एनटीपीसी NTPC
एक महारत्न कम्पनी

एन टी पी सी लिमिटेड
(भारत सरकार का उद्यम)
NTPC Limited
(A Govt. of India Enterprise)

कुड़गी / KUDGI

Ref.: NTPC/Kudgi/EMG/2024/274

Dated: 28.11.2024

To,
The Deputy Director General of Forests (C)
Ministry of Environment, Forest and Climate Change (MoEF&CC)
Integrated Regional Office,
Kendriya Sadan, 4th Floor, E & F Wings,
17th Main Road, IInd Block, Koramangala,
Bengaluru – 560 034 (Karnataka)

Sub.: Submission of Six Monthly Compliance Report for Environmental Clearance of NTPC Ltd., Kudgi STPS, Stage-I (3 x 800 MW) – Reg.

Ref.: 1) MoEF&CC Letter No. J 13012/06/2009-IA.II (T) dated 25.01.2012.
2) MoEF&CC Letter No. J 13012/65/2008-IA.II (T) dated 11.08.2020.
3) MoEF&CC Letter No. J 13012/06/2009-IA.II (T) dated 04.07.2022.

Dear Sir,

Please find enclosed herewith, the Six Monthly Compliance Status Report for the period April, 2024 - September, 2024 in respect of the Environmental Clearance conditions stipulated vide MoEF&CC letter no. J 13012/06/2009-IA.II (T) dated 25.01.2012 and subsequent amendments dated 11.08.2020 and 04.07.2022 respectively for NTPC Ltd., Kudgi Super Thermal Power Project, Stage-I (3 x 800 MW) located near village Kudgi, Tq. Basavana Bagewadi, Distt. Vijayapur, Karnataka.

Thanking you.

Yours sincerely,

(Amit More)
Dy. General Manager (EMG)

Encl.: as above.

Copy to:
1) The Member Secretary, KSPCB, Bengaluru.
2) The Environmental Officer, Regional Office - KSPCB, Vijayapura.

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कुड़गी / KUDGI

HALF-YEARLY COMPLIANCE STATUS REPORT

OF

ENVIRONMENT CLEARANCE

(MoEF&CC Letter No. J-13012/06/2009-IA.II(T) Dtd.25.12.2012)
(MoEF&CC Letter No. J-13012/65/2008-IA.II(T) Dtd.11.08.2020)
(MoEF&CC Letter No. J-13012/06/2009-IA.II(T) Dtd.04.07.2022)



SUBMITTED BY

NTPC LTD., KUDGI SUPER THERMAL POWER STATION STAGE-I (3 X 800 MW)

KUDGI, BASAVANA BAGEWADI (TAL.), VIJAYAPURA (DIST.),
KARNATAKA – 586 121

NOVEMBER - 2024

HALF YEARLY ENVIRONMENTAL MONITORING REPORT

(PERIOD: APRIL-2024 TO SEPTEMBER-2024)

COMPLIANCE STATUS OF ENVIRONMENTAL CLEARANCE CONDITIONS
vide Letter Nos. J- 13012/06/2009-IA. II (T) dtd. 25.01.2012, J-13012/65/2008-IA.II(T) dtd.11.08.2020 and J-13012/06/2009-IA.II(T) dtd.04.07.2022.

S. NO.	STIPULATION	STATUS AS ON 30.09.2024
i	Vision document specifying prospective plan for the site shall be formulated and submitted to the Regional Office of the Ministry within six months.	Complied, vision document has been prepared and submitted to the Regional Office (Southern Zone) MOEF&CC at Bangalore vide letter dated 11.07.2012.
ii	Land and water requirement shall be restricted as per latest CEA norms issued.	Land and water requirement for the project has been optimized and restricted as per the CEA norms.
iii	Scheme for implementation for harnessing solar power within the premises of the plant particularly at available roof tops shall be formulated and status of implementation shall be submitted to Regional Office of the Ministry from time to time.	Complied, solar panels having capacity of 1500KW have been installed at available rooftops of FWPH, Switchyard Building, Compressor House, O&M Store, TG Roof, Workshop Roof, Unit-1 IDCT, Railway Siding S&T Building, Fire Station Building in Plant and various Buildings in Township. In addition, 3.37MW of Hybrid Plant comprising of Solar and Wind project is already installed and commissioned.
iv	A study shall be undertaken through a reputed Govt. Organization/ Agriculture University on the impact on vegetation within 10 Km radius of the plant due to fly ash generated and action taken shall be submitted to the Ministry. The study shall be completed within one year of operation of the proposed plant.	Complied. The scientific study for assessment of impact on vegetation within 10 Km radius of the plant due to fly ash generated has been conducted through M/s Indian Agricultural Research Institute who is governed by Indian Council of Agricultural Research (ICAR-Govt. of India). Copy of report submitted along with EC compliance report dated 27.05.2023.
v	A wildlife conservation plan shall be formulated in consultation with the office of the Chief Wildlife Warden and duly vetted by the concerned Chief Wildlife Warden for immediate implementation. The plan shall have an in-built monitoring mechanism.	Complied. The Deputy Conservator of Forests, Karnataka Forest Department (KFD), Vijayapur Division vide letter no. B2/DCF/BIP/NTPC/W.L/2013-14 dated 03.02.2014 has communicated that there is no Wildlife Sanctuary, National Park or Protected Area in and around 10 Km radius of Kudgi STPS. In view of the above, no wildlife conservation plan is envisaged.
vi	Provision for installation of FGD shall be provided for future use.	Complying. Provision for installation of FGD was available. Installation works of FGD system for controlling SOx concentration in flue gas is in progress.

S. NO.	STIPULATION	STATUS AS ON 30.09.2024
		Successful trial has been taken for Unit-2 FGD. Erection works are in progress for Unit-1 & 3. As per MoEF&CC notification dated 05.09.2022, the timeline for compliance of SO_2 emission norms is 31.12.2026 for Category-C TPPs.
vii	Coal transportation to plant site shall be undertaken by rail and no road transportation shall be permitted.	Complied. The coal transportation to plant site is being undertaken through railways only.
viii	A detailed study on chemical composition of coal used, particularly heavy metal and radioactive contents shall be carried out through a reputed institute and report shall be submitted to Regional Office of the Ministry. Only after ascertaining its radioactive level shall fly ash be supplied to end user.	Complied. In compliance to the said stipulation, study of heavy metal analysis and radioactivity analysis of coal was carried out through CSIR-NCL & BRIT, Department of Atomic Energy respectively and the reports were submitted along with EC compliance reports dated 13.05.2017 and 19.11.2019.
ix	Fly ash shall not be used for mine void filling or for agricultural purpose.	Complied. Fly ash is not being used for mine void filling or for agricultural purposes.
x	The project proponent shall carry out a long term R&D on Boiler efficiency vis-à-vis large variation on ash content of coal and submit its findings to the Ministry at a later stage.	The records w.r.t. long term R&D on boiler efficiency and corresponding ash content are being carried out and compiled for all the 3 units. Copy of the data compiled up-to Dec-2022 submitted along with EC compliance report dated 27.05.2023.
xi	A stack of 275 m height with flue gas velocity not less than 22 m/s shall be installed and provided with continuous online monitoring equipment for SO_x, NO_x, PM_{10} and $PM_{2.5}$. Mercury emissions from stack may also be monitored on periodic basis.	Complied. ▪ A single flue stack for Unit-1 and bi-flue stack for Unit-2 & 3 having chimney height of 275m, is provided. ▪ Continuous Emission Monitoring System for online measurement of SO_2, NO_x, and Particulate Matter (PM) has been provided and the emissions are being monitored. Mercury emissions from stack are also monitored on periodic basis through MoEF&CC approved laboratory.
xii	High Efficiency Electrostatic Precipitators (ESPs) shall be installed to ensure that particulate emission does not exceed 50 mg/Nm^3.	Complied. High efficiency electrostatic precipitators (ESP) designed for achieving guaranteed efficiency of 99.97% have been installed and the emission of Particulate Matter (PM) as per applicable norms is being complied.
xiii	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	Complied. **Ash Handling Areas:** Dry ash is being pneumatically conveyed from ash hoppers to HCSD ash silos. 04 nos. HCSD silos having capacity of 625MT each are in use for supply of

S. NO.	STIPULATION	STATUS AS ON 30.09.2024
	other vulnerable dusty areas shall be provided.	ash to end-users. 04/06 nos. of fly ash (FA) silos having capacity of 1600MT are constructed and balance are under construction. The ash is being issued to Cement and RMC industries in closed bulkers only through HCSD silos provided with telescopic chutes. Un-utilized ash is disposed to ash dyke through High Concentration Slurry Disposal (HCSD) system through pipelines. **Coal Handling Areas:** Pre-wetting and water sprinkling arrangements are available for control of dust during unloading of coal at Wagon Tippler (WT) area. In addition, fog canons (mist canons) are also provided for mitigating the fugitive emissions in WT area. Closed coal conveyor system has been adopted for internal coal movement. The conveyors and Transfer Points (TPs) are provided with automatic Dry Fog Dust Suppression (DFDS) for controlling the fugitive dust. **Coal Stockyard:** Regular compaction of the coal stored in coal storage area (stockyard) is being carried out with the help of dozers and compactors which minimizes the potential of any fugitive dust. During reserved shutdown (RSD) periods, the stacked coal is covered with tarpaulin to avoid emanation of any fugitive dust. Dust suppression in coal stockyards by means of water spraying is being carried out on regular basis.
xiv	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.	Complying. Ash Utilization Plan has been prepared and all efforts are being made to achieve the targets in compliance to fly ash Gazette Notification dated 31.12.2021 and its subsequent amendment dated 30.12.2022. The annual compliance status of ash utilization is being submitted to the Regional Office (SZ), MOEF&CC at Bangalore regularly.

S. NO.	STIPULATION	STATUS AS ON 30.09.2024
xv	Fly ash shall be collected in dry form and storage facility (silos) shall be provided. Unutilized fly ash shall be disposed-off in the ash pond in the form of slurry form. Mercury and other heavy metals (As, Hg, Cr, Pb etc.) will be monitored in the bottom ash as also in the effluents emanating from the existing ash pond. No ash will be disposed-off in low lying area.	Complied. Ash management scheme is implemented consisting of Dry Ash Extraction System (DAES) for collection of fly ash with storage facility (silos), supply of ash to entrepreneurs for utilization and promoting ash utilization to maximum possible extent and safe disposal of unused ash in the ash pond. Dry ash is being pneumatically conveyed from ash hoppers to HCSD ash silos in dry form for supply to end-users i.e. Cement and RMC industries. Storage facility viz. 04 nos. HCSD silos having capacity of 625MT each are in use for supply of ash to end-users. 04/06 nos. of fly ash (FA) silos having capacity of 1600MT are constructed and balance are under construction. The plant is equipped with two ash disposal systems, [a] conventional wet slurry disposal with ash water re-circulation for bottom ash, and [b] High Concentration Slurry Disposal system (HCSD) for disposal of unused fly ash. In compliance to the said stipulation, periodic monitoring for mercury & heavy metals in the bottom ash and water emanating from ash pond is being carried out through MoEF&CC approved laboratory, the reports are enclosed herewith as Annex-1. No ash is disposed-off in the low-lying areas.
xvi	Ash pond water shall be re-circulated and utilized.	Complied. Ash Water Recirculation System (AWRS) is implemented for re-circulating the ash water from the ash pond area to the plant for its complete re-utilization in the ash handling system.
xvii	Ash pond shall be lined with HDPE/ LDPE lining or any other suitable impermeable media such that no leachate takes place at any point of time. Adequate safety measures shall also be implemented to protect the ash dyke from getting breached.	Complied. Suitable impermeable media lining provided in all ash dyke lagoons. The structure of ash dykes is designed, constructed and operated as per State of the Art engineering design and construction with adequate factor of Safety to avert any remote possibility of getting breached. Regular monitoring and inspection of ash dykes and an emergency response system ensure that there are no risks of failure as apprehended.

S. NO.	STIPULATION	STATUS AS ON 30.09.2024
xviii	Sulphur and ash contents in the coal to be used in the project shall not exceed 0.5% and <34% respectively at any given time. In case of variation of coal quality at any point of time fresh reference shall be made to the Ministry for suitable amendments to environmental clearance condition wherever necessary.	Complied. Sulphur content in the coal is checked on random basis and weighted average in the coal used is equal to or less than 0.5%. Further, MoEF&CC vide Notification no. S.O.1561(E) dated 21.05.2020 has amended and allowed use of coal by thermal power plants, without stipulations as regards ash content or distance.
xix	Hydro-geology of the area shall be reviewed annually from an institute/ organization of repute to assess impact of surface water and ground regime (especially around ash dyke). In case, any deterioration is observed, specific mitigation measures shall be undertaken and reports/ data of water quality monitored regularly and maintained shall be submitted to the Regional Office of the Ministry.	Complying. NTPC Kudgi has carried out a Hydrogeological study of the area through National Institute of Hydrogeology (NIH), Roorkee and the study report has been submitted to MoEF&CC vide HYC report dated 02.12.2017. The surface and ground water analysis are being carried out through MoEF&CC approved laboratory and the summary report is enclosed herewith as Annex-1. The study for review of hydrogeology of the area through National Institute of Hydrogeology (NIH), Roorkee is complete, and report is enclosed as Annex-2.
xx	No ground water shall be extracted for use in operation of the power plant even in lean season.	Complying. The water requirement for use in operation of the power plant is drawn from Almatti reservoir for which MoU with KBJNL, GoK dated 27.09.2014 is available for supply of 5.2TMC per annum water requirement.
xxi	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.	Noted.
xxii	Minimum required environmental flow suggested by the Competent Authority of the State Govt. shall be maintained in the Channel/ Rivers (as applicable) even in lean season.	The raw water is sourced from Almatti reservoir on Krishna river as per the MoU with Krishna Bhagya Jala Nigam Ltd. (KBJNL), Govt. of Karnataka dated 27.09.2014 and water drawl is being done in consultation with KBJNL to comply all applicable conditions. Almatti reservoir is under the administrative control of Govt. of Karnataka.
xxiii	COC of 4.0 shall be adopted.	Complied. A closed cycle cooling system has been designed and implemented for achieving minimum 4 Cycles of Concentration (COC) at NTPC Kudgi for conservation/ optimization of water requirement for the project.

S. NO.	STIPULATION	STATUS AS ON 30.09.2024
xxiv	Regular monitoring of ground water level shall be carried out by establishing a network of existing wells and constructing new piezometers. Monitoring around the ash pond area shall be carried out particularly for heavy metals (Hg, Cr, As, Pb) and records maintained and submitted to the Regional Office of this Ministry. The data so obtained should be compared with the baseline data so as to ensure that the ground water quality is not adversely affected due to the project.	Monitoring around the ash pond area is being carried out through MoEF&CC approved laboratory, particularly for heavy metals and records are maintained and submitted to Karnataka State Pollution Control Board (KSPCB) and MoEF&CC regularly. Ground water level monitoring has been carried out in and around the main plant and ash pond area by establishing a network of existing wells during the Hydro-geological study carried through M/s National Institute of Hydrology (NIH), Roorkee. The study for reviewing the hydrogeology of the area through National Institute of Hydrogeology (NIH), Roorkee is complete, and report is enclosed as Annex-2.
xxv	Monitoring surface water quality in the area 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 be undertaken.	Monitoring of surface water quality in the area is being carried out through MoEF&CC approved laboratory and the reports are submitted to the Regional Office (SZ) of MOEF&CC and KSPCB. Monitoring for heavy metals in ground water are also being carried out and its record submitted to KSPCB regularly.
xxvi	Waste water generated from the plant shall be treated before discharge to comply limits prescribed by the SPCB/ CPCB.	Complying. An effluent management scheme is implemented with the objective to treat the entire wastewater as per the prescribed statutory standards of KSPCB/ CPCB. It is submitted that during normal course of project operation the feasibility of zero discharge has been adopted based on maximum recycle/ reuse of wastewater for various plant usage thereby reducing and optimizing the quantities of water requirement and effluent generation to the extent feasible.
xxvii	The project proponent shall undertake rain water harvesting measures and shall develop water storage for use in operation of the plant. Rain water harvesting system shall be put in place which shall comprise of rain water collection from the built up and open area in the plant premises. Action plan for implementation shall be submitted to the Regional Office of the Ministry.	Rainwater harvesting structures have been constructed and measures are also being undertaken as per the site conditions.

S. NO.	STIPULATION	STATUS AS ON 30.09.2024
xxviii	Additional soil for levelling 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.	All levelling activity of the project site is being done from additional soil generated within the sites only with all necessary precautions to protect natural drainage system of the area.
xxix	At least three nearest village shall be adopted and basic amenities like development of roads, drinking water supply, primary health centre, primary school etc. shall be developed in co-ordination with the district administration.	Activities like road construction & development, providing bus shelters, development of sanitation facilities, drinking water facilities, providing medical equipment to Hospital, 24-hour ambulance facility, providing of tools and equipment to Government ITI, conducting health camps, providing additional infrastructure facilities in schools, distribution of books to students etc. have been carried out in villages near the project. Improvement of infrastructure of primary health centers of four villages & construction of additional classrooms in schools are in progress. All welfare activities under R&R scheme are being carried out in five surrounding villages namely Kudgi, Telgi, Masuti, Golsangi and Muttagi. • *In Golsangi village, new Primary Health Centre (PHC) building has been constructed and handed over to Dept. of Health & Family Welfare, Govt. of Karnataka.* • *Around 38 new classrooms have been constructed in above-mentioned five villages benefitting more than 20 Government Schools.* <u>During 2019-20:</u> • *NTPC Kudgi distributed School Notebooks worth Rs.12 Lakh to about 8000 students in the above-mentioned five villages.* <u>During 2020-21:</u> • *NTPC Kudgi distributed Library furniture worth Rs.4 Lakh for Golasangi RAD School and Madhri Badawne School.* <u>During 2021-22:</u> • *NTPC Kudgi installed 06 nos. Solar High Masts at Project Affected Villages.* • *Extended financial support of Rs.43 Lakh towards COVID Doctors remuneration.* • *Distributed 40,000 notebooks to Project Affected Village School Children.* <u>During 2022-23:</u> • *Under CSR – A month long Girl Empowerment Mission (GEM) program*

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		conducted for empowering girls by giving exposure of various activities and training including skills & self-defense to 42 girls from Project Affected Villages who are studying in 6th standard. • *Financial support of Rs.2 Lakh for village level Sports Meet.* • *Sponsorship of ITI Training at Government ITI, Vijayapura for 9 students of Project Affected Villages.* During 2023-24: - • *Under CSR – month long Girl Empowerment Mission (GEM) program conducted for 70 girls from Project Affected Villages who are studying in 6th standard.* • *Utkarsh Scholarship was awarded to 33 meritorious students who have excelled in 10th and 12th exams.* • *Zonal Sports Meet was conducted in Kudgi and Golasangi where NTPC Kudgi sponsored sports materials, trophies, certificates, medals worth Rs.75,161.* • *Financial Support of Rs.25,000 was provided to Telgi Panchayat for conducting Cultural Fair at Sangameshwara Temple.* During 2024-25: - • *Under CSR – month long Girl Empowerment Mission (GEM) program conducted for 40 girls from Project Affected Villages who are studying in 6th standard.*
xxx	A special scheme for upliftment of SC & ST population in the study area shall be formulated and implemented in a time bound manner. The project proponent shall also identify the rights of tribals under existing Laws and ensure its protection and implementation thereof.	Under Community Development (CD) initiatives, special scheme for upliftment of SC & ST population in the study area is being formulated and implemented in a time bound manner. Over a period of nine years, around 350 meritorious students (all categories including SC, ST, OBC) from neighboring villages have been awarded with Uttkarsh Scholarship along-with a solar lamp. Further, students of SC/ ST community of Govt. ITI, Vijayapura also got benefitted by the sponsorship program extended by industry. During FY 2020-21, industry have sponsored 10 students from surrounding project affected villages to Govt. ITI College as part of its skill upgradation program. Identification the rights of Under tribal – industry will support for Banjara Community for manufacturing of Banjara Dress items under Self-help group upliftment.

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		During 2022-23: Under CSR, a month-long Girl Empowerment Mission (GEM) program conducted for empowering girls by giving exposure of various activities and training including skills & self-defense to 16 girl children from SC and 1 girl child from ST from Project Affected Villages studying in 6th standard. During 2024-25: Under CSR, a month-long Girl Empowerment Mission (GEM) program conducted for empowering girls by giving exposure of various activities and training including skills & self-defense to 5 girl children from SC from Project Affected Villages studying in 6th standard.
xxxi	A comprehensive R&R action plan with requisite details such as details of land losers and financial budget for compensation etc. shall be submitted to the Regional Office of Ministry within four months. The R&R action plan shall also include scheme for upliftment of marginalized section who are indirectly affected on account of dependence for their sustenance on the land not owned by them.	A comprehensive R&R action plan with requisite details such as details of land losers and financial budget for compensation etc. has already been prepared and approved in consultation with representatives of PAPs, VDAC and Government of Karnataka. Implementation of the same is in progress. The Final R&R Plan has been submitted to the Regional Office (SZ) of MOEF&CC, Bangalore vide letter dated 16.10.2012.
xxxii	The project proponent shall also adequately contribute in the development of the neighboring villages. Special package with implementation schedule for providing potable drinking water supply in the nearby villages and schools shall be undertaken in a time bound manner.	Due to the setting up of Kudgi STPS, general facilities in the nearby areas have certainly developed. New opportunities for business and self-employment have been generated thereby increasing the cash flow in business. NTPC is making all efforts for developing infrastructural facilities and implementing various community development activities through; • Alternate employment opportunities to PAPs and local people, • Periodic health checkup program for the nearby villagers, • Opportunities to local people to enhance their businesses, • Development of infrastructure facilities viz. improvement in roads, bus shelters, public facilities, solar streetlamps, sanitation, toilets, medical, schools, sport facilities etc. are being implemented.
xxxiii	CSR schemes shall be undertaken based on need based assessment in and around the villages within 5 Km of the site and in constant consultation with the village Panchayat and the District	Various CSR schemes are being implemented based on need based survey within 5Km and in consultation with the Village Panchayat and the District Administration. • Infrastructural development i.e. improvement in roads, electricity, supply of

S. NO.	STIPULATION	STATUS AS ON 30.09.2024
	Administration. As part of CSR employment of local youth after imparting relevant training, as may be necessary shall be undertaken as committed.	drinking water, sanitation, educational institutions, and transportation facilities etc. • Scholarships to students and facilitation for sports, training for self-employment (computer, welding, bar-bending, carpentry, stitching, embroidery) etc. • Training/ financing facilitation for development of rural small-scale industries i.e. Bee-keeping, Poultry, Dairy Farming etc. Further, as part of Corporate Social Responsibility, NTPC Kudgi distributed 620 Nos. of desks to Schools at Dharwad worth Rs.12.5 Lakh during FY 2020-21. During Covid-19 pandemic in FY 2020-21, NTPC Kudgi committed Rs.15 Lakh to District Administration towards relief material and other essential items for distribution among stranded laborer. In addition, with the support of RIO, Bengaluru, NTPC Kudgi team has extended supporting hands for the distribution of Ration Kits worth of Rs.5 Lakh to needy and vulnerable group of people at Bengaluru. During FY 2023-24, 185 Nos. of desks to Schools at Kudgi and Telagi village worth Rs.10.00 Lakh were provided.
xxxiv	An amount of Rs.52.80 Crores shall be earmarked as one capital cost for CSR programme as committed by the project proponent. Subsequently a recurring expenditure of Rs. 10.60 Crores per annum till the life of the plant shall be earmarked as recurring expenditure for CSR activities. Details of the activities to be undertaken shall be submitted within six month along with road map for implementation.	Out of Rs.52.95 Crore earmarked for R&R expenditure, an amount of Rs.52.95 Crore (approx.) have been spent for R&R activities and the remaining is committed by NTPC Kudgi towards activities such as Tools and Equipment to Govt. ITI, Vijayapur, new classrooms for schools, improvement of infrastructure and medical equipment at nearby Primary Health Centers and construction of individual toilets etc. as decided in the Village Development Advisory Committee meeting chaired by Dy. Commissioner, Vijayapur. The condition has been deleted vide MoEF&CC amendment letter no. J-13012/65/2008-IA.II(T) dated 11.08.2020.
xxxv	It shall be ensured that an in-built monitoring mechanism for the CSR schemes identified is in place and annual social audit shall be got done from the nearest Government institute of repute in the region. The project proponent shall also submit the status of implementation of the scheme from time to time. The	Need Assessment Survey and Social Audit for community development program for nearby areas of NTPC Kudgi has been carried out through Department of Social Work, Karnataka State Akkamahadevi Women's University, Vijayapur. The said stipulation will be complied regarding implementation of an in-built monitoring mechanism for the CSR schemes and annual

S. NO.	STIPULATION	STATUS AS ON 30.09.2024
	achievements should be put on Company's website.	social audit from the reputed Government institute in the region. Further, Need Assessment Survey and Social Impact Evaluation Survey was completed through M/s Indian Institute of Corporate Affairs and the Final Report was submitted.
xxxvi	Green Belt consisting of 3 tiers of plantations of native species around the plant and 100 m width shall be raised (except in areas not feasible). The density of trees shall not be less than 2500 per ha with survival rate not less than 80%.	NTPC Kudgi is carrying out greenbelt development (including maintenance for subsequent 4 years) through Karnataka Forest Department in the plant and township, with plantation density not less than 2500 per ha and survival rate not less than 90% against the stipulated survival rate of 80%. A total tree plantation of more than 3.25 Lakh consisting of 3 tiers is done with native species of plants in and around the plant and 50m-100m width wherever feasible till date in an area of more than approx. 350 acres having survival rate of more than 90%. In addition, tree plantation of more than 5 Lakh saplings (including maintenance for subsequent 5 years) with an expenditure of Rs.3.5 Crore has been carried out through Karnataka Forest Department (KFD) in the four forest divisions namely Shivamogga, Sagara, Hunsur and Mandya forest divisions in an area of approx. 800 acres. During FY 2022-23, 2023-24 & 2024-25, about 20,000, 30,000 & 25,000 saplings resp. have also been planted in degraded Mamadapur reserved forest land in approx. 432 acres which consists of subsequent four-year maintenance.
xxxvii	An Environmental Cell shall be created at the project site itself and shall be headed by an officer of appropriate seniority and qualification. It shall be ensured that the Head of the Cell shall directly report to the Head of the organization.	Complied. An Environment Management Group (EMG) with qualified team headed by Deputy General Manager (EMG) is functional at Kudgi STPS and is reporting to the Head of the Project.
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.	Noted and being complied. Treated effluent conforming to standards is being re-circulated and reused within the plant only. An independent plant effluent drainage system is being provided to ensure that plant effluents do not mix with storm water drainage.
ii.	A sewage treatment plant shall be provided (as applicable) and the	Noted and being complied. All domestic sewage is treated in MBBR based Sewage Treatment Plant and entire treated sewage conforming to prescribed standards is utilized

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	treated sewage shall be used for raising greenbelt/ plantation.	for plantation & raising greenbelt to the extent possible through a treated water network.
iii.	Adequate safety measures shall be provided in the plant area to check/ minimize spontaneous fires in coal yard, especially during summer season. Copy of these measures with full details along with location plant layout shall be submitted to the Ministry as well as to the Regional Office of the Ministry.	Noted and being complied. Adequate number of fire spray & hydrant system for covering the entire power station including coal yard, all the auxiliaries and buildings in the plant area have been designed and being implemented. The system includes piping system, hydrants, valves, instrumentation, hoses, nozzles, hose boxes/ stations etc. Copy of fire safety measures details for CHP area and fire hydrant system has been submitted to Regional Office (SZ) of MOEF&CC at Bangalore vide HYC report dated 02.12.2017.
iv.	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.	License no. P/HQ/KA/15/2820(P359942) dated 06.11.2015 is available from Department of Explosives, Nagpur for importation and storage of Petroleum Class C in bulk. The sulphur content in the liquid fuel is not exceeding 0.5%. A detailed Disaster Management Plan (DMP) is prepared and finalized in consultation with Department of Factories, Boilers, Industrial Safety and Health, Govt. of Karnataka and regular mock drills are being conducted as per plan in order to address any eventuality in case of an accident.
v.	First Aid and sanitation arrangements shall be made for the drivers and other contract workers during construction phase.	All arrangements related to first aid, health & safety and sanitation for contract workers during construction phase of the project are kept under the EPC contract and compliance is ensured by NTPC. NTPC Kudgi is in its operation stage and therefore various measures implemented are as follows: • Adequate infrastructure facilities, such as sanitation, medical facilities, safety, and suitable water supply are provided. • Safety equipment such as earplugs and earmuffs, helmets, face shields, safety goggles etc. is being provided to personnel engaged in high-risk areas. • A First Aid Centre is established to provide immediate medical aid to the workers and their family members. A 24x7 hour ambulance is in service at site to transport injured workers to nearby hospitals.
vi	Noise levels emanating from turbines shall be so controlled such that the noise in the work zone shall be	Noted and being complied.

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	limited to 85 dB (A) from source. For people working in high noise area, protective requisite personal protective equipment like ear plugs/ 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.	Equipment are designed as per the specifications for complying with the stipulation. In addition, Personal Protective Equipment are also being provided to personnel working in high noise areas. Examination of workers engaged in noisy areas has been conducted as stipulated. The workers of generator halls and other high noise areas are being provided with appropriate ear protection devices.
vii	Regular monitoring of ambient air ground level concentration of SO_2, NO_x, $PM_{2.5}$ & PM_{10} 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.	Four numbers of CAAQM Stations have been provided and locations of these CAAQMS were finalized in consultation with KSPCB. In addition, one of the AAQMS (18^{th} Cross AAQMS) is equipped with meteorological station for monitoring the weather parameters such as wind speed & direction, temperature, rel. humidity, rainfall etc. Regular monitoring of ambient air ground level concentration of SO_2, NOx and $PM_{2.5}$ & PM_{10} is being carried out through MoEF&CC approved laboratory and records are being maintained. Online data connectivity arrangements for CAAQMS data to CPCB/ KSPCB have been provided. Periodic report along with the monitored AAQ data is being submitted at regular interval to the Regional Office (SZ) of MOEF&CC at Bangalore and the compliance report is being updated on the website of the company.
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.	NTPC Kudgi is in its operation stage and therefore necessary facilities such as sanitation facilities, First Aid Center, ambulance, provision of drinking water, canteen etc. have been made for the labour force working within the Plant.
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 letters informing that the project has been accorded environmental clearance letter, informing that the project has	The information of Environmental Clearance was published in Two newspapers. 1. "Deccan Herald" on 31.01.2012 in English. 2. "Vijaya Karnataka" on 31.01.2012 in vernacular (Kannada) language.

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	been accorded environmental clearance and copies of clearance letters are available with the State Pollution Control Board/ Committee and may also be seen at website of the Ministry of Environment and Forests at http:/www.envfor.nic.in.	
x	A copy of the clearance letter shall be sent by the proponent to concerned Panchayat, Zila Parishad/ Municipal Corporation, urban local body and the local NGO, if any, from whom suggestions/ representations, if any, received while processing the proposal. The clearance letter shall also be put on the website of the company by the proponent.	NTPC vide letter dated 30.01.2012 has forwarded the copy of Environmental Clearance to the Tahsildar, Basavana Bagewadi Taluka. The Environmental Clearance is also uploaded on the NTPC website.
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 pollutants levels namely SPM, RSPM, ($PM_{2.5}$ & PM_{10}), SO_2, 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.	The updated Half Yearly Compliance (HYC) report of EC conditions is regularly being submitted to the Regional Office (SZ) of MOEF&CC at Bangalore and uploaded on the NTPC website also as per the stipulations. The pollutant levels are also being displayed at the Main Gate of NTPC Kudgi.
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.	Complied. The Environment Statement for financial year ending 31st March 2024 (FY 2023-24) in prescribed Form-V (online submission as well as in hard copy) has been submitted to KSPCB vide letter dated 20.09.2024.
xiii	The project proponent shall submit six monthly reports on the status of the implementation of the stipulated environmental safeguards to the Ministry of Environment & Forests, its Regional Office, Central Pollution	Complied. The half yearly compliance report is being regularly submitted to the concerned statutory authority.

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	Control Board and State Pollution Control Board. The project proponent shall upload the status of compliance of the environment 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, Ministry of Environment & Forests.	The latest six-monthly progress report for the period of April 2024 to September 2024 is submitted herewith.
xiv	Regional Office of the Ministry of Environment & Forests 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 upload the compliance status in their website and update the same from time to time at least six monthly basis. Criteria pollutants levels including NOx (from stack and ambient air) shall be displayed at the main gate of the power plant.	A complete set of documents including Environmental Impact Assessment Report and Environment Management Plan along with the additional information/ clarifications as submitted to MOEF&CC have been forwarded on 13.02.2012 to the Regional Office (SZ) of MOEF&CC at Bangalore.
xv	Separate funds should 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 should not be diverted for other purposes and year-wise expenditure should be reported to the Ministry.	The requisite funds for environmental mitigation measures have been included in the project cost. The financial provision stipulated towards environmental mitigation measures shall not be diverted for other purposes.
xvi	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 the plant.	The Regional Office, KSPCB has been informed regarding commercial power production from Unit-I, II and III vide letters dated 01.08.2017, 30.12.2017 and 14.09.2018 respectively.
xvii	Full cooperation should 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.	Noted and compliance is being ensured.

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5	The Ministry of Environment and Forests reserves the right to revoke the clearance if conditions stipulated are not implemented to the satisfaction of the Ministry. The Ministry may also impose additional environmental conditions or modify the existing ones, if necessary.	Noted.
6	The environmental clearance accorded shall be valid for a period of 5 years to start of operations by the power plant.	Noted.
7	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 under the provisions of Environmental (Protection) Act, 1986.	Noted.
8	In case of any deviation or alteration in the project proposed including coal transportation system from those submitted to this Ministry for clearance, a afresh 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.	Noted.
9	The above stipulations would be enforced among others under the Water (Prevention and Control Pollution) Act, 1947, the Air (Prevention and Control of Pollution) Act. 1981, the Environment (Protection) Act, 1986 and rules there under, Hazardous Wastes (Management, Handling & Trans boundary Movement) Rules, 2008 and its amendments, the Public Liability Insurance Act, 1991 and its amendments.	Noted.
Compliance status of conditions stipulated in amendment to Environmental Clearance issued by MoEF&CC vide Letter No. J-13012/65/2008-IA.II(T) dtd.11.08.2020		
1	The undersigned is directed to refer your online application No.IA/OR/THE/105399/2019 dated 14.5.2019, IA/MH/THE/105566/2019 dated 16.5.2019, IA/KA/THE/105615/2019 dated 16.5.2019, IA/MP/THE/105718/2019	-

S. NO.	STIPULATION	STATUS AS ON 30.09.2024
	dated 17.5.2019 and IA/MH/THE/105652/2019 dated 17.6.2019 regarding amendment of EC conditions pertaining to implementation of Corporate Social Responsibility (CSR) activities.	
4	The specific condition no. xxxiv of the EC (Kudgi TPP) dated 25.1.2012 is as follows: *"An amount of Rs.52.80 Crores shall be earmarked as one-time capital cost for CSR programme as committed by the project proponent. Subsequently, a recurring expenditure of Rs.10.6 Crores per annum till the life of the plant shall be earmarked as recurring expenditure for CSR activities. Details of the activities to be undertaken shall be submitted within six month along with road map for implementation."*	-
7	It has been noted that you have requested for aligning the conditions w.r.t. CSR activities inline with the Section 135 of the Companies Act, 2013. The proposal was appraised by the EAC (Thermal Power) in its meeting held on 28.5.2019 and the EAC recommended to align the existing conditions inline with the Companies Act, 2013. The EAC also recommended to report the amount of 2% on profits to be spent under CSR, and the implementation of activities thereof.	-
8	The Ministry has examined the matter. It has been noted that the CSR is in the domain of Ministry of Corporate Affairs under Companies Act, 2013. The stipulation of conditions pertaining to CSR by MoEF&CC will create ambiguity in multiple reporting and duplication.	-
9	In view of the above, **the Ministry hereby deletes the above-mentioned conditions related to CSR in the Environmental Clearance *dated 17.2.2014, 27.12.2010, 25.1.2012, 22.3.2013 and 30.12.2010 with immediate effect.***	Noted w.r.t. condition no. xxxiv stipulated vide Environmental clearance dated 25.01.2012 for Kudgi STPP.

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10	All other conditions mentioned in this Ministry's letter no.J-13012/65/2008-IA.II(T) dated 17.2.2014, J-13012/95/2008-IA.II(T) dated 27.12.2010, J-13012/06/2009-IA.II(T) dated 25.1.2012, J-13012/125/2009-IA.II(T) dated 22.3.2013, and J-13012/65/2009-IA.II(T) dated 30.12.2010, shall remain the same, as applicable.	Noted and compliance is being ensured.
Compliance status of conditions stipulated in amendment to Environmental Clearance issued by MoEF&CC vide Letter No. J-13012/06/2009-IA.II(T) dtd.04.07.2022.		
(i)	Increase plantation area to 33% in periphery of the plant boundary.	A total tree plantation of more than 3.25 Lakh consisting of 3 tiers is done with native species of plants in and around the plant and 50m width wherever feasible till date in an area of more than 350 acres as stipulated vide initial EC dated 25.12.2012 having survival rate of more than 90%. Since, the condition of 33% plantation area was not stipulated in the initial EC dated 25.12.2012, space has now been earmarked to increase plantation area to fulfill the shortfall in phased manner. NTPC Kudgi has also proactively taken up massive afforestation through KFD in forest land in four forest divisions i.e. Sagar, Hunsur, Mandya and Shivamogga by planting more than 5 Lakh saplings in an area of approx. 800 acres during FY 2016-17. During FY 2022-23, 2023-24 & 2024-25, about 20,000, 30,000 & 25,000 saplings resp. have also been planted in degraded Mamadapur reserved forest land in approx. 432 acres which consists of subsequent four-year maintenance.
(ii)	Improve the soil quality in consultation with reputed institute so that plants can survive in the region.	Greenbelt development/ afforestation activities at NTPC Kudgi are being carried out through Karnataka Forest Department (KFD), Govt. of Karnataka, who are considered to be the experts in afforestation works. KFD has managed to maintain the survival percentage of plantation above 90% against 80% which is stipulated vide condition no. xxxvi of EC dated 25.01.2012, by adopting various measures including improvement of soil quality.
(iii)	Three row plantation along the boundary of 390 acres of land proposed to be diverted for development of Industrial Park. The plantation work will be completed prior to diversion of land.	Noted and compliance will be ensured.

S. NO.	STIPULATION	STATUS AS ON 30.09.2024
(iv)	24X7 online Continuous monitoring system for ambient air quality parameters SOx, NOx and PM shall be established with connected server to CPCB and SPCB.	Noted and compliance will be ensured.
(v)	Other conditions of the EC letter dated 25.01.2012 shall remain unchanged.	Noted and compliance is being ensured.
5	All other terms and conditions stipulated in the environmental clearance dated 25th January, 2012 and its amendment dated 11th August, 2020 shall remain unchanged.	Noted and compliance is being ensured.

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ANNEX-1

Abstract of Ambient Air Quality in and around NTPC Kudgi
(Period Apr-2024 - Sep-2024)

Location		PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	NO_X ($\mu g/m^3$)	CO (mg/m^3)	Ozone ($\mu g/m^3$)	Pb ($\mu g/m^3$)	NH_3 ($\mu g/m^3$)	C_6H_6 ($\mu g/m^3$)	B(a)P (ng/m^3)	As (ng/m^3)	Ni (ng/m^3)
Kudgi Village	Min.	38.2	16.6	5.2	11.3	0.3	13.0	<0.01	<20	<0.5	<0.5	<0.5	<5.0
	Max.	59.4	24.7	12.3	18.4	0.6	16.4	<0.01	<20	<0.5	<0.5	<0.5	<5.0
	Avg.	47.6	19.9	7.4	13.8	0.5	14.8	-	-	-	-	-	-
Near Ash-pond	Min.	39.6	18.5	4.3	11.7	0.5	12.4	<0.01	<20	<0.5	<0.5	<0.5	<5.0
	Max.	48.8	21.5	10.5	14.9	0.9	15.9	<0.01	<20	<0.5	<0.5	<0.5	<5.0
	Avg.	44.1	19.6	6.2	13.5	0.7	14.3	-	-	-	-	-	-
Telgi Village	Min.	38.7	16.8	4.3	11.0	0.4	12.5	<0.01	<20	<0.5	<0.5	<0.5	<5.0
	Max.	47.2	24.2	14.0	13.8	0.9	14.9	<0.01	<20	<0.5	<0.5	<0.5	<5.0
	Avg.	42.8	19.0	7.3	12.6	0.6	13.4	-	-	-	-	-	-
Coal Handling Plant	Min.	37.9	16.6	5.1	12.0	0.2	13.5	<0.01	<20	<0.5	<0.5	<0.5	<5.0
	Max.	65.6	25.0	14.4	15.9	0.5	17.5	<0.01	<20	<0.5	<0.5	<0.5	<5.0
	Avg.	47.7	20.2	8.0	14.0	0.4	15.5	-	-	-	-	-	-
Muttagi Village	Min.	36.5	20.2	6.1	12.6	0.5	11.8	<0.01	<20	<0.5	<0.5	<0.5	<5.0
	Max.	48.6	26.9	10.2	17.7	0.8	18.0	<0.01	<20	<0.5	<0.5	<0.5	<5.0
	Avg.	43.2	23.1	7.8	14.8	0.6	14.5	-	-	-	-	-	-
NAAQM Limits	-	100	60	80	80	2.0	100	1.0	400	5.0	1.0	6.0	20

Abstract of Unit-wise Stack Emission Values of NTPC Kudgi (Period Apr-2024 - Sep-2024)

Parameters	Stack of	Unit-wise Stack Emission Values			Norms
		Minimum	Maximum	Average	
Particulate Matter (PM)	Unit-1	25.0	28.5	27.0	30*
	Unit-2	23.1	28.6	26.2	
	Unit-3	22.1	29.9	26.4	
Sulphur Dioxide (SO2)	Unit-1	1175.5	1542.3	1397.5	100*
	Unit-2	1404.9	1635.2	1498.8	
	Unit-3	1270.6	1506.1	1401.9	
Oxides of Nitrogen (NOx)	Unit-1	380.0	546.4	450.3	450* 100* 100*
	Unit-2	399.5	571.6	464.0	
	Unit-3	344.6	525.5	441.8	

Note: *All values in mg/Nm^3.*

** Standards are applicable from 31.12.2024 for NOx emission and 31.12.2026 for SO_2 emissions as per MoEF&CC Noitification dated 05.09.2022.*

Abstract of Ambient Noise Levels in and around NTPC Kudgi (Period Apr-2024 - Sep-2024)

Parameters	Unit	Station Ambient Noise Levels			Standards [dB(A)]
		Minimum	Maximum	Average	
Industrial					
Day	[dB(A)]	65.5	74.9	70.5	75
Night	[dB(A)]	57.2	66.4	62.9	70
Residential					
Day	[dB(A)]	65.8	71.6	68.8	55
Night	[dB(A)]	60.3	64.2	62.2	45
Silence					
Day	[dB(A)]	67.4	73.9	70.9	50
Night	[dB(A)]	52.6	54.4	53.3	40

ANNEX-1 (Contd..)

Abstract of Treated Effluent (Main Plant) Analysis (Period Apr-2024 - Sep-2024)

Parameters	Unit	Treated Effluent (Main Plant)			Standards
		Minimum	Maximum	Average	
pH at 25°C	-	8.2	8.3	8.2	5.5 - 9
Temperature	°C	2.1	2.9	2.6	-
Colour	Hazen	Colorless	Colorless	-	-
Odour	-	Odourless	Odourless	-	-
Conductivity at 25 °C	µS/cm	1486	2041	1660	-
Total Dissolved Solids	mg/l	1087	1164	1125	-
Total Suspended Solids	mg/l	27	41	33	200
Oil & Grease	mg/l	<4.0	<4.0	-	10
Phenolic Compound as as C_6H_5OH	mg/l	<1.0	<1.0	-	1.0
Biochemical Oxygen Demand at 27 °C for 3 days	mg/l	6.0	6.8	6.4	30
Chemical Oxygen demand	mg/l	47.9	81.5	61.2	250
Chloride as Cl-	mg/l	208.5	258.6	223.9	-
Sulphate as SO_4	mg/l	164.8	217.0	188.8	-
Zinc as Zn	mg/l	0.024	0.037	0.031	-
Fluoride as F	mg/l	0.57	0.69	0.62	2
Bio-assay test	-	90%	90%	-	90% survival of fish after 96 hours in 100% effluent.
Sodium Absorption Ratio	mg/l	1.02	1.96	1.27	-
Residual Sodium Carbonate	mg/l	1.08	1.42	1.23	-
Free Residual Chlorine	mg/l	<0.1	<0.1	-	1
Dissolved Phosphate as P	mg/l	1.13	1.25	1.20	5
Total Chromium as Cr	mg/l	<0.002	<0.002	-	2
Dissolved Oxygen as O_2	mg/l	7.6	8.4	7.9	-
Total Copper as Cu	mg/l	<0.03	<0.03	-	3
Total Iron as Fe	mg/l	<0.01	<0.01	-	3
Mercury as Hg	mg/l	<0.0005	<0.0005	-	0.01
Cadmium as Cd	mg/l	<0.002	<0.002	-	0.1
Lead as Pb	mg/l	<0.002	<0.002	-	0.1
Arsenic as As	mg/l	<0.005	<0.005	-	0.2
Total Nitrogen	mg/l	5.78	8.15	6.60	-
Total Phosphate	mg/l	2.35	4.20	2.87	-
Ammoniacal Nitrogen	mg/l	2.28	5.26	3.18	50
Sulphide	mg/l	<0.1	<0.1	-	2
Faecal Coliform	MPN/100ml	19	27	23	-

ANNEX-1 (Contd..)

Abstract of Ash Pond Effluent Analysis (Period Apr-2024 - Sep-2024)

Parameters	Unit	Ash Pond Effluent			Standards
		Minimum	Maximum	Average	
pH at 25 °C	-	8.12	8.24	8.18	6.5 - 8.5
Oil & Grease	mg/l	<4.0	<4.0	-	20
Total Suspended Solids	mg/l	16.74	28.65	21.33	100
Temperature	°C	26.20	30.65	28.25	-
Conductivity at 25 °C	µS/cm	1586.3	1993.4	1735.3	-
Total Dissolved Solids	mg/l	1184.26	1329.47	1276.84	-
Dissolved Phosphate as P	mg/l	<0.6	<0.6	-	-
Chloride as Cl-	mg/l	342.86	425.38	374.50	-
Sulphate as SO_4	mg/l	125.7	159.7	138.5	-
Mercury	mg/l	<0.0005	<0.0005	-	-
Arsenic	mg/l	0.012	0.024	0.016	-
Chromium	mg/l	<0.002	<0.002	-	-
Lead	mg/l	<0.002	<0.002	-	-

Abstract of Treated STP Effluent Analysis (Period Apr-2024 - Sep-2024)

Parameters	Unit	STP Effluent			Standards
		Minimum	Maximum	Average	
pH at 25 °C	-	7.71	7.85	7.81	6.5 - 9.0
Temperature	°C	2.3	3.1	2.7	-
Total Suspended Solids	mg/l	13.4	18.5	15.9	<20
Conductivity at 25 °C	µS/cm	162.8	226.4	182.7	-
Total Dissolved Solids	mg/l	116.4	132.2	122.1	-
Chloride as Cl-	mg/l	35.2	41.7	37.4	-
Sulphate as SO_4	mg/l	14.1	20.6	17.7	-
Sulphide as S_2-	mg/l	<0.01	<0.01	-	-
Phosphate as P	mg/l	0.56	0.67	0.61	-
Phenolic Compound as C_6H_5OH	mg/l	<1.0	<1.0	-	-
Ammoniacal Nitrogen as N	mg/l	0.54	0.65	0.60	5
Biochemical Oxygen Demand at 27 °C for 3 days	mg/l	6.27	7.46	7.02	<10
Chemical Oxygen demand	mg/l	17.3	30.8	25.9	50
Total Nitrogen as N	mg/l	6.40	7.45	7.03	-
Oil & Grease	mg/l	<1.0	<1.0	-	-
Faecal Coliform	MPN/100ml	22	27	24	<100

ANNEX-1 (Contd..)

Abstract of Surface Water Quality
(Period Apr-2024 - Sep-2024)

Parameters	Unit	Surface Water			Standards
		Minimum	Maximum	Average	
pH at 25 °C	-	7.2	7.4	7.3	6.5-8.5
Temperature	°C	26.5	30.6	28.3	-
Colour	Hazen	2.3	3.6	2.8	Max 300
Odour	-	Unobjectionable	Unobjectionable	Unobjectionable	-
Conductivity at 25 °C	µS/cm	302.32	391.86	369.83	-
Turbidity	NTU	<1.0	<1.0	-	-
Total Dissolved Solids	mg/l	240.95	264.89	251.67	Max 1500
Nitrate Nitrogen	mg/l	5.86	8.46	7.05	50
Nitrite Nitrogen	mg/l	<0.01	<0.01	-	-
Calcium as Ca	mg/l	27.39	41.86	35.87	-
Magnesium as Mg	mg/l	7.92	12.63	9.68	-
Biochemical Oxygen Demand at 27 °C for 3 days	mg/l	<2.0	<2.0	-	Max 3
Chemical Oxygen Demand	mg/l	<4.0	<4.0	-	-
Chloride as Cl-	mg/l	31.76	40.28	36.77	Max 600
Sulphate as SO_4	mg/l	37.19	45.20	41.67	Max 400
Zinc as Zn	mg/l	<0.01	<0.01	-	Max 15
Fluoride as F	mg/l	0.61	0.79	0.72	Max 1.5
Ammoniacal Nitrogen as N	mg/l	<0.1	<0.1	-	-
Sodium as Na	mg/l	21.64	28.71	25.30	-
Potassium as K	mg/l	<1.0	<1.0	-	-
Carbonate Alkalinity as $CaCO_3$	mg/l	Nil	Nil	-	-
Bicarbonate Alkalinity as $CaCO_3$	mg/l	118.24	130.86	126.17	-
Total Phosphate as P	mg/l	<0.6	<0.6	-	-
Total Chromium as Cr	mg/l	<0.002	<0.002	-	Max 0.05
Dissolved Oxygen as O_2	mg/l	3.8	6.5	5.4	Min 4
Total Copper as Cu	mg/l	<0.01	<0.01	-	1.5
Total Iron as Fe	mg/l	<0.01	<0.01	-	0.5
Mercury as Hg	mg/l	<0.0005	<0.0005	-	-
Cadmium as Cd	mg/l	<0.002	<0.002	-	Max 0.01
Lead as Pb	mg/l	<0.002	<0.002	-	Max 0.1
Nickel as Ni	mg/l	<0.002	<0.002	-	-
Arsenic as As	mg/l	<0.005	<0.005	-	Max 0.2
Boron as B	mg/l	0.024	0.039	0.032	-
Total Coliforms	MPN/100 ml	Absent	Absent	-	Max 5000
Faecal Coliforms	MPN/100 ml	<2	<2	-	-

ANNEX-1 (Contd..)

Abstract of Ground Water Quality
(Period Apr-2024 - Sep-2024)

Parameters	Unit	Ground Water			Standards
		Minimum	Maximum	Average	
pH at 25°C	-	7.13	7.78	7.43	6.5-8.5
Temperature	°C	25.40	30.79	28.58	-
Colour	Hazen	<1.0	3.61	2.98	5
Odour	-	Agreeable	Agreeable	-	Agreeable
Conductivity at 25°C	µS/cm	520.42	631.75	579.42	-
Total Dissolved Solids	mg/l	335.84	394.18	359.19	500
Nitrate Nitrogen	mg/l	2.66	7.21	4.91	45
Nitrite Nitrogen	mg/l	<0.02	<0.02	-	-
Orthophosphate as P	mg/l	0	0	0	-
Chemical Oxygen demand	mg/l	<4.0	<4.0	-	-
Sodium as Na	mg/l	26.81	45.12	35.82	-
Potassium as K	mg/l	<1.0	12.11	7.74	-
Calcium as Ca	mg/l	21.50	39.51	28.55	75
Magnesium as Mg	mg/l	7.35	15.31	10.61	30
Carbonate Alkalinity as $CaCO_3$	mg/l	Nil	Nil	-	-
Bicarbonate Alkalinity as $CaCO_3$	mg/l	147.20	240.63	187.66	-
Chloride as Cl-	mg/l	48.31	135.89	104.17	250
Sulphate as SO_4	mg/l	14.26	46.85	28.71	200
Percent Sodium	mg/l	29.57	41.25	36.45	-
Sodium Absorption Ratio	mg/l	0.52	1.35	0.96	-
Fluoride as F	mg/l	0.06	0.37	0.19	1
Boron as B	mg/l	<0.01	<0.01	-	0.7
Mercury as Hg	mg/l	<0.0005	<0.0005	-	0.001
Cadmium as Cd	mg/l	<0.002	<0.002	-	0.003
Lead as Pb	mg/l	<0.002	<0.002	-	0.01
Arsenic as As	mg/l	<0.005	<0.005	-	0.01
Zinc as Zn	mg/l	<0.01	<0.01	-	5
Chromium as Cr	mg/l	<0.002	<0.002	-	0.05
Nickel as Ni	mg/l	<0.002	<0.002	-	0.02
Iron as Fe	mg/l	<0.01	0.04	-	1
Total Coliform	MPN/100ml	Absent	Absent	-	Shall not be detectable in any 100ml sample
Faecal Coliform	MPN/100ml	<2	<2	-	-

ANNEX-1 (Contd..)

Bottom Ash Report

Vardan Envirolab LLP
Laboratory: Plot No. 82A, Sector - 5, IMT Manesar, Gurugram - 122051 (HR)
ISO 9001 | ISO 14001 | ISO 45001

Test Report

Sample Number:	VEL/PE/06	Report No.:	VEL/PE/2408300006
Name & Address of the Party:	NTPC Limited. 1046 Kudgi Super Thermal Power Project Basavana Bagewadi, Bijapur, Karnataka, Pin- 586121	Format No.:	7.8 F-03
		Party Reference No.:	4000323576-057-1019 Date : 29.12.2023
Sample Description:	Bottom Ash Sample	Reporting Date:	06/09/2024
Location:	--	Period of Analysis:	30/08/2024 - 06/09/2024
Sample Collected By:	VEL Representative	Receipt Date:	30/08/2024
Sampling and Analysis Protocol:	As Per STP	Sampling Date:	27/08/2024
Parameter Required:	As Per Work Order	Sampling Quantity:	2.0 Kg.
Preservation:	Temp. Sealed In Zipper Pouch	Sampling Type:	Grab

S. No.	Parameters	Test Method	Results	Units
1.	pH at 25°C	VEL/EN/STP/53, Issue No-1 Issue date 01/11/2023	7.29	--
2.	Chromium Hexa (Cr+6)	VEL/HW/STP/03, Issue No-1 Issue date 01/11/2023	*BLQ(**LOQ-0.1)	mg/Kg
3.	Cadmium	VEL/HW/STP/03, Issue No-1 Issue date 01/11/2023	*BLQ(**LOQ-0.1)	mg/Kg
4.	Lead	VEL/HW/STP/03, Issue No-1 Issue date 01/11/2023	4.81	mg/Kg
5.	Cobalt	VEL/HW/STP/03, Issue No-1 Issue date 01/11/2023	*BLQ(**LOQ-0.1)	mg/Kg
6.	Manganese	VEL/HW/STP/03, Issue No-1 Issue date 01/11/2023	50.97	mg/Kg
7.	Copper	VEL/HW/STP/03, Issue No-1 Issue date 01/11/2023	12.42	mg/Kg
8.	Zinc	VEL/HW/STP/03, Issue No-1 Issue date 01/11/2023	21.93	mg/Kg
9.	Nickel	VEL/HW/STP/03, Issue No-1 Issue date 01/11/2023	2.37	mg/Kg
10.	Arsenic	VEL/HW/STP/03, Issue No-1 Issue date 01/11/2023	0.89	mg/Kg
11.	Mercury	VEL/HW/STP/03, Issue No-1 Issue date 01/11/2023	*BLQ(**LOQ-0.1)	mg/Kg
12.	Sodium Oxide (as Na2O)	SOP, SP-83, Issue No. 01:2013	0.31	%
13.	Magnesium (as MgO)	SOP, SP-83, Issue No. 01:2013	0.62	%
14.	Alumina (as Al2O3)	IS:1727-1967	1.72	%
15.	Silica (as SiO2)	IS:1727-1967	56.18	%
16.	Phosphorus Pentaoxide	IS:1727-1967	0.62	%
17.	Sulphur Trioxide (SO3)	IS:1727-1967	0.81	%

Note:- *BLQ: Below Limit of Quantification, **LOQ: Limit of Quantification, STP: Standard Testing Procedure

Reviewed By

Authorised Signatory

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ISO 9001 | ISO 14001 | ISO 45001

Test Report

Sample Number: VEL/PE/06			Report No.: VEL/PE/2408300006	
S. No.	Parameters	Test Method	Results	Units
18.	Potassium Oxide (as K2O)	SOP, SP-83, Issue No. 01:2013	2.78	%
19.	Calcium Oxide (as CaO)	SOP, SP-83, Issue No. 01:2013	7.86	%
20.	Titanium Oxide	SOP, SP-83, Issue No. 01:2013	0.02	%
21.	Manganese Oxide	SOP, SP-83, Issue No. 01:2013	0.65	%
22.	Iron Oxide (as Fe2O3)	IS:1727-1967	2.36	%

Note:- *BLQ: Below Limit of Quantification, **LOQ: Limit of Quantification, STP: Standard Testing Procedure

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VARDAN ENVIROLAB LLP Technical Manager
Reviewed By

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Test Report

Sample Number:	VEL/PE/07	Report No.:	VEL/PE/2408300007
Name & Address of the Party:	NTPC Limited. 1046 Kudgi Super Thermal Power Project Basavana Bagewadi, Bijapur, Karnataka, Pin- 586121	Format No.: Party Reference No.:	7.8 F-03 4000323576-057-1019 Date : 29.12.2023
Sample Description:	Bottom Ash Sample	Reporting Date:	06/09/2024
Location:	--	Period of Analysis:	30/08/2024 - 06/09/2024
Sample Collected By:	VEL Representative	Receipt Date:	30/08/2024
Sampling and Analysis Protocol:	As Per STP	Sampling Date:	27/08/2024
Parameter Required:	As Per Work Order	Sampling Quantity:	2.0 Kg.
Preservation:	Temp. Sealed In Zipper Pouch	Sampling Type:	Grab

S. No.	Parameters	Test Method	Results	Units
1.	pH at 25°C	VEL/EN/STP/53, Issue No-1 Issue date 01/11/2023	7.06	--
2.	Chromium Hexa (Cr+6)	VEL/HW/STP/03, Issue No-1 Issue date 01/11/2023	*BLQ(**LOQ-0.1)	mg/Kg
3.	Cadmium	VEL/HW/STP/03, Issue No-1 Issue date 01/11/2023	*BLQ(**LOQ-0.1)	mg/Kg
4.	Lead	VEL/HW/STP/03, Issue No-1 Issue date 01/11/2023	*BLQ(**LOQ-0.1)	mg/Kg
5.	Cobalt	VEL/HW/STP/03, Issue No-1 Issue date 01/11/2023	*BLQ(**LOQ-0.1)	mg/Kg
6.	Manganese	VEL/HW/STP/03, Issue No-1 Issue date 01/11/2023	55.91	mg/Kg
7.	Copper	VEL/HW/STP/03, Issue No-1 Issue date 01/11/2023	6.91	mg/Kg
8.	Zinc	VEL/HW/STP/03, Issue No-1 Issue date 01/11/2023	29.83	mg/Kg
9.	Nickel	VEL/HW/STP/03, Issue No-1 Issue date 01/11/2023	3.56	mg/Kg
10.	Arsenic	VEL/HW/STP/03, Issue No-1 Issue date 01/11/2023	0.76	mg/Kg
11.	Mercury	VEL/HW/STP/03, Issue No-1 Issue date 01/11/2023	*BLQ(**LOQ-0.1)	mg/Kg
12.	Sodium Oxide (as Na2O)	SOP, SP-83, Issue No. 01:2013	0.33	%
13.	Magnesium (as MgO)	SOP, SP-83, Issue No. 01:2013	0.67	%
14.	Alumina (as Al2O3)	IS:1727-1967	2.12	%
15.	Silica (as SiO2)	IS:1727-1967	58.21	%
16.	Phosphorus Pentaoxide	IS:1727-1967	0.54	%
17.	Sulphur Trioxide (SO3)	IS:1727-1967	0.78	%

Note: *BLQ: Below Limit of Quantification, **LOQ: Limit of Quantification, STP: Standard Testing Procedure.

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Test Report

Sample Number: VEL/PE/07			Report No.: VEL/PE/2408300007	
S. No.	Parameters	Test Method	Results	Units
18.	Potassium Oxide (as K2O)	SOP, SP-83, Issue No. 01:2013	2.51	%
19.	Calcium Oxide (as CaO)	SOP, SP-83, Issue No. 01:2013	8.16	%
20.	Titanium Oxide	SOP, SP-83, Issue No. 01:2013	0.02	%
21.	Manganese Oxide	SOP, SP-83, Issue No. 01:2013	0.73	%
22.	Iron Oxide (as Fe2O3)	IS:1727-1967	2.46	%

Note:- *BLQ: Below Limit of Quantification, **LOQ: Limit of Quantification, STP: Standard Testing Procedure

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----------xXx----------

ANNEX-2

HYDRO-GEOLOGICAL STUDY FOR KUDGI SUPER THERMAL POWER PROJECT VIJAYAPURA, KARNATAKA



Submitted to

NTPC LTD., KUDGI SUPER THERMAL POWER STATION (3X800MW), KUDGI, KARNATAKA

By

NATIONAL INSTITUTE OF HYDROLOGY
(An ISO 9001:2015 Institute under DoWR, RD and GR)
Ministry of Jal Shakti, Govt. of India
Roorkee – 247667 (UTTARAKHAND)

NOVEMBER 2024

HYDRO-GEOLOGICAL STUDY FOR KUDGI SUPER THERMAL POWER PROJECT VIJAYAPURA, KARNATAKA

STUDY TEAM

Project Director: Dr. M.K. Goel, Director

Principal Investigator: Dr. Sudhir Kumar, Director (Retired)

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Submitted by

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ACKNOWLEDGMENTS

The Principal Investigator is thankful to M/s National Thermal Power Corporation for sponsoring the consultancy on "***Hydro-Geological Study for Kudgi Super Thermal Power Project Vijayapura, Karnataka***" to National Institute of Hydrology, Roorkee. Thanks are due to ***Sh. Amit More,*** Deputy General Manager, NTPC, Kudgi and all other Officials of NTPC, Kudgi for extending all the help and support in completion of this report.

We are thankful to **Dr. M.K. Goel**, Director, National Institute of Hydrology, Roorkee for providing all administrative and financial support for the successful completion of the project.

The principal investigator is thankful to all the scientists and staff of NIH, who have directly or indirectly helped us in completing the project.



Sudhir Kumar

(Director (Retired) & Project Investigator)

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EXECUTIVE SUMMARY

India is the world's third largest producer and fourth largest consumer of electricity with an installed capacity of 442 GW as of 31 March 2024. Thermal power plants (coal based) constitute 49.23% and renewable power plants (including hydel) constituted 43% of total installed capacity.

National Thermal Power Corporation (NTPC), a Maharatna company, is India's largest energy conglomerate total installed capacity of the company is 76,442 MW (including JVs) comprising of 52 NTPC Stations (27 Coal based stations, 7 gas/liquid fuel-based stations, 1 Hydro based station, 1 small hydro based station & 16 solar PV), 45 Joint Venture stations (9 coal based, 1 gas/ liquid fuel based, 8 Hydro, 1 Small hydro, 19 Solar PV & 4 Wind based).

Coal is the major source of fuel to run the thermal power plants and is obtained through both surface and subsurface mining. Environmental hazards are present during the burning of coal in the power plant and also with the disposal of ash. Environmental impacts may be permanent/temporary, beneficial/ harmful, repairable/ irreparable, and reversible/ irreversible.

Ash produced as a result of burning of coal is generally carried as water slurry to ash pond for disposal. The water environment may get contaminated with heavy metals released from ash pond decant into the local surface water bodies and groundwater. This is harmful to the human consumption as well to the fisheries and other aquatic biota in the water body.

Environmental Clearance (EC) was accorded by the MoEF&CC vide letter No. J-13012/06/2009-IA.II (T) dated 25.01.2012 to NTPC Kudgi stipulating conditions for compliance. EC Condition no.(xix) stipulates, *"Hydrogeology of the area shall be reviewed annually from an institute/organization of repute to assess the impact of surface water and ground water regime especially around ash dyke. In case any deterioration is observed specific mitigation measures shall be undertaken and reports/data of water quality monitored regularly and maintained shall be submitted to the Regional Office of the Ministry".*

Keeping in view the above, NTPC Kudgi has awarded "Hydro-geological Study at NTPC Kudgi" to National Institute of Hydrology (NIH), Roorkee. In view of the

above, assessment and review of Hydrogeology to assess the impact of NTPC Kudgi on surface water and ground regime especially around ash dyke needs to be undertaken. Accordingly, the study has been conducted to assess the impact of thermal power plant on the soil, surface as well as groundwater regime in the area and suggest remedial measures, if any.

The study involved hydrogeological review, field-based investigations and laboratory analysis of soil, surface water and groundwater in and around project area have been carried out. The groundwater monitoring network (6 piezometers) have been installed around the ash dyke area. Seasonal sampling of surface water and groundwater have been carried out around 12 km radius of the project area to ascertain the impact of power plant activities on soil, surface water and groundwater.

The surface water samples for water quality and isotopic analysis have been collected from 14 locations including the ash pond and raw water reservoir in the project area during the pre-monsoon and post-monsoon season of the year 2021 and 2022. Also, the groundwater samples from total 16 ground water level monitoring wells (includes Open wells, Borewells) and 6 newly constructed piezometers were collected for groundwater quality and isotopic analysis during the pre-monsoon and post-monsoon season of the year 2021 and 2022. The water quality of the collected water samples were carried out for its general physical parameters (i.e. Temperature, EC, pH, TDS, Alkalinity, Hardness, DO, BOD, COD), major ions (Major Cations: Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} and NH^{4+} and the major anions: CO_3^{2-}/HCO_{3-}, Cl^{-}, F^{-}, NO^{3-}, SO_4^{2-}) and heavy metals (i.e., As, Cd, Cr, Hg, Pb and Zn). The results of the surface water and groundwater quality indicates that the chemical constituents in water sources of the area are well within the permissible limits prescribed by BIS (2012) for various uses of water including drinking and other domestic supplies.

A total of 10 samples of soils from 3 different depths (i.e., 5 cm (surface), 30 cm and 60 cm) were also collected for soil quality analysis (i.e. heavy metal concentrations in soils) in the project area. The analysis of soil samples collected from three depths indicates that there is no contamination of soils in the study area.

The ground water levels were measured using ground water level indicator in 20 monitoring wells during pre-monsoon and post-monsoon season of the year 2021 and 2022 and also groundwater level measured in the 6 newly constructed piezometers during the post-monsoon season of the year 2022. The depth to water table during pre-monsoon period varies from 3.31 to 11.1 m bgl and 0.75 to 7.63 m bgl during post-monsoon period. During post-monsoon period, water level shows a rise (>2 m) due to replenishment of aquifer by monsoon precipitation. DGPS survey was also carried out in the 26 wells to locate groundwater levels with respect to above mean sea level to understand groundwater flow direction in the study area. The results indicate that the ground water table in the area is slopping towards south and south-west. Thus, the flow of groundwater, in general, is towards Almati Dam located in South direction.

The isotopic investigations of the Surface water and groundwater interactions have been carried out using isotopic investigation to ascertain the interaction of ash pond water with groundwater. The isotopic signatures of groundwater were identified by collecting 16 samples from open well, tube wells and hand pumps and surface water samples (i.e., ponds) during the year 2021 and 2022. Most of the ash pond water shows high evaporative enrichment. The signature of high evaporative enrichment is not visible in the groundwater, which indicates that there is no seepage of ashpond water into groundwater. Therefore, it is concluded that the ashpond water is not contaminating groundwater through seepage. It needs to be mentioned that NTPC Kudgi has Zero Liquid discharge (ZLD) scheme therefore the ashpond water will not be discharged to any nearby water body. Ashpond water is being recycled by the NTPC for the purpose of preparing ash slurry, lagoon water is not used for drinking or domestic use.

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1. INTRODUCTION

1.1 Background

National Thermal Power Corporation (NTPC) Limited was set up by Govt. of India in November, 1975 with the objective of planning, promoting and organizing integrated development of thermal power in the country. In 1997 NTPC was conferred "Navratna" status by Govt. of India and in 2010, it became the first public sector company to be granted "Maharatna" status by Govt. of India. NTPC is now emerging as a well-diversified company on its way of becoming an Integrated Power Major, having entered into hydropower, coalmining, power trading, equipment manufacturing and power distribution business. Until September 2024, installed capacity of NTPC is 76,442 MW (including 17,274 MW through JVs) comprising of 52 NTPC Stations (27 Coal based stations, 7 gas/liquid fuel-based stations, 1 Hydro based station, 1 small hydro based station & 16 solar PV), 45 Joint Venture stations (9 coal based, 1 gas/liquid fuel based, 8 Hydro, 1 Small hydro, 19 Solar PV & 4 Wind based).

Kudgi Super Thermal Power Project of NTPC Ltd having capacity of 2400MW (3x800MW) is situated near Kudgi Village, Basavana Bagewadi taluk, Vijayapura district of Karnataka state. The source of water for the project is Almatti dam, built on Krishna River, located at a distance of approx. 18 km. The water requirement of Stage-I 3x800MW is estimated 7380 cum/hr. The consumptive water requirement for 4000MW (ultimate capacity) project shall be about 160 cusecs (5.2 TMC ft). Govt of Karnataka vide GO dated 30-01-2009 has allotted 5.2 TMC (160 cusecs) of water from Karnataka's share for industrial quota from Almatti dam subjected to creation of in-plant reservoir as per the industrial norms. The high concentration slurry disposal system (HCSD) has been installed for disposal of un-utilized fly ash and conventional wet slurry disposal system for disposal of bottom Ash with Ash Water Recirculation System (AWRS) for optimization of freshwater make-up. Environmental Clearance (EC) was accorded by the MoEF&CC vide letter No. J-13012/06/2009-IA.II (T) dated 25.01.2012 stipulating conditions to be complied by NTPC. EC Condition no.(xix) stipulates, *"Hydrogeology of the area shall be reviewed annually from an institute/organization of repute to assess the impact of surface water and ground regime especially around ash dyke. In case*

any deterioration is observed specific mitigation measures shall be undertaken and reports/data of water quality monitored regularly and maintained shall be submitted to the Regional Office of the Ministry.".

Keeping in view the above, NTPC Kudgi has awarded "Hydro-geological Study at NTPC Kudgi" to National Institute of Hydrology (NIH), Roorkee. In view of the above, assessment and review of Hydrogeology to assess the impact of NTPC Kudgi on surface water and ground regime especially around ash dyke needs to be undertaken.

1.2 Objective

The main objectives envisaged for the present consultancy study are as follows:

i) To assess and review the impact of Kudgi STPP Stage-I (3x800MW) on soil, surface water and groundwater regime especially around ash dyke.
ii) To suggest mitigation measures for remediation of surface water and ground water regime, if any.

1.3 Scope of The Study

The geographical extent of study area comprises of an area within 12 km from the periphery of the project components like Main Plant, Ash disposal area and Township. In addition, the source of water and location of intake point, type of intake structures (barrage, dam. Intake well, intake channel etc.) shall also be covered for the study, even if located beyond 12 km and significant for identification of the impact due to NTPC Kudgi. Further, any significant surface or ground water body located within 10-15 km which is likely to influence the project/get influenced from the project shall also be covered. To achieve the objectives, scope of work includes:

(A) Literature Review

The detailed literature for the documents/reports already available for the study area with various agencies such as Geological Survey of India, State Department of Geology and Mining, Central and State Water Boards, State Water Resources/Irrigation departments, Central Water Commission, India Meteorological Department etc. Based on the review of the literature available,

detailed plan for the study covering all the objectives shall be prepared.

(B) Field Studies

I) Hydro-geological investigations

i) Preparation of groundwater flow direction map in pre-monsoon and post-monsoon periods,

ii) Analysis of soil chemical properties, like EC, pH, major ions (Na, K, Ca, Mg, Fe, CO_3, HCO_3, Cl, SO_4, NO_3, F^-, and PO_4), and Heavy metals (Cd, Zn, Hg, As, Cr, Pb) at 10 selected locations at surface, 30 cm and 60 cm depth.

II). Surface water quality monitoring around the Ash-pond

i) Water quality parameters like, pH, EC, DO, BOD, COD, Major cations (Na, K, Ca, Mg, and Fe), major anions (CO_3, HCO_3, Cl, SO_4, NO_3, F-, and PO_4), and Heavy metals (Cd, Zn, Hg, As, Cr, Pb) of 12 water bodies (streams and ponds) near the Ash-pond and 4 samples from Ash-ponds during Pre and Post monsoon seasons.

III). Design of groundwater monitoring network around the Ash-pond area to check leachability from ash pond

i) Design of the groundwater level and quality observation network.

ii) Construction of 6 (Six) piezometers around the Ash-pond, particularly in the groundwater flow direction.

iii) Groundwater water quality parameters like, pH, EC, TDS, DO, Major cations (Na, K, Ca, Mg, and Fe), major anions (CO_3, HCO_3, Cl, SO_4, NO_3, F, and PO_4), and heavy metals (Cd, Zn, Hg, As, Cr, Pb) during Pre and Post monsoon seasons at 16 locations.

IV) Isotopic investigations to understand the ground water interaction with the ash pond area

i) Collection of samples from groundwater, surface water and, ash pond water (total 16 water samples) during pre and post monsoon seasons.

ii) Isotopic analysis (δD and $\delta^{18}O$) for finding the interaction of ash pond water with groundwater, if any.

2. METHODOLOGY

The methodology to be adopted for achieving various objectives and scope elements of the study is given in brief in **Table 1.**

Table 1: Methodology vis-a-vis objective/scope of the study

OBJECTIVE/ SCOPE	METHODOLOGY
A) LITERATURE REVIEW	
Review of available literature	Available reports of various agencies such as Geological Survey of India, State Department of Geology and Mining, Central and State Water Boards, State Water Resources/ Irrigation departments, Central Water Commission, India Meteorological Department etc. pertaining to the study area are reviewed.
B) FIELD STUDIES	
I. Hydrogeological investigations	
i) Preparation of groundwater flow direction map in pre-monsoon and post-monsoon periods	Field measurements were carried out to measure the ground water levels. Historical data of ground water levels were also collected and analyzed. GPS survey was carried out to determine the elevation of the groundwater sampling locations. The collected data was converted into groundwater elevation using the GPS data. Based on the groundwater elevation data, ground water contour map were prepared, to determine the groundwater flow direction. The analysis was carried out for both pre and post monsoon
ii) Analysis of soil chemical properties, like EC, pH, major ions (Na, K, Ca, Mg, Fe, CO_3, HCO_3, Cl, SO_4, NO_3, F-, and PO_4), and Heavy	Ten sampling locations were chosen to represent the area characteristics based on geology/land use. Physico-chemical parameters of soil were

metals (Cd, Zn, Hg, As, Cr, Pb) at 10 selected locations at surface, 30 cm and 60 cm depth.	determined as per IS-2720. Analysis for Heavy metals were carried out using ICP-OES.
II) Surface water quality monitoring around the Ash-pond	
Water quality parameters like, pH, EC, DO, BOD, COD, Major cations (Na, K, Ca, Mg, and Fe), major anions (CO_3, HCO_3, Cl, SO_4, NO_3, F^- and PO_4), and Heavy metals (Cd, Zn, Hg, As, Cr, Pb) of 12 water bodies (streams and ponds) near the Ash-pond and 4 samples from Ash-ponds during Pre and Post monsoon seasons	Surface water samples were collected from 10 water bodies (streams and nallas) and 4 samples from Ash Pond. Physical parameters such as EC, DO & pH were collected in-situ in the field using portable field instruments like water EC/pH meter, quality Sonde. The laboratory analysis of the water samples was carried out at National Institute of Hydrology, Roorkee. Standard methods following APHA guidelines were used for measurement of water quality parameters. In general, Electrometric method, Ion Chromatography, Spectroscopy, etc. shall be used for the analysis. Analysis was carried out for both pre and post monsoon
III) Design of groundwater monitoring network around the Ash-pond area to check leachability from ash pond	
i) Design of the groundwater level and quality observation network.	The monitoring network was developed based on the possible impact of the thermal plant on the ground water based on the ground water flow direction (ground water contour map), analysis of ground water level variation and analysis of ground water quality data
ii) Construction of 06 piezometers around the Ash-pond, particularly in the groundwater flow direction	Using standard field practice

IV) Groundwater quality monitoring	
Water quality parameters like, pH, EC, TDS, DO, Major cations (Na, K, Ca, Mg, and Fe), major anions (CO_3, HCO_3, Cl, SO_4, NO_3, F-, and PO_4), and heavy metals (Cd, Zn, Hg, As, Cr, Pb) during Pre and Post monsoon seasons at 16 locations (including 6 piezometers and 10 existing hand pumps and/or bore wells).	Ground water samples were collected from 22 locations from hand pumps and/or bore wells including 6 newly constructed piezometers. EC, DO & pH shall be collected in-situ in the field using portable field instruments like water EC/pH meter, quality Sonde. The laboratory analysis of the samples was carried out at the NIH, Roorkee. Standard methods following APHA guidelines shall be used for measurement of water quality parameters. Analysis shall be carried out for both pre and post monsoon
V) Isotopic investigations to understand the ground water interaction with the ash pond area	
i) Collection of samples from groundwater, surface water and, ash pond water (Total 48 water samples) during pre and post monsoon seasons. ii) Isotopic analysis (δD and $\delta^{18}O$) for finding the interaction of ashpond water with groundwater, if any.	Groundwater, surface water and ash water samples were collected from different sources such as hand pumps, tube wells, open wells, pond, reservoir and rivers for isotopic characterisation (δ^2H, $\delta^{18}O$) in 20 ml pre cleaned Polypropylene bottles. The water samples were analysed for δ^2H and $\delta^{18}O$ in the Stable Isotope Laboratory of the NIH, Roorkee using Continuous Flow Isotope Ratio Mass Spectrometer (CF-IRMS) and Dual Inlet Isotope Ratio Mass Spectrometer.
C) TO ASSESS AND REVIEW THE IMPACT OF STPP	
To assess and review the impact of power plant on soil, surface water and ground water regime (especially around ash dyke).	Based on the analysis and interpretation of the water quality data of soil, surface water and ground water & modelling studies
D) MITIGATION MEASURES, IF ANY	
To suggest mitigation measures	Mitigation measures for remediation of

for remediation of surface water and ground water regime, if any.	surface water and ground water regime have been suggested based on the likely impact of the thermal power plant on the quality and quantity regime of these water bodies

Table 2: Analytical methods and equipment used in the study

S.N.	Parameter	Method	Equipment
General Parameters			
1.	pH	Electrometric	pH Meter (Hach made)
2.	Conductivity	Electrometric	Conductivity Meter (Hach made)
3.	Total Dissolved Solids (TDS)	Electrometric	Conductivity/TDS Meter
4.	Dissolved Oxygen (DO)	Modified Winkler's Method	-
5.	Biological Oxygen Demand (BOD)	Winkler modified, Titration	-
6.	Chemical Oxygen Demand (COD)	Open Reflux Method	-
7.	Alkalinity	Titration by H2SO4	-
8.	Hardness	Titration by EDTA	-
Major Ions			
9.	**Cations:** Na, K, Ca, Mg, and Fe **Anions:** CO_3, HCO_3, Cl, SO_4, NO_3, F^-, and PO_4	Ion Chromatography	Ion Chromatograph
Heavy Metals			
10.	Cd, Zn, Hg, As, Cr, Pb	Absorption spectrometry	Atomic Absorption Spectrometer

3. STUDY AREA

3.1 Geographical Settings

The proposed site is located in village Kudgi of Basavana Bagewadi taluk, Vijayapura district, Karnataka. Project site is located at a distance of about 200 km from Hubli and about 220 km from Belgaum, and between latitudes 16029' N to 16032' N and longitudes 75047'30" E to 75050'00" E (***Figure 1***).

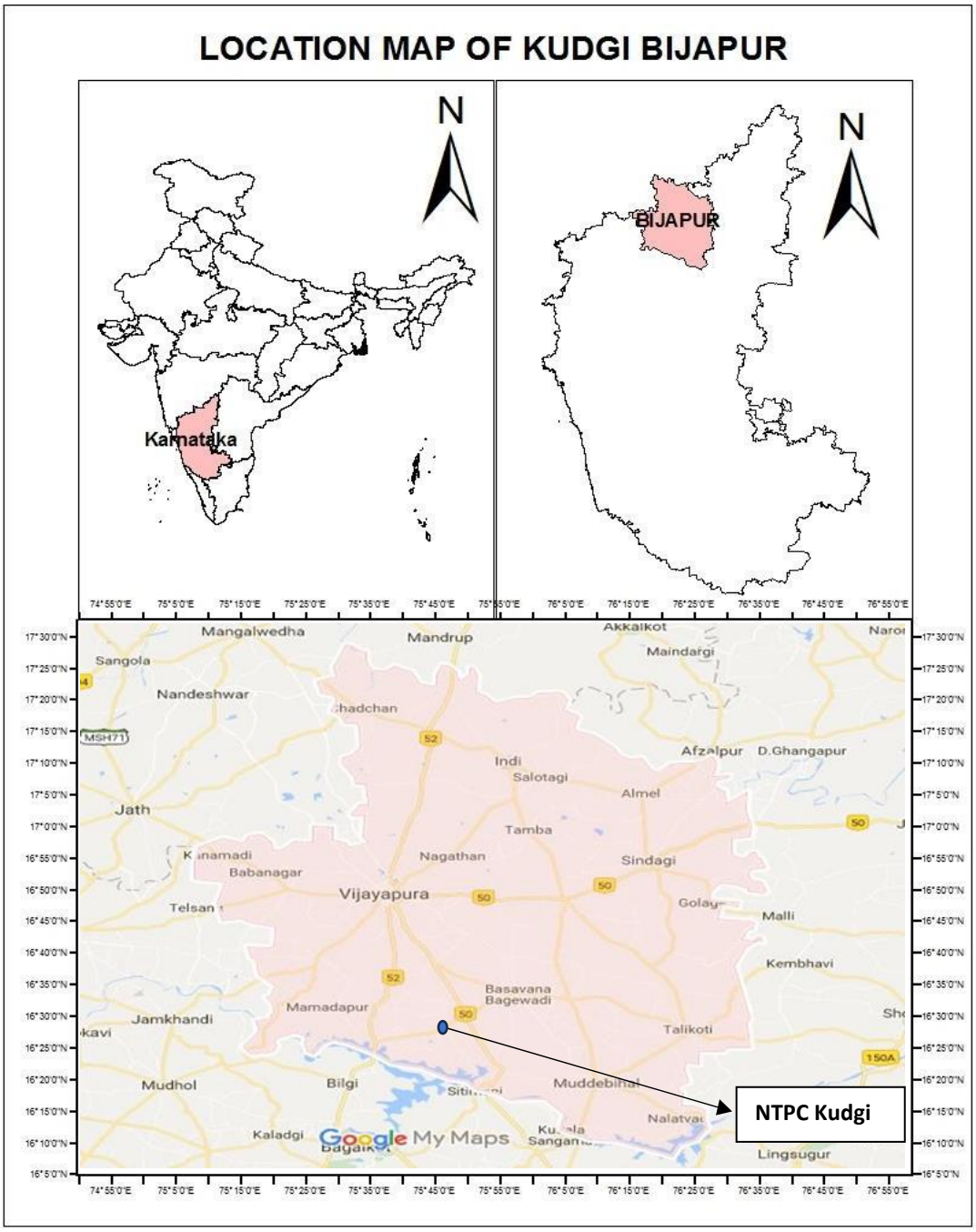


Figure 1: Location Map of Kudgi STPP

Kudgi is well connected to the major cities of Karnataka by Road and Rail Network. National Highway (NH-50) connecting Solapur and Chitradurga is passing at a distance of about 5 km. Cities near are Vijayapura and Bagalkot (40 km). The nearest rail line on Kudgi – Vijayapura passes about 0.5 km away from project site. The nearest airport is located at Hubli and have approximate distance 173 Km from proposed site. The study area covers a radius of 12 km from the site of the plant.

3.2 Climate

The district experiences semi-arid climate. Summers are extremely hot and moderate winter climate is experienced. Distribution of rainfall is unpredictable and inadequate in space and time, causing incidence of drought. The district experiences a temperature varies between 20°C and 42°C (***Figure 2***).

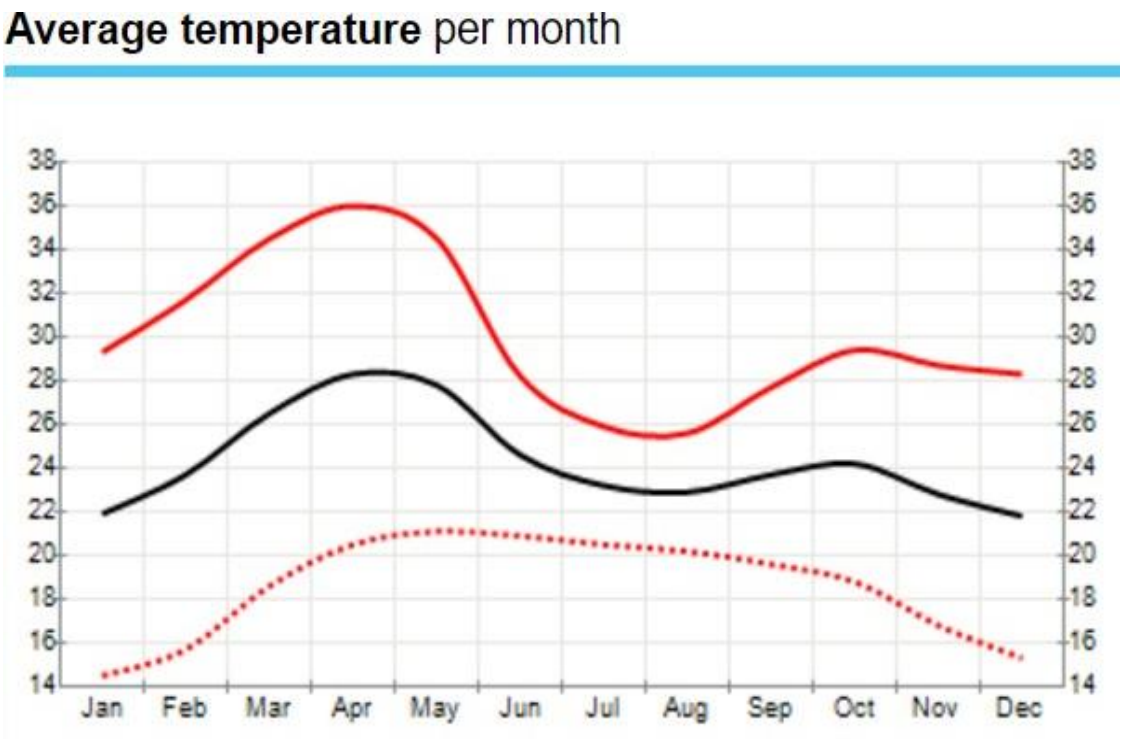


Figure 2: Climate chart of Vijayapura, Karnataka

The temperature begins to rise by the end of February, till the month May, Coldest months are December and January. The year is divided into summer season from March to May, monsoon season from June to September, post-monsoon season from October to November and winter is from December to February. The highest monthly rainfall recorded is 157 mm in September and

the lowest is 3mm in the month of January (***Figure 3***). The district receives an average annual rainfall of 578 mm. The normal rainfall of the district is 578 mm and the normal rainy days are 39 in a year.

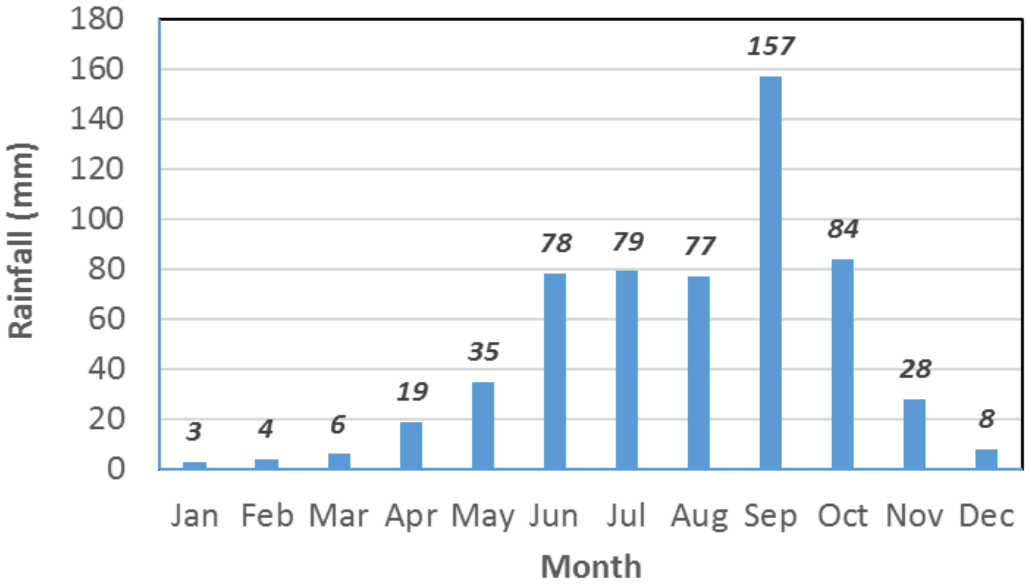


Figure 3: Normal monthly rainfall in Vijayapura district

(Source: http://raitamitra.kar.nic.in/agriprofile/rainfall.htm)

3.3 Physiography

The study area has an undulating topography mostly covered with Deccan Trap flows forming elevated grounds and at places covered by black cotton soil. The highest elevation is 603 m above mean sea level (amsl) near Kudgi railway station and the lowest elevation is 560 m is at Hire halla nala-road culvert in the south eastern part (16°30'23"N:75°51'15"E).

The area has four physiographic units: residual hills, pediments, pediplains and valleys. The entire district is categorized as Deccan Pediplain. The ground altitude varies from 470 to 650 m amsl. Topography is flat, gently sloping forming broad valleys and flat-topped hills. The northern belt is a succession of low rolling uplands devoid of vegetation.

3.4 Soils

The district is occupied by three types of soils, mostly in situ in nature viz. Black soils, Red sandy soils and mixed soils. Black soils derived from basaltic bedrock. These soils in upland areas are shallower and are deeper in valley

portions. The Don River valley has plains and consisting of rich tracks of deep black cotton soils stretching from west to east in the central part of the district. The infiltration characteristics are poor to moderate. The constant rate of infiltration varies from 0.75 to 2.5 cm/hr in the plains of Don River valley in central part of the district. These soils are alkaline in nature, low in potassium and nitrogen. Black cotton soils with high clay and humus content in low-lying areas. They have high moisture holding capacity and on drying up these soils develop open cracks. Red sandy soils derived from granites, gneisses and sandstones, are found in southern part of the district, with infiltration rates ranging from 2.6 to 3.8 cm/hr. mixed soils are derived from the fringe areas of Deccan traps, granites, gneisses, limestones and sandstones in Muddebial and Basavana Bagewadi taluks of Vijayapura district. These are dark greyish brown and dark brown to dark reddish brown in colour. Their texture varies from loam to clay. The infiltration characteristics of these soils are moderate to good in nature.

The soils are moderately erodible, excessively drained, stony and gravelly in nature. These soils are of shallow depth with medium nutrient status and are slightly acidic to neutral in reaction. They are low in organic matter content and have poor water retention capacity. These soils are unsuitable for normal crop husbandry. However, they may be utilised for forestry, pasture development and growing grasses. The soil is likely to be bearing non corrosive character. These soils occur of level to gently undulating terrain.

3.5 Geology

Regionally, the area lies within Deccan Trap volcanic terrain of Cretaceous to Eocene age. The basaltic flows are of 'aa' type with a characteristic 3-tier structure with a basal clinker, a middle massive and upper vesicular zone representing individual flows. In general, six flows have been delineated in the area numbering with thickness varying between 15 m to 45 m (Balasubramanian, 1983). The flows have a horizontal to sub horizontal disposition. The contact zone between the individual flows is marked by the presence of one or more features viz., 'Red bole', brecciated and fragmentary unit of the top part of the underlying flow, secondary zeolite, quartz and calcite.

The flows have geo-morphological expression marked by distinct slope-breaks. Laterite is reported to be present above 620 m level with some exception of its presence at the contact between Flows 3 and 4. At places the flow 5 is reported to have been completely lateralized. The flows in general show south to southwest gradient. Geological map of the area is shown in ***Figure 4***.

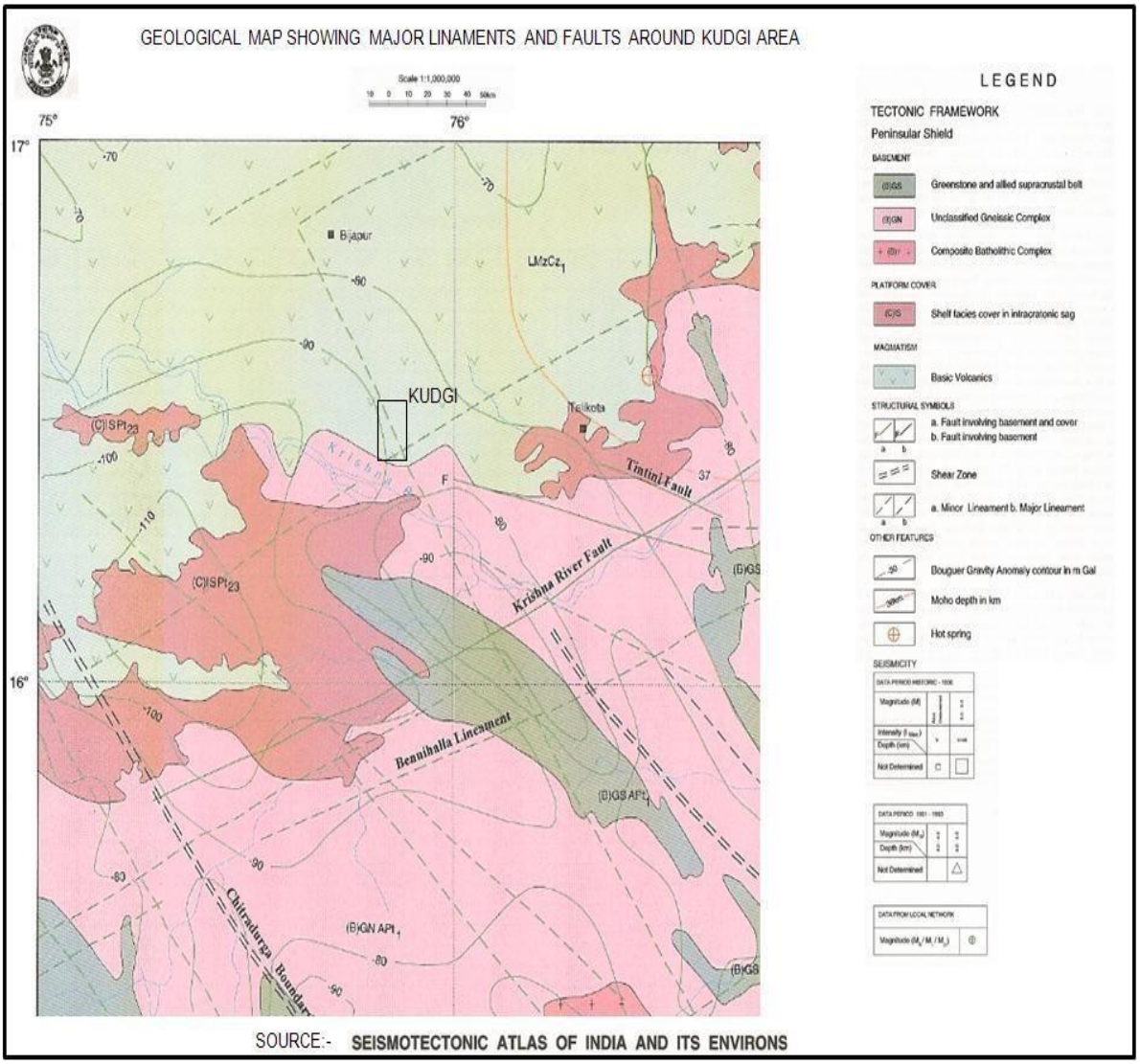


Figure 4: Geological map of the Kudgi and surrounding area

The Granites and Gneisses of Peninsular Gneissic Complex cover South and Southeastern part of Muddebial taluk, which forms the oldest formations in the district. They are seen as big, rounded, massive boulders and isolated hills. The granitic rocks are pink in colour, coarse grained with well-developed joints and are intruded by pegmatites, quartz veins and basic dolerite dykes. The depth of weathering in the district varies from 1 to 15 m. The Lower Bhima Series comprises of flaggy limestone and shales, orthoquartzites and

sandstones are overlying crystalline rocks, which are separated by Basal Conglomerates.

A conspicuous fault along the Krishna River course trending NE-SW is located at about 25 km south of the project area. Another two faults trending WNW-ESE and NW-SE (Tintini Fault) traverse the gneisses outside the Deccan Traps in the southern part, intersecting the Krishna River Fault. Two lineaments trending ENE-WSW and NNE-SSW traverse the Deccan traps close to the project area (GSI, 2001). Incidentally, the area falls under seismic zone II (Low Damage Risk Zone) as per Indian Seismological Institute (Seismic Zonation map of India, 2002).

3.6 Hydrogeology

The major part of the district is occupied by the basaltic flows of Deccan traps, which constitutes the main rock formation in the north and central part of the district. These basaltic flows belong to the sequence of Middle Deccan Traps of Upper Cretaceous to Lower Eocene Age. The formations of Granites and Gneisses of Peninsular Gneissic Complex and Bhima Series cover a small portion in south and southeastern part of the district.

The groundwater occurs under water table and semi-confined to confined conditions in weathered, fracture zones in basalts. The Deccan traps/basalts are the major litho-unit of the Vijayapura District. The basaltic lava flows are mostly horizontal to gently dipping. The contrasting water bearing properties of different lava flows control groundwater occurrence in them. The topography, nature and the extent of weathering, jointing and fracture pattern, thickness, depth of occurrence of vesicular basalt and occurrence of red-bole bed are the important factors, which play a major role in the occurrence and the movement of ground water in these rocks. Deccan basalts usually have medium to low permeability depending upon the presence of primary and secondary porosity. The weathered residuum serves as an effective groundwater repository in this region.

4 FIELD INVESTIGATIONS

Field visits to Kudgi Super Thermal Power Plant area and its adjoining area in 12 km radius were made during the period (March 2021- December 2022). Details of the field visits and the tasks carried out during the visits are given below in ***Table 3***.

Table 3: Tasks carried out during the field visits

S.N.	From	To	Day	Work
1	03.03.2021	04.03.2021	2 days	Reconnaissance survey and discussion with NTPC authorities and to identify the wells for collecting water samples
2	05.07.2021	05.07.2021	1 day	Collection of water samples and measuring depth to water levels in and around NTPC, Kudgi plant for quality analysis
3	06.01.2022	07.01.2022	2 days	Collection of post monsoon water samples and measuring depth to water levels
4	16.06.2022	17.06.2022	2 days	Collection of pre monsoon water samples and measuring depth to water levels in and around NTPC, Kudgi plant for quality analysis
5	06.09.2022	06.09.2022	1 day	Site selection for construction of 6 No's piezometers in and around Ash Pond sites.
6	01.12.2022	02.12.2022	2 days	Construction of 6 No's of piezometers in and around Ash Pond sites Collection of post-monsoon season water samples and depth to water level measurement, and soil samples collection.

4.1 Identification of Monitoring Wells

Water-level monitoring program depends on the network of observation wells selected expressly for the collection of water-level data in one or more specified aquifers. Ideally, the wells chosen for an observation well network will provide data representative of various topographic, geologic, climatic, and land-use environments. Decisions about the areal distribution and depth of completion

of observation wells also should consider the physical boundaries and geologic complexity of aquifers under study.

Total 26 water level monitoring wells (includes Open wells, Borewells and newly constructed piezometers) were identified, well distributed over the 12 km radius area. The coordinates, i.e., latitude, longitude and altitude of the ground surface of the monitoring wells was measured using the Global Positioning System (GPS).

4.2 Monitoring of Groundwater Levels

Water-level measurements from observation wells are the principal source of information about the hydrologic stresses acting on aquifers and how these stresses affect groundwater recharge, storage, and discharge. Water-level data measurement greatly depends on the intended use of the data. Depth to groundwater in an area indicates the requirement of drilling of water wells and the pump to be used to extract the groundwater, whereas, the water level distribution indicates the groundwater flow direction. In the present study, both the depth to groundwater and water level distribution in the 12 km radius area was measured using ground water level indicator.

4.3 Collection of Water Samples

The water and soil samples in the periphery of 12 km from different sources in and around the NTPC Kudgi site were collected.

The water samples were collected for Bore well and Open well (***Figure 5***). A total number of three samples were taken from each site for chemical analysis (heavy metals, cation and anion) and also collected for isotope analysis.

The water samples are collected in standard plastic wares. The water samples are collected directly from the sites, filtered and preserved as per standard procedures (BIS, 1988). In order to avoid any precipitation of trace elements, the samples collected for cations were acidified using HNO_3 to pH≈2 in the field whereas unfiltered samples were collected for analysis of anions (APHA, 2003). The details of the sites covered during the field visit are summarized and presented in the ***Table 3***.

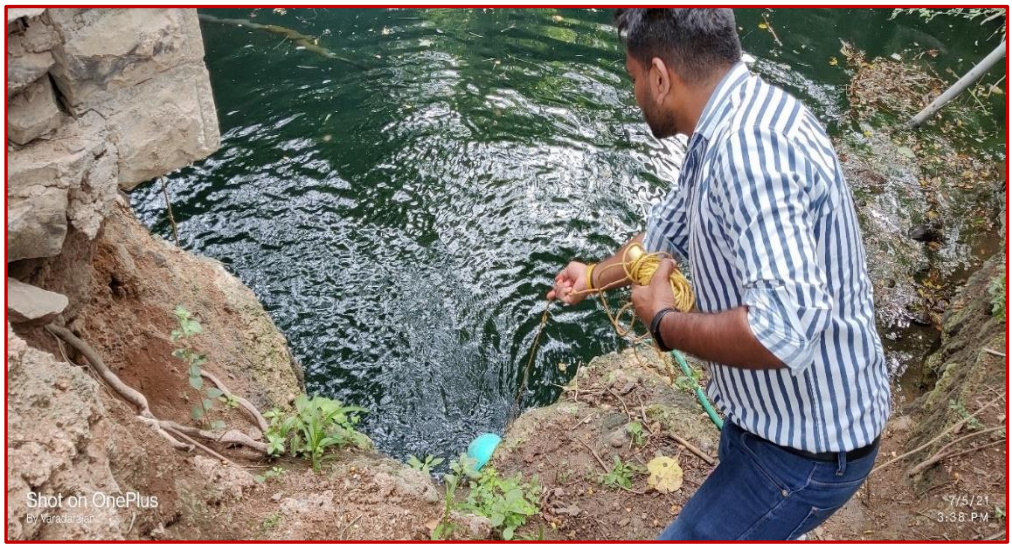


Figure 5: Collection of Water Sample from Open Well.

4.4 Collection of Water Samples

A systematic random sampling was done to collect the soil samples from the study area. Soil samples were collected from Soil horizon "A" after removing litter from the top surface layer and weight about 1 kg each from different agricultural fields where labelling and related information for each sample was recorded. Good quality; air tight plastic bags were used for sample collection and safe transfer to the laboratory for analysis. A total of 10 samples of soil were collected from the field during 2022.

5 HYDROGEOLOGICAL INVESTIGATIONS

The major part of the Vijayapura district is occupied by the basaltic flows of Deccan Traps. These basaltic flows belong to the sequence of Middle Deccan Traps of Upper Cretaceous to Lower Eocene Age. The formations of Granites and Gneisses of Peninsular Gneissic Complex and Bhima Series cover a small portion in south and southeastern part of the district.

The Granites and Gneisses of Peninsular Gneissic Complex cover south and southeastern part of Muddebial taluk, which forms the oldest formations in the district. They are seen as big, rounded, massive boulders and isolated hills.

The granitic rocks are pink in colour, coarse grained with well-developed joints and are intruded by pegmatites, quartz veins and basic dolerite dykes. The depth of weathering in the district varies from 1 to 15 m.

The Deccan traps / basalts are the major litho-unit of the Vijayapura taluk. The basaltic lava flows are mostly horizontal to gently dipping. The contrasting water bearing properties of different lava flows control groundwater occurrence in them. The topography, nature and the extent of weathering, jointing and fracture pattern, thickness, depth of occurrence of vesicular basalt and occurrence of red bole bed are the important factors, which play a major role in the occurrence and the movement of ground water in these rocks. Deccan basalts usually have medium to low permeability depending upon the presence of primary and secondary porosity. The weathered residuum serves as an effective ground water repository in this region.

5.1 Depth to Water Level

Depth to water level in Vijayapura district is generally shallow. The aquifers are in general under unconfined to semi confined conditions. In the study area, the water table was monitored in two seasons, i.e., pre-monsoon and post-monsoon for two years at 20 locations and for post monsoon (2022) in newly constructed 6 piezometers. Locational details and map of the water level measurement wells are given in ***Table 4*** and ***Figure 6***, respectively.

Table 4: Details of ground water table measurement wells in 12 km radius.

S.N.	Location	Type of Well	Longitude (°E)	Latitude (°N)	Altitude (m amsl)
1	Asangi	Open Well	75.742548	16.489079	556.71
2	Ronihal	Bore Well	75.703544	16.508324	557.28
3	Kalgurki	Bore Well	75.763849	16.570571	610.19
4	Mulvad	Bore Well	75.736551	16.589759	621.27
5	Yarnal	Bore Well	75.861055	16.611516	625.70
6	Nagaradinni	Open Well	75.749348	16.472477	551.35
7	Tadalgi	Open Well	75.795043	16.449268	550.73
8	Angadgiri	Open Well	75.857019	16.456466	561.00
9	Hunashyal	Bore Well	75.880347	16.433240	532.25
10	Kavalagi	Bore Well	75.816687	16.438897	550.15
11	Arasangi	Bore Well	75.800540	16.424397	529.61
12	Takkalki	Bore Well	75.910061	16.547356	612.26
13	Golsangi	Open Well	75.880084	16.491643	555.97
14	Hangargi	Bore Well	75.930096	16.476107	570.67
15	Kudgi	Open Well	75.837532	16.545332	598.08
16	Masuti	Open Well	75.785407	16.507334	578.02
17	Chiraldinni	Open Well	75.800526	16.467459	561.78
18	Mattihal	Bore Well	75.746712	16.460683	548.85
19	Telgi	Open Well	75.824304	16.476553	570.88
20	Talewad	Bore Well	75.813870	16.553432	608.58
21	Pz-1	Bore Well	75.795308	16.497828	578.91
22	Pz-2	Bore Well	75.795451	16.496266	573.93
23	Pz-3	Bore Well	75.796371	16.494762	572.71
24	Pz-4	Bore Well	75.797583	16.493185	573.14
25	Pz-5	Bore Well	75.806722	16.491985	576.05
26	Pz-6	Bore Well	75.812792	16.490637	579.32

Depth to water level measured are given in ***Table 5.***

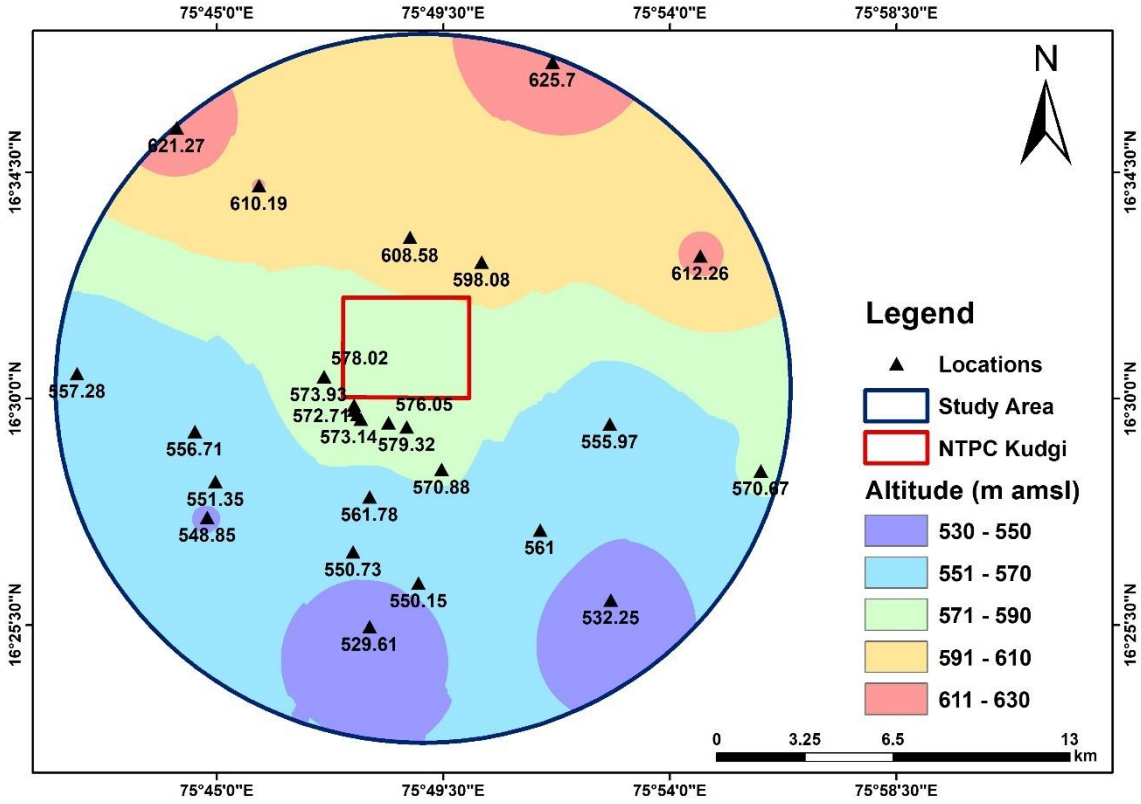


Figure 6: Location map of groundwater level measurement sites.

Table 5: Details of water table measurement in wells.

SN	Location	2021		2022	
		Pre-Monsoon (m bgl)	Post-Monsoon (m bgl)	Pre-Monsoon (m bgl)	Post-Monsoon (m bgl)
1	Asangi	8.06	4.80	7.87	5.12
2	Ronihal	6.80	3.65	6.60	3.96
3	Kalgurki	7.50	4.05	7.28	4.39
4	Mulvad	7.84	4.30	7.61	4.65
5	Yarnal	11.10	7.25	10.91	7.63
6	Nagaradinni	5.84	2.80	5.63	3.10
7	Tadalgi	3.58	0.75	3.34	1.03
8	Angadgiri	5.94	2.85	5.73	3.15
9	Hunashyal	5.19	2.30	4.98	2.58
10	Kavalagi	4.68	1.75	4.45	2.04
11	Arasangi	3.53	0.80	3.31	1.07
12	Takkalki	9.44	5.80	9.24	6.16
13	Golsangi	7.34	4.15	7.15	4.46
14	Hangargi	7.97	4.65	7.78	4.98
15	Kudgi	4.64	1.50	4.39	1.82
16	Masuti	9.16	5.70	8.97	6.04
17	Chiraldinni	6.00	2.90	5.79	3.21

18	Mattihal	5.66	2.65	5.45	2.95
19	Telgi	6.93	3.70	6.72	3.97
20	Talewad	7.56	4.10	7.34	4.44
21	Pz-1	NA	NA	NA	4.08
22	Pz-2	NA	NA	NA	1.76
23	Pz-3	NA	NA	NA	1.16
24	Pz-4	NA	NA	NA	2.02
25	Pz-5	NA	NA	NA	3.23
26	Pz-6	NA	NA	NA	5.52

Depth to water table map post-monsoon and pre-monsoon period for 2021 and 2022 in the study area are shown in ***Figure 7 to Figure 10,*** respectively. The depth to water table during pre-monsoon period varies from 3.31 to 11.1 m below ground level (bgl) and from 0.75 to 7.63 m bgl during post-monsoon period. The depth gradually reduces towards southern and south-western direction. During post-monsoon period water level shows a rise (>2 m) due to replenishment of aquifer by monsoon precipitation.

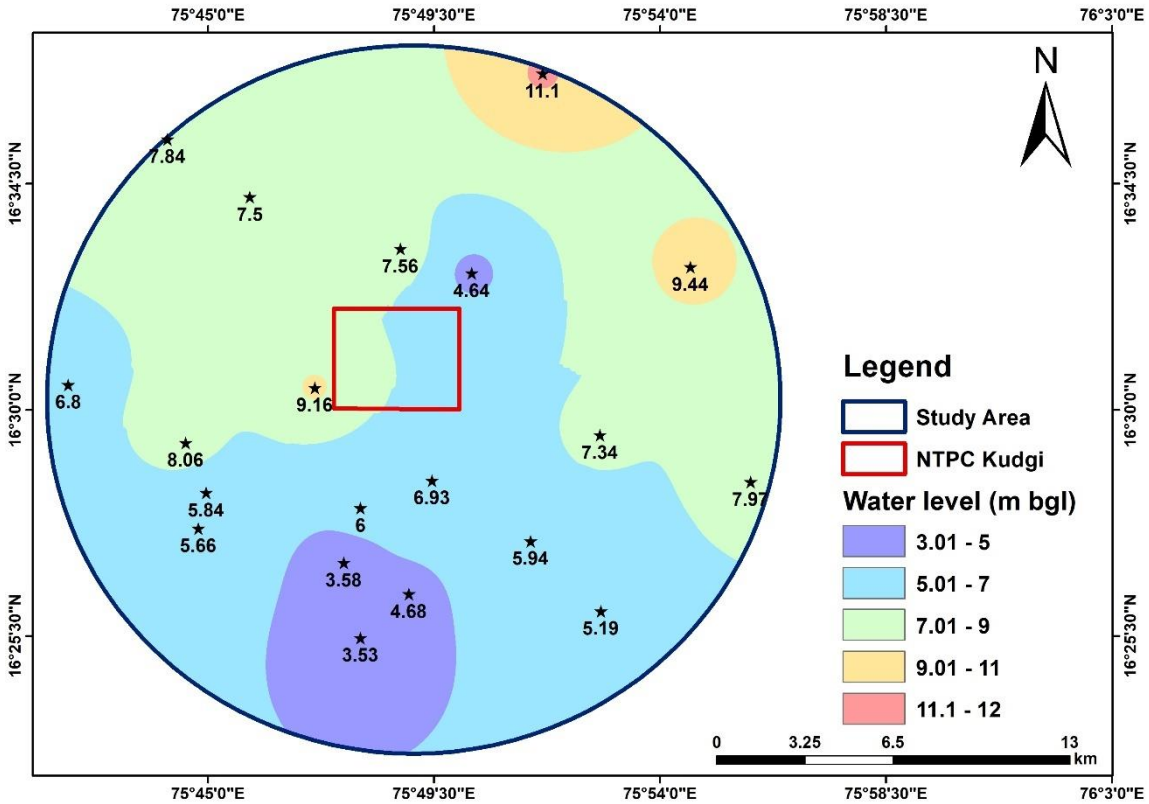


Figure 7: Depth to water table during Pre-Monsoon 2021

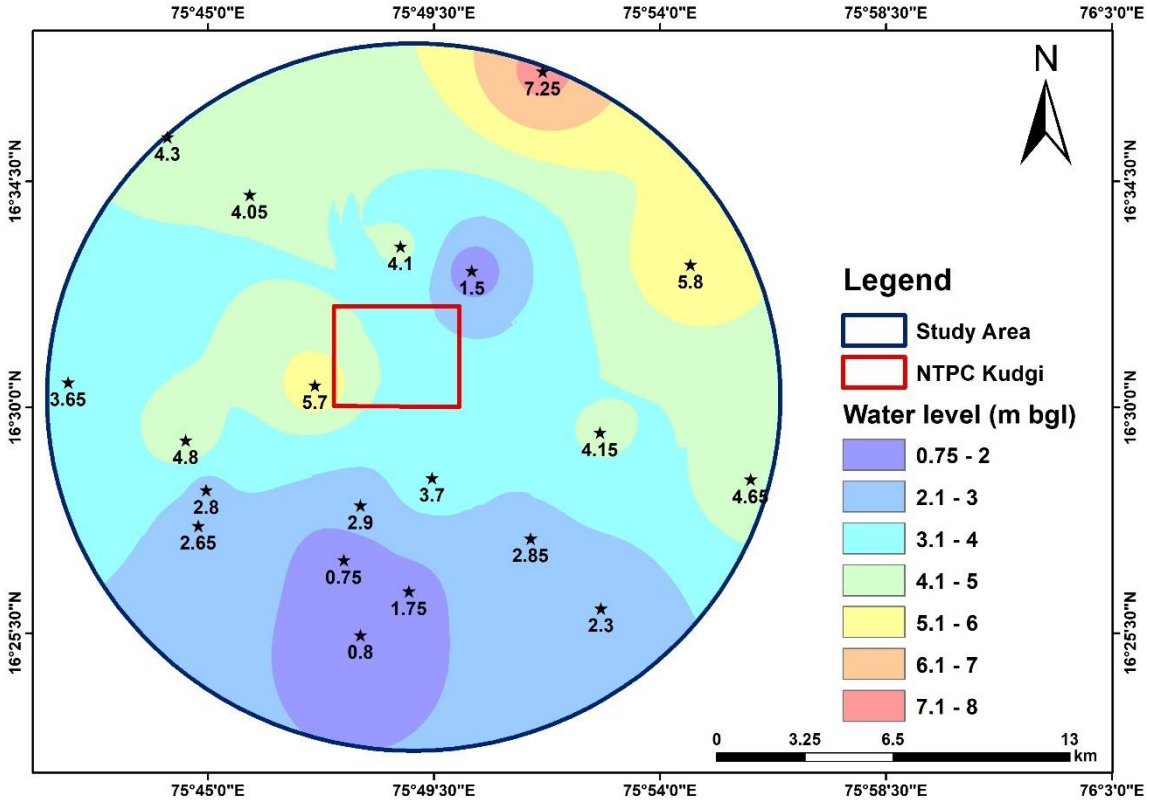


Figure 8: Depth to water table during Post-Monsoon 2021

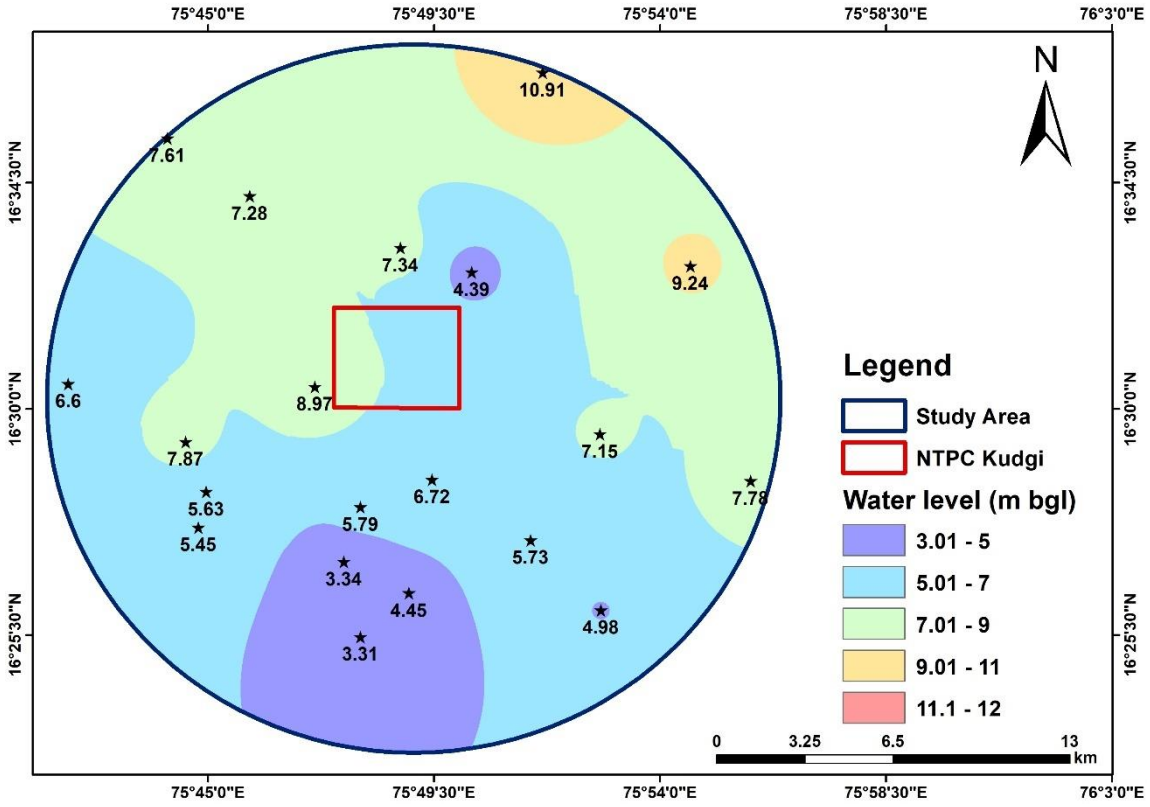


Figure 9: Depth to water table during Pre-Monsoon 2022

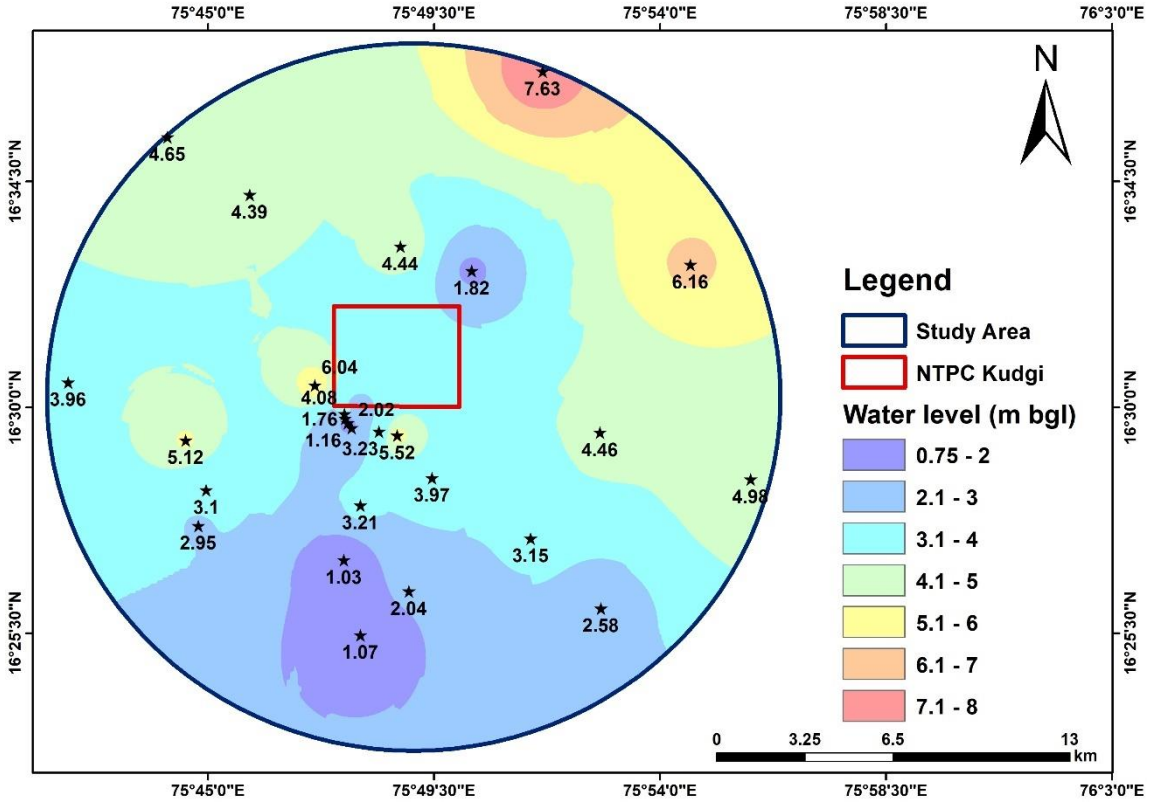


Figure 10: Depth to water table during Post-Monsoon 2022

5.2 Ground Water Flow Direction

The groundwater flow direction in the area has been ascertained from the water level map. Water levels in the wells were computed by subtracting the depth to water level from the ground level (RL). The post-monsoon and pre-monsoon water levels in various wells monitored during the field investigations are given in ***Table 6*** and shown in ***Figure 11 to Figure 14,*** respectively.

Table 6: Water table in 12 km radius area.

SN	Location	2021		2022	
		Pre-Monsoon	Post-Monsoon	Pre-Monsoon	Post-Monsoon
		(m bgl)	(m bgl)	(m bgl)	(m bgl)
1	Asangi	548.65	551.91	548.84	551.59
2	Ronihal	550.48	553.63	550.68	553.32
3	Kalgurki	602.69	606.14	602.91	605.8
4	Mulvad	613.43	616.97	613.66	616.62
5	Yarnal	614.60	618.45	614.79	618.07
6	Nagaradinni	545.51	548.55	545.72	548.25
7	Tadalgi	547.15	549.98	547.39	549.7
8	Angadgiri	555.06	558.15	555.27	557.85

SN	Location	2021		2022	
		Pre-Monsoon	Post-Monsoon	Pre-Monsoon	Post-Monsoon
		(m bgl)	(m bgl)	(m bgl)	(m bgl)
9	Hunashyal	527.06	529.95	527.27	529.67
10	Kavalagi	545.47	548.4	545.7	548.11
11	Arasangi	526.08	528.81	526.3	528.54
12	Takkalki	602.82	606.46	603.02	606.1
13	Golsangi	548.63	551.82	548.82	551.51
14	Hangargi	562.70	566.02	562.89	565.69
15	Kudgi	593.44	596.58	593.69	596.26
16	Masuti	568.86	572.32	569.05	571.98
17	Chiraldinni	555.78	558.88	555.99	558.57
18	Mattihal	543.19	546.2	543.4	545.9
19	Telgi	563.95	567.18	564.16	566.91
20	Talewad	601.02	604.48	601.24	604.14
21	Pz-1	NA	NA	NA	574.83
22	Pz-2	NA	NA	NA	572.17
23	Pz-3	NA	NA	NA	571.55
24	Pz-4	NA	NA	NA	571.12
25	Pz-5	NA	NA	NA	572.82
26	Pz-6	NA	NA	NA	573.8

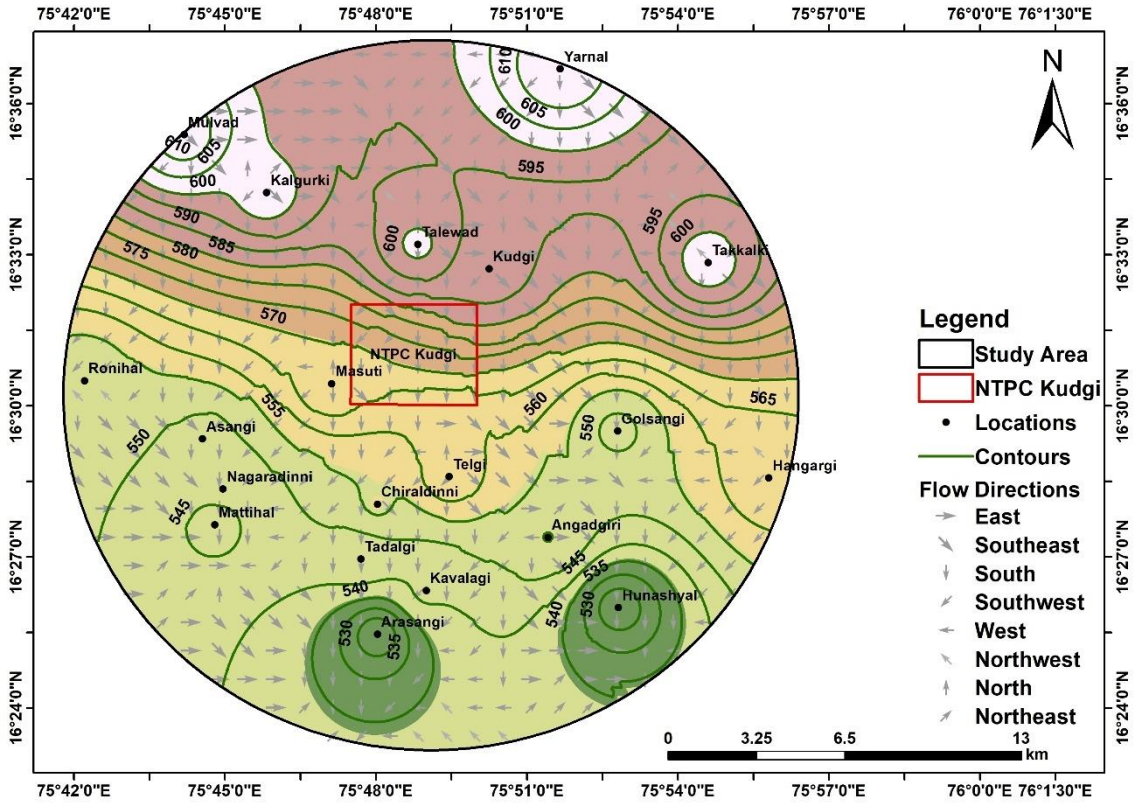


Figure 11: Water table and GW flow direction map (Pre-monsoon 2021)

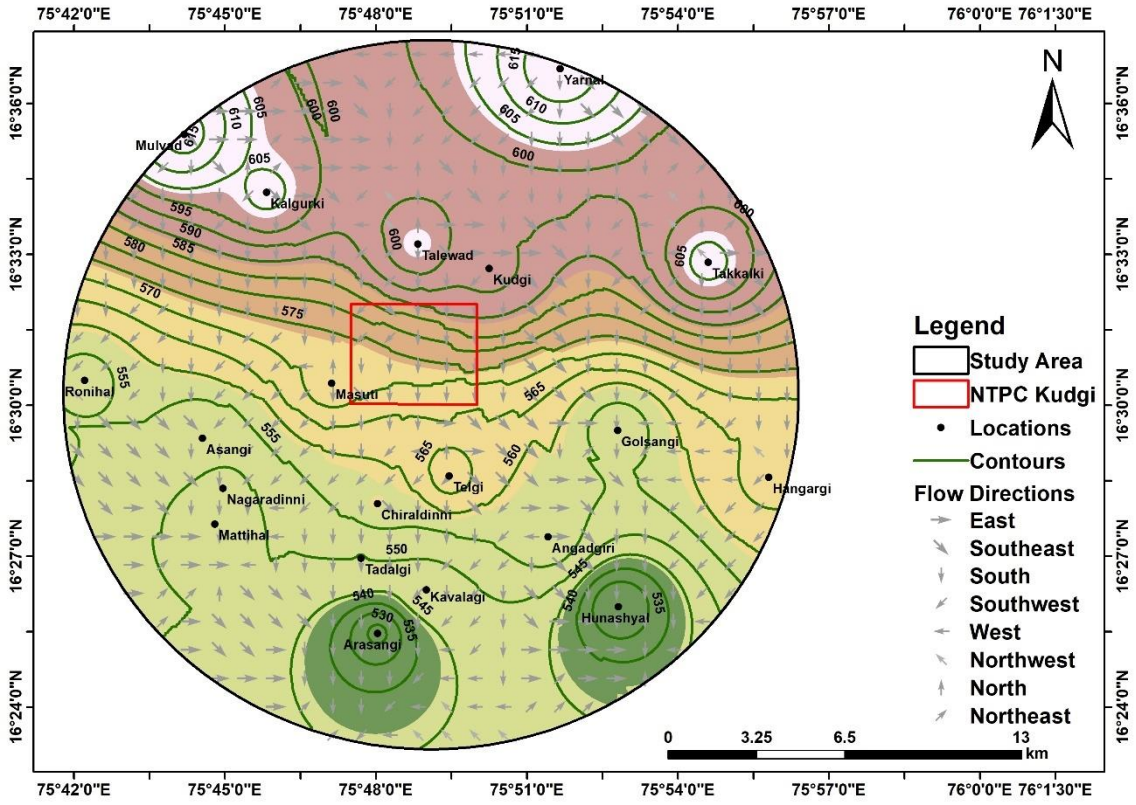


Figure 12: Water table and GW flow direction map (Post-monsoon 2021)

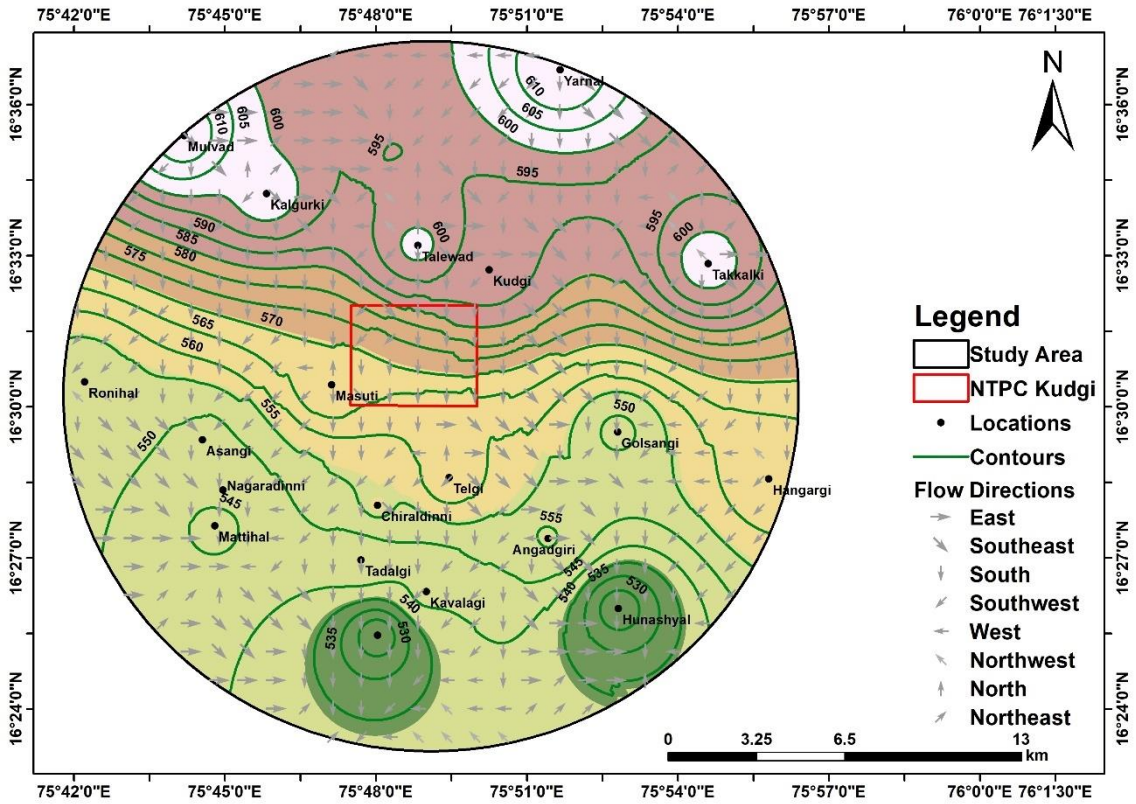


Figure 13: Water table and GW flow direction map (Pre-monsoon 2022)

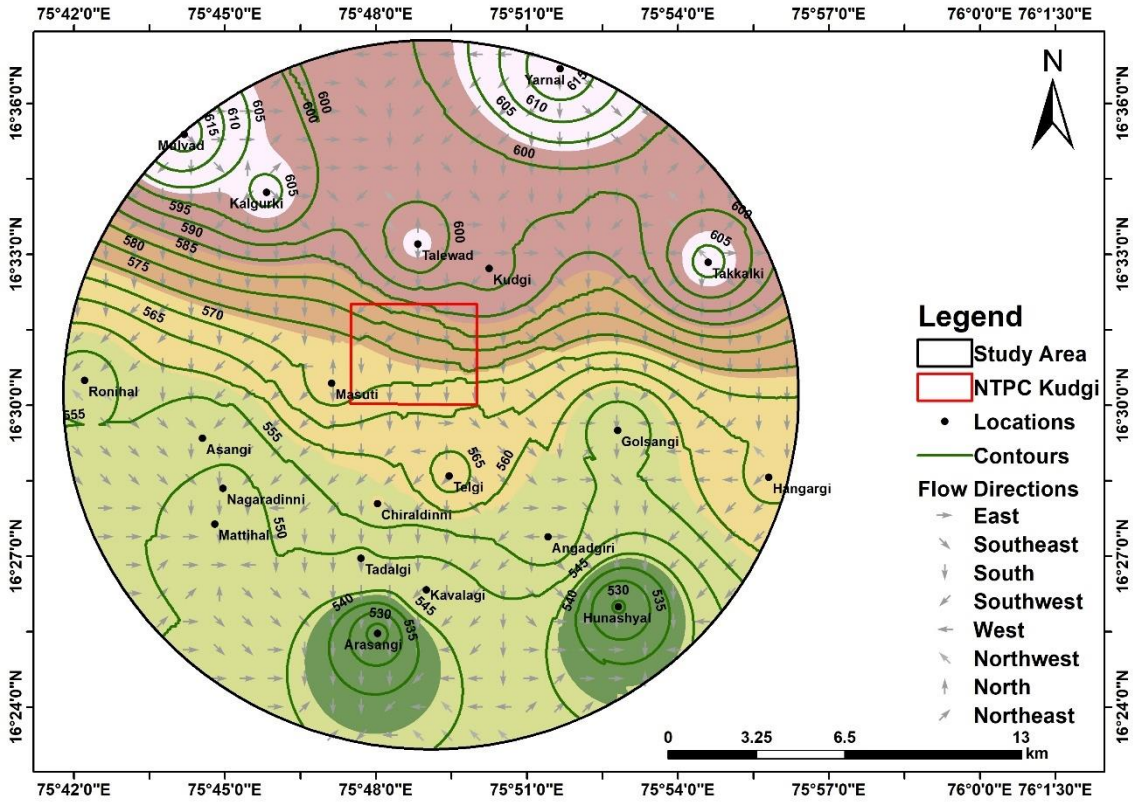


Figure 14: Water table and GW flow direction map post-monsoon 2022

Figures 11 to ***Figure 14*** indicate that the water table in the area is slopping towards south and south-west. Thus, the flow of groundwater, in general, is towards Almati Dam located in South direction.

6 WATER QUALITY

6.1 Background

Water quality is commonly assessed through the use of different parameters. The importance of these parameters depends on the use of the water. The term water quality therefore, must be considered relative to the use of water. In other words, the term 'water quality' can be defined as "physical, chemical and biological characteristics of water by which the user evaluates the acceptability of water". Water bodies having high water quality possess properties that make it a high valued resource to society and nature. Declining or low water quality impacts the value – economically, ecologically, and socially, if pollution enters a waterbody.

The quality of both surface water and groundwater is affected by natural and anthropogenic factors. The natural factors that affect water quality in rural and urban areas are similar. The composition of surface water and groundwater is dependent on e.g. geological, topographical, meteorological, hydrological and biological factors. It varies with seasonal differences in weather conditions, run-off volumes and water levels. Water quality is affected by both point and nonpoint sources of pollution in both the rural and urban areas. Some of these sources include sewage discharge, industrial discharge and agricultural run-off. Water quality is also affected by floods and droughts, as well as lack of awareness among end users.

6.2 Water Quality Parameters

6.2.1 General / Physical parameters

Physical parameters are physical aspects of water quality that help to determine whether water is polluted or not. The various physical parameters include Temperature, EC, pH, TDS, Alkalinity, Hardness, DO, BOD, COD, etc.

pH

pH is defined as log[H+], and is measured as intensity of acidity or alkalinity on a scale range 0-14. The pH (hydrogen ion concentration) of water is a very important parameter concerning water quality. In natural water, pH is governed by the equilibrium between carbon dioxide, bicarbonate and

carbonates ions and in general, ranges between pH 5.5 to 8.5. Most of the chemical reactions in aquatic environment are controlled by change in its value. It is a measure of how acidic/basic water is. The range goes from 0 to 14, with 7 being neutral. pH of less than 7 indicates acidity, whereas a pH of greater than 7 indicates a base.

Electrical Conductivity (EC)

Electrical Conductivity (EC) is the measure of the ability of an aqueous solution to convey an electric current. This ability depends upon the presence of ions, their total concentration, mobility, valence and temperature. Conductivity is a good and rapid method to measure the total dissolved solids and is directly related to total solids. Salinity is measured in terms of electrical conductivity is one of the most important water quality considerations for irrigational purposes.

The EC is a useful parameter of water quality for indicating salinity hazards. A high salt content (high EC) in irrigation water leads to formation of saline soil. On the basis of electrical conductivity values, Richards (1954) classified irrigation water in to four groups as shown in the ***Table 7***.

Table 7: Irrigation Water Quality Classification (after Richards 1954)

Water Class	Electrical Conductivity (μS/cm)	Pre-monsoon		Post-monsoon	
		No	%	No	%
Low	< 250	Nil	Nil	Nil	Nil
Medium	250 – 750	3	14	6	30
High	750 – 2250	18	86	14	70
Very High	>2250	Nil	Nil	Nil	Nil

Total Dissolved Solids (TDS)

Total Dissolved Solid (TDS) in water includes all dissolved material in solution, whether ionized or not. TDS is numerical sum of all mineral constituents dissolved in water and is expressed in mg/l. In natural water, dissolved solids are composed mainly of carbonates, bicarbonates, chlorides, sulphates, phosphates, nitrates, calcium, magnesium, sodium, potassium, iron and manganese etc. The palatability of water with a TDS level of less than about 600 mg/l is generally considered to be good; drinking-water becomes

significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/l.

TDS in drinking-water originates from natural sources, sewage, urban runoff and industrial wastewater. Concentrations of TDS in water vary considerably in different geological regions owing to differences in the solubility of minerals. No health-based guideline value for TDS has been proposed (WHO, 2011). BIS (2012) has prescribed 500 mg/l as the acceptable limit and 2000 mg/l as permissible limit in absence of alternate source for drinking and other domestic usage. Based on TDS contents, water can be classified in to four categories as fresh, brackish, saline and brine water (**Table 8**).

Table 8: Classification of water based on TDS

TDS (mg/l)	Water Quality
0 – 1,000	Fresh Water
1,000 – 10,000	Brackish Water
10,000 – 100,000	Saline Water
>100,000	Brine

Total Hardness (TH)

Hardness in water is caused by a variety of dissolved polyvalent metallic ions, predominantly calcium and magnesium cations. It is usually expressed as milligrams of calcium carbonate per liter. The degree of hardness of drinking-water is important for aesthetic acceptability by consumers. Hardness is the property of water, which prevents the lather (foam) formation with the soap and increased the boiling point of the water. Hardness is classified in four categories as soft water, hard water, moderately hard water & very hard water (**Table 9**).

Table 9: Hardness Classification of water

Hardness (mg/l)	Water Quality	% Sample	
		Pre-Monsoon	Post-Monsoon
0-75	Soft	5%	Nil
75-150	Moderately hard	76%	20%
150-300	Hard	5%	55%
>300	Very hard	14%	25%

Drinking-water can be a contributor to calcium and magnesium intake and could be important for those who are marginal for calcium and magnesium. Consumers are likely to notice changes in hardness. Public acceptability of the degree of hardness of water may vary considerably from one community to another. The taste threshold for the calcium ion is in the range of 100–300 mg/l, depending on the associated anion, and the taste threshold for magnesium is probably lower than that for calcium. In some instances, consumers tolerate water hardness in excess of 500 mg/l. BIS (2012) has prescribed 200 mg/l as acceptable limit and 600 mg/l as permissible limit in absence of alternate source for drinking and other domestic usage. No health-based guideline value is proposed for hardness in drinking-water (WHO, 2011).

Alkalinity

Alkalinity is a measure of the ability of water to neutralize acids. It is expressed in terms of $CaCO_3$ equivalent of the hydrogen ions neutralized. Alkalinity of water is mainly due to presence of bicarbonates, carbonates, hydroxides of sodium, potassium, calcium and magnesium. Highly alkaline waters are usually unpalatable and imparts a bitter taste to water. Alkalinity is the quantitative capacity of an aqueous solution to neutralize an acid. The presence of carbonates, bi-carbonates and hydroxides are the main cause of alkalinity in natural waters. Measuring alkalinity is important in determining a water sources' ability to neutralize acidic pollution from rainfall or wastewater. There can be long-term changes in the alkalinity of streams and rivers in response to human disturbances. Alkalinity is related to the pH of a solution (its basicity) but measures a different property. Roughly, the pH of a solution is a measure of how "strong" the bases are in a solution, whereas the alkalinity measures the "amount" of chemical bases. Total Hardness in water is caused by a variety of dissolved polyvalent metallic ions, predominantly calcium and magnesium cations. It is usually expressed as milligrams of calcium carbonate per liter. The degree of hardness of drinking-water is important for aesthetic acceptability by consumers.

Dissolved Oxygen (DO)

Dissolved Oxygen (DO) is an important indicator of the qualitative health of any

surface water body. More is the dissolved oxygen, better is the quality of water. The DO concentration depends not only on the relative dilutions but also on the rate of oxidation of organic material and re-aeration.

Biochemical Oxygen Demand (BOD)

The demand of oxygen from water to break down organic and inorganic wastes and sewage is known as biochemical oxygen demand (BOD). The more is the oxygen taken out from water, the less becomes the content of dissolved oxygen, thus, increasing the pollution in the river with a high BOD load. The amount of dissolved oxygen needed by bacteria to decompose the wastes determines the quality of wastewater. The problem arises when demand for dissolved oxygen exceeds available supply. Thus, BOD is a measure of oxygen required to sustain organisms like aerobes, protozoa etc.

Chemical Oxygen Demand (COD)

Chemical Oxygen Demand (COD) is a measurement of the oxygen requirement equivalent of organic matter that is susceptible to oxidation with the help of a strong chemical oxidant. It is an important, rapidly measured parameter as a means of measuring organic strength for streams and polluted water bodies.

6.2.2 Major Ions

Water contains positively charged ions (cations) and negatively charged ions (anions). These ions contribute to the salinity of the water. The major cations observed in the surface waters of the study area include Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} and NH^{4+} and the major anions are CO_3^{2-}/HCO_3^{-}, Cl^{-}, F^{-}, NO^{3-}, SO_4^{2-}, etc.

Sodium and Potassium

Sodium the sixth most common element is present in nearly all natural waters. The levels may vary from less than 1 mg /l to more than 500 mg /l. Relatively high concentrations may be found in brines and hard water softened by the sodium exchange process. Most of sodium salts are readily soluble in water, but take no active part in chemical reactions as do the salts of alkaline earths. For these reason sodium salts tend to remain in solution unless extracted during evaporation.

Potassium ranks seventh amongst the elements in order of abundance, yet its concentration reaches 20 mg/l. Two factors are responsible for the scarcity of potassium in groundwater, one being the resistance of potassium minerals to decomposition by weathering and the other the fixation of potassium in clay minerals formed due to weathering. Although potassium is nearly as abundant as sodium in igneous and metamorphic rocks, its concentration in groundwater is one-tenth or even one-hundredth that of sodium.

Calcium and Magnesium

Calcium occurs in water naturally and is mainly present as Ca^{2+}(aq), but it may also occur as $CaOH^{+}$ (aq) or Ca $(OH)^{2}$ (aq), or as $CaSO_4$. It may dissolve from rocks such as limestone, marble, calcite, dolomite, gypsum, fluorite and apatite. Calcium is a determinant of water hardness, because it can be found in water as Ca^{2+} ions. Calcium is largely responsible for water hardness, and may negatively influence toxicity of other compounds. Elements such as copper, lead and zinc are much more toxic in soft water.

Magnesium is mainly present as Mg^{2+} (aq) in water, but also as $MgOH^{+}$ (aq) and Mg $(OH)^{2}$ (aq). Magnesium is an important component of basic igneous rocks, volcanic rocks, metamorphic and sedimentary rocks. Most limestones also contain magnesium carbonate. Water solubility of magnesium hydroxide is 12 mg/l. Other magnesium compounds are clearly more water soluble, for example magnesium carbonate (600 mg/l). Mostly groundwater contains upto a few hundred ppm of magnesium.

The acceptable limit for calcium and magnesium for drinking water are 75 and 30 mg/l respectively while the maximum permissible limits area 200 and 100 mg/l respectively (BIS, 2012).

Carbonate / Bicarbonate

Carbonate, bicarbonate and hydroxide contribute to the alkalinity of water. When the total alkalinity of a water is due almost entirely to hydroxides, carbonates or bicarbonates, and the total dissolved solids is not greater than 500 mg/l, the carbonate and bicarbonate concentrations as $CaCO_3$ may be calculated from the sample pH and total alkalinity.

Chloride

Chloride (Cl-) is one of the major anions found in water and are generally combined with calcium, magnesium, or sodium. Since almost all chloride salts are highly soluble in water, the chloride content ranges from 10 to 100 mg/l. The bulk of chloride in groundwater is either from atmospheric sources or sea-water contamination. Chloride increases the electrical conductivity of water and thus increases its corrosivity. Chloride is present in all natural waters at greatly varying concentration depend on the geochemical conditions. Chlorides in natural waters can be attributed to leaching of chloride containing rocks and soils, discharges of effluents from chemical industries, ice-cream plant effluents, edible oil mill operations, sewage disposal, irrigation drainage, contamination from refuse leachates and sea water intrusion in coastal regions. Large amounts of chlorides reach to the receiving water through leaching of domestic sewage.

Fluoride

Fluoride is found in all natural waters in some concentration. Seawater typically contains about 1 mg/l while rivers and lakes generally exhibit concentrations of less than 0.5 mg/l. In groundwater, however, low or high concentrations of fluoride can occur, depending on the nature of the rocks and the occurrence of fluoride-bearing minerals. The concentration of fluoride in groundwater is limited due to the low solubility of most fluorides. The important fluorine bearing minerals are calcium fluorite, apatite, certain amphiboles and micas. Groundwater in most areas contains less than 1.5 ppm fluorides, but in some areas the concentration reaches above 5 ppm. The presence of fluoride in drinking water to the extent of 2 ppm may cause mottles enamel in teeth.

Sulfate

Sulfate appears in natural waters in a wide range of concentrations. The sulfate content of atmospheric precipitation is only about 2 ppm but in groundwater a wide range occurs due to reduction, precipitation, solution and concentration, as the water traverses through rocks. The origin of most sulfate compounds is the oxidation of sulfite ores, the presence of shales, or the industrial wastes.

Nitrate

Nitrates are colorless, odorless and tasteless nitrogen-oxygen chemical units which combine with various organic and inorganic compounds. Nitrates can also leach to the groundwater by downward movement of dissolved or suspended minerals, fertilizers, agricultural chemicals or other substances through the soil. The greatest contribution of nitrate in groundwater is from decaying organic matter, sewage wastes and nitrate fertilizers.

Phosphates

The element phosphorus is necessary for plant and animal growth. Nearly all fertilizers contain phosphates (chemical compounds containing the element, phosphorous). Phosphates enter waterways from human and animal waste, phosphorus rich bedrock, laundry, cleaning, industrial effluents, and fertilizer runoff.

6.2.3 Heavy Metals

The term heavy metal refers to any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations. Examples of heavy metals include Arsenic (As), Cadmium (Cd), Chromium (Cr), Mercury (Hg), Lead (Pb) and Zinc (Zn). Heavy metals can enter a water supply by industrial and domestic waste, or even from acidic rain breaking down soils and releasing heavy metals into streams, lakes, rivers, and groundwater.

Arsenic (As)

Arsenic (As) is the 20th most common element in the earth's crust and is emitted to the environment as a result of volcanic activity and industrial activities. Mining, smelting of non-ferrous metals and burning of fossil fuels are the major anthropogenic sources of As contamination of air, water, and soil (primarily in the form of As trioxide). The historical use of As containing pesticides has left large tracts of agricultural land contaminated. The use of As in the preservation of timber has also led to contamination of the environment. In nature, As occurs primarily in its sulfide form in complex minerals containing silver, lead, copper, nickel, antimony, cobalt, and iron. As is present in more than 200 mineral species, the most common of which is arsenopyrite. Terrestrial

abundance of arsenic is approximately 5mg/kg, although higher concentrations are associated with sulfide deposits. Sedimentary iron and manganese ores as well as phosphate-rock deposits occasionally contain levels of As up to 2900mg/kg (WHO, 2001).

Arsenic, from both natural and anthropogenic sources, is mainly transported in the environment by water. The form and concentration of arsenic depends on several factors, including whether the water is oxygenated (for example, arsenites predominate under reducing conditions such as those found in deep well-waters), the degree of biological activity (which is associated with the conversion of inorganic arsenic to methylated arsenic acids), the type of water source (for example, open ocean seawater versus surface freshwater versus groundwater), and the proximity of the water source to arsenic-rich geological formations and other anthropogenic sources (WHO, 2000, 2001). The concentration of arsenic in surface freshwater sources, like rivers and lakes, is typically less than 10µg/l, although it can be as high as 5mg/l near anthropogenic sources. Concentrations of As in open ocean seawater and groundwater average 1–2µg/l, although groundwater concentrations can be up to 3mg/l in areas with volcanic rock and sulfide mineral deposits (WHO, 2001).

Cadmium (Cd)

A rare element (about 0.2 gram per ton in Earth's crust), cadmium occurs in a few minerals and in small quantities in other ores, especially zinc ores, from which it is produced as a by-product. Most cadmium produced is electroplated onto steel, iron, copper, brass, and other alloys to protect them from corrosion. Groundwater seldom contains high levels of cadmium unless it is contaminated by mining or industrial wastewater, or seepage from hazardous waste sites. Soft or acidic water tends to dissolve cadmium and lead from water lines; cadmium levels are increased in water stagnating in household pipes.

Chromium (Cr)

Chromium is the 21st most abundant element in Earth's crust with an average concentration of 100ppm. It is also the seventh most abundant element on earth. Chromium compounds are found in the environment from the erosion of chromium-containing rocks, and can be redistributed by volcanic eruptions.

Typical background concentrations of chromium in environmental media are: atmosphere <10µg/m^3; soil <500mg/kg; vegetation <0.5mg/kg; freshwater <10µg/l; seawater <1µg/l; sediment <80mg/kg.

Chromium is present in the environment in several different forms. The most common forms are chromium(0), chromium(III), and chromium(VI). No taste or odor is associated with chromium compounds. Chromium(III) occurs naturally in the environment and is an essential nutrient. Chromium(VI) and chromium(0) are generally produced by industrial processes. The metal chromium, which is the chromium(0) form, is used for making steel. Chromium(VI) and chromium(III) are used for chrome plating, dyes and pigments, leather tanning, and wood preserving. Environment Protection Agency (EPA) classified chromium as a Group A Human Carcinogen, particularly of the lung through inhalation. Both trivalent and hexavalent chromium can cause allergic contact dermatitis.

Mercury (Hg)

In its inorganic form, mercury occurs abundantly in the environment, primarily as the minerals cinnabar and metacinnabar, and as impurities in other minerals. Mercury can readily combine with chlorine, sulfur, and other elements, and subsequently weather to form inorganic salts. Inorganic mercury salts can be transported in water and occur in soil. Dust containing these salts can enter the air from mining deposits of ores that contain mercury. Emissions of both elemental or inorganic mercury can occur from coal-fired power plants, burning of municipal and medical waste, and from factories that use mercury. Inorganic mercury can also enter water or soil from the weathering of rocks that contain inorganic mercury salts, and from factories or water treatment facilities that release water contaminated with mercury.

Human exposure to inorganic mercury salts can occur both in occupational and environmental settings. Occupations with higher risk of exposure to mercury and its salts include mining, electrical equipment manufacturing, and chemical and metal processing in which mercury is used. In the general population, exposure to mercuric chloride can occur through the dermal route from the use of soaps and creams or topical antiseptics and disinfectants.

Another, less well-documented, source of exposure to inorganic mercury salts among the general population is from their use in ethnic religious, magical, and ritualistic practices and in herbal remedies.

Lead (Pb)

Lead is a naturally occurring bluish-gray metal found in small amounts in the earth's crust. Lead can be found in all parts of our environment. Much of it comes from human activities including burning fossil fuels, mining, and manufacturing. Lead has many different uses. It is used in the production of batteries, ammunition, metal products (solder and pipes), and devices to shield X-rays. Because of health concerns, lead from gasoline, paints and ceramic products, caulking, and pipe solder has been dramatically reduced in recent years. The main lead-bearing mineral is galena (PbS), which is mostly found with zinc ores.

Zinc (Zn)

Zinc is the 24th most abundant element, with 75 parts per million in the Earth's crust. Zinc is present not only in rock and soil, but also in air, water and the biosphere – plants, animals and humans. Zinc is constantly being transported by nature, a process called natural cycling. Rain, snow, ice, sun and wind erode zinc-containing rocks and soil. Zinc levels in soil range from 5 to 770 parts per million, with an average of 64 parts per million. The atmosphere has just 30 ppb, while seawater has only 30 ppb. In ores, the element is usually found in combination with other base metals like copper and lead. Water is polluted with zinc, due to the presence of large quantities of zinc in the wastewater of industrial plants. This wastewater is not purified satisfactory. One of the consequences is that rivers are depositing zinc-polluted sludge on their banks. Zinc may also increase the acidity of waters.

Iron (Fe)

Iron makes up 5% of Earth's crust and is second in abundance to aluminum among the metals and fourth in abundance behind oxygen, silicon, and aluminum among the elements. Iron, which is the chief constituent of Earth's core, is the most abundant element in Earth as a whole (about 35 %). The main naturally occurring iron minerals are magnetite, hematite, goethite and

siderite. Weathering processes release the element into waters. Dissolved iron is mainly present as $Fe(OH)^{2+}$ (aq) under acidic and neutral, oxygen-rich conditions. Usually, iron occurring in groundwater is in the form of ferric hydroxide, in concentrations less than 0.5 ppm. Rainwater as it infiltrates the soil and underlying geologic formations dissolves iron, causing it to seep into aquifers that serve as sources of groundwater for wells. Although present in drinking water, iron is seldom found at concentrations greater than 10 milligrams per liter (mg/l) or 10 parts per million. However, as little as 0.3 mg/l can cause water to turn a reddish-brown color.

Manganese (Mn)

Manganese is one of the most abundant metals in soils, where it occurs as oxides and hydroxides, and it cycles through its various oxidation states. Manganese occurs principally as pyrolusite (MnO_2), Manganese compounds exist naturally in the environment as solids in the soils and small particles in the water. Manganese particles in air are present in dust particles. These usually settle to earth within a few days. Humans enhance manganese concentrations in the air by industrial activities and through burning fossil fuels. Manganese that derives from human sources can also enter surface water, groundwater and sewage water. Through the application of manganese pesticides, manganese will enter soils.

6.3 Surface Water Quality

As mentioned earlier, surface water samples have been collected from 14 locations including the ash pond and raw water reservoir. ***Figure 15*** provides the location map of the surface water sampling locations. The details of the sampling locations are provided in ***Table 10***. The various parameters of the surface samples including physical parameters, major ions and heavy metals have been determined. The results of analysis are presented in following sections.

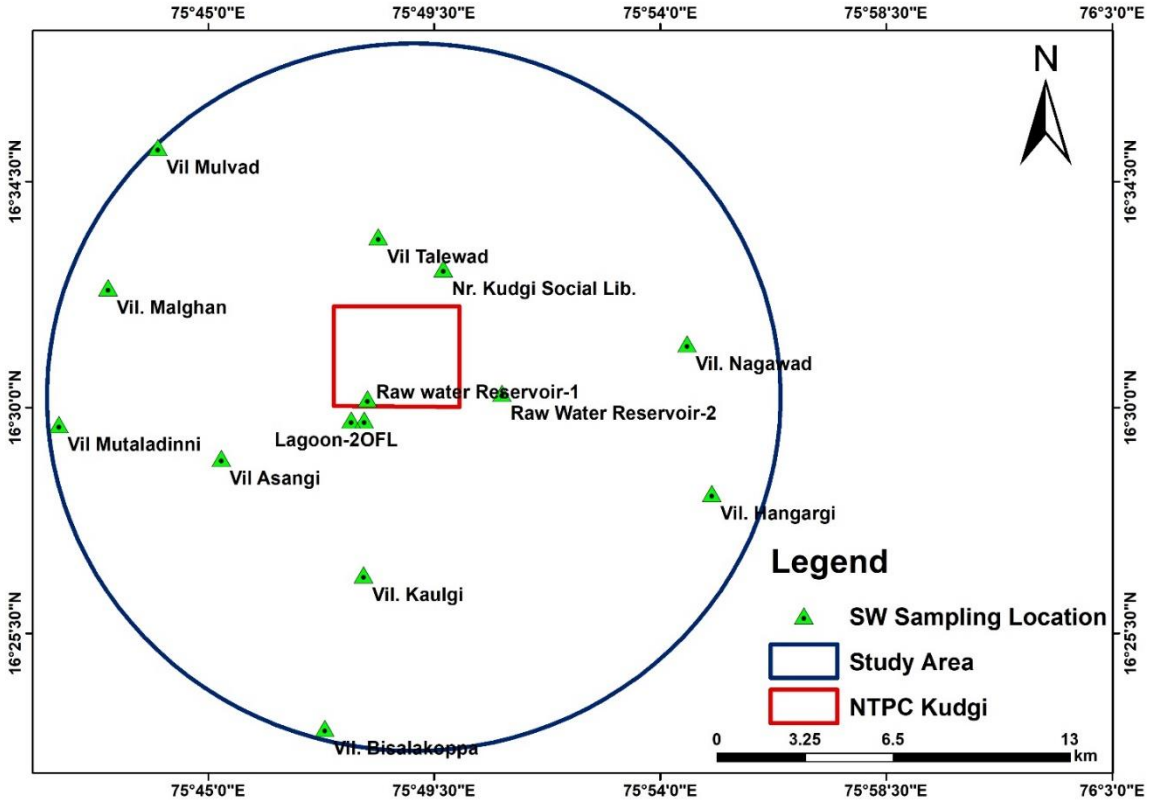


Figure 15: Location map of surface water sampling sites.

Table 10: Details of surface water sampling locations in the study area

S.N.	Location ID	Location Name	Source	Latitude (^{0}N)	Longitude (^{0}E)
1	SW-1	Raw water Reservoir-1	Raw Water Reservoir	16.502866	75.802910
2	SW-2	Raw water Reservoir-2	Raw Water Reservoir	16.504722	75.847497
3	SW-3	Lagoon-2	Ashpond	16.495882	75.801843
4	SW-4	OFL	Drain	16.495852	75.797546
5	SW-5	Vil. Nagawad	Check Dam	16.521166	75.909016
6	SW-6	Vil. Hangargi	Check Dam	16.471415	75.917230
7	SW-7	Vil. Bisalakoppa	Almatti Dam	16.393511	75.788823
8	SW-8	Vil. Kaulgi	Check Dam	16.444457	75.801609
9	SW-9	Vil Mulvad	Mulvad Lake	16.586389	75.733352
10	SW-10	Vil Talewad	Tank	16.556694	75.806502
11	SW-11	Vil Mutaladinni	Check Dam	16.494316	75.700568
12	SW-12	Vil Asangi	Check Dam	16.483102	75.754379
13	SW-13	Vil. Malghan	Check Dam	16.539807	75.716856
14	SW-14	Nr. Kudgi Social Lib.	Check Dam	16.546072	75.828087

6.3.1 Physical parameters (Surface Water)

Physical parameters are physical aspects of water quality that help to determine whether water is polluted or not. The various physical parameters include Temperature, EC, pH, TDS, Alkalinity, Hardness, DO, BOD, COD, etc. ***Tables 11 to 14*** present the physical parameters of the surface water locations monitored for the study area during July 2021 (Pre-monsoon), January 2022 (Post-monsoon), June 2022 (Pre-monsoon) and December 2022 (Post-monsoon), respectively.

Table 11: Physical parameters of surface water (Pre-Monsoon 2021)

S. N.	Site Code	Temp (^{0}C)	pH	EC (µS/cm)	TDS (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	DO (mg/l)	BOD (mg/l)	COD (mg/l)
1	SW-1	31.8	8.08	696	337	132	94	6.2	4.4	14
2	SW-2	31.4	7.96	686	332	146	108	6.1	5.1	14
3	SW-3	35.8	8.34	1523	1066	110	60	5.6	5.3	22
4	SW-4	32.8	8.44	1459	1021	198	146	5.6	5.1	25
5	SW-5	32.0	7.82	791	463	139	102	5.9	6.2	21
6	SW-6	31.6	7.89	715	479	135	167	5.4	7.7	17
7	SW-7	32.0	7.63	674	452	112	134	6.1	4.8	16
8	SW-8	32.9	7.56	809	542	153	174	5.7	6.1	18
9	SW-9	32.9	7.71	754	505	121	214	5.2	5.7	17
10	SW-10	31.8	7.91	782	524	105	211	5.3	6.3	20
11	SW-11	31.6	7.62	622	484	95	90	5.4	5.2	21
12	SW-12	31.8	7.77	739	495	163	156	5.8	5.1	18
13	SW-13	31.4	7.54	652	437	174	132	5.6	4.5	19
14	SW-14	30.8	7.68	698	468	142	175	5.2	5.1	21

Table 12: Physical parameters of surface water (Post-Monsoon 2021)

S. N.	Site Code	Temp (^{0}C)	pH	EC (µS/cm)	TDS (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	DO (mg/l)	BOD (mg/l)	COD (mg/l)
1	SW-1	19.1	8.01	448	234	148	142	6.5	3.9	13
2	SW-2	18.9	7.91	444	232	160	148	6.5	3.8	14
3	SW-3	21.5	8.31	1369	986	122	304	5.8	5.1	20
4	SW-4	19.7	8.33	1360	979	156	254	5.8	5.2	23
5	SW-5	19.2	7.63	633	443	143	142	6.1	5.2	21
6	SW-6	18.9	7.56	572	400	178	185	5.9	6.7	17
7	SW-7	19.2	7.71	539	377	136	164	6.3	4.6	16
8	SW-8	19.7	7.9	647	453	142	204	5.9	5.9	18
9	SW-9	19.7	7.62	603	422	158	247	5.6	5.3	17
10	SW-10	19.1	7.82	626	438	162	242	5.8	6.0	20
11	SW-11	18.9	7.89	578	404	132	170	5.7	4.2	21
12	SW-12	19.1	7.75	591	414	121	176	6.1	4.7	18
13	SW-13	18.9	7.59	522	365	133	184	5.4	4.1	19
14	SW-14	18.5	7.78	558	391	127	233	5.7	4.6	21

Table 13: Physical parameters of surface water (Pre-monsoon 2022)

S. N.	Site Code	Temp (^{0}C)	pH	EC (µS/cm)	TDS (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	DO (mg/l)	BOD (mg/l)	COD (mg/l)
1	SW-1	31.7	7.76	640	435	121	86	5.7	4.0	13
2	SW-2	31.3	7.64	631	446	134	99	5.6	4.7	13
3	SW-3	32.9	8.29	1844	1291	101	55	5.2	4.9	20
4	SW-4	32.8	8.1	1820	1274	182	134	5.2	4.7	23
5	SW-5	32.9	7.51	728	495	128	94	5.4	5.7	19
6	SW-6	32.5	7.57	658	447	124	154	5.0	7.1	16
7	SW-7	30.9	7.32	620	422	103	123	5.6	4.4	15
8	SW-8	32.9	7.26	744	506	141	160	5.2	5.6	17
9	SW-9	32.9	7.4	694	475	111	197	4.8	5.2	16
10	SW-10	31.7	7.58	719	489	97	194	4.9	5.8	18
11	SW-11	31.5	7.32	572	399	87	83	5.0	4.8	19
12	SW-12	31.7	7.46	680	462	150	144	5.3	4.7	17
13	SW-13	31.3	7.24	600	408	160	121	5.2	4.1	17
14	SW-14	32.6	7.37	642	437	131	161	4.8	4.7	19

Table 14: Physical parameters of surface water (Post-Monsoon 2022)

S. N.	Site Code	Temp (^{0}C)	pH	EC (µS/cm)	TDS (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	DO (mg/l)	BOD (mg/l)	COD (mg/l)
1	SW-1	21.0	7.49	412	293	136	131	6.0	3.6	12
2	SW-2	20.8	7.59	408	290	147	136	6.0	3.5	13
3	SW-3	23.7	7.98	1257	892	112	280	5.3	4.7	18
4	SW-4	21.7	7.93	1258	893	144	234	5.3	4.8	21
5	SW-5	21.1	7.32	462	328	132	131	5.6	4.8	19
6	SW-6	20.8	7.26	426	302	164	170	5.4	6.2	16
7	SW-7	21.1	7.4	412	293	125	151	5.8	4.2	15
8	SW-8	21.7	7.58	395	280	131	188	5.4	5.4	17
9	SW-9	21.7	7.32	355	252	145	227	5.2	4.9	16
10	SW-10	21.0	7.51	376	267	149	223	5.3	5.5	18
11	SW-11	20.8	7.57	332	236	121	156	5.2	3.9	19
12	SW-12	21.0	7.44	344	244	111	162	5.6	4.3	17
13	SW-13	20.8	7.29	280	199	122	169	5.0	3.8	17
14	SW-14	20.4	7.47	313	222	117	214	5.2	4.2	19

6.3.2 Major Ions (Surface Water)

Ions contain positively charged ions (cations) and negatively charged ions (anions) present in water. Major ions (Ca, Mg, Na, K, F, Cl, HCO_3, SO_4 NO_3, and PO_4) in the surface water from 14 locations. ***Table 15*** to ***Table 18*** present the major ion concentration in the surface water at locations monitored in the study area during July 2021 (Pre-monsoon, 2021), January 2022 (Post-

monsoon, 2021), June 2022 (Pre-monsoon, 2022) and December 2022 (Post-monsoon, 2022), respectively.

The major cations observed in the surface waters of the study area include Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} and NH^{4+} (***Tables 15 to 18***). The anion chemistry of the analyzed samples of the study area shows that F^{-}, Cl^{-}, HCO^{3-}, SO_4^{2-} NO_2^{-} and NO_3^{-} are the dominant anions in the surface waters of the study area. PO_4^{3-} was detected in low concentration.

Table 15: Major ions of surface water during Pre-Monsoon 2021

S. N.	Sample Code	Ca	Mg	Na	K	F	Cl	HCO_3	SO_4	NO_3	PO_4
		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1	SW-1	79.0	15.0	31.0	0.7	0.6	117.0	170.0	4.9	0.9	0.6
2	SW-2	76.0	19.0	39.0	0.7	0.5	122.0	178.0	4.6	0.9	0.6
3	SW-3	121.0	29.0	51.0	0.6	0.7	186.0	248.0	12.5	0.7	0.9
4	SW-4	129.0	27.0	56.0	0.5	0.8	193.0	262.0	14.3	0.2	0.8
5	SW-5	42.9	28.0	37.0	0.5	0.5	58.7	251.0	9.0	0.1	0.5
6	SW-6	45.7	25.3	28.0	1.8	0.3	64.4	210.0	8.2	1.1	0.8
7	SW-7	44.1	24.5	41.6	1.7	0.5	59.1	248.0	8.3	1.5	1.0
8	SW-8	46.4	31.5	25.2	4.7	0.3	50.1	238.0	7.9	1.8	1.1
9	SW-9	63.4	13.6	27.1	1.8	0.4	36.6	236.0	9.8	1.1	0.9
10	SW-10	48.6	26.7	25.9	1.9	0.1	33.8	259.0	5.5	1.8	1.0
11	SW-11	44.4	30.0	20.9	1.3	0.3	40.6	236.0	5.2	5.8	2.6
12	SW-12	25.6	29.4	41.2	1.9	0.6	40.8	232.0	8.6	4.0	2.0
13	SW-13	36.5	23.0	35.5	1.2	0.2	33.7	242.0	7.2	3.8	1.9
14	SW-14	32.7	25.2	36.7	1.2	0.6	27.3	264.0	6.1	3.2	1.6

Table 16: Major ions of surface water during Post-Monsoon 2021.

S. N.	Sample Code	Ca	Mg	Na	K	F	Cl	HCO_3	SO_4	NO_3	PO_4
		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1	SW-1	67.9	12.9	25.6	0.4	0.48	72.8	187.0	8.8	1.9	0.2
2	SW-2	59.3	16.3	34.7	0.4	0.43	75.9	195.8	8.6	1.7	0.2
3	SW-3	86.9	24.9	33.9	0.4	0.60	111.4	250.8	12.8	1.5	0.2
4	SW-4	93.7	23.2	46.3	0.3	0.65	120.1	278.2	11.1	0.4	0.1
5	SW-5	46.1	20.6	25.6	0.3	0.39	47.7	216.1	7.1	0.2	0.1
6	SW-6	39.3	21.8	23.1	1.2	0.26	40.1	231.0	6.4	2.1	0.2
7	SW-7	37.9	21.0	34.3	1.1	0.33	36.8	252.8	6.6	3.0	0.3
8	SW-8	39.9	27.1	20.8	3.1	0.24	31.2	259.0	8.5	3.6	0.4
9	SW-9	54.6	16.7	22.4	1.2	0.38	22.8	237.6	8.2	2.3	0.3
10	SW-10	41.8	22.9	21.4	1.3	0.10	21.0	244.6	6.6	3.6	0.4
11	SW-11	38.2	25.8	17.3	0.9	0.29	25.3	242.6	8.0	6.7	0.6
12	SW-12	22.0	25.3	34.1	1.2	0.54	25.4	235.2	4.7	8.1	0.7
13	SW-13	31.4	19.8	29.3	0.8	0.20	21.0	244.2	8.8	7.7	0.7
14	SW-14	28.1	21.7	26.8	0.8	0.55	17.0	266.4	5.8	0.4	0.1

Table 17: Major ions of surface water during Pre-Monsoon 2022

S. N.	Sample Code	Ca	Mg	Na	K	F	Cl	HCO_3	SO_4	NO_3	PO_4
		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1	SW-1	69.8	18.0	24.3	0.4	0.47	47.0	275	3.9	1.3	0.1
2	SW-2	68.8	20.1	26.0	0.3	0.58	51.0	284	4.1	1.2	0.1
3	SW-3	87.3	36.0	33.3	0.4	0.79	82.0	336	10.0	1.0	0.2
4	SW-4	85.5	33.6	46.8	0.3	0.82	85.0	341	12.2	1.4	0.2
5	SW-5	38.0	30.2	24.3	0.2	0.36	38.0	223	7.2	0.9	0.1
6	SW-6	46.4	31.7	21.6	1.5	0.37	43.7	265	6.6	1.5	0.2
7	SW-7	44.7	30.7	19.2	1.3	0.45	41.1	227	9.8	2.1	0.3
8	SW-8	47.2	38.8	19.1	0.9	0.24	44.1	265	8.7	2.5	0.3
9	SW-9	65.9	18.1	20.8	1.4	0.34	41.6	272	16.6	1.6	0.3
10	SW-10	49.6	33.3	19.7	1.6	0.32	37.8	255	14.0	2.5	0.3
11	SW-11	45.0	37.1	15.2	1.0	0.31	32.6	261	8.2	8.2	0.7
12	SW-12	24.3	36.5	33.5	1.5	0.54	37.8	249	14.1	5.6	0.6
13	SW-13	36.3	29.0	28.3	0.9	0.35	37.4	238	9.0	5.4	0.5
14	SW-14	32.1	31.6	27.4	0.9	0.43	22.6	279	12.1	3.0	0.4

Table 18: Major ions of surface water during Post-Monsoon 2022

S. N.	Sample Code	Ca	Mg	Na	K	F	Cl	HCO_3	SO_4	NO_3	PO_4
		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1	SW-1	47.0	19.7	25.2	0.3	0.38	34.6	218.4	4.6	1.4	0.2
2	SW-2	48.5	18.3	26.0	0.3	0.41	37.0	220.3	4.5	1.3	0.1
3	SW-3	85.1	33.7	32.4	0.3	0.60	81.6	321.0	9.6	1.1	0.2
4	SW-4	90.3	32.4	28.7	0.3	0.65	80.1	313.0	8.4	0.3	0.1
5	SW-5	24.6	24.0	21.2	0.2	0.32	24.8	222.9	4.3	0.2	0.1
6	SW-6	29.5	23.2	22.3	0.9	0.26	23.1	238.6	4.8	1.6	0.2
7	SW-7	43.4	18.5	25.8	0.3	0.33	31.6	230.4	4.9	2.2	0.2
8	SW-8	29.9	22.5	25.6	2.3	0.24	23.4	249.0	4.4	2.7	0.3
9	SW-9	36.9	16.3	26.8	0.9	0.28	17.1	249.5	4.2	1.7	0.2
10	SW-10	31.4	22.4	26.0	1.0	0.10	15.8	256.8	5.0	2.7	0.3
11	SW-11	28.6	25.1	23.0	0.6	0.29	19.0	254.7	4.0	3.0	0.3
12	SW-12	26.5	24.7	25.5	0.9	0.24	19.1	247.0	3.5	3.1	0.3
13	SW-13	23.5	24.4	32.0	0.6	0.20	15.7	256.4	4.6	4.8	0.4
14	SW-14	27.1	21.1	30.1	0.6	0.35	17.8	248.5	4.3	0.3	0.1

6.3.3 Heavy Metals / Trace elements (Surface Water)

Heavy metals (As, Cd, Cr, Fe, Hg, Mn, Pb, and Zn) of 14 water bodies (ponds, check dams, reservoir and ash pond, etc.) near the Ash-pond were analysed. Concentration of heavy metals in surface waters of the area are presented in ***Tables 19 to 22***.

Table 19: Trace elements in surface water during Pre-monsoon 2021

Sample ID	As	Cd	Cr	Fe	Hg	Mn	Pb	Zn
	ppb	Ppb	ppb	ppb	ppb	ppb	ppb	ppb
SW-1	ND	0.1	2.9	307.7	ND	33.4	0.7	18.5
SW-2	ND	0.1	4.4	272.1	ND	34.6	0.5	17.3
SW-3	ND	0.1	1.9	548.8	ND	41.0	1.0	25.3
SW-4	ND	0.1	2.2	454.3	ND	42.9	0.9	30.7
SW-5	ND	0.1	1.5	338.6	ND	12.7	0.8	16.5
SW-6	ND	0.0	1.7	156.9	ND	9.8	0.7	7.3
SW-7	ND	0.1	1.4	271.3	ND	31.2	1.5	18.2
SW-8	ND	0.1	1.8	199.9	ND	10.4	1.4	7.6
SW-9	ND	0.1	2.1	182.4	ND	11.4	1.0	7.3
SW-10	ND	0.1	3.0	119.3	ND	11.2	1.0	6.8
SW-11	ND	0.1	1.3	212.8	ND	15.7	0.8	7.2
SW-12	ND	0.1	1.9	180.2	ND	16.0	1.0	9.1
SW-13	ND	0.1	1.8	195.0	ND	16.2	0.5	8.4
SW-14	ND	0.1	2.2	177.3	ND	18.3	0.9	7.4

Table 20: Trace elements in surface water during Post-Monsoon 2021

Sample ID	As	Cd	Cr	Fe	Hg	Mn	Pb	Zn
	Ppb	Ppb	ppb	ppb	ppb	ppb	ppb	ppb
SW-1	ND	0.0	1.5	110.4	ND	20.4	0.3	10.5
SW-2	ND	0.1	2.0	125.5	ND	16.8	0.5	12.8
SW-3	ND	0.0	2.3	383.0	ND	114.2	0.6	15.0
SW-4	ND	0.0	3.6	57.8	ND	141.6	0.6	17.2
SW-5	ND	0.1	3.2	95.0	ND	30.6	0.8	8.4
SW-6	ND	0.1	1.3	80.2	ND	61.0	0.6	6.6
SW-7	ND	0.0	1.5	114.0	ND	40.4	0.5	10.3
SW-8	ND	0.1	2.2	63.0	ND	47.2	0.4	5.5
SW-9	ND	0.0	1.0	73.6	ND	53.4	0.3	4.3
SW-10	ND	0.0	1.4	85.0	ND	64.4	0.6	5.4
SW-11	ND	0.0	0.9	62.2	ND	33.4	0.3	6.8
SW-12	ND	0.0	3.3	113.8	ND	11.6	0.2	6.2
SW-13	ND	0.0	10.0	85.4	ND	23.2	0.4	6.4
SW-14	ND	0	1.5	199.8	ND	28.4	0.3	8.2

Table 21: Trace elements in surface water during Pre-Monsoon 2022

Sample ID	As	Cd	Cr	Fe	Hg	Mn	Pb	Zn
	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb
SW-1	ND	0.1	2.6	276.9	ND	36.8	0.6	14.8
SW-2	ND	0.1	4.0	244.8	ND	38.1	0.5	13.8
SW-3	ND	0.1	1.7	493.9	ND	45.1	0.9	20.3
SW-4	ND	0.1	1.9	408.8	ND	47.2	0.8	24.6
SW-5	ND	0.0	1.4	214.7	ND	14.0	0.7	8.1
SW-6	ND	0.0	1.5	141.2	ND	14.1	0.6	5.8
SW-7	ND	0.1	1.3	244.2	ND	34.3	1.4	14.2
SW-8	ND	0.1	1.6	179.9	ND	11.5	1.3	6.1
SW-9	ND	0.0	1.9	164.1	ND	12.6	0.9	5.8
SW-10	ND	0.1	2.7	107.3	ND	12.3	0.9	5.4
SW-11	ND	0.1	1.1	191.5	ND	17.3	0.7	5.8
SW-12	ND	0.0	1.7	162.2	ND	17.6	0.9	7.3
SW-13	ND	0.0	1.6	175.5	ND	17.8	0.5	6.7
SW-14	ND	0.1	2.0	159.6	ND	20.1	0.8	5.9

Table 22: Trace elements in surface water during Post-Monsoon 2022

Sample ID	As	Cd	Cr	Fe	Hg	Mn	Pb	Zn
	ppb	Ppb	ppb	ppb	ppb	ppb	ppb	ppb
SW-1	ND	0.0	1.4	99.3	ND	22.4	0.3	9.8
SW-2	ND	0.1	1.8	113.0	ND	18.5	0.5	10.3
SW-3	ND	0.0	2.1	344.7	ND	125.6	0.5	12.0
SW-4	ND	0.0	3.2	52.0	ND	155.8	0.5	13.7
SW-5	ND	0.1	2.8	85.5	ND	33.7	0.7	6.7
SW-6	ND	0.1	1.1	72.1	ND	67.1	0.5	5.3
SW-7	ND	0.0	1.4	75.6	ND	44.4	0.5	11.0
SW-8	ND	0.1	1.9	56.7	ND	51.9	0.4	4.4
SW-9	ND	0.0	0.9	66.2	ND	58.7	0.3	3.4
SW-10	ND	0.0	1.3	76.5	ND	70.8	0.5	4.3
SW-11	ND	0.0	0.8	55.9	ND	36.7	0.3	5.4
SW-12	ND	0.0	2.9	75.4	ND	12.8	0.2	5.0
SW-13	ND	0.0	4.5	76.9	ND	25.5	0.4	5.1
SW-14	ND	0.0	1.4	89.8	ND	31.2	0.3	6.6

6.4 Ground Water Quality

Total 16 ground water sources each during pre-monsoon and post-monsoon seasons were examined for selected parameters for baseline studies. In addition, samples from 6 piezometers constructed in December 2022 (post monsoon 2022) were also analysed for the ground water quality. Details of

sampling locations and map of sampling locations are shown in ***Table 23*** and ***Figure 16.***

Table 23: Details of groundwater sampling locations

S.N.	Location ID	Location	Source	Latitude (^{0}N)	Longitude (^{0}E)
1	GWQ-1	NTPC Substation	Bore well	16.4943	75.8407
2	GWQ-2	Laxman Talwar House	Bore well	16.5002	75.7925
3	GWQ-3	Tadalgi	Open Well	16.4596	75.7872
4	GWQ-4	Arasangi	Bore well	16.4218	75.8258
5	GWQ-5	Angadageri	Open Well	16.4576	75.8549
6	GWQ-6	Golasange	Open Well	16.4946	75.8778
7	GWQ-7	Mutagi	Bore well	16.5238	75.8859
8	GWQ-8	Kudgi	Open Well	16.5252	75.8089
9	GWQ-9	Talewad	Open Well	16.5570	75.8090
10	GWQ-10	Asangi	Open Well	16.4908	75.7421
11	GWQ-11	Hanamapur	Open Well	16.4382	75.7525
12	GWQ-12	Telgi	Bore well	16.4742	75.8190
13	GWQ-13	Nagaradinni	Open Well	16.4672	75.7480
14	GWQ-14	Masuti	Open Well	16.5158	75.8058
15	GWQ-15	Masuti	Bore well	16.5080	75.7858
16	GWQ-16	Chiraladinni	Bore well	16.4685	75.8008
17	GWQ-17	Pz-1	Piezometer	16.4978	75.7953
18	GWQ-18	Pz-2	Piezometer	16.4963	75.7955
19	GWQ-19	Pz-3	Piezometer	16.4948	75.7964
20	GWQ-20	Pz-4	Piezometer	16.4932	75.7976
21	GWQ-21	Pz-5	Piezometer	16.4920	75.8067
22	GWQ-22	Pz-6	Piezometer	16.4906	75.8128

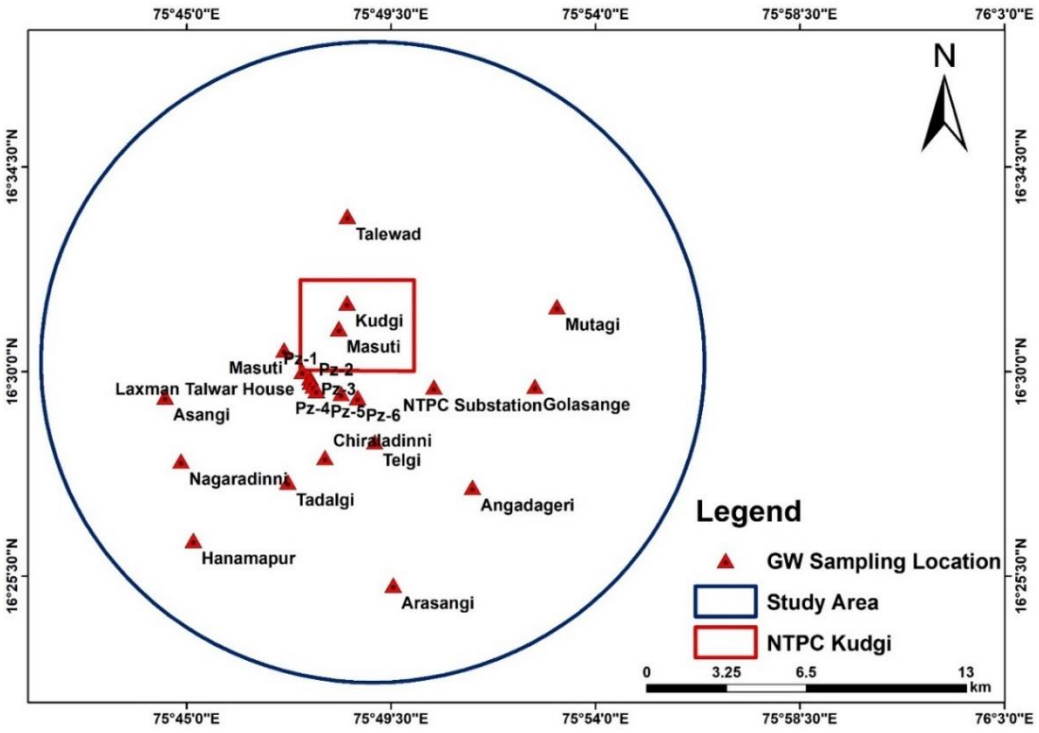


Figure 16: Location map of groundwater sampling sites.

6.4.1 Physical parameters (Groundwater)

Physical parameters are physical aspects of water quality that help to determine whether water is polluted or not. The various physical parameters include Temperature, EC, pH, TDS, alkalinity, Hardness, DO, BOD, COD, etc. ***Tables 24 to Table 27*** present the physical parameters of the surface water locations monitored for the study area during July 2021 (Pre-monsoon, 2021), January 2022 (Post-monsoon, 2021), June 2022 (Pre-monsoon, 2022) and December 2022 (Post-monsoon, 2022), respectively.

Table 24: Physical parameters of ground water (Pre-monsoon 2021)

S. N.	Site Code	Temp (^{0}C)	pH	EC (µS/cm)	TDS (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	DO (mg/l)
1	GWQ-1	24.6	7.5	878	588	109	402.0	5.6
2	GWQ-2	25.2	7.5	721	483	93	454.4	5.2
3	GWQ-3	24.5	7.6	889	596	108	293.4	5.2
4	GWQ-4	23.8	7.7	1047	702	124	236.7	5.7
5	GWQ-5	24.5	7.6	686	460	82	324.6	4.4
6	GWQ-6	23.1	7.6	1028	688	121	233.5	5.5
7	GWQ-7	23.7	7.4	958	642	116	377.4	5.9
8	GWQ-8	23.7	7.3	604	405	72	208.0	4.5
9	GWQ-9	23.1	7.4	614	411	73	220.9	4.2
10	GWQ-10	23.9	7.6	781	524	93	212.6	4.4
11	GWQ-11	25.0	7.8	917	615	108	219.7	5.0
12	GWQ-12	24.0	7.5	673	451	82	234.5	4.0
13	GWQ-13	23.2	7.3	904	606	109	281.2	5.2
14	GWQ-14	22.6	7.1	550	369	66	208.3	4.6
15	GWQ-15	23.8	7.5	483	324	59	189.3	4.1
16	GWQ-16	23.2	7.3	1079	723	127	248.5	5.8

Table 25: Physical parameters of ground water (Post-monsoon 2021)

S. N.	Site Code	Temp (^{0}C)	pH	EC (µS/cm)	TDS (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	DO (mg/l)
1	GWQ-1	22.9	7.6	857	574	107	347.9	5.3
2	GWQ-2	23.2	7.7	888	595	111	354.4	5.5
3	GWQ-3	23.4	7.8	999	669	126	250.4	5.5
4	GWQ-4	24.1	8.0	937	628	116	165.2	4.9
5	GWQ-5	23.2	7.6	949	636	115	251.4	5.3
6	GWQ-6	22.5	7.4	996	935	170	200.6	5.3
7	GWQ-7	25.4	8.4	849	770	142	283.7	5.0
8	GWQ-8	23.1	7.7	755	506	91	174.8	5.1
9	GWQ-9	23.6	7.8	672	450	83	202.1	4.4
10	GWQ-10	24.1	8.0	872	584	107	177.7	4.6
11	GWQ-11	22.8	7.6	847	567	105	196.3	4.6

S. N.	Site Code	Temp (^{0}C)	pH	EC (µS/cm)	TDS (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	DO (mg/l)
12	GWQ-12	21.6	7.2	932	625	116	238.8	5.2
13	GWQ-13	22.2	7.3	960	643	118	226.4	5.2
14	GWQ-14	23.7	7.7	776	520	100	189.0	5.9
15	GWQ-15	21.8	7.3	845	566	109	197.9	6.4
16	GWQ-16	22.9	7.6	890	597	110	204.2	4.8

Table 26: Physical parameters of ground water (Pre-monsoon 2022)

S. N.	Site Code	Temp (^{0}C)	pH	EC (µS/cm)	TDS (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	DO (mg/l)
1	GWQ-1	22.9	7.5	962	644	118	361.6	5.8
2	GWQ-2	22.6	7.5	762	510	95	407.0	5.1
3	GWQ-3	23.1	7.6	991	664	124	305.6	5.7
4	GWQ-4	23.5	7.7	1202	805	147	224.2	6.3
5	GWQ-5	23.2	7.6	754	505	93	295.6	4.6
6	GWQ-6	23.0	7.6	943	632	124	223.3	5.1
7	GWQ-7	22.3	7.4	1030	690	132	352.1	6.1
8	GWQ-8	22.2	7.3	678	454	80	195.9	4.8
9	GWQ-9	22.3	7.4	683	458	83	213.5	4.5
10	GWQ-10	22.9	7.6	878	589	110	195.7	4.7
11	GWQ-11	23.7	7.8	799	535	99	218.7	4.5
12	GWQ-12	22.5	7.5	737	494	90	204.1	4.1
13	GWQ-13	21.9	7.3	1008	675	124	233.1	5.5
14	GWQ-14	21.3	7.1	662	444	87	163.2	5.0
15	GWQ-15	22.6	7.5	558	374	73	211.9	4.7
16	GWQ-16	22.1	7.3	1016	681	125	249.7	5.6

Table 27: Physical parameters of ground water (Post-monsoon 2022)

S. N.	Site Code	Temp (^{0}C)	pH	EC (µS/cm)	TDS (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	DO (mg/l)
1	GWQ-1	23.1	7.6	697	467	128	266.1	4.2
2	GWQ-2	23.0	7.7	1146	768	206	187.6	5.9
3	GWQ-3	23.7	7.8	1077	722	135	153.9	5.4
4	GWQ-4	24.2	8.0	525	352	69	119.2	2.8
5	GWQ-5	23.7	7.6	1370	918	160	173.1	6.8
6	GWQ-6	22.6	7.4	1260	844	151	198.6	6.4
7	GWQ-7	25.9	8.4	814	545	99	173.8	5.4
8	GWQ-8	23.7	7.7	952	638	115	200.1	5.8
9	GWQ-9	24.6	7.8	691	463	87	192.4	3.9
10	GWQ-10	24.5	8.0	922	618	109	145.5	4.7
11	GWQ-11	23.1	7.6	790	529	98	158.9	4.2
12	GWQ-12	21.6	7.2	1350	905	171	268.2	5.9
13	GWQ-13	22.4	7.3	928	622	114	172.7	4.0
14	GWQ-14	23.8	7.7	1083	726	135	169.9	4.6
15	GWQ-15	22.4	7.3	1460	978	185	227.4	6.2

S. N.	Site Code	Temp (^{0}C)	pH	EC (µS/cm)	TDS (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	DO (mg/l)
16	GWQ-16	22.9	7.6	340	228	48	167.8	5.6
17	Pz-1	22.7	7.4	805	539	97	144.2	5.2
18	Pz-2	23.3	7.7	823	551	98	153.8	4.7
19	Pz-3	24.0	8.0	1069	716	128	178.2	6.0
20	Pz-4	24.2	8.0	1004	673	121	177.6	5.6
21	Pz-5	24.0	7.9	997	668	121	187.3	5.7
22	Pz-6	24.1	7.9	729	488	91	211.6	5.2

6.4.2 Major Ions (Ground water)

Ions contain positively charged ions (cations) and negatively charged ions (anions) present in water. Major ions (Ca, Mg, Na, K, F, Cl, HCO_3, SO_4, NO_3, and PO_4) in the surface water from 16 locations. ***Tables 28*** *to* ***Table 31*** present the major ion concentration in the surface water at locations monitored in the study area during July 2021 (Pre-monsoon, 2021), January 2022 (Post-monsoon, 2021), June 2022 (Pre-monsoon, 2022) and December 2022 (Post-monsoon, 2022), respectively.

Table 28: Major ions chemistry of ground water (Pre-monsoon 2021)

S. N.	Sample Code	Ca	Mg	Na	K	F	Cl	HCO_3	SO_4	NO_3	PO_4
		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1	GWQ-1	65	58	52	0.3	1.9	71	375	43	37	0.00
2	GWQ-2	75	65	47	0.4	2.8	65	438	44	56	0.19
3	GWQ-3	54	39	50	0.2	1.6	85	324	20	34	0.24
4	GWQ-4	42	32	62	0.8	0.7	76	258	16	33	0.28
5	GWQ-5	29	61	21	0.1	1.7	58	280	23	35	0.19
6	GWQ-6	39	33	68	0.3	0.3	79	288	10	45	0.58
7	GWQ-7	57	57	44	0.5	1.7	87	326	30	27	0.00
8	GWQ-8	29	33	38	0.2	1.9	30	274	10	37	0.45
9	GWQ-9	29	36	32	0.1	0.8	43	224	11	48	0.62
10	GWQ-10	34	31	39	0.2	1.1	64	217	12	35	0.38
11	GWQ-11	32	34	47	0.3	1.5	62	266	15	15	0.00
12	GWQ-12	43	31	32	0.2	1.6	48	252	16	36	0.33
13	GWQ-13	49	38	49	0.4	1.4	69	295	16	47	0.52
14	GWQ-14	26	35	77	0.2	1.4	73	273	14	54	0.67
15	GWQ-15	29	29	63	0.7	1.2	64	253	10	36	0.43
16	GWQ-16	36	38	60	0.2	1.2	61	318	14	33	0.31

Table 29: Major ions chemistry of Ground water (Post-monsoon 2021)

S. N.	Sample Code	Ca	Mg	Na	K	F	Cl	HCO_3	SO_4	NO_3	PO_4
		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1	GWQ-1	53	52	42	0.4	1.9	70	339	29	42.5	0.23
2	GWQ-2	63	48	38	0.2	2.1	71	337	31	46.2	0.25
3	GWQ-3	37	39	57	0.2	1.8	86	263	21	28.7	0.12
4	GWQ-4	18	29	70	0.4	1.0	66	231	13	19.6	0.11
5	GWQ-5	28	44	36	0.3	1.6	57	257	23	38.4	0.26
6	GWQ-6	35	28	88	0.7	2.7	87	313	14	23.8	0.16
7	GWQ-7	45	42	39	0.7	1.6	80	266	24	40.7	0.29
8	GWQ-8	27	26	35	0.2	1.3	38	233	11	21.7	0.17
9	GWQ-9	29	32	34	0.1	2.3	49	201	13	32.8	0.33
10	GWQ-10	29	26	37	0.1	2.0	58	193	15	18.3	0.06
11	GWQ-11	36	26	43	0.2	2.0	62	227	15	24.5	0.16
12	GWQ-12	35	37	40	0.3	2.0	73	234	17	19.1	0.04
13	GWQ-13	37	33	54	0.7	3.2	66	262	21	38.4	0.30
14	GWQ-14	34	26	71	0.3	2.3	78	236	14	43.5	0.49
15	GWQ-15	24	33	69	0.6	1.2	89	249	17	21.9	0.08
16	GWQ-16	33	30	63	0.6	2.0	65	284	20	13.2	0.00

Table 30: Major ions chemistry of ground water (Pre-monsoon 2022)

S. N.	Sample Code	Ca	Mg	Na	K	F	Cl	HCO_3	SO_4	NO_3	PO_4
		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1	GWQ-1	61	51	45	0.5	1.6	66	344	28	43.5	0.26
2	GWQ-2	81	50	33	0.1	1.7	57	408	33	41.7	0.15
3	GWQ-3	47	46	49	0.2	1.6	81	310	20	31.7	0.19
4	GWQ-4	21	42	70	0.4	1.6	78	256	16	35.0	0.32
5	GWQ-5	26	56	18	0.0	1.5	55	265	21	46.7	0.43
6	GWQ-6	35	33	123	0.8	2.0	113	386	17	27.5	0.17
7	GWQ-7	57	51	54	1.4	1.3	104	307	26	42.5	0.28
8	GWQ-8	39	24	38	0.1	2.0	29	263	11	30.0	0.32
9	GWQ-9	28	35	31	0.0	0.8	41	214	11	12.5	0.03
10	GWQ-10	26	32	40	0.1	1.4	72	209	14	21.7	0.12
11	GWQ-11	35	32	49	0.1	1.8	61	276	18	26.7	0.15
12	GWQ-12	39	26	27	0.1	1.3	45	237	13	16.7	0.06
13	GWQ-13	42	31	53	0.5	1.5	66	291	17	23.3	0.11
14	GWQ-14	21	27	86	0.4	1.7	76	282	16	22.5	0.11
15	GWQ-15	29	34	57	0.2	1.8	64	266	15	20.0	0.08
16	GWQ-16	39	37	62	0.6	1.6	67	326	17.8	26.7	0.15

Table 31: Major ions chemistry of ground water (Post-monsoon 2022)

S. N.	Sample Code	Ca	Mg	Na	K	F	Cl	HCO_3	SO_4	NO_3	PO_4
		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1	GWQ-1	31	46	37	0.20	2.2	71.5	266	14.5	36.0	0.36
2	GWQ-2	32	26	32	0.20	1.7	89.0	150	16.1	3.6	0.00
3	GWQ-3	22	24	69	0.20	2.3	88.0	144	22.8	47.7	0.42
4	GWQ-4	12	22	76	0.10	0.6	62.0	170	16.9	32.4	0.26
5	GWQ-5	27	26	68	0.70	2.2	45.0	216	23.2	70.2	0.78
6	GWQ-6	29	31	70	1.00	1.7	64.0	252	14.7	32.4	0.30
7	GWQ-7	24	28	34	0.10	2.4	46.0	154	12.4	59.4	0.78
8	GWQ-8	21	36	29	0.40	1.0	52.5	152	15.5	58.5	0.72
9	GWQ-9	29	29	37	0.10	1.7	61.5	128	16.6	98.1	1.36
10	GWQ-10	25	20	31	0.10	1.9	35.5	146	16.6	44.1	0.46
11	GWQ-11	24	24	32	0.20	1.2	61.5	130	11.1	37.8	0.45
12	GWQ-12	22	52	60	0.70	1.6	122.5	205	20.5	18.0	0.00
13	GWQ-13	17	32	61	1.00	1.8	62.0	180	28.4	60.7	0.54
14	GWQ-14	29	24	46	0.10	1.2	81.5	134	11.2	49.4	0.64
15	GWQ-15	19	44	83	0.80	1.7	134.0	198	25.5	62.5	0.62
16	GWQ-16	21	28	66	1.00	1.6	63.0	196	26.8	24.4	0.00
17	Pz-1	13	27	27	1.70	1.2	42.1	144	12.3	32.4	0.34
18	Pz-2	16	28	33	1.55	2.1	38.8	159	17.0	26.1	0.15
19	Pz-3	19	32	36	1.11	2.3	49.7	172	18.5	20.7	0.04
20	Pz-4	12	36	72	0.98	0.8	52.0	262	16.3	25.2	0.15
21	Pz-5	13	38	51	1.47	1.2	57.1	202	16.0	38.9	0.38
22	Pz-6	17	41	61	1.84	0.9	56.0	296	14.0	39.4	0.42

6.4.3 Heavy Metals/Trace elements (Groundwater)

Heavy metals (As, Cd, Cr, Fe, Hg, Mn, Pb, and Zn) of 14 water bodies (ponds, check dams, reservoir and ash pond, etc.) near the Ash-pond were analysed. Concentration of heavy metals in surface waters of the area are presented in ***Tables 32 to 35.***

Table 32: Trace / Heavy Metals in ground water (Pre-monsoon 2021)

S. N.	Sample ID	As (ppb)	Cd (ppb)	Cr (ppb)	Fe (ppb)	Hg (ppb)	Mn (ppb)	Pb (ppb)	Zn (ppb)
1	GWQ-1	BDL	0.1	1.3	2769	BDL	368	0.6	5.7
2	GWQ-2	BDL	0.1	2.0	2448	BDL	381	0.5	5.3
3	GWQ-3	BDL	0.1	0.8	4939	BDL	451	0.9	7.8
4	GWQ-4	BDL	0.1	1.0	4088	BDL	472	0.8	9.4
5	GWQ-5	BDL	0.0	0.7	2147	BDL	240	0.7	3.1
6	GWQ-6	BDL	0.0	0.7	1412	BDL	191	0.6	2.2
7	GWQ-7	BDL	0.1	0.6	2442	BDL	343	1.4	5.5
8	GWQ-8	BDL	0.1	0.8	1799	BDL	115	1.3	2.3
9	GWQ-9	BDL	0.0	0.9	1641	BDL	126	0.9	2.2
10	GWQ-10	BDL	0.1	1.4	1073	BDL	123	0.9	2.1
11	GWQ-11	BDL	0.1	0.6	1915	BDL	173	0.7	2.2

12	GWQ-12	BDL	0.0	0.8	1622	BDL	176	0.9	2.8
13	GWQ-13	BDL	0.0	0.8	1755	BDL	178	0.5	2.6
14	GWQ-14	BDL	0.1	1.0	1596	BDL	201	0.8	2.3
15	GWQ-15	BDL	0.1	0.7	1296	BDL	161	0.6	2.0
16	GWQ-16	BDL	0.1	0.9	1673	BDL	223	0.7	2.1

Table 33: Trace / Heavy metals in ground water (Post-monsoon 2021)

S. N.	Sample ID	As (ppb)	Cd (ppb)	Cr (ppb)	Fe (ppb)	Hg (ppb)	Mn (ppb)	Pb (ppb)	Zn (ppb)
1	GWQ-1	BDL	0.0	0.7	993	BDL	224	0.7	4.2
2	GWQ-2	BDL	0.1	0.9	1130	BDL	185	1.0	3.9
3	GWQ-3	BDL	0.0	1.0	1447	BDL	856	1.2	4.6
4	GWQ-4	BDL	0.0	1.6	520	BDL	958	1.4	5.3
5	GWQ-5	BDL	0.1	1.4	855	BDL	337	0.6	2.6
6	GWQ-6	BDL	0.1	0.6	721	BDL	671	0.3	2.0
7	GWQ-7	BDL	0.0	0.7	756	BDL	444	0.4	4.2
8	GWQ-8	BDL	0.1	1.0	567	BDL	519	0.5	1.7
9	GWQ-9	BDL	0.0	0.5	662	BDL	587	0.5	1.3
10	GWQ-10	BDL	0.0	0.6	765	BDL	708	0.7	1.7
11	GWQ-11	BDL	0.0	0.4	559	BDL	367	0.5	2.1
12	GWQ-12	BDL	0.0	1.5	754	BDL	128	0.4	1.9
13	GWQ-13	BDL	0.0	2.2	769	BDL	255	0.4	2.0
14	GWQ-14	BDL	0.0	0.7	898	BDL	312	0.4	2.5
15	GWQ-15	BDL	0.1	0.6	638	BDL	392	0.3	1.8
16	GWQ-16	BDL	0.0	0.6	728	BDL	422	0.4	2.1

Table 34: Trace / Heavy Metals in ground water (Pre-monsoon 2022)

S. N.	Sample ID	As (ppb)	Cd (ppb)	Cr (ppb)	Fe (ppb)	Hg (ppb)	Mn (ppb)	Pb (ppb)	Zn (ppb)
1	GWQ-1	BDL	0.1	1.4	2611	BDL	429	0.5	5.2
2	GWQ-2	BDL	0.1	1.4	2298	BDL	490	0.7	5.8
3	GWQ-3	BDL	0.2	1.7	3730	BDL	471	0.3	6.1
4	GWQ-4	BDL	0.2	1.7	2372	BDL	500	0.4	6.4
5	GWQ-5	BDL	0.2	1.3	1990	BDL	358	0.2	4.9
6	GWQ-6	BDL	0.1	0.9	1306	BDL	273	0.3	3.7
7	GWQ-7	BDL	0.3	1.3	2283	BDL	358	0.2	4.9
8	GWQ-8	BDL	0.3	0.9	1707	BDL	254	0.3	3.5
9	GWQ-9	BDL	0.2	1.1	1537	BDL	292	0.3	4.0
10	GWQ-10	BDL	0.2	1.4	944	BDL	382	0.5	5.3
11	GWQ-11	BDL	0.2	1.4	1770	BDL	325	0.2	4.5
12	GWQ-12	BDL	0.2	1.2	1506	BDL	302	0.3	4.2
13	GWQ-13	BDL	0.1	1.3	1622	BDL	330	0.3	4.5
14	GWQ-14	BDL	0.2	1.6	1435	BDL	401	0.4	5.5
15	GWQ-15	BDL	0.1	1.3	1160	BDL	328	0.3	4.5
16	GWQ-16	BDL	0.2	1.3	1544	BDL	328	0.3	4.5

Table 35: Trace / Heavy Metals in ground water (Post-monsoon 2022)

S. N.	Sample ID	As	Cd	Cr	Fe	Hg	Mn	Pb	Zn
		(ppb)	(ppb)	(ppb)	(ppb)	(ppb)	(ppb)	(ppb)	(ppb)
1	GWQ-1	BDL	0.0	1.4	2483	BDL	224	0.3	7.6
2	GWQ-2	BDL	0.1	1.8	2824	BDL	185	0.5	7.3
3	GWQ-3	BDL	0.0	2.1	3618	BDL	656	0.5	8.5
4	GWQ-4	BDL	0.0	3.2	1299	BDL	598	0.5	9.8
5	GWQ-5	BDL	0.1	2.8	2136	BDL	337	0.7	4.9
6	GWQ-6	BDL	0.1	1.1	1803	BDL	671	0.5	3.8
7	GWQ-7	BDL	0.0	1.4	1889	BDL	444	0.5	7.8
8	GWQ-8	BDL	0.1	1.9	1418	BDL	519	0.4	3.3
9	GWQ-9	BDL	0.0	0.9	1656	BDL	587	0.3	2.4
10	GWQ-10	BDL	0.0	1.3	1911	BDL	708	0.5	3.1
11	GWQ-11	BDL	0.0	0.8	1398	BDL	367	0.3	3.8
12	GWQ-12	BDL	0.0	2.9	1884	BDL	128	0.2	3.7
13	GWQ-13	BDL	0.0	4.5	1922	BDL	255	0.4	4.0
14	GWQ-14	BDL	0.0	1.4	2244	BDL	312	0.3	4.7
15	GWQ-15	BDL	0.1	1.1	1594	BDL	392	0.2	3.3
16	GWQ-16	BDL	0.0	1.3	1819	BDL	422	0.2	4.0
17	Pz-1	BDL	0.0	1.9	3272	BDL	391	0.5	8.6
18	Pz-2	BDL	0.1	2.6	1921	BDL	589	0.7	6.8
19	Pz-3	BDL	0.1	1.6	1874	BDL	599	0.5	5.4
20	Pz-4	BDL	0.0	1.1	1813	BDL	610	0.4	5.1
21	Pz-5	BDL	0.0	1.1	1821	BDL	610	0.4	3.5
22	Pz-6	BDL	0.0	1.4	2075	BDL	413	0.3	4.4

6.5 Concluding Remarks

6.5.1 Surface water

Surface water samples for four seasons were analysed for physio-chemical parameters (pH, EC, TDS, hardness, alkalinity, DO, BOD and COD), major ions (Ca, Mg, Na, K and F, Cl, HCO_3, SO_4, NO_3 and PO_4) and Trace/Heavy metals (As, Cd, Cr, Fe, Hg, Mn, Pb and Zn).

- The pH of the surface water bodies in the area falls in the range of 7.2 to 8.4 in pre-monsoon whereas in post-monsoon it varied from 7.2 to 8.3. The pH values for all of the samples (except ash pond) are well within the limits (6.5-8.5) prescribed by BIS (2012) for drinking and other domestic supplies.

- The TDS of the surface water bodies in the area falls in the range of 332.0 to 556.8 mg/l in pre-monsoon whereas in post-monsoon it varied from 198.8 to 986.0 mg/l. The TDS of surface water is well within the permissible limits (2000 mg/l) prescribed by BIS (2012) for drinking and other domestic supplies.
- The alkalinity of the surface water bodies ranges from 87.0 to 198.0 mg/l in pre-monsoon whereas in post-monsoon it ranges from 111.0 to 178.0 mg/l.
- The hardness of the surface water bodies in the area falls in the range of 55.0 to 214.0 mg/l in pre-monsoon whereas in post-monsoon it varied from 131.0 to 304.0 mg/l. In the present study, all the analysed samples falls within the permissible limit (600 mg/l) of BIS 2012 during both the seasons.
- The DO of the surface water bodies in the area falls in the range of 4.0 to 7.7 mg/l in pre-monsoon whereas in post-monsoon it varied from 3.5 to 6.7 mg/l.
- The BOD of the surface water bodies in the area falls in the range of 4 to 7.7 mg/l in pre-monsoon whereas in post-monsoon it varied from 3.5 to 6.7 mg/l.
- The COD of the surface water bodies in the area falls in the range of 13.0 to 25.0 mg/I in pre-monsoon whereas in post-monsoon it varied from 12.0 to 23.0 mg/l.
- Major cations include Ca, Mg, Na, K and Fe. Alkali metals dominate the surface water chemistry of the buffer zone of Kudgi Thermal Power plant. In general surface water follows the abundance order of Ca> Na> Mg > K in pre and post-monsoon period. Major anions are within acceptable limits as prescribed by BIS (2012).
- Major Anions shows that HCO_3, Cl, NO_3 and SO_4 are the dominant anions in surface water and follows the abundance order of HCO_3> Cl >SO_4>NO_3 -and PO_4, in the study area during pre-monsoon and post-

monsoon seasons. Major anions are within acceptable limits as prescribed by BIS (2012). Heavy/Trace metals

- Fe content in the study area varies from 107.3 to 548.8 ppb during pre-monsoon and 52 to 383 ppb during post-monsoon seasons. Iron content is within acceptable limits (300 ppb), except in ashpond water, as prescribed by BIS (2012).
- Different heavy metals, i.e., Fe, As, Cd, Cr, Hg, Pb, and Zn have been analysed. All the other Heavy/ Trace metals concentration (at two locations during pre-monsoon) are well within the acceptable limit for all the samples during pre-monsoon and post-monsoon seasons.

The analysis indicates that the chemical constituents in surface water of the area are well within the permissible limits prescribed by BIS (2012) for various uses of water including drinking and other domestic supplies.

6.5.2 Groundwater quality

The groundwater samples were analyzed for physio-chemical parameters (pH, EC, TDS, hardness and alkalinity), major ions (Ca, Mg, Na, K and Cl) and Trace /Heavy Metals (As, Cd, Cr, Fe, Hg, Mn, Pb and Zn). The analysis indicates that the chemical constituents of most of the locations are well within the permissible limits prescribed by BIS (2012) for various uses of water including drinking and other domestic supplies.

- A perusal of hydro-chemical data shows that ground water in the study area is mildly alkaline having average pH values 7.6 and varying from 7.2 to 7.8 during pre-monsoon season, whereas during post-monsoon the pH varies from 7.2 to 8.4. The pH values are within permissible limit as per the guidelines of the Bureau of Indian Standards (BIS, 2012).
- The electrical conductivity of the ground water samples during pre and post monsoon varied between 323 to 805 µS/cm and 228 to 1460 µS/cm. Average EC values during pre and post monsoon was observed between 876 and 917 µS/cm for ground water sample, respectively.
- In pre and post-monsoon period, all of the groundwater samples have TDS less than 1000 mg/l and falling under freshwater category. However,

in all the groundwater samples TDS values under the BIS (2012) permissible limit (2000 mg/l) for drinking water and other domestics uses, whereas the groundwater is hard at few locations.

- The alkalinity in groundwater ranges from 59 to 147.0 mg/l in pre-monsoon whereas in post-monsoon it ranges from 49.0 to 205.0 mg/l.
- The hardness of the groundwater in the area falls in the range of 163.2 to 454.4 mg/l in pre-monsoon whereas in post-monsoon it varied from 119.2 to 354.4 mg/l. In the present study, all the analysed samples falls within the permissible limit (600 mg/l) of BIS 2012 during both the seasons.
- The DO of the ground water samples in the area ranges from 4.0 to 6.3 mg/l in pre-monsoon and 2.8 to 6.8 mg/l in post-monsoon, though the BIS (2012) have not recommended any safe limit of dissolved oxygen (DO) in case of groundwater samples for drinking purpose.
- The major cations in the ground water includes Ca, Mg, Na and K. The ground water is dominated by Na>Mg>Ca>K during pre-monsoon and post-monsoon season.
- Fluoride (F) content in the groundwater of the study area varies from 0.3 to 2.8 mg/l during pre-monsoon and 0.6 to 3.2 mg/l during post-monsoon seasons. Flouride content is more than permissible limits (1.5 mg/l) in groundwater at many locations, as prescribed by BIS (2012).
- The anion follows the abundance order of HCO_3>Cl>SO_4>NO_3 >PO_4 in majority of the groundwater samples in premonsoon and post-monsoon. All the anions are present within the acceptable limits as prescribed by BIS (2012) for drinking water.
- In the present study, 7 heavy/trace metals, i.e., Zn As, Cd, Cr, Hg, Pb and Iron (Fe+), have been analysed for all the collected samples. Statistical summary of analysed samples for metals concentration revels that all metals (Zn, As, Cd, Cr, Pb, Hg) present in traces and concentration were well within the acceptable limit. Fe content in the study area varies from 94.4 to 493.9 ppb during pre-monsoon and 52 to

361.8 ppb during post-monsoon seasons. Iron content is within acceptable limits (300 ppb), except in ashpond water, as prescribed by BIS (2012).

The analysis indicates that in general, the chemical constituents in groundwater of the area are well within the permissible limits prescribed by BIS (2012) for various uses of water including drinking and other domestic supplies. The ashpond water contain high TDS and Fe content.

It needs to be mentioned that NTPC Kudgi has Zero Liquid discharge (ZLD) scheme therefore the ashpond water will not be discharged to any nearby water body and Ashpond water is being recycled by the NTPC for the purpose of preparing ash slurry, lagoon water is not used for drinking or domestic use.

6. ISOTOPIC INVESTIGATIONS

6.1 Background

Isotopes play a vital role in studying the origin, age, occurrence and distribution of groundwater in a region recharge mechanism, determination of groundwater flow direction and velocity; interconnections and interaction between aquifers; and identification of recharge areas and sources. Isotopes can also be applied to study surface water and groundwater interaction; tracing sources of pollutants including sea water intrusion and salinization mechanism. In the present study, groundwater and surface water samples were collected for isotopic characterization in the 12 km zone (***Figure 17***).



Figure 17: Collection of samples for isotopic analysis

The sampling locations for isotopic analysis are shown in ***Figure 18*** and the details of sampling locations are given in ***Table 36***. To identify the isotopic signatures of groundwater, samples were collected from open well, tube wells and hand pumps and surface water samples were collected from ponds and river. For the analysis of $\delta^{2}H$, $\delta^{18}O$, 20 ml of water sample was collected in pre cleaned polypropylene bottles (Tarson make). The bottles were rinsed profusely at site with sample water and filled with water samples, tightly capped (to prevent evaporation and exchange with the atmospheric moisture) and brought to the laboratory for isotopic analysis. On site measurements like sample temperature, pH, conductivity along with all other relevant site information were also recorded.

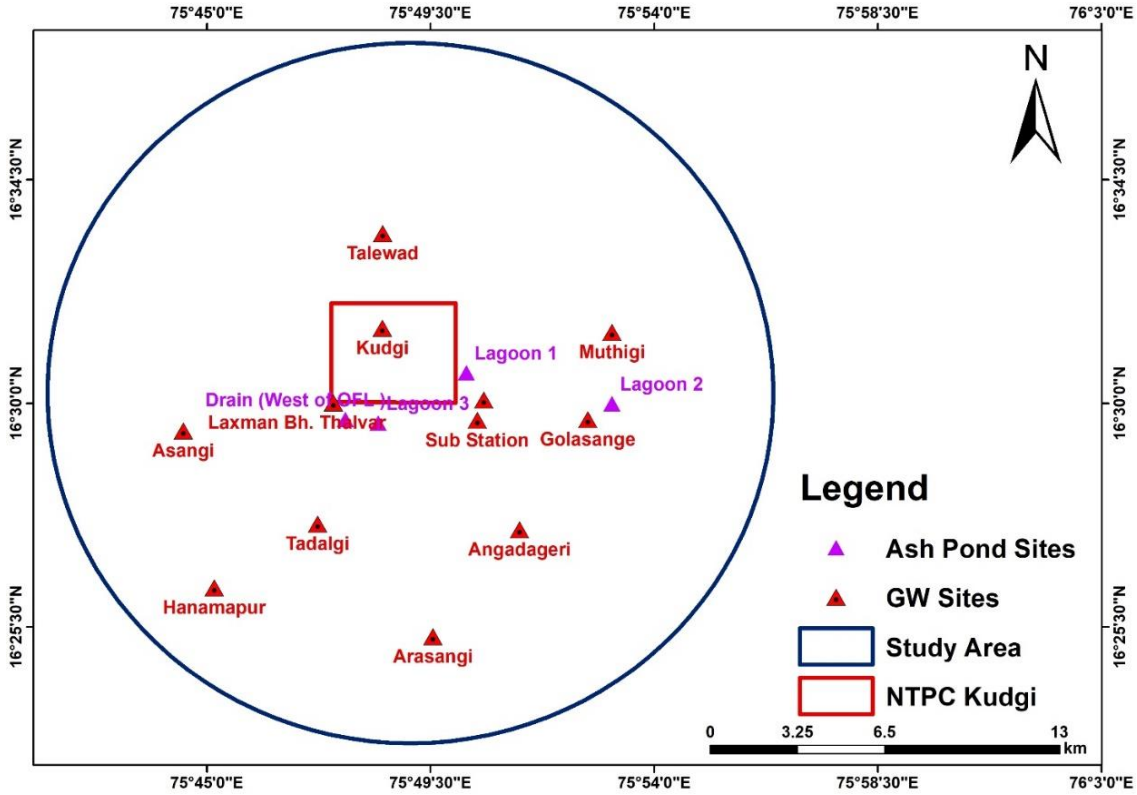


Figure 18: Location map of sites for isotopic analysis

Table 36: Details of sample collection locations for isotopic analysis

SI. No	Sample ID	Location	Source	Latitude (^{0}N)	Longitude (^{0}E)
Groundwater					
1	GWI-1	Tadalgi	Open Well	16.4596	75.7872
2	GWI-2	Arasangi	Bore Well	16.4218	75.8258
3	GWI-3	Angadageri	Open Well	16.4576	75.8549
4	GWI-4	Golasange	Open Well	16.4946	75.8778
5	GWI-5	Muthigi	Bore Well	16.5238	75.8859
6	GWI-6	Laxman Bh. Thalvar	Bore Well	16.5002	75.7925
7	GWI-7	Near Cooling Tower	Bore Well	16.5012	75.8429
8	GWI-8	Sub Station	Bore Well	16.4943	75.8407
9	GWI-9	Kudgi	Open Well	16.5252	75.8089
10	GWI-10	Talewad	Open Well	16.5570	75.8090
11	GWI-11	Asangi	Open Well	16.4908	75.7421
12	GWI-12	Hanamapur	Open Well	16.4382	75.7525
Ash Pond water					
1	SWI-1	Lagoon 1	Ash Pond	16.5102	75.8371
2	SWI-2	Lagoon 2	Ash Pond	16.4998	75.8859
3	SWI-3	Lagoon 3	Ash Pond	16.4934	75.8075
4	SWI-4	Drain (West of OFL)	OFL	16.4946	75.7965

The oxygen and hydrogen isotope measurements were carried out using a Dual Inlet Isotope Ratio Mass Spectrometer (GV instruments, UK) with automatic sample preparation units. For oxygen and hydrogen isotopes, 400μL water samples were taken and hook beads were used as catalyst. Along with each batch of samples, secondary standards developed with reference to primary standards (i.e., V-SMOW, SLAP, GISP) were also measured and the final δ-values were calculated using a triple point calibration equation. The overall precision, based on 10 points repeated measurements of each sample, was with the ±0.1‰ for $\delta^{18}O$ and ±1‰ for δD.

6.2 Isotopic Composition of Water

Isotopic composition of ash pond and ground water in the study area is given in ***Table 37***.

Table 37: Stable isotopic composition of water

			Jul, 2021			Dec, 2021			Mar, 2022		
S. N.	**ID**	**Source**	**$\delta^{18}O$ (‰)**	**$\delta^{2}H$ (‰)**	**d-Ex (‰)**	**$\delta^{18}O$ (‰)**	**$\delta^{2}H$ (‰)**	**d-Ex (‰)**	**$\delta^{18}O$ (‰)**	**$\delta^{2}H$ (‰)**	**d-Ex (‰)**
1	GWI-1	OW	-1.2	-8.5	1.1	-0.5	-5.8	-1.8	-1.3	-9.9	0.5
2	GWI-2	BW	-2.8	-16.9	5.5	-0.8	-5.2	1.2	-2.1	-12.7	4.1
3	GWI-3	OW	-2.8	-17.8	4.6	-1.8	-9.0	5.4			
4	GWI-4	OW			0.0	-1.4	-8.3	2.9	-1.2	-8.5	1.1
5	GWI-5	BW	1.2	9.1	-0.5	-1.3	-12.3	-1.9	0.2	4.6	3.0
6	GWI-6	BW	-0.8	-4.2	2.2	-0.3	-1.5	0.9	-1.4	-6.4	4.8
7	GWI-7	BW	0.1	-0.4	-1.2	-0.2	-1.7	-0.1	-1.2	-6.2	3.4
8	GWI-8	BW	-0.3	-3.8	-1.4	-1.9	-13.6	1.6	-1.0	-5.1	2.9
9	GWI-9	OW	-0.3	-1.6	0.8	0.1	-0.3	-1.1	-0.6	-5.4	-0.6
10	GWI-10	OW				-0.5	-3.5	0.5	-0.8	-7.1	-0.7
11	GWI-11	OW	-1.9	-13.3	1.9	-1.2	-7.1	2.5	-1.2	-8.2	1.4
12	GWI-12	OW	-1.2	-8.8	0.8	-2.1	-12.7	4.1	-1.1	-4.5	4.3
13	SWI-1	AP	2.5	13.8	-6.2	3.8	20.5	-9.9	3.3	17.5	-8.9
14	SWI-2	AP	3.4	19.4	-7.8	4.3	25.3	-9.1	3.4	16.1	-11.1
15	SWI-3	AP	2.5	12.0	-8.0	2.2	9.7	-7.9	2.5	12.0	-8.0
16	SWI-4	OFL	-0.3	-3.8	-1.4	1.1	8.3	-0.5	0.3	0.2	-2.2

OW- Open Well, BW-Bore Well, AP-Ash Pond

6.3 $\delta^{18}O$ and $\delta^{2}H$ Relationship

The $\delta^{18}O$ and $\delta^{2}H$ relationship of shallow groundwater and Ash Pond water has been developed (***Figure 19***). The regression analysis between $\delta^{18}O$ and $\delta^{2}H$ of

the data gives the best fit line (BFL) as:

$$\delta^2H = 5.83 * \delta^{18}O - 1.50 \quad (n = 39, r^2 = 0.958)$$

where, n is the number of samples and r is the correlation coefficient.

The local meteoric water line (LMWL) thus derived for the study period is (eq.1) has slightly less slope as that of global meteoric water line (GMWL) of Craig (1961) which was modified by Rozanski et al. (1993) (eq.2) represents average global freshwater composition. The GMWL is developed on the basis of exhaustive isotope data collected through the IAEA/WMO worldwide network. The local and global meteoric water lines are

$$\delta^2D = 6.9 * \delta^{18}O + 5.44 \quad \text{(LMWL)} \quad (1)$$

$$\delta D = (8.17\pm0.1)*\delta^{18}O + (11.27\pm0.6) \quad \text{(GMWL)} \quad (2)$$

Meteoric water line is the best-fit line of the $\delta^{18}O$ and δD content of the fresh waters. Craig (1961) after a global survey of stable isotope contents in freshwaters proposed a GMWL, which was later modified by Rozanski et al. (1993). The GMWL is essentially a global average of several LMWL. The LMWL is controlled by the local climatic conditions and the source of the vapour mass, particularly the slope of the line is influenced by the secondary evaporation. The knowledge of LMWL is essential for regional or local hydrological studies.

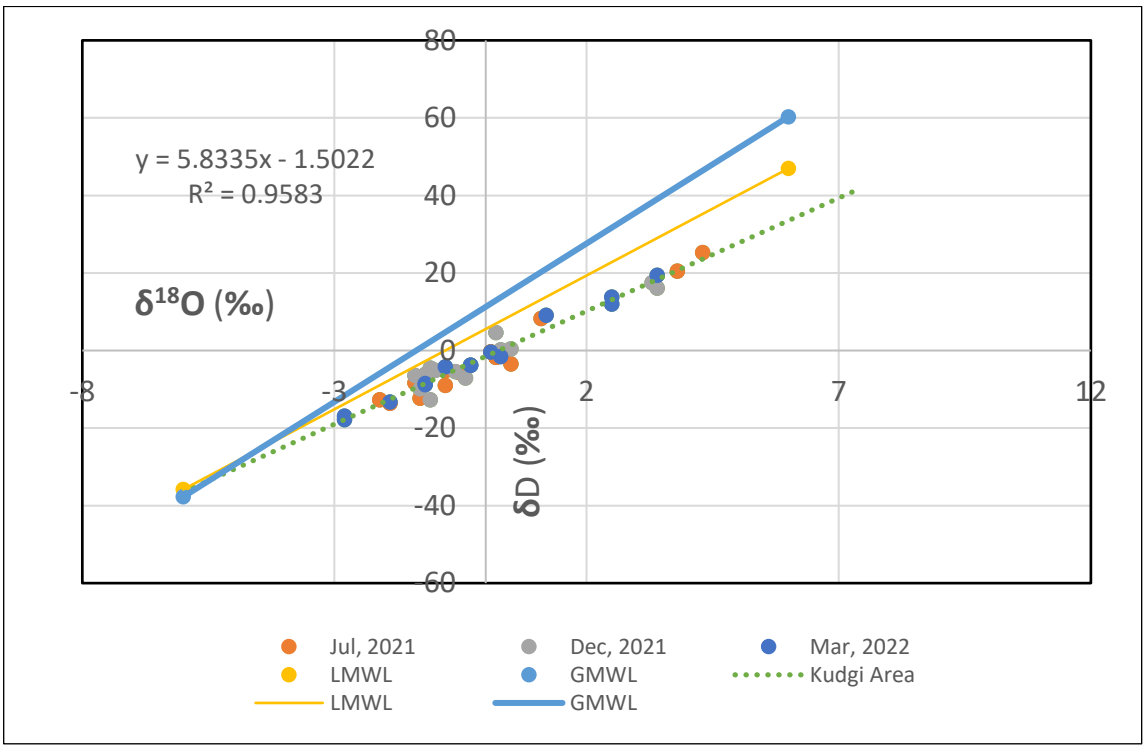


Figure 19: $\delta^{18}O$ –δ^2H plot of groundwater with surface water.

Most of the samples fall below the GMWL and LMWL indicates about the evaporative enrichment of groundwater and ash water in the region (***Figure 19***). The less slope and intercept in comparison of GMWL indicate the evaporative nature of groundwater as well as surface water. The major source of groundwater in the study area are precipitation. Evaporative nature indicates evaporative fractionation of rainwater in the dry climatic conditions during the recharge process.

6.4 d-Excess

The isotopic imprints of evaporation are also recorded in the form of a parameter called d-excess. The d-excess or d-index means the surplus deuterium relative to the Craig's Line. The extent to which $\delta^{18}O$ is more fractionated compared to $\delta^{2}H$ can be defined by Dansgaard (1964) as below:

$$\text{d-excess (d)} = \delta^{2}H - 8*\delta^{18}O \ (‰) \qquad (8)$$

The d-excess (d) as defined above represents the excess $\delta^{2}H$ than 8 times $\delta^{18}O$ for any water body or vapour. The magnitude of equilibrium fractionation (condensation) for $\delta^{2}H$ is about 8 times to that for $\delta^{18}O$. Thus, due to evaporation (non-equilibrium fractionation) from a water body, the D-excess of the evaporating water decreases while it increases in water vapour. The plot of rainwater and groundwater is shown in ***Figure 20***.

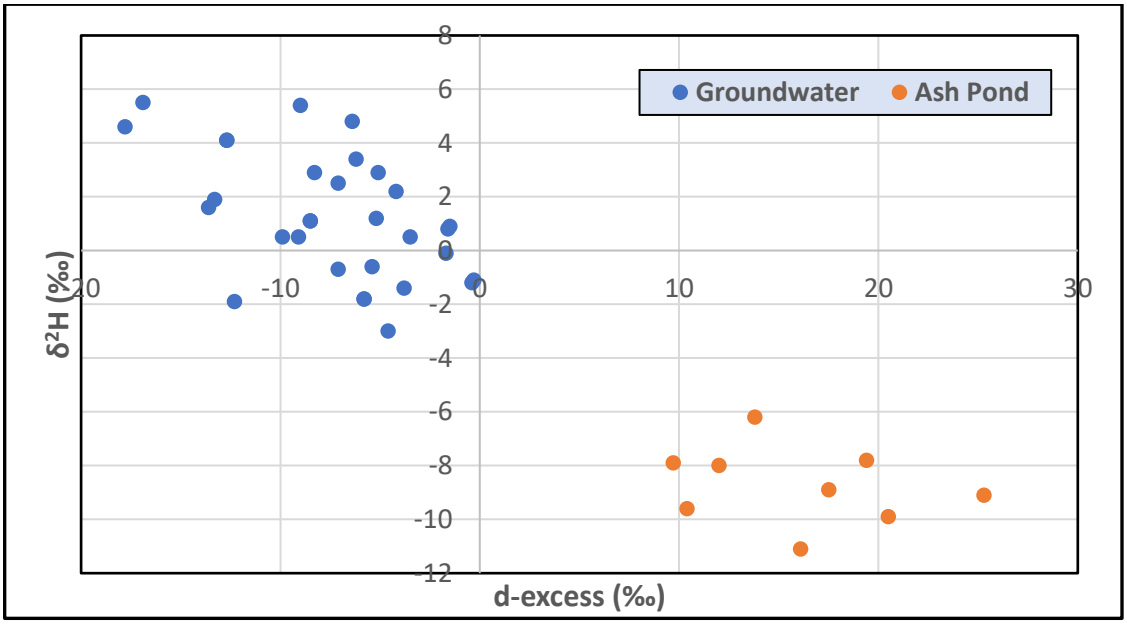


Figure 20: $\delta^{18}O$ - d-excess plot of groundwater

The groundwater having high d-excess value (i.e., 5‰ to 13‰) indicates less or no fractionation during the recharge. It means groundwater with high d-excess is indicating less or insignificant evaporative enrichment during the recharge process (***Figure 20***). Low d excess value indicates fractionation of water due to evaporation in the cooling and storage in ash ponds.

Most of the ash pond water shows high evaporative enrichment. The signature of high evaporative enrichment is not visible in the groundwater, which indicates that there is no seepage of ashpond water into groundwater.

Therefore, it is concluded that the ashpond water is not contaminating groundwater through seepage.

7. SOIL QUALITY

Soil is a highly complex heterogeneous matrix, which is essential to life on earth. This complex matrix can be viewed as a combination of the following three components: (i) inorganic materials- quartz, clays and other minerals; (ii) dead biomass or natural soil organic matter (SOM), and (iii) living biomass (Stevenson 1994; Bohn et al. 2001). It is also a primary factor on which all other terrestrial trophic systems depend (Prescott et al. 2003; Pelczar et al. 2003). The soil supplies various organic and inorganic materials to the plants and enhances the microbial population. It acts as filter for aqueous and solid inputs including rain, domestic wastes, industrial effluent, pesticides and other chemicals. This in turn, is influenced by the human activities in the particular site as different activities cause the accumulation of harmful substances into the environment (Humpries 2007). Since these activities introduce extraneous substances into the soil, the microbial biota which is a major catalyst in transformation taking place in soil are affected. Generally, soil not only serves as sink for the chemical pollutants but also acts as a natural buffer by controlling the transport of chemical elements and substances to the environment (Kabata-Pendias and Pendias 2001).

Soil samples were collected from 10 locations during pre-monsoon and post-monsoon seasons for analysis of heavy metals. The samples were collected from 3 depths, i.e., 5 cm (surface), 30 cm and 60 cm. The location of sample collection is shown in ***Table 38*** and ***Figure 21***.

Table 38: Details of soil sampling sites

S. N.	Code	Depth of soil samples	Name of the Location	Latitude (^{0}N)	Longitude (^{0}E)
1	S-1	Surface (5cm),30cm,60cm)	Hanamapur	16.4382	75.7525
2	S-2	Surface (5cm),30cm,60cm)	Tadalgi	16.4596	75.7872
3	S-3	Surface (5cm),30cm,60cm)	Arasangi	16.4218	75.8258
4	S-4	Surface (5cm),30cm,60cm	Angadageri	16.4576	75.8549
5	S-5	Surface (5cm),30cm,60cm	Golasange	16.4946	75.8778
6	S-6	Surface (5cm),30cm,60cm	Masuti	16.5037	75.7749
7	S-7	Surface (5cm),30cm,60cm	Muthigi	16.5238	75.8859
8	S-8	Surface (5cm),30cm,60cm	Laxman Bhimappa Thalvar	16.5002	75.7925
9	S-9	Surface (5cm),30cm,60cm	Talewad	16.5570	75.8090
10	S-10	Surface (5cm),30cm,60cm	Asangi	16.4908	75.7421

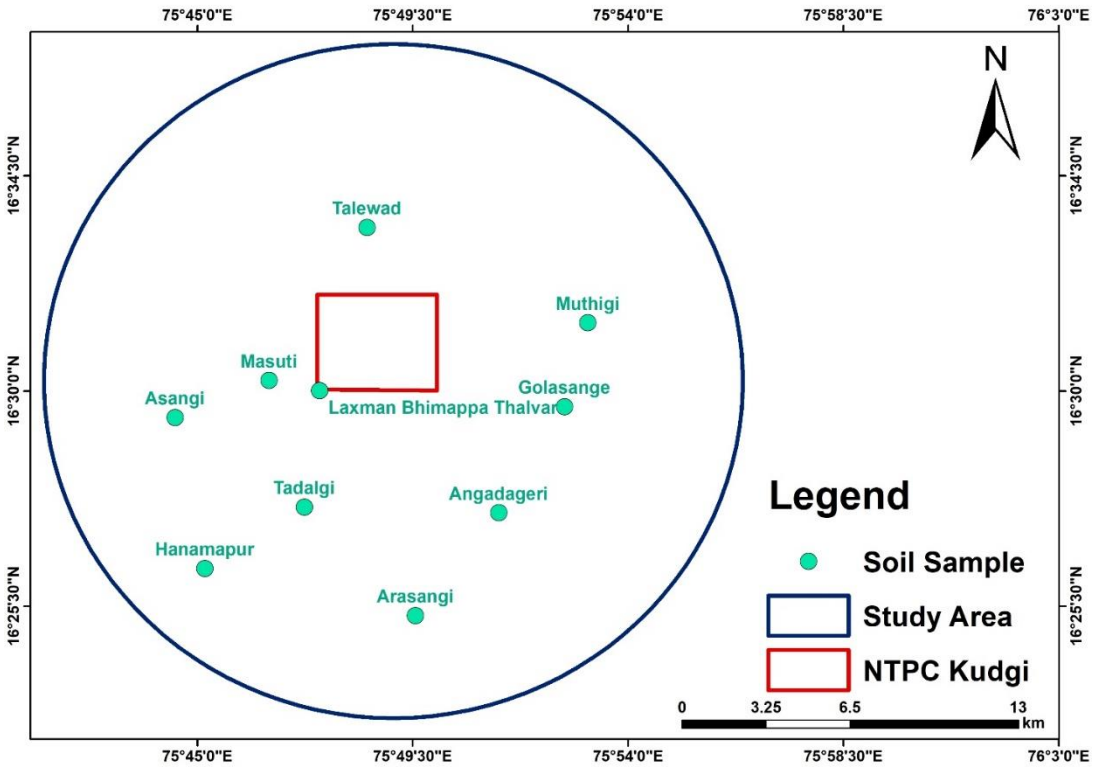


Figure 21: Location map of soil sample collection.

7.1 Laboratory Analysis

- The soil samples were first air dried, cleaned, crushed and were kept in glass bottles for drying in oven at 110 °C overnight and passed through 2mm mesh sieves.
- 1 gram of dry soil sample was weighed into 250ml digestive tube, followed by the addition of 10ml conc. HNO_3 and the mixture solution was heated at 120^0C for 30 to 45 minutes.
- After cooling, 5ml of $HClO_4$ was added and the mixture was boiled at 150^0C for 30 minutes until white fumes appeared and again 20ml of distilled water was added to check further release of fumes by boiling the solution.
- The digested samples were cooled, filtered with Whatman no. 42 filter paper and diluted to 50ml with de-ionised water for further analysis. The digestions were completed in digestion tube following standard procedures as described by Chaturvedi and Sankar (2006).
- The concentrations of heavy metals (As, Cd, Cr, Hg, Pb, Zn) were determined using ICP spectrophotometer.

- Appropriate drift blank was taken before the analysis of samples, which consists of distilled water. This was to verify whether decontamination procedures and laboratory protocols are adequate (Koterba et al. 1995).

7.2 Heavy Metal concentration in Soil

The quality of soil in the study area depends on the concentration of heavy metals. The level of heavy metals in the soil varies from place to place with respect to the nature of land-use and anthropogenic activities. The main objective of soil quality investigation was to assess any possible seasonal changes in the distribution of selected metal and identify the potential impact of industrialization and urbanization. Awasthi (2000) under Prevention of Food Adulteration (PFA) Act no 37 of 1954, has recommended the heavy metal standards in soil (***Table 39***) and these have been used for the present study. Based on this standard, soil of the study area has been categorized as desirable, permissible and unfit for cultivation.

Table 39: Heavy Metal Standard in Soil

Sl. No.	Heavy Metal	Min. Desirable limit (mg/Kg)	Max. Permissible limit (mg/Kg)
1.	As	Not defined	Not defined
2.	Cd	3	6
3.	Cr	400	Not defined
4.	Hg	Not defined	Not defined
5.	Pb	250	500
6.	Zn	300	600

(Awasthi 2000)

The analysis of soil samples collected from three depths, i.e., 5 cm (surface), 30 cm and 60 cm, indicates that there is no contamination of soils in the study area (**Table 40**).

Table 40: Heavy Metals (mg/Kg) in Soils of the area

S. No.	Arsenic			Cadmium			Chromium			Mercury			Lead			Zinc		
	5 cm	30 cm	60 cm	5 cm	30 cm	60 cm	5 cm	30 cm	60 cm	5 cm	30 cm	60 cm	5 cm	30 cm	60 cm	5 cm	30 cm	60 cm
Pre-monsoon																		
S1	ND	ND	ND	0.30	0.40	0.27	1.44	1.24	1.45	ND	ND	ND	11.32	10.41	12.61	25.71	28.11	17.96
S2	ND	ND	ND	0.45	0.62	0.42	3.73	1.82	2.76	ND	ND	ND	17.39	15.32	14.87	39.49	41.36	46.65
S3	ND	ND	ND	0.46	0.63	0.42	1.98	1.52	2.00	ND	ND	ND	17.81	12.78	16.83	39.32	34.51	24.80
S4	ND	ND	ND	0.25	0.33	0.22	0.83	1.06	0.84	ND	ND	ND	9.37	8.87	9.23	21.19	23.95	10.38
S5	ND	ND	ND	0.18	0.28	0.21	1.22	1.03	1.22	ND	ND	ND	7.98	8.67	11.98	19.79	23.41	15.21
S6	ND	ND	ND	0.28	0.33	0.21	1.23	1.35	1.24	ND	ND	ND	9.25	11.32	10.62	20.10	30.56	15.36
S7	ND	ND	ND	0.21	0.27	0.19	1.32	0.81	1.33	ND	ND	ND	7.64	6.82	8.34	17.88	18.41	16.49
S8	ND	ND	ND	0.19	0.29	0.19	0.94	0.94	0.95	ND	ND	ND	8.11	7.92	9.31	17.87	21.38	11.79
S9	ND	ND	ND	0.19	0.31	0.18	0.93	0.95	0.94	ND	ND	ND	8.61	7.98	10.32	17.33	21.55	11.63
S10	ND	ND	ND	0.22	0.51	0.41	1.07	1.66	1.07	ND	ND	ND	14.28	13.92	12.13	18.35	17.58	13.31
Post-monsoon																		
S1	ND	ND	ND	0.36	0.40	0.43	0.89	0.87	0.80	ND	ND	ND	14.28	12.40	12.86	20.90	13.97	18.66
S2	ND	ND	ND	0.47	0.46	0.49	2.30	2.27	1.23	ND	ND	ND	9.37	32.19	19.75	32.11	36.27	28.67
S3	ND	ND	ND	0.50	0.64	0.66	1.22	1.21	1.22	ND	ND	ND	7.64	17.11	19.66	31.97	19.28	28.54
S4	ND	ND	ND	0.21	0.33	0.35	0.51	0.50	0.66	ND	ND	ND	9.25	7.16	10.60	17.23	8.07	15.38
S5	ND	ND	ND	0.30	0.29	0.33	0.75	0.74	0.62	ND	ND	ND	17.81	10.50	9.90	16.09	11.83	14.37
S6	ND	ND	ND	0.31	0.33	0.34	0.76	0.75	0.63	ND	ND	ND	11.32	10.60	10.05	16.34	11.94	14.59
S7	ND	ND	ND	0.33	0.27	0.30	0.81	0.80	0.56	ND	ND	ND	14.18	11.38	8.94	14.54	12.82	12.98
S8	ND	ND	ND	0.24	0.29	0.30	0.58	0.57	0.56	ND	ND	ND	18.34	8.13	8.94	14.53	9.16	12.97
S9	ND	ND	ND	0.23	0.31	0.29	0.57	0.56	0.54	ND	ND	ND	10.12	8.02	8.67	14.09	9.04	12.58
S10	ND	ND	ND	0.27	0.31	0.38	0.66	0.65	3.06	ND	ND	ND	9.56	9.19	9.18	19.96	10.35	17.82
ND – Not detected																		

None of the heavy metals exceeds the limit recommended by Awasthi (2000)

8. CONSTRUCTION OF PIEZOMETER WELLS

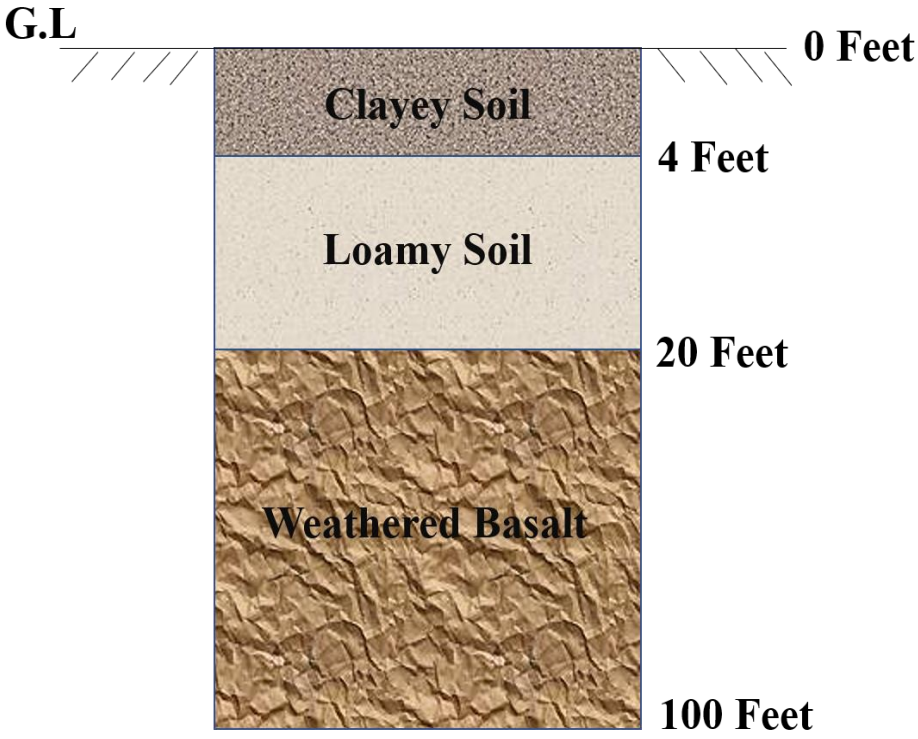
Kudgi, NTPC is situated in Basavana Bagewadi taluk of Vijayapura District. In Basavana Bagevadi Taluk, there are mainly two types of aquifer systems; 1. Aquifer-I (Phreatic aquifer) comprising of Weathered Basalt and 2. Aquifer-II (Fractured aquifer) comprising Fractured Basalt.

In Basavana Bagevadi Taluk, fractured basalt is the major water bearing formation. A small portion is covered with granite, limestone and laterite. Groundwater occurs within the jointed and fractured basalt under semi-confined to confined conditions.

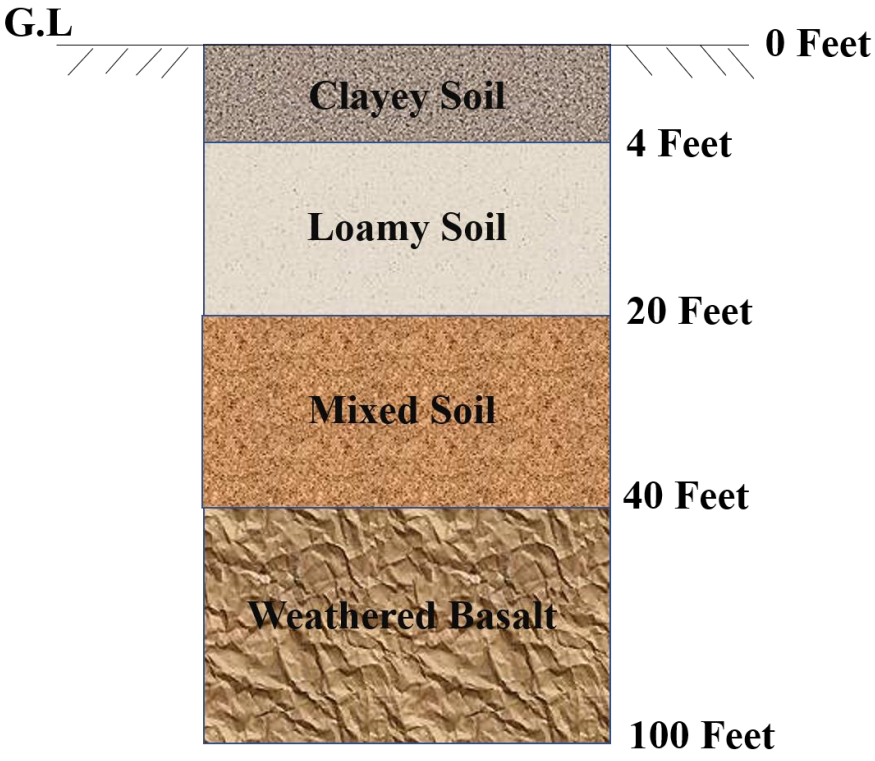
Six (06) piezometer wells were drilled (up to 30 m depth) along the downstream side of Ash Pond during 1-3 Dec 2022. The location of piezometers is also shown in ***Figure 22*** and the lithologs of the piezometers are shown in ***Figure 23.*** Weathered basalt is the only water bearing formation and is the ***phreatic aquifer***.



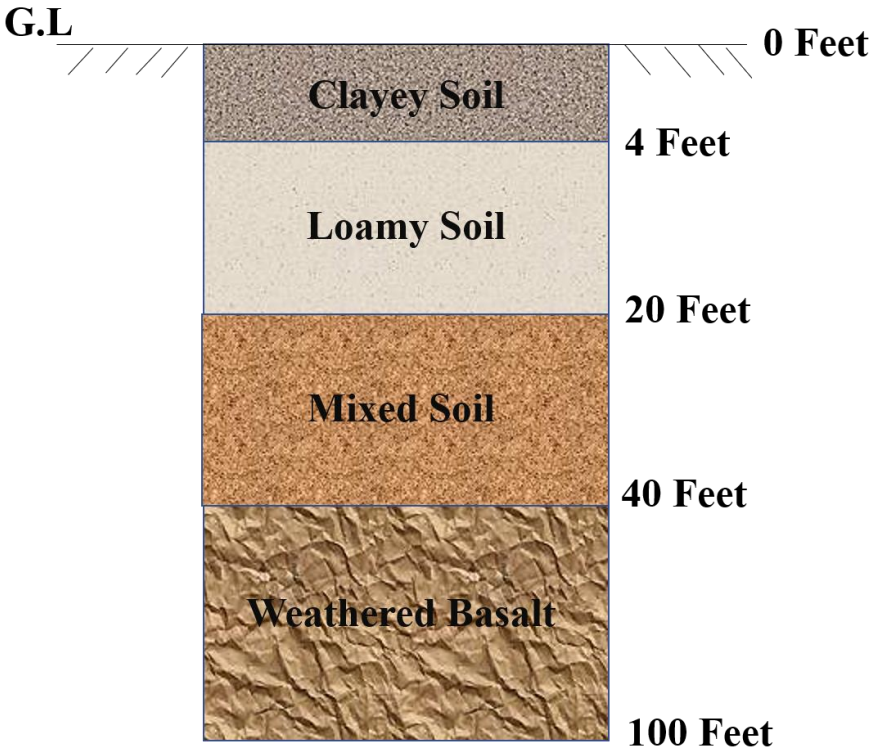
Figure 22: Location of piezometers drilled along the Ashponds



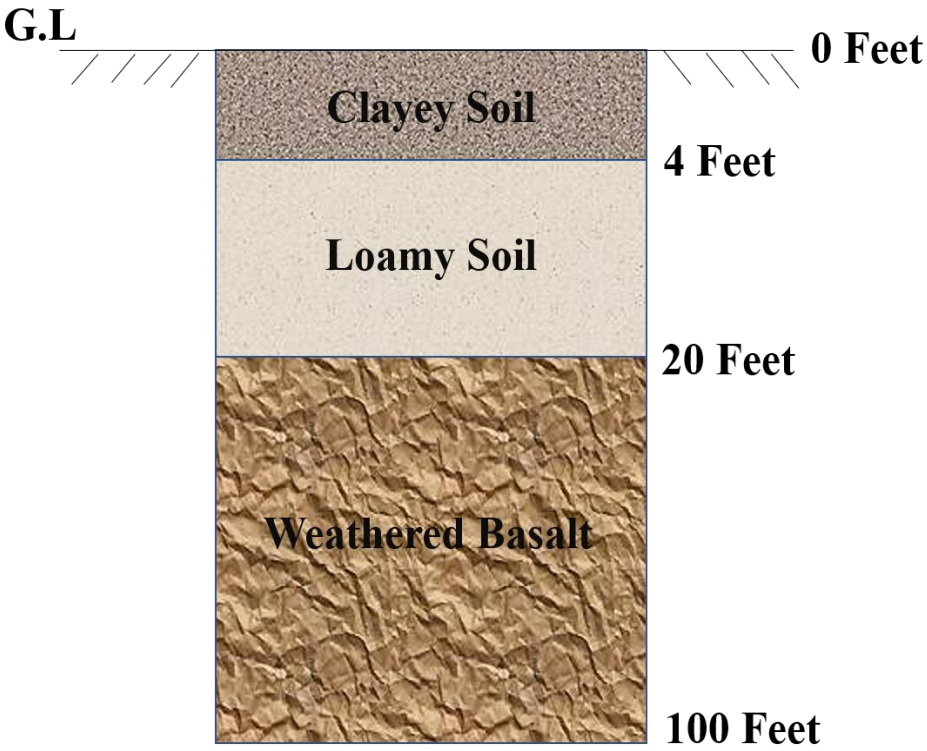
Piezometer Well No.1



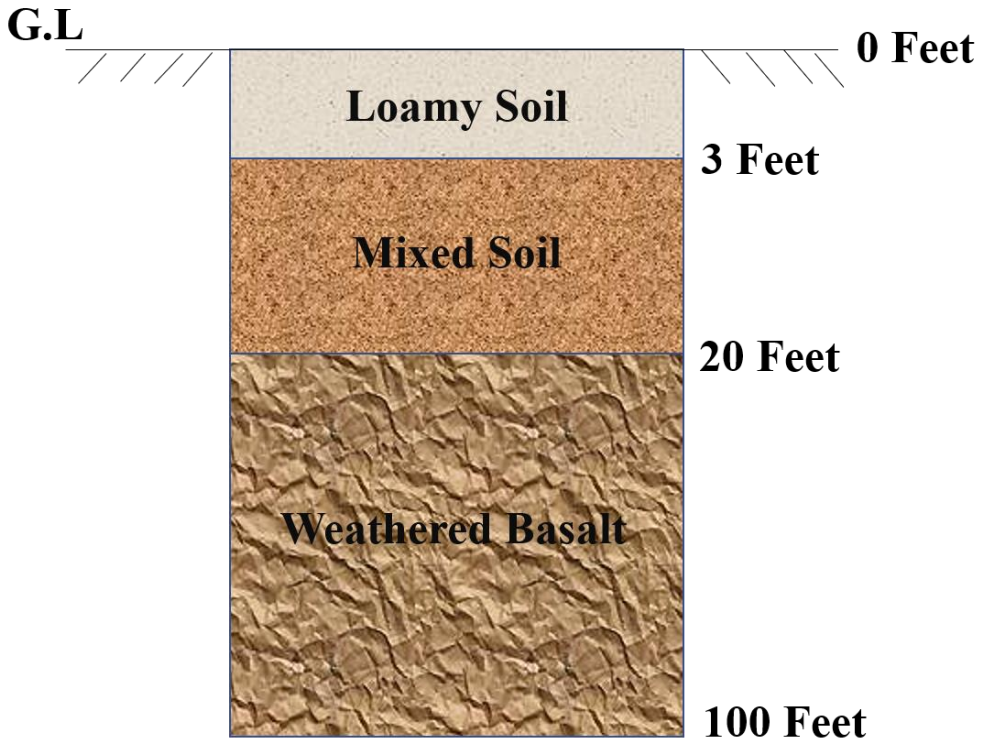
Piezometer Well No.2



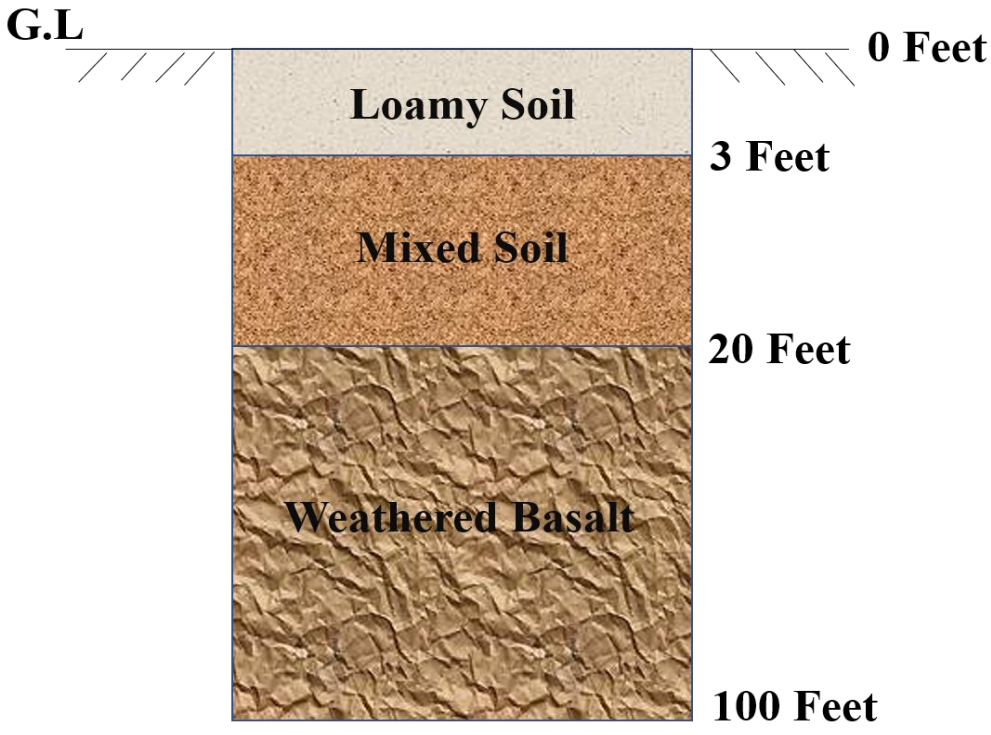
Piezometer Well No.3



Piezometer Well No.4



Piezometer Well No.5



Piezometer Well No.6

Figure 23: Lithologs of the six piezometers constructed around Ashponds

Details of the piezometers are given in ***Table 41.***

Table 41: Details of piezometers installed along ash dyke

S.N.	Piezometer No.	Latitude (^{0}N)	Longitude (^{0}E)	Altitude (m)	Depth to Water Level (m)	Water Level (m)
1.	Pz-1	75.795308	16.497828	578.91	21.95	556.96
2.	Pz-2	75.795451	16.496266	573.93	16.19	557.74
3.	Pz-3	75.796371	16.494762	571.71	14.19	557.52
4.	Pz-4	75.797583	16.493185	573.14	12.35	560.79
5.	Pz-5	75.806722	16.491985	586.05	21.23	564.82
6.	Pz-6	75.812792	16.490637	589.32	22.35	566.97

9. CONCLUSIONS AND RECOMMENDATIONS

9.1 Summary

The present study "Hydro-Geological Study for Kudgi Super Thermal Power Project Vijayapura, Karnataka" was conducted to assess the impact of power plant on the surface as well as groundwater in the project area. NTPC Kudgi is located near village Kudgi in Basavana Bagewadi block of Vijayapura District, Karnataka. This is a coal-based power plant and having power generating capacity 3x800 MW.

The study involved hydrogeological review, field-based investigations and laboratory analysis of soil, surface water and groundwater in and around project area have been carried out. The groundwater monitoring network (6 piezometers) have been installed around the ash dyke area. Seasonal sampling of surface water and groundwater have been carried out around 12 km radius of the project area to ascertain the impact of power plant activities on soil, surface water and groundwater. Also, surface water and groundwater interactions have been carried out using isotopic investigation to ascertain the interaction of ash pond water with groundwater.

The surface water samples for water quality and isotopic analysis have been collected from 14 locations including the ash pond and raw water reservoir in the project area during the pre-monsoon and post-monsoon season of the year 2021 and 2022. Also, the groundwater samples from total 16 ground water level monitoring wells (includes Open wells, Borewells) and 6 newly constructed piezometers were collected for groundwater quality and isotopic analysis during the pre-monsoon and post-monsoon season of the year 2021 and 2022. The water quality of the collected water samples were carried out for its general physical parameters (i.e. Temperature, EC, pH, TDS, Alkalinity, Hardness, DO, BOD, COD), major ions (Major Cations: Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} and NH^{4+} and the major anions: CO_3^{2-}/HCO_{3-}, Cl^{-}, F^{-}, NO^{3-}, SO_4^{2-}) and heavy metals (i.e., As, Cd, Cr, Hg, Pb and Zn). A total of 10 samples of soils from 3 different depths (i.e., 5 cm (surface), 30 cm and 60 cm) were also collected for soil quality analysis (i.e. heavy metal concentrations in soils) in the project area.

The ground water levels were measured using ground water level indicator in 20 monitoring wells during pre-monsoon and post-monsoon season of the year 2021 and 2022. The groundwater monitoring network (6 piezometers) have been installed around the ash dyke area and groundwater level measured during the post-monsoon season of the year 2022. DGPS survey was also carried out in the 26 wells to locate groundwater levels with respect to above mean sea level to understand groundwater flow direction in the study area. The isotopic signatures of groundwater were identified by collecting 16 samples from open well, tube wells and hand pumps and surface water samples (i.e., ponds) during the year 2021 and 2022.

9.2 Conclusions

- Major part of the Vijayapura district is occupied by the basaltic flows of Deccan Traps.
- Deccan basalts usually have medium to low permeability depending upon the presence of primary and secondary porosity.
- In the project area, weathered basalt is the only water bearing formation and is the phreatic aquifer.
- Depth to water level in Vijayapura district is generally shallow. The aquifers are in general under unconfined to semi confined conditions.
- The results of the surface water and groundwater quality indicates that the chemical constituents in water sources of the area are well within the permissible limits prescribed by BIS (2012) for various uses of water including drinking and other domestic supplies.
- The analysis of soil samples collected from three depths indicates that there is no contamination of soils in the study area.
- The depth to water table during pre-monsoon period varies from 3.31 to 11.1 m bgl and 0.75 to 7.63 m bgl during post-monsoon period. During post-monsoon period, water level shows a rise (>2 m) due to replenishment of aquifer by monsoon precipitation.

- The results indicate that the ground water table in the area is slopping towards south and south-west. Thus, the flow of groundwater, in general, is towards Almati Dam located in South direction.
- The isotopic investigations indicates that the major source of groundwater in the study area are precipitation.
- Most of the ash pond water shows high evaporative enrichment. The signature of high evaporative enrichment is not visible in the groundwater, which indicates that there is no seepage of ashpond water into groundwater. Therefore, it is concluded that the ashpond water is not contaminating groundwater through seepage.
- It needs to be mentioned that NTPC Kudgi has Zero Liquid discharge (ZLD) scheme therefore the ashpond water will not be discharged to any nearby water body. Ashpond water is being recycled by the NTPC for the purpose of preparing ash slurry, lagoon water is not used for drinking or domestic use.

9.3 Recommendations

Based on the various findings of the study, following recommendations are made:

- It is recommended to do the regular monitoring of soil and water quality sampling (surface water and ground water) for ascertaining any contamination of surface water and ground water resources due to leakage/seepage of Ash Pond water in and around the project area so that remedial measures can be taken appropriately.
- It is recommended that the proper and regular O&M of the installed groundwater monitoring network should be carried out for its smooth functioning.

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ANNEXURE

Annexure – I

Water quality standards by CPCB

Designated Best Use	Class	Primary Water Quality Criteria
Drinking water source without conventional treatment but with chlorination	A	Total coliform organisms (MPN/100 ml) shall be 50 or less; pH between 6.5 and 8.5; Dissolved Oxygen 6 mg/l or more, and BOD 2 mg/l or less
Outdoor bathing (organized)	B	Total coliform organisms (MPN/100 ml) shall be 500 or less; pH between 6.5 and 8.5; Dissolved Oxygen 5 mg/l or more, and Biochemical Oxygen Demand 3 mg/l or less
Drinking water source with conventional treatment	C	Total coliform organisms (MPN/100 ml) shall be 5000 or less; pH between 6 and 9; Dissolved Oxygen 4 mg/l or more, and Biochemical Oxygen Demand 3 mg/l or less
Propagation of wildlife and fisheries	D	pH between 6.5 and 8.5; Dissolved Oxygen 4 mg/l or more, and Free ammonia (as N) 1.2 mg/l or less
Irrigation, industrial cooling & controlled disposal	E	pH between 6.0 & 8.5; EC less than 2250 µS/cm, SAR less than 26, and Boron less than 2 mg/l

Annexure – II

Water quality Standards as per BIS

S.N.	Parameter and Unit	A	B	C	D	E
1	Taste	None	-	-	-	-
2	Odour	Un obj.	-	-	-	-
3	Colour (True) (Hazen Unit)	10	300	300	-	-
4	pH (max) (min:6.5)	8.5	8.5	8.5	8.5	8.5
5	Conductivity (25^0C) µS/cm	-	-	-	1000	2250
6	DO (mg/l)(minimum)	6	5	4	4	-
7	BOD (3d, 27^0C) (mg/l)	2	3	3	-	-
8	Total Coliforms (MPN/100 ml)	50	500	5000	-	-
9	TDS (mg/l)	500	-	1500	-	2100
10	Oil and Grease (mg/l)	-	-	0.1	0.1	-
11	Mineral Oil (mg/l)	0.01	-	-	-	-
12	Total Hardness (mg/l as $CaCO_3$)	300	-	-	-	-
13	Chlorides (mg/l as Cl)	250	-	600	-	600
14	Sulphates (mg/l as SO_4)	400	-	400	-	1000
15	Nitrates (mg/l as NO_3)	20	-	50	-	-
16	Free CO_2 (mg/l)	-	-	-	6	-
17	Free NH_3 (mg/l as N)	-	-	-	1.2	-
18	Fluorides (mg/l as F)	1.5	1.5	1.5	-	-
19	Calcium (mg/l)	80.10	-	-	-	-
20	Magnesium (mg/l)	24.28	-	-	-	-
21	Copper (mg/l)	1.5	-	1.5	-	-
22	Iron (mg/l)	0.3	-	50	-	-
23	Manganese (mg/l)	0.5	-	-	-	-

(Class A – Drinking water without conventional treatment but after disinfection. Class B –Water for outdoor bathing. Class C – Drinking water with conventional treatment followed by disinfection. Class D – Water for fish culture and wild life propagation. Class E – Water for irrigation, industrial cooling and controlled waste disposal)

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