sandstone, shale and conglomerates of Rawalpindi and Siwalik formations, which range in age from lower Miocene to Middle Pliocene.

3.1.2 Project Geology

Bedrock units in the project area belong to Eocene to Pliocene age sedimentary formations of marine and fluviatile origin. The marine facies are predominantly the Panoba shale and Kohat limestone formations of lower to middle Eocene age, whereas the fluviatile facies consist of sandstone, shale, and conglomerates belonging to the Rawalpindi and Siwalik Groups with ages ranging from lower Miocene to Middle Pliocene.

The geology in the project area has been strongly affected by late tectonic activity in the Himalaya system. Strata in the immediate area of the project features are moderately folded and a number of faults traverse the region, including the Kurram Tangi fault which passes approximately 17 km upstream of the dam site. In addition to the Kurram Tangi Fault, several other important faults are known to exist within a 100-km-radius of the dam site. The significance of these to the project, including their relative activity is discussed in a separate technical report. Further details on the tectonics are presented in Section 3.1.3 below.

No major faults have been identified at or are known to be present in the foundation of the principal project features. A number of shear zones and minor local faults have been observed but these are not thought to be of significant concern.

The Kurram Tangi Dam site is located where the Kurram River enters a narrow gorge eroded through well-bedded Siwalik strata. Sandstone beds, interbedded with lesser amounts of shale and conglomerate form the dominant lithology in the foundation of the dam and spillway. Similar sandstone with varying amounts of shale occurs at the sites of the Kaitu Weir, powerhouse, and diversion structures and at each of the other weir, tunnel, and powerhouse sites. These rock units are exposed in the project area at almost all structure locations and overburden cover is limited to nullah and associated alluvial areas. The river channel and larger nullahs are mostly filled with alluvial deposits of gravelly sand, sandy gravel, cobbles, and occasional boulders.

3.1.3 Tectonics

The rocks in the area have been affected due to late tectonic activity in the Himalaya system, by which they have been folded and elevated. Due to the late tectonic movement of Himalayan orogeny the area shows a number of broad synclines and anticlines, which have also been noticed, in the vicinity of the proposed dam site. The downstream part of the proposed structure is highly disturbed as compared to upstream part, which is relatively less disturbed and exhibits gentle dips.

A number of faults traverse the region including the Kurram Tangi Fault, which passes approximately 17 km upstream of the proposed reservoir of the KTDP. Another fault known as Karak Thrust is estimated to pass approximately 4 km downstream of the main dam and approximately 500 m downstream of Powerhouse No. II.

A number of other known regional faults also pass near the area under study. The following are the main structures of the area / region:

a. Daryoba Anticline
b. Zarwan Fault
c. Bhittani Fault
d. Surghar Fault
e. Kala Bagh Fault
f. Kundal Fault

3.2 Previous Studies of the Kurram Tangi Dam Area

There have been a series of geological studies and investigations of the KTDP since it was first identified in 1955. Pre-feasibility investigations, conducted on behalf of Water and Power Development Authority (WAPDA) in November 1991, included 12 boreholes drilled at the dam site area. Starting in 2004, feasibility phase investigations included 25 additional boreholes; 10 holes were drilled in the main dam site area, six holes were drilled in the Kaitu River area, six holes were drilled in the Powerhouse No. 2 area, and 3 holes were drilled in the Powerhouse No. 3 area. Borrow areas and water sources were also investigated.

The project consists of construction of multiple structures at various locations for irrigation and power generation system i.e. dam, weirs, tunnels, powerhouses and I\irrigation system.

For the ease of construction purposes the KTDP was divided in to three (3) components (See Figure B):

A. Component 1: Consists of Kaitu Weir, a Power Tunnel, Powerhouse No. IV (18 MW), the Sheratalla Canal System, and Powerhouse No. V (0.4 MW).

B. Component 2:

Consists of:

I) A 98 m high and 315 m long Dam, a Spillway, 16 ft and 20 ft diameter diversion tunnels the later of which will be converted to a power tunnel for the powerhouse, and Powerhouse No. I (38 MW).

II) Weir II, Power Tunnel and 10.4 MW Powerhouse No. II.

III) Weir III, Power Tunnel and 16.5 MW Powerhouse No. III.

C. Component – 3: Modifications to the Kurram Garhi Headworks, Civil Canal System and Proposed Thal Canal System**.**

Summaries of basic site geology and geotechnical investigations of each of the components are given in the following subsections.

3.2.1 Component 1

a) Kaitu Weir

The boreholes performed for the Kaitu Weir site are summarized in Table 3-2.

Table 3-2: Kaitu Weir Site Geology and Geotechnical Investigations

Sr. No.	Bore Hole No	Location	Ground Elevation (ft)	Drilled Depth (ft)	Lithology		Remarks
					Overburden (ft)	Rock (ft)	
1	KW-1	River Bed	2334	60	20.9	39.1	
2	KW-2	Left Abutment	2330	50	2.0	48.0	
3	KW-3	Right Abutment	2377.5	71	26.0	45.0	

b) Kaitu Feeder Tunnel

The boreholes performed for the Kaitu Feeder Tunnel site are summarized in Table 3-3.

Table 3-3: Kaitu Feeder Tunnel Site Geology and Geotechnical Investigations

Sr. No.	Bore Hole No	Location	Ground Elevation (ft)	Drilled Depth (ft)	Lithology		Remarks
					Overburden (ft)	Rock (ft)	
1	KW-4	Tunnel	2410	74	29	45	
2	KW-5	Tunnel	2413	110	0	110	
3	KW-6	Tunnel Outlet	2417	108	29	79	

c) Powerhouse No. IV (18 MW)

Boreholes data has not been collected, to date, for the Powerhouse No. IV site.

d) Powerhouse No. V (0.4 MW)

Borehole data has not been collected, to date, for the Powerhouse No. V site.

e) Sheratalla Canal System

Borehole data has not been collected, to date, for the Sheratalla Canal System.

3.2.2 Component 2

a) Main Dam

The boreholes performed for the main dam site during the pre-feasibility stage are summarized in Table 3-4. The main dam site includes the spillway, diversion and power tunnels, and Powerhouse No. 1 (38 MW).

Table 3-4: Dam Site (Pre-Feasibility) Geology and Geotechnical Investigations

Sr. No.	Bore Hole No	Location	Ground Elevation (ft)	Drilled Depth (ft)	Lithology		Remarks
					Overburden (ft)	Rock (ft)	
1	KTL-1	Left Abutment	2077.34	300.5	0 - 0	0 - 300.5	
2	KTL-2	Left Abutment	1960	235	0 - 2	2 – 233.0	
3	KTL-3	Left	2050	300	0 - 0	0 – 298.0	

		Abutment					
4	KTL-4	Left Abutment	1927	163'-2"	0 - 0	0 - 163.2	
5	KTL-4A	Left Abutment	1902	135	0 - 0	0 - 135	
6	KTL-5	Left Abutment	1876	110	0 - 0	0 - 110	
7	KTR-1	Right Abutment	2113.75	300	0 - 0	0 - 300	
8	KTR-2	Spillway	2255.11	251	0 - 0	0 - 251	
9	KTR-3	Spillway	1919.57	110	0 - 5	5 - 105	
10	KTR-3A	Spillway	1919.57	122	0 - 0	0 - 122	
11	KTV-1	River Valley	1818.75	202	0 - 18	18 - 184	
12	KTV-2	River Valley	1874.08	252	0 - 8	8 - 244	

The boreholes performed for the Main Dam site during the feasibility stage are summarized in Table 3-5.

Table 3-5: Dam Site (Feasibility) Geology and Geotechnical Investigations

Sr. No.	Bore Hole No	Location	Ground Elevation (ft)	Drilled Depth (ft)	Lithology		Remarks
					Overburden (ft)	Rock (ft)	
1	KTV-3			150'			
2	KTV-4	Cofferdam Up Stream Toe	1836	101.5'	0 - 19	19 - 82.5	
3	KTV-5	Dam Upstream Toe	1835	304'	0 - 18	18 - 286	
4	KTV-6	Down Stream Shoulder	1827	151'	0 - 20	20 - 137	
5	KTV-7	Spillway/ Stilling Basin	1818.18	200'	0 - 18	18 - 182	
6	KTV-8	Cofferdam Up Stream Toe	1837'	100	0 - 6	06- 94	
7	KTR-9	Right Abutment	1832	150	0 - 0	0 - 150	
8	KTL-6	Left Abutment	1935	200	0 - 0	0 - 200	
9	KTR-4	Right Abutment	1963	300	0 - 0	0 - 300	
10	KTR-6	Right Abutment	1847.7	150	0 - 4	4 - 146	
11	KTR-8	Right Abutment Tunnel Inlet	1971	150	0 - 0	0 - 150	

b) Weir – II

The boreholes performed for the Weir II are summarized in Table 3-6. The Weir II site includes a power tunnel, and Powerhouse No. II (10.4 MW).

Table 3-6: Weir-II Geology and Geotechnical Investigations

Sr. No.	Bore Hole No	Location	Ground Elevation (ft)	Drilled Depth (ft)	Lithology		Remarks
					Overburden (ft)	Rock (ft)	
1	KTPT-1	Tunnel Inlet	1876.8	103	0 - 0	0 - 103	
2	KTPT-2	Weir	1781.05	60	0 - 24	24 - 60	
3	KTPT-3	Weir	1806.04	65	0 - 34	34 - 65	
4	KTPT-4	Tunnel Alignment	1849.33	100	0 - 0	0 - 100	
5	KTPT-5	Tunnel Outlet	1820	100	0 - 0	0 - 100	
6	KTPT-6	Powerhouse	1736.77	100	0 - 0	0 - 100	

c) Weir- III

The boreholes performed for the Weir III site are summarized in Table 3-7. The Weir III site includes a power tunnel, and Powerhouse No. III (16.5 MW).

Table 3-7: Weir-III Geology and Geotechnical Investigations

Sr. No.	Bore Hole No	Location	Ground Elevation (ft)	Drilled Depth (ft)	Lithology		Remarks
					Overburden (ft)	Rock (ft)	
1	KPH/3-1	Weir	1626	100	0 - 22	22 - 100	
2	KPH/3-2	Weir	1622	101	0 - 43	43 - 101	
3	KPH/3-2A	Weir Of Tunnel-II	1633.34	101	0 - 25	25 - 101	

d) Saddle Dam

In the Feasibility Report (2004) and Detail Engineering Design (2011) there was no discussion regarding the need of a Saddle Dam at the northeast side of the reservoir rim. It was first indicated in the Preamble of the Initial Review Report (2012) by MMP (Pvt) Ltd. As follows:

"The Major finding of this Initial Design Review is the identification of a low survey point in the North East of Reservoir rim. This essentially will require a saddle dam to close the low peripheral space for which the ground investigation and topographic survey will be very important and essentially needed".

This statement clearly indicates that a low survey point for the construction of a saddle dam was not studied during the Feasibility and Detail Design stage; hence no geological and geotechnical investigation data is available for the saddle dam.

It is proposed that for the saddle dam a topographic survey, geotechnical investigations and detailed design should be carried out during the mobilization period of the main contractor during the construction phase.

3.2.3 Component 3

Component 3 consists of the following:

a) A new head regulator at the Kurram Garhi Headworks on its left abutment.
b) A canal known as Thal Canal will take-off from this new head regulator. It will be 198,000 ft (37.5 miles) long and will have a full supply discharge of 343.6 cusecs. The canal system will

have 14 distributaries, 7 minors and 2 sub-minors of about 73 miles. The canal will irrigate about 68,000 acres of the Thal Plains.

c) Remodelling of Existing Civil and Marwat Canals: Civil canals with collective length of 200 miles were done many years ago by land owners. They are to be renovated and remodeled. Concrete lining of main canal including improvement of structures is part of the Project scope.

No geological and geotechnical investigation has been carried out, to date, for Component 3.

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4 GEOLOGICAL ASSESSMENT AND EVALUATION

4.1 Component 1

4.1.1 Kaitu Weir

The Kaitu River is a tributary of the Kurram River, joining it about 5 km downstream of the proposed Kurram Tangi Dam site. It is proposed to construct a 20 ft high weir, at about 250 ft upstream of the existing bridge on Kaitu River. The main purpose of this weir is to use its water, particularly during flood events, for irrigation purposes as well as for power generation; however surplus water will be diverted into the Kurram Tangi Reservoir through a tunnel or channel.

Surface geological mapping of this site is shown in plan on Figure. 2.10 (Annexure A) and on geological section K-K on Figure 2.11 (Annexure A) of the Feasibility Study Report, 2004. It can be seen in the surface geological map that the proposed weir site and its appurtenant structures are to be placed on the massive sandstone on the left abutment; however a few shale and gritty sandstone beds have also been found alternating with sandstone beds. The right abutment area is covered with overburden material of different composition. The area close to and sloping towards the river generally consists of scree, sandy gravels and cobbles, whereas further away from the river, overburden consisting of sand, gravels and cobbles is available in compacted form which is in contact with sandstone, alternating with shale and gritty sandstone. The river valley section is filled with loose sand, gravels and occasional boulders. The surface geological mapping of the covered area does not show any structural deformation. The exposed beds generally strike N40°E and dip 30° SE. The joints are generally sparsely spaced.

Three investigation boreholes, two in the valley and one on the right abutment (See Figure C), were drilled. These are also shown on the geologic section on Figure 2.11 (Annexure A). The boreholes indicate that sandstone bedrock is covered by about 20 ft of overburden in the river valley and on the right abutment. It is therefore suggested that the foundation of the weir should be placed on bedrock after removing the overburden. The rock condition as described in the borehole logs is moderately hard to hard. Selected samples from boreholes were tested in the laboratory. Test results show that the unconfined compressive strength of foundation rock is in the range 32 to 71 MPa. The modulus of elasticity ranges from 2.40 E+03 to 8.26 E+03 MPa and Poisson's Ratio range from 0.064 to 0.678. The permeability as recorded during drilling through lugeon test is generally low. It is inferred from these results that the engineering properties of the available sandstone rock are suitable for weir foundation and the structures should be designed accordingly.

4.1.2 Kaitu Feeder Tunnel

The proposed Kaitu Feeder tunnel is a 6,100 ft long 14 ft diameter free flow tunnel. The main purpose of this tunnel was to discharge flow in Olam Algadnullah which will carry the water into the Kurram Tangi Reservoir. An open channel will also be constructed before the tunnel to carry the flow from resident excluder.

A surface geological map (Figure 2.12, Annexure A) and geologic section BB', (Figure 2.13, Annexure A) were prepared along the tunnel alignment. The geological map shows that a major part of the tunnel passes under the overburden material consisting of sand and gravels. Alternating sandstone and shale beds are present in the inlet area. It is anticipated from the geology of the area that alternating beds of sandstone and shale will be present under the overburden. The sandstone is moderately hard to hard whereas shale is soft to moderately hard. Joint are not well defined. No prominent shears or other major discontinuities were mapped in the area. The general strike and dip of bedding in the area is N40°E/30° SE.

Two investigation boreholes, KW-4 and KW-6 were drilled at different locations along the tunnel alignment. They are shown on the geologic section provided on Figure 2.11 (Annexure A) and on geological plan shown on Figure 2.12 sheets 1 to 6 (Annexure A). The borehole logs indicate that shale has been encountered at a shallow depth under the overburden.

The surface geological map of the Kaitu Weir site, (Figure 2.10, Annexure A), indicates that the left

abutment of the proposed weir site (also the intake portal of the Kaitu Feeder Tunnel) is made up of massive sandstone beds with few shale and gritty sandstone beds. Geologic section BB' shown on Figure 2.13 (Annexure A) indicates that the Kaitu Feeder Tunnel will be constructed mostly in shale.

Because of comparatively soft character of shale, necessary protective supports and measures will be required during excavation as well as in the design of the tunnel. The permeability values noted in the test results is generally low.

4.1.3 Proposed Canal Systems

Kaitu Weir Command Area:

To provide irrigation to the Sheratalla and Spaira Ragha Plains, and to divert surplus flow from Kaitu River into Kurram Tangi Reservoir, a diversion weir at Kaitu River has been proposed.

Sheratalla Plain

The planned scheme in this area includes a 17 mile long canal and includes tunnel, and originates from the right bank of Kaitu Weir. It will have a full supply discharge of 82.5 cfs and will irrigate an area of 12,300 acres in the Sheratalla Plain.

The Sheratalla Plain is formed by alluvium washed from the local sandstone and shale hills. Alluvial fans, a piedmont plain, nullah beds and low hills constitute this plain. Overall topography is undulating. Some 60% of the entire area is littered with gravels, cobbles and boulders. The nullah beds are completely covered by varying thicknesses of cobbles, gravels and boulders. The major part of the piedmont plain surface is free of stones and is covered by fine grained materials.

Spaira Ragha Plain

A canal 37,000 ft long will originate from the left bank of Kaitu Weir. The canal will have a full supply of 29.15 cfs. The Spaira Ragha area is a weathered rock plain consisting mainly of weathered sandstone. The area also includes a piedmont plain made up of alluvial fans and weathered shale material. The soils in the main part of the terrace i.e. weathered sand plain are up to 2 meters deep in the main valley. The soil depth reduces from the valley center to the nearby hills. Clay content increases towards the valley center. Sandstone is exposed at the lowest part of the Spaira Ragha and the weathered. Areas underlain by shale are frequently severely eroded into deep gullies at places.

4.1.4 Powerhouse No. IV and V (18 MW & 0.4 MW)

Powerhouse No. IV (18 MW)

The proposed powerhouse is located on the right bank of Kurram Tangi Reservoir where the Kaitu Feeder Tunnel enters into the reservoir as shown on Figure 3.12 (Annexure B) of the Detailed Engineering Design Report. The powerhouse area is covered with overburden which varies from 8 to 28 ft thick. Overburden consists of gravels and boulders embedded in a silty sandy matrix, clay content increases towards the periphery of the reservoir having permeability from 2.077×10^{-5} to 1.75×10^{-6} cm/sec. Shale is present under the overburden which has swell potential and slakes slowly when exposed to the atmosphere. Silty sandstone grits are observed at a few places. Water pressure tests show a permeability maximum of 2 Lugeons.

An investigation borehole, KW- 6, on the Kaitu feeder tunnel outlet portal was considered for evaluation of the powerhouse location. The geotechnical aspects are presently based on the previously available information which reveals that the foundation rock (shale) is reasonably sound to sustain the expected load of the structure. Moreover, due to time constraint and late consideration for powerhouse detailed investigations are considered to be carried out during construction phase.

Powerhouse No. V (0.4 MW)

The proposed powerhouse is located on the Sheratalla canal at RD 38+000. The powerhouse area is covered with overburden, which according to previous investigations, varies from 8 to 28 ft in

thickness. Overburden consists of gravels and boulders embedded in a clayey silty matrix. Alternating beds of sandstone and shale underlay the overburden.

An investigation borehole, KPH/3-2A, has been recommended for the location of Powerhouse No. V. The geotechnical aspects are presently based on the previously available information which reveals that the foundation rocks are reasonably sound to sustain the expected load of the structure. Detailed investigations should be carried out during the construction phase.

4.2 Component 2

4.2.1 Main Dam

The Kurram Tangi Dam site is located at a place where a relatively wide valley ends in a narrow gorge as Kurram River cuts through a series of parallel sub-vertical ridges. At the proposed dam site, the valley is quite narrow and bedrock is not expected to be very deep near the proposed dam site. The abutment slopes are irregular with small gullies almost parallel to the dam axis.

The surface geological mapping has provided the basis to develop typical geologic sections and interpretation of geology at the dam site area. The surface geologic map Figure 3.1 (Annexure B) shows thick sandstone beds outcropping on both the abutments. There are numerous outcrops and the most significant overburden deposits are limited to nullah and associated alluvial slopes. The narrow river channel is mostly filled with alluvial material consisting of sandy gravels, cobblers and occasional boulders. Some shale beds have been noted on the upstream and downstream side of the major sandstone beds.

The exposed rocks are generally weathered. The weathering cover is estimated to vary from 10 ft to 15 ft. Bedding has a general strike is N60°E and dip ranges from 60° to 80° SE. Minor local faults and shear zones have been found and are shown on the map. Joints are closely spaced and well developed, particularly in hard sandstone.

A geologic section D-D was developed along the proposed dam axis as shown on Figure 2.5 (Annexure A). The dam axis and the section line were shown on the surface geologic map (Fig. 2.3, Appendix-1, Geology). It is noted that a massive sandstone bed is present all along the dam alignment. This sandstone is generally of good quality and fresh under a thin layer of weathering.

Two investigation boreholes KTV-1 and KTV-2, were drilled to 202 and 252 ft deep, respectively, during the pre-feasibility study and 6 boreholes KTV-3, KTV-4, KTV-5 KTV-6, KTV-7 and KTV-8 150, 101, 304, 151, 200 and 100 ft deep respectively were drilled during the feasibility study along the dam axis and the Nullah bed to find engineering properties of sub-surface strata and the depth of the bedrock under the overburden (See Figure D).

It was concluded that the rock is moderately strong to strong. The results of permeability test (Packer test) show low permeability ranging from 1 to 5 Lugeons. Laboratory tests were carried out on some selected core samples; their results and the RQD recorded in the logs indicate that the rock condition is generally good.

Right Abutment

The geological map (Figure 3.1, Annexure B), site plan (Figure 2.3, Annexure A) and section (Figure 2.6, Annexure A) show that a thick sandstone bed, which forms the right abutment of the proposed dam axis, is a dominant rock unit. This bed is overlain and underlain by a series of alternating comparatively thin and subordinate beds of shale and sandstone. The bedding strike is normal to river flow with steep downstream dip (N60°E / 70° to 80° SE). Some of the area is covered with over burden, mostly alluvial in nature, consisting of sandy gravels, cobbles and occasional boulders. The geological map had not shown any significant structural deformation in the area. Minor shear zones have been observed; however these have little significant impact on the overall geotechnical properties of the rock mass.

A vertical borehole KTR-1 and another Borehole KTR-9 was drilled with angle of 30 degrees with vertical, and plotted on the section. The rock quality as per RQD is good and the sandstone was of

low permeability. Borehole KTR-8 was drilled near the inlet portal and encountered alternate shale and sandstone bed as noted in the borehole log. The characteristics of these rock units are almost same as described earlier.

Left Abutment

The geologic map (Figure 3.1, Annexure B) shows that the prominent sandstone bed is well exposed, and is the continuation of the same sandstone bed exposed on the right abutment, almost the same strike and dip i.e. N60°E/70° SE; however thin shale and sandstone beds are also associated with the massive sandstone bed.

The sub-surface geological conditions prevailing at the left abutment area have been depicted on the geologic section C-C, (Figure 2.7, Annexure A). The section line is shown on Figure 2.3, Annexure A). The section shows that sandstone is dominant at the left abutment on either side of the dam axis, which is almost of similar nature as on the right abutment.

Valley Section

The valley section at the proposed dam axis is about 150 ft wide and estimated to be about 20 ft to 30 ft deep, mostly filled with cobbles, gravels and some coarse to fine sand. The gravels mostly consist of particles of quartzite, diorite, limestone and sandstone.

Geologic section B-B was developed along the valley as shown on Figure 2.8 (Annexure A).

The section line is shown on the surface geologic map (Figure 2.3, Annexure A) which shows that a major part along the valley is filled with alluvial material consisting of sandy gravels and cobbles, loose rounded to sub-rounded and poorly graded. Both sides of the valley slopes are partly covered with overburden material. Investigation boreholes KTV-4, KTV-5 and KTV-8 were drilled in the area where the slab is to be placed and in the vicinity of cofferdam. According to borehole information the top of bedrock is at about 20 ft deep in the area. The bedrock is generally competent and of good quality. The laboratory tests show that unconfined strength ranges from 10.7 to 48 MPa. In general, the foundation condition is good and suitable for the proposed structure in the valley section under the overburden of almost 20 ft thick, which is evident from the results of drilling of boreholes KTV-1, KTV-3 and KTV-6.

Spillway

The proposed spillway for the Concrete Faced Rockfill Dam (CFRD) is located on the right abutment. The crest of the spillway has almost the same alignment as that of dam axis, and is founded on the same sandstone ridge. It is a gated overflow type with standard ogee shape weir structure with chute and stilling basin.

The surface geological map (Figure. 2.3, Annexure A) shows that massive sandstone is exposed in the greater part of the spillway area. The exposed sandstone rock which will form the foundation is fairly indurated, moderately strong to strong having variable particle size and cementing material. The bedding strike is almost normal to river flow generally recorded as N65°E and dips of the beds ranges 65 to 70 degrees in the downstream direction. Joints are generally sparsely spaced due to massive nature of the sandstone.

A geologic section of the spillway, Section S-S, was developed and is shown on Figure 2.9 (Annexure A). The geologic section depicts that the thick massive sandstone bed is available under the spillway crest as well as under the greater part of the chute. However, some part of chute together with stilling basin will be founded on siltstone / shale beds with interlayered sandstone. Investigation boreholes KTR-3A and KTV-7 were drilled in the vicinity of the chute area. The water pressure test results show very low permeability.

Diversion and Power Tunnels

In order to divert river flows during construction, and later for releasing water from the dam for power generation and irrigation, two tunnels on the right abutment of the dam are proposed. Tunnel one, known as the Power Tunnel, would be of 20 ft diameter and the second tunnel, known

as the diversion or low level tunnel, would be of 14 ft diameter.

The proposed tunnels are shown on the surface geologic map (Figure 2.3, Annexure A). The twin tunnels are closely spaced and the overall geology would be same for both. It can be seen on the surface geologic map (Figure 2.3, Annexure A) that the major part of both the tunnels will pass through the massive sandstone bed. The sandstone is generally moderately hard to hard and the beds are dipping in the downstream direction at angle of 70 to 75 degrees. The shale beds which will be encountered are softer and weaker.

The tunnel alignment is shown on geologic section A-A, (Figure 2.6, Annexure A) which was prepared for the right abutment. Generally, the rock conditions along the tunnel alignment are good and there appear to be no problems with the tunnel excavation; however, soft rock zones will need proper support and treatment. No seepage is expected during excavation as the ground water table was not been encountered during drilling.

Powerhouse No. I (38 MW)

The proposed Powerhouse No. I is located on the right bank of Kurram River downstream of the dam. Its location is shown on Figure 2.3, (Annexure A). Borehole KTR-6 was drilled to ascertain the rock properties and sub-surface conditions under the powerhouse. The bedding dip/strike at this location is N65°E / 75° SE. The permeability, as determined from tests in the borehole, is low (max. 2 Lugeon).

Reservoir Area

The surface geological mapping of the reservoir area could not be carried out due to restricted access to the area. As a result, assessments of landslide hazards, mass movement, or location of significant tectonic structures (faults and shear zones) could not be performed. We know the region is tectonically affected; hence a number of minor faults may be present in the area. A major fault known as Kurram Fault passes through the northern part of the reservoir which is about 17 km upstream from the dam site. Such hazards may have the potential to affect river flow (e.g. blockage), or impact water seepage from the reservoir. The presence of active faults in the reservoir area could have an influence on potential reservoir triggered seismicity. Slope stability studies have not been conducted at the dam site in the area immediately upstream of the dam.; however a preliminary level Reservoir Geological map has been prepared (Figure E) with the help of satellite Google image in order to identify the physiography and lithological units of the reservoir area during the present study. The identified lithological units are marked on the satellite image with the help of physical features interpretation and the available geological literature of the regional and local dam site geology.

The reservoir area is generally underlain by the Panoba Shale, which is overlain by the Habih Rahai limestone. This in turn is overlain by the Kamlial formation of the Rawalpindi Group which is the dominant rock unit at the dam site and in the reservoir area. The Kamlial Formation consists of sandstone and shale. The sandstone is mostly massive, fine to medium grained, moderately hard to hard, sparsely jointed, associated with thin alternate beds of shale / siltstone. The shale is thinly bedded, soft to medium hard, moderately jointed, interbedded with thickly bedded to massive sandstone. Alluvial Riverbed and Terrace Deposits are widespread in the reservoir area. These consist of loose to medium dense, sandy silty gravels and cobbles with few boulders, gravel and cobbles are rounded to sub rounded.

It is strongly recommended to carry out geological mapping of the reservoir area along with the Neo-tectonic Studies upstream and downstream of the dam site in order to study the behavior of the reservoir after impounding.

4.2.2 Weir – II

The surface geological mapping of the Weir II site are presented on Figure 2.14 (Annexure A). The river channel of Kurram River at the proposed weir site is about 640 ft wide. The river channel bed is filled with alluvial material mostly consisting of sandy gravel, cobbles and occasional boulders.

Sandstone bedrock is exposed on the right abutment of the weir. The left abutment slopes are covered with overburden material that consists mostly of loose to semi consolidated sandy gravel and few boulders. The general strike of the beds in the area is N60°E with 75° SE dip.

Geologic section AA', prepared along the weir axis, is shown on Figure 2.15 (Annexure A). Three investigations boreholes (KTPT-1, KTPT-2 and KTPT-3) were drilled in the valley floor along the weir axis. Bedrock was found in all three holes, covered by 24 to 32 ft of unconsolidated alluvium. The laboratory test results reveal that the bedrock sandstone is strong and of good quality. The shale is softer and relatively weak. The permeability testing shows very low Lugeon values.

Tunnel for Powerhouse No. II

Surface geological mapping along the tunnel alignment is shown on Figure 2.16 (Annexure A). The geology maps show that alternating beds of sandstone and shale are exposed along the tunnel. At places, the beds are quite thin. The tunnel will run across the bedding strike, which is generally in the N60°E direction. The bedding dips from 60 to 85° NE towards the tunnel outlet. No prominent structural discontinuities or structural abnormalities were noted in the surface mapping.

The geologic section, shown on Figure 2.17 (Annexure A), shows alternating beds of strata along the tunnel alignment. It is noted that a 100 ft length which, has insufficient cover, will need appropriate additional support and appropriate excavation methods. Four boreholes were proposed to be drilled along the tunnel alignment to determine the sub-surface conditions of available rock as well as to collect core samples for laboratory testing. Two of these boreholes have been completed to date, one at the inlet and the other at the outlet location of the tunnel. These boreholes confirm the presence of alternating shale and sandstone beds as assessed from surface geology. The results of laboratory tests indicate that compression strength of sandstone ranges from 10 to 27 MPa which is reasonably good whereas shale is softer and ranges from 5 to 7 MPa. The permeability of the strata is low. Due to presence of non-homogenous strata special care, support and treatment will be required during excavation.

Powerhouse No. II (10.4 MW)

The location of the proposed powerhouse is shown on the surface geologic map of the tunnel on Figure 2.16 (Annexure A). Powerhouse No. II is located on a thick sandstone bed, that underlain by thin beds of shale. Borehole KTPT-6 was drilled at the powerhouse site. Unconfined compressive strength testing of sandstone core samples from this borehole indicated strength values of 22 MPa. It is inferred that the foundation rock is sound and is a suitable foundation for the proposed powerhouse.

4.2.3 Weir – III

The proposed 75 ft high Weir III, across Kurram River, will be located about 22,000 ft downstream of the Weir – II site.

The surface geological map of the weir site is shown on Figure 2.19 (Annexure A). The map indicates that most of the river channel along the weir axis is covered with overburden material and that sandstone beds are exposed on both abutments. The general bedding strike direction is normal to river flow and the strata dips 50 to 75 degrees in the NE direction. The surface geological mapping does not show any structural anomaly in the area.

Section AA', shown on Figure 2.19 (Annexure A), is developed along the proposed weir axis. This shows that the major part of the weir will be founded on river alluvial material. In order to determine the sub-surface geology, particularly the depth of overburden, three investigation boreholes KPH/3-1, KPH/3-2 & KPH/3-2A were drilled along the axis. The bedrock in boreholes KPH/3-1 and KPH/3-2A was encountered at about 20 ft depth whereas in borehole KPH/3-2 it is over 40 ft which is probably due to presence of soft shale in the main channel. The overlying alluvial overburden is extremely permeable. The bed rock permeability is below 5 Lugeons.

Power Tunnel – III

A 16 ft diameter pressure tunnel, which will be about 3250 ft long, is proposed to supply water to Powerhouse No. III. The surface geological mapping along the tunnel alignment is shown on Figure 2.20 (Annexure A). The surface geologic map shows that alternating beds of sandstone and shale are exposed along the entire alignment of the tunnel. The sandstone is dominant rock type. Shale beds are also well exposed but they are thinly bedded. The beds strike across the tunnel alignment and dip steeply towards the inlet portal. No significant structural discontinuities or anomalies have been mapped.

Three boreholes, KPH/3-3, KPH/3-4 and KPH/3-5, all located along the tunnel axis were recommended in previous studies. This work was not carried out and it is strongly recommended to drill these proposed boreholes during next stage of studies.

Powerhouse No. III (16.5 MW)

The proposed powerhouse is located on an exposed sandstone bed which is shown on the surface geological map Figure 2.20 (Annexure A). The bedding strike direction is generally NW and the strata dip steeply into the hill towards river side. The joints are generally moderately to widely spaced in the vicinity of the powerhouse location. No significant abnormality or geological structure has been noted in the geological mapping at the powerhouse location.

In order to explore the sub-surface rock conditions an investigation borehole was proposed at the powerhouse location during the feasibility investigation. This work was not done and it should be carried out during the detailed design phase of the project.

4.3 Component 3

4.3.1 Construction of New Head Regulator at Kurram Garhi Headworks

A new head regulator at Kurram Garhi Headworks on its left abutment has been proposed. A canal known as Thal Canal will begin at this new head regulator. Thal Canal will be 198,000 ft (37.5 miles) long. The canal system will have 14 distributaries, 7 minors and 2 sub-minors of about 73 miles.

No geological and geotechnical investigations data (i.e. geological map of the command area of the Thal canal and the Kaitu Weir, excavation of the test pits along the main canals and investigation boreholes at the structure locations) is available from the previous studies. This data is quite important in order to know the sub-surface conditions for up gradation/remodeling of the existing and proposed new canal system. In the following paragraphs a brief description of physiography and geological conditions of the command areas of the Thal Canal, Sheratalla Plain and Spaira Ragha Plains are based on the satellite image interpretation studies.

4.3.2 Proposed New Thal Canal System

About 90% of the soils have been developed in the piedmont plain and about 10% in the river plain. Sandy loam and sandy clay loam is the major textural class; however clays and loamy sands form a significant part of the landscape. Another landscape unit of the command area constitutes the alluvium from Kurram River. This is brown to dark brown in color and dominantly silty clay in texture. Some silty clay loams are also found.

A geotechnical investigation has not been performed for this system. Sampling and testing shall be performed during the construction phase.

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5 CONSTRUCTION MATERIALS

Large quantities of different types of construction materials are required for the various components of the KTDP. The project requires materials for the CFRD, spillway, tunnel lining, underground works, powerhouse structures, canal lining, etc.

Availability of construction materials in the vicinity of the KTDP site has been one of the major considerations in locating and selecting the type of dam at Kurram Tangi. The type of dam can also be influenced by the materials available from the excavation at the dam site and borrows areas. For the KTDP the construction materials available mainly include sandstone and river alluvium consisting of sand and gravels. The potential borrow areas has been identified and are shown on Figure 4.1 (Annexure B). Additionally, potential sources of concrete aggregate have been identified. Twenty-four pits were proposed to evaluate the quantity and quality of the material available as well as to obtain selected samples for laboratory testing. These test pits have yet to be excavated.

Summary descriptions of the various construction materials are as follows:

Rockfill Material: A RFRD type dam has been selected to be constructed at the proposed dam site. It is assessed from field observations and limited laboratory testing that the sandstone rock is suitable for use as rockfill material. It is estimated that the material available from the required excavations for the spillway, powerhouse, diversion works and main dam will be enough to meet the requirements of a rockfill for the dam. However, sandstone is also available in sufficient quantity in the vicinity of the dam site to meet any shortfall if needed**.**

Filter and Drain Material: The fine filter material (sand) and the coarse filter material (fine gravels) will be obtained from the river alluvium. Borrowed material will need appropriate washing and/or crushing followed by screening to the required sizes.

Fine and Coarse Concrete Aggregate: Studies carried out to date indicate that requirements of the course aggregates can be met from river gravel and terrace gravels after processing. These areas are in the close vicinity of the dam, weirs, powerhouses and irrigation structures in the main river channels. The river gravels are clean, coarse to fine, well graded, sub-rounded to rounded and mostly composed of limestone, sandstone, diorite and quartzite.

These studies also indicate that the requirements of fine aggregates will have to be met by crushing of gravel as enough quantity of sand is not available in the vicinity of the site.

Cement: Investigations performed to date show that there are few cement factories which are considered suitable for supply of the required quantities of cement needed for the project. Due to the potential alkali reactivity of concrete aggregates, slag or natural pozollanic material may need to be used with OPC.

Water for Concrete: The main source of water is Kurram and Kaitu Rivers. A number of water samples were collected from different locations and tested at a laboratory. Laboratory test results showed that the water available from these rivers is of good quality and can safely be used in the construction of the dam and other structures.

Reinforcing Steel: There are several ISO certified steel re-rolling mills located in Islamabad and Hattar Industrial Estate. The mills would be capable of producing reinforcing steel according to the required standards of the project.

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6 CONCLUSIONS

An assessment of the available data indicates the following:

Component 1: Sufficient geological investigations have been carried out for most of the structures of Component 1 to establish overall project feasibility and enable realistic cost estimates. The current investigations have not identified any fatal flaws and the level of geological detail supports the current project layouts and structure designs. Further fieldwork including additional geological mapping and boreholes, is needed to enable detailed design to be completed.

Component 2: Sufficient geological investigations have been carried out for the Component 2 scheme to establish overall project feasibility and enable realistic cost estimates. The current investigations have not identified any fatal flaws and the level of geological detail supports the current project layouts and structure designs. Further work, including additional geological mapping and boreholes, is needed to enable detailed design to be completed. It is noted that further work is needed to evaluate the reservoir area, but current assessments of the satellite imagery and regional geology maps indicate that there are no significant unfavorable issues.

Component 3: No geological site investigations have been carried out for this scheme. Given precedent experiences in this area, the overall scheme is reasonable and the conceptual layouts and designs are appropriate. Feasibility level designs and more accurate cost estimates must be verified by a field investigation program that includes drilling, geological mapping and a construction materials assessment.

Construction Materials: Various sources of construction materials have been identified and some testing has been carried out. It is concluded that, in general, there are sufficient natural aggregates and other construction materials available in the project area to meet construction requirements. Further testing work is needed.

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7 RECOMMENDATIONS

7.1 Component 1

7.1.1 Kaitu Weir

The project consultant should arrange for drilling of the previously planned investigation boreholes at the new location of the weir and incorporate the borehole data into the design of the subject structure. It is noted that the previous three boreholes were drilled at the original alignment, some 200ft to 300ft downstream from the present one. Geological conditions have been inferred from this original location. New drilling is needed at the actual site of the weir.

7.1.2 Kaitu Feeder Tunnel

Additional investigation boreholes should be drilled prior to the construction phase. Core logging should include engineering geology descriptions and the estimation of rock mechanics indices such as RMR and Q in order to study the tunnel excavation and support parameters. The project consultant should select suitable locations for the drill hole locations.

7.1.3 Powerhouse No. IV and V

Due to the late designs of these additional powerhouses no investigation boreholes were drilled. WAPDA should ask the project consultants to propose a geotechnical investigation plan for these two powerhouses for the foundation evaluation.

7.1.4 Sheratalla Canal System

It is recommended that the project consultant should prepare an appropriate geotechnical investigation plan along the canal route. The geotechnical investigation plan should include excavation of test pits at suitable intervals along the canal route. A comprehensive laboratory testing should also be done on the samples collected from the test pits in order to determine the design parameters.

7.2 Component 2

7.2.1 Diversion and Power Tunnel

The project consultant should assess RMR values from the exposed rock outcrop to determine the rock condition and tunnel support during tunnel excavation.

7.2.2 Dam Reservoir Area

Surface geologic mapping of the reservoir area was not carried out due to the security reason in the project area. The security situation is still unfavorable and it will be difficult to make a traverse approximately 10 km u/s side along the river channel and the adjoining areas.

It is recommended to use satellite image of 0.6 m resolution for the reservoir geologic mapping. Lithological units can easily be identified; geologic and tectonic features can also be identified along with erosional features which can cause river blocked etc. The presence of active faults in the reservoir area can also be identified from the satellite image. Slope stability studies can also be studied in the near vicinity of the upstream side of the dam abutments.

A preliminary level Reservoir Geological map was prepared with the help of satellite Google image interpretation during the present study. The lithological units are marked on the satellite image with the help of physical features interpretation and the available geological literature of the regional and local dam site geology from the feasibility and detail design reports. Emphasis will be paced on the identification of geomorphic features such as landslides, debris flows and other features which could impact on reservoir safety and operation.

An attempt has also been made to identify the structure deformations relevant to the regional and local tectonics features. Kurram Thrust Fault traverses approximately 17 km upstream of the reservoir as reported in the feasibility and detail design report. Another fault known as Karak Thrust also traverse approximately 4 km downstream of the main dam and approximately 500 m

downstream of Powerhouse No. II which needs ground verification. In spite of these two regionally known faults some minor shear zones and local faults were also reported which need local verification by ground truthing. The intensity/severity of these faults for the project could be decided after complete study of the geotectonic of the project area. Study of the existing available geological and tectonic data indicates that structurally site geology does not show any major feature of concern in the near vicinity of the dam site and the reservoir area.

A preliminary geological map of the reservoir is presented as Figure E.

7.2.3 Tunnel for Powerhouse No. II

The project consultant should make arranges for the drilling of the remaining two investigation boreholes and perform a RMR assessment of the exposed rock outcrops for the tunnel for Powerhouse No. II before the tunnel excavation starts in order to know the unforeseen geological conditions and rock support selection.

7.2.4 Tunnel and Powerhouse No. III

Three proposed exploratory boreholes which were planned during feasibility stage for the Powerhouse No. III tunnel area should be drilled during the next project design phase. The RMR assessment should also been done from the exposed rock outcrop.

7.3 Component 3

It is recommended that the project consultant should prepare a proper geotechnical investigation plan along with the surface geological mapping of the structures. The geotechnical investigation plan should include drilling of boreholes at structure locations and excavation of the test pits at a suitable intervals along the canal route. A comprehensive laboratory testing should also be done on the samples collected from the boreholes and test pits in order to determine the design parameters.

7.4 Construction Materials

The project design consultant should enlarge the sources inventory and to address specific material related issues for the project. The newly identified sources should be investigated in detail and in accordance with the site specific conditions.

The proposed plan to excavate the 24 test pits to determine the depth, extent and estimate the quantity of fine and course aggregate material for filters and concrete aggregate should be executed before the construction phase is started. The test pit locations should be marked on the map after ground verification of the availability of the stated material.

The available laboratory test results for rock fill material, fine and coarse aggregate and cement are incomplete. These have been sufficient to identify general availability of various construction materials but further work is needed. The following testing of rock fill, fine and coarse aggregate for filters and concrete aggregate, and cement are recommended to finalize construction materials assessments.

1. Identification of potential rock quarries nearest to the project area.
2. Sampling and testing of host rock of identified rock quarries.
3. Determination of the suitability of riverbed deposits and crushed rock obtained from required excavations as a source of concrete aggregates, asphalt and filter materials.
4. Identification, investigation and testing of the river/ terrace deposits for coarse and fine aggregates.
5. Identification, sampling and testing of natural sand deposits/ manufacturing sand.
6. Potential of ASR study in the sources of construction materials.
7. Availability of cement and pozzolan materials.
8. Suitability of the river water for the production and curing of concrete.
9. Petrographic studies to delineate reactive materials in the aggregates and Mortar bar tests (ASTM C1260) on the aggregates

List of Figures

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Figure B: Project Location Plan
Figure C: Borehole Location Plan Kaitu Weir Site
Figure D: Borehole Location Plan Dam Site Area
Figure E: Preliminary Reservoir Geological Map

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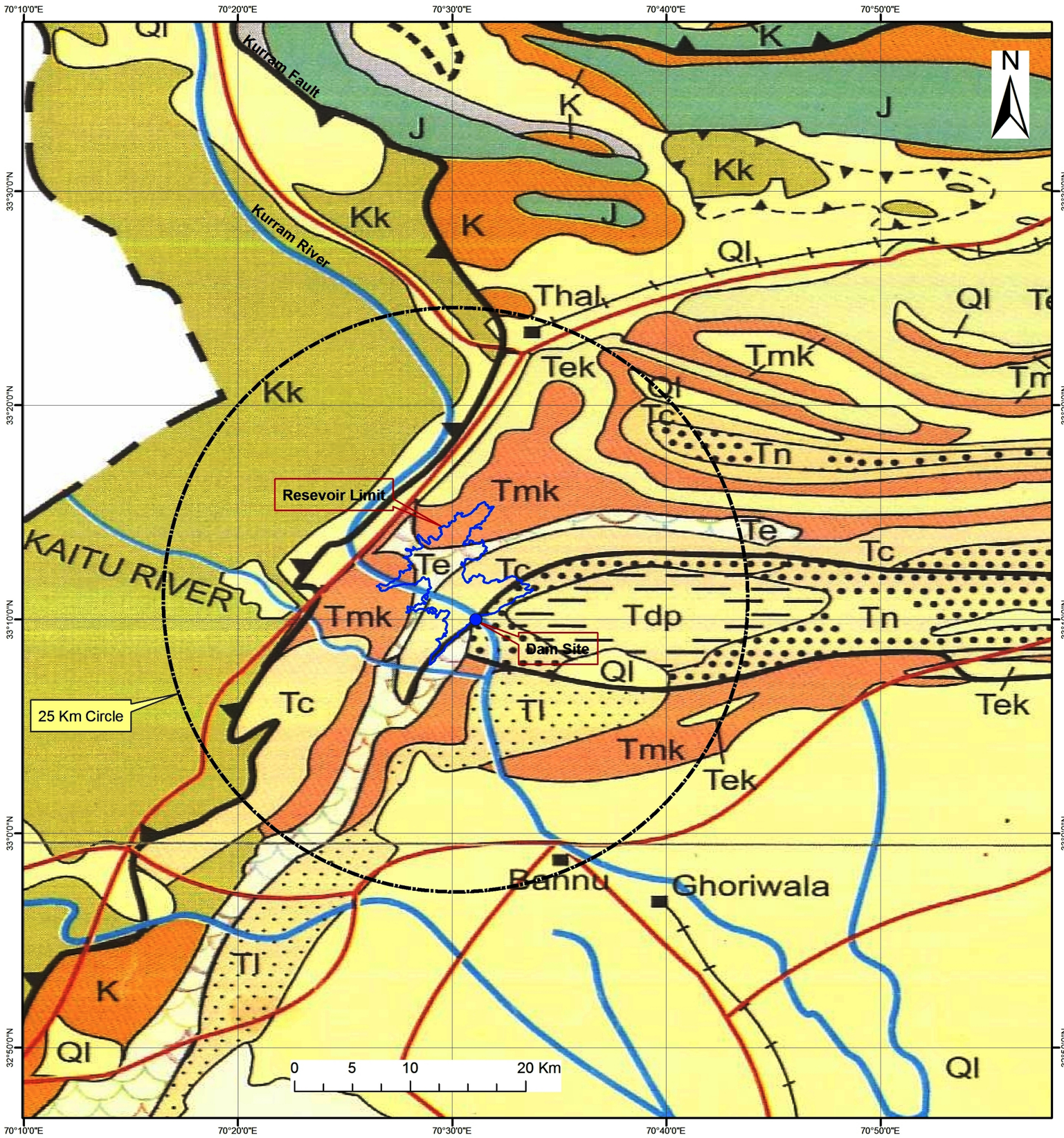
Figure-A



KOHAT / BANNU / PARACHINAR / KHISOR, BHITTANI AREA

PLIOCENE (Siwalik Group)

Tdp — **Dhok Pathan Formation:** Upper member: Friable sandstone with conglomerate lenses and reddish-brown and gray clay. Lower Member: Soft sandstone with conglomerate.

Tn — **Nagri Formation:** Greenish gray medium to coarse grained, thick bedded to massive, sandstone, friable with interbeds of dull red clay.

Tc — **Chinji Formation:** Red clay with brownish gray siltstone & subordinate conglomerate is found at places.

MIOCENE

Tmk — **Kamlial Formation:** Greenish to Gray sandstone with alteration of siltyclay, siltstone and clay stone.

Tmm — **Murree Formation:** Red, maroon, purple, greenish gray sandstone and claystone with subordinate intraformational conglomerate.

EOCENE

Tek — **Kohat Formation:** Habib Rahi limestone Member: Thin to thick bedded limestone, greenish-gray shale; brownish-red clay with beds of sandstone and conglomerate Foraminifera common. **Sadkal Member;** Thick bedded Green, greenish gray shale. **Kaladhand Member;** Limestone, thin bedded, interbedded with shale, Foraminifera common throughout. **Mami Khel Clay/ Kuldana Formation;** Brownish-red clay, contains beds of sandstone and conglomerate.Variegated siltstone, shale and limestone. **Chorgali Formation;** Gray limestone and greenish gray marl. **Margalla Hill Formation;** Gray limestone with subordinate marl and shale. **Shekhan Limestone & Jatta gypsum;** Northern facies: Limestone, thin-bedded to massive, gypsiferous, shale and gypsum beds at top. Southern facies, gypsum bedded to massive & banded. **Panoba Shale & Bahadur Khel Salt;** Northern facies: Shale, grayish-green to light-olive to brownish-green, silty, soft. Southern facies: Rock salt, white to blackish white, thick bedded to massive some clear salt crystals at some places. **Sakesar Limestone;** Limestone, cream to light-brown, fine to medium crystalline, massive, rubbly surface; Foraminifera common.

PALEOCENE

Tp — **Patala Formation:** Shale, dark-gray to olive green, hard, splintery, changes eastward into inter bedded shale and nodular limestone. **Lockhart Limestone:** Limestone, dark-gray to black , massive nodular fetid odor with subordinate marl and shale. **Hangu Formation:** Sandstone, white, thin to medium bedded, quartzose stains rusty brown, crossed bedded, with carbonaceous shale and clay, contains coal seam near top. At places contains laterite bed at the base.

CRETACEOUS

K — **Darsamand Limestone / Kawagarh Formation:** Limestone, dense thin-bedded to massive, changes eastward into gray marl and shale with subordinate limestone. Limestone, thin bedded partly nodular, argillaceous. **Lumshiwal Formation;** Sandstone, white, quartzose, very hard, stains brown, changes eastward into sandstone, greenish, grayish-brown, flaggy, glauconitic. **Chichali Formation;** Greenish gray glauconitic sandstone and green shale. Contains belemnites and ammonites.

Kq — **Quartzite Unit:** North of Parachinar. Quartzite, white, light gray to brownish white, medium-bedded to massive, very hard, conglomeratic; contains basic igneous intrusive in extreme north west; probable cretaceous age.

JURASSIC

J — **Samana Suk Limestone:** Limestone, gray to dark gray, medium to thick bedded, oolitic, with beds of mega fossil fragments. Partly metamorphose limestone, known locally as marble, in the extreme of Parachinar NWFP. **Shinawari Formation:** Limestone, marl and shale. Limestone, gray to light gray, thin to medium bedded contains shale intercalations with marl beds, light gray nodular, argillaceous. **Datta Formation:** Limestone, gray to dark gray, thin to medium bedded, and interbedded nodular marl; calcareous shale, red in places; and sandstone, quartzose, ferruginous and calcareous. Contains scattered oolitic and mega fossil fragments.

Tl — **Litra Formation:** Light gray to brown sandstone, thick bedded and massive, strongly cross bedded, some beds coarsely micaceous, granetiferous, silty and clayey. Includes conglomerate of rounded pebbles and cobbles. Includes subordinate brown and brownish-red siltstone and claystone.

Te — **Drazinda Shale:** Dark-brown to gray claystone, gypsiferous, contains aboundant Foraminifera, lamellibranchs, and some Bryozoa and echinoids. Also includes persistent beds of sandstone which are calcareous and thin to thick bedded in the middle part.

Pir Koh Limestone: Light gray, fine grained argillaceous limestone, contains abundant Foraminifera, with subordinate interbeds of dark gray calcareous claystone.

Domanda Shale: Dark-brown and greenish gray soft claystone. Fossiliferous, gypsiferous near middle, calcareous and splintery near base.

Habib Rahi Limestone: Brown, hard, fine grained, thin bedded limestone. Middle part argillaceous; contains Foraminifera.

Baska Shale: Green and greenish-gray claystone, near base it is sandy bright red and purple in color, contains alabaster in nodules, veins, and as in bedded form, also contains gypsiferous limestone and marl. The limestone contains Forminifera near top of the formation.

Ql — **Quaternary Alluvium:** Unconsolidated deposit of gravel, sand, silt and clay.

Kk — **Kurram Facies:** Western facies, consisting of shale, variegated red, brown and green; limestone, light gray, in places mottled pink and light gray, lithographic, very thin bedded, platy; and sandstone, brown or gray conglomeratic. Present in western part of the area. Age Triassic-Palaeocene.

Source : Geological Map of Pakistan, 2006 (GSP)

Kurram Tangi Dam Project
Regional Geological Map

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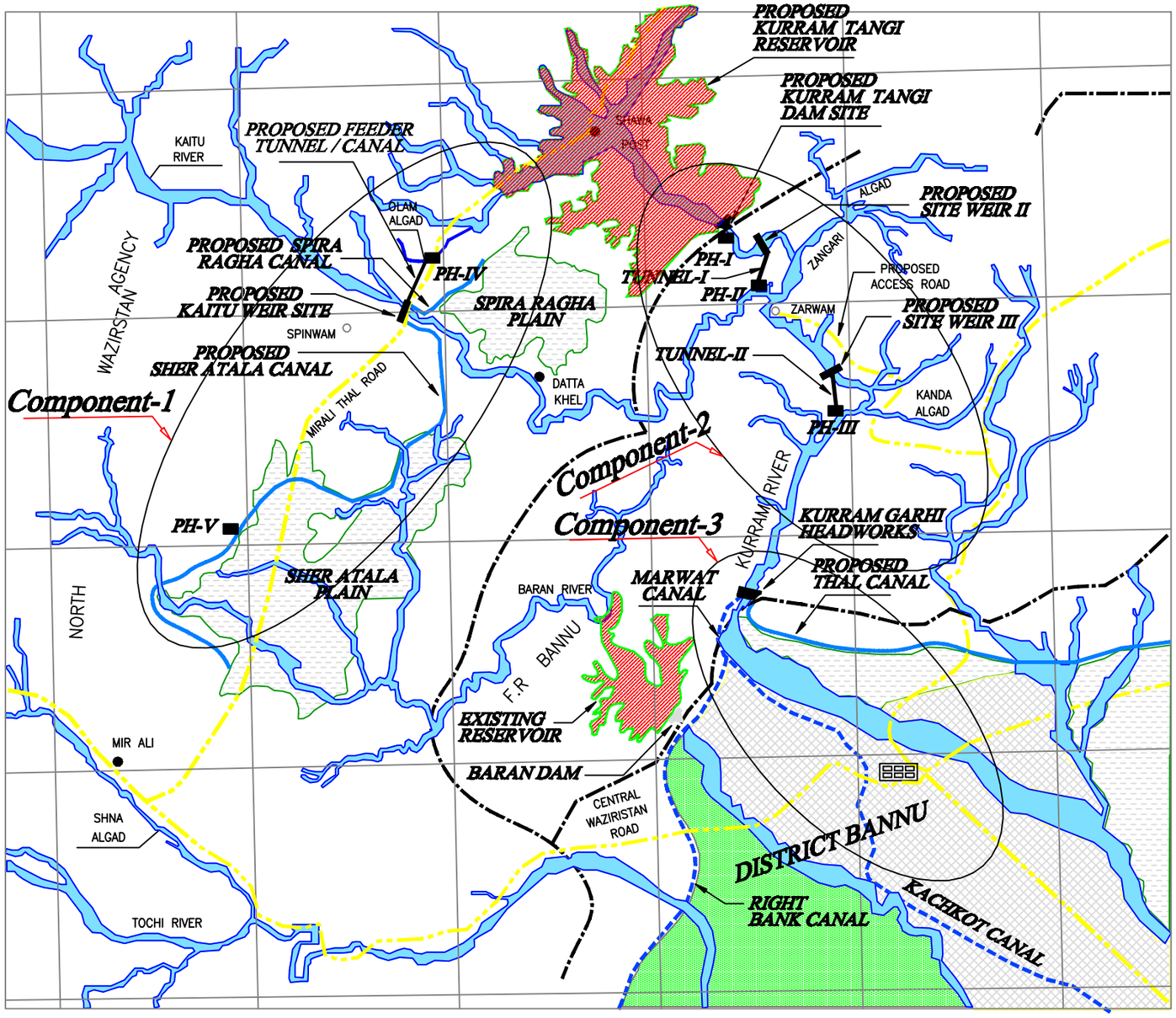
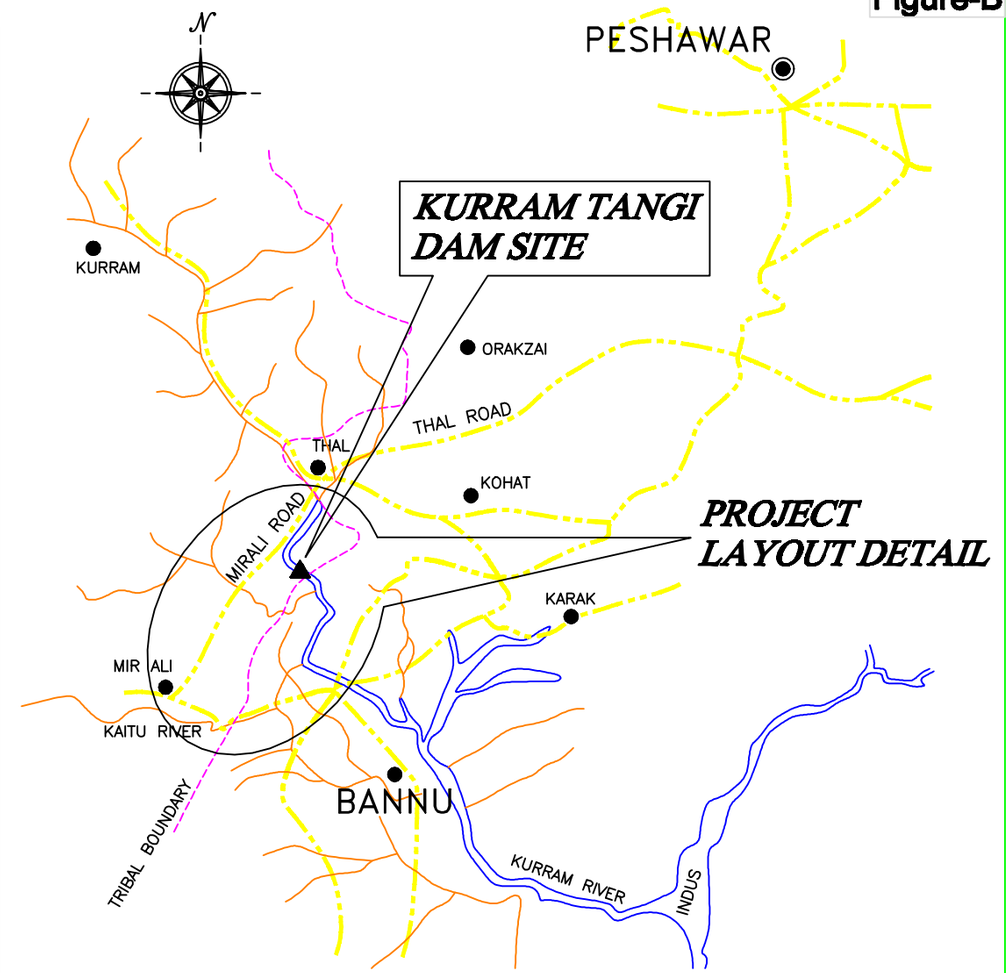
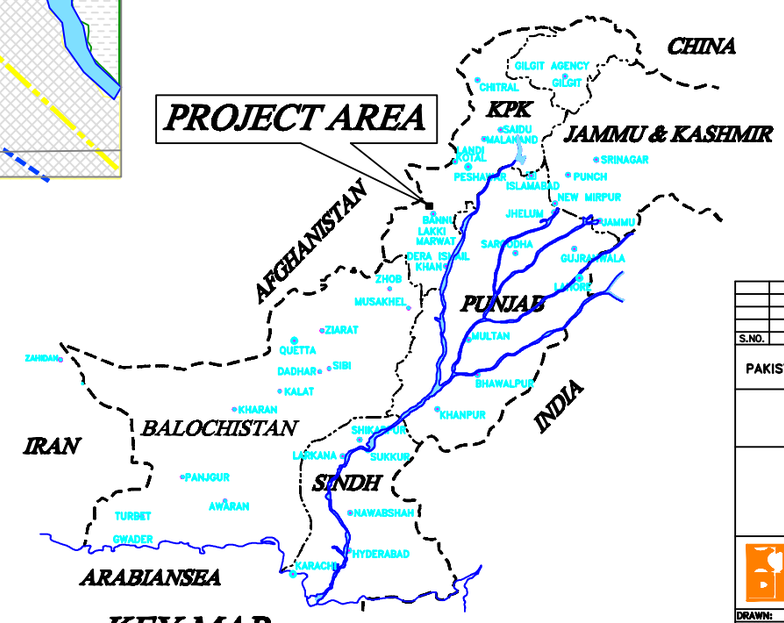
Figure-B



PROJECT LAYOUT DETAIL



PROJECT VICINITY MAP



KEY MAP

LEGEND :-

- ROAD
- EXISTING CANAL
- PROPOSED CANAL
- PROVINCIAL BOUNDARY
- RIVER
- CITY / TOWN
- PH — PROPOSED POWER HOUSE
- WEIR SITE
- DAM SITE
- RESERVOIR

PROPOSED COMMAND AREA

- UNDER CIVIL CANALS
- UNDER MARWAT CANALS
- NEW COMMAND AREA

S.NO.	DATE	DESCRIPTIONS	CHECK

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

KURRAM TANGI DAM PROJECT

PROJECT LOCATION PLAN

KURRAM TANGI DAM CONSULTANTS
188 –Y, COMMERCIAL AREA, PHASE–III,
D.H.A, LAHORE.

DRAWN:	M. NADEEM	DATE: OCT, 2007	REV. No.
DESIGNED	–	DRAWING NO.	
CHECKED:	KHALID KHAN	KTDP–GEN–001	
APPROVED:	JAMIL ANWER		

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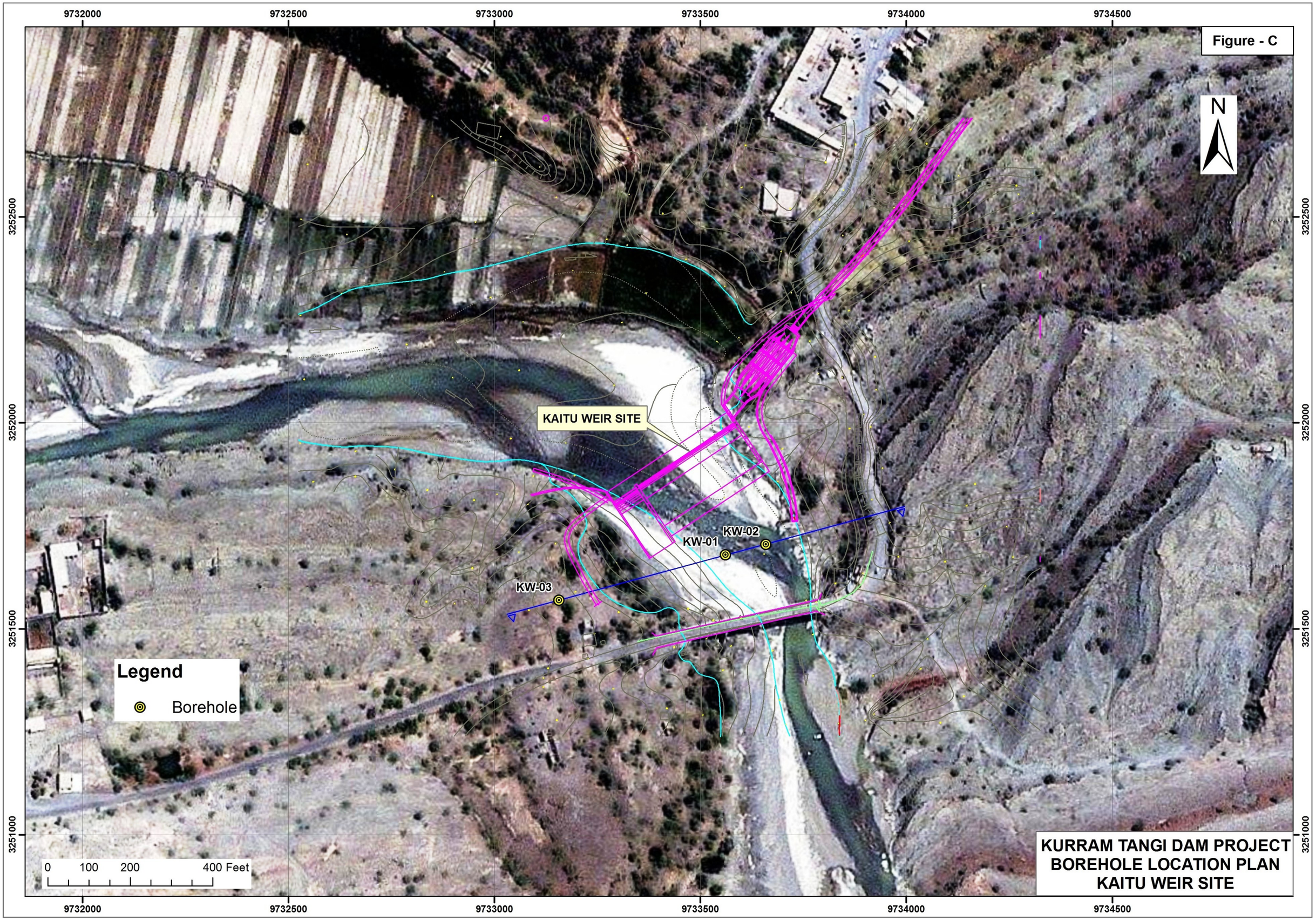
Figure - C
N
KAITU WEIR SITE
KW-01
KW-02
KW-03
Legend
Borehole
0 100 200 400 Feet
9732000
9732500
9733000
9733500
9734000
9734500
3252500
3252000
3251500
3251000
KURRAM TANGI DAM PROJECT
BOREHOLE LOCATION PLAN
KAITU WEIR SITE

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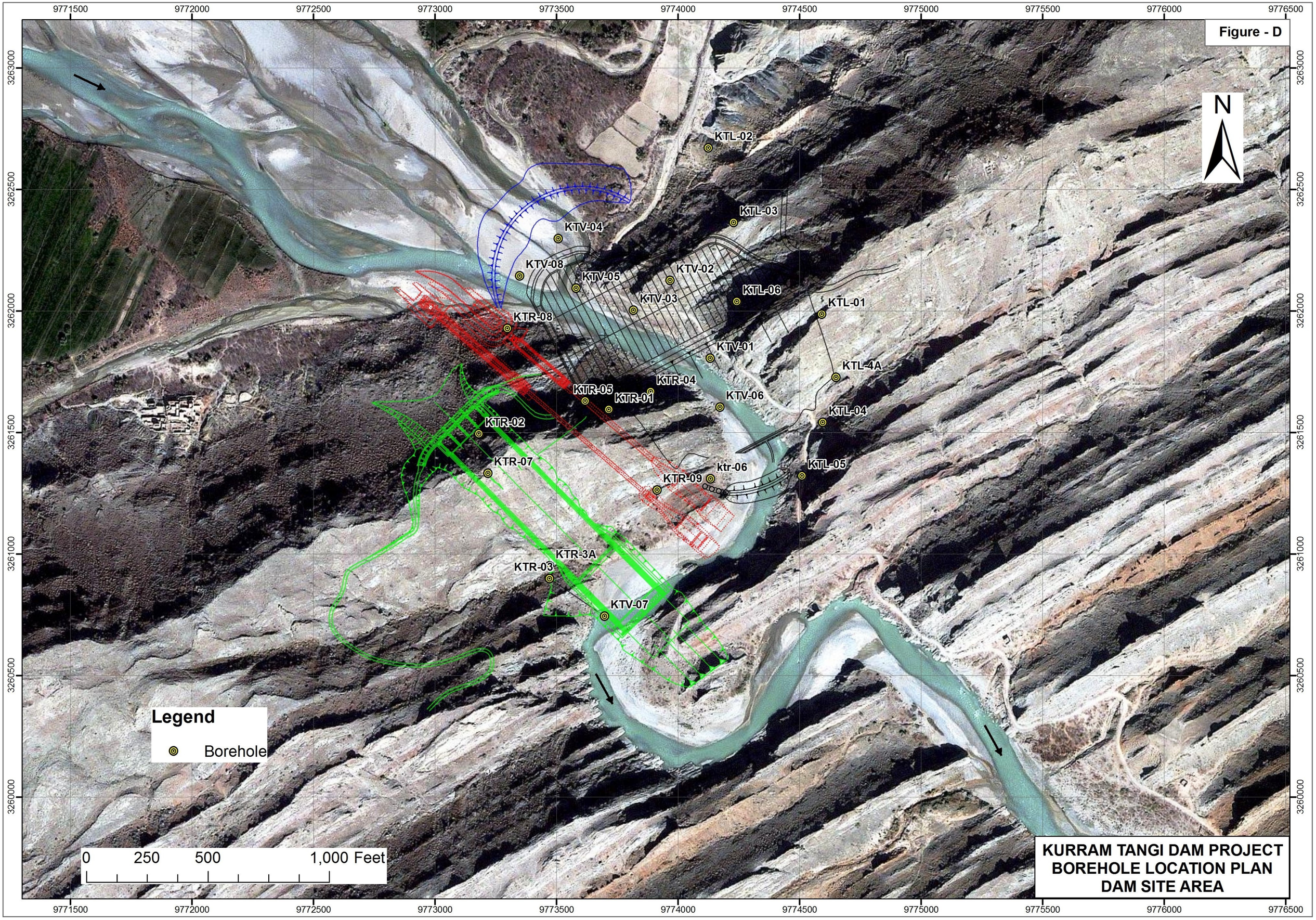
Figure - D
N
KTL-02
KTL-03
KTV-04
KTV-08
KTV-05
KTV-02
KTV-03
KTL-06
KTL-01
KTR-08
KTV-01
KTL-4A
KTR-04
KTR-05
KTR-01
KTV-06
KTL-04
KTR-02
KTR-07
ktr-06
KTR-09
KTL-05
KTR-3A
KTR-03
KTV-07
Legend
Borehole
0 250 500 1,000 Feet
KURRAM TANGI DAM PROJECT
BOREHOLE LOCATION PLAN
DAM SITE AREA
9771500
9772000
9772500
9773000
9773500
9774000
9774500
9775000
9775500
9776000
9776500
3263000
3262500
3262000
3261500
3261000
3260500
3260000

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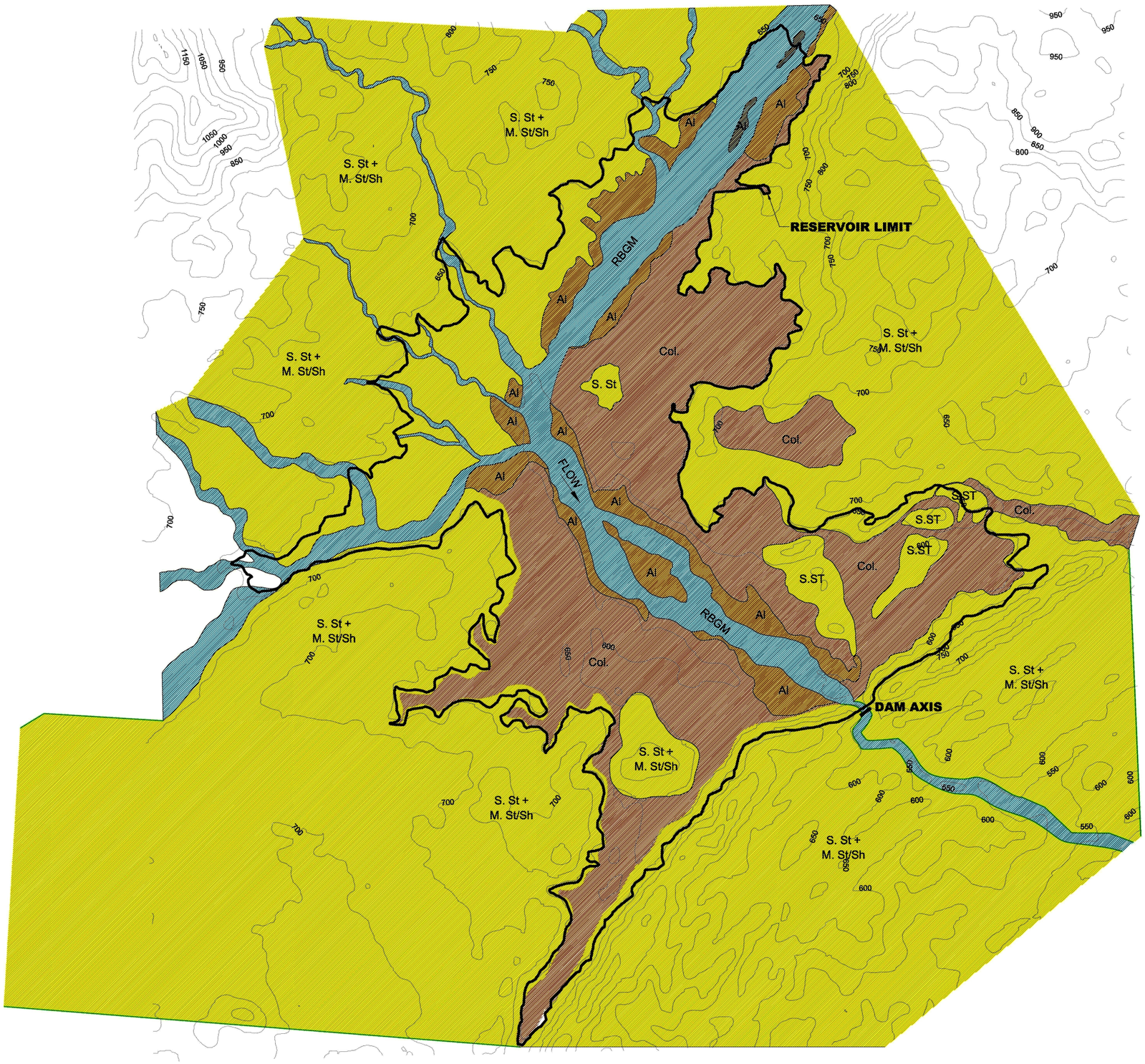
Figure -E



N

LEGEND

SANDSTONE+ SILTSTONE / SHALE	S. St + M. St/Sh
RIVER BED GRAVEL SAND, GRAVEL, BOULDER	RBGM
RIVER TERRACES (ALLUVIUM)	Al
COLLUVIUM	Col.

DESCRIPTION

SANDSTONE

Massive, fine to medium grained, moderately hard to hard, sparsely jointed, associated with thin alternate beds of shale/ siltstone.

SILTSTONE / SHALE

Thinly bedded, soft to moderately hard, moderately jointed, interbedded with thickly bedded to massive sandstone.

RIVER TERRACES (ALLUVIUM)

Loose to medium dense, sandy silty gravel and cobble with few boulders. Gravel and cobble are rounded to sub rounded.

COLLUVIUM

Loose to medium dense, sandy silty gravel and cobble. Gravel and cobbles are angular to sub angular and mostly of sandstone origin.

RBGM

River bed gravel, cobble and boulders with silt and sand.

NOTE

1. The preliminary geological map of the reservoir prepared by visual interpretation of google satellite image.
2. Base contour map developed from SRTM data.

0 2000 4000 6000 8000 10000 ft.

SCALE

KURRAM TANGI DAM PROJECT

PRELIMINARY RESERVOIR GEOLOGICAL MAP

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Annexure A : Figures and Maps from KTDP Feasibility Report 2004

Figure 2.3: Surface Geological Map of Dam Site
Figure 2.5: Geological Section along Dam Axis (D-D)
Figure 2.6: Geological Section Right Abutment (A-A)
Figure 2.7: Geological Section Left Abutment (C-C)
Figure 2.8: Geological Section along River Channel (B-B)
Figure 2.9: Geological Section along Spillway (S-S)
Figure 2.10: Geological Map of Kaitu Weir
Figure 2.11: Geological Section along Kaitu Weir (K-K)
Figure 2.12: Geological Map Kaitu Feeder Tunnel (6 sheets)
Figure 2.13: Geological Section (BB') along Kaitu Feeder Tunnel
Figure 2.14: Geological Map of Weir for Powerhouse-II
Figure 2.15: Geological-Section (AA') along Weir for Powerhouse-II
Figure 2.16: Geological Map of Power Tunnel-II (4 sheets)
Figure 2.17: Geological Section along Power Tunnel-II
Figure 2.19: Geological Section along Weir of Powerhouse-III (AA')
Figure 2.20: Geological Map of Power Tunnel-III

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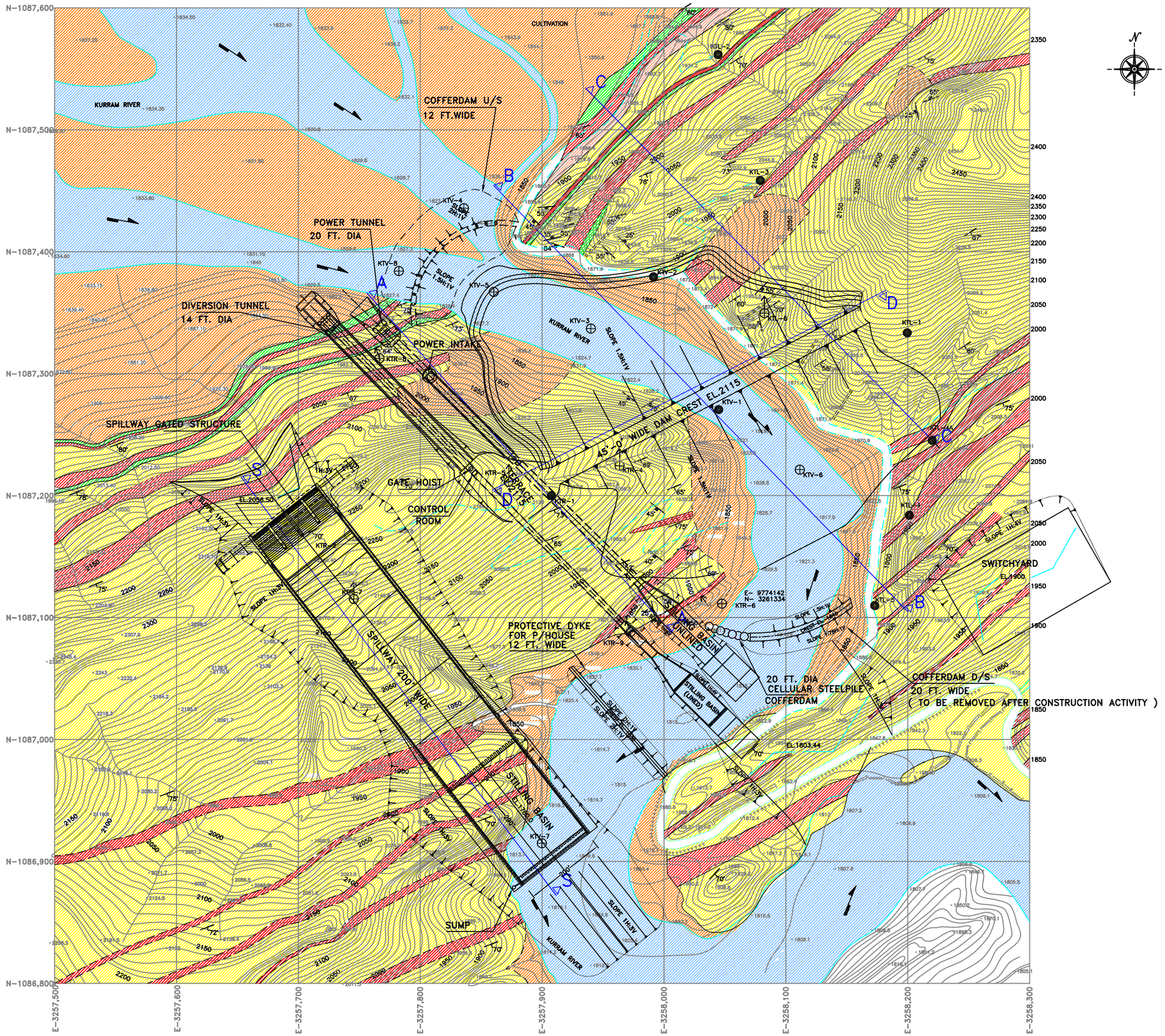

LEGEND

- SANDSTONE
- SILTSTONE + SHALE
- RIVER (SAND, GRAVELS, BOULDERS)
- OVERBURDEN (SCREE, ALLUVIUM)
- LIMESTONE
- MARL+SANDSTONE
- BORE HOLE COMPLETED UP TO 1994
- PROPOSED BORE HOLE FOR FEASIBILITY
- PROPOSED INCLINED BORE HOLE FOR FEASIBILITY
- DIP STRIKE OF JOINTS — 80°
- DIP STRIKE OF BEDS — 87°
- FAULT — F
- SHEARZONE

NOTES

ALL COORDINATES ARE IN YARDS

ALL TOPOGRAPHY ARE IN FEET

0 250 500 FEET

S.NO.	DATE	DESCRIPTIONS	CHECK

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

KURRAM TANGI DAM PROJECT

SURFACE GEOLOGICAL MAP OF DAM SITE

KURRAM TANGI DAM CONSULTANTS
188 -Y, COMMERCIAL AREA, PHASE-III,
D.H.A, LAHORE.

DRAWN:	M. NADEEM	DATE: DEC. 2003	REV. No.
SURVEYED:	ARSHAD HASHMI	FIGURE NO. 2.3	
CHECKED:	JAFAR HASSAN		
APPROVED:	JAMIL ANWER		

E:\NADEEM\KURRAM TANGI\FEASIBILITY-R\GEO-MAIN-DAM\FIG-2.3.dwg

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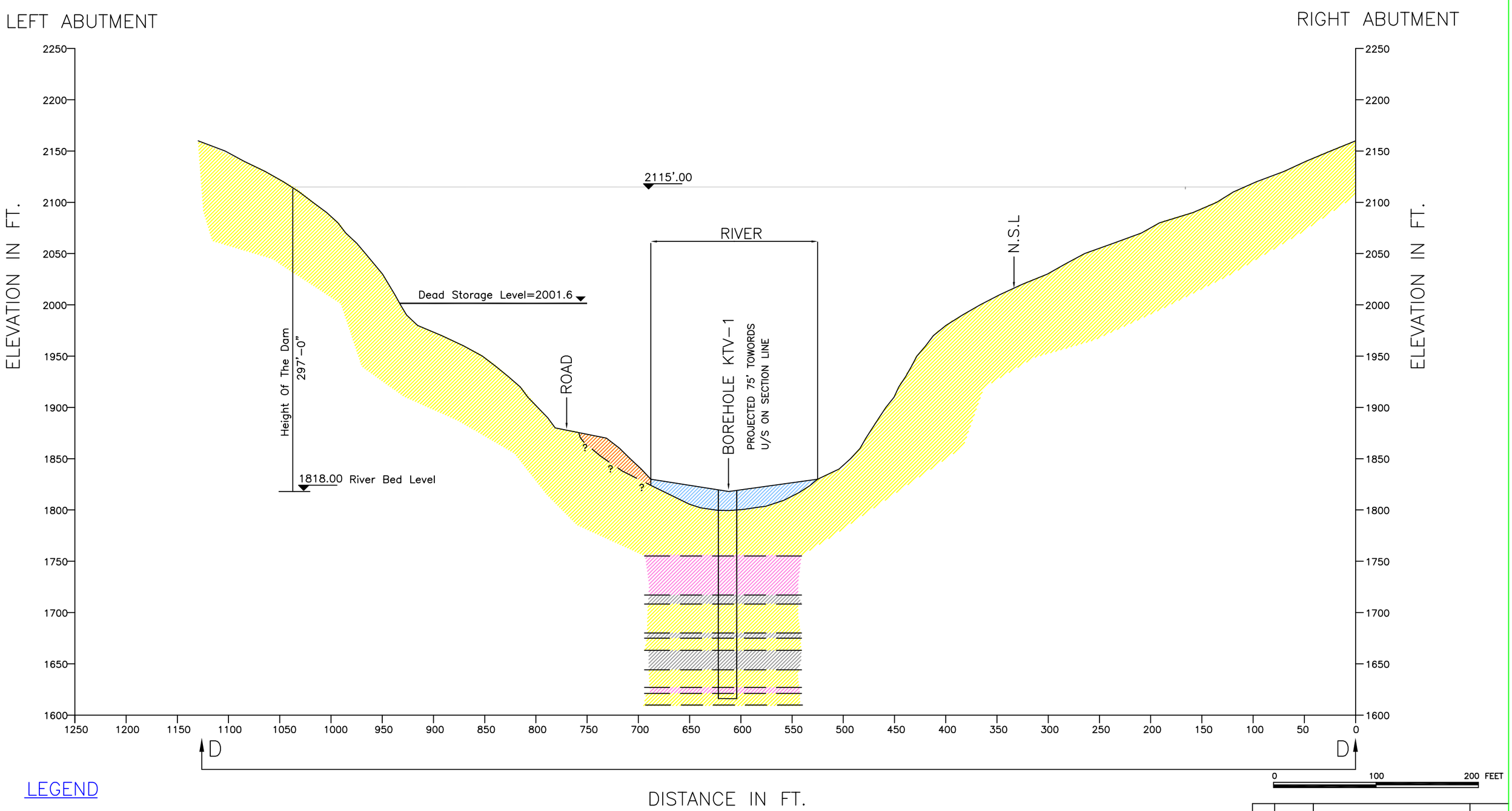

LEGEND

SANDSTONE _____

OVERBURDEN
(SCREE, ALLUVIUM) _____

SILITY SAND STONE _____

CONGLOMARATIC SAND STONE __

RIVER CHANNEL
(SAND, GRAVELS, BOULDERS) __

NOTE:

FOR SECTION LINE D–D PLEASE REF. TO SURFACE GEOLOGICAL MAP FIGURE NO–2.3

S.NO.	DATE	DESCRIPTIONS	CHECK

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

KURRAM TANGI DAM PROJECT

GEOLOGICAL SECTION
ALONG DAM AXIS (D–D)

KURRAM TANGI DAM CONSULTANTS
188 –Y, COMMERCIAL AREA, PHASE–III,
D.H.A, LAHORE.

DRAWN:	SAIF ULLAH	DATE: DEC. 2003	REV. No.
SURVEYED:	ARSHAD HASHMI	FIGURE NO.	
CHECKED:	JAFFAR HASSAN	2.5	
APPROVED:	JAMIL ANWER		

E:\NADEEM\KURRAM TANGI\FEASIBILITY-R\GEO-MAIN-DAM\GEO-SECTION\FIG-2.5.dwg

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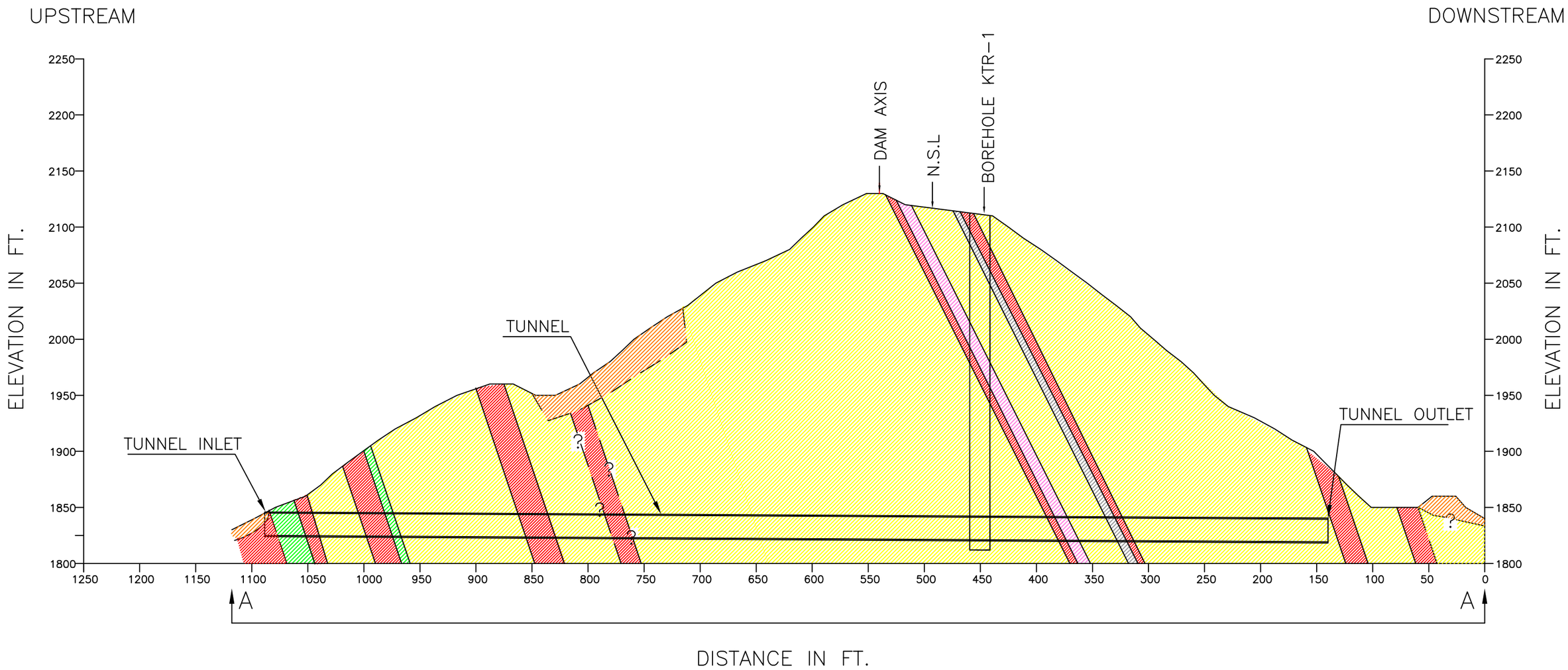

LEGEND

- SANDSTONE
- SHALE+SILTSTONE
- OVERBURDEN (SCREE, ALLUVIUM)
- LIMESTONE SHALLY
- SILITY SAND STONE
- CONGLOMARATIC SAND STONE

0 100 200 FEET

NOTE:

FOR SECTION LINE A–A PLEASE REF. TO SURFACE GEOLOGICAL MAP FIGURE NO–2.3

S.NO.	DATE	DESCRIPTIONS	CHECK

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

KURRAM TANGI DAM PROJECT

GEOLOGICAL SECTION
RIGHT ABUTMENT (A–A)

KURRAM TANGI DAM CONSULTANTS
188 –Y, COMMERCIAL AREA, PHASE–III,
D.H.A, LAHORE.

DRAWN:	M. NADEEM	DATE: DEC. 2003	REV. No.
SURVEYED:	ARSHAD HASHMI	FIGURE NO.	
CHECKED:	JAFAR HASSAN	2.6	
APPROVED:	JAMIL ANWER		

E:\NADEEM\KURRAM TANGI\FEASIBILITY-R\GEO-MAIN-DAM\GEO-SECTION\FIG-2.6.dwg

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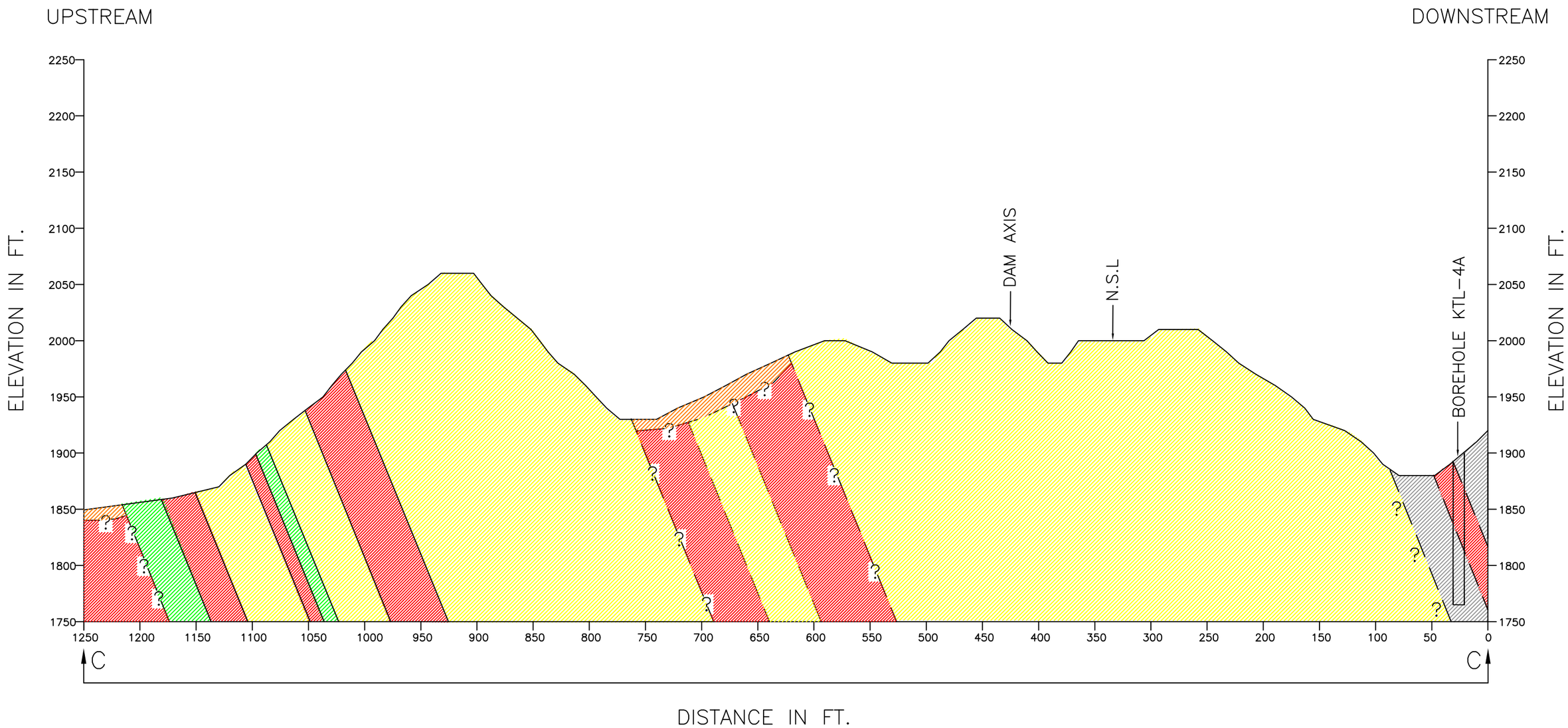

LEGEND

SANDSTONE _____

SHALE+SILTSTONE _____

OVERBURDEN (SCREE, ALLUVIUM) _____

LIMESTONE SHALLY _____

SILITY SAND STONE _____

NOTE:

FOR SECTION LINE C–C PLEASE REF. TO SURFACE GEOLOGICAL MAP FIGURE NO–2.3

0 100 200 FEET

S.NO.	DATE	DESCRIPTIONS	CHECK

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

KURRAM TANGI DAM PROJECT

GEOLOGICAL SECTION
LEFT ABUTMENT (C–C)

KURRAM TANGI DAM CONSULTANTS
188 –Y, COMMERCIAL AREA, PHASE–III,
D.H.A, LAHORE.

DRAWN:	M. NADEEM	DATE: DEC. 2003	REV. No.
SURVEYED:	ARSHAD HASHMI	FIGURE NO.	
CHECKED:	JAFAR HASSAN	2.7	
APPROVED:	JAMIL ANWER		

E:\NADEEM\KURRAM TANGI\FEASIBILITY-R\GEO-MAIN-DAM\GEO-SECTION\FIG-2.7.dwg

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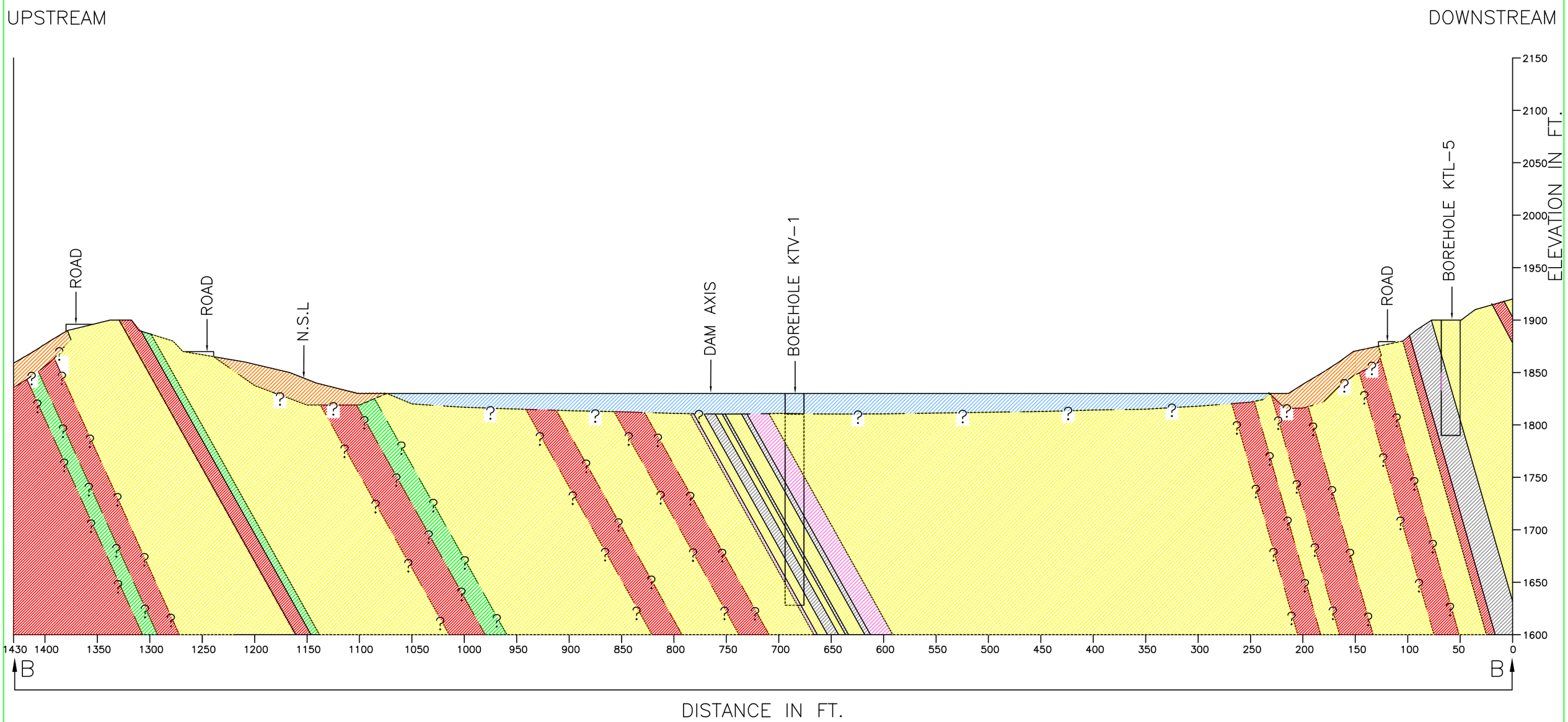

LEGEND

- SANDSTONE _____
- SHALE+SILTSTONE _____
- OVERBURDEN (SCREE, ALLUVIUM) _____
- LIMESTONE SHALLY _____
- SILITY SAND STONE _____
- CONGLOMARATIC SAND STONE __
- RIVER CHANNEL (SAND, GRAVELS, BOULDERS) __

NOTE:

FOR SECTION LINE BB PLEASE REF. TO SURFACE GEOLOGICAL MAP FIGURE NO-2.3

0 100 200 FEET

S.NO.	DATE	DESCRIPTIONS	CHECK

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

KURRAM TANGI DAM PROJECT

GEOLOGICAL SECTION ALONG RIVER CHANNEL (B-B)

KURRAM TANGI DAM CONSULTANTS
188 -Y, COMMERCIAL AREA, PHASE-III, D.H.A, LAHORE.

DRAWN:	M. NADEEM	DATE: DEC. 2003	REV. No.
SURVEYED:	ARSHAD HASHMI	FIGURE NO.	
CHECKED:	JAFFAR HASSAN	2.8	
APPROVED:	JAMIL ANWER		

E:\NADEEM\KURRAM TANGI\FEASIBILITY-R\GEO-MAIN-DAM\GEO-SECTION\FIG-2.8.dwg

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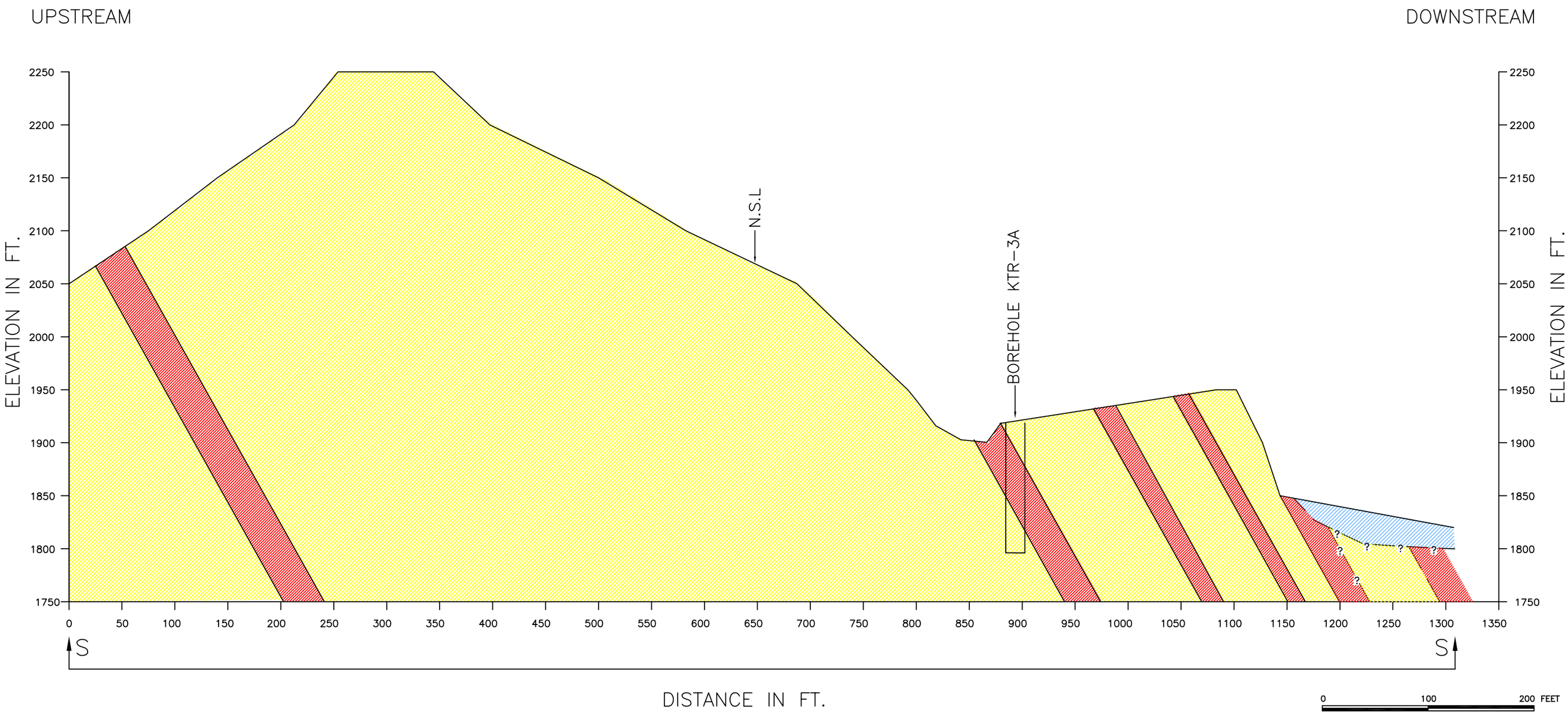

LEGEND

SANDSTONE _____

SHALE+SILTSTONE _____

RIVER CHANNEL
(SAND, GRAVELS, BOULDERS) __

NOTE:

FOR SECTION LINE S–S PLEASE REF. TO SURFACE GEOLOGICAL MAP FIGURE NO–2.3

S.NO.	DATE	DESCRIPTIONS	CHECK

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

KURRAM TANGI DAM PROJECT

GEOLOGICAL SECTION
ALONG SPILLWAY (S–S)

KURRAM TANGI DAM CONSULTANTS
188 –Y, COMMERCIAL AREA, PHASE–III,
D.H.A, LAHORE.

DRAWN:	M. NADEEM	DATE: DEC. 2003	REV. No.
SURVEYED:	ARSHAD HASHMI	FIGURE NO.	
CHECKED:	JAFAR HASSAN	2.9	
APPROVED:	JAMIL ANWER		

E:\NADEEM\KURRAM TANGI\FEASIBILITY-R\GEO-MAIN-DAM\GEO-SECTION\FIG-2.9.dwg

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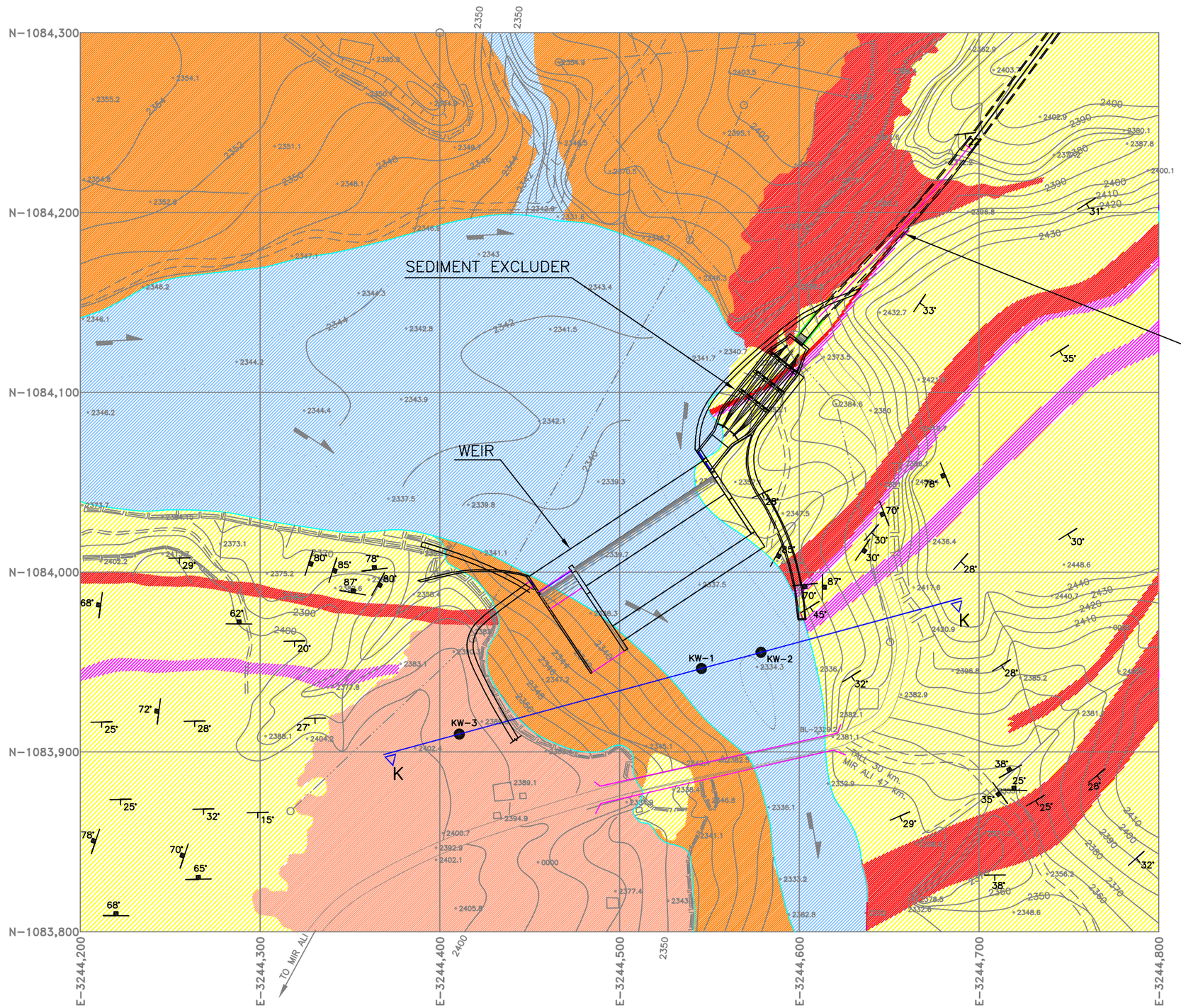

LEGEND

- SANDSTONE
- SHALE+SILTSTONE
- OVERBURDEN (SCREE, ALLUVIUM)
- OVERBURDEN (Compacted) (SAND, GRAVELS)
- SAND STONE GRITTY
- RIVER CHANNEL (SAND, GRAVELS, BOULDERS)
- BORE HOLE COMPLETED
- DIP STRIKE OF JOINTS — 80°
- DIP STRIKE OF BEDS — 87°

0 200 400 FEET

NOTES

ALL COORDINATES ARE IN YARDS

ALL TOPOGRAPHY ARE IN FEET

S.NO.	DATE	DESCRIPTIONS	CHECK

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

KURRAM TANGI DAM PROJECT

GEOLOGICAL MAP OF KAITU WEIR

KURRAM TANGI DAM CONSULTANTS
188 -Y, COMMERCIAL AREA, PHASE-III, D.H.A, LAHORE.

DRAWN:	M. NADEEM	DATE: DEC. 2003	REV. No.
SURVEYED:	ARSHAD HASHMI	FIGURE NO. 2.10	
CHECKED:	JAFFAR HASSAN		
APPROVED:	JAMIL ANWER		

E:\NADEEM\KURRAM TANGI\FEASIBILITY-R\KAITU-FEEDER-CANAL\GEOLOGY\KAITU-WEIR-OLD\FIG-2.10.dwg

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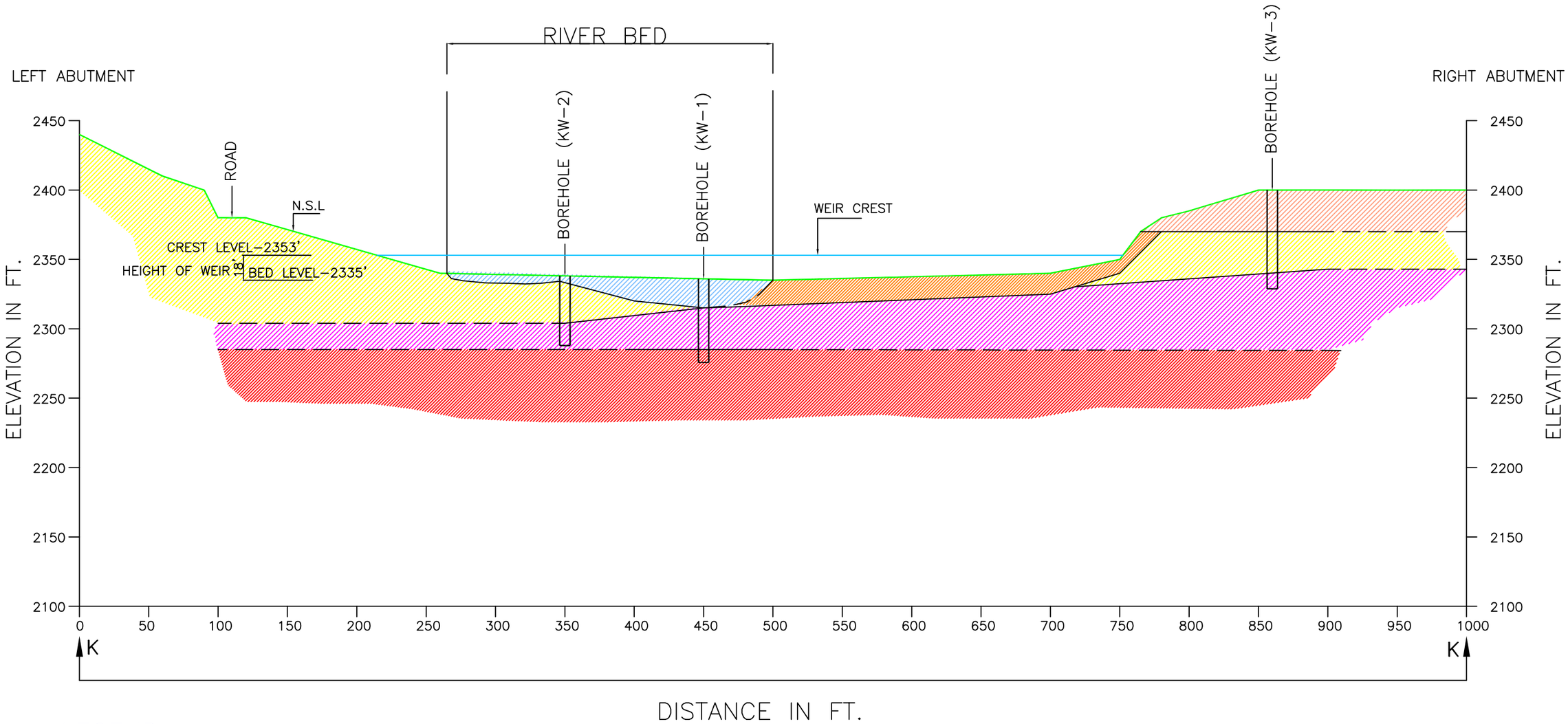

LEGEND

- SANDSTONE
- SHALE + SILTSTONE
- OVERBURDEN (SCREE, ALLUVIUM)
- OVERBURDEN (Compacted) (SAND, GRAVELS
- SAND STONE GRITTY
- RIVER CHANNEL (SAND, GRAVELS, BOULDERS)

NOTE:

FOR SECTION LINE (K–K') REFER TO GEOLOGICAL MAP OF KAITU WEIR (FIGURE NO–2.10)

0 80 160 FEET

S.NO.	DATE	DESCRIPTIONS	CHECK

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

KURRAM TANGI DAM PROJECT

GEOLOGICAL SECION ALONG KAITU WEIR (K–K)

KURRAM TANGI DAM CONSULTANTS
188 –Y, COMMERCIAL AREA, PHASE–III, D.H.A, LAHORE.

DRAWN:	M. NADEEM	DATE: DEC. 2003	REV. No.
SURVEYED:	ARSHAD HASHMI	FIGURE NO. 2.11	
CHECKED:	JAFFAR HASSAN		
APPROVED:	JAMIL ANWER		

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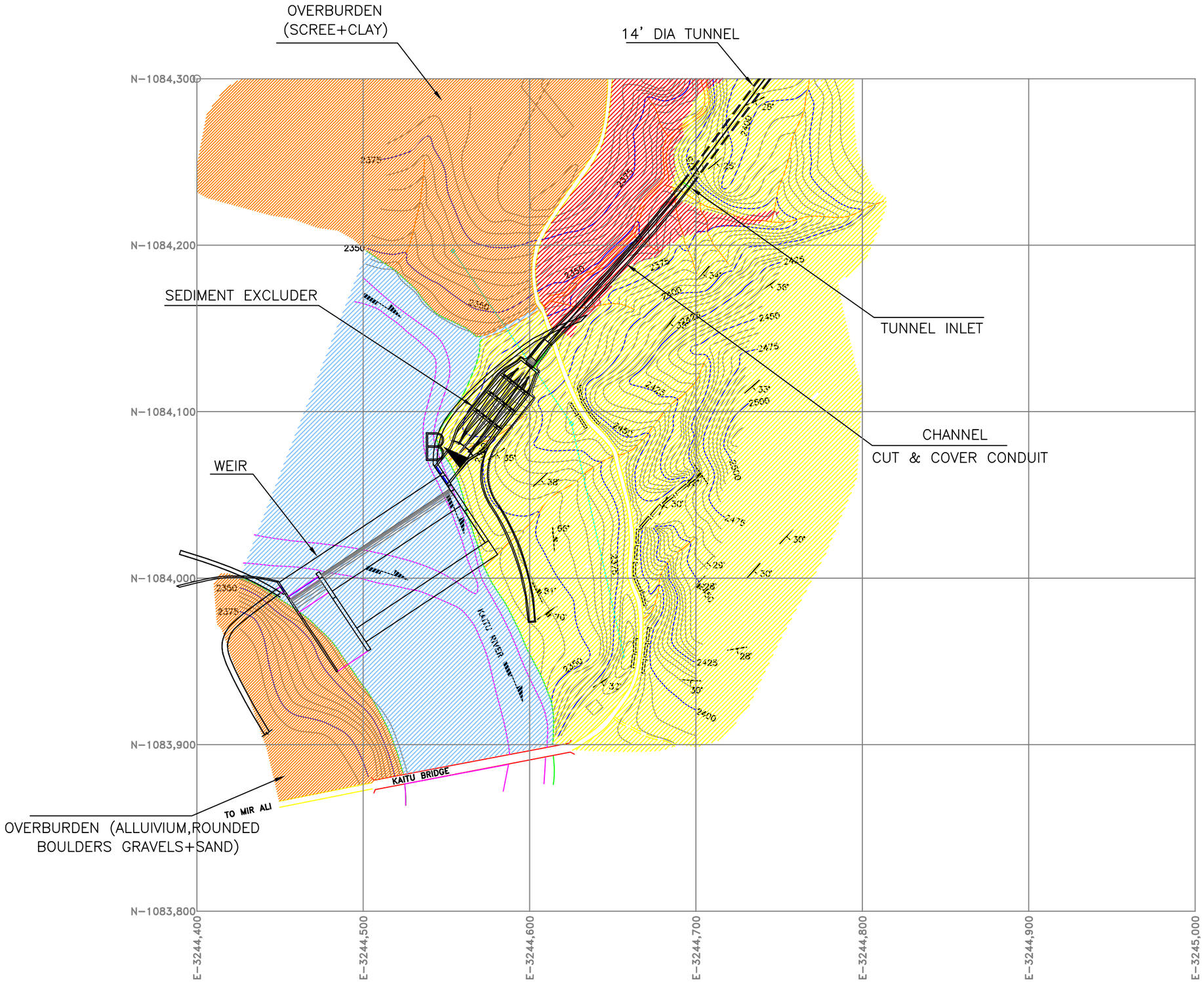
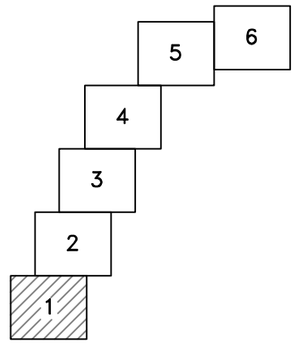


LEGEND

- SHALE
- SANDSTONE
- RIVER(KAITU)
- OVERBURDEN
- BORE HOLE (COMPLETD)
- DIP STRIKE OF JOINTS — 80°
- DIP STRIKE OF BEDS — 87°
- GRAVEYARD

INDEX



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S.NO.	DATE	DESCRIPTIONS	CHECK

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

KURRAM TANGI DAM PROJECT

GEOLOGICAL MAP
KAITU FEEDER TUNNEL

KURRAM TANGI DAM CONSULTANTS
188 -Y, COMMERCIAL AREA, PHASE-III,
D.H.A, LAHORE.

DRAWN:	M. NADEEM	DATE: DEC. 2003	REV. No.
SURVEYED:	A. HASHMI	FIGURE NO.	
CHECKED:	J. HASAN	2.12	
APPROVED:	JAMIL ANWER		

E:\NADEEM\KURRAM TANGI\FEASIBILITY-R\KAITU-FEEDER-CANAL\GEOLOGY\FIG-2.12-1.dwg

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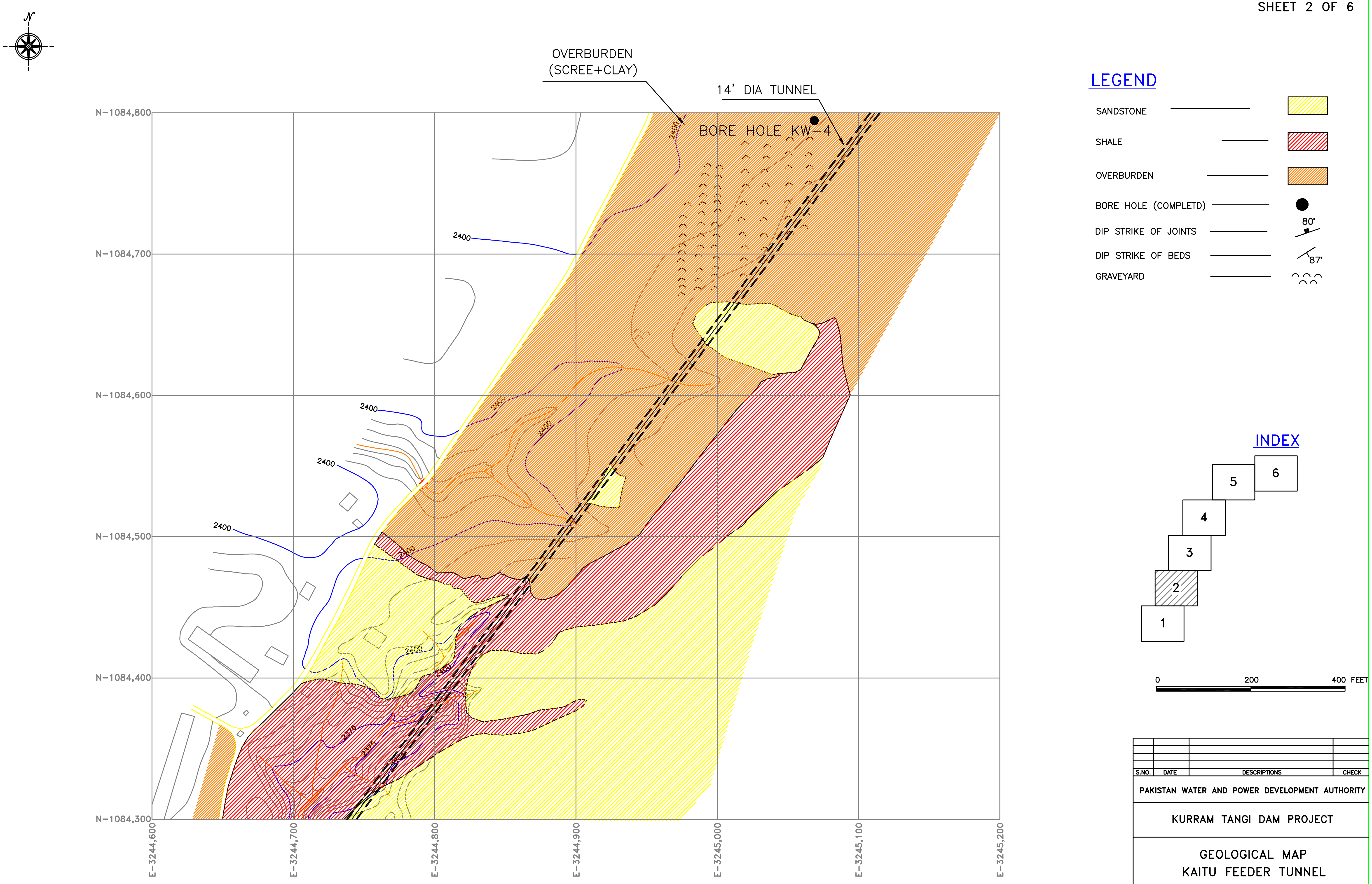

S.NO.	DATE	DESCRIPTIONS	CHECK

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

KURRAM TANGI DAM PROJECT

GEOLOGICAL MAP
KAITU FEEDER TUNNEL

KURRAM TANGI DAM CONSULTANTS
188 -Y, COMMERCIAL AREA, PHASE-III,
D.H.A, LAHORE.

DRAWN:	M. NADEEM	DATE: DEC. 2003	REV. No.
SURVEYED:	A. HASHMI	FIGURE NO.	
CHECKED:	J. HASAN	2.12	
APPROVED:	JAMIL ANWER		

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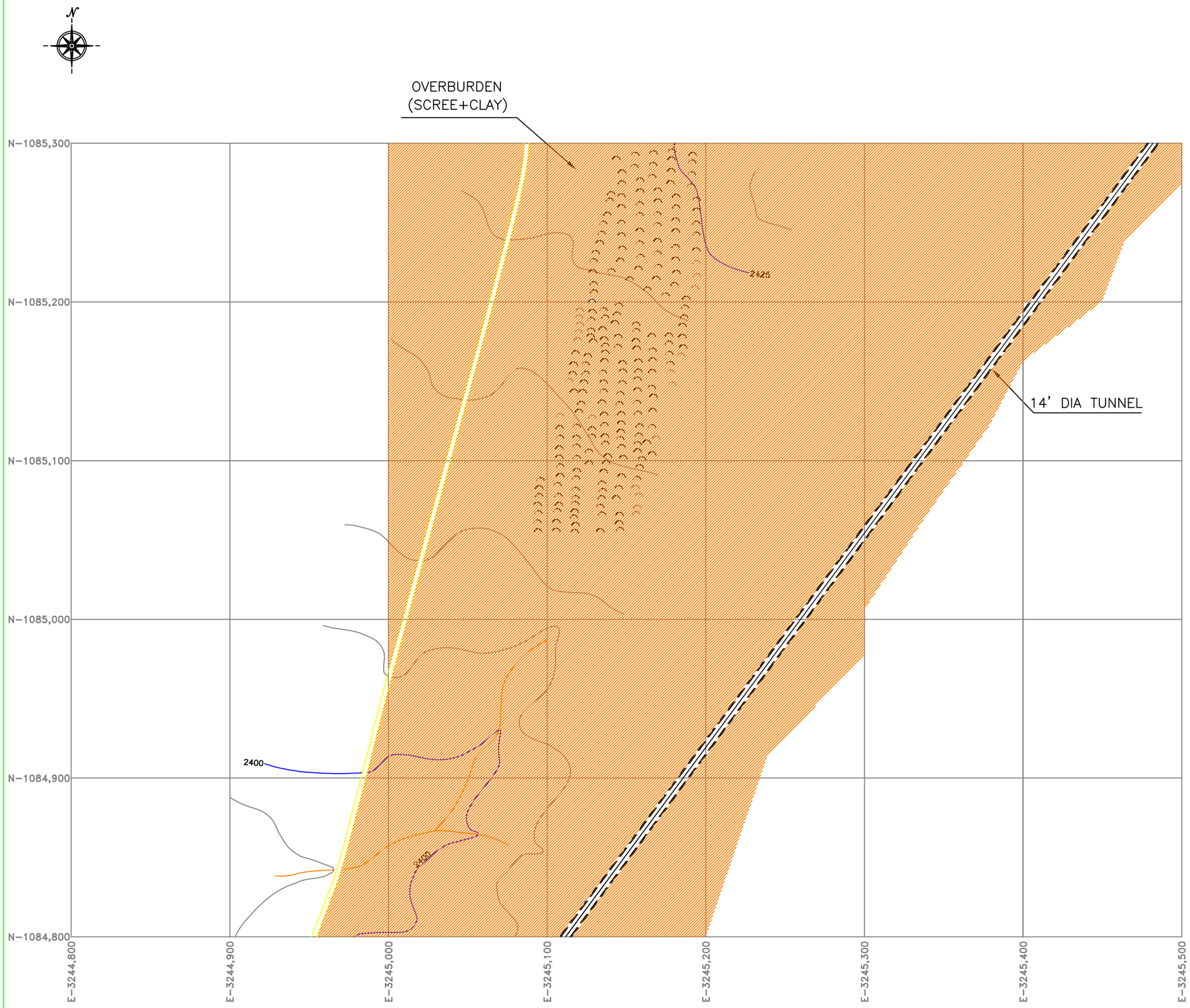
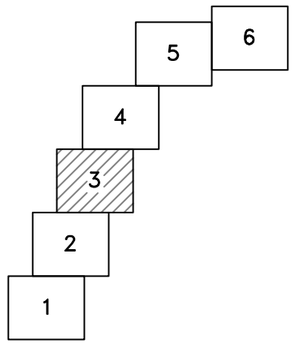


LEGEND

OVERBURDEN _____

GRAVEYARD _____

INDEX



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PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

KURRAM TANGI DAM PROJECT

GEOLOGICAL MAP
KAITU FEEDER TUNNEL

KURRAM TANGI DAM CONSULTANTS
188 -Y, COMMERCIAL AREA, PHASE-III,
D.H.A, LAHORE.

DRAWN:	M. NADEEM	DATE: DEC. 2003	REV. No.
SURVEYED:	A. HASHMI	FIGURE NO.	
CHECKED:	J. HASAN	2.12	
APPROVED:	JAMIL ANWER		

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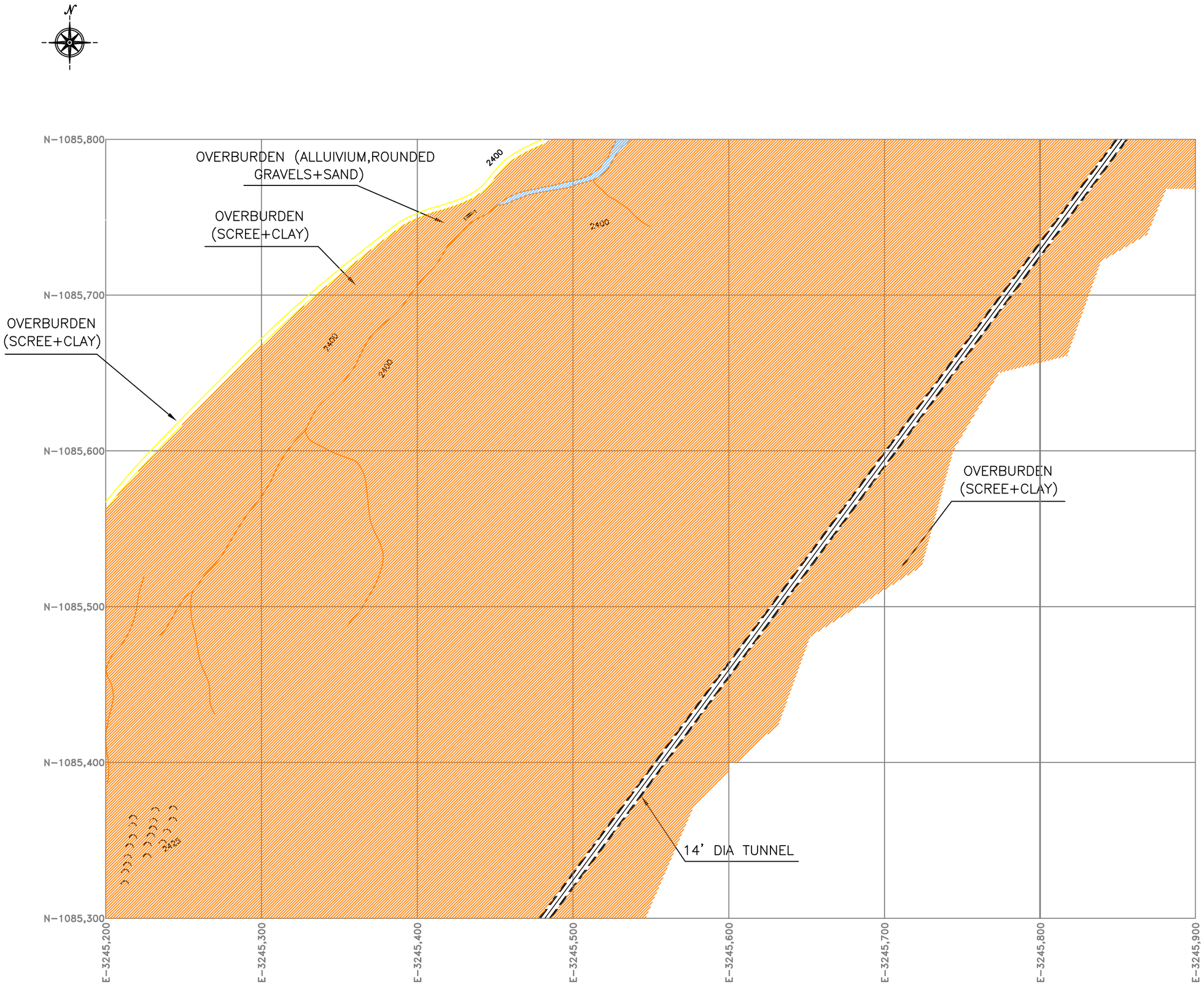


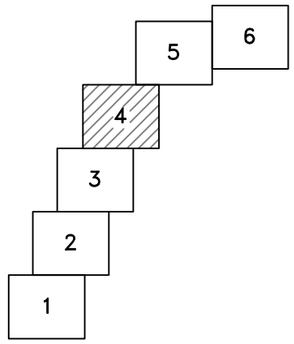
LEGEND

RIVER(KAITU) _____

OVERBURDEN _____

GRAVEYARD _____

INDEX



0 200 400 FEET

S.NO.	DATE	DESCRIPTIONS	CHECK

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

KURRAM TANGI DAM PROJECT

GEOLOGICAL MAP
KAITU FEEDER TUNNEL

KURRAM TANGI DAM CONSULTANTS
188 -Y, COMMERCIAL AREA, PHASE-III,
D.H.A, LAHORE.

DRAWN:	M. NADEEM	DATE: DEC. 2003	REV. No.
SURVEYED:	A. HASHMI	FIGURE NO.	
CHECKED:	J. HASAN	2.12	
APPROVED:	JAMIL ANWER		

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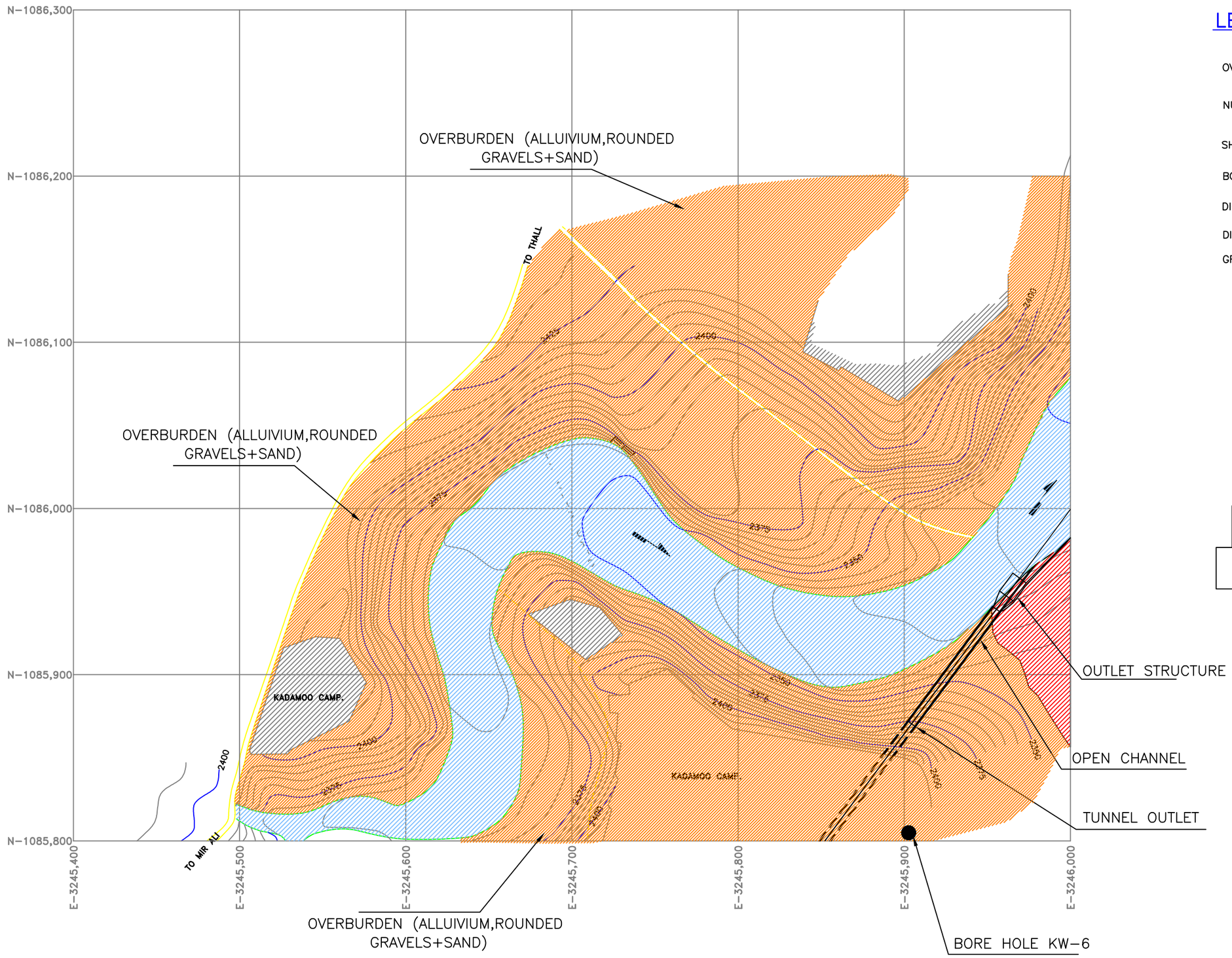
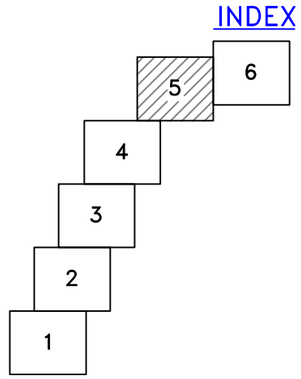


LEGEND

- OVERBURDEN
- NULLAH
- SHALE(BASKA)
- BORE HOLE (COMPLETD)
- DIP STRIKE OF JOINTS — 80°
- DIP STRIKE OF BEDS — 87°
- GRAVEYARD

INDEX



0 200 400 FEET

S.NO.	DATE	DESCRIPTIONS	CHECK

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

KURRAM TANGI DAM PROJECT

GEOLOGICAL MAP
KAITU FEEDER TUNNEL

KURRAM TANGI DAM CONSULTANTS
188 -Y, COMMERCIAL AREA, PHASE-III,
D.H.A, LAHORE.

DRAWN:	M. NADEEM	DATE: DEC. 2003	REV. No.
SURVEYED:	A. HASHMI	FIGURE NO.	
CHECKED:	J. HASAN	2.12	
APPROVED:	JAMIL ANWER		

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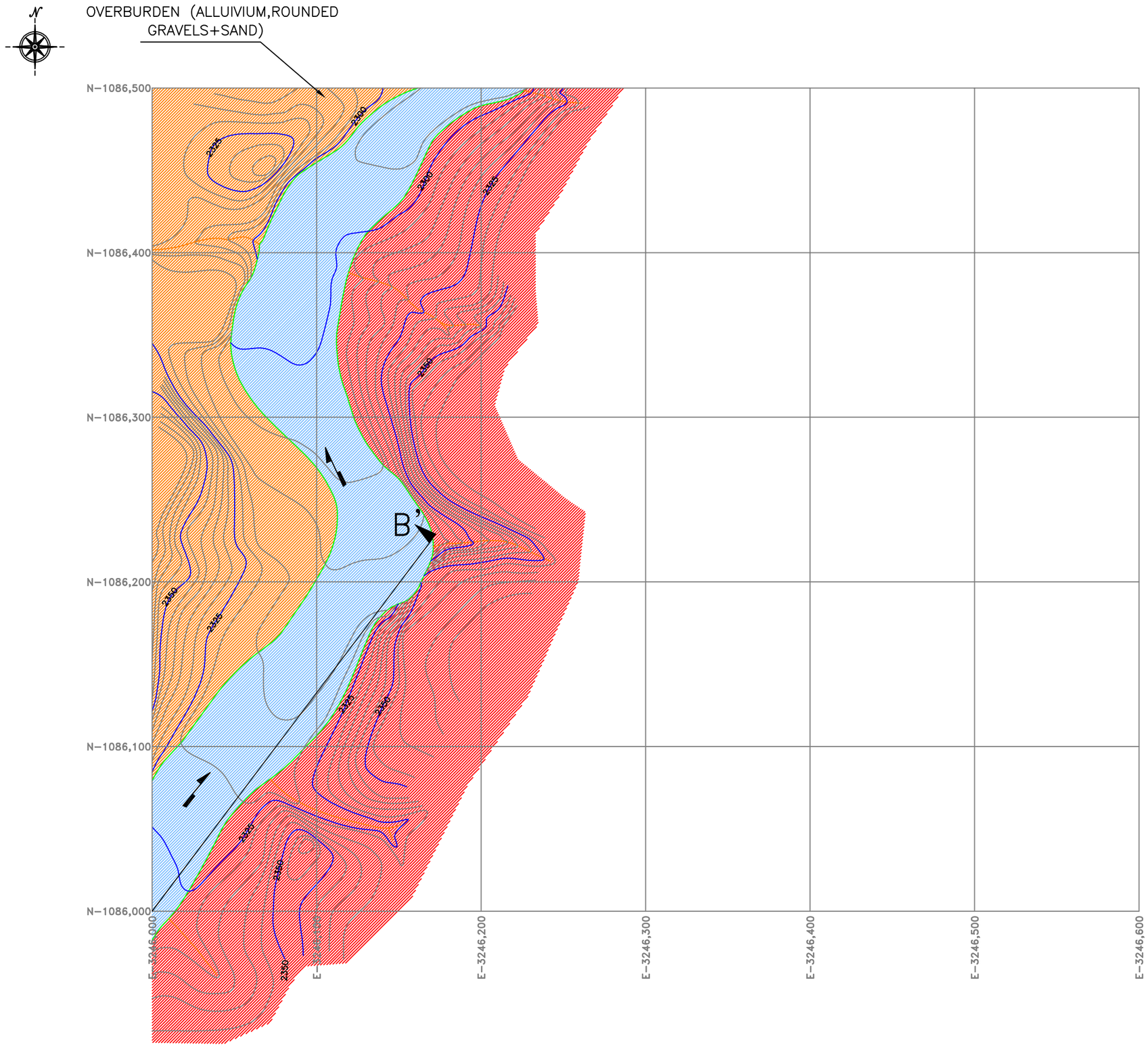
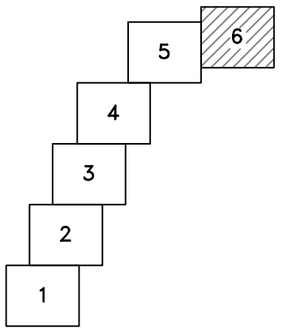


LEGEND

- NULLAH
- OVERBURDEN
- SHALE(BASKA)
- GRAVEYARD

INDEX



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S.NO.	DATE	DESCRIPTIONS	CHECK

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

KURRAM TANGI DAM PROJECT

GEOLOGICAL MAP
KAITU FEEDER TUNNEL

KURRAM TANGI DAM CONSULTANTS
188 -Y, COMMERCIAL AREA, PHASE-III,
D.H.A, LAHORE.

DRAWN:	M. NADEEM	DATE: DEC. 2003	REV. No.
SURVEYED:	A. HASHMI	FIGURE NO.	
CHECKED:	J. HASAN	2.12	
APPROVED:	JAMIL ANWER		

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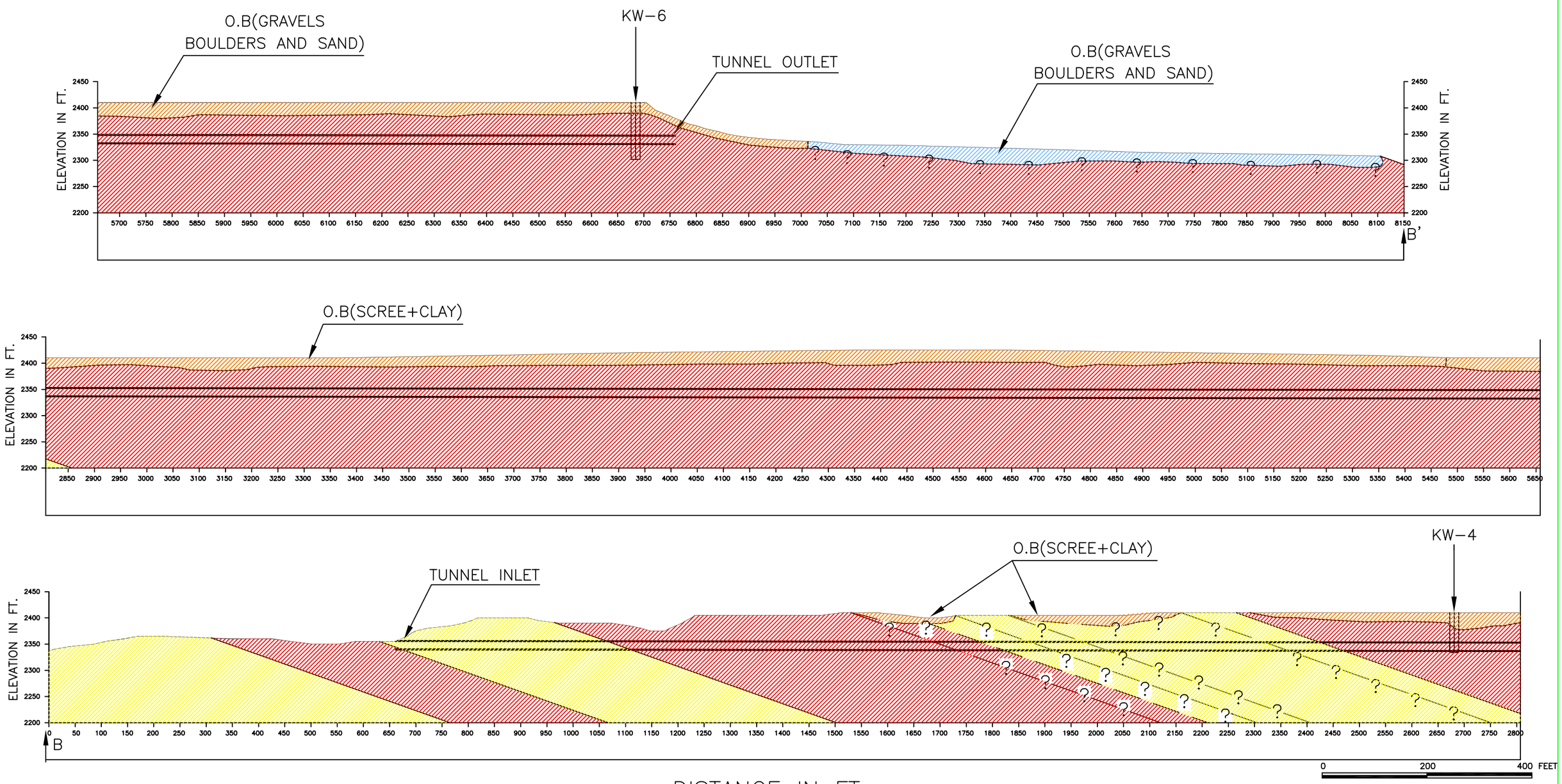

LEGEND:

- NULLAH CHANNEL
- SHALE
- SANDSTONE
- OVERBURDEN

NOTE:

FOR SECTION LINE (BB') PLEASE REFER TO GEOLOGICAL MAP OF KAITU FEEDER TUNNEL (FIGURE NO-2.12)

S.NO.	DATE	DESCRIPTIONS	CHECK

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

KURRAM TANGI DAM PROJECT

GEOLOGICAL SECTION (BB')
ALONG KAITU FEEDER TUNNEL

KURRAM TANGI DAM CONSULTANTS
188 -Y, COMMERCIAL AREA, PHASE-III,
D.H.A, LAHORE.

DRAWN:	M. NADEEM	DATE: DEC. 2003	REV. No.
SURVEYED:	A. HASHMI	FIGURE NO.	
CHECKED:	J. HASAN	2.13	
APPROVED:	JAMIL ANWER		

E:\NADEEM\KURRAM TANGI\FEASIBILITY-R\KAITU-FEEDER-CANAL\GEOLOGY\FIG-2.13.dwg

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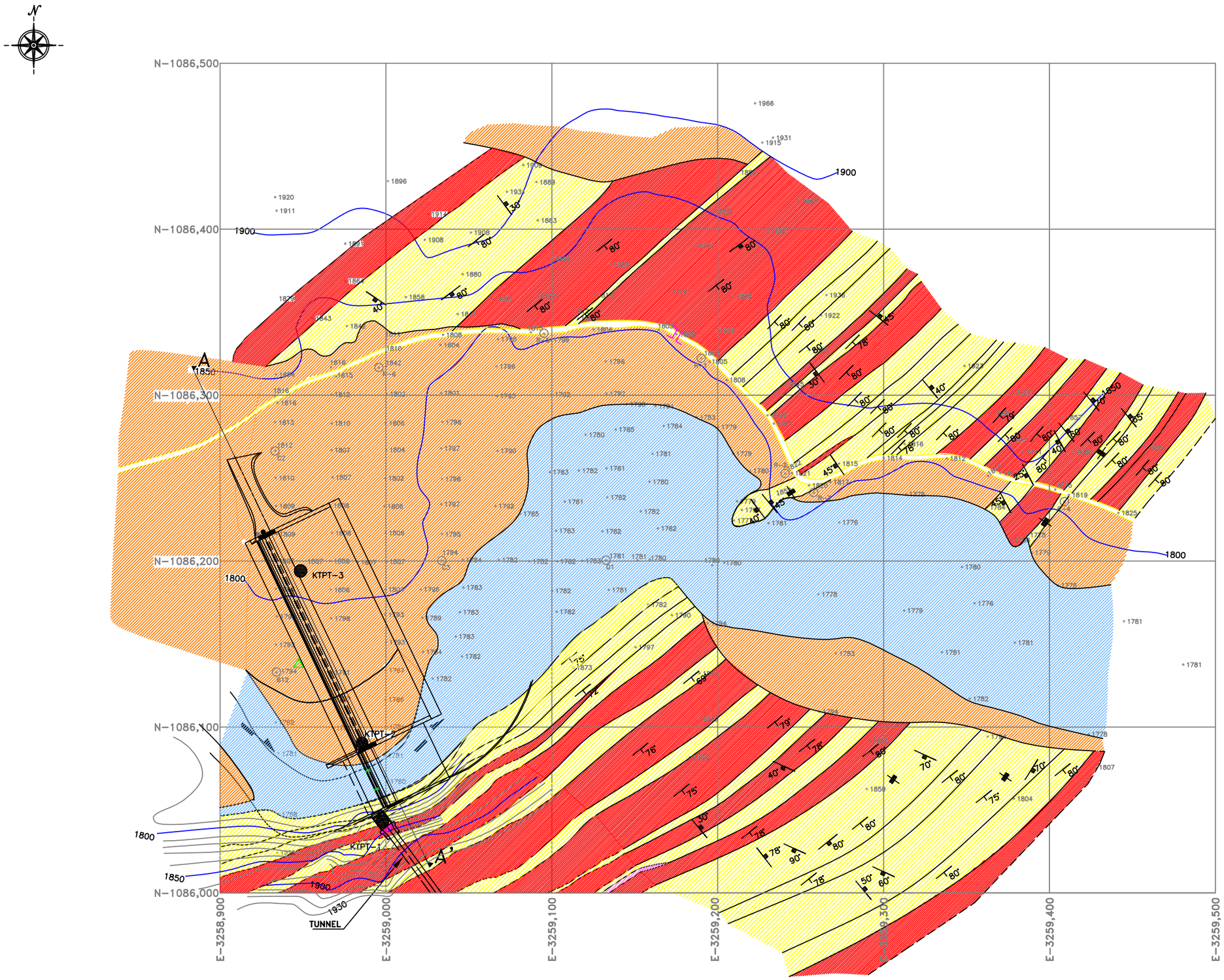

LEGEND

- SANDSTONE
- SHALE+SILTSTONE
- OVERBURDEN (SCREE, ALLUVIUM)
- CONGLOMARATIC SAND STONE
- RIVER CHANNEL (SAND, GRAVELS, BOULDERS)
- BORE HOLE COMPLETED — KTPT
- DIP STRIKE OF JOINTS — 80°
- DIP STRIKE OF BEDS — 87°

0 200 400 FEET

S.NO.	DATE	DESCRIPTIONS	CHECK

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

KURRAM TANGI DAM PROJECT

GEOLOGICAL MAP OF WEIR FOR POWER HOUSE-II

KURRAM TANGI DAM CONSULTANTS
188 -Y, COMMERCIAL AREA, PHASE-III, D.H.A, LAHORE.

DRAWN:	SAIF ULLAH	DATE: DEC. 2003	REV. No.
SURVEYED:	ARSHAD HASHAMI	FIGURE NO. 2.14	
CHECKED:	JAFAR HASSAN		
APPROVED:	JAMIL ANWER		

E:\NADEEM\KURRAM TANGI\FEASIBILITY-R\TUNNEL-2\geology\FIG-2.14.dwg

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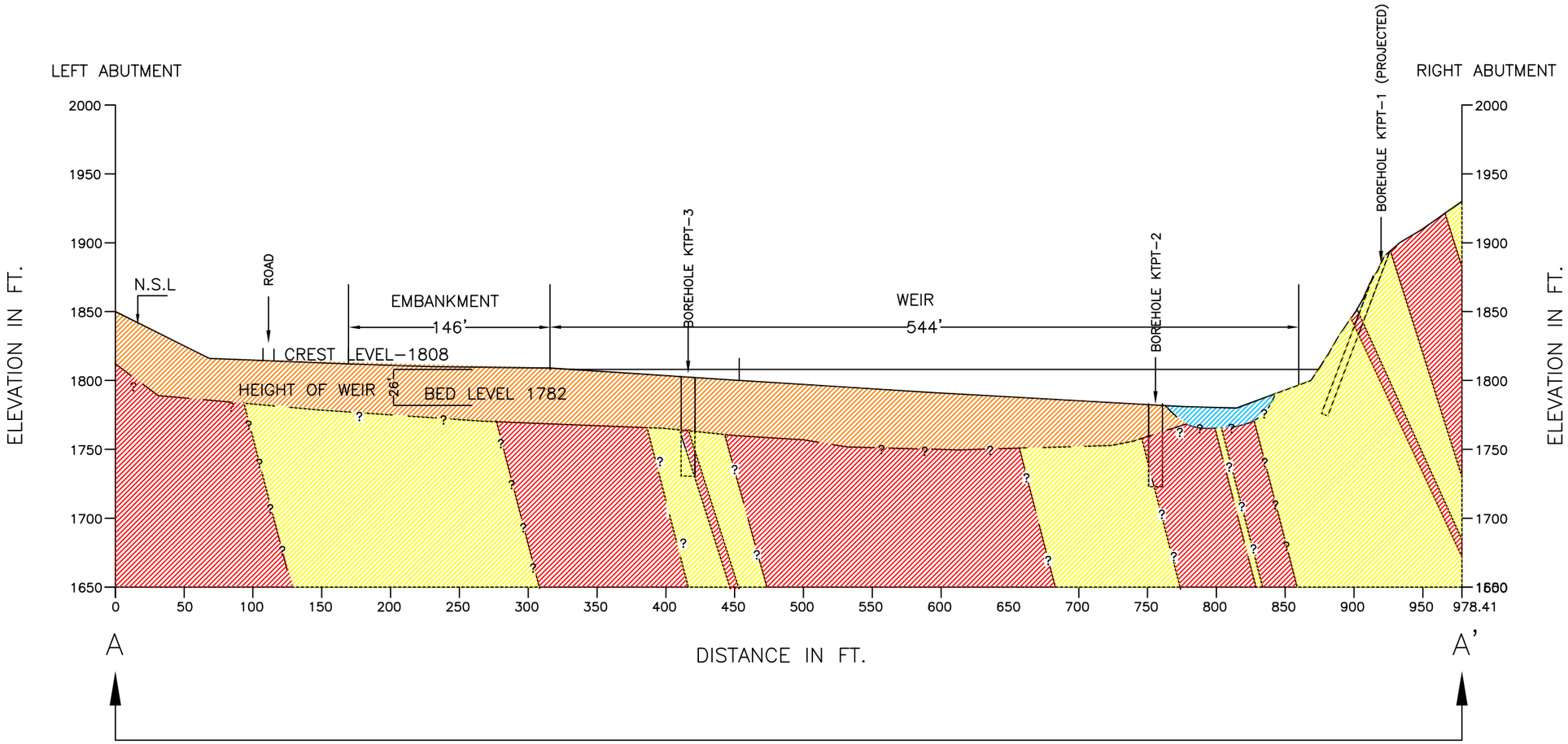

0 100 200 FEET

LEGEND:

- RIVER CHANNEL
- SHALE
- SANDSTONE
- OVERBURDEN

NOTE

FOR SECTION A–A' REFERS TO GEOLOGICAL MAP OF WEIR FOR POWER HOUSE–II(FIGURE NO–2.14)

S.NO.	DATE	DESCRIPTIONS	CHECK

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

KURRAM TANGI DAM PROJECT

GEOLOGICAL–SECTION (AA') ALONG WEIR OF POWER HOUSE–II

KURRAM TANGI DAM CONSULTANTS
188 –Y, COMMERCIAL AREA, PHASE–III,
D.H.A, LAHORE.

DRAWN:	M. NADEEM	DATE: DEC. 2003	REV. No.
SURVEYED:	ARSHAD HASHMI	FIGURE NO.	
CHECKED:	JAFAR HASSAN	2.15	
APPROVED:	JAMIL ANWER		

E:\NADEEM\KURRAM TANGI\FEASIBILITY-R\TUNNEL-2\geology\FIG-2.15.dwg

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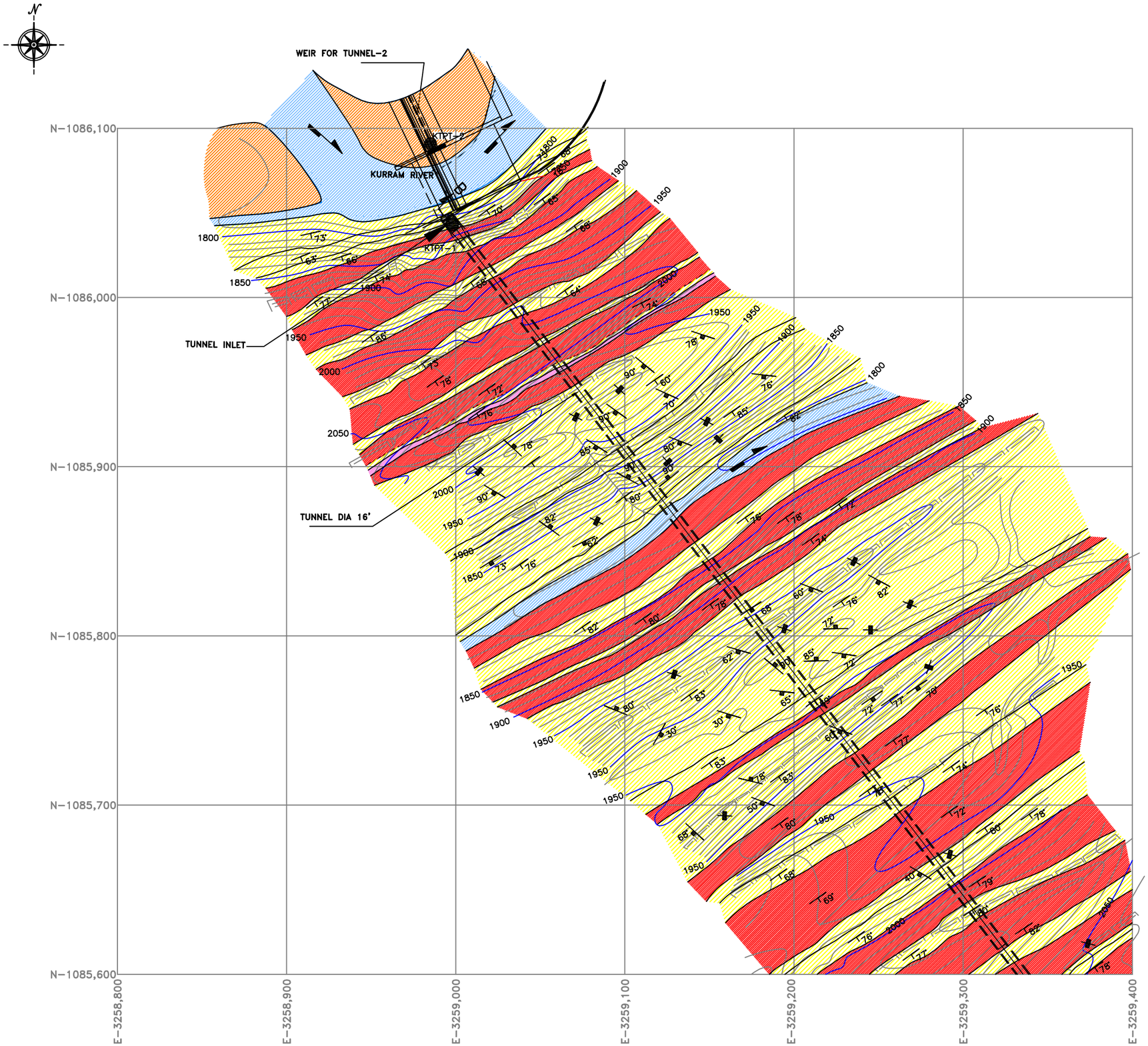

LEGEND

- SANDSTONE
- SHALE+SILTSTONE
- OVERBURDEN (SCREE, ALLUVIUM)
- CONGLOMARATIC SAND STONE
- RIVER CHANNEL (SAND, GRAVELS, BOULDERS)
- BORE HOLE COMPLETED — KTPT
- DIP STRIKE OF JOINTS — 80°
- DIP STRIKE OF BEDS — 87°

0 200 400 FEET

S.NO.	DATE	DESCRIPTIONS	CHECK

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

KURRAM TANGI DAM PROJECT

GEOLOGICAL MAP OF POWER TUNNEL-II

KURRAM TANGI DAM CONSULTANTS
188 -Y, COMMERCIAL AREA, PHASE-III,
D.H.A, LAHORE.

DRAWN:	SAIF ULLAH	DATE: DEC. 2003	REV. No.
SURVEYED:	ARSHAD HASHMI	FIGURE NO.	
CHECKED:	JAFAR HASSAN	2.16	
APPROVED:	JAMIL ANWER		

E:\NADEEM\KURRAM TANGI\FEASIBILITY-R\TUNNEL-2\geology\FIG-2.16-1.dwg

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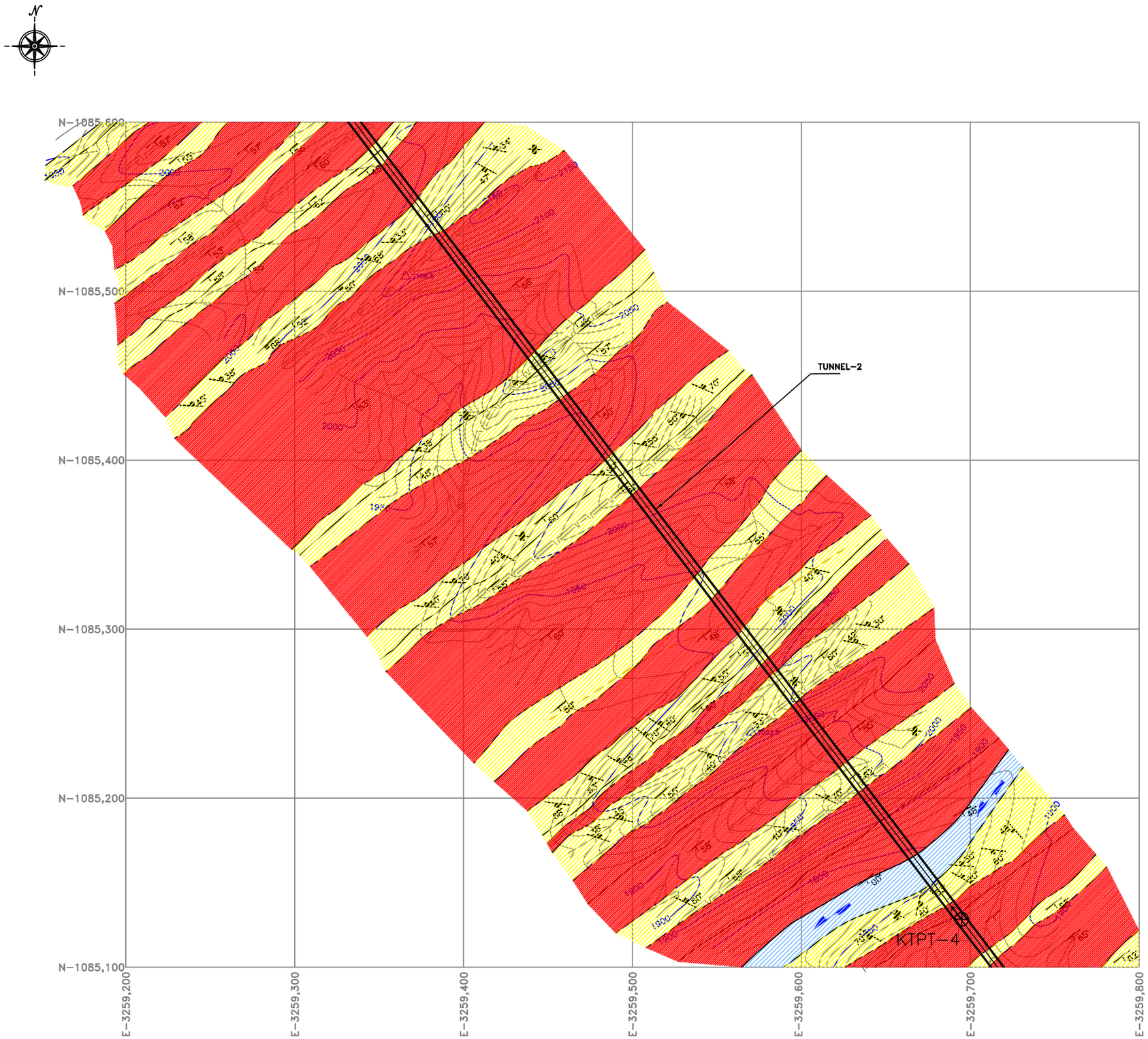

LEGEND

- SANDSTONE
- SHALE+SILTSTONE
- RIVER CHANNEL (SAND, GRAVELS, BOULDERS)
- PROPOSED INCLINED BORE — KTPT
- DIP STRIKE OF JOINTS — 80°
- DIP STRIKE OF BEDS — 87°

0 200 400 FEET

S.NO.	DATE	DESCRIPTIONS	CHECK

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

KURRAM TANGI DAM PROJECT

GEOLOGICAL MAP OF POWER TUNNEL-II

KURRAM TANGI DAM CONSULTANTS
188 -Y, COMMERCIAL AREA, PHASE-III,
D.H.A, LAHORE.

DRAWN:	SAIF ULLAH	DATE: DEC. 2003	REV. No.
SURVEYED:	ARSHAD HASHMI	FIGURE NO.	
CHECKED:	JAFAR HASSAN	2.16	
APPROVED:	JAMIL ANWER		

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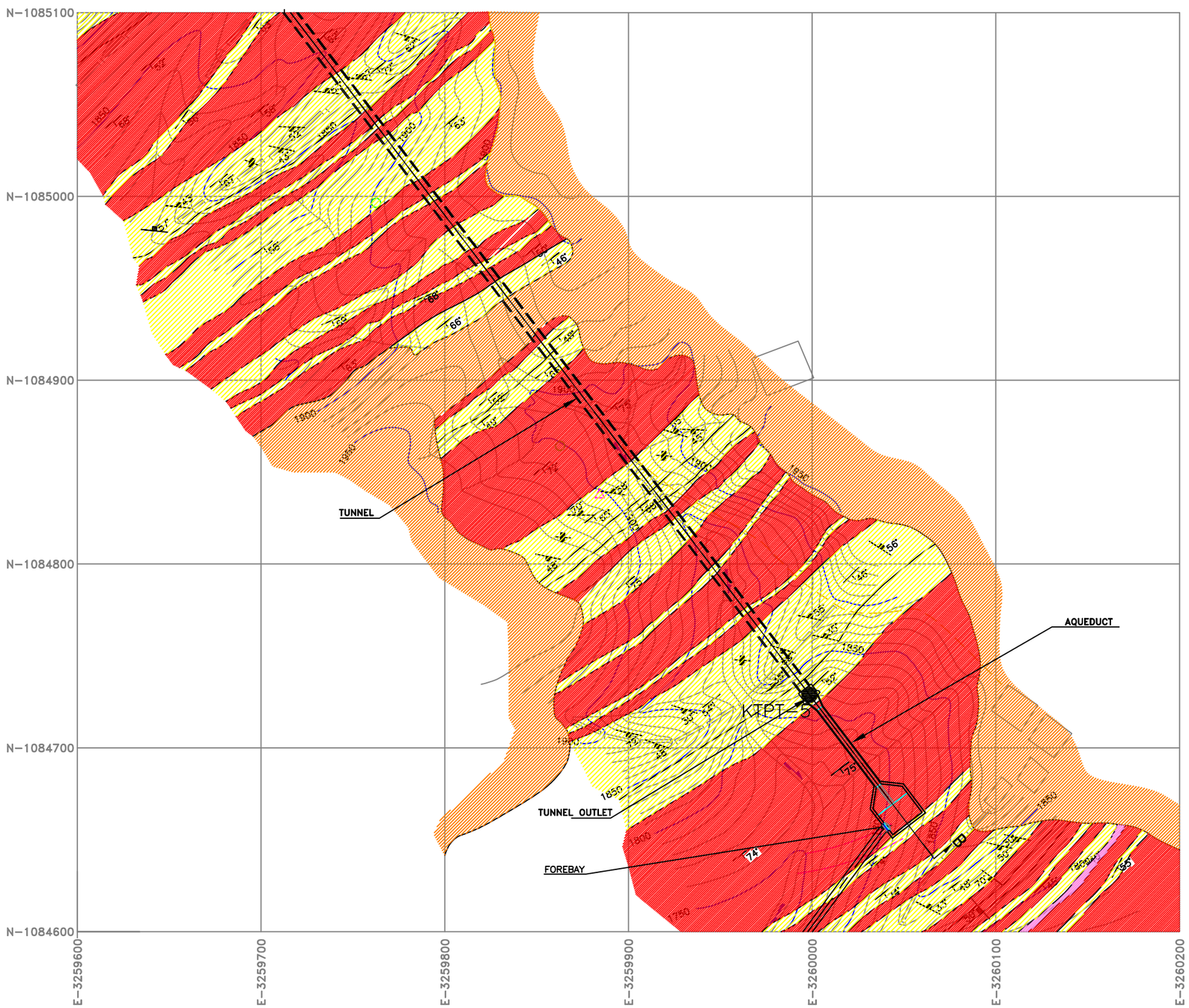

LEGEND

- SANDSTONE
- SHALE+SILTSTONE
- OVERBURDEN (SCREE, ALLUVIUM)
- CONGLOMARATIC SAND STONE
- BORE HOLE COMPLETED — KTPT
- DIP STRIKE OF JOINTS — 80°
- DIP STRIKE OF BEDS — 87°

0 200 400 FEET

S.NO.	DATE	DESCRIPTIONS	CHECK

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

KURRAM TANGI DAM PROJECT

GEOLOGICAL MAP OF POWER TUNNEL-II

KURRAM TANGI DAM CONSULTANTS
188 -Y, COMMERCIAL AREA, PHASE-III,
D.H.A, LAHORE.

DRAWN:	SAIF ULLAH	DATE: DEC. 2003	REV. No.
SURVEYED:	ARSHAD HASHMI	FIGURE NO.	
CHECKED:	JAFAR HASSAN	2.16	
APPROVED:	JAMIL ANWER		

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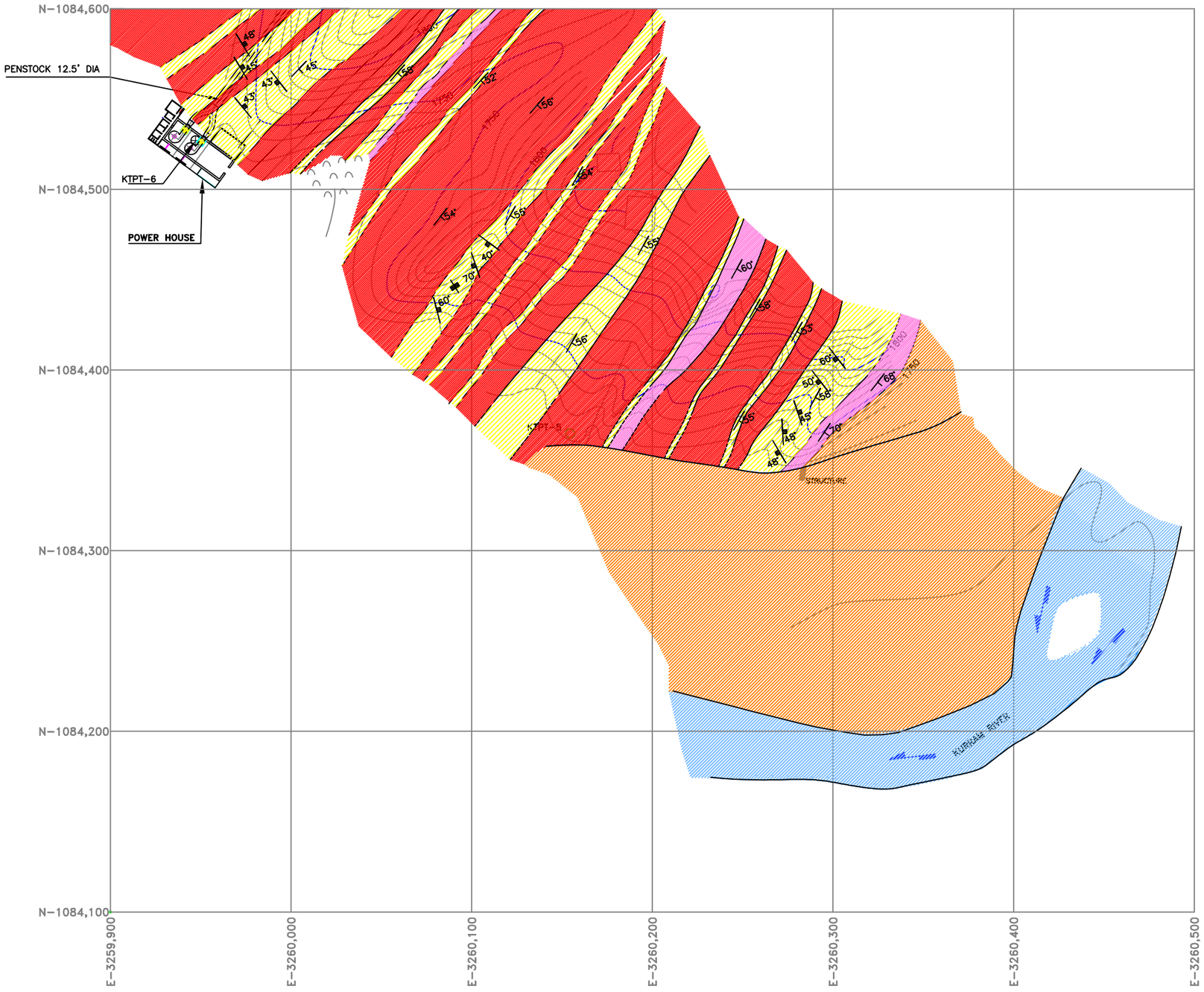

LEGEND

- SANDSTONE
- SHALE+SILTSTONE
- OVERBURDEN (SCREE, ALLUVIUM)
- CONGLOMARATIC SAND STONE
- PROPOSED INCLINED BORE — KTPT
- DIP STRIKE OF JOINTS — 80°
- DIP STRIKE OF BEDS — 87°

0 200 400 FEET

S.NO.	DATE	DESCRIPTIONS	CHECK

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

KURRAM TANGI DAM PROJECT

GEOLOGICAL MAP OF POWER TUNNEL-II

KURRAM TANGI DAM CONSULTANTS
188 -Y, COMMERCIAL AREA, PHASE-III,
D.H.A, LAHORE.

DRAWN:	SAIF ULLAH	DATE: DEC. 2003	REV. No.
SURVEYED:	ARSHAD HASHMI	FIGURE NO.	
CHECKED:	JAFAR HASSAN	2.16	
APPROVED:	JAMIL ANWER		

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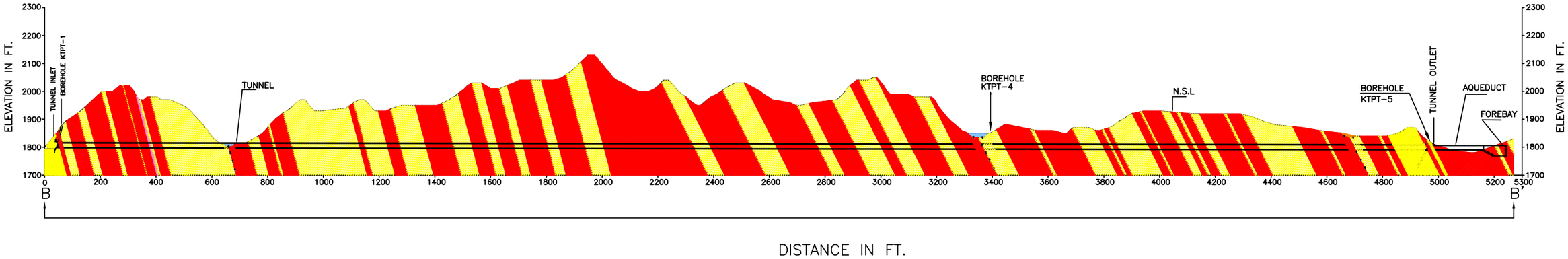

0 400 800 FEET

LEGEND:

- NULLAH
- SHALE
- SANDSTONE
- CONGLOMARATIC
- OVERBURDEN

NOTE

FOR SECTION B–B' REFERS TO
GEOLOGICAL MAP OF POWER TUNNEL–II (FIGURE NO–2.16)

S.NO.	DATE	DESCRIPTIONS	CHECK

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

KURRAM TANGI DAM PROJECT

GEOLOGICAL SECTION ALONG
POWER TUNNEL –II

KURRAM TANGI DAM CONSULTANTS
188 –Y, COMMERCIAL AREA, PHASE–III,
D.H.A, LAHORE.

DRAWN:	M. NADEEM	DATE: DEC. 2003	REV. No.
SURVEYED:	ARSHAD HASHMI	FIGURE NO.	
CHECKED:	JAFFAR HASSAN	2.17	
APPROVED:	JAMIL ANWER		

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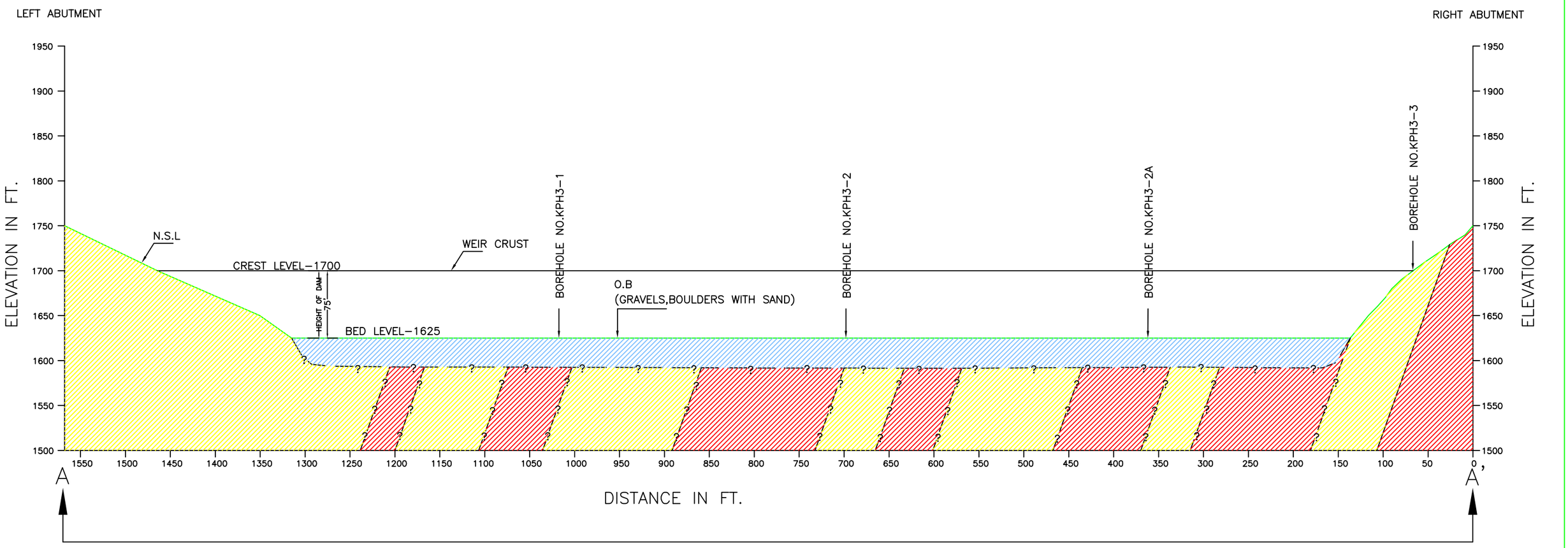

0 120 240 FEET

LEGEND:

- NULLAH CHANNEL
- SHALE
- SANDSTONE

NOTE:

FOR SECTION LINE (AA') REFER TO GEOLOGICAL MAP OF WEIR FOR POWER HOUSE–III (FIGURE NO–2.18)

S.NO.	DATE	DESCRIPTIONS	CHECK

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

KURRAM TANGI DAM PROJECT

GEOLOGICAL SECTION ALONG WEIR OF POWER HOUSE–III(AA')

KURRAM TANGI DAM CONSULTANTS
188 –Y, COMMERCIAL AREA, PHASE–III,
D.H.A, LAHORE.

DRAWN:	M. NADEEM	DATE: DEC. 2003	REV. No.
SURVEYED:	ARSHAD HASHMI	FIGURE NO. 2.19	
CHECKED:	JAFAR HASSAN		
APPROVED:	JAMIL ANWER		

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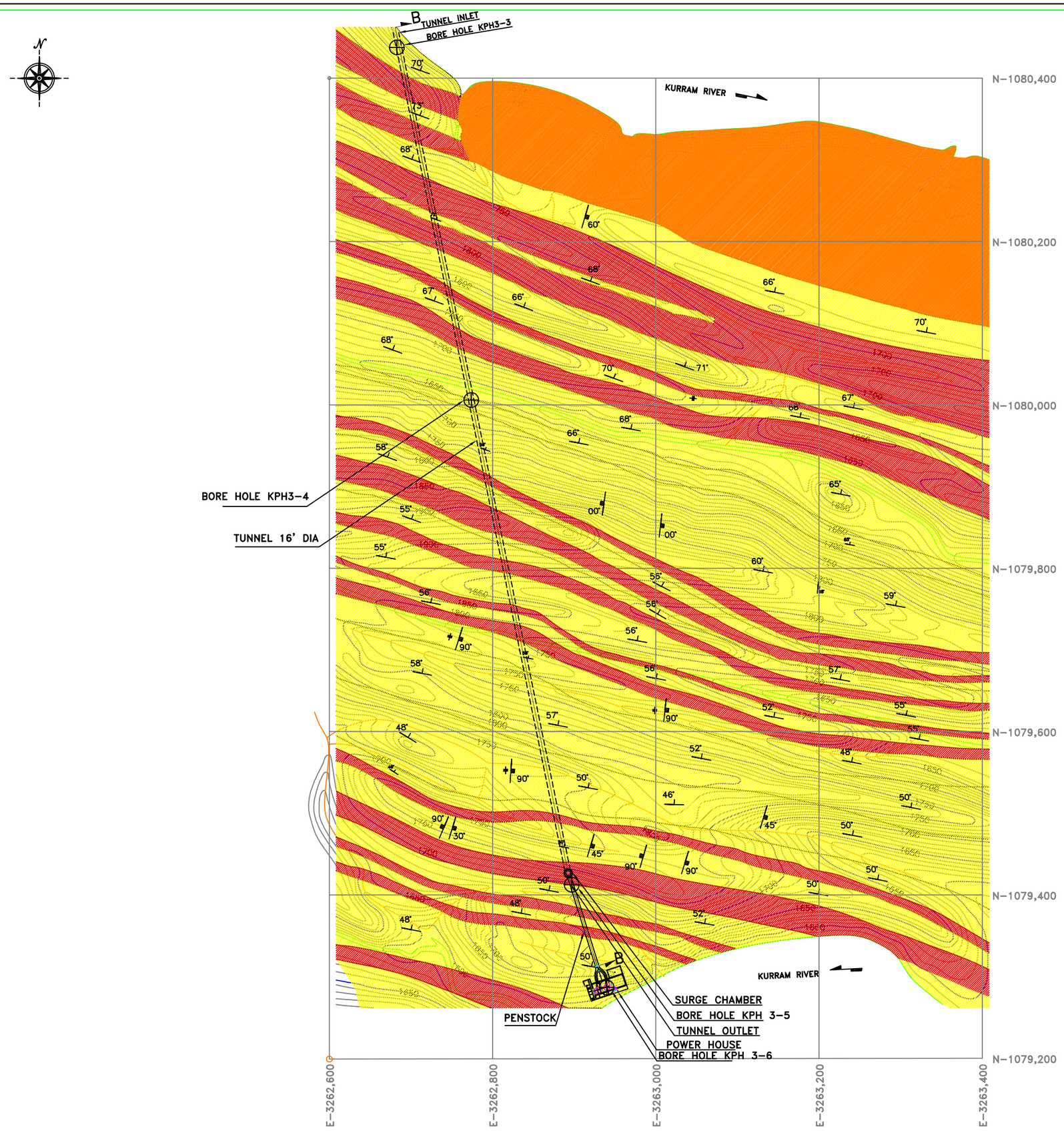

LEGEND

SANDSTONE _____

SHALE _____

OVERBURDEN _____
(SCREE, ALLUVIUM)

BORE HOLE PROPOSED _____

DIP STRIKE OF JOINTS _____ 80°

DIP STRIKE OF BEDS _____ 87°

NOTES

ALL COORDINATES ARE IN YARDS
ALL TOPOGRAPHY ARE IN FEET

0 400 800 FEET

S.NO.	DATE	DESCRIPTIONS	CHECK

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

KURRAM TANGI DAM PROJECT

GEOLOGICAL MAP OF
POWER TUNNEL-III

KURRAM TANGI DAM CONSULTANTS
188 -Y, COMMERCIAL AREA, PHASE-III,
D.H.A, LAHORE.

DRAWN:	M. NADEEM	DATE: DEC. 2003	REV. No.
SURVEYED:	ARSHAD HASHMI	FIGURE NO.	
CHECKED:	JAFAR HASSAN	2.20	
APPROVED:	JAMIL ANWER		

E:\NADEEM\KURRAM TANGI\FEASIBILITY-R\TUNNEL-3\GEO-FINAL\Fig-2.20.dwg

Annexure B : Figures and Maps from KTDP Detailed Design Report 2011

Figure (KTDP-DDR-)3.1: Surface Geological Map of Dam Site
Figure (KTDP-DDR-)3.12: Geological Section (BB') along Kaitu Feeder Tunnel
Figure (KTDP-DDR-)4.1: Kurram Tangi Dam Potential Borrow Areas for Concrete Aggregate

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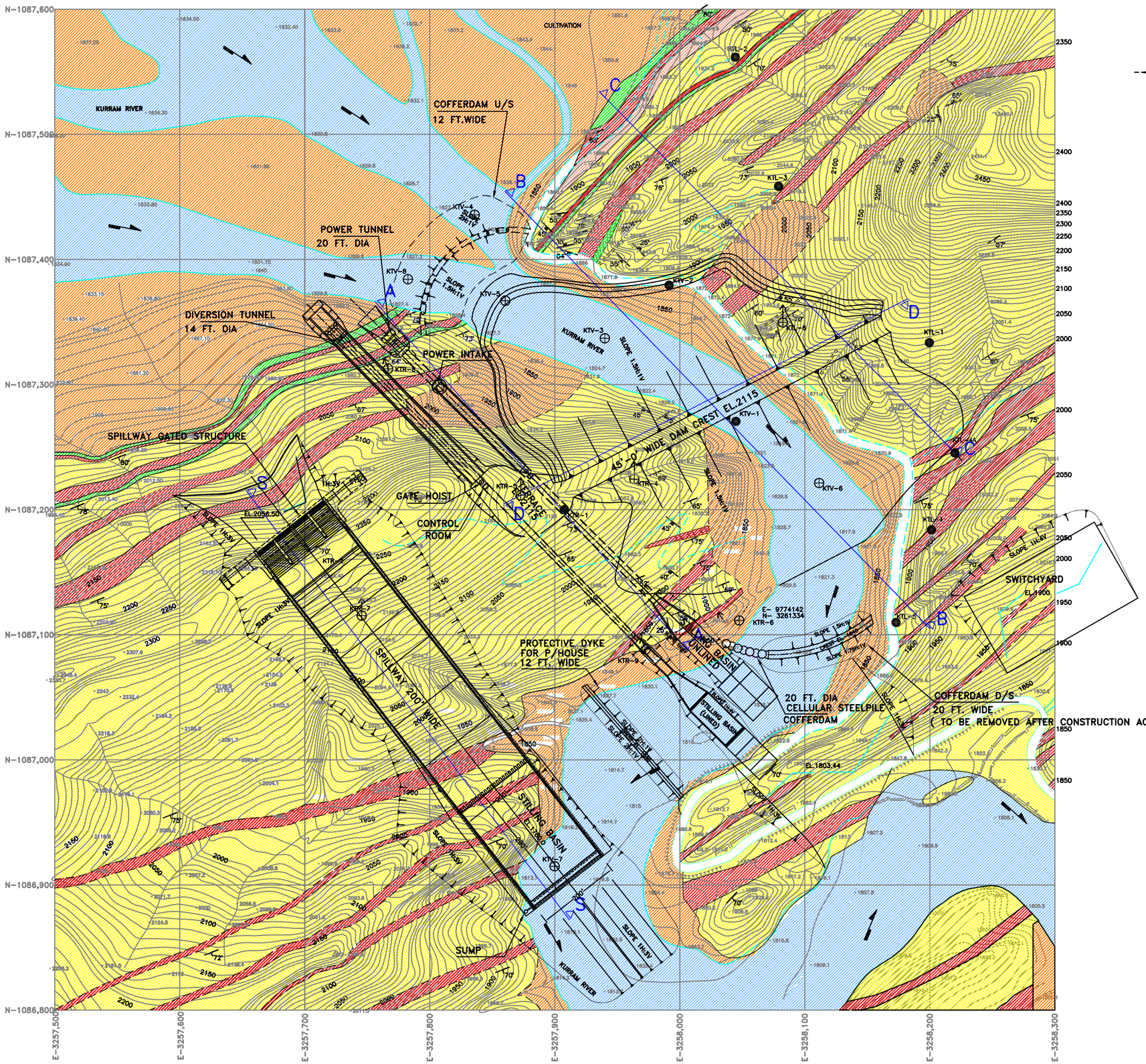

LEGEND

- SANDSTONE
- SILTSTONE + SHALE
- RIVER (SAND, GRAVELS, BOULDERS)
- OVERBURDEN (SCREE, ALLUVIUM)
- LIMESTONE
- MARL+SANDSTONE
- BORE HOLE COMPLETED UP TO 1994
- PROPOSED BORE HOLE FOR FEASIBILITY
- PROPOSED INCLINED BORE HOLE FOR FEASIBILITY
- DIP STRIKE OF JOINTS — 80°
- DIP STRIKE OF BEDS — 87°
- FAULT — F F
- SHEARZONE — =======

NOTES

ALL COORDINATES ARE IN YARDS

ALL TOPOGRAPHY ARE IN FEET

0 250 500 FEET

S.NO.	DATE	DESCRIPTIONS	CHECK

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

KURRAM TANGI DAM PROJECT

SURFACE GEOLOGICAL MAP OF DAM SITE

KURRAM TANGI DAM CONSULTANTS
188 -Y, COMMERCIAL AREA, PHASE-III,
D.H.A, LAHORE.

DRAWN:	M. NADEEM	DATE: DEC. 2010	REV. No.
SURVEYED:	ARSHAD HASHMI	DRAWING NO.	
CHECKED:	JAFAR HASSAN	KTDP-DDR-3.1	
APPROVED:	JAMIL ANWER		

E:\NADEEM\KURRAM TANGI\FEASIBILITY-R\GEO-MAIN-DAM\FIG-2.3.dwg

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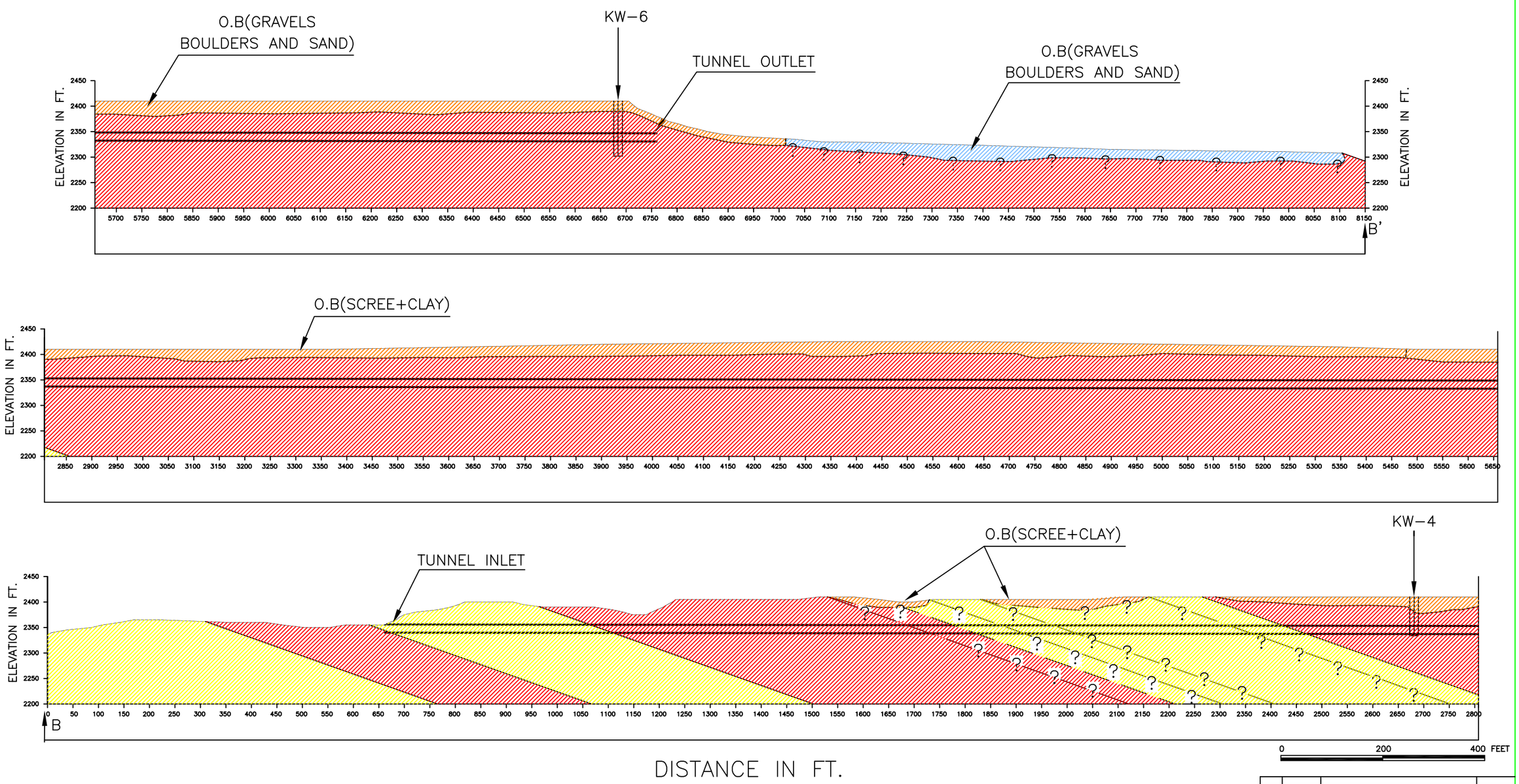

LEGEND:

- NULLAH CHANNEL
- SHALE
- SANDSTONE
- OVERBURDEN

S.NO.	DATE	DESCRIPTIONS	CHECK

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

KURRAM TANGI DAM PROJECT

GEOLOGICAL SECTION (BB')
ALONG KAITU FEEDER TUNNEL

KURRAM TANGI DAM CONSULTANTS
188 -Y, COMMERCIAL AREA, PHASE-III,
D.H.A, LAHORE.

DRAWN:	M. NADEEM	DATE: DEC. 2010	REV. No.
SURVEYED:	A. HASHMI	DRAWING NO.	
CHECKED:	J. HASAN	KTDP-DDR-3.12	
APPROVED:	JAMIL ANWER		

E:\NADEEM\KURRAM TANGI\FEASIBILITY-R\KAITU-FEEDER-CANAL\GEOLOGY\FIG-2.13.dwg

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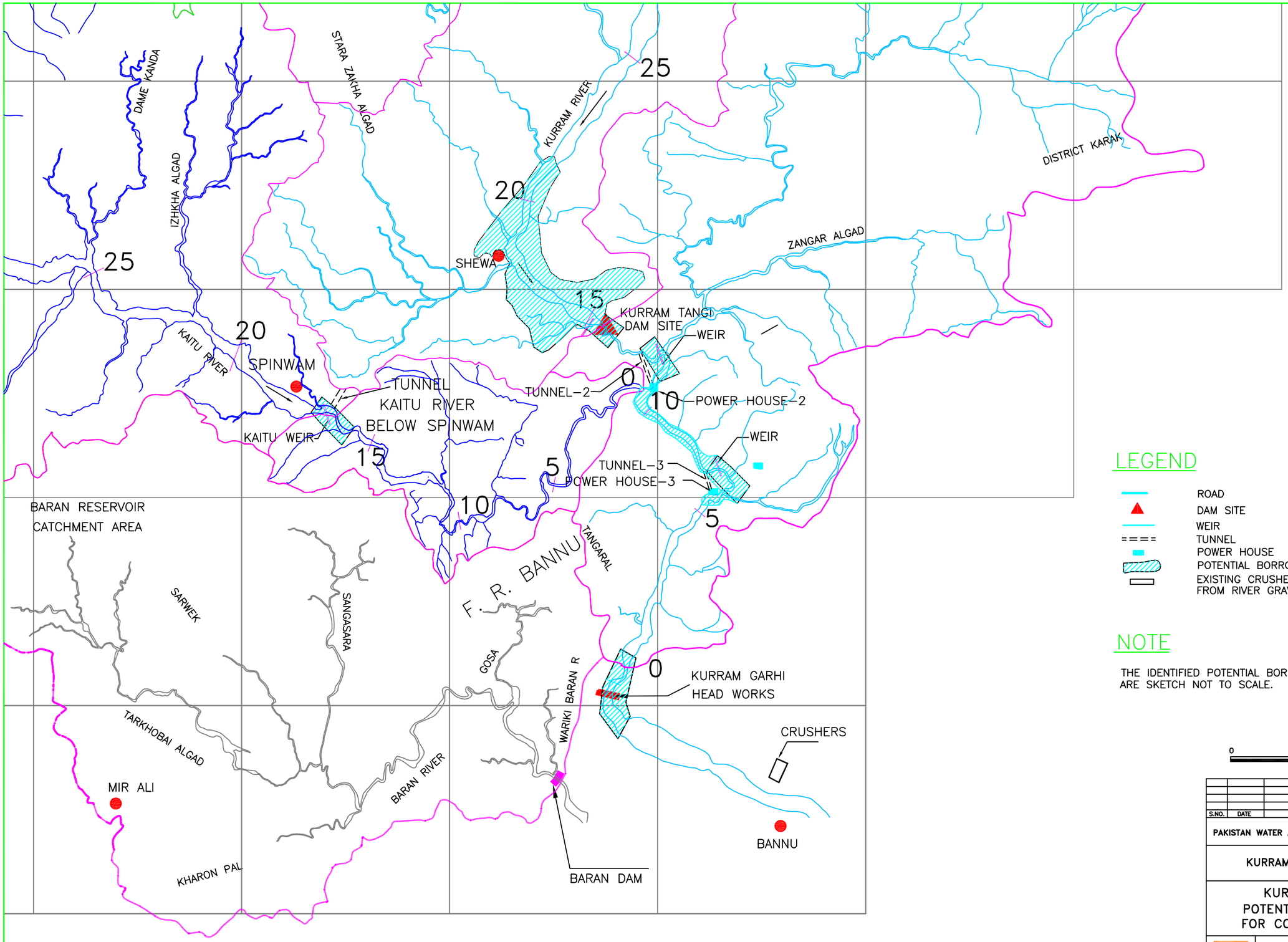

LEGEND

- ROAD
- DAM SITE
- WEIR
- TUNNEL
- POWER HOUSE
- POTENTIAL BORROW AREA FOR AGGREGATES
- EXISTING CRUSHERS,MANUFACTURER OF SAND FROM RIVER GRAVELS

NOTE

THE IDENTIFIED POTENTIAL BORROW AREAS ARE SKETCH NOT TO SCALE.

0 14000 28000 FEET

S.NO.	DATE	DESCRIPTIONS	CHECK

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY

KURRAM TANGI DAM PROJECT

KURRAM TANGI DAM
POTENTIAL BORROW AREAS
FOR CONCRETE AGGREGATE

KURRAM TANGI DAM CONSULTANTS
188 -Y, COMMERCIAL AREA, PHASE-III,
D.H.A, LAHORE.

DRAWN:	M. NADEEM	DATE: DEC, 2010	REV. No.
DESIGNED:	ARSHAD HASHMI	DRAWING NO.	
CHECKED:	JAFAR HASSAN	KTDP-DDR-4.1	
APPROVED:	JAMIL ANWER		