FIELD SEASON 1980-81 TO 83-84

GEOTECHNICAL REPORT ON THE JAMRANI DAM PROJECT, GOLA RIVER, NAINITAL DISTRICT, UTTAR PRADESH

(WITH EIGHT PLATES)

BY

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GEOLOGICAL SURVEY OF INDIA

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contents
CONTENTS

List of Plates :

I. Regional Geological map of the area around Jamrani Dam site, Nainital District, U.P.
II. Photogeological and geomorphological map of the area around Jamrani dam site.
III. Geological map of Dam site.
IV. Geological section along the proposed Dam axis.
V. Stereoplots of bedding and Joint planes at Dam site.
VI. Geological log of Drill hole No-21.
VII. Geological log of Drill hole No-25
VIII. Map showing tentative depths of clay in 'K', L-X and 'L' areas.

X-X-X-X-X-X-X-X

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A B S T R A C T

i) Geotechnical investigation for a dam across Gola river near Jamrani village, Nainital district, U.P. for irrigation and drinking purposes were continued in the period under reference.

ii) The proposed dam site is located on sandstone alternating with minor siltstone/claystone bands brought in contact with a thrust (Krol thrust) a little north of the dam site. In view of the project area lying in the seismic zone IV of the Indian sub-continent and also because of the nearness of the Krol thrust to the proposed dam site, it is warranted to duly provide for necessary seismic factor in the design for the safety of the structure.

iii) The proposed site is prima facie suitable for a concrete as well as a rock fill dam. Sufficient quantities of construction material for both the types of dam are also likely to be available in the project area. However, for a rockfill dam with clay core, the major geotechnical problem would be the location of spillway. In case of a concrete dam, the foundation grade rocks of varying physical properties will have to be adquately treated to render them monolithic to ensure against differential settlement. Type of the dam has to be decided.

INTRODUCTION :

1. The feasibility stage geological investigations of the proposed Jamrani Dam P roject were commenced in 1973. A number of progress reports and study notes covering various geotechnical investigations on the project have been issued since then. The present report incorporates the geotechnical data collec ted by the authors during the field seasons 1980-81 to 1983-84, against item No.EG/53 0/NR/UP/73/73 of approved field programme of Geological Survey of India for these field seasons. The investigations during field season 1980-81 were attended to by the first author 136 days), during 1981-82 by the second and thir authors (76 days and 110 days respectively) and during 1982-83 and 1983-84 by the second author (296 days and 237 days respectively). The work done comprised :

Field season	Detailed mapping (1:1000 scale)	Traverse mapping 1:63,360/ 50,000 scale.	Prep. of geol ogical section 1:1000	Pit logging.	Drift logging 1:100	Drill hole core logg. exam.
1980-81	0.06 sq.km.	26 L.km.	810 L.m.	53.4m	16m	53.5m
1981-82	0.35 sq.km.	7.5 L.km.	-	-	-	-
1982-83 & 1983-84	0.241 sq.km	78 L.km.		-	-	-

Mapping on :

i) 1:8000 scale = 0.652 sq.km.

ii) 1:7500Scale = 0.7 sq.km.

No. of field tests attended = 19

In-situ test-site mapping = 10 sq.m.

In 1980-81 Field season ,reconnaissance traverses were also taken in the new Lanibagh Dam site area of Jamrani dam project when cores of drill holes I and II driven to 22.5m and 35m respectively on right bank were examined. The hole II encountered bed rock at 30.5m depth.

2. The project envisages construction of a dam across Gola river near Jamrani village (29°16' :79°36'36" ;53O/11) Nainital district, U.P. The height of the dam was originally proposed to be 145m. The same has subsequently been reduced to 130m(in 1982-83).Also, the initially proposal to have a rock fill dam with a central clay core,a chute spillway on the right bank and a diversion tunnel on the left bank,received a set back when doubts were raised about the availability of clay core material in the dam site area. However,presently two alternatives,viz a rock fill dam with clay core and concrete dam , are under consideration.

-2-

5. The proposed dam site is located on the Lower Siwalik rocks (comprising mainly sandstone alternating with siltstone /clay stone) which are juxtaposed along the Krol thrust, with granite/gneissic rocks towards north in the project area. The presence of the thrust in the vicinity of the dam and the location of the project within seismic zone-IV of the tethian sub-continent warrant due provisions of seismic factor in the design for safety of the structure.

4. The geological investigations done so far indicate that the proposed dam site is prima facie suitable for a rock fill as well as a concrete dam. Construction material for both the structure is also likely to be available in sufficient quantities within reasonably short distance from the dam site. Type of the dam is yet to be decided.

5. The investigations were carried out under the overall guidance and supervision of Sri K.N.Srivastava, Director, Engineering Geology division (East) Geological Survey of India and Sri B.K.Aalok, Geologist (Sr.) and Party Chief on Projects, Dehradun, who visited the project in March, 19 and June 1984 and extended suggestions in preparation of the report. The author thankfully acknowledge the facilities and co-operation extended by the project authorities.

II- REGIONAL GEOLOGY AND SEISMICITY :

6. Regional geological mapping of the area around the project was done by S.P.Nautiyal (1943-44). The tectonic sequence of the rocks encountered in the area from north to south (J-angpangi, et.al. 1969-70) is as given below :-

	------- Ramgarh Thrust -------
Bhimtal Formation	Gritty quartzite, pink quartzite pebbly at base, purple and green slates, phyl and p ink- siliceous limestones with ba acidic intrusives and extrusives.
	----- Krol Thrust (Main Boundary Fault
Lower Siwalik Formation	Sandstone, siltstone, claystones and psudoconglomerates.

7. The prominent structural features of the project area are Krol thrust (Main Boundary Fault), and faults trending N7-SE, E to NNW - S to SSE and NNE - SSW. The Krol thrust, a major tectonic feature of Himalaya, is well defined in the area, where rocks of the Shimla Formation are thrust over the younger Lower Siwaliks along it. (Plate-I). The thrust generally dips at an angle of 40° to 50° towards north. Its nearest trace is about 500m from the Jamuni dam site on the right abutment. It is also exposed in the reservoir area about 3.5km away from the dam site. The thrust zone is mostly covered with debris. Aerial photo studies conducted by Chhibber (1977) indicate definite evidence of neotectonic activity along the thrust plane on the right bank of Lugar Gad close to its confluence with Gola river, where it has caused several vertical displacements (Plate-II).

8. For monitoring movements, if any, along the thrust plane a number of survey pillars have been established on both of its sites, and precision levelling observation taken in 1982 by Survey of India. It is felt that for meaningful results, these observations should be taken periodically, at least once in a year. It is apprehended that some of the precision levelling pillars may not give correct picture because of their installation at rather unfavourable locations. One such pillar is located just near the edge of the steep rock slope about 30m downstream of the dam axis on the right bank, where presence of open joints can cause its settlement. It is always preferable to secure the pillar with the in situ rock to ensure that the movements recorded are those of bed rock. Incidentally, the dam site is located is seismic zone IV and as such suitable seismic factors should be incorporated in the design of the dam.

III. GEOLOGY OF THE DAM SITE :

9. The geological mapping of the dam site on 1:1000 scale carried out earlier was not duly controlled due to non-availability of a detailed contour map. This necessitated further work and accordingly revised detailed mapping of the site on the Survey of India topographic sheets has been in progress taken up since 1981. A total of about 0.84 sq.km area had been geologically mapped since 1973. This include 0.17 sq.km covered during 1983-84.

The dam proper at Jaurani dam site is located on the Lower Siwaliks which consist of sandstone with alternate bands of siltstone and claystone. These generally trend in NW-SE direction with dip of 30° to 50° towards NE (i.e. upstream) direction. They are traversed by a number of joints which when plotted on a stereonet give the following centres of concentrations (Plate-V).

STRIKE	DIP	REMARKS
1. N39°W-S39°E	40°/N51°E	Bedding joint
2. N28°E-S28°W	60°/N62°W	Joint (J_1)
3. N65°W-S65°E	59°/S25°W	Joint (J_2)
4. N50°E-S50°W	69°/N40°W	Joint (J_3)
5. N50°W-S50°E	51°/S40°W	Joint (J_4)

The bedding and joints control the drainage and topography on either bank and are also responsible for major landslides in the area.

11. Joints are well developed in the sandstone which is grey or brown coloured and fine to coarse grained. Concentration of biotite along the bedding planes of the sandstone renders it flaggy. At places, it is friable due to poor cementation. The claystone is grey, brown or purple coloured. At its contacts with sandstone it shows effects of shearing to 10 to 15cms. It is highly weathered near the surface. The siltstone is dark grey coloured and usually well cemented and hard. It is micaceous at places.

12. The topography on the left bank is guided by the dip slope of the beds and the alternate arrangement of the different bands is not very conspicuous, except where these have been differentially eroded. It is characterised by ridges and depressions marked by wide nalas (Plate-III). The erosion by the stream has caused several slips, both in the upstream and downstream of the dam axis.

13. The slope on the right bank of the river is controlled by a joint set dipping at 50° to 70° towards southwest (i.e. valley side). The ridges and depressions, formed due to differential weathering and erosion of alternating sandstone and claystone bands, extend across the dam axis. Slope failures have taken places where the toe of rock mass controlled by the south-westerly dipping joints is eroded and overhang created.

14 The dam axis on the left bank is located on a 40m to 50m wide ridge of sand stone above El. 650m which extends upto the top of the dam. The dam at its top will have a length of 427m of which 69m lies in the river bed, 217m on the left banks and 141m on the right bank. The entire river bed is covered by river borne boulders and sand. The rock outcrops are seen on the abutments only.

IV. GEOTECHNICAL PROPERTIES OF ROCKS :

15. To determine the geotechnical properties of rocks. The following in-situ tests were got done by Central Soil Material Research Station (CSMRS), New Delhi.

i) Cyclic Plate Load Tests :

To study the deformation characteristics of rocks 'cyclic plate load tests' were carried out at fifteen locations on the right bank. The results as given in Memorandum No 2-B (February 1981) are tabulated in Appendix-I. The analysis of the results reveals that the modulus of deformation for sandstone near the river bed varies from 0.008×10^5 kg/cm^2 to 0.072×10^5 kg/cm^2 and in the drift No R-I, from 0.021×10^5 kg/cm^2 to 0.174×10^5 kg/cm^2. For claystone, near the river bed, it varies from 0.008×10^5 kg/cm^2 to 0.11×10^5 kg/cm^2 and the drift from 0.033×10^5 kg/cm^2 to 0.251×10^5 kg/cm^2. For siltstone, near the river bed, if is 0.024×10^5 kg/cm^2.

ii) Flat Jack Tests :

17. Six numbers of 'flat jack tests', three each on sandstone and claystone, have been carried out. The results are tabulated in Appendix-II. The values of modulus of deformation obtained from horizontal slots and vertical slots does not show appreciable difference in sandstones. Most of the values vary from 0.05×10^5 kg/cm^2 to 0.081×10^5 kg/cm^2. For claystone, the modulus of deformation obtained from vertical slots ranges from 0.0227×10^5 kg/cm^2 to 0.0256×10^5 kg/cm^2, and is 0.0113×10^5 kg/cm^2 for the test conducted in Horizontal slots

18. From the above it is evident that the values of modulus of deformation for sandstone, siltstone and claystone do not show appreciable difference. The poor value may be due to the selection of unfavourable test sites. Further since most of the tests were carried out under dry conditions, there may be significant reduction in the respective values under saturated condition (When the reservoir is full).

It is understood that the above two tests carried out subsequently have indicated good values of bearing capacity. The same may be made available for analysis.

iii) In-situ shear Test:

19. Two number of tests were carried out for rock over rock, one each for claystone and sand stone. Three number of tests were carried out for concrete over rock, one each for sandstone, siltstone and claystone, using 70cmx70cmx35cm size block of concrete. The results are tabulated in Appendix -III.

20. The compressive strength of sandstone varies from 214 kg/cm^2 to 432 kg/cm^2 under dry conditions and from 204 kg/cm^2 to 218 kg/cm^2 under wet conditions. For siltstone, it is 513 kg/cm^2 under dry conditions. The compressive strength of claystone has not been determined. Tests for the same, under dry and saturated conditions, may be conducted for better appraisal.

V. SUB-SURFACE EXPLORATION :

i) Drifting :

21. To explore the abutment conditions, two drifts DR-I(El 692m) and DR-2 (761m) have been excavated on the right abutment for 37.5m and 33m respectively. In general, they have encountered good rock and have been self supporting even after the collapse of timber supports. The lateral depth to sound and fresh rock in them is 24m and 18m respectively. The approximate depth of weathering may be of the order of 10 to 15m.

22. On the left abutment also two exploratory drifts i.e. DL-1 (El 689.6m) and DL-2 (El 771.0m), have been put in sandstone. Their respective lengths are 35.5m and 34m. The drift DL-1, has been unfavourable aligned very close to a nala and as such it has not established the lateral depth of sound rock. In the drift DL-2, sound rock is available after 15m. The expected depth of stripping of abutment may be 13 to 15m.

ii) Drilling :

23. In all 22 drill holes have been put in the dam site area. Logging of the first 20 holes drilled before 1981 could not be carried out as the cores have not been found in order. Two drill holes, DH No-21 on left abutment and DH No-25 on right abutment have been drilled from El 645.3m, and El 644.85m respectively after December1982 to probe the foundation rock. Both these hole are located close to the river bed and have been drilled to depths of 70m and 69.5m respectively (Plate VI &VIII). Before 1981 five drill holes have been put on either abutments andthree in the river bed section. From the available data only the depths of overburden encountered by these drill holes, may be determined.

24. Thick bands of sandstone, with alternate siltstone and claystone bands have been encountered in the holes drilled recently. Siltstone is hard and compact and individual bands ranges in thickness from 1 to 8m, claystone band are less than 2.5m in thickness. Weathering effects have been seen upto a maximum depth of 9.5m.

25. In DH-21, the percent core recovery is generally good. It ranges from 40% to 60% upto 18m and more than 70% further down. The Rock Quality Designation(RQD) is poor upto the depth of 18m, but further down, it is good (75% to 90%) to excellent 90% to 100%).

26. In DH-25, the percent core recovery is generally more than 50% down to the depth of 39.5m and further down more than 70%. The RQD is generally poor (25% to 50%) upto the depth of 54.5m, except for short reaches, where it is fair (50% to 75%). Further down it is good to excellent.

27. The water percolation tests carried out in the holes indicate that permeability in general decreases with depth. It ranges from 10 to 30 Lugeons down to 35m depth and comes down to less then 10 lugeons further beyond. It is felt that a few more drill holes along the dam axis may have to be done for better assessment of foundation conditions.

VI. AVAILABILITY OF CONSTRUCTION MATERIAL :

1. Concrete Gravity alternative :

28. It has been estimated that the total required quantity of 20 Lac m^3 of coarse and fine aggregates would be available in the river bed with in 3km downstream of the dam site.

2. Rock fill alternative :

29. The estimated required quantities of construction materials are as follows :

i) River borne material = 22.70 lac m^3
ii) Crushed rock = 28.94 lac m^3
iii) Clay core = 9.90 lac m^3
iv) Graded filter = 10.70 lac m^3

It is understood that the total requirement of river borne material is available within 5kms of the dam site. The filter material is also proposed to be obtained by screening the river borne material. The crushed rock is proposed to be quarried from Barajala about 2.5kms downstream of the dam site.

30. Position regarding availability or otherwise of clay core material in sufficient quantity has been doubtful till recently. A preliminary survey of a number of prospective areas has lately been undertaken, which has shown encouraging restuls. It has been decided to establish 20 lakh m^3 of clay core material so that the required quantity of about 10 lac m^3 of clay may be recovered from them after accounting for the losses due to stripping, borrows and transit and quality control rejects. In this connection five borrow areas, namely 'K' 'L' 'L-X' 'A' and 'G' are presently under consideration of the project authorities. Preliminary geological investigations of all these areas, except 'A' area, for estimation of clay reserves have also been carried out. Preliminary geological mapping of 'K', 'L' & 'L-X' area has been carried out covering a total area of about 0.65 sqkm on 1:8 scale (Plate-VIII).

31. The clay available in these areas is of heterogenous variety. In fact, the clay to silt size fractions, which form about 40% to 60% of the bulk of the amount are found mixed with rock pieces, ranging in size from few cms to about 1.0m. These rock pieces/blocks are generally of sandstone.

32. It has not been possible to establish the depth of clay reserves in these areas so far, because systematic explorations by means of pits, could not be implemented due to non availability of land, mostly under terraced cultivation. Other sub surface data available is also inadequate. Therefore the depth of clay taken for the purpose of calculation of reserves is mainly based on geological mapping and geomorphological setting of the areas. The probable average depths

for individual blocks are indicated in the map and the same will have to be ascertained by systematic explorations. The prospective areas are individually discussed in the following lines :

i) 'K' area : -

33. It is located about 50 m downstream of the dam axis to the left of the Gola river, between El± 640m and El± 340m. A northeasterly flowing nala marks the boundary towards north. Further, the area is dissected by two ephemeral nalas roughly flowing towards North. Terraced cultivation is being carried out partly in the prospective area.

34. It is understood that a total of 11 pits have been excavated in this area, upto El±710m , to depths ranging from 1.5m to 5.05m before 1982. But they are of little help in reserve calculations since they have not been deepened down to bed rock level. Also the records regarding their location, the type of material encountered in them etc. have not been properly maintained.

35. The depth of clay, indicated in the map(Plate-VIII) tentative and will have to be substantiated by systematic subsurface explorations. However, the preliminary investigations indicate a total reserve of about 12,20,000 m^3, based on the visual estimation, 40% of the total reserve has to be deducted to account for the excessive oversized rock blocks/ boulders. This leaves the clay core grade reserve of the order of 7,32,000 m^3. The estimate, it is felt, is modest, and the detailed explorations are expected to prove more than the above inferred reserves.

'L-X' area :

36. This area is located in the northern vicinity of 'K' area, beyond the northeasterly flowing nala. Separating these two areas from one another. It is bounded by another Easterly flowing nala towards north. The area lies between El ± 640m and El±850m. The slope generally has a thin cover of overburden comprising clay and abundant rock blocks/boulders. In-situ rock exposures are also observed at places in the nala cuts.

37. Based on the geomorphology of the area, two prospective locations have been demarcated for further explorations. Though no subsurface explorations have been carried

out in that area so far, it is felt that the thickness of clay in these locations may be more than 6m. Deducting 40% for the oversized fractions from the estimated total reserves, the core grade clay available in these two locations may be 2,77,000 m^3.

'L' area :

38. It is located to the North of 'L-X' area adjoining the easterly flowing nala and lies between El± 635m and El± 755m (Plate-VIII). Part of the area is supporting terrace cultivation.

39. It is understood that a total of 18 pits have been excavated here so far. However the required details of as many as 17 pits excavated before 1982 are not available. A solitary pit dug at El 715 to a depth of 7.5m during 1983-84 is located close to the easterly flowing nala. Clay with good soil value is encountered in the entire depth of the pit which has not yet reached the bed rock level. Boulder size fraction (+6mm) is more (about 40%) near the surface, while below 6.5m dark grey coloured clay with less than 10% of boulder size fraction, is exposed till the bottom. The estimated core grade clay reserves, after deducting 40% for oversized material, are about 3,08,000 m^3 in this area.

'G' area :

40. This area is located about 6km downstream of the dam axis to the left of Gala river between El±604m and El± 920m. The area towards East and West is bounded by N-S trending ridges and towards South by E-W trending ridge. These ridges have in-situ rock exposures. Two major nalas and a number of minor ones are draining the area. The prospective area has a slope of the order of 20° to 30° towards north with thick vegetation.

41. It is understood that a number of pits were excavated in the area before 1981, the records of which are not available. However, 12 pits have been excavated during 1983-84 most of them to depths ranging from 6.0 to 9.0m. None of them has touched the bed rock. Though the detailed geological mapping of the area is yet to be taken up, a preliminry assessment of clay reserves has been attempted on the basis of traverses. The total prospestive area, calculated from the topographical map is about 7 km^2. Assuming an average thickness of clay to be 6m and deducting 50% for the oversi

fractions, the core grade clay reserves may be about 21 lakh m^2

'A' area :

42. This area is located about 6km downstream of the dam axis to the right of the Gola river, above the Kathgodam-Jamrani road. A number of pits have been excavated in this area before 1982. One of the pits located close to the road, has, on examination, indicated clay of good P.I. value (3) with less than 20% of oversized boulders. Further systematic explorations may prove the potentiality of the area.

VII CONCLUSIONS AND RECOMMENDATIONS :

43. Geotechnical investigations of Jamrani dam project, which envisages construction of a 130m high storage dam for irrigation purpose, have been in progress since 1973.

44. The Lower Siwalik rocks towards north are in contact with granite/basic rocks along the Krol thrust. The thrust is exposed about 0.5km towards north of the dam site. It also passes through the reservoir area about 3.5km from the dam site. It is believed to have been activated in the recent times. It is suggested to monitor the movements, if any, along this plane, periodically by precision levelling. For quantitative estimation of water loss along this plane under impoundment conditions, the earlier suggested inclined drill hole across the thrust plane and water pressure tests in the thrust zone, may be taken up.

45. The rocks exposed at the dam site comprise sandstone with alternate bands of siltstone and claystone, belonging to Lower Siwalik Formation. These generally trend in NW-SE direction with dips of 30° to 55° towards NE direction and are traversed by a number of joints.

46. The subsurface exploration at the dam site includes 4 drifts and 22 drill holes. However only two drill holes could be logged thoroughly Scanty data that could be gathered from other drill holes could only be used to mark the overburden/rock contact. At least four more drill holes each about 50m deep, need be drilled along the dam axis two in the river bed and one each on either abutment for probing the foundation grade rock conditions.

47. The water percolation test results indicate the ne for curtain grouting at the foundation grade. It is suggest to carry out grouting tests at that level, for evaluating groutability of rocks there.

48. The values of modulus of deformation obtained from in-situ cyclic plate load tests for rocks near the river bed are lower as compared to those inside the drift No DR-1 in cating physically better rock in the drift. However, the mo of deformation values obtained from plate load tests do not show appreciable difference for sandstone, siltstone and cla stones though those obtained from flat jack tests are better for sandstone than for claystone.

49. An analysis of compressive strength of sandstone an siltstone core samples, as determined in laboratory, shows reduction in values by about 30% to 50% under wet conditions Since all the insitu tests were carried out under dry condi- tions, there may be significant reduction in the values unde saturated conditions, when the reservoir is full. It is sug ested that in situ and laboratory tests under dry and satura conditions may be carried extensively at the sites of variou compenents of the dam. Claystone too may be subjected to th tests.

50. The engineers and geologists have been working on t suitability of th type of dam and a number of proposal have been considered from time to time. However, presently only two alternatives namely rock-fill dam with clay core and concrete dam are being actively considered. The proposed site is prima facie suitable for both a concrete as well as a rock fill dam. Type of the dam may be decided so that further geological investigations are planned accordingly.

51. For rock-fill dam, the major geotechnical problem is the spillway which is imposing serious design and exe- cution problems due to unfavourable geological and topogra- phical conditions. The excavations on the left abutment are likely to cause dip slope failures and will require extensive protective treatments. While on the right abutme having steep valley slopes above the top of the dam, cons- truction of spillway may involve huge excavations with conn ected slope stability problems.

52. Though this problem can be solved by having a concrete dam with overflowing spillway, the main problem lies in the foundation treatments, since the foundation grade rocks have varying physical properties. The claystone bands, which become more plastic under saturated conditions, may form about 20 to 25% of the bulk rock mass at foundation grade. The width of claystone bands varies from 1 to 3m. They will require adequate treatments in case of concrete dam. Further grouting tests, to be carried out, may bring out groutability characteristics of the rocks as well as the improvements, if any, in the bearing capacity of the foundation rocks. It is understood that the plate bearing tests carried out recently have indicated good values of bearing capacity.

53. Sufficient quantities of the construction materials for the concrete gravity dam alternative are available within 3 km downstream of the dam site. For rock-fill dam alternative also, all construction materials, except clay, are available in sufficient wquantities within 5 kms from the dam site, to be obtined from the river bed and a quarry. The preliminary geological investigations indicate that the required quantity of clay for clayey core may be available from 'K' 'L-X' and 'L' areas located in the downstream vicinity of dam site. The shortages, if any can be, met with from 'A' and'G' areas, about 6 kms away from the dam site.

54. The clay deposits under investigation occur along the hill slopes which are generally thickly vegetated. Excavation for clay may trigger landslides due to removal of toe material. As such, the excavation has to be carefully planned and executed to avoid/minimise environmental hazards in the area.

Sd/-	Sd/-	Sd/-
(R.V. IYER)	(R. ANBALAGAN)	(R.K.SANWAL)

-x-x-x-x-x-x-x-x-

APPENDIX-I

RESULTS OF IN-SITU CYCLIC PLATE LOAD TEST

Sl. No.	Location/ Type of Test	Cycle No.	Load in Tonnes	Stream in kg/cm^2	Gross deformation cm	Permanent set cm	Elastic Deformation cm	E_d kg/cm^2 x 10	E_E kg/cm^2 x 10	Ratio $\frac{E_E}{E_d}$
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1.	River side	I	16	12.37	0.598	0.556	0.042	0.007	0.095	13.57
	RT BANK	II	32	25.47	0.999	0.895	0.104	0.008	0.077	9.63
	VERTICAL SANDSTONE 'B'	III	50	39.79	1.483	1.277	0.206	0.008	0.061	7.63
2.	River Side	I	10	7.95	0.307	0.282	0.025	0.008	0.0998	12.40
	RT BANK	II	20	15.92	0.615	0.511	0.104	0.008	0.048	6.0
	VERTICAL	III	40	31.83	1.103	0.851	0.252	0.009	0.040	4.44
	CLAYSTONE 'A'	IV	50	39.79	1.415	1.106	0.309	0.009	0.040	4.44
3.	River Side	I	12	9.55	0.080	0.074	0.009	0.036	0.33	9.24
	RT BANK	II	20	15.92	0.149	0.117	0.032	0.033	0.156	4.66
	VERTICAL SANDSTONE 'C'	III	45	35.81	0.323	0.233	0.09	0.035	0.125	3.56
4.	River Side	I	12	9.55	0.189	0.173	0.016	0.0158	0.187	11.85
	RT BANK	II	32	25.46	0.374	0.325	0.049	0.021	0.163	7.76
	VERTICAL SILTSTONE 'D'	III	47	37.40	0.486	0.383	0.191	0.024	0.114	4.74

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
5.	River Side	II	16	12.73	0.066	0.046	0.02	0.06	0.2	3.33
	BANK	II	32	25.46	0.111	0.07	0.041	0.072	0.195	2.70
	VERTICAL	III	42	33.42	0.148	0.088	0.06	0.071	0.175	2.46
	SANTSTONE 'E'									
6.	19.5M. DR-1	II	10	2.26	0.0323	0.0105	0.0128	0.041	0.108	2.63
	VERTICAL	II	20	4.53	0.0735	0.046	0.0275	0.036	0.097	2.69
	CLAYSTONE	III	40	9.05	0.1583	0.0979	0.0604	0.034	0.088	2.59
		IV	60	13.58	0.225	0.1375	0.0675	0.036	0.118	3.28
7.	23.75M DR-1	II	10	2.26	0.0053	0.0033	0.002	0.253	0.666	2.65
	VERTICAL	II	20	4.53	0.0138	0.0078	0.006	0.193	0.444	2.3
	CLAYSTONE	III	40	9.05	0.0343	0.0198	0.0145	0.155	0.367	2.37
8.	24.65M DR-1	I	10	2.26	0.027	0.019	0.008	0.049	0.166	3.39
	VERTICAL	II	20	4.53	0.065	0.052	0.013	0.041	0.205	5.0
	CLAYSTONE	III	40	9.05	0.125	0.091	0.034	0.043	0.157	2.05
		IV	48	10.87	0.14	0.095	0.045	0.046	0.142	3.09
9.	30.6M DR-1	I	12	14.24	0.0583	0.0243	0.034	0.034	0.059	1.74
	VERTICAL	II	40	14.15	0.174	0.126	0.048	0.038	0.139	3.66
	SANDSTONE	III	60	21.22	0.233	0.156	0.077	0.043	0.13	3.02
		IV	80	28.30	0.276	0.183	0.094	0.048	0.142	2.96
10.	32.85M DR-1	I	12	7.55	0.041	0.026	0.015	0.065	0.177	2.73
	VERTICAL	II	32	20.12	0.111	0.068	0.043	0.064	0.165	2.58
	SANDSTONE	III	40	25.15	0.141	0.081	0.06	0.063	0.148	2.35
		IV	75	47.15	0.222	0.131	0.092	0.075	0.22	2.95

11. 37.5M DR-1 vertical SANDSTONE	I	12	7.55	0.121	0.128	0.003	0.021	0.85	40.47
	II	35	15.72	0.186	0.174	0.012	0.029	0.213	7.34
	III	55	34.58	0.268	0.218	0.050	0.044	0.234	5.32
12. 20.0M DR-1 HORIZONTAL CLAYSTONE	I	20	4.53	0.0116	0.0016	0.0101	0.23	0.267	1.16
	II	40	9.05	0.0476	0.0185	0.0291	0.112	0.1835	1.68
	III	60	13.58	0.012	0.0515	0.0497	0.079	0.101	2.04
	IV	70	15.85	0.1262	0.0632	0.063	0.074	0.142	2.0
13. 27.2M DR-1 HORIZONTAL CLAYSTONE	I	16	5.66	0.062	0.0058	0.0101	0.043	0.266	6.2
	II	40	14.25	0.2	0.146	0.054	0.033	0.123	3.73
	III	60	21.22	0.3	0.307	0.093	0.033	0.147	3.24
	IV	80	28.3	0.39	0.293	0.097	0.034	0.137	4.04
14. 32.35M DR-1 HORIZONTAL SANDSTONE	I	20	4.53	0.007	0.0036	0.0034	0.38	0.723	1.9
	II	40	9.05	0.03	0.0186	0.0114	0.174	0.457	2.68
	III	60	13.58	0.0653	0.0323	0.033	0.122	0.242	1.98
	IV	70	15.85	0.0815	0.0463	0.0353	0.114	0.264	2.32
15. River Side BT BANK VERTICAL CLAYSTONE 'F'	I	16	12.72	0.036	0.029	0.007	0.11	0.57	5.18
	II	32	25.46	0.08	0.052	0.028	0.099	0.285	10.1
	III	40	31.83	0.107	0.08	0.027	0.093	0.37	13.7
	IV	48	38.2	0.134	0.096	0.038	0.089	0.32	3.5

Remarks :

$$E = \frac{Pn\ (1-u^2)}{Wo\ \sqrt{A}}$$

P = Max. load in kg., Wo = Deformation in cm. corresponding to load.
n = a constant = 0.96 for circular plates, U = poisson's ratio = 0.28
A = Area of plate in cm^2, Ed = Deformation modulus corresponding to Gross deformation
E = Modulus of elasticity corresponding to elastic deformation.

1. 2. 3. 4. 5.

APPENDIX-II

RESULTS OF FLAT JACK TEST

Sl. No.	Location/ Type of test	Cycle No.	Stress in kg/cm^2	Gross deformation cm.	Permanent cm	Elastic Deformation cm	E_d kg/cm^2 x 10^5	E_E kg/cm^2 x 10^5	Ratio $\frac{E_E}{E_d}$
1.	FJT-1 HORTZ SLOT(Claystone)	1	1.5x10.52	0.4618	0.189	0.2726	0.0113	0.0191	1.69
2.	FJT-2 VERT SLOT (Claystone)	1	4 x 10.52	0.3304	0.1936	0.1368	0.025	0.061	2,44
3.	FJT-3 VERT. SLOT (Claystone)	1	3 x 1052	0.2438	0.0823	0.161	0.0256	0.039	1.52
		2	4 x 10.52	0.3668	0.1518	0.215	0.0227	0.0388	1.71
4.	FJT-4 VERT.SLOT (SANDSTONE)	1	3 x 10.52	0.0066	0.021	0.0556	0.081	0.112	1.37
		2	6 x 10.52	0.1586	0.0474	0.1086	0.08	0.115	1.43
		3	9 x 10.52	0.236	0.058	0.178	0.08	0.105	1.32
5.	FJT-5 VERT.SLOT (SANDSTONE)	1	3.5x 10.52	0.145	0.053	0.92	0.05	0.079	1.58
		2	5 x 10.52	0.203	0.078	0.125	0.051	0.083	1.62
6.	FJT-6 HORT.SLOT (SANDSTONE)	1	3.5 x 10.52	0.13	0.023	0.107	0.056	0.068	1.21
		2	6 x 10.52	0.2308	0.082	0.1688	0.054	0.074	1.37

APPENDIX-III

TABLE - A

RESULTS OF IN-SITU SHEAR TESTS (ROCK OVER ROCK)

Sl. No.	Type of Test and size	Location/R.D.	Shear Stress kg/cm^2	Normal stress kg/cm^2	Ratio	Shear Friction paramet rs
1	2	3.	4.	5.	6.	7.
1.	Rock over Rock DR-1 Claystone 70cm x70cm x 35cm	21	7.89	3.13	2.52	C=3. 14kg/cm^2
		22.5	13.8	6.76	2.04	
		23.85	12.81	5.47	2.34	ϕ =58.6^0
		25.3	7.29	2.46	2.96	
2.	Rock over Rock DR-1 Sandstone 70cm x 70cm x 35 cm	32.1	11.83	7.25	1.60	C=0.3 kg/cm^2
		33.55	10.25	3.77	2.72	
		34.8	14.0	5.79	2.42	ϕ=69.40
		36.1	17.74	6.28	2.82	

TABLE - B

RESULTS OF IN-SITU SHEAR TESTS CONCRETE TO RICK

1.	2.	3.	4.	5.	6.	7.
1.	(Siltstone) DR-4 70cm x 70cm x 35 cm	A	11.14	11.14	1.0	C = 0.7 kg/cm^2
		B	4.73	5.35	0.88	
		C	2.76	2.78	0.99	ϕ = 39^0
		D	5.42	7.57	0.72	
2.	(Sandstone) DR-4 70cm x 70cm x 35cm	21.75	5.91	2.1	2.81	C = 0.8 kg/cm^2
		23.55	2.96	1.81	1.64	ϕ = 67^0
		25.3	11.83	4.7	2;52	
		27.2	11.97	0.53	3.72	
3.	(Claystone) DR-1 70cm x 70 cm x 35 cm	21	8.87	10.54	0.84	C = 2 kg/cm^2
		22.5	6.90	5.93	1.16	
		23.5	4.34	3.2	1.36	ϕ= 40^0
2.		23.8	8.87	8.50	1.04	

APPENDIX-IV

REFERENCES

1. I & P Circle, Irrigation Deptt., Bareilly. (March 1974) Jamrani Dam Project Volumes 1 to 3.

2. Dayal, H.M. (April, 1973) A geotechnical note on the Ranibath and Jamrani dam sites on Gola river Nainital distt. U.P. (with five plates) Unpublished report of GSI for the field season 1972-73)

3. Dayal, H.M. (Dec. 1973) Second Geotechnical note on the interpretations of drilling data, Jamrani dam sites, Gola river, Nainital distt., U.P. (with three plates)(Unpublished report of GSI for the F.S. 1972-73)

4. Dayal, H.M. (Jan. 1974) Third geotechnical note on the proposed dam and the appurtenant structure sites and interpretayions of drilling data, Jamrani dam site, Gola project, Nainital distt., U.P. (with 3 plates)Unpublished report of GSI for FS 1973-74)

5. Dayal, H.M. (Mar. 1975) Fourth geotechnical note on the Jamrani dam project, Gola river, Nainital district, U.P. (with 7 plates) (unpublished report on GSI for field season 1973-74)

6. Dayal, H.M. (Feb. 1976) Fifth geotechnical report on the Jamrani dam project, Gola river Nainital distt, U.P. (with six plates) (Unpublished report of GSI for the field season 1974-75)

7. Jain, M.S. (Mar1975) A geotechnical review of the salient features of the Jamrani dam site, Gola river, Nainital distt., U.P. (Unpublished report of GSI)

8. Sharan, K.B. (April1975) Report on prefield photo-interpretation of Goel catchment area, Nainital distt., UP for engineering geological studies (Unpublished report of photogeology Div, NR, GSI)

9. Dayal, H.M. (March 1976) 6th Geotechnical note on the Jamrani dam project, Gola river Nainital distt., UP(with 14th plates)(unpublished report of GSI for the F.S. 1976-77)

10. Jaitly, J.N. (Geotechnical report on the Jamrani dam project on river Gola, distt, Nainital, UP (Unpublished report of GSI for the field season 1979-80)

PLATE-I

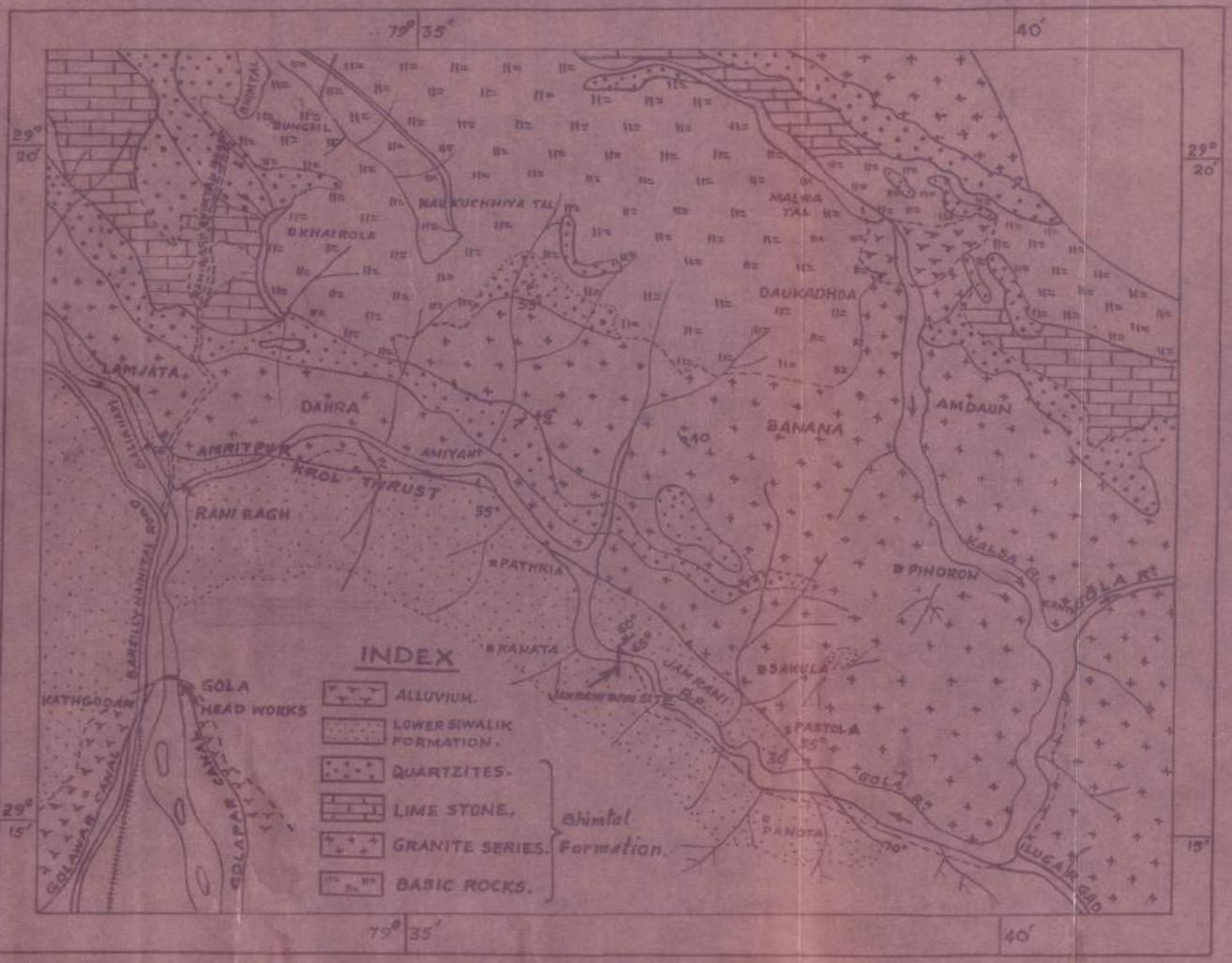
REGIONAL GEOLOGICAL MAP OF THE AREA AROUND JAMRANI DAM SITE, NAINITAL DISTRICT, U.P.

(GEOLOGY AFTER S.P. NAUTIYAL, 1943-44)

SCALE

KM. 1 0 1 2 3 KM.

MILES 1 0 1 2 MILES



TRACED BY:-
(P. Joshi)
D/M. J.D.C. Dn. II

DRG. No. JDP/40 Dt. 18-7-84

(K. ANBALAGAN)
G.S.I.

PLATE - II

PHOTOGEOLOGICAL AND GEOMORPHOLOGICAL MAP OF THE AREA AROUND JAMRANI DAM SITE

(BASED ON UNCONTROLLED MOSASIC & WITHOUT FIELD CHECKS)

SCALE:- 1:70,000 (Approx.)

NOTE:-

Co-ordinates are approximate

INDEX

- T TERRACES.
- FINE TO MEDIUM CLASTICS.
- META SEDIMENTS.
- EXTRUSIVES.

SYMBOL

- PHOTO DIP.
- RIDGE.
- FAULT.
- SLIDES.
- FAN.
- DAM SITE.
- BREAKE IN SLOPE.
- NT NEOTECTIONIC FAULT.

J. B. CHHIBER
G.S.I.

DRG. NO:- JBC/39 Dt:- 16-7-84

JAMRANI DAM PROJECT

GEOLOGICAL MAP OF DAM SITE

SCALE

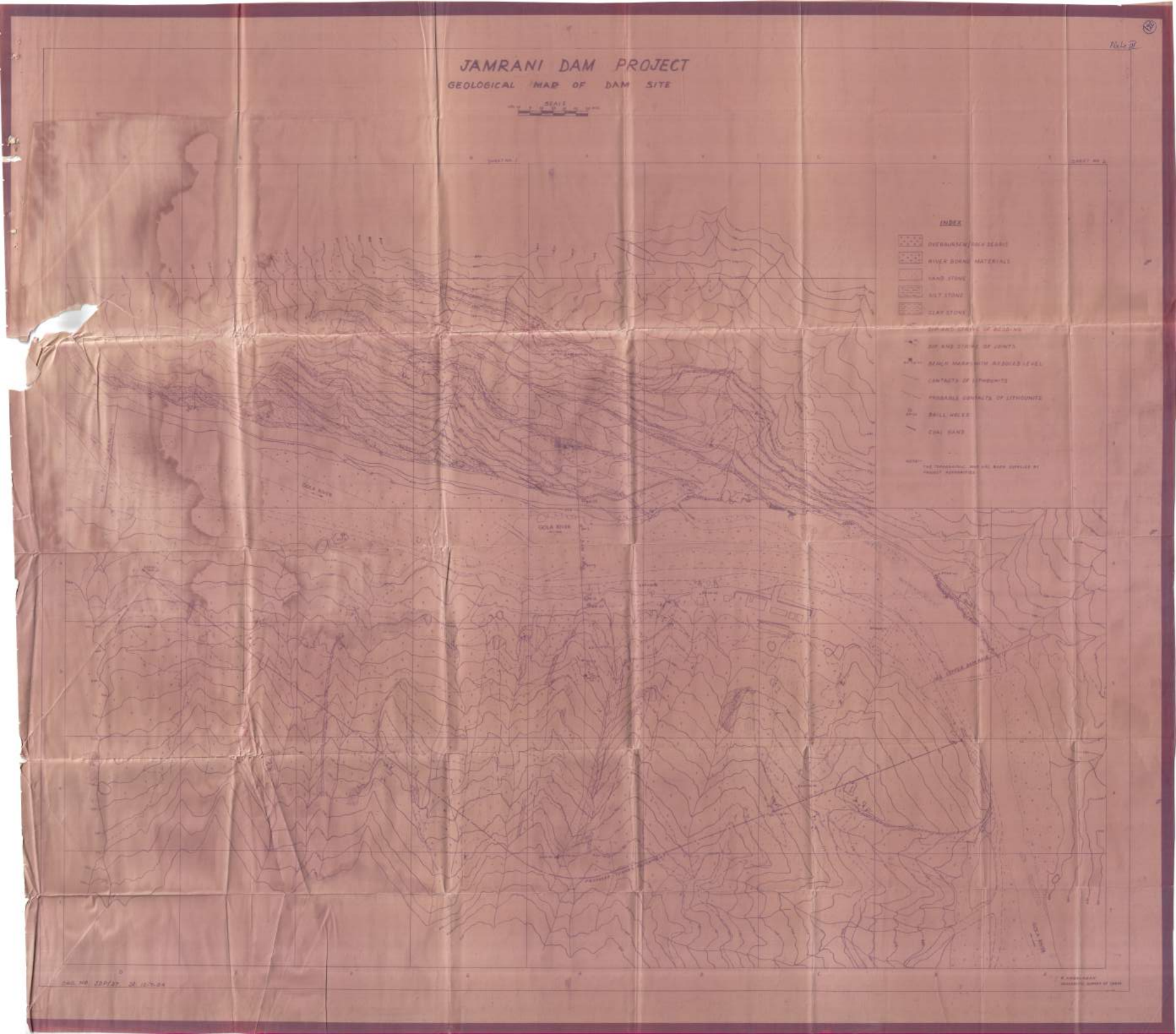


PLATE No.- 22

JAMRANI DAM PROJECT

GEOLOGICAL SECTION ALONG THE PROPOSED DAM AXIS

INDEX

- OVERBURDEN
- RIVER BORNE MATERIALS
- SAND STONE
- CLAY STONE
- GRIT STONE
- LIMIT OF STRATUM

NOTES:-

1. FOR SECTION LINE REFER DRG. NO. JDP/SEOT. 13. Y. 84.
2. THE SECTION LINE HAS BEEN DEVELOPED FROM SURVEY OF INDIA MAP PROVIDED BY PROJECT AUTHORITIES.
3. THE AVAILABLE SUBSURFACE DATA HAS BEEN INCLUDED UPTO JULY 1984
4. THE LITHOUNITS HAVE GOT PINCHING AND SHELLING NATURE AS OBSERVED IN THE SURFACE, THEREFORE THE THICKNESS OF INDIVIDUAL BANDS MAY NOT BE UNIFORM.

DRG. NO. JDP/SS OF 11.84

R. ANBALAGAN
GEOLOGICAL SURVEY OF INDIA

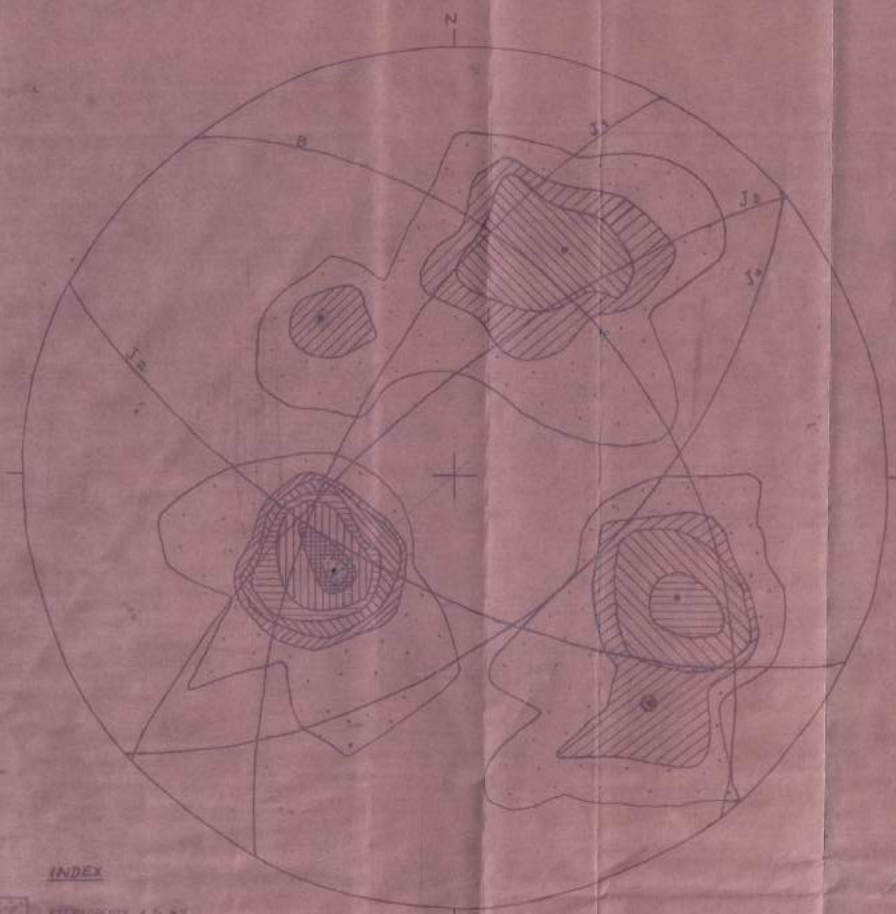
PLATE - X

(112)

JAMRANI DAM PROJECT

STEREOPLOTS OF BEDDING AND JOINT PLANES

AT DAM SITE



INDEX

- STEREOPLOTS 1 to 2%
- STEREOPLOTS 2 to 3%
- STEREOPLOTS 3 to 5%
- STEREOPLOTS 5 to 10%
- STEREOPLOTS 10 to 20%
- STEREOPLOTS 20 to 25%
- STEREOPLOTS > 25%

B — GREAT CIRCLE REPRESENTING BEDDING PLANE CORRESPONDING TO CENTRE OF POLE CONCENTRATION.

J_1, J_2, J_3, J_4 — GREAT CIRCLES REPRESENTING JOINT PLANES CORRESPONDING TO CENTRES OF POLE CONCENTRATION.

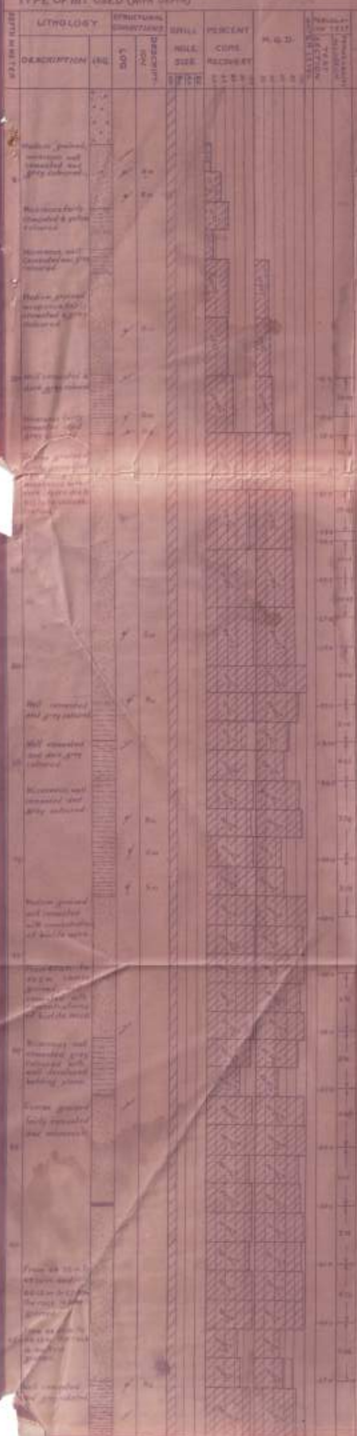
DRG NO. JDP/8 DT. 6-11-82.

R. ANBALAGAN
R. K. SANWAL
GEOLOGICAL SURVEY OF INDIA

GEOLOGICAL LOG OF DRILL HOLE

PROJECT — JAMRANI DAM PROJECT.
STATE — U. P. CO-ORDINATES
FEATURES — DAM AXIS LEFT ABUTMENT. COLLER EL. 649.31 M
STARTED — 14-12-1982 COMPLETED — 7-1-1983
TYPE OF BIT USED (WITH DEPTH)

HOLE NO. — 21
BEARING OF HOLE —
ANGLE WITH HORIZONTAL/VERTICAL
TOTAL DEPTH — 70 M.



SPECIAL OBSERVATIONS AND INTERPRETATIONS

OVERBURDEN :- [illegible]

ROCK :- [illegible]

[illegible]

INDEX

- OVERBURDEN
- SAND STONE
- SILT STONE
- CLAY STONE
- COAL
- ATTITUDE OF BEDDING
- ATTITUDE OF JOINT
- Sm – JOINT PLANE SMOOTH
- RO – JOINT PLANE ROUGH

SCALE :- 1cm = 1m

BY :- R. [illegible]
Geological Survey of India

DRG. No. [illegible]

GEOLOGICAL LOG OF DRILL HOLE

PROJECT – JAMRANI DAM PROJECT.
STATE – U. P.
FEATURES – DAM AXIS, RIGHT ABUTMENT.
STARTED – 23-11-1983.
TYPE OF BIT USED (WITH DEPTH)

CO-ORDINATES | METRE / LEVEL
ROAD LEVEL
COLLER EL. 644.71 M
(COMPLETED – 28-1-1984.

HOLE NO – 25
BEARING OF HOLE –
ANGLE WITH HORIZONTAL – 90°
TOTAL DEPTH – 49.5 M

DEPTH IN METRES	LITHOLOGY DESCRIPTION	LOG	STRUCTURAL INDICATIONS STRIKE	DIP DIRECTION	DRILL HOLE SIZE	PERCENT CORE RECOVERY	R.Q.D.	WEATHERING ZONES	PERMEABILITY IN LUGEONS	SPECIAL OBSERVATIONS AND INTERPRETATIONS
0	Soil overburden, brownish & grey coloured.									OVERBURDEN :- The overburden extends from the surface down to the depth of 2.0 m. It comprises the fill materials of the road.
5	The general grey coloured & fairly compact rock with thin layers and bands of sandstone, occasional contraction.									ROCK :- Lower Siwalik sedimentary rocks are encountered from 2.0 m downwards, comprising alternate bands of sandstone, siltstone and claystone. The sandstones are grey coloured, fairly consolidated, and fine to medium grained near surface, grading into coarse grained at depth. The bedding planes are very often marked by thin dark layers due to mica/biotite and mussovite concentrations. The siltstones are generally dark grey coloured, well consolidated, hard and occasionally with minor intercalations of claystones. The claystones are grey to dark grey coloured, micaceous and fairly well consolidated with intercalations of siltstones occurring as subordinate band fragments. The weathering effects are seen down to a depth of about 7.5 m. The percent core recovery below 12 m is in general more than 90% and below 20.0 m, it is practically more than 95% except between 34.0 m and 39.5 m where it is understood that a small piece of impervious fallen during water test has blocked the drilled core barrel for poor core recovery. The rock quality designation (R.Q.D.) is generally poor (25% to 50%) down to a depth of 34.5 m except for short reaches where R.Q.D. is fair (50% to 75%). Further down R.Q.D. is good (75% to 90%) to excellent (90% to 100%). Water percolation tests have been done in the drill hole in stages, under low (20 PSI) medium (100 PSI to 120 PSI) high (150 PSI) pressures, in upward and return cycles. On analysing the permeabilities in terms of lugeon for different cycles, the representative value is chosen based on inferred flow conditions. An examination of these results shows that permeability, barring the first few stages, between 12 m to 18 m, and 33 m to 38 m, generally decreases as the depth increases from 18 m to 36.27 m, the permeability values are 10 to 15 lugeons and further down the values are less than 10 lugeons.
10	Medium grained, micaceous, fairly compact and grey coloured.									
15	Dark grey coloured soft argillaceous bed, micaceous, occasional intercalations of clay stone.									
20	Medium grained, grey coloured, micaceous, fairly consolidated & massive.									
25	Coarse grained, fairly consolidated & grey coloured with thin dark layers due to more micaceous inclusions.									
30	Soft and friable.									
35	Dark grey coloured and compacted mixed sand and mudstone.									
40	Coarse grained, occasionally conglomeratic & grey coloured.									
45	Hard cemented band with intercalations of siltstone consisting of conglomeration of fragments.									
50	Coarse grained, fairly consolidated, and hard grey coloured with thin dark layers due to built up of coarser materials.									

INDEX

- OVERBURDEN.
- SAND STONE.
- SILT STONE.
- CLAY STONE.
- COAL.
- DIP OF BEDDING.
- DIP OF JOINTS.
- Sm – JOINT PLANE SMOOTH.
- Ro – JOINT PLANE ROUGH.

SCALE :- 1 cm = 1 m.

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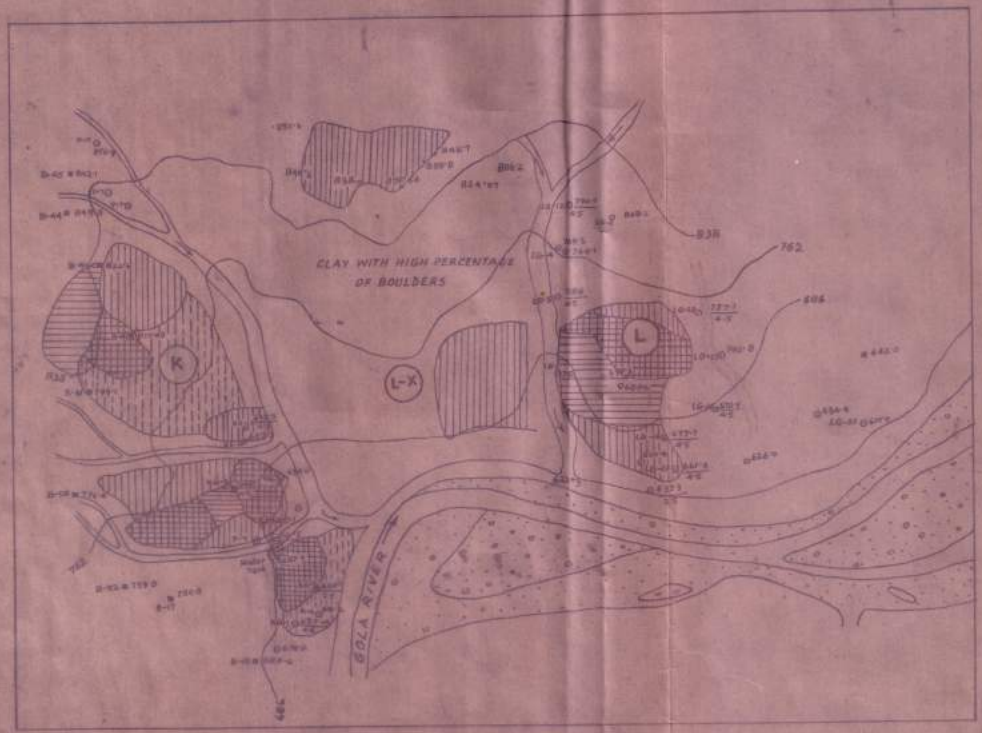
DRG. No. JDP/32 DT. 3-6-84

PLATE - VIII

JAMRANI DAM PROJECT

MAP SHOWING TENTATIVE DEPTHS OF CLAY IN 'K' 'L-X' AND 'L' AREAS

SCALE - 1:8000



INDEX

- DEPTH OF CLAY 8 M.
- DEPTH OF CLAY 7 M.
- DEPTH OF CLAY 6 M.
- DEPTH OF CLAY 5 M.

NOTE :—

1. THE TOPOGRAPHICAL MAP HAS BEEN SUPPLIED BY PROJECT AUTHORITIES.
2. THE DEPTH OF CLAY ARE TENTATIVE BASED ON SURFACE GEOLOGICAL AND GEOMORPHOLOGICAL SET UP OF THE AREA AS WELL AS THE EXPLORATION PITS.

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DRG. NO:- JDP/81 Dt. 2-8-84