



Annexure-I

J-11015/276/2011-IA.II (M)
Government of India
Ministry of Environment, Forests and Climate Change

3rd Floor, Vayu Block,
Indira Paryavaran Bhawan, Jor Bagh Road,
Aliganj, New Delhi-110003

Dated: 19.04.2017

To

The CMD
M/s NTPC Ltd.,
NTPC Bhawan, Scope Complex,
7, Institutional Area, Lodhi Road,
New Delhi-110003.

Sub: *Permission disposal of fly ash (1.2 MTPA) generated from 460 MW Talcher TPP of M/s NTPC Ltd. into mine void of South Balanda OPC of M/s Mahanadi Coalfields Ltd., in Talcher Coalfields, District. Angul, Odisha - extension of permission reg.*

Sir,

This has reference to your online application dated 23.11.2017 and documents submitted vide your letter dated 8.2.2017 on the above subject. It is noted that permission for the above pilot project proposal was accorded by the Ministry (based on EAC recommendation) on 05.09.2013 for a period of one year, subject to various studies on the impacts of ash disposal in mine voids. The said permission was extended for one year (based on EAC recommendation) on 02.03.2015 subject to compliance of interim Orders and final Judgment of Hon'ble NGT. Additional studies to be conducted by NTPC/NEERI were also prescribed. The said permission has been further extended for one year vide Ministry's letter dated 11.04.2016.

2. It has been noted that Integrated Hydro-geological, Geophysical, Hydrochemical and Groundwater flow and solute transport modeling studies around ash filled South Balanda Mine voids in Angul Dist., Odisha have been undertaken during 2012-2016 by NEERI, Nagpur. Assessment of Bioaccumulation of trace metals in flora and fauna due to backfilling of ash from Talcher Thermal Power Station in mine voids of South Balanda Mine has been conducted by NEERI, Nagpur. Isotope hydrochemical investigation on the impact of flyash disposal in opencast coal mine quarries to groundwater quality at Talcher has been conducted by BARC, Mumbai.

3. Capacity of allotted mine voids quarry no.2, 3A & 3B of South Balanda is 16.73 million cubic metres. Ash filled in mines till January, 2017 is 12.88 million cubic metres. Available void in South Balanda is 3.85 million cubic metres which can cater to discharge of ash slurry from Talcher Thermal Power Station till 2021.

4. Ash characterisation results indicate that the ash samples comes under the class F with percentage of SiO₂ (42.81-72.51%), Al₂O₃ (18.77-30.92%), Fe₂O₃ (1.04-6.16%), TiO₂(0.61-1.69%).

5. Ground water level (above mean sea level) contours indicate that the groundwater flow direction is towards Brahmani River. All the parameters (major cations and anions) were well within the permissible limits of BIS standards except for Fluoride and Nitrate which showed elevated concentrations in 3 samples. Petrographic studies carried out by NEERI in 2014 established the presence of fluoride and aluminium bearing minerals in the study area. The remote sensing and

land use land classification study had established the elevated concentration of nitrate to the proximity of the samples to the built up areas and agricultural fields.

6. The water extraction tests and water elution tests (leachate tests) show that the leaching of metals may occur only under extremely acidic conditions in laboratory. Under normal environmental conditions, the leaching of heavy metals and trace elements is insignificant. Hydraulic conductivity measurements found to be 10-9cm/sec which indicates that the ash column at the mine void has very poor permeability.

7. The drilling at the ash void indicates that the top unconfined aquifer at the site is now occupied by poor permeable ash column. The modelling of solute transport of the supernatant (with TDS 210 mg/l) indicate that high concentrated plume (210 mg/l) will move 280 m, 568 m, 852 m and 1140 m distance in 5 years, 10 years, 15 years and 20 years.

8. The comprehensive analysis of the water chemistry of sources in the vicinity of the mine void, piezometer and the supernatant indicate that no systematic increase in the concentration of trace elements like As, Pb and Hg is observed in the sampling campaign carried out since 2012. The results of all the studies indicate that the disposal of ash from Talcher TPS in the voids of South Balanda Mine has no adverse impact on ground water quality. The poor permeability of the ash deposits in the mine void prevents movement of ash water into the adjoining aquifers and prevents ground water contamination. Besides, the drilling data at the mine voids support the presence of clay and coal seam below the ash column. The presence of underlying impermeable clay along with the poor permeable ash column retards the movement of the toxic trace elements to the underlying aquifers.

9. Studies suggest that the ash can be effectively used in backfilling and reclamation of mine voids, without any risk of ground water contamination and without any need of lining.

10. The matter was placed before the Re-constituted Expert Appraisal Committee (Thermal Power) in its 4th Meeting held on 16.3.2017. In acceptance of the recommendation of the Re-constituted Expert Appraisal Committee (Thermal Power) and in view of the information/clarification furnished by you, with respect to the above project, the **Ministry hereby accords the permission to continue the disposal of fly ash for the maximum quantity of 1.2 MTPA on temporary basis for a further period of five years w.e.f from 10.4.2017** subject to following conditions.

- i. A pilot project shall be explored for implementation for Cenosphere extraction from flyash and manufacturing of by-products in consultation with organizations like CSIR, ISM (IIT) Dhanbad.
- ii. As recommended by NEERI, Ash characterisation, hydro-geological studies, leachability of trace metals, monitoring of trace elements in the supernatant, pH of the water and the piezometers on a quarterly basis and reports shall be submitted to the Ministry and it's regional office annually.
- iii. Radio tracer studies shall be continued once in six months and the findings of the study shall be submitted to the Ministry and its Regional office annually.
- iv. Bioaccumulation and bio-magnification tests shall be conducted on surrounding flora and fauna (tree leaves, vegetation, crop yields and cattle population etc) during pre-monsoon and post monsoon to find out any trace metals escaped through groundwater or runoff and the reports shall be submitted to the Ministry annually.

- v. Surface runoff and supernatant water, in any case shall not be allowed to flow into the surroundings. It shall be collected by providing adequate drains around the mine. As proposed the supernatant water along with surface runoff shall be treated and re-used for ash mixing and plant operations. Surface and ground water quality along with existing piezometric wells shall be monitored quarterly and the reports shall be submitted to the Ministry annually.
 - vi. After the mine void reaches its full capacity, 30 cm sweet soil lining and proper compacting be provided on the top to avoid any wash off during reason. Reclamation activities along with greenbelt development shall be carried out in consultation with M/s MCL in accordance with approved Mine Closure Plan. An action plan in this regard shall be submitted to the Ministry and its Regional Office.
 - vii. Only decanted water from mine, make up water from treated effluents such as cooling tower blow down and treated sewage water shall be used for making ash slurry. Raw water withdrawal from Brahmani river for purpose of making ash slurry shall be minimized. Downstream impacts of water withdrawal from Brahmani River shall be studied and report submitted to the Ministry.
 - viii. Mercury in flyash shall be periodically monitored by Inductively Coupled Plasma Mass Spectrometry (ICP-MS).
 - ix. Details of month-wise quantity of flyash disposed and water consumption along with nature of water shall be submitted to Ministry.
 - x. Half-yearly Compliance report for all the stipulated conditions in this permission shall be submitted to the Ministry and its Regional Office.
 - xi. The flyash utilization shall be in compliance with Flyash Notification and its amendments issued from time to time by the Ministry.
 - xii. Third party evaluation/Environment Audit shall be conducted annually for reviewing the compliance conditions stipulated in the clearances along with the baseline data/studies to be carried out during the period of temporary permission.
 - xiii. Compliance of EC/amendment conditions, Environment (Protection) Act, 1986, Rules and MoEF&CC Notifications issued time to time shall be done by an Environment Officer to be nominated by the Project Head of the Company who shall be responsible for implementation and necessary compliance timely.
11. All other studies & conditions prescribed in the earlier permissions dated 05.09.2013, 02.03.2015 and 11.04.2016 shall also be complied with by NTPC and other concerned, as applicable.
12. Any appeal against this permission shall lie with the National Green Tribunal, of preferred, within 30 days as prescribed under Section 16 of the National Green Tribunal Act, 2010.

This issues with the approval of the Competent Authority.

Yours faithfully,


(Dr. S. Kerketta)
Director

Copy to:

1. The Secretary, Ministry of Power, Shram Shakti Bhawan, Rafi Marg, New Delhi 110001.
2. The Chairman, Central Electricity Authority, Sewa Bhawan, R.K. Puram, New Delhi-110066.
3. The Chairman, Central Pollution Control Board, Parivesh Bhawan, CBD-cum-Office Complex, East Arjun Nagar, Delhi- 110032.
4. The Director General of Mines Safety, Head Office Dhanbad-826016, Jharkhand.
5. The Additional Principal Conservator of Forests (APCCF), Regional Office (EZ), Ministry of Environment, Forests and Climate Change, A/3, Chandesekharapur, Bhubaneswar - 751023.
6. The Principal Secretary, Department of Forest and Environment, Government of Odisha, Bhubaneswar.
7. The CMD, Mahanadi Coalfields Limited, Jagriti Vihar, Burla, Sambalpur-768020, Odisha.
8. The Chairman, Orissa State Pollution Control Board, A-118, Nilkanta Nagar, Unit - VIII, Bhubaneswar- 751 012.
9. The District Collector, Angul District, Odisha.
10. Guard/Monitoring file.
11. Website of MoEF&CC.


(Dr. S. Kerketta)
Director



No. J-13012/31/2009-IA.II(T)
Government of India
Ministry of Environment, Forest and Climate Change

Indira Paryavaran Bhawan,
3rd Floor, Vayu Wing
Jor Bagh Road,
Aliganj, New Delhi-110003

Dated: 12.9.2018

To

The General Manager (Environmental Engineering)
M/s NTPC Ltd.
NTPC Bhawan, Scope Complex,
7, Institutional Area, Lodhi Road,
New Delhi-110003.

Phone No. 011-30003200; E-mail: environment.ntpc@gmail.com.

Sub: 2x660 MW (Stage-III, Expansion) Coal based Ultra Super Critical Talcher Thermal Power Project, Near Talcher Town, Tehsil Talcher Sadar, Angul District, Odisha by M/s NTPC Ltd-reg. Environmental Clearance.

Sir,

The undersigned is directed to refer your online application No. **IA/OR/THE/66791/2014** dated 16.2.2018, Ministry's letter dated 9.5.2018 and the documents submitted vide letter dated 8.6.2018 w.r.t the aforesaid project.

2. It has been noted that ToR for establishing 2x660 MW Talcher Thermal Power Project (Expansion) has been issued vide Ministry's letter dated 22.10.2014 which was valid for two years, i.e. till 21.10.2016. Further, ToR has been extended for one year, i.e. till 21.10.2017 on 13.1.2017 and for one more year, i.e. till 21.10.2018 on 15.9.2017. Proposed project is listed as Category 'A' project at Sl.No.1(d) of Schedule of EIA Notification, 2006 and subsequent amendments.

3. It has been noted that M/s NTPC is proposing to enhance the capacity of Talcher Thermal Power Station (TTPS) by adding 2 nos. units of 660 MW each, as Talcher Thermal Power Project (TTPP) Stage-III (2x660 MW). Proposed Power Plant is located within the premises of Talcher Thermal Power Station (TTPS) is situated near Talcher town in Angul district of Odisha having existing capacity of 460 MW [Stage-I (4x60 MW) + Stage-II (2x110 MW)]. The project was implemented by erstwhile Orissa State Electricity Board (OSEB) and was subsequently taken over by NTPC on 03.06.1995 and is under commercial operation. NTPC vide letter No. 01/CP/SP/CEA dated 14.06.2017 to CEA, has indicated phasing out/retiring of the Talcher Thermal Power Plant 460 MW (4x60 MW and 2x 110 MW) by 31.12.2023.

4. The proposed power project is located in Talcher Critically Polluted Area having a cluster of steel, aluminium, thermal power, chemical and mining industries etc. as identified by the CPCB. A moratorium on Environmental Clearance for the project located in areas of Angul, Talcher (Odisha) was imposed by MOEF&CC vide OM dated 13.01.2010 and subsequently lifted vide OM dated 31.03.2011.

5. It has been noted that the total land requirement for proposed project is 446 acres. No additional land acquisition is envisaged for proposed expansion Stage-III

(2x660 MW) of TTPS. The plant facilities for this expansion stage would be accommodated within the land available in the existing power station and township of Talcher TPS, Stage-I & II. Total land required for proposed expansion project is about 193 acres, including 2.337 acres of government forest land near upstream of Samal Barrage on Brahmani River, is proposed to be acquired from state government. Make-up Water Pipelines (about 30 km) are proposed to be laid along the Right Bank Canal of Samal Barrage up to TTPP. About 223 acres of land would be required for Right of Use (ROU) for about 30 meter wide corridor and about 30 Km long pipeline. In-principle (Stage-I) approval for diversion of 0.95 ha forest land for construction of intake water pump house at Samal, Talcher in Angul District has been obtained vide Ministry's (RO, Bhubaneswar) letter dated 12.6.2018.

6. It has been informed by you that there are no defense installations, National Parks, Wildlife Sanctuary, Elephant/Tiger Reserve, Elephant corridors and other wildlife protected areas etc. within 10 km radius. However, one (Ananta Sayi Vishnu at Saranga) monument of archaeological importance and some Reserve/Protected Forests are located within 10 km of the proposed project site.

7. Coal requirement for Talcher TPP Stage-III (2 x 660 MW) is estimated to be about 6.9 MTPA considering 85% PLF. Expected Coal quality is Total moisture 11 – 17%, Ash content is 34% (maximum), GCV is 2900-4100 kcal/kg, Sulphur: 0.5-0.55%. The envisaged mode of coal transportation from the coal mines to the power plant is by Rail in BOBR wagons. The rakes shall be unloaded at the track hopper terminal. Coal will be transported by Rail.

8. It has been informed that Standing Linkage Committee (Long-Term) for Power Sector, Ministry of Coal, Government of India has recommended the long term coal linkage with subsidiaries of CIL to the proposed Talcher TPP Stage-III (2x660 MW) at its meeting held on 10.04.2018. Ministry of Coal has issued Minutes of Meeting dated 15.05.2018 stating that coal for Talcher TPP will be supplied from CIL. The linked mine/Subsidiary for Talcher TPP Stage-III (2x660 MW) project has not been identified by Coal India Limited (CIL) as yet. It is expected that coal mine of Mahanadi Coalfields will be allotted for the proposed project. In order to meet ash content up to 34%, coal from CIL fields can be suitably blended to achieve ash content of coal less than 34%. Further setting up of a coal washery and its operation requires huge volume of water and land which NTPC may not be in a position to do so. However, NTPC will put all its efforts to impress upon CIL to supply the required quality of coal.

9. It has been further informed by you that the makeup water required at inlet of various locations involving the process of the power generation, cooling, ventilation, service water, and Ash handling, ash slurry system etc is 3800 m³/hr. Water Balance Diagram of about 5 Cycle of Concentration (COC) is envisaged for the proposed project. WRD, Government of Odisha vide letter dated 04.06.2018 has allocated 16.49 cusecs of water for existing plant and 39 cusecs of water in phased manner for operation of proposed Talcher Thermal Power Project Stage-III (2x660 MW).

10. It has been informed by you that Ultra-super critical technology envisaged to be used in proposed Talcher TPP which has steam parameters higher than supercritical/ sub-critical technology. In preliminary design consideration main steam pressure will be 270 kg/cm² (a) at HPT inlet, main steam temperature at HPT inlet will be 600°C and hot reheat steam temperature at IPT inlet will be 600°C. Adoption of Ultra-super critical technology with above USC steam parameters will increase the plant efficiency by approximately 3.12 % point, while the carbon emission would reduce by approximately 7.5% per kWhr.

11. The expansion of Talcher Thermal Power Project with addition of Stage-III (2x660 MW) involves demolition of old quarters and common facilities in existing township/infrastructures. The existing township/ infrastructures (about 190 acres) will be demolished in phased manner. No additional raw water reservoir is proposed for expansion project (Stage-III). However, existing raw water reservoir of Talcher TPS would be relocated and utilized for Stage-III also.

12. It has been noted that a railway siding already exists within project site which will be extended with use of proposed railway land. Construction of marshalling yard on railway land (about 30 acres) is envisaged, and its availability on lease from railways will be explored. The ash pipeline is envisaged to be laid along the existing ash pipeline towards MCL mine voids. The ash pipe line from bifurcate point (from existing route) to Jagannath Mine voids will be laid on MCL land after consultation with MCL. NTPC already has provision of MGR System at existing Talcher TPS, which is around 3 kms from MCL mines siding, it has conveyor system for transportation of coal. Talcher TPS stage-III (2x660 MW), NTPC shall take care of the norms laid down by Ministry of Power for transportation of coal by closed pipe conveyor system/MGR system, whichever is applicable.

13. It has been noted that the baseline data was collected during 1st March 2015 to 31th May 2015 (Pre-monsoon Season) within a study area of 10 km radial distance around the proposed Talcher Thermal Power Project Stage-III (2x660 MW). Ambient Air Quality monitoring commenced from 03rd March, 2015 and was extended up to 06th June, 2015 to collect adequate number of samples. The predominant wind direction at site is from WNW and West direction. Ambient air quality has been collected from seven locations. Air quality (98 percentile values) is in the range of PM₁₀: 70-112 µg/m³, PM_{2.5}: 29-48 µg/m³, SOX: 18.6-27.4 µg/m³, NOX: 22.1-31.1 µg/m³, Hg: <0.001 µg/m³ & O₃: 27.6-39.6 µg/m³.

14. It has been noted that one month additional baseline ambient air quality data has been collected from 2.5.2018 to 29.5.2018 at four locations (two locations from the stations mentioned in the EIA report and two from continuous AAQ Stations at Talcher TPS) as suggested by EAC. The data has been compared with the Odisha SPCB values. The SO₂ and NO₂ values are well within the National Ambient Air Quality Standards (NAAQS). However, the PM₁₀ & PM_{2.5} are slightly higher than the NAAQS in downwind direction. The values are slightly higher due to domestic coal burning, Brick Kiln, poor road conditions, and other industrial activities in the area. Although the values recorded by consultant hired by NTPC are on higher side but in most of the locations, it is at par with the Odisha SPCB.

15. Cumulative prediction of air quality for the worst case scenario considering for stack height 150 /275 m for Talcher TPS Stage-III (2x660 MW) is enclosed. For the stack height of 275 m, the maximum ground level concentrations (98 percentile) for PM, SO₂ and NO_x was observed 91.57, 35.98 and 39.68 µg/m³ including the resultant incremental value of 2.57, 8.58 and 8.58 for respectively at the distance of 1600, 1300 and 1300 m in E and ESE direction. Whereas, for the stack height of 150 m, the maximum ground level concentrations (98 percentile) for PM, SO₂ and NO_x was observed to be 91.74, 36.50 and 40.20 µg/m³ including the resultant incremental value of 2.74, 9.10 and 9.10, respectively at the distance of 1600, 1300 and 1300 m in E and ESE direction.

16. The noise levels observed are in the range of during day time 46.5 – 63.7 dB(A) and for night time 36.6 – 53.2 dB(A) for the various zones. The ambient noise levels of the study area are well within the National Ambient Standards for Noise w.r.t residential area, commercial area, silence zone and industrial area categories.

17. Surface water quality of Samal Barrage, Brahmini River at different locations is found to meet the BDU Criteria class "C" of CPCB except BOD concentration in few of the samples. No metallic contamination was found in surface water samples.

18. The pH value of water samples in all the location (ranging from 7.25-7.92) did not show any significant variations and all the values were within permissible limit. The EC values were found to be in the range of 345 - 1220 μ mhos/cm. The electric conductivity values of Chalagarh Village are high with respect to other locations. The chloride values in ground water sample found in the range of 26 - 212 mg/l. The chloride concentration for all ground water samples was within desirable as well as permissible limit of IS. The total hardness value in ground water sample found in the range of 120 - 385 mg/l and found within permissible range. Calcium and Magnesium concentration for all ground water samples were within permissible range. The concentration of Nitrates as NO₃ found to be in the range of 0.26 - 4.1 mg/l. The concentration of Nitrates was reported to be within the desirable as well as permissible limit of IS. Zinc is within the desirable limit at all locations, while Fe was observed more than permissible limit only at Chalagarh. The concentration of Cu was observed within the desirable limit. Other metals in ground water were below detection limit. All the parameters (except Fe at one location) in ground water sample of study area are well within the permissible limit of Indian Standard IS: 10500.

19. Soils of the study area are moderately fertile in the study area with medium level of available nutrients. Soils are observed generally slightly to moderately alkaline in nature. Most of the study area soils are with medium to high level of organic carbon contents as well as organic matter. Soils are low to medium in available nitrogen content. Medium phosphorous levels were also observed in the soils of study area. Low to medium potassium levels are observed in the soil of the area.

20. No threatened species of flora and fauna are found in the study area. There are 142 urban and rural settlements situated in the study area 10 km radius from the proposed plant. As per 2011 census, 2,08,929 persons were inhabited in these 142 settlements out of which 63,680 are from SC/ST. Literacy levels in the study area at 74.15% as per 2011 census data.

21. No ground water source will be tapped for meeting the water requirements during operation phase of power plant. The entire water requirement of the project will be drawn from Samal Barrage on Brahmani River.

22. It is proposed to use closed cycle cooling system with cooling towers would be adopted for condenser and auxiliary cooling. The system has been optimized to operate at about 5 Cycles of Concentration (COC) for conservation of water.

23. Executive Engineer, Head works Division, Samal vide letter dated 24.05.2018 has provided the details of Upstream of Samal Barrage. It has informed that provision of drawl of water from Upstream of Samal Barrage is 9.909 m³/sec. and there currently are no proposed/upcoming power plants in this area. The availability of water after considering the existing project at Upstream of Samal Barrage is 1.808 m³/sec (63.85 Cusecs) which is more than the water requirement (39 Cusecs) for proposed Talcher TPP Stage-III (2x660 MW). Executive Engineer, Angul Irrigation Division, Hakimpada, Angul vide letter dated 29.05.2018 has provided the details of downstream of Samal Barrage. Further, it is also informed that Department of Water Resources, Govt. of Odisha has allocated 35.81 Cusecs of water from downstream of Samal Barrage to M/s NSL Nagapatnam Power & Infratech Limited. But currently construction of said project not started and not withdrawing the water from Brahmani River.

24. As the project is designed with Zero Liquid Discharge (ZLD), the wastewater from the project during normal operations will not be discharged outside into any water body. Approx. 750 m³/hr of wastewater will be generated from various process of the power plant viz. CT Blow down, Clarifier Sludge, Tube settler sludge, Filter Backwash, Boiler Blowdown, DM Neutralization Pit and Domestic Sewage.

25. Approximately 80% (1.84 MTPA) of it will be flyash and balance 20% (0.46 MTPA) will be in the form of bottom ash. Ash generated from the power plant will be utilized as per MOEF&CC notifications (03.11.2009 & amendment dated 25.01.2016). The Ash generated from Talcher TPS Stage-I & II (existing units 460MW) is already being disposed in Balanda mine voids 2 & 3. NTPC Talcher is also issuing dry flyash to flyash brick manufacturing units and asbestos cement units. The ash generated from the proposed Talcher Stage-III is proposed to be disposed in the Mine Voids of Jagannath Mines (abandoned mine voids of MCL). Jagannath mine is located about 14 km away from the plant. The permission for disposal of ash in mine voids of Jagannath mines will be obtained from MoEF&CC separately. Gypsum produced by the FGD system is envisaged to be removed by conveyers to a storage shed for further use by cement industries or disposal in an environmentally friendly manner.

26. It is proposed to install adequately designed, high efficiency electrostatic precipitator having an efficiency that limits the outlet emission to 30 mg/Nm³. NOx emission values from the steam generator shall be limited to the applicable values by employing low NOx burners (LNB), combustion staging and reducing NOx in the tail flue gas using either SNCR (selective non-catalytic reduction) or SCR (selective catalytic reduction) technology as applicable. Wet lime stone based flue gas desulphurization (FGD) system shall be installed at the tail end of the steam generator downstream of the ESP to capture SO₂. To facilitate wider dispersal of pollutants and gaseous pollutions, a 150 m/275 m high twin-flue reinforced concrete chimney is envisaged after ESP. The chimney shall be provided with personal access doors and sampling ports for continuous online monitoring. Talcher TPS Stage-III has provision of dust suppression system in the Coal Handling Plant (CHP) area to minimize suspended particulate matter in the working area. The dust suppression consists of water spraying which shall be provided along the conveyor belts.

27. Public Hearing was conducted by Odisha SPCB on 12.07.2017 at D.A.V. School, Talcher TPS, Talcher, Odisha with presence of about 1300 people. Public Hearing was chaired by Sh. Sh. Srinibas Behera, ADM Angul and other member of panel was Sh. Binod Bihari Dash, Regional officer, OSPCB, Angul. NTPC official made presentation about proposed Talcher TPP Stage-III (2x660 MW) and EIA study before public. The main issues raised by public are employment, free education, free health facilities at Talcher TPS hospital, free electricity, infrastructure development, drinking water, CSR and pollution due to fly ash and other emissions etc. Local people protested initially for these issues but later on supported the said project for development of area.

28. CPCB vide letter dated 06.04.2018 has issued directions to the existing Talcher TPS (460 MW), under Section-5 of Environmental Protection Act, 1986, for installation of pollution control equipment's (FGD, Low NOx burners, providing Over Fire Air (OFA), retrofit of ESP) to comply New Emission norms of MoEF&CC by 31.12.2020. It is also directed by CPCB that plant shall not operate beyond 31.12.2020, if it fails to comply with new/revised emission limits for SO₂, NOx and PM.

29. NTPC Talcher Thermal Power Plant (460 MW) was inspected on 23.05.2018 and monitoring was carried out on 23.05.2018 & 24.05.2018 by SPCB, Odisha to verify the status of compliance of Consent to Operate. Point-wise compliance and monitoring report of Odisha SPCB vide letter dated 29.05.2018 for Consent to Operate dated 31.03.2018 for existing Talcher Thermal Power Plant for Phase-I: 4x60 MW and Phase-II: 2x110 MW has been submitted.

30. The Community Development initiatives of Talcher TPS are broadly planned in the area of Education, Health, Infrastructure/asset Creation, Water supply, women empowerment, Capacity building and other Welfare activities, etc. The proposed draft Plan for Community Development activities and implementing Public Hearing commitments for Talcher Stage-III (2x660 MW) has been prepared. The Capital budget is envisaged around Rs 19.50 Crs.

31. Total estimated project cost is Rs. 7,732.35 Crores. A cost provision Rs.2016.5 crores towards providing environmental measures Environmental Management Plan which includes Rs. 5 crores towards afforestation, greenbelt & landscaping has been made in project cost. Greenbelt of 8.09 Ha is proposed to be developed. In addition, 12.14 Ha around Talcher TPS in nearby villages will be developed with greenbelt if land is provided by the Government. Employment during construction phase is 1500. It has been informed by you that no litigations/court cases are pending against the project or existing power plant.

32. The proposal for grant of Environmental Clearance has been considered in the 16th and 18th meeting of EAC (Thermal Power) held on 19.4.2018 and 27.6.2018. Project proponent along with EIA Consultants M/s EQMS India Pvt. Ltd. (QCI-NABET Accredited Consultant for Category 'A' Thermal Power Projects, accreditation certificate valid till 21.5.2018), have made the presentation. In acceptance of the recommendations of the Re-constituted EAC (Thermal Power) in its 18th meeting held on 27.6.2018 and in view of the information, clarifications, documents submitted by you, **the Ministry hereby accords the Environmental Clearance to the 2x660 MW (Stage-III, Expansion) Coal based Ultra Super Critical Talcher Thermal Power Project** as per the Project Activity listed at Sl.No.1(d) of the Schedule under the provisions of EIA Notification dated September 14, 2006 and subsequent amendments therein subject to compliance of the following Specific and General conditions.

A. Specific Conditions:

- (i) Ash ponds near Village Jhadiamba (133.848 acres) and Village Santhapada (156.538 acres) shall not be taken up as the ash is proposed to dispose it in the abandoned mine voids.
- (ii) The Ash content and Sulphur contents in the Coal shall not exceed 34% and 0.55%, respectively. In case of change in coal characteristics, a fresh reference is to be made to Ministry for reviewing the incremental impact, if any and adequacy of the conditions.
- (iii) The capital CSR/CER budget shall be in line with Ministry's OM dated 1.5.2018 or Rs.19.5 crores whichever is higher. The amount shall be implemented during project construction in the surrounding villages.
- (iv) As the coal source is determined, the details regarding characteristics of coal along with transport mode shall be submitted to Ministry. Coal transportation shall be done by rail only. In any event, coal shall not be transported by road.
- (v) The ash which is sent to South Balanda mines shall be mixed with 8% lime before disposing into the mines.

- (vi) The new emission standards notified vide Ministry's S.O.3305(E) dated 7.12.2015 shall be achieved for existing units as per the extended timelines given by CPCB. Further, the proposed units shall achieve new emissions standards from the date of commissioning of the plant.
- (vii) Considering the proposed project is located in the Talcher Critically Polluted Area, the stack height of 275 m shall be erected to achieve maximum dispersion.
- (viii) The ash pond near Village Santhapada shall not be used as it is near to Brahmani River and high chances of breaching and contaminating the water body.
- (ix) As per the Revised Tariff Policy notified by Ministry of Power vide dated 28.01.2016, project proponent shall explore the use of treated sewage water from the Sewage Treatment Plant of Municipality/ local bodies/ similar organization located within 50 km radius of the proposed power project to minimize the water drawl from River Brahmani/other surface water bodies.
- (x) Compliance of EC conditions, E(P) Act, 1986, Rules and MoEF&CC Notifications issued time to time shall be achieved by a qualified environment officer to be nominated by the Project Head of the Company who shall be responsible for implementation and necessary compliance.
- (xi) Thermal Power Plant shall achieve specific water consumption, zero liquid discharge and emission standards as per MoEF&CC Notification S.O. 3305(E) dated 7.12.2015 or subsequent notifications issued time to time.
- (xii) MoEF&CC Notification G.S.R 02(E) dated 2.1.2014 regarding use of raw or blended or beneficiated or washed coal with ash content not exceeding 34% shall be complied with, as applicable.
- (xiii) MoEF&CC Notifications on flyash utilization S.O. 763(E) dated 14.09.1999, S.O. 979(E) dated 27.08.2003, S.O. 2804(E) dated 3.11.2009, S.O. 254(E) dated 25.01.2016 and subsequent amendments issue time to time shall be complied with.
- (xiv) Construction and inert waste generated during phasing out of existing plants shall be disposed as per Construction and Demolition Waste Management Rules, 2016.
- (xv) Vision document specifying prospective plan for the site shall be formulated and submitted to the Regional Office of the Ministry within **six months**.
- (xvi) Harnessing solar power within the premises of the plant particularly at available roof tops shall be carried out and status of implementation including actual generation of solar power shall be submitted along with half yearly monitoring report.
- (xvii) Online continuous monitoring system for stack emission, ambient air and effluent shall be installed.
- (xviii) High Efficiency Electrostatic Precipitators (ESPs) shall be installed to ensure that particulate emission does not exceed 30 mg/Nm³ or as would be notified by the Ministry, whichever is stringent. Adequate dust extraction system such as cyclones/bag filters and water spray system in dusty areas such as in coal handling and ash handling points, transfer areas and other vulnerable dusty areas shall be provided along with an environment friendly sludge disposal system.
- (xix) Adequate dust extraction system such as cyclones/ bag filters and water spray system in dusty areas such as in coal handling and ash handling points, transfer areas and other vulnerable dusty areas shall be provided.

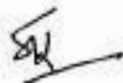
- (xx) Monitoring of surface water quantity and quality shall also be regularly conducted and records maintained. The monitored data shall be submitted to the Ministry regularly. Further, monitoring points shall be located between the plant and drainage in the direction of flow of ground water and records maintained. Monitoring for heavy metals in ground water shall also be undertaken and results/findings submitted along with half yearly monitoring report.
- (xxi) A well designed rain water harvesting system shall be put in place within six months, which shall comprise of rain water collection from the built up and open area in the plant premises and detailed record kept of the quantity of water harvested every year and its use.
- (xxii) No water bodies including natural drainage system in the area shall be disturbed due to activities associated with the setting up/operation of the power plant.
- (xxiii) Additional soil for leveling of the proposed site shall be generated within the sites (to the extent possible) so that natural drainage system of the area is protected and improved.
- (xxiv) Fly ash shall be collected in dry form and storage facility (silos) shall be provided. Mercury and other heavy metals (As, Hg, Cr, Pb etc.) shall be monitored in the bottom ash. No ash shall be disposed off in low lying area.
- (xxv) No mine void filling will be undertaken as an option for ash utilization without adequate lining of mine with suitable media such that no leachate shall take place at any point of time. In case, the option of mine void filling is to be adopted, prior detailed study of soil characteristics of the mine area shall be undertaken from an institute of repute and adequate clay lining shall be ascertained by the State Pollution Control Board and implementation done in close co-ordination with the State Pollution Control Board.
- (xxvi) Fugitive emission of fly ash (dry or wet) shall be controlled such that no agricultural or non-agricultural land is affected. Damage to any land shall be mitigated and suitable compensation provided in consultation with the local Panchayat.
- (xxvii) Green Belt consisting of three tiers of plantations of native species all around plant and at least 50 m width shall be raised. Wherever 50 m width is not feasible a 20 m width shall be raised and adequate justification shall be submitted to the Ministry. Tree density shall not be less than 2500 per ha with survival rate not less than 80 %.
- (xxviii) The project proponent shall formulate a well laid Corporate Environment Policy and identify and designate responsible officers at all levels of its hierarchy for ensuring adherence to the policy and compliance with the conditions stipulated in this clearance letter and other applicable environmental laws and regulations.
- (xxix) CER schemes identified based on need based assessment shall be implemented in consultation with the village Panchayat and the District Administration starting from the development of project itself. As part of CER prior identification of local employable youth and eventual employment in the project after imparting relevant training shall be also undertaken. Company shall provide separate budget for community development activities and income generating programmes.
- (xxx) CER activities will be carried out as per OM No. 22-65/2017-IA.II dated 01.05.2018 or as proposed by the PP in reference to Public Hearing or as

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- earmarked in the EIA/EMP report along with the detailed scheduled of implementation with appropriate budgeting.
- (xxxix) For proper and periodic monitoring of CSR activities, a CSR committee or a Social Audit committee or a suitable credible external agency shall be appointed. CSR activities shall also be evaluated by an independent external agency. This evaluation shall be both concurrent and final.

B) General Conditions:

- (i) The treated effluents conforming to the prescribed standards only shall be re-circulated and reused within the plant. Arrangements shall be made that effluents and storm water do not get mixed.
- (ii) A sewage treatment plant shall be provided (as applicable) and the treated sewage shall be used for raising greenbelt/plantation.
- (iii) Storage facilities for auxiliary liquid fuel such as LDO/ HFO/LSHS shall be made in the plant area in consultation with Department of Explosives, Nagpur. Sulphur content in the liquid fuel will not exceed 0.5%. Disaster Management Plan shall be prepared to meet any eventuality in case of an accident taking place due to storage of oil.
- (iv) First Aid and sanitation arrangements shall be made for the drivers and other contract workers during construction phase.
- (v) Noise levels emanating from turbines shall be so controlled such that the noise in the work zone shall be limited to 85 dB(A) from source. For people working in the high noise area, requisite personal protective equipment like earplugs/ear muffs etc. shall be provided. Workers engaged in noisy areas such as turbine area, air compressors etc shall be periodically examined to maintain audiometric record and for treatment for any hearing loss including shifting to non-noisy/less noisy areas.
- (vi) Regular monitoring of ambient air ground level concentration of SO₂, NO_x, PM_{2.5} & PM₁₀ and Hg shall be carried out in the impact zone and records maintained. If at any stage these levels are found to exceed the prescribed limits, necessary control measures shall be provided immediately. The location of the monitoring stations and frequency of monitoring shall be decided in consultation with SPCB. Periodic reports shall be submitted to the Regional Office of this Ministry. The data shall also be put on the website of the company.
- (vii) Utilization of 100% Fly Ash generated shall be made from 4th year of operation. Status of implementation shall be reported to the Regional Office of the Ministry from time to time.
- (viii) Provision shall be made for the housing of construction labour (as applicable) within the site with all necessary infrastructure and facilities such as fuel for cooking, mobile toilets, mobile STP, safe drinking water, medical health care, crèche etc. The housing may be in the form of temporary structures to be removed after the completion of the project.
- (ix) The project proponent shall advertise in at least two local newspapers widely circulated in the region around the project, one of which shall be in the vernacular language of the locality concerned within seven days from the date of this clearance letter, informing that the project has been accorded environmental clearance and copies of clearance letter are available with the Delhi Pollution Control Committee and may also be seen at the Website of MoEF&CC at <http://envfor.nic.in>.



- (x) A copy of the clearance letter shall be sent by the proponent to concerned Panchayat, Zila Parisad / Municipal Corporation, urban local Body and the Local NGO, if any, from whom suggestions/representations, if any, were received while processing the proposal. The clearance letter shall also be put on the website of the Company by the proponent.
 - (xi) The proponent shall upload the status of compliance of the stipulated environmental clearance conditions, including results of monitored data on their website and shall update the same periodically. It shall simultaneously be sent to the Regional Office of MOEF, the respective Zonal Office of CPCB and the SPCB. The criteria pollutant levels namely; SPM, RSPM (PM_{2.5} & PM₁₀), SO₂, NO_x (ambient levels as well as stack emissions) shall be displayed at a convenient location near the main gate of the company in the public domain.
 - (xii) The environment statement for each financial year ending 31st March in Form-V as is mandated to be submitted by the project proponent to the concerned State Pollution Control Board as prescribed under the Environment (Protection) Rules, 1986, as amended subsequently, shall also be put on the website of the company along with the status of compliance of environmental clearance conditions and shall also be sent to the respective Regional Offices of the Ministry by e-mail.
 - (xiii) **The project proponent shall submit six monthly reports on the status of the implementation of the stipulated environmental safeguards to MoEF&CC, its Regional Office, Central Pollution Control Board and State Pollution Control Board. The project proponent shall upload the status of compliance of the environmental clearance conditions on their website and update the same periodically and simultaneously send the same by e-mail to the Regional Office, MoEF&CC.**
 - (xiv) The progress of the project shall be submitted to CEA on six monthly basis.
 - (xv) Regional Office of the MoEF&CC will monitor the implementation of the stipulated conditions. A complete set of documents including Environmental Impact Assessment Report and Environment Management Plan along with the additional information submitted from time to time shall be forwarded to the Regional Office for their use during monitoring. Project proponent will up-load the compliance status in their website and up-date the same from time to time at least six monthly basis. **Criteria pollutants levels including NO_x (from stack & ambient air) shall be displayed at the main gate of the power plant.**
 - (xvi) Separate funds shall be allocated for implementation of environmental protection measures along with item-wise break-up. These cost shall be included as part of the project cost. The funds earmarked for the environment protection measures shall not be diverted for other purposes and year-wise expenditure should be reported to the Ministry.
 - (xvii) The project authorities shall inform the Regional Office as well as the Ministry regarding the date of financial closure and final approval of the project by the concerned authorities and the dates of start of land development work and commissioning of plant.
 - (xviii) Full cooperation shall be extended to the Scientists/Officers from the Ministry / Regional Office of the Ministry / CPCB/ SPCB who would be monitoring the compliance of environmental status.
- C) An as built or as completed report on EMP to be submitted stating the scope/extent of work envisaged in the EIA along with estimated cost vis-à-vis the

actual completed works and cost incurred. A certificate/completion certificate accordingly, shall have to be submitted before commissioning of the TPP.

33. The Ministry reserves the right to revoke the clearance if conditions stipulated are not implemented to the satisfaction. The Ministry may also impose additional environmental conditions or modify the existing ones, if necessary.

34. The environmental clearance accorded **shall be valid for a period of 7 years** from the date of issue of this letter to start operations by the power plant.

35. Concealing factual data or submission of false/fabricated data and failure to comply with any of the conditions mentioned above may result in withdrawal of this clearance and attract action under the provisions of Environment (Protection) Act, 1986.

36. In case of any deviation or alteration in the project proposed including coal transportation system from those submitted to this Ministry for clearance, a fresh reference should be made to the Ministry to assess the adequacy of the condition(s) imposed and to add additional environmental protection measures required, if any.

37. The above stipulations would be enforced among others under the Water (Prevention and Control of Pollution) Act, 1974, the Air (Prevention and Control of Pollution) Act, 1981, the Environment (Protection) Act, 1986 and rules there under, Hazardous Wastes (Management, Handling & Transboundary Movement) Rules, 2008 and its amendments, the Public Liability Insurance Act, 1991 and its amendments.

38. Any appeal against this environmental clearance shall lie with the National Green Tribunal, if preferred, within 30 days as prescribed under Section 16 of the National Green Tribunal Act, 2010.

This issues with the approval of the Competent Authority.


Yours faithfully,


(Dr. S. Kerketta)
Director, IA.I

Copy to:-

1. The Secretary, Ministry of Power, Shram Shakti Bhawan, Rafi Marg, New Delhi 110001.
2. The Chairman, Central Electricity Authority, Sewa Bhawan, R.K. Puram, New Delhi-110066.
3. The Chairman, Central Pollution Control Board, Parivesh Bhawan, CBD-cum-Office Complex, East Arjun Nagar, Delhi- 110032.
4. The Additional Principal Chief Conservator of Forests (C), Ministry of Environment, Forest and Climate Change, Regional Office (EZ),A/3, Chandrasekharpur, Bhubaneswar-751023.
5. The Additional Chief Secretary, Department of Forest and Environment, Government of Odisha, Secretariat, Bhubaneswar-751001.
6. The Chairman, Odisha State Pollution Control Board, A-118, Nilkanta Nagar, Unit-VIII, Bhubaneswar-751012.

7. The District Collector, Angul District, Govt. of Odisha, Mishrapada, Angul, Odisha-759122.
8. Guard file/Monitoring file.
9. Website of MoEF&CC.


(Dr. S. Kerketta)
Director, IA.I



ମହାନଦୀ କୋଲଫିଲ୍ଡ୍‌ସ୍ ଲିମିଟେଡ୍
MAHANADI COALFIELDS LIMITED

(A Subsidiary of Coal India Limited)

P.O.- Jagruti Vihar, Dist-Sambalpur-768020 (Orissa)
 Tel./ Fax: 0663 - 2542798, Fax: 0663-2542770
 Phone: PBX: 0663 - 2542461 to 2542469



Ref. No. MCL/NO. G. & E. CRRAS / 2459

Date: 17/11/09

OFFICE ORDER

The following voids of Jagannath OCP have been allocated for ash filling as detailed below.

1. Quarry no VII (3.96M cum) to TIPS(NTPC)
- Quarry no IV (6.43M cum) to TIPS(NTPC)
- 2. Quarry no VIII (17.82M cum) to STPS, Karaha
3. Quarry no IV (17.00 M. cum) to Bhusan Steel

This has been approved by competent authority.

Encl: plan showing the voids in Jagannath OCP

B.N. Shukla
 (B.N. Shukla)
 General Manager (C&E)

Distribution:-

1. Director (Tech/P&P), MCL- For kind information
2. GM, Jagannath Area
3. GM, Env, MCL Hqs
- ✓ 4. Mx. TIPS(NTPC) (Talcher thermal), PO- Talcher Thermal, Dist- Angul (Orissa), PIN-759101
5. Mx. STPS (NTPC) (Talcher Karaha), PO-Deapshika, dist- Angul(Orissa), PIN-759147
6. M/s Bhusan Steel Limited, At Narasdrapur, PO-kashpanga, Via-Meramaundali, dist-dhanbad (Orissa), PIN-759121

For preparation of Scheme with provision for plantation etc to be submitted after duly approved by the Pollution Control Board.

→ DGM (Env)
 DGM (PCS)
 let us try for VIII & others for Env.
Bill

3092
 21/11/09



Mahanadi Coalfields Limited
(A Subsidiary of Coal India Limited)
A Mini Ratna Company

ମହାନଦୀ କୋଲମିନ୍‌ସ୍‌ଲିମିଟେଡ
ଏକ ମିନି ରାଟନା କମ୍ପାନୀ

Mahanadi Coalfields Limited
(A Subsidiary of Coal India Limited)
OFFICE OF THE GENERAL MANAGER (CP&P)

Ref. No: MCL/HQRS/GM(CP&P)/1375

Date: 18/03/2014

To
The Executive Director
Talcher Kaniha
Talcher Super Thermal Power Station
PO- Deepshikha - 759147
Dist- Angul(Odisha)

Handwritten: 19/3
GM (present)

Sub: Simultaneous usage of Quarry no.VIII of Jagannath OCP by both the power stations i.e. TSTPS, Kaniha and TTPS, Talcher for mine void filling by fly ash.

Dear Sir,

MCL has approved the proposal of simultaneous usage of Quarry no.VII of Jagannath OCP by both the power stations i.e. TSTPS, Kaniha and TTPS, Talcher for mine void filling by fly ash

This is for NOC from Orissa State Pollution Control Board and pilot study to evaluate the impact of fly ash in the mine void as per directive of MOEF

Yours faithfully

Handwritten signature
18/3/14

(B N Shukla)
General Manager (CP&P)

Copy to :

- 1. Director (Tech./F&P), MCL- For kind information
- 2. RED (ER-II) ,NTPC Limited, Bhubaneswar- For kind information

Handwritten: Al f. mine void file (14A)

Corporate Address: ATPO, 2nd Flr, Bada, Tal. B., Bhubaneswar (Odisha) Pin Code: 751013
Bhilai Office: At: 250012, Bhubaneswar (Odisha) Pin Code: 751012



J. 13011/14/94-IA.II (T) pt.
Government of India
Ministry of Environment, Forests and Climate Change

3rd Floor, Vayu Block,
Indira Priyadarshan Bhawan, Jor Bagh Road,
Ajgaraj, New Delhi 110003

Dated: 20.9.2018

To

The CMD
M/s NTPC Ltd.,
NTPC Bhawan, Scope Complex,
7, Institutional Area, Lodhi Road,
New Delhi-110003.

Sub: Disposal of fly ash generated from Talcher Super Thermal Power Station (Stage-I:2x500 MW & Stage-II: 4x500 MW) into abandoned mine voids of Jagannath OPC of Mahanadi Coalfields Limited in Talcher, Dist. Angul, Odisha by M/s NTPC Limited- rag. temporary permission for disposal of flyash.

Sir,

This has reference to your online application No. **IA/OR/THE/10212/1996** dated 2.1.2017, Ministry's letter dated 26.5.2017 and documents submitted vide your letter dated 8.8.2018 on the above subject.

2. It has been noted that the Environmental Clearance for the 2x500 MW (Stage-I) Talcher Thermal Super Thermal Power Plant has been issued vide Ministry's letter No.25/5/84-EN.2/IA dated 17.2.1988. Further, the Environmental Clearance for 4x500 MW (Stage-II) has been issued vide Ministry's letter No.J.13011/14/94-IA.II ted 17.5.1996. Subsequently, an amendment in the EC dated 17.5.1996 for not acquiring additional ash pond has been issued vide Ministry's letter dated 23.2.1998. Another amendment in the EC dated 17.5.1996 has been issued for waving off the lining/grouting for the ash pond vide Ministry's letter dated 25.12.2002.

3. It has been noted that you have requested the Coal to Talcher Super Thermal Power Station is being supplied by Talcher coalfields (Lingaraj block) of Mahanadi Coalfields Ltd. Coal is transported to NTPC-TSTPS from Lingaraj coal mines of MCL through a 39 km MGR railway transportation system. The station generates approximately 5.5 MTPA of total ash (flyash and bottom ash) and could utilised only 38-43%. The source of water is from Samal Barrage Reservoir on river Brahmani.

4. It has been noted that the unutilised ash is being disposed into two ash disposal areas (Stage-I: 750 acres and Stage-II: 840 acres) located at about 7 km N-W of the plant. Stage-I ash pond is nearly full in capacity and Stage-II ash pond is critical capacity and will last up to 2020. Further, M/s MCL has allotted Quarry no.8 of Jagannath OCP to NTPC for backfilling ash from TSTPS.

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5. It has been noted that M/s NTPC conducted Hydro-geological studies, characterisation and leachate studies conducted by NEERI. As suggested by EAC, market survey to assess ash utilisation potential for various uses in the vicinity of power plant has been conducted. Further, analysis of scientific and engineering alternatives for disposal of ash from Talcher STPP has been conducted by CMPDI. Slurry pumping through pipeline is recommended for the distance of approximately 20 km.

6. It has been informed that the ground water levels have been monitored. The results show that during pre-monsoon season, maximum depth of groundwater is observed at 12.95 metres below ground level (bgl) at Village Ekdid to minimum depth at 2.10 mbgl at village Jagannathpur. During post monsoon season, maximum depth of groundwater is found at 5.98 m bgl and minimum depth found at 1.21 m bgl at village Deulbara.

7. It has been noted that the Stage-I Forest Clearance for diversion of 38.726 ha has been accorded for mine void filling project of Talcher Super Thermal Power Station, Kaniha, NTPC Ltd. vide Ministry's Eastern Regional Office letter dated 12.7.2018.

8. The matter was placed before the Re-constituted Expert Appraisal Committee (Thermal Power) in its 34th and 4th meetings held on 29-30.4.2015 and 16.3.2017. In acceptance of the recommendation of the Re-constituted Expert Appraisal Committee (Thermal Power) in its meeting held on 16.3.2017 and in view of the information/clarification furnished by you, with respect to the above project, **the Ministry hereby accords the temporary permission for backfilling of flyash in the abandoned mine voids of Quarry no.8 of Jagannath Opencast Mine of M/s MCL for the maximum quantity of 20,000 tonnes of ash per day from Talcher STPS for a period of five years** subject to following conditions.

- i. A pilot project shall be explored for implementation for Cenosphere extraction from flyash and manufacturing of by products in consultation with organizations like CSIR, ISM (IT) Dhanbad. [HOP- TalcherSTPP](#)
- ii. As recommended by NEERI, Ash characterisation, hydro-geological studies, leachability of trace metals, monitoring of trace elements in the supernatant, pH of the water and the piezometers on a quarterly basis and reports shall be submitted to the Ministry and its regional office annually. [HOP- Talcher/Env.Engg](#)
- iii. Radio tracer studies shall be continued once in six months and the findings of the study shall be submitted to the Ministry and its Regional office annually. [HOP- Talcher/Env.Engg](#)
- iv. Bioaccumulation and bio-magnification tests shall be conducted on surrounding flora and fauna (tree leaves, vegetation, crop yields and cattle population etc) during pre-monsoon and post monsoon to find out any trace metals escaped through groundwater or runoff and the reports shall be submitted to the Ministry annually [HOP- Talcher/Env.Engg](#)
- v. Surface runoff and supernatant water, in any case shall not be let into surroundings. It shall be collected by providing adequate drains around the

mine. As proposed the supernatant water along with surface runoff shall be treated and re used for ash mixing and plant operations. Surface and ground water quality along with existing piezometric wells shall be monitored quarterly and the reports shall be submitted to the Ministry annually. [HOP- Talcher](#)

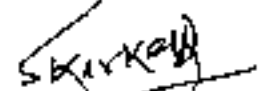
vi. Current state of flyash utilisation shall be in compliance with Flyash Notification and its amendments issued time to time. [HOP- Talcher/Ash Magmt-CC](#)

9. All other conditions stipulated in the Ministry's letters dated permissions dated 17.2.1988, 17.5.1996 and 26.12.2002 shall remain same, as applicable.

10. Any appeal against this permission shall lie with the National Green Tribunal, if preferred, within 30 days as prescribed under Section 16 of the National Green Tribunal Act, 2010.

This issues with the approval of the Competent Authority.


Yours faithfully,



(Dr. S. Kerketta)
Director, I.A.I.

Copy to:

1. The Secretary, Ministry of Power, Shram Shakti Bhawan, Rafi Marg, New Delhi-110001.
2. The Chairman, Central Electricity Authority, Sewa Bhawan, R.K. Puram, New Delhi-110066.
3. The Chairman, Central Pollution Control Board, Parivesh Bhawan, Circum-Office Complex, East Arjun Nagar, Delhi- 110032.
4. The Director General of Mines Safety, Head Office Dhanbad 826016, Jharkhand.
5. The Additional Principal Conservator of Forests (APCCF), Regional Office (EZ), Ministry of Environment, Forests and Climate Change, A/3, Chandrasekharpur, Bhubaneswar - 751023
6. The Principal Secretary, Department of Forest and Environment, Government of Odisha, Bhubaneswar.
7. The CMD, Mahanadi Coalfields Limited, Jagriti Vihar, Burla, Sambalpur 768020, Odisha.
8. The Chairman, Orissa State Pollution Control Board, A-118, Nilkanta Nagar, Unit - VIII, Bhubaneswar- 751012.
9. The District Collector, Angul District, Mysrapada, Angul, Odisha 759122.
- 10 Guard/Monitoring file
- 11 Website of MoEF&CC.



(Dr. S. Kerketta)
Director, I.A.I.

A Report On

Disposal of Ash
From
Talcher Thermal Power Station
Into
Exhausted Quarry No. 4 & 7 of
Jagannath Mines



A Maharatna Company

NTPC Limited

(A Government of India Enterprise)

October, 2018

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1.0 Introduction

NTPC is operating Talcher Thermal Power Station (TTPS) near Talcher town, Distt. Angul, Odisha with a total installed capacity of 460 MW (Stage-I: 4x60 MW + Stage-II: 2x110 MW). The project was established by erstwhile Orissa State Electricity Board (OSEB), Govt. of Odisha (Stage-I Units commissioned during 1967-69 and Stage-II Units commissioned during 1982-83). The plant was taken over by NTPC on 03.06.1995 and is under commercial operation since then.

TTPS is about 4 Km from Talcher Town and about 25 Km from district headquarters Angul between 20° 54' 02"N - 20° 55' 05"N latitudes and 85° 12' 10"E – 85° 13' 00"E longitudes. It is covered by Survey of India Toposheet (F45 T/1 and F45 T/5 on 1:50,000 scale). The nearby gram panchayats are Santhapada, Jagannathpur, Bantol, and Gurujanguli. Nearest railway station named 'Talcher' is on Talcher-Cuttack section of North Eastern Railway (renamed East Coast Railway) at about 2 Km. However, a small railway station named 'Talcher Thermal' is located near project boundary. The area is accessible by NH-23 (renamed NH-149) at about 1 Km. The nearest commercial airport is at Bhubaneshwar (i.e. Biju Patnaik International Airport) located at an aerial distance of 90 Km approx. and about 150 Km by road.

The coal requirement of TTPS is approximately 3.5 Million Tonnes Per Annum (MTPA) which is received from Lingaraj and Kaniha mines of M/s Mahanadi Coalfields Limited. The ash generation is to the tune of approximately 1.1 MTPA. TTPS is a pit-head thermal power project, having advantage of coal source being located near the project and cost of coal transportation being minimal. However, due to a large number of power plants located in the region and low demand of ash/ ash based products for construction in the area, the Talcher area is an ash surplus zone. At the time of takeover, the ash dyke was filled up and the ash utilisation was very low. NTPC installed various systems for collection of dry ash, supply of ash to the entrepreneurs and ash utilisation at a cost of Rs. 5 Crores.

The project has an in-house Ash Brick Plant & Ash Bricks are used for construction activities. Further, NTPC changed the mode of disposal of ash into mine voids of South Balanda, with an expenditure of about Rs. 68 Crores. South Balanda Coal Mine of MCL is the first Open Cast Mine in India where mining operation started in 1959 and the coal production started in year 1961. Mining operation was closed in year 2005, with 90.4 Million Cu. Meter space available as mine voids. Prior to start of ash filling from TTPS into South Balanda mine voids, NTPC undertook certain scientific studies through CMPDIL based on which Odisha State Pollution Control Board (OSPCB) granted No Objection Certificate for ash filling on 12.05.2004. Filling of ash into Quarry Nos. 2, 3A & 3B of South Balanda Open Cast Mines of MCL started in Sep., 2005. Later environmental clearance for backfilling of ash was also obtained from time to time, latest being accorded by MoEF&CC vide letter dated 19.04.2017.

NTPC-TTPS is planning to implement Stage-III (2x660 MW) for which environment clearance has been accorded by MoEF&CC vide letter dated 12.09.2018. It is

proposed to operate the existing units of TTPS till 2022/ 2023, i.e. till the new units of 2x660 MW under Stage-III, are operational.

The ash from TTPS, Stage-I and II is being filled in the South Balanda mine voids since 2005 and the same is likely to be filled within a few years' time. Further, the ash from Stage-III is also proposed to be disposed in the abandoned mine voids.

In view of the above, it is proposed to dispose-off the ash from existing units of TTPS into the exhausted Quarry No. 4 and 7 of Jagannath OCP (copy of mine voids allocation by MCL vide letter dated 14.11.2009 enclosed as Annexure-III) located at about 12-14 Km from the project. Further, as soon as the new units (Stage-III, 2x660 MW) become operational, the ash generated from these units is also proposed to be disposed in the afore-mentioned abandoned mine void quarry no. 4 & 7. Once the void is completely filled up, the same shall be reclaimed and vegetated with native plant species. This will help in restoring the topography as well as enhancing the local aesthetics.

The exhausted/ abandoned Quarry No. 4, 7 and 8 of Jagannath Mines of MCL, Talcher Area are located in District - Angul, Odisha, between 20° 56' 21"N - 20° 57' 28"N latitudes and 85° 07' 55"E - 85° 09' 45"E longitudes. These quarries are surrounded by adjacent South Balanda OCP in South, Bharatpur OCP in the West, Ananta OCP in the North and Talcher UG mine in the East. This block covers an area of 4.5 sq. km. and is included in the Survey of India topo sheet no. 73H/1. Abandoned Quarry No. 4 & 7 at Jagannath Area of M/s MCL have a void capacity of approx. 10.39 mCum, for the purpose of filling of Ash generated from TTPS. The proposed ash pipeline is envisaged to be laid along the existing ash pipeline towards South Balanda mine voids of MCL. The ash pipeline from bifurcate point (i.e. from existing route) onward to Jagannath Mine voids will be laid on the land under the possession of MCL after due consultation with MCL.

During the summer period, the quarry no. 7 becomes dry but quarry no 4 and 8 are partly filled with water. The dip side of quarry no. 7 is from west to east and quarry 8 is from east to west. Both the quarries are partly backfilled with OB materials and only last dip cut section is left for storing the monsoon runoff water.

Quarry No. 8 is partly filled with water and partly covered with over burden which have consolidated and grown vegetation over time. MoEF&CC vide letter dated 20.09.2018 have accorded temporary permission based on the scientific studies conducted by NTPC w.r.t. abandoned quarries of South Balanda and Jagannath Mines of MCL for backfilling of flyash generated from Talcher Super Thermal Power Project (TSTPP, 3000 MW) in the mine voids of Quarry No. 8 of Jagannath OCP for the maximum quantity of 20,000 tonnes of ash per day for a period of five years i.e. till 20.09.2023. Quarry No. 4 and 7 of Jagannath Mines are adjacent to this quarry.

2.0 Background of Ash Filling in Mine Voids

Utilisation of Fly ash in thermal power plant is a major problem in the areas like Talcher, due to presence of a cluster of thermal power projects and low demand of ash and ash based products. The coal rich state like Odisha is a hub for power generation in the country and large areas of private/ government/ agricultural/ forest land are required for coal mining, power plants as well as for ash disposal. The ash utilisation potential of the state is already low and the ash disposal will require thousands of Acres of additional private/ government/ agricultural/ forest land for ash disposal, in addition to land required for coal mines and power plants. It will, therefore, be a win-win situation for all the stakeholders if the ash is filled in mine voids and the voids are reclaimed through vegetation.

Filling of mine voids with fly ash not only saves huge quantity of land requirement for ash disposal but also reduces associated environmental issues in reclaiming the mined out area for making its gainful use. All the Collectors and District Magistrates have been requested by Odisha state pollution Control Board to identify the abandoned quarries in their districts, so that the thermal power plants can take advantage of the identified quarries for fill-up of the same by fly ash. The permission of ash disposal in mine void of MCL by MOEF&CC to various thermal power plants in Odisha state is given in Table-2.1.

Table-2.1: Thermal Power Plants who have been allotted with Mine Void by MCL and MoEF Clearance

Sl. No.	Thermal Power Plant	Mine Void Allotted	Capacity (in Mcum)	Year of commencement of filling of void
1	TTPS-I&II (NTPC), Talcher	South Balanda	14.73	2005
2	TSTPS (NTPC), Kaniha	Jagannath OCP (Quarry No. 8)	17.82	Not yet started
3	NALCO, CPP, Angul	Bharatpur OCP	13.0	Not yet started
4	Bhushan Steel Ltd., Angul	Jagannath OCP	17.0	2014
5	Nava Bharat Ventures Ltd., Dhenkanal	South Balanda	8.83 Lakh	2008

Mcum- Million Cubic Meter

NTPC has already undertaken a number of studies to assess the impacts of ash filling in mine voids since 2012-13, as follows:

Name of the study	Under taken through
Hydro-geological Investigation	M/s. CMPDI, Ranchi
Fly Ash Characterization such as its Reactivity & Movement	M/s. NEERI, Nagpur
Impact Assessment of ash fill sites on water resources in the surrounding area of South Balanda mine pit and old ash pond area.	M/s. NEERI, Nagpur

Study of Effects due to ash fill sites of TTPS on Flora & Fauna in the surrounding area of South Balanda Mine pit and Jagannath mine pit	M/s. NEERI , Nagpur
Tracer study to understand the pathway of movement of Fly Ash / Leachate in aquifer	M/s. BARC, Mumbai

The studies envisage addressing the objectives by a holistic approach integrating the following aspects:

- Hydrogeology
- Hydrochemistry
- Radioactivity
- Geophysical studies
- Groundwater flow and mass transport modeling
- Impacts of ash filling on the flora and fauna of the area

One of the most striking feature of the ash deposits in the mine voids was revealed through the core drilling within the deposits. When ash is placed in the mine voids with water, fine particles of ash move along water and clogs the pores of soil/ fine cracks in rocks. This process continues till all the pores/ cracks are blocked and the ash gets consolidated on its own weight. Clogging of the pores/ cracks creates an impermeable interface along the surface of mine void while the consolidated layer itself has very low permeability. This results into an impermeable block at bottom and a loose layer at the top. As the filling progresses, the impermeable block grows upwards. As it takes about 1-1.5 years for a layer to consolidate, the movement of the water/ ash particle during that period may be only few inches in the soil, after which it is sealed. The consolidated lower layer acts as a solid impermeable mass of ash, which neither has free pore water nor allows any water to pass through it. Therefore, there is no risk of ground water contamination due to ash water or further disposal of ash slurry on top of it. As the mass of ash itself is impermeable, there is no need for lining of the mine void also.

The above hypothesis is supported by observations during core drilling tests inside actual ash deposits in South Balanda Mine Voids, during which it was observed that :

- Extremely low permeability of ash deposits (10^{-9} cm/s) (due to fine size of ash particles) indicating no lateral or vertical movement of water through deposits
- Almost dry (moist ash with no free water) core samples at greater depths indicating no vertical/ horizontal percolation
- Further, no change in ash characteristics (chemical constituents, leachates and radioactivity) were observed at greater depths, indicating that there are no effects of aging on the ash and leachate characteristics

Based on outcome of the above scientific studies, Consent to Operate from Odisha SPCB and Permission by MOEF&CC are being accorded.

3.0 Project and Surrounding Areas

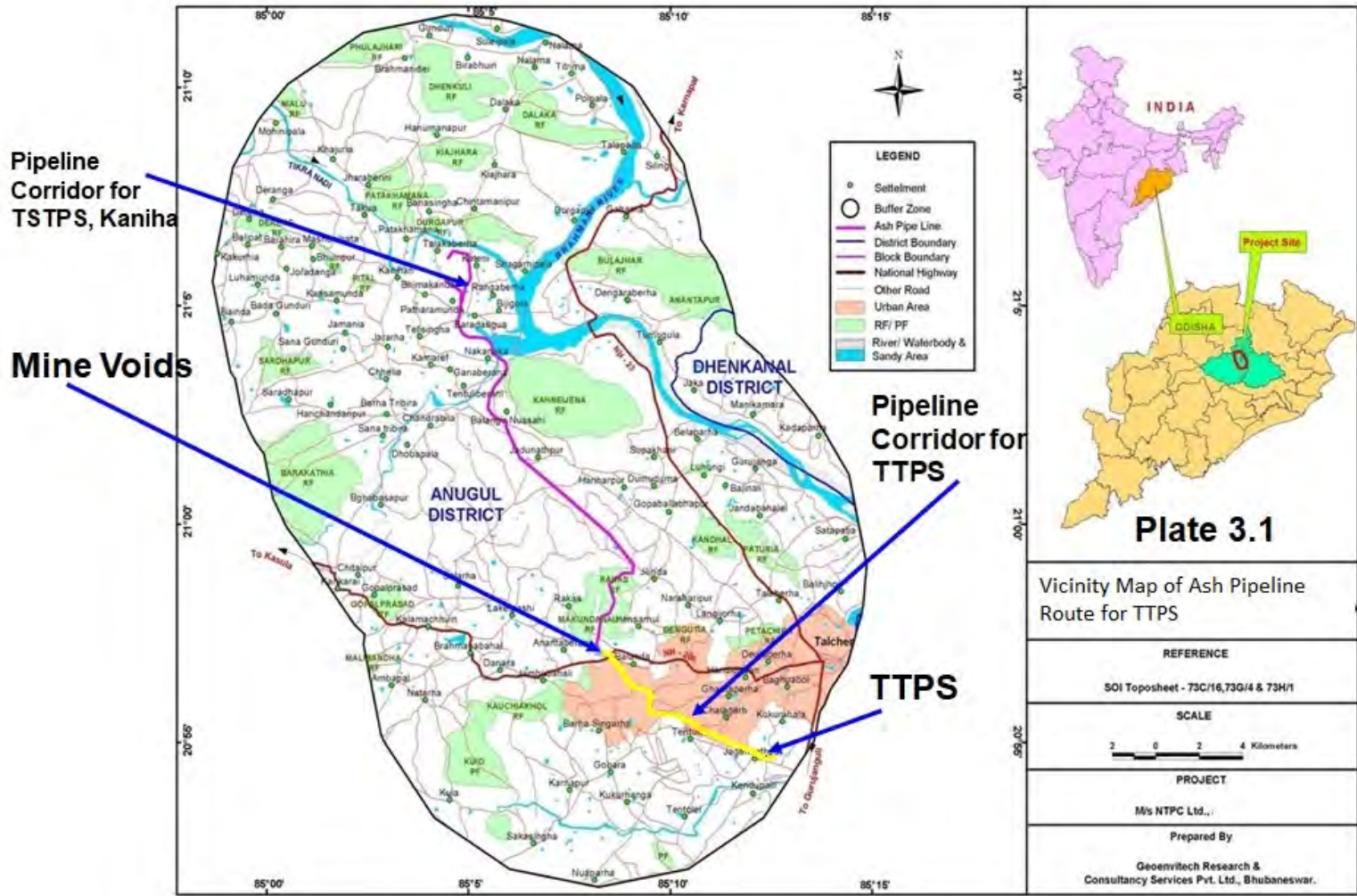
Talcher Thermal Power Station (TTPS) is located near Talcher town, Distt. Angul, Odisha. The site is 4 KM from Talcher Town and about 25 Km from district headquarters. Nearest railway station is at Talcher on Talcher-Cuttack section of North Eastern Railway at about 2 Km. The nearest commercial airport is at Bhubaneswar (i.e. Biju Patnaik International Airport) located at an aerial distance of 90 Km approx. and about 150 Km by road. Exhausted mine void nos. 4, 7 and 8 of Jagannath mine are located in the Jagannath geological block of Mahanadi Coalfields. Jagannath Block lies between latitude 20° 54' 02"N - 20° 55' 05"N latitudes and 85° 12' 10"E – 85° 13' 00"E longitudes. The distance of the disposal site from the station will be approximately 12-14 Km. It is surrounded by adjacent South Balanda OCP in South, Bharatpur OCP in the West, Ananta OCP in the North and Talcher UG mine in the East. A map covering both the power project as well as mine void is presented at Plate 3.1. This also shows the proposed route for pipeline for carrying ash slurry from project to the mine void and overflow from mine void to the project.

The Jagannath block covers an area of 4.5 sq. km and is included in the Survey of India topo sheet no. 73H/1. During the summer period, the quarry no. 7 becomes dry but quarry no 4 and 8 are partly filled with water. The dip side of quarry no. 7 is from west to east and quarry 8 is from east to west. Both the quarries are partly backfilled with OB materials and only last dip cut section is left for storing the monsoon runoff water.

Plate 3.2 shows distribution of mines in and around Jagannath OCP. The mines and their working status in and around 5 Km of the Jagannath Quarry 4, 7 & 8 are presented in 20 3.1.

Table 3.1: Mining Activities in and around Jagannath Quarry 4, 7 & 8

Boundary	Limits	Status
East	Talcher Underground mine	Working Mine
	Handidua Underground mine	Mining Stopped
	Deulbera Underground mine	Mining Discontinued
West	Bharatpur Open cast mine	Working Mine
North West	Balaram Open cast mine	Working Mine
North	Ananta Open cast mine	Working Mine
	Bhubaneswari Open cast mine	Working Mine
North East	Lingaraj Open cast mine	Working Mine
South	South Balanda OCP	De-coaled mine – Under backfilling with ash from TTPS since 2005
South West	Nandira Underground	Working Mine



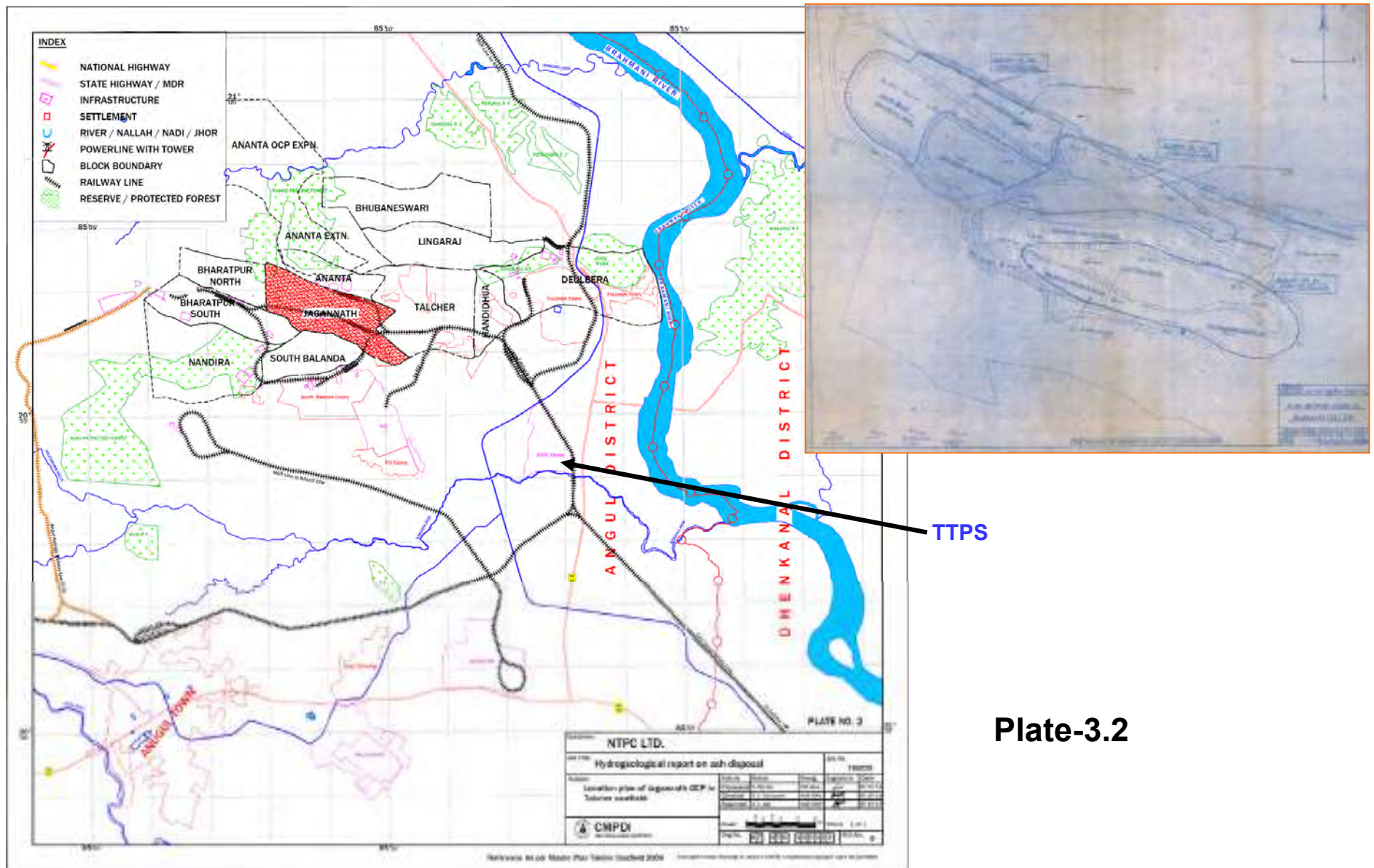


Plate 3.3 shows Google Map for South Balanda and Jagannath mine area. Aerial photographs of Jagannath Mine Void and the facilities located on its periphery are presented in Plates 3.4 and 3.5 respectively. Based on these, the following are observed:

- Quarry No. 8 is partly filled with water and partly covered with over burden which have consolidated and grown vegetation over time
- Quarry No. 8 is surrounded by Quarry Nos. 4 and 7; and road and railway line and
- the entire complex of Jagannath Mine void (Quarry Nos. 4, 7 and 8) is surrounded by other working and abandoned mines.



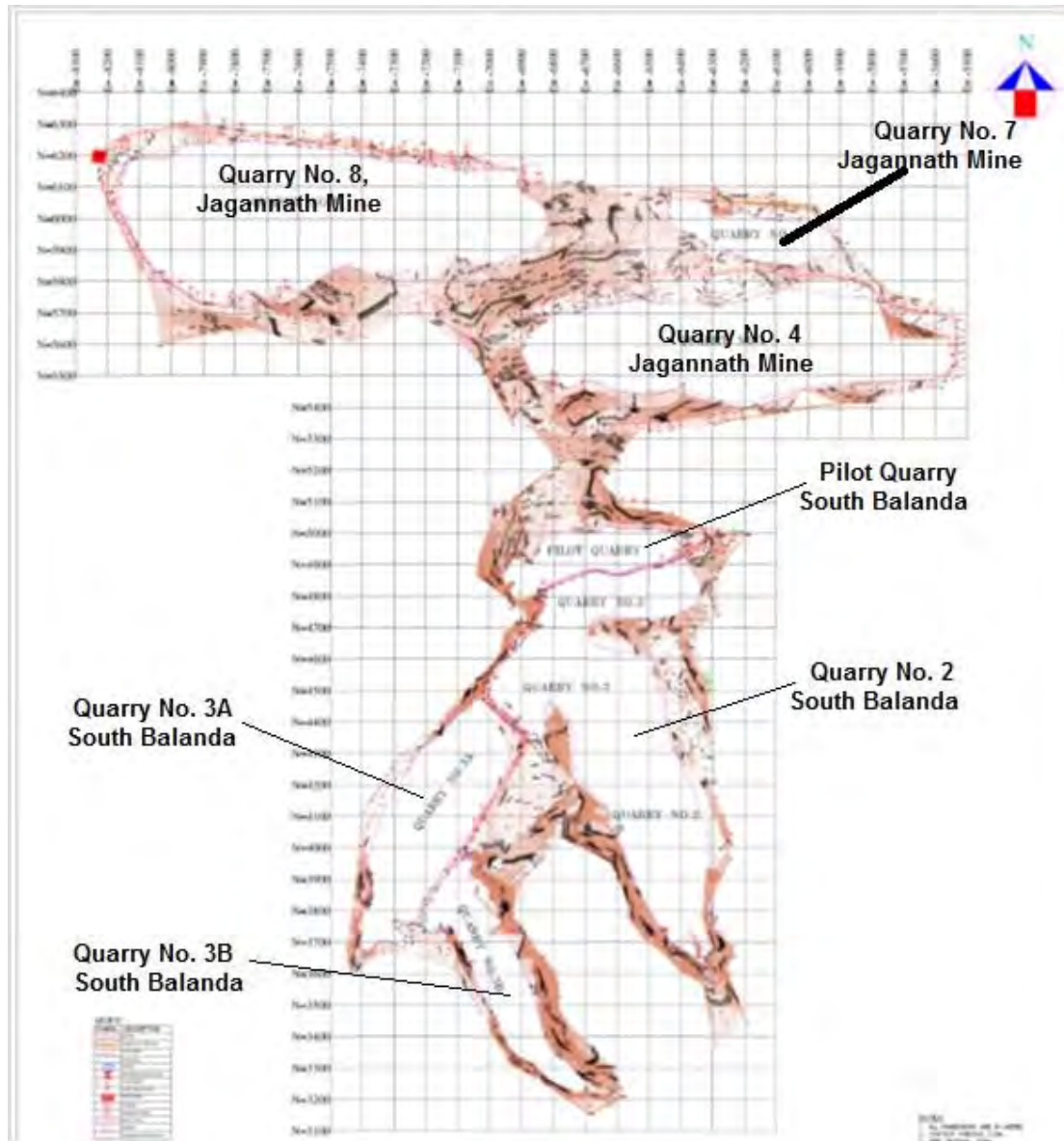


Plate 3.4
Location of Mine Voids

Aerial photographs of Jagannath Mine Void and the facilities located on its periphery



Plate 3.5

- **1** : North - Mine Void-7 , South - Mine Void 8, East - Mine Void-7, West - Road, Rail line
- **2** : North - Road & Mine Void-7, South - Road, Mine Void 8, East - Mine Void 8, West - Road, Rail line
- **3** : North - Road, South - Patch of land to be used for AWP/P , East - Mine Void 8, West - Road, Rail line
- **4** : North - Mine Void 8, South - Road & Rail line, East - Road, West - Road
- **5** : North - Mine Void 8, South - Road & Rail line, East - Road, West - Road , Mine Void 8
- **6** : North – Road to Mine Void 7. South - Mine Void 8. East - Road. Mine Void 4. West – Mine Void 8



Plate 3.6

4.0 Alternate Modes of Transport and Disposal of Ash

4.1 Ash Transport Systems

This section analyses various modes of transport and disposal of ash and discusses their suitability with respect to Talcher TPS – Jagannath Mine Void combination. At present, the following methods are used in India for transportation of ash:

1. Transport of dry ash through pipeline using pneumatic conveying system – mostly used for transport of ash from ESP to Buffer Hoppers/ Silo, inside the plants/ adjacent cement plants.
2. Transport of dry ash through Dumpers/ Trucks - used by user agencies (cement, aggregate, brick manufacturers etc.)
3. Transport of dry ash through MGR System – recently evolved at few stations for long range transport of ash.
4. Transport of moist ash through Belt Conveyors – used at National Capital Thermal Power Project of NTPC Limited at Dadri, for dry ash disposal
5. Transport of wet ash (lean slurry or high concentration slurry) through pipeline – most widely used method for ash disposal system in India

Due to the presence of Calcium Oxide, fly ash has cementing property, which vanishes after mixing with water. Therefore, whenever the transport of ash is intended for its use (like manufacture of cement, RMC, concrete, brick, tile etc.), dry mode of transport is preferred. However, it requires elaborate arrangements and it is costly. Therefore, whenever the ash has to be transported for disposal, wet methods are preferred, which are more convenient and economical. Slurry Pumping through pipeline is widely used in India and it can be implemented with minimum modification of existing system (minimum cost and time for modification) and can be easily operated. In view of the above, slurry disposal system through pipeline is proposed for transport of ash from Talcher TPS to Quarry No. 4 and 7 of Jagannath Mine Voids as is currently being practiced for disposal of ash from TTPS into mine voids of South Balanda.

4.2 Ash Disposal Systems in India

In India mainly four types of ash disposal is adopted for ash from power plants:

1. Wet Disposal in lean slurry form into ash dyke/ mine voids
2. Wet Disposal in High Concentrated Slurry form into ash dykes
3. Dry Disposal in Ash Mound form

The details of all the above systems are described in the following sections.

4.2.1 Wet Disposal in Lean Slurry Form:

This system is widely used in India. The system consists of extraction of fly ash from electrostatic precipitator (ESP), conveying to fly ash silos, slurry mixing tanks and pumping slurry to disposal area using centrifugal pumps. The ash slurry is made with

a ratio of 6:1 to 7:1 between water and ash and it is a free flowing slurry, with a lot of free water.

Ash disposal lagoons are formed by constructing dykes (embankments) made of earth/ ash or using natural depressions such as mine voids and the slurry is discharged into the lagoons from pipelines. Ash particles settle in the lagoons and clear water is decanted above the ash surface. Decanted water is taken out through water escape structures, which is re-circulated to plant through an ash water recirculation system (AWRS) for further use in ash disposal system.

A photograph of a typical lean slurry system is shown in Plate 5.1.



Plate 4.1: Lean Slurry Disposal System

Fresh deposits of ash are in the form of marsh. However, over a period of time, specially when overlain by several layers, these deposits get consolidated into high density layers with no free water. Lean Slurry Ash Disposal system has following advantages:

- ⦿ Cost effective due to relatively simple system.
- ⦿ No special technology required, only centrifugal pumps are used.
- ⦿ Slurry can be disposed to long distances, if required, booster pumps can be used.
- ⦿ Ash water is re-circulated after decantation.

However, at the same time, this system has following disadvantages too:

- ⦿ Due to high velocity wear and tear of pipes is more
- ⦿ The dykes are designed as dams and are always filled with slurry, with a risk of breach/ seepage. It needs continuous watch.

4.2.2 Wet Disposal in High Concentration Slurry Form:

This system is similar to the lean slurry system, except for the ratio of ash and water (concentration of 60% to 75% of ash by weight). Due to high concentration of ash, it is pumped through high pressure piston diaphragm slurry pumps to disposal area and

needs seamless steel pipes for conveying slurry. However, flexible pipes are used at disposal area.

High concentration slurry is homogeneous in nature which ensures that no water is released when slurry is discharged in the ash disposal area. Dense, compact deposit is formed with rapid drying. High concentration slurry attains relatively steep slopes at the time of disposal. A photograph of a typical lean slurry system is shown in Plate 5.1.



Plate 4.2: High Concentration Slurry Flowing on Slopes which dries out by the time it travels 30-40 m from the source

High Concentration Slurry Disposal (HCSD) system has the following advantages and disadvantages.

Advantages of High Concentration Slurry Disposal (HCSD):

- ⦿ HCSD reduces water and land requirement, it is eco-friendly, no leachate discharge
- ⦿ Low water consumption with respect to lean slurry disposal and no release of free water at disposal
- ⦿ As the slurry travels at slow speed, wear and tear of pipes is less
- ⦿ High concentration slurry is easy to dig and can be used for various purposes at a later stage
- ⦿ Low maintenance of ash dyke
- ⦿ Danger of breaching of dyke is negligible.

Disadvantage of High Concentration Slurry Disposal (HCSD):

- ⦿ Ash pipes often get choked due to high concentration slurry
- ⦿ Seamless steel pipes for conveying HC slurry are required.
- ⦿ High concentration slurry disposal requires very high pressures and can be transported to a limited distance only.

4.2.3 Dry Ash Disposal System:

This system is entirely different from the previous two systems. In the dry ash disposal system, furnace bottom ash (FBA) and pulverized fly ash (PFA) are transported from Hydro bins and Silos respectively to ash mound site on fixed belt conveyors in enclosed gantries. FBA and PFA are conveyed separately. In the ash mound area ash is disposed off by various types of equipment like fixed, extendable, shiftable, slewable and mobile belt conveyors, a crawler mounted boom spreader, a crawler mounted bucket wheel reclaimer and a variety of wheeled and crawler mounted mobile equipment.

At present, it is being used at only one station of NTPC i.e. National Capital Thermal Power Station at Dadri.

This is first of its kind which uses conveyor belts to dispose-off moistened ash in form of ash mound. For surface stabilization and dust suppression at the mound, a number of measures are applied depending upon the nature of surface (flat, finished slope or natural ash dump surface), such as surface compaction & landscaping, sprinkling of water and polymers, spreading of cut grass and vegetation by growing grass, shrubs & trees. As the mound construction proceeds & finished slopes are available, the same are covered with grass & plantation. It is to proposed to cover the entire ash mound area by plantation.

Photographs of dry ash disposal system are shown as below:



Plate 4.3: Dry Ash Mound at NCTPS, Dadri (Working Front)



Plate 4.4: Dry Ash Mound at NCTPS, Dadri (After Stabilization and Plantation)

Dry ash Disposal has several advantages over the above two systems:

- ⦿ Less land requirement
- ⦿ Less water requirement
- ⦿ No risk of ground water pollution
- ⦿ Progressive restoration of ash disposal site as useful land in the form of Park

However, it has certain constraints and disadvantages too, such as:

- ⦿ High maintenance cost.
- ⦿ Dependency on weather/ climate conditions. It has to be discontinued during rains.
- ⦿ Constraints of distance. It is feasible only if disposal area is near to the plant.

Apart from Techno-economic consideration and capital and operating costs, the most important factor for selecting the system in the present case is the presence of water in the mine void. Due to presence of huge quantity of water (1.23 Mm³) and connection with the aquifer, it is not possible to empty the mine void before filling. Under such circumstances, the use of dry ash disposal system or HCSD system has no advantage, as the ash will immediately disperse into the water body rather than remaining compact/ consolidated mass.

In view of the above, it is proposed to utilize the lean phase slurry disposal system through pipe lines, which offers the following advantages:

- ⦿ Proven technology
- ⦿ Better acceptability
- ⦿ Cheaper indigenous technology

- ⦿ Lower maintenance and energy requirements
- ⦿ Adequate mine void capacity for ash disposal available
- ⦿ No additional requirement of land for ash storage/disposal

Proposed system shall consist of single stage pumping system with horizontal centrifugal slurry duty pumps of adequate capacity and pressure rating. The salient features of ash disposal system proposed for TTPS, Stage-III is as following:

Table 4.1: Salient Features of Ash Disposal System Proposed for TTPS, Stage-III (2x660 MW) – Jagannath Mine voids (4 &7)

Ash Disposal Pipeline Corridor	Ash slurry pipeline existing route up to south Balanda mine voids for Existing Stage-II of TTPS & I is enclosed at Annexure-IA . Ash slurry pipeline proposed route up to Jagannath mine voids (quarry no. 4 &7) for Existing Stage-I & II and proposed Stage-III of TTPS is enclosed at Annexure-IB .
Length	About 14 Km
Process of Ash Slurry Making	Bottom ash generated from the boiler (collected in Bottom Ash hopper) and part fly ash generated from ESP (collected in ESP hopper) is mixed with water in suitable proportions to form a lean ash slurry. The slurry is transported in pipes for disposal.
Details of Ash Slurry Pumping System	Scheme diagram of Ash Slurry Disposal System is enclosed at Annexure-II
Scheme	Ash disposal system will be sized for slurry form disposal of ash. Bottom ash generated from the boiler and part fly ash generated from ESP is fed to the Ash Slurry sump in the form of lean slurry through ash slurry trenches. Ash slurry pumps are utilized to pump lean ash slurry from the ash slurry sump upto the ash disposal area identified at abandoned Jagannath OCP mine voids of MCL (Quarry No. 4 & 7) through pipelines.
Total Capacity of Jagannath Mine Void Quarry Nos. 4 & 7	10.39 Million Cum.
Details of AWRS	Scheme diagram of AWRS is enclosed at Annexure-III.
Scheme	The decanted water from mine void shall be pumped out by barge mounted to an over ground sump of AWRS Pumphouse located near the disposal area. The water from this overground sump shall be pumped back to the ash water sump situated inside the power plant. This recovered water shall be utilized for ash slurry preparation thereby reducing the requirement of raw make-up water for the purpose.

5.0 Post-filling Reclamation of Land

The design of surface contours and land profile will be in consonance with the surrounding features. The post-closure operation will be planned to have vegetation of preferably indigenous species for providing stability to the filled in site and improve the aesthetics. The filled in quarry no. 4 and 7 will be vegetated and will become a part of the overall post-mining land use pattern envisaged in the mine closure plan of the Jagannath OCP. For vegetation, three tier plantation approach will be followed and this will help in overall eco-restoration of the area. A conceptual diagram of the reclaimed mine void is presented in Plate 5.1 .

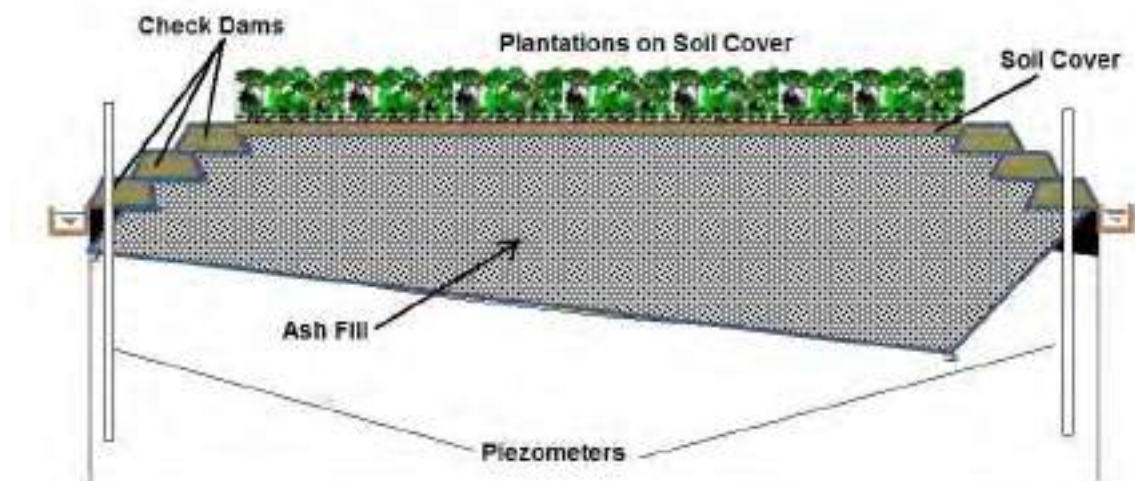


Plate 5.1: Conceptual Plan for Reclamation of Mine Void

In addition, the following measures are proposed to be undertaken:

- i. Storm water drains to be constructed for channelizing the run-off water away from the disposal site.
- ii. Provide 30 cm thick soil cover.
- iii. For closure of the backfilled site, plantation of native varieties of tree on the backfilled site for development of green vegetation shall be done. This will also help in checking the surface run-off, prevent the water from percolation and maintaining the aesthetics of the surrounding in general.
- iv. For vegetation purpose, preference is given to local species and mixed culture. The species will be selected carefully from the following groups for quick reclamation:
 - Nitrogen fixing multipurpose tree species for fuel wood and timber (avoiding fruit bearing and fodder species)
 - Forestry type tree species.
 - Tree species with dense foliage for shade.
 - Native species.

5.1 List of Tree Species Recommended for Plantation

The list of some tree species and grasses recommended for afforestation on the filled on ash and its surrounding areas is as given below:

Table 5.1: Recommended Plant Species

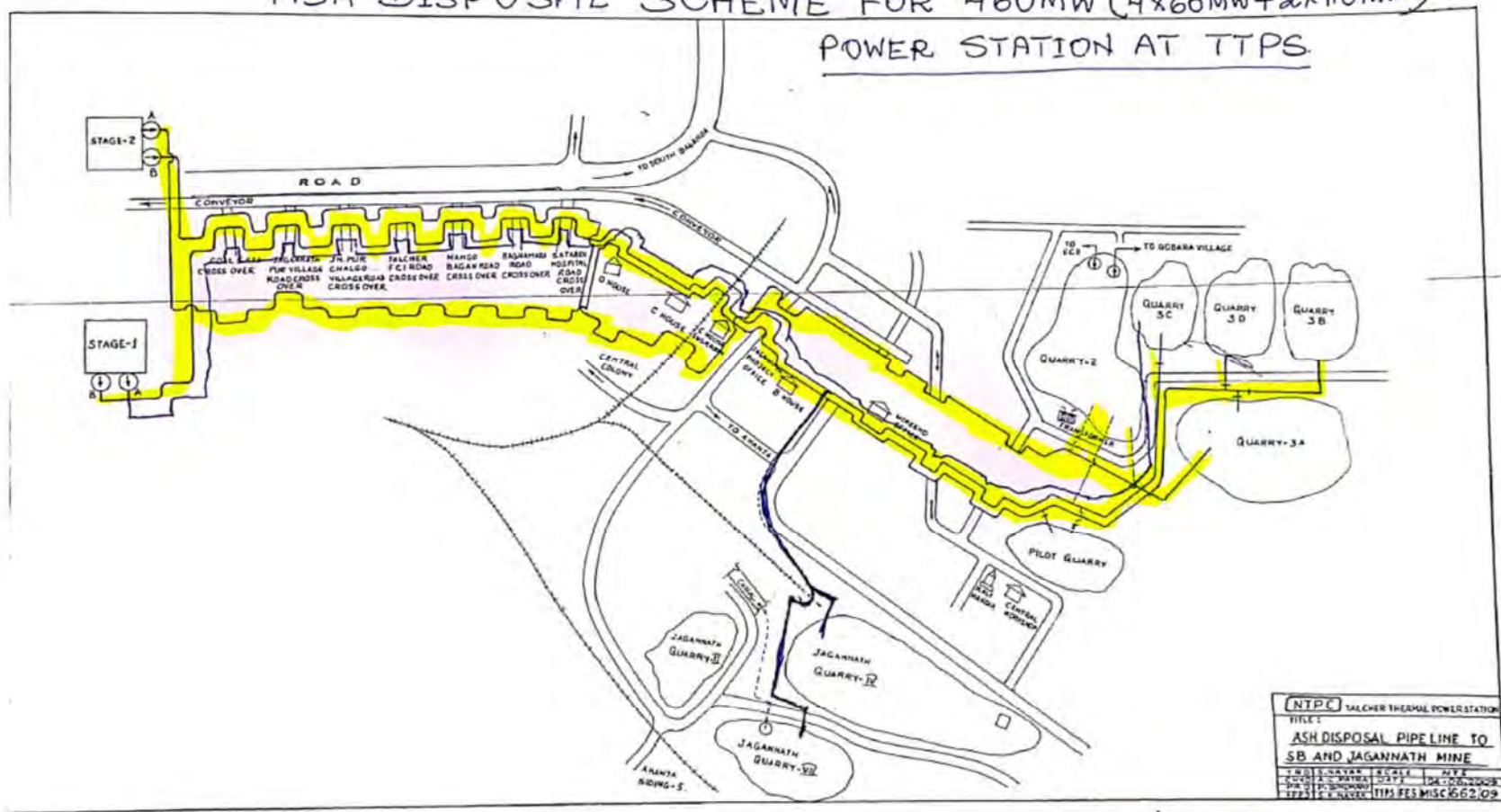
Sl. No.	Name of the Plant	Botanical name
1	Ashok	<i>Saraca asoca</i>
2	Neem	<i>Azadirachta indica</i>
3	Babul	<i>Acacia nilotica</i>
4	Palash	<i>Butea monosperma</i>
5	Shisham	<i>Dalbergia sissoo</i>
6	Amaltas	<i>Cassia fistula</i>
7	Gulmohar	<i>Delonix regia</i>
8	Kasood	<i>Cassia Siamea</i>
9	Karanaj	<i>Pongamia pinnata</i>
10	Marvel grass	<i>Dicanthium annulatum</i>
11	Dhanwantary/Khara	<i>Cymbopogon martini</i>
12	Duba	<i>Cynodon dactylon</i>
13	Keuti	<i>Cyperus corymbosis</i>
14	Sinkhola	<i>Heteropogon contortus</i>
15	Bena	<i>Chrysopogon sp</i>
16	Kirayat	<i>Andrographis paniculata</i>
17	Red ley	<i>Hemigraphis sp</i>
18	Peechi	<i>Lindernia sp</i>

5.2 Post Closure Monitoring

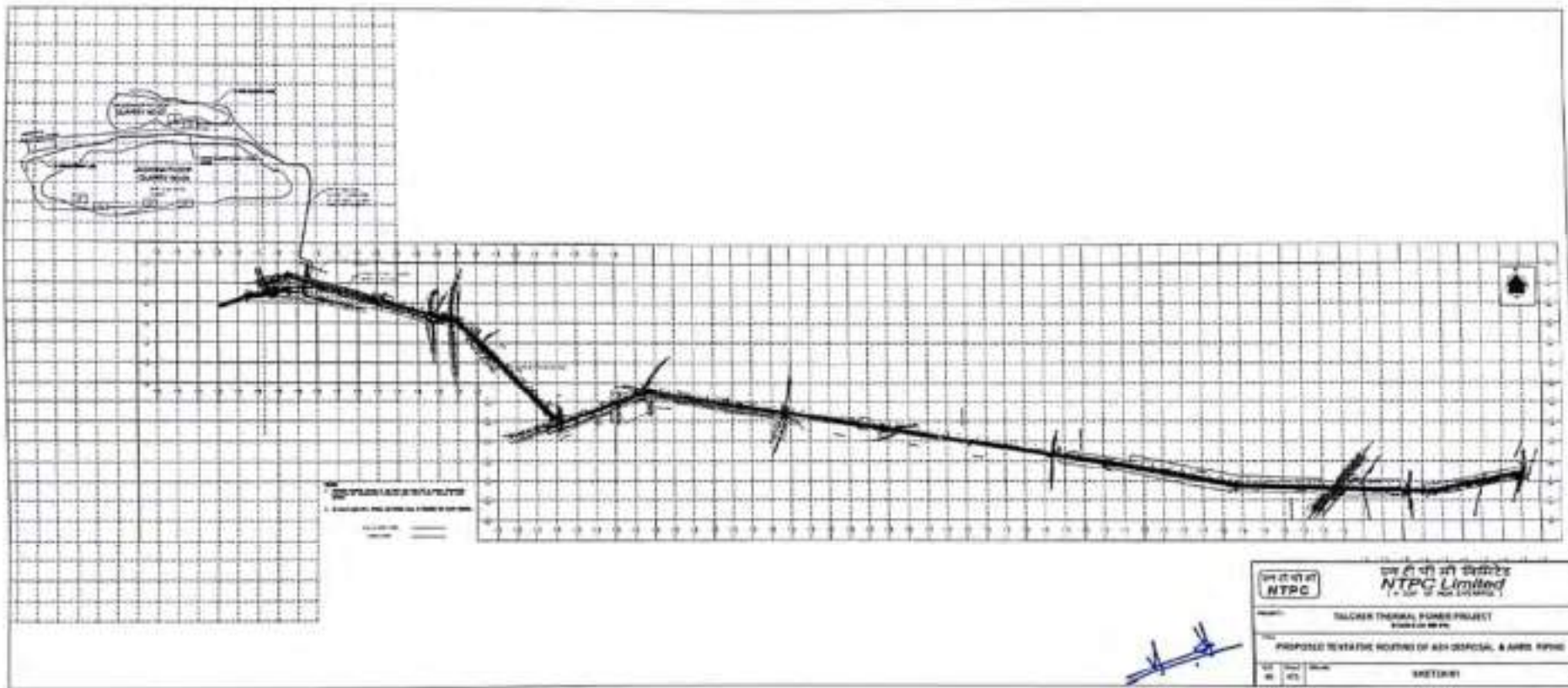
The water quality of surrounding wells will be monitored for a period of three years. In the event of deterioration of water quality, suitable preventive/ corrective action will be undertaken.

ANNEXURE - 1A

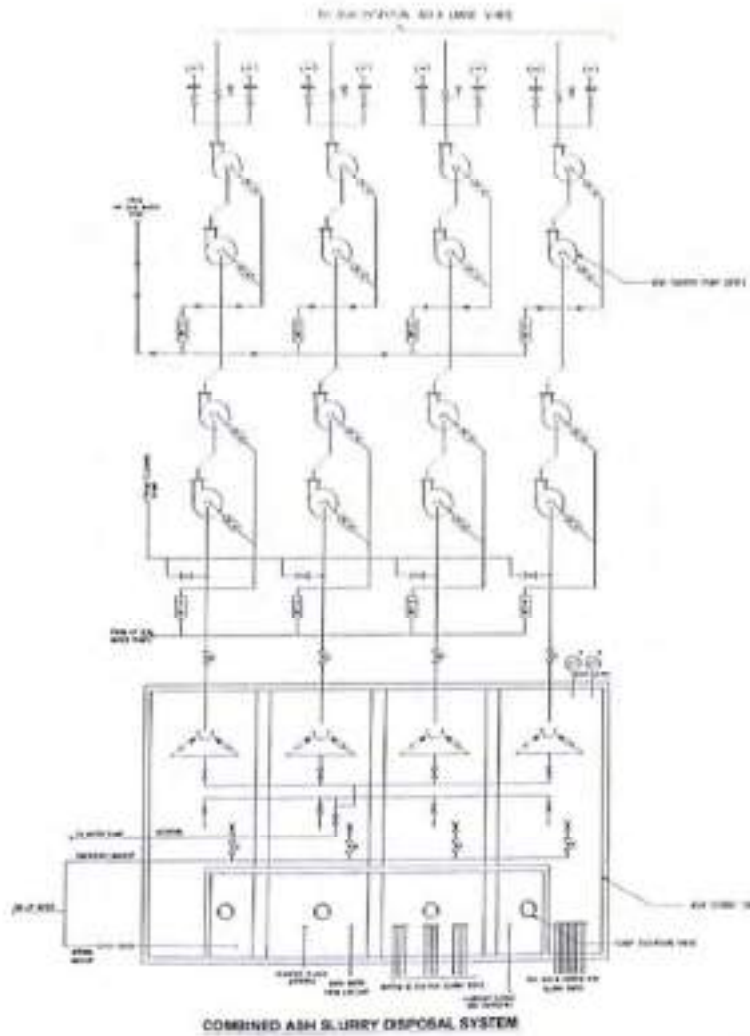
ASH DISPOSAL SCHEME FOR 460MW (4x60MW+2x110MW)
POWER STATION AT TTPS



ANNEXURE - 1B



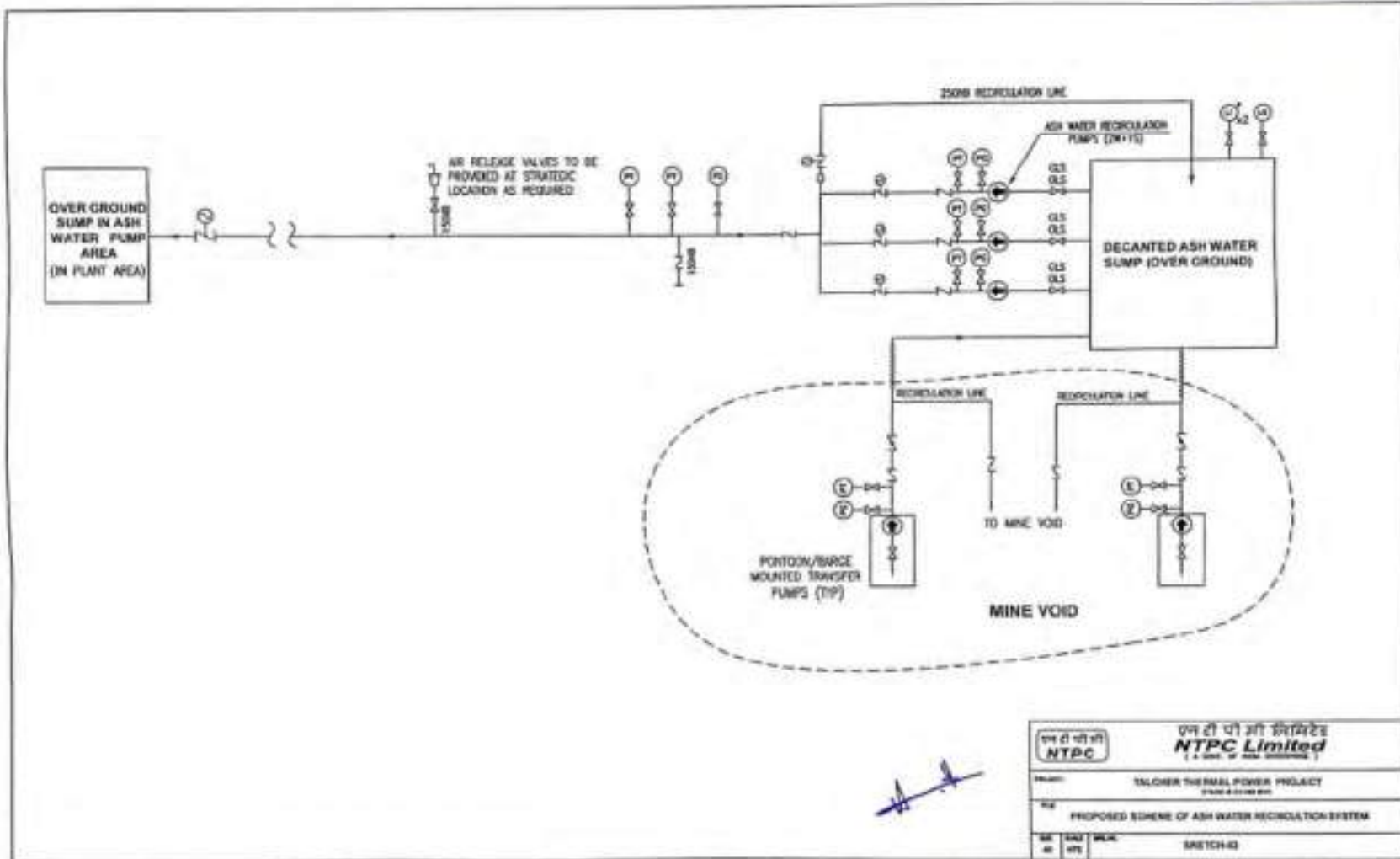
ANNEXURE-II



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		एन टी पी सी लिमिटेड NTPC Limited <small>(A GOVT. OF INDIA ENTERPRISE)</small>	
PROJECT		TALCHER THERMAL POWER PROJECT STAGE-II (2x330 MW)	
TITLE		PROPOSED SCHEME OF ASH SLURRY DISPOSAL	
SHEET NO.	DATE	DRAWN BY	SKETCH-02

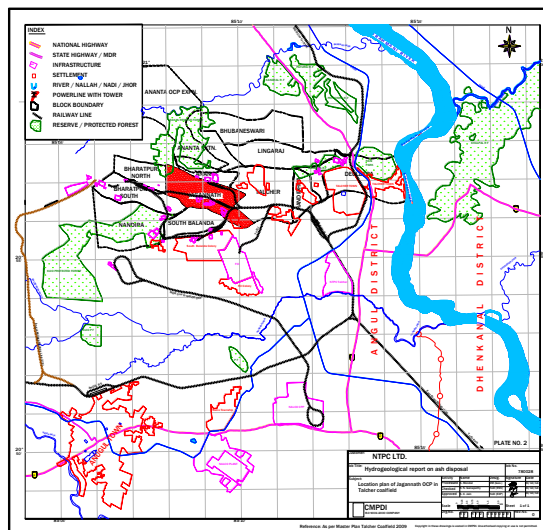
ANNEXURE-III



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CMPDI.**

**FINAL REPORT
ON
HYDROGEOLOGICAL INVESTIGATION FOR
DISPOSAL OF ASH IN MINE VOIDS (QUARRY NOS. 4, 7
& 8) IN JAGANNATH OCP OF
JAGANNATH AREA OF MCL
TALCHER COALFIELD
ODISHA**



**FOR
NTPC LIMITED
NOVEMBER 2014**



**EXPLORATION DEPARTMENT
REGIONAL INSTITUTE - VII**

CMPDI

**(A Subsidiary of Coal India Ltd.)
BHUBANESWAR, ODISHA**

EXECUTIVE SUMMARY

1.0 INTRODUCTION

1.1 OVERVIEW

Central Mine Planning & Design Institute Limited (CMPDI) was assigned the job of hydrogeological investigation for disposal of ash in Jagannath OCP (quarry no. 4, 7 & 8) by M/s NTPC Limited through purchase order no. 5500011473-037-1026, dt. 27/11/2012 and CMPDI (HQ) letter no. CMPDI/BD/A (004)/23, dt. 08/02/2013. This study was entrusted to CMPDI to address the concern of Ministry of Environment and Forest (Govt. of India) regarding environment & need for safe disposal of flyash.

1.2 LOCATION

Jagannath OCP, Talcher coalfield is a working mine, the exhausted mine voids no. 4, 7 & 8 located in the Jagannath block. It lies between latitude 20° 56' 00" and 20° 57' 31"N and longitudes 85° 8' 39" and 85° 10' 2"E. The block under report covers an area of 4.5 sq.kms. and is included in the Survey of India Toposheet No.F45T1 (Old Toposheet no: 73 H/1; RF 1:50,000).

1.3 COMMUNICATION

Jagannath OCP is well connected to state capital Bhubaneswar through rail and road. It is approximately 160 kms. from Bhubaneswar by road. The nearest railway station is Talcher and is approximately 8 kms. The nearest airport is Biju Patnaik International Airport at Bhubaneswar at a distance of 165 kms. District headquarters Angul is approximately 30 km from the ash disposal site. NTPC's Kaniha power plant is about 35 km from ash disposal site and is well connected by rail and road.

1.4 PHYSIOGRAPHY AND DRAINAGE

The topography of study area is gently undulating with surface elevation varying from 103 m in SE to 150 m in NW above msl. Entire study area in north is drained by Bangaru Jhor, in south by Nandira Jhor and in east by seasonal streams. These streams are ultimately joining in the North-South flowing Brahmani river east of the study area.

1.5 CLIMATE

The annual average rainfall in the study area is around 1256.55 mm. The highest temperature recorded was 45.3 °C in June 2012 while the lowest temperature was 5.5 °C in November 1996.

2.0 GEOLOGY

Jagannath block mainly comprises 3 coal seams viz.seam I,II & III and a local seam (Index seam). Seam-II & III of Barakar formations and seam-I of Karharbari formations are exposed. The Jagannath block is bounded by two major faults viz. faultF1-F1 in the south with northerly throw of 40 to 85 m and fault F5-F5 in the north with southerly throw of 90 to 125 m. The area is traversed by 6 major faults. The dip of the strata varies from 2.5 ° to 10 ° towards north and strike of the bed is generally East-West with minor swings.

3.0 HYDROLOGY

The study area dominantly falls under the influence of Bangaru Jhor and Nandira Jhor basin. The area of the Bangaru Jhor and Nandira Jhor basin are 130 sq. km and 193 sq. km respectively.The drainage density of Bangaru Jhor and Nandira Jhor basin are 1.52 km/square km and 0.88 km/square km respectively.

4.0 SITE INVESTIGATION PROGRAMME

A network of existing thirty one open dug wells was established over an area of 5 kms radius from the study area to monitor the water table variation and to assess the hydraulic head of the water table in the phreatic aquifer.

In order to evaluate the present state of water quality in and around study area, 12 open dugwells, 10 hand pumps, 14 piezometers, 6 surface water stations and 4 mine water stations were identified for the study. In total, eighteen piezometers were constructed, developed and tested in and around the study area.

5.0 HYDROGEOLOGY

5.1 AQUIFER DISPOSITION FOR JAGANNATH OCP

Two aquifers are distinguished namely Karharbari aquifer and Basal Barakar aquifer in the study area. Groundwater in these aquifers occurs in unconfined and confined hydraulic conditions.

5.2 ESTIMATION OF HYDRAULIC PROPERTIES

Hydraulic conductivity signifies the dominant role of secondary porosity in aquifer development. The hydraulic conductivity of the tested piezometers ranges from 0.010 m/day to 1.716 m/day.

5.3 PRESENT GROUNDWATER LEVELS IN PHREATIC AQUIFER

Thirty one dug wells were monitored across various villages in and around the study area. Two sets of water level contour maps, one for pre monsoon season and other for post monsoon season were prepared.

The water level contour coincides with the topography of the study area. The pre and post monsoon groundwater level contour indicate a predominant groundwater

divide in middle of the study area trending SW to NE, which divides the whole study area into two halves. In one half the ground water is flowing towards Bangaru Jhor in north direction and in other half, the water is moving towards Nandira Jhor in south east direction.

5.4 HISTORICAL GROUNDWATER LEVEL TRENDS

Two dug wells from Danara village and Dera village (as monitored by Environmental Monitoring Cell of CMPDI, RI-VII) has been chosen to show the trend of historical groundwater level.

5.5 PIEZOMETRIC SURFACE FOR THE STUDY AREA

The piezometric head contour map depicts a maximum piezometric head in the south eastern part of the study area whereas the minimum piezometric head is seen in north western part. The piezometric surface slopes from South East to North West towards Bangaru Jhor.

5.6 WATER BALANCE IN THE BUFFER ZONE (WITHIN 5 KM RADIUS) OF THE STUDY AREA

Water balance in the buffer zone of the study area was carried out. Total Annual recharge estimated for 5 km radius buffer zone of Jagannath OCP is 50.35 Mm³. Surplus water available per annum from the annual rainfall recharge after meeting the future requirement for unirrigated and cultivable waste land is 16.22 Mm³.

5.7 HYDROMETEROLOGY

Probability analysis reveals that the chances of occurrences of minimum rainfall (743.80 mm) are 98%. Similarly the chances of occurrence of 1297.94 mm of rainfall are 50% and that of maximum rainfall i.e. 1549.56 mm is only 3%.

5.8 GROUNDWATER RECHARGE DISCHARGE RELATIONSHIP

The major part of recharge area is highly concentrated to the north western edge of the study area whereas the discharge area is concentrated towards the south and south eastern part of the study area.

6.0 HYDROCHEMISTRY

6.1 SAMPLE ANALYSIS PROGRAMME

Water sampling together with laboratory analysis was undertaken to determine the presence of surface and subsurface water contamination. Chemical analysis of ground water, surface water, and mine water includes the determination of the concentrations of inorganic constituents including heavy metals.

6.2 ANALYTICAL RESULTS AND INTERPRETATION

Surface water collected and analysed from various locations in and around Jagannath OCP shows elevated concentration of dissolved oxygen levels and sulphate.

Mine water collected and analysed from various locations in and around Jagannath OCP are within permissible limits.

Groundwater from dug wells, tube wells and piezometers in the study area show neutral to alkaline nature. The shallow groundwater of the phreatic aquifer shows elevated concentration of inorganic analytes like Calcium, Chloride, Total Dissolved Solids (TDS), Fluoride, Total alkalinity and Total Hardness. Sulphate is also observed at elevated concentration in few shallow groundwater samples.

The deeper aquifer shows elevated concentration of few heavy metals in pre-monsoon season only. Heavy metals like lead (Pb) is uniformly present in almost all piezometer location except at piezometer SJL-6. Manganese (Mn) is also reported at

elevated concentration at three piezometer locations (SJL-2, SJL-4, and SJL-8). Iron and Cadmium is also reported at elevated concentration at SJL-1 and SJL-2 respectively. Inorganic constituents like TDS and Calcium are reported from couple of locations viz. SJL-3 in pre-monsoon season and SJL-4 & SJL-7 in post monsoon season.

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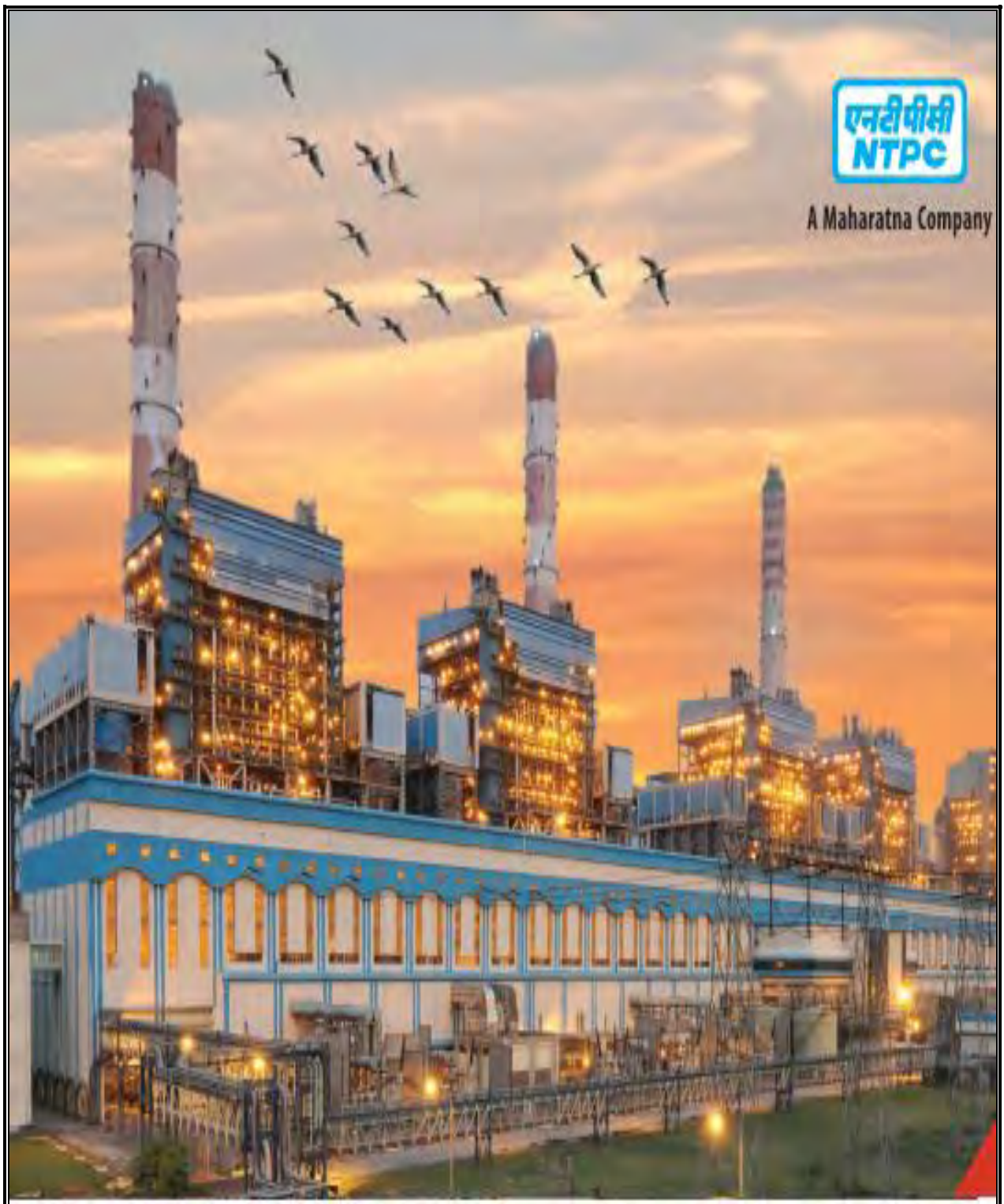
ABBREVIATIONS

S.NO	ABBREVIATION	DESCRIPTION
1.	%	Percent
2.	°c	Degree celcius
3.	Al	Aluminium
4.	As	Arsenic
5.	b/w	Between
6.	BIS	Bureau of Indian Standards
7.	BOD	Biological oxygen demand
8.	C ₆ H ₅ OH	Phenolics
9.	Ca	Calcium
10.	CaCO ₃	Calcium carbonate
11.	Cd	Cadmium
12.	Cl	Chloride
13.	cm/hr	Cubic meter per hour
14.	CMPDI	Central Mine Planning and Design Institute
15.	COD	Chemical oxygen demand
16.	Cr ⁶⁺	Hexavalant Chromium
17.	Cu	Copper
18.	DO	Disolved oxygen
19.	E, W, N, S	East, West, North, South
20.	F	Fluoride
21.	F1	Fault number one
22.	Fe	Iron
23.	Fluc.	Fluctuation
24.	GSI	Geological Survey of India
25.	HP	Horse power
26.	HQ	Headquarter
27.	hrs.	Hours
28.	IMD	Indian Meterological Department
29.	IS	Indian Standard

S.NO	ABBREVIATION	DESCRIPTION
30.	km.	Kilometer
31.	km/hr	Kilometer per hour
32.	km/sq km	Kilometer per square kilometer
33.	Km/sq. km	kilometer per square kilometer
34.	km/year	Kilometer per year
35.	KV	Kilo volt
36.	lph.	Liter per hour
37.	m amsl.	Meter above mean sea level
38.	m bmp	Meter below measuring point
39.	M cum	Million cubic meters
40.	M cum/annum	Million cubic meter per annum
41.	m.	Meter
42.	m/annum	Meter per annum
43.	m/s	Meter per second
44.	m/sec.	Meter per second
45.	m ² /day	Meter square per day
46.	m ³	Cubic Meter
47.	Max.	Maximum
48.	mbgl	Meter below ground level
49.	mcm	Million cubic meters
50.	mg/L	Miligram per litre
51.	min	Minnute
52.	Min.	Minimum
53.	MLD	Million litre per day.
54.	mm	Mili meter
55.	mm.	Millimeter
56.	mm/year	Millimeter per year
57.	Mm ³	Million meter cube
58.	Mm ³ /annum	Million meter cube per annum
59.	Mn	Manganese
60.	MoEF	Ministry of Environment and Forest

S.NO	ABBREVIATION	DESCRIPTION
61.	MMT	Million metric tonnes
62.	MT	Metric tonnes
63.	N	Nitrogen
64.	Na	Sodium
65.	NH	National Highway
66.	Ni	Nickle
67.	No.	Number
68.	NO ₃	Nitrate
69.	NTPC	National Thermal Power Corporation
70.	OCP	Open Cast Mine
71.	ORP	Oxydation Reduction Potential
72.	Pb	Lead
73.	PO	Project office
74.	PVC	Pollyvinyl chloride
75.	RI	Regional Institute
76.	Se	Selenium
77.	SO ₄	Sulphate
78.	Sq. km	Square Kilometer
79.	TCLP	Toxicity Characteristic Leaching Procedure
80.	TDS	Total dissolved solids
81.	TKN	Total Kjeldahl Nitrogen
82.	TSS	Total suspended solids
83.	TSTPS	Talcher Super Thermal Power Station
84.	TTPS	Talcher Thermal Power Station
85.	U/G	Underground mine
86.	UGP	Underground project
87.	Zn	Zinc

Figure 1: Talcher Super Thermal Power Station of NTPC at Kaniha, Odisha



Source: NTPC Limited

Chapter – 1

INTRODUCTION

1.1 GENERAL

Central Mine Planning & Design Institute Limited (CMPDI) was assigned the job of comprehensive hydrogeological investigation for disposal of ash in Jagannath OC (quarry no. 4, 7 & 8) and South Balanda OCP (quarry no. 2, 3a & 3b). This hydrogeological investigation work has reference to NTPC purchase order no. 5500011473-037-1026, dt. 27/11/2012 and CMPDI (HQ) letter no. CMPDI/BD/A (004)/23 dt. 08/02/2013. NTPC Limited has reported that coal mine quarry number 4, 7 & 8 of Jagannath OCP of Mahanadi Coalfields Limited at Talcher has been allocated to them for disposal of flyash jointly by Talcher Super Thermal Power Station (TSTPS), Kaniha and Talcher Thermal Power Station (TTPS), Talcher. In this context, appreciating the overall concern for the environment and need for safe disposal of flyash, Ministry of Environment & Forest (Govt. of India) has directed NTPC to carry out detailed hydrogeological study in and around quarry number 4, 7 & 8 of Jagannath OCP.

1.2 BACKGROUND INFORMATION OF THERMAL POWER STATION

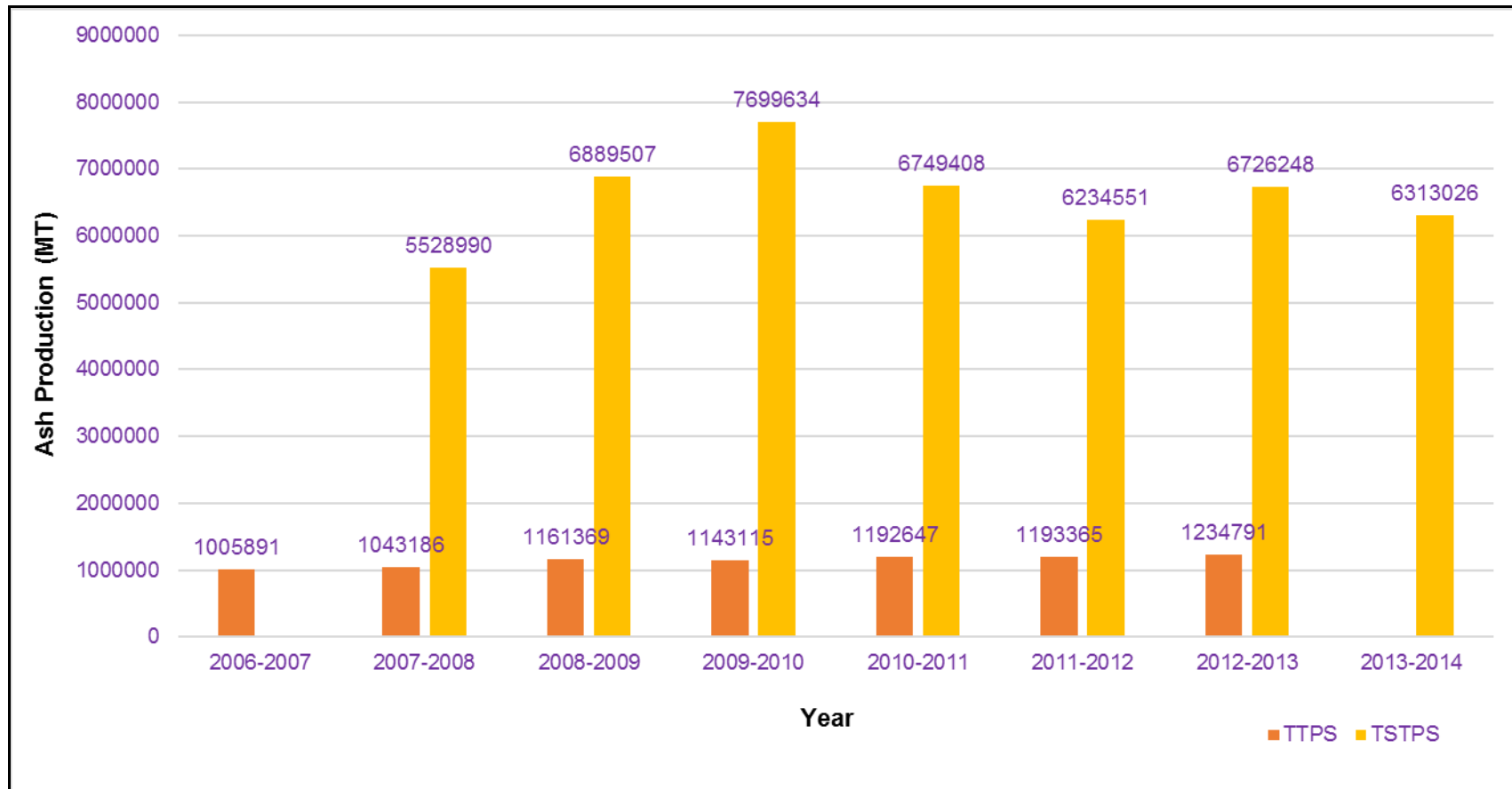
Talcher Super Thermal Power Station (TSTPS), Kaniha (figure-1) is one of the largest pit head thermal power plants of NTPC family with an installed capacity of 3000 MW. To convert heat energy into electrical energy in a thermal plant, coal water and air are used as main raw material. Using boilers, turbine and generator assembly, power is generated. The whole process is subdivided into three sub process- steam generation, turbine process and power generation. The steam is generated by converting heat energy available in coal in association with air and water. In turbine process, the available heat in steam is converted into mechanical energy which acts as a prime mover for the generators. In generator, mechanical energy is converted into electrical energy i.e. power.

Approximately 8500-9000 MT (metric tonnes) of coal is consumed in a day at TTPS. Coal consumption at TSTPS is approximately 19.0 MMT per year. In process, power plants of NTPC generate significant amount of ash in Talcher area. Generation of ash is about 3300-3500 MT per day in TTPS and 18000-19000 MT per day at TSTPS. By burning power grade coal of Talcher coalfield, coal ash constituting 80% fly ash and 20 % bottom ash is generated.

Present ash storage and disposal mechanism installed by NTPC is state of art technology specially designed for removing bottom ash and fly ash. Ash is collected from all units viz. boiler and their associated ducts hoppers, air pre-heaters hopper and electrostatic precipitator hopper. Bottom ash generated from coal combustion is continuously collected in water impounded bottom ash hoppers and periodically transferred to the ash slurry sump through hydro ejectors and associated pipe lines. The collected ash slurry from this ash slurry sump is further transferred to ash disposal area (Ash Dyke) through series of ash slurry pump. Such ash dyke is located approximately 6-10 km from the NTPC plant. Similarly fly ash collected from air pre-heater duct hoppers, economizer bypass duct hoppers and electrostatic precipitator hopper are continuously evacuated to collector tank. Flyash is transferred from collection point to collection tank through a high power suction system, where it is mixed with water. Resultant fly ash slurry is transported to ash slurry sump through gravity sluice trenches. After the ash is settled in the ash dyke, clean water flows to the over flow lagoon through wells and collected in overflow lagoon. The ash water recirculation system pumps this water from the over flow lagoon to the plant where it is again used in ash handling system.

Historical data of ash generation at TTPS and TSTPS is given in figure 2. Segment wise utilization of flyash at TSTPS and TTPS is compiled in table 1.2.A and table 1.2.B respectively. Salient feature of both power plants are compiled and presented in table 1.2.C.

Figure-2: Year wise Ash Generation at NTPC Power Plants, Talcher Odisha



Source: NTPC Limited

Table – 1.2.A: Segment wise Utilization of Flyash at TSTPS, Talcher Odisha.

Segment	Unit	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
Ash Production	MT	5528990.00	6889507.00	7699634.00	6749408.00	6234551.00	6726248.00	6313026.00
Usage of Ash Disposal		460749.00	574126.00	641636.00	562451.00	519546.00	560521.00	526086.00
Cement	MT	17491.00	0.00	0.00	0.00	0.00	0.00	0.00
RMC	MT	3100.00	3993.00	4855.00	2375.00	0.00	0.00	0.00
Asbestos	MT	0.00	16113.00	21723.00	12736.00	16520.00	19243.00	25689.00
Non NTPC Land Dev.	MT	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NTPC Land Dev.	MT	416150.00	434950.00	541000.00	801118.00	120400.00	87800.00	204526.00
Bottom Ash Cover	MT	0.00	NA	121100.00	396736.00	339553.00	354300.00	360450.00
Dyke Raising	MT	730750.00	886000.00	807600.00	980148.00	1233700.00	1576370.00	1862519.00
Peripheral Filling	MT	0.00	0.00	0.00	0.00	0.00	293088.00	0.00
Dyke Strengthening	MT	0.00	0.00	0.00	0.00	0.00	115000.00	0.00
Fly Ash Brick Units	MT	13614.00	21392.00	36333.00	55867.00	62183.00	82231.00	42272.00
NTPC Brick Units	MT	20473.00	13902.00	11448.00	10549.00	21835.00	21737.00	12628.00
Agriculture Dev	MT	0.00	0.00	0.00	0.00	7.00	0.00	0.00
Export	MT	0.00	2959.00	1643.00	0.00	0.00	0.00	0.00
Cenosphere	MT	196.00	45.00	70.00	46.00	40.00	140.00	0.00
Ash Utilization	MT	1201774.00	1379354.00	1545772.00	2259575.00	1794238.00	2549909.00	2508084.00
Ash Utilization	%	21.74	20.02	20.08	33.48	28.78	37.91	39.73

Source: NTPC Limited

Table – 1.2.B: Segment wise Utilization of Flyash at TTPS, Talcher Odisha.

Year	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013
Ash Bricks (NTPC) (MT)	6077.00	3324.00	1827.00	488.00	2836.00	4215.00	4225.00
Ash Bricks (Others) (MT)	9632.00	12512.00	6475.00	7318.00	2967.00	13618.00	27440.00
Asbestos (MT)	17716.00	10024.00	9810.00	7079.00	7324.00	6616.00	5560.00
Agriculture Show Case Project (MT)	-	-	35.00	44.00	-	-	-
Mines Back Filling (MT)	972388.00	1017326.00	1143222.00	1128186.00	1179520.00	1168496.00	1197566.00
Land Fill (MT)	78.00	-	-	-	-	420.00	-
Utilization (%)	92.12	97.12	100.00	100.00	100.00	100.00	100.00

Source: NTPC Limited

Table – 1.2.C: Salient feature of NTPC power Plants in Talcher, Odisha.

Sl. No.	Particulars	Details	
		TTPS Talcher	TSTPS Kaniha
1.	Location	Near Talcher Town, Distt. Angul (Odisha), Western part of Talcher coalfield	P.O. : Deepshikha, Distt. Angul (Odisha), Northern part of Talcher coalfield
2.	Capacity	460 MW	3000 MW
3.	Source of Coal	Talcher coalfield (2.8 MT/ annum)	Mahanadi Coalfields & Lingaraj Coalmines, Talcher coalfield
4.	Source of Water	River Brahmani	Samal Reservoir
5.	Cooling System	Closed cycle with Cooling towers	Closed cycle with Cooling towers
6.	Ash Disposal System	Wet Slurry Disposal	Wet Slurry Disposal
7.	Beneficiary State	Odisha	Odisha, West Bengal, Andhra Pradesh, Tamil Nadu, Bihar, Jharkhand, Assam
8.	Nearest Railway station	Talcher Town	Talcher Town
9.	Nearest Airport	Bhubaneswar	Bhubaneswar

Source: NTPC Limited

1.3 SCOPE OF INVESTIGATION

The hydrogeological investigation is being carried out to establish hydrogeological characteristics and evaluate groundwater quality in areas not covered by previous investigations by installation of new piezometers, collection and analysis of groundwater samples, hydraulic testing in new wells, monitoring of existing open dug wells, collection of water samples from hand pumps, mine water and surface waters within the radius of 5km in and around the abandoned mine voids in quarry no. 4, 7 & 8 of Jagannath OCP. Detailed scope of hydrogeological investigations as per the work order is as follows:

- Collection of available geological and hydrogeological data.
- Identification of control wells in and around 5 km radius of the mine under reference.
- Determination of RL for all the hydrograph stations and piezometers.
- Preparation of inventory of wells and other water abstraction water bodies and monitoring for at least two seasons (pre monsoon and post monsoon).
- Defining aquifer geometry through geological cross sections.
- Defining hydrogeology of the mine with emphasis on the general direction of ground water movement and seasonal (pre monsoon and post monsoon) water quality trends, water level fluctuations etc.
- Site selection for installation of piezometers.
- Preparation of schemes for Drilling, construction and development of eighteen piezometers around the mine and monitoring water quality and water level of different aquifers.
- Testing of piezometers in order to observe and evaluate the aquifer parameters.
- Obtaining water samples from different sources (dug wells, hand pumps, piezometers, mine & nalla/ streams) for water quality analysis at predetermined intervals (pre monsoon and post monsoon).
- Defining surface and groundwater relation.
- Establishing groundwater recharge/discharge relationship.

- Target aquifers most likely to be affected by the mine after reclamation.
- Impact of groundwater influence of the surrounding area
- Preparation of a report from these investigations.

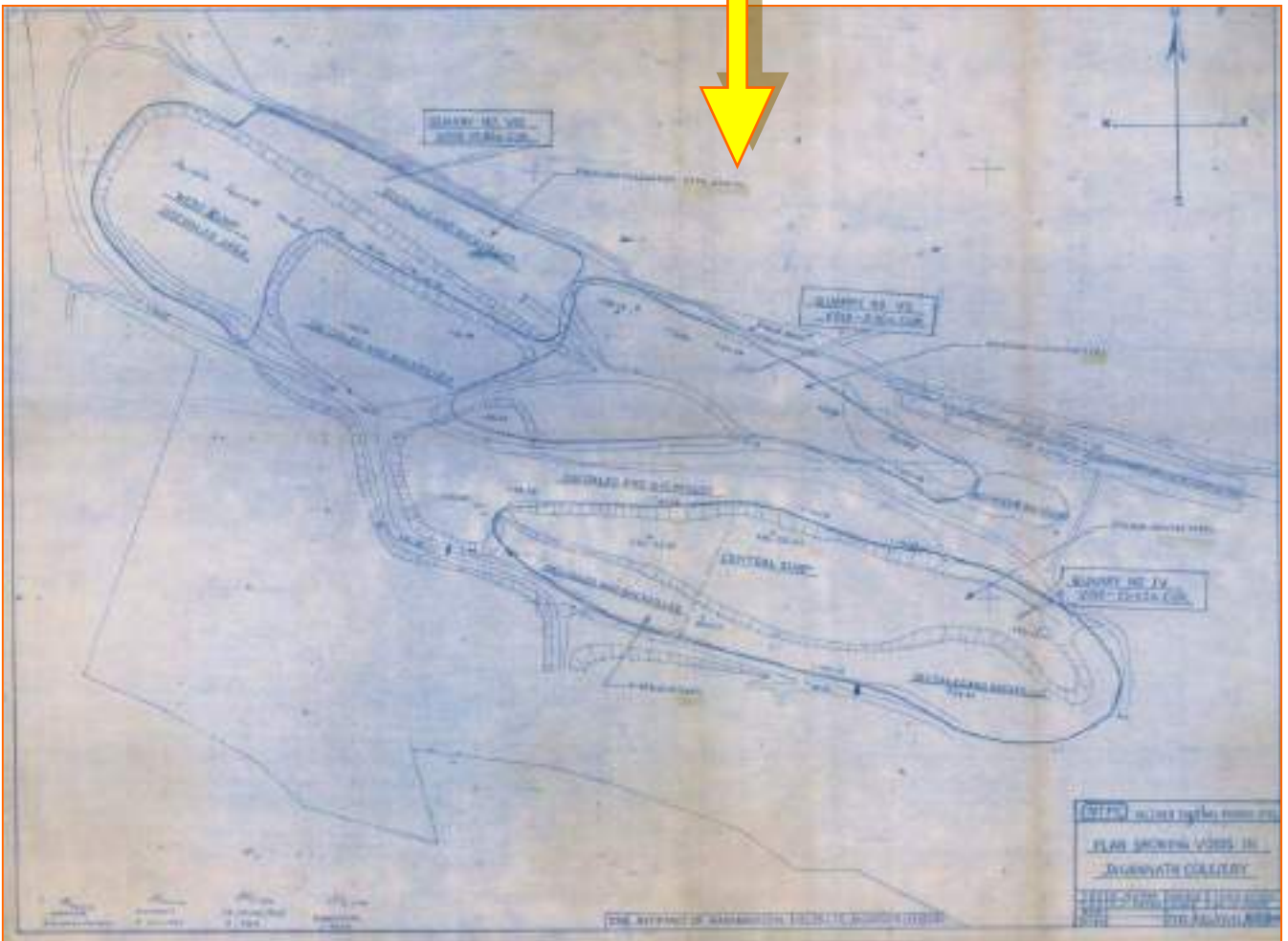
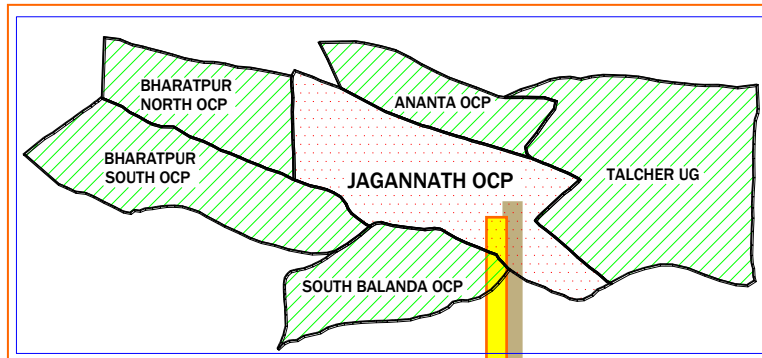
1.4 LOCATION

Jagannath OCP (figure- 3) is a running mine. Its exhausted mine voids no. 4, 7 & 8 are located in the Jagannath geological block. The site limits are given in table 1.4.A. Jagannath block lies between latitude 20° 56' 04" and 20° 57' 31"N and longitudes 85° 8' 39" and 85° 10' 2"E. The block under report covers an area of 4.5 sq.kms. and is included in the Survey of India Toposheet No.F45T1 (Old Toposheet no: 73 H/1; RF 1:50,000) (Plate no. 2). The corridor showing ash disposal pathway from TSTPS to Jagannath OCP decoaled voids is given in Plate no. 7.

Table 1.4.A: Limits of the Site.

Boundary	Limits
East	Bounded by Talcher U/G mine
West	Limited by Bharatpur OCP
North	Bounded by Ananta OCP
South	Bounded by South Balanda

Figure 3: Jagannath OCP, Talcher coalfield, Odisha



Source: NTPC Limited

1.5 COMMUNICATION

Jagannath OCP of Talcher coalfield is well connected to state capital Bhubaneswar through rail and road. It is approximately 160 kms. from Bhubaneswar by road and can be accessed through NH 42/ NH 5. The nearest railway station is Talcher at approximately 8km. The nearest airport is Biju Patnaik International Airport at Bhubaneswar at a distance of about 165 kms. District (HQ) Angul is approximately 30 km from the ash disposal site. NTPC Kaniha power plant is about 35 km from ash disposal site and is well connected by rail and road.

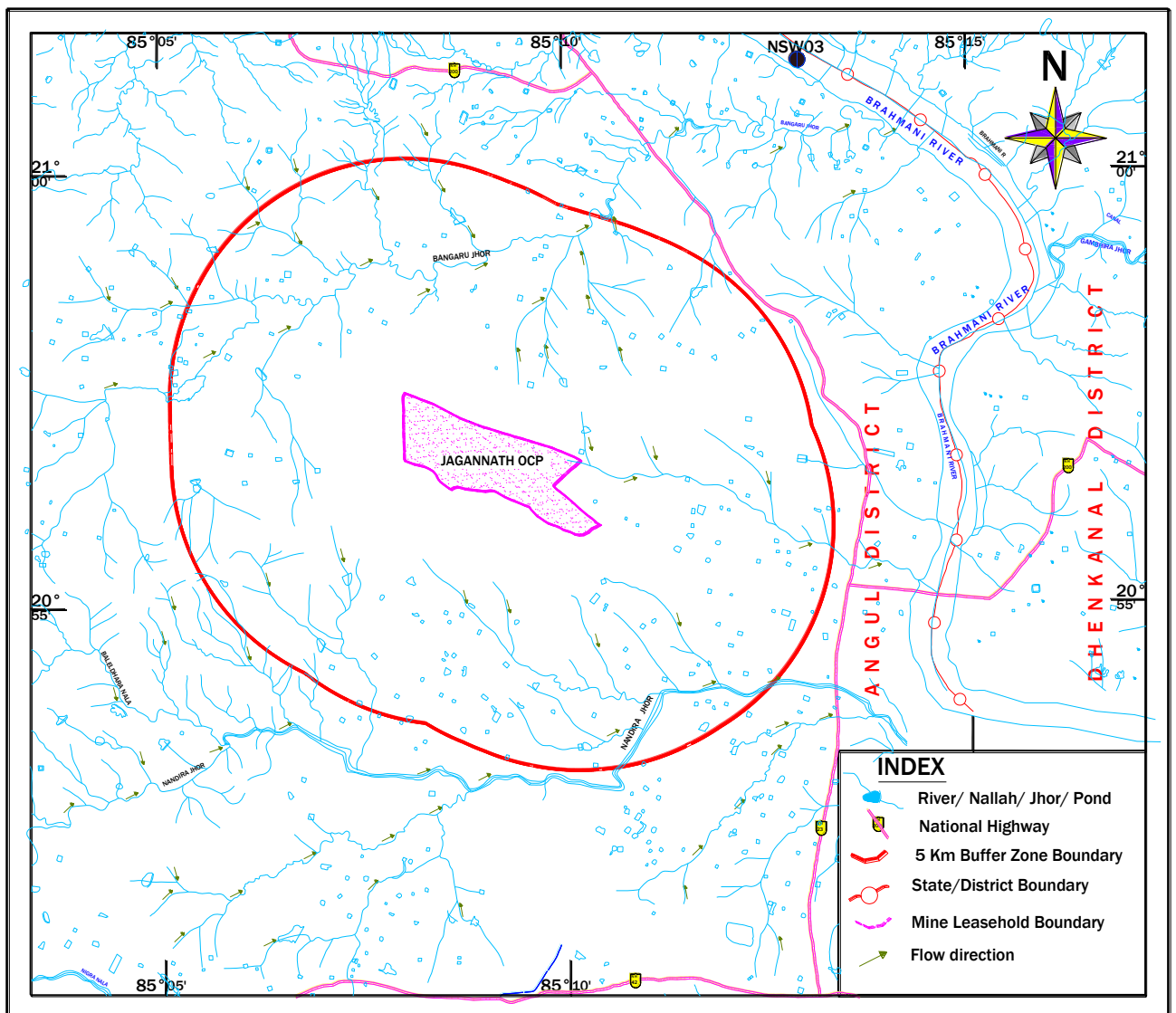
1.6 PREVIOUS INVESTIGATIONS AND ANALYTICAL DATA OF THE AREA

Talcher Coalfield contains huge reserves of power grade coal. The coal seams are about 25 to 30 m thick. These thick seams however contain large number of dirt bands within them. As such the seams record very high percentage of ash, generally around 40%. This high ash content in coal possess potential problem in its disposal after combustion of carbonaceous matter in power plants. In order to facilitate dumping of such huge quantity of coal ash, some of the voids were identified in decoaled mines in Talcher coalfield. Jagannath is an open cast mine having three numbers of exhausted voids. These exhausted decoaled voids have been allotted to M/s NTPC Limited for filling the flyash. Detailed hydrogeological investigation previously has not been undertaken at decoaled quarry no. 4, 7 & 8 of Jagannath OCP.

1.7 PHYSIOGRAPHY & DRAINAGE

General topography of the study area is gently undulating and surface elevation varies from 103 m in SE to 150 m in NW above msl. A gravel ridge forms northern boundary of the block. Rock exposures are limited to few sandstones and pebble beds. Entire study area in north is drained by Bangaru Jhor, in south by Nandira Jhor and east by seasonal streams. These streams are ultimately joining in the North-South flowing River Brahmani east of the study area (Plate no. 3, Figure 4).

Figure 4: Drainage in and around Jagannath OCP, Talcher coalfield, Odisha



1.8 CLIMATE

Long term (1992-2012) meteorological data of Angul collected from IMD, Bhubaneswar has been reproduced below in table-1.8.A.

Table 1.8.A: Climatic Details of Study Area, Distt. Angul, Odisha

Item	Parameters	Particulars
Rainfall	Range	743.80 to 1549.56 mm
	Annual average	1256.55 mm.
Temperature range (monthly mean of daily temperature)	Minimum	5.5°C (Nov., 1996)
	Maximum	45.3°C (June, 2012)
Relative humidity range (monthly mean of daily RH)	Minimum	31%
	Maximum	88%
Wind speed range (monthly mean of daily wind speed)	Min at 8:30 hr	2 km/hr
	Max at 8:30 hr	6 km/hr
	Min at 17:30 hr	1 km/hr
	Max at 17:30 hr	8 km/hr

Source: IMD Bhubaneswar

1.9 LIMITATION

The report is based on the application of scientific principles and professional judgement to certain facts with resultant subjective interpretations. Professional judgements expressed herein are based within the limits of existing available data, scope of work and schedule.

1.10 ACKNOWLEDGEMENT

Name and designation	Broad area/level of association
CMPDI (HQ) Ranchi	
Shri A. K. Debnath, CMD	For formulating corporate level objective, sanctioning of resources and overall monitoring.
Shri S. Saran, Director (T/CRD)	For continuous guidance and for providing the required facilities during the course of the study.
Shri Naeem Ahmad, Ex-GM (Exploration)	For deployment of resources, cordial support and encouragement.
Shri A. Das GM (Exploration)	For cordial support and encouragement.
Shri. D. Basu, GM (Environment)	For extending necessary support for efficient and timely completion of analysis of water sample.
Shri T.K Samanta, GM (BDD)	For extending all support during budgeting, presales and for continuous coordination with client.
Shri Pabhu Prasad, CM (Geology)	For extending necessary help and overall guidance.
Shri. S. Panja, CM (Geology)	For extending necessary help during finalization of piezometer location and for his technical guidance.
CMPDI, RI-VII, Bhubaneswar	
Shri D. Bhattacharya, RD, (RI-VII)	For proper mobilization of resources, arranging all round facilities and appropriate work environment.
Shri M.D Nayak, GM (Geology)	For extending necessary help in the management & execution of the project.

Name and designation	Broad area/level of association
Environment Department	For extending help during sampling and shipment of water samples to the CMPDI laboratory at Ranchi.
Planning & Design Department	For providing necessary documents and plans during execution of the project.
Exploration Department	For providing necessary information and also for the support in completing the project.
Mahanadi Coalfields Limited	For extending necessary help during field investigations.
NTPC LIMITED	
<p>Shri V.B Fadnavis, ED, NTPC Kaniha</p> <p>Shri U. K. Dasgupta, GM, (Maintenance)</p> <p>Shri A.K Kamila, AGM (EMG & AU)</p> <p>Shri. R. N Das AGM (Operation)</p> <p>Dr. K. Pradhan, Dy. Manager (Environment)</p>	<p>For providing all possible arrangements for safe working environment and necessary logistics in the field during the course of study.</p>

1.11 PERSONNEL ASSOCIATED

Name and designation	Broad area / level of association
Anirban Mondal, Asst. Manager (Geology) Sukanta Mondal, Dy. Manager (Geology)	Project execution, hydrogeological field investigation and preparation of report.
K.S Ganpathy, CM & HOD (Environment)	Technical guidance and assessment of report.
Tulsi Das, CM, (Geology)	Overall guidance during report preparation and report reviewing.
S.C Jain, GM (Geology)/ HOD (Exploration)	Overall guidance, constant supervision and quality assurance of all deliverables.

Chapter – 2

GEOLOGY

2.1 INTRODUCTION

Talcher coalfield constitutes southeastern member of Lower Gondwana basins within Mahanadi Valley graben. This coalfield spreads over 1800 sq km area within Dhenkanal, Angul and Sambalpur districts of Odisha (Plate no. 1) and is limited by latitudes 20° 53'00" N and 21° 12' 00" N and longitudes 84° 20' 00" E and 85° 23' 00" E. The sedimentary strata of Talcher coalfields comprises of Talchir, Karharbari, Barakar, Barren measure and unidentified Kamthi Formations.

2.2 GEOLOGICAL FORMATIONS

2.2.1 PRE-CAMBRIAN BASEMENT

The Gondwana sediments rest unconformably on the pre-cambrian basement rocks comprising granites with pegmatite veins, hornblende gneisses, porphyritic gneisses, etc. The pre-Cambrian rocks form low ridges and isolated hillocks along the boundary of the basin.

2.2.2 TALCHIR FORMATION

A pile of glacial and pre-glacial deposits marks the base of Gondwana sediments. Talchirs comprise diamictites, varves and fine to medium grained greenish sandstones. These rocks are well exposed along the southern boundary of the basin.

2.2.3 KARHARBARI FORMATION

Talchir formations are overlain by Karharbari formation, which is exposed as a narrow strip along the southern margin of the basin. These formations contain massive medium to coarse grained sandstones, which are characteristically pale

brownish yellow in colour. In addition, thin shale bands and some superior quality coal seams are developed.

2.2.4 BARAKAR FORMATION

Barakar formation overlies Karharbaris and is characterized by a thick and conspicuous basal conglomerate horizon at its base. The conglomerate contains well-rounded quartz and quartzite clasts of various sizes embedded in a sandy matrix. The basal conglomerate unit is overlain by a thick sequence (more than 500m) of medium to coarse-grained greyish feldspathic sandstones, grey to dark grey shale, carbonaceous shale, thick coal seams mostly interbanded with shale and clay bands. Barring central and western part of the basin, it occurs extensively.

2.2.5 BARREN MEASURES

Barren Measure Formation is conformably overlain by Kamthi Formation and is characterized by greenish grey to buff coloured pebble and coarse to medium grained highly ferruginous sandstone.

2.2.6 KAMTHI FORMATION

Kamthi Formation is well exposed and stands out conspicuously as high hills and plateaus in western part of the coalfield. It comprises of fine to medium grained light grey to reddish sandstone and shale at the base and pale greenish sandstone with rare pink clay, ferruginous coarse grained to pebbly sandstone at top.

2.2.7 LATERITE

The laterite comprises of lateritised detrital pebble bed. Patches of alluvium occur mainly in the eastern part and laterites of Cenozoic age in the central part of the basin respectively.

Stratigraphic succession of Talcher coalfield is given in table-2.2.A.

Table – 2.2.A: Stratigraphic sequence of geological formations in Talcher coalfield. (After GSI, 1997)

Group	Age	Formation	Thickness (m)	Lithology	
GONDWANA SUPER GROUP	Quaternary	Quaternary Deposits (Recent)	40+	Colluvial fills, sand, silt deposits and clay of older alluvium, older and younger flood plain deposits, channel fills etc.	
	Cenozoic	Laterite	40+	Laterites, laterised detrital pebble bed.	
	Upper Permian to Lower Triassic	Undifferentiated Kamthi formation	575+	Fine to medium-grained light gray to reddish sandstone and shale at the base and pale greenish sand stones with rare shale and pink clay bands, ferruginous coarse grained to pebbly sandstone at top.	
	----- Unconformity -----				
	Upper Permian	Barren Measure	461+	Greenish grey to buff coloured pebbly, coarse to medium grained highly ferruginous sandstone with variable proportions of K-feldspar.	
	Lower Permian	Barakar Formation	500+	Medium to coarse-grained greyish feldspathic sandstone, grey to dark grey shale and coal seams and Basal Barakar conglomerates.	
	Lower Permian	Karharbari Formation	279+	Pale brownish yellow coloured massive medium to coarse-grained sandstone containing clasts of Talchir shale and coal seams.	
	Upper Carboniferous to Lower Permian	Talchir Formation	321+	Diamictite, sandstone, needle shale, turbidite, rhythmite and varves.	
	----- Unconformity -----				
		Archaean (?) to Lower Proterozoic	Pre-Cambrian Metamorphics		Granites, gneisses and associated supra-crustals.

2.3 GEOLOGICAL STRUCTURE OF THE COALFIELD

Talcher coalfield depicts a northwesterly plunging synclinal structure. The strike of strata in southern part of the coalfield is E-W with a dip of 3° to 8° towards north. Northerly dip of strata is maintained up to northern boundary of the coalfield. The basin appears to close in south and east as Talchir and/or Karharbari

Formations lie unconformably over the Precambrian basement. The strike swings from E-W in south to N-S in the east. At the northwestern corner of the coalfield, easterly dip has been recorded which indicates the possibility of the closure of the basin in the west also.

Structurally, there are three sets of faults. Most common of all these faults is the one which is almost parallel to the strike of the strata i.e. E-W or so. Another set of faults trends WNW-ESE or NW-SE as can be noticed in the eastern part in Bharatpur-Lingaraj region. The third set of faults trending NE-SW is prominent in south-central part of the coalfield. The throw of faults varies from a few metres to hundreds of meters. E-W trending faults with southerly dip occur in the coalfield. The southerly orienting faults are repetition of thick barakar coal seams favouring opencast mining.

2.4 WEATHERING

All rock types in the area show effect of weathering. Among the rock types occurring in Talcher coalfields, the Basal conglomerate is by far the most resistant to weathering processes in comparison with sandstone, shale and coal in the order of decreasing resistance. The conglomerates, owing to their relatively high resistance are forming ridges and the cementing material has weathered and hence disintegrated into rock waste. The ridges are thus comprised of loose boulders with sandy matrix washed off to some extent.

The sandstone, shale and coal occupy the relatively plain areas because they are easily weathered and transported. At places, the sandstones and shales are leached of their silica content appreciably and converted into laterites and clay.

The depth of weathering in the rock formations of the area is moderate ranging from 5 to 15 mbgl.

2.5 STRATIGRAPHIC SEQUENCE OF JAGANNATH BLOCK

Occurrence of 3 main coal seams viz. III, II & I and a local seam (Index seam) have been proved under the cover of soil/ sub-soil/ weathered mantle by detailed exploration in Jagannath block. In this block, seam-III & II belonging to the Barakar formations and seam-I of Karharbari formations are exposed. Index seam/ Index horizon, otherwise known as marker horizon, has also been proved in this block. The sequence of coal seams and their intervening parting as established by exploration is given in table-2.5.A.

Table-2.5.A: Sequence of Coal Seams and Intervening Parting in Jagannath Block, Talcher coalfield, Odisha.

Formation	Lithology	Thickness range (m)	
RECENT	Soil/weathered mantle	1.50	33.25
BARAKARS	Sandstone/ Sandyshale	12.90	27.56
	Seam-III	6.95	15.40
	Sandstone/ Sandyshale	1.68	22.08
	Seam-II	34.90	46.70
	Sandstone, pebbly sandstone/conglomerate (Boulder bed)	29.65	47.75
KARHARBARI	Sandstone (Coal seam Index)*	67.86	97.52
	Seam-I Top	1.15	6.34
	Sandy shale/ sandstone	0.46	8.15
	Seam-I Middle & Bott. combined	6.79	13.99
	Seam-I Middle	2.98	6.65
	Sandy shale/ sandstone	1.00	5.33
	Seam-I Bottom	3.53	7.78

* Index seam occurs in the eastern part of the block, thickness ranging from 0.50 to 3.33m.

2.6 STRUCTURE OF JAGANNATH BLOCK

The Jagannath block is bounded by two major faults viz. F1-F1 in the south with northerly throw of 40 to 85m and fault F5-F5 in the north with southerly throw of 90 to 125. The faults are heading towards each other forming the graben. The general strike of beds in this block is E-W with minor local variations (i.e. SE-NW, SW-NE). The dip of the strata varies from 2.5° to 10° towards north and is generally between 5° - 7° .

The area is traversed by 6 major faults i.e F1-F1 to F6-F6. In addition, occurrence of few minor faults/ slips within the area can not be ruled out. In general, the faults are steeply dipping and the dip varies between 70° to 75° . Normally the faults are having less throw in the western part and greater throw towards the eastern part of the block. The description of faults is given in table-2.6.A.

Table-2.6.A: Description of faults as interpreted in Jagannath Block, Talcher coalfield, Odisha.

Sl.No.	Fault	Trend	Direction of throw	Amount of throw (m)
1.	F1-F1	NW-SE to E-W	Northerly	40-85
2.	F2-F2	NE-SW	Northwesterly	10-35
3.	F3-F3	NW-SE to E-W	Southerly	5-35
4.	F4-F4	E-W to NW-SE	Southerly	10-75
5.	F5-F5	E-W to NW-SE	Southerly	90-125
6.	F6-F6	E-W	Southerly	7-15

Chapter – 3

HYDROLOGY

3.1 INTRODUCTION

Drainage basin is a tool for quantitative measurement of hydrogeological cycle. In a drainage basin, the catchment or water shed forms a system boundary through which any sort of excess precipitation flows off through its principal streams. The characteristics of a basin at any given time contribute to the hydrologic variations in space. The characteristics to be considered include geometry of the basin, such as area, relief, orientation, shape, drainage density, channel frequency and drainage configuration. Over time, a stream system achieves a particular drainage pattern through its network of stream channels and tributaries as determined by different geological/ geographical factors. Drainage patterns are classified on the basis of their texture and form. Their shape or pattern develops in response to the local topography and subsurface geology. Drainage channels develop where surface runoff is enhanced and earth materials provide least resistance to erosion. Drainage pattern in Talcher coalfield varies from parallel to dendritic in nature. (Plate no.3). The study area falls under the influence of Bangaru Jhor and Nandira Jhor pre-dominantly, which are the tributary of Brahmani river which control the overall drainage pattern of the coalfield.

3.2 DRAINAGE ANALYSIS

Bangaru Jhor flowing towards north of the study area and Nandira Jhor flowing in south of the study area constitute two major water bodies. Both these channels are 5th order streams in the study area. The drainage basin map of Bangaru Jhor and Nandira Jhor are prepared on a topographic map of 1:50,000. The highest 5th order stream segment of the Bangaru Jhor basin, appears to form near village Arkhapal. For Nandira Jhor highest 5th order stream segment is formed near village Rankasingha.

3.3 NANDIRA JHOR BASIN ANALYSIS

Nandira Jhor flowing in the southern part of the study area (Plate no. 4) is one of the main drainage tributary of the Brahmani river in Talcher coalfield. Nandira Jhor originates near Barkerjang and near Poranga it forms a 2nd order stream, near Berhashar it forms 3rd order stream and continues to drain easterly, near Kuio, Nandira Jhor becomes a 4th order stream. It continues its easterly flow and near Rankasingha village it attains 5th order before meeting with Brahmani river further towards east of the study area. Nandira Jhor traverses almost 29 km from its place of origin before it meets Brahmani river.

The total catchment area of Nandira Jhor as estimated is about 193 km². Nandira Jhor, a fifth order magnitude stream has drainage pattern constituting 202 number of channel segments and 171.815 kms of total length altogether for all orders of streams segments. The average width of the Nandira Jhor sub basin is calculated at approximately between 20m to 210 m a.m.s.l. The Nandira Jhor basin appears to takes the shape of an elongation.

Hydrological parameters of the basin are given in table 3.4.1.C.

3.3.1 STREAM ORDER AND STREAM LENGTHS

The first step in drainage basin analysis is designation of stream orders. In Nandira Jhor basin the 5th order is highest stream order and it is formed near Rankasingha village. Thus Nandira Jhor is designated as 5th order stream. The number of segments in each order for this Nandira Jhor basin has been estimated and tabulated in table 3.3.1.A.

Table-3.3.1.A: Stream Orders and Stream Lengths of Nandira Jhor basin, around Jagannath OCP, Talcher coalfield, Odisha.

Order u	Number of segments Nu	Log Nu	Lengths (kms) Lu	Mean length of channel Lu
1	147.00	2.167	93.728	0.637
2	43.00	1.633	35.764	0.831
3	9.00	0.954	15.923	1.766
4	2.00	0.301	12.973	6.486
5	1.00	0.000	13.427	13.427

Source: Groundwater Baseline Survey in and around Ananta & Hingula OC Project, Talcher Coalfield, CMPDI, Bhubaneswar, 2013.

Mean length of channel is a dimensional property revealing the characteristic size of components of drainage network and its contributing basin surfaces. Channel length is measured geographically and therefore it almost represents the true length. The stream numbers and length typifying the basin govern the channel storage capacity as per the following formula.

$$\bar{L}_u = \frac{\sum_{i=1}^N L_u}{N_u}$$

Where,

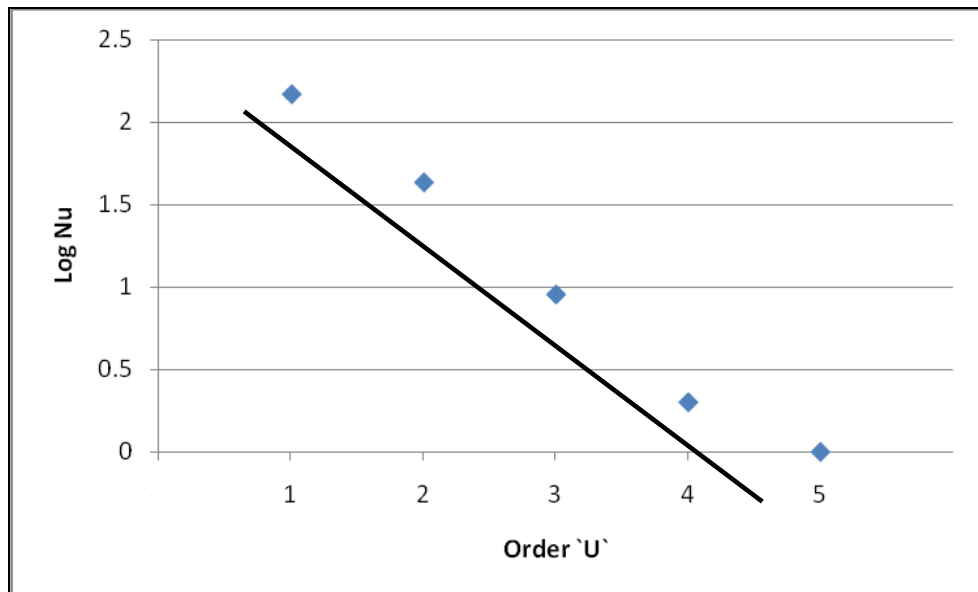
\bar{L}_u is Mean length of channel

N_u is Number of segments in a particular order of stream

L_u is the total length of all the streams for a particular order of stream

It is observed that mean length of the stream is directly proportional with that of the order of the stream (figure-5). The bifurcation ratio of Nandira Jhor basin is calculated by plotting logarithm of number of stream segments on ordinate against order on the abscissa. The antilog of the slope of the straight line gives the bifurcation ratio. The slope of line is calculated to be 0.53. Hence the bifurcation ratio of Nandira Jhor comes out to be 3.38 which as per the classification of Strahler, A.N (1964) indicate that the geological structures have little influence on the distortion of drainage pattern.

Figure-5: Log Nu Vs Order of Stream for Nandira Jhor Basin, around Jagannath OCP, Talcher coalfield, Odisha



The drainage density is calculated as total length of all the streams and rivers in a drainage basin divided by total area of the drainage basin. It is a measure of how well or how poorly a watershed is drained by stream channels. The drainage density calculated for this basin is equal to 0.88 km/km². Based on calculated value, it can be inferred that Nandira Jhor basin lies on a highly permeable landscape with small potential for run-off.

The stream frequency is a measure of topographic texture and expressed as the ratio of streams in a drainage basin to the area of the basin. In Nandira Jhor basin the stream frequency is calculated to be 1.04/Km².

The form factor, R_f , of Nandira Jhor subbasin have been calculated below as suggested by Horton.

$$R_f = \text{Area of Basin}(\text{km}^2)/(\text{Length of the basin})^2$$

$$\text{Area} = 193 \text{ km}^2; \text{Length} = 29 \text{ km};$$

The form factor of Nandira Jhor subbasin comes out to be 0.22.

The circularity ratio (R_c) gives the shape of the basin. It is calculated by the formula as given below:

$R_c = \text{Area of Basin} / \text{Area of the circle having same perimeter as that of the basin.}$

Area of Basin = 193 Km²; Area of the circle = 412.38 Km²

The calculated value of circularity ratio for Nandira Jor basin comes out to be 0.47.

The elongation ratio, (R_e) for Nandira Jhor basin is calculated by using the formula as given below;

$R_e = \text{Diameter of the basin} / \text{Length of the basin}$

Diameter = 11.7Km; Length = 29Km

The calculated value of elongation ratio for Nandira Jor basin comes out to be 0.40.

3.4 BANGARU JHOR BASIN ANALYSIS

Bangaru Jhor drains towards the northern part of the study area. Bangaru Jhor (Plate-5) emerges as seasonal third order stream in Ambapal, Natara and Kalamchhuin village areas and flows into Satyavadi sagar, which is a manmade small surface water reservoir located between Brahmanbahal and Kalamchhuin villages. Right from Satyavadi sagar the river flows in an almost northeasterly direction through Joragadia, Arkhapal and Radharamanpur village where it forms a 5th order stream before draining into the Brahmani river near Dharampur village in the extreme eastern parts of the coalfield. Tributaries of Bangaru Jhor separately drain areas around Jambubahali, Anantaberini and Lachmanpur villages. The general width of the river varies from 5 to 25 metres and depth varies from 2 to 4.5 metres depending on the local topography.

The hydrological parameters of the basin are given in table-3.4.1.C.

3.4.1 STREAM ORDER AND STREAM LENGTHS

In Bangaru Jhor basin, the Bangaru Jhor is a 5th order stream and it is formed near Arkhupal village.

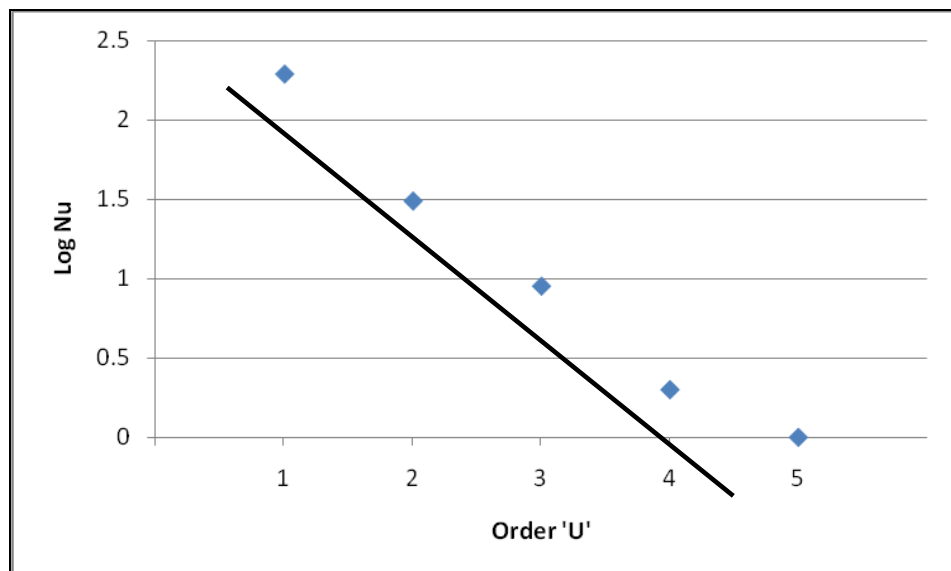
The number of segments in each order for this Bangaru Jhor basin has been tabulated in table –3.4.1.A.

Table-3.4.1.A: Stream orders and stream lengths of Bangaru Jhor basin, around Jagannath OCP, Talcher coalfield, Odisha.

Order u	Number of segments Nu	Log Nu	Lengths in kms Lu	Mean length of channel Lu
1	196.00	2.292	111.64	0.570
2	31.00	1.491	40.74	1.314
3	9.00	0.954	17.42	1.936
4	2.00	0.301	15.52	7.760
5	1.00	0.000	12.80	12.800

Source: Hydrology of Talcher Coalfield, Orissa, India, CMPDI, Ranchi, 1988.

Figure-6: Log Nu Vs Order of Stream for Bangaru Jhor Basin, around Jagannath OCP, Talcher Coalfield, Odisha



The regression coefficient, b, for this basin was determined from slope of the regression line. The value is in the order of 0.65 for Bangaru Jhor basin. (Figure-6)

Bifurcation Ratio (R_b) = $\log b - 1$

The antilog of the regression coefficient (b) is bifurcation ratio of the basin and it is calculated as 4.46.

Bifurcation ratio characteristically ranges between 3.0 and 5.0 for watersheds in which geologic structures do not distort the drainage pattern (Strahler, A.N. 1964). The bifurcation ratio obtained for Bangaru Jhor falls within the above range hence geological structures did not distort the drainage of this basin.

The drainage density of Bangaru Jhor basin has been computed as 1.52km/sq.km. The low drainage density (less than 2.5) is obtained in regions of highly resistant or highly permeable subsoil under dense vegetative cover and low relief.

The stream frequency of Bangaru Jhor basin has been computed as 1.83 per sq.km. This stream frequency broadly refers the compact nature of the geological formation.

Basin shape has an important bearing in hydrological characteristics and may conceivably affect the stream discharge. Bangaru Jhor basin is a fan shaped or more or less semicircular in nature and it produces sudden peak flood than the fern shape or elongated basin. Thus the basin shape plays an important role in correlation of rainfall and runoff phenomena. Horton's (1962) Form Factor is a simple ratio of watershed area to basin length from mouth to the opposite side. The circularity ratio compares the area of water shed to the area of circle having the same perimeter (Miller; 1952). Elongation is the ratio of a diameter of a circle with the basin area to the maximum length parallel to the principal drainage line. The parameters calculated for the basin shape are given in table 3.4.1.B.

Table-3.4.1.B: Average slope of the channel segments of given order of Bangaru Jhor, around Jagannath OCP, Talcher Coalfield, Odisha.

Order u	Vertical distance in meter Hn	Horizontal distance in meters Ln	Slope Sn = Hn/Ln
1	33.54	2850	0.0117
2	13.72	2600	0.0052
3	1.52	1350	0.0110
4	33.54	9650	0.0035
5	9.14	7550	0.0012

Source: Hydrology of Talcher Coalfield, Orissa, India, CMPDI, Ranchi, 1988

The form factor, R_f , of Bangaru Jhor subbasin have been calculated as suggested by Horton.

$$R_f = \text{Area of Basin (km}^2\text{)} / (\text{Length of the basin})^2$$

$$\text{Area} = 130 \text{ km}^2; \text{Length} = 24 \text{ km};$$

The form factor of Bangaru Jhor sub basin comes out to be 0.23.

The circularity ratio (R_c) gives the shape of the basin. It is calculated by the formula as given below:

$R_c = \text{Area of Basin} / \text{Area of the circle having same perimeter as that of the basin.}$

$$\text{Area of Basin} = 130 \text{ Km}^2; \text{Area of the circle} = 286 \text{ Km}^2$$

The calculated value for Bangaru Jhor basin comes out to be 0.45.

The elongation ratio, (R_e) for Bangaru Jhor basin is calculated by using the formula as follows;

$$R_e = \text{Diameter of the basin} / \text{Length of the basin}$$

$$\text{Diameter} = 12.86 \text{ Km}; \text{Length} = 24 \text{ Km}$$

The calculated value for Bangaru Jhor basin comes out to be 0.54.

Table 3.4.1.C: Summary of Hydrological parameters of the sub basins around Jagannath OCP, Talcher coalfield, Odisha.

Name of Basin	Nandira Jhor	Bangaru Jhor
Area of Basin in Km ² (Au)	193.00	130.00
Perimeter of Basin in Km (P)	71.90	60.00
Basin length in Km (L)	29.00	24.00
Diameter of Circle with basin area in Km (D)	11.45	12.86
Area of the circle having the same perimeter of the basin in Km ² (AC)	412.38	286.00
Form Factor Rf= Au/L ² (RF)	0.22	0.23
Circularity ratio Rc = Au/Ac (Rc)	0.47	0.45
Elongation ratio Re=d/L (Re)	0.40	0.54

Chapter – 4

SITE INVESTIGATION PROGRAM

4.1 INTRODUCTION

This section of report, details the scope of work carried out at site.

4.2 IDENTIFICATION OF CONTROL WELLS

As a part of the comprehensive hydrogeological investigation, a network of existing thirty one open dug wells spread over an area of 5 kms radius from Jagannath OCP area were established to monitor the water table variation and to assess the hydraulic head of the water table in the phreatic aquifer. In order to evaluate the present state of water quality in and around abandoned mines voids, 4, 7 & 8 in Jagannath OCP, twelve numbers of open dug wells, ten hand pumps, fourteen piezometers, six surface water stations and four number of mine water stations were identified for the study. The locations of all the control wells are shown in Plate no. 6. The location of piezometers present along the boundary of Jagannath OCP are also shown in Plate no. 6.

4.3 INSTALLATION OF PIEZOMETER

CMPDI officers along with NTPC officials conducted site reconnaissance in and around Jagannath OCP to finalize and fix location of eighteen new piezometers. Post site reconnaissance, CMPDI submitted the design and technical specifications i.e. diameter of piezometer, total depth of individual piezometer, casing specifications and construction details etc. for all eighteen piezometers to NTPC (letter no CMDP/RI-7/EXPLO/2013/360). Out of the eighteen piezometers, eight are present on the northern and eastern boundary of Jagannath OCP and three are sharing common boundary with South Balanda OCP towards south.

The piezometers were drilled by NTPC through “M/s Venkateswara Borewell Services”, under the supervision of NTPC officers. All piezometers were drilled using

a direct rotary drilling rig. Prior to the advancement of each boring, boreholes were advanced to at least 1.0 m bgl at the boring location to check for the presence of underground utilities. The depths of completed piezometers ranged from 51 – 117 m below ground level. The variation in orientation of piezometers was due to variation in lithology, dip of geological strata, extent of mining disturbance, aquifer characteristics in each drilling location and accessibility and availability of the space for construction of piezometers.

4.3.1 SPECIFICATION OF PIEZOMETER

The piezometers generally comprised of 21m - 48 m of screen (150 mm diameter, factory slotted heavy duty PVC pipe, slot size 1 mm) and remaining length of heavy duty PVC blank casing. All pipe joints were flush threaded. All piezometers were provided with bottom bail plug.

Washed, well graded gravel with diameter (3 mm - 5 mm) larger than the screen slot size was shrouded in the boring annular space between wall of the boreholes and casing. Thick seal made of clay material was placed at top of the gravel filter pack. The remaining annular space was filled by grouting the Portland cement up to the surface. Central guide was provided at appropriate depths for stability and verticality to the deeper piezometers. Piezometer details are provided in table-4.3.A and 4.3.B.

Piezometers were constructed with casing extended sufficiently above ground level (0.50-0.88 m above ground surface) to avoid submergence in the event of flooding. A sanitary cover/ seal of Portland cement concrete was used around the piezometer and was graded to drain away from the well to protect the well from direct surface water percolation. All piezometers were subsequently capped and locking arrangements were made to ensure safety.

Schematic diagram of piezometer construction and specifications are presented in Annexure 1.

Table- 4.3.A: Details of Piezometer in and around Jagannath OCP, Talcher coalfield, Odisha.

Piezometer ID	Location	Position Slotted PVC casing Intervals (m)	Total Slotted PVC casing length (m)	Total Depth (m)
SJC-1	Ananta Substation (Between Ananta OCP and Jagannath OCP)	12-24	42	105
		36-45		
		84-105		
SJM-2	Mid of Ananta OCP and Jagannath OCP at the northern edge	84-96	24	114
		102-114		
SJM-4	CTPL workshop	12-24	27	60
		36-48		
		54-57		
SJM-4	CTPL workshop	60-66	33	117
		78-90		
		102-117		
SJM-5	Central colony (Jagannath area) near Police Beat house	18-36	21	54
		48-51		
SJC-5	Central colony (Jagannath area) near Police Beat house	18-30	41	105
		42-54		
		66-78		
		90-105		
SJM-6	Near Ananta PO office	30-42	45	108
		54-66		
		72-84		
		96-105		
SJM-7	Near Ananta Sliding	30-42	48	108
		54-66		
		72-84		
		96-108		

Table- 4.3.B: Details of Piezometer sharing common boundary with South Balanda OCP, Talcher coalfield, Odisha.

Piezometer ID	Location	Position Slotted PVC casing Intervals (m)	Total Slotted PVC casing length	Depth (m)
SJL-3	Jagannath Workshop	27-39	36	108
		51-63		
		75-81		
		99-108		
SJU-8	Eastern side of Balanda railway	9-15	21	51
		24-33		
		42-48		
SJM-8	Eastern side of Balanda railway	51-57	30	108
		66-78		
		90-102		

4.4 DEVELOPMENT OF PIEZOMETER

After installation, piezometers were developed by continuous flushing out of water for 5 to 6 hours using compressed air at 200 to 300 PSI to ensure good hydraulic continuity between the piezometer and the aquifer.

Airline pipe of size 1.5 inch were lowered up to five meter from the final depth of each piezometer and clamped tightly and placed at the top of the piezometer. Groundwater was flushed out of the piezometers for a maximum period of 5 to 6 hours. Air pressure was constantly maintained at a steady rate to ensure correct measurement of discharge. Prior to flushing, static water level at each piezometer was recorded. Flushed out water was properly drained to pass through a V-notch. Readings of outflow of the water was monitored at every 15 minutes interval using the V-notch plate. Schematic V-Notch arrangement in field is given in figure-7.

After flushing out of water from the piezometer for desired duration, the air compressor was stopped and water level indicator was lowered immediately to measure maximum drawdown and subsequent recovery of water into the piezometer. Recovery water level was measured in all piezometers in format given in table 4.4.A.

Table- 4.4.A: Development interval for all Piezometer in and around Jagannath OCP, Talcher coalfield, Odisha.

At Interval(s) of	Time
30 sec	For first 5min
60 sec	Till 10 th min
120 sec	Till 20 th min
300 sec	Till 50 th min
600 sec	Till 120 th min
1200 sec	Till water level reaches a steady state recovery

Figure-7: V-Notch arrangement for measuring Discharge



4.5 PUMPING TEST

A pumping test is a controlled field experiment in which a well is pumped at a controlled rate and water-level response (drawdown) is measured in one or more surrounding observation wells and optionally in the pumped well (control well) itself. Response data from pumping tests are used to estimate the hydraulic properties of the aquifers, evaluate the well performance and identify the aquifer boundaries.

Based on the results of yield test conducted by CMPDI hydrogeologist, the report having discharge range and pump head was submitted to M/s NTPC vide letter no. CMPDI/RI-7/DG/5.71/1362 dated 31.12.2013. Pumping test was conducted in suitable piezometers in January 2014 by CMPDI hydrogeologist. Pumping test assembly specification is given in table 4.5.A.

Multistage submersible pumps of desired specification (1 HP & 2 HP) were used for carrying out pumping test. An assembly consisting submersible pump compiled with electric cable and discharge pipe was lowered till desired depth inside piezometer. This pump assembly was clamped tightly at the top of the piezometer. Delivery pipe was also lowered till desired depth for lowering of water level indicator for continuous water level monitoring during pumping and recovery time of the aquifer. Submersible pump was powered through 7KV diesel run generator and operated using an electric switch panel.

Static water level was measured prior to start of pumping test. Continuous water level drawdown was measured in the same pumping well at specified intervals for 720 min, thereafter the pump was shut down and recovery of water into the piezometer was measured at desired interval for a time period till water in piezometer regains its initial static water level. Pumping test data for tested piezometers is presented in Annexure-II.

Table 4.5.A: Pumping Test Assembly Specification for piezometers in and around Jagannath OCP, Talcher coalfield, Odisha.

Piezometer ID	Location	Pump Capacity	Pump installation Depth (m)	Total Depth of piezometer (m)
SJC-1	Ananta Substation (Between Ananta OCP and Jagannath OCP)	1HP	70	105
SJL-2	Mid of Ananta OCP and Jagannath OCP at the northern edge	1HP	70	114
SJL-3	Jagannath Workshop	1HP	70	108
SJL-4	CTPL workshop	1HP	70	117
SJU-5	Central colony (Jagannath area) near Police Beat house	2HP	45	54
SJC-5	Central colony (Jagannath area) near Police Beat house	2HP	70	105
SJL-6	Near Ananta PO office	2HP	70	108
SJL-7	Near Ananta Sliding	1HP	70	108
SJL-8	Eastern side of Balanda railway	1HP	70	108

4.6 SLUG INJECTION TEST

A slug test is carried out by creating an instantaneous change in the water level of a well and observing the recovery of the water level with time. The change is created by a known volume of water quickly poured into the well. This causes a sudden rise in the water level which subsequently diminishes towards the original water level as water flows out of the well into the formation. Slug injection test was carried out in two piezometers (table 4.6. A). Slug injection test data for the two piezometers are given in Annexure-II.

Table-4.6.A: Slug Injection Test Parameters for piezometers in and around Jagannath OCP, Talcher coalfield, Odisha.

Piezometer ID	Location	Slug Volume (Litre)	Total Depth of piezometer (m)
SJU-4	CTPL workshop	117	60
SJU-8	Eastern side of Balanda railway	45	51

4.7 WATER SAMPLING

4.7.1 GROUND WATER SAMPLING

CMPDI carried out the sampling of groundwater from existing open dugwells, hand pumps and newly installed piezometers. A total sum of thirty six (36) number of groundwater samples in pre-monsoon season and thirty five (35) number of groundwater samples in post monsoon season were collected for both Jagannath OCP and South Balanda OCP combined. The details of the location of the sample stations are given in Table 4.7.1.A, 4.7.1.B and 4.7.1.C and shown in Plate no. 6.

Due to expansion of mining activity in the immediate vicinity of village Jilinda, the open dug well in village Jilinda (NDW-3) could not be sampled for post monsoon season.

Table-4.7.1.A: Open Dug Well Sampling Location Details in and around Jagannath OCP, Talcher coalfield, Odisha.

Sample ID	Village	Details of Sampling Location
NDW-1	Gobara	Gobara chowk
NDW-2	Rakas	In between platform constructed under IPDP-93, Bharatpur project, In front of house of Sri Basanta Barik.
NDW-3	Jilinda	Inside the field, Road side (Moorum+Khoa)
NDW-4	Langijorha	Dismantled house between Nita Sahoo and Padmini Pradhan (Shop)
NDW-5	Dera	In front of House of Sridhar Nayak
NDW-6	Ghantapara	Near road side and Mangala Mandir
NDW-7	Danara	In front of Birinchi Mahapatra, besides road
NDW-8	Tentulei	In front of House of Sri Chatura Sahoo and Mangala Mandir
NDW-9	Hensamul	Near village club
NDW-10	Barha Singarha	In front of House of Sri Grish Chandra Sahoo and Akram Behera
NDW-11	South Balanda	Balanda Market well
NDW-12	Barhajorha	Well between house of Sri Sudhakar Behera and Birbar Behera (Village road side)

Table 4.7.1.B: Tube well Sampling Location Details in and around Jagannath OCP, Talcher coalfield, Odisha.

Sample ID	Village	Details of Sampling Location
NTW-1	Rakas	UP school
NTW-2	Bharatpur	Bharatpur township tube well water
NTW-3	Barha Singhara	In front of House of Sri Charan Behera
NTW-4	Danara	In front of house of Ravindra Biswal, besides road
NTW-5	Dera	In front of House of Sridhar Nayak
NTW-6	Tentulai	In front of House of Sri Chatura Sahoo and Mangala Mandir
NTW-7	Ghatapara	Near road side and Mangala Mandir
NTW-8	South Balanda	Balanda colony tube well water
NTW-9	Langijorha	Village Mandap
NTW-10	Barhajorha	In front of house of Kalyan Sahu

**Table 4.7.1.C: Piezometer Sampling Location Details
in and around Jagannath OCP, Talcher coalfield, Odisha.**

Sample ID	Details of Sampling Location
SJC- 1	At Ananta Substation (between Ananata OCP and Jagannath OCP)
SJL- 2	Mid of Ananta OCP & Jagannath OCP at northern edge
SJL- 3	At Jagannath Work shop
SJL- 4	At CTPL work shop
SJU- 4	At CTPL work shop
SJC- 5	Near Police beat house at Central colony
SJL- 6	Near Ananta PO office
SJL- 7	Near Ananta Railway siding
SJL- 8	Eastern Side of Balanda Railway siding (Opposite rest shelter)
SJL- 9	At Balanda CHP
SJU- 9	At Balanda CHP
SJL- 10	In front of Balanda colliery store & Opposite regional store.
SJU- 11	At Nandira 132 KV Substation
SJC- 11	At Nandira 132 KV Substation

4.7.2 MINE WATER SAMPLING

CMPDI carried out sampling of mine water at four locations for both Jagannath OCP and South Balanda OCP combined. The sample details are given in Table 4.7.2.A.

**Table-4.7.2.A: Mine Water Sampling Station
in and around Jagannath OCP, Talcher coalfield, Odisha.**

Sample ID	Location	Details of Sampling Location
NMW-1	South Balanda	Ash pond discharge water from Balanda OCP excavation near Balanda OCP central workshop
NMW-2	Jagannath OC	Mine discharge water at water loading at point quarry no. 4.
NMW-3	Bharatpur OCP	Mine discharge water from Bharatpur OCP
NMW-4	Ananta OCP	Mine discharge water from Ananta OCP

4.7.3 SURFACE WATER SAMPLING

CMPDI carried out surface water sampling at six places for both Jagannath OCP and South Balanda OCP combined. Surface water samples were collected from the top 30 cm of water column. Due care was taken to avoid skimming the surface of water and disturbing sediments, if any, during sample collection. The sample details are given in Table 4.7.3.A.

Table-4.7.3.A: Surface Water Sampling location around Jagannath OCP, Talcher coalfield, Odisha.

Sample ID	Village	Details of Sampling Location
NSW-1	Raghunathpur	Upstream of Study area in Bangaru Jhor
NSW-2	Arkhapal	Downstream of study area in Bangaru Jhor
NSW-3	Gurujanga	Upstream of confluence of Bangaru Jhor and River Brahamani.
NSW-4	Tentulai	Upstream of study area in Nandira Jhor
NSW-5	Kamlang	Downstream of confluence of Nandira Jhor and River Brahamani.
NSW-6	Gurujanguli	Downstream of study area in Nandira Jhor

4.8 SAMPLE COLLECTION AND SHIPMENT DETAILS

Prescribed quantity of collected surface, mine water and groundwater samples were placed directly into sample bottles, labeled, catalogued on Chain-of-Custody forms and placed in dispatch boxes for shipment to the CMPDI laboratory at Ranchi for required analysis. The samples reached laboratory within specified holding times.

4.9 BOREHOLE LITHOLOGY

Drill sludge samples were collected at every one meter interval up to termination depth. Samples were preserved in transparent polythene pouch and labeled properly by drilling agency. The site-specific geological data was gathered by CMPDI from the preserved sludge samples. A summary of the general site geology obtained from lithological logging of newly installed piezometers is provided in Annexure –VIII.

Chapter – 5

HYDROGEOLOGY

5.1 REGIONAL HYDROGEOLOGY OF TALCHER COALFIELD

A detailed hydrogeological study was carried out by Hydrogeological unit of CMPDI, Ranchi for Nandira block during the period 1981 to 1984 covering eastern part of the Talcher coalfield. Subsequently a detailed hydrogeological study had been conducted by Directorate of Mining & Geology, Department of Steel and Mines, Govt. of Orissa for Gopalprasad block of Talcher coalfield in 1990. Besides above, the subsurface hydrogeological information was augmented for this project from the Hydrogeological Study Report for backfilling of fly ash in abandoned Bharatpur south mine. The abstract of Hydrogeological studies carried out by CMPDI, Ranchi in Talcher coalfield is given in the following paragraphs:

- I. Detailed hydrological studies reveal that Singhada jhor proto-basin and Bangaru jhor sub-basin are of 5th order streams draining into the Brahmani River.
- II. The drainage density of Singhada jhor and Bangaru jhor basins are 1.75 and 1.52 km/sq.km and their stream frequencies are 2.09 and 1.83 per sq.km respectively. Both the basins are morphometrically similar.
- III. The annual total run-off in Singhada jhor is 332.45, 237.97 and 545.19 mm of which the base flow accounts to 164.80, 90.91 and 167.25 mm in 1983, 1984 and 1985 respectively.
- IV. Ground water in the area occurs under both unconfined and confined conditions. The weathered mantle, recent alluvium and laterites act as unconfined aquifer or phreatic aquifer.
- V. The annual fluctuation of water levels range from 2 to 12 m in the area. In Singhada jhor basin, the water level fluctuation ranges from 4 to 6 m and in Bangaru jhor basin it is 6 to 10 m. Expectedly, the areas comprising of ground water divides have recorded high fluctuations.

-
- VI. The water table configuration coincides with the topography of the area with an average hydraulic gradient of 0.3 percent.
 - VII. There are a few localized ground water troughs and mounds and the watershed boundaries in general coincide with the ground water divides.
 - VIII. The average hydraulic conductivity of unconfined aquifer for the study area is 2.83 m per day.
 - IX. The discharge ranges from 0.54 to 94.00 cubic meters per day.
 - X. The drawdown varies from 0.37 to 3.20 m on an average pumping of 65 minutes.
 - XI. The specific capacity varies from 0.048 to 13.46 cum/hr/m. The specific yield of the area is 4 percent.
 - XII. For the confined aquifer, the peizometric head is at 170 m in the western and 80 m above mean sea level in the eastern parts. The piezometric head fluctuation is around 1.4 meters annually.
 - XIII. The pumping tests conducted on the well tapping confined aquifers indicate the transmissivity range of 1 to 20 sq.meters per day and the storativity ranges from 4.5×10^{-4} to 7.8×10^{-4} .
 - XIV. The hydraulic conductivity of the aquifer ranges from 0.1 to 1.5 meters per day. The discharge varies from 33 to 316 cubic meters per day with a drawdown of 5 to 30 meters under pumping conditions.
 - XV. The groundwater temperature of unconfined aquifer varies from 22⁰C to 30⁰C, whereas of the confined aquifer, it varies from 32⁰C to 48⁰C.

5.2 AQUIFER DISPOSITION FOR TALCHER COALFIELD

Hydrogeological studies at Talcher Coalfield reveals that the following aquifers are identified in the ascending order from the data of sub surface geological and ground water exploration studies of the past. Exploratory data for coal and ground water have also been analysed to understand the disposition of aquifers. Details of aquifers found in Talcher coalfield are given in Table 5.2.A.

Table - 5.2.A: Details of aquifers found in Talcher coalfield.

Name of the aquifer	Formations	Range of thickness in m.	Confining beds
Phreatic aquifer	Detrital mantle, river alluvium soils,	10 to 20	--
Upper Barakar aquifer	Barakar sandstones	5 to 40	Coal seam IX & shales.
Middle Barakar aquifer	Barakar sandstones	5 to 30	Coal seam VI & Shales.
Lower Barakar aquifer	Barakar sandstones	10 to 50	Coal seam III & Shales
Basal aquifer	Basal Barakar conglomerates and sandstones. Karharbari sandstones.	60 to 120	Coal seam II & Shales.
Karharbari aquifer	Karharbari sandstone	> 30	Coal seam I & Shales.

Source: Hydrology of Talcher Coalfield, Orissa, India, CMPDI, Ranchi, 1988

From the above table the aquifers in Talcher coalfield have been broadly classified as shallow & deep aquifer and have been referred as unconfined and

confined aquifers respectively representing their mode of occurrence. The division between confined and unconfined is entirely gradational. The term semi-confined is used for the intermediate condition.

In Talcher coalfield, ground water occurs in the porous colluvial material and weathered mantle as well as in the joints, fissures and fractures. These are at shallow depths in the partly weathered rocks and deep seated fresh rocks. Though shale, coal, mud stones etc. act as confining horizon but the very nature of these confining horizon permits considerable vertical flow. As these confining horizons have very poor hydraulic conductivity in horizontal directions, these horizons also act as barrier boundaries when they get juxtaposed with water bearing horizon because of geological disturbance.

The large pore spaces in the fine grained sedimentary rocks provide storage for huge quantities of water. The porosity of fine grained sediments decreases with depth of deeper depositional environment.

Cemented sandstones and conglomerates made sedimentary formation hard and compact which offer very limited scope to be considered as aquifers in themselves. When these formations are geologically disturbed by faulting, jointing and fracturing produces secondary porosity. This secondary porosity when it is saturated with ground water forms good aquifer. As a rule formations are found to become thinner and fine grained at increasing distances from the source of sediments. These lateral gradations are of great significance with respect to the occurrence and movement of ground water.

5.3 AQUIFER DISPOSITION FOR JAGANNATH OCP

On the basis of geological exploration data, in the order of superposition, two formations namely Karharbari and Basal Barakar formations are encountered in this block. Two aquifer formations are distinguished namely Karharbari aquifer and Basal Barakar aquifer.

5.3.1 Karharbari Aquifer

This is the lower most aquifer considered in the present study area. This aquifer outcrops south of active mining area i.e. south of Talcher, Balanda and Nandira Mines. This aquifer is expected to spread over the entire coalfields with the general strike of east west and a gentle dip of 3 to 4° towards north. This aquifer consists of Karharbari sandstones and Talcher greenish sandstone. These sandstones are associated with shales and coal seam-I, which act as confining bed. Ground water in this aquifer occurs in the confining hydraulic condition. At outcrop areas, these sandstones are highly weathered and support dug wells for domestic water supply needs.

5.3.2 Basal Aquifer

This aquifer represents the lowermost granular horizons of the area. This aquifer is bounded by Karharbari coal seam-I at the bottom and weathered sandstones and shale at the top. This aquifer outcrops in the southern parts of the area. In outcrop region the aquifer material is weathered and essentially unconfined. Basal aquifer consists of Karharbari sandstones and Basal Barakar conglomerates. The sandstones and conglomerates are weathered. The primary porosity seldom exists. However, the secondary porosity induced during the post depositional weathering accounts for most of their yields.

5.4 ESTIMATION OF HYDRAULIC PROPERTIES

Hydrogeological investigations were carried out in the constructed and developed 11 nos. of piezometers in and around study area (Plate 6). The main motive behind the installation of piezometer was to determine hydraulic conductivity to know the extent of mining disturbance, piezometric head of the aquifers encountered in the area and quality of groundwater within maximum extent of the radius of influence from mine boundary. Transmissibility of the aquifer material around 11 piezometer was estimated through different estimation tests such as slug test, drawdown test and recovery test. From this transmissibility, permeability of the test horizons were estimated and given in table no 5.4.A and the plots are shown in Annexure VII. The average permeability has been taken into consideration for further interpretations and analysis.

5.4.1 ESTIMATION OF HYDRAULIC PROPERTIES THROUGH SLUG INJECTION TEST

A slug test is carried out by causing an instantaneous change in the water level of a well and observing the recovery of the water level with time. The change is caused by a known volume of water quickly poured into the well. This causes a sudden rise in the water level which subsequently diminishes towards the original water level as water flows out of the well into the formation. From this, the coefficient of transmissibility of the aquifer material in the immediate vicinity of the well can be estimated by an equation developed by Theis (1935) for a vertical instantaneous line sink. Slug injection test was carried out in 2 piezometer to estimate the permeability of the material in the immediate vicinity of the well

A suitable apparatus and water tanker of known flow rate were used for instantaneous injection of water into the well. Water level measurements were made through battery operated water level sounder. Before slug injection was made, initial water level in the piezometers was recorded. After injection of a known quantity of

Table - 5.4.A: Aquifer parameters determined from piezometers in and around Jagannath OCP, Talcher coalfield.

Piezometer No.	Location	Total depth of piezometer (m)	Piezometric head of the aquifer (m bmp)	Permeability calculated through pumping drawdown test (m/day)	Permeability calculated through recovery test (m/day)	Permeability calculated through slug test (m/day)	Averaged Permeability or hydraulic conductivity (m/day)
SJC 1	Mid of Ananta and Jagannath OCP (near Kali mandir)	105	38.80	0.079	0.050	—	0.065
SJL 2	At Ananta substation	114	34.50	0.148	0.138	—	0.143
SJL 3	At Jagannath workshop	108	15.09	0.061	0.066	—	0.064
SJU 4	At CTPL workshop	60	6.44	—	—	0.085	0.085
SJL 4	At CTPL workshop/office	117	6.55	—	0.010	—	0.010
SJU 5	At central colony	54	7.28	1.851	1.581	—	1.716
SJC 5	At central colony	105	7.25	0.795	0.726	—	0.761
SJL 6	Near Ananta Project office	108	4.58	0.473	0.320	—	0.397
SJL 7	Near Ananta railway siding	108	15.78	0.095	0.118	—	0.107
SJU 8	Eastern side of Balanda railway siding	51	2.31	—	—	0.215	0.215
SJL 8	Eastern side of Balanda railway siding	105	1.80	0.112	0.081	—	0.097

water into the well, rapid water level measurements were made. The water level is recorded with respect to time of slug injection is given in Annexure-II. The water level data thus recorded is taken for computation of transmissibility. The residual head at any instance is the difference between the observed water level and initial water level. In making a slug injection test, the duration of injection was recorded and the average of these times was used as the origin time in analysing the water level measurements. The residual head "s" was plotted against the reciprocal of the time since the slug was injected "1/tm" on rectangular co-ordinate graph paper. A straight line through points plotted from the observed data passes through the origin. The following equation gives the transmissibility of the aquifer material in the immediate vicinity of the test sites provided Arbitrary selection of the point on the straight line and substitution of those values of residual head "s" and the reciprocal of the time since injection of slug "1/tm".

$$T = \frac{114.6 \times Q \times 1/tm}{s}$$

Where

T = Co-efficient of transmissibility

Q = Volume of water in cubic meter

1/tm = Reciprocal of the time in minutes since injection of slug

s = Residual head in "m"

5.4.2 ESTIMATION OF HYDRAULIC PROPERTIES THROUGH PUMPING TEST

A pumping test is a controlled field experiment in which a well is pumped at a constant discharge and water-level response (drawdown) is measured in one or more surrounding observation wells and optionally in the pumped well (control well) itself. Response data from pumping tests are used to estimate the hydraulic properties of aquifers to evaluate well performance and identify aquifer boundaries. In the study area, pumping test was carried out in 9 piezometer to derive the hydraulic parameters. Drawdown data of the pumping test was plotted in the semi

logarithmic paper. Analysis involves matching a straight line to drawdown data plotted as a function of the logarithm time since the start of pumping. By employing modified non-equilibrium equation, drawdown and time data taken during the pumping test to derive information on the hydraulic characteristics. The following expression has been used to estimate hydraulic characteristics of the aquifer.

The recovery data of the pumping wells shows the depth to water measurements in the pumping well and the residual drawdown for time intervals measured from both the beginning of pumping test and the beginning of recovery period. These intervals are designated as t and t' respectively. The ratio of the two time periods t/t' are then calculated. The values of S' are plotted against corresponding values of t/t' in semi-logarithmic graph paper.

After analysing the pumping and recovery data, transmissivity for the aquifers has been estimated from the following expressions.

$$T = \frac{0.183 Q}{\Delta S}$$

Where

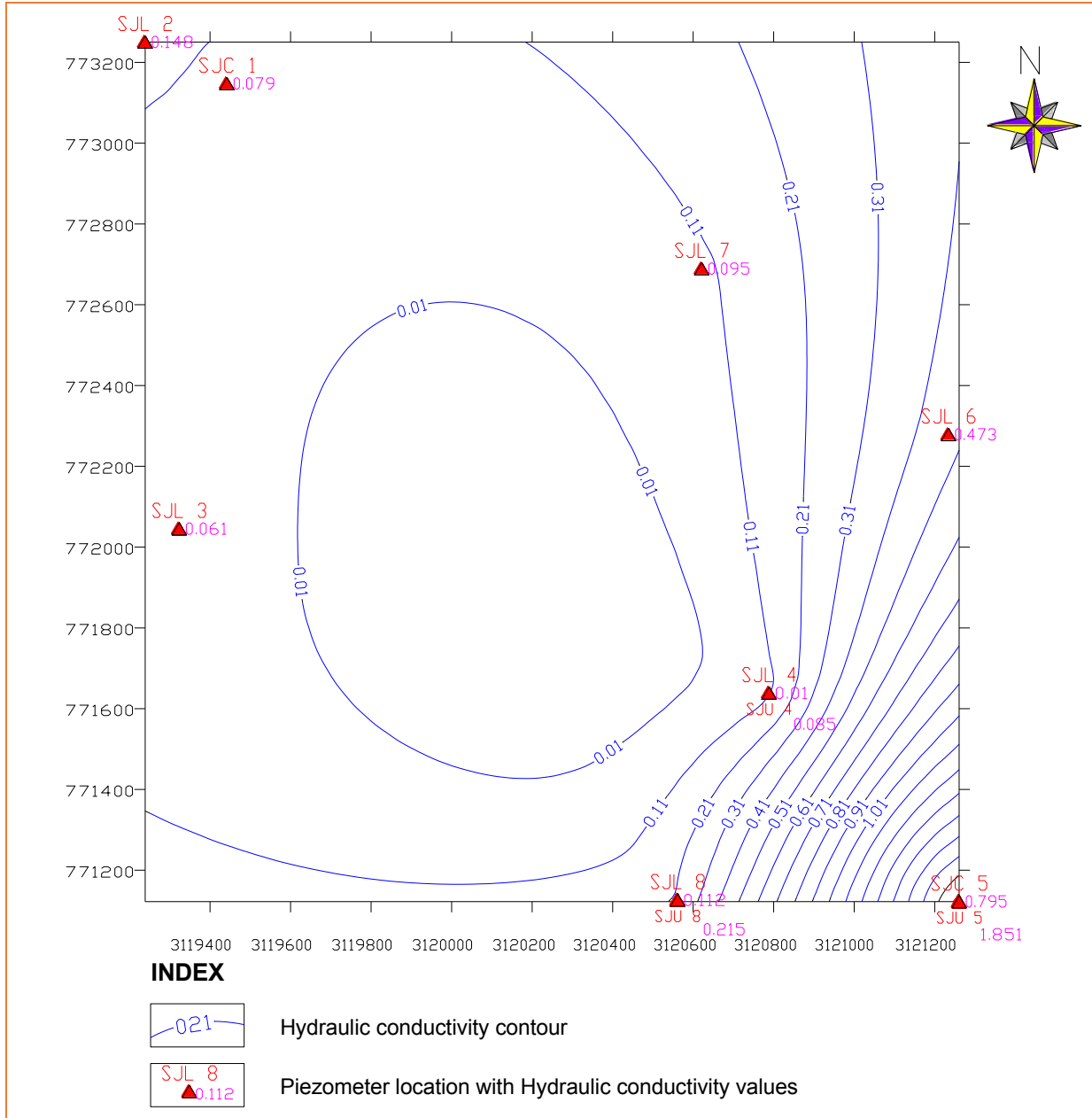
T = Co-efficient of transmissivity, in m^2/day

Q = Pumping rate, in m^3/day

ΔS = Slope of the time drawdown graph expressed as the change in drawdown between any two times of the log scale whose ratio is 10 (one log cycle)

After the calculation of hydraulic conductivity, a hydraulic conductivity contour map was prepared to see the variations in the behaviour of hydraulic conductivity. The hydraulic conductivity of the tested piezometers ranges from 0.010 m/day to 1.716 m/day. Piezometer, SJU -5 has the highest hydraulic conductivity and the least was encountered in SJL -4. Earlier studies proved that secondary porosity is the main cause for the formation of aquifer in this coalfield area. Hence, it can be inferred from hydraulic conductivity contour (figure 8) that south eastern part of the study area has more hydraulic conductivity which signifies the dominant role of secondary porosity in aquifer development.

Figure 8: Hydraulic conductivity contour map in and around Jagannath OCP, Talcher coalfield, Odisha



5.5 PRESENT GROUNDWATER LEVELS IN PHREATIC AQUIFER

The depth of groundwater within 5 km radius in and around the study area are determined by measuring the groundwater levels in the dug well (Plate-6). The water in these dug wells represents the hydraulic head of water table aquifers. After calibrating the water table to reduced level, groundwater contour map of the study area is prepared. The list of hydrograph stations studied in the study area is given in Annexure-IV. In totality, 31 dug wells were monitored across various villages in and around the study area.

It was observed for pre-monsoon season that the maximum depth of water below ground level was 12.95 mbgl in village Ekdal and minimum depth of water below ground level at 2.10 mbgl at village Jagannathpur. Twenty three percent (23%) of dug wells had been observed with very shallow groundwater levels ranging between 0 to 4 mbgl, around sixty four percent (64%) of the dug wells had groundwater levels in the range of 4 to 8 m bgl and only thirteen percent (13%) of the dug wells had deeper groundwater levels between 8 to 13 m bgl.

For post monsoon season, maximum depth of water below ground level was 5.98 m bgl in village Ekdal and minimum depth of water below ground level at 1.21 m bgl in village Deulbera. Seventy seven percent (77%) of dug wells had been observed with very shallow groundwater levels ranging between 0 to 4 m bgl, and twenty three percent (23%) of the dug wells had groundwater levels between 4 to 8 m bgl.

Water level contour map, flow directional map and surface map for pre-monsoon and post-monsoon season has been prepared and presented in figure 9 to figure 14.

Figure 9: Water level contour map of Pre monsoon season in and around Jagannath OCP, Talcher coalfield, Odisha

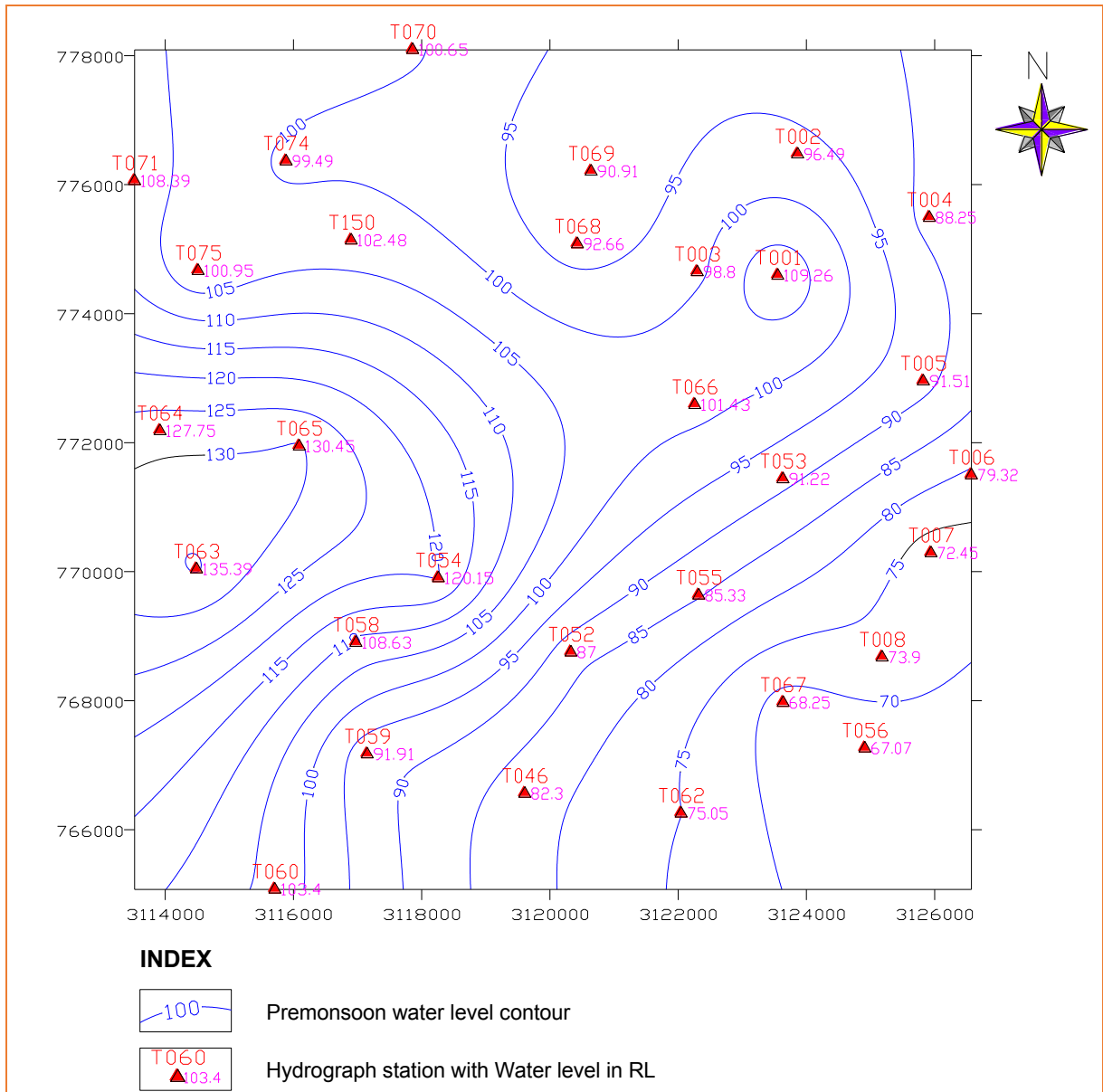


Figure 10: Water level contour surface map of Pre monsoon season in and around Jagannath OCP, Talcher coalfield, Odisha

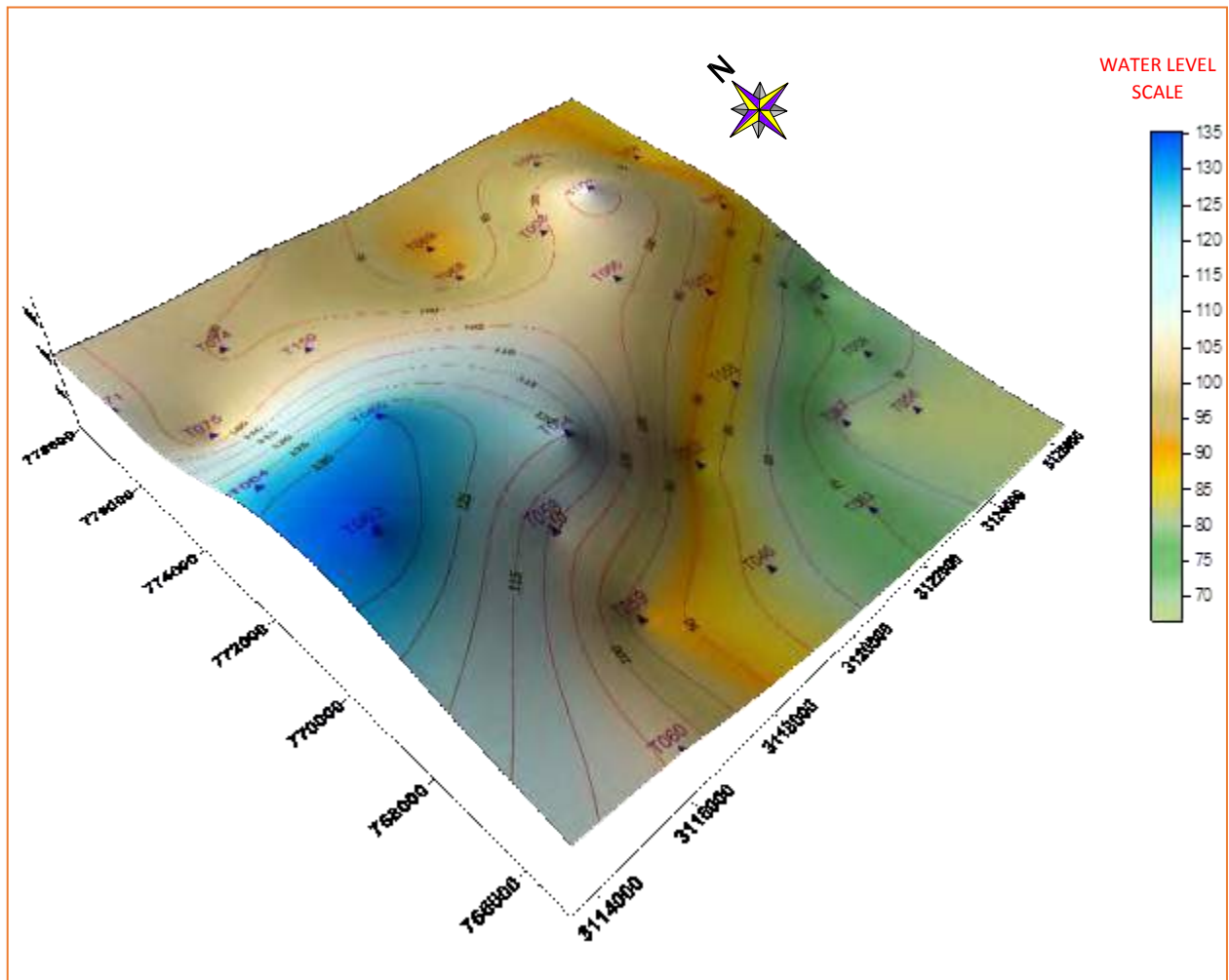


Figure 11: Flow directional map of Pre monsoon season in and around Jagannath OCP, Talcher coalfield, Odisha

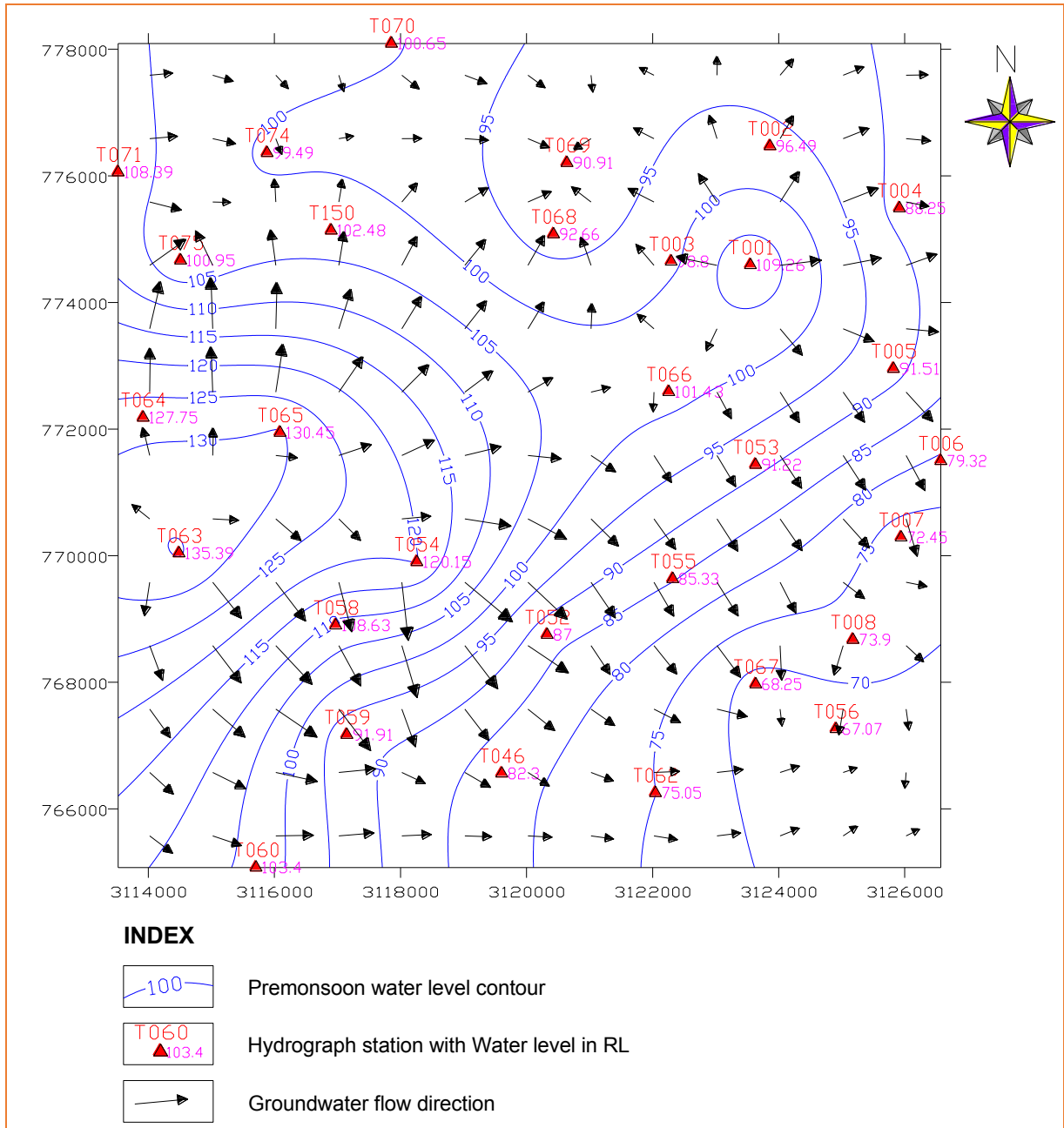


Figure 12: Water level contour map of Post monsoon season in and around Jagannath OCP, Talcher coalfield, Odisha

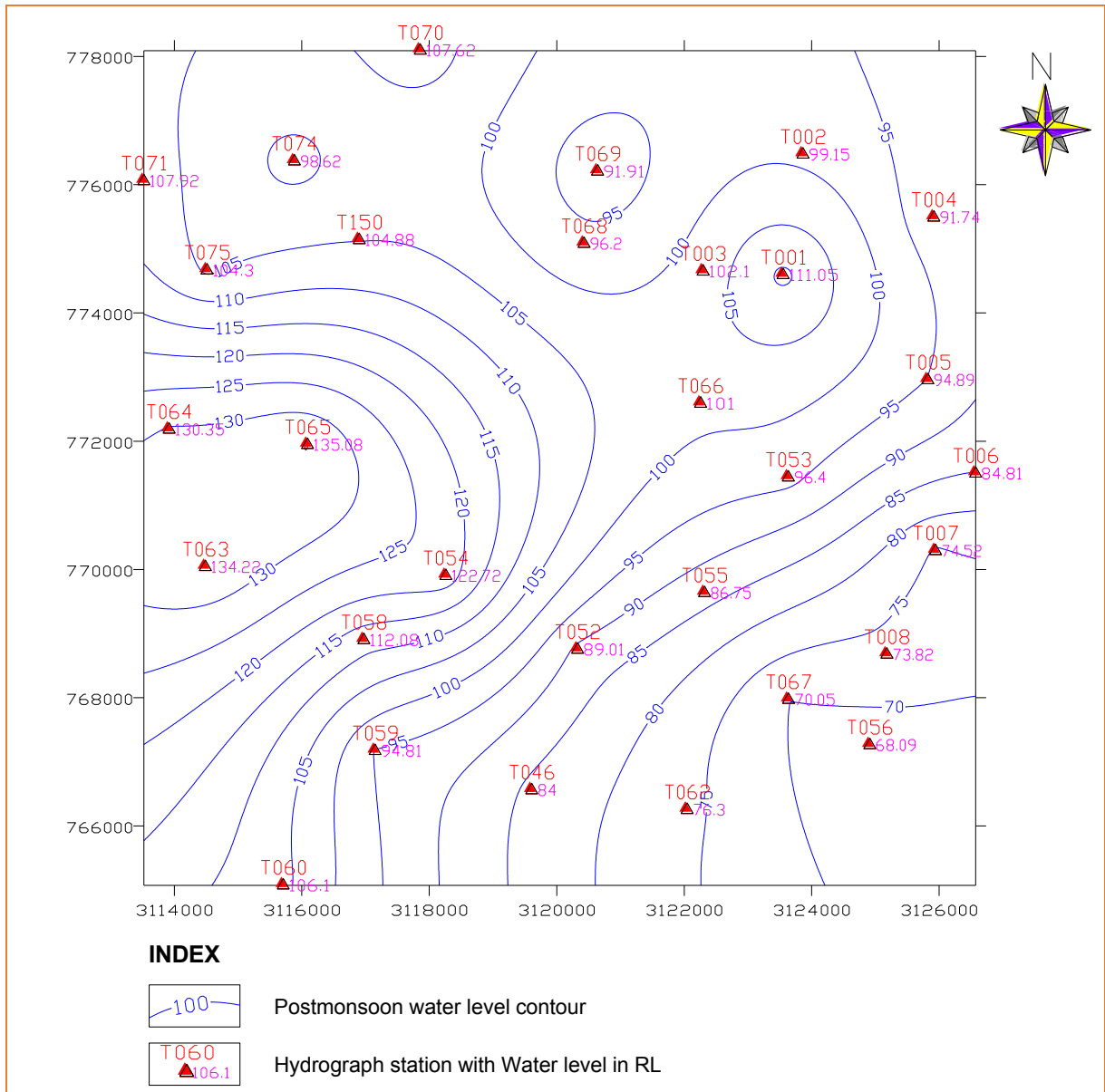


Figure 13: Water level contour surface map of Post monsoon season in and around Jagannath OCP, Talcher coalfield, Odisha

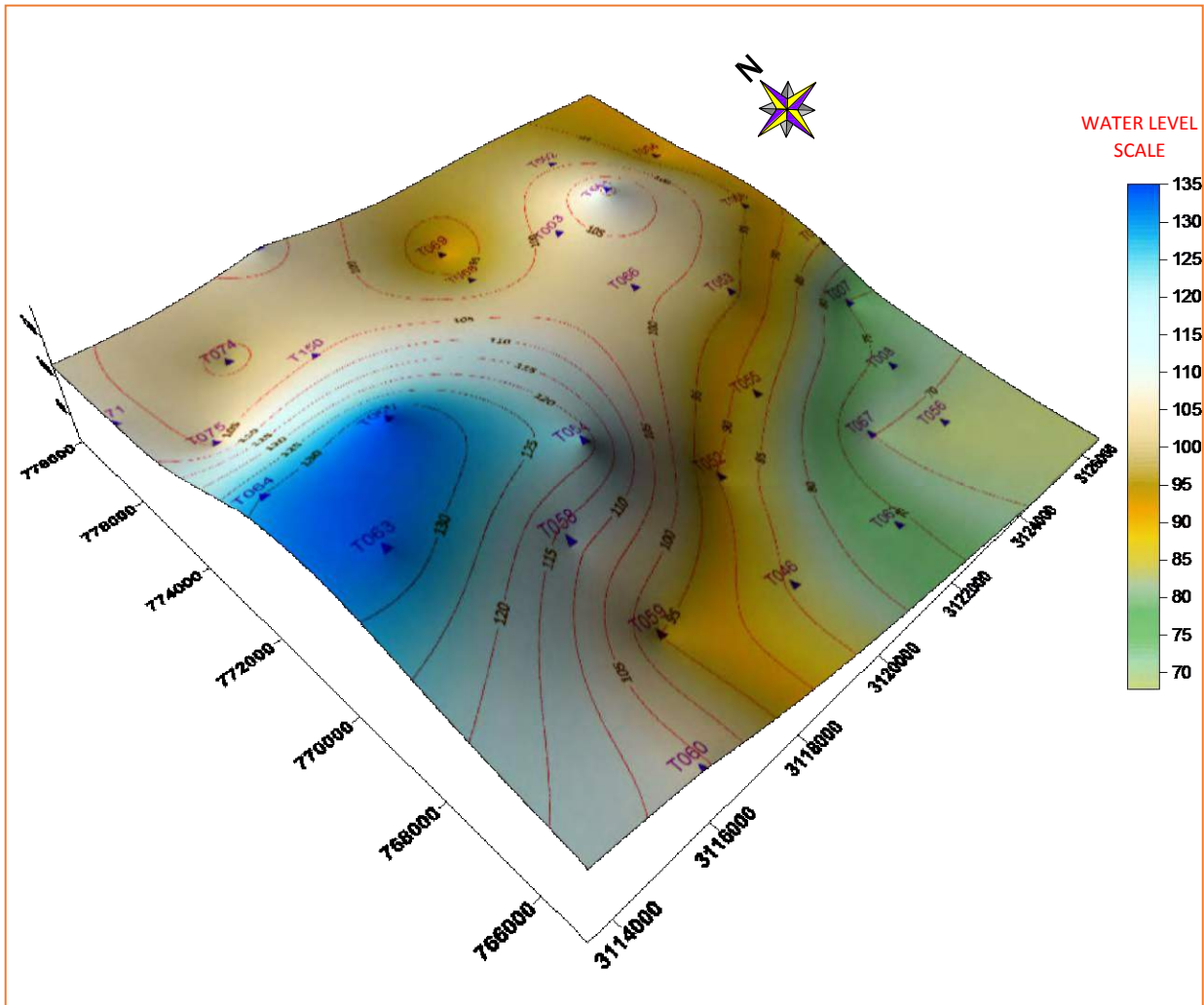
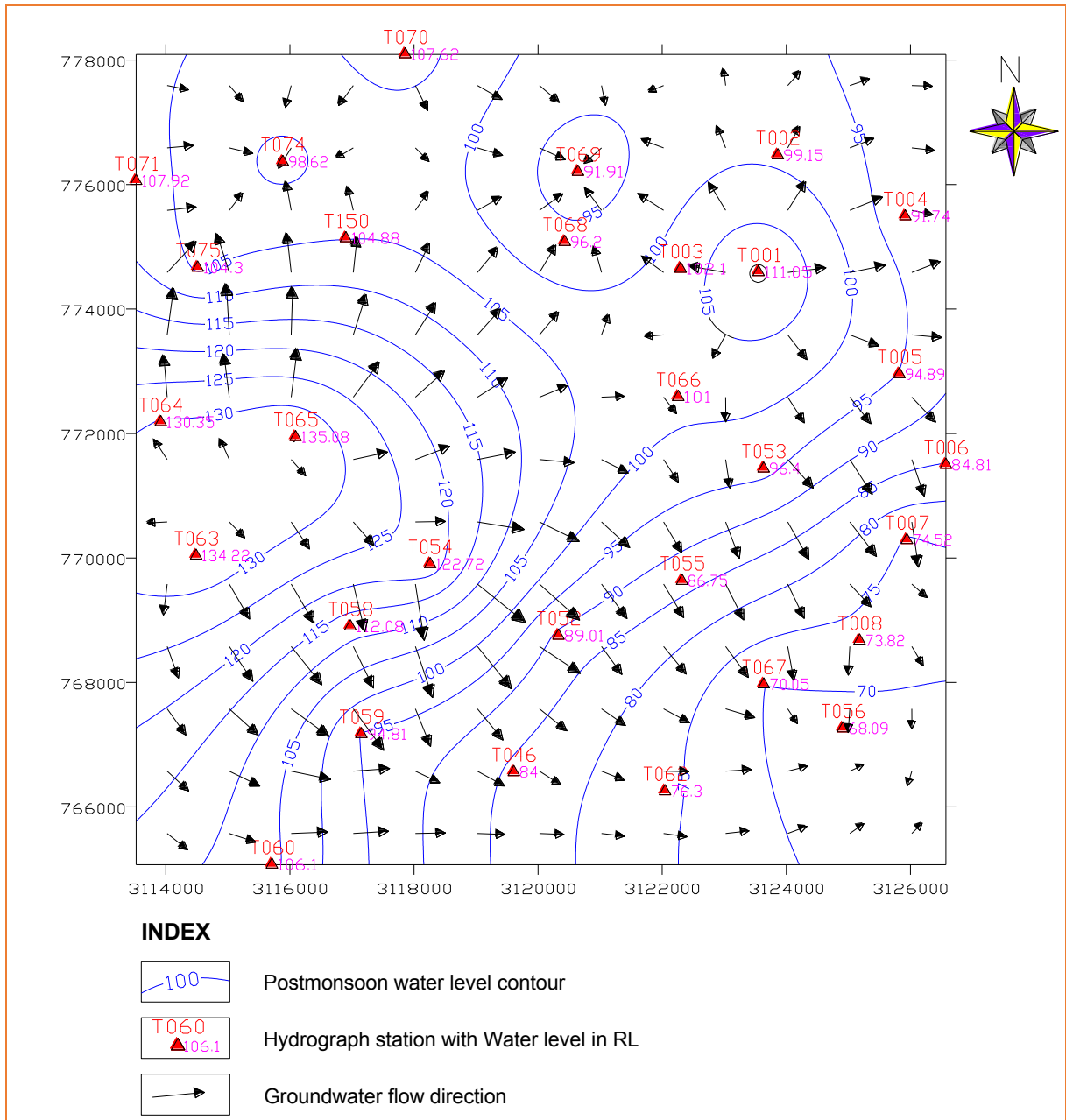


Figure 14: Flow directional map of Post monsoon season in and around Jagannath OCP, Talcher coalfield, Odisha



It can be observed from the pre monsoon contour that a predominant groundwater divide is present in middle of the study area trending SW to NE. This divides the whole study area into two halves. In the northern half the ground water is flowing towards north direction and in southern part, the water is moving towards south east direction. This can be observed from the detailed study of the pre monsoon water level flow directional contour in figure 11. The groundwater divide can be seen clearly in the water level contour surface map which is shown in figure 10.

Similarly, for post monsoon season also a predominant groundwater divide is seen in the middle of the study area trending SW to NE. Here also the groundwater in the northern half flows in the northern direction and in the southern half of the study area groundwater level flow in south eastern direction. This can be observed from the detailed study of the pre monsoon water level flow directional contour in figure 14. The groundwater divide can be seen clearly in the water level contour surface map which is shown in figure 13.

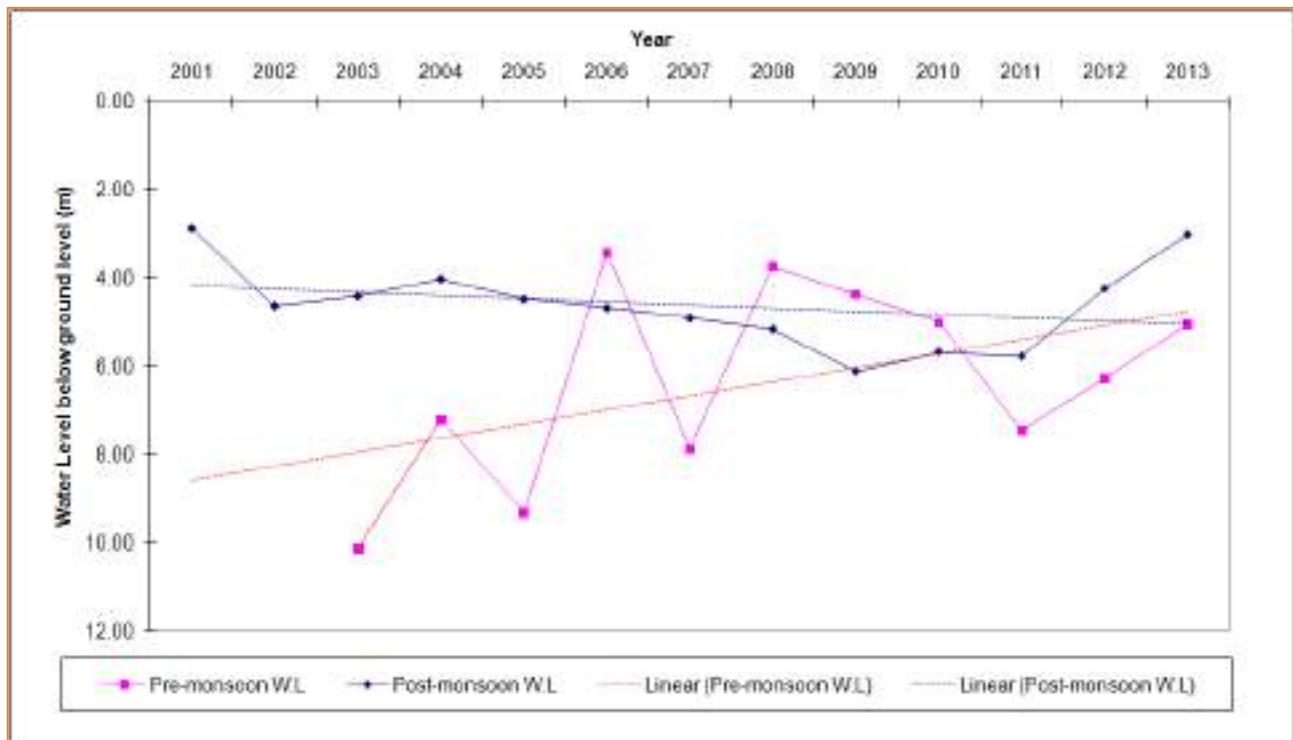
5.6 HISTORICAL GROUNDWATER LEVEL TRENDS

Routine Environmental Monitoring Cell of CMPDI, RI-VII, has been monitoring the groundwater levels in the Talcher coalfield. The permanent observation well which has been chosen to show the behaviour of historical groundwater level are from Danara village and Dera village.

Since, all the data are observed data monitored at the point of time, so the changes in groundwater levels from season to season in dug wells may be due to recharge of dug wells from mine water discharge and the hydrostatic pressure of underlined semi confined aquifers. The monitored dug wells are located in phreatic (unconfined) aquifer in which ground water flow is controlled by gravity.

As per the data available from routine environment monitoring cell, CMPDI, the historical groundwater level (2001-2013) in Danara village for pre monsoon season varies from 3.42 m bgl to 10.12 m bgl. Post monsoon water level varies from 2.87 m bgl to 6.10 m bgl. The pre and post monsoon water level trend of Danara village is shown in figure 15. Pre monsoon water level of Danara village well shows an increasing trend. This signifies that the groundwater is influenced by the recharge through mine water. The treated mine water is supplied to all water scarcity villages nearer to the mines.

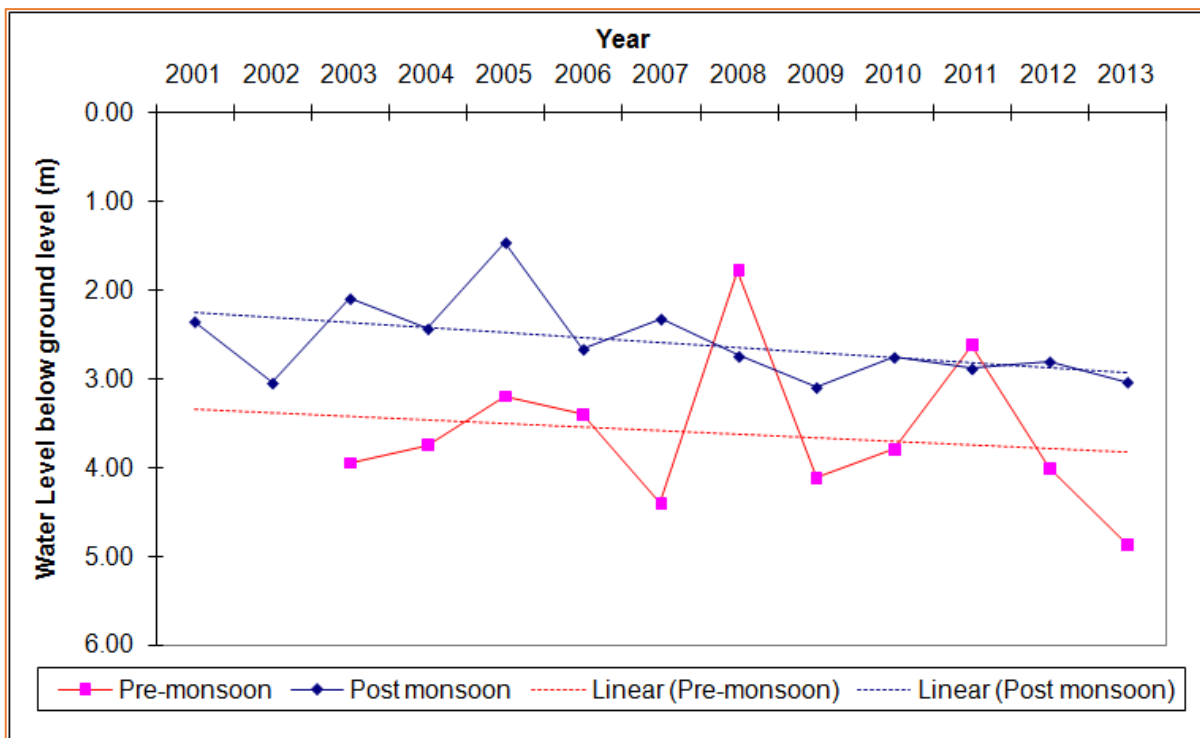
Figure 15: Pre & Post monsoon groundwater levels of Danara village dug well (3.7 kms west of Jagannath OCP), Talcher coalfield, Odisha



Source: Routine Environmental Monitoring Cell, CMPDI, RI-VII.

Historical groundwater level (2001-2013) in Dera village for pre monsoon season varies from 1.78 m bgl to 4.87 m bgl. Post monsoon water level varies from 1.47 m bgl to 3.10 m bgl. The pre and post monsoon water level trend of Dera village is shown in figure 16.

Figure 16: Pre and Post monsoon groundwater levels of Dera village dug well (0.94 kms East of Jagannath OCP), Talcher coalfield, Odisha



Source: Routine Environmental Monitoring Cell, CMPDI, RI-VII.

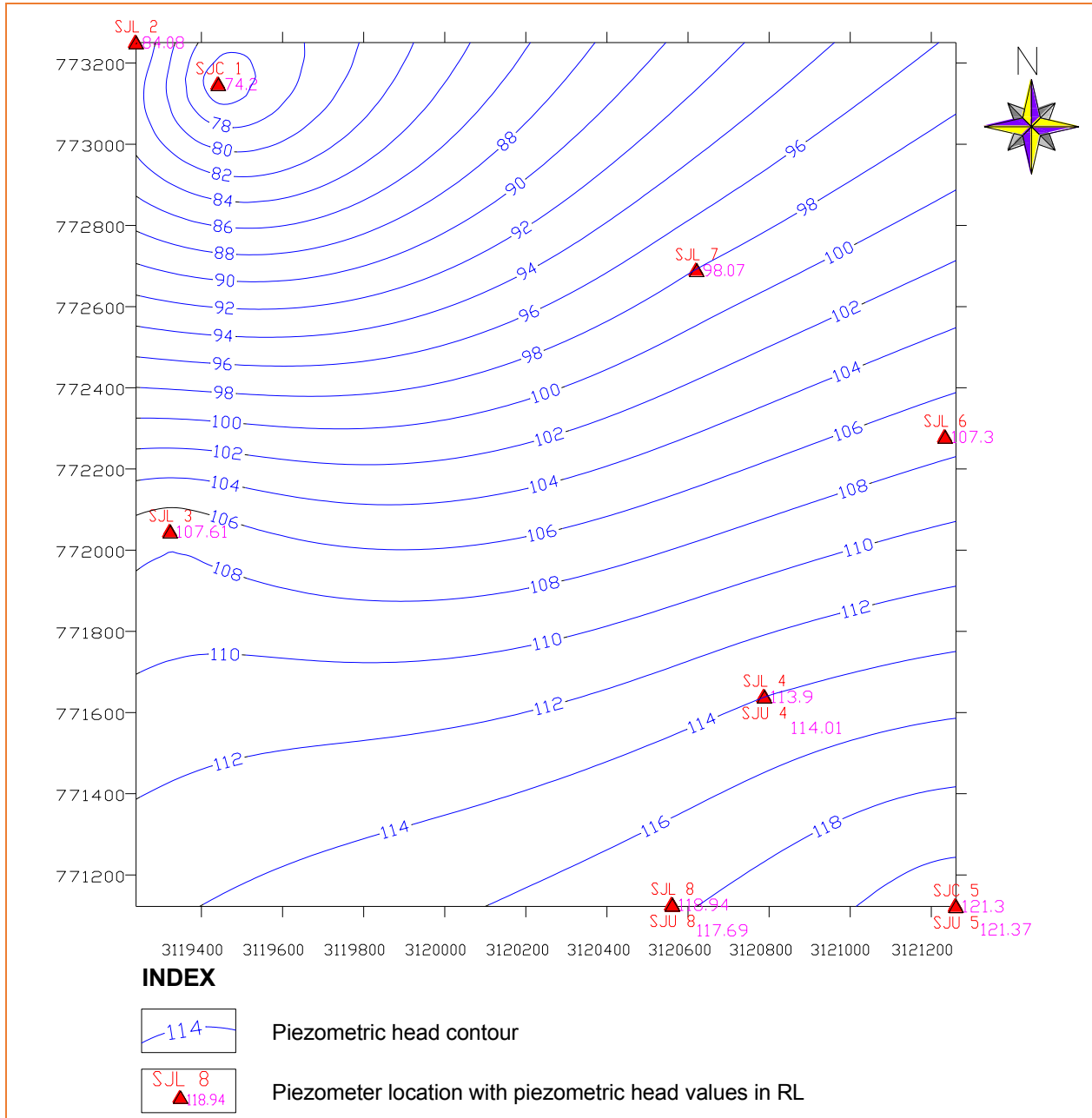
5.7 PIEZOMETRIC SURFACE FOR THE STUDY AREA

The elevation, to which water will rise in artesian wells, or well penetrating through confined aquifers, defines the piezometric surface. This surface may be either above or below land surface. Strictly speaking, piezometric surface means a measure of pressure. The piezometric surface, however, is determined by both water pressure and the elevation of the aquifer.

The force potential causing groundwater flow is directly proportional to the elevation of water levels in wells drilled in both confined and unconfined aquifers. The term potentiometric maps are representative of a single flow system within an aquifer. Based on this data a piezometric map (figure 17) has been drawn for the study area. All care has been taken to distinguish between water levels of confined and unconfined aquifers in preparation of this map. As a rule the piezometric surface is much smoother than the water levels.

The piezometric head contour map depicts a maximum piezometric head in the south eastern part of the study area whereas the minimum piezometric head is seen in north western part. The piezometric surface slopes from south east to north west towards Bangaru Jhor.

Figure 17: Piezometric head contour map in and around Jagannath OCP, Talcher coalfield, Odisha



5.8 WATER BALANCE IN THE BUFFER ZONE (WITHIN 5 KM RADIUS) OF THE STUDY AREA

There is an intricate relationship between surface water and ground water. In the monsoon time, till the aquifer attains its original ground water level, the surface water bodies like stream flow, ponds & lakes recharge the aquifer. As soon as the ground water recoups and attains its level, the groundwater contributes water to the surface water bodies. After post-monsoon period, this process is reversed again as the ground water level gets lowered from the original level. This recharge and discharge system of the area brings surface water and ground water relationship complicated. The water balance studies of this area untie the above referred intricate relationship of surface and ground water. Water balance study was carried out on the basis of land use details and the information from the report of the Ground Water Resource Estimation Committee (June, 1997). Water balance study is given in the following paragraphs:

A Estimate for ground water availability (by rainfall infiltration method)

▪ Demographic & geographic details

i	Geographical area of buffer zone (Gb)	=	142.32 km ²
ii	Forest area (Fa)	=	43.14 km ²
iii	Total cultivable area (Cv)	=	41.32 km ²
iv	Irrigated agricultural land	=	4.49 km ²
v	Unirrigated area (Cu)	=	36.84 km ²
vi	Cultivable wasteland (Cw)	=	37.23 km ²

vii	Water spread area (Ws)		
	# River & stream	=	1.68 km ²
	# Ponds & lakes	=	1.96 km ²
viii	Total population of buffer zone [updated up to 2001]	=	1,45,439
ix	Total cattle population (@ of 4.35 per family) [updated up to 2001] Cattle population was decided from the District Statistical Hand Book of 2001, Angul.	=	1,26,532
	▪ Hydro-geological parameters		
i	Average annual rainfall (A) (from 1992 - 2012)	:	1.257 m
ii	Water level fluctuation in the representative wells (Z) [as per CMPDI]	:	6 to 10 m
iii	Infiltration index of the area (Ii) [based on report of the Ground Water Resource Estimation Committee, June 1997]		
	# Weathered granite, gneiss and schist with low clay content	:	8 %
	# Barakar formation (semi-consolidated)	:	12 %
	# Talchir and Karharbari formations (consolidated)	:	6 %
iv	Specific yield of the area in the buffer zone (Sy) [based on CMPDI investigation]	:	4 %
v	Seepage from water spread area (Sws) [based on CGWB & GEC reports]	:	0.210 m/annum
vi	Losses due to evapo-transpiration [based on CGWB, GEC report and Circular Memo No. HG 7/1832/78 dated 05/7/1978 from the Office of the CE, PWD, Ground Water, Chennai-17]	:	15 %
vii	Seepage from river, streams, etc. (Srs) [based on	:	0.0211 m/day

CGWB, GEC report and Circular Memo No. HG 7/1832/78 dated 05/7/1978 from the Office of the CE, PWD, Ground Water, Chennai-17]

- viii Return flow from irrigated area for wet crop like paddy, etc. (Rf) (Based on GEC report, June, 1997) : 0.67/crop

B Hydrologic budget for the buffer zone

- Annual ground water recharge estimate
- **Estimation of ground water recharge through rainfall infiltration (Rarf)**

(a) Recharge through rainfall in Barakar formations

$$R_g = A \times R \times li$$

$$\text{Where } A = 75.02 \text{ km}^2$$

$$R = 1.257 \text{ m}$$

$$li = 12 \%$$

$$\text{So, } R_g = 11.31 \text{ Mm}^3$$

(b) Recharge through rainfall in Talchir & Karharbari formations

$$R_g = A \times R \times li$$

$$\text{Where } A = 62.86 \text{ km}^2$$

$$R = 1.257 \text{ m}$$

$$li = 6 \%$$

$$\text{So } R_g = 4.74 \text{ Mm}^3$$

(c) Recharge through metamorphic rocks

$$R_g = A \times R \times li$$

$$\text{Where } A = 4.43 \text{ km}^2$$

$$R = 1.257 \text{ m}$$

$$li = 8 \%$$

$$\text{So } R_g = 0.45 \text{ Mm}^3$$

Total annual recharge through rainfall infiltration (Rarf) [a+b+c] = 16.50 Mm³

- **Estimation of ground water recharge through other sources (Raos)**

(a) Recharge through water spread area

$$R_g = A \times S_{ws}$$

$$\begin{aligned} \text{Where } A &= 1.96 \text{ km}^2 \\ S_{ws} &= 0.210 \text{ m/annum} \\ \text{So } R_g &= 0.19 \text{ Mm}^3 \end{aligned}$$

(b) Recharge through river (Sr)

$$R_g = A \times S_r$$

$$\begin{aligned} \text{Where } A &= 1.52 \text{ km}^2 \\ S_r &= 3.80 \text{ m/annum} \\ \text{So } R_g &= 5.78 \text{ Mm}^3 \end{aligned}$$

(c) Recharge through Streams (Ss)

$$R_g = A \times S_s$$

$$\begin{aligned} \text{Where } A &= 0.16 \text{ km}^2 \\ S_s &= 1.899 \text{ m/annum} \\ \text{So } R_g &= 0.30 \text{ Mm}^3 \end{aligned}$$

(d) Recharge through irrigated area

$$R_g = A \times R_f$$

$$\begin{aligned} \text{Where } A &= 4.49 \text{ km}^2 \\ R_f &= 0.67 \text{ m/wet crop} \\ \text{So } R_g &= 3.01 \text{ Mm}^3 \end{aligned}$$

(e) Recharge through mine discharge

$$R_g = M_a \times I_i$$

Where M_a : Annual mine discharge from all 6 mines = 11.00 Mm³
 I_i : Infiltration index for mine dewatered discharge = 20%

$$\text{So } R_g = 2.20 \text{ Mm}^3$$

Total annual recharge from other sources = 11.48 Mm³
 (Raos)[a+b+c+d+e]

- **Estimation of mine inflow as mine water (Ramw)**

Estimated average annual mine inflow = 22.37 Mm³
(direct stratification + strata seepage) for
All 6 mines around the project

Therefore, total annual recharge in the buffer zone = 50.35Mm³
(Rarf+Raos+Ramw)

- **Inventory of ground water utilization**

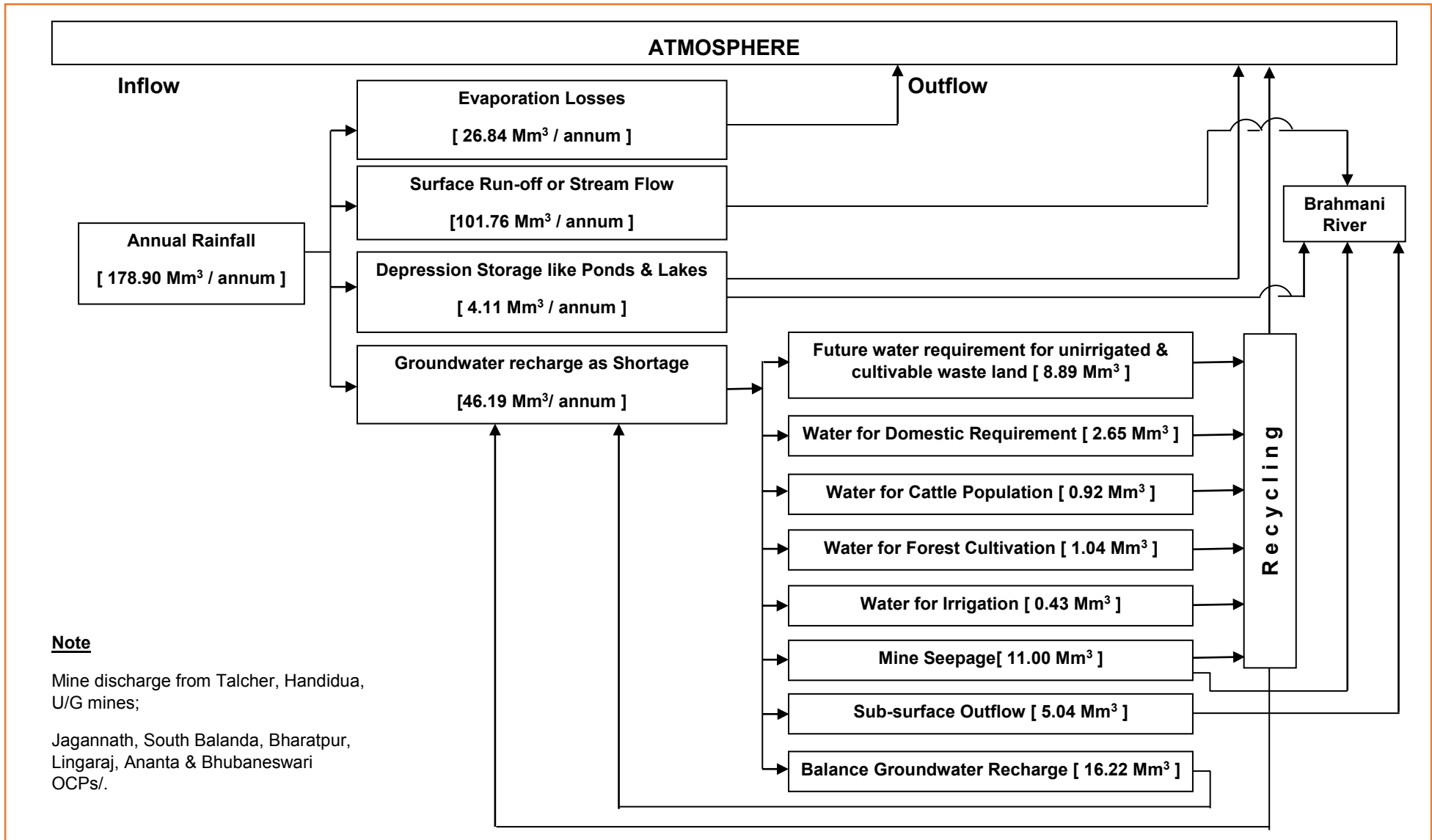
- i. Ground water required (Di) for irrigating 4.49 km² (449 ha) of agricultural land @ 10,000 l/day/ha for 120 days (20% goes as seepage)\$: 0.43 Mm³
 - ii. Ground water required (Dh) for human population of 1,45,439 @ 60 l/day/capita for 365 days\$\$: 2.65 Mm³
 - iii. Ground water required (Df) for forest area of 43.14 km² (4314 ha) @ 2000 l/day/ha for 120 days\$: 1.04 Mm³
 - iv. Ground water required (Dc) for cattle population of 1,26,532 @ 20 l/day for 365 days\$: 0.92 Mm³
 - v. Mine pumping as mine seepage : 11.00 Mm³
 - vi. Mine water industrial use : 4.16 Mm³
 - vii. Ground water losses (Dso) due to sub-surface out-flow & evapo-transpiration (As per GEC norms) : 5.04 Mm³
- Total water discharge (losses) : 25.24 Mm³

\$ Source : Forest Research Institute, Madhya Pradesh
\$\$ As per GEC Norms.

-
- **Ground water availability for unirrigated and cultivable wasteland**
 - i. Unirrigated area (Cu) = 3684 ha
 - ii. Cultivable wasteland (Cw) = 3723 ha
 - iii. Total (Cu+Cw) = 7407 ha
 - iv. Water required for irrigating 7407 ha of land @ 10,000 l/day/ha for 120 days = 8.89 Mm³
 - v. Out of 8.89 Mm³ of water used for irrigation of unirrigated and cultivable wasteland, 20% is again recharged into the aquifer. Hence, the required net water for application is (0.8 x 8.89) = 7.11 Mm³
 - vi. Assuming additional future irrigation of 7407 ha of hitherto unirrigated (Cu) and cultivable wasteland (Cw), the net discharge from the ground water aquifer will be (=25.24+8.89) = 34.13 Mm³
 - vii. Surplus water available per annum from the groundwater after meeting the future requirements for unirrigated and cultivable wasteland is (=50.35–34.13) = 16.22 Mm³

From the above water balance studies, it is estimated that there is surplus water available per annum from ground water annual recharge after catering to the future requirement in the buffer zone.

Figure 18: Flowchart showing water balance statement for the area within 5 km radius buffer zone of Jagannath OCP, Talcher coalfield



5.9 HYDROMETEROLOGY

The available climatological data from the Indian Meteorological Department at Angul observatory have been considered for long term variation in the coalfield such as formation and types of precipitation. Precipitation in the area is in the form of rain. The estimation of amount of rainfall is utmost importance to many hydrogeological problems in the area. The measurement of rainfall data help to establish rainfall runoff relationship and fluctuations in water level both in surface and subsurface of the basin.

Mean annual rainfall from 1992-2012 was estimated to 1256.55 mm. The maximum is recorded at 1549.56 mm and minimum at 743.80 mm Distribution of rainfall is given in table 5.9.A. Refer Annexure V for details.

Table 5.9.A: Annual Rainfall Distribution in Angul District.

Sl. No.	Range of Rainfall (mm)		No. of Years	Percentage of Distribution (%)
1	0	200	NIL	NIL
2	201	400	NIL	NIL
3	401	600	NIL	NIL
4	601	800	1	4.76
5	801	1000	1	4.76
6	1001	1200	5	23.80
7	1201	1400	9	42.85
8	1401	1600	5	23.80
9	1601	1800	NIL	NIL

The Probability percentage of amount of rainfall in the study area has been worked out by simple probability of rank method. The results are tabulated in table-5.9.B Mean annual rainfall in study area is arranged in descending order of magnitude and in computations for probability analysis, Chegodaye equation has been used. Probability percentage $P = (m - 0.3 / n + 4) * 100$.

Where P is Probability; m is rank of variant; n is number of variant

Probability analysis reveals that the chances of occurrences of minimum rainfall (743.80 mm) are 98%. Similarly the chances of occurrence of 1297.94 mm of rainfall are 50% and that of maximum rainfall i.e 1549.56 mm is only 3%.

Table 5.9.B: Probability percentage of amount of rainfall in Angul District.

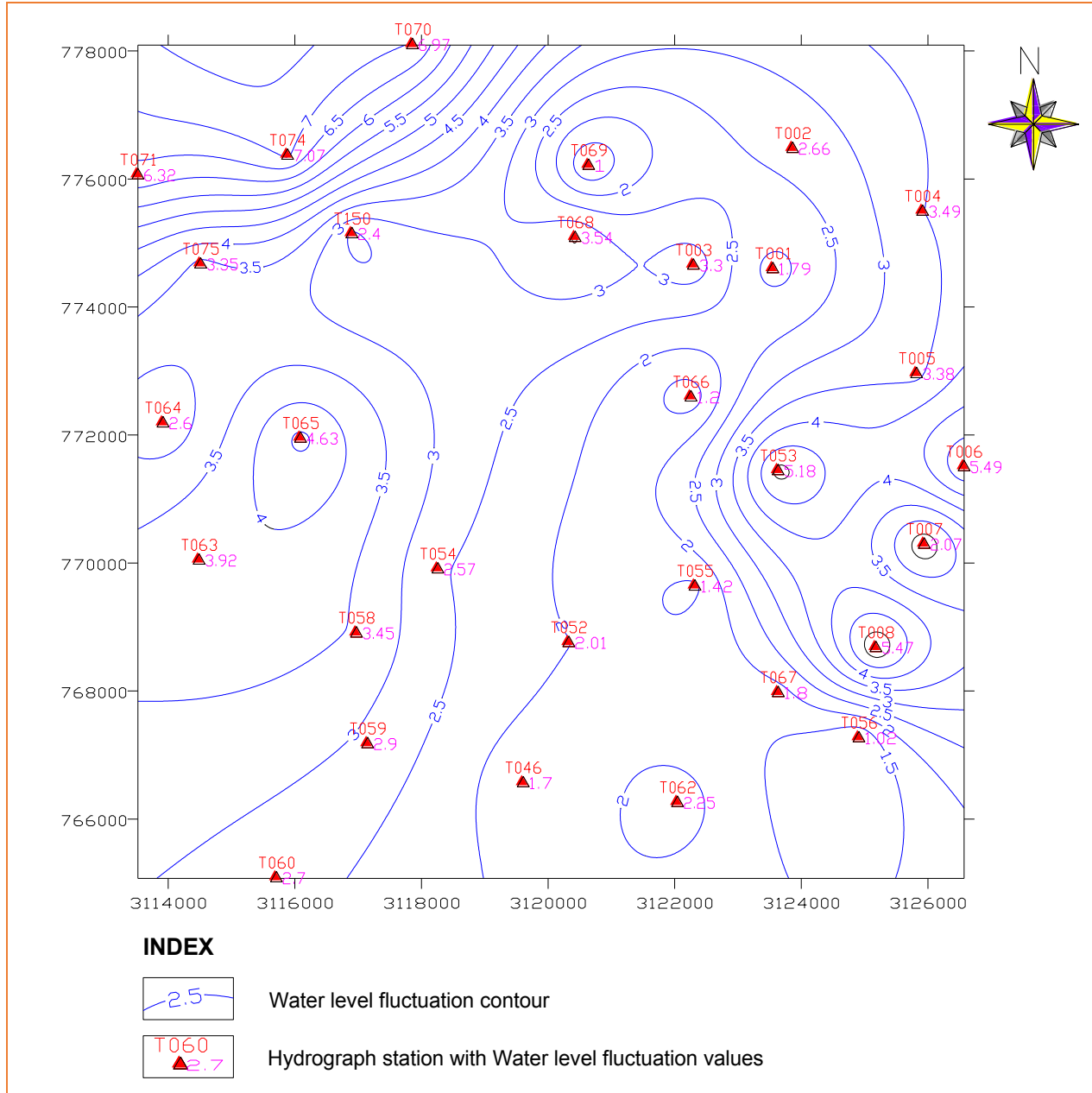
Sl. No.	Year	Rain fall (mm)	No. of Variant (n)	Rank of Variant (m)	Probability (%)
1	2001	1549.56	21	1	3.33
2	1994	1464.30	21	2	8.08
3	1997	1454.00	21	3	12.83
4	1993	1427.40	21	4	17.58
5	1995	1409.38	21	5	22.34
6	2005	1396.80	21	6	27.09
7	2008	1393.10	21	7	31.84
8	1999	1365.10	21	8	36.60
9	1998	1350.11	21	9	41.35
10	2003	1328.40	21	10	46.10
11	2009	1297.94	21	11	50.85
12	1992	1297.60	21	12	55.60
13	2010	1240.90	21	13	60.36
14	2011	1225.60	21	14	65.11
15	2000	1165.30	21	15	69.87
16	2006	1121.60	21	16	74.62
17	2004	1116.10	21	17	79.37
18	2012	1069.40	21	18	84.12
19	2007	1039.00	21	19	88.88
20	1996	932.20	21	20	93.63
21	2002	743.80	21	21	98.38

5.10 GROUNDWATER RECHARGE –DISCHARGE RELATIONSHIP

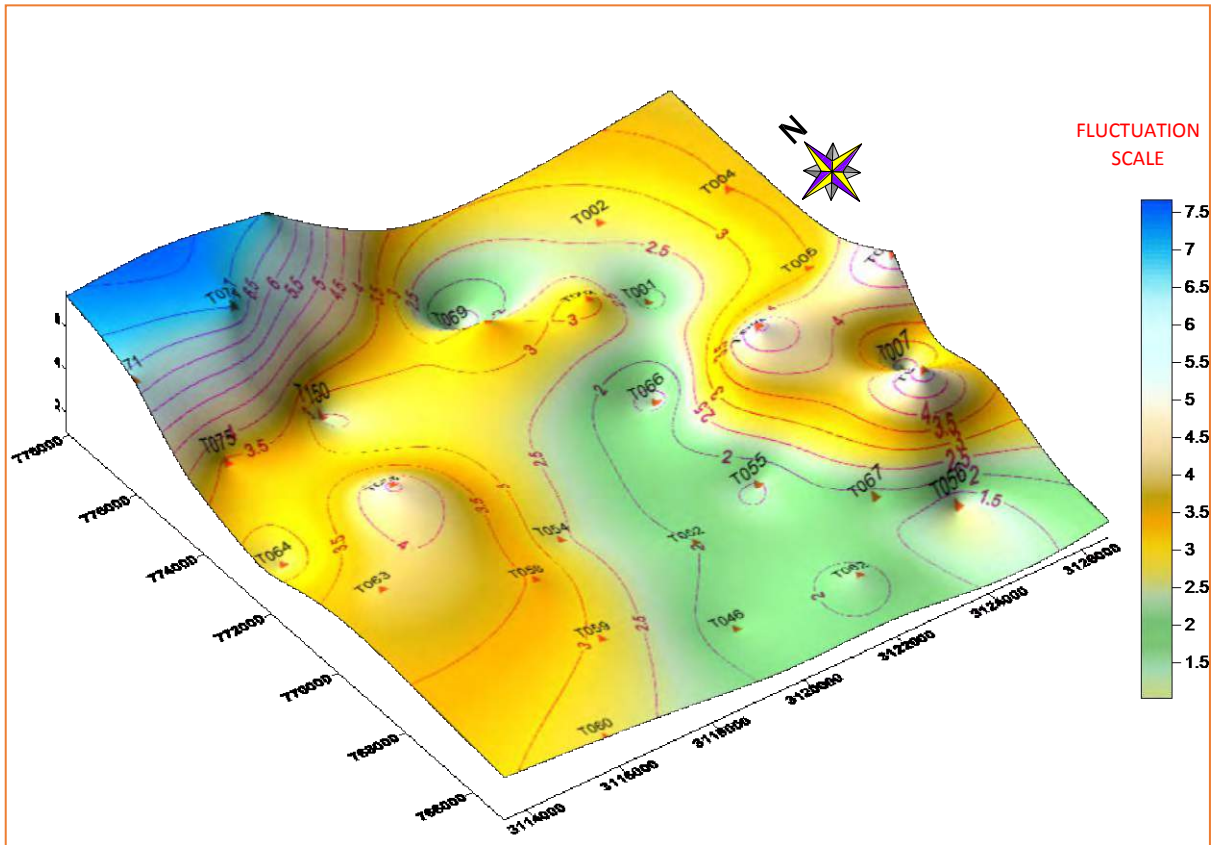
The unconfined aquifer in the entire study area gets recharged by direct precipitation infiltrating into the top formation. Thus the entire area acts as recharging and discharging zone so far as unconfined aquifer is concerned. The confined aquifer in the recharge zones get recharged through direct precipitation received by the unconfined aquifer, whereas in the discharge zones the confined aquifer are being recharged by inflow of groundwater entering into the area from recharge areas.

Groundwater recharge – discharge relationships can also be understood by plotting fluctuations maps for pre monsoon water levels to post monsoon water level. The fluctuation contour of pre and post monsoon water level data ranges from 1.5 m to 7.5 m. For the study area a fluctuation map was prepared which shows fluctuation mounds and sinks which is shown in figures 19 and 20. By observing the fluctuation map it can be inferred that major part of recharge area is been concentrated highly to the north western edge of the study area. The discharge area is concentrated in the south and south eastern part of the study area. The discharge areas can be also be confirmed by the presence of voids created during mining activities.

**Figure- 19: Fluctuation contour map
in and around Jagannath OCP, Talcher coalfield, Odisha**



**Figure 20: Fluctuation surface map
in and around Jagannath OCP, Talcher coalfield, Odisha**



Chapter – 6

HYDROCHEMISTRY

6.1 OVERVIEW

Flyash is defined as a heterogeneous mixture of amorphous and crystalline phases and is generally fine powdered ferroaluminosilicate material with Al, Ca, Fe, Na and Si as the predominant constituting elements. Thermal Power stations using power grade coal or lignite as fuel generate large quantity of flyash as a by-product after the coal combustion. Power plants of NTPC in Talcher generate significant amount of flyash in the area. With the commissioning of super thermal power plants and with the increasing use of low grade coal of high ash content, the current production of ash is about 3300-3500 MT per day in TTPS and 18000-19000 MT per day at TSTPS.

The quality of ground water and surface water is resultant of all processes and reactions that have acted on water from the moment it condensed in the atmosphere to the time it is discharged by a well or spring. Any chemical analysis of a water sample represents the quality of water in a small part of a water-yielding zone at a particular instant time. Concentrations of major, minor and trace inorganic constituents in groundwater are controlled by numerous factors including availability of elements in soil and rock through which the water moves, the sequence in which subsurface water comes in contact with soil and rock, rates of geo-chemical and biochemical processes and influence of land and water use activities on all the above. Quality of groundwater is not constant and a comparison of current and historical data for a particular sampling site may show temporal changes in one or more quality parameters. Trends may show either improvement or degradation of water quality but, in most cases, it reflects the effects of changing land and water use practices.

Coal contains significant quantities of various trace elements, and during combustion of coal, these trace elements are enriched as a result of carbon loss and the trace elements in general associated with the surface of the ash particles due to evaporation and condensation. The characteristics of the coal used and the type of the installation deployed in generating the solid combustion wastes have a direct influence on chemical and mineralogical composition of flyash. Depending upon the source and makeup of the coal being burned, the components of flyash vary considerably. The chemical composition and trace metal concentration of the flyash generated in thermal power plants of NTPC in Talcher are given in table 6.1.A and in table 6.1.B respectively.

Table 6.1.A: Flyash Chemical Composition of NTPC Power Plant, Talcher, Odisha.

TPP	Flyash chemical characteristics (%)										
	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	S	K ₂ O	TiO ₂	CaO	MgO	Na ₂ O	P ₂ O ₅	SO ₃
FA-TTPS	58.90	29.32	4.40	92.62	0.23	1.82	0.60	0.46	0.79	0.02	0.51
BA-TTPS	63.01	19.13	6.40	88.54	0.23	1.50	0.90	0.39	1.92	0.32	0.30
PA-TTPS	60.73	25.88	4.80	91.41	0.25	1.65	0.62	0.47	0.86	0.22	0.21

Source: NTPC limited

FA-Flyash; BA-Bottom Ash; PA- Pulverised Ash.

Table 6.1.B: Flyash Trace Metal Composition of NTPC Power Plant, Talcher, Odisha.

TPP	Trace Metal (mg/Kg)									
	Zn	Cd	Co	Mn	Pb	Ni	Cr	V	Cu	Hg
FA-T	200	N.D	20	300	400	150	230	100	5050	0.0004
BA-T	120	N.D	10	390	300	100	4050	1050	3200	0.0004
PA-T	170	N.D	10	290	330	600	190	100	2400	N.D

Source: NTPC limited

ND-Not Detected during Analysis

FA-Flyash; BA-Bottom Ash; PA- Pulverised Ash.

6.2 SAMPLE ANALYSIS PROGRAM

Water sampling together with laboratory analysis was undertaken to determine the presence of surface and subsurface water contamination, if any and define the baseline value of water quality in and around Jagannath OCP, Talcher coalfield, Odisha. Chemical analysis of ground water, surface water, and mine water includes the determination of the concentrations of inorganic constituents including heavy metals.

6.2.1 GROUNDWATER

Groundwater samples were collected from existing open dugwells, hand pumps and newly installed piezometers. Total thirty six (36) groundwater samples were collected in pre-monsoon season and total of thirty five (35) groundwater samples were collected in post monsoon season and analysed for a predetermined analytical standard suite of analytes comprising of twenty six parameters. (Table 6.2.1.A, page 77).

Due to expansion of mining activities in the immediate vicinity of the village Jilinda dug well, the sample of dug well of village Jilinda could not be sampled for post monsoon season. The sampling location plan is presented in Plate-6.

6.2.2 MINE WATER

CMPDI carried out the sampling of mine water at four locations for the hydrogeological investigation. The details of parameter analysed in each mine water sample is given in table 6.2.2.A (page 78).

6.2.3 SURFACE WATER

CMPDI carried out surface water sampling at six places within 5 km radius of South Balanda OCP. Surface water samples were collected from the top 30 cm of water column. Due care was taken to avoid skimming the surface of water and disturbing sediments, if any, during sample collection. The details of parameter analysed in each surface water sample is given in table 6.2.3.A (page 79).

Table 6.2.1.A: Groundwater Sampling and Analytical Parameter Details in and around Jagannath OCP, Talcher coalfield, Odisha.

Sl. No.	Sample ID	Source	Parameter Analysed
1.	NDW-1	Open Dug wells	I. Colour
2.	NDW-2		II. Odour
3.	NDW-3		III. Taste
4.	NDW-4		IV. Turbidity
5.	NDW-5		V. pH value
6.	NDW-6		VI. Total hardness(as Ca CO ₃)
7.	NDW-7		VII. Iron (as Fe)
8.	NDW-8		VIII. Chlorides (as Cl)
9.	NDW-9		IX. Dissolved solids
10.	NDW-10		X. Calcium (as Ca)
11.	NDW-11		XI. Copper(as Cu)
12.	NDW-12		XII. Manganese (as Mn)
13.	NTW -1	Tube wells/ Hand pumps	XIII. Sulphate (as SO ₄)
14.	NTW -2		XIV. Nitrate (as NO ₃)
15.	NTW -3		XV. Fluoride, (as F)
16.	NTW -4		XVI. Residual free chlorine
17.	NTW -5		XVII. Cadmium(as Cd)
18.	NTW -6		XVIII. Selenium (as Se)
19.	NTW -7		XIX. Arsenic (as As)
20.	NTW -8		XX. Lead (as Pb)
21.	NTW -9		XXI. Zinc (as Zn)
22.	NTW -10		XXII. Hexavalent chromium (as Cr ₆₊)
23.	SJC 1,	Piezometers	XXIII. Boron
24.	SJL 2		XXIV. Phenolics (as C ₆ H ₅ OH)
25.	SJL 3		XXV. Alkalinity
26.	SJL 4		XXVI. Faecal coliform (as MPN/100 ml)
27.	SJU 4		
28.	SJC 5		
29.	SJL 6		
30.	SJL 7		
31.	SJL 8		
32.	SJL 9		
33.	SJU 9		
34.	SJL 10		
35.	SJU 11		
36.	SJC 11		

Table 6.2.2.A: Mine Water Sampling and Analytical Parameter Details in and around Jagannath OCP, Talcher coalfield, Odisha.

Sl. No	Sample No.	Source	Parameters Analysed
1.	NMW -1	South Balanda Mine water	I. Colour II. Odour III. Total suspended solids IV. pH value V. Temperature (°C) VI. Oil & grease VII. Total residual chlorine
2.	NMW -2	Jagannath OCP	VIII. Ammonical nitrogen(as N) IX. Total Kjeldahl nitrogen(as NH ₃) X. Free ammonia (as NH ₃) XI. BOD (3 days 27°C) XII. COD
3.	NMW -3	Bharatpur OCP	XIII. Arsenic (as As) XIV. Lead (as Pb) XV. Cadmium (as Cd) XVI. Hexavalent chromium (as Cr ⁺⁶) XVII. Total chromium XVIII. Copper (as Cu) XIX. Zinc (as Zn) XX. Selenium (as Se)
4.	NMW -4	Ananta OCP	XXI. Nickel, (as Ni) XXII. Fluoride (as F) XXIII. Dissolved phosphates(as P) XXIV. Sulphide (as S) XXV. Phenolic compounds(as C ₆ H ₅ OH) XXVI. Manganese (as Mn) XXVII. Iron (as Fe) XXVIII. Nitrate nitrogen (as N)

Table-6.2.3.A: Surface Water Sampling and Analytical Parameter Details around Jagannath OCP, Talcher coalfield, Odisha.

SI. No.	Sample ID	Source	Parameters Analysed
1.	NSW-1	Upstream of Study area in Bangaru Jhor	I. Colour II. Total Suspended Solids III. Dissolved oxygen IV. pH value V. Iron (as Fe) VI. Chlorides (as Cl) VII. Total dissolved solids VIII. Copper (as Cu) IX. Sulphates (as SO ₄) X. Nitrates (as NO ₃) XI. Fluorides (as F) XII. Cadmium (as Cd) XIII. Selenium (as Se) XIV. Arsenic (as As) XV. Lead (as Pb) XVI. Zinc (as Zn) XVII. Hexavalent chromium XVIII. BOD(3 days at 27°C) XIX. Phenolic compounds (as C ₆ H ₅ OH) XX. Total Hardness (CaCO ₃)
2.	NSW-2	Downstream of study area in Bangaru Jhor	
3.	NSW-3	Upstream of confluence of Bangaru Jhor and River Brahmani.	
4.	NSW-4	Upstream of study area in Nandira Jhor	
5.	NSW-5	Downstream of confluence of Nandira Jhor and River Brahmani.	
6.	NSW-6	Downstream of study area in Nandira Jhor	

6.3 ANALYTICAL RESULTS AND INTERPRETATION

6.3.1 SURFACE WATER

Among the six (06) surface water samples collected and analysed from six locations in both the seasons i.e pre-monsoon as well as post-monsoon season, the dissolved oxygen is found to exceed the threshold limit in all samples as per IS:2296 Inland Surface water class C limit. Sulphate is also present in excess of permissible limit in NSW-1 (upstream of Study area in Bangaru Jhor) in pre-monsoon season. Fluoride is observed at concentration exceeding permissible limits in NSW-6

(sample collected downstream of study area in Nandira Jhor) in pre-monsoon season. Complete analytical results are provided in Annexure III.A.

6.3.1.1 Dissolved Oxygen (DO)

Dissolved Oxygen varies between 5.10 mg/L to 5.60 mg/L in the pre-monsoon season and between 5.20 mg/L to 5.60 mg/L during post-monsoon season. The maximum permissible concentration of DO as per IS:2296 Inland Surface water class C limit is 4.00 mg/L.

6.3.1.2 Biological Oxygen Demand (BOD)

BOD range between 1.10 mg/L to 2.20 mg/L for pre-monsoon and the same is present below detection limits in post-monsoon season for all samples except surface water sample NSW-2 observed at 2.14 mg/L. The maximum permissible concentration as per IS:2296 Inland Surface water class C limit is 3.00 mg/L.

6.3.1.3 pH

pH range between 6.65 to 8.10 in pre-monsoon season and between 7.65 to 8.40 in post-monsoon season. The maximum permissible concentration as per IS:2296 Inland Surface water class C limit is 6.50-8.50.

6.3.1.4 Total Suspended Solids (TSS)

TSS is present in concentration between 2.00 mg/L to 14.00 mg/L in pre-monsoon season and between 6.00 mg/L to 14.00 mg/L in post-monsoon season. The maximum permissible concentration as per IS:2296 Inland Surface water class C limit is 1500.00 mg/L.

6.3.1.5 Chloride (Cl)

Chloride is present in concentration between 12.00 mg/L to 46.00 mg/L in pre-monsoon season and between 8.00 mg/L to 56.00 mg/L in post-monsoon

season. The maximum permissible concentration as per IS:2296 Inland Surface water class C limit is 600.00 mg/L.

6.3.1.6 Total Dissolved Solids (TDS)

Total Dissolved Solids is present in concentration between 84.00 mg/L to 1072.00 mg/L in pre- monsoon season and between 64.00 mg/L to 636.00 mg/L in post-monsoon season. The maximum permissible concentration as per IS:2296 Inland Surface water class C limit is 1500.00 mg/L.

6.3.1.7 Zinc (Zn)

Zinc is present in mine water sample NSW-5 in concentration of 0.17 mg/L in both season. The maximum permissible concentration as per IS:2296 Inland Surface water class C limit is 15.00 mg/L.

6.3.1.8 Sulphate (SO₄)

Sulphate is present in surface water sample in concentration between 6.00 mg/L to 600.00 mg/L in pre- monsoon season and between 8.00 mg/L to 192.00 mg/L in post-monsoon season. The maximum permissible concentration as per IS:2296 Inland Surface water class C limit is 400.00 mg/L.

6.3.1.9 Fluoride (F)

Fluoride is present in concentration between 0.51 mg/L to 1.74 mg/L in pre-monsoon season and between 0.31 mg/L to 0.97mg/L in post-monsoon season. The maximum permissible concentration as per IS:2296 Inland Surface water class C limit is 1.50 mg/L.

6.3.1.10 Nitrate (NO₃)

Nitrate is present in concentration between 1.33 mg/L to 5.76 mg/L in pre-monsoon season and between 1.77 mg/L to 11.52 mg/L in post-monsoon season. The maximum permissible concentration as per IS:2296 Inland Surface water class C limit is 50.00 mg/L.

6.3.1.11 Total Hardness (CaCO₃)

Total Hardness ranges between 56.00 mg/L to 876.00 mg/L in pre-monsoon season and between 36.00 mg/L to 428.00 mg/L in post-monsoon season.

Other parameters analysed in surface water including heavy metals were present in concentration below detection limits. Refer Annexure III.A for complete analytical results.

6.3.2 MINE WATER

Among the four (04) mine water samples that were collected and analysed from four on-site mine water discharge locations in both pre-monsoon and post-monsoon season, no analyte in any of the samples were reported in concentration exceeding the MOEF-Schedule VI Standard. Complete analytical results are provided in Annexure III.

6.3.2.1 pH

pH varies between 7.12 to 7.66 in the pre-monsoon season and between 5.68 to 7.30 during post-monsoon season. Recommended level for mine effluent water as per MOEF-Schedule VI Standard is 5.5-9.0.

6.3.2.2 Biological Oxygen Demand (BOD)

BOD ranges between 1.20 mg/L to 1.80 mg/L for both pre-monsoon and post-monsoon season. The maximum permissible concentration as per MOEF-Schedule VI Standard is 30.00 mg/L.

6.3.2.3 Chemical Oxygen Demand (COD)

COD ranges between 15.00 mg/L to 20.00 mg/L in pre-monsoon season and between 15.00 mg/L to 25.00 mg/L in post-monsoon season. The maximum permissible concentration as per MOEF-Schedule VI Standard is 250.00 mg/L.

6.3.2.4 Total Suspended Solids (TSS)

TSS is present in concentration between 2.00 mg/L to 8.00 mg/L in pre-monsoon season and between 6.00 mg/L to 12.00 mg/L in post-monsoon season. The maximum permissible concentration as per MOEF-Schedule VI Standard is 100.00 mg/L.

6.3.2.5 Total Kjeldahl Nitrogen (TKN as NH₃)

TKN is present in concentration between 2.10 mg/L to 2.31 mg/L in pre-monsoon season and between 2.83 mg/L to 3.61 mg/L in post-monsoon season. The maximum permissible concentration as per MOEF-Schedule VI Standard is 100.00 mg/L.

6.3.2.6 Amonical Nitrogen

Amonical Nitrogen is present in concentration between 0.02 mg/L to 0.03 mg/L in pre- monsoon season and between 0.02 mg/L to 0.05 mg/L in post-monsoon season. The maximum permissible concentration as per MOEF-Schedule VI Standard is 50.00 mg/L.

6.3.2.7 Zinc

Zinc is present in mine water sample NMW-3 in concentration of 0.03 mg/L in both seasons. The maximum permissible concentration as per MOEF-Schedule VI Standard is 5.00 mg/L.

6.3.2.8 Fluoride

Fluoride is present in concentration between 0.94 mg/L to 1.66 mg/L in pre-monsoon season and between 0.97 mg/L to 1.32 mg/L in post-monsoon season. The maximum permissible concentration as per MOEF-Schedule VI Standard is 2.00 mg/L.

6.3.2.9 Dissolved phosphate

Dissolved Phosphate is present in concentration between 0.30 mg/L to 0.40 mg/L in pre-monsoon season and between 0.10 mg/L to 0.40 mg/L in post-monsoon season. The maximum permissible concentration as per MOEF-Schedule VI Standard is 5.00 mg/L.

6.3.2.10 Manganese (Mn)

Manganese (Mn) is present in concentration ranging between 0.17 mg/L to 0.35 mg/L in pre-monsoon season and reported at concentration of 0.59 mg/L in sample NMW-1 only during post-monsoon season. The maximum permissible concentration as per MOEF-Schedule VI Standard is 2.00 mg/L.

6.3.2.11 Nitrate Nitrogen

Nitrate Nitrogen is present in concentration between 0.50 mg/L to 1.70 mg/L in pre-monsoon season and between 0.30 mg/L to 1.10 mg/L in post-monsoon season. The maximum permissible concentration as per MOEF-Schedule VI Standard is 10.00 mg/L.

6.3.3 GROUNDWATER

Ground water samples were collected and analysed from open dug wells, tube wells and newly installed piezometers from various locations in both pre-monsoon and post-monsoon season. It may be noted that for interpretation purpose, analytical results from of piezometers lying on the peripheral (northern and eastern) boundary of Jagannath OCP (SJC-1, SJL-2, SJU-4, SJL-4, SJC-5, SJL-6, and SJL-7) and those sharing common boundary with South Balanda OCP (SJL-3 and SJL-8) are considered. Along with these, analytical results from all twelve open dug wells and all ten tube wells/ hand pumps are considered for interpretation of groundwater quality in phreatic aquifer in the study area. The reported concentrations of parameters were compared with BIS 10500 drinking water standards for assessing variance. Complete analytical results are given in Annexure III.C.

6.3.3.1 pH

A pH of 7.0 indicates neutrality of a solution. Values higher than 7.0 denote increased alkalinity; values lower than 7.0 indicate increased acidity. Recommended level for public water supplies ranges from 6.5 to 8.5. pH values in phreatic aquifer in the study area range from 7.19 to 7.98 in the pre-monsoon season and from 6.09 to 8.61 in post monsoon season. pH in deeper aquifer range from 7.67 to 8.07 in the pre-monsoon season and from 6.74 to 8.26 during post-monsoon season. The ground water in the area may be described as alkaline in nature. Contours of pH concentration as observed from village dug wells water sample, tube well water and water sample from piezometers are presented in figures 21 to 24.

Figure- 21: Pre-monsoon pH concentration contour map of water sample from Open Dug wells & Tube well in and around Jagannath OCP, Talcher coalfield, Odisha

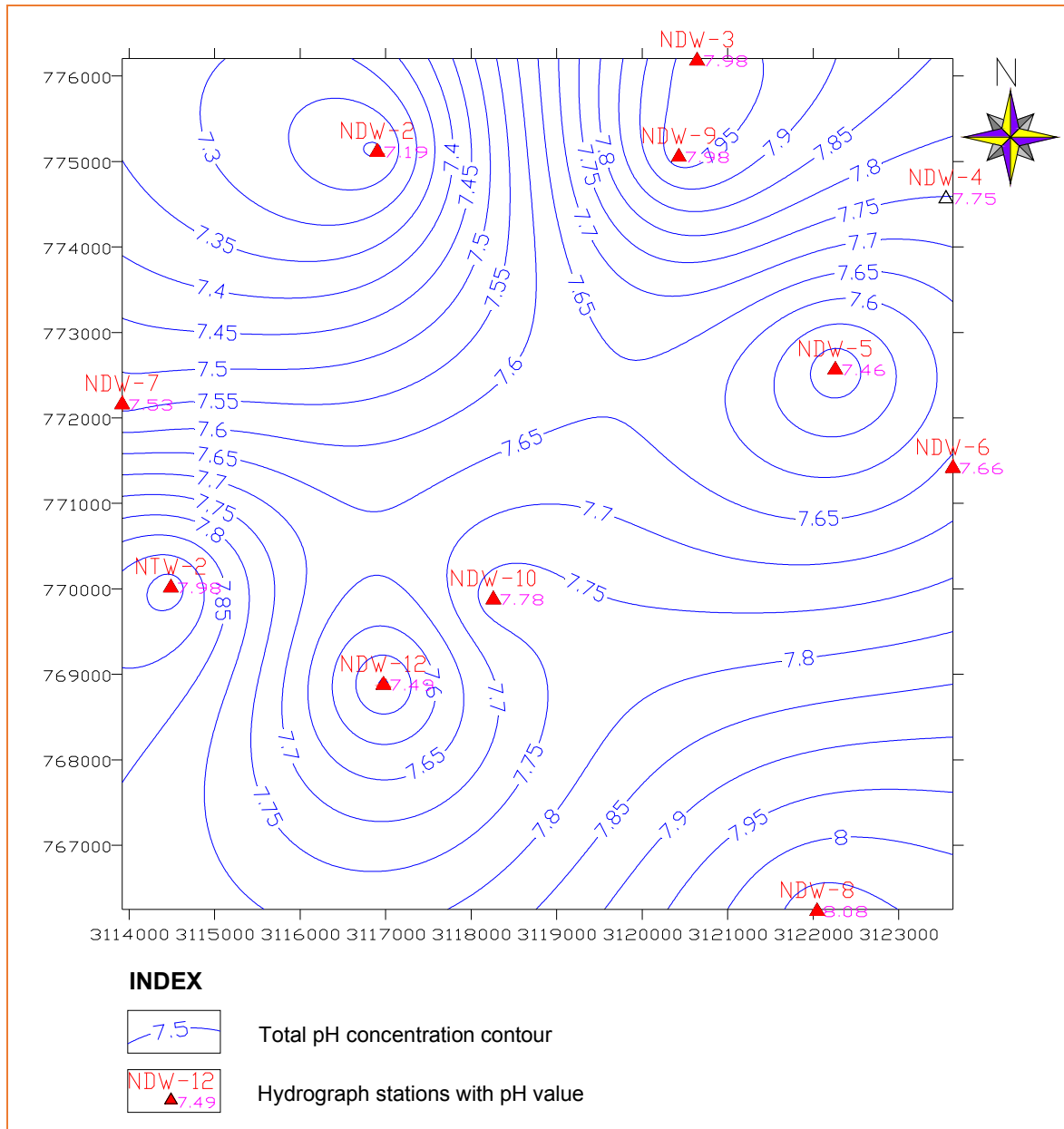


Figure-22: Post-monsoon pH concentration contour map of water sample from Open Dug wells & Tube well in and around Jagannath OCP, Talcher coalfield, Odisha

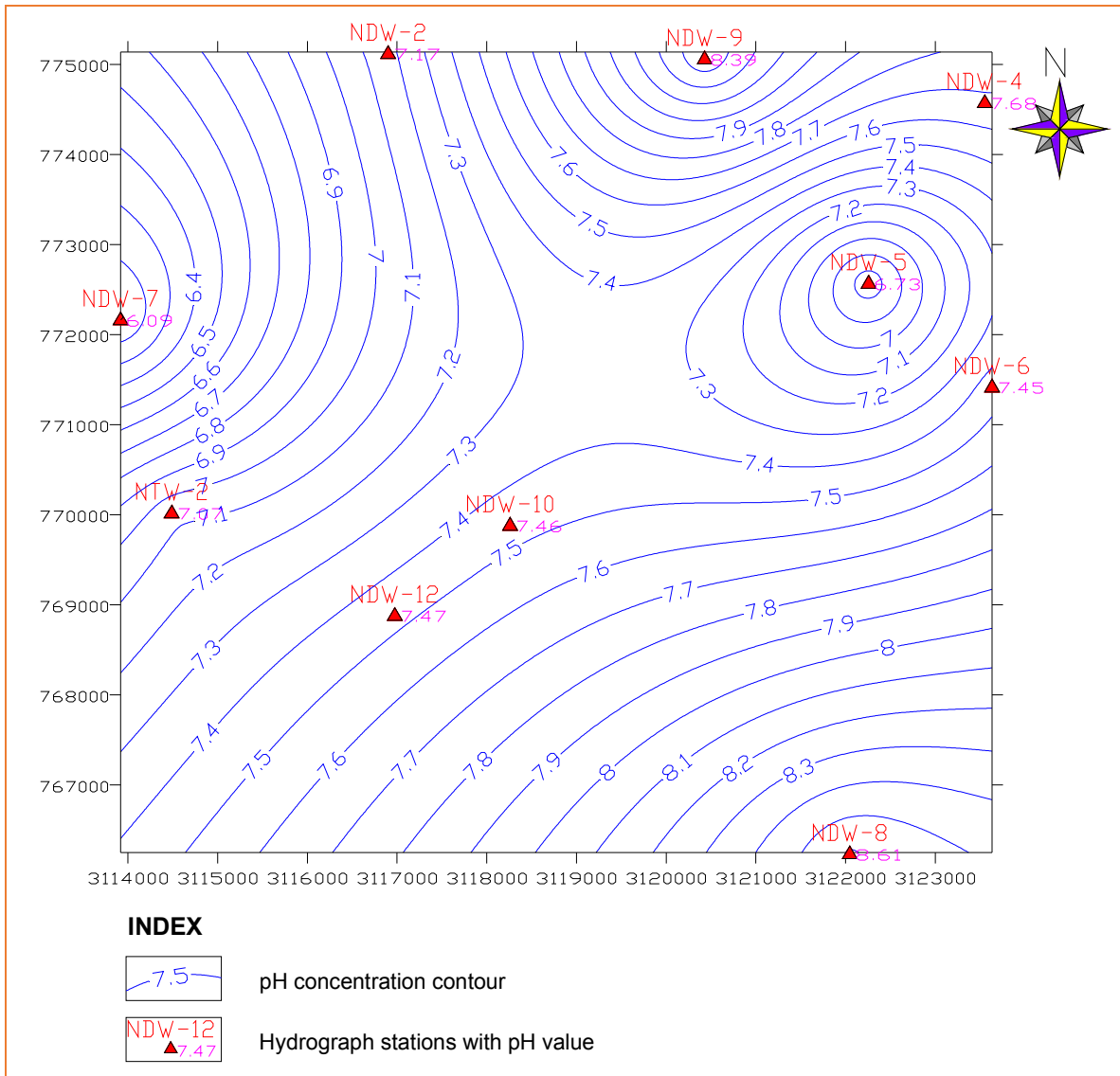


Figure-23: Pre-monsoon pH concentration contour map of water sample of piezometers in and around Jagannath OCP, Talcher coalfield, Odisha

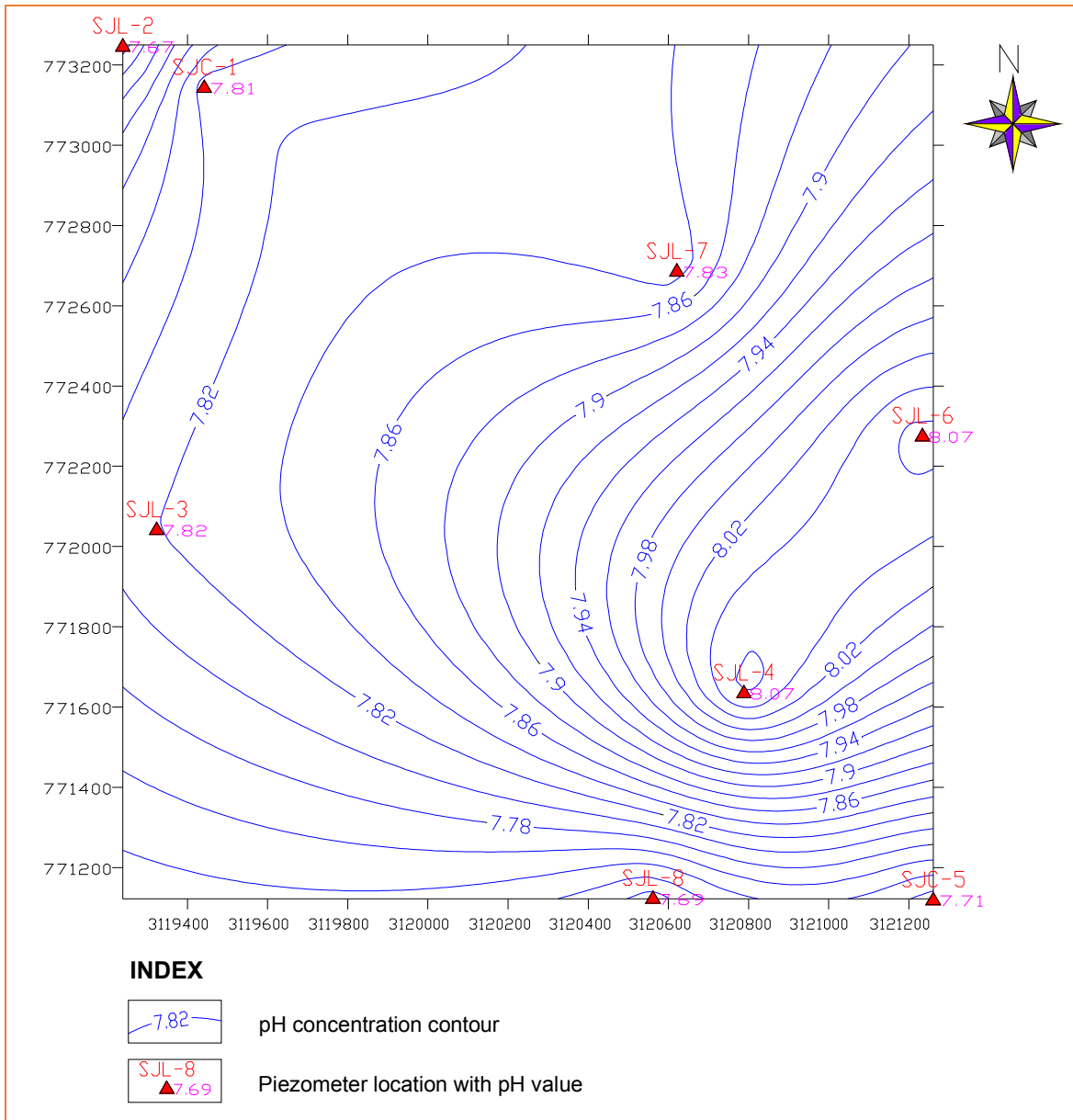
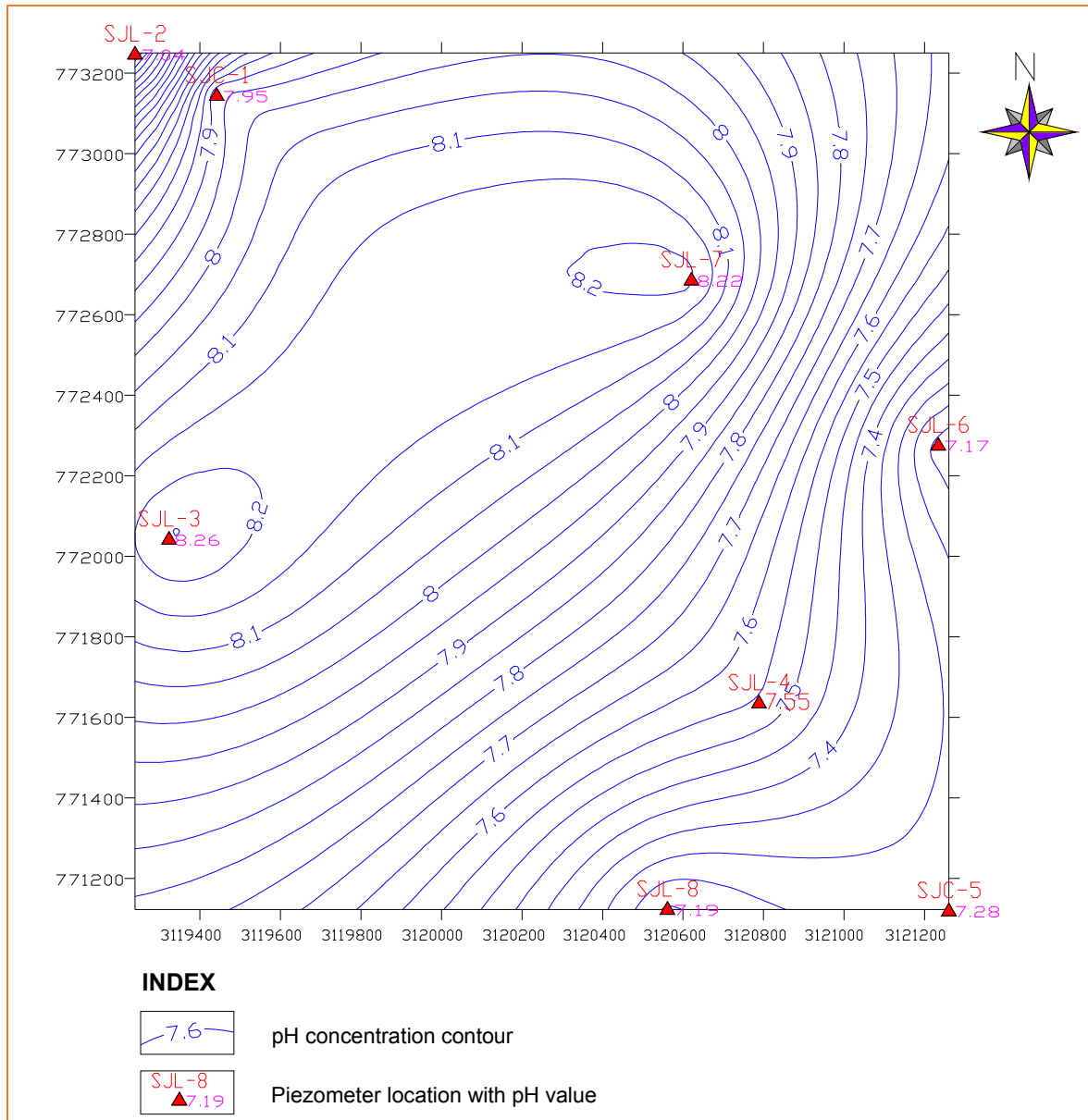


Figure-24: Post-monsoon pH concentration contour map of water sample of piezometers in and around Jagannath OCP, Talcher coalfield, Odisha



6.3.3.2 Total Alkalinity

Total Alkalinity in phreatic aquifer range between 24.00 to 332.00 in pre-monsoon season and between 12.00 to 1808.00 in post-monsoon season. In deeper aquifer, total alkalinity range between 20.00 to 224.00 in pre-monsoon season and between 32 to 176 in post-monsoon season. The maximum permissible concentration as per BIS 10500 Standard is 200. Contours of Total Alkalinity as observed from village dug wells water sample, tube well water and water sample from piezometers are given in figures 25 to 28.

Figure- 25: Pre-monsoon Total Alkalinity concentration contour map of water sample from Open Dug wells & Tube well in and around Jagannath OCP, Talcher coalfield, Odisha

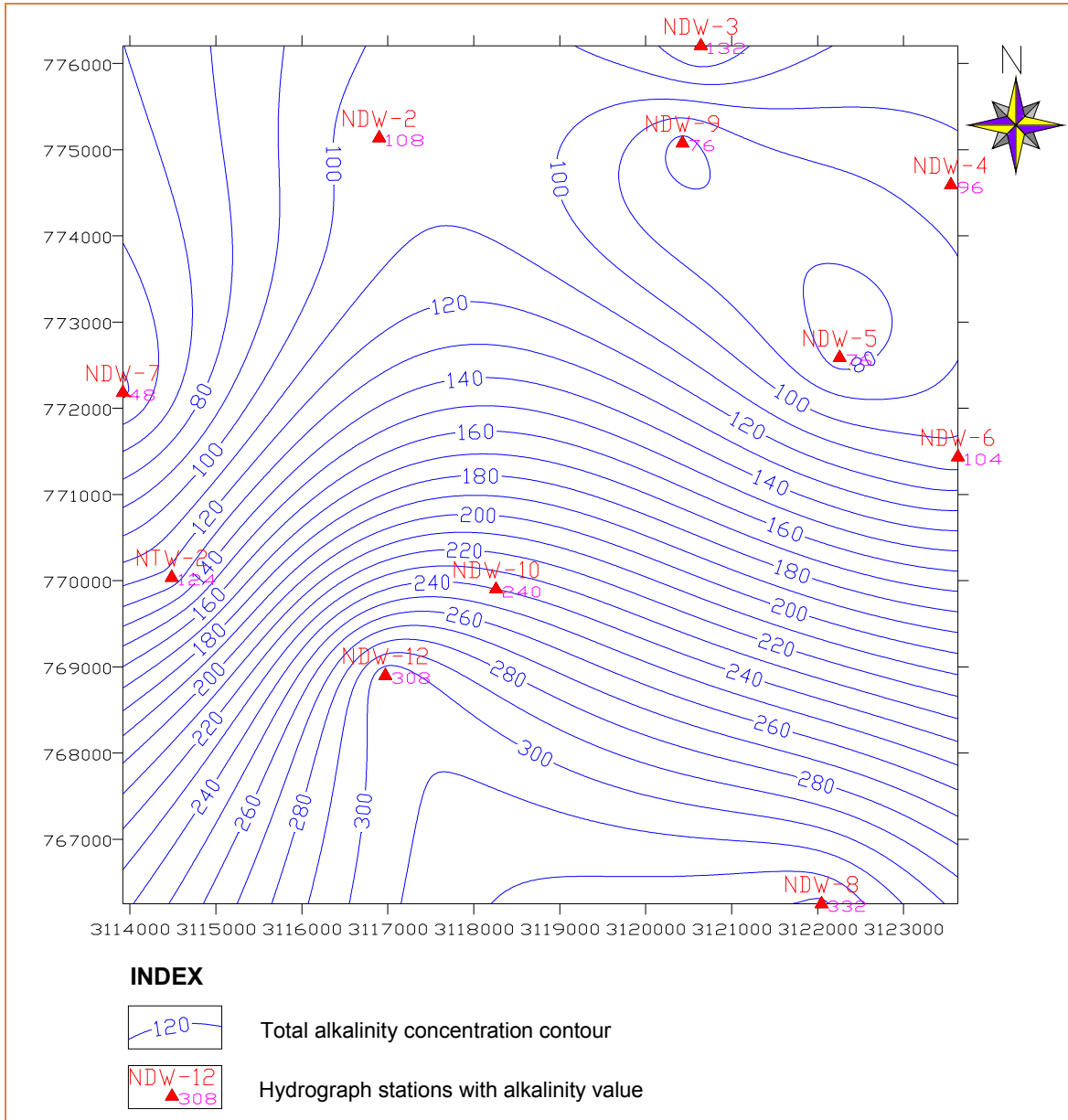


Figure- 26: Post-monsoon Total Alkanity concentration contour map of water sample from Open Dug wells & Tube well in and around Jagannath OCP, Talcher coalfield, Odisha

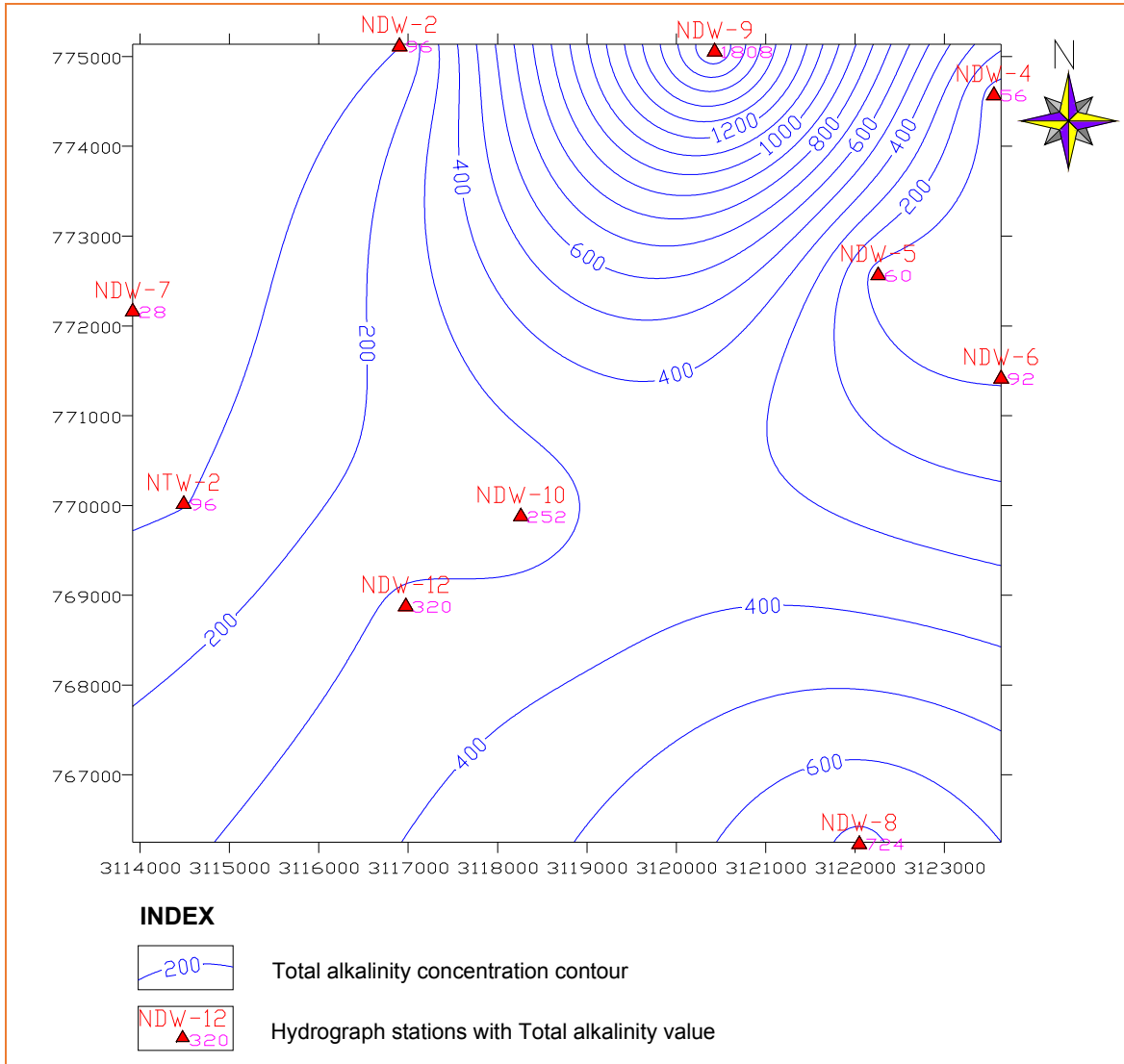


Figure-27: Pre-monsoon Total alkalinity concentration contour map of water sample of piezometers in and around Jagannath OCP, Talcher coalfield, Odisha

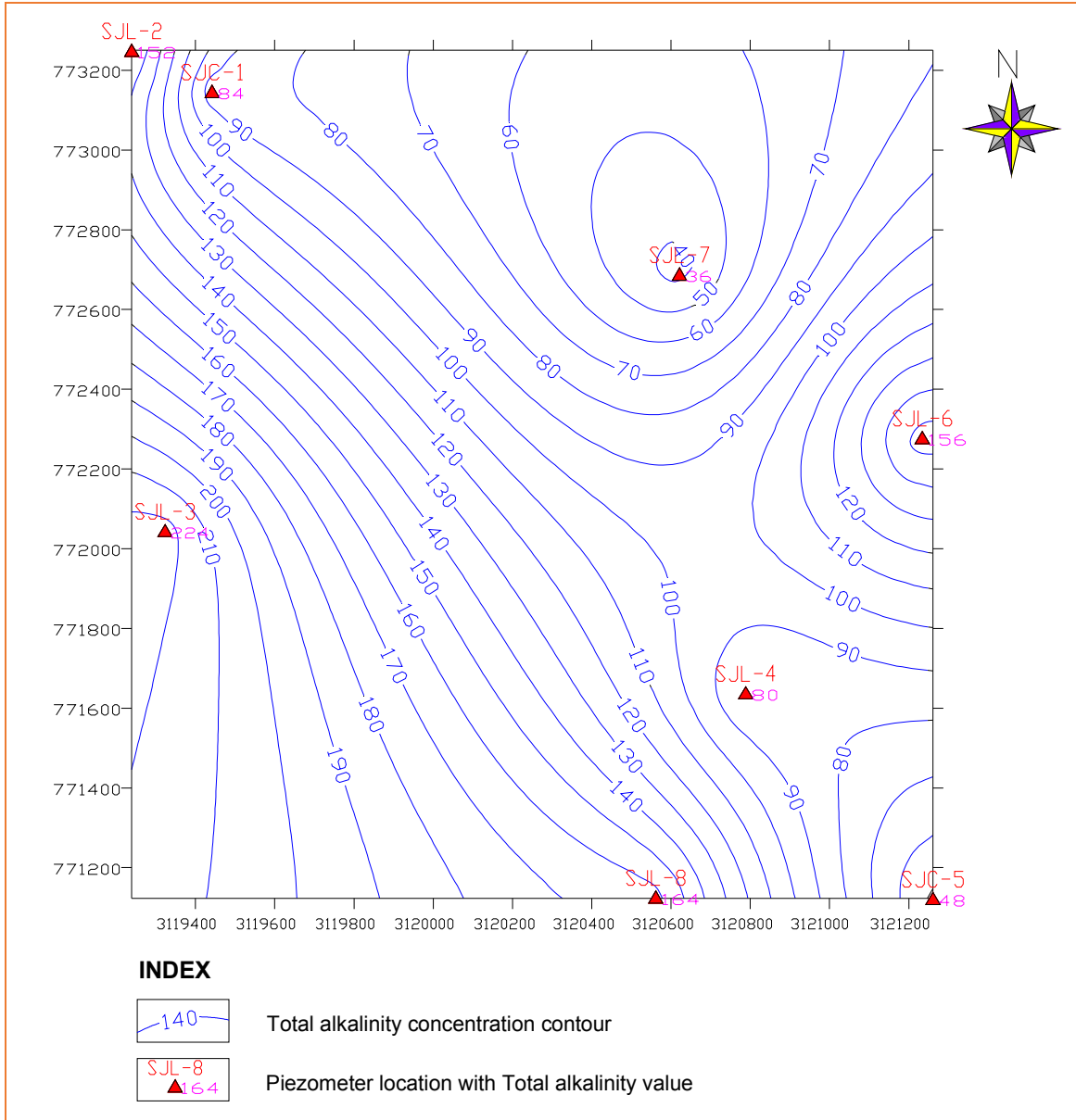
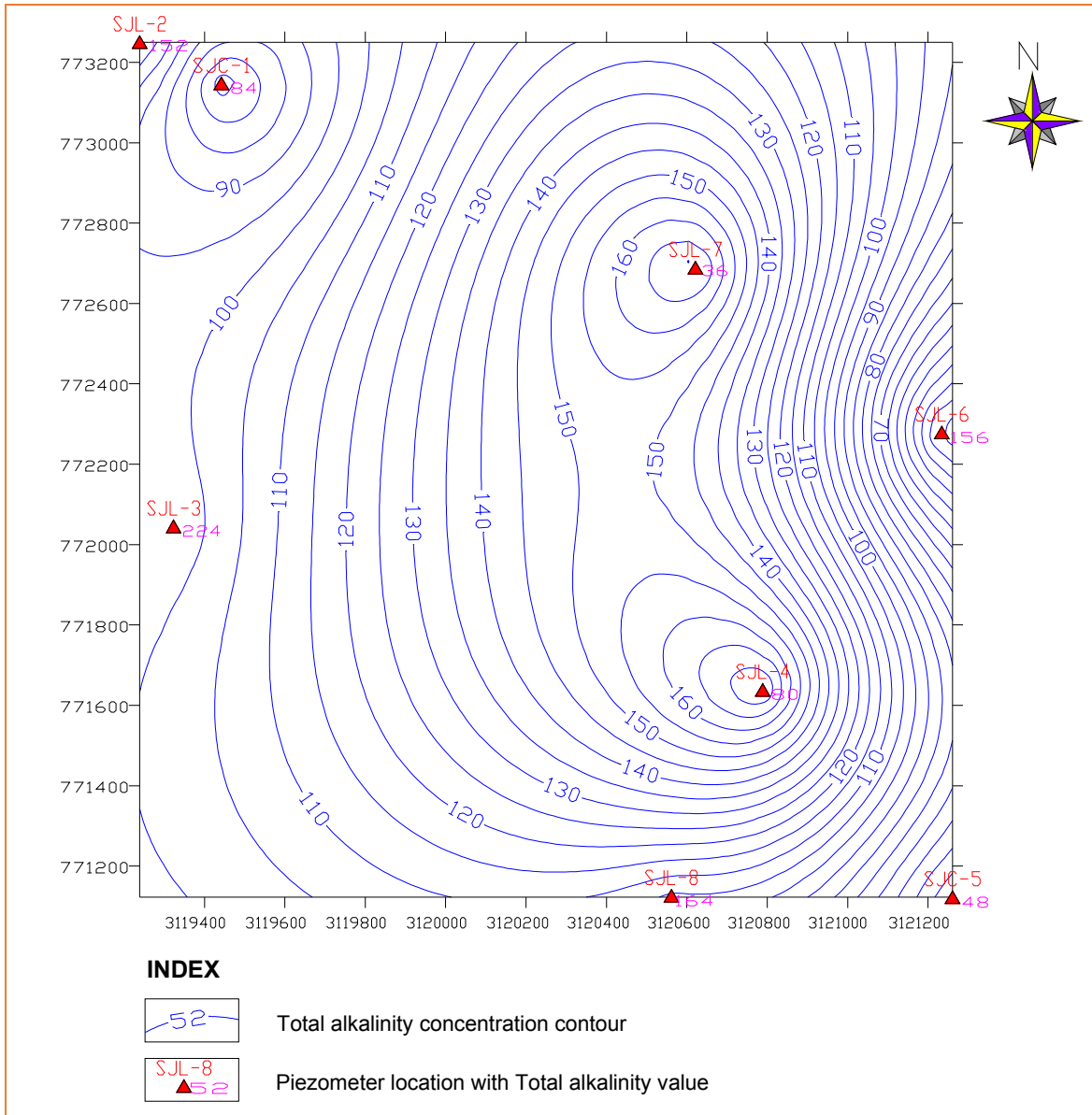


Figure-28: Post-monsoon Total Alkalinity concentration contour map of water sample of piezometers in and around Jagannath OCP, Talcher coalfield, Odisha



6.3.3.3 Total Dissolved Solids (TDS)

The total dissolved solids in phreatic aquifer range between 86.00 mg/L to 1246.00 mg/L in pre-monsoon season and between 64.00 mg/L to 6188.00 mg/L in post-monsoon season. In deeper aquifer, TDS range between 88.00 mg/L to 566.00 mg/L in pre-monsoon season and between 98.00 mg/L to 548.00 mg/L in post-monsoon season. Water containing more than 1000.00 mg/L of dissolved solids is unsuitable for many purposes. Recommended maximum limit for public water supplies is 500.00 mg/L BIS 10500 drinking water standards. It may be noted that groundwater in phreatic zone dominantly show elevated concentration of TDS, groundwater in deeper aquifers collected from installed piezometer show relatively lower/ normal concentration of TDS. Contours of TDS concentration as observed from village dug wells water sample, tube well water and water sample from piezometers are given in figures 29 to 32.

Figure-29: Pre-monsoon TDS concentration contour map of water sample from Open Dug wells & Tube well in and around Jagannath OCP, Talcher coalfield, Odisha

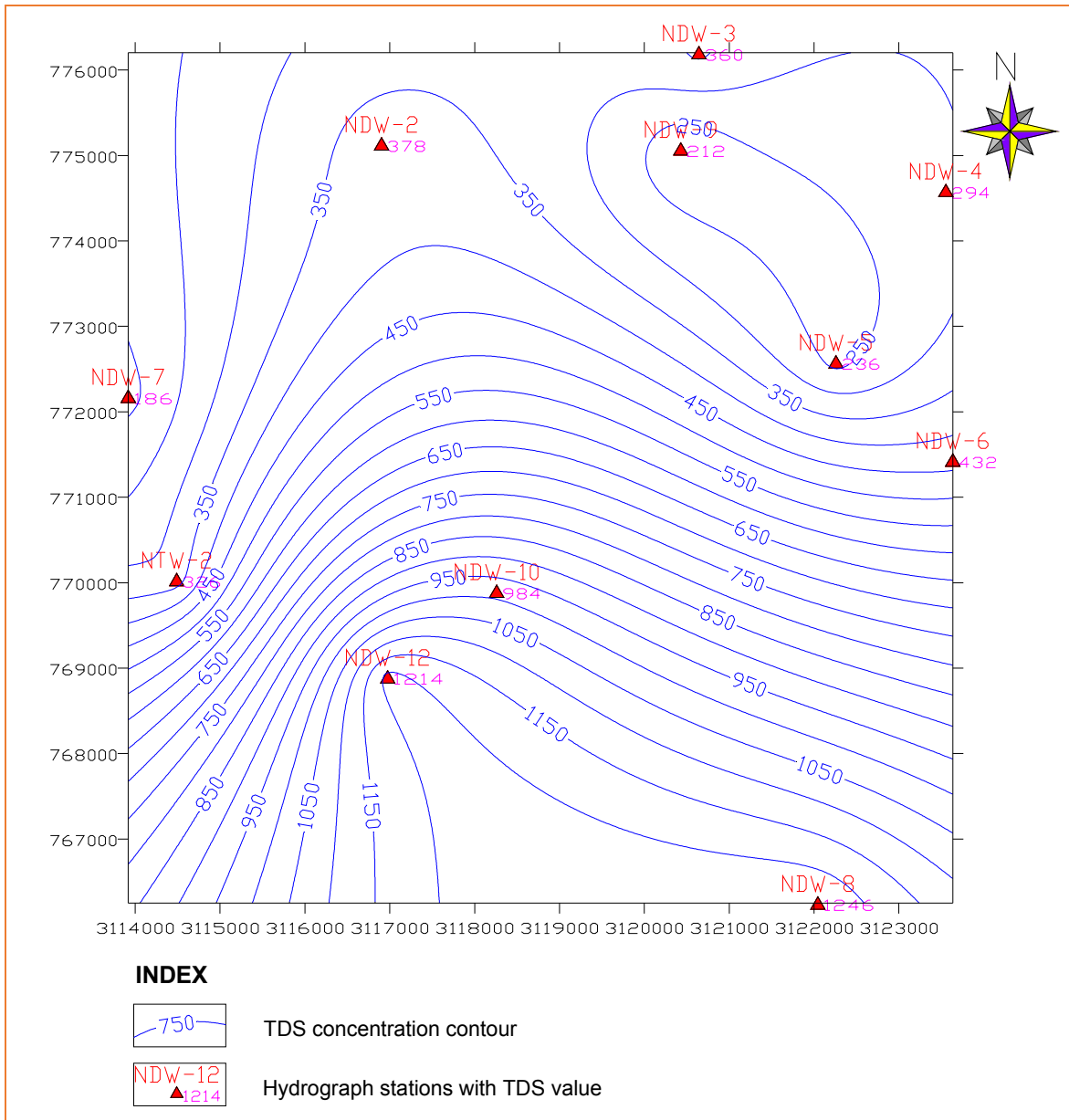


Figure-30: Post-monsoon TDS concentration contour map of water sample from Open Dug wells & Tube well in and around Jagannath OCP, Talcher coalfield, Odisha

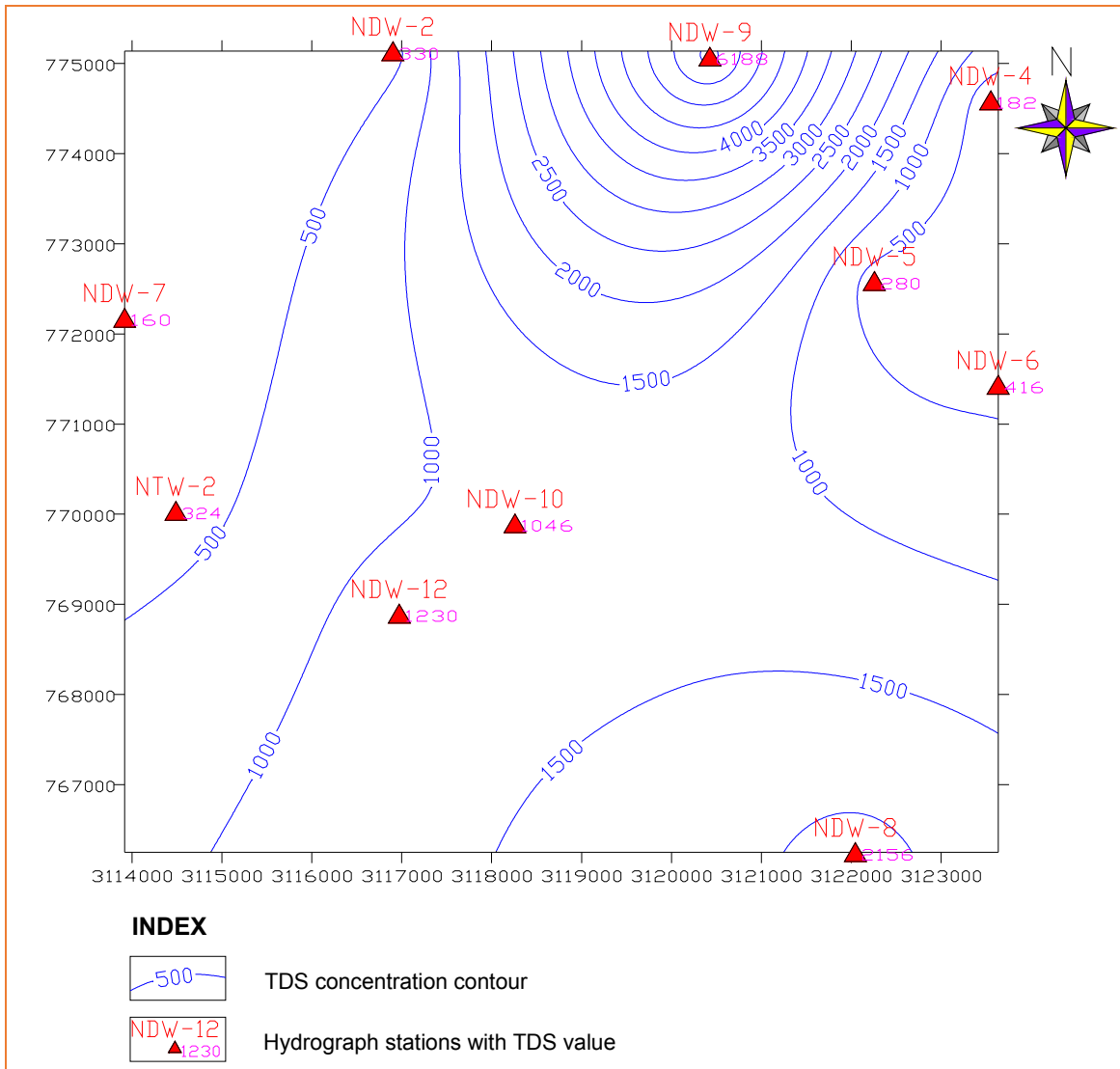


Figure-31: Pre-monsoon TDS concentration contour map of water sample of piezometers in and around Jagannath OCP, Talcher coalfield, Odisha

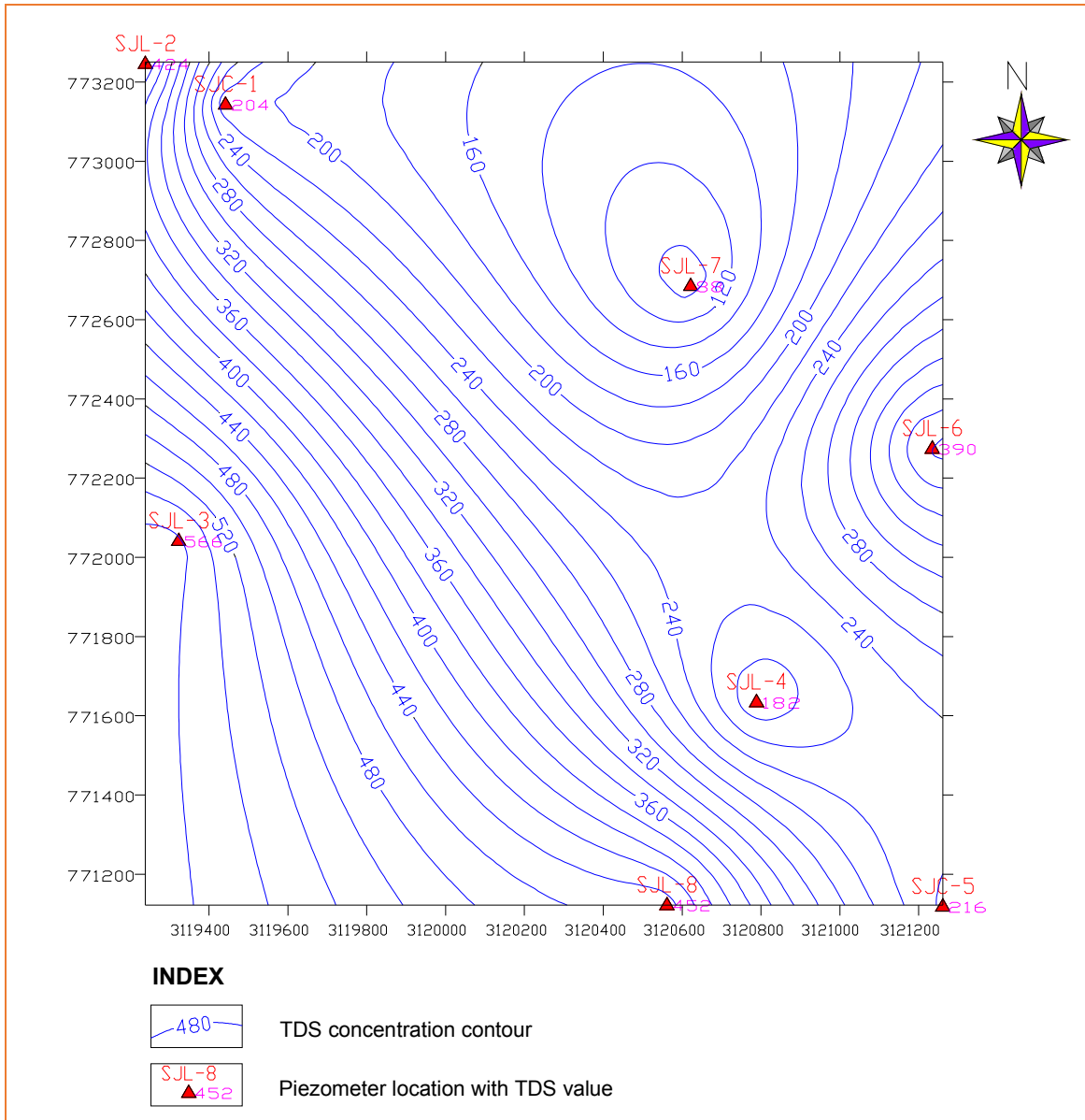
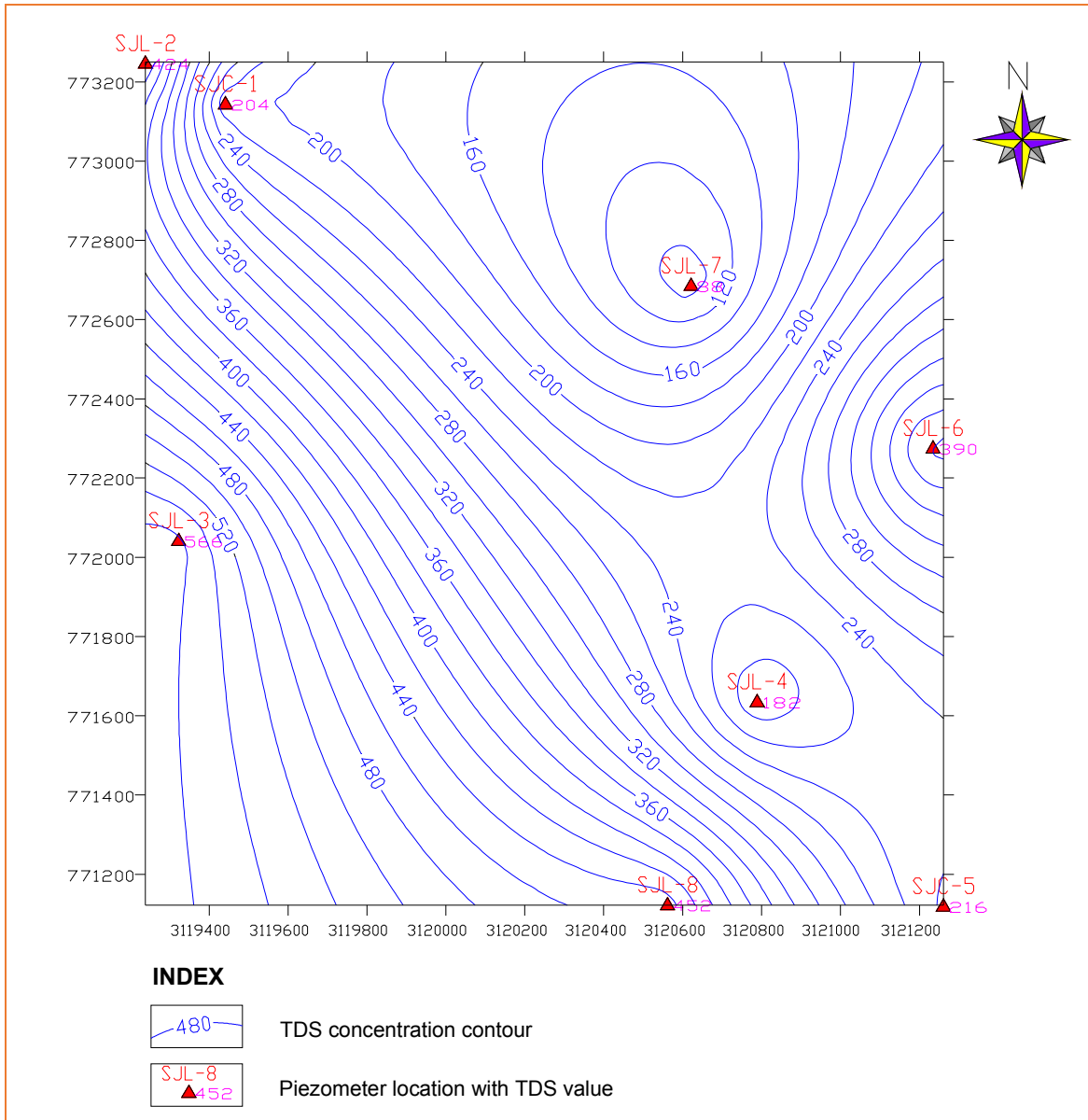


Figure-32: Post-monsoon TDS concentration contour map of water sample of piezometers in and around Jagannath OCP, Talcher coalfield, Odisha



6.3.3.4 Total Hardness

Hardness, as CaCO_3 , in phreatic aquifer range between 44.00 to 548.00 mg/L in pre-monsoon season and between 32.00 to 3404.00 mg/L in post-monsoon season. In deeper aquifer, hardness range between 60.00 to 408.00 in pre-monsoon season and between 64.00 to 304.00 in post-monsoon season. Recommended maximum limit for public water supplies is 300.00 mg/L as per BIS 10500 drinking water standards. Contours of Total Hardness concentration as observed from village dug wells water sample, tube well water and water sample from piezometers are given in figures 33 to 36.

Figure-33: Pre-monsoon Total Hardness concentration contour map of water sample from Open Dug wells & Tube well in and around Jagannath OCP, Talcher coalfield, Odisha

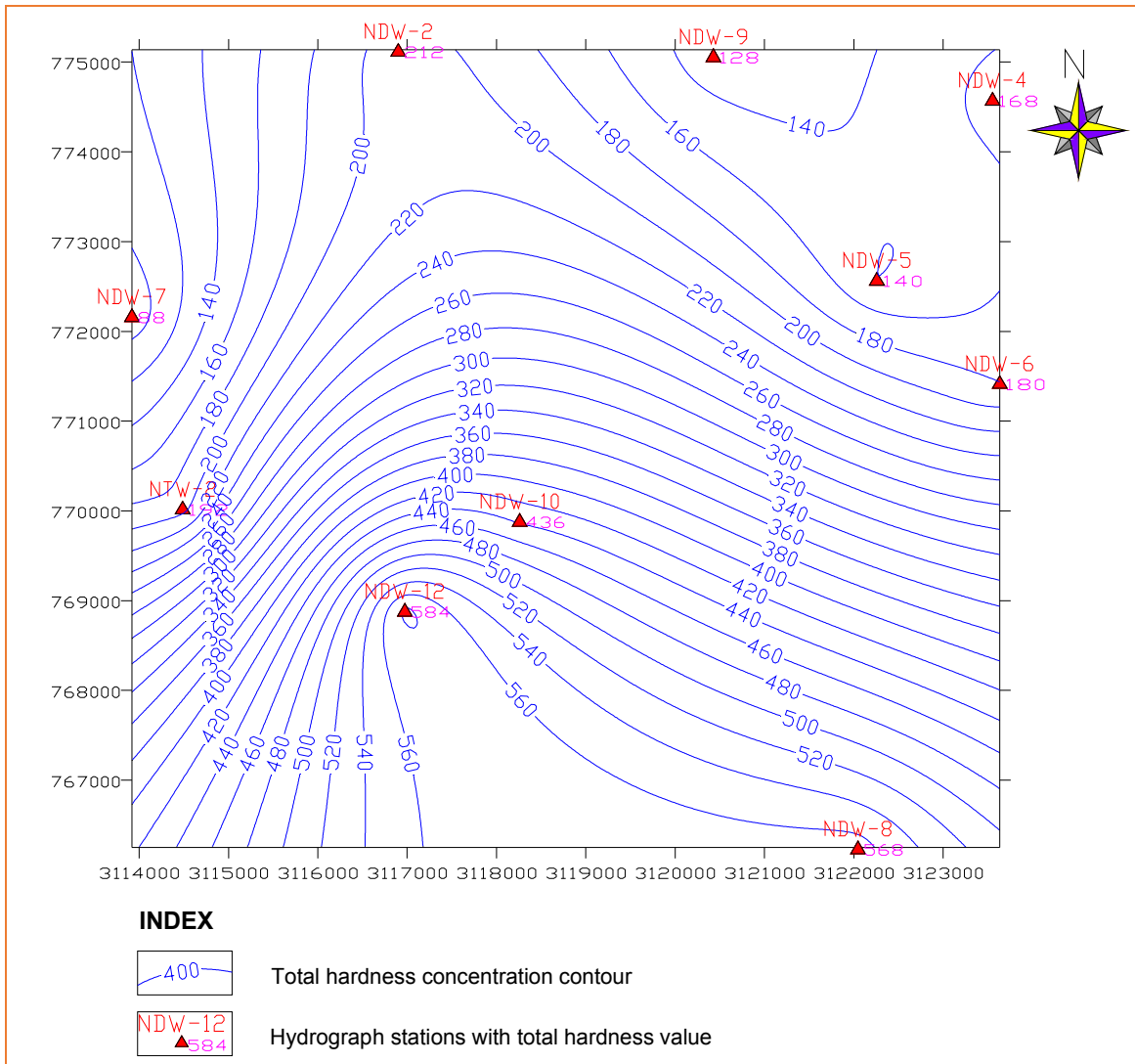


Figure-34: Post-monsoon Total Hardness concentration contour map of water sample from Open Dug wells & Tube well in and around Jagannath OCP, Talcher coalfield, Odisha

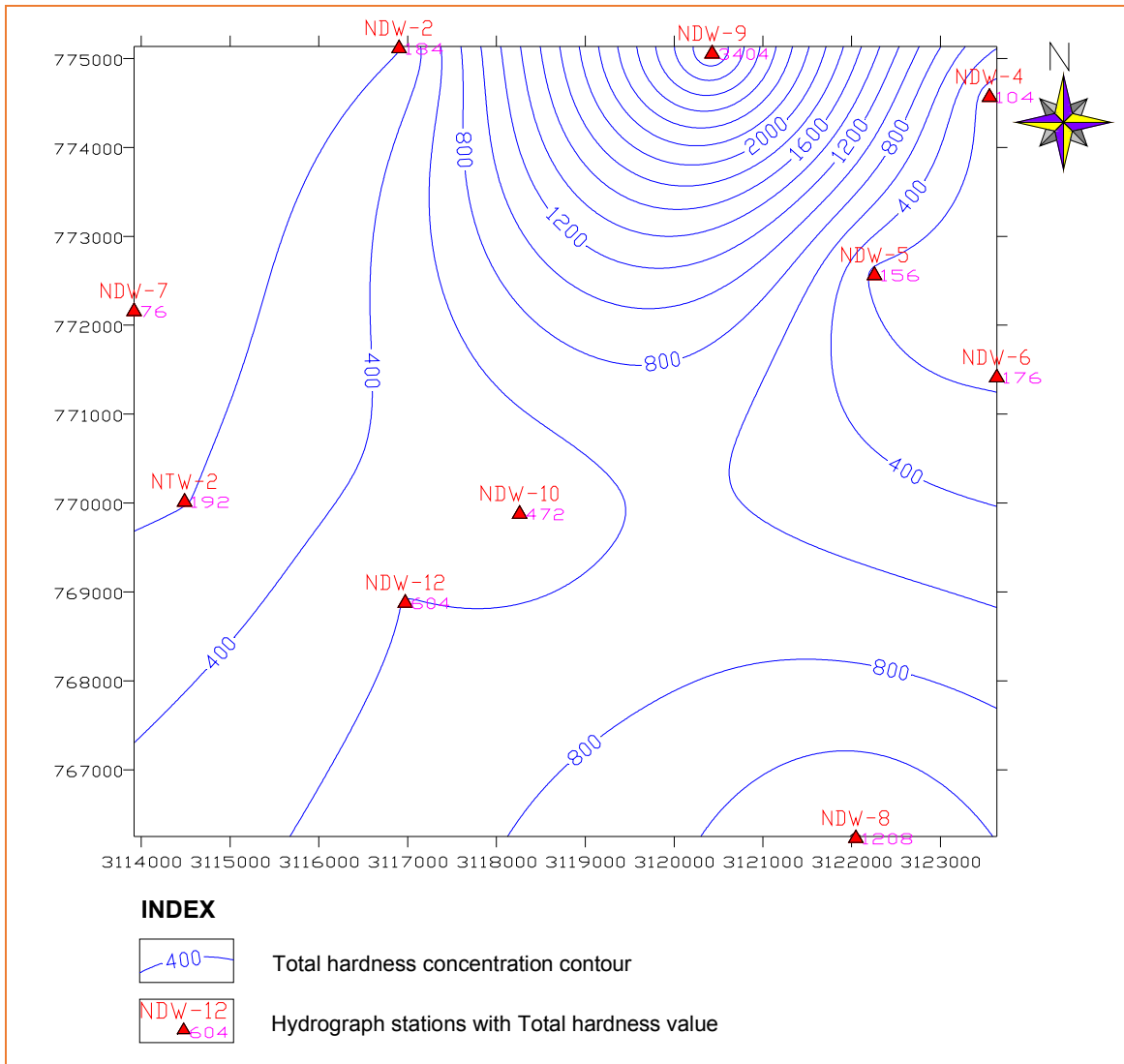


Figure-35: Pre-monsoon Total Hardness concentration contour map of water sample of piezometers in and around Jagannath OCP, Talcher coalfield, Odisha

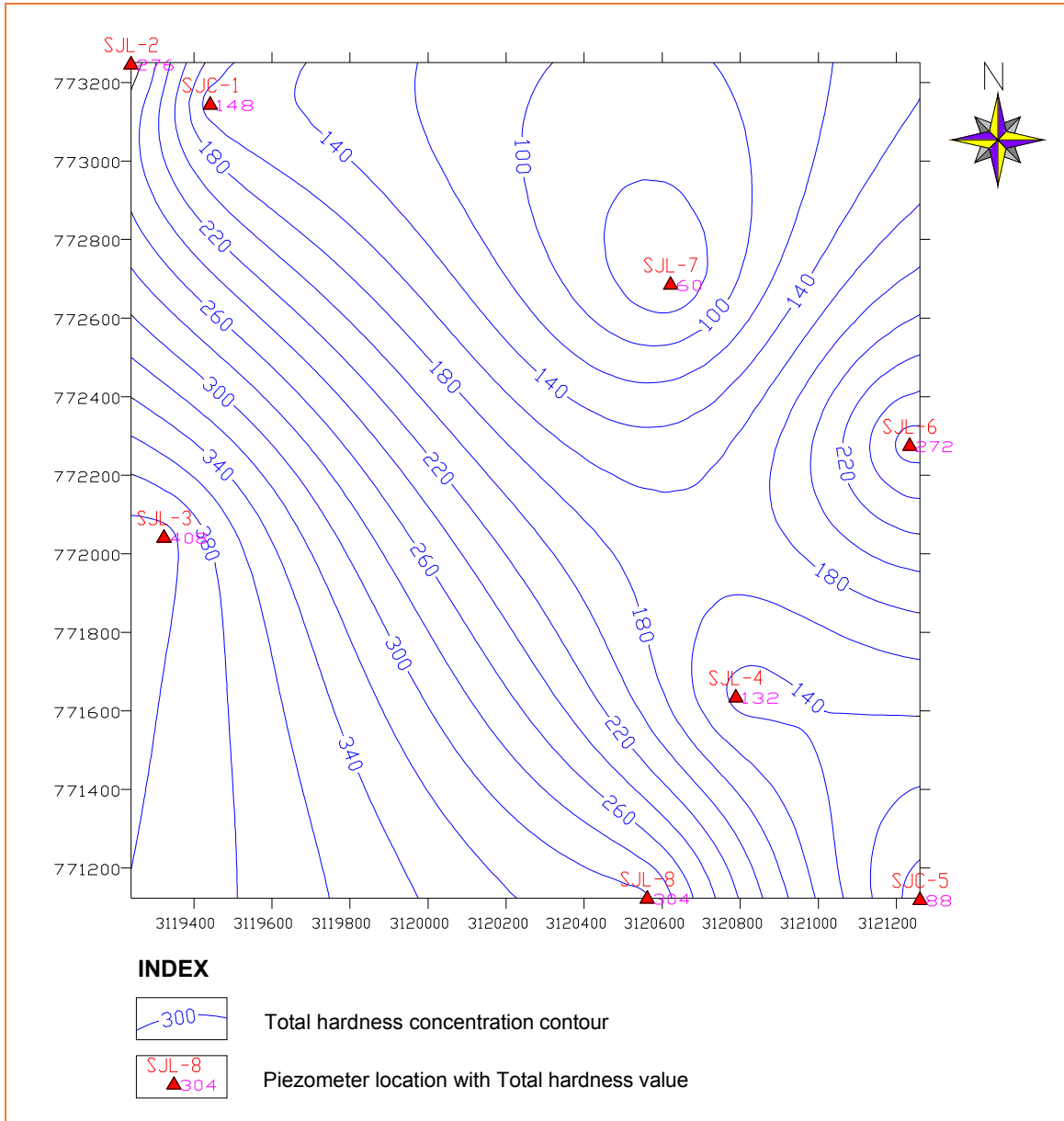
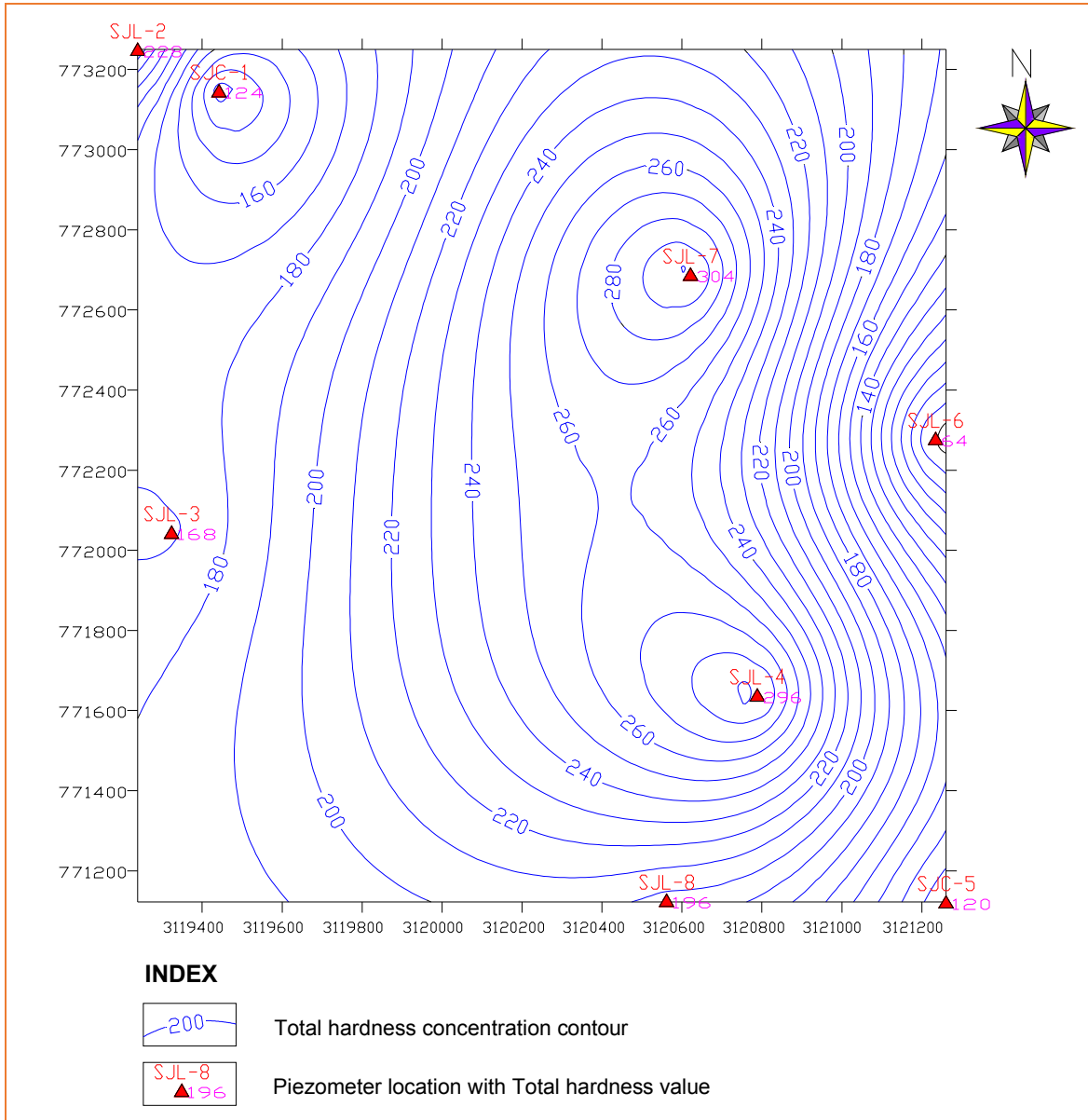


Figure-36: Post-monsoon Total Hardness concentration contour map of water sample of piezometers in and around Jagannath OCP, Talcher coalfield, Odisha



6.3.3.5 Calcium (Ca)

Calcium concentration in phreatic aquifer range between 11.20 mg/L to 142.40 mg/L in pre-monsoon season and between 8.00 mg/L to 773.00 mg/L in post-monsoon season. In deeper aquifer, calcium ranges between 14.40 mg/L to 94.40 mg/L in pre-monsoon season and between 12.80 mg/L to 720.00 mg/L in post-monsoon season in the study area. Recommended maximum limit for public water supplies is 75.00 mg/L as per BIS 10500 drinking water standards. Water hardness is primarily measured with amount of calcium in groundwater. Based on analytical results it may be concluded that groundwater in Talcher coalfield is generally Hard. Water hardness in most groundwater is naturally occurring from weathering of sedimentary rock and calcium bearing minerals. Hardness may also be induced into groundwater system by infiltration of mining industry effluent. Contours of Calcium concentration as observed from village dug wells water sample, tube well water and water sample from piezometers are given in figures 37 to 40.

Figure-37: Pre-monsoon Calcium concentration contour map of water sample from Open Dug wells & Tube well in and around Jagannath OCP, Talcher coalfield, Odisha

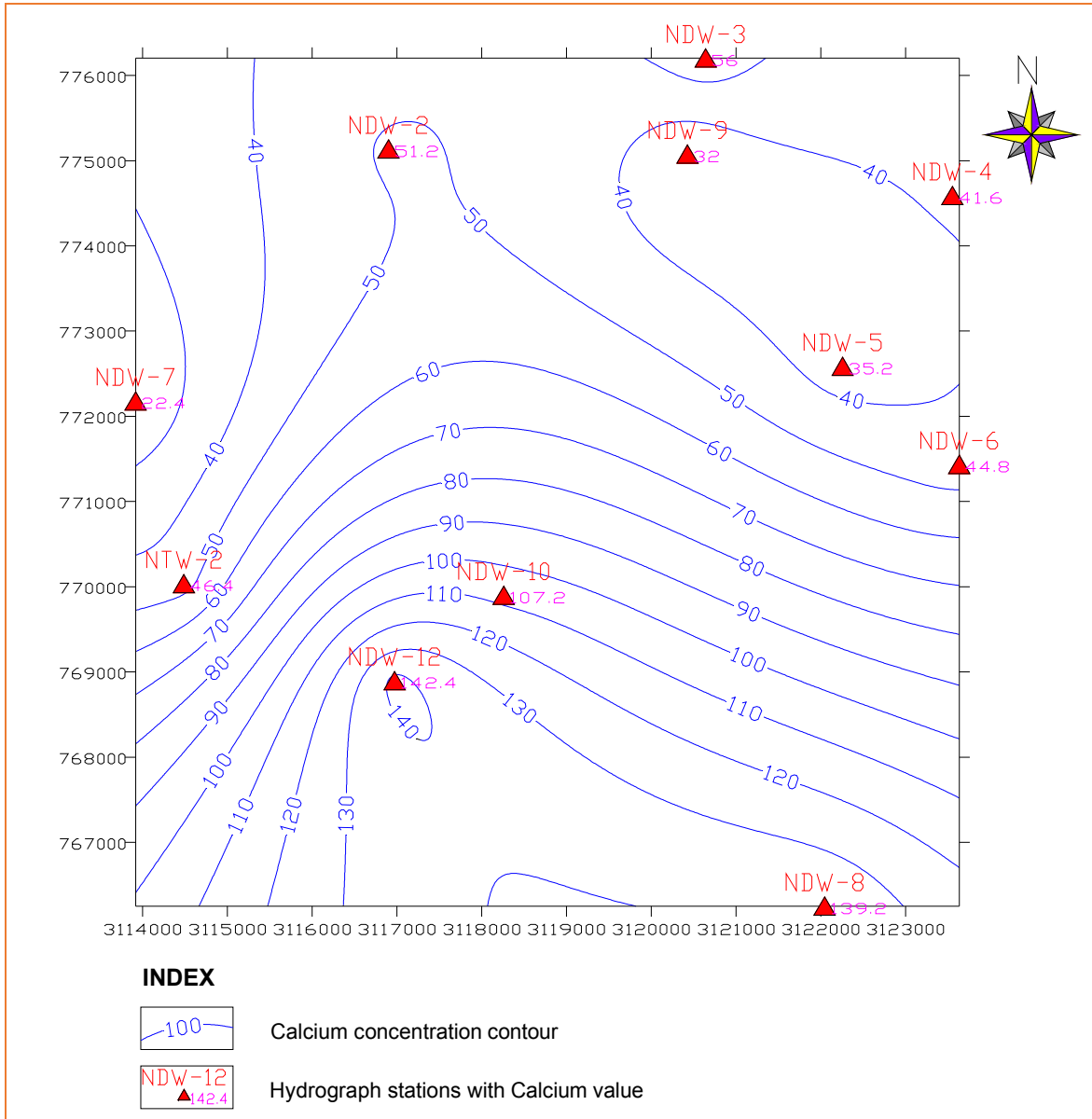


Figure-38: Post-monsoon Calcium concentration contour map of water sample from Open Dug wells & Tube well in and around Jagannath OCP, Talcher coalfield, Odisha

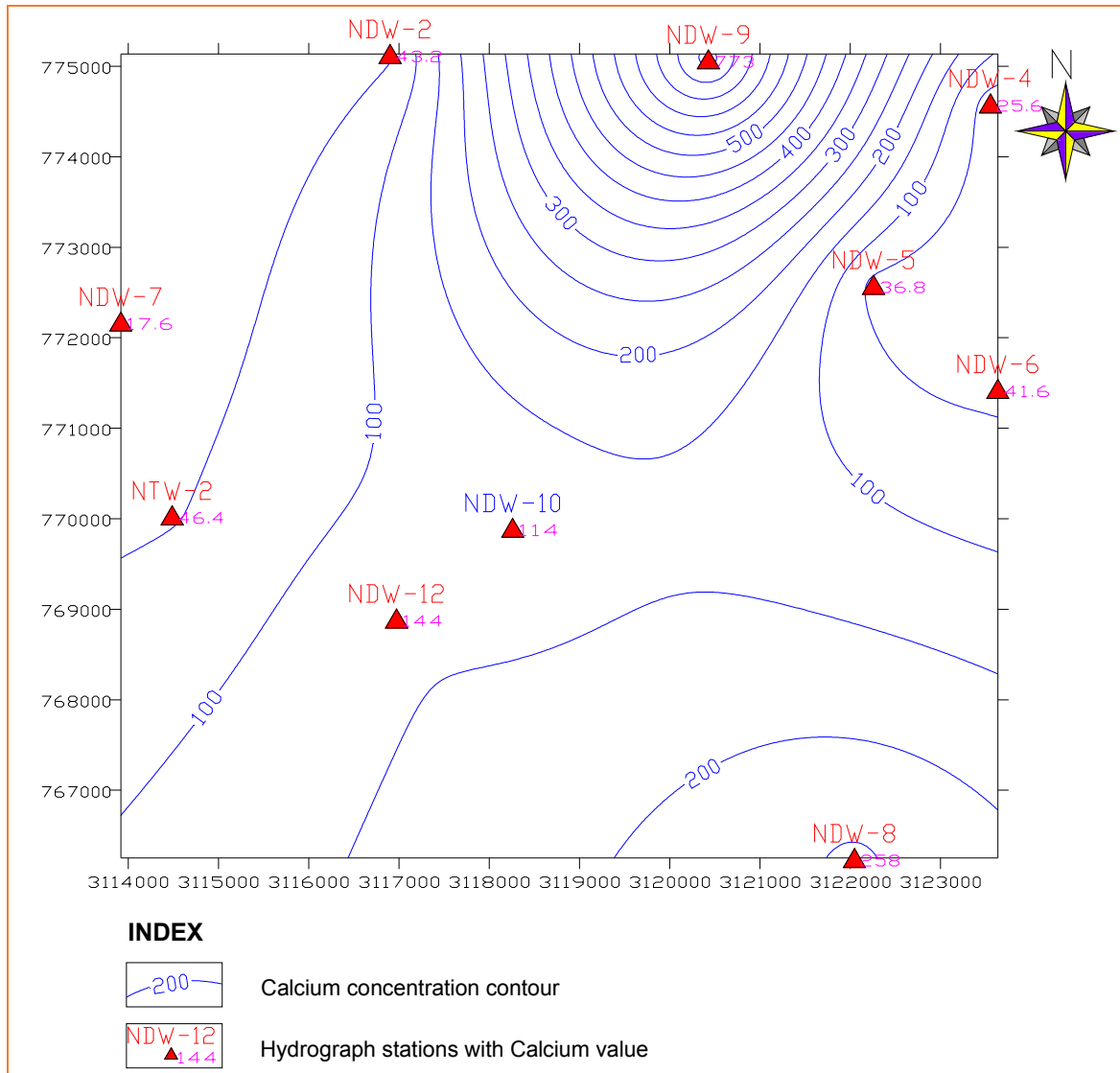


Figure-39: Pre-monsoon Calcium concentration contour map of water sample of piezometers in and around Jagannath OCP, Talcher coalfield, Odisha

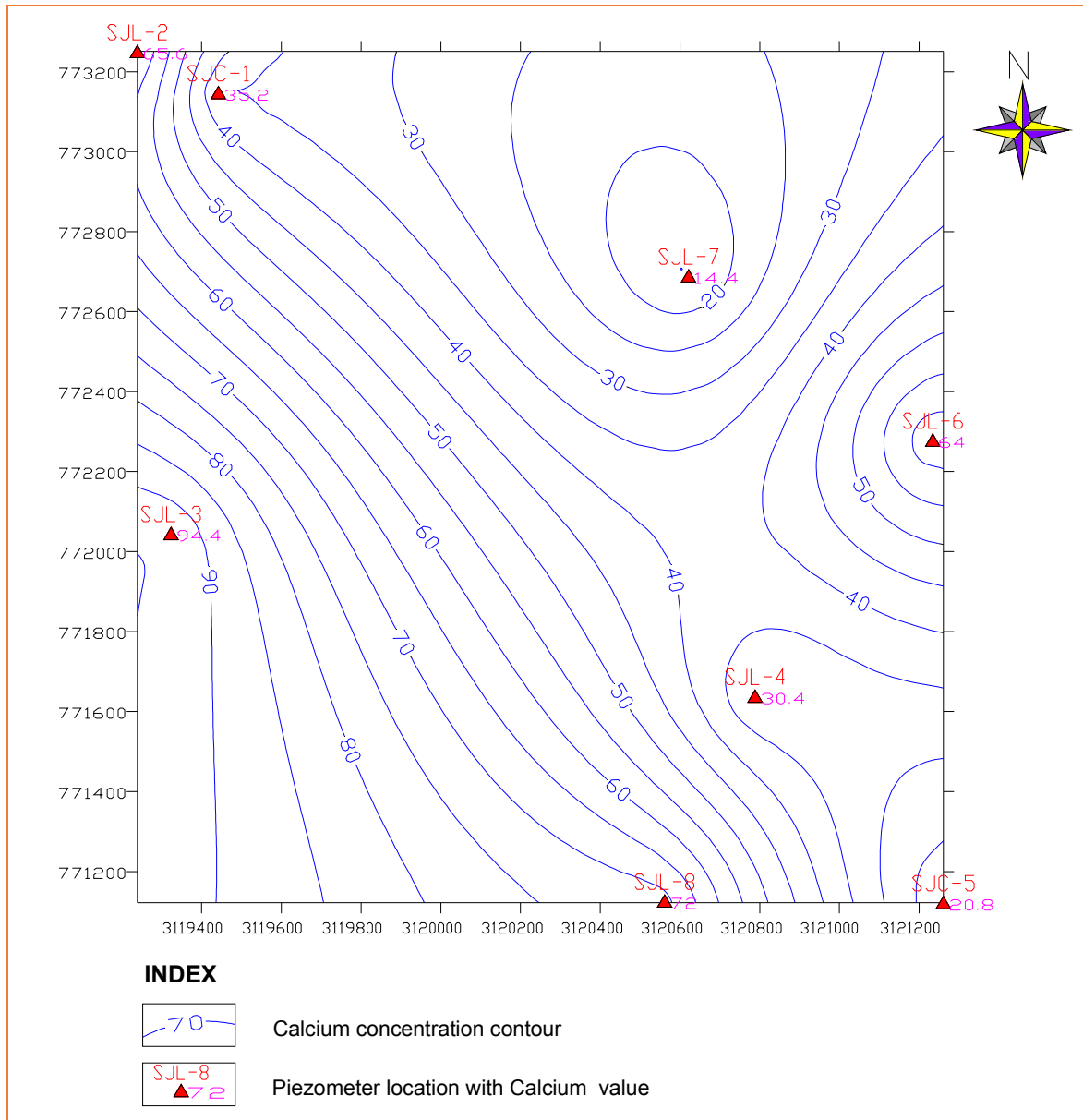
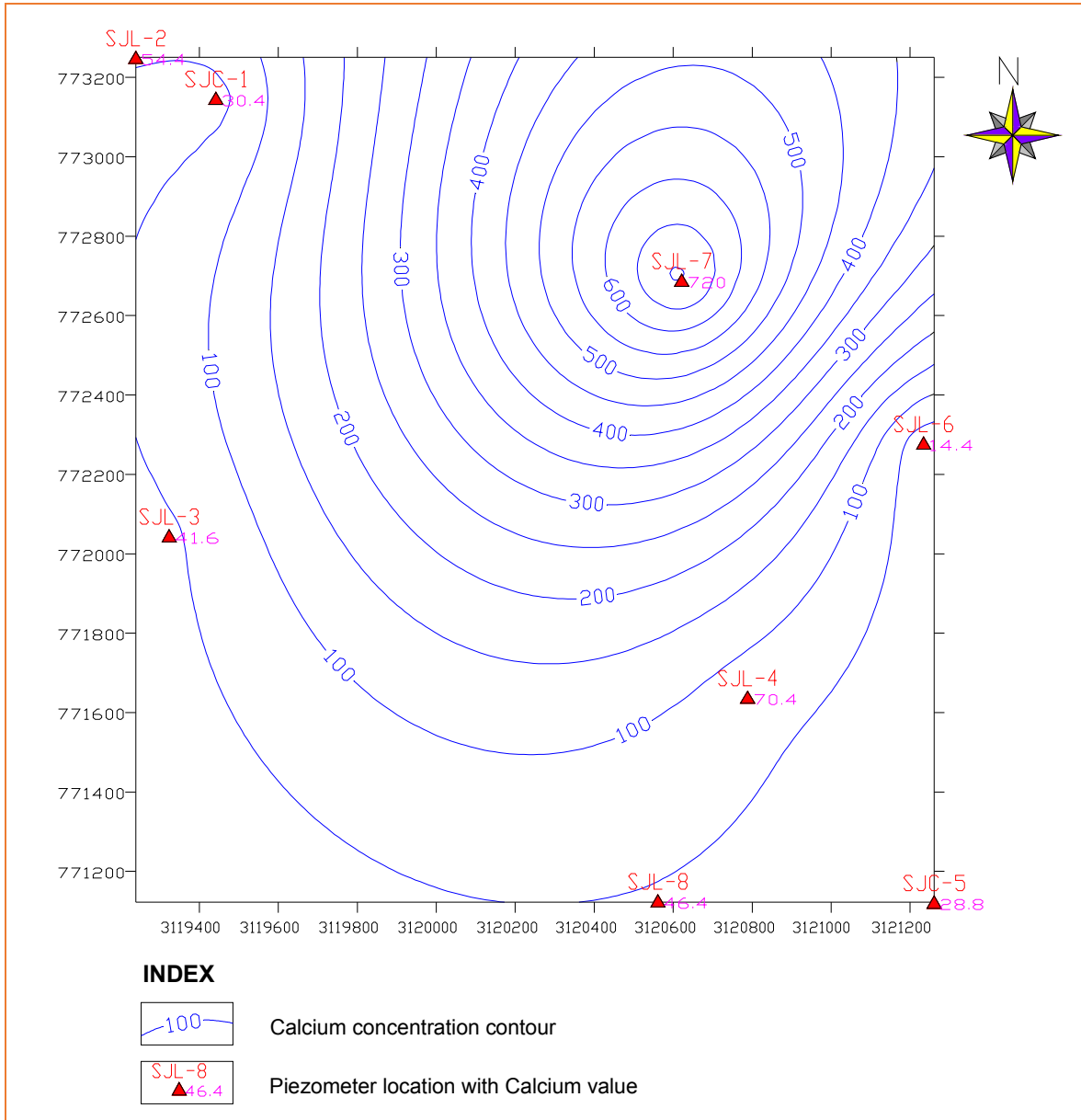


Figure-40: Post-monsoon Calcium concentration contour map of water sample of piezometers in and around Jagannath OCP, Talcher coalfield, Odisha



6.3.3.6 Manganese (Mn)

Manganese (Mn) is metal that occur naturally in soils, rocks and minerals. In the aquifer, groundwater comes in contact with these solid materials dissolving them, releasing their constituents to the water. Manganese concentration in phreatic aquifer range ranges from 0.06 mg/L to 0.25 mg/L in pre-monsoon season and from 0.02 mg/L to 0.24 mg/L in post-monsoon season. In deeper aquifer, manganese ranges between 0.02 mg/L to 2.81 mg/L in pre-monsoon season and present in only at one location at SJU- 4 with concentration of 0.21 mg/L in post-monsoon season in the study area. Recommended maximum limit for public water supplies is 0.10 mg/L as per BIS 10500 drinking water standards. The extent to which Mn dissolve in groundwater depends on the amount of oxygen, if groundwater is oxygen poor, manganese will dissolve more readily. The amount of dissolved manganese in groundwater vary seasonally for a given well. Usually this is associated with an influx of oxygenated water from the surface during periods of high recharge. This oxygenated water will prevent manganese from dissolving and the water abstracted from the well will have low concentrations of Mn.

6.3.3.7 Sulphate

Sulphate is formed by oxidation of pyrite and other sulphides widely distributed in sedimentary rocks of the study area. Concentrations of sulphate from less than 0.20 mg/L to more than 100,000 mg/L are found in nature. The lowest concentrations of sulphate are in rainwater and sub-surface waters subject to sulphate reduction. Ground water derived from sediments generally contains less than 100.00 mg/L and may contain less than 1 mg/L if sulphate-reducing bacteria are active in the soil through which recharge water has percolated. In the study area, sulphate concentrations ranges from 1.00 mg/L to 59.00 mg/L in pre-monsoon season and from 11.00 mg/L to 1016.00 mg/L in post-monsoon season in phreatic zone and in deeper aquifer sulphate concentration ranges from 16.00 mg/L to 128.00 mg/L in pre-monsoon season and from 19.00 mg/L to 96.00 mg/L in post-monsoon season. Recommended maximum limit for public water supplies is 200.00

mg/L. Contours of Sulphate concentration as observed from village dug wells water sample, tube well water and water sample from piezometers are given in figures 41 to 44.

Figure-41: Pre-monsoon Sulphate concentration contour map of water sample from Open Dug wells & Tube well in and around Jagannath OCP, Talcher coalfield, Odisha

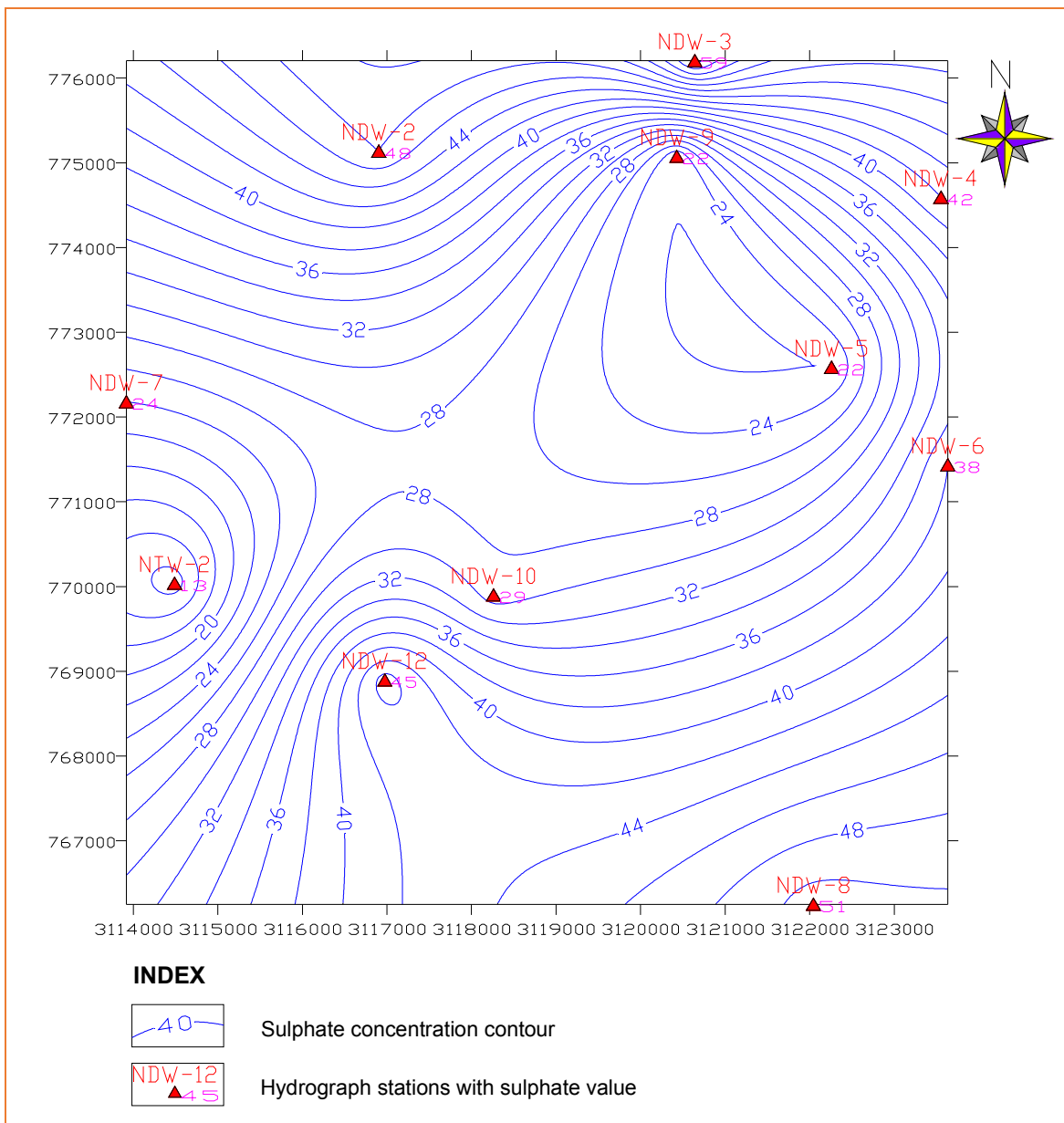


Figure-42: Post-monsoon Sulphate concentration contour map of water sample from Open Dug wells & Tube well in and around Jagannath OCP, Talcher coalfield, Odisha

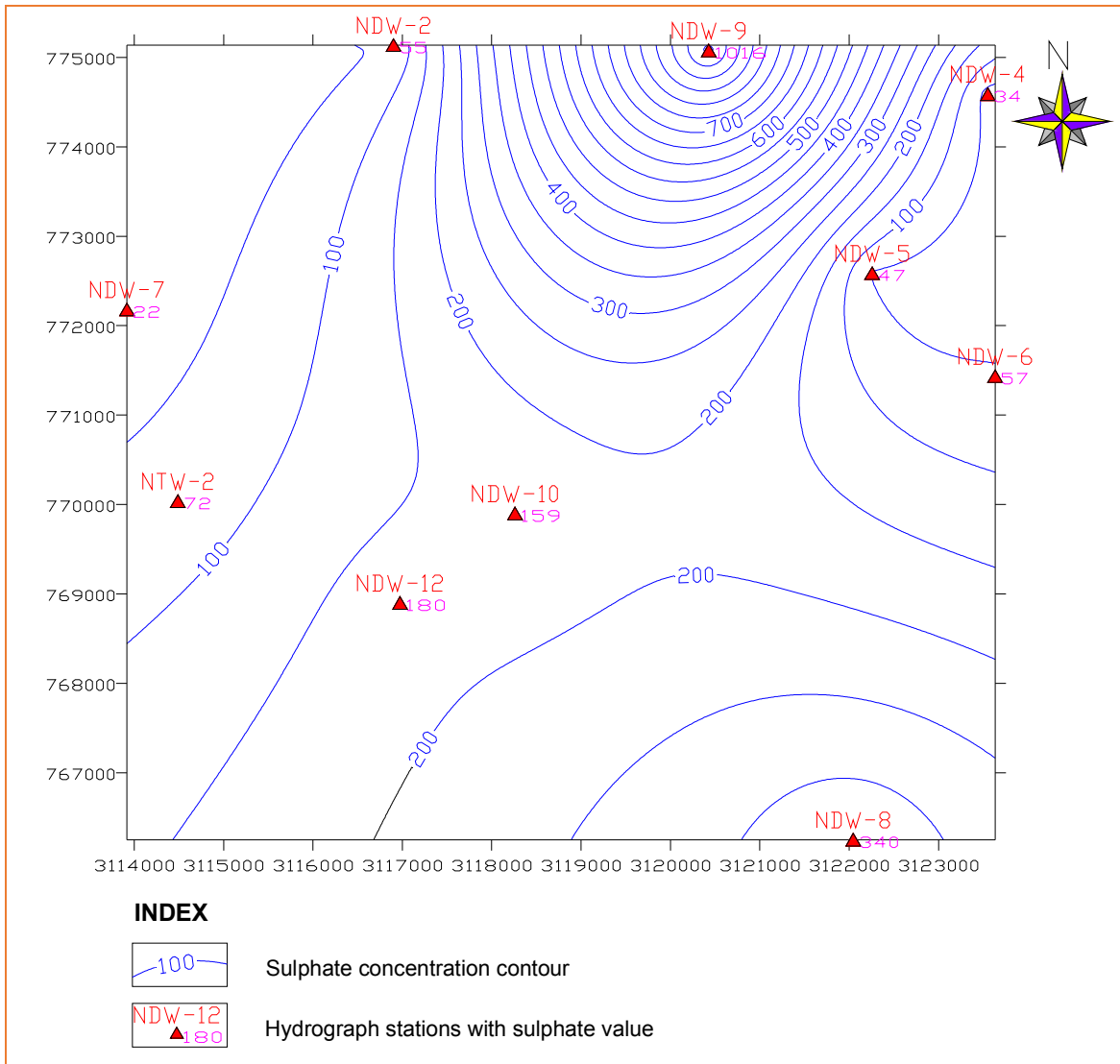


Figure-43: Pre-monsoon Sulphate concentration contour map of water sample of piezometers in and around Jagannath OCP, Talcher coalfield, Odisha

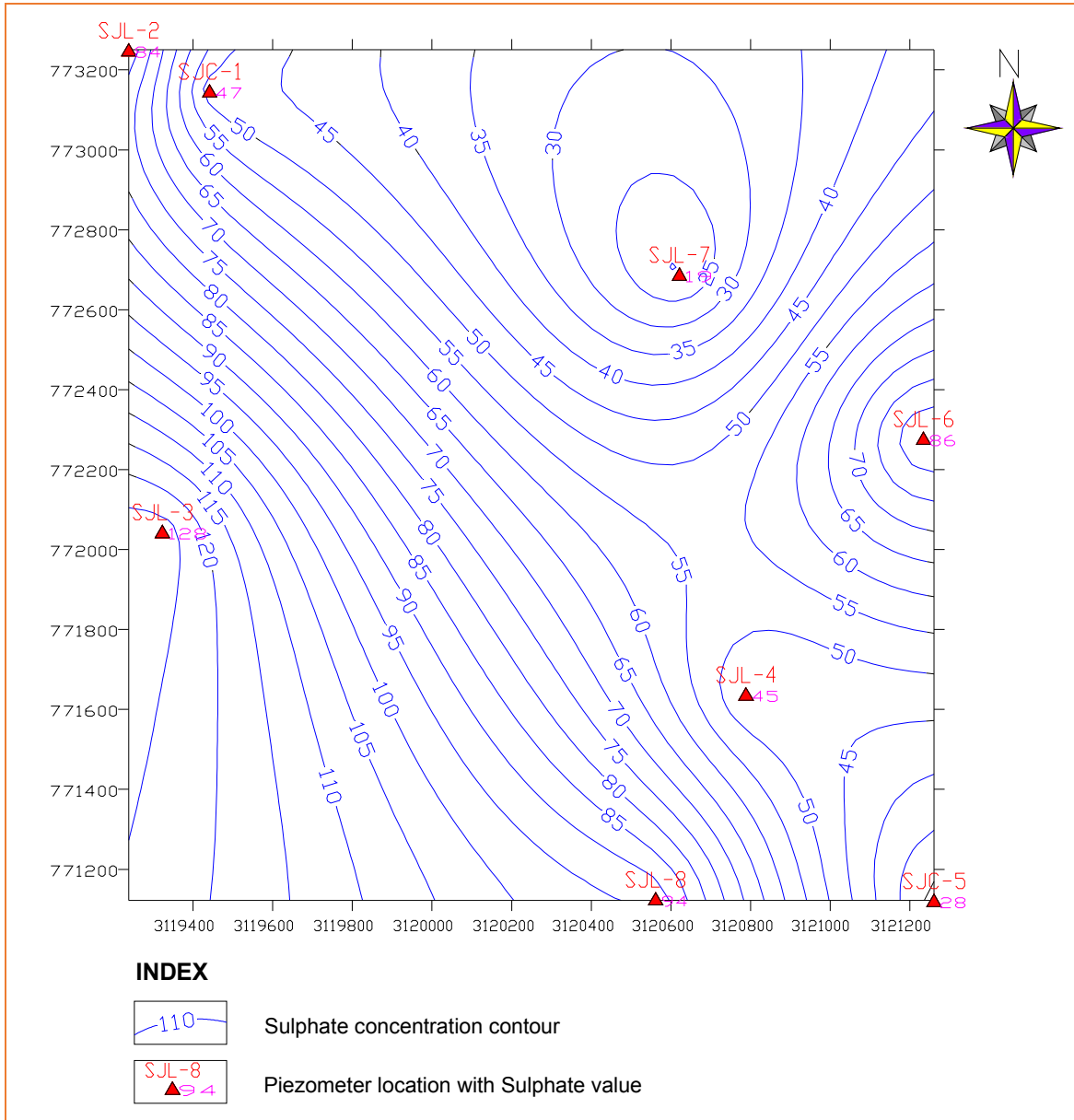
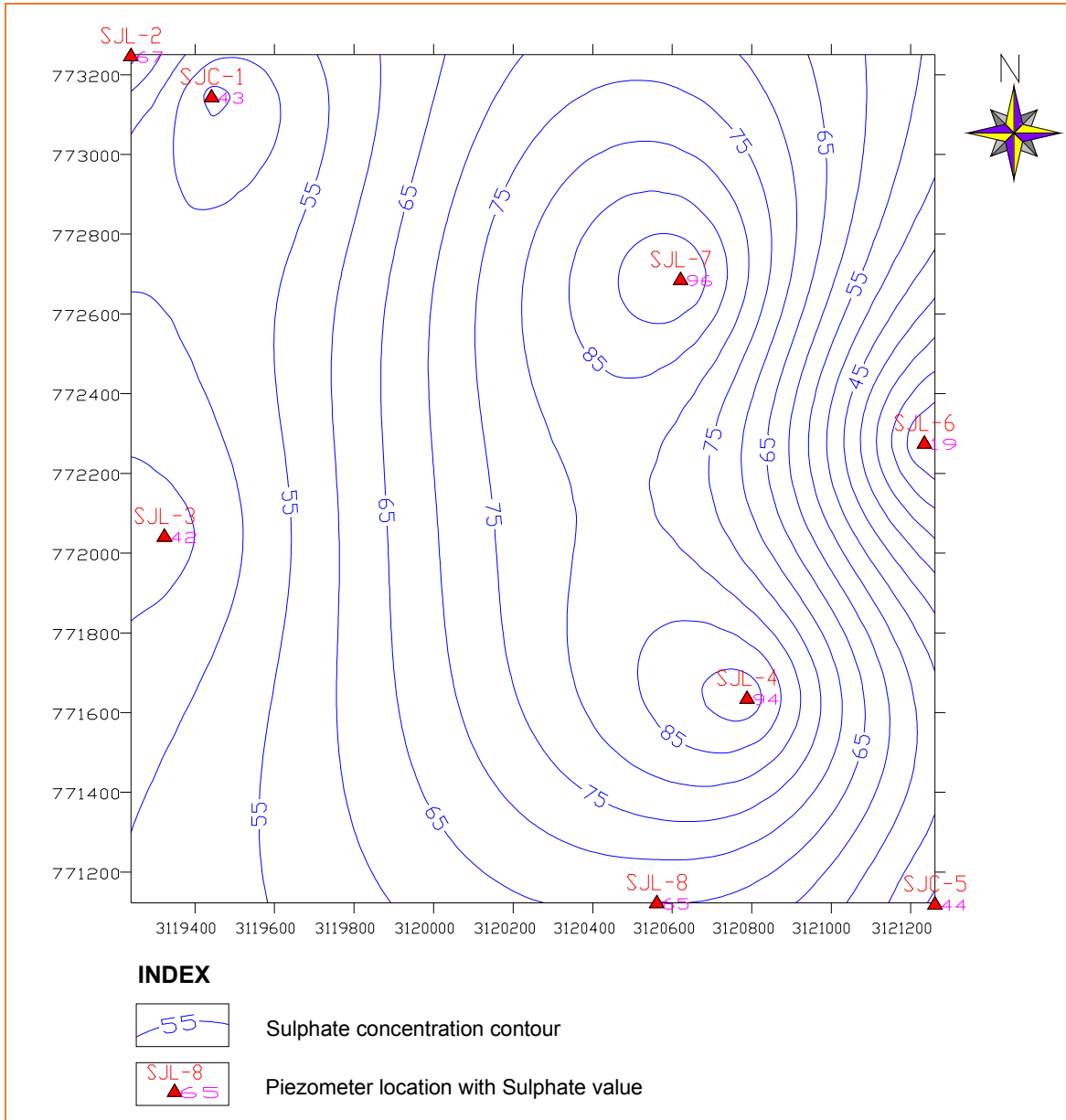


Figure-44: Post-monsoon Sulphate concentration contour map of water sample of piezometers in and around Jagannath OCP, Talcher coalfield, Odisha



6.3.3.8 Nitrate

In the study area, nitrate concentrations ranges from 0.44 mg/L to 29.70 mg/L in pre-monsoon season and from 1.33 mg/L to 32.80 mg/L in post-monsoon season in phreatic aquifer and in deeper aquifer nitrate concentration ranges from 2.66 mg/L to 7.53 mg/L in pre-monsoon season and from 3.99 mg/L to 7.97 mg/L in post-monsoon season. Mandatory maximum limit for drinking water supplies is 45.00 mg/L. Contours of Nitrate concentration as observed from village dug wells water sample, tube well water and water sample from piezometers are given in figures 45 to 48.

Figure-45: Pre-monsoon Nitrate concentration contour map of water sample from Open Dug wells & Tube well in and around Jagannath OCP, Talcher coalfield, Odisha

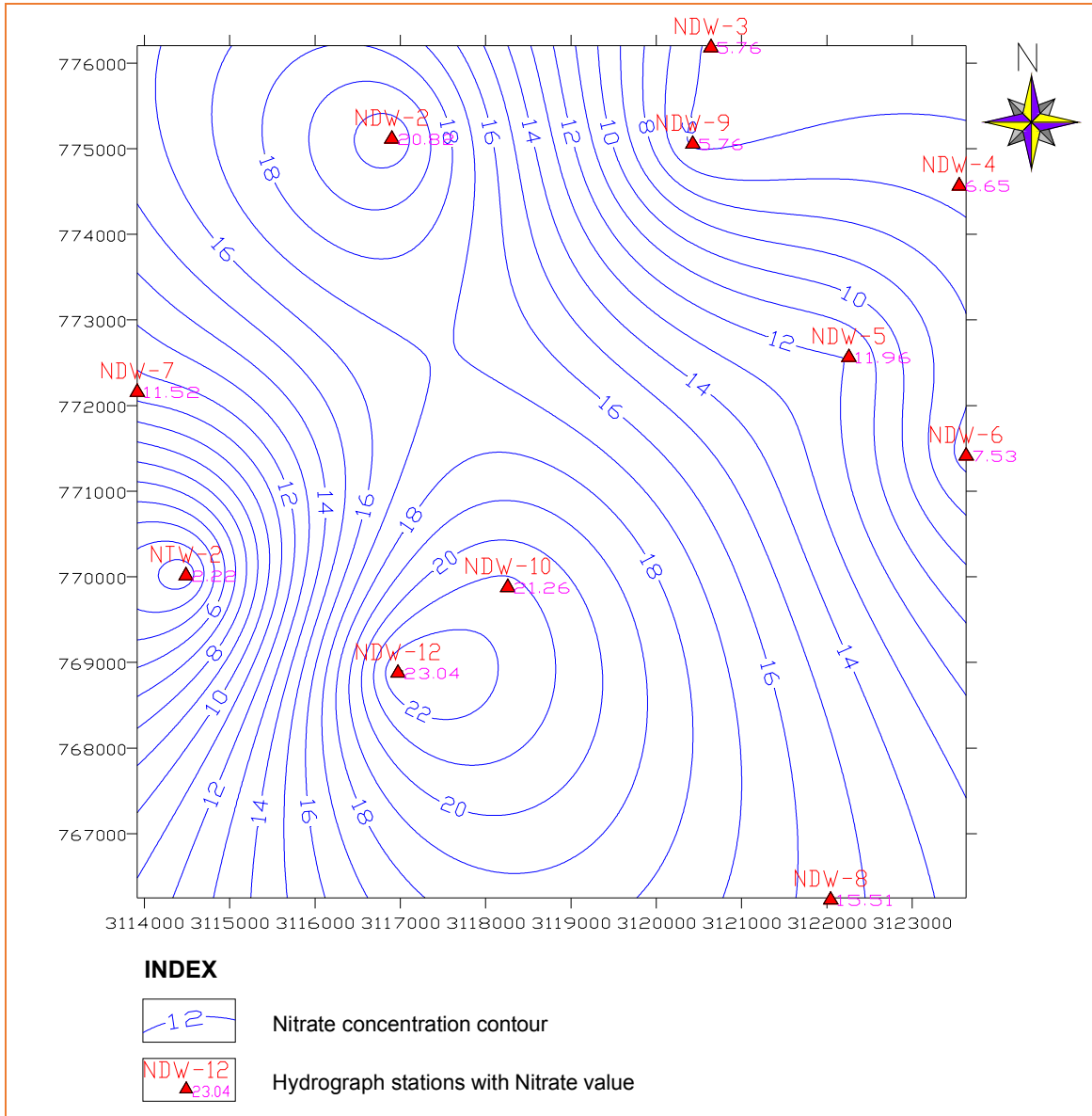


Figure-46: Post-monsoon Nitrate concentration contour map of water sample from Open Dug wells & Tube well in and around Jagannath OCP, Talcher coalfield, Odisha

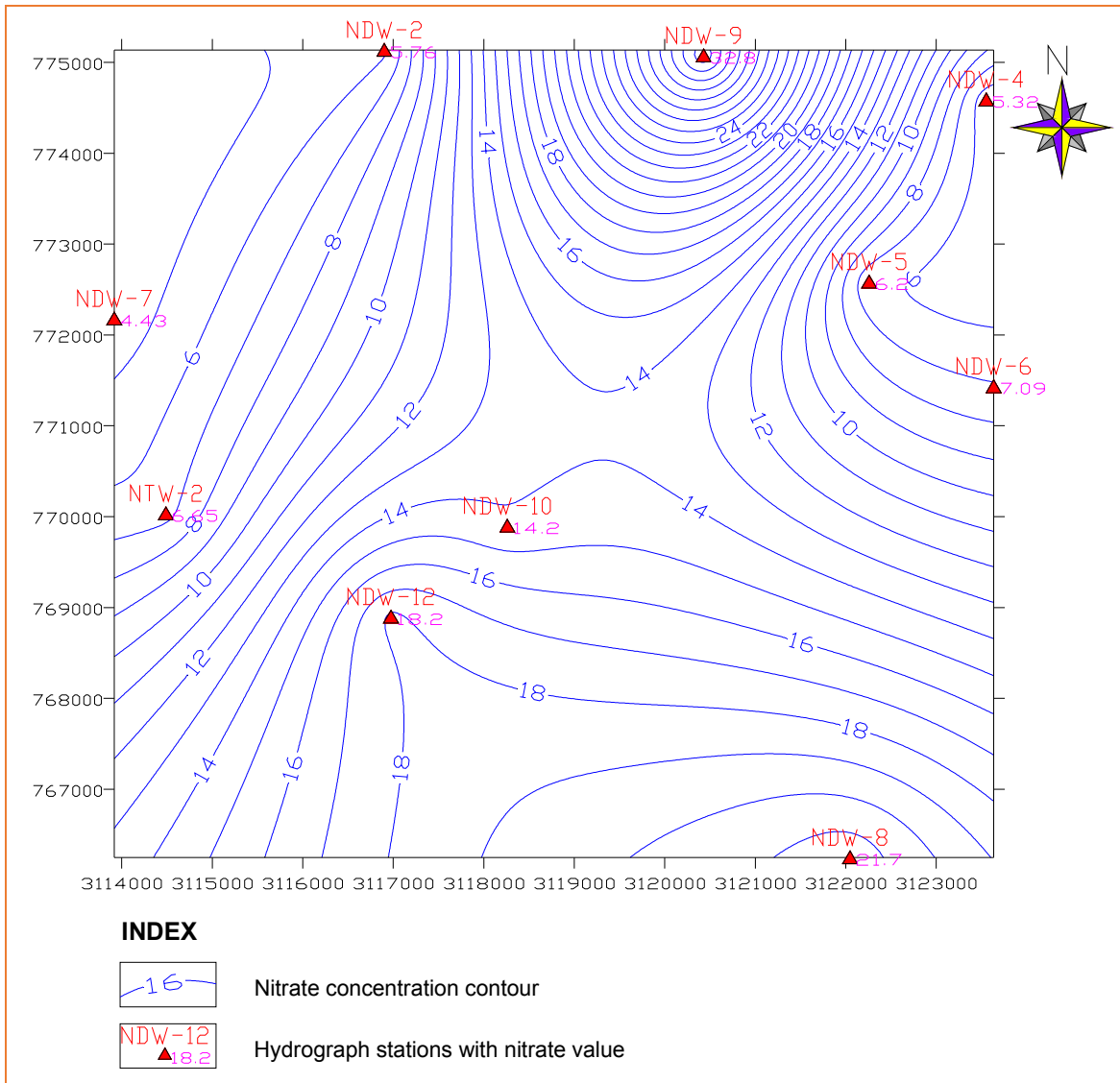


Figure-47: Pre-monsoon Nitrate concentration contour map of water sample of piezometers in and around Jagannath OCP, Talcher coalfield, Odisha

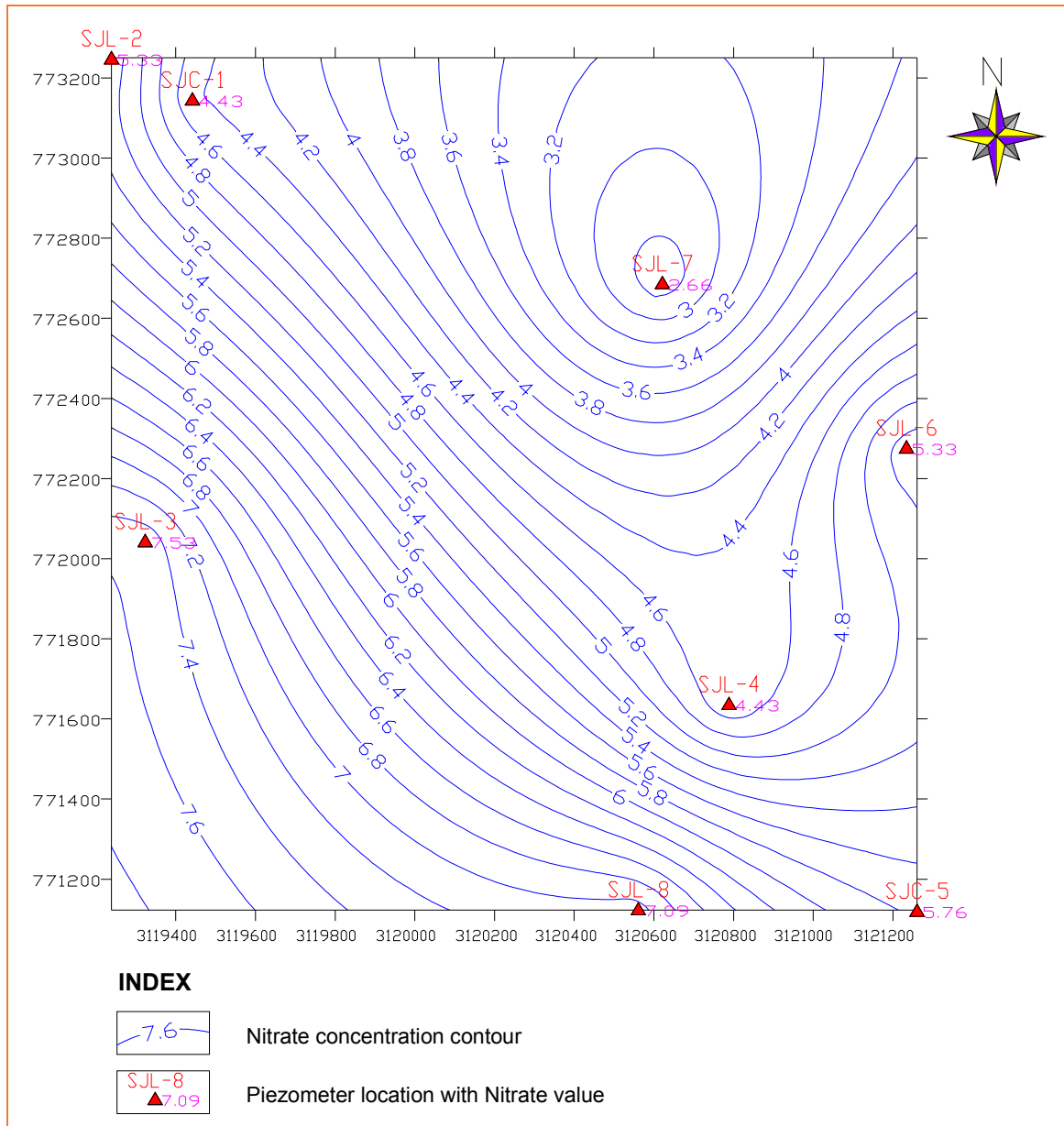
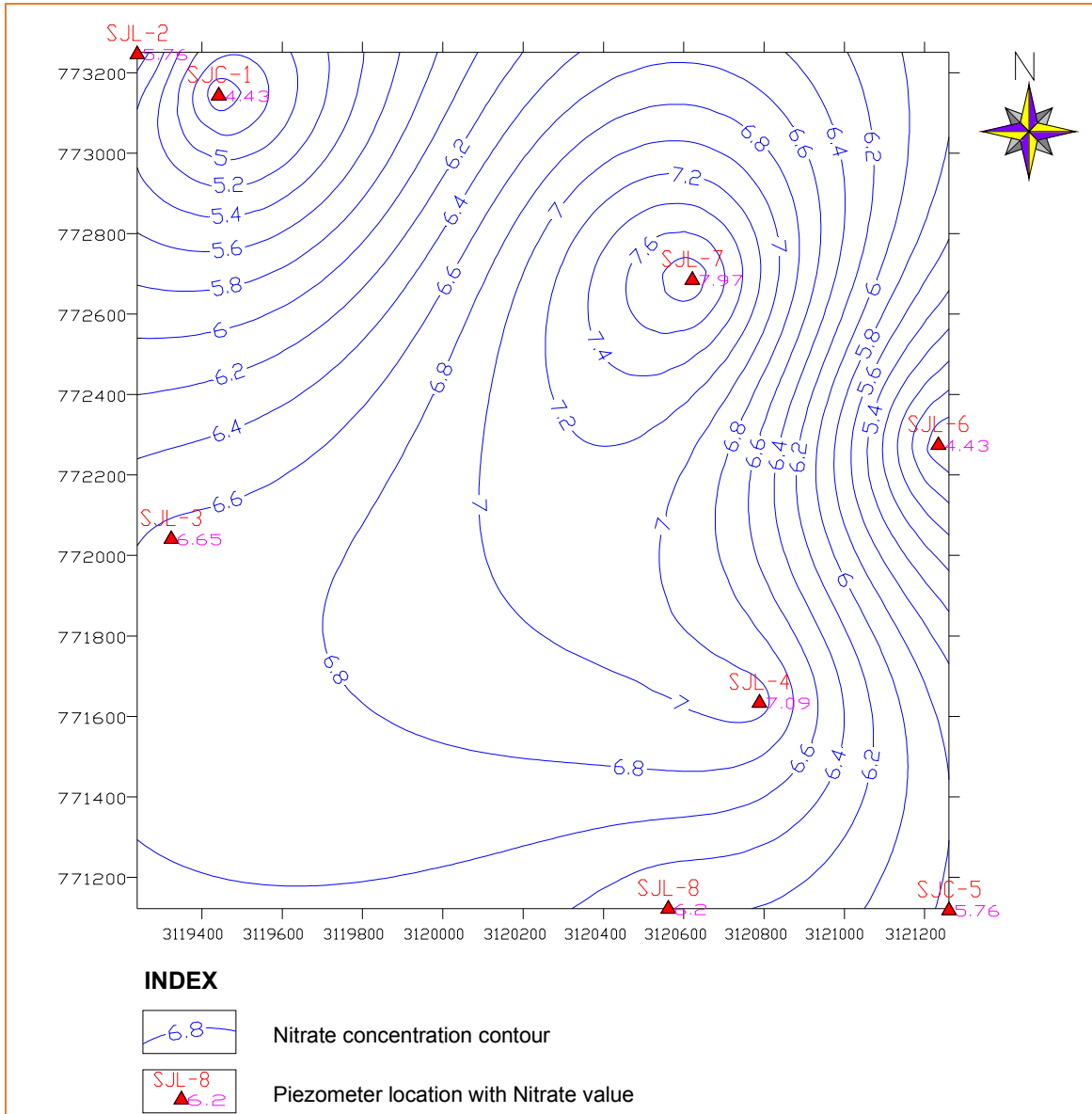


Figure-48: Post-monsoon Nitrate concentration contour map of water sample of piezometers in and around Jagannath OCP, Talcher coalfield, Odisha



6.3.3.9 Zinc

Zinc is present in phreatic aquifer in concentration ranging from 0.02 mg/L to 0.36 mg/L in pre-monsoon season and from 0.01 mg/L to 0.34 mg/L in post-monsoon season and in deeper aquifer zinc concentration ranges from 0.02 mg/L to 0.73 mg/L in pre-monsoon season and not detected in post-monsoon season. Recommended maximum limit for public water supplies is 5.00 mg/L as per BIS 10500 drinking water standards.

6.3.3.10 Fluoride

Fluoride is present in phreatic aquifer in concentration between 0.02 mg/L to 1.68 mg/L in pre- monsoon season and between 0.04 mg/L to 1.67 mg/L in post-monsoon season and in deeper aquifer, fluoride concentration ranges from 0.10 mg/L to 0.65 mg/L in pre-monsoon season and from 0.08 mg/L to 0.70 mg/L in post-monsoon season. Recommended maximum limit for public water supplies is 1.00 mg/L as per BIS 10500 drinking water standards. Most of the fluoride found in groundwater is naturally occurring from the breakdown of rocks and soils or weathering. Fluoride can also come from runoff and infiltration of chemical fertilizers in agricultural areas and sewage treatment system discharges in groundwater system. Activated alumina filtration, distillation, ion exchange or reverse osmosis treatment methods can reduce the concentration of fluoride in drinking water but are expensive for use in small water systems or households.

Contours of Fluoride concentration as observed from village dug wells water sample, tube well water and water sample from piezometers are presented in figures 49 to 52.

Figure-49: Pre-monsoon Fluoride concentration contour map of water sample from Open Dug wells & Tube well in and around Jagannath OCP, Talcher coalfield, Odisha

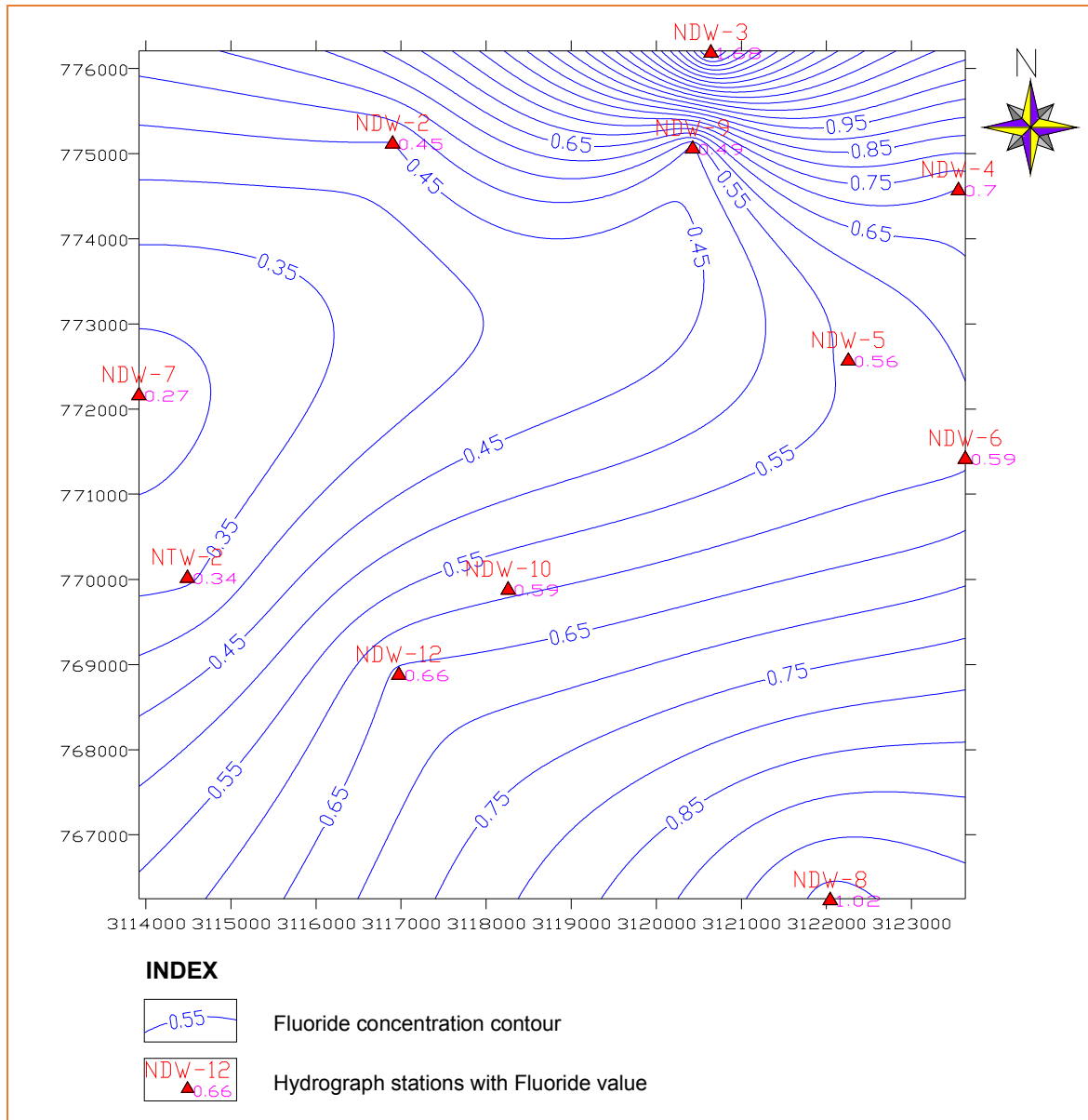


Figure-50: Post-monsoon Fluoride concentration contour map of water sample from Open Dug wells & Tube well in and around Jagannath OCP, Talcher coalfield, Odisha

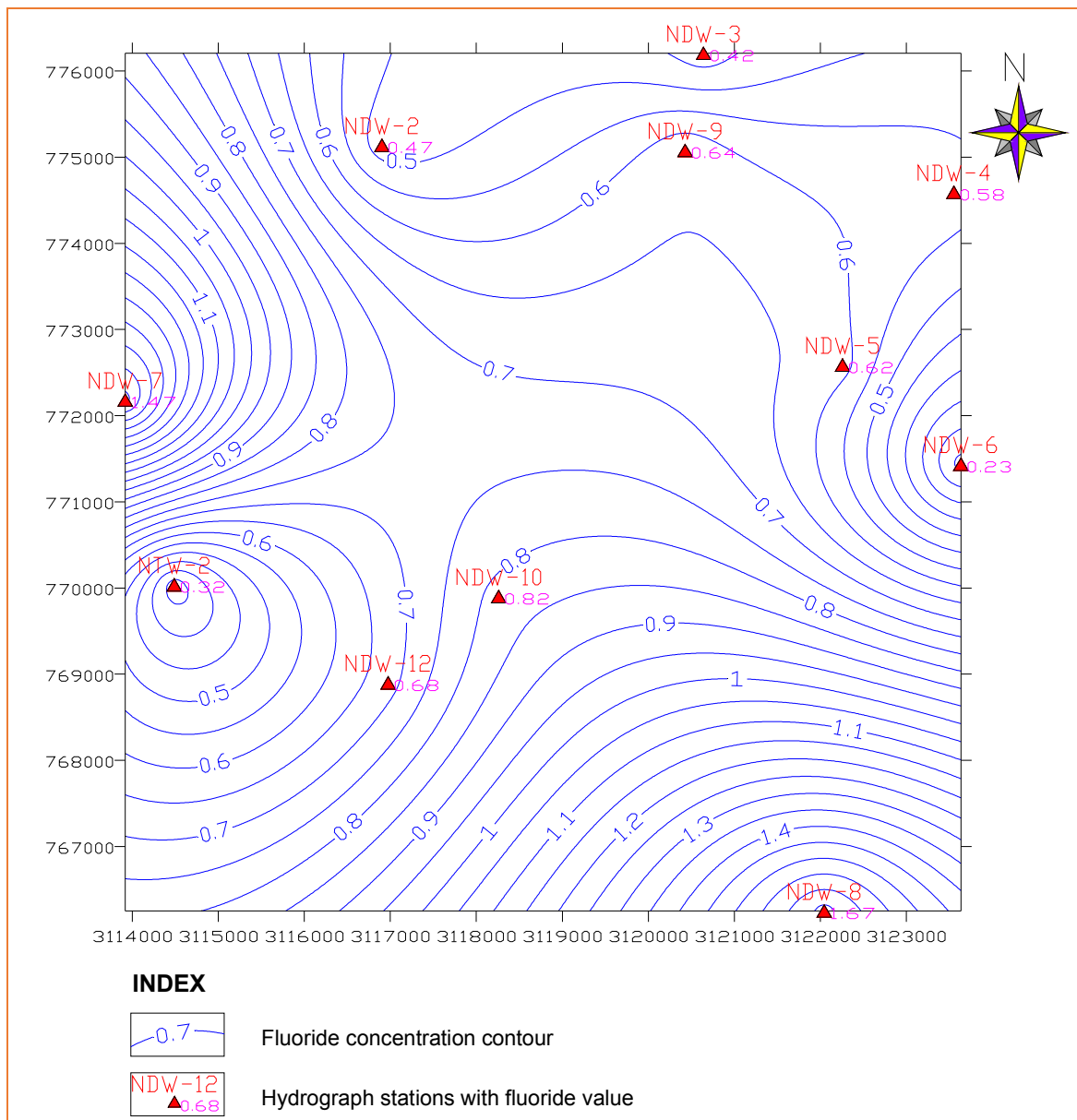


Figure-51: Pre-monsoon Fluoride concentration contour map of water sample of piezometers in and around Jagannath OCP, Talcher coalfield, Odisha

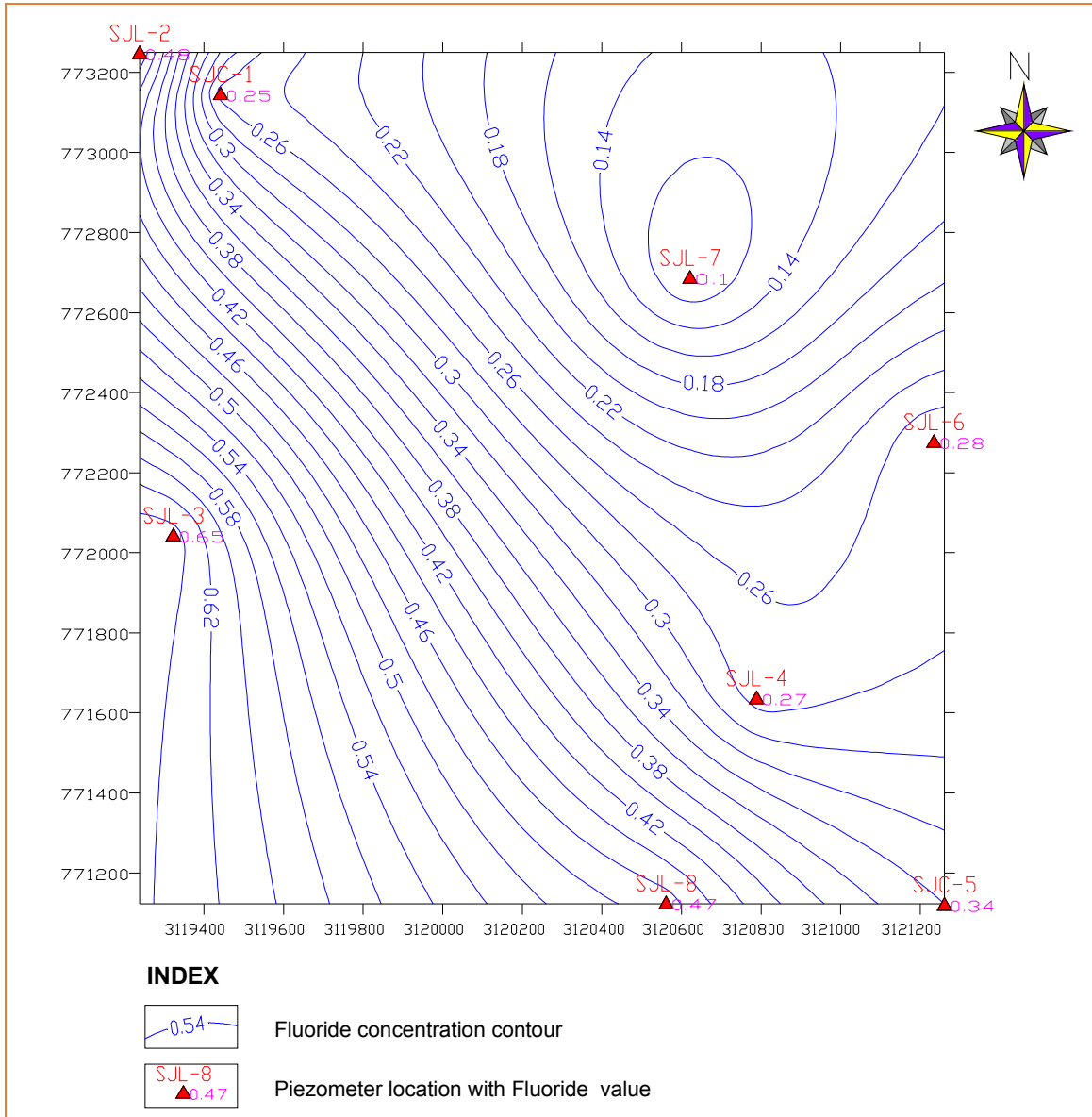
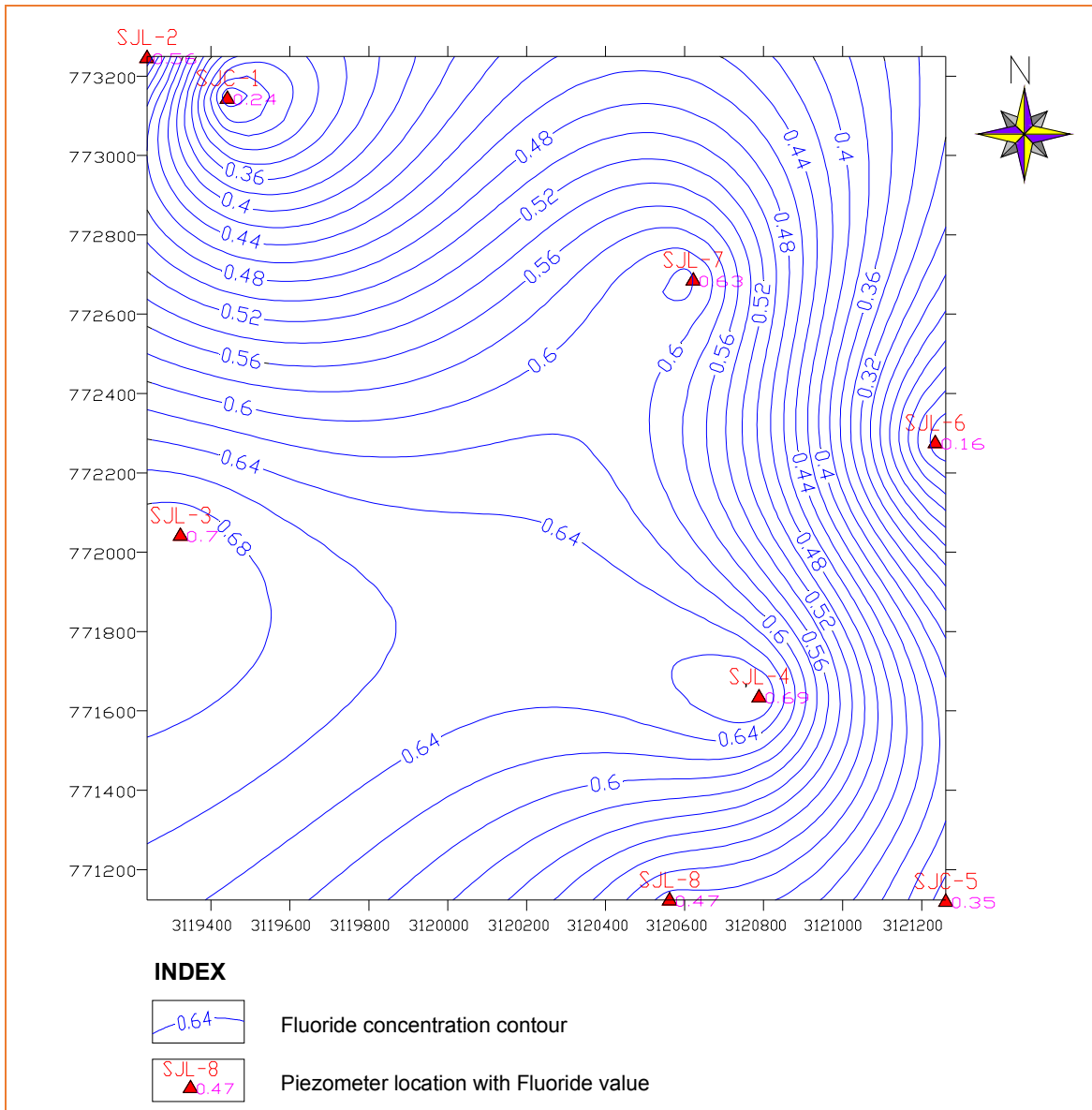


Figure-52: Post-monsoon Fluoride concentration contour map of water sample of piezometers in and around Jagannath OCP, Talcher coalfield, Odisha



6.3.3.11 Chloride

Chloride is present in phreatic aquifer in concentration between 18.00 mg/L to 370.00 mg/L in pre- monsoon season and between 8.00 mg/L to 680.00 mg/L in post-monsoon season and in deeper aquifer chloride concentration ranges from 14.00 mg/L to 40.00 mg/L in pre-monsoon season and from 8.00 mg/L to 76.00 mg/L in post-monsoon season. Recommended maximum limit for public water supplies is 250.00 mg/L as per BIS 10500 drinking water standards. High chloride concentrations in groundwater can be attributed to both natural and anthropogenic sources like normal run off, excessive use of inorganic fertilizers, landfill leachates, septic tank effluents, animal feeds, industrial effluents and irrigation drainage. Contours of Chloride concentration as observed from village dug wells water sample, tube well water and water sample from piezometers are presented in figures 53 to 56.

Figure-53: Pre-monsoon Chloride concentration contour map of water sample from Open Dug wells & Tube well in and around Jagannath OCP, Talcher coalfield, Odisha

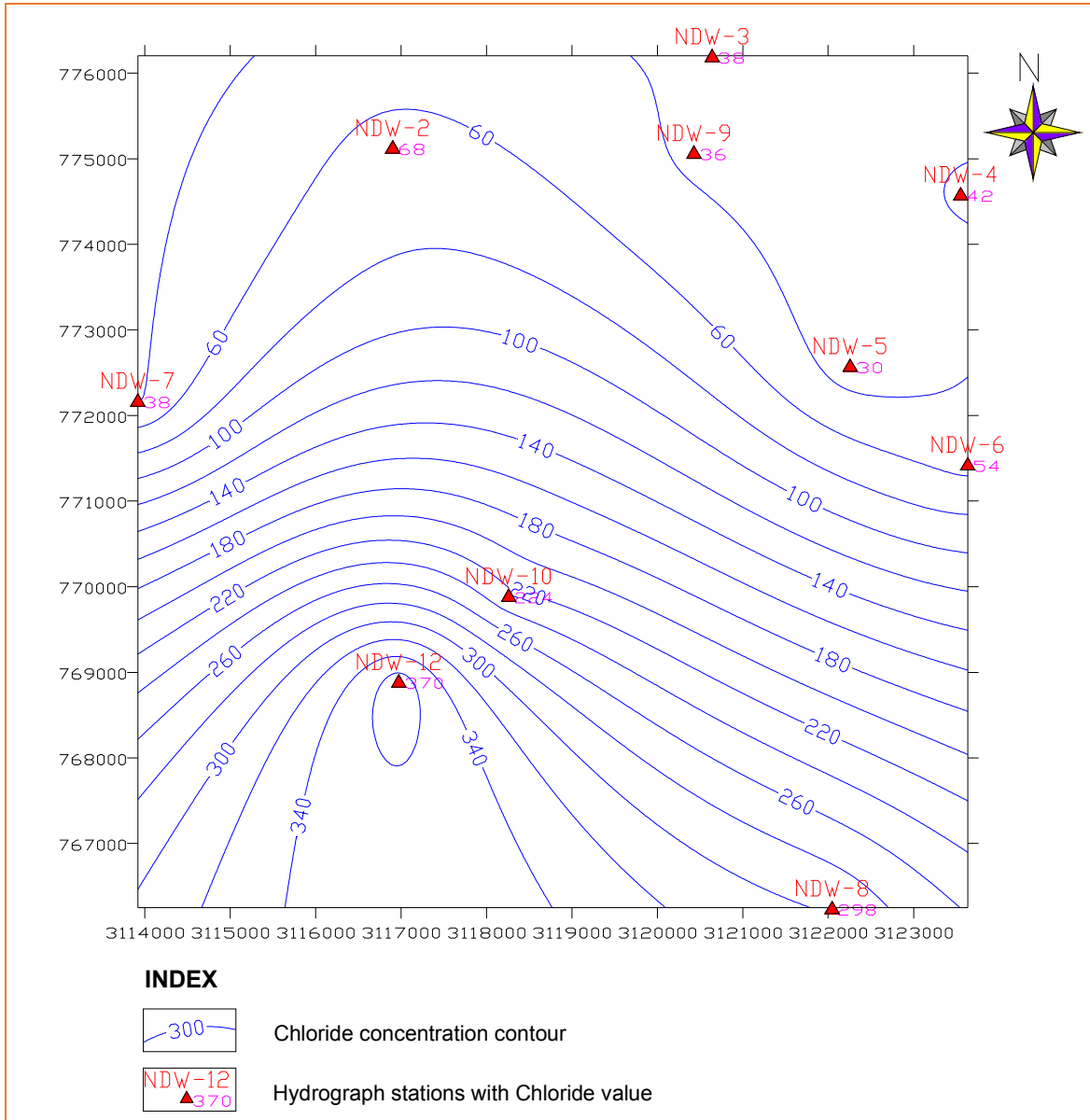


Figure-54: Post-monsoon Chloride concentration contour map of water sample from Open Dug wells & Tube well in and around Jagannath OCP, Talcher coalfield, Odisha

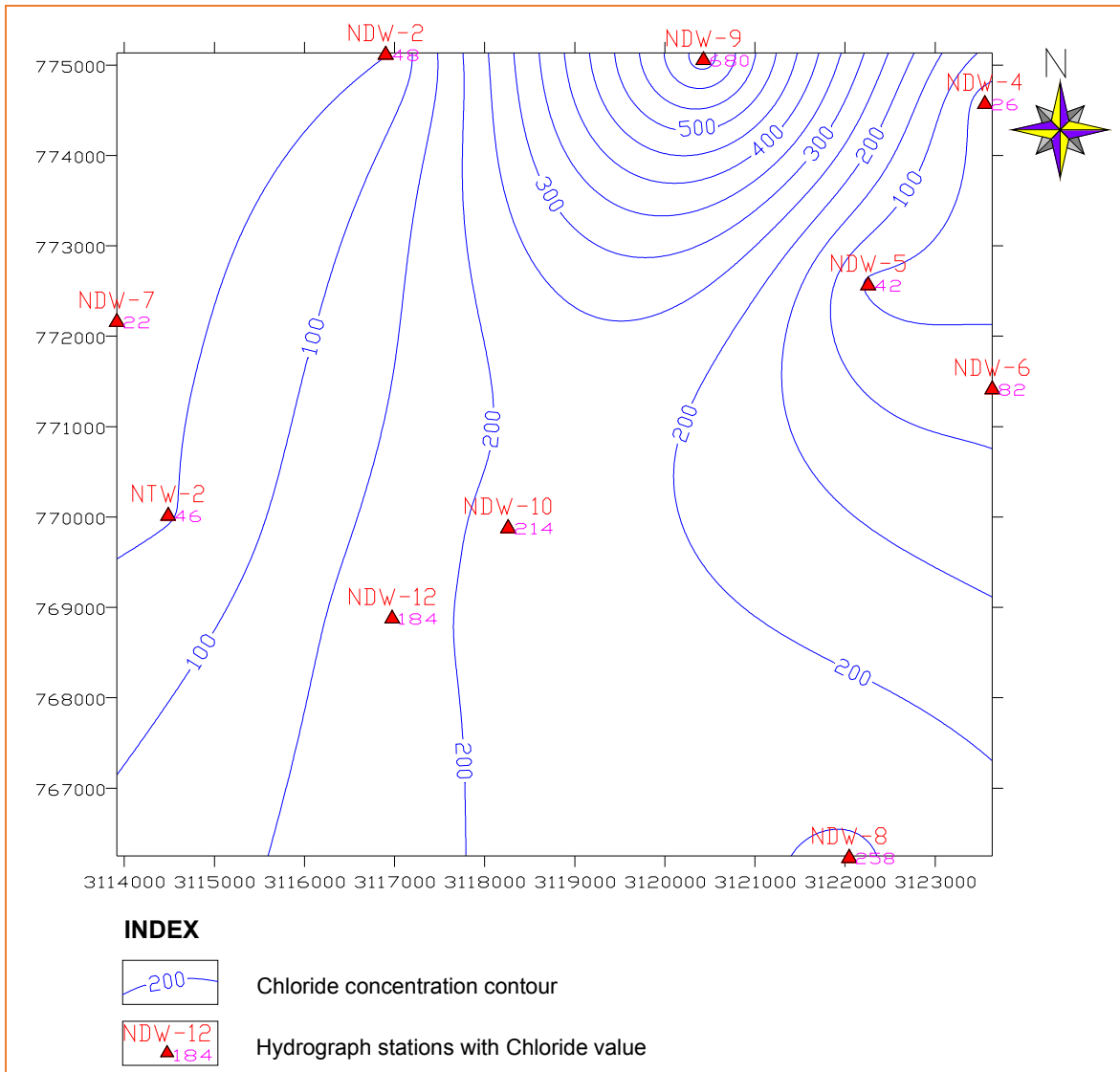


Figure-55: Pre-monsoon Chloride concentration contour map of water sample of piezometers in and around Jagannath OCP, Talcher coalfield, Odisha

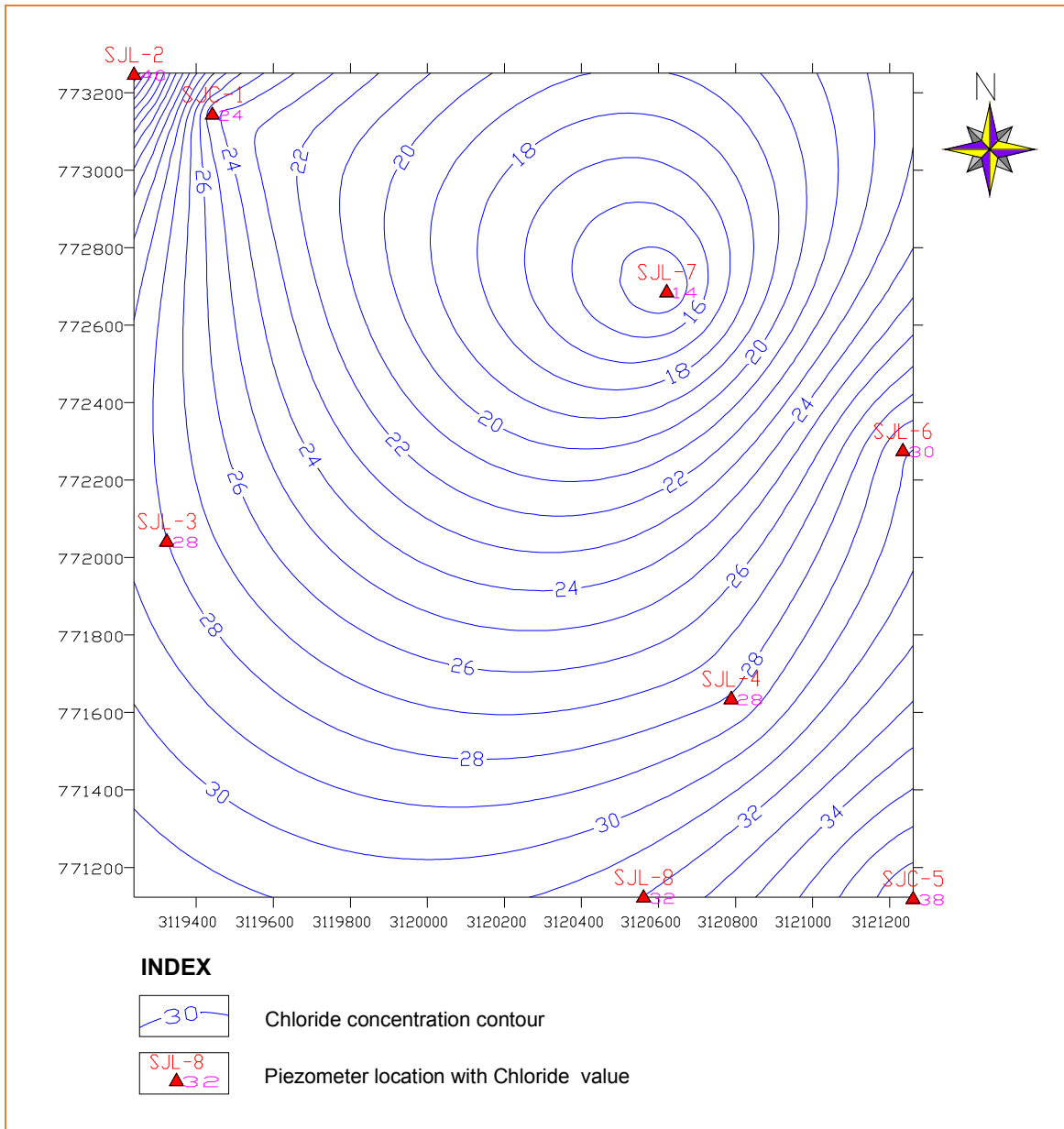
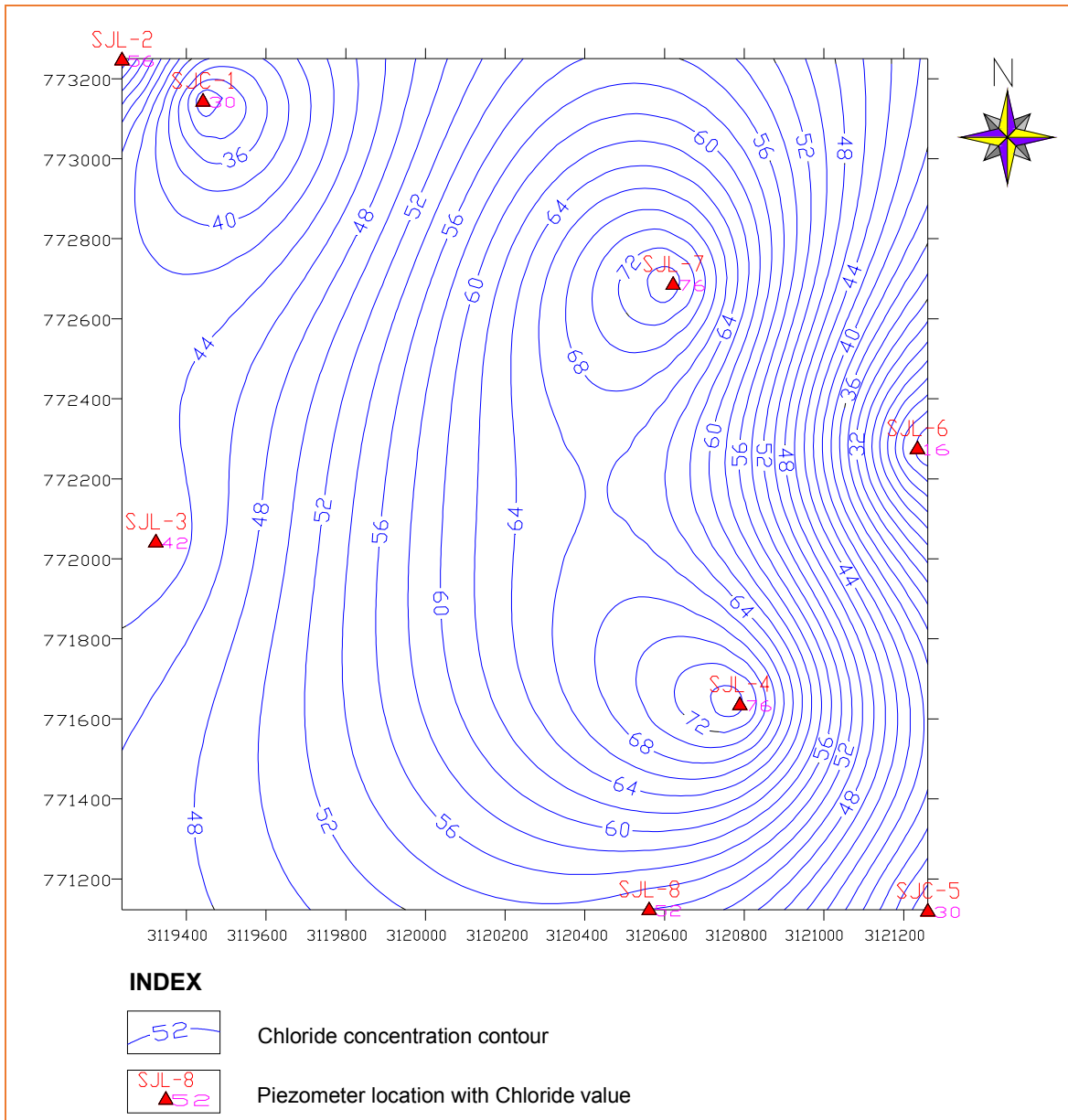


Figure-56: Post-monsoon Chloride concentration contour map of water sample of piezometers in and around Jagannath OCP, Talcher coalfield, Odisha



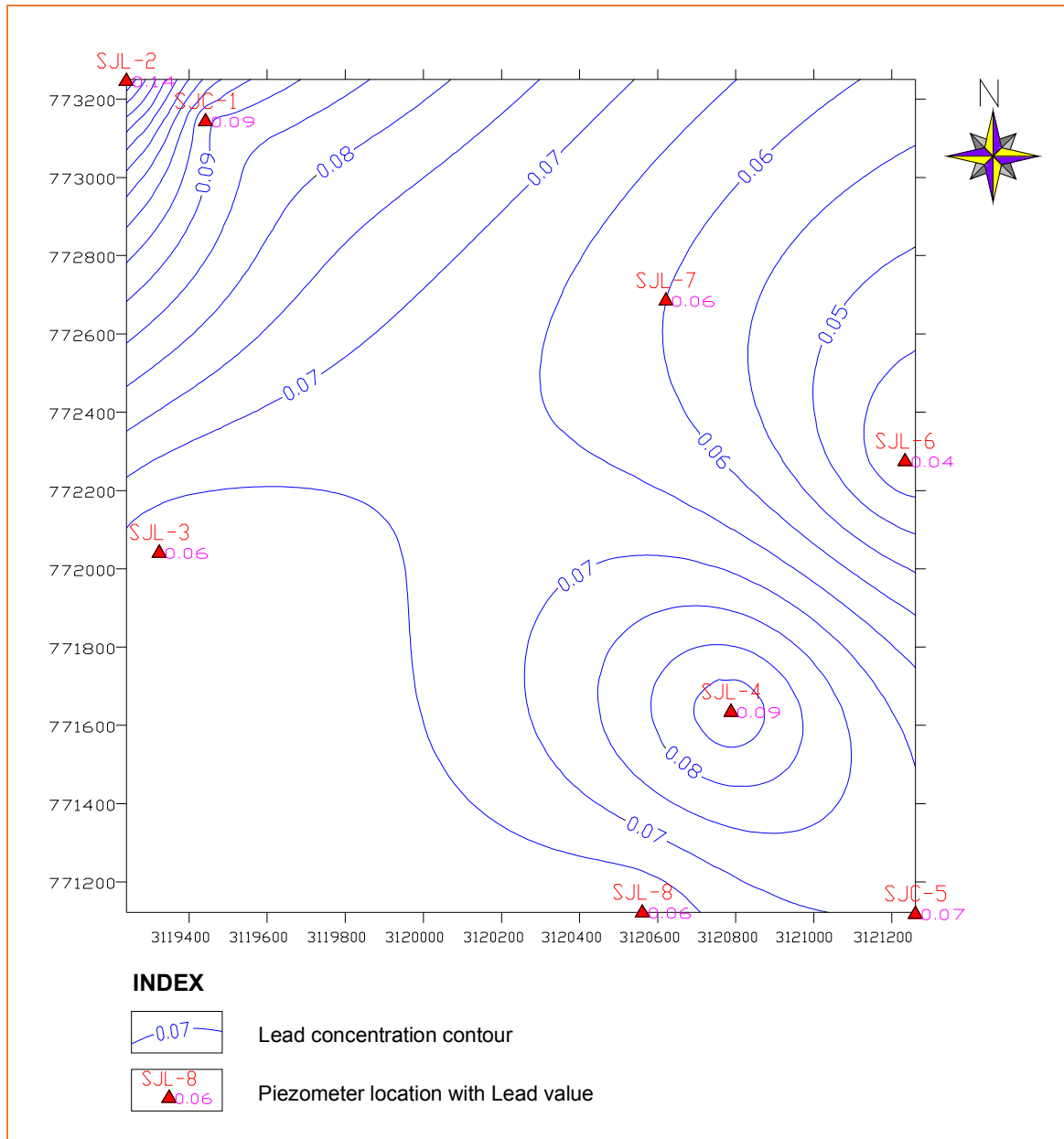
6.3.3.11 Iron (Fe)

In the study area, iron is present below detection limit in phreatic aquifer and in deeper aquifer iron is detected at SJC-1 with concentration 1.27 mg/L in pre-monsoon season and present below detection limit in post-monsoon season. The recommended maximum iron concentration for drinking water is 0.30 mg/L. The extent to which iron dissolve in groundwater depends on the amount of oxygen, if groundwater is oxygen poor, iron will dissolve more readily. The amount of dissolved iron in groundwater vary seasonally for a given well. Usually this is associated with an influx of oxygenated water from the surface during periods of high recharge. This oxygenated water will prevent iron from dissolving and the water pumped from the well will have low concentrations of iron.

6.3.3.12 Lead (Pb)

In the study area, lead concentration in phreatic aquifer is detected below detection limit during both sampling events in pre-monsoon and post monsoon season. In deeper aquifer lead concentration ranges from 0.06 mg/L to 0.14 mg/L in pre-monsoon season and it is observed below the detection limit for post-monsoon season. The recommended maximum lead concentration for drinking water is 0.05 mg/L. Contours of lead concentration as observed from water sample from piezometers are presented in figures 57.

Figure-57: Pre-monsoon Lead concentration contour map of water sample of piezometers in and around Jagannath OCP, Talcher coalfield, Odisha



6.3.3.13 Cadmium (Cd)

In the study area, cadmium concentration in phreatic aquifer is detected below detection limit in both premonsoon and post monsoon season. In deeper aquifer, cadmium is present at concentration 0.09 mg/L in only one piezometer location SJL-2 in pre-monsoon season and present below detection limit in all piezometer location in post-monsoon season. The recommended maximum cadmium concentration for drinking water is 0.005 mg/L. Cadmium may be released to water by natural weathering processes, by discharge from industrial facilities or sewage treatment plants, atmospheric deposition, by leaching from landfills or soil, or phosphate fertilizers.

6.3.4 INTERPRETATION OF ANALYTICAL RESULTS

Based on current analysis result of groundwater samples, it may be observed that there are two distinct spheres of exceedance of analytes. The shallow groundwater of the phreatic aquifer in the study area shows elevated concentration of inorganic analytes like Calcium, Chloride, TDS, Fluoride, Total alkalinity and Total Hardness. Sulphate is also observed at elevated concentration in few shallow phreatic aquifer groundwater samples. The water samples collected from newly installed piezometers shows elevated concentration of few heavy metals in pre-monsoon season only. Heavy metals like Lead (Pb) uniformly present in almost all piezometer location except at piezometer location SJL-6. Manganese is also reported at elevated concentration at three piezometer locations (SJL-2, SJL-4, and SJL-8). Iron and Cadmium is also reported at elevated concentration at SJL-1 and SJL-2 respectively. Inorganic constituents like TDS and Calcium are reported from couple of locations viz. SJL-3 in pre-monsoon season and SJL-4 & SJL-7 in post monsoon season.

Presence of Lead (Pb) in concentration exceeding BIS 10500 drinking water standards in groundwater samples from most piezometers in study area indicates possibility of deep seated source of Pb and may be attributed to geogenic factors.

However continuous groundwater monitoring will help further understanding the source of lead in the area. It may be noted that hydrogeological investigation at Bharatpur OCP (Bharatpur South mine) by CMPDI in the year 2003 reported presence of lead in trace amount in groundwater samples of phreatic aquifer collected from villages Nakeiposhi, Dasrathipur, Padmabatipur, South Balanda and Hensamul.

High Calcium and TDS concentrations can be attributed to weathering of sedimentary rock and calcium bearing minerals. Very localized presence of Iron and Cadmium above recommended levels indicates impact possibly due to anthropogenic activity.

In the study area, groundwater is primary source of drinking water. It was reported that neighbouring residential and industrial areas use groundwater as the source of water supply. Therefore, groundwater sensitivity (potential significance of any impact, in case groundwater gets contaminated, also a hypothetical indicator) at study area is considered to be very high due to:

- dependence on groundwater resources for potable water supply; and
- proximity of receptors within approximately 1 km radius from the study area.

It is recommended to implement monitoring system of groundwater to assess attenuation rate of current analytes, active on-site releases and any other potential contamination sources. It is also recommended that no usage of deeper aquifer groundwater abstracted onsite for any sensitive applications without appropriate filtration. Heavy metals such as iron, manganese, lead, and cadmium can dissolve from soil into groundwater as a process of leaching, thus it is also recommended that sampling and analysis of soil samples at various depths below ground level in and around the study area may be undertaken to evaluate background concentration of heavy metals and inorganic constituents in weathered zone.

The disposal of flyash is considered a potential source of contamination due to the enrichment and surface association of trace elements in the ash particles. The elements Manganese, Barium, Vanadium, Cobalt, Chromium, Nickel, Zinc, Selenium, Lead, Mercury, and Sulphur in coal are volatile to a significant extent in the combustion process. During transport, disposal, and storage phases, the residue from coal combustion are subjected to leaching effects of rain and part of the undesirable components in the ash may pollute both ground and surface waters. This solid residue (flyash) can be leached in higher concentrations than drinking water standards and can cause contamination in drinking water sources. Flyash contains trace amounts of metals that may have negative effects on human health and on plants. Hence, it is recommended that Toxicity Characteristic Leaching Procedure (TCLP) studies should be undertaken to understand the leaching potential of heavy metals present in flyash generated from power plants of NTPC.

The main mode of disposal of flyash to ash disposal sites from the power plant is in the form of slurry after mixing with water. Studies have shown that dissolution of heavy metals is based on the chemistry of the water. pH of water is a prime factor along with other parameters like dissolved oxygen (DO), oxidation-reduction potential (ORP), specific conductivity and temperature that affect mobility of these metals. Also given the fact that the neighbouring areas are occupied by many industries which emit many harmful toxic gases into the atmosphere, the possibility of rain water being acidic cannot be ruled out in the study area. Hence it is recommended that acidic water chemical reaction test of the flyash may be undertaken to understand the mobility and chemical behaviour of heavy metals with acidic waters.

6.4 HISTORICAL PHREATIC AQUIFER GROUNDWATER QUALITY

Available phreatic aquifer groundwater quality data from dug wells from nearby villages Rakas, Dera, Jilinda and tube well of Jagannath project office of both pre-monsoon and post-monsoon season for the period 2008 to 2013 was collected from Environment department monitoring cell of RI-VII, CMPDI to understand variation and background distribution of parameters like pH, Iron, Chloride, Dissolved Solids, Calcium, Sulphate, Nitrate, Fluoride, Zinc in phreatic aquifer. The concentration is plotted in figures 58 to 93. Details are compiled and presented in Annexure III.D. Year on year (2008 to 2013) variation of the analytes and their increasing or decreasing trends from village dugwell water and tubewell water are compiled in table 6.4.A.

Table 6.4.A Year on Year Trends of Analytes in and around Jagannath OCP, Talcher coalfield, Odisha

Analytes	pH		Fe		Cl		TDS		Ca		SO ₄		NO ₃		F		Zn	
	Pr	Po	Pr	Po	Pr	Po	Pr	Po	Pr	Po	Pr	Po	Pr	Po	Pr	Po	Pr	Po
Rakas	↓	↓	↓	↑	↑	↓	↑	↓	↑	↓	↑	↓	↓	↓	↑	↓	↓	↓
Jilinda	↓	↓	↓	↓	↑	↑	↑	↑	↓	↓	↓	↑	↓	↓	↓	↓	↓	↓
Dera	↓	↓	↓	↓	↓	↑	↓	↑	↓	↑	↓	↓	↓	↑	↓	↓	↓	↓
Jagannath PO	↑	↓	↓	↓	↑	↓	↑	↓	↓	↓	↓	↓	↓	↑	↔	↓	↓	↓

Pr- Pre-Monsoon; Po-Post Monsoon; ↑ Increasing Trends; ↓ Decreasing Trends; ↔ Stable

Figure-58: Variation of pH in dug well water in village Rakas, around Jagannath OCP, Talcher coalfield, Odisha

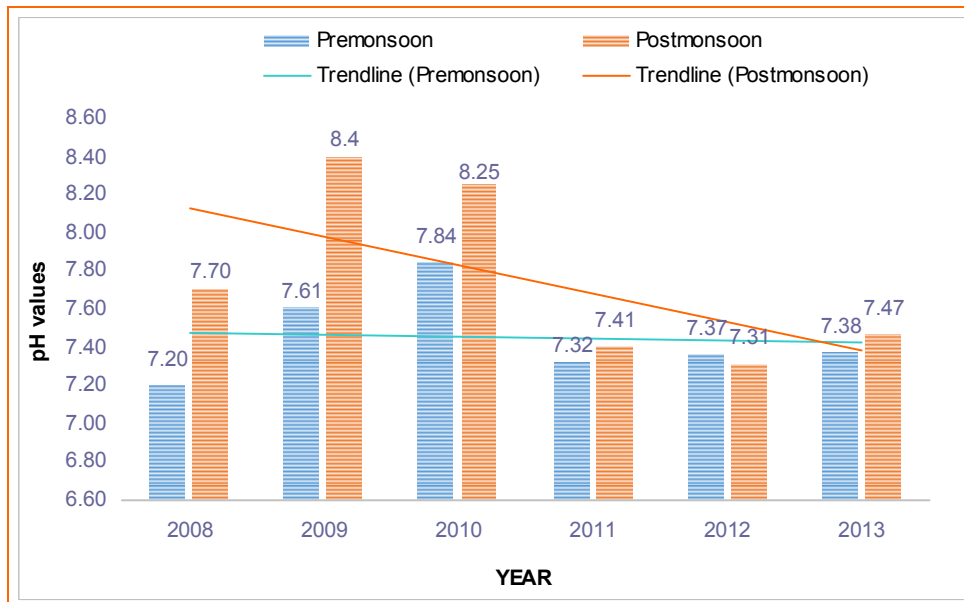


Figure-59: Variation of Iron in dug well water in village Rakas, around Jagannath OCP, Talcher coalfield, Odisha

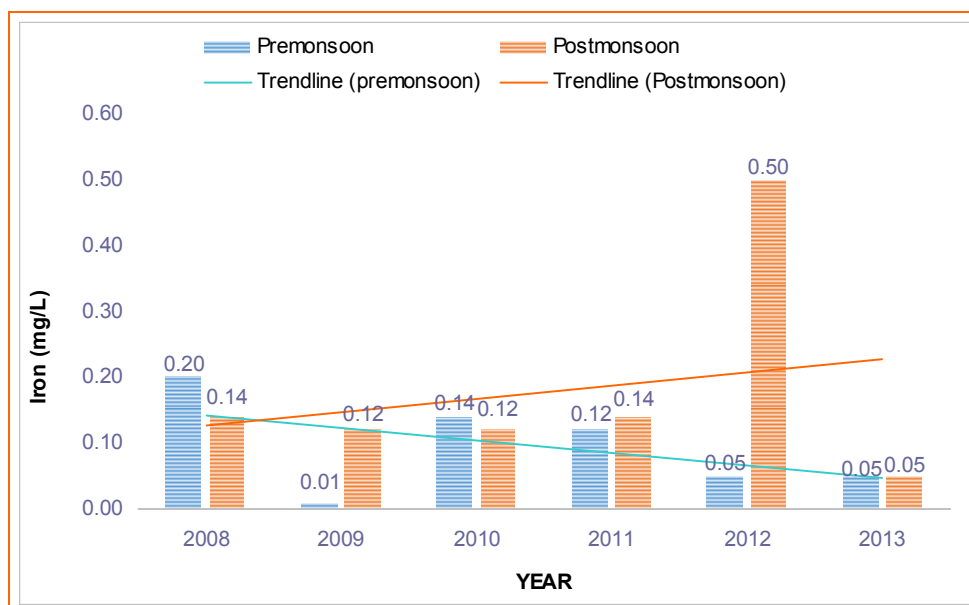


Figure-60: Variation of Chloride in dug well water in village Rakas, around Jagannath OCP, Talcher coalfield, Odisha

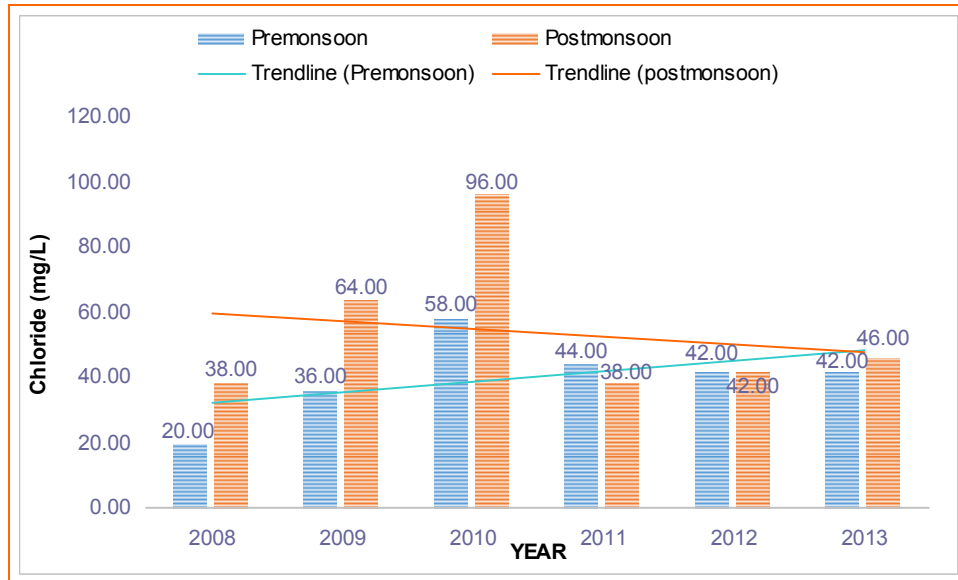


Figure-61: Variation of TDS in dug well water in village Rakas, around Jagannath OCP, Talcher coalfield, Odisha

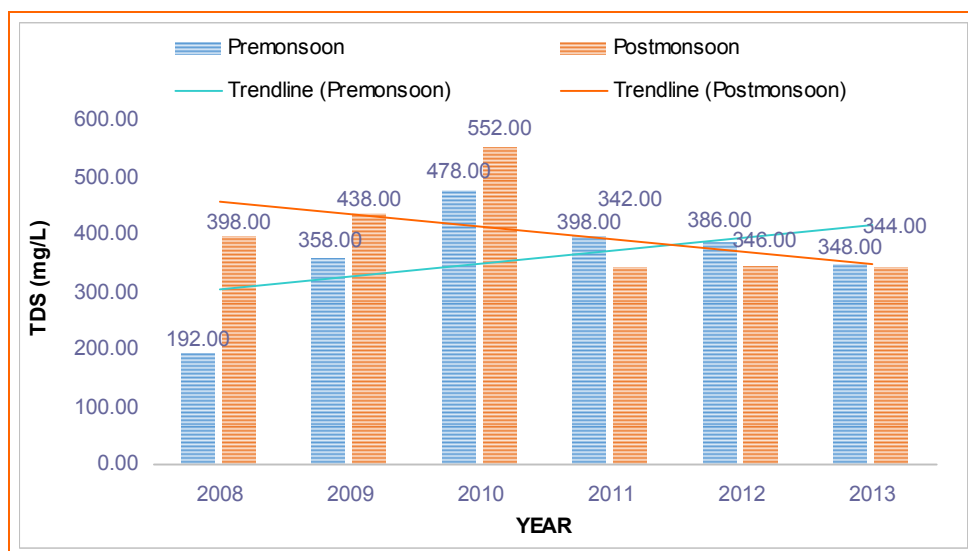


Figure-62: Variation of Calcium in dug well water in village Rakas, around Jagannath OCP, Talcher coalfield, Odisha

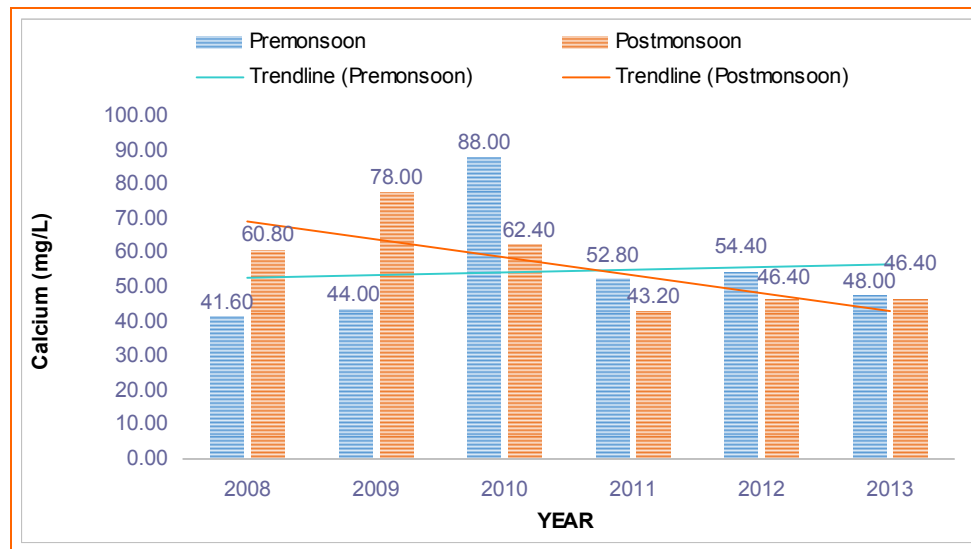


Figure-63: Variation of Sulphate in dug well water in village Rakas, around Jagannath OCP, Talcher coalfield, Odisha

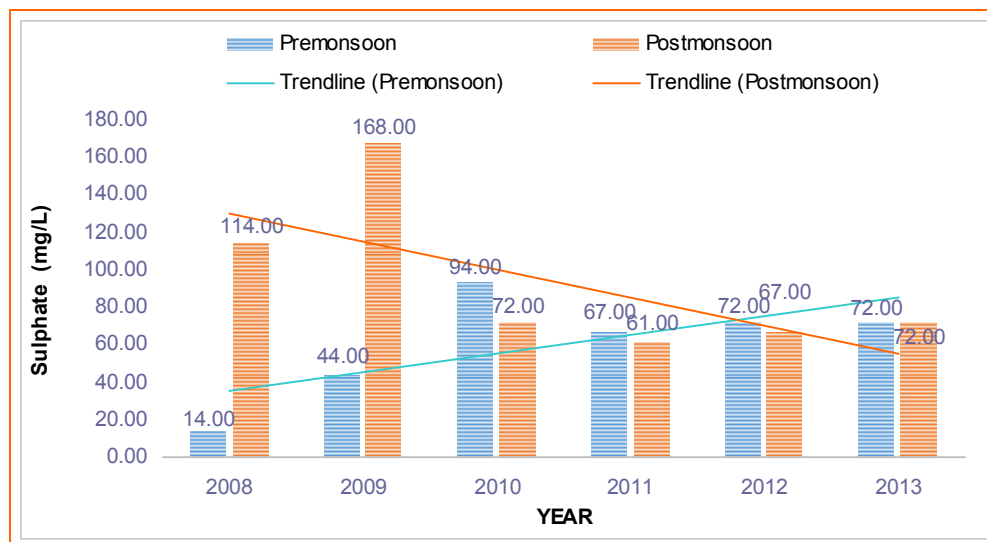


Figure-64: Variation of Nitrate in dug well water in village Rakas, around Jagannath OCP, Talcher coalfield, Odisha

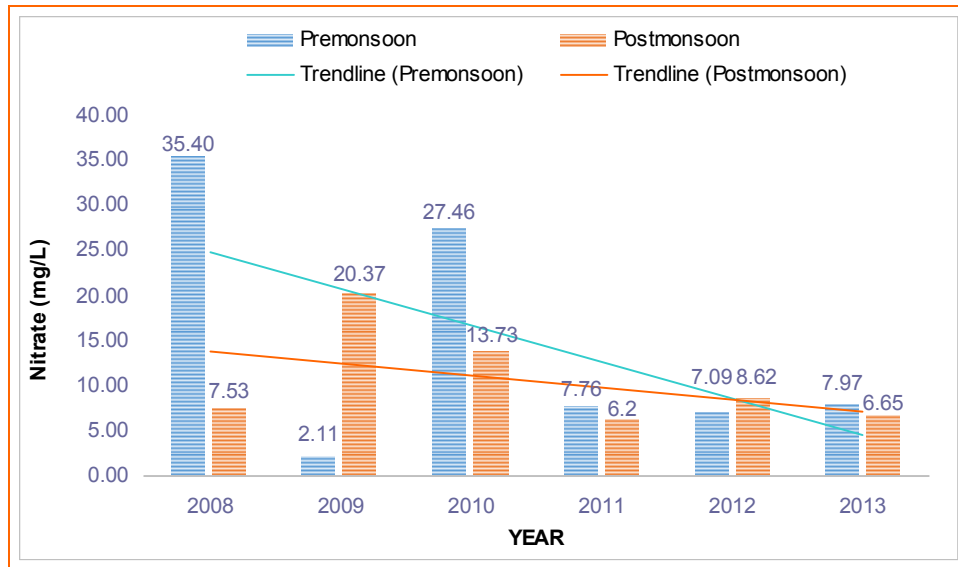


Figure-65: Variation of Fluoride in dug well water in village Rakas, around Jagannath OCP, Talcher coalfield, Odisha

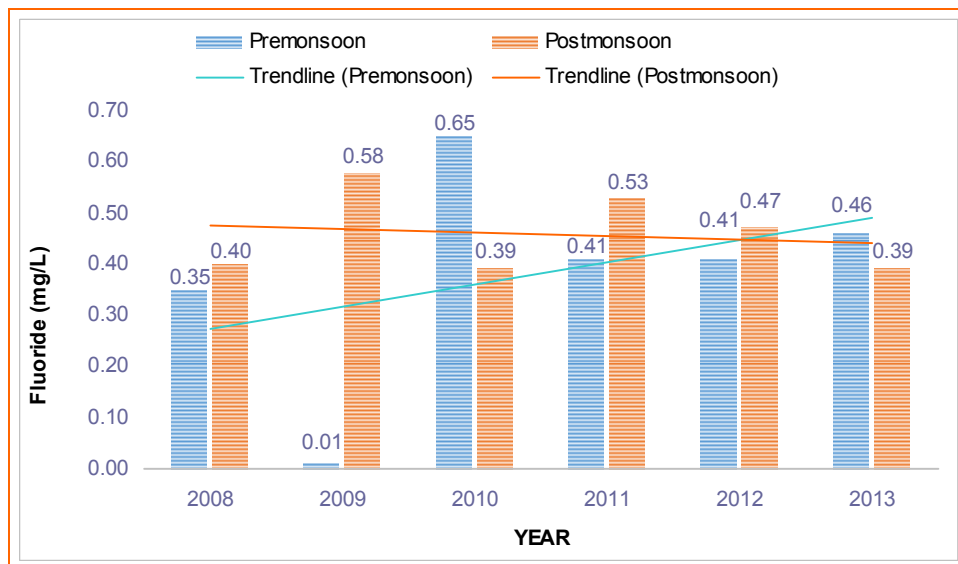


Figure-66: Variation of Zinc in dug well water in village Rakas, around Jagannath OCP, Talcher coalfield, Odisha

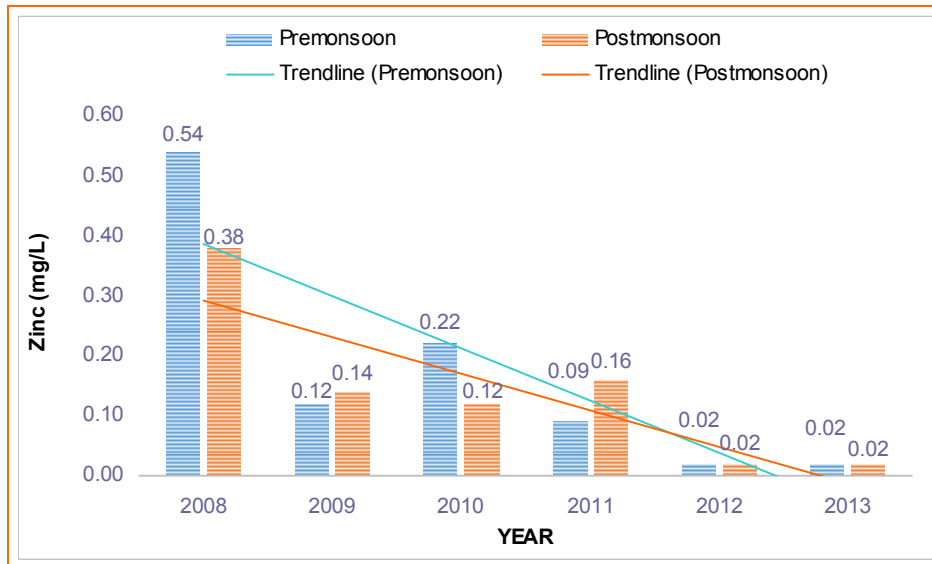


Figure-67: Variation of pH in dug well water in village Jilinda, around Jagannath OCP, Talcher coalfield, Odisha

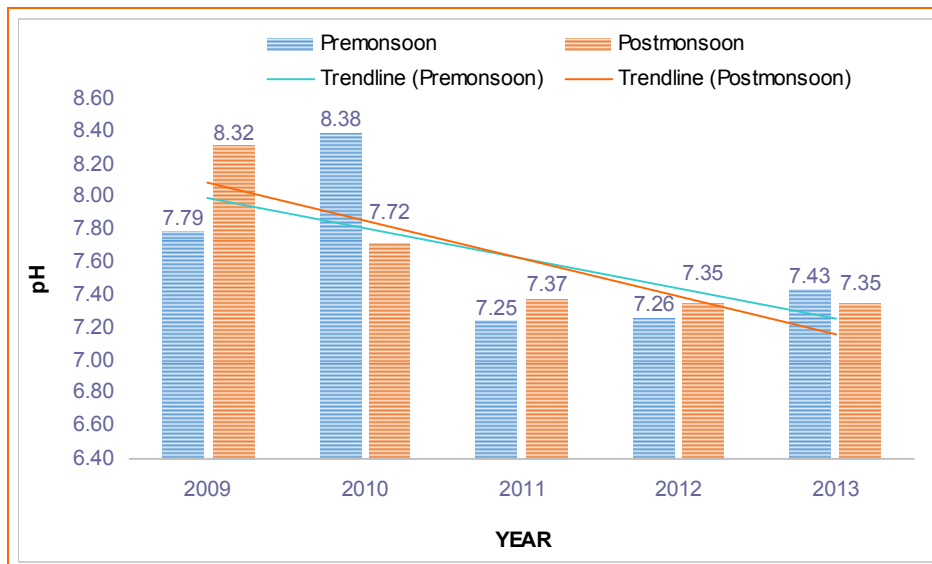


Figure-68: Variation of Iron in dug well water in village Jilinda, around Jagannath OCP, Talcher coalfield, Odisha

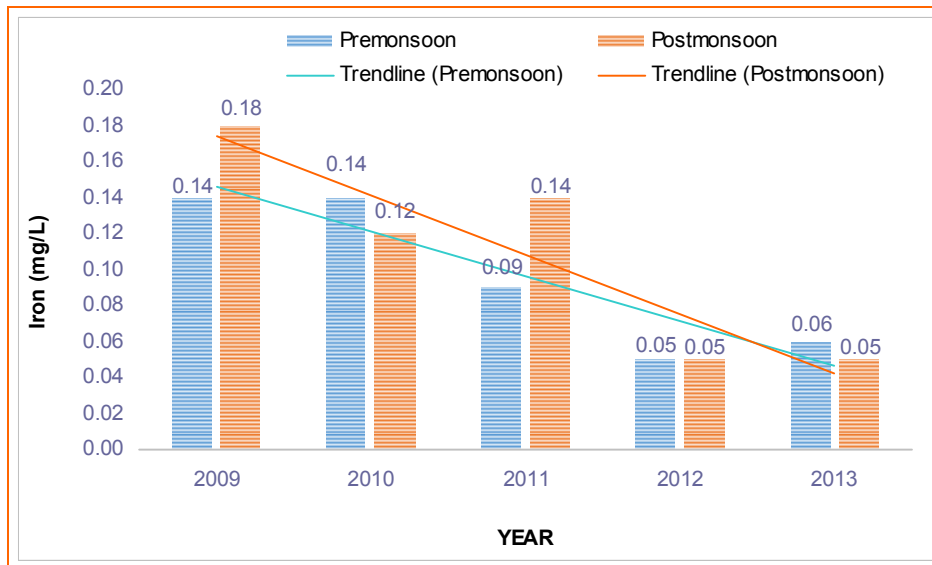


Figure-69: Variation of Sulphate in dug well water in village Jilinda, around Jagannath OCP, Talcher coalfield, Odisha

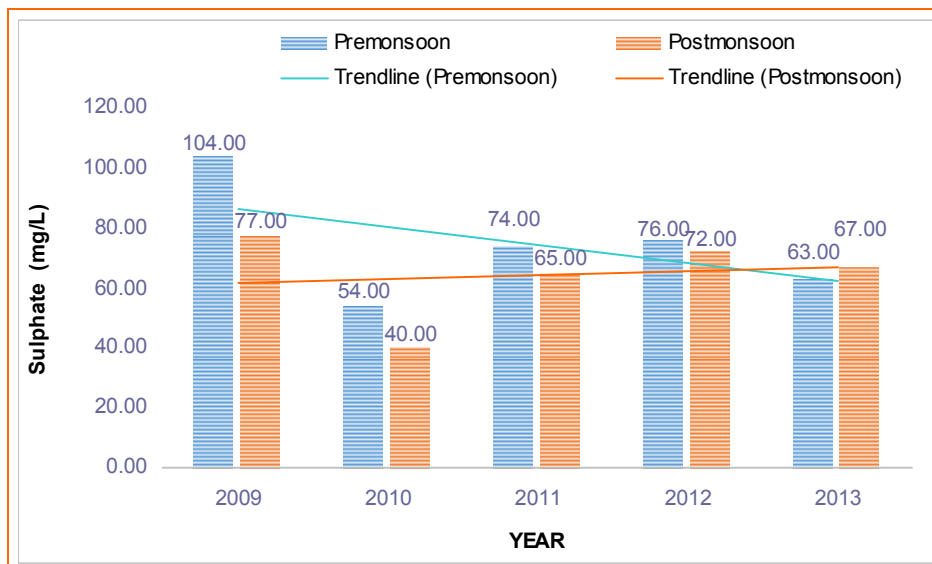


Figure-70: Variation of TDS in dug well water in village Jilinda, around Jagannath OCP, Talcher coalfield, Odisha

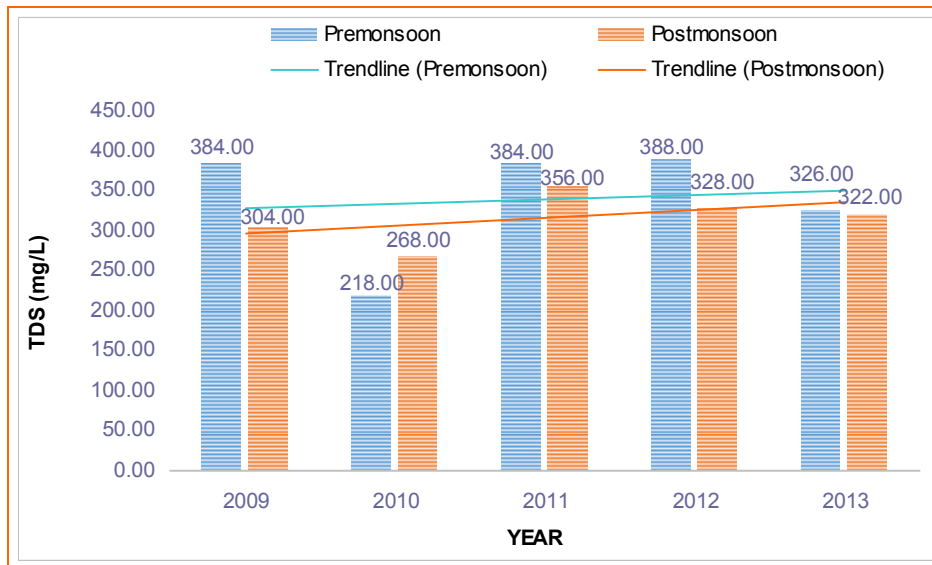


Figure-71: Variation of Calcium in dug well water in village Jilinda, around Jagannath OCP, Talcher coalfield, Odisha

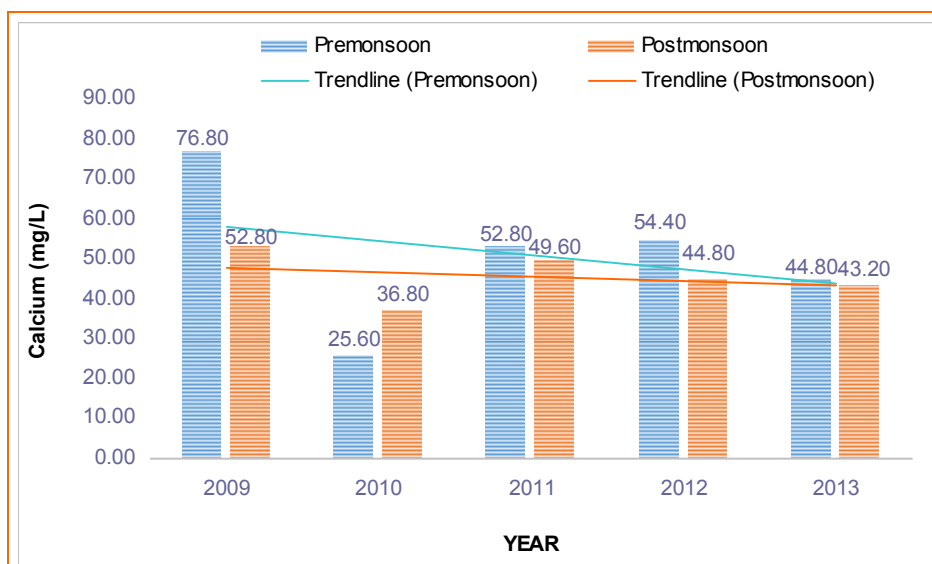


Figure-72: Variation of Chloride in dug well water in village Jilinda, around Jagannath OCP, Talcher coalfield, Odisha

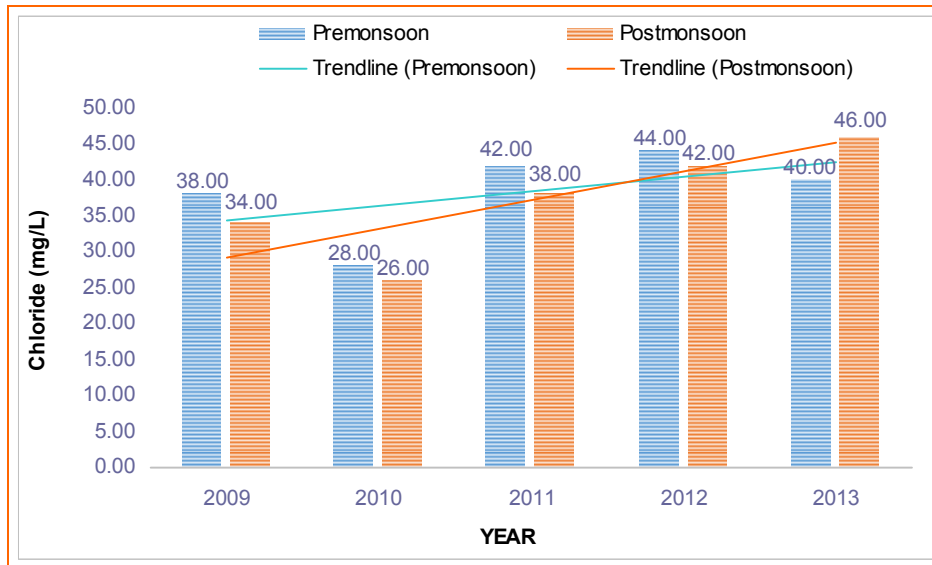


Figure-73: Variation of Nitrate in dug well water in village Jilinda, around Jagannath OCP, Talcher coalfield, Odisha

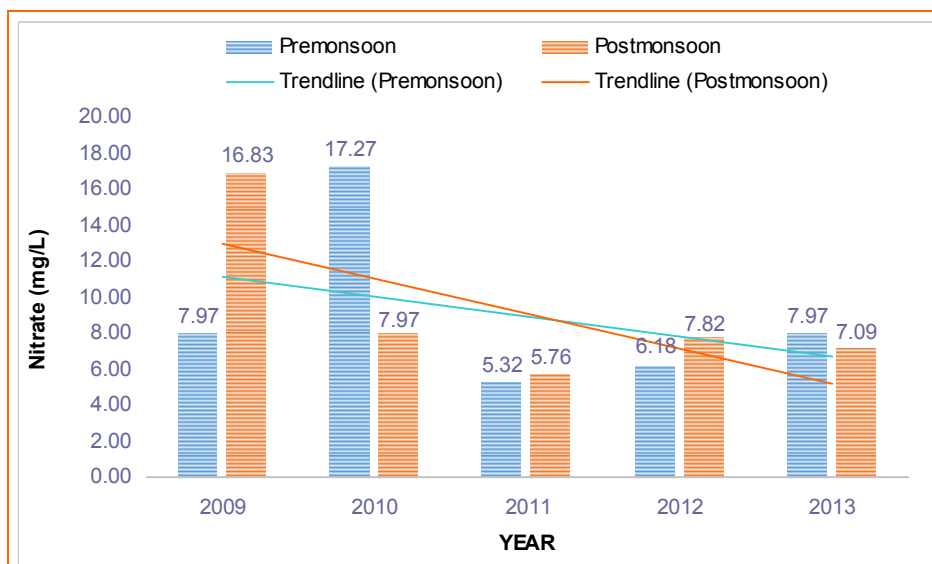


Figure-74: Variation of Fluoride in dug well water in village Jilinda, around Jagannath OCP, Talcher coalfield, Odisha

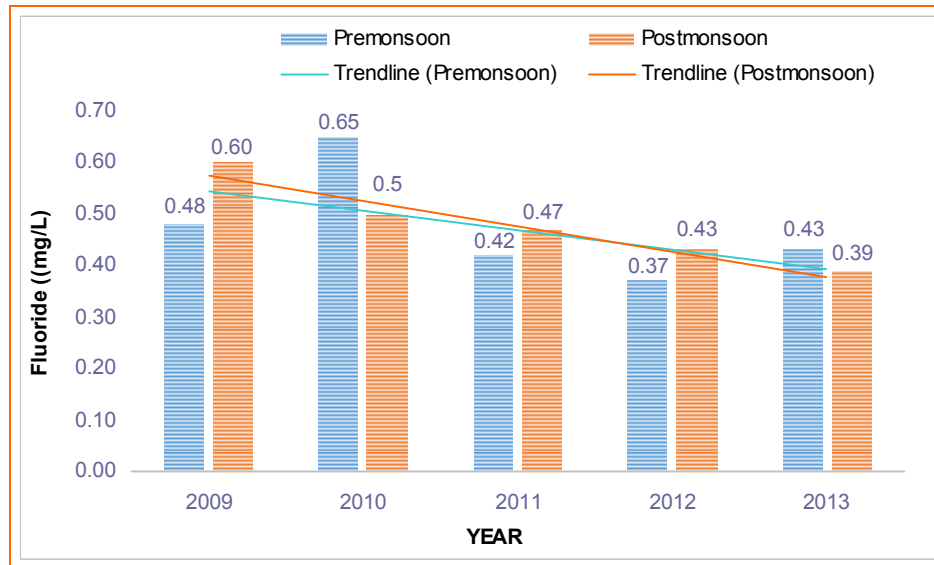


Figure-75: Variation of Zinc in dug well water in village Jilinda, around Jagannath OCP, Talcher coalfield, Odisha

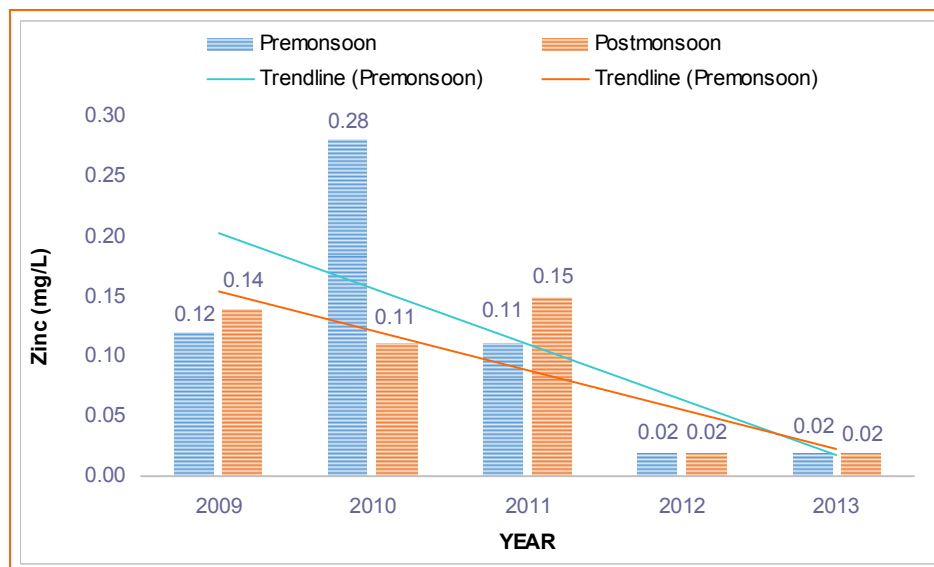


Figure-76: Variation of pH in tube well water at Jagannath PO, around Jagannath OCP, Talcher coalfield, Odisha

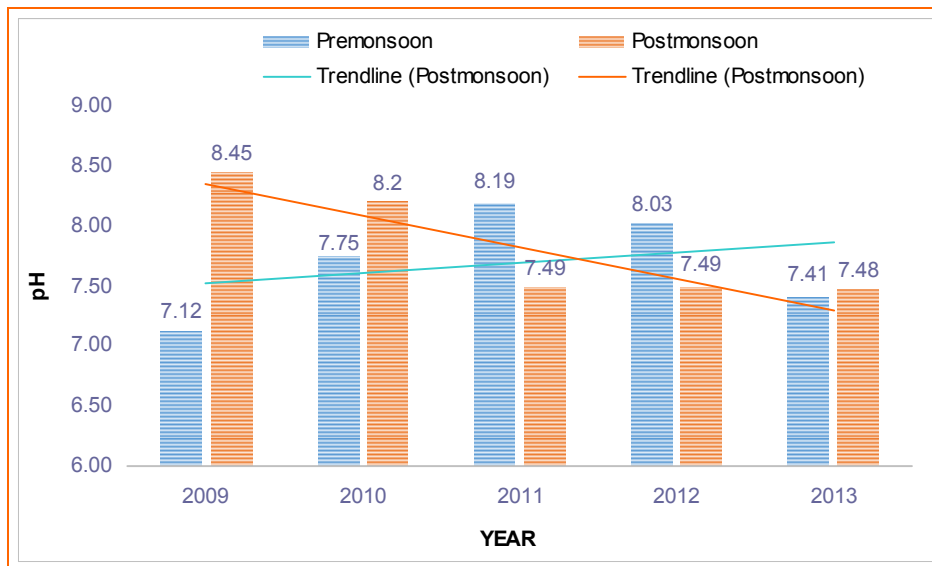


Figure-77: Variation of Iron in tube well water at Jagannath PO, around Jagannath OCP, Talcher coalfield, Odisha

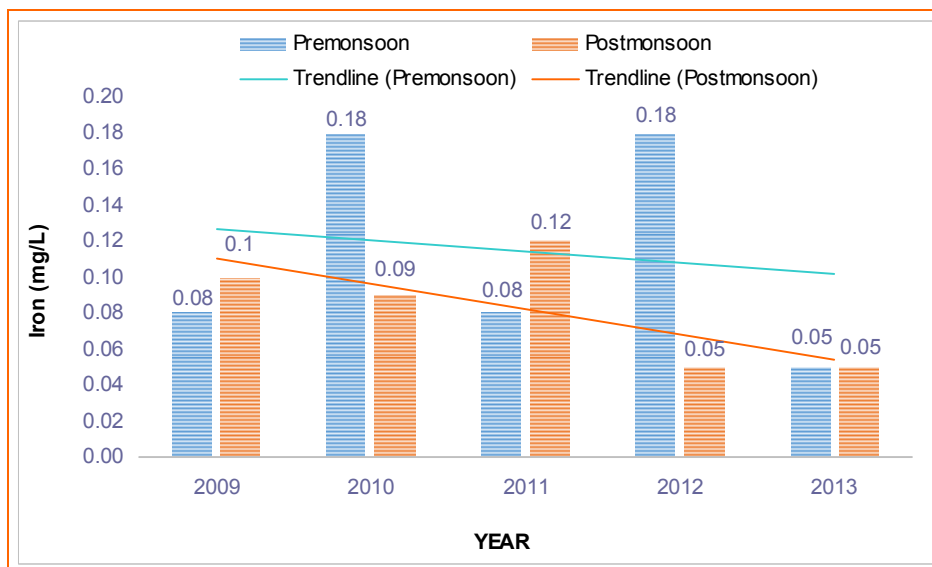


Figure-78: Variation of Chloride in tube well water at Jagannath PO, around Jagannath OCP, Talcher coalfield, Odisha

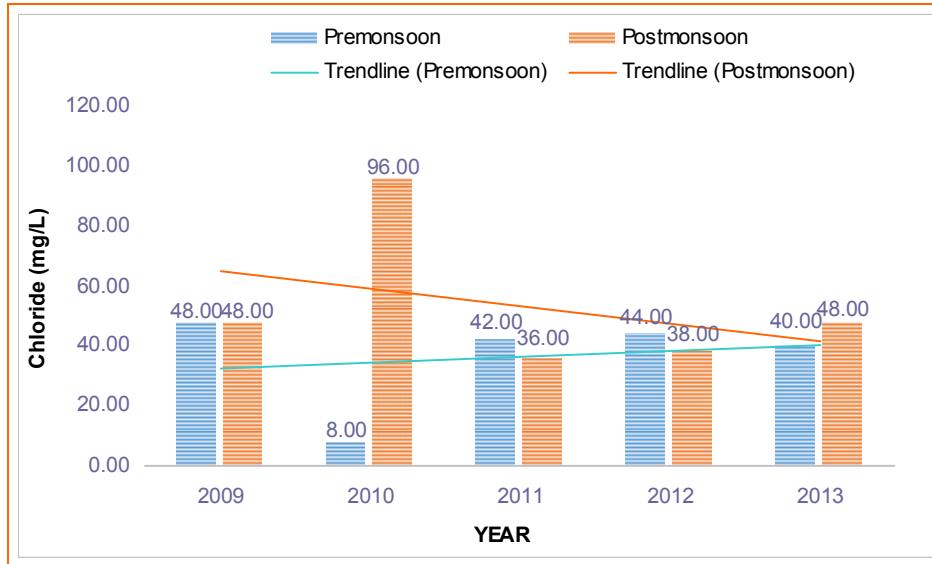


Figure-79: Variation of TDS in tube well water at Jagannath PO, around Jagannath OCP, Talcher coalfield, Odisha

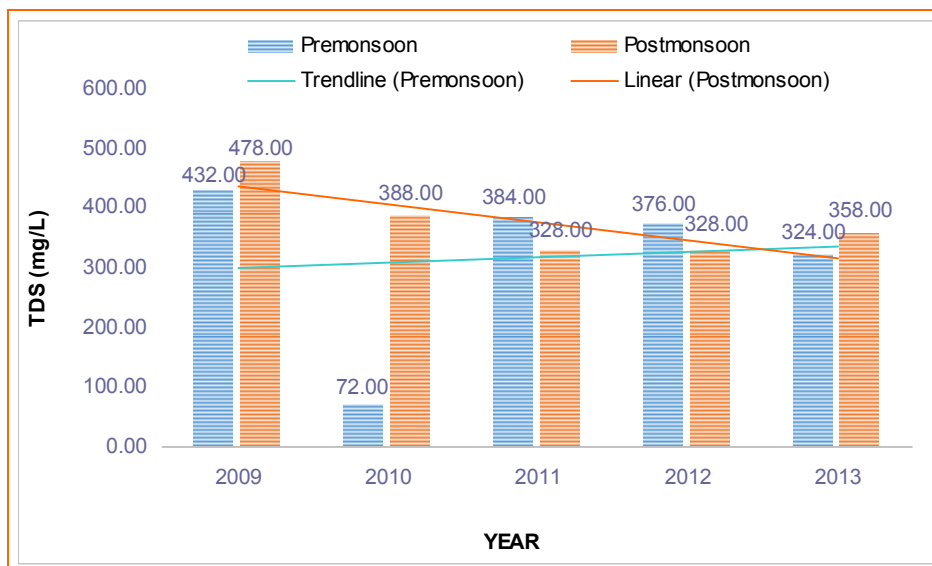


Figure-80: Variation of Calcium in tube well water at Jagannath PO, around Jagannath OCP, Talcher coalfield, Odisha

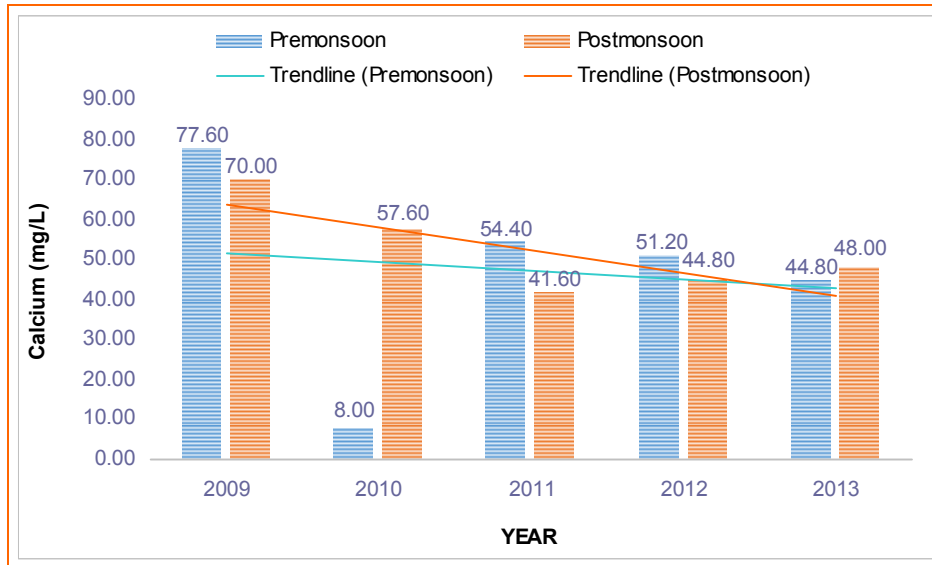


Figure-81: Variation of Sulphate in tube well water at Jagannath PO, around Jagannath OCP, Talcher coalfield, Odisha

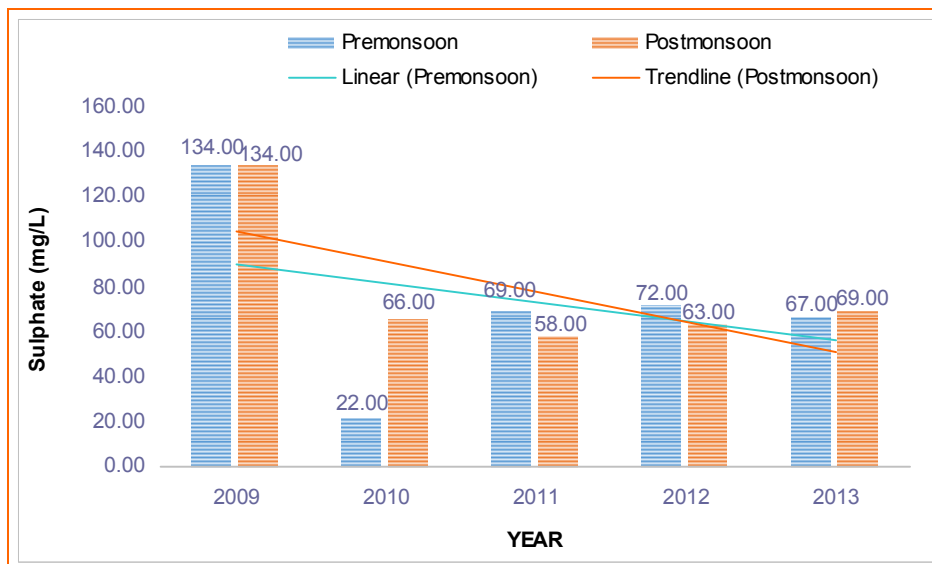


Figure-82: Variation of Nitrate in tube well water at Jagannath PO, around Jagannath OCP, Talcher coalfield, Odisha

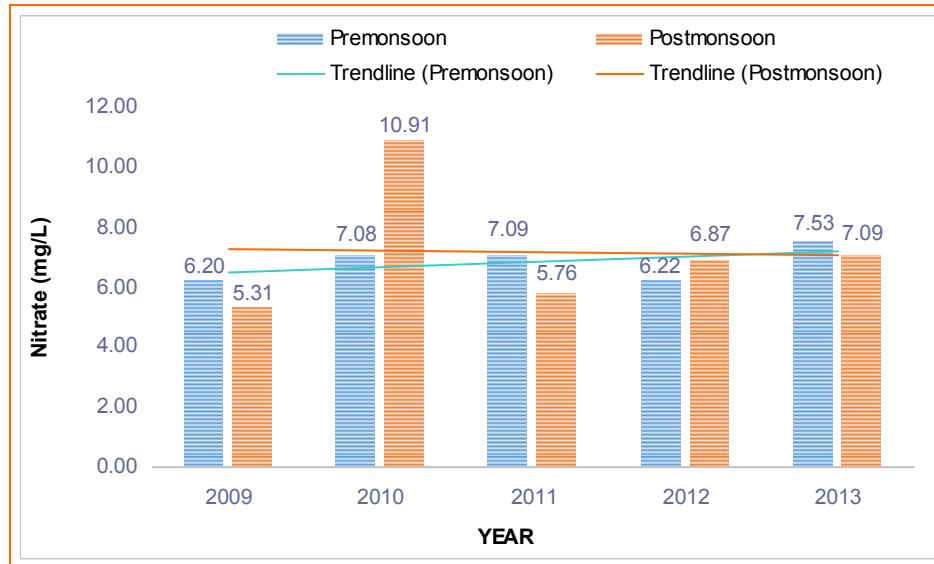


Figure-83: Variation of Fluoride in tube well water at Jagannath PO, around Jagannath OCP, Talcher coalfield, Odisha

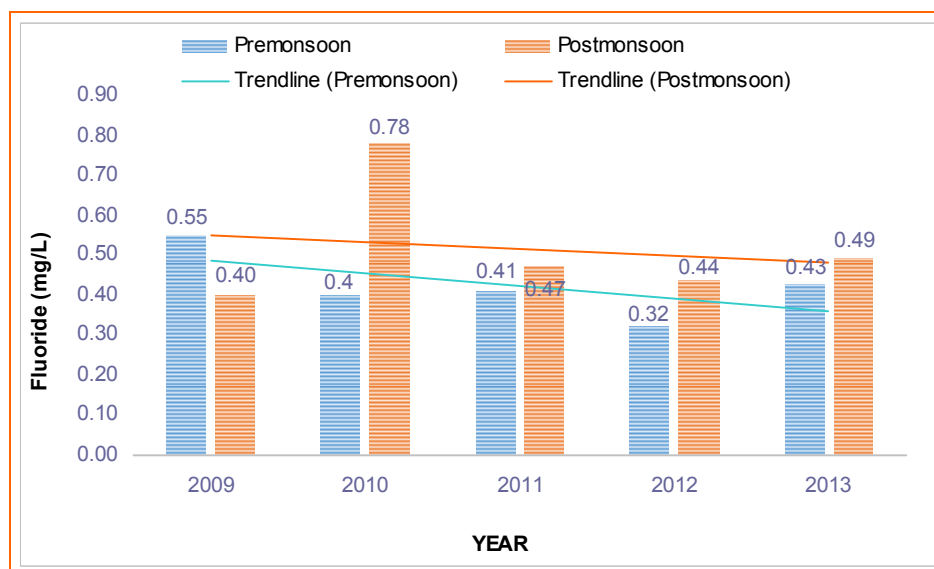


Figure-84: Variation of Zinc in tube well water at Jagannath PO, around Jagannath OCP, Talcher coalfield, Odisha

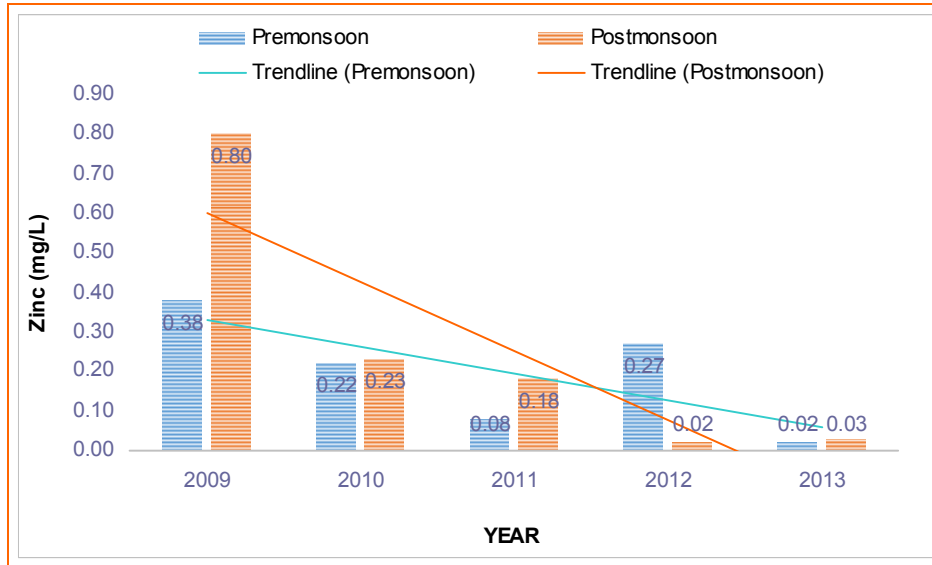


Figure-85: Variation of pH in dug well water in village Dera, around Jagannath OCP, Talcher coalfield, Odisha

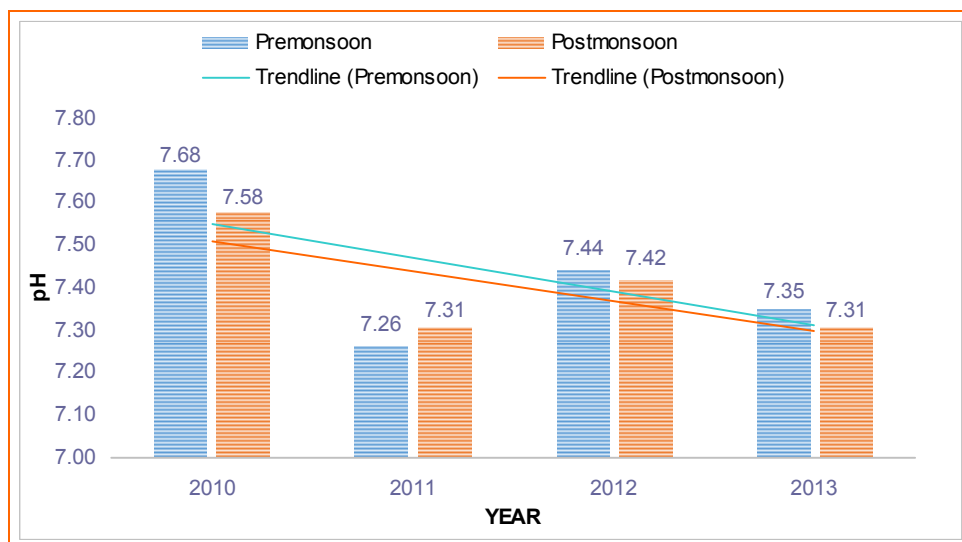


Figure-86: Variation of Iron in dug well water in village Dera, around Jagannath OCP, Talcher coalfield, Odisha

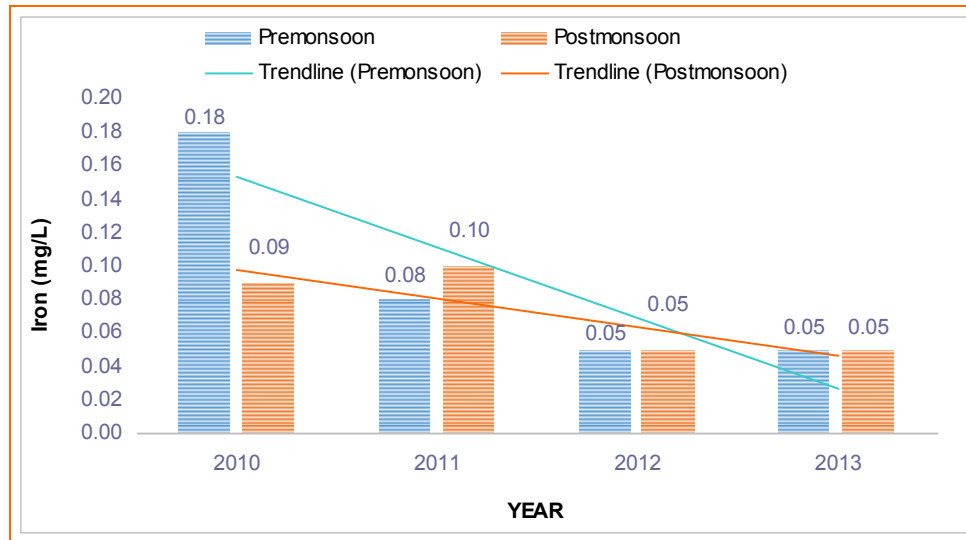


Figure-87: Variation of Chloride in dug well water in village Dera, around Jagannath OCP, Talcher coalfield, Odisha

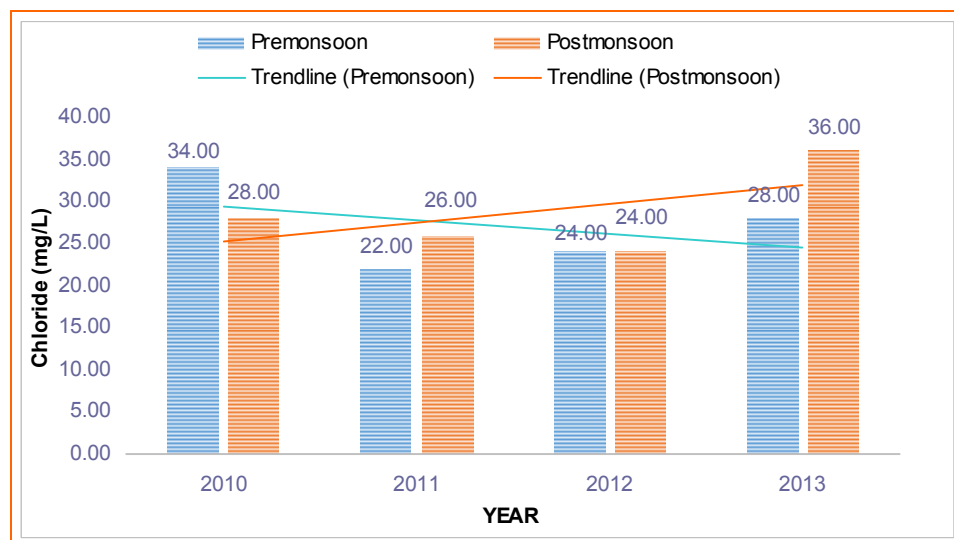


Figure-88: Variation of TDS in dug well water in village Dera, around Jagannath OCP, Talcher coalfield, Odisha

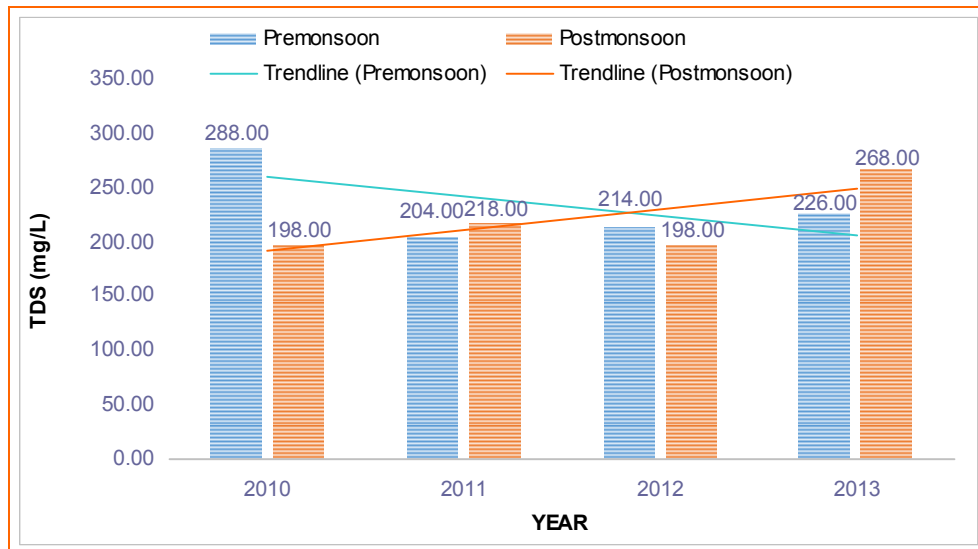


Figure-89: Variation of Calcium in dug well water in village Dera, around Jagannath OCP, Talcher coalfield, Odisha

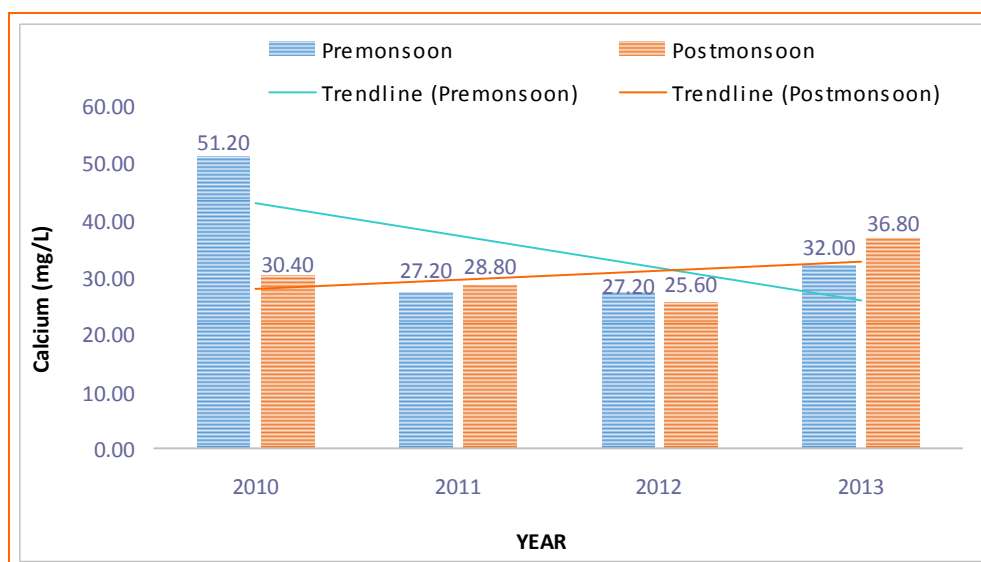


Figure-90: Variation of Sulphate in dug well water in village Dera, around Jagannath OCP, Talcher coalfield, Odisha

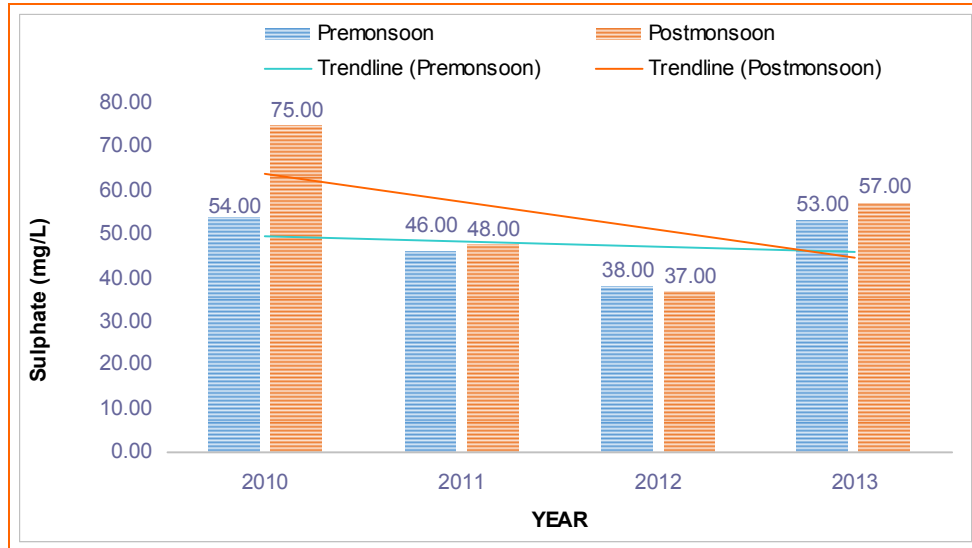


Figure-91: Variation of Nitrate in dug well water in village Dera, around Jagannath OCP, Talcher coalfield, Odisha

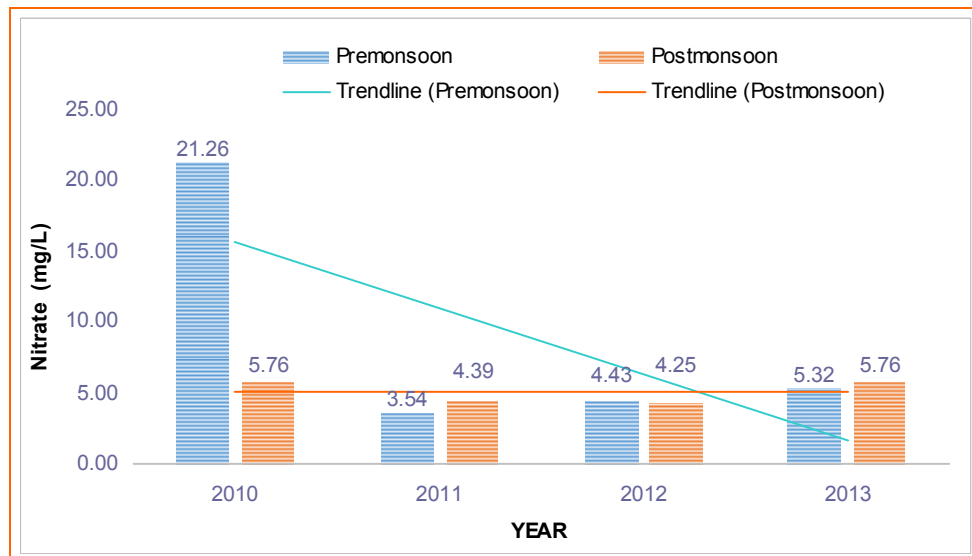


Figure-92: Variation of Flouride in dug well water in village Dera, around Jagannath OCP, Talcher coalfield, Odisha

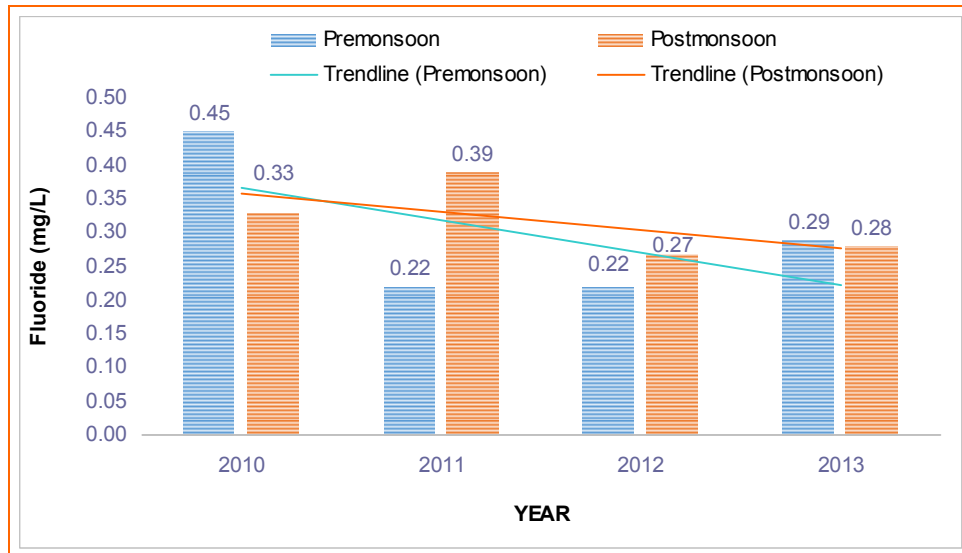
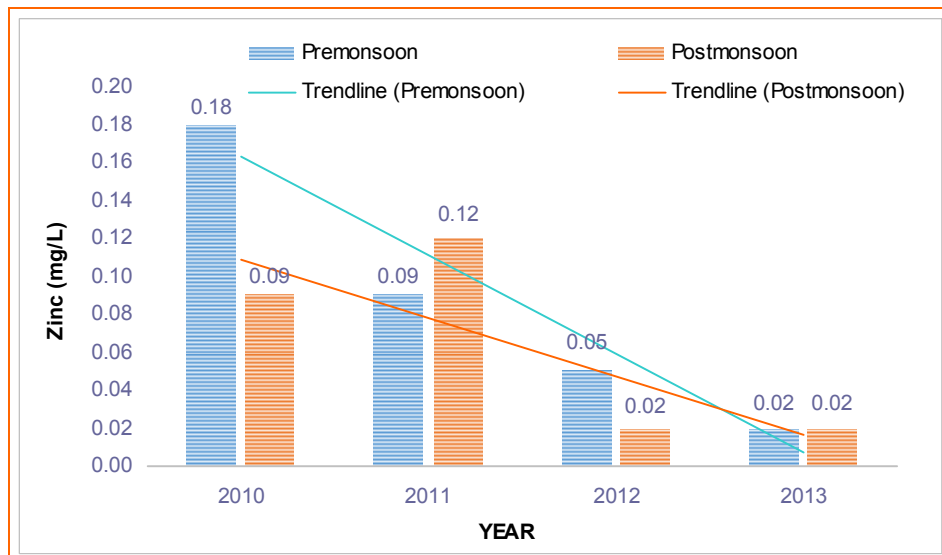


Figure-93: Variation of Zinc in dug well water in village Dera, around Jagannath OCP, Talcher coalfield, Odisha



Chapter – 7

CONCLUSION

- I. Hydrogeological investigations were carried out in and around the Jagannath OCP with the objective to determine the hydrogeology of the mine area with emphasis on general direction of groundwater movement, seasonal water quality changes and assessment of the need to assess base line values of the surface and groundwater to assess the impact on groundwater during and after filling the flyash.
- II. Jagannath OCP, chosen as the area of study, is located in the south eastern part of Talcher coalfield and comprises Barakar and Karharbari formations. These formations are underlain by Talchir formation. The strata have gentle northerly dip of about 5° to 7° in Jagannath OCP.
- III. In the study area, coal seams have been mined out leaving huge voids, which have been identified as potential sites for backfilling ash by NTPC.
- IV. Precipitation is the only source of groundwater recharge to the aquifers. The annual average rainfall in the study area is around 1257 mm. The highest temperature recorded was 45.3 °C in June 2012 while the lowest temperature was 5.5 °C in November 1996. The study area is a part of Bangaru jhor and Nandira jhor sub basin. The drainage density of Bangaru jhor and Nandira jhor basin are 1.52 km/square km and 0.88 km/square km respectively.
- V. Two aquifers namely, Basal aquifer and Karharbari aquifers are encountered in the area. Groundwater in these aquifers occurs in unconfined and confined hydraulic conditions.
- VI. In pre-monsoon season in the study area, the maximum depth of water below ground level was 12.95 m in village Ekdal and minimum depth of water below ground level was 2.10 mbgl in Jagannathpur village.

-
- VII. During the post-monsoon season in study area, the maximum depth of water below ground level was 5.98 m in village Ekdal and minimum depth of water below ground level is 1.21 m in village Deulbera.
- VIII. The water level contour coincides with the topography of the study area.
- IX. It can be observed from the pre and post monsoon water level contour, that there is a predominant groundwater divide in middle of the study area SW to NE trending, which divides the whole study area into two halves. In one half of area, the ground water is flowing towards Bangaru jhor in north direction and in other half, the water is moving towards Nandira Jhor in south east direction.
- X. The hydraulic conductivity ranges from 0.010 m/day to 1.716 m/day. The permeability of the aquifer in the study area is influenced by the geological structural disturbance and compactness of the geological strata.
- XI. Piezometric head (in RL) ranges from 76 to 120 m amsl.
- XII. During pumping test discharge ranges from 0.61 lps to 2.16 lps.
- XIII. Hydraulic conductivity signifies the dominant role of secondary porosity in aquifer development.
- XIV. Total Annual recharge estimated within 5 km radius buffer zone of Jagannath OCP is 50.35 Mm³. Surplus water available per annum from the groundwater after meeting the future requirement for unirrigated and cultivable waste land is 16.22 Mm³. From water balance studies, it is estimated that there is surplus water available per annum from ground water annual recharge after catering to the existing demographic settlements.
- XV. Surface water collected and analysed from various locations in and around Jagannath OCP shows higher concentration of dissolved oxygen levels and sulphate.

-
- XVI. Mine water collected and analysed from various locations in and around Jagannath OCP are within permissible limits as per MOEF-Schedule VI Standard.
- XVII. It is observed that the groundwater from dug wells, tube wells and piezometers in the study area is neutral to alkaline in nature.
- XVIII. Based on current analytical result of groundwater samples, it may be observed that there are two distinct spheres of exceedance of analyte. The shallow groundwater of the phreatic aquifer shows higher concentration of inorganic analytes like Calcium, Chloride, TDS, Fluoride, Total alkalinity and Total Hardness. Sulphate is also observed at higher concentration in few shallow groundwater samples. The deeper aquifer shows higher concentration of few heavy metals in pre-monsoon season only. Heavy metals like lead (Pb) is uniformly present in almost all piezometer location except at piezometer SJL-6. Manganese (Mn) is also reported at higher concentration at three piezometer locations (SJL-2, SJL-4, and SJL-8). Iron and Cadmium is also reported at higher concentration at SJL-1 and SJL-2 respectively. Inorganic constituents like TDS and Calcium are reported from couple of locations viz. SJL-3 in pre-monsoon season and SJL-4, SJL-7 in post monsoon season.
- XIX. Presence of Lead (Pb) in water samples from most piezometers in study area indicates possibility of deep seated source of Pb and may be attributed to geogenic factors. High Calcium and TDS concentrations can be attributed to weathering of sedimentary rock and calcium bearing minerals. Very localized presence of Iron and Cadmium above recommended levels indicates impact possibly due to anthropogenic activity.

Chapter – 8

RECOMMENDATION

- I. Since, groundwater is the primary source of drinking water in the study area, therefore, proper precaution and care should be taken during backfilling of ash in decoaled mine voids.
- II. It is recommended to implement the monitoring system of groundwater quality (four times yearly) to assess fluctuation rate of current analytical constituents, active on-site releases and any other potential contamination sources which can affect the groundwater.
- III. If elevated concentration of heavy metals and other pollutants are persistent in groundwater after implementing a monitoring system, it may be recommended to develop a contaminant fate transport model to understand the movement and chemical alteration of contaminants as they move through the subsurface.
- IV. Soil sampling and analysis in and around the study area may be undertaken to evaluate concentration of heavy metals and other pollutants.
- V. It is recommended that acidic water chemical reaction test of the flyash may be undertaken to understand the mobility and chemical behaviour of heavy metals with acidic waters.
- VI. Usage of deeper aquifer groundwater abstracted in the study area for any sensitive application like drinking is recommended with appropriate filtration.

FINAL REPORT

ON

**HYDROGEOLOGICAL INVESTIGATION FOR
DISPOSAL OF ASH IN MINE VOIDS (QUARRY
NOS. 4, 7 & 8) IN JAGANNATH OCP OF
JAGANNATH AREA OF MCL,**

**TALCHER COALFIELD,
ODISHA**

PLATES

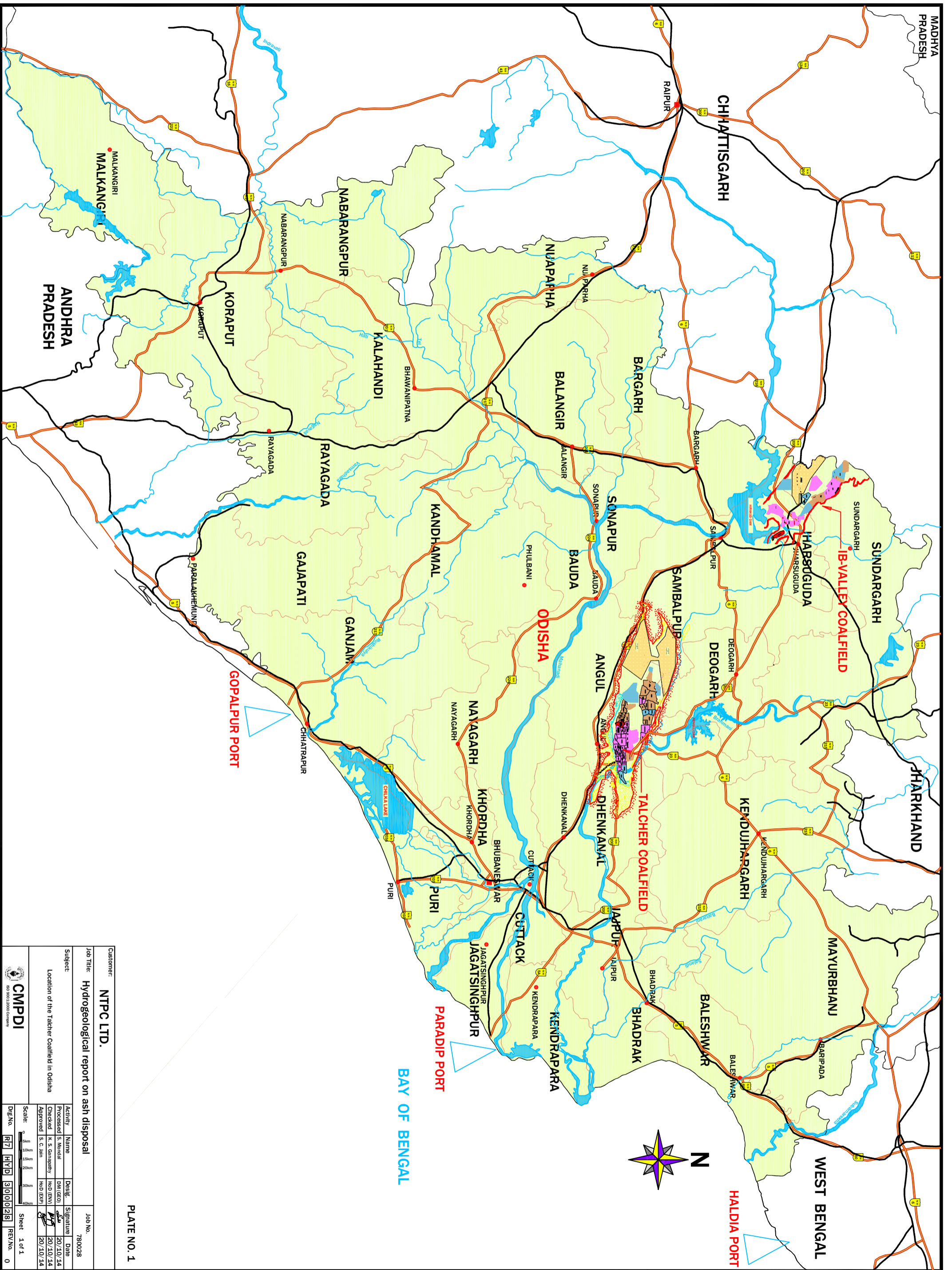


PLATE NO. 1

Customer: **NTPC LTD.**

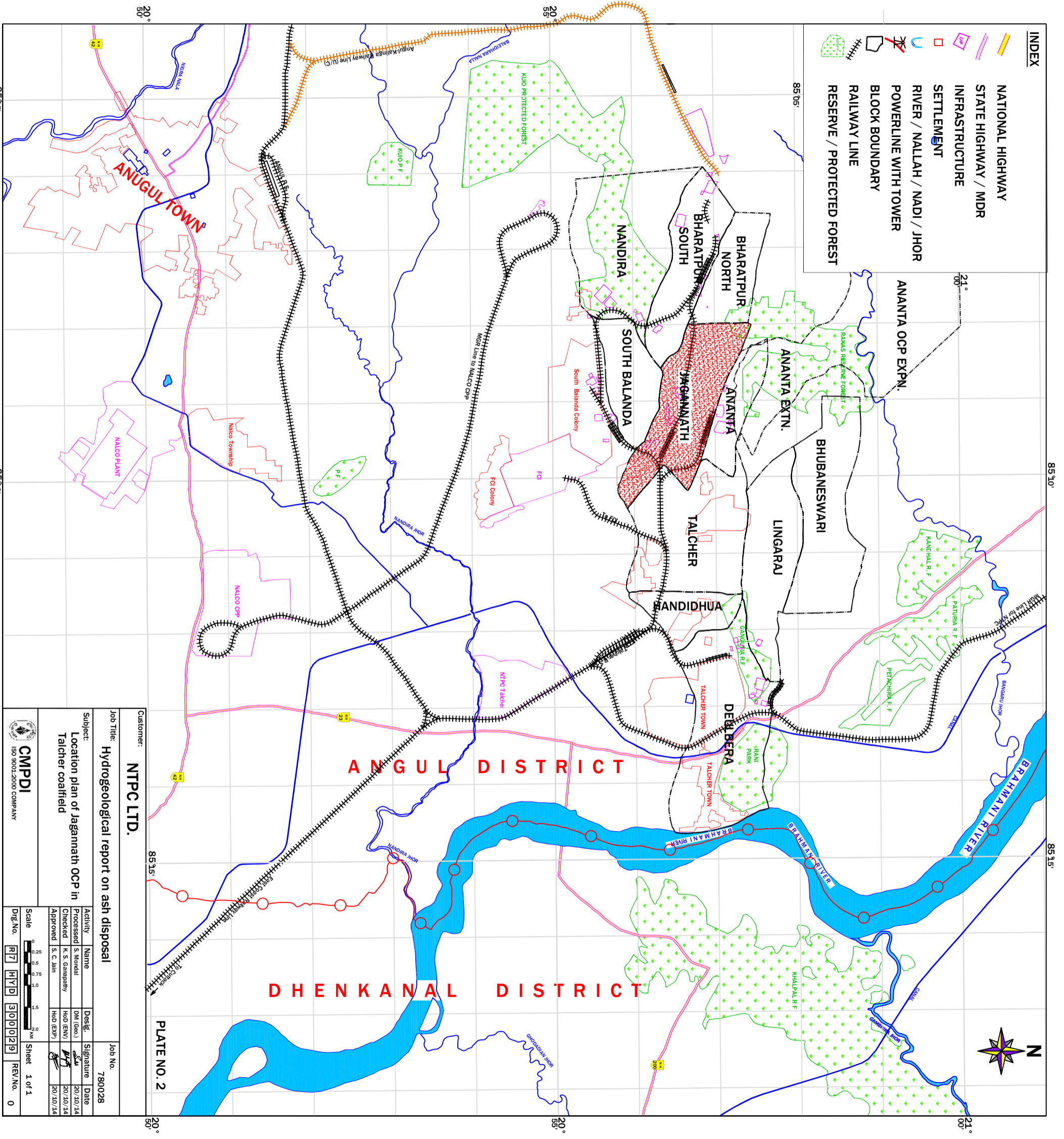
Job Title: **Hydrogeological report on ash disposal**

Job No. 780028

Subject	Name	Design.	Signature	Date
Location of the Talcher Coalfield in Odisha	Checked	K. S. Ganapaty	[Signature]	20/10/14
	Approved	S. C. Jain	[Signature]	20/10/14



Scale: 0 5km 10km 15km 20km 25km 30km 35km 40km	Sheet 1 of 1
Dwg.No. R7 HYD 300028	REV.No. 0



INDEX

- NATIONAL HIGHWAY
- STATE HIGHWAY / MDR
- INFRASTRUCTURE
- SETTLEMENT
- RIVER / NALLAH / NADI / JHOR
- POWERLINE WITH TOWER
- BLOCK BOUNDARY
- RAILWAY LINE
- RESERVE / PROTECTED FOREST

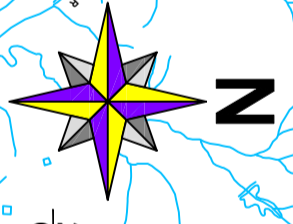
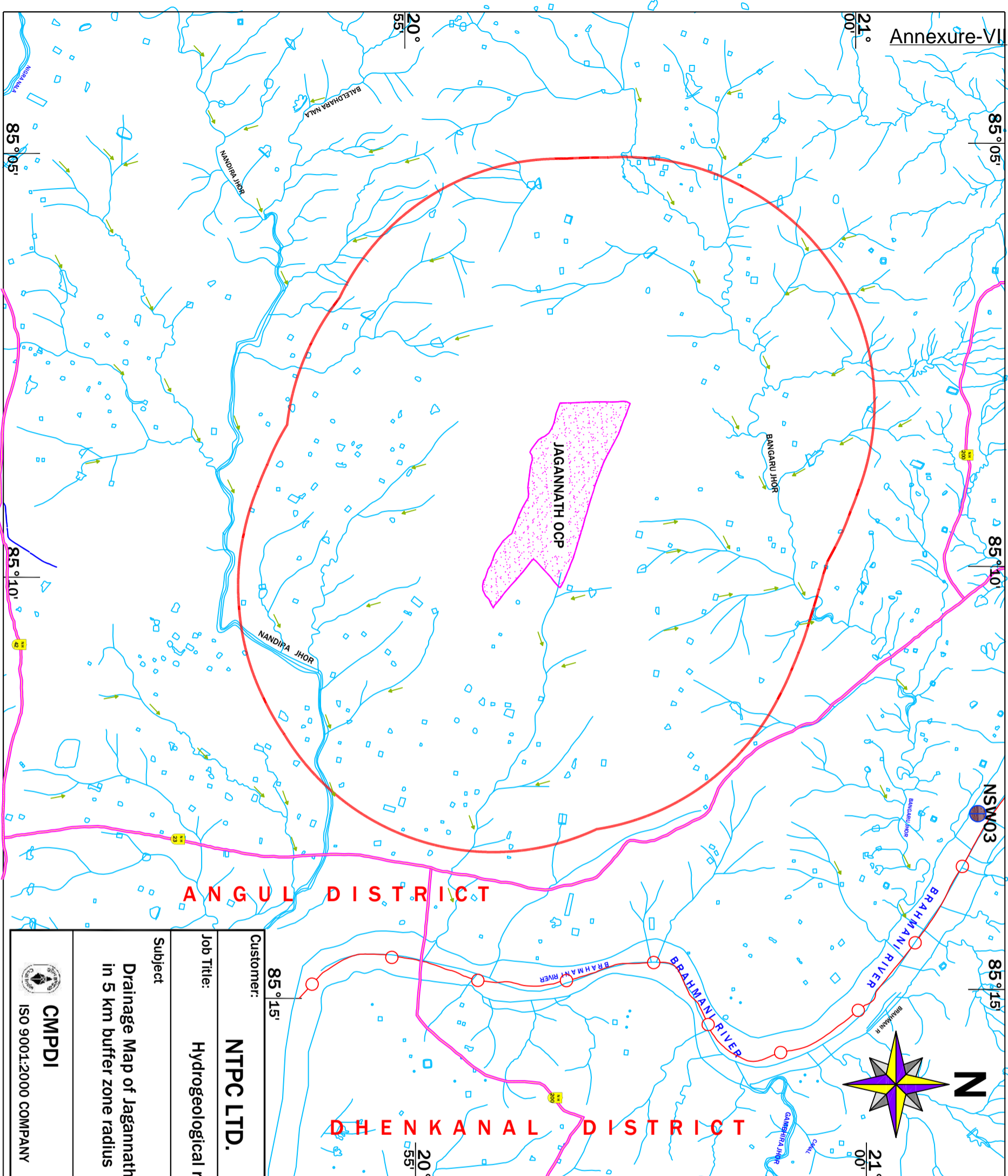
Customer: **NTPC LTD.**
 Job Title: **Hydrogeological report on ash disposal**
 Subject: **Location plan of Jagannath OCP in Talcher coalfield**

Activity	Name	Desig.	Signature	Date
Processed	S. Mondal	DM (Geo)		20/10/14
Checked	K. S. Ganapathy	HOD (ENV)		20/10/14
Approved	S. C. Jain	HOD (EXP)		20/10/14

Job No. **780028**
 Scale: 1:50,000
 Dwg. No. **R7 HYD 300029** Sheet **1 of 1**
 REV. No. **0**



Reference: As per Master Plan Talcher Coalfield 2009
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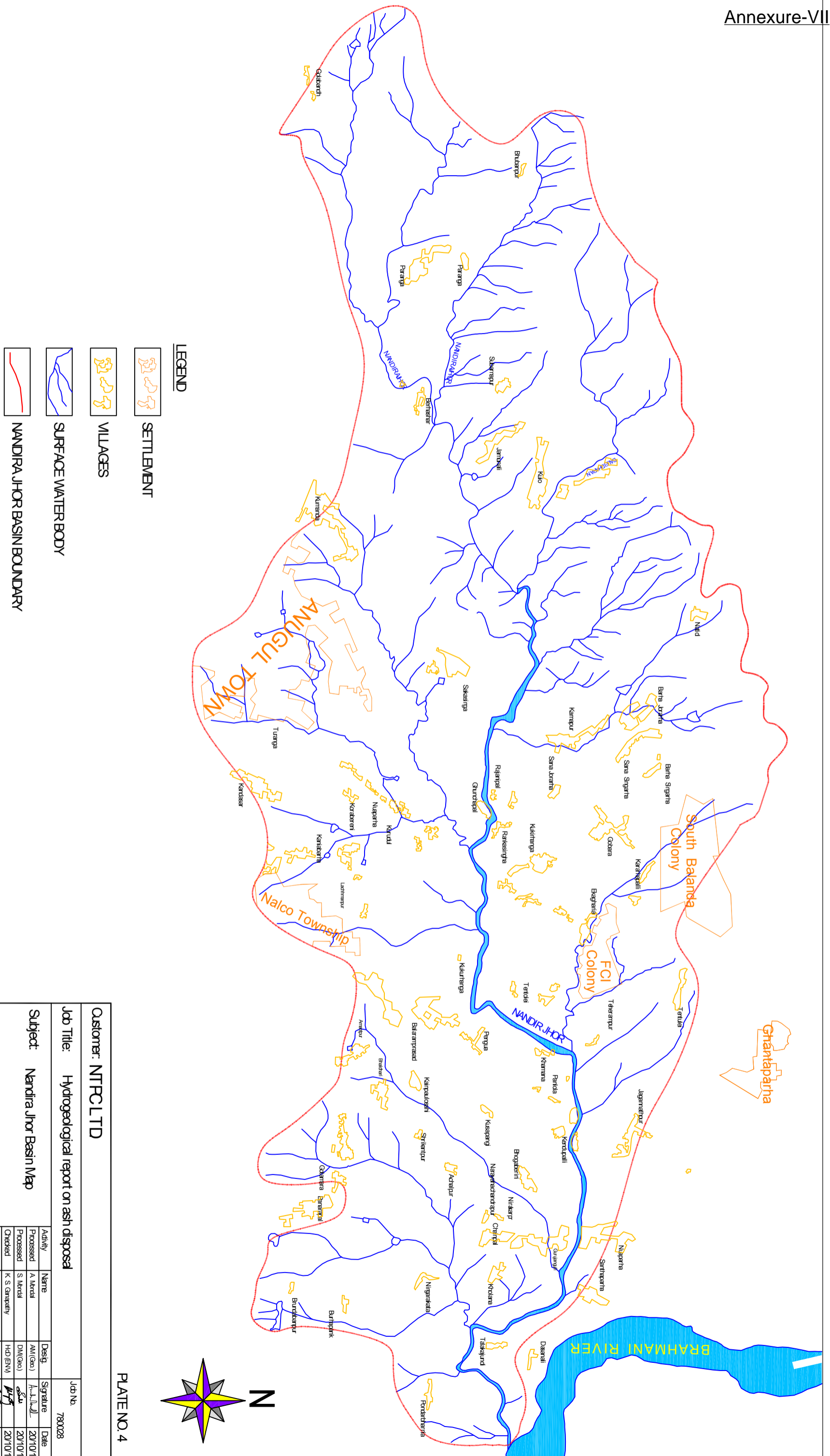


INDEX

- River/ Nallah/ Jhor/ Pond
- National Highway
- 5 Km Buffer Zone Boundary
- State/District Boundary
- Mine Leasehold Boundary
- Flow direction

PLATE NO. 3

Customer: NTPCLTD.		Job No. 780028			
Job Title: Hydrogeological report on ash disposal		Job No. 780028			
Subject: Drainage Map of Jagannath OCP in 5 km buffer zone radius		Activity	Name		
CMPDI ISO 9001:2000 COMPANY		Processed	S. Mondal		
		Checked	K.S.Ganapathy		
		Approved	S. C. Jain		
		Design. DM (Geo) HOD (Env.) HOD (Exp.)		Signature	Date
Scale				Sheet 1 of 1	
Dwg.No. R7 HYD 300030		REV.No. 0			

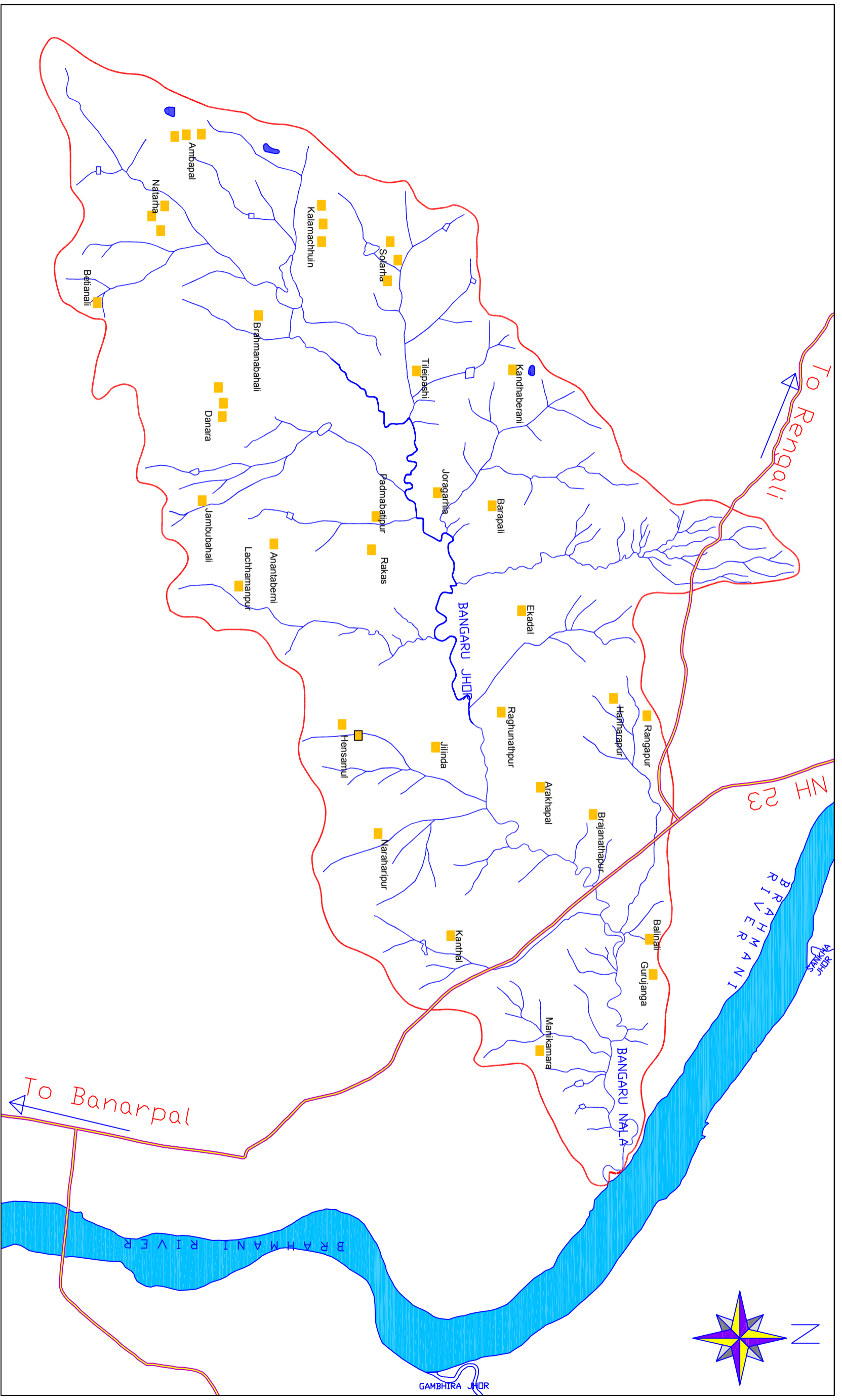


- LEGEND**
-  SETTLEMENT
 -  VILLAGES
 -  SURFACE WATER BODY
 -  NANDIRA JHOR BASIN BOUNDARY

PLATE NO. 4

Customer: NTFCLTD		Job No.	780028
Job Title: Hydrogeological report on ash disposal			
Subject: Nandira Jhor Basin Map	Activity	Name	Desig.
	Processed	A. Nanda	AM(Geo)
	Checked	K. S. Choudhary	HdD (ENV)
	Approved	S. C. Jain	HdD (EP)
Scale		Sheet	1 of 1
Dwg No. R7		HVD	31010311
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INDEX

CATCHMENT AREA

BANGARU NALA

NATIONAL HIGHWAY

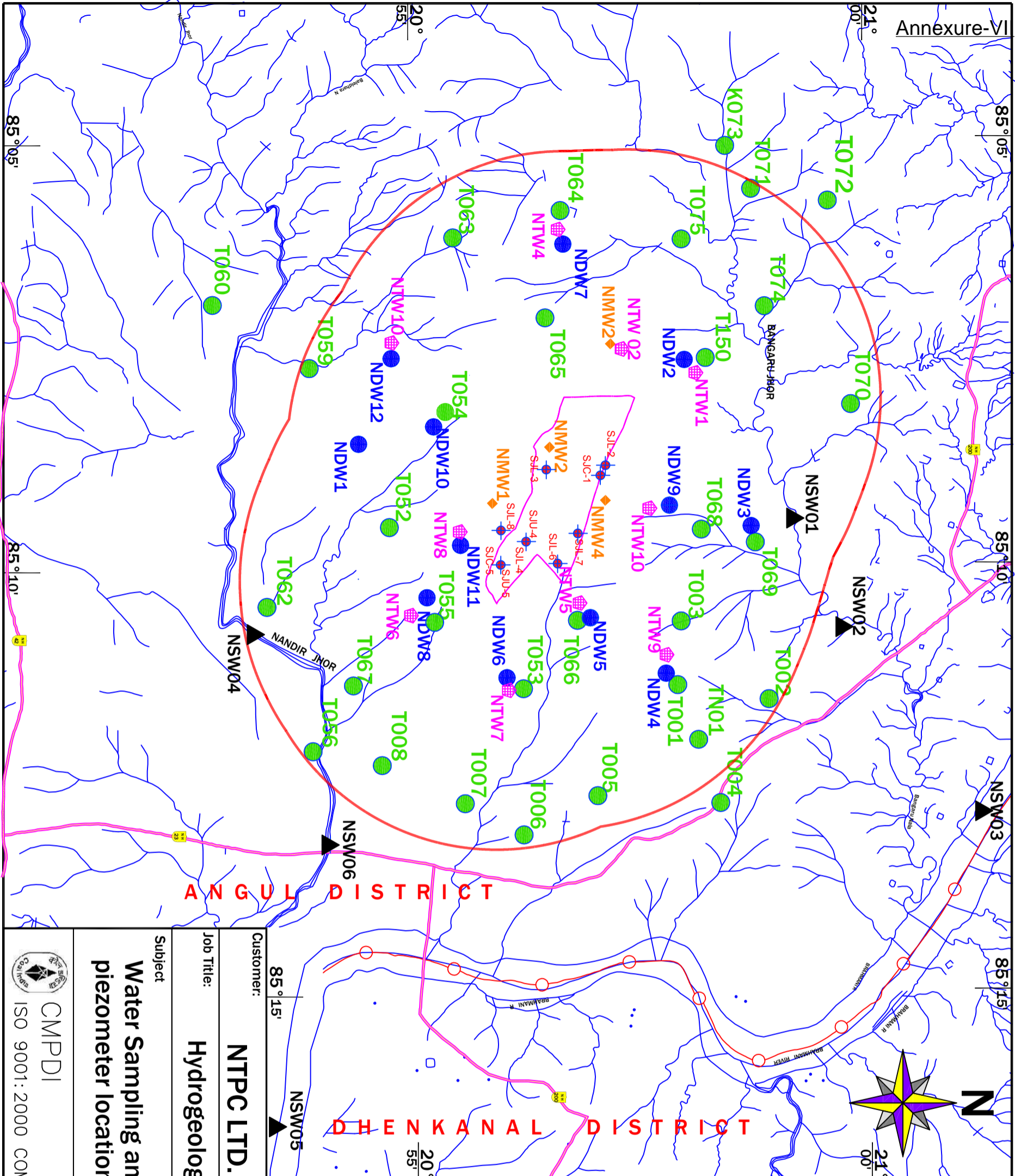
VILLAGE

PLATE NO. 5

Customer		NTPC LTD.	
Job Title		Hydrogeological report on ash disposal	
Subject		Bangaru Jhor Basin Map	
Activity	Name	Designation	Signature
Processed	S.Mondal	D.M.(Geo.)	
Checked	K.S.Ganapathy	HOD(Env.)	
Approved	S. C. Jain	HOD(EXP.)	
Scale		Sheet	
0 5 10 15 20 Km		1 of 1	
Drg. No.	REV. No.		
R17	0		
H1YD	300032		

CMPDI
ISO 9001:2000 COMPANY





- INDEX**
- River/ Nallah/ Jhor/ Pond
 - Piezometer location point
 - Hydrograph station
 - Surface water sampling location
 - Tube well water sampling location
 - Mine water sampling location
 - Dug well water sampling location
 - 5 Km Buffer Zone Boundary
 - State/District Boundary
 - Jagannath Mine Leasehold Boundary
 - National Highway

PLATE NO. 6

Customer: **NTPC LTD.**

Job Title: **Hydrogeological report on ash disposal**

Job No. **780028**

Subject: **Water Sampling and piezometer location plan**

Activity	Name	Desig.	Signature	Date
Processed	S. Mondal	DM (Geo)		20/10/14
Checked	K.S.Ganapathy	HOD (Env.)		20/10/14
Approved	S. C. Jain	HOD (Exp.)		20/10/14

CMPDI
ISO 9001:2000 COMPANY

Scale		Sheet	1 of 1
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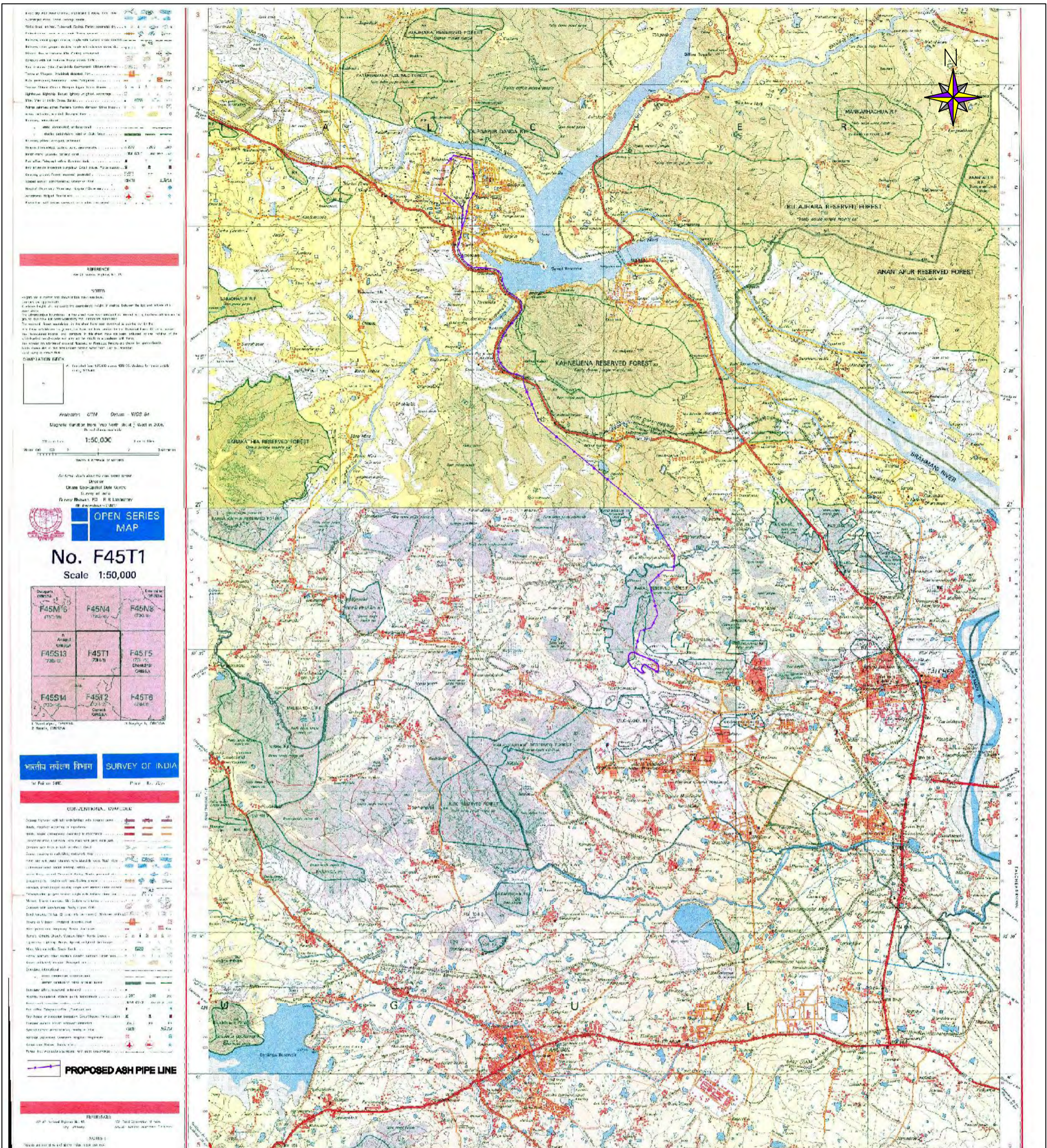


Plate no. 7

REFERENCE
 No. of Survey Sheet: 1/1

UNIT
 Meter

PROJECTION
 UTM Datum: WGS 84
 Magnetic Variation from true: about 4.5' East in 2014.

SCALE
 1:50,000

OPEN SERIES MAP
No. F45T1
 Scale 1:50,000

F45M6 (730/0)	F45N4 (730/0)	F45N8 (730/0)
F45S13 (730/0)	F45T1 (730/0)	F45T5 (730/0)
F45S4 (730/0)	F45T2 (730/0)	F45T8 (730/0)

भारतीय सर्वेक्षण विभाग SURVEY OF INDIA

सर्वेक्षण संकेतिकावली

PROPOSED ASH PIPE LINE

REFERENCES

Customer: NTPC LTD.		Job No. 780028	
Job Title: Hydrogeological report on ash disposal		Signature	
Subject Plan showing corridor for ash disposal	Activity	Name	Design.
	Processed	S. Mondal	DM(Geo)
	Checked	T. Das	CM(Geo)
Approved	S. C. Jain	HDD(Exp.)	Date
Scale	Not to Scale	Sheet 1 of 1	
Drg.No. 77 HYD 300058		REV.No. 0	

Source: NTPC Limited

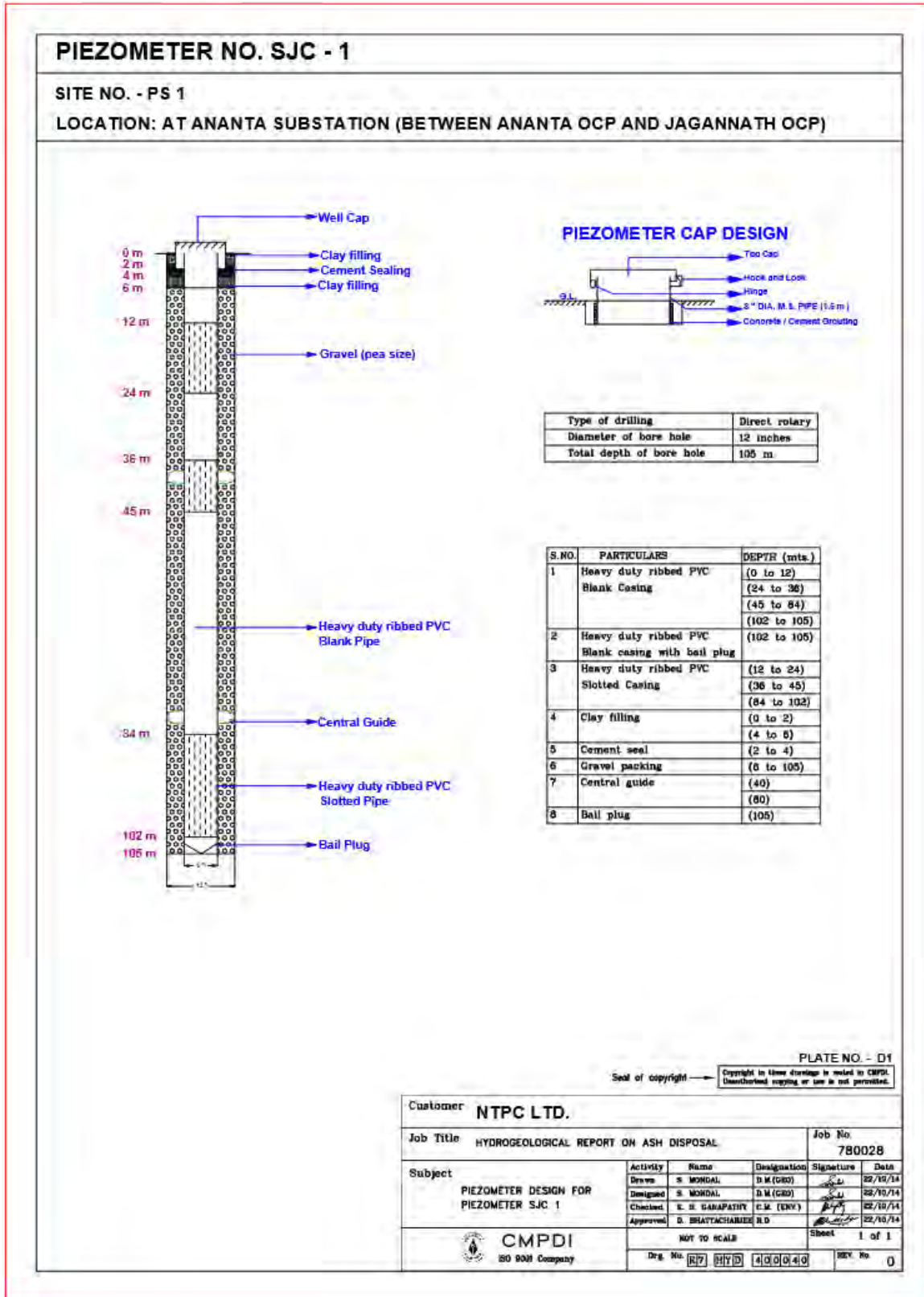


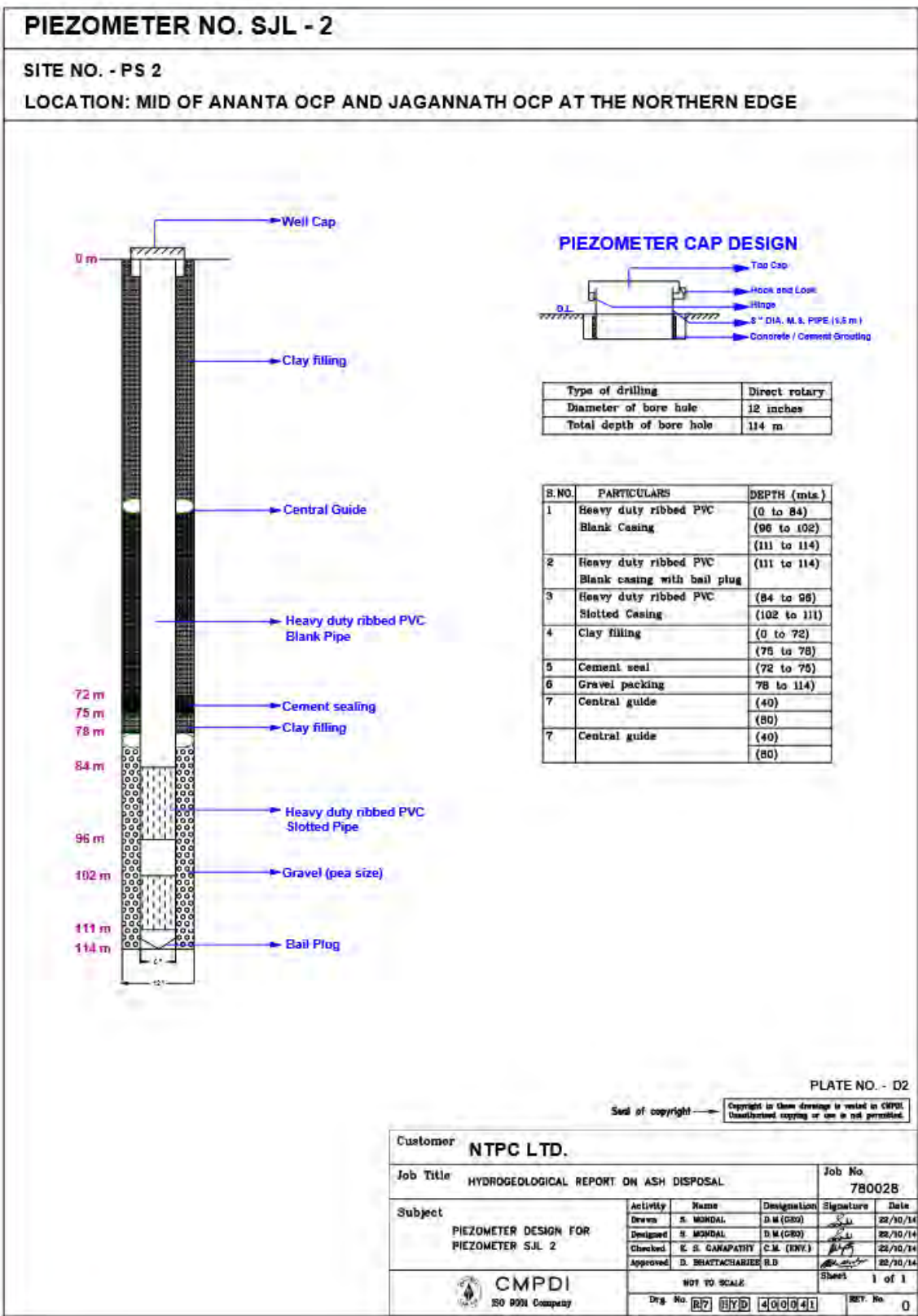
FINAL REPORT
ON
**HYDROGEOLOGICAL INVESTIGATION FOR
DISPOSAL OF ASH IN MINE VOIDS (QUARRY
NOS. 4, 7 & 8) IN JAGANNATH OCP OF
JAGANNATH AREA OF MCL,**
TALCHER COALFIELD,
ODISHA

ANNEXURE - I

Schematic diagram of piezometer construction and specifications in and around Jagannath OCP, Talcher Coalfield, Odisha.

ANNEXURE I

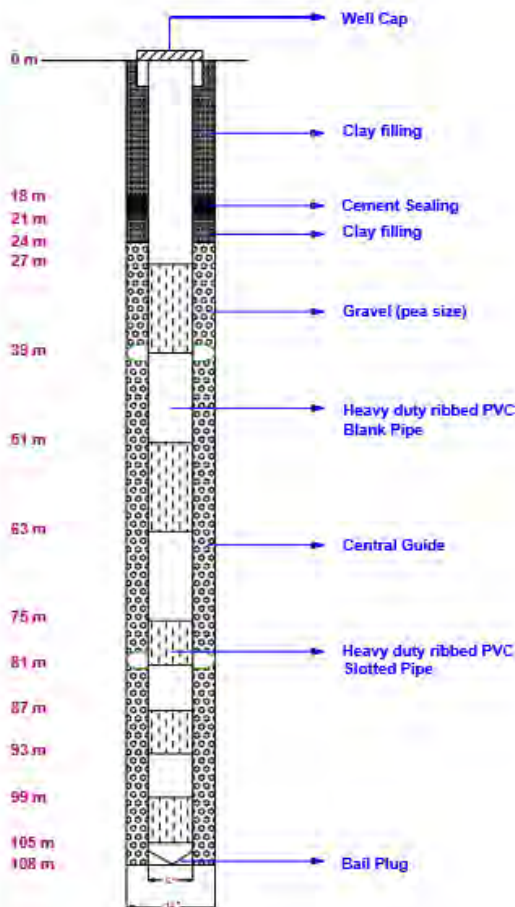




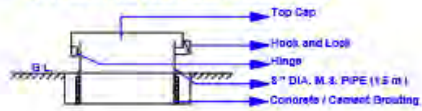
PIEZOMETER NO. SJL 3

SITE NO. - PS 3

LOCATION: AT JAGANNATH WORKSHOP



PIEZOMETER CAP DESIGN



Type of drilling	Direct rotary
Diameter of bore hole	12 inches
Total depth of bore hole	108 m

S.NO.	PARTICULARS	DEPTH (mts.)
1	Heavy duty ribbed PVC Blank Casing	(0 to 27)
		(27 to 51)
		(51 to 75)
		(75 to 99)
2	Heavy duty ribbed PVC Blank casing with bail plug	(105 to 108)
3	Heavy duty ribbed PVC Slotted Casing	(27 to 39)
		(39 to 51)
		(51 to 63)
		(63 to 75)
4	Clay filling	(0 to 18)
		(18 to 24)
5	Cement seal	(18 to 21)
6	Gravel packing	(6 to 105)
7	Central guide	(40)
		(80)

PLATE NO. - D3

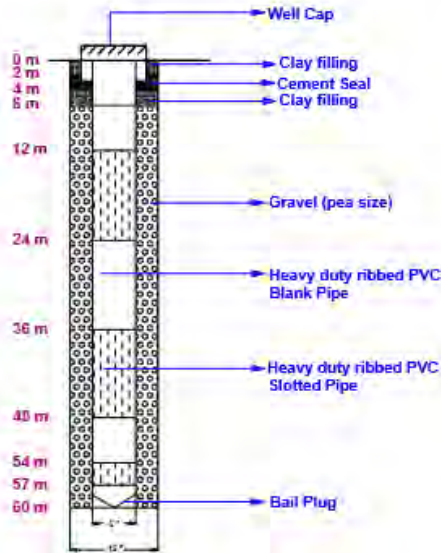
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Customer NTPC LTD.		Job No 780028	
Job Title HYDROGEOLOGICAL REPORT ON ASH DISPOSAL		Job No 780028	
Subject PIEZOMETER DESIGN FOR PIEZOMETER SJL 3	Activity	Name	Designation
	Drawn	S. MONDAL	D.M. (GSD)
	Designed	S. MONDAL	D.M. (GSD)
	Checked	K. S. GANAPATHY	C.M. (ENV.)
Approved	D. BHATTACHARJEE	R.D.	
		NOT TO SCALE	
		Dwg. No. R/7 HYD 400/042	Sheet 1 of 1

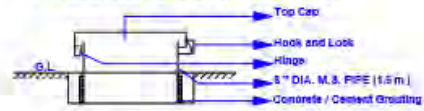
PIEZOMETER NO. SJU 4

SITE NO. - PS 4

LOCATION: AT CTPL WORKSHOP/OFFICE



PIEZOMETER CAP DESIGN



Type of drilling	Direct rotary
Diameter of bore hole	12 inches
Total depth of bore hole	60 m

S.NO.	PARTICULARS	DEPTH (mts.)
1	Heavy duty ribbed PVC	(0 to 12)
	Blank Casing	(24 to 36)
		48 to 54)
2	Heavy duty ribbed PVC	(57 to 60)
	Blank casing with ball plug	
3	Heavy duty ribbed PVC	(12 to 24)
	Slotted Casing	(36 to 48)
		(54 to 57)
4	Clay filling	(0 to 2)
		(4 to 6)
5	Cement seal	(2 to 4)
6	Gravel packing	(6 to 60)

PLATE NO. - D4

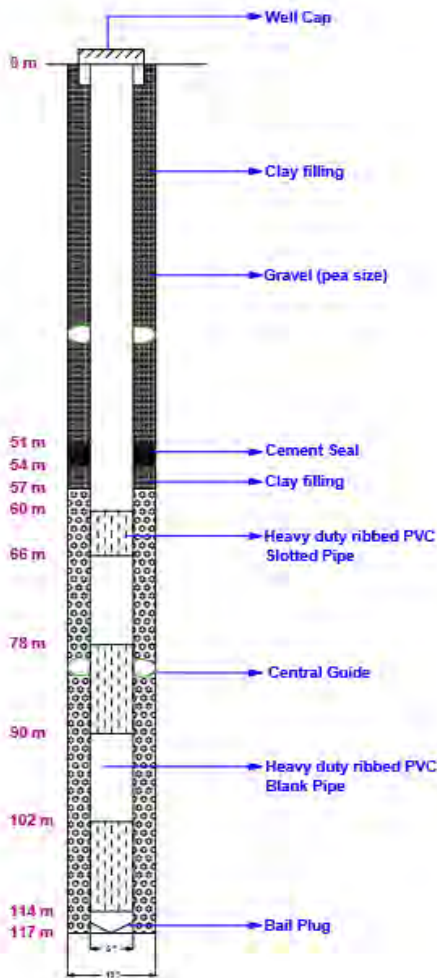
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Customer NTPC LTD.		Job No 780028	
Job Title HYDROGEOLOGICAL REPORT ON ASH DISPOSAL		Subject PIEZOMETER DESIGN FOR PIEZOMETER SJU 4	
Activity	Name	Designation	Signature
Drawn	S. MONDAL	D.M (CRO)	[Signature]
Designed	S. MONDAL	D.M (CRO)	[Signature]
Checked	C. S. KANAPATHY	C.M (ENV.)	[Signature]
Approved	G. BHATTACHARJEE	R.D	[Signature]
NOT TO SCALE		Sheet	1 of 1
CMPDI 30 9691 Company		Drw. No. R77 HYD 400043	REV. No. 0

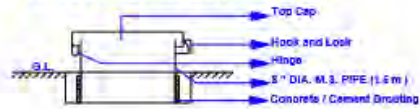
PIEZOMETER NO. SJL 4

SITE NO. - PS 4

LOCATION: AT CTPL WORKSHOP/OFFICE



PIEZOMETER CAP DESIGN



Type of drilling	Direct rotary
Diameter of bore hole	12 inches
Total depth of bore hole	117 m

S.NO.	PARTICULARS	DEPTH (mts.)
1	Heavy duty ribbed PVC Blank Casing	(0 to 80)
		(86 to 78)
		(90 to 102)
		(114 to 117)
2	Heavy duty ribbed PVC Blank casing with bail plug	(114 to 117)
3	Heavy duty ribbed PVC Slotted Casing	(80 to 66)
		(78 to 90)
		(102 to 114)
4	Clay filling	(0 to 51)
		(54 to 57)
5	Cement seal	(51 to 54)
6	Gravel packing	(57 to 117)
7	Central guide	(40)
		(80)
7	Central guide	(40)
		(80)

PLATE NO. - D5

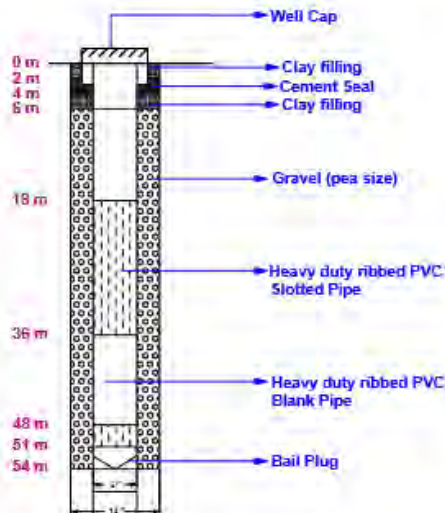
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Customer NTPC LTD.		Job No. 780028	
Job Title HYDROGEOLOGICAL REPORT ON ASH DISPOSAL		Job No. 780028	
Subject PIEZOMETER DESIGN FOR PIEZOMETER SJL 4	Activity	Name	Designation
	Drawn	S. MONDAL	D.M (SRO)
	Designed	S. MONDAL	D.M (SRO)
	Checked	K. S. GANAPATHY	C.M. (ENV.)
Approved	D. BHATTACHARJEE	R.D.	
CMPDI ISO 9001 Company		NOT TO SCALE	Sheet 1 of 1
		Dwg. No. R7 HYD 400044	REV. No. 0

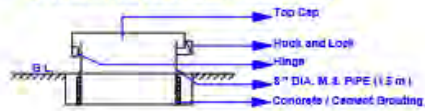
PIEZOMETER NO. SJU 5

SITE NO. - PS 5

LOCATION: AT CENTRAL COLONY (JAGANNATH AREA) NEAR POLICE BEAT HOUSE



PIEZOMETER CAP DESIGN



Type of drilling	Direct rotary
Diameter of bore hole	12 inches
Total depth of bore hole	54 m

S.NO.	PARTICULARS	DEPTH (mts.)
1	Heavy duty ribbed PVC	(0 to 18)
	Blank Casing	(36 to 48)
		(51 to 54)
2	Heavy duty ribbed PVC Blank casing with bail plug	(51 to 54)
3	Heavy duty ribbed PVC Slotted Casing	(18 to 36)
4	Clay filling	(0 to 2)
		(4 to 6)
5	Cement seal	(2 to 4)
6	Gravel packing	(6 to 54)

PLATE NO. - D6

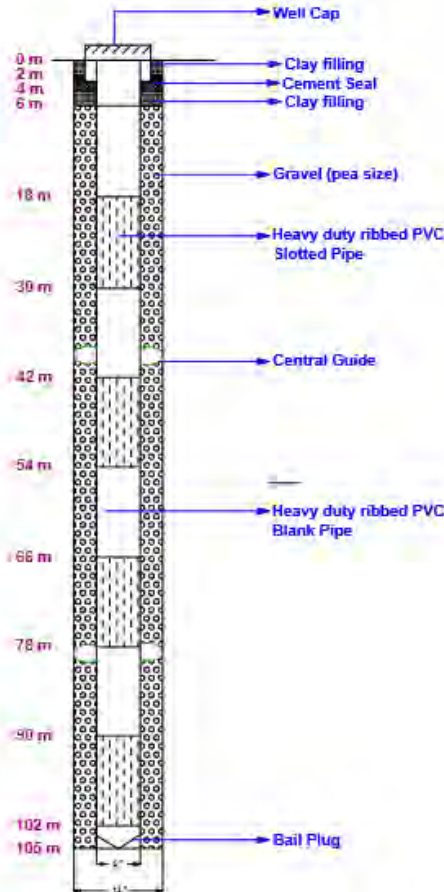
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Customer NTPC LTD.		Job No 780028	
Job Title HYDROGEOLOGICAL REPORT ON ASH DISPOSAL		Job No 780028	
Subject PIEZOMETER DESIGN FOR PIEZOMETER SJU 5	Activity	Name	Designation
	Drawn	S. MONDAL	D.M.(CRD)
	Designed	S. MONDAL	D.M.(CRD)
	Checked	K. S. GANAPATHY	C.M.(HYV.)
	Approved	D. BHATTACHARJEE	J.D.
CMPDI 250 Years Company	NOT TO SCALE		Sheet 1 of 1
	Drw. No. R7 HYD 400048	REV. No 0	

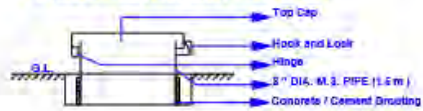
PIEZOMETER NO. SJC 5

SITE NO. - PS 1

LOCATION: AT CENTRAL COLONY (JAGANNATH AREA) NEAR POLICE BEAT HOUSE



PIEZOMETER CAP DESIGN



Type of drilling	Direct rotary
Diameter of bore hole	12 inches
Total depth of bore hole	105 m

S.NO.	PARTICULARS	DEPTH (mts.)
1	Heavy duty ribbed PVC Blank Casing	(0 to 18)
		(30 to 42)
		(54 to 66)
		(78 to 90)
		(102 to 105)
2	Heavy duty ribbed PVC Blank casing with bail plug	(102 to 105)
3	Heavy duty ribbed PVC Slotted Casing	(18 to 30)
		(42 to 54)
		(66 to 78)
		(90 to 102)
4	Clay filling	(0 to 2)
		(4 to 6)
5	Cement seal	(2 to 4)
6	Gravel packing	(6 to 105)
7	Central guide	(40)
		(80)

PLATE NO. - D7

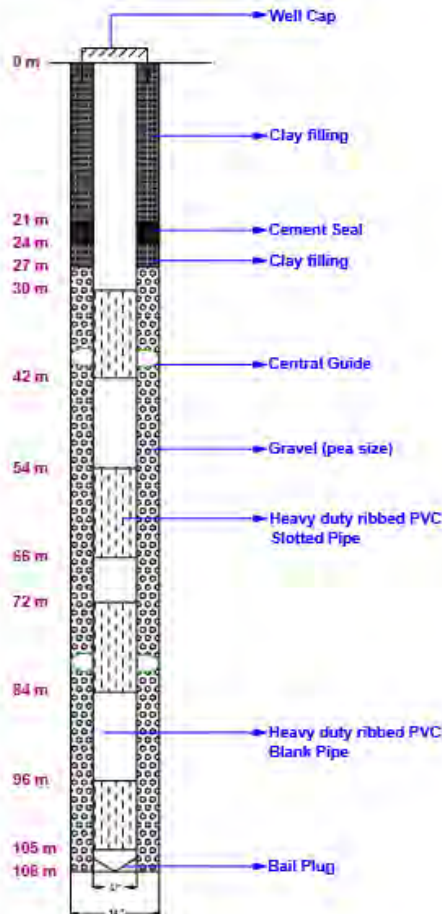
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Customer NTPC LTD.		Job No. 780028	
Job Title HYDROGEOLOGICAL REPORT ON ASH DISPOSAL		Job No. 780028	
Subject PIEZOMETER DESIGN FOR PIEZOMETER SJC 5	Activity	Name	Designation
	Drawn	S. MONDAL	D.M (DSO)
	Designed	S. MONDAL	D.M (DSO)
	Checked	E. S. GANAPATHY	C.M. (ENR.)
	Approved	D. BHATTACHARJEE	I.D.
CMPDI ISO 9001 Company		Sheet 1 of 1 NOT TO SCALE Dig. No. R7 HYD 400048 REV. No. 0	

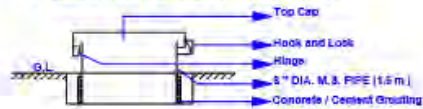
PIEZOMETER NO. SJL 6

SITE NO. - PS 6

LOCATION: NEAR ANANTA PO OFFICE



PIEZOMETER CAP DESIGN



Type of drilling	Direct rotary
Diameter of bore hole	12 inches
Total depth of bore hole	108 m

S.NO.	PARTICULARS	DEPTH (mts.)
1	Heavy duty ribbed PVC Blank Casing	(0 to 30)
		(42 to 54)
		(66 to 72)
		(84 to 96)
2	Heavy duty ribbed PVC Blank casing with bail plug	(105 to 108)
		(80)
3	Heavy duty ribbed PVC Slotted Casing	(30 to 42)
		(54 to 66)
		(72 to 84)
4	Clay filling	(0 to 21)
		(24 to 27)
5	Cement seal	(21 to 24)
6	Gravel packing	(27 to 106)
7	Central guide	(40)

PLATE NO. - D8

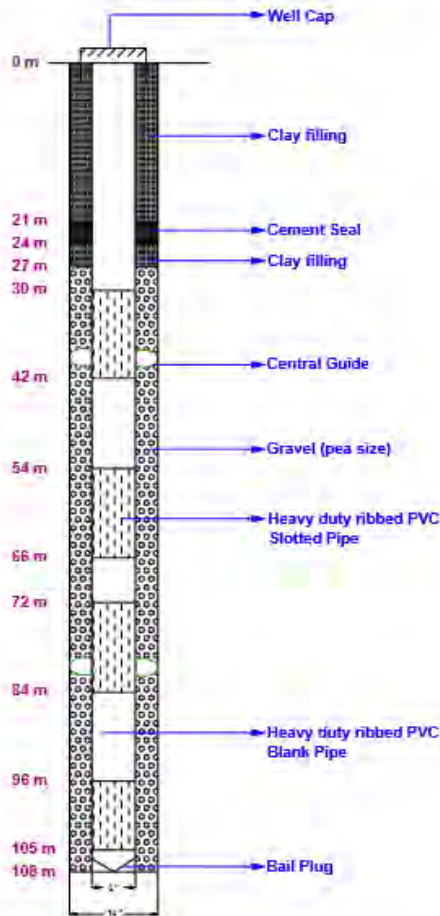
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Customer	NTPC LTD.				
Job Title	HYDROGEOLOGICAL REPORT ON ASH DISPOSAL			Job No.	780028
Subject	Activity	Name	Designation	Signature	Date
	Drawn	S. MONDAL	D.M (CSD)	[Signature]	22/10/14
	Designed	S. MONDAL	D.M (CSD)	[Signature]	22/10/14
	Checked	K. S. GANAPATHY	C.M. (ENV.)	[Signature]	22/10/14
	Approved	D. BHATTACHARJEE	R.D.	[Signature]	22/10/14
NOT TO SCALE				Sheet	1 of 1
 CMPDI ISO 9001 Company		Drg. No. 07 HYD 400047	REV. No. 0		

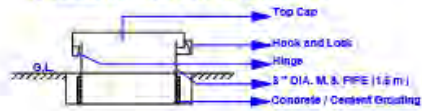
PIEZOMETER NO. SJL 7

SITE NO. - PS 7

LOCATION: NEAR ANANTA RAILWAY SIDING



PIEZOMETER CAP DESIGN



Type of drilling	Direct rotary
Diameter of bore hole	12 inches
Total depth of bore hole	108 m

S.NO	PARTICULARS	DEPTH (mts.)
1	Heavy duty ribbed PVC Blank Casing	(0 to 30)
		(42 to 54)
		(66 to 72)
		(84 to 108)
2	Heavy duty ribbed PVC Blank casing with bail plug	(105 to 108)
3	Heavy duty ribbed PVC Slotted Casing	(30 to 42)
		(54 to 66)
		(72 to 84)
4	Clay filling	(0 to 21)
		(24 to 27)
5	Cement seal	(21 to 24)
6	Gravel packing	(27 to 108)
7	Central guide	(40)
		(80)

PLATE NO. - D9

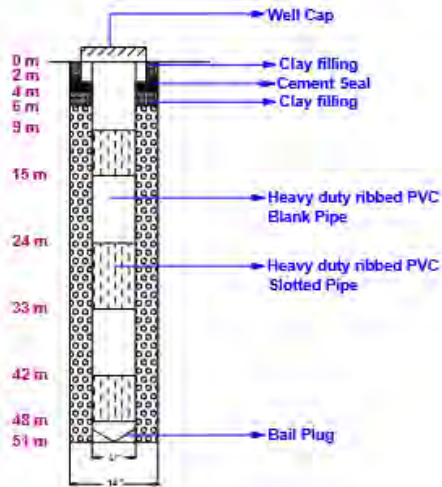
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Customer NTPC LTD.		Job No. 780028	
Job Title HYDROGEOLOGICAL REPORT ON ASH DISPOSAL		Job No. 780028	
Subject PIEZOMETER DESIGN FOR PIEZOMETER SJL 7	Activity	Name	Designation
	Drawn	S. MONDAL	D.M (GRD)
	Designed	S. MONDAL	D.M (GRD)
	Checked	K. S. KARAPATHY	C.M. (ENV.)
	Approved	D. BHATTACHARJEE	R.D.
CMPDI ISO 9001 Company	NOT TO SCALE		Sheet 1 of 1
	Drw. No. R7	HYD	400048
		REV. No.	0

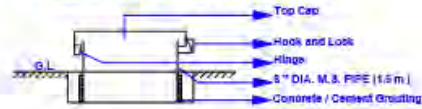
PIEZOMETER NO. SJU 8

SITE NO. - PS 8

LOCATION: EASTERN SIDE OF BALANDA RAILWAY SIDING (OPPOSITE REST SHELTER)



PIEZOMETER CAP DESIGN



Type of drilling	Direct rotary
Diameter of bore hole	12 inches
Total depth of bore hole	51 m

S.NO.	PARTICULARS	DEPTH (mts.)
1	Heavy duty ribbed PVC Blank Casing	(0 to 8)
		(15 to 24)
		(33 to 42)
		(48 to 51)
2	Heavy duty ribbed PVC Blank casing with bail plug	(48 to 51)
3	Heavy duty ribbed PVC Slotted Casing	(8 to 15)
		(24 to 33)
		(42 to 48)
4	Clay filling	(0 to 2) (4 to 8)
5	Cement seal	(2 to 4)
6	Gravel packing	(8 to 51)

PLATE NO. - D10

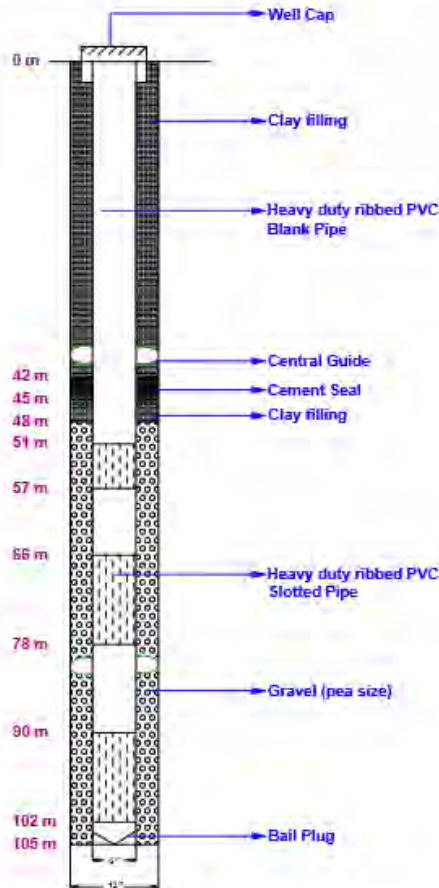
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Customer NTPC LTD.		Job No 780028	
Job Title HYDROGEOLOGICAL REPORT ON ASH DISPOSAL		Job No 780028	
Subject PIEZOMETER DESIGN FOR PIEZOMETER SJU 8	Activity	Name	Designation
	Drawn	S. NORDAL	D.M (GRD)
	Designed	S. NORDAL	D.M (GRD)
	Checked	K. S. KARAPATHY	C.M. (ENV.)
Approved	D. BHATTACHARYA	R.D.	
CMPDI ISO 9001 Company		NOT TO SCALE	Sheet 1 of 1
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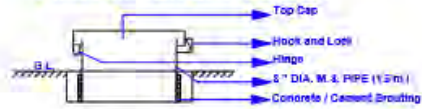
PIEZOMETER NO. SJL 8

SITE NO. - PS 8

LOCATION: EASTERN SIDE OF BALANDA RAILWAY SIDING (OPPOSITE REST SHELTER)



PIEZOMETER CAP DESIGN



Type of drilling	Direct rotary
Diameter of bore hole	12 inches
Total depth of bore hole	105 m

S.NO.	PARTICULARS	DEPTH (mts.)
1	Heavy duty ribbed PVC Blank Casing	(0 to 51)
		(57 to 66)
		(78 to 80)
		(102 to 105)
2	Heavy duty ribbed PVC Blank casing with bail plug	(102 to 105)
3	Heavy duty ribbed PVC Slotted Casing	(51 to 57)
		(66 to 78)
4	Clay filling	(90 to 102)
		(0 to 42)
5	Cement seal	(42 to 48)
6	Gravel packing	(48 to 105)
7	Central guide	(+0)
		(80)

PLATE NO. - D11

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Customer NTPC LTD.		Job No. 780028	
Job Title HYDROGEOLOGICAL REPORT ON ASH DISPOSAL		Subject PIEZOMETER DESIGN FOR PIEZOMETER SJL 8	
Activity	Name	Designation	Signature
Drawn	S. MONDAL	D.M.(Geo)	[Signature]
Designed	S. MONDAL	D.M.(Geo)	[Signature]
Checked	E. S. GANAPATHY	C.M. (ENV.)	[Signature]
Approved	D. BHATTACHARJEE	R.D.	[Signature]
			Sheet 1 of 1
NOT TO SCALE Dwg. No. R7 HYD 400060			REV. No 0

FINAL REPORT
ON
**HYDROGEOLOGICAL INVESTIGATION FOR
DISPOSAL OF ASH IN MINE VOIDS (QUARRY
NOS. 4, 7 & 8) IN JAGANNATH OCP OF
JAGANNATH AREA OF MCL,**

**TALCHER COALFIELD,
ODISHA**

ANNEXURE - II

**Details of Pumping Test and Slug Test conducted in and
around Jagannath OCP, Talcher Coalfield, Odisha.**

Time (hr)	Time in minutes since pumping started in mins.	Pumping water level in m bmp	Pumping water level in m bgl	Drawdown (m)	Remarks (discharge in lps)
	17.00	53.79	53.21	14.41	
	18.00	53.99	53.41	14.61	
	19.00	54.19	53.61	14.81	
	20.00	54.34	53.76	14.96	
	22.00	54.63	54.05	15.25	
	24.00	54.80	54.22	15.42	
	26.00	55.05	54.47	15.67	
	28.00	55.20	54.62	15.82	
	30.00	55.38	54.80	16.00	0.58
	35.00	55.59	55.01	16.21	
	40.00	55.90	55.32	16.52	
	45.00	56.08	55.50	16.70	
	50.00	56.31	55.73	16.93	
	55.00	56.50	55.92	17.12	
	60.00	56.59	56.01	17.21	
	70.00	56.79	56.21	17.41	
	80.00	56.92	56.34	17.54	
	90.00	56.80	56.22	17.42	
	100.00	56.89	56.31	17.51	
	110.00	56.90	56.32	17.52	
	120.00	56.85	56.27	17.47	
	140.00	56.89	56.31	17.51	
	160.00	56.95	56.37	17.57	
	180.00	57.15	56.57	17.77	
	200.00	57.31	56.73	17.93	
	220.00	57.37	56.79	17.99	
	240.00	57.42	56.84	18.04	
	300.00	57.68	57.10	18.30	
	360.00	57.97	57.39	18.59	
	420.00	58.05	57.47	18.67	
	480.00	58.12	57.54	18.74	
07.45 PM	540.00	58.08	57.50	18.70	0.58

Note: 0.50 is equivalent to 30 seconds

Time (hr)	Time in minutes since pumping started in mins.	Pumping water level in m bmp	Pumping water level in m bgl	Drawdown (m)	Remarks (discharge in lps)
	20.00	21.61	20.76	5.83	
	22.00	21.65	20.80	5.87	
	24.00	21.76	20.91	5.98	
	26.00	21.86	21.01	6.08	
	28.00	21.98	21.13	6.20	
	30.00	22.06	21.21	6.28	0.88
	35.00	22.30	21.45	6.52	
	40.00	22.43	21.58	6.65	
	45.00	22.60	21.75	6.82	
	50.00	22.69	21.84	6.91	
	55.00	22.79	21.94	7.01	
	60.00	22.90	22.05	7.12	
	70.00	23.10	22.25	7.32	
	80.00	23.25	22.40	7.47	
	90.00	23.29	22.44	7.51	
	100.00	23.55	22.70	7.77	
	110.00	23.71	22.86	7.93	
	120.00	23.81	22.96	8.03	0.88
	140.00	21.02	20.17	5.24	
	160.00	24.18	23.33	8.40	
	180.00	24.38	23.53	8.60	
	200.00	24.51	23.66	8.73	
	220.00	24.79	23.94	9.01	
	240.00	24.87	24.02	9.09	
	300.00	25.14	24.29	9.36	
	360.00	25.45	24.60	9.67	
	420.00	25.64	24.79	9.86	
	480.00	25.89	25.04	10.11	0.85
	540.00	26.04	25.19	10.26	
	600.00	26.20	25.35	10.42	
01.30 AM	660.00	26.34	25.49	10.56	

PUMPING TEST DATA

Well no.	: SJL 3	Location	: At Jagannath workshop
SWL	: 15.09 m bmp	Discharge	: 0.80 lps
Total depth	: 108 m	Pump start	: 12.30 PM
Diameter	: 50 mm / 300 mm	Pump stopped	: 11.30 PM
MP	: 0.70 m above ground level		

Time (hr)	Time in minutes since pumping started in mins.	Pumping water level in m bmp	Pumping water level in m bgl	Drawdown (m)	Remarks (discharge in lps)
12.30 PM	0.50	15.72	15.02	0.63	
	1.00	16.72	16.02	1.63	
	1.50	17.25	16.55	2.16	
	2.00	18.00	17.30	2.91	
	2.50	18.41	17.71	3.32	
	3.00	19.12	18.42	4.03	
	3.50	19.65	18.95	4.56	
	4.00	20.00	19.30	4.91	
	4.50	20.62	19.92	5.53	
	5.00	21.15	20.45	6.06	0.81
	5.50	21.68	20.98	6.59	
	6.00	22.10	21.40	7.01	
	6.50	22.50	21.80	7.41	
	7.00	22.97	22.27	7.88	
	7.50	23.28	22.58	8.19	
	8.00	23.70	23.00	8.61	
	8.50	24.00	23.30	8.91	
	9.00	24.55	23.85	9.46	
	9.50	24.82	24.12	9.73	
	10.00	25.22	24.52	10.13	0.79
	11.00	25.90	25.20	10.81	
	12.00	26.50	25.80	11.41	
	13.00	27.05	26.35	11.96	
	14.00	27.60	26.90	12.51	
	15.00	28.05	27.35	12.96	
	16.00	28.60	27.90	13.51	
	17.00	28.90	28.20	13.81	
	18.00	29.35	28.65	14.26	
	19.00	29.80	29.10	14.71	

Time (hr)	Time in minutes since pumping started in mins.	Pumping water level in m bmp	Pumping water level in m bgl	Drawdown (m)	Remarks (discharge in lps)
	20.00	30.16	29.46	15.07	
	22.00	30.92	30.22	15.83	
	24.00	31.62	30.92	16.53	
	26.00	32.30	31.60	17.21	
	28.00	32.58	31.88	17.49	
	30.00	32.94	32.24	17.85	
	35.00	33.90	33.20	18.81	
	40.00	34.38	33.68	19.29	
	45.00	34.95	34.25	19.86	
	50.00	35.28	34.58	20.19	
	55.00	35.70	35.00	20.61	
	60.00	35.97	35.27	20.88	0.80
	70.00	36.30	35.60	21.21	
	80.00	36.65	35.95	21.56	
	90.00	36.70	36.00	21.61	
	100.00	36.78	36.08	21.69	
	110.00	36.90	36.20	21.81	
	120.00	37.18	36.48	22.09	
	140.00	37.27	36.57	22.18	
	160.00	37.35	36.65	22.26	
	180.00	37.68	36.98	22.59	
	200.00	37.74	37.04	22.65	
	220.00	37.81	37.11	22.72	
	240.00	37.90	37.20	22.81	
	300.00	37.98	37.28	22.89	
	360.00	38.30	37.60	23.21	
	420.00	38.50	37.80	23.41	
	480.00	38.72	38.02	23.63	
	540.00	38.84	38.14	23.75	
	600.00	38.94	38.24	23.85	
11.30 PM	660.00	39.08	38.38	23.99	0.81

Time (hr)	Time in minutes since pumping started in mins.	Pumping water level in m bmp	Pumping water level in m bgl	Drawdown (m)	Remarks (discharge in lps)
	20.00	6.84	5.96	2.26	
	22.00	7.10	6.22	2.52	
	24.00	7.51	6.63	2.93	
	26.00	7.71	6.83	3.13	
	28.00	8.07	7.19	3.49	
	30.00	8.53	7.65	3.95	
	35.00	9.73	8.85	5.15	1.83
	40.00	10.43	9.55	5.85	
	45.00	11.38	10.50	6.80	
	50.00	12.55	11.67	7.97	
	55.00	12.99	12.11	8.41	
	60.00	13.41	12.53	8.83	1.83
	70.00	14.70	13.82	10.12	
	80.00	15.48	14.60	10.90	
	90.00	16.80	15.92	12.22	
	100.00	17.40	16.52	12.82	
	110.00	17.90	17.02	13.32	
	120.00	18.64	17.76	14.06	1.83
	140.00	19.78	18.90	15.20	
	160.00	20.74	19.86	16.16	
	180.00	22.01	21.13	17.43	
	200.00	22.85	21.97	18.27	
	220.00	23.93	23.05	19.35	
	240.00	24.55	23.67	19.97	
	300.00	26.34	25.46	21.76	
	360.00	28.84	27.96	24.26	
	420.00	31.22	30.34	26.64	
	480.00	32.78	31.90	28.20	
	540.00	33.84	32.96	29.26	
	600.00	34.80	33.92	30.22	
01.30 AM	660.00	35.90	35.02	31.32	1.83

Time (hr)	Time in minutes since pumping started in mins.	Pumping water level in m bmp	Pumping water level in m bgl	Drawdown (m)	Remarks (discharge in lps)
	20.00	7.97	7.42	0.72	
	22.00	8.00	7.45	0.75	2.20
	24.00	8.03	7.48	0.78	
	26.00	8.06	7.51	0.81	
	28.00	8.07	7.52	0.82	
	30.00	8.11	7.56	0.86	
	35.00	8.16	7.61	0.91	
	40.00	8.22	7.67	0.97	
	45.00	8.23	7.68	0.98	
	50.00	8.27	7.72	1.02	
	55.00	8.32	7.77	1.07	
	60.00	8.35	7.80	1.10	2.00
	70.00	8.40	7.85	1.15	
	80.00	8.49	7.94	1.24	
	90.00	8.55	8.00	1.30	
	100.00	8.57	8.02	1.32	
	110.00	8.60	8.05	1.35	
	120.00	8.64	8.09	1.39	2.20
	140.00	8.70	8.15	1.45	
	160.00	8.78	8.23	1.53	
	180.00	8.82	8.27	1.57	
	200.00	8.89	8.34	1.64	
	220.00	8.92	8.37	1.67	
	240.00	8.97	8.42	1.72	
	300.00	9.06	8.51	1.81	
	360.00	9.14	8.59	1.89	
	420.00	9.20	8.65	1.95	
	480.00	9.26	8.71	2.01	
	540.00	9.32	8.77	2.07	
	600.00	9.37	8.82	2.12	
07.15 PM	660.00	9.41	8.86	2.16	2.00

PUMPING TEST DATA

Well no. : SJU 5 **Location** : At central colony
SWL : 7.28 m bmp **Discharge** : 2.16 lps
Total depth : 54 m **Pump start** : 07.15 AM
Diameter : 150 mm / 300 mm **Pump stopped** : 05.15 PM
MP : 0.65 m above ground level

Time (hr)	Time in minutes since pumping started in mins.	Pumping water level in m bmp	Pumping water level in m bgl	Drawdown (m)	Remarks (discharge in lps)
07.15 AM	0.50	7.40	6.75	0.12	
	1.00	7.44	6.79	0.16	
	1.50	7.49	6.84	0.21	
	2.00	7.52	6.87	0.24	
	2.50	7.55	6.9	0.27	
	3.00	7.58	6.93	0.30	
	3.50	7.61	6.96	0.33	
	4.00	7.62	6.97	0.34	
	4.50	7.64	6.99	0.36	
	5.00	7.68	7.03	0.40	2.22
	5.50	7.69	7.04	0.41	
	6.00	7.70	7.05	0.42	
	6.50	7.71	7.06	0.43	
	7.00	7.73	7.08	0.45	
	7.50	7.74	7.09	0.46	
	8.00	7.77	7.12	0.49	
	8.50	7.78	7.13	0.50	
	9.00	7.79	7.14	0.51	
	9.50	7.80	7.15	0.52	
	10.00	7.82	7.17	0.54	
	11.00	7.84	7.19	0.56	
	12.00	7.86	7.21	0.58	
	13.00	7.89	7.24	0.61	
	14.00	7.91	7.26	0.63	
	15.00	7.93	7.28	0.65	2.00
	16.00	7.95	7.3	0.67	
	17.00	7.97	7.32	0.69	
	18.00	7.99	7.34	0.71	
	19.00	8.01	7.36	0.73	

Time (hr)	Time in minutes since pumping started in mins.	Pumping water level in m bmp	Pumping water level in m bgl	Drawdown (m)	Remarks (discharge in lps)
	20.00	8.03	7.38	0.75	
	22.00	8.06	7.41	0.78	
	24.00	8.08	7.43	0.80	
	26.00	8.11	7.46	0.83	
	28.00	8.13	7.48	0.85	
	30.00	8.16	7.51	0.88	2.00
	35.00	8.23	7.58	0.95	
	40.00	8.29	7.64	1.01	
	45.00	8.32	7.67	1.04	
	50.00	8.35	7.7	1.07	
	55.00	8.38	7.73	1.10	
	60.00	8.41	7.76	1.13	2.22
	70.00	8.49	7.84	1.21	
	80.00	8.53	7.88	1.25	
	90.00	8.60	7.95	1.32	
	100.00	8.66	8.01	1.38	
	110.00	8.68	8.03	1.40	
	120.00	8.71	8.06	1.43	2.22
	140.00	8.81	8.16	1.53	
	160.00	8.81	8.16	1.53	
	180.00	8.88	8.23	1.60	
	200.00	8.93	8.28	1.65	
	220.00	8.98	8.33	1.70	
	240.00	9.02	8.37	1.74	2.22
	300.00	9.12	8.47	1.84	
	360.00	9.20	8.55	1.92	
	420.00	9.27	8.62	1.99	
	480.00	9.36	8.71	2.08	2.22
	540.00	9.38	8.73	2.10	
05.15 PM	600.00	9.38	8.73	2.10	

Time	Time in minutes since pumping started in mins.	Pumping water level in m bmp	Pumping water level in m bgl	Drawdown (m)	Remarks (discharge in lps)
	20.00	12.84	12.01	10.95	
	22.00	12.96	12.13	11.07	
	24.00	13.12	12.29	11.23	1.00
	26.00	13.22	12.39	11.33	
	28.00	13.28	12.45	11.39	
	30.00	13.39	12.56	11.50	
	35.00	13.74	12.91	11.85	
	40.00	13.89	13.06	12.00	
	45.00	14.08	13.25	12.19	
	50.00	14.23	13.40	12.34	
	55.00	14.42	13.59	12.53	
	60.00	14.62	13.79	12.73	0.96
	70.00	14.95	14.12	13.06	
	80.00	15.14	14.31	13.25	
	90.00	15.36	14.53	13.47	
	100.00	15.55	14.72	13.66	
	110.00	15.59	14.76	13.70	
	120.00	15.74	14.91	13.85	0.88
	140.00	15.82	14.99	13.93	
	160.00	16.04	15.21	14.15	
	180.00	16.14	15.31	14.25	
	200.00	16.49	15.66	14.60	
	220.00	16.70	15.87	14.81	
	240.00	17.00	16.17	15.11	
	300.00	17.42	16.59	15.53	
	360.00	17.69	16.86	15.80	
	420.00	18.08	17.25	16.19	
	480.00	18.38	17.55	16.49	
	540.00	18.68	17.85	16.79	
	600.00	19.05	18.22	17.16	
10.30 PM	660.00	19.09	18.26	17.20	0.88

PUMPING TEST DATA

Well no. : SJL 2 **Location** : At Ananta substation
SWL : 34.50 m bmp **Discharge** : 0.66 lps
Total depth : 114 m **Pump start** : 11.30 AM
Diameter : 150 mm / 300 mm **Pump stopped** : 08.30 PM
MP : 0.58 m above ground level

Time (hr)	Time in minutes since pumping started in mins.	Pumping water level in m bmp	Pumping water level in m bgl	Drawdown (m)	Remarks (discharge in lps)
11.30 AM	0.50	35.87	35.29	1.37	
	1.00	37.24	36.66	2.74	
	1.50	38.54	37.96	4.04	
	2.00	39.10	38.52	4.60	
	2.50	40.12	39.54	5.62	
	3.00	40.85	40.27	6.35	
	3.50	41.34	40.76	6.84	
	4.00	41.92	41.34	7.42	
	4.50	42.48	41.90	7.98	
	5.00	43.12	42.54	8.62	0.68
	5.50	43.67	43.09	9.17	
	6.00	44.07	43.49	9.57	
	6.50	44.52	43.94	10.02	
	7.00	44.85	44.27	10.35	
	7.50	45.17	44.59	10.67	
	8.00	45.62	45.04	11.12	
	8.50	45.88	45.30	11.38	
	9.00	46.17	45.59	11.67	
	9.50	46.48	45.90	11.98	
	10.00	46.72	46.14	12.22	
	11.00	47.17	46.59	12.67	
	12.00	47.57	46.99	13.07	
	13.00	47.87	47.29	13.37	
	14.00	48.20	47.62	13.70	
	15.00	48.44	47.86	13.94	0.61
	16.00	48.69	48.11	14.19	
	17.00	48.91	48.33	14.41	
	18.00	49.11	48.53	14.61	
	19.00	49.31	48.73	14.81	

Time (hr)	Time in minutes since pumping started in mins.	Pumping water level in m bmp	Pumping water level in m bgl	Drawdown (m)	Remarks (discharge in lps)
	20.00	49.46	48.88	14.96	
	22.00	49.75	49.17	15.25	
	24.00	49.92	49.34	15.42	
	26.00	50.17	49.59	15.67	
	28.00	50.32	49.74	15.82	
	30.00	50.50	49.92	16.00	0.68
	35.00	50.71	50.13	16.21	
	40.00	51.02	50.44	16.52	
	45.00	51.20	50.62	16.70	
	50.00	51.43	50.85	16.93	
	55.00	51.62	51.04	17.12	
	60.00	51.71	51.13	17.21	
	70.00	51.91	51.33	17.41	
	80.00	52.04	51.46	17.54	
	90.00	51.92	51.34	17.42	
	100.00	52.01	51.43	17.51	
	110.00	52.02	51.44	17.52	
	120.00	51.97	51.39	17.47	
	140.00	52.01	51.43	17.51	
	160.00	52.07	51.49	17.57	
	180.00	52.27	51.69	17.77	
	200.00	52.43	51.85	17.93	
	220.00	52.49	51.91	17.99	
	240.00	52.54	51.96	18.04	
	300.00	52.80	52.22	18.30	
	360.00	53.09	52.51	18.59	
	420.00	53.17	52.59	18.67	
	480.00	53.24	52.66	18.74	
8.30 PM	540.00	53.20	52.62	18.70	0.68

Time (hr)	Water Level (m)	Time after pumping stopped (t') (min)	Time after pumping started (t) (min)	t/t'	Residual draw down (m)
	44.16	18.00	558.00	31.00	5.36
	44.00	19.00	559.00	29.42	5.20
	43.83	20.00	560.00	28.00	5.03
	43.60	22.00	562.00	25.55	4.80
	43.34	24.00	564.00	23.50	4.54
	43.14	26.00	566.00	21.77	4.34
	42.99	28.00	568.00	20.29	4.19
	42.79	30.00	570.00	19.00	3.99
	42.52	35.00	575.00	16.43	3.72
	42.31	40.00	580.00	14.50	3.51
	42.09	45.00	585.00	13.00	3.29
	41.92	50.00	590.00	11.80	3.12
	41.80	55.00	595.00	10.82	3.00
	41.64	60.00	600.00	10.00	2.84
	41.55	70.00	610.00	8.71	2.75
	41.42	80.00	620.00	7.75	2.62
	41.35	90.00	630.00	7.00	2.55
	41.27	100.00	640.00	6.40	2.47
	41.23	110.00	650.00	5.91	2.43
	41.20	120.00	660.00	5.50	2.40
	41.07	140.00	680.00	4.86	2.27
	40.97	160.00	700.00	4.38	2.17
	40.88	180.00	720.00	4.00	2.08
	40.87	200.00	740.00	3.70	2.07
	40.80	220.00	760.00	3.45	2.00
11.45 PM	40.78	240.00	780.00	3.25	1.98

Time (hr)	Water Level (m)	Time after pumping stopped (t') (min)	Time after pumping started (t) (min)	t/t'	Residual draw down (m)
	20.11	18.00	678.00	37.67	5.18
	20.06	19.00	679.00	35.74	5.13
	20.06	20.00	680.00	34.00	5.13
	20.00	22.00	682.00	31.00	5.07
	19.88	24.00	684.00	28.50	4.95
	19.80	26.00	686.00	26.38	4.87
	19.73	28.00	688.00	24.57	4.80
	19.62	30.00	690.00	23.00	4.69
	19.48	35.00	695.00	19.86	4.55
	19.32	40.00	700.00	17.50	4.39
	19.19	45.00	705.00	15.67	4.26
	19.06	50.00	710.00	14.20	4.13
	18.92	55.00	715.00	13.00	3.99
	18.79	60.00	720.00	12.00	3.86
	18.65	70.00	730.00	10.43	3.72
	18.51	80.00	740.00	9.25	3.58
	18.37	90.00	750.00	8.33	3.44
	18.17	100.00	760.00	7.60	3.24
	18.12	110.00	770.00	7.00	3.19
	18.03	120.00	780.00	6.50	3.10
	17.82	140.00	800.00	5.71	2.89
	17.65	160.00	820.00	5.13	2.72
	17.48	180.00	840.00	4.67	2.55
	17.37	200.00	860.00	4.30	2.44
	17.30	220.00	880.00	4.00	2.37
	17.15	240.00	900.00	3.75	2.22
06.30 AM	16.94	300.00	960.00	3.20	2.01

RECOVERY TEST DATA

Well no. : SJL 3 **Location** : At Jagannath workshop
SWL : 15.09 m bmp **Discharge** : 0.80 lps
Total depth : 108 m **Pump start** : 12.30 PM
Diameter : 150 mm / 300 mm **Pump stopped** : 11.30 PM
MP : 0.70 m above ground level

Time (hr)	Water Level (m)	Time after pumping stopped (t') (min)	Time after pumping started (t) (min)	t/t'	Residual draw down (m)
11.30 PM	37.80	0.50	660.50	1321.00	23.41
	37.00	1.00	661.00	661.00	22.61
	36.61	1.50	661.50	441.00	22.22
	36.06	2.00	662.00	331.00	21.67
	35.40	2.50	662.50	265.00	21.01
	34.91	3.00	663.00	221.00	20.52
	34.42	3.50	663.50	189.57	20.03
	33.95	4.00	664.00	166.00	19.56
	33.46	4.50	664.50	147.67	19.07
	33.01	5.00	665.00	133.00	18.62
	32.66	5.50	665.50	121.00	18.27
	32.20	6.00	666.00	111.00	17.81
	31.79	6.50	666.50	102.54	17.40
	31.49	7.00	667.00	95.29	17.10
	31.09	7.50	667.50	89.00	16.70
	30.74	8.00	668.00	83.50	16.35
	30.41	8.50	668.50	78.65	16.02
	30.10	9.00	669.00	74.33	15.71
	29.72	9.50	669.50	70.47	15.33
	29.38	10.00	670.00	67.00	14.99
	28.77	11.00	671.00	61.00	14.38
	28.18	12.00	672.00	56.00	13.79
	27.65	13.00	673.00	51.77	13.26
	27.13	14.00	674.00	48.14	12.74
	26.70	15.00	675.00	45.00	12.31
	26.17	16.00	676.00	42.25	11.78
	25.73	17.00	677.00	39.82	11.34

Time (hr)	Water Level (m)	Time after pumping stopped (t') (min)	Time after pumping started (t) (min)	t/t'	Residual draw down (m)
	25.29	18.00	678.00	37.67	10.90
	24.92	19.00	679.00	35.74	10.53
	24.55	20.00	680.00	34.00	10.16
	23.85	22.00	682.00	31.00	9.46
	23.18	24.00	684.00	28.50	8.79
	22.64	26.00	686.00	26.38	8.25
	22.13	28.00	688.00	24.57	7.74
	21.69	30.00	690.00	23.00	7.30
	20.77	35.00	695.00	19.86	6.38
	20.00	40.00	700.00	17.50	5.61
	19.40	45.00	705.00	15.67	5.01
	18.93	50.00	710.00	14.20	4.54
	18.56	55.00	715.00	13.00	4.17
	18.26	60.00	720.00	12.00	3.87
	17.61	70.00	730.00	10.43	3.22
	17.28	80.00	740.00	9.25	2.89
	17.16	90.00	750.00	8.33	2.77
	17.01	100.00	760.00	7.60	2.62
	16.87	110.00	770.00	7.00	2.48
	16.73	120.00	780.00	6.50	2.34
	16.67	140.00	800.00	5.71	2.28
	16.51	160.00	820.00	5.13	2.12
	16.38	180.00	840.00	4.67	1.99
	16.26	200.00	860.00	4.30	1.87
03.10 AM	16.01	220.00	880.00	4.00	1.62

RECOVERY TEST DATA

Well no. : SJL 6 **Location** : Near Ananta Project office
SWL : 4.58 m bmp **Discharge** : 1.80 lps
Total depth : 108 m **Pump start** : 2.30 PM
Diameter : 150 mm / 300 mm **Pump stopped** : 1.30 AM
MP : 0.88 m above ground level

Time (hr)	Water Level (m)	Time after pumping stopped (t') (min)	Time after pumping started (t) (min)	t/t'	Residual draw down (m)
1.30 AM	32.52	0.50	660.50	1321.00	28.82
	30.93	1.00	661.00	661.00	27.23
	29.77	1.50	661.50	441.00	26.07
	28.74	2.00	662.00	331.00	25.04
	27.92	2.50	662.50	265.00	24.22
	26.92	3.00	663.00	221.00	23.22
	26.12	3.50	663.50	189.57	22.42
	25.22	4.00	664.00	166.00	21.52
	24.07	4.50	664.50	147.67	20.37
	23.37	5.00	665.00	133.00	19.67
	22.52	5.50	665.50	121.00	18.82
	21.73	6.00	666.00	111.00	18.03
	20.81	6.50	666.50	102.54	17.11
	20.04	7.00	667.00	95.29	16.34
	19.28	7.50	667.50	89.00	15.58
	18.41	8.00	668.00	83.50	14.71
	17.63	8.50	668.50	78.65	13.93
	16.95	9.00	669.00	74.33	13.25
	16.33	9.50	669.50	70.47	12.63
	15.72	10.00	670.00	67.00	12.02
	14.58	11.00	671.00	61.00	10.88
	13.62	12.00	672.00	56.00	9.92
	12.49	13.00	673.00	51.77	8.79
	11.51	14.00	674.00	48.14	7.81
	10.44	15.00	675.00	45.00	6.74
	9.67	16.00	676.00	42.25	5.97
	8.80	17.00	677.00	39.82	5.10

Time (hr)	Water Level (m)	Time after pumping stopped (t') (min)	Time after pumping started (t) (min)	t/t'	Residual draw down (m)
	8.04	18.00	678.00	37.67	4.34
	7.41	19.00	679.00	35.74	3.71
	6.72	20.00	680.00	34.00	3.02
	5.35	22.00	682.00	31.00	1.65
	4.41	24.00	684.00	28.50	0.71
	4.24	26.00	686.00	26.38	0.54
	4.22	28.00	688.00	24.57	0.52
	4.19	30.00	690.00	23.00	0.49
	4.18	35.00	695.00	19.86	0.48
	4.13	40.00	700.00	17.50	0.43
	4.09	45.00	705.00	15.67	0.39
	4.05	50.00	710.00	14.20	0.35
	4.05	55.00	715.00	13.00	0.35
	4.04	60.00	720.00	12.00	0.34
	4.00	70.00	730.00	10.43	0.30
	3.98	80.00	740.00	9.25	0.28
03.00 AM	3.96	90.00	750.00	8.33	0.26

Time (hr)	Water Level (m)	Time after pumping stopped (t') (min)	Time after pumping started (t) (min)	t/t'	Residual draw down (m)
	8.04	18.00	678.00	37.67	1.34
	8.02	19.00	679.00	35.74	1.32
	8.01	20.00	680.00	34.00	1.31
	7.98	22.00	682.00	31.00	1.28
	7.96	24.00	684.00	28.50	1.26
	7.93	26.00	686.00	26.38	1.23
	7.90	28.00	688.00	24.57	1.20
	7.88	30.00	690.00	23.00	1.18
	7.84	35.00	695.00	19.86	1.14
	7.80	40.00	700.00	17.50	1.10
	7.76	45.00	705.00	15.67	1.06
	7.71	50.00	710.00	14.20	1.01
	7.67	55.00	715.00	13.00	0.97
	7.65	60.00	720.00	12.00	0.95
	7.60	70.00	730.00	10.43	0.90
	7.56	80.00	740.00	9.25	0.86
	7.51	90.00	750.00	8.33	0.81
	7.46	100.00	760.00	7.60	0.76
	7.45	110.00	770.00	7.00	0.75
	7.42	120.00	780.00	6.50	0.72
	7.40	140.00	800.00	5.71	0.70
	7.31	160.00	820.00	5.13	0.61
	7.29	180.00	840.00	4.67	0.59
	7.26	200.00	860.00	4.30	0.56
10.55 PM	7.24	220.00	880.00	4.00	0.54

RECOVERY TEST DATA

Well no. : SJU 5 **Location** : At central colony
SWL : 7.28 m bmp **Discharge** : 2.16 lps
Total depth : 54 m **Pump start** : 07.15 AM
Diameter : 150 mm / 300 mm **Pump stopped** : 05.15 PM
MP : 0.65 m above ground level

Time (hr)	Water Level (m)	Time after pumping stopped (t') (min)	Time after pumping started (t) (min)	t/t'	Residual draw down (m)
05.15 PM	8.58	0.50	600.50	1201.00	1.95
	8.53	1.00	601.00	601.00	1.90
	8.5	1.50	601.50	401.00	1.87
	8.46	2.00	602.00	301.00	1.83
	8.43	2.50	602.50	241.00	1.80
	8.41	3.00	603.00	201.00	1.78
	8.39	3.50	603.50	172.43	1.76
	8.36	4.00	604.00	151.00	1.73
	8.32	4.50	604.50	134.33	1.69
	8.31	5.00	605.00	121.00	1.68
	8.29	5.50	605.50	110.09	1.66
	8.27	6.00	606.00	101.00	1.64
	8.27	6.50	606.50	93.31	1.64
	8.25	7.00	607.00	86.71	1.62
	8.24	7.50	607.50	81.00	1.61
	8.22	8.00	608.00	76.00	1.59
	8.20	8.50	608.50	71.59	1.57
	8.19	9.00	609.00	67.67	1.56
	8.18	9.50	609.50	64.16	1.55
	8.15	10.00	610.00	61.00	1.52
	8.13	11.00	611.00	55.55	1.50
	8.11	12.00	612.00	51.00	1.48
	8.09	13.00	613.00	47.15	1.46
	8.07	14.00	614.00	43.86	1.44
	8.04	15.00	615.00	41.00	1.41
	8.03	16.00	616.00	38.50	1.40
	8.01	17.00	617.00	36.29	1.38

Time (hr)	Water Level (m)	Time after pumping stopped (t') (min)	Time after pumping started (t) (min)	t/t'	Residual draw down (m)
	8.00	18.00	618.00	34.33	1.37
	7.98	19.00	619.00	32.58	1.35
	7.96	20.00	620.00	31.00	1.33
	7.94	22.00	622.00	28.27	1.31
	7.91	24.00	624.00	26.00	1.28
	7.89	26.00	626.00	24.08	1.26
	7.86	28.00	628.00	22.43	1.23
	7.83	30.00	630.00	21.00	1.20
	7.79	35.00	635.00	18.14	1.16
	7.75	40.00	640.00	16.00	1.12
	7.70	45.00	645.00	14.33	1.07
	7.67	50.00	650.00	13.00	1.04
	7.65	55.00	655.00	11.91	1.02
	7.61	60.00	660.00	11.00	0.98
	7.57	70.00	670.00	9.57	0.94
	7.52	80.00	680.00	8.50	0.89
	7.48	90.00	690.00	7.67	0.85
	7.45	100.00	700.00	7.00	0.82
	7.42	110.00	710.00	6.45	0.79
	7.40	120.00	720.00	6.00	0.77
	7.21	140.00	740.00	5.29	0.58
	7.15	160.00	760.00	4.75	0.52
08.15 PM	7.10	180.00	780.00	4.33	0.47

Time (hr)	Water Level (m)	Time after pumping stopped (t') (min)	Time after pumping started (t) (min)	t/t'	Residual draw down (m)
	6.23	18.00	678.00	37.67	5.17
	6.09	19.00	679.00	35.74	5.03
	5.96	20.00	680.00	34.00	4.90
	5.66	22.00	682.00	31.00	4.60
	5.35	24.00	684.00	28.50	4.29
	5.07	26.00	686.00	26.38	4.01
	4.83	28.00	688.00	24.57	3.77
	4.63	30.00	690.00	23.00	3.57
	4.23	35.00	695.00	19.86	3.17
	3.94	40.00	700.00	17.50	2.88
	3.71	45.00	705.00	15.67	2.65
	3.52	50.00	710.00	14.20	2.46
	3.37	55.00	715.00	13.00	2.31
	3.26	60.00	720.00	12.00	2.20
	3.01	70.00	730.00	10.43	1.95
	2.81	80.00	740.00	9.25	1.75
	2.65	90.00	750.00	8.33	1.59
	2.61	100.00	760.00	7.60	1.55
	2.58	110.00	770.00	7.00	1.52
	2.53	120.00	780.00	6.50	1.47
	2.44	140.00	800.00	5.71	1.38
	2.35	160.00	820.00	5.13	1.29
	2.30	180.00	840.00	4.67	1.24
	2.23	200.00	860.00	4.30	1.17
	2.14	220.00	880.00	4.00	1.08
	2.08	240.00	900.00	3.75	1.02
03.30 AM	2.03	300.00	960.00	3.20	0.97

Time (hr)	Water Level (m)	Time after pumping stopped (t') (min)	Time after pumping started (t) (min)	t/t'	Residual draw down (m)
	39.28	18.00	558.00	31.00	4.78
	39.12	19.00	559.00	29.42	4.62
	38.95	20.00	560.00	28.00	4.45
	38.72	22.00	562.00	25.55	4.22
	38.46	24.00	564.00	23.50	3.96
	38.26	26.00	566.00	21.77	3.76
	38.11	28.00	568.00	20.29	3.61
	37.91	30.00	570.00	19.00	3.41
	37.64	35.00	575.00	16.43	3.14
	37.43	40.00	580.00	14.50	2.93
	37.21	45.00	585.00	13.00	2.71
	37.04	50.00	590.00	11.80	2.54
	36.92	55.00	595.00	10.82	2.42
	36.76	60.00	600.00	10.00	2.26
	36.67	70.00	610.00	8.71	2.17
	36.54	80.00	620.00	7.75	2.04
	36.47	90.00	630.00	7.00	1.97
	36.39	100.00	640.00	6.40	1.89
	36.35	110.00	650.00	5.91	1.85
	36.32	120.00	660.00	5.50	1.82
	36.19	140.00	680.00	4.86	1.69
	36.09	160.00	700.00	4.38	1.59
	36.00	180.00	720.00	4.00	1.50
	35.99	200.00	740.00	3.70	1.49
	35.92	220.00	760.00	3.45	1.42
12.30 AM	35.90	240.00	780.00	3.25	1.40

Data of slug injection test in piezometer no. SJU 4

Location : At CTPL workshop
 Initial water level : 6.44 m bmp
 Quantity of slug injected : 117 lts.

Time (min.)	Time (since slug injected) (tm) (min.)	Depth of water below measuring point (meter)	Residual head (meter)	1/tm (1/min.)
0.50	0.30	2.83	3.61	3.333
0.75	0.55	2.95	3.49	1.818
1.00	0.80	3.08	3.36	1.250
1.25	1.05	3.18	3.26	0.952
1.50	1.30	3.35	3.09	0.769
1.75	1.55	3.45	2.99	0.645
2.00	1.80	3.60	2.84	0.556
2.25	2.05	3.69	2.75	0.488
2.50	2.30	3.79	2.65	0.435
2.75	2.55	3.89	2.55	0.392
3.00	2.80	4.00	2.44	0.357
3.25	3.05	4.08	2.36	0.328
3.50	3.30	4.16	2.28	0.303
3.75	3.55	4.23	2.21	0.282
4.00	3.80	4.33	2.11	0.263
4.25	4.05	4.41	2.03	0.247
4.50	4.30	4.46	1.98	0.233
4.75	4.55	4.55	1.89	0.220
5.00	4.80	4.56	1.88	0.208
5.25	5.05	4.61	1.83	0.198
5.50	5.30	4.66	1.78	0.189
5.75	5.55	4.71	1.73	0.180
6.00	5.80	4.78	1.66	0.172
6.25	6.05	4.81	1.63	0.165
6.50	6.30	4.86	1.58	0.159
6.75	6.55	4.90	1.54	0.153
7.00	6.80	4.94	1.50	0.147
7.25	7.05	4.97	1.47	0.142
7.50	7.30	4.98	1.46	0.137
7.75	7.55	4.98	1.46	0.132
8.00	7.80	4.90	1.54	0.128
8.25	8.05	4.86	1.58	0.124

Time (min.)	Time (since slug injected) (tm) (min.)	Depth of water below measuring point (meter)	Residual head (meter)	1/tm (1/min.)
8.50	8.30	4.80	1.64	0.120
8.75	8.55	4.75	1.69	0.117
9.00	8.80	4.75	1.69	0.114
9.25	9.05	4.73	1.71	0.110
9.50	9.30	4.70	1.74	0.108
9.75	9.55	4.69	1.75	0.105
10.00	9.80	4.69	1.75	0.102
10.25	10.05	4.67	1.77	0.100
10.50	10.30	4.66	1.78	0.097
10.75	10.55	4.67	1.77	0.095
11.00	10.80	4.66	1.78	0.093
11.25	11.05	4.66	1.78	0.090
11.50	11.30	4.66	1.78	0.088
11.75	11.55	4.66	1.78	0.087
12.00	11.80	4.65	1.79	0.085
12.25	12.05	4.61	1.83	0.083
12.50	12.30	4.57	1.87	0.081
12.75	12.55	4.53	1.91	0.080
13.00	12.80	4.51	1.93	0.078
13.25	13.05	4.46	1.98	0.077
13.50	13.30	4.43	2.01	0.075
13.75	13.55	4.41	2.03	0.074
14.00	13.80	4.38	2.06	0.072
14.25	14.05	4.36	2.08	0.071
14.50	14.30	4.30	2.14	0.070
14.75	14.55	4.33	2.11	0.069
15.00	14.80	4.31	2.13	0.068
15.25	15.05	4.29	2.15	0.066
15.50	15.30	4.30	2.14	0.065
15.75	15.55	4.29	2.15	0.064
16.00	15.80	4.29	2.15	0.063
16.25	16.05	4.28	2.16	0.062
16.50	16.30	4.28	2.16	0.061
16.75	16.55	4.27	2.17	0.060
17.00	16.80	4.27	2.17	0.060
17.25	17.05	4.26	2.18	0.059
17.50	17.30	4.26	2.18	0.058
17.75	17.55	4.26	2.18	0.057

Time (min.)	Time (since slug injected) (tm) (min.)	Depth of water below measuring point (meter)	Residual head (meter)	1/tm (1/min.)
18.00	17.80	4.26	2.18	0.056
18.25	18.05	4.25	2.19	0.055
18.50	18.30	4.25	2.19	0.055
18.75	18.55	4.25	2.19	0.054
19.00	18.80	4.25	2.19	0.053
19.25	19.05	4.25	2.19	0.052
19.50	19.30	4.25	2.19	0.052
19.75	19.55	4.24	2.20	0.051
20.00	19.80	4.25	2.19	0.051
20.25	20.05	4.25	2.19	0.050
20.50	20.30	4.25	2.19	0.049
20.75	20.55	4.23	2.21	0.049
21.00	20.80	4.24	2.20	0.048
21.25	21.05	4.24	2.20	0.048
21.50	21.30	4.23	2.21	0.047
21.75	21.55	4.24	2.20	0.046
22.00	21.80	4.24	2.20	0.046
22.25	22.05	4.24	2.20	0.045
22.50	22.30	4.24	2.20	0.045
22.75	22.55	4.24	2.20	0.044
23.00	22.80	4.25	2.19	0.044
23.25	23.05	4.23	2.21	0.043
23.50	23.30	4.23	2.21	0.043
23.75	23.55	4.23	2.21	0.042
24.00	23.80	4.23	2.21	0.042
24.25	24.05	4.23	2.21	0.042
24.50	24.30	4.23	2.21	0.041
24.75	24.55	4.23	2.21	0.041
25.00	24.80	4.23	2.21	0.040
25.25	25.05	4.23	2.21	0.040
25.50	25.30	4.23	2.21	0.040
25.75	25.55	4.22	2.22	0.039
26.00	25.80	4.22	2.22	0.039
26.25	26.05	4.22	2.22	0.038
26.50	26.30	4.22	2.22	0.038
26.75	26.55	4.22	2.22	0.038
27.00	26.80	4.22	2.22	0.037
27.25	27.05	4.22	2.22	0.037

Time (min.)	Time (since slug injected) (tm) (min.)	Depth of water below measuring point (meter)	Residual head (meter)	1/tm (1/min.)
27.50	27.30	4.21	2.23	0.037
27.75	27.55	4.21	2.23	0.036
28.00	27.80	4.20	2.24	0.036
28.25	28.05	4.20	2.24	0.036
28.50	28.30	4.20	2.24	0.035
28.75	28.55	4.20	2.24	0.035
29.00	28.80	4.20	2.24	0.035
29.25	29.05	4.20	2.24	0.034
29.50	29.30	4.20	2.24	0.034
29.75	29.55	4.20	2.24	0.034
30.00	29.80	4.20	2.24	0.034
30.25	30.05	4.20	2.24	0.033
30.50	30.30	4.19	2.25	0.033
30.75	30.55	4.19	2.25	0.033
31.00	30.80	4.19	2.25	0.032
31.25	31.05	4.19	2.25	0.032
31.50	31.30	4.19	2.25	0.032
31.75	31.55	4.19	2.25	0.032
32.00	31.80	4.19	2.25	0.031
32.25	32.05	4.19	2.25	0.031
32.50	32.30	4.19	2.25	0.031
32.75	32.55	4.19	2.25	0.031
33.00	32.80	4.19	2.25	0.030
33.25	33.05	4.18	2.26	0.030
33.50	33.30	4.18	2.26	0.030
33.75	33.55	4.18	2.26	0.030
34.00	33.80	4.18	2.26	0.030
34.25	34.05	4.18	2.26	0.029
34.50	34.30	4.18	2.26	0.029
34.75	34.55	4.18	2.26	0.029
35.00	34.80	4.18	2.26	0.029
35.25	35.05	4.18	2.26	0.029
35.50	35.30	4.18	2.26	0.028
35.75	35.55	4.18	2.26	0.028
36.00	35.80	4.17	2.27	0.028
36.25	36.05	4.17	2.27	0.028
36.50	36.30	4.17	2.27	0.028
36.75	36.55	4.17	2.27	0.027

Time (min.)	Time (since slug injected) (tm) (min.)	Depth of water below measuring point (meter)	Residual head (meter)	1/tm (1/min.)
37.00	36.80	4.17	2.27	0.027
37.25	37.05	4.17	2.27	0.027
37.50	37.30	4.17	2.27	0.027
37.75	37.55	4.17	2.27	0.027
38.00	37.80	4.17	2.27	0.026
38.25	38.05	4.17	2.27	0.026
38.50	38.30	4.17	2.27	0.026
38.75	38.55	4.17	2.27	0.026
39.00	38.80	4.17	2.27	0.026
39.25	39.05	4.17	2.27	0.026
39.50	39.30	4.17	2.27	0.025
39.75	39.55	4.17	2.27	0.025
40.00	39.80	4.17	2.27	0.025
40.25	40.05	4.17	2.27	0.025
40.50	40.30	4.17	2.27	0.025
40.75	40.55	4.17	2.27	0.025
41.00	40.80	4.17	2.27	0.025
41.25	41.05	4.17	2.27	0.024
41.50	41.30	4.17	2.27	0.024
41.75	41.55	4.17	2.27	0.024
42.00	41.80	4.17	2.27	0.024
42.25	42.05	4.17	2.27	0.024
42.50	42.30	4.17	2.27	0.024
42.75	42.55	4.17	2.27	0.024
43.00	42.80	4.17	2.27	0.023
43.25	43.05	4.17	2.27	0.023
43.50	43.30	4.17	2.27	0.023
43.75	43.55	4.17	2.27	0.023
44.00	43.80	4.17	2.27	0.023
44.25	44.05	4.17	2.27	0.023
44.50	44.30	4.17	2.27	0.023
44.75	44.55	4.17	2.27	0.022
45.00	44.80	4.16	2.28	0.022
45.25	45.05	4.16	2.28	0.022
45.50	45.30	4.16	2.28	0.022
45.75	45.55	4.16	2.28	0.022
46.00	45.80	4.16	2.28	0.022
46.25	46.05	4.16	2.28	0.022

Time (min.)	Time (since slug injected) (tm) (min.)	Depth of water below measuring point (meter)	Residual head (meter)	1/tm (1/min.)
46.50	46.30	4.16	2.28	0.022
46.75	46.55	4.16	2.28	0.021
47.00	46.80	4.16	2.28	0.021
47.25	47.05	4.16	2.28	0.021
47.50	47.30	4.16	2.28	0.021
47.75	47.55	4.16	2.28	0.021
48.00	47.80	4.16	2.28	0.021
48.25	48.05	4.16	2.28	0.021
48.50	48.30	4.16	2.28	0.021
48.75	48.55	4.16	2.28	0.021
49.00	48.80	4.16	2.28	0.020
49.25	49.05	4.16	2.28	0.020
49.50	49.30	4.16	2.28	0.020
49.75	49.55	4.16	2.28	0.020
50.00	49.80	4.16	2.28	0.020
50.25	50.05	4.16	2.28	0.020
50.50	50.30	4.16	2.28	0.020
50.75	50.55	4.16	2.28	0.020
51.00	50.80	4.16	2.28	0.020
51.25	51.05	4.16	2.28	0.020
51.50	51.30	4.16	2.28	0.019
51.75	51.55	4.15	2.29	0.019
52.00	51.80	4.15	2.29	0.019
52.25	52.05	4.15	2.29	0.019
52.50	52.30	4.15	2.29	0.019
52.75	52.55	4.15	2.29	0.019
53.00	52.80	4.15	2.29	0.019
53.25	53.05	4.15	2.29	0.019
53.50	53.30	4.15	2.29	0.019
53.75	53.55	4.15	2.29	0.019
54.00	53.80	4.15	2.29	0.019
54.25	54.05	4.15	2.29	0.019
54.50	54.30	4.15	2.29	0.018
54.75	54.55	4.15	2.29	0.018
55.00	54.80	4.15	2.29	0.018
55.25	55.05	4.15	2.29	0.018
55.50	55.30	4.15	2.29	0.018
55.75	55.55	4.15	2.29	0.018

Time (min.)	Time (since slug injected) (tm) (min.)	Depth of water below measuring point (meter)	Residual head (meter)	1/tm (1/min.)
56.00	55.80	4.15	2.29	0.018
56.25	56.05	4.15	2.29	0.018
56.50	56.30	4.15	2.29	0.018
56.75	56.55	4.14	2.30	0.018
57.00	56.80	4.14	2.30	0.018
57.25	57.05	4.14	2.30	0.018
57.50	57.30	4.14	2.30	0.017
57.75	57.55	4.14	2.30	0.017
58.00	57.80	4.14	2.30	0.017
58.25	58.05	4.14	2.30	0.017
58.50	58.30	4.14	2.30	0.017
58.75	58.55	4.14	2.30	0.017
59.00	58.80	4.14	2.30	0.017
59.25	59.05	4.14	2.30	0.017
59.50	59.30	4.14	2.30	0.017
59.75	59.55	4.14	2.30	0.017
60.00	59.80	4.14	2.30	0.017

Data of slug injection test in piezometer no. SJU 8

Location : Eastern side of Balanda railway siding (opposite rest shelter)
 Initial water level : 2.31 m bmp
 Quantity of slug injected : 45 lts.

Time (min.)	Time (since slug injected) (tm) (min.)	Depth of water below measuring point (meter)	Residual head (meter)	1/tm (1/min.)
0.25	0.17	0.70	1.66	5.88
0.50	0.42	1.30	1.06	2.3810
0.75	0.67	1.47	0.89	1.4925
1.00	0.92	1.30	1.06	1.0870
1.25	1.17	1.86	0.50	0.8547
1.50	1.42	1.86	0.50	0.7042
1.75	1.67	1.90	0.46	0.5988
2.00	1.92	1.95	0.41	0.5208
2.25	2.17	1.98	0.38	0.4608
2.50	2.42	2.03	0.33	0.4132
2.75	2.67	2.06	0.30	0.3745
3.00	2.92	2.07	0.29	0.3425
3.25	3.17	2.08	0.28	0.3155
3.50	3.42	2.09	0.27	0.2924
3.75	3.67	2.11	0.25	0.2725
4.00	3.92	2.11	0.25	0.2551
4.25	4.17	2.13	0.23	0.2398
4.50	4.42	2.14	0.22	0.2262
4.75	4.67	2.14	0.22	0.2141
5.00	4.92	2.15	0.21	0.2033
5.25	5.17	2.15	0.21	0.1934
5.50	5.42	2.16	0.20	0.1845
5.75	5.67	2.17	0.19	0.1764
6.00	5.92	2.17	0.19	0.1689
6.25	6.17	2.18	0.18	0.1621
6.50	6.42	2.18	0.18	0.1558
6.75	6.67	2.18	0.18	0.1499
7.00	6.92	2.19	0.17	0.1445
7.25	7.17	2.19	0.17	0.1395
7.50	7.42	2.19	0.17	0.1348
7.75	7.67	2.19	0.17	0.1304

Time (min.)	Time (since slug injected) (tm) (min.)	Depth of water below measuring point (meter)	Residual head (meter)	1/tm (1/min.)
8.00	7.92	2.20	0.16	0.1263
8.25	8.17	2.21	0.15	0.1224
8.50	8.42	2.21	0.15	0.1188
8.75	8.67	2.21	0.15	0.1153
9.00	8.92	2.22	0.14	0.1121
9.25	9.17	2.22	0.14	0.1091
9.50	9.42	2.22	0.14	0.1062
9.75	9.67	2.23	0.13	0.1034
10.00	9.92	2.23	0.13	0.1008
10.25	10.17	2.23	0.13	0.0983
10.50	10.42	2.23	0.13	0.0960
10.75	10.67	2.23	0.13	0.0937
11.00	10.92	2.24	0.12	0.0916
11.25	11.17	2.24	0.12	0.0895
11.50	11.42	2.24	0.12	0.0876
11.75	11.67	2.24	0.12	0.0857
12.00	11.92	2.24	0.12	0.0839
12.25	12.17	2.24	0.12	0.0822
12.50	12.42	2.25	0.11	0.0805
12.75	12.67	2.25	0.11	0.0789
13.00	12.92	2.25	0.11	0.0774
13.25	13.17	2.25	0.11	0.0759
13.50	13.42	2.25	0.11	0.0745
13.75	13.67	2.25	0.11	0.0732
14.00	13.92	2.25	0.11	0.0718
14.25	14.17	2.25	0.11	0.0706
14.50	14.42	2.26	0.10	0.0693
14.75	14.67	2.26	0.10	0.0682
15.00	14.92	2.26	0.10	0.0670
15.25	15.17	2.26	0.10	0.0659
15.50	15.42	2.26	0.10	0.0649
15.75	15.67	2.26	0.10	0.0638
16.00	15.92	2.26	0.10	0.0628
16.25	16.17	2.26	0.10	0.0618
16.50	16.42	2.26	0.10	0.0609
16.75	16.67	2.27	0.09	0.0600
17.00	16.92	2.27	0.09	0.0591
17.25	17.17	2.27	0.09	0.0582

Time (min.)	Time (since slug injected) (tm) (min.)	Depth of water below measuring point (meter)	Residual head (meter)	1/tm (1/min.)
17.50	17.42	2.27	0.09	0.0574
17.75	17.67	2.27	0.09	0.0566
18.00	17.92	2.27	0.09	0.0558
18.25	18.17	2.27	0.09	0.0550
18.50	18.42	2.27	0.09	0.0543
18.75	18.67	2.27	0.09	0.0536
19.00	18.92	2.27	0.09	0.0529
19.25	19.17	2.27	0.09	0.0522
19.50	19.42	2.27	0.09	0.0515
19.75	19.67	2.28	0.08	0.0508
20.00	19.92	2.28	0.08	0.0502
20.25	20.17	2.28	0.08	0.0496
20.50	20.42	2.28	0.08	0.0490
20.75	20.67	2.28	0.08	0.0484
21.00	20.92	2.28	0.08	0.0478
21.25	21.17	2.28	0.08	0.0472
21.50	21.42	2.28	0.08	0.0467
21.75	21.67	2.28	0.08	0.0461
22.00	21.92	2.28	0.08	0.0456
22.25	22.17	2.28	0.08	0.0451
22.50	22.42	2.28	0.08	0.0446
22.75	22.67	2.28	0.08	0.0441
23.00	22.92	2.28	0.08	0.0436
23.25	23.17	2.28	0.08	0.0432
23.50	23.42	2.28	0.08	0.0427
23.75	23.67	2.28	0.08	0.0422
24.00	23.92	2.28	0.08	0.0418
24.25	24.17	2.28	0.08	0.0414
24.50	24.42	2.28	0.08	0.0410
24.75	24.67	2.28	0.08	0.0405
25.00	24.92	2.28	0.08	0.0401
25.25	25.17	2.28	0.08	0.0397
25.50	25.42	2.28	0.08	0.0393
25.75	25.67	2.28	0.08	0.0390
26.00	25.92	2.28	0.08	0.0386
26.25	26.17	2.28	0.08	0.0382
26.50	26.42	2.28	0.08	0.0379
26.75	26.67	2.28	0.08	0.0375

Time (min.)	Time (since slug injected) (tm) (min.)	Depth of water below measuring point (meter)	Residual head (meter)	1/tm (1/min.)
27.00	26.92	2.28	0.08	0.0371
27.25	27.17	2.28	0.08	0.0368
27.50	27.42	2.28	0.08	0.0365
27.75	27.67	2.28	0.08	0.0361
28.00	27.92	2.28	0.08	0.0358
28.25	28.17	2.28	0.08	0.0355
28.50	28.42	2.28	0.08	0.0352
28.75	28.67	2.29	0.07	0.0349
29.00	28.92	2.29	0.07	0.0346
29.25	29.17	2.29	0.07	0.0343
29.50	29.42	2.29	0.07	0.0340
29.75	29.67	2.29	0.07	0.0337
30.00	29.92	2.29	0.07	0.0334
30.25	30.17	2.29	0.07	0.0331
30.50	30.42	2.29	0.07	0.0329
30.75	30.67	2.29	0.07	0.0326
31.00	30.92	2.29	0.07	0.0323
31.25	31.17	2.29	0.07	0.0321
31.50	31.42	2.29	0.07	0.0318
31.75	31.67	2.29	0.07	0.0316
32.00	31.92	2.29	0.07	0.0313
32.25	32.17	2.29	0.07	0.0311
32.50	32.42	2.29	0.07	0.0308
32.75	32.67	2.29	0.07	0.0306
33.00	32.92	2.29	0.07	0.0304

FINAL REPORT
ON
**HYDROGEOLOGICAL INVESTIGATION FOR
DISPOSAL OF ASH IN MINE VOIDS (QUARRY
NOS. 4, 7 & 8) IN JAGANNATH OCP OF
JAGANNATH AREA OF MCL,**

**TALCHER COALFIELD,
ODISHA**

ANNEXURE - III

**Details of Analytical Results in and around Jagannath OCP,
Talcher Coalfield, Odisha.**

ANNEXURE – III.B

MINE WATER ANALYSIS RESULTS IN THE STUDY AREA

PRE-MONSOON

Sl. No.	Sample code	Sampling Period	Colour & odour	TSS	PH	Temp.	O&G	Total residual chlorine	Ammonical Nitrogen	TKN	Free ammonia	BOD	COD	As	Pb	Cr ⁺⁶	Total Chromium	Cu	Zn	Se	Cd	Ni	F	Dis. Phosphate	Sulphide	Phenolics	Mn	Fe	Nitrate nitrogen
				(mg/L)		Deg. Celcius	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
1	NMW-1	May-13	Accept	8.00	7.66	27.00	<1.00	Nil	0.03	2.20	<0.02	1.80	20.00	<0.01	<0.05	<0.01	<0.10	<0.02	<0.02	<0.01	<0.005	<0.10	1.66	0.40	<0.02	<0.001	0.28	<0.05	0.50
2	NMW-2	May-13	Accept	2.00	7.62	27.00	<1.00	Nil	0.03	2.10	<0.02	1.20	15.00	<0.01	<0.05	<0.01	<0.10	<0.02	<0.02	<0.01	<0.005	<0.10	1.14	0.30	<0.02	<0.001	0.28	<0.05	0.50
3	NMW-3	May-13	Accept	4.00	7.12	27.00	<1.00	Nil	0.02	2.31	<0.02	1.30	15.00	<0.01	<0.05	<0.01	<0.10	<0.02	0.03	<0.01	<0.005	<0.10	1.10	0.40	<0.02	<0.001	0.35	<0.05	1.70
4	NMW-4	May-13	Accept	2.00	7.58	27.00	<1.00	Nil	0.02	2.26	<0.02	1.20	15.00	<0.01	<0.05	<0.01	<0.10	<0.02	<0.02	<0.01	<0.005	<0.10	0.94	0.40	<0.02	<0.001	0.17	<0.05	1.40
MoEF -SCH VI Standard			Accept	100	5.50 - 9.00		10.00	1.00	50.00	100.00	5.00	30.00	250.00	0.20	0.10	0.10	2.00	3.00	5.00	0.05	.	3.00	2.00	5.00	2.00	1.00	2.00	3.00	10.00
Legends				Above Permissible Limit																									

POST- MONSOON

Sl. No.	Sample code	Sampling Period	Colour & odour	TSS	PH	Temp.	O&G	Total residual chlorine	Ammonical Nitrogen	TKN	Free ammonia	BOD	COD	As	Pb	Cr ⁺⁶	Total Chromium	Cu	Zn	Se	Cd	Ni	F	Dis. Phosphate	Sulphide	Phenolics	Mn	Fe	Nitrate nitrogen
				(mg/L)		Deg. Celcius	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
1	NMW-1	Dec-13	Accept	10.00	7.30	19.00	<2.00	Nil	0.05	3.61	<0.02	1.40	20.00	<0.01	<0.05	<0.01	<0.10	<0.02	0.307	<0.01	<0.005	0.115	1.32	0.20	<0.02	<0.001	0.59	<0.06	1.10
2	NMW-2	Dec-13	Accept	6.00	6.91	19.00	<1.00	Nil	0.02	2.83	<0.02	1.20	15.00	<0.01	<0.05	<0.01	<0.10	<0.02	<0.02	<0.01	<0.005	<0.10	1.08	0.10	<0.02	<0.001	<0.02	<0.06	0.80
3	NMW-3	Dec-13	Accept	12.00	5.68	19.00	<1.00	Nil	0.04	3.45	<0.02	1.60	25.00	<0.01	<0.05	<0.01	<0.10	<0.02	0.03	<0.01	<0.005	<0.10	0.98	0.20	<0.02	<0.001	<0.02	<0.06	0.30
4	NMW-4	Dec-13	Accept	8.00	6.44	19.00	<1.00	Nil	0.04	3.27	<0.02	1.80	20.00	<0.01	<0.05	<0.01	<0.10	<0.02	<0.02	<0.01	<0.005	<0.10	0.97	0.40	<0.02	<0.001	<0.02	<0.06	0.50
MoEF -SCH VI Standard			Accept	100.00	5.50 - 9.00		10.00	1.00	50.00	100.00	5.00	30.00	250.00	0.20	0.10	0.10	2.00	3.00	5.00	0.05	.	3.00	2.00	5.00	2.00	1.00	2.00	3.00	10.00
Legends				Above Permissible Limit																									

GROUNDWATER ANALYSIS RESULTS IN THE STUDY AREA

PRE- MONSOON

A. Open Dug Well & Handpump/ Tube Well

Sl. No.	Sample code	Sampling Period	Colour	Odour	Turbidity	PH	Tot. Alkalinity	Tot. Hardness	Fe	Chloride	Res. Free chlorine	TDS	Ca	Cu	Mn	SO ₄	NO ₃	F	Se	As	Pb	Cd	Zn	Cr ⁺⁶	B	Faecal col.as MPN/100ml	Phenolics								
							(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)								
1	NDW-1	May-13	4	Unobje	5.00	7.78	136.00	240.00	BDL	76.00	NIL	512.00	59.20	BDL	0.19	50.00	5.76	0.60	BDL	BDL	BDL	<0.005	0.02	BDL	BDL	Nil	<0.001								
2	NDW-2	May-13	2	Unobje	3.00	7.19	108.00	212.00	BDL	68.00	NIL	378.00	51.20	BDL	0.25	48.00	20.82	0.45	BDL	<0.01	<0.05	<0.005	0.36	<0.01	<0.01	Nil	<0.001								
3	NDW-3	May-13	8	Unobje	11.00	7.98	132.00	228.00	BDL	38.00	NIL	360.00	56.00	BDL	0.18	59.00	5.76	1.68	BDL	BDL	<0.05	<0.005	0.03	<0.01	<0.01	Nil	<0.001								
4	NDW-4	May-13	4	Unobje	5.00	7.75	96.00	168.00	BDL	42.00	NIL	294.00	41.60	BDL	0.17	42.00	6.65	0.70	BDL	BDL	<0.05	<0.005	0.02	<0.01	<0.01	Nil	<0.001								
5	NDW-5	May-13	3	Unobje	4.00	7.46	76.00	140.00	BDL	30.00	NIL	236.00	35.20	BDL	0.18	22.00	11.96	0.56	BDL	BDL	<0.05	<0.005	BDL	<0.01	<0.01	Nil	<0.001								
6	NDW-6	May-13	5	Unobje	6.00	7.66	104.00	180.00	BDL	54.00	NIL	432.00	44.80	BDL	0.06	38.00	7.53	0.59	BDL	BDL	<0.05	<0.005	0.29	<0.01	<0.01	Nil	<0.001								
7	NDW-7	May-13	5	Unobje	6.00	7.53	48.00	88.00	BDL	38.00	NIL	186.00	22.40	BDL	BDL	24.00	11.52	0.27	BDL	<0.01	<0.05	<0.005	BDL	<0.01	<0.01	Nil	<0.001								
8	NDW-8	May-13	6	Unobje	8.00	8.08	332.00	568.00	BDL	298.00	NIL	1246.00	139.20	BDL	BDL	51.00	15.51	1.02	BDL	<0.01	<0.05	<0.005	BDL	<0.01	<0.01	Nil	<0.001								
9	NDW-9	May-13	3	Unobje	5.00	7.98	76.00	128.00	BDL	36.00	NIL	212.00	32.00	BDL	BDL	22.00	5.76	0.49	BDL	<0.01	<0.05	<0.005	BDL	<0.01	<0.01	Nil	<0.001								
10	NDW-10	May-13	6	Unobje	7.00	7.78	240.00	436.00	BDL	224.00	NIL	984.00	107.20	0.02	<0.05	29.00	21.26	0.59	<0.01	<0.01	<0.05	<0.005	BDL	<0.01	<0.01	Nil	<0.001								
11	NDW-11	May-13	4	Unobje	5.00	7.73	184.00	328.00	BDL	238.00	NIL	782.00	80.00	<0.02	<0.05	34.00	29.68	0.50	<0.01	<0.01	<0.05	<0.005	BDL	<0.01	<0.01	Nil	<0.001								
12	NDW-12	May-13	2	Unobje	4.00	7.49	308.00	584.00	BDL	370.00	NIL	1214.00	142.40	<0.02	<0.02	45.00	23.04	0.66	<0.01	<0.01	<0.05	<0.005	BDL	<0.01	<0.01	Nil	<0.001								
1	NTW-1	May-13	2	Unobje	3.00	7.47	52.00	92.00	<0.05	BDL	NIL	148.00	22.40	BDL	BDL	8.00	1.77	0.02	<0.01	<0.01	<0.05	<0.05	BDL	<0.01	<0.01	Nil	<0.001								
2	NTW-2	May-13	2	Unobje	4.00	7.98	124.00	192.00	<0.05	BDL	NIL	326.00	46.40	BDL	BDL	13.00	2.22	0.34	<0.01	<0.01	<0.05	<0.005	BDL	<0.01	<0.01	Nil	<0.001								
3	NTW-3	May-13	2	Unobje	4.00	7.82	88.00	144.00	<0.05	BDL	NIL	232.00	35.20	BDL	BDL	4.00	1.77	0.32	<0.01	<0.01	<0.05	<0.005	BDL	<0.01	<0.01	Nil	<0.001								
4	NTW-4	May-13	2	Unobje	4.00	7.88	52.00	92.00	BDL	44.00	NIL	148.00	22.40	BDL	BDL	1.00	0.44	0.14	<0.01	<0.01	<0.05	<0.005	BDL	<0.01	<0.01	Nil	<0.001								
5	NTW-5	May-13	2	Unobje	3.00	7.21	60.00	116.00	BDL	30.00	NIL	182.00	28.80	BDL	BDL	2.00	0.44	0.08	<0.01	<0.01	<0.05	<0.005	BDL	<0.01	<0.01	Nil	<0.001								
6	NTW-6	May-13	2	Unobje	3.00	7.64	148.00	276.00	BDL	64.00	NIL	610.00	67.20	BDL	BDL	22.00	3.99	1.15	<0.01	<0.01	<0.05	<0.005	BDL	<0.01	<0.01	Nil	<0.001								
7	NTW-7	May-13	6	Unobje	8.00	7.31	24.00	44.00	BDL	24.00	NIL	86.00	11.20	BDL	BDL	35.00	2.22	0.08	<0.01	<0.01	<0.05	<0.005	BDL	<0.01	<0.01	Nil	<0.001								
8	NTW-8	May-13	5	Unobje	6.00	7.55	48.00	84.00	BDL	18.00	NIL	136.00	20.80	BDL	BDL	20.00	0.44	0.16	<0.01	<0.01	<0.05	<0.005	BDL	<0.01	<0.01	Nil	<0.001								
9	NTW-9	May-13	2	Unobje	4.00	7.38	116.00	220.00	BDL	38.00	NIL	366.00	51.20	BDL	BDL	2.00	2.66	0.45	<0.01	<0.01	<0.05	<0.005	0.30	<0.01	<0.01	Nil	<0.001								
10	NTW-10	May-13	3	Unobje	4.00	7.46	184.00	348.00	BDL	126.00	NIL	636.00	86.40	BDL	BDL	3.00	10.19	1.01	<0.01	<0.01	<0.05	<0.005	BDL	<0.01	<0.01	Nil	<0.001								
IS: 10500 Drinking water Standards			5	Unobje	5.00	6.50 - 8.50	200.00	300.00	0.30	250.00	0.20	500.00	75.00	0.05	0.10	200.00	45.00	1.00	0.01	0.05	0.05	0.01	5.00	0.05	1.00	NIL	0.001								
Legends		Above Permissible Limits			BDL		Below Detection Limit																												

POST- MONSOON

A. Open Dug Well & Tube Well

Sl. No.	Sample code	Dt. of sampling	Colour	Odour	Turbidity	pH	Tot. Alkalinity	Tot. Hardness	Fe	Chloride	Res. Free chlorine	TDS	Ca	Cu	Mn	SO ₄	NO ₃	F	Se	As	Pb	Cd	Zn	Cr ⁶⁺	B	Faecal col.as MPN/ 100ml	Phenolics		
								(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)		(mg/L)		
1	NDW-1	Dec-13	3	Unobje	5.00	7.67	348.00	652.00	<0.06	164.00	NIL	1168.00	155.00	<0.03	<0.02	184.00	16.00	1.54	<0.01	<0.01	<0.05	<0.005	<0.01	<0.01	<0.01	<0.01	NIL	<0.001	
2	NDW-2	Dec-13	3	Unobje	4.00	7.17	96.00	184.00	<0.06	48.00	NIL	330.00	43.20	<0.03	<0.02	55.00	5.76	0.47	<0.01	<0.01	<0.05	<0.005	<0.01	<0.01	<0.01	<0.01	NIL	<0.001	
3	NDW-4	Dec-13	3	Unobje	5.00	7.68	56.00	104.00	<0.06	26.00	NIL	182.00	25.60	<0.03	<0.02	34.00	5.32	0.42	<0.01	<0.01	<0.05	<0.005	<0.01	<0.01	<0.01	<0.01	NIL	<0.001	
4	NDW-5	Dec-13	2	Unobje	5.00	6.73	60.00	156.00	<0.06	42.00	NIL	280.00	36.80	<0.03	<0.02	47.00	6.20	0.58	<0.01	<0.01	<0.05	<0.005	<0.01	<0.01	<0.01	<0.01	NIL	<0.001	
5	NDW-6	Dec-13	4	Unobje	5.00	7.45	92.00	176.00	<0.06	82.00	NIL	416.00	41.60	<0.03	<0.02	57.00	7.09	0.62	<0.01	<0.01	<0.05	<0.005	0.011	<0.01	<0.01	<0.01	NIL	<0.001	
6	NDW-7	Dec-13	4	Unobje	6.00	6.09	28.00	76.00	<0.06	22.00	NIL	160.00	17.60	<0.03	<0.02	22.00	4.43	0.23	<0.01	<0.01	<0.05	<0.005	<0.01	<0.01	<0.01	<0.01	NIL	<0.001	
7	NDW-8	Dec-13	7	Unobje	10.00	8.61	724.00	1208.00	<0.06	258.00	NIL	2156.00	258.00	<0.03	<0.02	340.00	21.70	1.47	<0.01	<0.01	<0.05	<0.005	<0.01	<0.01	<0.01	<0.01	NIL	<0.001	
8	NDW-9	Dec-13	2	Unobje	4.00	8.39	1808.00	3404.00	<0.06	680.00	NIL	6188.00	773.00	<0.03	<0.02	1016.00	32.80	1.67	<0.01	<0.01	<0.05	<0.005	<0.01	<0.01	<0.01	<0.01	NIL	<0.001	
9	NDW-10	Dec-13	6	Unobje	8.00	7.46	252.00	472.00	<0.06	214.00	NIL	1046.00	114.00	<0.03	<0.02	159.00	14.20	0.64	<0.01	<0.01	<0.05	<0.005	<0.01	<0.01	<0.01	<0.01	NIL	<0.001	
10	NDW-11	Dec-13	5	Unobje	7.00	6.55	253.00	576.00	<0.06	188.00	NIL	1130.00	138.00	<0.03	0.24	183.00	16.00	0.82	<0.01	<0.01	<0.05	<0.005	0.341	<0.01	<0.01	<0.01	NIL	<0.001	
11	NDW-12	Dec-13	3	Unobje	5.00	7.47	320.00	604.00	<0.06	184.00	NIL	1230.00	144.00	<0.03	<0.02	180.00	18.20	0.68	<0.01	<0.01	<0.05	<0.005	0.014	<0.01	<0.01	<0.01	NIL	<0.001	
1	NTW-1	Dec-13	3	Unobje	4.00	7.41	64.00	116.00	<0.06	22.00	NIL	184.00	27.20	<0.03	<0.02	35.00	5.32	0.04	<0.01	<0.01	<0.05	<0.005	<0.01	<0.01	<0.01	<0.01	NIL	<0.001	
2	NTW-2	Dec-13	2	Unobje	4.00	7.07	96.00	192.00	<0.06	46.00	NIL	324.00	46.40	<0.03	<0.02	72.00	6.65	0.32	<0.01	<0.01	<0.05	<0.005	<0.01	<0.01	<0.01	<0.01	NIL	<0.001	
3	NTW-3	Dec-13	3	Unobje	5.00	6.99	64.00	140.00	<0.06	32.00	NIL	224.00	35.20	<0.03	0.021	51.00	5.76	0.31	<0.01	<0.01	<0.05	<0.005	<0.01	<0.01	<0.01	<0.01	NIL	<0.001	
4	NTW-4	Dec-13	3	Unobje	4.00	7.98	204.00	368.00	<0.06	94.00	NIL	674.00	88.00	<0.03	<0.02	104.00	7.97	0.76	<0.01	<0.01	<0.05	<0.005	<0.01	<0.01	<0.01	<0.01	NIL	<0.001	
5	NTW-5	Dec-13	2	Unobje	4.00	6.76	56.00	140.00	<0.06	32.00	NIL	234.00	33.60	<0.03	0.14	45.00	5.76	0.26	<0.01	<0.01	<0.05	<0.005	0.069	<0.01	<0.01	<0.01	NIL	<0.001	
6	NTW-6	Dec-13	2	Unobje	3.00	7.78	136.00	244.00	<0.06	76.00	NIL	498.00	57.60	<0.03	<0.02	82.00	5.76	0.93	<0.01	<0.01	<0.05	<0.005	0.044	<0.01	<0.01	<0.01	NIL	<0.001	
7	NTW-7	Dec-13	5	Unobje	8.00	6.54	12.00	32.00	<0.06	8.00	NIL	64.00	8.00	<0.03	<0.02	11.00	1.33	0.05	<0.01	<0.01	<0.05	<0.005	<0.01	<0.01	<0.01	<0.01	NIL	<0.001	
8	NTW-8	Dec-13	5	Unobje	7.00	7.09	44.00	92.00	<0.06	20.00	NIL	154.00	22.40	<0.03	0.092	27.00	3.99	0.18	<0.01	<0.01	<0.05	<0.005	0.015	<0.01	<0.01	<0.01	NIL	<0.001	
9	NTW-9	Dec-13	3	Unobje	4.00	6.83	40.00	96.00	<0.06	24.00	NIL	176.00	22.40	<0.03	<0.02	28.00	4.43	0.13	<0.01	<0.01	<0.05	<0.005	<0.01	<0.01	<0.01	<0.01	NIL	<0.001	
10	NTW-10	Dec-13	2	Unobje	4.00	7.45	196.00	368.00	<0.06	92.00	NIL	664.00	88.00	<0.03	<0.02	102.00	7.97	0.98	<0.01	<0.01	<0.05	<0.005	<0.01	<0.01	<0.01	<0.01	NIL	<0.001	
IS: 10500 Drinking water Standards			5	Unobje	5.00	6.50 -8.50	200	300	0.30	250.00	0.20	500.00	75.00	0.05	0.10	200.00	45.00	1.00	0.01	0.05	0.05	0.01	5.00	0.05	1.00	Nil	0.001		
Legends		Above Permissible Limits			BDL	Below Detection Limit																							

PRE- MONSOON

A. Piezometer

Sl No.	Sample code	Dt. of sampling	Colour	Odour	Turbidity	PH	Tot. Alkalinity (mg/L)	Tot. Hardness (mg/L)	Fe (mg/L)	Chloride (mg/L)	Res. Free chlorine (mg/L)	TDS (mg/L)	Ca (mg/L)	Cu (mg/L)	Mn (mg/L)	SO ₄ (mg/L)	NO ₃ (mg/L)	F (mg/L)	Se (mg/L)	As (mg/L)	Pb (mg/L)	Cd (mg/L)	Zn (mg/L)	Cr ⁺⁶ (mg/L)	B (mg/L)	Faecal col. as MPN/100ml (mg/L)	Phenolics (mg/L)
1	SJC1	07.04.14	2	Unobje	4.00	7.81	84.00	148.00	1.27	24.00	NIL	204.00	35.20	<0.03	0.03	47.00	4.43	0.25	<0.01	<0.01	0.09	<0.005	0.63	<0.01	<0.01	NIL	<0.001
2	SJL2	07.04.14	2	Unobje	3.00	7.67	152.00	276.00	<0.05	40.00	NIL	424.00	65.60	<0.03	0.18	84.00	5.33	0.48	<0.01	<0.01	0.14	0.09	0.73	<0.01	<0.01	NIL	<0.001
3	SJL3	07.04.14	2	Unobje	2.00	7.82	224.00	408.00	<0.05	28.00	NIL	566.00	94.40	<0.03	0.02	128.00	7.53	0.65	<0.01	<0.01	0.06	<0.005	0.02	<0.01	<0.01	NIL	<0.001
4	SJL4	07.04.14	2	Unobje	2.00	8.07	80.00	132.00	<0.05	28.00	NIL	182.00	30.40	<0.03	0.19	45.00	4.43	0.27	<0.01	<0.01	0.09	<0.005	0.12	<0.01	<0.01	NIL	<0.001
5	SJC5	07.04.14	3	Unobje	5.00	7.71	48.00	88.00	<0.05	38.00	NIL	216.00	20.80	<0.03	0.03	28.00	5.76	0.34	<0.01	<0.01	0.07	<0.005	0.02	<0.01	<0.01	NIL	<0.001
6	SJL6	07.04.14	3	Unobje	3.00	8.07	156.00	272.00	<0.05	30.00	NIL	390.00	64.00	<0.03	<0.02	86.00	5.33	0.28	<0.01	<0.01	<0.05	<0.005	<0.01	<0.01	<0.01	NIL	<0.001
7	SJL7	07.04.14	2	Unobje	4.00	7.83	36.00	60.00	<0.05	14.00	NIL	88.00	14.40	<0.03	<0.02	19.00	2.66	0.10	<0.01	<0.01	0.06	<0.005	<0.01	<0.01	<0.01	NIL	<0.001
8	SJL8	07.04.14	3	Unobje	4.00	7.69	164.00	304.00	<0.05	32.00	NIL	452.00	72.00	<0.03	2.81	94.00	7.09	0.47	<0.01	<0.01	0.06	<0.005	0.05	<0.01	<0.01	NIL	<0.001
9	SJU4	07.04.14	2	Unobje	4.00	7.51	32.00	60.00	<0.05	30.00	NIL	162.00	14.40	<0.03	0.08	22.00	4.87	0.26	<0.01	<0.01	0.07	<0.005	0.08	<0.01	<0.01	NIL	<0.001
IS: 10500 Drinking water Standards			5	Unobje	5.00	6.50 - 8.50	200.00	300.00	0.30	250.00	0.20	500.00	75.00	0.05	0.10	200.00	45.00	1.00	0.01	0.05	0.05	0.01	5.00	0.05	1.00	NIL	0.001
Above Permissible Limits																											

POST- MONSOON

A. Piezometer

Sl. No.	Sample code	Sampling Period	Colour	Odour	Turbidity	pH	Tot. Alkalinity	Tot. Hardness	Fe	Chloride	Res. Free chlorine	TDS	Ca	Cu	Mn	SO ₄	NO ₃	F	Se	As	Pb	Cd	Zn	Cr ⁺⁶	B	Faecal col.as MPN/ 100ml	Phenolics	
									(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)		(mg/L)	
1	SJC 1	Dec-13	2	Unobje	3.00	7.95	72.00	124.00	<0.05	30.00	NIL	216.00	30.40	<0.03	<0.02	43.00	4.43	0.24	<0.01	<0.01	<0.05	<0.005	<0.01	<0.01	<0.01	<0.01	NIL	<0.001
2	SJL 2	Dec-13	2	Unobje	2.00	7.04	112.00	228.00	<0.05	56.00	NIL	402.00	54.40	<0.03	<0.02	67.00	5.76	0.56	<0.01	<0.01	<0.05	<0.005	<0.01	<0.01	<0.01	<0.01	NIL	<0.001
3	SJL 3	Dec-13	2	Unobje	4.00	8.26	96.00	168.00	<0.05	42.00	NIL	294.00	41.60	<0.03	<0.02	42.00	6.65	0.70	<0.01	<0.01	<0.05	<0.005	<0.01	<0.01	<0.01	<0.01	NIL	<0.001
4	SJL 4	Dec-13	2	Unobje	3.00	7.55	176.00	296.00	<0.05	76.00	NIL	536.00	70.40	<0.03	<0.02	94.00	7.09	0.69	<0.01	<0.01	<0.05	<0.005	<0.01	<0.01	<0.01	<0.01	NIL	<0.001
5	SJC 5	Dec-13	2	Unobje	4.00	7.28	60.00	120.00	<0.05	30.00	NIL	216.00	28.80	<0.03	<0.02	44.00	5.76	0.35	<0.01	<0.01	<0.05	<0.005	<0.01	<0.01	<0.01	<0.01	NIL	<0.001
6	SJL 6	Dec-13	2	Unobje	4.00	7.17	32.00	64.00	<0.05	16.00	NIL	112.00	14.40	<0.03	<0.02	19.00	4.43	0.16	<0.01	<0.01	<0.05	<0.005	<0.01	<0.01	<0.01	<0.01	NIL	<0.001
7	SJL 7	Dec-13	2	Unobje	4.00	8.22	172.00	304.00	<0.05	76.00	NIL	548.00	720.00	<0.03	<0.02	96.00	7.97	0.63	<0.01	<0.01	<0.05	<0.005	<0.01	<0.01	<0.01	<0.01	NIL	<0.001
8	SJL 8	Dec-13	2	Unobje	2.00	7.19	104.00	196.00	<0.05	52.00	NIL	366.00	46.40	<0.03	<0.02	65.00	6.20	0.47	<0.01	<0.01	<0.05	<0.005	<0.01	<0.01	<0.01	<0.01	NIL	<0.001
9	SJU 4	Dec-13	2	Unobje	2.00	6.74	20.00	56.00	<0.05	8.00	NIL	98.00	12.80	<0.03	0.02	16.00	3.99	0.08	<0.01	<0.01	<0.05	<0.005	<0.01	<0.01	<0.01	<0.01	NIL	<0.001
IS: 10500 Drinking water Standards			5	Unobje	5.00	6.50 - 8.50	200.00	300.00	0.30	250.00	0.20	500.00	75.00	0.05	0.10	200.00	45.00	1.00	0.01	0.05	0.05		5.00	0.05	1.00	NIL	0.00	
Legends		Above Permissible Limits																										

ANNEXURE – III.D

HISTORICAL GROUNDWATER ANALYSIS RESULTS IN THE STUDY AREA

LOCATION: JAGANNATH PO TUBEWELL WATER

YEAR	pH		Fe (mg/L)		Cl (mg/L)		TDS (mg/L)		Ca (mg/L)		SO ₄ (mg/L)		NO ₃ (mg/L)		F (mg/L)		Zn (mg/L)	
	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon
2009	7.12	8.45	0.08	0.10	48.00	48.00	432.00	478.00	77.60	70.00	134.00	134.00	6.20	5.31	0.55	0.40	0.38	0.80
2010	7.75	8.20	0.18	0.09	8.00	96.00	72.00	388.00	8.00	57.60	22.00	66.00	7.08	10.91	0.40	0.78	0.22	0.23
2011	8.19	7.49	0.08	0.12	42.00	36.00	384.00	328.00	54.40	41.60	69.00	58.00	7.09	5.76	0.41	0.47	0.08	0.18
2012	8.03	7.49	0.18	0.05	44.00	38.00	376.00	328.00	51.20	44.80	72.00	63.00	6.22	6.87	0.32	0.44	0.27	0.02
2013	7.41	7.48	0.05	0.05	40.00	48.00	324.00	358.00	44.80	48.00	67.00	69.00	7.53	7.09	0.43	0.49	0.02	0.03
Limit	6.50-8.50		0.30		250.00		500.00		75.00		200.00		45.00		1.00		5.00	

VILLAGE: RAKAS DUGWELL WATER

YEAR	pH		Fe (mg/L)		Cl (mg/L)		TDS (mg/L)		Ca (mg/L)		SO ₄ (mg/L)		NO ₃ (mg/L)		F (mg/L)		Zn (mg/L)	
	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon
2008	7.20	7.70	0.20	0.14	20.00	38.00	192.00	398.00	41.60	60.80	14.00	114.00	35.40	7.53	0.35	0.40	0.54	0.38
2009	7.61	8.40	0.01	0.12	36.00	64.00	358.00	438.00	44.00	78.00	44.00	168.00	2.11	20.37	0.01	0.58	0.12	0.14
2010	7.84	8.25	0.14	0.12	58.00	96.00	478.00	552.00	88.00	62.40	94.00	72.00	27.46	13.73	0.65	0.39	0.22	0.12
2011	7.32	7.41	0.12	0.14	44.00	38.00	398.00	342.00	52.80	43.20	67.00	61.00	7.76	6.20	0.41	0.53	0.09	0.16
2012	7.37	7.31	0.05	0.50	42.00	42.00	386.00	346.00	54.40	46.40	72.00	67.00	7.09	8.62	0.41	0.47	0.02	0.02
2013	7.38	7.47	0.05	0.05	42.00	46.00	348.00	344.00	48.00	46.40	72.00	72.00	7.97	6.65	0.46	0.39	0.02	0.02
Limit	6.50-8.50		0.30		250.00		500.00		75.00		200.00		45.00		1.00		5.00	

VILLAGE: JILINDA DUGWELL WATER

YEAR	pH		Fe (mg/L)		Cl (mg/L)		TDS (mg/L)		Ca (mg/L)		SO ₄ (mg/L)		NO ₃ (mg/L)		F (mg/L)		Zn (mg/L)	
	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon
2009	7.79	8.32	0.14	0.18	38.00	34.00	384.00	304.00	76.80	52.80	104.00	77.00	7.97	16.83	0.48	0.60	0.12	0.14
2010	8.38	7.72	0.14	0.12	28.00	26.00	218.00	268.00	25.60	36.80	54.00	40.00	17.27	7.97	0.65	0.50	0.28	0.11
2011	7.25	7.37	0.09	0.14	42.00	38.00	384.00	356.00	52.80	49.60	74.00	65.00	5.32	5.76	0.42	0.47	0.11	0.15
2012	7.26	7.35	0.05	0.05	44.00	42.00	388.00	328.00	54.40	44.80	76.00	72.00	6.18	7.82	0.37	0.43	0.02	0.02
2013	7.43	7.35	0.06	0.05	40.00	46.00	326.00	322.00	44.80	43.20	63.00	67.00	7.97	7.09	0.43	0.39	0.02	0.02
Limit	6.50-8.50		0.30		250.00		500.00		75.00		200.00		45.00		1.00		5.00	

VILLAGE: DERA DUGWELL WATER

YEAR	pH		Fe (mg/L)		Cl (mg/L)		TDS (mg/L)		Ca (mg/L)		SO ₄ (mg/L)		NO ₃ (mg/L)		F (mg/L)		Zn (mg/L)	
	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon
2010	7.68	7.58	0.18	0.09	34.00	28.00	288.00	198.00	51.20	30.40	54.00	75.00	21.26	5.76	0.45	0.33	0.18	0.09
2011	7.26	7.31	0.08	0.10	22.00	26.00	204.00	218.00	27.20	28.80	46.00	48.00	3.54	4.39	0.22	0.39	0.09	0.12
2012	7.44	7.42	0.05	0.05	24.00	24.00	214.00	198.00	27.20	25.60	38.00	37.00	4.43	4.25	0.22	0.27	0.05	0.02
2013	7.35	7.31	0.05	0.05	28.00	36.00	226.00	268.00	32.00	36.80	53.00	57.00	5.32	5.76	0.29	0.28	0.02	0.02
Limit	6.50-8.50		0.30		250.00		500.00		75.00		200.00		45.00		1.00		5.00	

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ODISHA**

ANNEXURE - IV

Pre monsoon and Post monsoon water level data and open dug well in and around Jagannath OCP, Talcher Coalfield, Odisha.

ANNEXURE – IV

**WATER LEVELS OF OPEN DUG WELLS IN 5 KM RADIUS BUFFER ZONE OF JAGANNATH OCP,
TALCHER COALFIELD, ODISHA**

PRE MONSOON

Well No	Village Name	Period of Study	Location	Private or Govt./ Owner name	Type of Well	Well Lining	Physical topographical setting	Diameter of well (m)	Height of Parapet from Ground (m)	Total depth (m)	Depth to water below ground level (m)
T070	EKADAL	May, 2013	In front of house of Bikala Biswal & Baishidhar Pradhan	Govt.	Dug well	RCC ring	Plain	1.25	0.65	15.25	12.95
T071	TILEIPOSHI	May, 2013	In front of house of Sri Chakradhar Pradhan & beside road	Govt.	Dug well	Stone lining	Plain	2.15	0.45	9.40	2.61
T074	JORAGARHIA	May, 2013	In front of house of Sri Saroj Pradhan & Dilip Pradhan	Govt.	Dug well	Stone lining	Plain	1.85	0.60	11.45	3.51
T069	JILINDA	May, 2013	In side the field, Road side (moorum+Khoa)	Govt.	Dug well	Brick lining	Plain	2.25	0.60	5.65	4.09
T002	KANDHAL	May, 2013	Near lower primary school (Orissa Board)	Govt.	Dug well	Brick lining	Plain	2.40	0.70	9.65	6.71
T004	BANAMALIPUR (Bidyadharpur)	May, 2013	Near Kali Mandir, in front of house of Champai Dehuri, near NH-23	Govt.	Dug well	Brick lining	Plain	2.45	0.75	7.90	6.65
T005	DEULBERA	May, 2013	In front of house of Sri Magata Nayak, in front of village club (Deulbera)	Govt.	Dug well	Brick lining	Plain	1.60	0.50	6.70	4.59
T001	LANGIJORHA	May, 2013	Dismanteled house between Nita Sahoo & Padmini Pradhan (Shop)	Govt.	Dug well	Brick lining	Plain	1.95	0.70	11.95	4.54

Well No	Village Name	Period of Study	Location	Private or Govt./ Owner name	Type of Well	Well Lining	Physical topographical setting	Diameter of well (m)	Height of Parapet from Ground (m)	Total depth (m)	Depth to water below ground level (m)
T003	AMBAMUNDA	May, 2013	In front of house of Sri Gadhadar Pradhan	Govt.	Dug well	Brick lining	Plain	2.52	0.55	7.65	6.20
T068	HENSAMUL (NuaSahi)	May, 2013	Road side, inside the field	Govt.	Dug well	Brick lining	Low lying	2.25	0.65	6.85	4.84
T075	LAKEIPOSHI (CN-14)	May, 2013	In front of Kothaghar and beside road	Govt.	Dug well	Brick lining	Plain	1.60	0.40	13.35	6.55
T150	RAKAS (Bahal)	May, 2013	In between platform constructed under IPDP-93, Bharatpur project, In front of house of Sri Basanta Barik	Govt.	Dug well	Brick lining + stone lining	Low lying	1.95	0.45	11.55	7.52
T064	DANARA (CN-25)	May, 2013	In front of Birinchi Mahapatra, besides road	Govt.	Dug well	Stone lining	Plain	2.25	0.55	9.95	5.05
T065	JAMBUBAHALI	May, 2013	Near primary school (UP school)	Govt.	Dug well	Brick lining	Plain	2.00	0.45	9.50	8.25
T006	BAGHUABAL	May, 2013	In front of house of Hurdananda Sahoo, village road side	Govt.	Dug well	Brick lining	Plain	2.00	0.40	10.20	8.18
T053	GHANTAPARH A	May, 2013	Near road side and Mangala Mandir	Govt.	Dug well	Brick lining	Plain	3.00	0.75	15.25	8.88
T055	TENTULEI	May, 2013	In front of House of Sri Chatura Sahoo, Mangala Mandir	Govt.	Dug well	RCC and Stone	Plain	1.60	0.45	7.75	3.37
T052	KARARHAPALLI	May, 2013	In between house of Tharu Bhutia and Hunsu Bhutia	Govt.	Dug well	RCC	Plain	2.25	0.60	7.50	5.60
T054	BARHASINGAR HA	May, 2013	In front of house of Sri Girish Chandra Sahoo, Akram Behera	Govt.	Dug well	Brick lining	Plain	2.10	0.55	8.45	4.55

Well No	Village Name	Period of Study	Location	Private or Govt./ Owner name	Type of Well	Well Lining	Physical topographical setting	Diameter of well (m)	Height of Parapet from Ground (m)	Total depth (m)	Depth to water below ground level (m)
T058	BARHAJORARH A	May, 2013	Well between house of Sri Sudhakar Behera and Birbar Behera (Village road side)	Govt.	Dug well	Stone Lining	Plain	2.25	0.55	10.80	6.37
T059	SANAJORARHA (Karnapur)	May, 2013	In front of house of Sri Bamdev Behera, village road side	Govt.	Dug well	Stone lining	Low lying	1.75	0.55	9.95	6.09
T046	KUKURHANGA (Kukudanga)	May, 2013	Near pond, well situated right side of the field	Govt.	Dug well	Stone/ ring lining	Low lying	2.35	0.30	6.95	3.70
T062	TENTULIE	May, 2013	In front house of Sri Gokula Nanda Nayak (village road side)	Govt.	Dug well	Stone lining	Low lying	2.60	0.40	5.60	3.95
T056	KENDUPALLI	May, 2013	In front side of house of Sri Krupa Rout (road side), Nakhi Bhai	Govt.	Dug well	Stone Lining	Low lying	1.90	0.50	5.60	4.93
T008	JAGANNATHPUR	May, 2013	Front side house of Sri Birendra Dhara (UP school and Elevated School on the way) approx 150m	Govt.	Dug well	Brick lining	Low lying	3.70	0.30	7.65	2.10
T007	BANTOL	May, 2013	Village road side	Govt.	Dug well	Brick lining	Low lying	2.15	0.55	8.00	5.05
T063	NATIDI	May, 2013	UP school campus	Govt	Dug well	RCC	High	2.65	0.70	8.50	3.41
T067	THERAMPUR	May, 2013	Near UP school, road side	Govt	Dug well	Stone lining	Plain	2.60	0.45	9.00	6.75
T066	DERA	May, 2013	Near Market, Opp. To ground, Pumping well station.	Govt.	Dug well	Brick and Concrete	Plain	1.90	0.70	6.50	4.87
TN 01	TALBERA	May,	In front of house of Prabhat ACharya (Advocate)	Govt.	Dug well	Stone lining	Plain	1.80	0.70	9.50	6.91

Well No	Village Name	Period of Study	Location	Private or Govt./ Owner name	Type of Well	Well Lining	Physical topographical setting	Diameter of well (m)	Height of Parapet from Ground (m)	Total depth (m)	Depth to water below ground level (m)
		2013									
T060	SAKASINGHA (HarijanSai)	May, 2013	In front of house of Sridhar Nayak	Govt.	Dug well	Stone Lining	Plain	1.90	0.70	6.50	6.30

POST MONSOON

Well No	Village Name	Period of Study	Location	Private or Govt./ Owner name	Type of Well	Well Lining	Physical topographical setting	Diameter of well (m)	Height of Parapet from Ground (m)	Total depth (m)	Depth to water below ground level (m)
T070	EKADAL	Nov., 2013	In front of house of Bikala Biswal & Baishidhar Pradhan	Govt.	Dug well	RCC ring	Plain	1.25	0.65	15.25	5.98
T071	TILEIPOSHI	Nov., 2013	In front of house of Sri Chakradhar Pradhan & beside road	Govt.	Dug well	Stone lining	Plain	2.15	0.45	9.40	3.08
T074	JORAGARHIA	Nov., 2013	In front of house of Sri Saroj Pradhan & Dilip Pradhan	Govt.	Dug well	Stone lining	Plain	1.85	0.60	11.45	4.38
T002	KANDHAL	Nov., 2013	Near lower primary school (Orissa Board)	Govt.	Dug well	Brick lining	Plain	2.40	0.70	9.65	4.05
T004	BANAMALIPUR (Bidyadharpur)	Nov., 2013	Near Kali Mandir, in front of house of Champai Dehuri, near NH-23	Govt.	Dug well	Brick lining	Plain	2.45	0.75	7.90	3.16
T005	DEULBERA	Nov., 2013	In front of house of Sri Magata Nayak, in front of village club (Deulbera)	Govt.	Dug well	Brick lining	Plain	1.60	0.50	6.70	1.21
T001	LANGIJORHA	Nov., 2013	Dismanteled house between Nita Sahoo & Padmini Pradhan (Shop)	Govt.	Dug well	Brick lining	Plain	1.95	0.70	11.95	2.75

Well No	Village Name	Period of Study	Location	Private or Govt./ Owner name	Type of Well	Well Lining	Physical topographical setting	Diameter of well (m)	Height of Parapet from Ground (m)	Total depth (m)	Depth to water below ground level (m)
T003	AMBAMUNDA	Nov., 2013	In front of house of Sri Gadhadhar Pradhan	Govt.	Dug well	Brick lining	Plain	2.52	0.55	7.65	2.90
T068	HENSAMUL (NuaSahi)	Nov., 2013	Road side, inside the field	Govt.	Dug well	Brick lining	Low lying	2.25	0.65	6.85	1.30
T075	LAKEIPOSHI (CN-14)	Nov., 2013	Infront of Kothaghar and beside road	Govt.	Dug well	Brick lining	Plain	1.60	0.40	13.35	3.20
T150	RAKAS (Bahal)	Nov., 2013	In between platform constructed under IPDP-93, Bharatpur project, In front of house of Sri Basanta Barik	Govt.	Dug well	Brick lining + stone lining	Low lying	1.95	0.45	11.55	5.12
T064	DANARA (CN-25)	Nov., 2013	In front of Birinchi Mahapatra, besides road	Govt.	Dug well	Stone lining	Plain	2.25	0.55	9.95	2.45
T065	JAMBUBAHALI	Nov., 2013	Near primary school (UP school)	Govt.	Dug well	Brick lining	Plain	2.00	0.45	9.50	3.62
T006	BAGHUABAL	Nov., 2013	In front of house of Hurdananda Sahoo, village road side	Govt.	Dug well	Brick lining	Plain	2.00	0.40	10.20	2.69
T053	GHANTAPARHA	Nov., 2013	Near road side and Mangala Mandir	Govt.	Dug well	Brick lining	Plain	3.00	0.75	15.25	3.70

Well No	Village Name	Period of Study	Location	Private or Govt./ Owner name	Type of Well	Well Lining	Physical topographical setting	Diameter of well (m)	Height of Parapet from Ground (m)	Total depth (m)	Depth to water below ground level (m)
T055	TENTULEI	Nov., 2013	In front of House of Sri Chatura Sahoo, Mangala Mandir	Govt.	Dug well	RCC ring and Stone	Plain	1.60	0.45	7.75	1.95
T052	KARARHAPALLI	Nov., 2013	In between house of Tharu Bhutia and Hunsu Bhutia	Govt.	Dug well	RCC	Plain	2.25	0.60	7.50	3.59
T054	BARHASINGAR HA	Nov., 2013	In front of house of Sri Girish Chandra Sahoo, Akram Behera	Govt.	Dug well	Brick lining	Plain	2.10	0.55	8.45	1.98
T058	BARHAJORARHA A	Nov., 2013	Well between house of Sri Sudhakar Behera and Birbar Behera (Village road side)	Govt.	Dug well	Stone Lining	Plain	2.25	0.55	10.80	2.92
T059	SANAJORARHA (Karnapur)	Nov., 2013	In front of house of Sri Bamdev Behera, village road side	Govt.	Dug well	Stone lining	Low lying	1.75	0.55	9.95	3.19
T046	KUKURHANGA (Kukudanga)	Nov., 2013	Near pond, well situated right side of the field	Govt.	Dug well	Stone/ ring lining	Low lying	2.35	0.30	6.95	2.00
T062	TENTULIE	Nov., 2013	In front house of Sri Gokula Nanda Nayak (village road side)	Govt.	Dug well	Stone lining	Low lying	2.60	0.40	5.60	1.70
T056	KENDUPALLI	Nov., 2013	In front side of house of Sri Krupa Rout (road side), Nakhi Bhai	Govt.	Dug well	Stone Lining	Low lying	1.90	0.50	5.60	3.91

Well No	Village Name	Period of Study	Location	Private or Govt./ Owner name	Type of Well	Well Lining	Physical topographical setting	Diameter of well (m)	Height of Parapet from Ground (m)	Total depth (m)	Depth to water below ground level (m)
T008	JAGANNATHPUR	Nov., 2013	Front side house of Sri Birendra Dhara (UP school and Elevated School on the way) approx 150m	Govt.	Dug well	Brick lining	Low lying	3.70	0.30	7.65	2.18
T007	BANTOL	Nov., 2013	Village road side	Govt.	Dug well	Brick lining	Low lying	2.15	0.55	8.00	2.98
T063	NATIDI	Nov., 2013	UP school campus	Govt.	Dug well	RCC	High	2.65	0.70	8.50	4.58
T067	THERAMPUR	Nov., 2013	Near UP school, road side	Govt.	Dug well	Stone lining	Plain	2.60	0.45	9.00	4.95
T066	DERA	Nov., 2013	Near Market, Opp. To ground, Pumping well station.	Govt.	Dug well	Brick and Concrete	Plain	1.90	0.70	6.50	5.30
TN 01	TALBERA	Nov., 2013	In front of house of Prabhat ACharya (Advocate)	Govt.	Dug well	Stone lining	Plain	1.80	0.70	9.50	2.95
T060	SAKASINGHA (HarijanSai)	Nov., 2013	In front of house of Sridhar Nayak	Govt.	Dug well	Stone Lining	Plain	1.90	0.70	6.50	3.90

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ANNEXURE - V

**Monthly Rainfall data for the period 1992-2012 in Angul
District, Odisha.**

ANNEXURE-V

MONTHLY RAINFALL DATA FOR THE PERIOD OF 1992 - 2012 IN ANGUL DISTRICT, ODISHA

Monthly Rainfall Data of Angul																					
MONTH	Year: - 1992	Year: - 1993	Year: - 1994	Year: - 1995	Year: - 1996	Year: - 1997	Year: - 1998	Year: - 1999	Year: - 2000	Year: - 2001	Year: - 2002	Year: - 2003	Year: - 2004	Year: - 2005	Year: - 2006	Year: - 2007	Year: - 2008	Year: - 2009	Year: - 2010	Year: - 2011	Year: - 2012
	Total Rainfall in millimeter	Total Rainfall in millimeter	Total Rainfall in millimeter	Total Rainfall in millimeter	Total Rainfall in millimeter	Total Rainfall in millimeter	Total Rainfall in millimeter	Total Rainfall in millimeter	Total Rainfall in millimeter	Total Rainfall in millimeter	Total Rainfall in millimeter	Total Rainfall in millimeter	Total Rainfall in millimeter	Total Rainfall in millimeter	Total Rainfall in millimeter	Total Rainfall in millimeter	Total Rainfall in millimeter	Total Rainfall in millimeter	Total Rainfall in millimeter	Total Rainfall in millimeter	Total Rainfall in millimeter
JAN	9.2	0.0	0.0	52.4	24.2	20.4	14.0	0.0	0.0	0.0	8.8	0.0	11.2	36.8	0.0	1.6	69.4	0.0	2.0	0.0	105.8
FEB	8.0	0.0	41.4	117.4	17.0	0.0	27.0	0.0	40.2	0.0	0.0	4.4	8.4	0.8	0.0	25.2	7.4	0.0	1.2	38.2	0.0
MAR	3.2	5.8	0.0	39.9	2.0	28.6	75.7	0.0	2.6	21.9	1.8	6.7	33.0	54.6	15.2	15.2	9.2	2.9	108.4	13.8	0.0
APR	41.1	90.8	28.0	83.0	0.0	152.4	27.0	18.0	24.2	14.4	45.6	23.8	66.4	44.6	24.4	46.4	24.6	0.0	0.0	44.6	2.5
MAY	43.0	93.2	55.6	333.1	47.8	25.8	47.8	141.3	95.4	49.8	74.7	43.4	81.8	78.2	78.2	64.7	30.9	57.2	119.1	57.8	35.9
JUN	90.5	270.2	157.8	117.5	256.8	163.0	308.5	159.8	182.3	293.3	89.2	221.6	142.4	161.0	153.8	195.4	277.2	48.5	142.2	149.4	105.2
JUL	537.8	435.6	348.7	139.3	172.2	174.6	287.0	213.8	337.5	558.0	70.6	209.2	351.6	525.2	252.7	198.3	231.4	589.1	280.2	86.4	261.6
AUG	302.4	254.6	571.5	210.6	250.6	497.8	153.0	250.9	313.3	353.6	203.0	328.4	175.4	39.8	449.1	113.5	333.2	196.2	282.4	384.2	257.0
SEP	150.0	256.0	213.6	172.1	55.0	297.2	224.2	308.5	163.0	129.2	230.9	180.4	113.9	226.6	112.6	366.9	409.4	59.4	140.2	418.0	175.3
OCT	112.4	21.2	46.7	55.4	100.2	25.2	112.5	272.4	3.0	121.2	13.6	254.5	132.0	222.2	27.6	11.8	0.4	136.4	119.2	33.2	54.2
NOV	0.0	0.0	1.0	88.6	6.4	10.4	73.4	0.4	3.8	8.2	5.6	23.8	0.0	6.0	8.0	0.0	0.0	104.1	0.0	0.0	71.9
DEC	0.0	0.0	0.0	0.0	0.0	58.6	0.0	0.0	0.0	0.0	0.0	32.2	0.0	1.0	0.0	0.0	0.0	104.1	46.0	0.0	0.0
Total	1297.60	1427.40	1464.30	1409.38	932.20	1454.00	1350.11	1365.10	1165.30	1549.56	743.80	1328.40	1116.10	1396.80	1121.60	1039.00	1393.10	1297.94	1240.90	1225.60	1069.40

Source: IMD Bhubaneswar

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DISPOSAL OF ASH IN MINE VOIDS (QUARRY
NOS. 4, 7 & 8) IN JAGANNATH OCP OF
JAGANNATH AREA OF MCL,**

**TALCHER COALFIELD,
ODISHA**

ANNEXURE - VI

Photo documentation - Selected field photographs.

PHOTO DOCUMENTATION



Photo 1: Exploratory Drilling Rig deployed for drilling boreholes in and around Jagannath OCP, Talcher coalfield, Odisha.



Photo 2: Piezometer constructed in and around Jagannath OCP, Talcher coalfield, Odisha.



Photo 3: Drilling cutting sample at piezometer location in and around Jagannath OCP, Talcher coalfield, Odisha.



Photo 4: Gravels used for piezometer construction in and around Jagannath OCP, Talcher coalfield, Odisha.



Photo 5: CMPDI team undertaking development test in and around Jagannath OCP, Talcher coalfield, Odisha.



Photo 6: Pumping test assembly deployed in and around Jagannath OCP, Talcher coalfield, Odisha.



Photo 7: CMPDI team collecting groundwater sample from tube well in and around Jagannath OCP, Talcher coalfield, Odisha.



Photo 8: CMPDI team collecting groundwater sample from open dug well in and around Jagannath OCP, Talcher coalfield, Odisha.



Photo 9: CMPDI team collecting surface water sample from Brahmani river in and around Jagannath OCP, Talcher coalfield, Odisha.



Photo 10: CMPDI team collecting mine water sample in and around Jagannath OCP, Talcher coalfield, Odisha.

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NOS. 4, 7 & 8) IN JAGANNATH OCP OF
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ODISHA

ANNEXURE - VII

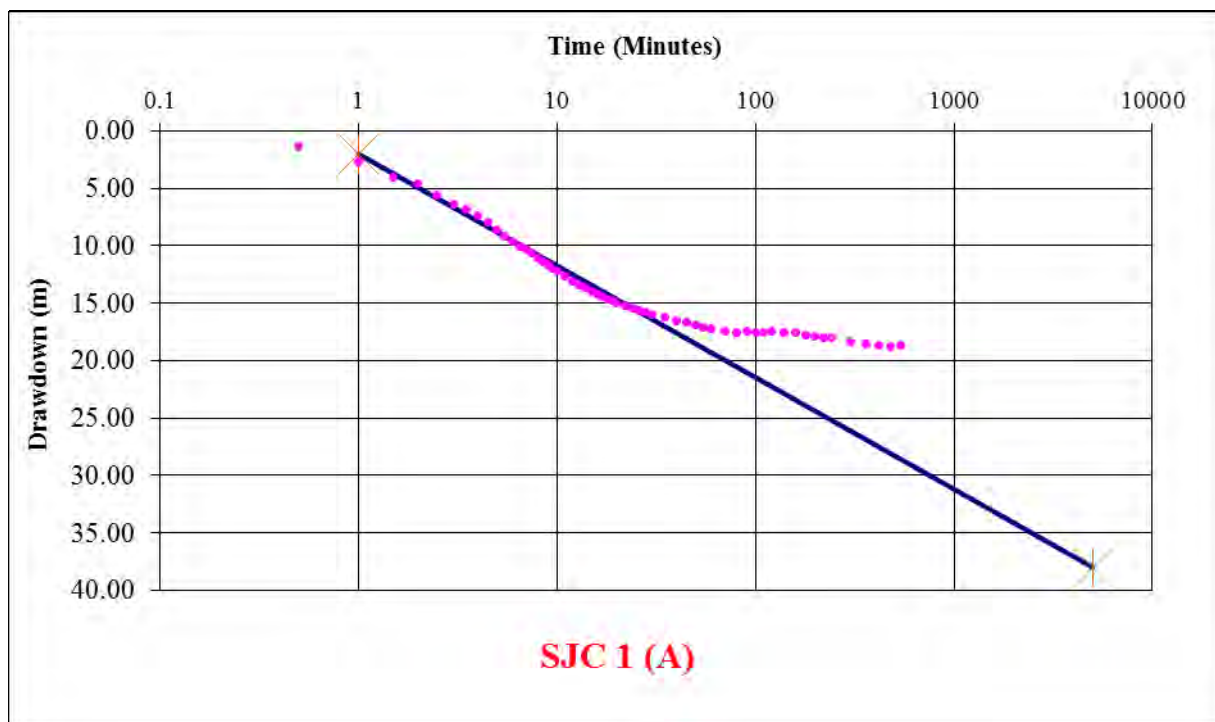
Pumping drawdown test, recovery test and slug test data plots, in and around Jagannath OCP, Talcher coalfield, Odisha.

ANNEXURE VII

**PUMPING DRAWDOWN TEST, RECOVERY TEST AND SLUG TEST
DATA PLOTS IN AND AROUND JAGANNATH OCP, TALCHER
COALFIELD, ODISHA**

**Plot 1: Time drawdown plot for Piezometer no. SJC 1 around Jagannath OCP,
Talcher coalfield, Odisha.**

(With first best fit straight line matching)

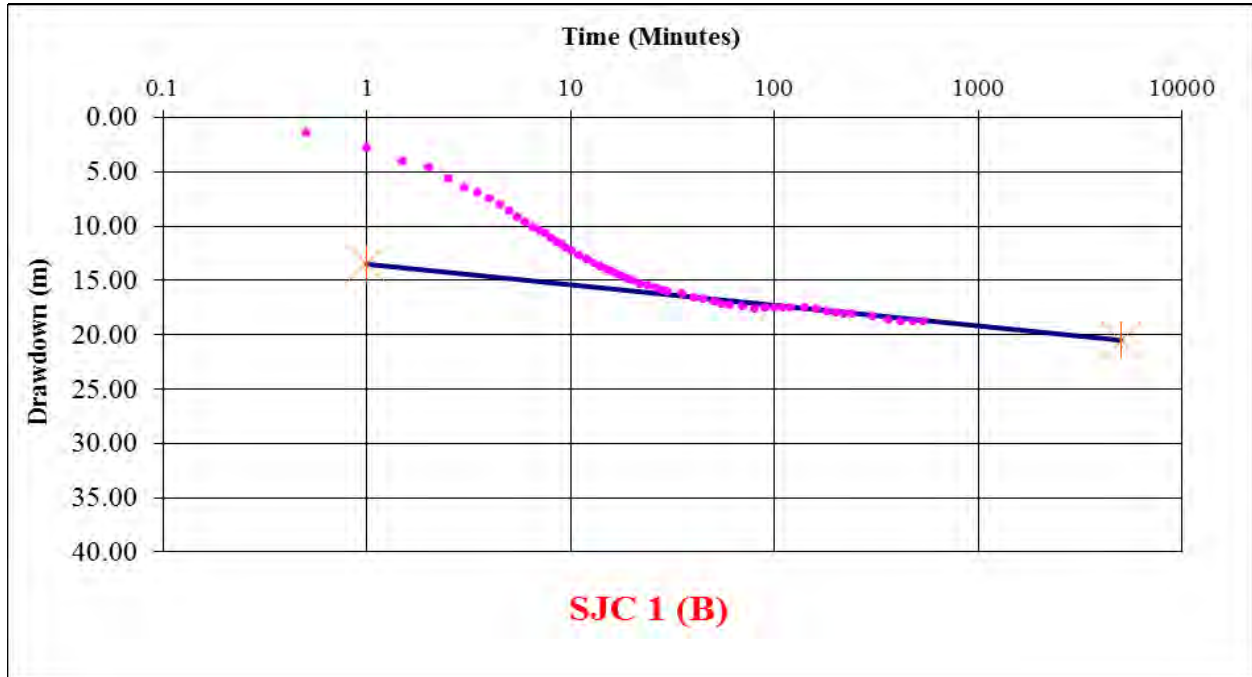


Index:

- Observed draw down values at pre-determined intervals

**Plot 2: Time drawdown plot for piezometer no SJC 1 around Jagannath OCP,
Talcher coalfield, Odisha.**

(With second best fit straight line matching)

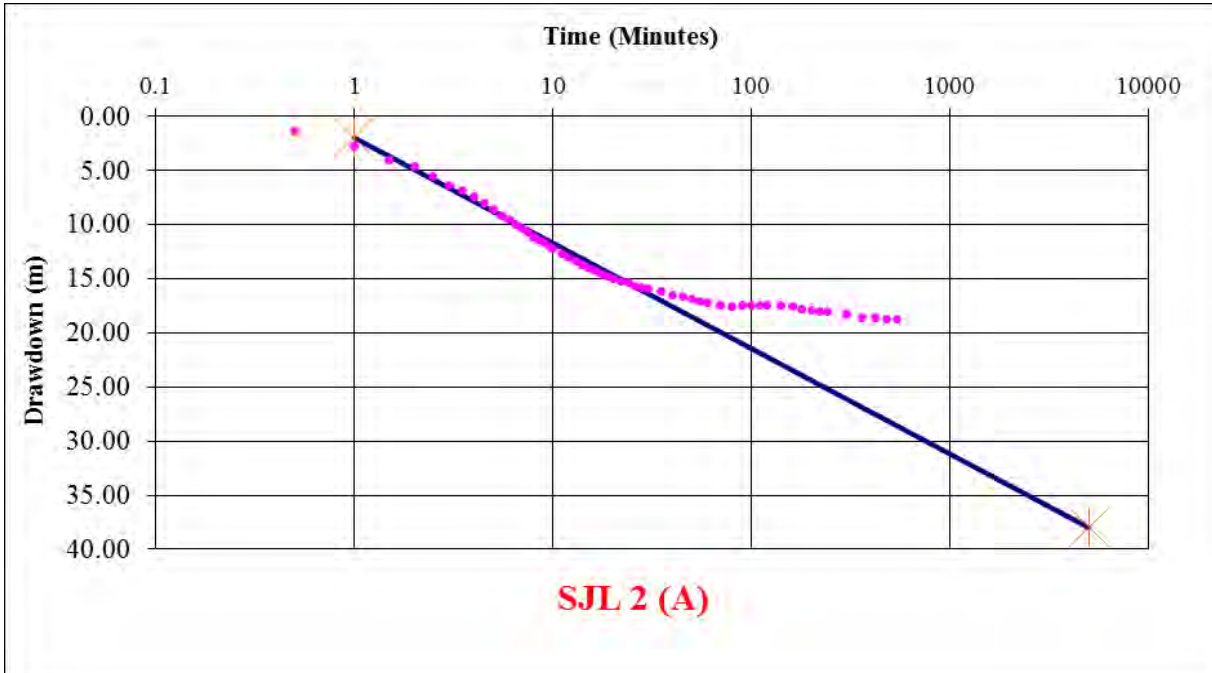


Index:

- Observed draw down values at pre-determined intervals

**Plot 3: Time drawdown plot for piezometer no SJL 2 around Jagannath OCP,
Talcher coalfield, Odisha.**

(With first best fit straight line matching)



Index:

- Observed draw down values at pre-determined intervals

**Plot 4: Time drawdown plot for piezometer no SJL 2 around Jagannath OCP,
Talcher coalfield, Odisha.**

(With second best fit straight line matching)

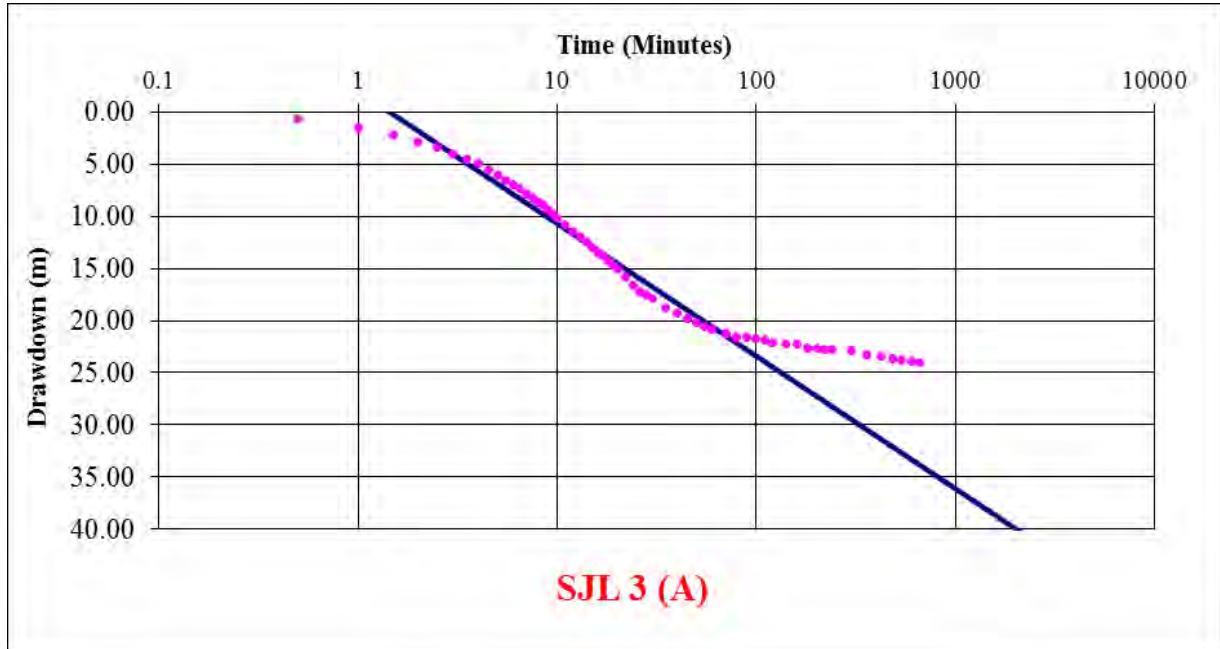


Index:

- Observed draw down values at pre-determined intervals

**Plot 5: Time drawdown plot for piezometer no SJL 3 around Jagannath OCP,
Talcher coalfield, Odisha.**

(With first best fit straight line matching)



Index:

- Observed draw down values at pre-determined intervals

**Plot 6: Time drawdown plot for piezometer no SJL 3 around Jagannath OCP,
Talcher coalfield, Odisha.**

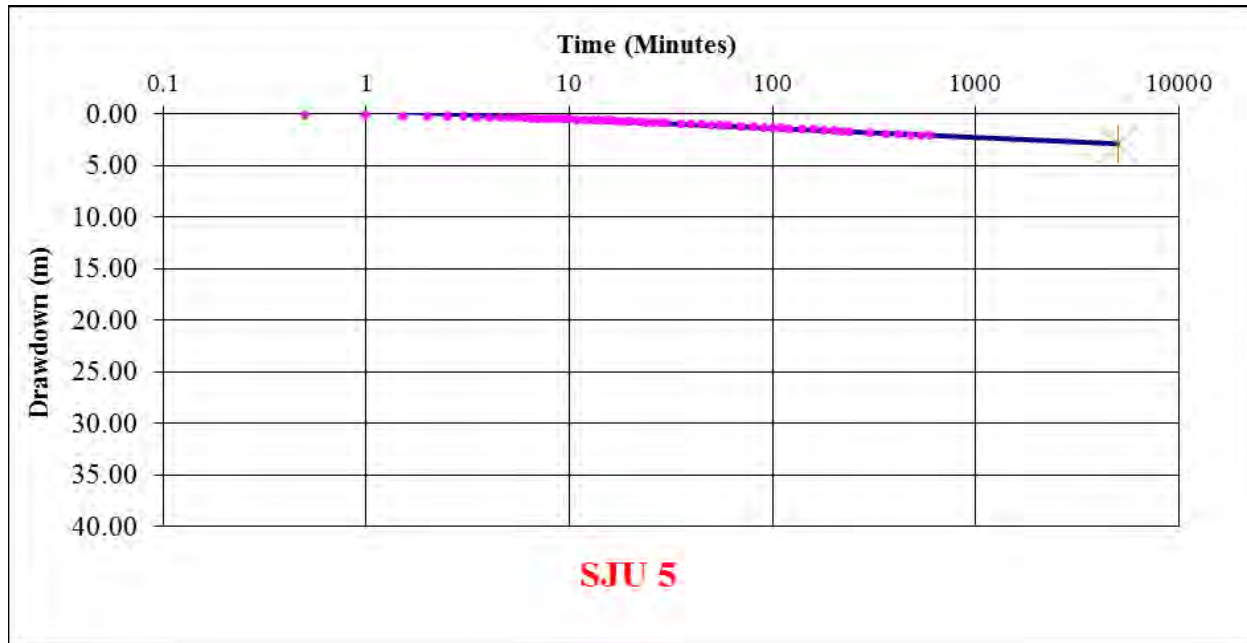
(with second best fit straight line matching)



Index:

- Observed draw down values at pre-determined intervals

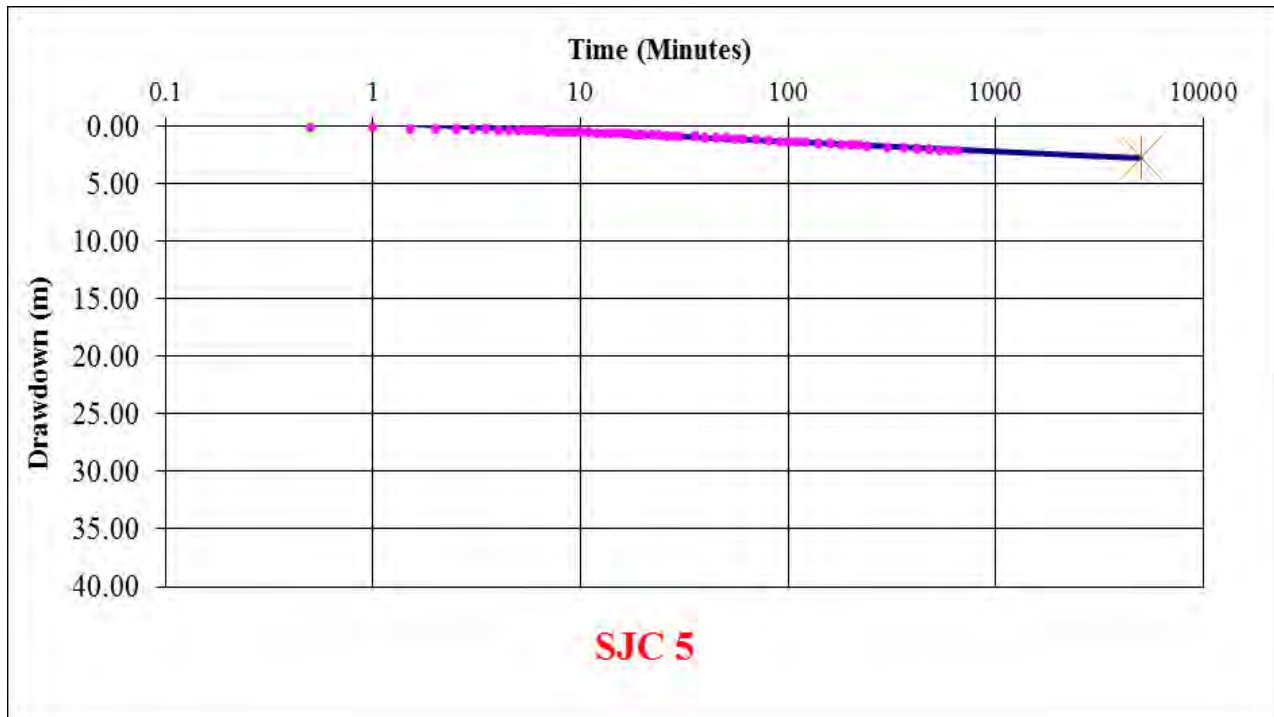
Plot 7: Time drawdown plot for piezometer no SJU 5 around Jagannath OCP, Talcher coalfield, Odisha.



Index:

- Observed draw down values at pre-determined intervals

Plot 8: Time drawdown plot for piezometer no SJC 5 around Jagannath OCP, Talcher coalfield, Odisha.

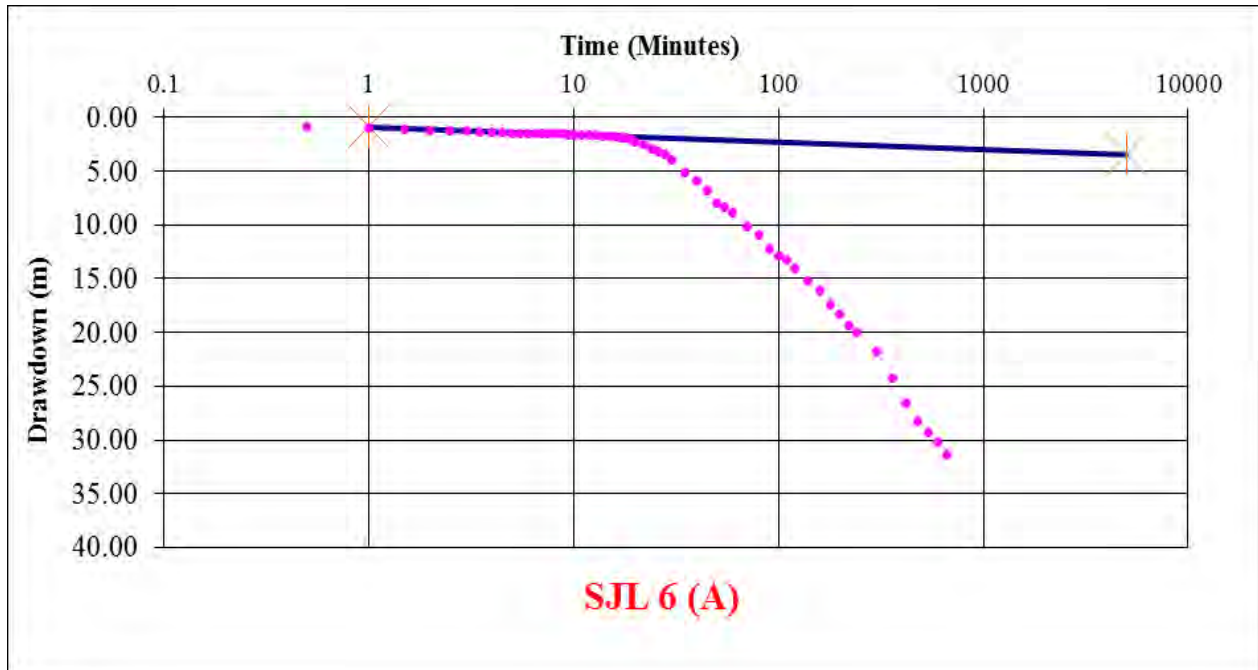


Index:

- Observed draw down values at pre-determined intervals

**Plot 9: Time drawdown plot for piezometer no SJL 6 around Jagannath OCP,
Talcher coalfield, Odisha.**

(With first best fit straight line matching)

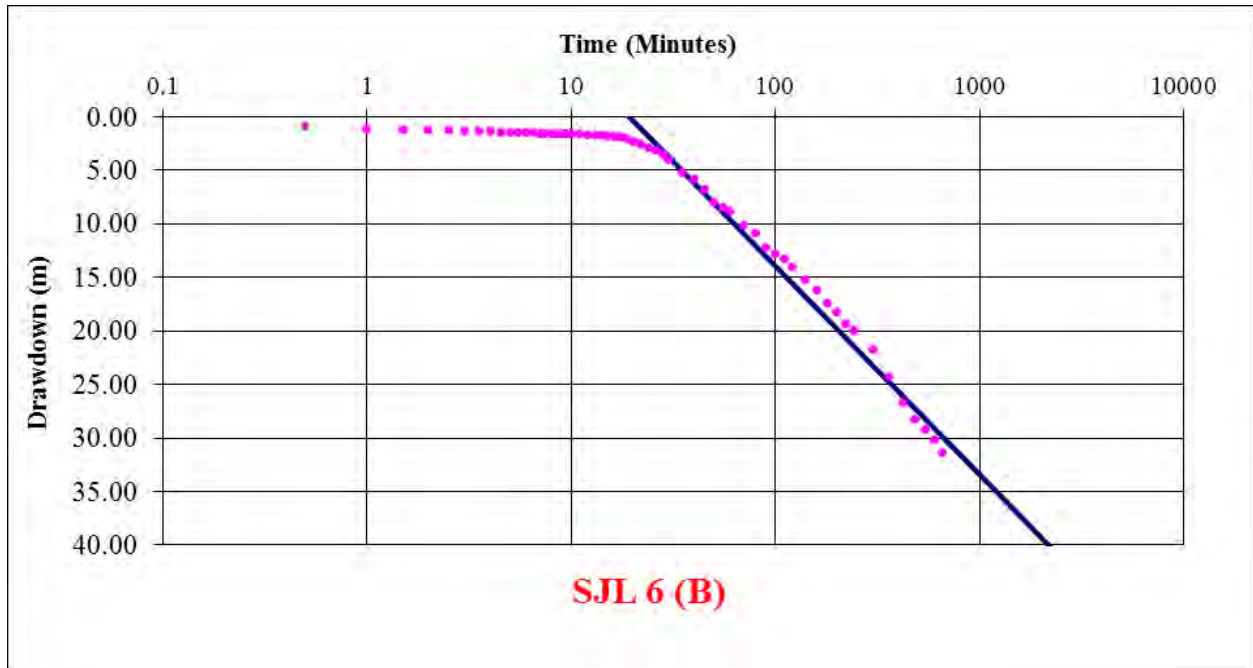


Index:

- Observed draw down values at pre-determined intervals

**Plot 10: Time drawdown plot for piezometer no SJL 6 around Jagannath OCP,
Talcher coalfield, Odisha.**

(with second best fit straight line matching)



Index:

- Observed draw down values at pre-determined intervals

Plot 11: Time drawdown plot for piezometer no SJL 7 around Jagannath OCP, Talcher coalfield, Odisha.



Index:

- Observed draw down values at pre-determined intervals

Plot 12: Time drawdown plot for piezometer no SJL 8 around Jagannath OCP, Talcher coalfield, Odisha.

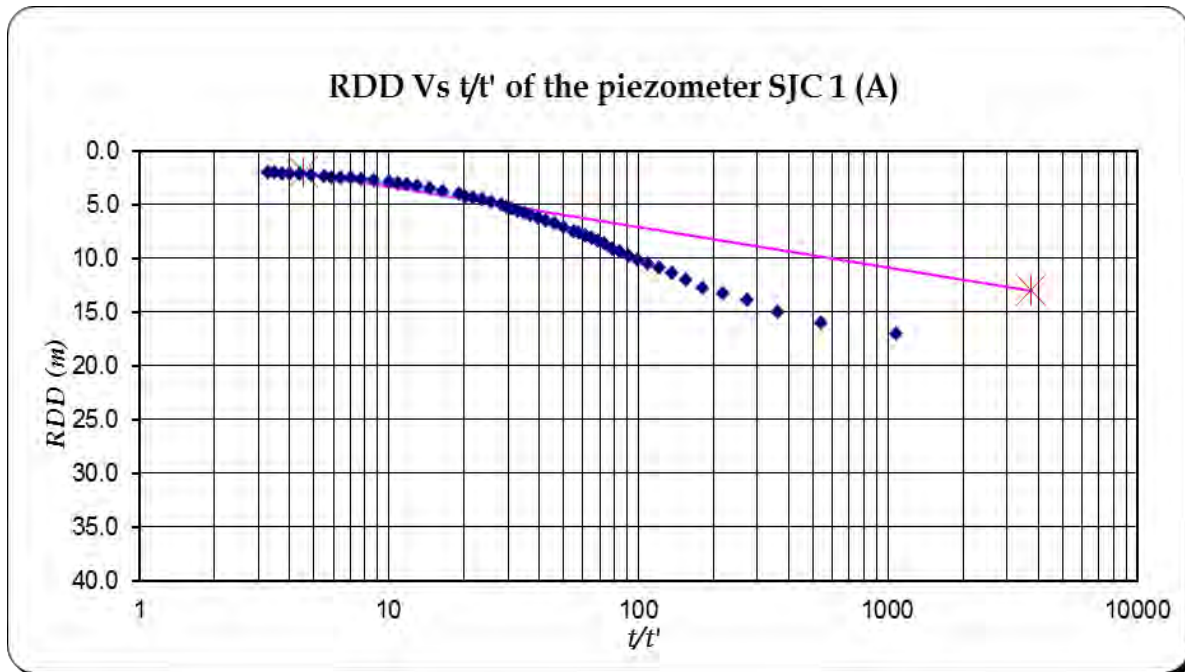


Index:

- Observed draw down values at pre-determined intervals

**Plot 13: Recovery plot for piezometer no SJC 1 around Jagannath OCP,
Talcher coalfield, Odisha.**

(with first best fit straight line matching)

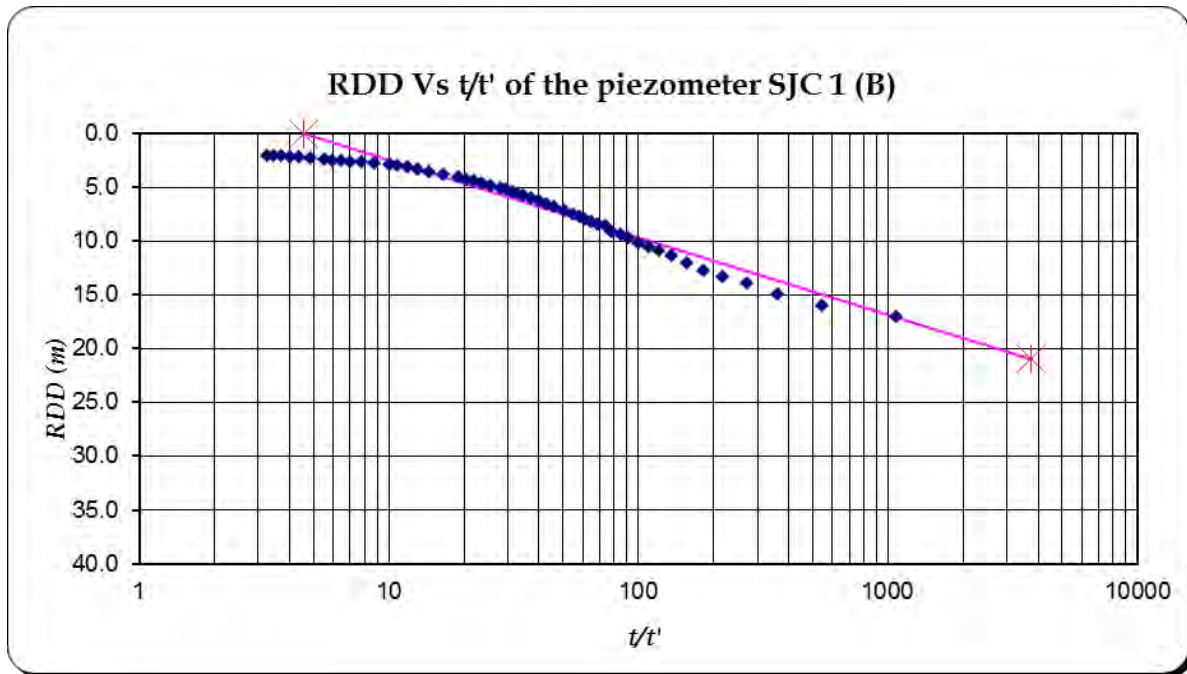


Index:

- ◆ Observed recovery values at pre-determined intervals

**Plot 14: Recovery plot for piezometer no SJC 1 around Jagannath OCP,
Talcher coalfield, Odisha.**

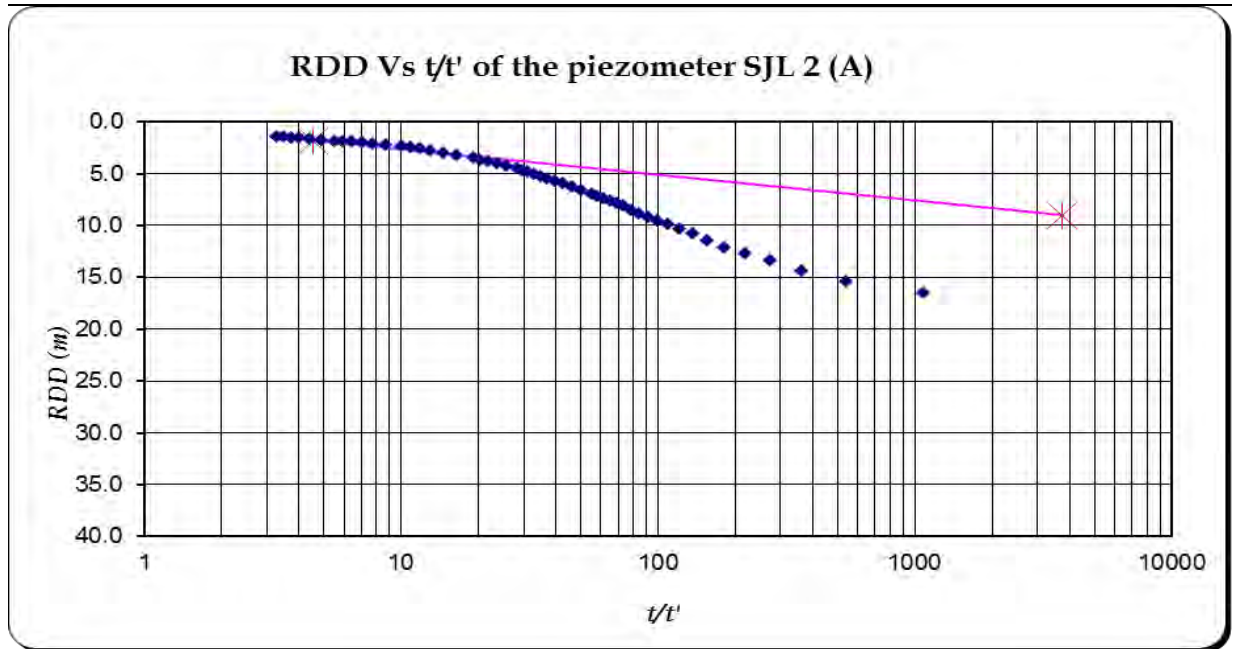
(with second best fit straight line matching)



Index:

- ◆ Observed recovery values at pre-determined intervals

**Plot 15: Recovery plot for piezometer no SJL 2 around Jagannath OCP,
Talcher coalfield, Odisha.
(with first best fit straight line matching)**

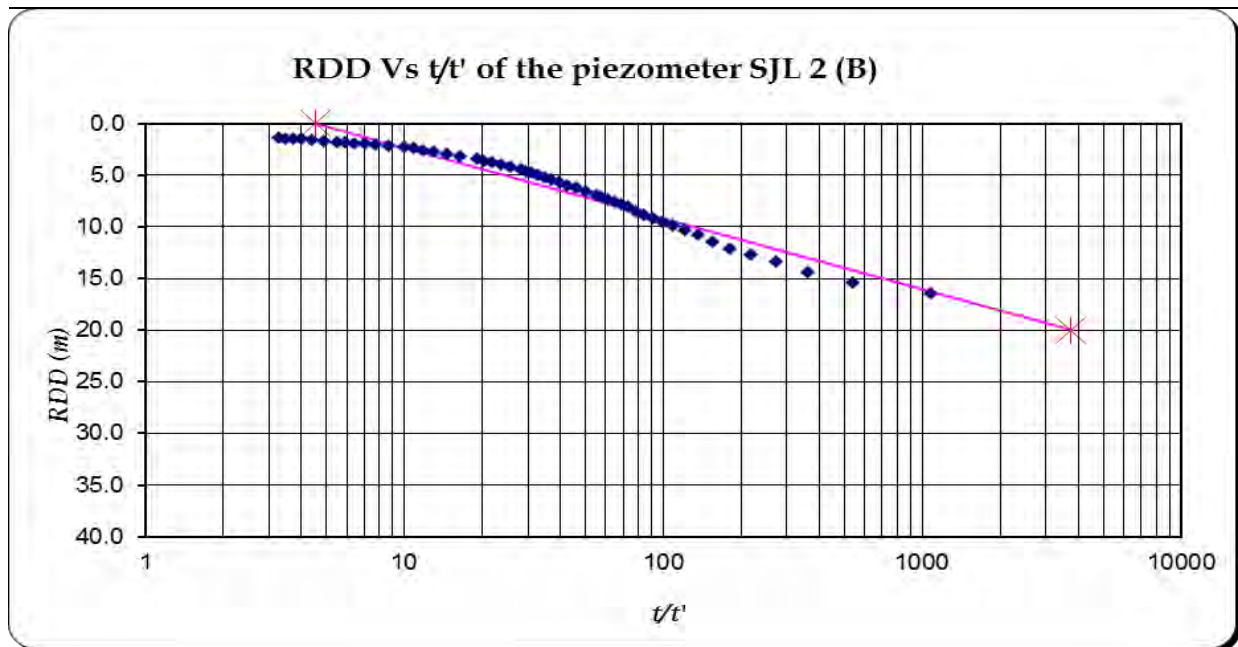


Index:

- ◆ Observed recovery values at pre-determined intervals

**Plot 16: Recovery plot for piezometer no SJL 2 around Jagannath OCP,
Talcher coalfield, Odisha.**

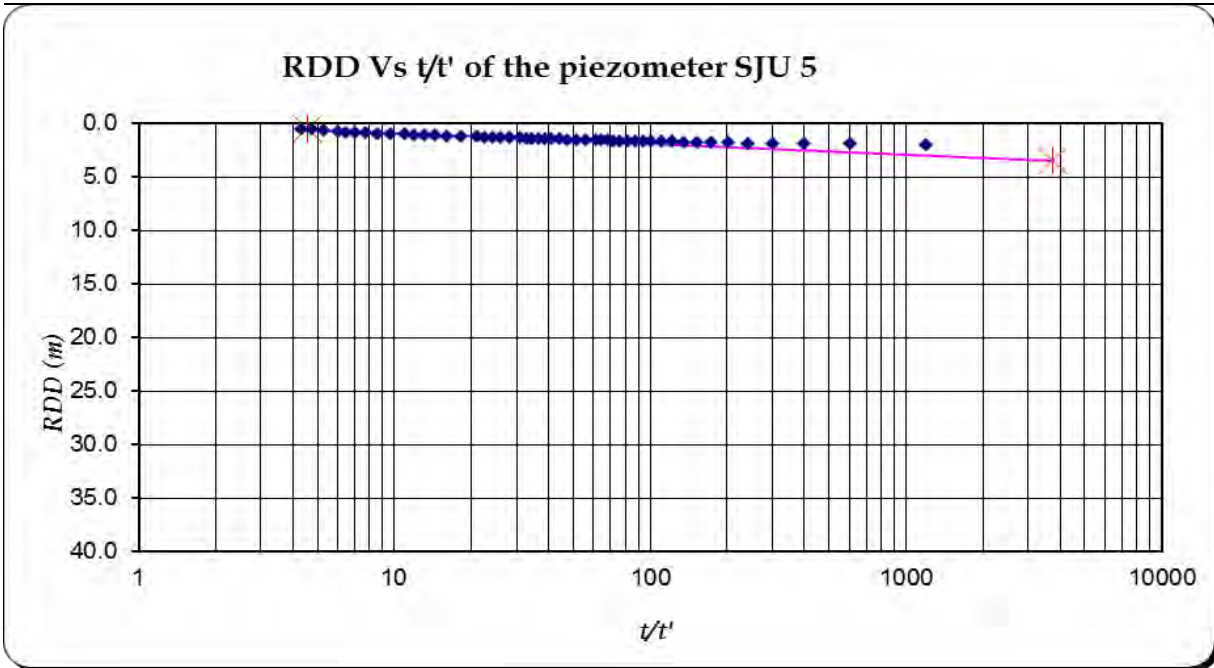
(with second best fit straight line matching)



Index:

- ◆ Observed recovery values at pre-determined intervals

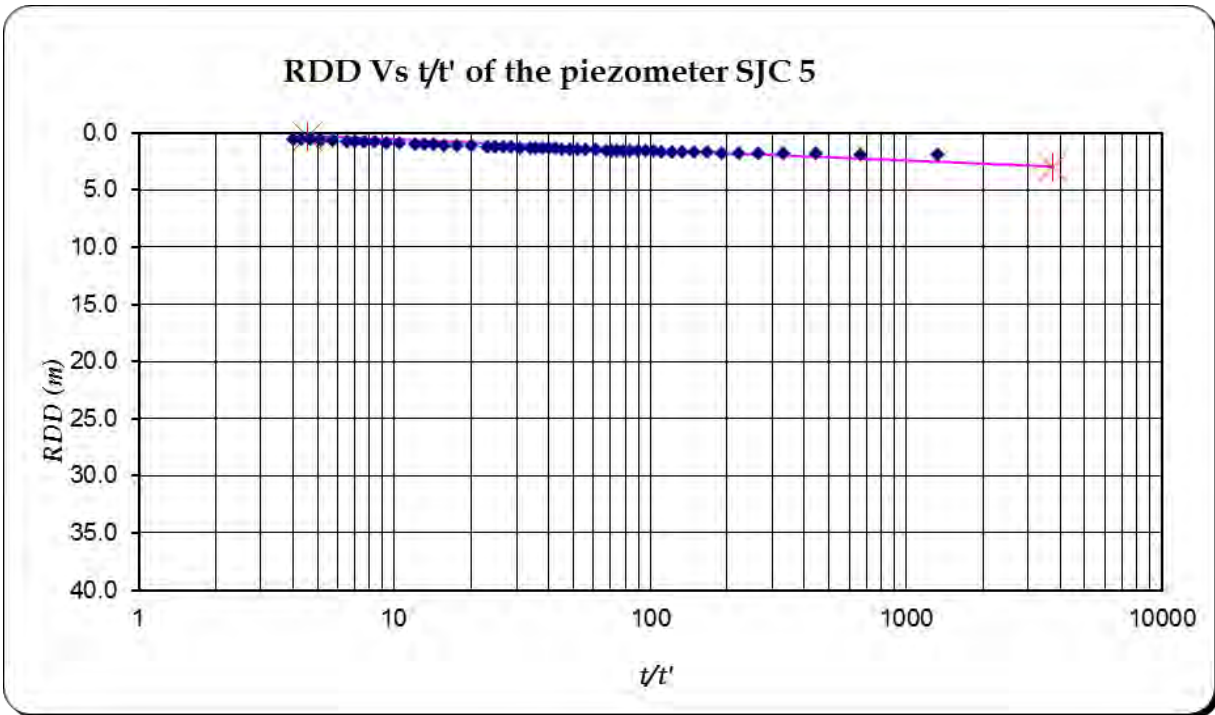
Plot 17: Recovery plot for piezometer no SJLU 5 around Jagannath OCP, Talcher coalfield, Odisha.



Index:

- ◆ Observed recovery values at pre-determined intervals

**Plot 18: Recovery plot for piezometer no SJC 5 around Jagannath OCP,
Talcher coalfield, Odisha.**

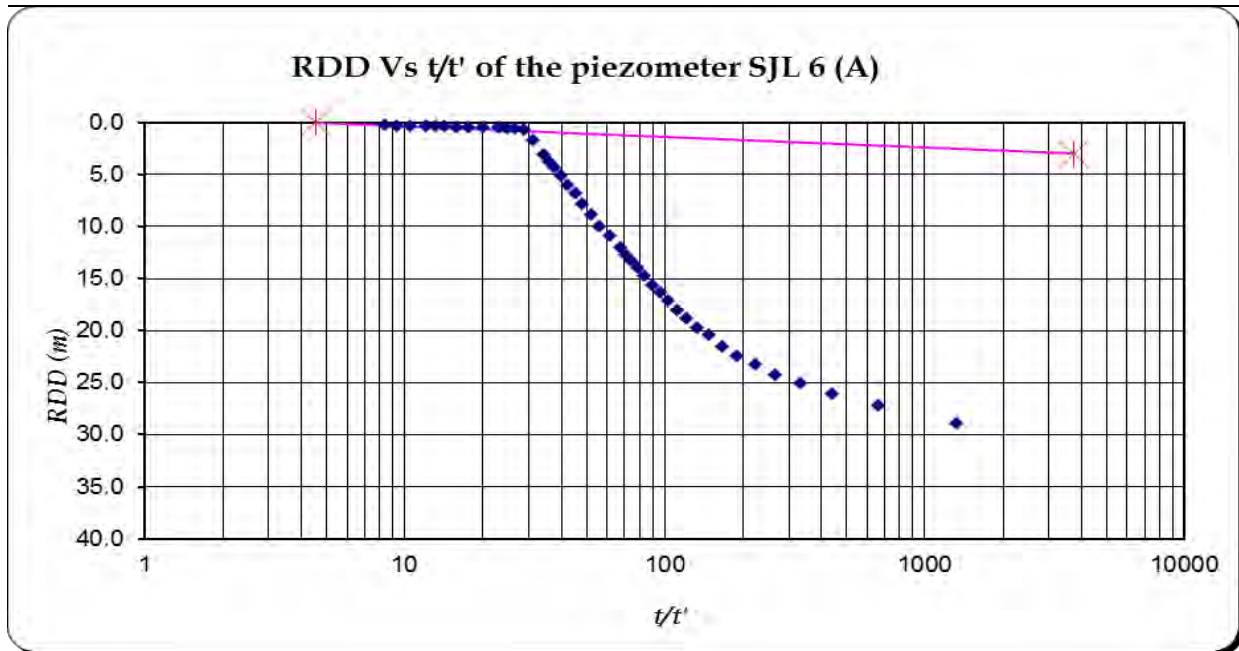


Index:

- ◆ Observed recovery values at pre-determined intervals

**Plot 19: Recovery plot for piezometer no SJL 6 around Jagannath OCP,
Talcher coalfield, Odisha.**

(with first best fit straight line matching)

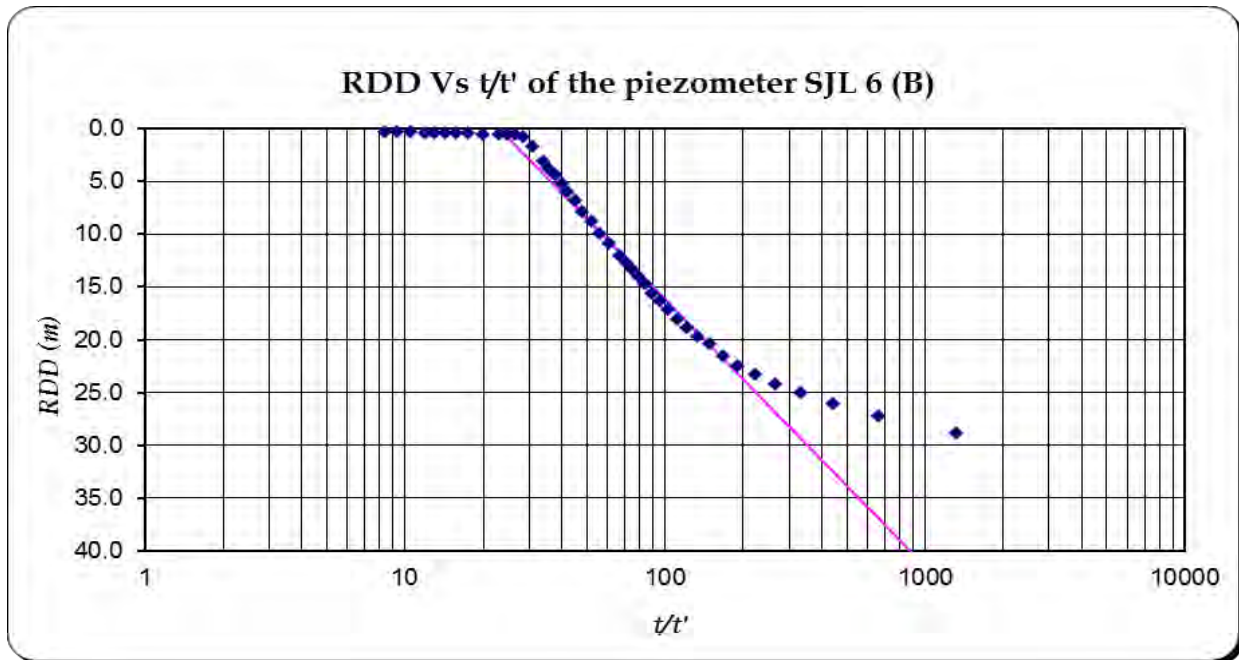


Index:

- ◆ Observed recovery values at pre-determined intervals

**Plot 20: Recovery plot for piezometer no SJL 6 around Jagannath OCP,
Talcher coalfield, Odisha.**

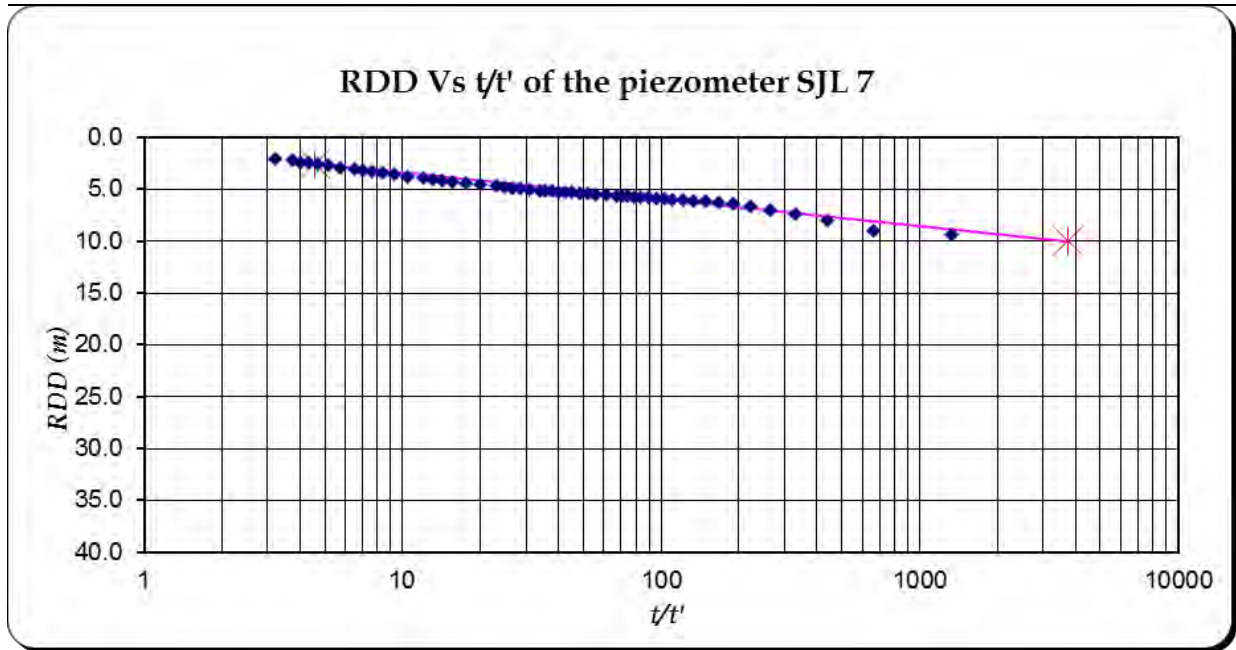
(with first best fit straight line matching)



Index:

- ◆ Observed recovery values at pre-determined intervals

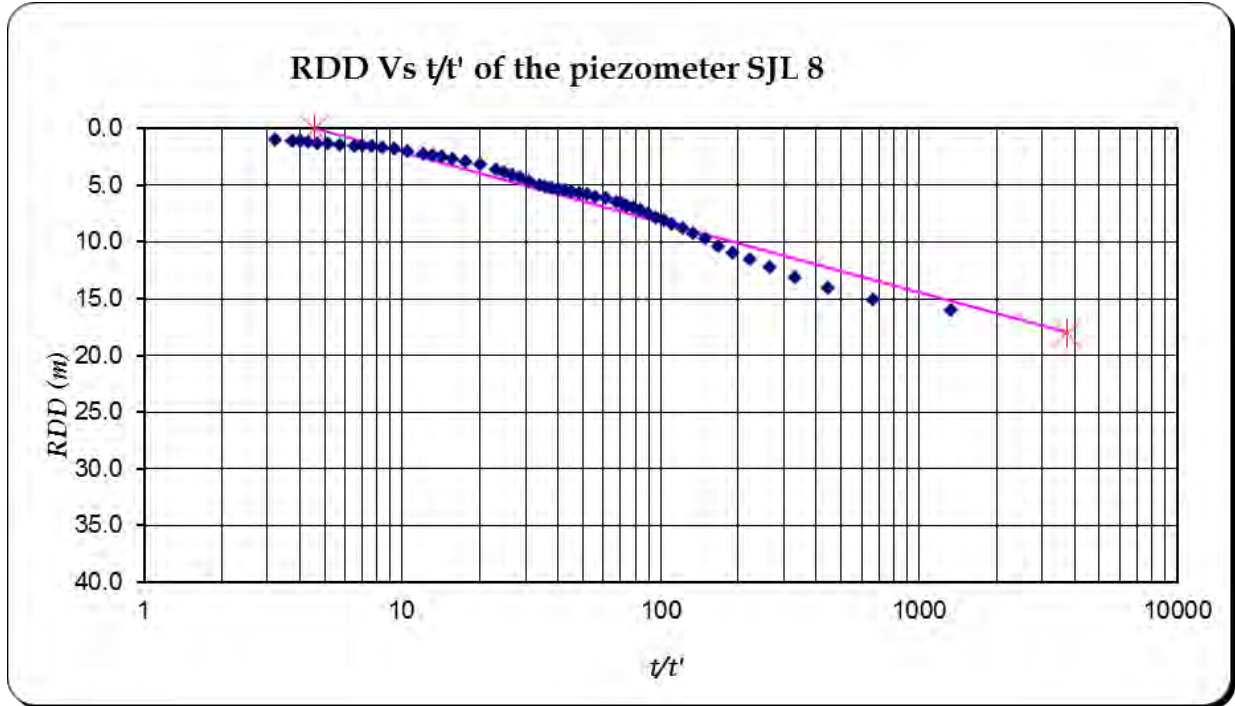
**Plot 21: Recovery plot for piezometer no SJL 7 around Jagannath OCP,
Talcher coalfield, Odisha.**



Index:

- ◆ Observed recovery values at pre-determined intervals

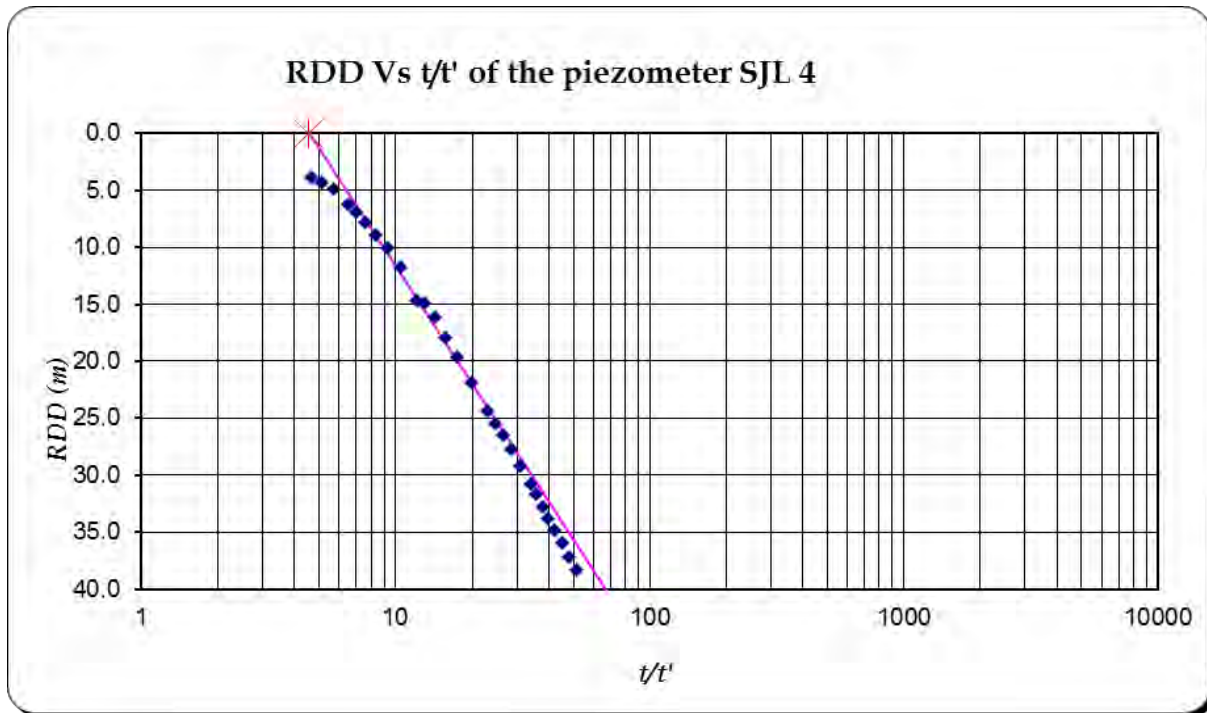
**Plot 22: Recovery plot for piezometer no SJL 8 around Jagannath OCP,
Talcher coalfield, Odisha.**



Index:

- ◆ Observed recovery values at pre-determined intervals

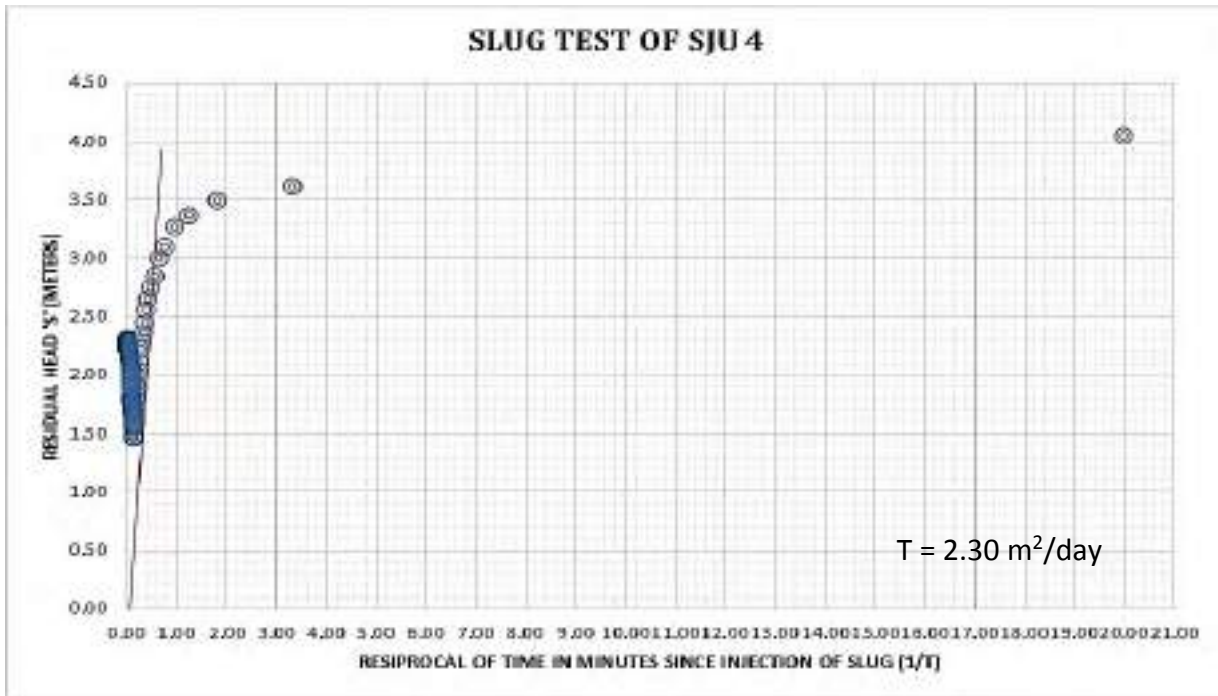
**Plot 23: Recovery plot for piezometer no SJL 4 around Jagannath OCP,
Talcher coalfield, Odisha.**



Index:

- ◆ Observed recovery values at pre-determined intervals

Plot 24: Graph showing decline of residual head for Piezometer no. SJU 4 around Jagannath OCP, Talcher coalfield, Odisha.



Index

- ⊙ Residual draw down values

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ANNEXURE - VIII

**Site specific lithology as observed from drill cutting of
piezometers in and around Jagannath OCP, Talcher Coalfield,
Odisha.**

ANNEXURE VIII

**SITE SPECIFIC LITHOLOGY AS OBSERVED FROM DRILL
CUTTINGS OF PIEZOMETERS IN AND AROUND JAGANNATH OCP,
TALCHER COALFIELD, ODISHA.**

**Location - Piezometer SJC 1: At Ananta Substation between Ananta OCP &
Jagannath OCP)**

Depth (m)	Lithology
00.00 to 01.00	Weathered material
01.00 to 03.00	Reddish brown weathered material
03.00 to 04.00	Brown weathered material
04.00 to 06.00	Greyish weathered material with coarse grained sand
06.00 to 09.00	Greyish brown coarse grained sand with silt
09.00 to 10.00	Greyish white fine grained sand with silt
10.00 to 11.00	Greyish white fine grained sand
11.00 to 12.00	Dark grey fine grained sand with silt
12.00 to 15.00	Dark grey medium grained sand
15.00 to 16.00	Dark grey coarse grained sand
16.00 to 17.00	Dark grey fine grained sand with silt
17.00 to 18.00	Black carbonaceous material
18.00 to 28.00	Dark Grey coarse grained sand with silt
28.00 to 30.00	Dark grey medium grained sand
30.00 to 34.00	Dark Grey coarse grained sand with silt
34.00 to 41.00	Dark grey medium grained sand
41.00 to 46.00	Dark grey medium grained sand with silt
46.00 to 51.00	Dark grey coarse grained sand
51.00 to 58.00	Greyish white Medium grained sand
58.00 to 59.00	Greyish white Medium grained sand with silt
59.00 to 84.00	Greyish white Medium grained sand
84.00 to 88.00	Greyish white fine grained sand
88.00 to 90.00	Greyish white medium to fine grained sand
90.00 to 92.00	Greyish white fine grained sand
92.00 to 93.00	Greyish white medium to fine grained sand
93.00 to 96.00	Greyish white fine grained sand
96.00 to 100.00	Greyish white medium to fine grained sand
100.00 to 105.00	Black carbonaceous material

Location - Piezometer SJL 2: Mid of Ananta OCP and Jagannath OCP at the Northern Edge

Depth (m)	Lithology
00.00 to 01.00	Light brown weathered material
01.00 to 02.00	Dark brown weathered material
02.00 to 06.00	Brown weathered material
06.00 to 09.00	Greyish brown coarse grained sand with silt
09.00 to 11.00	Greyish white fine grained sand with silt
11.00 to 12.00	Dark grey fine grained sand with silt
12.00 to 14.00	Dark grey medium grained sand
14.00 to 16.00	Dark grey coarse grained sand
16.00 to 18.00	Dark grey fine grained sand with silt
18.00 to 19.00	Black carbonaceous material
19.00 to 27.00	Dark Grey coarse grained sand with silt
27.00 to 29.00	Dark grey medium grained sand
29.00 to 33.00	Dark Grey coarse grained sand with silt
33.00 to 39.00	Dark grey medium grained sand
39.00 to 47.00	Dark grey medium grained sand with silt
47.00 to 51.00	Dark grey coarse grained sand
51.00 to 58.00	Greyish medium grained sand
58.00 to 59.00	Greyish medium grained sand with silt
59.00 to 69.00	Greyish medium grained sand
69.00 to 74.00	Greyish fine grained sand
74.00 to 84.00	Greyish medium grained sand
84.00 to 87.00	Greyish fine grained sand
87.00 to 90.00	Greyish white medium to fine grained sand
90.00 to 91.00	Greyish white fine grained sand
91.00 to 93.00	Greyish white medium to fine grained sand
93.00 to 96.00	Greyish white fine grained sand
96.00 to 100.00	Greyish white medium to fine grained sand
100.00 to 105.00	Black carbonaceous material

Location - Piezometer SJL 3: At Jagannath Workshop

Depth (m)	Lithology
00.00 to 02.00	Yellowish weathered material
02.00 to 03.00	Elastic yellowish weathered material
03.00 to 04.00	Yellowish Silty sand
04.00 to 05.00	Greyish yellow coarse grained sand
05.00 to 07.00	Greyish yellow coarse grained sand with silt
07.00 to 10.00	Greyish coarse grained sand with silt
10.00 to 12.00	Greyish medium grained sand with silt
12.00 to 20.00	Greyish coarse grained sand with silt
20.00 to 21.00	Greyish fine grained sand with silt
21.00 to 22.00	Greyish medium grained sand with silt
22.00 to 23.00	Greyish fine grained sand with silt
23.00 to 27.00	Dark Grey medium grained sand with silt
27.00 to 28.00	Black carbonaceous material
28.00 to 30.00	Greyish medium grained sand with silt
30.00 to 34.00	Black carbonaceous material
34.00 to 41.00	Greyish medium grained sand with silt
41.00 to 42.00	Black carbonaceous material
42.00 to 43.00	Greyish medium grained sand with silt
43.00 to 44.00	Black carbonaceous material
44.00 to 45.00	Greyish medium grained sand with silt
45.00 to 50.00	Black carbonaceous material
50.00 to 60.00	Dark Grey coarse grained sand with silt
60.00 to 69.00	Greyish white medium grained sand
69.00 to 74.00	Greyish coarse grained sand with chalk like material
74.00 to 79.00	Greyish white coarse grained sand
79.00 to 80.00	Greyish white very coarse grained sand
80.00 to 89.00	Greyish white medium grained sand
89.00 to 90.00	Greyish coarse grained sand with silt
90.00 to 92.00	Greyish coarse grained sand
92.00 to 97.00	Greyish medium grained sand
97.00 to 98.00	Greyish coarse grained sand
98.00 to 99.00	Greyish medium grained sand
99.00 to 100.00	Greyish fine to medium grained sand
100.00 to 108.00	Greyish medium grained sand

Location - Piezometer SJL-4: CTPL Workshop

Depth (m)	Lithology
00.00 to 02.00	Reddish brown weathered material
02.00 to 09.00	Greyish white weathered material
09.00 to 21.00	Light brown coarse grained sand
21.00 to 24.00	Yellowish brown fine grained sand with silt
24.00 to 27.00	Greyish white fine grained sand
27.00 to 30.00	Greyish white medium to coarse grained sand
30.00 to 31.00	Greyish fine to medium grained sand
31.00 to 38.00	Greyish white fine grained sand
38.00 to 41.00	Greyish fine to medium grained sand
41.00 to 45.00	Greyish white medium grained sand
45.00 to 47.00	Greyish white medium to coarse grained sand
47.00 to 48.00	Light brown medium to coarse grained sand
48.00 to 49.00	Light Grey medium grained sand
49.00 to 50.00	Greyish white fine to medium grained sand
50.00 to 51.00	Greyish white coarse grained sand
51.00 to 52.00	Greyish white fine grained sand
52.00 to 53.00	Greyish coarse grained sand
53.00 to 56.00	Greyish white fine grained sand
56.00 to 58.00	Greyish white medium grained sand
58.00 to 60.00	Greyish white coarse grained sand with silt
60.00 to 65.00	Brown medium grained sand
65.00 to 66.00	Medium to coarse grained sand
66.00 to 73.00	Greyish white fine to medium grained sand
73.00 to 80.00	Dark grey fine to medium grained sand
80.00 to 89.00	Greyish medium grained sand
89.00 to 93.00	Greyish very coarse grained sand
93.00 to 95.00	Greyish medium to coarse grained sand
95.00 to 96.00	Greyish coarse grained sand
96.00 to 105.00	Greyish medium to coarse grained sand
105.00 to 108.00	Greyish white fine grained sand

Location - Piezometer SJU-4: CTPL Workshop

Depth (m)	Lithology
00.00 to 02.00	Light brown coarse grain sand with pebbles
02.00 to 06.00	Reddish brown mix of silt and gravel
06.00 to 41.00	Reddish brown to light brown coarse grain sand with gravels
41.00 to 55.00	Greyish loose coarse grained sand with carbonaceous material
55.00 to 60.00	Grey colour medium to fine grained sand

Location - Piezometer SJU-5: Central Colony (Jagannath Area)

Near Police Beat House

Depth (m)	Lithology
00.00 to 02.00	Reddish fine grained silty sand
02.00 to 06.00	Reddish white medium grain sand with calcareous material
06.00 to 09.00	Reddish white fine grain sand with clay
09.00 to 12.00	Reddish white fine grain sand
12.00 to 15.00	Light brown medium grained sandstone
15.00 to 18.00	Dark brown medium grain sand
18.00 to 19.00	Dark brown medium to coarse grain sand
19.00 to 20.00	Dark brown medium grain sand
20.00 to 23.00	Dark brown medium to coarse grain sand
23.00 to 24.00	Dark brown medium grain sand
24.00 to 27.00	Light grey medium grain sand
27.00 to 28.00	Light grey fine to medium grain sand
28.00 to 29.00	Light grey fine grain sand
29.00 to 31.00	Light grey medium to coarse grain sand
31.00 to 35.00	Light grey medium grain sand
35.00 to 38.00	Light grey medium to coarse grain sand
38.00 to 40.00	Light grey medium grain sand
40.00 to 42.00	Light grey medium to coarse grain sand
42.00 to 47.00	Black fine grain silty sand with carbonaceous matter
47.00 to 50.00	Black fine grain sand with carbonaceous matter
50.00 to 55.00	Dark grey coarse grain sand

Location - Piezometer SJC-5: Central Colony (Jagannath Area) Near Police Beat House

Depth (m)	Lithology
00.00 to 02.00	Reddish fine grained silty sand
02.00 to 06.00	Reddish white medium grain sand with calcareous material
06.00 to 08.00	Reddish white fine grain sand with clay
08.00 to 12.00	Reddish white fine grain sand
12.00 to 16.00	Light brown medium grained sandstone
16.00 to 18.00	Dark brown medium grain sand
18.00 to 19.00	Dark brown medium to coarse grain sand
19.00 to 23.00	Dark brown medium grain sand
23.00 to 24.00	Dark brown medium to coarse grain sand
24.00 to 25.00	Dark brown medium grain sand
25.00 to 27.00	Grey medium grain sand
27.00 to 29.00	Grey fine grain sand
29.00 to 30.00	Grey fine grain sand
30.00 to 31.00	Grey medium to coarse grain sand
31.00 to 34.00	Grey medium grain sand
34.00 to 38.00	Light grey medium to coarse grain sand
38.00 to 40.00	Light grey medium grain sand
40.00 to 42.00	Light grey medium to coarse grain sand
42.00 to 47.00	Black fine grain silty sand with carbonaceous matter
47.00 to 50.00	Black fine grain sand with carbonaceous matter
50.00 to 55.00	Dark grey coarse grain sand
55.00 to 56.00	Greyish coarse grained sand
56.00 to 58.00	Greyish medium grained sand
58.00 to 61.00	Greyish coarse grained sand with silt
61.00 to 64.00	Brown medium grained sand
64.00 to 66.00	Medium to coarse grained sand
66.00 to 73.00	Greyish white fine to medium grained sand
73.00 to 80.00	Dark grey fine to medium grained sand
80.00 to 86.00	Greyish medium grained sand
86.00 to 91.00	Greyish very coarse grained sand
91.00 to 94.00	Greyish medium to coarse grained sand
94.00 to 95.00	Greyish coarse grained sand
96.00 to 99.00	Light grey coarse grained sand
99.00 to 101.00	Greyish medium grained sand
101.00 to 102.00	Greyish coarse grained sand
102.00 to 105.00	Greyish medium grained sand

Location - Piezometer SJL 6: Near Ananta PO office

Depth (m)	Lithology
00.00 to 02.00	Brown weathered material
02.00 to 03.00	Light Brown weathered material
03.00 to 04.00	Light brown Silty sand
04.00 to 05.00	Light brown coarse grained sand
05.00 to 07.00	Yellow medium grained sand
07.00 to 10.00	Yellow coarse grained sand with silt
10.00 to 12.00	Light brown medium grained sand with silt
12.00 to 20.00	Light brown coarse grained sand with silt
20.00 to 21.00	Light brown fine grained sand with silt
21.00 to 23.00	Light brown medium grained sand with silt
23.00 to 25.00	Greyish fine grained sand with silt
25.00 to 27.00	Dark Grey medium grained sand with silt
27.00 to 28.00	Greyish fine grained sand with silt
28.00 to 31.00	Greyish medium grained sand with silt
31.00 to 33.00	Black carbonaceous material
33.00 to 37.00	Greyish medium grained sand with silt
37.00 to 41.00	Greyish fine grained sand with silt
41.00 to 42.00	Black carbonaceous material
42.00 to 43.00	Greyish medium grained sand with silt
43.00 to 44.00	Black carbonaceous material
44.00 to 45.00	Greyish medium grained sand with silt
45.00 to 50.00	Black carbonaceous material
50.00 to 60.00	Dark Grey coarse grained sand with silt
60.00 to 69.00	Greyish white medium grained sand
69.00 to 74.00	Greyish coarse grained sand with chalk like material
74.00 to 79.00	Greyish white coarse grained sand
79.00 to 80.00	Greyish white very coarse grained sand
80.00 to 89.00	Greyish white medium grained sand
89.00 to 90.00	Greyish coarse grained sand with silt
90.00 to 92.00	Greyish coarse grained sand
92.00 to 97.00	Greyish medium grained sand
97.00 to 98.00	Greyish coarse grained sand
98.00 to 99.00	Greyish medium grained sand
99.00 to 100.00	Greyish fine to medium grained sand
100.00 to 108.00	Greyish medium grained sand

Location - Piezometer SJL-7: Near Ananta Railway sliding

Depth (m)	Lithology
00.00 to 02.00	Brown weathered material
02.00 to 03.00	Light Brown weathered material
03.00 to 04.00	Light brown Silty sand
04.00 to 05.00	Light brown coarse grained sand
05.00 to 07.00	Yellow medium grained sand
07.00 to 10.00	Yellow coarse grained sand with silt
10.00 to 12.00	Light brown medium grained sand with silt
12.00 to 20.00	Light brown coarse grained sand with silt
20.00 to 21.00	Light brown fine grained sand with silt
21.00 to 23.00	Light brown medium grained sand with silt
23.00 to 25.00	Greyish fine grained sand with silt
25.00 to 27.00	Dark Grey medium grained sand with silt
27.00 to 28.00	Greyish fine grained sand with silt
28.00 to 31.00	Greyish medium grained sand with silt
31.00 to 33.00	Black carbonaceous material
33.00 to 37.00	Greyish medium grained sand with silt
37.00 to 41.00	Greyish fine grained sand with silt
41.00 to 42.00	Black carbonaceous material
42.00 to 43.00	Greyish medium grained sand with silt
43.00 to 44.00	Black carbonaceous material
44.00 to 45.00	Greyish medium grained sand with silt
45.00 to 50.00	Black carbonaceous material
50.00 to 60.00	Dark Grey coarse grained sand with silt
60.00 to 69.00	Greyish white medium grained sand
69.00 to 74.00	Greyish coarse grained sand with chalk like material
74.00 to 79.00	Greyish white coarse grained sand
79.00 to 80.00	Greyish white very coarse grained sand
80.00 to 89.00	Greyish white medium grained sand
89.00 to 90.00	Greyish coarse grained sand with silt
90.00 to 92.00	Greyish coarse grained sand
92.00 to 95.00	Greyish medium grained sand
95.00 to 97.00	Greyish coarse grained sand
97.00 to 99.00	Greyish medium grained sand
99.00 to 100.00	Greyish fine to medium grained sand
100.00 to 101.00	Greyish medium grained sand
101.00 to 105.00	Greyish medium to coarse grained sand
105.00 to 106.00	Greyish coarse grained sand
106.00 to 108.00	Greyish medium grained sand

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**Study of fly ash characterization of ash fill sites of Talcher
Thermal Power Plant and leaching characteristics'
of mine pit water at South Balanda mine pit**

Submitted to

**M/s National Thermal Power Corporation Ltd
(Talcher, Angul District, Odisha)**



CSIR-National Environmental Engineering Research Institute
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May 2014

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FOREWORD

National Thermal Power Corporation (NTPC) operates 460 MW coal based power plant situated 140 km from Bhubaneswar in Angul district of Odisha state. It generates about 10 lakh tonne per annum of ash which is being disposed in slurry form in abandoned South Balanda mine of Mahanadi Coalfields Limited. The ash disposal site of abandoned South Balanda mine pit covers an area of 92.82 hectare. NTPC retained **CSIR-NEERI** to undertake study to establish ash characteristics, assess impacts of ash disposal on groundwater and delineate measures to mitigate adverse impacts on groundwater quality. The study adopted a holistic approach integrating various tools like hydrogeology, groundwater chemistry, ash characterization, and groundwater flow and solute transport modelling. The **HELP** model was employed to simulate impacts of ash disposal in the abandoned mine on groundwater quality in the surrounding watershed.

Groundwater quality data surrounding ash disposal site indicate that heavy metals and other physico-chemical parameters (except fluoride) remain within permissible standards of drinking water as per BIS 10500:2012. Fly ash was acidic whereas bottom ash and pond ash were neutral. The major constituents of fly ash are SiO₂ (58.9% to 63.01%), Al₂O₃ (19.13% to 29.32%) and Fe₂O₃ (4.4% to 6.4%) and minor constituents (K₂O, TiO₂, CaO, MgO, Na₂O, Na₂O, P₂O₅ and SO₃) meet the general requirements of ASTM C-618 Standards. Leaching studies (TCLP and SPLP) indicate that fly ash, bottom ash and pond ash are non-hazardous; and heavy metals viz., arsenic (≤ 0.105 mg/l), cadmium (≤ 0.003158 mg/l), chromium (≤ 0.0084 mg/l) and lead (≤ 0.0118 mg/l) are below the regulatory level as per RCRA guidelines (US-EPA, 2006). Leaching studies (TCLP and SPLP) indicate that ash samples are non-hazardous as per RCRA guidelines.

The solute transport modeling of conservative elements for the existing ash pond indicates that the elements will move to a maximum distance of 931 m over 20 year period commencing from November 2012. Based on the analysis of the data and the modeling results, monthly monitoring of groundwater quality has been recommended as long as the ash disposal is carried out in the abandoned mine.

The cooperation rendered by the staff of NTPC, Talcher, Odisha is gratefully acknowledged.

May 12, 2014



(Satish R. Wate)

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Executive Summary

Power sector is one of the fastest growing sectors in India and it supports the economic growth of the nation. The coal based power plant has been increasing steadily and is poised for further growth in the 12th Five-Year Plan. The present installed capacity of power Plants is about 2, 05,340.26 MW and thermal power Plants account for about 66.44% of the total installed capacity. Talcher Thermal Power Station (TTPS) at Talcher in Angul District (Odisha) is a 4×60 MW and 2×110 MW coal based power station which is situated about 15 km from the Angul town in Odisha. The unused ash is mixed with water and the resultant slurry is disposed in abandoned south Balanda mine pit spread over 92.82 ha.

The present study aims at assessing the movement and reactivity of fly ash in groundwater and to establish the physico-chemical and mineralogical characteristics of fly ash and bottom ash. An integrated approach has been adopted in this study by utilizing various tools like hydrogeology, groundwater chemistry, fly ash characterization and groundwater flow and solute transport modeling, HELP modeling studies. The water quality analysis has been carried out for the six observation wells. Sampling and analysis for the mine pit water at various depths has been carried out in pre-monsoon and post monsoon season for the major cations, anions and trace elements.

The results of fly ash analysis revealed that fly ash was acidic in nature whereas bottom ash and pond ash were neutral in nature. Moisture content in samples varied from 0.87% to 29% and insoluble residue was in the range of 27.58% to 47.36% with carbon content being in the range of 0.0427 % to 2.445%. The major constituents in the samples are SiO_2 , Al_2O_3 and Fe_2O_3 . The major crystalline phases in samples were quartz and mullite as observed from elemental analysis and FTIR analysis. Leaching studies (TCLP and SPLP) reveals that collected samples were non-hazardous in nature where the concentration of As, B, Cd, Cr, and Pb were all well below the regulatory levels.

The possible impact of the ash pond on the groundwater sources was also studied by attempting the simulation using the Mass Transport Modeling (MT3D). The modeling of the solute transport for the south Balanda mine indicates that the conservative ions will move to a maximum distance of 931 m over a 20 year period starting from November 2012.

Annexure-VIII

The **HELP model** indicates that over a ten year period an additional head of approximately **25 ft i.e. 8.33 m is likely to be built up**. It is necessary that TTPS should monitor the groundwater level in the boreholes drilled in the immediate downstream of the abandoned mine pit at South Balanda. The monitoring should be done monthly as long as the ash disposal is carried out in the study area. Tracer study should be carried out to examine any hydraulic connectivity between the mine pit and the groundwater sources in the vicinity of the mine pit.

Chapter-I

INTRODUCTION

1.1 Preamble

The NTPC-Talcher Thermal Power Plant is a 460 MW (4×60 MW and 2×110 MW) coal based power station situated about 15 km from the Angul town in Odisha. The power station generates about 3500 tons of ash per day. The generated ash is mixed with water and the resultant slurry is transported and disposed in the abandoned mine pit of the South Balanda Mine of the Mahanadi Coal fields Ltd (MCL). The abandoned mine pit covers an approximate area of 92.82 ha (Figure 1.1). In this view, it is essential to establish the characteristics of fly ash and mine pit water and hence prepare an environmental management plan for safe disposal of ash in coal mines.

CSIR-NEERI has been assigned the task of conducting detailed study of fly ash characterization of ash fill sites of Talcher Thermal Power Station and leaching characteristics of mine pit water at South Balanda mine pit

The task has been taken up with the following objectives:

- Establishment of fly ash characteristics' like reactivity and movement
- Characterization of mine pit water for major cations/anions and trace elements
- Physico-chemical and mineralogical characterization of fly ash collected directly from ESP hopper and bottom ash collected from bottom ash furnace
- Development of a model to predict the movement of leachate in the groundwater system
- Suggestion of suitable mitigation measures and prepare environmental management plan (EMP) for safe disposal of ash in coal mines

1.2 Approach of the Study

Keeping in view the broad objectives, the approach/methodology is as follows:

- Delineation of the study area on the basis of watershed concept and preparation of a base map of the study area
- A network of key observation wells to be set up in the mine pit area for water level measurement and groundwater sampling. The monitoring has to be undertaken for both the pre-monsoon and post-monsoon seasons
- Collection of fly ash directly from ESP hopper and bottom ash furnace for physico-chemical and mineralogical characterization of fly ash
- Collection and characterization of mine pit water at different depths for major physico-chemical parameters. The vertical profiling for the collection of mine pit

water samples would be carried at 4 levels i.e., bottom of the mine –pit water, 1/3rd depth, 2/3rd depth and at the top of the mine pit water

- Characterize and quantify the physical-chemical-geotechnical interactions of ash and ash water through TCLP and SPLP tests
- Development of the groundwater flow and solute transport model to predict the movement of leachate in groundwater system
- Development of the HELP model to estimate the hydraulic head built up due to disposal of ash in abandoned mine pit
- Preparation of EMP to mitigate the adverse impacts on the surrounding environment



Figure 1.1 Ash pond of Talcher Thermal Power Station (TTPS)

1.3 Tasks Undertaken

- A network of few observation wells has been set up for water level measurement and groundwater quality analysis. The present study is based on the post-monsoon and pre-monsoon sampling and analysis
- Collection and characterization of mine pit water at different depths for major cations/anions
- Collection of fly ash directly from ESP hopper and bottom ash from bottom ash furnace
- Collection of ash pond samples for fly ash characterization
- Development of the HELP model and the groundwater flow and solute transport model

Chapter-II

STUDY AREA

2.1 Location

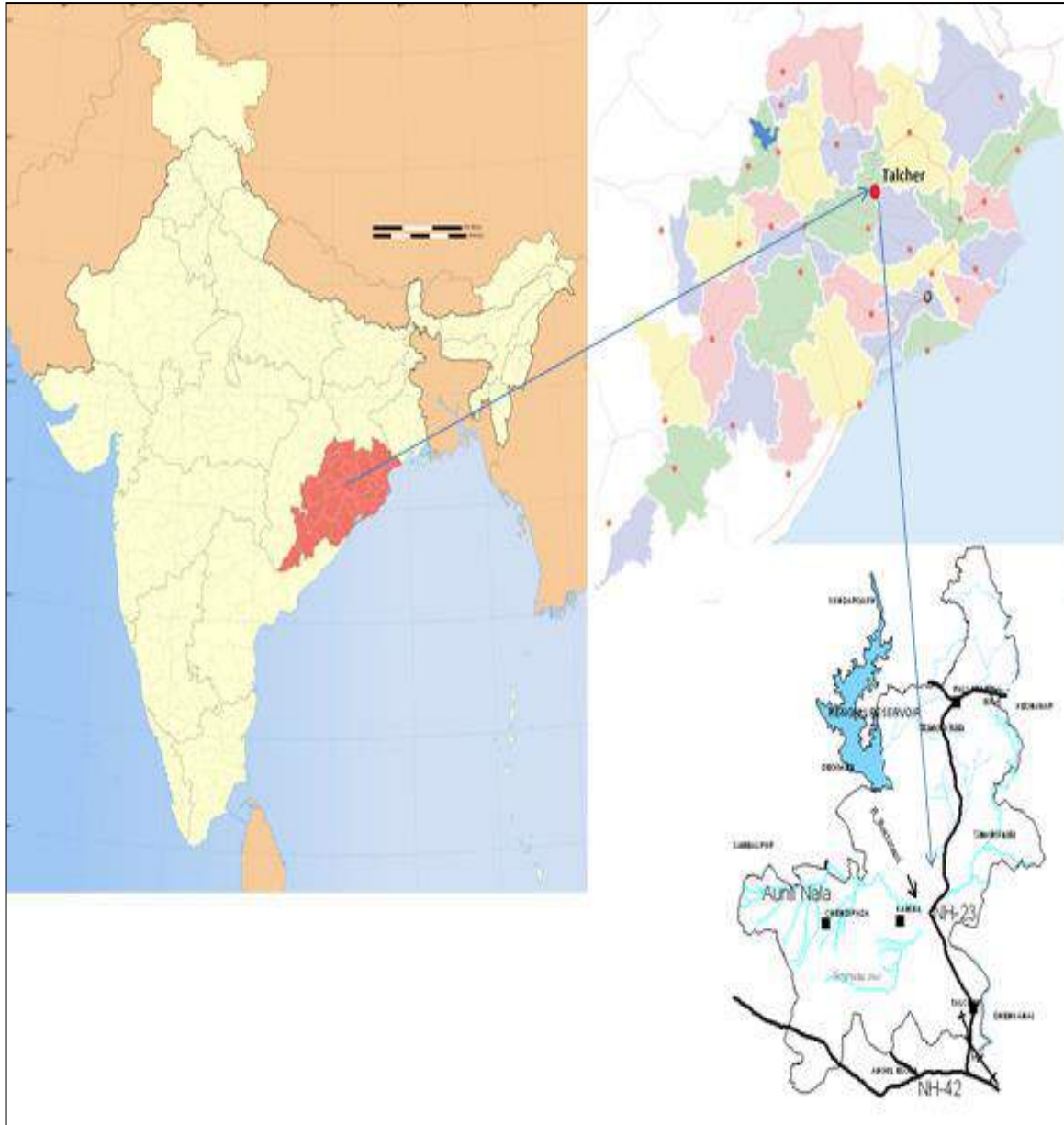


Figure 2.1 Location map of the study area

The NTPC-Talcher Thermal Power Station (TTPS) lies in between latitudes $20^{\circ} 52' 00''$ N to $20^{\circ} 59' 00''$ N and longitudes $85^{\circ} 07' 30''$ E and $85^{\circ} 15' 30''$ E. It is covered by Survey of India Toposheet (F45 T/1 and F45 T/5 on 1:50,000 scale). It is located in Talcher town in the Angul district of Odisha. The TTPS is approximately 15km from Angul city (Figure 2.1).

2.2 Climate

The study area experiences tropical monsoon climate with mild winter and hot summer. The area receives rainfall mostly from the southwest monsoon and the rainy season extends from May to September every year. The average annual rainfall of the study area is approximately 1250 mm.

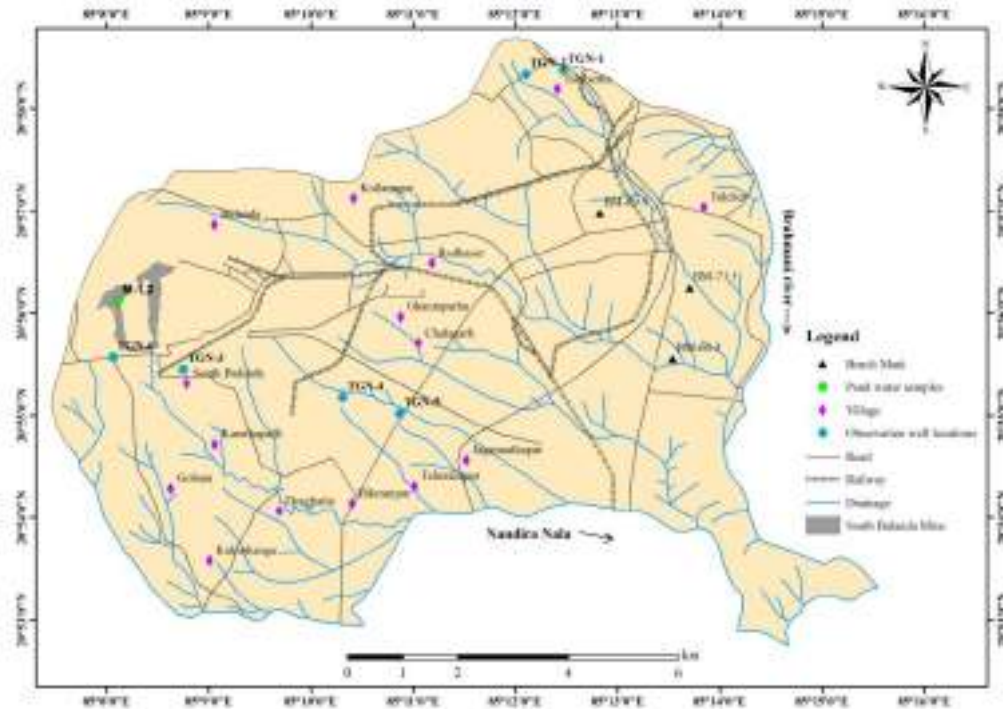


Figure 2.2 Basemap of the study area

2.3 Physiography and Landuse

The study area (Figure 2.2) constitutes northern part of Angul district. The area is mainly drained by the river Brahmani. The area constitutes various physiographic features such as alluvial plain, mountain ranges, flood plains and water bodies. The elevation of the area above mean sea level (amsl) ranges from 58m to 139m and the slope is towards the southeast direction and is towards the Brahmani river.

2.4 Geological set up

The Talcher coal fields constitute the southeastern member of Lower Gondwana basins within the Mahanadi valley graben. The sedimentary strata of Talcher coal fields comprise of Talcher, karabhari, barakar and supra-barakar formations. The area is broadly divided into Barakar formation, talcher formation and small portion of granitoids which is eastern ghat super group of formation. The barakar formation is characterized by a thick and conspicuous

basal conglomerate horizon at the base. The conglomerate contains well rounded quartz and quartz clasts of various sizes embedded in a sandy matrix.

The basal conglomerate unit is overlain by a thick sequence of medium to coarse-grained grayish feldspathic sandstones, gray to dark gray shale, carbonaceous shale, thick coal seams mostly inter banded with shale and clay bands. The talcher formation covers the central portion of the area which belongs to carbonaceous to Permian age comprising of sandstone, shale and tillite rocks. Talchers comprise diamictites, varves and fine to medium grained sandstones. These rocks are well exposed in the central portion of the area through the outcrops. The south east and south west corners of the area are covered partially by granitoids which comprise gneiss and khondalites.

2.5 Hydrogeology

The area falls in the Brahmani tributary. The area is underlain by semi-consolidated Gondwana formation comprising of mainly sandstone and shale. The sandstone when weathered and fractured form good aquifer. Rainfall and seepage from the Brahmani river are the principal sources of groundwater recharge in the area. Groundwater occurs under water table condition in the weathered zone and under semi-confined to confined condition in the fracture zone. The depth of the drilled wells varies from 70 m to 310 m (bgl) and the yield ranges from 0.56 lps to 3.7 lps (CGWB, 2010).

Chapter-III

METHODOLOGY OF DATA **COLLECTION**

3.1 General

Primary data has been generated by undertaking extensive field survey in the month of November 2012 (post-monsoon season) and May 2013 (Pre-monsoon season). Secondary data has been collected through interaction with Talcher Thermal Power Station (TTPS) officials and the local villagers in and around the study area.

3.2 Groundwater sampling and analysis

A network of key observation wells (6 nos) has been set up in the study area (Figure 2.2). The co-ordinates (latitude/longitude) of the observation wells were noted with the help of hand held GPS of Garmin make (Table 3.1). Groundwater samples have been collected from the identified observation wells. Mine pit water samples (Table 3.2) have been collected at various depths of the mine pit (top, 1/3rd depth, 2/3rd depth and bottom) in the post-monsoon season. For physico-chemical parameters and heavy metal analysis, the samples were collected in pre-cleaned 500 ml and 100 ml polyethylene bottles respectively. Concentrated HNO₃ was added to the heavy metal samples for preservation. Parameters namely, pH and temperature were measured in the field itself. The physico-chemical parameters were analyzed by following the standard protocols (APHA, 2005). The heavy metal analysis was done by using ICP-AES (Model JY24, Make: JobinYon). The detection limit for Fe, Mn, Zn, Pb, Cd, Cr and Cu are 0.0062 ppm, 0.0014 ppm, 0.005 ppm, 0.05 ppm, 0.002 ppm, 0.02 ppm and 0.005 ppm respectively. The parameters namely Na and K were analyzed by Flame Photometer (Model- CL361).

3.3 Groundwater Level Measurement

The observation well network consisted of India Mark II hand-pumps. The water level was obtained using Electric Contact Gauze (KL010) manufactured by M/S OTT Pvt. Ltd (Germany). The groundwater level has been obtained with respect to below ground level (bgl). Subsequently, a reduced level was undertaken to obtain the elevation of all the observation wells in the study area. Accordingly, the groundwater flow direction is established.

Table 3.1 Observation well network in the study area

Sample ID	Latitude	Longitude	Well Type	Description
TGN-1	20° 58' 22.9"	85° 12' 28.1"	HP	Talebarh village, on the lhs of the NH 23 highway road towards Khandal village
TGN-2	20° 58' 20.4"	85° 12' 5.9"	HP	Beside Narayana mandir, Bhalungakaamar
TGN-3	20° 55' 27.1"	85° 08' 44.6"	HP	MCFL staff quarters, near MaaTarani temple, in front of JMQ/6 qtr and MCFL executive hostel, village: south Balanda
TGN-4	20° 55' 10.6"	85° 10' 18.4"	HP	Tentulai village, near Mangla temple, on cement road, at Mr. PramodGuchhat residence
TGN-5	20° 55' 01.2"	85° 10' 51.6"	HP	Tentulai village towards Talcher-Angul road
TGN-6	20° 55' 34.1"	85° 08' 03.6"	HP	Bharatpurgobarachowk, near truck garage, temple

* lhs – left hand side * HP – hand pump

Table 3.2 Mine pit water samples collected at various depths

S.No.	Sample ID	Depth at which sample was collected
1.	TS-1	At top surface of the mine pit (0 m)
2.	TS-2	At bottom of the mine pit (6 m)
3.	TS-3	At 2/3 rd depth of the mine pit (4 m)
4.	TS-4	At 1/3 rd depth of the mine pit (2 m)

3.4 Fly ash sample collection

The physico-chemical, mineralogical and morphological characterization of mineral wastes have been carried out by collecting fly ash and bottom ash samples from the thermal power plant. The fly ash was collected directly from the electrostatic precipitator (ESP) in dry condition, whereas the bottom ash was collected directly in wet form from bottom ash hopper. The pond ash sample was collected from the storage tank where the bottom ash and fly ash were mixed in a specified ratio and transported through long pipes to the South Balanda mine pit.

The fly ash (FA) was collected directly from the electro-static precipitator (ESP) hopper in dry condition. The FA sample was collected from each hopper of the ESP and then composite sample was prepared by mixing same amount of fly ash collected from each hopper. The collected fly ash sample was stored in air tight cylindrical container prior to the analysis. The bottom ash (BA) and pond ash (PA) were collected directly in wet form from the outlet of the bottom ash hopper and ash pond respectively and were stored in air tight cylindrical container before analysis. Figures 3.1 (a), (b), (c), (d) shows the CCR (Coal

Combustion Residues) sampling locations. The physico-chemical parameters i.e. pH, moisture content, acid insoluble residue, loss on ignition (LOI) was determined as per Indian standards; carbon content was analyzed by CHNS analyzer. The mineralogical characteristics i.e. XRD and FTIR were analyzed with the help of X-ray diffraction method and FTIR analyzer respectively. Leaching behavior of CCR samples i.e TCLP was analyzed as per US EPA SW-846 method, 1311 and SPLP as per US EPA SW-846 method 1312.



Figure 3.1 a) Collection of fly ash from ESP b) Collection of bottom ash from bottom ash hopper



Figure 3.1 c), d) Collection of pond ash samples from ash pond

3.5 Parameters of fly ash characterization

The physico-chemical properties of CCR samples i.e. moisture content, loss on ignition (LOI) and acid insoluble residue were determined as per IS-4032. For determination of LOI, 1 gram of sample was taken in a platinum crucible and kept in muffle furnace in a temperature range of 900°C to 1000°C and the final weight loss was measured. The acid insoluble residue was determined as per IS 4032-1985, where 1 gram of sample was successively acid treated. The pH of CCR sample was determined using IS 2720 Part-III, where material was dissolved in powdered form in water in 1:20 (m/v) ratio, stirred properly and the pH was measured. The

carbon content in mineral waste samples was determined by CHNS analyzer (Vario EL-III) where CCR samples were well dried, grounded, homogenized and 1 mg of the samples was packed in tin boat. The tin boat was then tightly closed and samples were properly shaped into a cube, so that no bits of tin foil protrude from the fold. After this, the samples were placed in appropriate sample trays of CHNS analyzer and run to get the results. Trace metal/heavy metal analysis of the CCR samples was conducted by ICP-OES after acid digestion method (USEPA-Method 3050B) where 1 gram (dry weight) of sample was digested with repeated additions of nitric acid and hydrogen peroxide, then diluted to a final volume of 100 mL. Mercury was analyzed through hydride generation by mercury analyzer (Milestone DMA-80), where one gram of homogenized dry sample was weighed into a sampling boat, which is made of a non-amalgamating thermally stable material used for containment and transport of the solid sample for thermal decomposition. The sampling boat was then inserted into the instrument and mercury content was determined.

Major elements i.e. SiO_2 , Al_2O_3 , Fe_2O_3 , TiO_2 and minor elements i.e. K_2O , CaO , MgO , Na_2O , P_2O_5 , SO_3 of CCR samples were determined using X-ray fluorescence (PANalytical PW-2403), where a properly dried sample were crushed with the help of motor pastel kept in a glass slide which was exposed to X ray in XRD instrument. Mineralogical characteristics were determined by X-ray diffraction using $\text{Cu-K}\alpha$ radiation (RigakuMiniflex II). Element analysis of the mineral waste sample was conducted by XRF instrument (PANalytical PW-2403). In XRF analysis, pellets of various samples were produced by 30 tonne pressure and using polyvinyl acetate as a non additive binder. After the preparation of pellets, they were placed into the XRF instrument for analysis. The function group analysis was done by Fourier Transform Infrared Spectroscopy (FTIR) where sample was mixed with potassium bromide and crushed in motor pastel and exposed to infrared in FTIR.

3.6 Standard Leaching Procedure

3.6.1 Toxicity Characteristic Leaching Procedure (TCLP)

Standard leaching procedure has been developed for the assessment of the mobility of hazardous substances into an aqueous phase and for the evaluation of their environmental impact. A commonly used test for the determination of the leaching characteristics of fly ash is the **Toxicity Characteristic Leaching Procedure (TCLP)** established by the US Environmental Protection Agency (US EPA, 1992). The TCLP is designed to determine the mobility of both organic and inorganic analytes present in liquid, solid and multiphase wastes. The procedure is carried out in an assembly (Figure 3.2) which has an orbital shaker

with fixed rotations per minute (RPM). This procedure provides a uniform method to compare the tendency of inorganic elements to leach out from fly ash samples into moderate-to-highly acidic aqueous environments. The testing methodology is used to determine if a waste is characteristically hazardous (D-List) or not. The extract is analyzed for substances appropriate to the protocol. The toxicity characteristic leaching procedure (TCLP) was conducted as per United States Environmental Protection Agency (US EPA SW-846 method, 1311), where 10 gram of CCR samples were taken with extraction fluid in 1:20 ratio (m/v). The extraction assembly at room temperature was tightly closed and kept in orbital shaker at 30 ± 2 rpm for 18 hours. Figure 3.2 shows the TCLP experimental assembly. The suspension was filtered and filtrates for heavy metals were analyzed by ICP-OES. The TCLP extraction fluid was prepared by mixing 5.7 ml of glacial acetic acid, 500 ml of deionized water and later 64.3 ml of 1N NaOH was added and the volume was made up to 1 Liter. The pH of extraction fluid was maintained at 4.9.



Figure 3.2 Assembly for TCLP and SPLP

3.6.2 Synthetic Precipitation Leaching Procedure (SPLP)

The major objective of the EPA 1312 method, namely **Synthetic Precipitation Leaching Procedure (SPLP)** is to determine the mobility of inorganic phases present in waste materials in acid conditions caused by acidic rain. The pH adjustment of the extraction fluid is made by adding acidic mixture of sulphuric and nitric acids to reagent water. The synthetic precipitation leaching procedure was designed in such a way that it can simulate the leaching

of heavy metals from solid wastes or contaminated soils with an extraction fluid similar to slightly acidic rainfall. The Synthetic Precipitation Leaching Procedure (SPLP) was conducted as per United States Environmental Protection Agency (SPLP, US EPA SW-846 method 1312), where 10 gram of CCR samples were taken with extraction fluid in 1:20 ratio (mass/volume). The extraction assembly at room temperature was tightly closed and kept in orbital shaker at 30 ± 2 rpm for 18 hours. Figure 3.3 shows the SPLP experimental assembly. The suspensions were filtered and filtrate for heavy metals were analyzed by ICP-OES. The SPLP extraction fluid was prepared by adjusting and maintaining the pH of deionized water to 4.2 by adding sulphuric acid / nitric acid in the ratio of 60/40 by volume.

3.7 Development of the Conceptual Model

3.7.1 Objectives of Groundwater Modeling

Groundwater modelling is an important tool frequently used in studies of groundwater systems. Groundwater modelling can be applied to issues of groundwater management like the optimization of pumping and infiltration rates, optimal location of pumping and injection wells, different kinds of groundwater quality/contamination problems and conjunctive use of surface water and groundwater for different purposes like meeting the water requirements in different sectors like agriculture, domestic and industries.

They can also be used in an interpretive sense to study the controlling parameters in a site specific setting. Models can also be used to study processes in a generic geological setting like understanding the surface water-groundwater interaction. Models can be effectively used to determine the legal determination of responsibility.

3.7.2 Groundwater Flow Equations

The groundwater flow is governed by the Darcy's law and the conservation of mass. The governing mathematical equations for groundwater flow are developed from the fundamental principle of conservation of mass of fluid and the Darcy's law.

A general equation for conservation of mass may be expressed as:

$$\begin{aligned} \text{Rate of mass inflow} - \text{rate of mass outflow} + \text{rate of mass reduction/consumption} \\ = \text{rate of mass accumulation} \end{aligned}$$

The Darcy's law states that the flow per unit area per unit time is directly proportional to the change in head and inversely proportional to the length of the flow path.

$$V = K (\partial h / \partial x) \dots\dots\dots (3.1)$$

Where,

V = flow per unit area per unit time

K = hydraulic conductivity

$\partial h / \partial x$ = hydraulic gradient

In steady state condition, the groundwater flow equation is given by:

$$\frac{\partial}{\partial x} \left(\frac{K_{xx} \partial h}{\partial x} \right) + \frac{\partial}{\partial y} \left(\frac{K_{yy} \partial h}{\partial y} \right) + \frac{\partial}{\partial z} \left(\frac{K_{zz} \partial h}{\partial z} \right) + W = 0 \dots\dots\dots (3.2)$$

Where,

K_{xx} = hydraulic conductivity in the x-direction

K_{yy} = hydraulic conductivity in the y-direction

K_{zz} = hydraulic conductivity in the z-direction

W is the source or sink term

h is the hydraulic head

3.7.3 Solute Transport Equations

The governing equations for the transport of solute in groundwater can be derived by taking the mass balance of the dissolved pollutant over a static elementary volume, $\Delta V = \Delta x \Delta y \Delta z$.

The transport equations were developed by Zheng (1990).

It can be written as follows:

- Change in solute mass stored = excess solute mass diffusion into volume
 + excess solute mass inflow over outflow or mass transport by convection
- + solute mass added by injection/filtration
 - solute mass lost by withdrawal
 - solute mass lost by decay
 - solute mass lost by reaction
 - solute mass adsorbed on solid interface

3.7.4 Features of Visual MODFLOW (2011.1)

The Visual MODFLOW (2011.1) is designed to simulate flow and mass transport in the saturated medium. The groundwater flow is simulated by the well-established MODFLOW engine (Mc.Donald and Harbaugh, 1988) and the solute transport is simulated by the MT3D (Zheng 1990). Besides, particle tracking can be simulated by using the MODPATH module.

MODFLOW is a Modular 3-dimensional finite difference groundwater flow model and it simulates steady and non-steady flow in three dimensions for an irregularly shaped flow system in which aquifer layer can be confined, unconfined, or a combination of confined and unconfined. Flow from external sources, such as flow to wells, areal recharge, evapo-transpiration, flow to drains and flow through river, can be simulated.

MODFLOW uses a modular structure wherein similar program functions are grouped together. The modular structure consists of a main program and a large number of independent subroutines called “modules”. The modules, in turn, have been grouped into “packages”. Each package deals with a specific aspect of the hydrological system to be simulated. For example, the option Well package simulates the effect of wells (pumping wells/injection wells); the River package simulates the effect of river on the groundwater system. The Drain package simulates the effect of any drain pipe on the groundwater system. The EVT package simulates the evapo-transpiration from the system. The recharge package, RCH simulates the recharge due to precipitation or artificial means.

3.8 Summary of MODFLOW Packages

3.8.1 Basic package (BAS)

The Basic package handles a number of administrative tasks for the model. It reads data for:

- i. The discretization of the model domain with a mesh of blocks called cells, the location of which are described in terms of rows, columns and layers.
- ii. The selection of major options and the designation of their input unit numbers. For a given model, the user has to select the major options by specifying a unit number of input files.
- iii. The cells are specified as variable-head, constant-head or inactive cells. For specifying the initial condition, the starting heads’ for the first time step are specified by the user.

- iv. The user specifies the length of the stress period, the number of time steps at each stress period, and the time step multiplier.

3.8.2 Block-centered flow package (BCF)

The Block-centered flow package (BCF) computes the conductance components of the finite-difference equation which determine the flow between adjacent cells. It also computes the terms that determine the rate of movement of water to and from storage.

3.8.3 River Package (RIV)

Rivers contribute water to the groundwater system or drain water from it depending on the head gradient between the river and the groundwater. The purpose of the river package (RIV) is to simulate the effect of flow between river and groundwater systems. To do this, a river or a stream is divided into reaches so that each reach is completely contained in a single cell. Stream aquifer seepage is simulated between each reach and the model cell that contains that reach. It is assumed that there is no change in the stream stage because of the stream-aquifer interaction.

$$Q_{RIV} = C_{RIV} * (H_{RIV} - h_{i,j,k}) \text{ for } h_{i,j,k} > R_{BOT} \dots\dots\dots (3.3)$$

or,
$$Q_{RIV} = C_{RIV} * (H_{RIV} - R_{BOT}) \text{ for } h \leq R_{BOT} \dots\dots\dots (3.4)$$

Where,

Q_{RIV} : Flow between the stream and aquifer

C_{RIV} : $K*L*W/M$, is the hydraulic conductance of stream-aquifer interconnection. K is the conductivity of the streambed, L is the length of the stream reach, W is the width of the stream reach, and M is the thickness of the streambed

H_{RIV} : the stream level

$h_{i,j,k}$: groundwater head at the node in the cell underlying the stream reach

R_{BOT} : elevation of the bottom of the streambed layer

If hydrological conditions indicate that seepage from a stream will increase as the local water table declines, but will reach the limiting condition when water table reaches the elevation h, R_{BOT} should be taken equal to h_i , and C_{RIV} should be calculated as $K*L*W/(H_{RIV}-h_i)$. Because the vertical hydraulic gradient beneath the stream is approximately one, seepage from stream into cell i,j,k is given approximately by the product $K*L*W$.

3.8.4 Recharge Package (RCH)

The recharge package is one of the important modules of MODFLOW. The recharge package (RCH) is designed to simulate aerially distributed recharge to the groundwater flow system. Most commonly, areal recharge to the groundwater are from the precipitation infiltration. The recharge is often adjusted during calibration. Recharge applied to the model is defined as

$$QR_{i,j} = I_{k,n} * \Delta R_j * \Delta C_i \dots \dots \dots (3.5)$$

Where,

$QR_{i,j}$: recharge to the cell (i,j) [L^3T^{-1}]

$I_{i,j}$: recharge flux to the map area, $\Delta R_j * \Delta C_i$ of cell [LT^{-1}]

In this package, values of recharge flux, $I_{i,j}$, are read into a two dimensional array. The cell within each vertical column to which recharge is applied is specified through the recharge option code. The options include:

- i. Application of recharge to model layer 1. There is no recharge added to no-flow cells.
- ii. Application of recharge to any cell in the vertical column as specified by layer numbers. No recharge is added to the no-flow cells.
- iii. Application of recharge to the uppermost active cell in the vertical column provided there is no constant head cell above it in the column. If there is a constant-head cell in a vertical column of cells and there is no active cell above, then no recharge is applied to this column.

3.8.5 Well Package (WEL)

The Well package (WEL) is designed to simulate the inflow or outflow through recharging or pumping wells. Wells are handled in the Well package by specifying the location of each individual well and its pumping rate, Q. Negative values of Q are used to indicate well discharge, while positive values of Q indicate a recharging well.

3.8.6 Drain Package (DRN)

The Drain Package is designed to simulate the effect of both open and closed drains. The Drain Package works in much the same way as the River Package, except the leakage from the drain to the aquifer is not allowed. The drain is assumed to run only partially full, so that head within the drain is approximately equal to the median drain elevation, $d_{i,j,k}$, and to prevail only locally. The head at the model node, $h_{i,j,k}$, is actually an average value for the cell

and is assumed to prevail at some distance from the drain. The head losses between the $h_{i,j,k}$ and $d_{i,j,k}$ are assumed to be caused by the three flow processes: the convergent flow towards the drain, flow through material of different conductivity immediately around the drain, and flow through the wall of the drain. If the total head loss, $h_{i,j,k} - d_{i,j,k}$ may be assumed proportional to the discharge, QD , the drain function can be described by the equation pair:

The coefficient, $CD_{i,j,k}$ is a lumped conductance describing all the head losses mentioned above. Attempts could be made to calculate values of CD by developing approximate equations for conductance for the three flow processes, and then calculate the equivalent series of conductance. If $h-d$ is not accurately known, CD is usually adjusted during the model calibration in order to match measured values of QD to model calculated values.

3.8.7 Evapo-transpiration Package (ET)

The evapo-transpiration package (ET) simulates the effects of plant transpiration and the direct evaporation in removing water from the saturated groundwater. Evapo-transpiration is applied to only one cell in each vertical column beneath the map area. The user designates the cell using one of the two options:

- i. Evapo-transpiration is always drawn from the uppermost layer of the model. No evapo-transpiration occurs in no-flow or constant-head cells.
- ii. The cell, from which the evapo-transpiration is to be taken, is specified by the user in a two-dimensional array.

3.8.8 General Head boundary Package (GHB)

The General Head Boundary (GHB) package simulates flow into or out of a cell i,j,k from an external source. The flow into a cell is assumed proportional to the difference between the head in the cell and the head assigned to the external source, i.e.

$$Q_{bi,j,k} = C_{bi,j,k} * (h_{bi,j,k} - h_{i,j,k}) \dots \dots \dots (3.6)$$

Where,

$Q_{bi,j,k}$: flow into cell i,j,k from the source [L^3T^{-1}]

$C_{bi,j,k}$: conductance between the external source and the cell i,j,k [L^2T^{-1}]

$h_{bi,j,k}$: head assigned to the external source [L]

$h_{i,j,k}$: head in the cell [L]

Since flow into or out of the cell continues to increase without limit as the head difference between the cell and the source increases, one should be careful in using the GHB package.

3.8.9 Solution technique packages

The system of difference equations generated can be solved by different solvers. The solver module has different solvers like SIP, SSOR, PCG, AMG and WHS.

3.9 Mass Transport Modeling

The mass transport model computes the solute concentration in the groundwater system at any specified time and space. The theoretical framework for the equation describing the solute transport has been well documented in the literature (Bear, 1979). The solute transport in the present study has been attempted by the **MT3D** module of the Visual MODFLOW software (2011.1).

MT3D is a Modular 3-Dimensional solute Transport model for simulating changes in concentration of single species miscible contaminants in groundwater considering advection, dispersion and some simple chemical reactions with various types of boundary conditions and external sources or sinks in ground water systems. **MT3D** is based on a modular structure to permit simulation of transport components independently or jointly. It interfaces directly with the USGS finite-difference groundwater flow model MODFLOW, for the head solution, and supports all the hydrologic and discretization features of MODFLOW. The modular structure of the MT3D transport model makes it possible to simulate processes like advection, dispersion, source/sink mixing and chemical reactions independently.

The **MT3D** code has a comprehensive set of solution options, including the method of characteristics (MOC), the modified method of characteristics (MMOC), a hybrid method of characteristics (HMOC) and the standard finite-difference method (FDM). The availability of these solution options in one program and the continuing enhancement and expansion capabilities makes MT3D uniquely suitable for handling a wide range of field problems of very different nature.

3.9.1 Solute Transport Equation

$$-\frac{\partial(v_1C)}{\partial x_j} + \frac{\partial}{\partial x_i} \left(D_{ij} \frac{\partial C}{\partial x_j} \right) \pm q_s \frac{C_s}{\theta} - \lambda \left(C + p_b \frac{S}{\theta} \right) = R \frac{\partial C}{\partial t} \dots \dots \dots (3.7)$$

The first term represents the advection term, second term is the dispersion, third term is the sink/source, fourth is the reactions term and last is the retardation term.

Where,

C: dissolved concentration of species k

θ : porosity of the subsurface medium

t: time

x_i : distance along the respective Cartesian coordinate axis.

D_{ij} : hydrodynamic dispersion coefficient tensor

v_i : seepage or linear pore water velocity

q_s : volumetric flow rate per unit volume of aquifer representing source/sink

C_s : concentration of the source or sink for species k

ΣR_n : chemical reaction term

3.9.2 Solution Techniques

The model **MT3D** uses mixed Eulerian-Lagrangian approach to the solution of the advective-dispersive-reactive equation, based on a combination of the method of characteristics and the modified method of characteristics. This approach combines the strength of the method of characteristics for eliminating numerical dispersion and the computational efficiency of the modified method of characteristics.

3.9.3 Overall Structure of MT3D

The computer program of the **MT3D** transport model uses a modular structure similar to **MODFLOW** consisting of a main program and a large number of highly independent subroutines, called modules, which in turn are grouped into packages. Each of these packages deal with a single aspect of the transport simulation. The similarity between **MT3D** and **MODFLOW** in the program structure and design is intended to facilitate the use of the **MT3D** transport model in conjunction with **MODFLOW**.

The simulation time is divided into stress periods, within which stress parameters are constant. Each stress period, in turn is divided into a series of time steps. The hydraulic heads and fluxes at each time step are solved by the flow model and used by the transport model. Each time step used in obtaining the head solution is further divided into a number of smaller time increments, termed as transport steps, within which the hydraulic heads and fluxes are assumed constant.

Prior to entering the stress period loop, the program executes three procedures which pertain to simulation as a whole. In the Define procedure, the simulation problem is defined; i.e. the size of the model, the number of stress periods, and the various transport options to be used in the simulation are specified. In the Allocate procedure, computer memory is allocated for the data arrays whose dimensions depend on the parameters specified in the Define procedure. In the Read & prepare procedure, the input data that are constant throughout the simulation are read and processed. These input data include spatial and temporal discretization information, boundary conditions, initial conditions, transport parameters, solution parameters, and output control options.

The first procedure within the stress period loop is the Stress procedure which obtains timing information for the current stress period: the length of the stress period, the number of time step within the stress period, and the length of each time step. A second read & prepare procedure then reads and prepares input data which are constant within the current stress period, i.e. the concentrations of those sources or sinks that need to be specified. The transport model obtains the location, type, and flow rates of all sources and sinks simulated in the flow model from an unformatted head and flow file saved by the flow model.

Within the time step loop, a third read & prepares procedure reads and processes the hydraulic heads and flow terms saved by the flow model, automatically incorporating specified hydrologic boundary conditions. The coefficient procedure then calculates certain coefficients that are constant within each time step of the head solution, such as the dispersion coefficient.

The transport step loop contains four procedures. The Advance procedure determines an appropriate step size for use in the current transport step. The Solve procedure solves each transport component with an explicit mixed Eulerian-Lagrangian solution scheme and calculates the mass into or out of the aquifer through each component. The Budget procedure calculates and prepares global mass balance information and the Output procedure prints or saves simulation results as needed according to the user-specified output control options. The general procedures outlined in the preceding discussion are implemented for each of the four components in the transport equation: advection, dispersion, sink/source mixing, and chemical reactions. The implementation is done through the use of individual modules which in turn are grouped into a package, called Advection package (ADV), Dispersion package (DSP), Sink & source mixing package (SSM), and Chemical reaction package (RCT). In

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addition to the four transport component packages, the MT3D model program includes three additional packages: the Basic transport package (BTN), the Flow model interface package (FMI) and the Utility package (UTL).

Chapter-IV

RESULTS AND DISCUSSION

4.1 Groundwater Level

Ground water level conveys useful information about the groundwater system. The temporal variation of the groundwater level conveys the characteristics like its recharge potential due to precipitation. The ground water level has been measured in the observation well (6nos) in the post-monsoon (November 2012) and pre-monsoon seasons (May 2013). It was observed (Table 4.1) that the post-monsoon water level (bgl) varied from 1.65m (TGN-3) to 16.64 m (TGN-5). During pre-monsoon (May 2013), the water level varied from 1.6m (TGN-4) to 20.1m (TGN-5). The reduced level so obtained was used to convert the water level (bgl) to water level (amsl). The water level indicates that the general trend of groundwater flow direction is toward south east direction.

Table 4.1 Water level (amsl-m) in observation well network during post-monsoon 2012 and pre-monsoon season 2013

Sample ID	RL (m)	BGL(m)	AMSL(m)	BGL(m)	AMSL(m)
		post-monsoon 2012		pre-monsoon 2013	
TGN-1	81.18	7.34	73.84	3.9	77.28
TGN-2	82.46	10.57	71.89	16.5	65.96
TGN-3	115.55	1.65	113.90	2.7	112.85
TGN-4	92.99	2.8	90.19	1.6	91.39
TGN-5	91.35	16.64	74.71	20.1	71.25
TGN-6	128.35	4.97	123.38	5.8	122.55

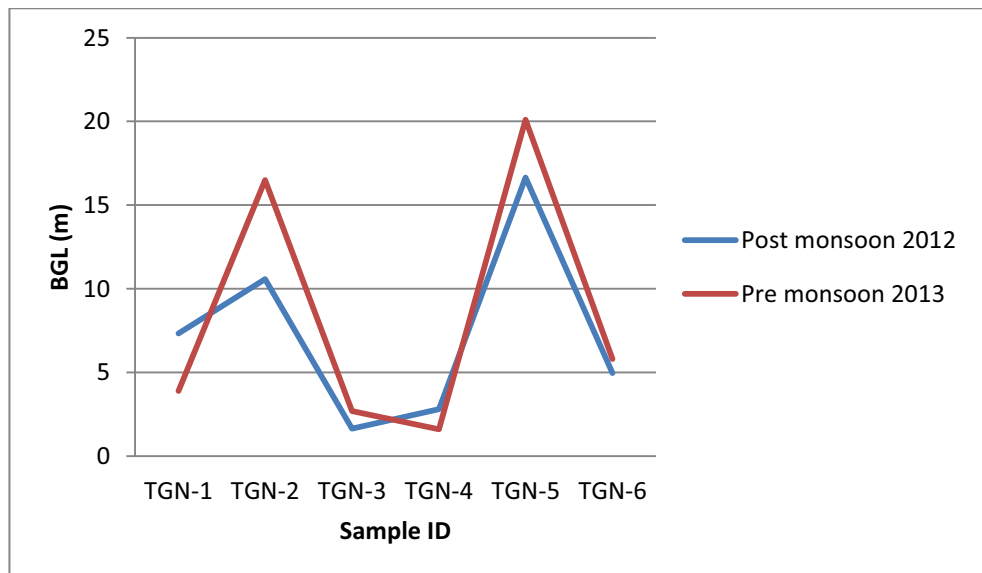


Figure 4.1 Groundwater level (bgl-m) plot of the observation wells

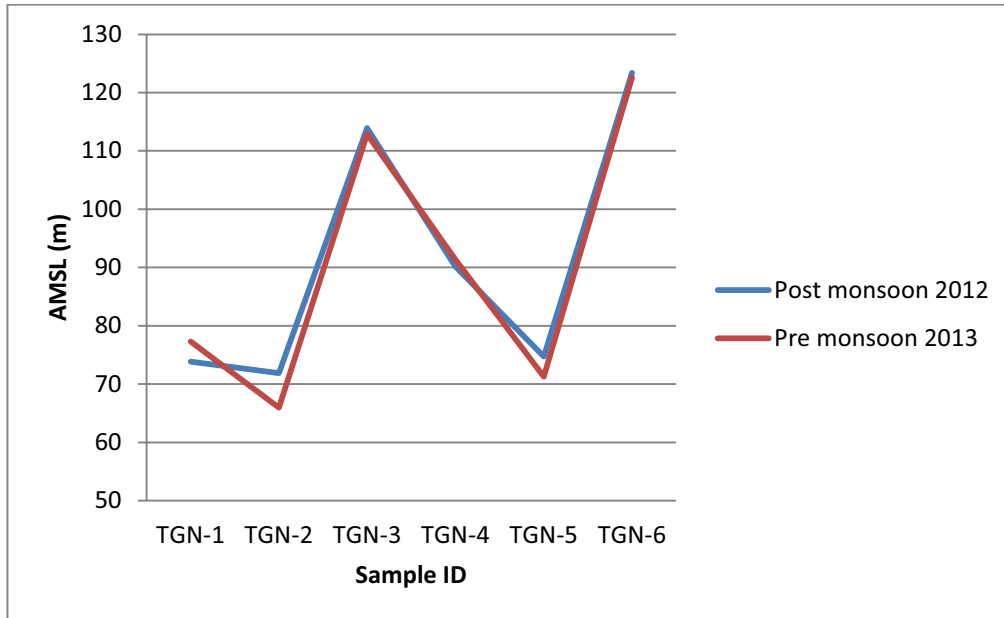


Figure 4.2 Groundwater level (amsl-m) plot of the observation wells

4.2 Groundwater Quality

The analysis of major cations, anions and trace elements (Tables 4.2, 4.3 and 4.4) of the groundwater samples brings out the following findings about the key parameters like TDS, Cl⁻, NO₃⁻, F⁻ and SO₄⁻² in both the seasons. Monitoring and analysis of groundwater quality is one of the major objectives of the study during post-monsoon 2012 (November) and pre-monsoon (May 2013). The key parameters like TDS, Cl, NO₃, F and SO₄ (Tables 4.2 & 4.3) were taken into consideration for the analysis which show significant impact on groundwater quality and they are compared (Table 4.4) with the Bureau of Indian Standards (BIS 10500:1991). The concentration of important parameters is briefly discussed below.

pH: The pH of the samples varied from 6.8 (TGN-6) to 7.7 (TGN-5) in the post-monsoon and 6.87 (TGN-6) to 7.89 (TGN-5) in pre-monsoon respectively. pH is found to be within acceptable range of 6.5 to 8.5 as per BIS standards for all the samples (10500:1991).

TDS (Total Dissolved Solids): The TDS of the samples varied from 157 mg/L (TGN-3) to 672 mg/L (TGN-1) during post-monsoon and 134 mg/L (TGN-3) to 572 mg/L (TGN-1) in pre-monsoon respectively (Table 4.3). The results showed that the higher value of TDS was found in TGN-1 during both post-monsoon and pre-monsoon season which is in the upstream of the South Balanda Mine. The TDS values of the other samples are within the permissible limit as per BIS standard (1991:10500).

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Chloride: The Chloride of the samples varied from 9 mg/L (TGN-3) to 91 mg/L (TGN-5) during post-monsoon season and 14 mg/L (TGN-3) to 76 mg/L (TGN-5) in pre-monsoon respectively. It was observed that the chloride concentration in all the samples was within the permissible limit of BIS standard (1991:10500) in both the seasons.

Sulphate: The Sulphate concentration varied in the range 2.6 mg/L (TGN-5) to 155 mg/L (TGN-1) in the post-monsoon and 2 mg/L (TGN-2) to 110 (TGN-4) in the pre-monsoon season respectively. The sulphate concentration in all the samples was within the permissible limit of BIS standard (1991:10500) in both the seasons

Nitrate: The Nitrate concentration varied in the range 1 mg/L (TGN-3 & TGN-6) to 57 mg/L (TGN-2) during post-monsoon and ND (TGN-3& TGN-6) to 8 mg/L (TGN-5) in pre-monsoon respectively. All the samples except for TGN-2 during the post monsoon season were within the permissible limit of BIS standard (1991:10500) (Tables 4.2 & 4.3). The major source for nitrate contamination may be due to the land use and land cover pattern i.e., local habitation and agricultural practices in the area

Fluoride: The Fluoride concentration varied in the range 0.1 mg/L (TGN-3) to 1.5 mg/L (TGN-4 & TGN-5) in the post-monsoon and 0.2 mg/L (TGN-3& TGN-6) to 1.5 mg/L (TGN-1 & TGN-5) in the pre-monsoon respectively (Tables 4.2 & 4.3). All the samples were within the permissible limits as per BIS standard.

Table 4.2 Concentration of major cations/anions in observation well network, post-monsoon (November) 2012

Sample ID	pH	Turbidity (NTU)	EC ($\mu\text{s}/\text{cm}$)	TDS (mg/L)	T.Hard as CaCO_3 (mg/L)	Ca Hard as CaCO_3 (mg/L)	Mg Hard as CaCO_3 (mg/L)	Na^+ (mg/L)	K^+ (mg/L)	T. Alk (mg/L)	Cl^- (mg/L)	SO_4^{2-} (mg/L)	NO_3^- (mg/L)	PO_4^{3-} (mg/L)	F ⁻ (mg/L)
TGN-1	7.1	41.7	1120	672	412	256	156	15	8.2	396	70	155	45	5.2	1.4
TGN-2	7.1	121	498	299	236	120	116	14	5.7	216	10	135	57	3.4	1.0
TGN-3	7.2	7	261	157	80	152	88	16	18	29	9	3	1	ND	0.1
TGN-4	7.6	0.3	1018	611	312	392	244	36	58	96	74	14.5	14	0.04	1.5
TGN-5	7.7	6	1116	670	264	352	192	39	124	66	91	2.6	15	0.05	1.5
TGN-6	6.8	1.4	303	182	108	116	72	11	20	12	29	5.2	1	ND	0.2

*ND- Not Detected

Table 4.3 Concentration of major cations/anions in observation well network, pre-monsoon (May) 2013

Sample ID	pH	Turbidity (NTU)	EC ($\mu\text{s}/\text{cm}$)	TDS (mg/L)	T.Hard as CaCO_3 (mg/L)	Ca Hard as CaCO_3 (mg/L)	Mg Hard as CaCO_3 (mg/L)	Na^+ (mg/L)	K^+ (mg/L)	T. Alk (mg/L)	Cl^- (mg/L)	SO_4^{2-} (mg/L)	NO_3^- (mg/L)	PO_4^{3-} (mg/L)	F ⁻ (mg/L)
TGN-1	7.58	1.31	953	572	392	104	288	77	16	416	68	54	1	0.1	1.5
TGN-2	7.41	1.84	450	270	248	68	180	11	7	264	22	2	1	ND	1.1
TGN-3	7.43	25.2	223	134	104	52	52	10	4	104	14	5	ND	0.2	0.2
TGN-4	7.71	0.9	880	528	348	120	228	66	12	304	54	110	6	ND	1.2
TGN-5	7.89	1.23	857	514	300	56	244	84	3	320	76	72	8	ND	1.5
TGN-6	6.87	4.48	333	200	116	80	36	31	5	136	30	18	ND	ND	0.2

Table 4.4 Range of key parameters of groundwater samples in the study area

S. No	Parameters	Range (mg/L)		BIS limits for drinking water (mg/L)	No. of samples exceeding BIS permissible limit in post-monsoon	No. of samples exceeding BIS permissible limit in pre-monsoon
		Post-monsoon 2012	Pre-monsoon 2013			
1	Total Dissolved Solids (TDS)	157 (TGN-3) - 672 (TGN-1)	134(TGN-3) - 572 (TGN-1)	2000	0	0
2	Chloride (Cl ⁻)	9 (TGN-3) - 91 (TGN-5)	14 (TGN-3) - 76 (TGN-5)	1000	0	0
3	Sulphate (SO ₄ ²⁻)	2.6 (TGN-5) - 155 (TGN-1)	2 (TGN-2) - 110 (TGN-4)	400	0	0
4	Nitrate (NO ₃ ⁻)	1 (TGN-3 & TGN-6) - 57 (TGN-2)	ND (TGN-3 & TGN-6) - 8 (TGN-5)	45	1	0
5	Fluoride (F ⁻)	0.1 (TGN-3) - 1.5 (TGN-4 & TGN-5)	0.2 (TGN-3 & TGN-6) - 1.5 (TGN-1 & TGN-5)	1.5	0	0

4.3 Heavy Metals

The concentration of iron in the study period i.e., post-monsoon varied from 0.7 mg/L (TGN-4) to 7.8 mg/L (TGN-5). All the samples except for TGN-4 were beyond the permissible limits (< 1.0 mg/L) of BIS standards. The higher concentration of iron in the groundwater samples may be due to the laterite geological nature in the study area. Arsenic was detected in two of the samples (TGN-1 and TGN-2) but was within the permissible limits of BIS during the post-monsoon season (Table 4.5). The samples were analyzed for arsenic by the arsenic detection kit developed by NEERI wherein the detection limit is 10 ppb. In pre-monsoon, Arsenic is not detected in any groundwater sample (Table 4.6).

Table 4.5 Trace elements of the samples of observation well samples during Post-monsoon (November) 2012

S. No.	Sample ID	Al	As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
1	TGN-1	ND	0.01	ND	ND	ND	ND	4	0.2	ND	0.03	8.1
2	TGN-2	0.3	0.01	ND	ND	ND	ND	4.2	0.2	ND	0.04	3.7
3	TGN-3	0.07	ND	ND	ND	ND	ND	1.6	0.3	ND	ND	0.1
4	TGN-4	ND	ND	ND	ND	ND	ND	0.7	0.01	ND	ND	0.2
5	TGN-5	0.1	ND	ND	ND	ND	0.1	7.8	0.08	ND	ND	0.1
6	TGN-6	0.03	ND	ND	ND	ND	ND	5.0	0.4	ND	ND	7.2

*All units are in mg/L

Table 4.6 Trace elements of the samples of observation well samples during Pre-monsoon (May) 2013

S. No.	Sample ID	Al	As	Cd	B	Cr	Cu	Fe	Mn	Ni	Pb	Zn
1	TGN-1	ND	ND	0.0002	0.045	0.0008	0.002	11.42	0.11	0.0018	0.014	0.75
2	TGN-2	ND	ND	0.0004	0.028	0.004	0.017	17.06	0.18	0.002	0.12	7.78
3	TGN-3	0.045	ND	0.0003	ND	0.0012	ND	23.95	0.24	ND	0.002	0.24
4	TGN-4	ND	ND	0.0001	ND	0.001	0.002	3.28	0.025	0.0002	0.003	0.12
5	TGN-5	0.31	ND	0.0001	ND	0.0045	0.089	3.77	0.072	0.002	0.015	2.82
6	TGN-6	0.065	ND	0.0005	0.006	0.005	0.001	25.48	0.16	0.0008	0.03	19.63

*All units are in mg/L

4.4 Mine pit water quality analysis

The mine pit water samples have been collected at various depths of the mine pit and analyzed in the laboratory for major physico-chemical parameters and heavy metals in the post-monsoon season. In the pre-monsoon season, samples have been collected from the standing mine water and running water and analyzed in the laboratory for major physico-chemical parameters and heavy metals. The analysis of major cations, anions and trace elements of the mine pit samples in the post-monsoon and pre-monsoon seasons (Table 4.7& 4.8) brings out the following findings about the key parameters like TDS, Cl⁻, NO₃⁻, F⁻ and SO₄²⁻ in post-monsoon season. The key parameters like TDS, Cl, NO₃, F and SO₄ were taken into consideration for the analysis which shows significant impact. Other physico-chemical parameters were also analyzed and compared with the Bureau of Indian Standards (BIS 10500:1991).

pH: The pH of the samples were found in between 6.9 (TS-1) to 7.7 (TS-4). pH is found to be within acceptable range of 6.5 to 8.5 as per BIS standards for all the samples during both the seasons.

TDS (Total Dissolved Solids): TDS results show that it varies in the range 276 mg/L (TS-3) to 312 mg/L (TS-4) during post-monsoon (Table 4.7). The TDS values ranges within the permissible limit as per BIS standard (1991:10500) for all the samples during both the seasons.

Chloride: Chloride varies in the range of 22 mg/L (TS-2 & TS-4) to 24 mg/L (TS-1 & TS-3) during post-monsoon season (Table 4.7). It was observed that the chloride concentration in all the samples was within the permissible limit of BIS standard (1991:10500) during both the seasons.

Sulphate: Sulphate concentration varies in the range 124 mg/L (TS-1) to 185 mg/L (TS-4) in the period of post-monsoon 2012. The sulphate concentration in all the samples was within the permissible limit of BIS standard (1991:10500) during both the seasons.

Nitrate: Nitrate concentration varies in the range 0.5 mg/L (TS-4) to 1.2 mg/L (TS-2) during post-monsoon season (Table 4.7). The nitrate concentration during both the seasons was found to be within the permissible limits of BIS standards

Fluoride: The Fluoride concentration varies in the range 4 mg/L (TS-1 & TS-2) to 4.2 mg/L (TS-4) (Table 4.7) during post monsoon season and found to be in the range of 6.2 mg/L to 6.6 mg/L during pre-monsoon season (Table 4.8).

Table 4.7 Concentration of major cations/anions of mine pit water, post-monsoon (November) 2012

Sample ID	pH	Turbidity (NTU)	EC (µs/cm)	TDS (mg/L)	T.Hard as CaCO ₃ (mg/L)	Ca Hard as CaCO ₃ (mg/L)	Mg Hard as CaCO ₃ (mg/L)	Na ⁺ (mg/L)	K ⁺ (mg/L)	T. Alk (mg/L)	Cl ⁻ (mg/L)	SO ₄ ²⁻ (mg/L)	NO ₃ ⁻ (mg/L)	PO ₄ ⁻ (mg/L)	F ⁻ (mg/L)
TS-1	6.9	6.99	476	286	212	108	104	17	12.2	20	24	124	1	0.023	4
TS-2	7.6	12.48	500	300	208	108	100	19	11.8	20	22	175	1.2	1.1	4
TS-3	7.2	5.55	460	276	196	128	68	15	7.8	20	24	178	0.8	0.3	4.1
TS-4	7.7	3.86	520	312	228	140	88	11	6.5	36	22	185	0.5	0.01	4.2

*ND- Not Detected

Table 4.8 Concentration of major cations/anions of mine pit water, pre-monsoon (May) 2013

Sample ID	pH	Turbidity (NTU)	EC (µs/cm)	TDS (mg/L)	T.Hard as CaCO ₃ (mg/L)	Ca Hard as CaCO ₃ (mg/L)	Mg Hard as CaCO ₃ (mg/L)	Na ⁺ (mg/L)	K ⁺ (mg/L)	T. Alk (mg/L)	Cl ⁻ (mg/L)	SO ₄ ²⁻ (mg/L)	NO ₃ ⁻ (mg/L)	PO ₄ ⁻ (mg/L)	F ⁻ (mg/L)
TS-1	6.45	28.3	737	442	184	108	76	50	19	40	54	218	11	0.1	6.6
TS-2	7	14.3	617	370	156	156	0	59	16	32	74	110	4	ND	6.2

4.5 Heavy Metals

The concentration of iron in the study period i.e., post-monsoon varied from 0.5 mg/L (TS-1) to 5.1mg/L (TS-3). All the samples except for TS-1 were beyond the permissible limits (< 1.0 mg/L) of BIS standards (Table 4.9).

Arsenic was detected in all of the samples during the post-monsoon season and not detected during the pre monsoon season. The samples were analyzed for arsenic by the arsenic detection kit developed by NEERI wherein the detection limit is 10 ppb.

Table 4.9 Trace elements of the samples of mine pit water during Post monsoon (November) 2012

S. No.	Sample ID	Al	As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
1	TS-1	0.7	0.03	ND	0.02	ND	ND	0.5	1.3	ND	0.1	0.04
2	TS-2	3.3	0.02	ND	0.01	ND	ND	4.7	0.8	0.04	0.01	0.1
3	TS-3	0.6	0.02	ND	ND	ND	ND	5.1	0.7	0.03	0.01	0.08
4	TS-4	0.5	0.04	ND	ND	ND	ND	4.5	0.7	0.04	0.01	0.2

*All units in mg/L

Table 4.10 Trace elements of the samples of mine pit water during Pre monsoon (May) 2013

S. No.	Sample ID	Al	As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
1	TS-1	0.9	ND	ND	0.04	ND	ND	1.3	1.7	ND	0.12	0.07
2	TS-2	4.1	ND	ND	0.03	ND	ND	5.3	0.9	0.06	0.01	0.3

*All units in mg/L

4.6 Fly ash analysis

4.6.1 Physico-chemical analysis of the CCR samples

Physico-chemical properties of CCR depend on numerous factors, such as the composition of feed coal, pulverizing and combustion conditions, conditions of deposition of fly ash and method of collection. Solution pH is a master variable that controls leaching and mobility of potential groundwater contaminant that may be present in CCR. The pH value (Table 4.11) of collected fly ash sample was acidic in nature i.e. 4.4 and that of bottom ash and pond ash was 6.65 and 6.7 respectively which is neutral in nature. The acidic nature of fly ash was due to the presence of amorphous (oxalate-extractable) iron content and neutral nature of bottom ash and pond ash was due to the presence of small amounts of Ca and Mg oxides that form during combustion of coal (Theis et al., 1977). Moisture content in CCR samples varied from 0.87% to 29% (Table 4.11). Moisture content in bottom ash and pond ash was higher as compared to

fly ash as they were collected directly from the bottom ash hopper and pond ash area which is water quenched. The bottom ash and pond ash samples were collected in wet form and hence moisture content was more as compared to dry fly ash. Insoluble residue in CCR samples varied in the range of 27.58% to 47.36%. The major source of insoluble residue is silicates and alumino-silicates which are non-cementing material (Kraiwood et al., 2000). The Loss of ignition (LOI) of the mineral waste includes the mass loss from oxidation of carbon, decomposition of carbonates and loss of water. However, it seems that carbon is, generally, the substance most responsible for ignition loss (Paya et al., 1995). The LOI content of collected CCR samples varied from 0.46% to 4.42% which satisfy the requirements of IS-3812. The amount of carbon content in CCR samples varied from 0.427% to 2.445%. The amount of carbon content was observed due to the presence of unburned carbon during coal combustion.

Table 4.11 Physico-chemical characteristics of the CCR samples

TPP/Chemical characteristics	Sample	pH	Moisture Content (%)	Acid Insoluble Residue (%)	LOI(%)	C (%)
NTPC-Talcher	Fly ash	4.4	0.87	32.3	0.46	0.427
	Bottom ash	6.65	19	27.58	4.42	2.445
	Pond Ash	6.7	29	47.36	1	0.569

4.6.2 Major, minor and trace metal analysis

Depending upon the source and make-up of the coal being burned, the components of CCR vary considerably, but all CCR includes substantial amounts of SiO₂ (silicon oxide both amorphous and crystalline) Al₂O₃ (aluminium oxide), Fe₂O₃ (iron oxide) and calcium oxide (CaO), both being endemic ingredients in many coal-bearing rock strata. The major constituents in the CCR samples are SiO₂ (58.9% to 63.01%), Al₂O₃ (19.13% to 29.32%) and Fe₂O₃ (4.4% to 6.4%) followed by minor elements K₂O, TiO₂, CaO, MgO, Na₂O, Na₂O, P₂O₅ and SO₃ as elements in the form of oxides, silicates and alumino-silicates (Table 4.12). It is seen that all the CCR samples meet the general requirements of ASTM C-618 Class F fly ash and IS:3812-1981, where the sum of SiO₂, Al₂O₃ and Fe₂O₃ content in fly ash should be higher than 70% for class F fly ash and CaO content should be less than 10% (ASTM C-618).

Table 4.12 Major and minor element characteristics of CCR samples

TPP	Fly ash chemical characteristics (%)										
	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	S*	K ₂ O	TiO ₂	CaO	MgO	Na ₂ O	P ₂ O ₅	SO ₃
FA-T	58.9	29.32	4.4	92.62	0.23	1.82	0.6	0.46	0.79	0.02	0.51
BA-T	63.01	19.13	6.4	88.54	0.23	1.5	0.9	0.39	1.92	0.32	0.3
PA-T	60.73	25.88	4.8	91.41	0.25	1.65	0.62	0.47	0.86	0.22	0.21
IS-3812 (Specification of Pulverized Fuel ash)											
Siliceous FA	35	-	-	70	-	-	-	5	1.5	-	3
	(Min)			(Min)				(Max)	(Max)		(Max)
Calcareous FA	25	-	-	50	-	-	-	5	1.5	-	3
	(Min)			(Min)				(Max)	(Max)		(Max)

The trace metal analysis (Table 4.13) result reveals that in the collected CCR samples, the most abundant trace elements are Cu ranging from 2400 mg/kg to 5050 mg/kg, Cr varying from 190mg/kg to 4050 mg/kg, Pb concentration was 300mg/kg to 400 mg/kg, Mn ranging from 290mg/kg to 390 mg/kg, Ni concentration varying from 100mg/kg to 600 mg/kg, Zn varying from 120mg/kg to 200 mg/kg, V concentration varying from 100 mg/kg to 1050 mg/kg. The trace metal concentration also shows that the concentration of Co was less i.e 10mg/kg to 20 mg/kg as compared to other heavy metals. It was also observed that there were very low concentrations of Hg in CCR samples i.e. 0.0004mg/kg and in pond ash no Hg content was observed. In general, heavy metal content in fly ash was greater than bottom ash and pond ash except Mn, Ni, Cr, V. Considerable variation can be found in the CCR heavy metal concentration both between the different power plant samples and between samples from the same power plant. Difference between the power stations can mainly be attributed to the use of different types of coal, combustion condition, and collection condition. The difference between the heavy metals of CCR samples from the same power plant may be due to the difference in the mass of the elements. Elements having lower mass can be carried and precipitated with the fly ash, while elements having higher mass may settle rapidly after combustion and be enriched in bottom ash. It has also been reported that the composition of trace elements in fly ash even from a single coal fired power plant may vary measurably on a daily basis (Snigdha S. et al., 2006).

Table 4.13 Trace metal characteristics of CCR samples

TPP	Fly ash Trace Metal (mg/kg)									
	Zn	Cd	Co	Mn	Pb	Ni	Cr	V	Cu	Hg
FA-T	200	N.D.	20	300	400	150	230	100	5050	0.0004
BA-T	120	N.D.	10	390	300	100	4050	1050	3200	0.0004
PA-T	170	N.D.	10	290	330	600	190	100	2400	ND

4.7 Mineralogical composition

The mineralogical characteristics of CCR are mainly dependent upon the geological features related to formation and deposition of coal and the combustion condition. The most common and predominant phases are quartz, mullite, hematite, magnetite and lime apart from other minor constituents.

Mineralogical analysis by XRD (X-Ray Diffraction) of CCR samples indicates that the major crystalline phases in CCR samples are quartz and mullite (Figures 4.3, 4.4, 4.5). The presence of quartz and mullite was attributed to the presence of SiO_2 and Al_2O_3 in CCR. In order to determine the functional groups and nature of fly ash, an FTIR (Fourier Transform Infrared spectroscopy) spectrum was evaluated.

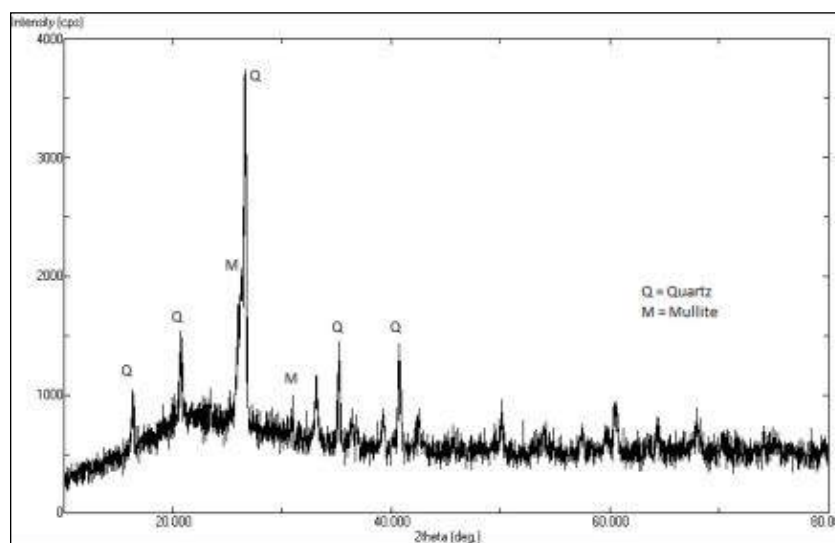


Figure 4.3 XRD patterns of Fly Ash

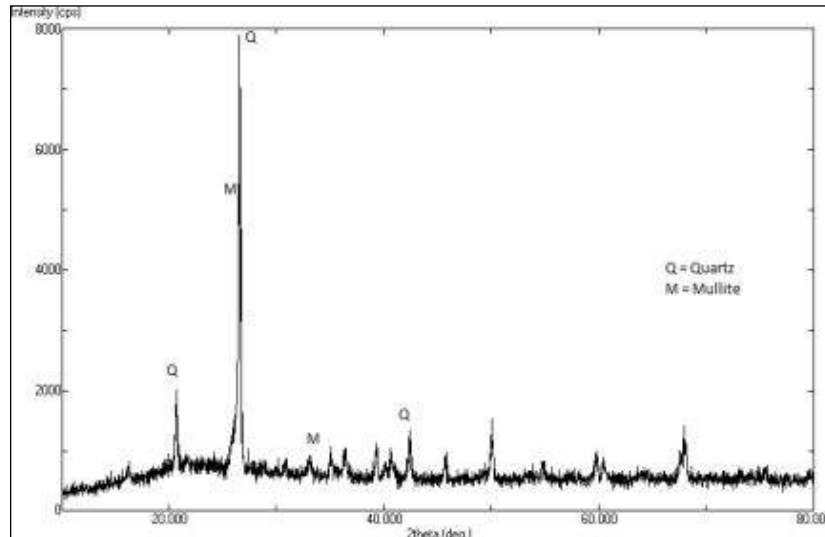


Figure 4.4 XRD patterns of Bottom Ash

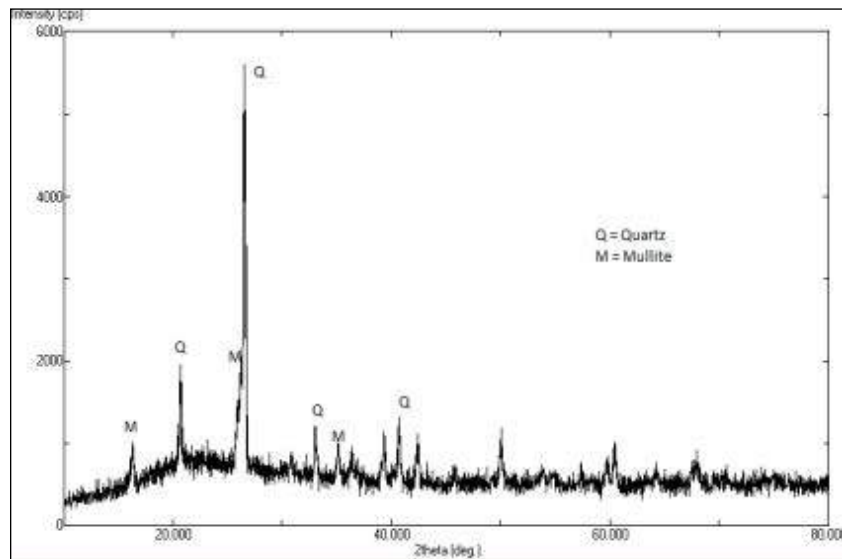


Figure 4.5 XRD patterns of Pond Ash

As shown in Figures 4.6, 4.7, 4.8 the spectrum is complex in nature due to the presence of several mineralogical phases containing numerous functional groups. The peak at around 1040 cm^{-1} was a characteristics bond corresponding to Si-O-Si and a stretching bond corresponding to O-Si-O was recorded at 460 cm^{-1} . The FTIR spectra indicated that the dominant functional groups in CCR sample are Si and O.

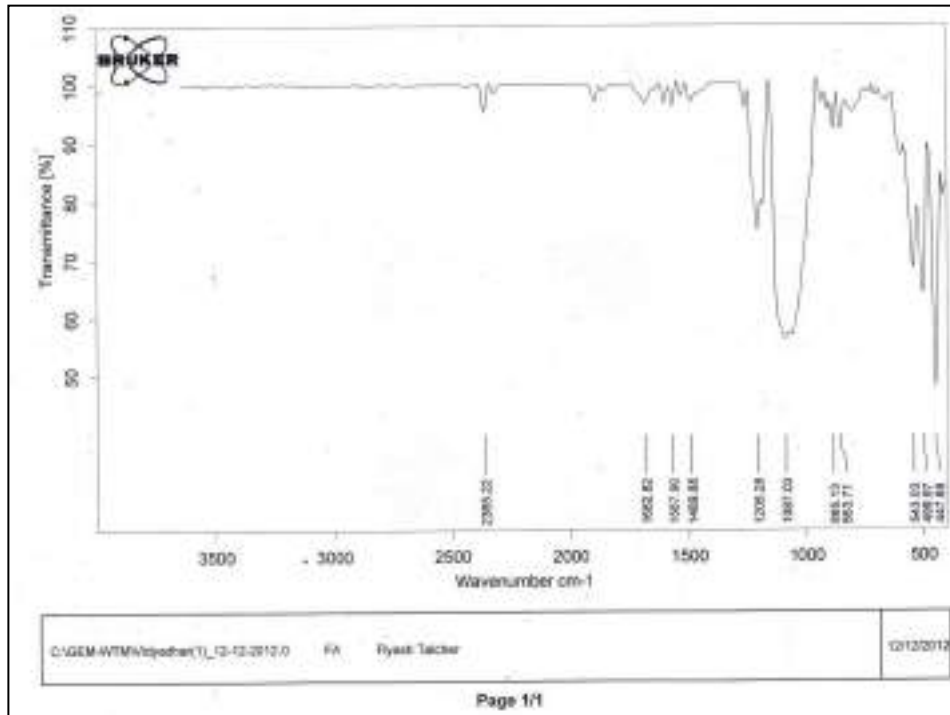


Figure 4.6 FTIR spectra of Fly Ash

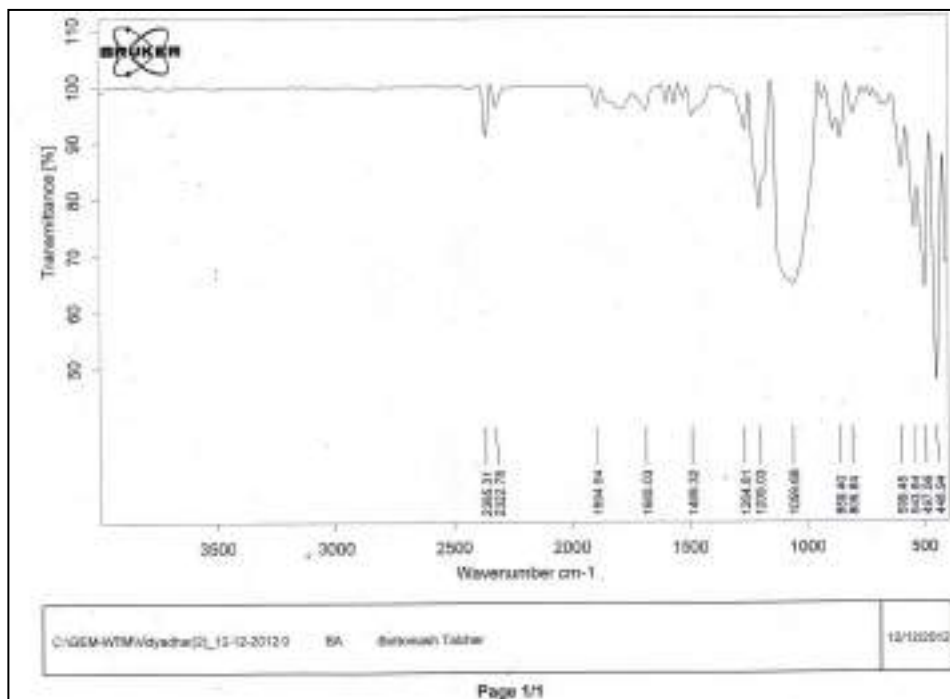


Figure 4.7 FTIR spectra of Bottom Ash

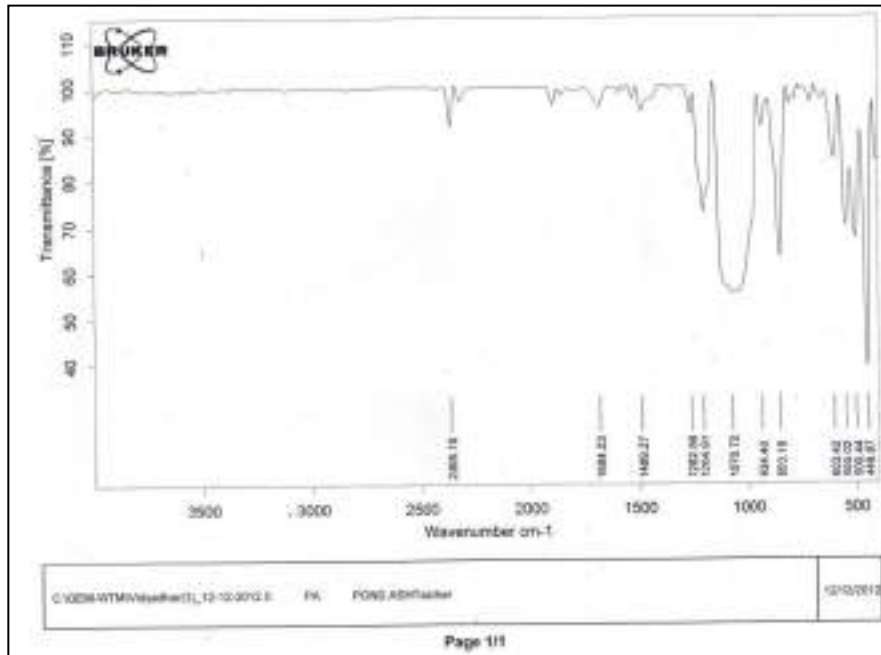


Figure 4.8 FTIR spectra of Pond Ash

4.8 Toxicity Characteristic Leaching Procedure (TCLP)

The results of the standard leaching experiments are summarized in Table 4.14. The toxicity characteristic leaching procedure (TCLP) was conducted as per US EPA SW-846, method-1311. The trace metal concentrations of 12 metals during the TCLP are shown in Table 4.14. It can be observed from TCLP test that the concentration of Al was higher as compared to other heavy metals. The concentration of Al varied from 0.3403 mg/L to 4.628 mg/L followed by Zn (0.53 mg/L to 0.714 mg/L), As (0.04089 mg/L to 0.2842 mg/L), Fe (0.0281 mg/L to 0.1286 mg/L) and the concentration of other heavy metals were minimal. During the TCLP test, it was also observed that the concentration of Barium (Ba) was not detected. Based upon this leaching studies, none of the CCR samples would fail the TCLP for high As, B, Cd, Cr, and Pb, as they were all well below the regulatory level of 5 mg/L for As, Cr, Pb, 100 mg/L for B and 1 mg/L for Cd respectively. These leaching studies reveal that collected CCR samples were non-hazardous in nature as per RCRA guidelines (U.S. EPA., 1986).

Table 4.14 TCLP Trace metal concentrations

Samples/ metals	FA-T (mg/L)	BA-T (mg/L)	PA-T (mg/L)	Regulatory level by USEPA-RCRA-D List (mg/L)
Al	4.628	0.3403	1.048	-
As	0.2842	0.04318	0.04089	5
Ba	N.D	N.D.	N.D.	100
Cd	0.0087	0.001435	0.00415	1
Co	0.0177	0.0055	ND	-
Cr	0.0137	0.0066	0.0101	5

Cu	0.3072	0.0225	0.0455	-
Fe	0.1286	0.0281	0.086	-
Mn	0.3216	0.06772	0.1337	-
Ni	0.05837	0.02797	0.009	-
Pb	0.01275	0.0087	0.0225	5
Zn	0.633	0.714	0.53	-

4.9 Synthetic Precipitation and Leaching Procedure (SPLP)

Synthetic precipitation leaching procedure (SPLP) was conducted as per US EPA SW-846 method-1312. The synthetic precipitation leaching procedure (SPLP, SW-846 method 1312), was designed to simulate the leaching of metals and organics from wastes or contaminated soils with an extraction fluid similar to slightly acidic rainfall. The trace metal concentrations of 12 metals during the SPLP are shown in Table 4.15. It can be observed from SPLP test that similar to TCLP, the concentration of Al was higher compared to other heavy metals. The concentration of Al was varying from 0.3703 mg/L to 2.485 mg/L followed by Zn (0.00547 mg/L to 0.13 mg/L), As (0.09387 mg/L to 0.105 mg/L), Mn (0.006945 mg/L to 0.2478 mg/L) and the concentration of other heavy metals was minimal. During SPLP test, it was also observed that the concentration of Barium (Ba) was not detected and concentration of Pb was not detected in fly ash and pond ash samples. Based upon this leaching studies, none of the CCR samples would fail the SPLP for high As, B, Cd, Cr, and Pb, as they were all well below the regulatory level of 5 mg/L for As, Cr, Pb, 100 for mg/L B and 1 mg/L for Cd respectively. These leaching studies reveal that collected CCR samples were non-hazardous in nature as per RCRA guidelines (U.S. EPA, 1986).

Table 4.15 SPLP Trace metal concentrations

Samples/ metals	FA-T (mg/L)	BA-T (mg/L)	PA-T (mg/L)	Regulatory level by USEPA-RCRA-D List (mg/L)
Al	2.485	0.3703	1.063	-
As	0.105	ND	0.09387	5
Ba	ND	ND	ND	100
Cd	0.003158	0.00014	0.00038	1
Co	0.01188	0.00098	ND	-
Cr	0.00135	ND	0.0084	5
Cu	0.0617	0.0025	0.007	-
Fe	0.01577	0.1062	0.209	-
Mn	0.2478	0.006945	0.0217	-
Ni	0.05242	ND	0.002236	-
Pb	ND	0.0118	ND	5
Zn	0.13	0.00547	0.0119	-

4.10 Development of the conceptual Groundwater flow and solute transport model

Development of the conceptual model is the most important aspect in the groundwater modeling exercise. The calibration of the model is to a large extent dependent on the conceptual model. The primary data and the secondary data are relied heavily to develop the conceptual model. The conceptual model entails defining the model area, defining the aquifer system, identification of the appropriate model boundary, assigning the appropriate boundary conditions and assigning the reliable input stresses like the recharge, groundwater withdrawal through the pumping wells.

One of the key aspects in conceptual modeling is the assignment of appropriate values of the aquifer properties like the hydraulic conductivity and storativity. The aquifer geometry has to be conceptualized with the help of available lithologs. In the present study, the data from the observation wells, Geophysical soundings, pumping pattern in the villages has been used partly in the conceptualization of the system.

In the present study, the study area has been delineated on the basis of the sub water shed principle. The hydraulic conductivity of the study area has been assigned on the basis of the reports from CMPDI (2003). It is subsequently refined during the manual calibration.

4.10.1 Design of the model grid

The study area was discretized into 79 rows and 100 columns (Figure 4.9). The cells outside the watershed were marked inactive as they do not contribute to the groundwater system of the model area under consideration.

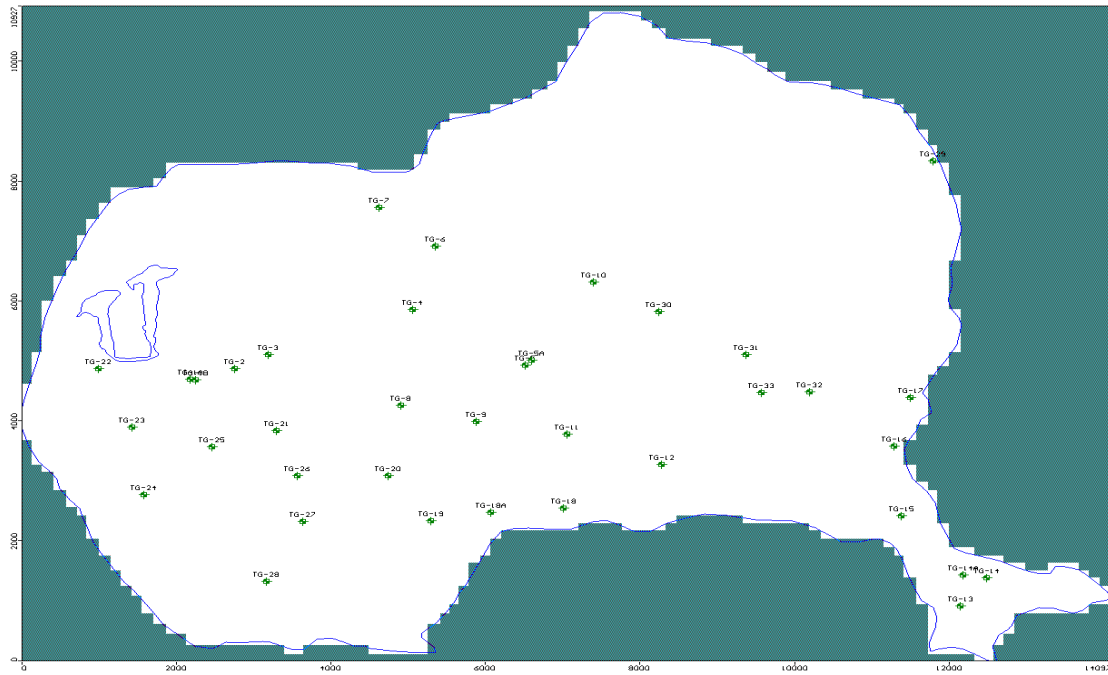


Figure 4.9 Discretized model with the observation wells (shown as green circles)

A two layer groundwater system was conceptualized by taking into account the hydrogeology of the study area.

4.10.2 Modflow Input values

The various input values to the MODFLOW are shown in the following sections:

4.10.3 Hydraulic conductivity

The hydraulic conductivity values (Table 4.16) have been assigned for the two layer model based on the transmissivity values and layer thickness values obtained during from TDEM Survey and the subsequent manual calibration (Figure 4.10). The values assigned are as follows:

Table 4.16 Hydraulic conductivity values in the model

Zone	Kx (m/s)	Ky (m/s)	Kz (m/s)
Green	1.14E-4	1.14E-4	1.14E-5
Navy Blue	1.59E-4	1.59E-4	1.59E-5
Dark cyan	1.59E-4	1.59E-4	1.59E-5
Red	1.04E-4	1.04E-4	1.04E-5
Pink	1.04E-4	1.04E-4	1.04E-5
Gold	1.04E-4	1.04E-4	1.04E-5

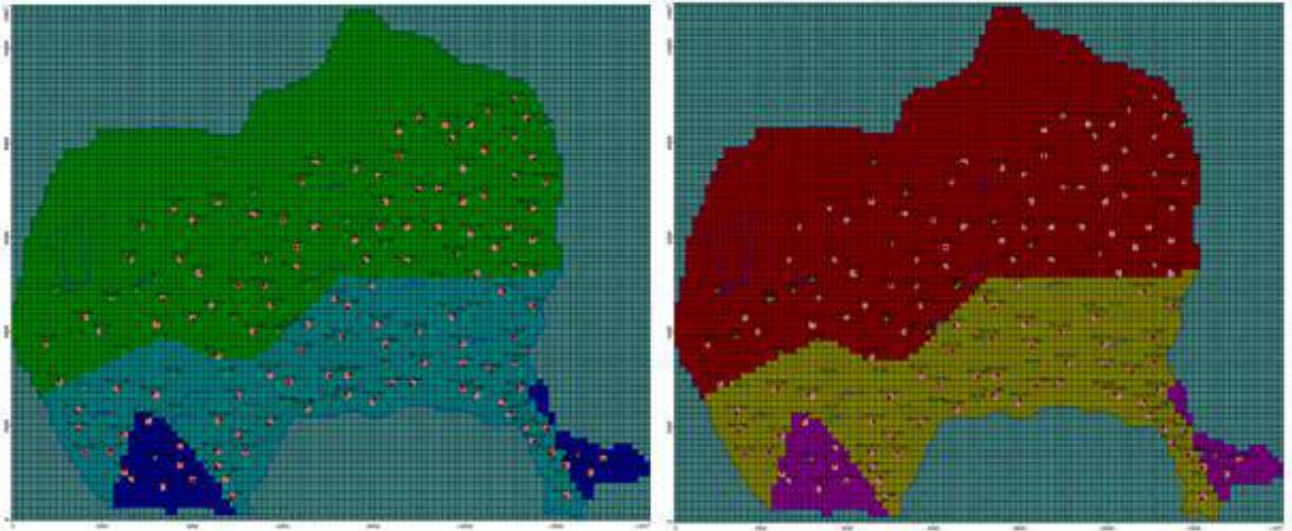


Figure 4.10 Hydraulic conductivity of the study area (layer 1 and layer 2)

4.10.4 Wells

Initially, 6 key observation wells have been selected in the study area. The wells are mostly the Indian Mark II hand pumps and open wells. Besides, all the Indian Mark II wells used for supplying water to the villages have been included in the pumping well network. Based on the village population in and around the industrial cluster and CGWB norms of 60 lpcd, the approximate draft is estimated for each well.

4.10.5 Initial Heads

To start solving the groundwater flow simulation, MODFLOW requires an initial guess for the head values in the model. The initial head values are also used to calculate the drawdown values, as measured by the difference between starting head and the calculated head. An initial head of value 141.503m has been assigned to start with the simulation

4.10.6 Boundary conditions

Every model requires an appropriate set of boundary conditions to represent the system's relationship with the surrounding systems. In the case of the groundwater flow model, boundary conditions will describe the exchange of flow between the different components in the model.

4.11 Flow Boundary conditions

4.11.1 Constant head boundary conditions

The constant head boundary condition is used to fix the head value in selected grid cells regardless of the system conditions in the surrounding grid cell, thus acting as an infinite source of water entering the system or as an infinite sink for water leaving the system. Therefore, constant head boundary conditions have significant influence on the results of the simulation. The existing groundwater level data in the study area have been considered in assigning the constant head boundary conditions.

The western part has the highest head value and the eastern part has the lowest head value. Hence, the groundwater flow direction is from western part towards the eastern part (towards Brahmini river). Hence, constant heads have been defined in the western part of the study area to constrain the groundwater flow within the upper limit of the heads obtained in the field (Figure 4.11).

4.11.2 River boundary conditions

The river package simulates the surface water/ groundwater interaction via a seepage layer separating the surface water body from the groundwater system. In the present study, the Brahmini river and Nandira Nala serves as a river boundary condition (Figure 4.11).

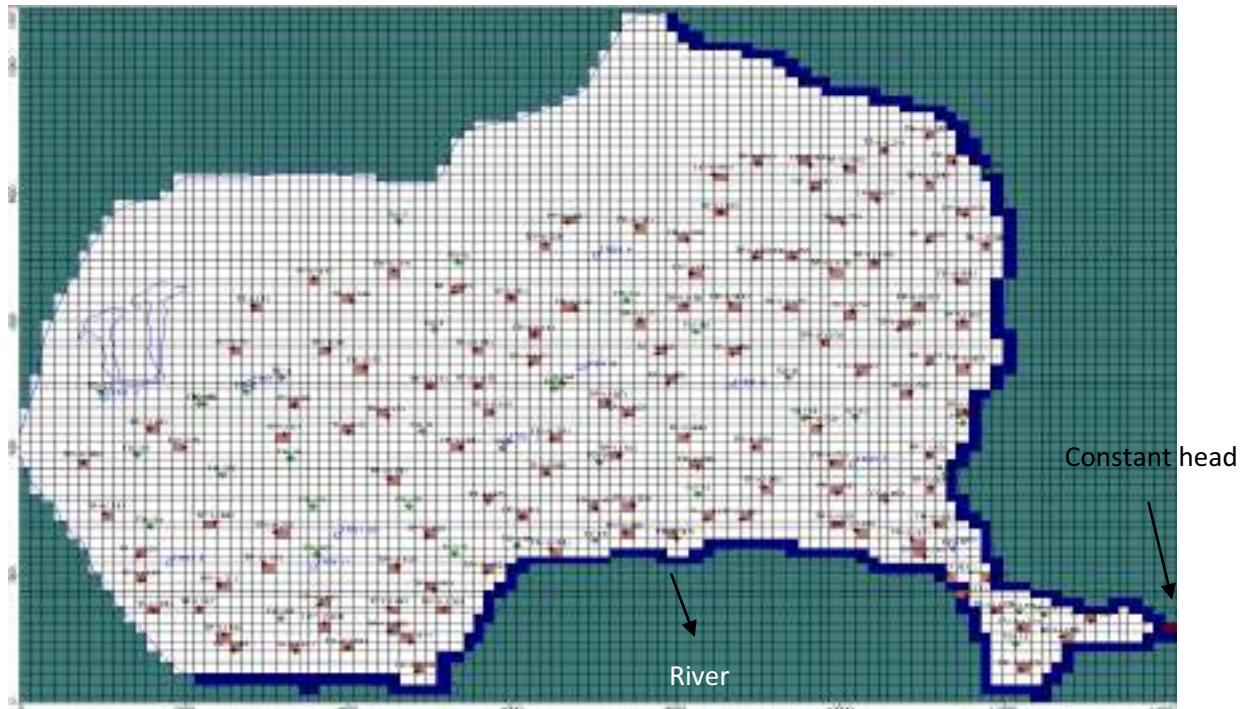


Figure 4.11 Constant head and River boundary condition

4.11.3 Recharge boundary condition

The recharge package is typically used to simulate the distributed recharge to the groundwater system. As the aquifer is basically unconfined, the recharge occurs as a result of precipitation percolating into the groundwater system. However, recharge package can be used to simulate the recharge from sources other than precipitation, such as irrigation, artificial recharge or seepage from a pond. It is generally assumed to be a percentage of precipitation. This percentage ranges from 10% to 13% depending on many factors that include:

- the predominant land use and vegetation type
- the surface topography (slope)
- the soil cover material

In the present study, the established norm of 10%-13% of the precipitation is considered in assigning the recharge to the study area (NABARD, 2006). Based on the rainfall data, the recharge assigned has been assigned depending on the topography and geology of the study area. However, the blue zone has been assigned the recharge of 210mm/year, the green and

cyan zones have been assigned the recharge of 80mm/year and red zone which is the south balanda mine zone has been assigned a recharge of 800 mm/yr in the study area (Figure 4.12) and the manual adjustment during the calibration procedure. The high recharge of 800 mm/yr in the south balanda mine region is due to the fact that there is direct rainfall to the mine pit.

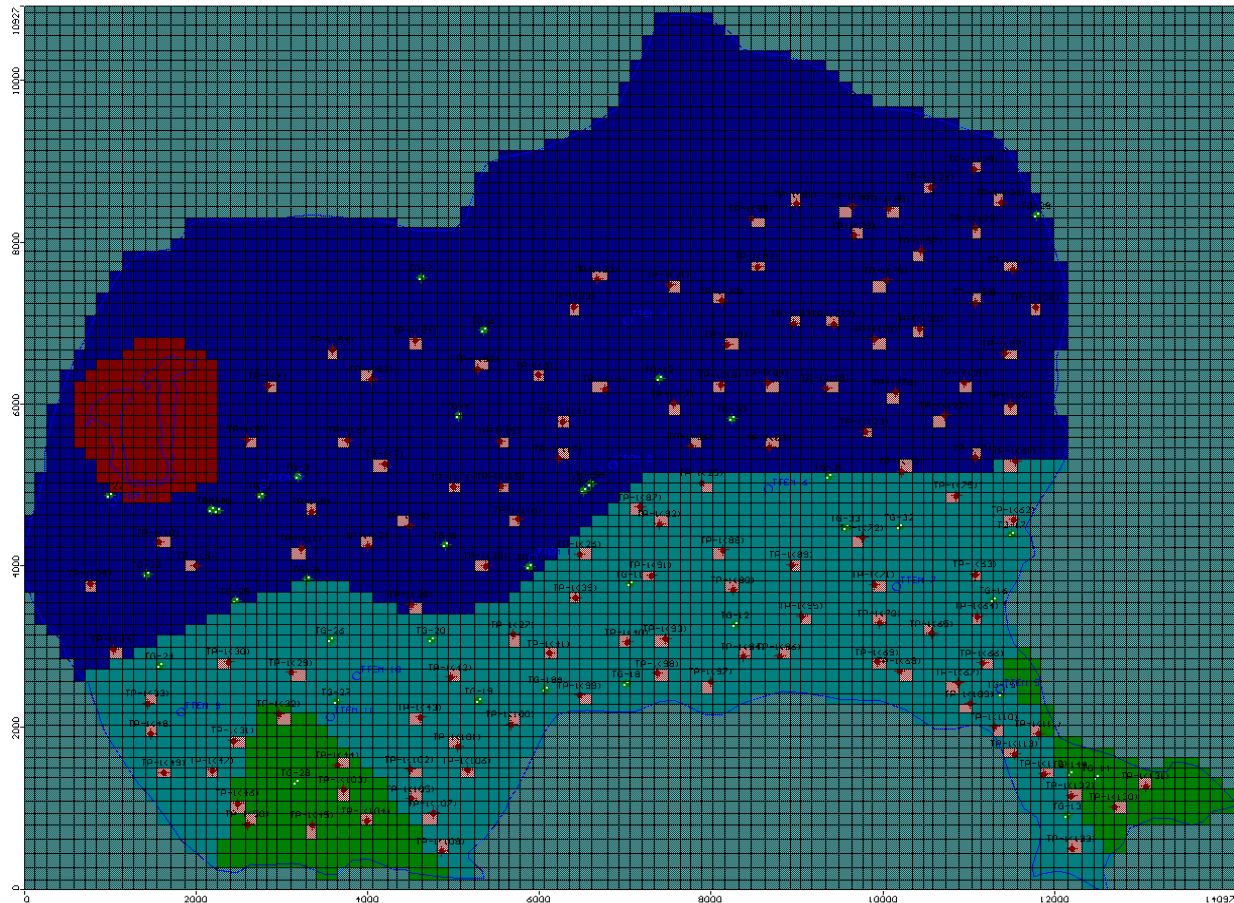


Figure 4.12 Recharge boundary condition

4.11.4 MT3D Input values

The hydrochemical data have been considered in assigning the input values in the mass transport model.

4.11.5 Initial concentration

In view of lack of historical groundwater quality data, assigning the background concentration had to be done with caution. The initial concentration for the study area is taken as 200 mg/L for which is the value obtained from the groundwater quality analysis data.

4.11.6 Mass transport boundary conditions

The solution of the governing equations for mass transport requires the specification of the boundary conditions.

4.11.7 Constant concentration boundary condition

The constant concentration boundary condition acts as a contaminant source providing solute mass to the model domain in the form of a known concentration. Constant concentration zone is assigned only in the south balanda mine pit and it needs to be mentioned that the ash disposal will continue for another 7 years. Hence, the loading at the pit is simulated for 7 years when the pit is going to be closed and the prediction scenario is made for 20 years. The solutes are concentrated initially in this zone before they eventually advance to the aquifer system. The approximate concentration of the TDS obtained from the water samples collected from ash pond is 500 mg/L which is input to the model as the constant concentration (Figure 4.13).

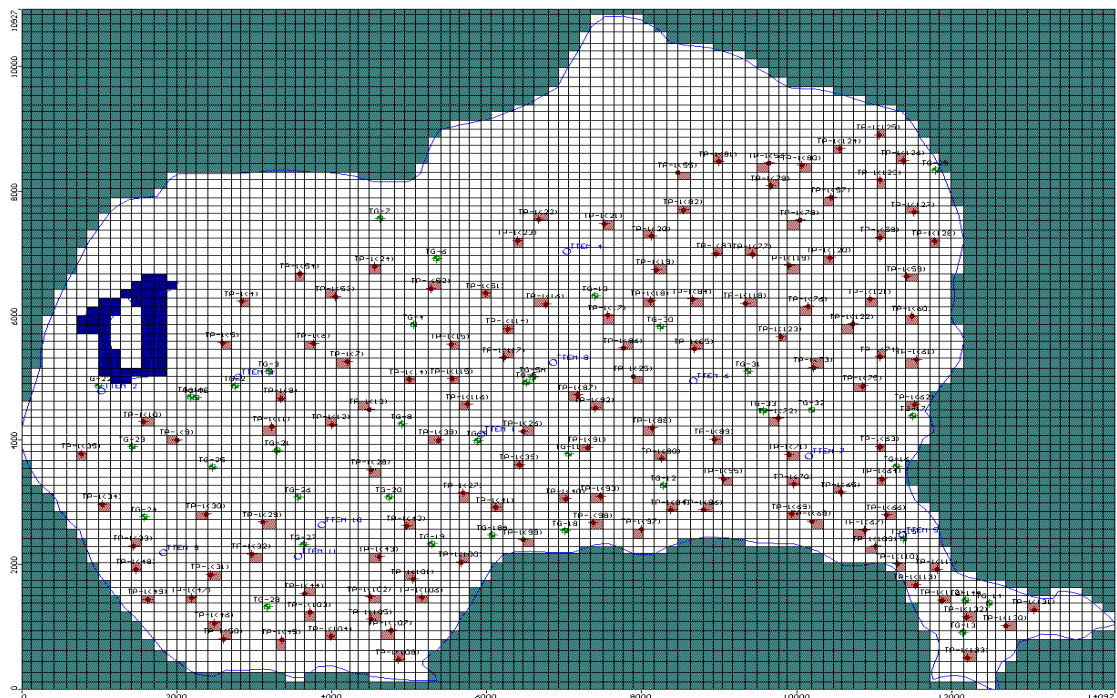


Figure4.13 Constant concentration boundary condition

4.12 Modeling Results

4.12.1 Flow Modeling

A steady state model has been developed using the post-monsoon 2012 groundwater level data of the study area. As long time water level data is not available in the study area, steady state model has been attempted. The calculated head contours (Figure 4.14) were obtained after the simulation of the groundwater flow model.

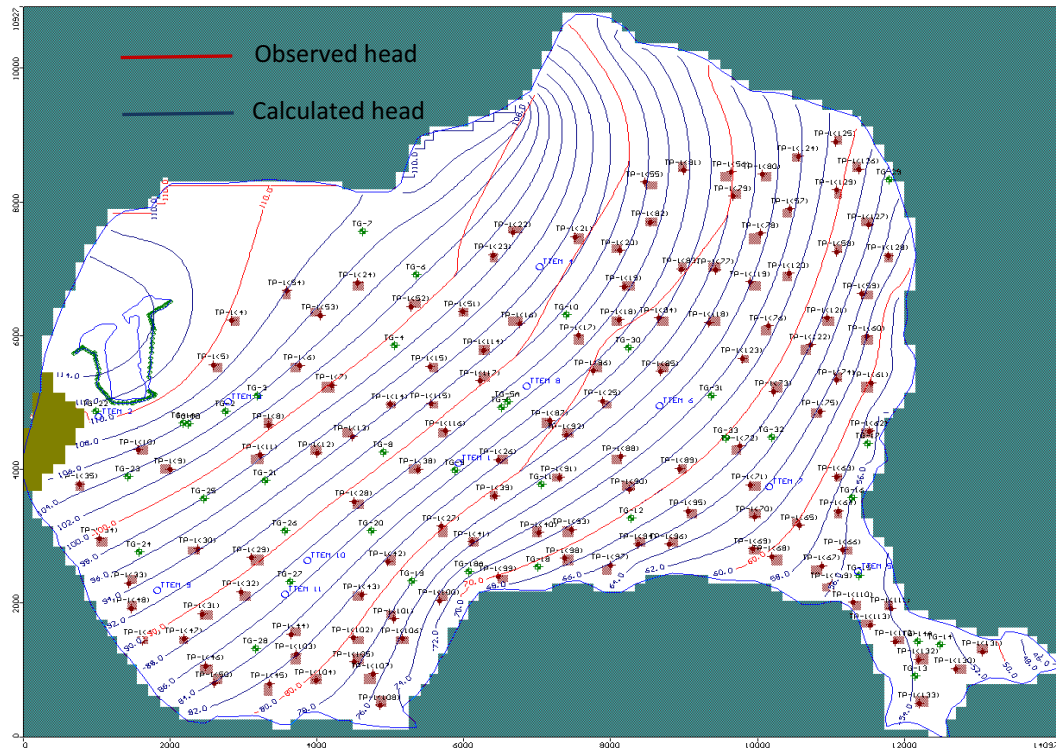


Figure 4.14 Computed water level contours for post-monsoon 2012

The calibration plot (Figure 4.15) shows that most of the observation wells follow 95% confidence interval except for very few observation wells. It can also be observed that most of the wells fall in the 95% confidence interval line which shows that the calculated head results simulated from the groundwater flow model are in line with the observed head obtained from the field data. The deviations can be from uncertainties in the pumping rates. However, a correlation of 0.949 was observed between the observed head and the calculated head.

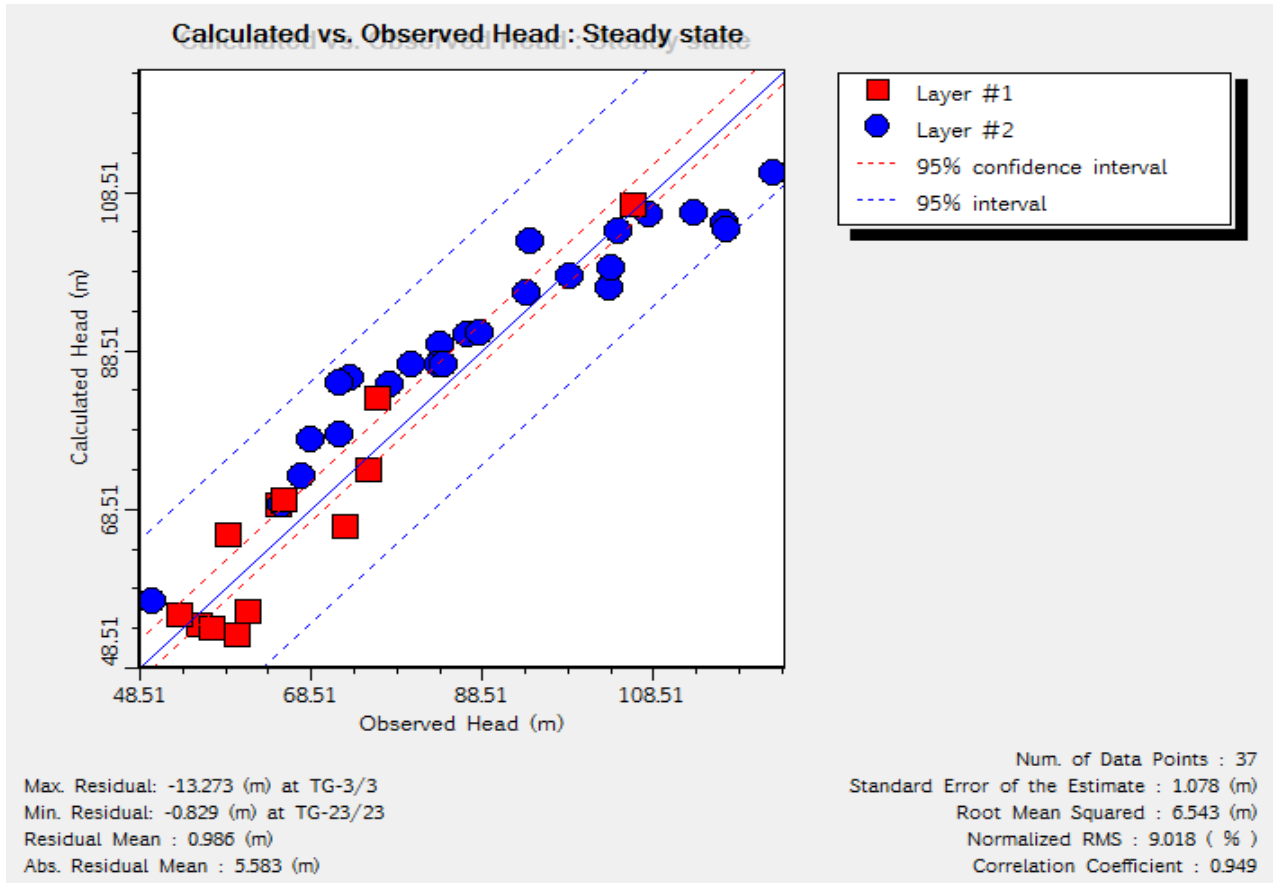


Figure 4.15 Calibration plot with respect to post-monsoon 2012 water level

4.12.2 Mass Transport Modeling

The calibrated flow model constitutes the input for mass transport modeling. A constant concentration of 500 mg/L has been assigned for the south Balanda mine pit which is identified as the constant concentration zone (Figure 4.16).

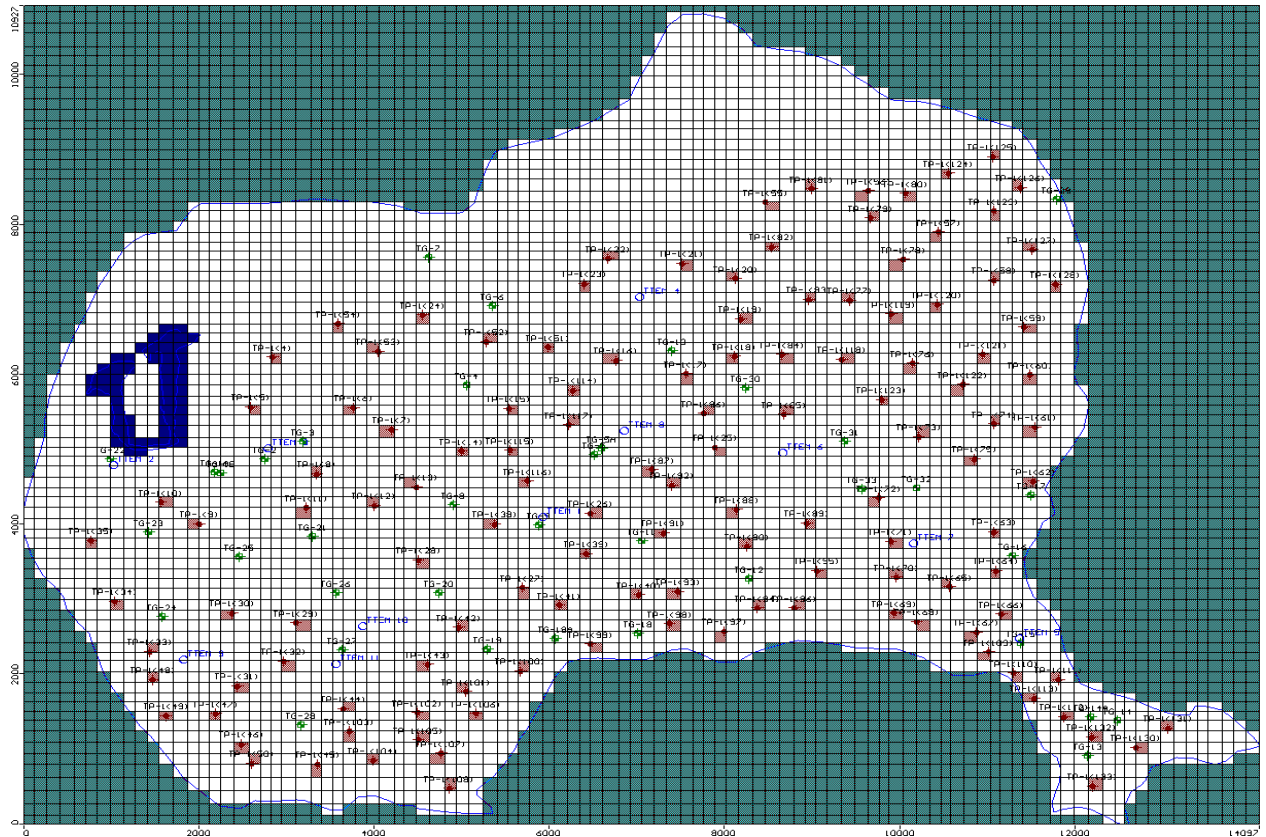


Figure 4.16 Constant concentration zone in the model

A background concentration of 200 mg/L has been assumed for the model. The mass transport model has been developed for prediction of the contaminant's migration over the next 20 years starting from post monsoon 2012 assuming that the loading at the mine pit continues for another 7 years. The predicted concentration after 20 years (Figure 4.17) indicates that the plume will move by nearly 931 m (approx) and the maximum concentration in the plume will be less than 200 mg/L. The migration pattern (Figure 4.17) indicates that the plumes will have high concentration (close to 500 mg/L) in the pond and the concentration outside the pond reduces with distance. This indicates that the contamination due to plume from the ash pond on the wells is not very significant. None of the observation wells surrounding the ash pond are likely to be affected due to the migration of the plume in the coming 20 years starting from November 2012 subjected to the prevailing hydrological stresses. This scenario is valid for conservative parameters assuming that the present hydrological stresses do not vary.

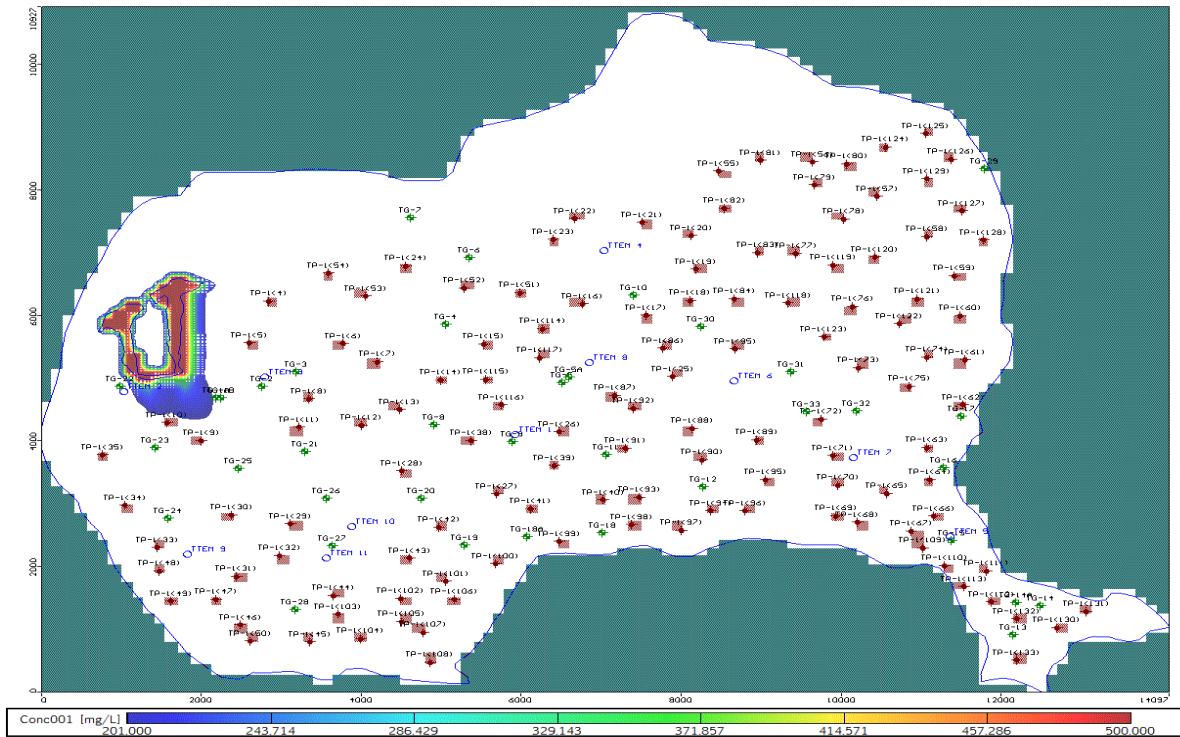


Figure 4.17 Prediction of the migration of the contaminant after 20 years (7 years loading ending in 2019)

4.13 Findings

The groundwater flow and mass transport modelling indicate that concentration of 200 mg/L will have plumes travelling approximately 931 m (approx) over a period of 20 years starting from November 2012. The scenario is valid for conservative parameters assuming that the hydrological stresses do not vary. The solute transport model in the present study is only simulated for advection and dispersion processes. Reaction mechanism has not been incorporated in the present study and is likely to introduce uncertainty in the predictions of the solute transport model. In fact, the movement of reactive species will be still less as compared to the prediction for conservative elements. The present model has not considered the existence of any deep agricultural bore wells in the study area as data were not available.

Chapter-V

ANALYSIS AND INTERPRETATION BY HELP **MODEL**

5.0 Analysis and Interpretation by HELP model

The HELP model is a versatile tool for predicting landfill hydrologic processes and testing the effectiveness of landfill designs, therefore enabling the prediction of landfill design failure resulting in groundwater contamination. HELP has become a requirement for obtaining landfill operation permits in the USA.

5.1 Basic features of HELP model

The quasi-two dimensional hydrologic model accepts the following input data:

- i) weather (Precipitation, solar radiation, temperature, evapo-transpiration parameters
- ii) Soil (porosity, field capacity, wilting point and hydraulic conductivity)
- iii) Engineering design data (liners, leachate and run off collection systems, surface slope).

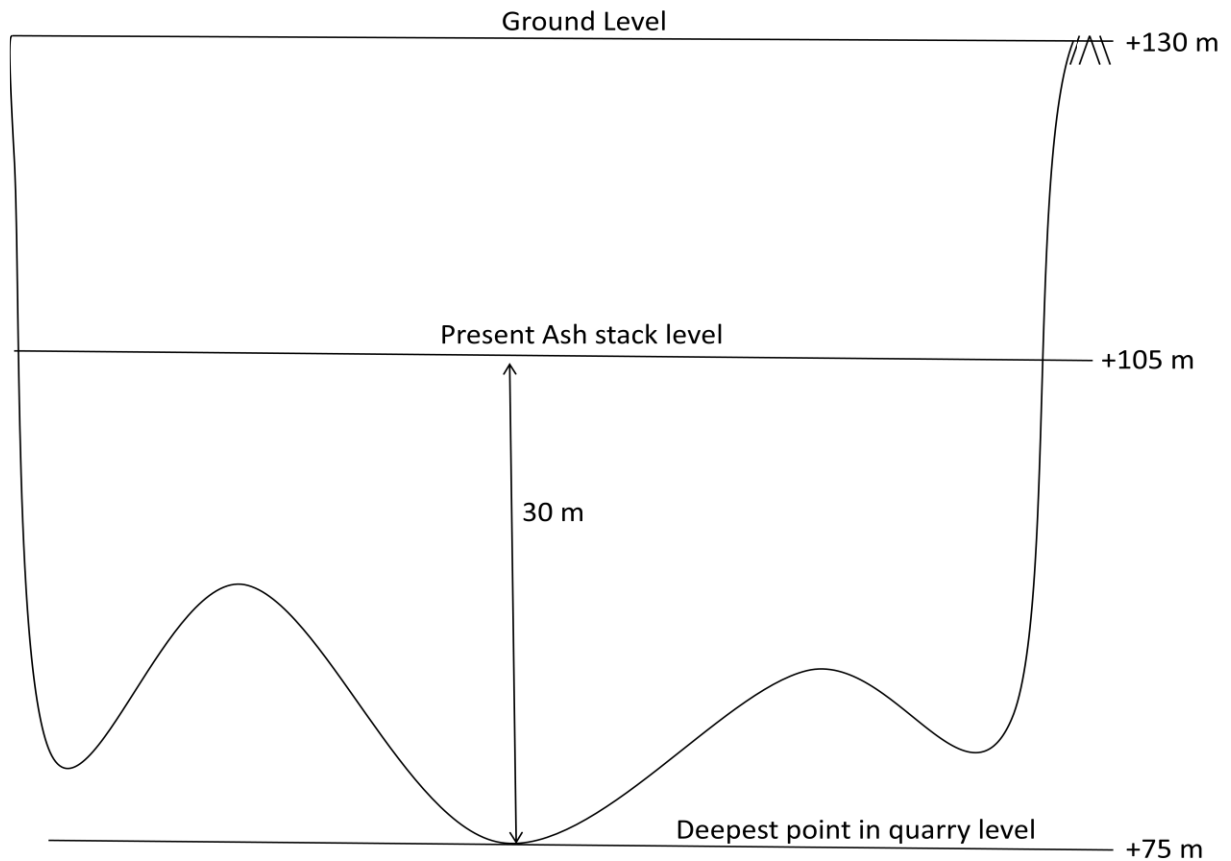
In the present study, the parameters mentioned at iii) are not applicable as the disposal site does not have the features mentioned above. The model is simulated as stack of ash over the underlying sandy clay loam moderately compacted. The latitude and longitude of the ash pond location have been provided to the weather generator module for estimation of the weather parameters.

5.2 Simulation of head using HELP model

The following details (Figure 5.1) as shared by NTPC-Talcher have been considered in conceptualization of the model.

The level (RL) of the base of the South Balanda Mine pit: + 75 m

The average height of the ash stack on the mine pit: 30 m (approx.) from the deepest point of the quarry level.



**Figure 5.1 Schematic cross section of the ash disposal site at South Balanda
(Source:TTPS)**

The simulated head over a ten year period indicates an additional head of approximately **25 ft** i.e. **8.33 m (Figure 5.2)**. The additional head due to the ash stack is in addition to the normal groundwater head in the study area. It is necessary that TTPS should monitor the groundwater level in the boreholes drilled in the immediate downstream of the abandoned mine pit at South Balanda. The monitoring should be done monthly as long as the ash disposal is carried out in the study area.

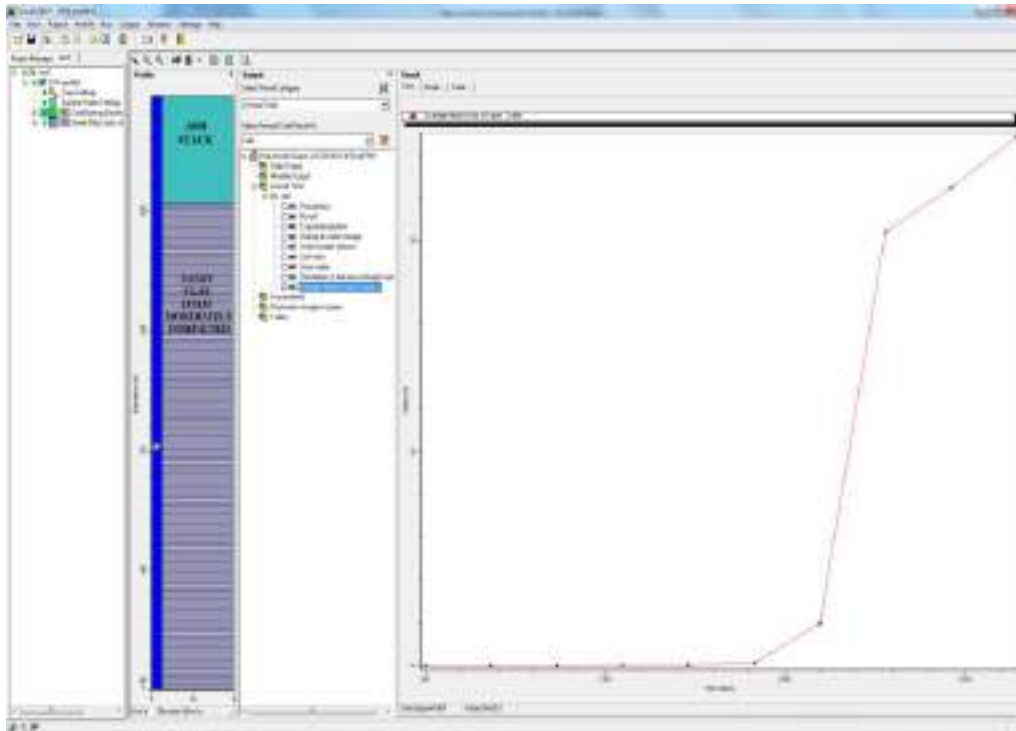


Figure 5.2 Simulated head over a 10-year period using HELP model

Chapter-VI

FINDINGS AND FUTURE WORK

6.1 Findings

Based on the water level measurements, groundwater quality, mine pit water analysis of the collected samples and physico-chemical, mineralogical and leaching characteristic of collected CCR samples following findings emerge from the study:

1. High nitrate concentration was observed in one of the groundwater sample namely TGN-2 during post monsoon season which exist in the upstream of the area. The observed values were found to be beyond the permissible limit as per BIS standard. The reason for the high nitrate concentration may be due to the existing land use/land cover pattern. All the remaining samples were within the permissible limit of BIS standard
2. The presence of high fluoride concentration gives the reasons whether it is due to geogenic nature or anthropogenic stresses
3. The higher concentration of iron is observed in most of the groundwater samples which may be due to the presence of laterite geological nature
4. The other physico-chemical parameters were within the permissible limits of BIS standard
5. Collected fly ash was acidic in nature but bottom ash and pond ash were neutral in nature
6. Moisture content in CCR samples varied from 0.87% to 29%
7. Insoluble residue in CCR samples was in the range of 27.58% to 47.36%
8. The amount of carbon content in CCR sample was ranging from 0.0427 % to 2.445%
9. The major constituents in the CCR sample are SiO_2 , Al_2O_3 and Fe_2O_3 followed by minor elements K_2O , TiO_2 , CaO , MgO , Na_2O , Na_2O , P_2O_5 and SO_3 . The CCR samples meet the general requirements of ASTM C-618 Class F fly ash and IS: 3812-1981
10. The most abundant trace elements are Cu, Cr, Pb, Mn, Ni, Zn, V, Co, Mo, V and Mn. The heavy metal analysis also shows that the concentration of Hg was very low and in pond ash it was not detected
11. The major crystalline phases in CCR samples were quartz and mullite which can be also observed from elemental analysis and FTIR analysis
12. Leaching studies (TCLP and SPLP) reveals that collected CCR samples were non-hazardous in nature as per RCRA guidelines where the concentration of As, B, Cd, Cr, and Pb were all well below the regulatory levels

13. In the present study, it is observed that the contaminant migration over a 20 year period will be over a distance of 931m (approx). The simulation is only based on the transport by advection and dispersion. It does not take into account any reaction mechanism. The existing wells in the study area are not likely to be affected subject to the prevailing hydrological stresses. Significant development of groundwater resources by installing deep bore wells for pumping may alter the impact of the ash disposal at South Balanda Mine Pit on the groundwater quality
14. The HELP model indicates that over a ten year period an additional head of approximately **25 ft i.e. 8.33 m is likely to be built up**

6. Recommendations

- It is necessary that TTPS should monitor the groundwater level in the boreholes drilled in the immediate downstream of the abandoned mine pit at South Balanda
- The monitoring should be done monthly as long as the ash disposal is carried out in the study area. The monitoring should be done for the water level as well as the key trace elements, namely Arsenic, Fluoride, Mercury, Lead. The water level time series data should be checked regularly to see any increase in the water level with time
- Tracer study should be carried out to examine any hydraulic connectivity between the mine pit and the groundwater sources in the vicinity of the mine pit

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