भारत सरकार
Government of India
जल शक्ति मंत्रालय,
Ministry of Jal Shakti,
जल संसाधन, नदी विकास और गंगा संरक्षण विभाग,
Department of Water Resources,
River Development and
Ganga Rejuvenation

केंद्रीय भूमि जल बोर्ड
Central Ground Water Board

NAQUIM 2.0

जलभृत प्रबंधन योजना
Aquifer Management Plan
भलस्वा लैंडफिल साइट, एन सी टी दिल्ली
Bhalaswa Landfill Site, N.C.T Delhi

N.C.T Delhi
2024

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Bhalaswa Landfill Site, N.C.T Delhi

प्राथमिक ताप्रकार: जल प्रदूषित क्षेत्र
Priority Type: Water Contaminated Area

N.C.T Delhi
2024

CENTRAL GROUND WATER BOARD

MINISTRY OF WATER RESOURCES, RIVER DEVELOPMENT & GANGA REJUVENATION

MINISTRY OF JAL SHAKTI
GOVERNMENT OF INDIA

GROUND WATER CONTAMINATION STUDIES AROUND BHALASWA LANDFILL SITE, N.C.T, DELHI

CONTRIBUTORS

Team Lead	Sh. S.K. Mohiddin	Regional Director
Expert (Hydrogeology)-1	Sh. Vandlabu Praveen Kumar	Assistant Hydrogeologist (AHG)
Expert (Geophysics)	Smt. Mamta	Senior Technical Assistant (GP)

STATE UNIT OFFICE, NCT, DELHI
JUNE 2024

डॉ. सुनील कुमारअम्बास्ट
Dr. Sunil Kumar Ambast

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन, नदी विकास और गंगा संरक्षण विभाग
केंद्रीय भूमि जल बोर्ड
Government of India
Ministry of Jal Shakti
Department of Water Resources, River Development and Ganga Rejuvenation
Central Ground Water Board

MESSAGE

It gives me immense pleasure to present the "Ground Water Contamination Studies around Bhalaswa Landfill Site." This report is a significant step towards the sustainable management of groundwater resources in the region, reflecting our ongoing commitment to safeguarding this vital resource.

The NAQUIM 2.0 initiative has been developed with the goal of providing detailed, issue-specific groundwater management solutions tailored to the needs of the Bhalaswa Landfill Site. Through meticulous aquifer mapping, data collection, and chemical analysis, this report offers valuable insights into the groundwater dynamics of the area and proposes scientifically backed management strategies for its sustainable use. This report will also helpful for identification of flow direction of contaminants.

I extend my sincere gratitude to the dedicated team of hydrogeologists, geophysist and other experts whose tireless efforts have made this report possible. Their collaborative work exemplifies our commitment to addressing groundwater challenges with precision and care.

I am confident that this report will serve as a crucial resource for policymakers, planners, and stakeholders involved in groundwater management, ensuring the long-term availability and quality of groundwater in Bhalaswa Landfill Site. Together, let us continue to work towards a water-secure future.

Dr. Sunil Kumar Ambast
Chairman

टी. बी. एन. सिंह
T.B.N. Singh

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन, नदी विकास और गंगा संरक्षण विभाग
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Central Ground Water Board

सत्यमेव जयते

MESSAGE

I am pleased to present the "Ground Water Contamination Studies around Bhalaswa Landfill Site." This report is a testament to our dedication to advancing groundwater management practices in landfill areas and ensuring the sustainable use of this precious resource in the region.

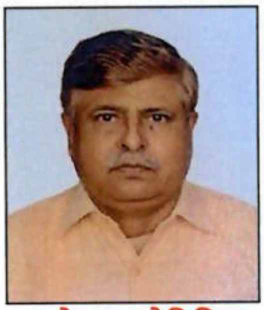
The NAQUIM 2.0 project represents a significant leap forward in our understanding of the complex groundwater systems in Bhalaswa Landfill Site. By integrating cutting-edge technology with traditional hydrogeological methods, this report provides a comprehensive analysis of the area's aquifers, offering actionable insights for effective management and conservation.

I commend the entire team of experts, including hydrogeologists, geophysicst and support staff, for their unwavering commitment and collaborative efforts in bringing this report to fruition. Their expertise and diligence are reflected in the detailed findings and recommendations presented here, which will undoubtedly serve as a valuable guide for sustainable groundwater management.

This report is not just a document but a call to action for all stakeholders involved in groundwater management. It is my hope that the strategies outlined within will be implemented effectively, contributing to the long-term water security and resilience of Bhalaswa Landfill Site.

31/01/2025

T B N Singh
Member (CGWA)



सय्येद क मोहिद्दिन
S K Mohiddin

सत्यमेव जयते

भारत सरकार
जल शक्ति मंत्रालय
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FOREWORD

"Ground Water Contamination Studies around Bhalaswa Landfill Site" study addresses the significant challenges faced by Bhalaswa Landfill Site, including severe groundwater contamination, over-extraction for urban, industrial, and agricultural needs, and deteriorating water quality. These issues, compounded by rapid urbanization and inadequate recharge, highlight the urgent need for effective and sustainable groundwater management strategies.

The NAQUIM 2.0 study for Bhalaswa Landfill Site offers an in-depth understanding of the region's aquifer systems. By conducting detailed hydrogeological mapping, geophysical surveys, and water quality assessments, the study proposes scientifically robust and practically implementable management strategies.

This report is the result of the dedicated efforts of an exceptional team. I extend my heartfelt gratitude to Sh. Vandlabu Praveen Kumar, Assistant Hydrogeologist (AHG), Smt. Mamta, Geophysicist (STA) whose specialized knowledge and collaborative efforts have enriched the quality of this report.

This report is intended to serve as a vital resource for policymakers, planners, and stakeholders, providing them with the tools to make informed decisions for Ground Water Contamination Studies around Bhalaswa Landfill Site. I am confident that the strategies outlined here will significantly contribute to addressing the groundwater challenges and ensuring the block's water security and overall economic growth.

S. K. Mohiddin
Regional Director

ACKNOWLEDGEMENT

The author acknowledges with deep gratitude Dr. Sunil Kumar Ambast, Chairman, Central Ground Water Board, for providing the opportunity to prepare the "Ground Water Contamination Studies around Bhalaswa Landfill Site”. Sincere thanks are extended to T.B.N. Singh, Member, CGWA, for his invaluable guidance, encouragement, and suggestions during the preparation of this report. The author also expresses heartfelt thanks to Shri S. K. Mohiddin, Regional Director and Team Leader Central Ground Water Board, State Unit Office, NCT, Delhi for his valuable guidance and constant encouragement throughout the process.

I am also grateful to Ms. Kriti Mishra, SC-C, Sh. Gyanendra Rai, STA-HG for providing guidance at various stages of the study. Thanks are also due to Sh. S. Ashok Kumar, STA-HG, who carefully went through the draft copy of this report, corrections and his help in map preparation.

Efforts of Shri. Shashi Kant Singh, Scientist ‘D’ for his help provided in the analysis and interpretation of geophysical data, Cross section preparation is gratefully acknowledged. I would like to give thanks to Mrs. Prachi Gupta, Scientist – ‘D’, regarding report correction and thanks to Sh. Rinkumoni Burman, ACH for his help to the preparation of chemical maps. The author extended their thanks to CWC Chemical Laboratory officials for Bacteriological Analysis and Sh. Chandan Gupta, STA (GP) for geophysical surveys.

The author is grateful to the technical section, RODC, and library of the CGWB, SUO, Delhi, as well as to state agencies, for providing various necessary data, without which this report would not have been completed.

Lastly, I would like to thank all those who helped in various stages of this effort.

Sh. Vandlabu Praveen Kumar
Assistant Hydrogeologist (AHG)

EXECUTIVE SUMMARY

The normal annual rainfall of NCT Delhi is 611.8 mm. The rainfall increases from the southwest to the northwest. About 81% of the annual rainfall is received during the monsoon months of July, August, and September. The rest of the annual rainfall is received as winter rain and as thunderstorm rain in the pre and post-monsoon months. NCT Delhi is occupied by quartzite inter-bedded with mica schist belonging to Delhi Super Group (Delhi ridge) overlain by unconsolidated sediments of Quaternary to Recent age. The thickness of overlying alluvium is highly variable on the eastern and western sides of the ridge. It is generally thicker (>300m) on the west of the ridge. The study area falls under alluvial deposits.

The sanitary landfill (SFL) site at Bhalaswa is one of the three major landfill sites in Delhi and it is situated in the Model town tehsil of the North District. The total area of the SFL, Bhalaswa is 52 acres (21.06 Hectors). About 2500 MT/day of solid waste is being dumped at this site and the filling of this site was commissioned in 1994. The solid waste received at the site is levelled, restructured, and compacted by hydraulic bulldozers. The height of the dump is about 60-65 meters from the surrounding ground level. The elevation in the area is from 206-221 m above MSL.

The area is underlain by quaternary alluvium of about 200 m thick, below which weathered and fractured quartzite is present. Based on the lithology and geophysical logs, a generalized sub-surface geological cross-section shows that the area is underlain by fine to medium sand (Yamuna sand) mixed with coarse gravel up to a depth of about 40 mbgl below which older alluvium consisting of predominantly clay with silt and kankar is present. The groundwater development in the areas is mainly through shallow hand pumps and shallow tube wells of 30 to 40 m depth. The yield of tube wells varies from 400 to 600 LPM. The Hydraulic Conductivity is 9 m/day in the area.

For the purpose of demarcation of groundwater contamination in the area, three buffer zones have been drawn i.e., 1 Km Buffer Zone, 2 Km Buffer Zone & 5 Km Buffer Zone. The density of sampling and groundwater level monitoring is high at 1 Km buffer zone and gradually reducing the sample locations. Depth to water level in June 2023 varies from 3.56 to 12.88 mbgl and in Nov-2023 varies from 3.17 to 14.90 mbgl. Water levels are shallow i.e., about 3.56 (June) mbgl and 3.17(Nov) mbgl at near Bhalaswa Lake, and deep water levels at i.e., 12.88 (June) and 14.90 (Nov) Haiderpur. Analysis of water table contours of June 2023 & Nov-2023 indicates that regional groundwater flows are towards the East i.e., towards Yamuna River. Water table contour in the area varies from 212 to 196 m amsl but local ground water flow pattern is different. It flows towards JJ Clusters located north of the SLF, Near Transport Nagar. The groundwater flows in the southern part i.e., the Jahangirpuri area towards South Eastern direction.

The general groundwater quality in Bhalaswa area is brackish. Groundwater is not used for drinking purposes. The ground water is mostly used for washing and cleaning purposes. Based on pre-monsoon water quality results, pH of most of the groundwater samples is more than 7 i.e., slightly alkaline. The pH of leachate samples is about 8. The electrical conductivity of leachate samples is 39000 µS/cm and 38845 µS/cm. Out of 10 groundwater samples, 7 samples are showing EC more than the permissible limit (>3000 µS/cm). Fluoride and Nitrate is more than the permissible limit in leachate samples. Heavy metals Iron, Arsenic, Chromium and Nickel have been found more than the permissible limit in 2 leachate samples. Only 1 leachate sample showed Uranium, lead, and Manganese more than the permissible limit. Out of 10 groundwater samples 5 samples showed manganese more than the permissible limit (0.3mg/l).

A total 10 samples were collected for bacteriological analysis and got them analyzed from CWC laboratory. In leachate samples, faecal coliform bacteria count is 130000 and 390000 MPN/100 ml. In ground water samples it varies from 18 MPN/100 ml to 390000 MPN/100 ml. Out of 10 samples 9 samples are showing faecal coliform bacteria count more than permissible limit i.e., 1000 MPN/100 ml. The range of total coliform bacteria varies from 36 to 160,00, 000 MPN/100ml. Thus, the groundwater in and around SLF sites is highly bacteriologically contaminated. A total of 7 Stakeholder feedback forms were collected from stakeholders during the field. Most of the Tube wells are at shallow depth as they mentioned in the stakeholder forms. Most of the tube wells/Hand Pumps are used for washing & Cleaning, Construction purposes only. For drinking purposes they are depending on DJB to supply water. Some Stakeholders informed us that the water colour gets transformed to yellow colour after 2-3 hours. As discussed in the field with the locals, it has been learned that the locals do not consume the groundwater for drinking purposes. Hence the health issues related to the groundwater could not be ascertained.

For precise demarcation of groundwater contamination, a total of 41 samples were collected. The samples were earlier submitted to Chemical Lab, NWR Chandigarh, and later on shifted to WR, Jaipur for Major elements analysis, and for trace metals, samples were submitted to NR, Lucknow. VES data indicates that freshwater sediments are followed by the saline water sediments. The thickness of freshwater sediments is thin in major study areas. The depth to fresh–saline water interface varies from 22mbgl to 65mbgl. Groundwater quality below the fresh saline water interface is saline all through up to the bedrock.

The Depth to water level recorded in the Study area during June 2023 varied from 3.56 to 12.88 meters below ground level (mbgl). Groundwater level data from a total of 14 observation wells have been analyzed. The Depth to water level recorded in the study area during November 2023 varied from 2.86 to 14.90 mbgl. Groundwater level data from a total of 18 observation wells have been analyzed. Based on the water table elevation follows the topography of the area and overall ground water flow direction is towards Yamuna River. Internal groundwater flow direction is different. In the western part of the study area flow direction is towards a trough near the landfill area and southern part groundwater flow direction is towards the north. Bhalaswa Lake acts as a divider regarding groundwater flow.

The electrical conductivity value of pre-monsoon ground water samples in the Bhalaswa study area has been found to vary from 330 to 8755 µS/cm at 25ºC and in post-monsoon, it varies from 680-10890 µS/cm at 25ºC. EC in excess of 3000 µS/cm value has been observed in more than 50% of the study area. Nitrate in excess of the maximum permissible limit has been reported from 24% of post-monsoon samples. In heavy metal analysis, two leachate samples have shown more than the permissible limit for Fe, Cr, As and Ni. Only one leachate sample has shown more than the permissible limit for U, Mn, Pb and Cd. In Basic analysis, Leachate samples have been shown to exceed the permissible limit for EC, Cl, Fluoride and Nitrate. And for Bacteriological analysis both the leachate samples have shown total and fecal coliform. In Basic analysis 37.5% of wells showing Chloride and 6.25% of wells are showing Fluoride beyond the permissible limit in pre-monsoon. And 18.42%, 13.15% and 26.31% of wells are showing beyond permissible of CL, F and No_3 respectively. Excess Fluoride has been reported from isolated pockets in the study area. Concentration of Iron (Fe) has been found to range from BDL to 6.7 mg/land exceeded the maximum permissible limit of 1 mg/l in 12.5% of the total analysed pre-monsoon groundwater samples. For post-monsoon, concentration of Iron (Fe) has been found to range from 0.075mg/l to 9.75mg/land exceeded the maximum permissible limit of 1 mg/l in 21%.

In pre-monsoon, the concentration of Arsenic (As) in groundwater has been found to vary from BDL to 0.038 mg/l. In post-monsoon, the concentration of As varies from Below the Detectable Limit to 0.129mg/l. 6.2% of pre-monsoon samples and 13% of post-monsoon samples exceed the maximum permissible limit of 0.01 mg/l prescribed by BIS in drinking water (IS-10500:2012). Lead (Pb) concentration has been reported to vary from BDL to 0.0016 mg/l in pre-monsoon and it varies from 0.001-0.011 mg/l in post-monsoon. Sporadic occurrence of Pb in excess of the maximum permissible limit of 0.01 mg/l (IS-10500:2012) has been reported in 2.6% of post-monsoon samples. Excess Pb in groundwater may be due to pollution from industries and landfill sites. The concentration of Uranium (U) has been found to vary from BDL to 0.01769 mg/l in pre-monsoon and it varies from 0.003 to 0.035 mg/l in post-monsoon. The concentration of Uranium 2.6% of post-monsoon samples exceeds the maximum permissible limit of 0.03 mg/l prescribed by BIS in drinking water (IS-10500:2012).

The bacteriological test carried out in eight groundwater samples and 2 leachate samples of the Bhalaswa study area- shows the presence of total coliform and faecal coliform in all eight groundwater samples and 2 leachate samples. All the available data as well as data generated during the course of the present study were integrated and aquifer disposition maps were prepared. Bhalaswa Study area covers five assessments i.e., Model Town, Alipur, Civil Lines, Saraswati Vihar, and Rohini. The annual extractable groundwater resource is 6374 ha. m. The total annual groundwater recharge has been estimated as 6957.85 ham. The total annual groundwater draft (as of 2023) has been estimated to be 4808.83 ha. M.

Out of 5 tehsils in the study area, 2 are ‘Safe’, 2 are ‘Semi-Critical’, and the remaining 1 tehsil is ‘Critical’. In addition, most of the study areas are shallow water levels where ground water withdrawal is limited due to the presence of poor-quality water. Groundwater withdrawal is recommended for its use after blending. This will create void space in the aquifer, which would be recharged during subsequent monsoon and help in improving groundwater quality. In areas, where fresh groundwater is underlain by saline water, it is recommended that saline water occurring at deeper levels may be withdrawn and used after blending or may be used for uses other than drinking and domestic Rainwater harvesting and artificial recharge measures are recommended in areas having water levels deeper than 8 mbgl.

Najafgarh Supplementary drain flowing through the study area, to avoid groundwater pollution along the drains, it is suggested that only treated waste water must be allowed to flow in the drains. Lining of drains is also recommended. Instances of pollution have also been reported around landfill sites. Necessary measures to protect ground water quality should be taken by the concerned State agencies by locating and designing landfill sites in a proper scientific manner.

कार्यकारी सारांश

एन. सी टी दिल्ली की सामान्य वार्षिक वर्षा 611.8 मिमी है। वर्षा दक्षिण-पश्चिम से उत्तर-पश्चिम की ओर बढ़ती है। वार्षिक वर्षा का लगभग 81% जुलाई, अगस्त और सितंबर के मानसून महीनों के दौरान प्राप्त होता है।वार्षिक वर्षा का शेष भाग शीतकालीन वर्षा के रूप में और मानसून से पहले और बाद के महीनों में गरज के साथ वर्षा के रूप में प्राप्त होता है।एन सी टी दिल्ली में दिल्ली सुपर ग्रुप (दिल्ली रिज) से संबंधित क्वार्टजाइट, मिका शिस्ट के साथ inter bedded पाई जाती हैं और इसके ऊपर क्वाटर्नरी से लेकर Recent युग तक की असंगठित sediments पाए जाते हैं। रिज के पूर्वी और पश्चिमी किनारों पर ऊपरी जलोढ़ की मोटाई अत्यधिक परिवर्तनशील है । यह आम तौर पर रिज के पश्चिम में अधिक मोटा (>300 मीटर) है। अध्ययन क्षेत्र जलोढ़ निक्षेपों के अंतर्गत आता है।

भलस्वा में स्थित सैनिटरी लैंडफिल (एसएफएल) साइट दिल्ली की तीन प्रमुख लैंडफिल साइटों में से एक है और यह उत्तरी जिले की मॉडल टाउन तहसील में स्थित है। भलस्वा (SFL) का कुल क्षेत्रफल 52 एकर (21.06 हेक्टेयर) है। इस स्थल पर प्रतिदिन लगभग 2500 मीट्रिक टन ठोस कचरा डाला जाता है और इस स्थल को भरने का काम 1994 में शुरू किया गया था। साइट पर प्राप्त ठोस कचरे को हाइड्रोलिक बुलडोजर द्वारा समतल, पुनर्गठित और संकुचित किया जाता है। डंप की ऊंचाई आसपास के जमीनी स्तर से लगभग 60-65 मीटर ऊपर है जो आसपास के भूमि स्तर से अधिक है। क्षेत्र की ऊंचाई समुद्र स्तर से 206 - 221 मीटर ऊपर है।

यह क्षेत्र लगभग 200 मीटर मोटी quaternary alluvium द्वारा ढका हुआ है, जिसके नीचे अपक्षयित एवं खंडित क्वार्टजाइट पाया जाता है।लिथोलॉजी और भूभौतिकीय लॉग के आधार पर, एक सामान्यीकृत उप-सतह भूवैज्ञानिक क्रॉस-सेक्शन से पता चलता है कि यह क्षेत्र लगभग 40 एमबीजीएल की गहराई तक मोटे बजरी के साथ मिश्रित महीन से मध्यम रेत (यमुना रेत) से ढका हुआ है, जिसके नीचे मुख्य रूप से गाद और कंकर के साथ पुरानी जलोढ़ मिट्टी मौजूद है। क्षेत्रों में भूजल विकास मुख्य रूप से 30 से 40 मीटर गहराई के उथले हैंडपंपों और उथले ट्यूबवेलों के माध्यम से होता है। ट्यूबवेलों की yield 400 से 600 lpm तक होती है। क्षेत्र की hydraulic conductivity 9 मीटर/दिन है।

क्षेत्र में भूजल प्रदूषण के सीमांकन के उद्देश्य से, तीन बफर जोन तैयार किए गए हैं, यानी 1 किलोमीटर बफर जोन, 2 किलोमीटर बफर जोन और 5 किलोमीटर बफर जोन। नमूनाकरण और भूजल स्तर की निगरानी का घनत्व 1 किमी बफर जोन में अधिक है और धीरे-धीरे नमूना स्थानों को कम रखा गया है। जून 2023 में जलस्तर 3.56 से 12.88 मीटर के बीच था, और नवम्बर 2023 में यह 3.17 से 14.90 मीटर तक था।भलस्वा झील के पास जल स्तर उथला है, जून में 3.56 मीटर और नवम्बर में 3.17 मीटर गहराई, जबकि हैदरपुर में जल स्तर गहरा हैं, जून में 12.88 मीटर और नवम्बर में 14.90 मीटर। जून 2023 और नवम्बर 2023 के water table contour के विश्लेषण से यह संकेत मिलता है कि क्षेत्रीय भूजल प्रवाह पूर्व की ओर है, यानी यमुना नदी की ओर।क्षेत्र में water table contour 212 से 196 mamsl तक है जो कि स्थानीय भूजल प्रवाह पैटर्न भिन्न है। यह SLF के उत्तर में, ट्रांसपोर्ट नगर के पास

स्थित JJ Cluster की ओर बहती है। दक्षिणी भाग यानी जहांगीरपुरी क्षेत्र में भूजल दक्षिण पूर्वी दिशा की ओर बहता है।

भलस्वा क्षेत्र में सामान्य भूजल खारा है। इस भूजल को पीने के लिए उपयोग में नहीं लाया जाता है। भूजल का मुख्य रूप से धोने और सफाई के उद्देश्यों के लिए उपयोग किया जाता है। प्री मॉनसून-भू जल गुणवत्ता परिणामों के आधार पर, अधिकांश भूजल नमूनों का pH 7 से अधिक है, अर्थात् यह हल्का क्षारीय है। लिचेट नमूनों का pH लगभग 8 है। लिचेट नमूनों की Electrical Conductivity 39000 µS/cm और 38845 µS/cm है। 10 भूजल नमूनों में से 7 नमूनो में EC अनुमत सीमा से अधिक (>3000 µS/cm) हैं। लिचेट नमूनों में फ्लोराइड और नाइट्रेट की मात्रा अनुमत सीमा से अधिक है। भारी धातुएं जैसे आयरन, आर्सेनिक, क्रोमियम और निकल 2 लिचेट नमूनों में अनुमत सीमा से अधिक पाई गई हैं। केवल 1 लिचेट नमूने में यूरेनियम, सीसा, और मैंगनीज की मात्रा अनुमत सीमा से अधिक पाई गई। 10 भूजल नमूनों में से 5 नमूनों में मैंगनीज की मात्रा अनुमत सीमा (0.3mg/l) से अधिक पाई गई।

कुल 10 नमूने बैक्टीरियोलॉजिकल विश्लेषण के लिए एकत्रित किए गए थे और उन्हें CWC प्रयोगशाला से विश्लेषण कराया गया। लिचेट नमूनों में, फीकल कॉलिफॉर्म बैक्टीरिया की गणना 130000 और 390000 MPN/100 मि .ली. है।भू-जल नमूनों में यह 18 MPN/100 मि ली. से. 390000 MPN/100 मि ली. तक होती है।.10 नमूनों में से 9 नमूने फीकल कॉलिफॉर्म बैक्टीरिया की गणना अधिक दिखा रहे हैं, अर्थात 1000 MPN/100 मि ली. से अधिक। कुल. कॉलिफॉर्म बैक्टीरिया की सीमा 36 से 1,60,00,000 MPN/100 मि ली. तक.होती है। इस प्रकार, SLF स्थलों के आसपास का भूजल बैक्टीरियोलॉजिकल रूप से अत्यधिक प्रदूषितहै। क्षेत्र में 7 Stakeholder feedback forms एकत्रित किए गए थे। अधिकांश ट्यूबवेल्स की गहराई उथली है, जैसा कि feedback forms में उल्लेख किया गया है। अधिकांश ट्यूबवेल्सहैं/ड पंप केवल धोने और सफाई, निर्माण कार्य के लिए उपयोग किए जाते हैं। पीने के पानी लिए Stakeholder DJB पर निर्भर हैं, जो पानी आपूर्ति का कार्य करते हैं। कुछ हितधारकों ने सूचित किया कि पानी 2-3 घंटों के बाद पीला रंग में बदल जता है। क्षेत्र में स्थानीय लोगों से चर्चा करने पर यह पता चला कि वे पीने के लिए भूजल का उपयोग नहीं करते। इसलिए, भूजल से संबंधित स्वास्थ्य समस्याओं का निर्धारण नहीं किया जा सका।

भूजल प्रदूषित के सटीक निर्धारण के लिए कुल 41 नमूने एकत्रित किए गए। ये नमूने पहले रासायनिक प्रयोगशाला, NWR चंडीगढ़ में भेजे गए थे, और बाद में प्रमुख तत्वों के विश्लेषण के लिए WR, जयपुर में भेजे गए, तथा ट्रेस धातुओं के लिए नमूने NR, लखनऊ में भेजे गए। VES डेटा से यह संकेत मिलता है कि मीठे पानी की सतह के बाद खारे पानी की सतह है। प्रमुख अध्ययन क्षेत्रों में मीठे पानी की सतह की मोटाई पतली है। ताजे और खारे पानी की सीमा की गहराई 22 मीटर से 65 मीटर के बीच है। ताजे खारे पानी की सीमा के नीचे का भूजल की गुणवत्ता खारी है, जो bed rock तक है।

अध्ययन क्षेत्र में जून 2023 के दौरान जल स्तर की गहराई 3.56 मीटर से 12.88 मीटर के बीच रिकॉर्ड की गयी है। कुल14 अवलोकन कुओं से प्राप्त भूजल स्तर डेटा का विश्लेषण किया गया है। अध्ययन क्षेत्र में नवम्बर 2023 के दौरान जल स्तर की गहराई 2.86 मीटर से 14.90 मीटर के बीच थी। कुल 18 अवलोकन कुओं से प्राप्त भूजल स्तर

डेटा का विश्लेषण किया गया है। water level की ऊंचाई क्षेत्र की भौगोलिक संरचना के अनुरूप है, और समग्र भूजल प्रवाह की दिशा यमुना नदी की ओर है। आंतरिक भूजल प्रवाह की दिशा अलग है। अध्ययन क्षेत्र के पश्चिमी भाग में प्रवाह दिशा लैंडफिल क्षेत्र के पास एक गर्त की ओर है, जबकि दक्षिणी भाग में भूजल प्रवाह की दिशा उत्तर की ओर है। भलस्वा झील water level के संदर्भ में एक विभाजक के रूप में कार्य करती है।

भलस्वा अध्ययन क्षेत्र में प्री-मानसून भूजल नमूनों की electrical conductivity 25ºC पर 330 से 8755 µS/cm तक पाई गयी है और मानसून के बाद, यह 25ºC पर 680-10890 µS/cm तक पाई गयी है। 3000 µS/cm से अधिक EC,अध्ययन क्षेत्र के 50% से अधिक हिस्से में पाई गयी है। पोस्ट मॉनसून नमूनों में-24% में नाइट्रेट की मात्रा अधिक पाई गई है जो अनुमत सीमा से अधिक है। भारी धातु विश्लेषण में, दो लिचेट नमूनों में Fe, Cr, As और Ni की मात्रा अनुमत सीमा से अधिक पाई गई है। केवल एक लिचेट नमूने में U, Mn, Pb और Cd की मात्रा अनुमत सीमा से अधिक पाई गई। बेसिक विश्लेषण में, लिचेट नमूनों में EC, क्लोराइड, फ्लोराइड और नाइट्रेट की मात्रा अनुमत सीमा से अधिक पाई गई है। और बैक्टीरियोलॉजिकल विश्लेषण में दोनों लिचेट नमूनों में कुल और फीकल कॉलिफॉर्म पाया गया। प्रीमॉनसून में-, बेसिक विश्लेषण में, 37.5% कुओं में क्लोराइड और 6.25% कुओं में फ्लोराइड की मात्रा अनुमत सीमा से अधिक पाई गई है । और 18.42 %, 13.15 % और 26.31 % कुओं में क्रमशः क्लोराइड, फ्लोराइड और नाइट्रेट की मात्रा अनुमत सीमा से अधिक पाई गई अध्ययन क्षेत्र में अलग अलग स्थानों- पर फ्लोराइड की अधिक मात्रा पाई गई है। आयरन(Fe) की सांद्रता 0 से 6.7 mg/l तक पाई गई है और यह 12.5% प्री मॉनसून विश्लेषित भूजल नमूनों में-1 mg/l की अनुमत सीमा से अधिक पाई गई है ।पोस्ट मानसून में Fe की सांद्रता 0.075 mg/l से 9.75 mg/l तक पाई गई है और यह 21% नमूनों में 1 mg/l की अनुमत सीमा से अधिक पाई गई है।

प्रीमॉनसून में-, भूजल में आर्सेनिक (As) की सांद्रता BDL से 0.038 mg/l तक पाई गई है। पोस्टमॉनसून में-, As की सांद्रता डिटेक्टेबल लिमिट से नीचे से लेकर 0.129 mg/l तक पाई गई है। 6.2% प्री मॉनसून नमूनों और-13% पोस्ट मॉनसून नमूनों में-BIS द्वारा निर्धारित पीने के पानी के लिए 0.01 mg/l की अधिकतम अनुमत सीमा से अधिक आर्सेनिक पाया गया है (IS-10500:2012) । सीसा (Pb) की सांद्रता प्री मॉनसून में-BDL से 0.0016 mg/l के बीच पाई गई है और पोस्ट मॉनसून में यह-0.001 से 0.011 mg/l के बीच पाई गई है। पोस्ट मॉनसून के-2.6% नमूनों में सीसे की सांद्रता अधिकतम अनुमत सीमा 0.01 mg/l से अधिक पाई गई है ।(IS-10500:2012)। भूजल में सीसे की अधिकता संभवतः उद्योगों और लैंडफिल साइटों से होने वाले प्रदूषण के कारण हो सकती है। यूरेनियम)U) की सांद्रता प्री मॉनसून में-BDL से 0.01769 mg/l तक पाई गई है और पोस्ट मॉनसून में यह-0.003 से 0.035 mg/l तक पाई गई है। पोस्ट मॉनसून के-2.6% नमूनों में यूरेनियम की सांद्रता 0.03 mg/l की अधिकतम अनुमत सीमा से अधिक पाई गई है, जो BIS द्वारा पीने के पानी के लिए निर्धारित की गई है(IS-10500:2012) ।

भालास्वा अध्ययन क्षेत्र में आठ भूजल नमूनों और 2 लीचेट नमूनों पर किए गए बैक्टीरियोलॉजिकल परीक्षण में सभी आठ भूजल नमूनों और 2 लीचेट नमूनों में कुल कोलिफॉर्म और फेकल कोलिफॉर्म बैक्टीरिया की उपस्थिति पाई गई। उपलब्ध सभी डेटा और वर्तमान अध्ययन के दौरान प्राप्त डेटा को एकीकृत किया गया और aquifer disposition maps तैयार किए गए। भालास्वा अध्ययन क्षेत्र में पाँच (assessment Unit) आकलन तहसील शामिल हैं, मॉडल टाउन, अलीपुर, सिविल लाइन्स, सरस्वती विहार, और रोहिणी। वार्षिक निकालने योग्य भूजल संसाधन 6374 हैक्टेयर मीटर (ham) है। कुल वार्षिक भूजल पुनर्भरण 6957.85 हैक्टेयर मीटर (ham) अनुमानित किया गया है। कुल वार्षिक भूजल ड्राफ्ट (2023) तक 4808.83 हैक्टेयर मीटर (ham) अनुमानित किया गया है।

अध्यान क्षेत्र के 5 तहसीलों में से 2 सुरक्षित', 2 सेमी क्रिटिकल' और-1 तहसील क्रिटिकल' है। इसके अलावा', अधिकांश अध्ययन क्षेत्रों में जल स्तर उथला है, जहां खराब गुणवत्ता वाले पानी की उपस्थिति के कारण भूजल का निष्कासन सीमित है।इन क्षेत्रों में भूजल निष्कासन के बाद इसे मिश्रण करके उपयोग में लाया जाए। इससे Aquifer में रिक्त स्थान बनेगा, जिसे आगामी मानसून के दौरान पुनः recharge किया जाएगा जिससे भूजल गुणवत्ता में सुधार होगा। उन क्षेत्रों में, जहां ताजे भूजल के नीचे खारा पानी मौजूद है, यह सुझाव दिया गया है कि गहरे स्तरों पर मौजूद खारी पानी को निष्कासित करके मिश्रण के बाद उपयोग किया जाए और इसे पीने और घरेलू उपयोगों के अलावा अन्य कार्यों के लिए इस्तेमाल किया जा सकता है। जिन क्षेत्रों में जल स्तर 8 मीटर से गहरा हे इन क्षेत्रों में वर्षा जल संचयन और कृत्रिम पुनर्भरण उपायों की सलाह दी जाती है।

अध्यान क्षेत्र से गुजरने वाली नजफगढ़ अनुपूरक नाली के माध्यम से भूजल प्रदूषण को रोकने के लिए, यह सुझाव दिया जाता है कि केवल उपचारित अपशिष्ट जल को ही नालियों में बहने दिया जाए। नालियों की लाइनिंग की भी सिफारिश की गई है। लैंडफिल स्थलों के आसपास प्रदूषण के मामले भी रिपोर्ट किए गए हैं।सभी संबंधित राज्य एजेंसियों भूजल गुणवत्ता की गुणबत्ता के लिए आवश्यक उपाय उठाया जाना चाहिए, और लैंडफिल स्थलों को उचित वैज्ञानिक तरीके से स्थानांतरित और डिज़ाइन किया जाना चाहिए।

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1 Introduction

1.1 General Remarks

The National Aquifer Mapping and Management programme (NAQUIM) was carried out by CGWB from 2012 to 2023 in which detailed mapping of aquifers of India were carried out in the entire country, covering a mappable area of ~25 Lakh km^2. The findings of NAQUIM studies are being utilized by many agencies, especially the State government agencies involved in ground water management and water supply. Major areas where NAQUIM outputs have been used include

- Drinking water source finding and source sustainability
- Sites for Artificial Recharge
- Safe Drinking water sources in Arsenic affected areas
- Assured irrigation through ground water in areas that have adequate ground water potential.
- Implementation of water conservation and AR schemes
- Ground Water Regulation based on NAQUIM recommendation
- Rejuvenation of Hot springs
- Atal Bhujal Yojana – Participatory Ground Water Management

Under NAQUIM programme, aquifer management plan for NCT, Delhi was prepared during 2016-17, which was circulated all the stakeholders for implementation. Though the NAQUIM outputs have been useful for sustainable ground water management in numerous ways as enumerated above, large-scale implementation of its recommendations at ground level by the user agencies has been lacking. As per the feedback received from the agencies using the NAQUIM outputs, major limitations of the NAQUIM studies include i) non availability of printed maps at usable scales and ii) lack of site-specific recommendations for implementation at Panchayat or village level. Keeping the above limitations in mind and considering the future requirements, broad objectives of NAQUIM 2.0 studies will be i) providing information in higher granularity with a focus on increasing density of dynamic data like ground water level, ground water quality etc. ii) providing issue based scientific inputs for ground water management up to Panchayat level, iii) providing printed maps to the users and iv) putting in place a strategy to ensure implementation of the recommended strategies. Involving state agencies in the studies for a sense of ownership. The present study "Groundwater contamination studies around Bhalaswa Landfill site, NCT, Delhi was carried out under NAQUIM 2.0 during AAP 2023-24.

1.2 Sanitary Landfill Sites

The rate of urbanization is very high in developing countries like India. The level of urbanization of the country is expected to rise to 38% by the year 2026. Provision for civic services like water supply and sanitation has become an uphill task as the state is unable to provide and augment the required resources, both natural and human resources, for the maintenance of the cities. In the past municipal garbage dumps (sanitary landfills are only a recent technology) were unlined and sited with little regard to local hydrogeology. The disposal of such huge volumes of solid waste by open dumping has many environmental impacts. When solid waste is dumped in low-lying areas, it comes in contact with groundwater or rainwater along with run-off resulting the generation of leachate, a mineralized liquid with high dissolved organic matter, inorganic substances, and heavy metals. Open dumping of Municipal solid waste (MSW) leads to degradation of groundwater by generating leachate and its seepage into the ground. Management of domestic and industrial waste, which includes collection and scientific disposal of these waste materials, needs to be given top priority. Lack of proper collection and disposal of the waste is resulting into secondary problems like pollution of ground water, surface water, soil and air pollution. Ground water contamination is one of the major problems associated with improper waste disposal. Moreover, presence of dumping grounds in highly urbanized environments is directly resulting in health hazards for the people residing in the surrounding areas. Leaching of hazardous elements in the ground water in surrounding areas of landfill sites is reported from different sanitary landfill sites of all over the world. But areal depth demarcation and movement of pollutant plume is highly unpredictable and comprehensive studies of both hydrogeology and hydrogeochemistry is required to demonstrate and predict plume movement.

1.3 Solid Waste Generation in NCT, Delhi

The Municipal Corporation of Delhi (MCD), New Delhi Municipal Council (NDMC) and Delhi Cantonment Board (DCB) manage waste collection and disposal in different parts of Delhi. Before the year 1994, the solid waste disposal in Delhi was not thoroughly systematic and the solid wastes were dumped into nearby low-lying areas. A few of the low-lying areas have been developed into major landfill, which cover almost entire municipal and industrial dumps. Though, these sites were not scientifically designed with proper linings precautions is being taken to properly maintain these sites through clay cover and the construction of drains to drain off the leachates generated in the landfills. These sites may be major point sources of pollution due to the absence of proper lining. At present, in Delhi, the estimated quantity of waste generated was 11352 TPD and disposal of solid waste was 3000 TPD. Year-wise daily solid waste generation is given in ***Table No.1.***

The continuous generation of solid waste has developed several landfill areas and the land is retrieved for various purposes. There are four major categories of landfills in Delhi.

1. Landfills depleted and retrieved land is used for various purposes. The various landfill sites under this category with their areal extension and year of completion is given in **Annexure-I**.
2. Active landfills where the present filling is taking place. At present filling is being taking place in four sites (Fig.1). The sites are:

i. **Gazipur Near dairy farm.** The total area of the site is 70 acres. About 2500 MT/day of solid waste is received here. Filling in this landfill site commenced in 1993 and the service zones for this landfill site is East Delhi, New Delhi, Central Delhi

ii. **Bhalaswa -I & Bhalaswa-II**. The total area of the site is about 50 acres and about 2500 MT/day of solid waste is also dumped here. The dumping of solid waste started in 1984 and the service zone is Rohini, West Delhi, Najafgarh, Narela

iii. **Okhla Phase-III.** The total area of the site is 32 acres. About 1000 MT per day solid waste is being dumped here. The filling of this site commenced in 1994 and the service zone for this site is South Delhi and parts of Central Delhi.

iv. **Narela-Bawana-**The first engineered landfill site in Delhi and is spread over 150 acres. In 2011, the Municipal Corporation of Delhi (MCD) has begun operations at this site. This Site will take handle from Rohini and Civil Lines zones and has an initial capacity to handle 1000 tonnes per day, with plans to expand that to 4000 tonnes per day.

Table 1:Year-wise Daily Solid Waste Generation

Year	Solid waste generation (TPD)
2018-19	10614
2019-20	10470.57
2020-21	10990
2021-22	11108
2022-23	11352

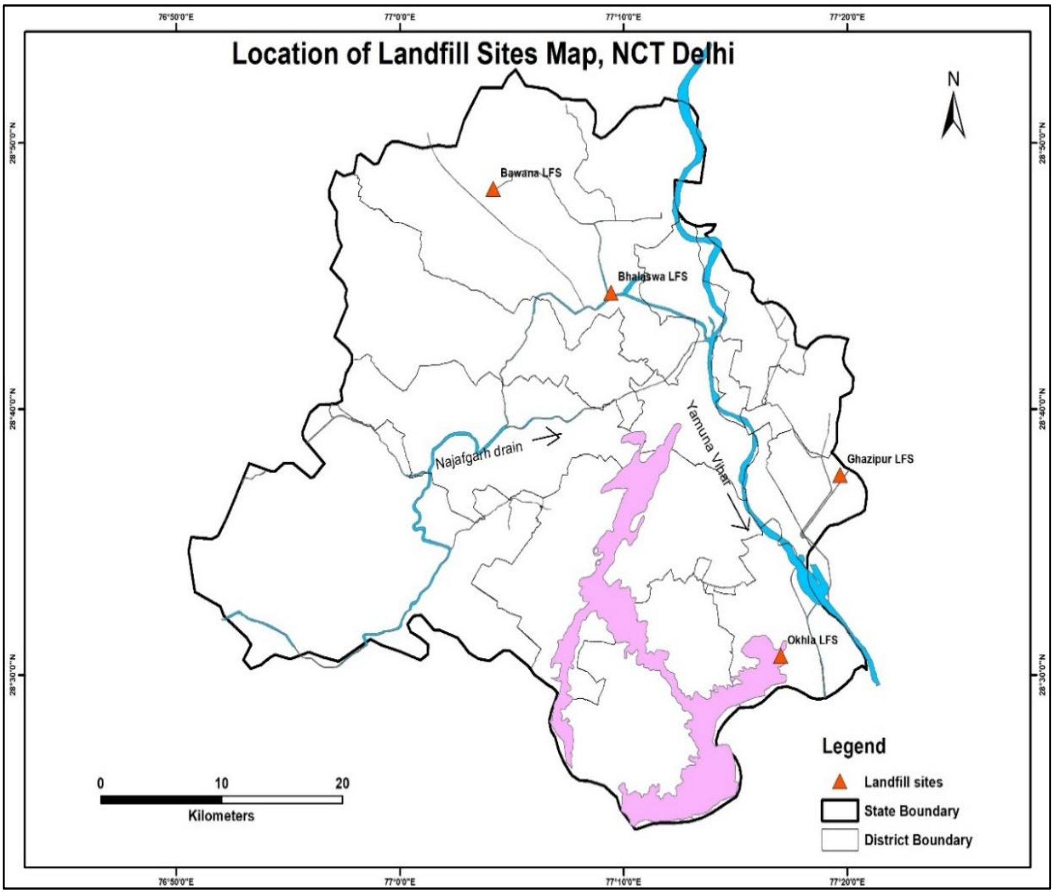


Figure 1: Active Landfill sites location map, NCT Delhi

1.3.1 Physico-chemical characters of Solid Waste in NCT, Delhi

The solid waste ***Fig 2*** disposal sites in Delhi receive both domestic and industrial solid waste, as there are no separate waste disposal sites for industries. The physical and chemical characters of solid wastes generated in Delhi are given in ***Table 2*** and ***Table 3*** respectively.

From the physical characters of the solid waste, it is observed the waste is being generated from domestic as well as other sectors like industries and constructional activities. The organic material is just 44.17% and the inorganic material is 55.83%. Chemically solid waste consists of high percentage of inorganic material, the calorific value is very low as compared to the global solid waste.

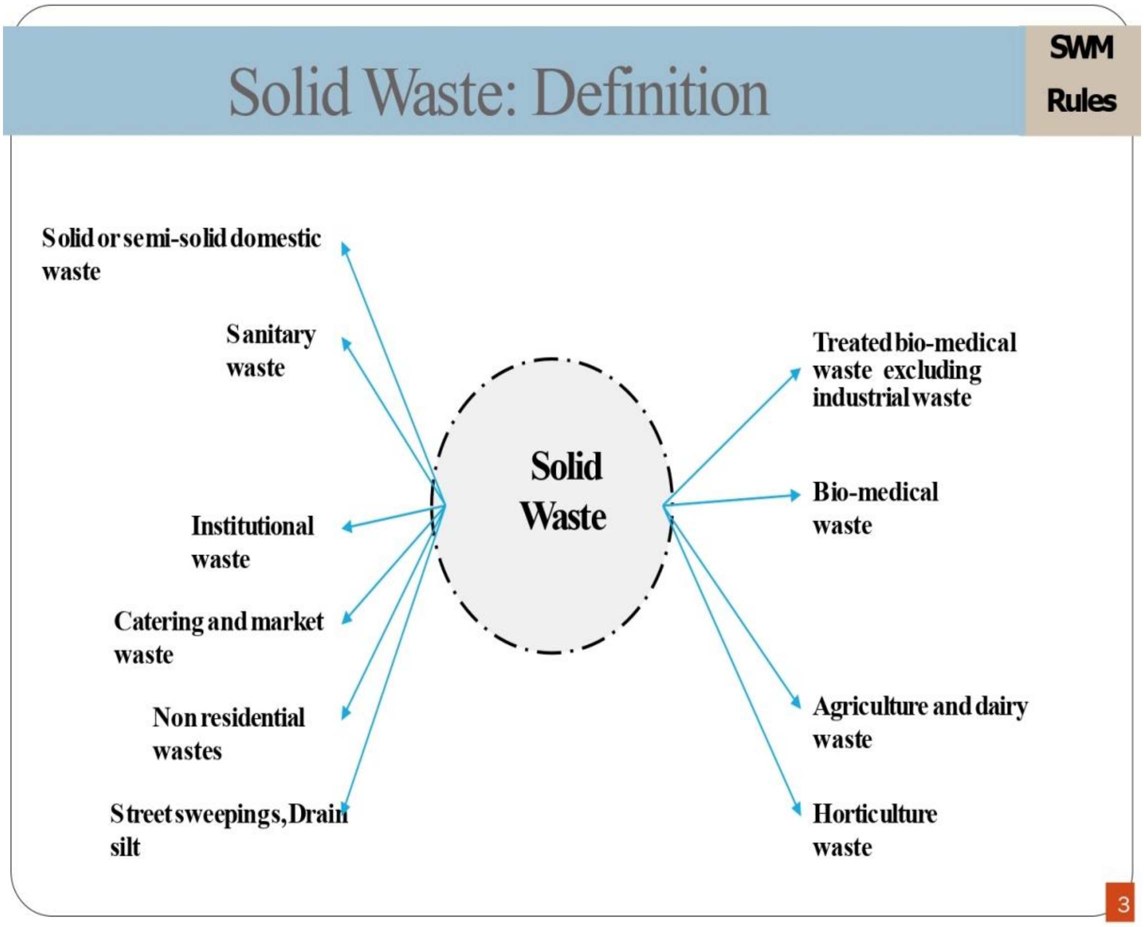


Figure 2: Solid Waste

Table 2: Physical Characters of solid waste

Parameters	Nature of Material	Average percentage
Bio-degradable	Organic material	38.6%
Paper		5.57%
Plastic	Inorganic material	6.03%
Metal		0.23%
Glass & Crockery		0.99%
Bio resistant (Leather, Rubber & Synthetic)		13.89%
Inert (stone, brick, ashes)		34.7%

Table 3: Chemical Characters of Solid Waste

Parameters	Average Share in Percentage
Moisture	43.65%
Organic Carbon	20.47%
Nitrogen as N	0.85%
Phosphorous as P205	0.34%
Potassium as K20	0.69%
C/N Ratio	24.08%
Calorific Value	712.50 K Cal/kg

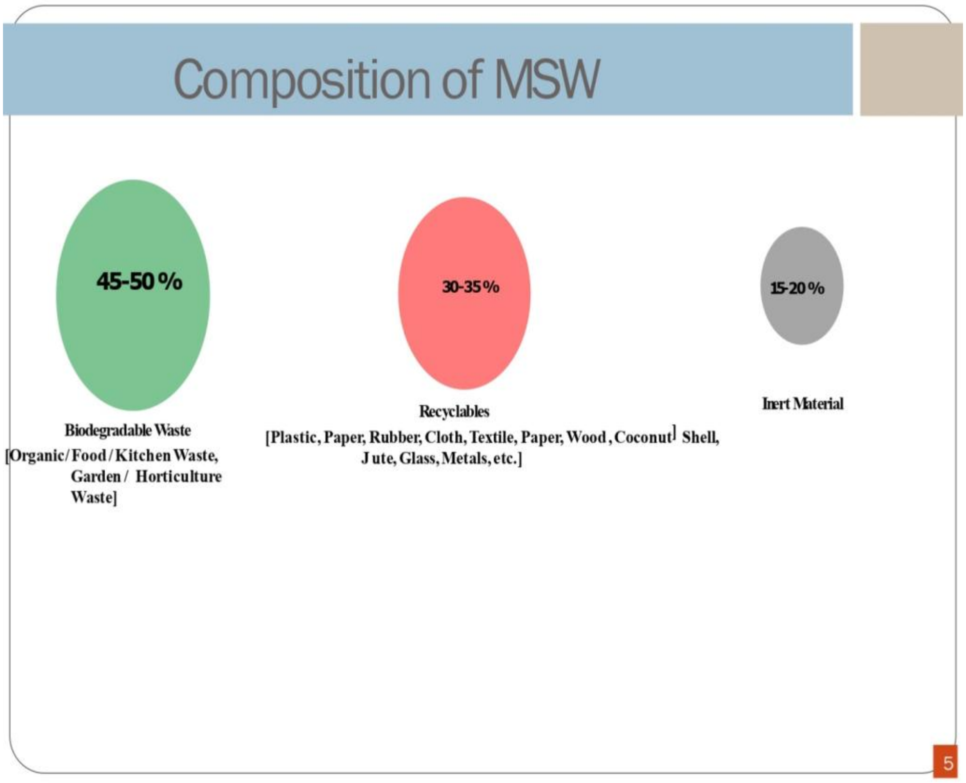


Figure 3: Composition of Municipal Solid Waste (MSW)

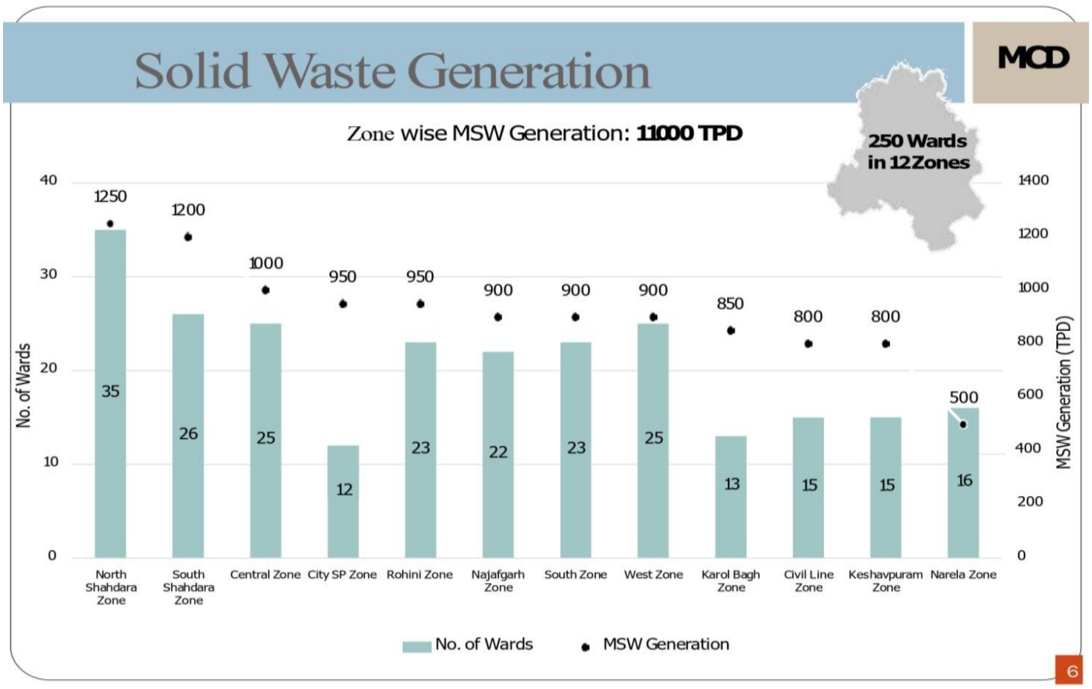


Figure 4: Solid Waste Generation zone wise in NCT Delhi

Figure 5: Field photos while collecting Leachate

1.4 Leachate

Solid waste undergoes many physical chemical and biological changes on a landfill site, this process degrades the organic fraction of the waste along with the moisture content and suitable temperature. The percolating rainwater leads to the generation of a highly contaminated liquid called leachate, which contains large amounts of organic matter like Ammonia nitrogen, heavy metal, and chlorinated organic compounds with inorganic salt. The composition and characteristics of landfill leachate vary with age, precipitation, waste type and composition and weather variation. That can be classified into three types based on the landfill leachate: old, intermediate and young. The classification and characteristic of landfill leachate is given in the table-4. BOD and COD of young leachate is generally found high (4000-13000 mg/l) and (30000-60000 mg/l) respectively. BOD/ COD ratio ranging from 0.4 to 0.7, ammonium nitrogen varies 500 to 2,000 mg/l and the pH found to be very low up to 4. As the landfill age increases and the fatty acid decomposition by anaerobic bacteria is about a period of 10 years it changes the characteristics of the leachate with a low COD, less than 4000 mg per liter and pH range is 7.5 - 8.5 with low biodegradability.

Table 4: Classification of leachate

S.No	Type of Leachate	Young	Intermediate	Old
1.	Age (Year)	<5	5-10	>10
2.	pH	<6.5	6.5-7.5	>7.5
3.	COD (mg/l)	>10000	4000-10000	<4000
4.	Organic Compound	80% VFA	5% to 30% VFA + Humic & Fluvic Acid	Humic & Fluvic Acid
5.	Ammonia Nitrogen (mg/l)	<400	NA	>400
6.	TOC/COD	<0.3	0.3-0.5	>0.5
7.	Heavy Metals (mg/l)	Low to Med	Low	Low
8.	Biodegradability	Important	Medium	Low

If the **leachate** is not properly handled, the landfill from which it originates can become a highly serious source of groundwater pollution, due to the possibility of leachate penetration into the soil, surface water and groundwater.

1.5 Previous Work

Municipal as well as industrial waste dumped in low lying areas may be the potential source of ground water pollution. Central Ground Water Board (CGWB) carried out systematic hydrogeological surveys during 1976-77 & 1982-83. Groundwater samples were also collected from these sites during the survey and analyzed for major elements with a view to compare them against drinking water standards. CGWB published the status of groundwater quality around landfill sites based on these studies [6]. CGWB & CPCB collaborative study, 1999 has also showed poor groundwater quality near different landfill sites. CGWB has constructed shallow piezometers of 15 m depth on landfill sites during Field Season Programme during 1999-2000 and carried out the depth wise analysis for the chemical quality of groundwater. At the same time, detailed sampling of adjacent area has also been done to study the vertical and horizontal movement of ground water pollution plume. This study established unambiguously that ground water is being contaminated near landfill sites. Sunil Kumar & A.L. Ramanathan [7] carried out hydro-chemical analysis of ground water from the Bhalaswa SLF site from May, 2003 to June, 2005. BARC and CGWB joint collaborative study on Application of Isotope Techniques in Groundwater Contamination Studies in selected Sanitary Landfill Sites in Delhi during 2003-2005. Their findings of their study suggest that very high concentration of heavy metals and anions are present in the ground water of Bhalaswa Area. Bharat Jhamnani and SK Singh has carried out the simulation studies for the migration of Chloride from landfill sites which shows that the simulation results are in consonance with the observed concentration of Chloride in the vicinity of landfill facility. It is observed that leachates from Bhalaswa landfill was found to be having a high concentration of chloride as well as DOC and COD.

1.6 Objectives of the study

A sizable number of populations in NCT, Delhi depends on ground water for their domestic and in some areas for drinking purposes. The objective of this study is:

- Ground water conditions in the proposed study area including detailed quality analysis
- Ground water flow pattern mapping
- Decipher the Aquifer Geometry and Aquifer properties
- Identification of areal extent of ground water pollution due to pollution plume movement
- Conservation of aquifers from Landfill pollutions
- Identification of recharge sources and recharge zones near landfill sites.
- Preparation of suitable recharge plans for the proposed area to arrest the pollution plume movement and preparation of alternate water supply plan for the people living in the vicinity of SLF site.

1.7 Methodology

This study has been done to analyse the groundwater contamination in and around the Bhalaswa landfill site. The total area considered for the study around the Bhalaswa Land Fill site is about 20 Sq. Km. The total area of the Bhalaswa land fill (dumping area) is =52acre=0.21SqKm. The dumping yard is 60-65 m height from surrounding areas. Three buffer zones have been drawn for assessment of the contamination of ground water i.e., 1 Km Buffer Zone, 2 Km Buffer Zone and 5 Km Buffer Zone. The density of sampling and water level monitoring is high at 1 Km buffer zone and gradually reducing the sample locations. The available data was analysed for the demarcation of aquifer system and establishment of groundwater flows for collection of ground water samples as per the flow pattern in the area. 10 no. of VES have been done around landfill site to delineate 2D aquifer disposition of the study area in a larger scale. Pre-monsoon and post-monsoon Ground water sampling were done from hand pumps, shallow tube wells at around landfill site for chemical and bacteriological analysis. Pre-monsoon and post-monsoon Groundwater monitoring has done to know the ground water flow direction. Contamination flow movements were established based on the hydrochemistry and ground water flow pattern.

2 Geology and Hydrogeology

2.1 Study area and Geology

Bhalaswa is the second largest active landfill where filling of garbage is still going on. The sanitary landfill in this area is spread east and west of Grand Trunk (GT) Road and is located about 10 km west of river Yamuna. This landfill falls in topographical depression and filling has started taking in early 80's. The landfill, which is present at the crossing of G.T. Karnal Road and Outer Ring Road, has been abandoned and G.T. Road has been developed on that. Landfill operation at the present site has been started from 1992 to the eastern side of G.T. road and still continuing. Meanwhile, in 2000, the dumping was also started on western side of G.T. Karnal Road just south of Sanjay Gandhi Transport Nagar. The dumping of the garbage is limited to about 50 acres of land and the total area of landfill site is around 70 Acres.

The study area is underlain by newer alluvium which in turn is underlain by older alluvial formation followed by weathered and fractured quartzite of the Delhi super group. The generalized stratigraphy is presented in ***Table 5.***

Table 5: Generalized Stratigraphic Units of NCT Delhi (compiled after GSI Study)

Alluvium	Newer Alluvium	Unconsolidated, inter-bedded lenses of sand, silt gravel and clay confined to narrow flood plains of Yamuna River and Aeolian deposit of South Delhi.
	Older Alluvium	Unconsolidated thickness varies up to 300m. Inter-bedded, inter-fingering deposits of sand, clay and Kankar, poor to Moderately sorted.
Delhi Super Group	Alwar Quartzite	Well stratified, thick bedded, brown to buff color, hard and compact, intruded locally by pegmatite and quartz veins inter-bedded with mica schist.

The landfill is not scientifically lined as the pit is only used as a dump site. It has only got a layer of malba topped with soil, instead of having a layer of plastic or a special type of clay layer requi red for asecure landfill. About 2500 MT/day solid waste is being dumped at this site and the filling of this site commissioned in 1994.This landfill site is not designed as per the schedule 3 of MSWs rules which came into effect in year 2000. The solid waste received at the site is levelled, restructuring and compacted by the hydraulic bulldozers. The height of the dump is about 62 meters in 2019 from surrounding ground level. The elevation in the area is from 207-216 m above MSL. The landfill is owned by the Municipal Corporation of Delhi and as per MCD, the total legacy waste will be cleared by 2025. Status of bio-mining legacy waste at Bhalaswa is given ***Table 6.***

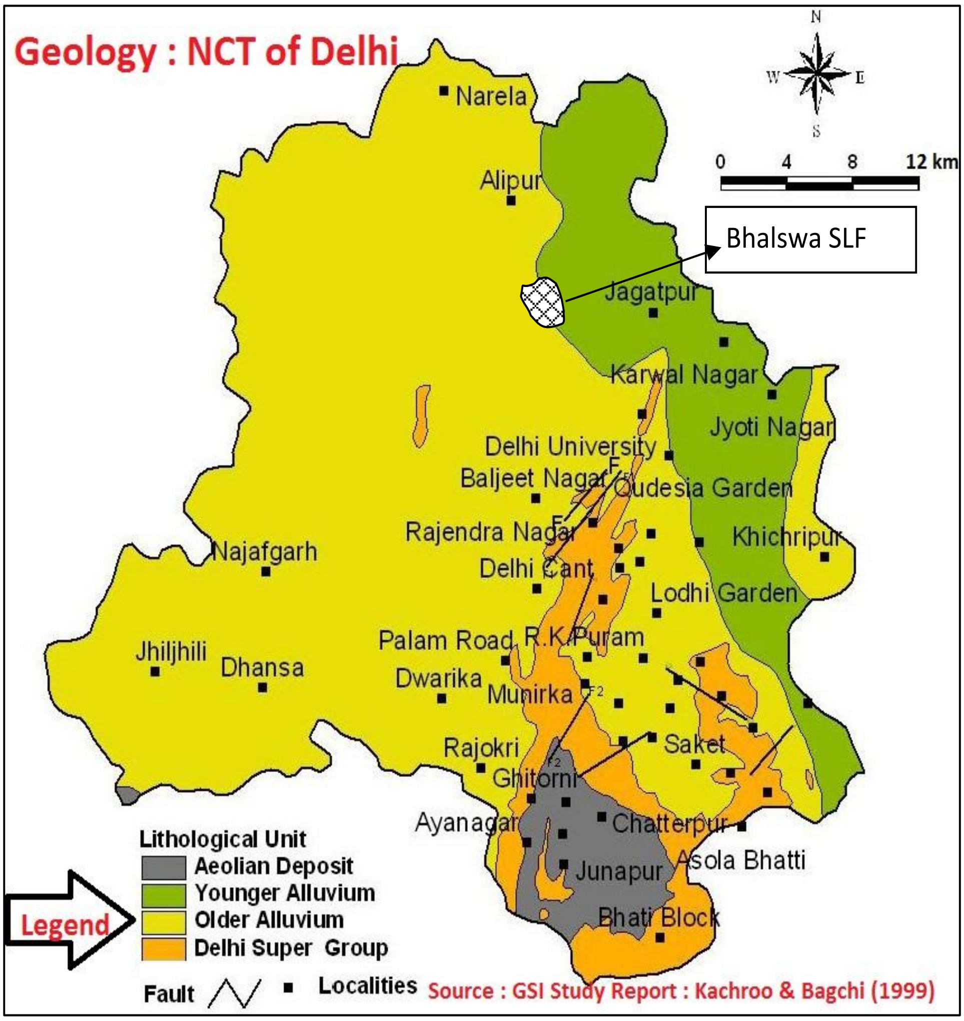


Figure 6: Geology Map of NCT Delhi

Table 6: Status of Bio-mining Legacy Waste at Bhalaswa (As on 29-02-2024)

Dump site	Quantity of Legacy Waste Dumped (July, 2019) (Lakh ton)	Total Quantity of Legacy Waste Bio-mined (SinceOct,2019-29-02-2024) (Lakh Ton)	Legacy Waste (Volumetric assessment through Drone Survey, June-2022) Above Ground (Lakh Ton)	Quantity of Fresh MSW dumped from July,2022 to 29-02-2024 (Lakh Ton)	Total Quantity of Legacy Waste Bio-mined From July,2022 to 29-02-2024 (Lakh Ton)	Balance Quantity of waste at Dump Site (Lakh Ton)	Revised time line for 100% Remediation (Earlier Timeline-May,2024)
Bhalaswa	80	59.88	73	15.40	34.91	53.49	2025

Three buffer zones have been drawn for assessment of the contamination of ground water i.e., 1 Km Buffer Zone, 2 Km Buffer Zone & 5 Km Buffer Zone. The 5 Km buffer covers parts of 3 districts i.e., North, North West and Central ***Fig.7.***

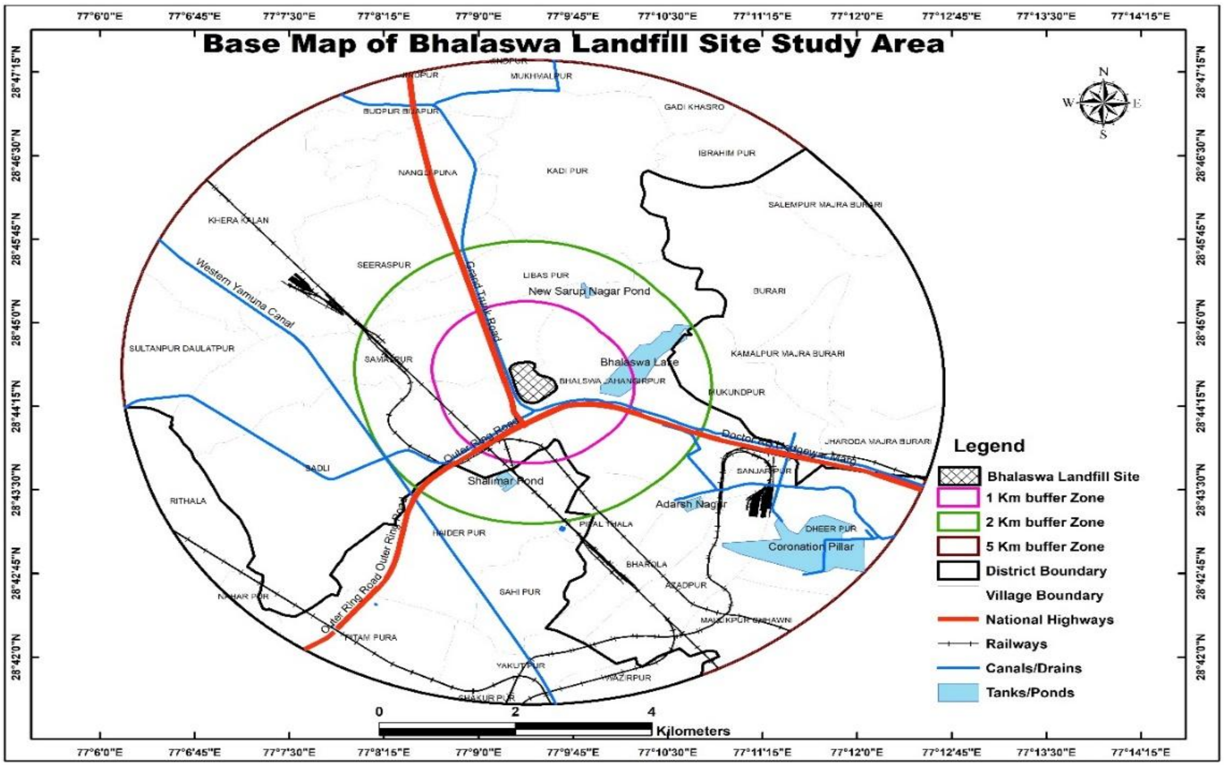


Figure 7: Study area map with buffer zones

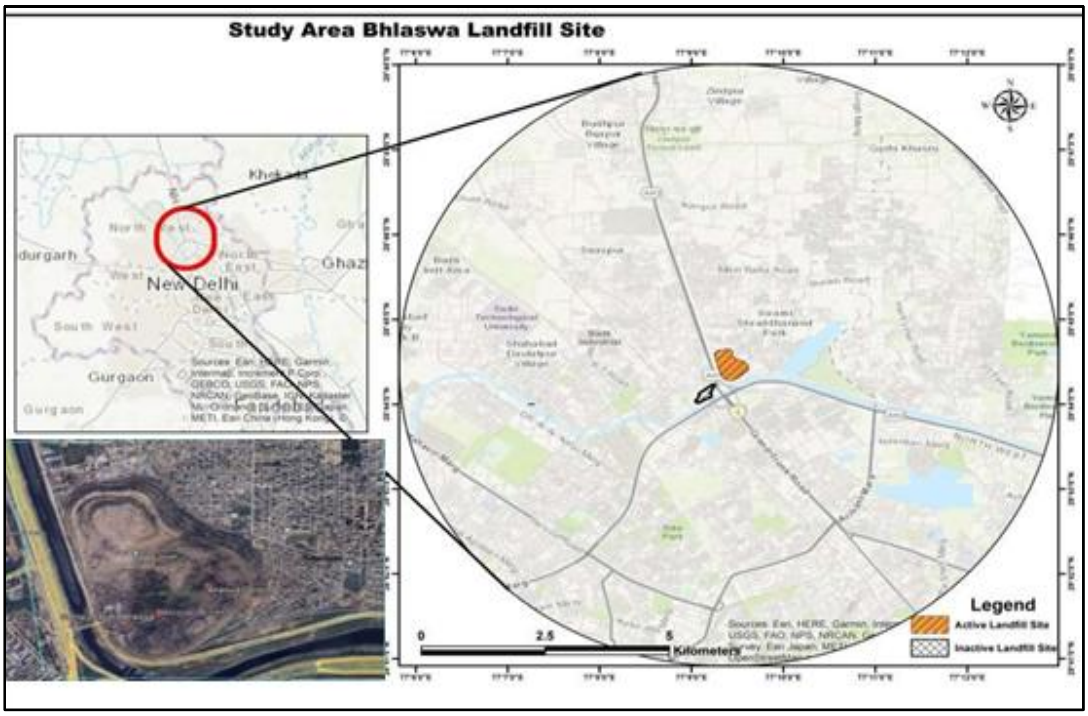


Figure 8: Study area location map

2.2 Climate and Rainfall

The climate of NCT, Delhi is mainly influenced by its inland position and the prevalence of air of the continental type during the major part of the year. Delhi has a humid sub-tropical climate with long and hot summers and cold winters. Only during the three-monsoon months July, August and September the air of oceanic origin penetrates to this region and causes increased humidity, cloudiness and precipitation. The year can broadly be divided into four seasons. The cold season starts in late November and extends to about the beginning of March. This is followed by the hot season, which lasts till about the end of June, the onset of monsoon. The monsoon continues till the last week of September. The end of monsoon marks the arrival of a transition season. The two post monsoon months October and November constitute a transition period, called autumn, from the monsoon to winter condition.

2.2.1 Temperature

The cold season starts towards the latter half of November when both day and night temperatures drop rapidly with the advance of the season. January is the coldest month with the mean daily maximum temperature at 21.3ºC and the mean daily minimum at 7.3ºC. In the winter months during cold waves which affect the State in the wake of western disturbances passing across north India, minimum temperatures may sometimes go down to the freezing point of water. From about the middle of March, the temperature begins to rise fairly rapidly. May and June are the hottest months. While the day temperature is higher in May, the nights are warmer in June. From April the hot wind known locally as ‘loo’ blows and the weather is unpleasant. In May and June, maximum temperature may sometimes reach 46 or 47 ºC. With the advance of the monsoon into the area towards the end of June or the beginning of July, day temperatures drop appreciably while the night temperatures remain high. In October the day temperatures are as in the monsoon months but the nights are cooler.

2.2.2 Rainfall Pattern

The normal annual rainfall in the State is 611.8 mm. About 81% of the annual rainfall is received during the monsoon months July, August and September. The rest of the annual rainfall is received as winter rain and as thunderstorm rain in the pre and post monsoon months. There is large variation of rainfall from year to year. During the 113-year period 1901-2013, 1933 was the year with the highest annual rainfall, which amounted to 251% of the normal. In 1951, the year with the lowest rainfall only 44% of the normal annual rainfall was received.

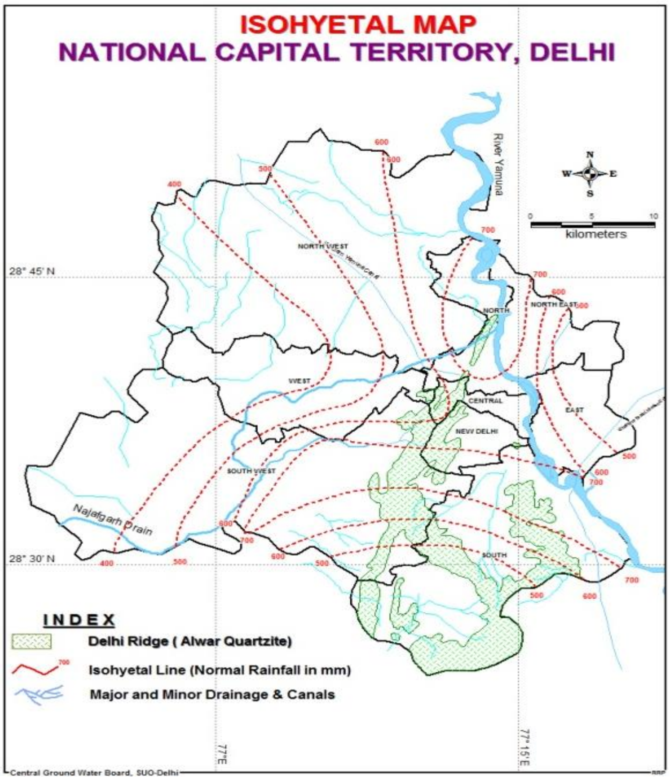


Figure 9: Study Isohyetal Map of NCT Delhi

On an average, rainfall intensity of 2.5 mm or more falls on 27 rainy days in a year. Of these, 19 days are during the monsoon months. Two to three days in June are rainy. In other months, except in November and in the first half of December when it is practically rainless, rain falls on a day or two only in each month. The heaviest rainfall in 24 hours recorded at any station in the State was 495.3 mm at Delhi (Safdarjung) on September 9, 1875. The rainfall in NCT Delhi increases from the Southwest to the Northwest ***Fig 9.*** However, a slight increase in rainfall is observed towards the Yamuna River. Rainfall in last ten years in NCT, Delhi is given in ***Table 7.***

Table 7: Year-wise rainfall from 2014 to 2023

Year	Rainfall (mm)
2014	440.4
2015	547.5
2016	656.1
2017	512.49
2018	543.97
2019	499.44
2020	485.4
2021	972.34
2022	668.58
2023	746.58

2.3 Physiography & Drainage

The study area is around 6.5 km away from Yamuna River. Yamuna River flows across Delhi in a south-southeasterly direction with vast flood plain, marked by a bluff of 3 to 4 m on either bank. Surface elevation varies from 221 m above mean sea level at western side of Bhalaswa LFS to 206 m above mean sea level at eastern side of Bhalaswa LFS. The slope direction is south west to North East direction, towards Yamuna River. The river Yamuna passes through the eastern part of Delhi area. The river Yamuna is the only perennial river flowing in a southerly direction.

2.4 Geomorphology

The ground water availability in NCT, Delhi is controlled by the hydrogeological situation characterized by the occurrence of different landforms developed on different geological formations. Entire area of NCT, Delhi can be grouped into three broad geomorphic units:

- Rocky surface
- Older Alluvial Plain
- Flood Plain of Yamuna River

Study area covers part of the older alluvial Plain and Flood Plain of Yamuna ***Fig.6 & Fig.10.***

***Older Alluvial Plain*:** Depending upon the morphological expressions/ features, the gently undulatory terrain is described as Older Alluvial Plain. Older Alluvial Plain occupying western and southwestern part of the of the study area.

Flood Plain of river Yamuna: The low-lying flat surface representing the Flood Plain of river Yamuna occupying northern, northeastern and eastern parts of the study area is an important geomorphic unit. This belt has good potential for ground water development. It forms the erosional terrace. The Yamuna Active Flood Plain represents the wide belt bounded on both the sides by Eastern and Western bunds and is naturally prone to annual/periodic floods being in the flood way and flood fringe zone of river Yamuna. It forms depositional terrace and is characterized by abandoned channels, cut-off meanders, meander scrolls, point bars and channel bars. Presence of number of cut- off meanders in the Yamuna Flood Plain suggests oscillatory shifting of river. The lake near Bhalaswa Landfill is one of the remnants of large meander channel.

2.5 Hydrogeological Framework

NAQUIM 1.0 studies reveal that this area is characterized by unconsolidated Quaternary alluvial deposits. No basement has been encountered till the explored depth of 300m. Thick pile of alluvium over the basement rock is composed of sediment strata of varied nature in an alternate fashion of geological setting. Along the Yamuna flood plain alternations of sand and silt with kankar with thin lenses of clay are available down to the drilled depth of 250 m. In the western side of the study area, fine to medium sand and silt are occurred frequently down to depth of 50 – 65 m along with buff coloured clay admixed with coarse kankars. Below this depth thickness of clay formation increases. In the eastern part falling in Yamuna flood plain, sand is dominant aquifer, while clay is dominant in the western part giving rise to salinity due to improper flushing and long residence time of water in the formation. The semi-plastic and plastic clay beds are also common at deeper depth i.e. 80 to 250 mbgl. The granular zones (fine sand and silt with kankar) at deeper depth are not as frequent as in the shallower depth. Thickness of sand lenses decreases away from the Yamuna flood plain towards the west. The fresh-saline water interface varies greatly in the study area.

All along the western Yamuna Canal and along Yamuna Flood Plain it is deeper (40 to 70 m), whereas in rest of the area it varies from 22 to 40 m in depth. It was also observed from the exploratory wells that salinity of water increases with depth and there is no fresh water aquifer at deeper levels.

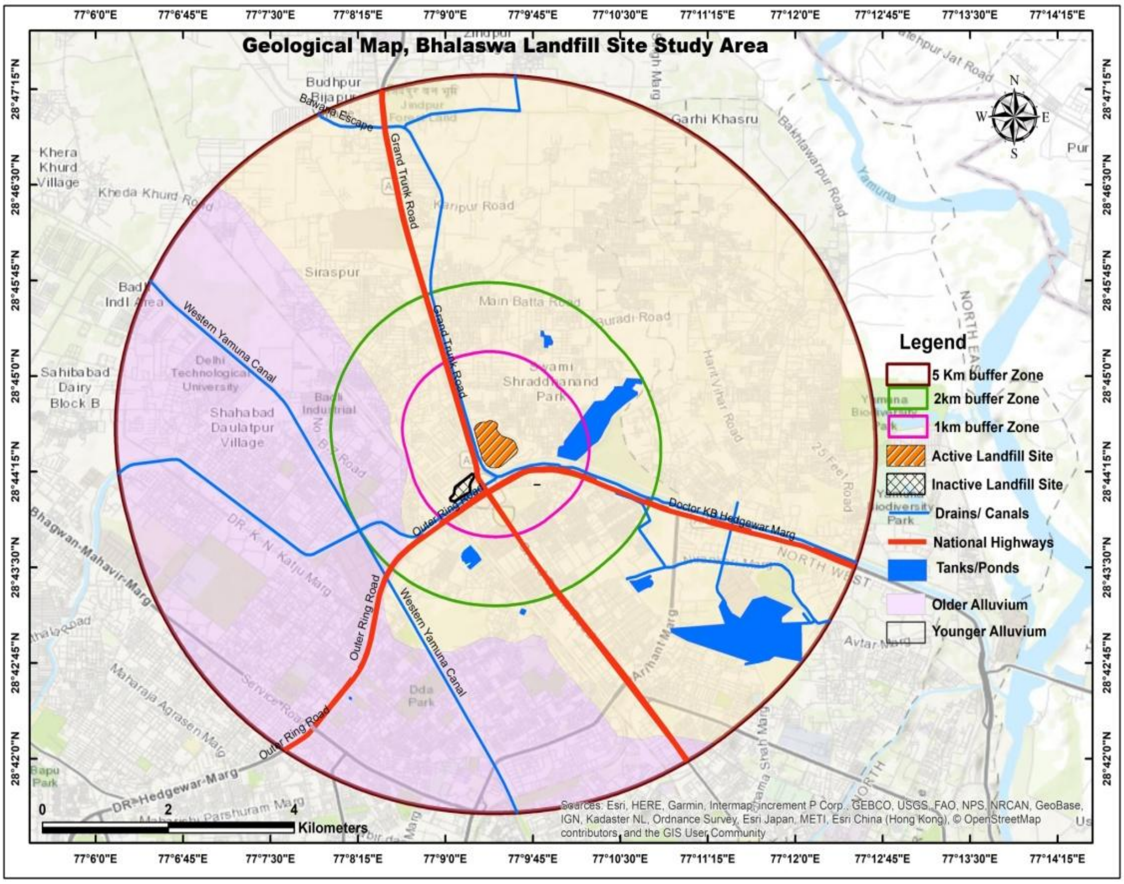


Figure 10: Geological map of the study area.

2.6 Ground Water Exploration

Central Ground Water Board has constructed a number of piezometers and exploratory tube wells around the Bhalaswa SLF to study the nature of aquifer material and its characters. Moreover, during 2000, CGWB has constructed three shallow piezometers of 15 m depth near landfill site.

Table 8: Details of piezometers

S.No.	Location	Granular Zones encountered (mbgl) From - to	Depth to water levels (mbgl) in May, 2000	Lithology
1.	About 50m south east of SLF in the land of Flood Control Department	9.5-12.5 12.5-15	3.2	Fine sand silt with minor Kankars
2.	About 15m north-eastern boundary of SLF, near transformer	2-10.5 10.2-15	0.8	Fine Sand Silty Clay
3.	Southeast of SG transport Nagar and west of GT Karnal Road near SLF boundary	2-10 12-15	4.15	Sand with silt Silty Clay

The details of these piezometers have been given in ***Table 8*** Clay horizon is present. A deep tube well in the vicinity of landfill site had been drilled with a purpose of getting lithological log ***Table 9*** and geophysical log ***Table 10. Table 8*** suggests that the SLF site is underlain by fine sand up to 12 m depth below which the silty.

Based on the lithologs and geo-physical logs, a generalized sub-surface geological cross section (Fig.9) shows that the area is underlain by fine to medium sand (Yamuna sand) mixed with coarse gravel up to a depth of about 40 mbgl below which older alluvium consisting of predominantly clay with silt and kankar is present. A well inventory of hand pumps, shallow tube wells and deep tube wells in and around SLF site has been carried out. The hydrogeological information is given in **Annexure-II**.

Table 9: Lithological Log

Depth range in mbgl	Thickness(m)	Lithology
0.00-14.45	14.85	Light yellow clay with minor coarse to gravel size kankar
14.45-21.35	6.9	Sand with clay silt admixed with fine sand and kankars
21.35-24.13	2.78	Gravel and kankars with minor silt and fine sand
24.13-34.10	9.97	Silty clay with traces of kankar
34.10-41.89	7.79	Gravel with minor silt and fine sand
41.89-51.46	9.57	Sand fine grained along with tracers of gravel
51.46-65.10	13.64	Clay with Silt
65.10-131.55	66.45	Sticky clay
131.55 -134.55	3.00	Gravel with fie sand

Table 10: Geophysical Log of Piezometer at Bhalaswa SLF, Delhi

Depth ranges in mbgl	Thickness of Granular Zone deciphered	Remarks
6-10.00	4.00 m	The quality of ground water is fresh up to the depth of 45m
25.00-30.00	5.00	
31.00-35.00	4.00	
40.50-43.50	2.00	Below 45m quality of water is marginally saline.
87.00-89.00	2.00	
92.5- 96.00	3.50	
110.00 – 114.00	3.00	

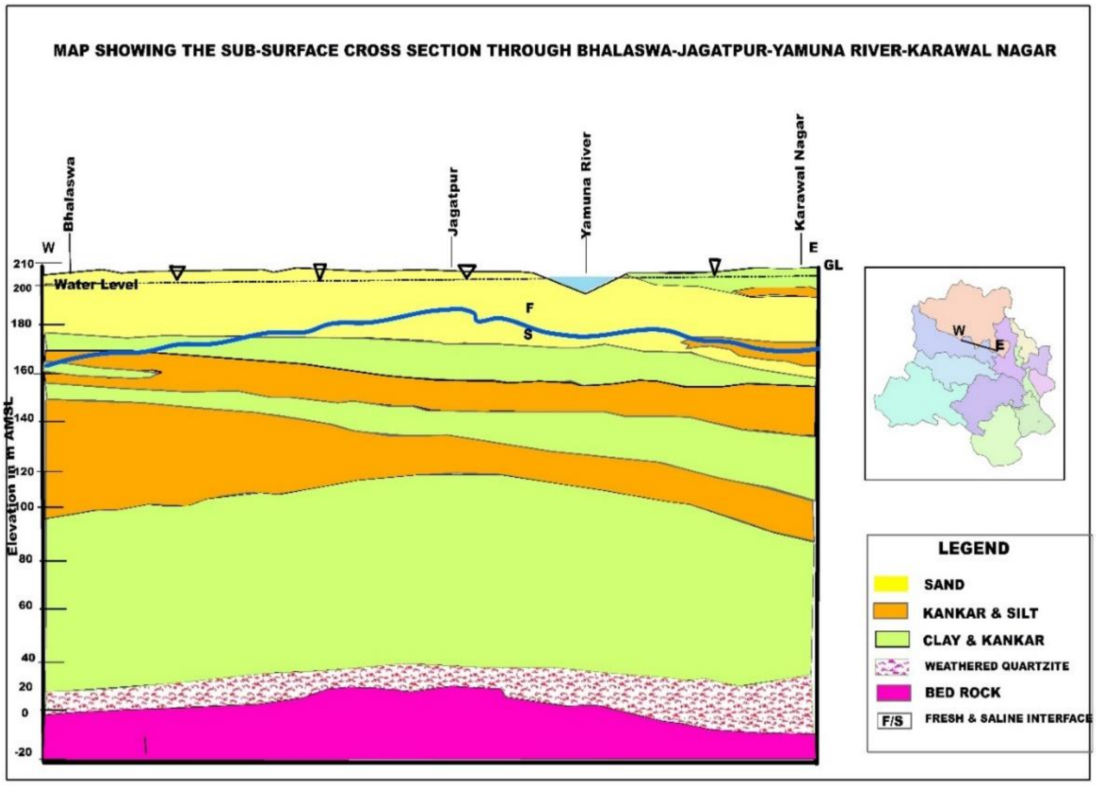


Figure 11: sub-surface geological cross-section

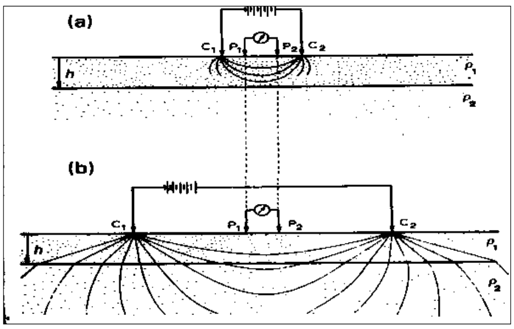
2.7 Geophysical investigations

Surface geophysical methods provide a relatively quick and inexpensive means to characterize the sub-surface. Surface geophysical methods measure the physical properties of the sub-surface such as electrical conductivity or resistivity, magnetic permeability, density, or acoustic velocity etc. Electrical surface geophysical methods are used to detect changes in the electrical properties of the sub-surface. The electrical properties of soils and rocks are determined by water content, mineralogical clay content, salt content, porosity and the presence of metallic minerals. However, typically the resistivity of the water has a larger effect on the bulk resistivity than the soil or rock type. Variations in these electrical properties of soils and rocks, either vertically or horizontally, produce variations in the electrical signature measured by surface geophysical instrument. Changes in the received signal can be related to changes in the composition, extent, and physical properties of the soils and rocks within the sub-surface. However, to effectively detect these differences there must be a contrast in their properties to be measured. The target to be detected or geologic feature to be defined must have properties significantly different from "background" conditions like that of ground water in sand, boulder background.

Surface geophysical resistivity surveys are usually designed to measure the electrical resistivity of sub-surface materials by making measurements at the earth surface. In Vertical Electrical Sounding (VES), the vertical (depth wise) variations in the resistivity of the sub-surface are measured. This is done by imposing an electrical field in the ground by a pair of electrodes at varying spacing expanding symmetrically from a central point, while measuring the surface expression of the resulting potential field with additional pair of electrodes at the appropriate spacing (Figure 2). For an array of current electrodes (C1 & C2) or A & B, and potential electrodes (P1 & P2) or M & N, the 'apparent resistivity', 'ρ_a' is expressed by the equation:

$$\rho_a = \pi R * \left[\frac{\{(AB/2) + (MN/2)\} * \{(AB/2) - (MN/2)\}}{MN} \right]$$

Where R = resistance { R = △V / I },
I is the current introduced in the earth,
△V is the potential difference between the potential electrodes,
AB = distance between the current electrodes A & B and
MN= distance between the potential electrodes M & N.



(a) Electrodes position for shallow measurements.
(b) Electrodes position for deeper measurements, keeping observation points same.
The values of apparent resistivity (ρ_a :- product of resistance and geometric factor) in ohm-m are plotted against the related half-current electrode separation on double logarithmic scale paper of moduli 62.5 mm, for interpretation by curve matching technique and Resistivity Sounding Interpretation software. The interpreted result gives the resistivity of different layers and the depth of various interfaces underneath.

2.8 Data Acquisition

Attempts were made to gather maximum information about the sub-surface features using an appropriate mix of different techniques viz. hydrogeological reconnaissance, toposheet study, geophysical surveys etc. The integration of information, so collected, helped progressively to focus on the targeted zones.

A total of 10 Vertical Electrical Soundings (VES) with Schlumberger electrode configuration were carried out at Bhalaswa Landfill surrounding areas ***Table 11 & Fig.12.*** The prime objective of the survey was to find out the effect of landfill sites to the groundwater of those areas. . To achieve the above objectives the VES were conducted using the SSR MP ATS resistivity meter, manufactured by Integrated Geo Instruments & Services Private Limited , Hyderabad. Most of VES were conducted with the current electrode separation (AB) ranging from 80 to 500 m. Current electrode separation was expanded in in accordance with the availability of area and with appropriate MN separation.

Table 11: Details of VES locations

VES No.	Location	Latitude	Longitude	Elevation (mamsl)
1	Near Majlis Park Metro station, Jahangirpuri	28.7290794	77.18154568	207
2	Mukundpur 1 near Bhalaswa	28.7405429	77.1738813	212
3	Mukundpur 2 Along Bhalaswa lake	28.7419403	77.172471	208
4	Near Bhalaswa Golf Course	28.7366835	77.1737749	211
5	DDA Park, Bhalaswa	28.734531	77.161061	203
6	Near nala, Jahangirpuri	28.733575	77.151769	214
7	Sector-19, DDA Park, Rohini	28.732805	77.14719	215
8	Plain Land opposite Vasant Dada Nagar	28.744552	77.151669	213
9	Swaroop Nagar Park, Bhalaswa	28.7512805	77.152479	212
10	Shradhanad Park, Near Bhalaswa Diary	28.749048	77.163617	207

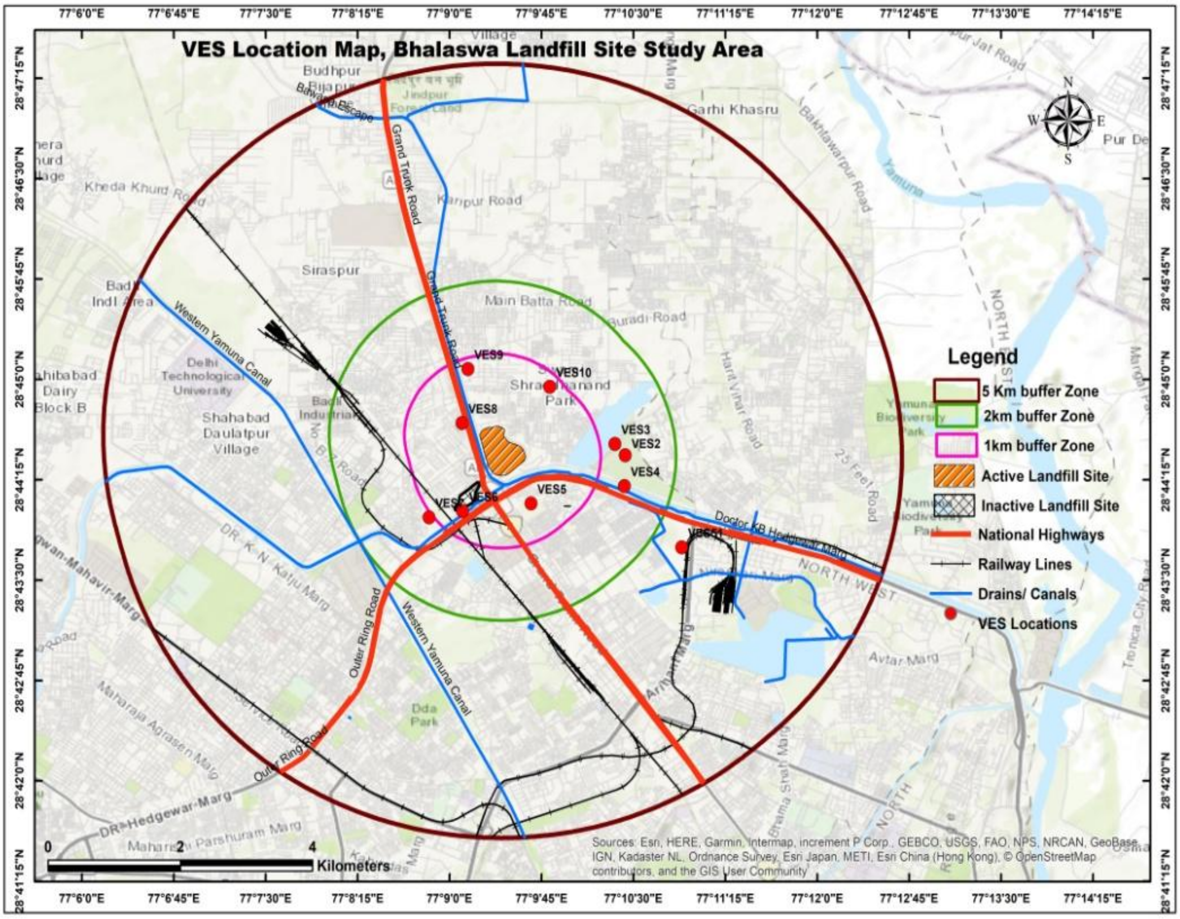


Figure 12: VES Location map

2.9 Aquifer Disposition Based on VES Data

The panel diagram ***Fig.13*** was prepared to know the distribution of fresh and saline aquifers. Four geological layers have been delineated on the basis of resistivity values. Top soil with silt occurs very thin and is distributed throughout the area investigated. Fine sand and Kankar is also very limited thickness. The thickness of fresh water zone is more in the south-western and southern sides of the area and is limited in the south-eastern, north-western and eastern parts. The thickness of fresh water zone varies from 22 to 65 m. No fresh water occurs below 65 m. No bedrock has been observed up to the depth of 250 m ***Fig.14.***

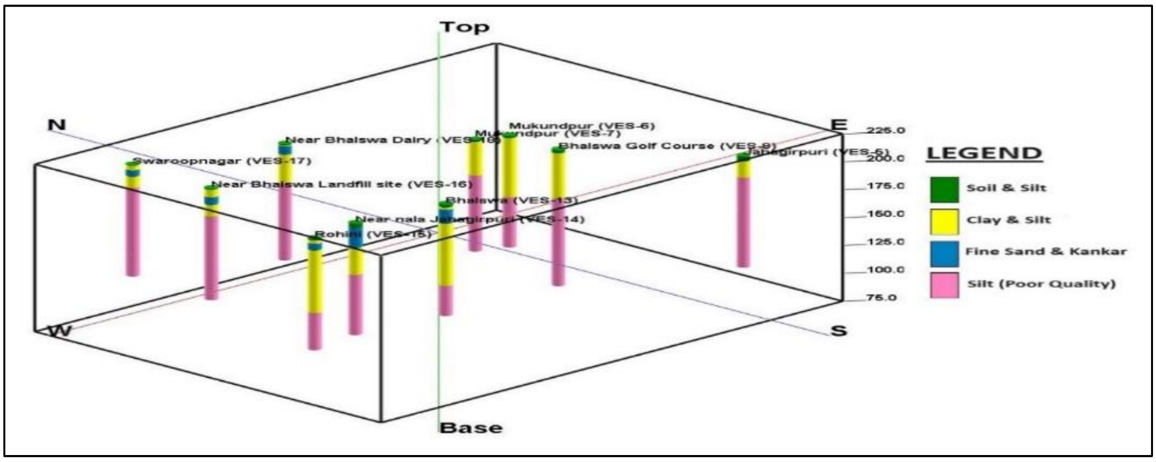


Figure 13: Panal diagram of the Study area.

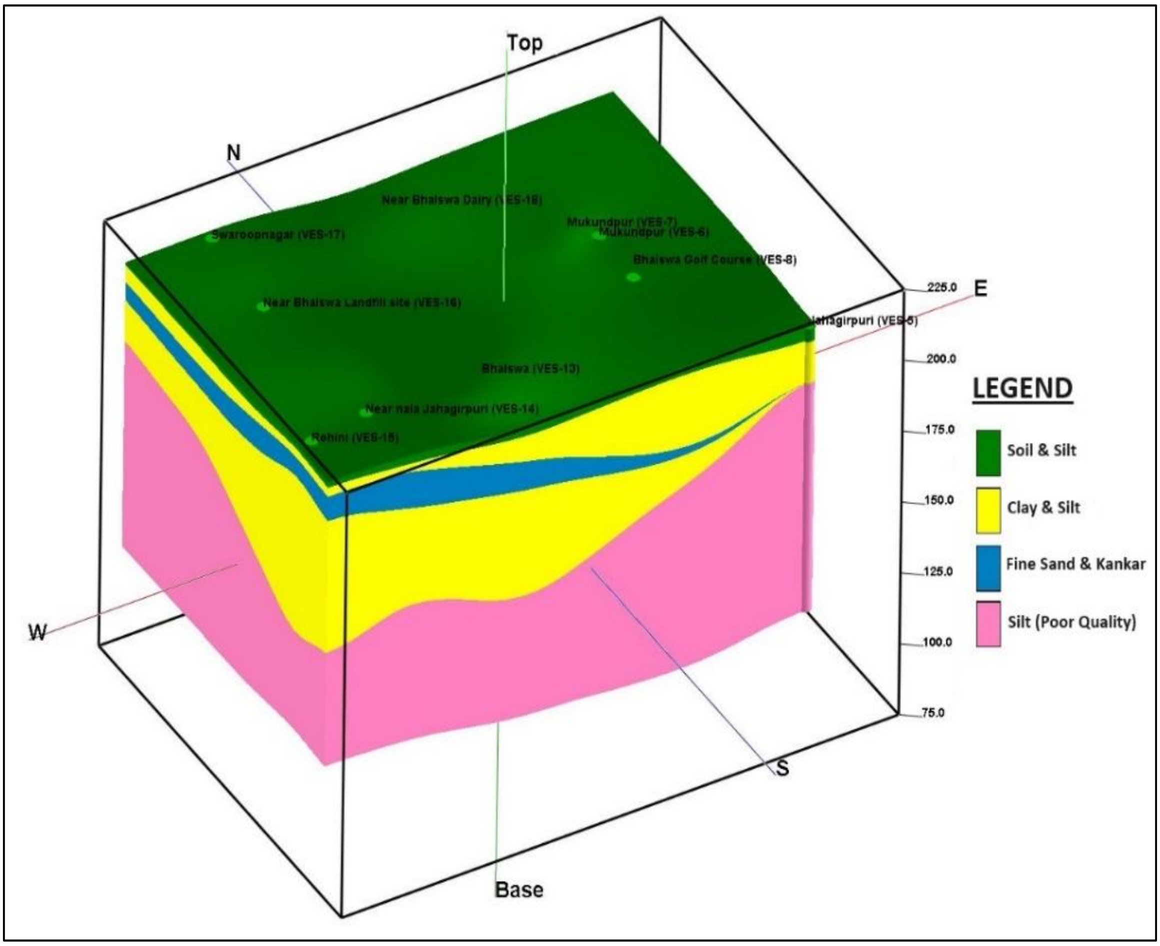


Figure 14: Panal diagram of the Study area.

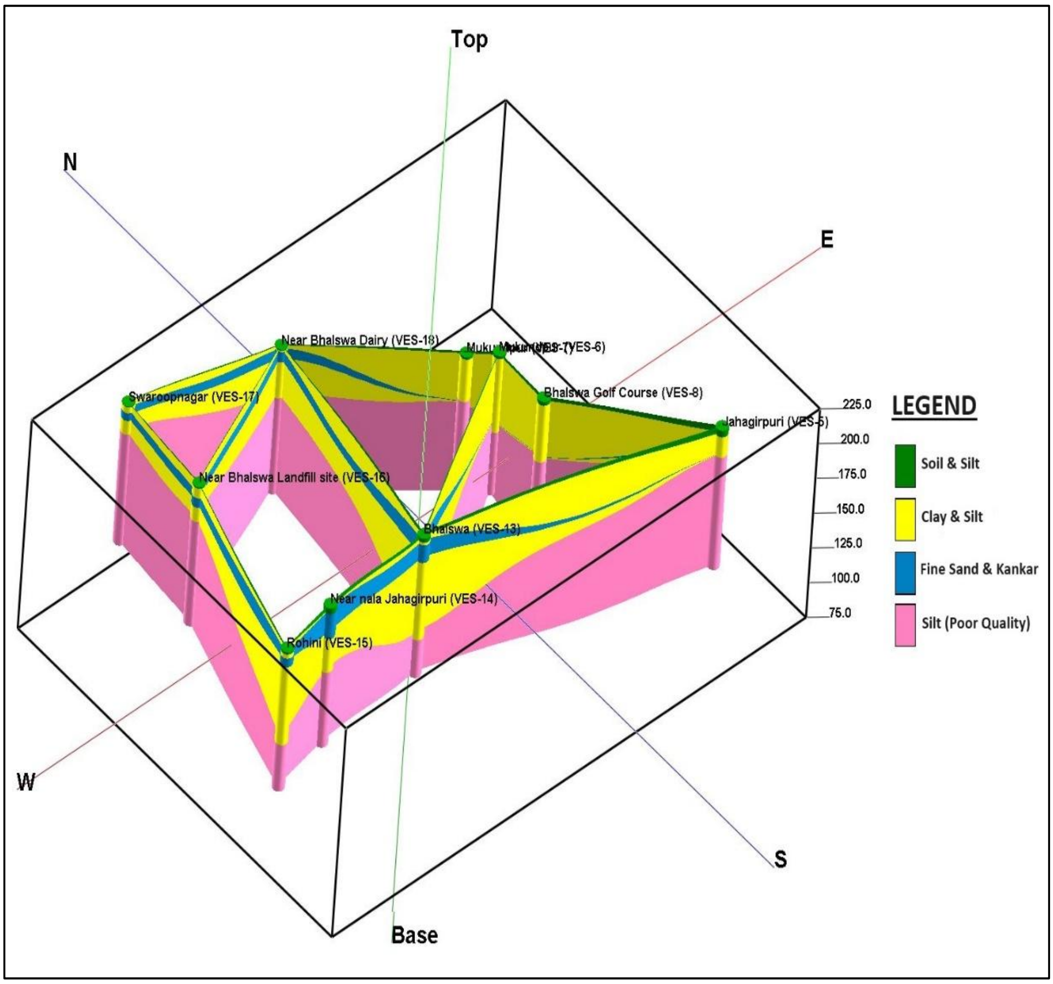


Figure 15 : Panal diagram of the Study area.

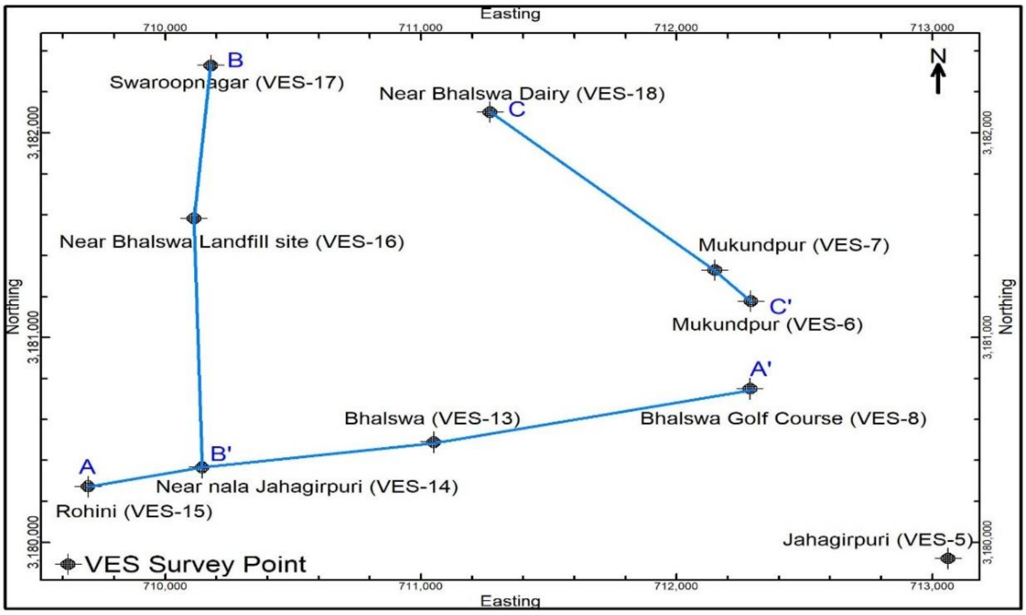


Figure 16: VES Cross-sections at Study area

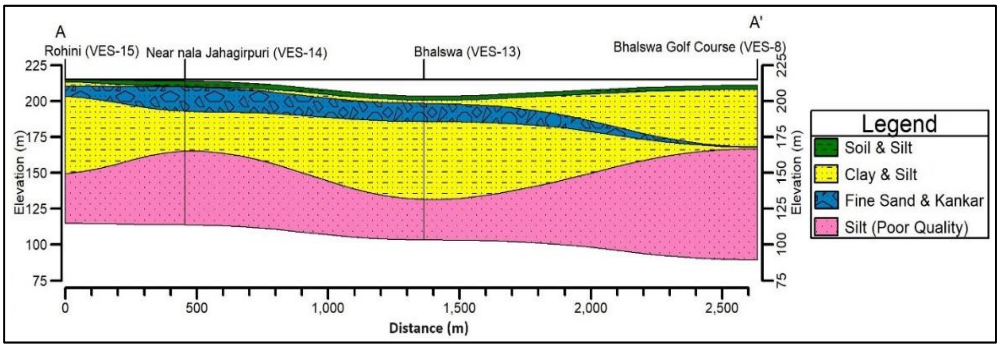


Figure 17: VES Cross-sections AA'

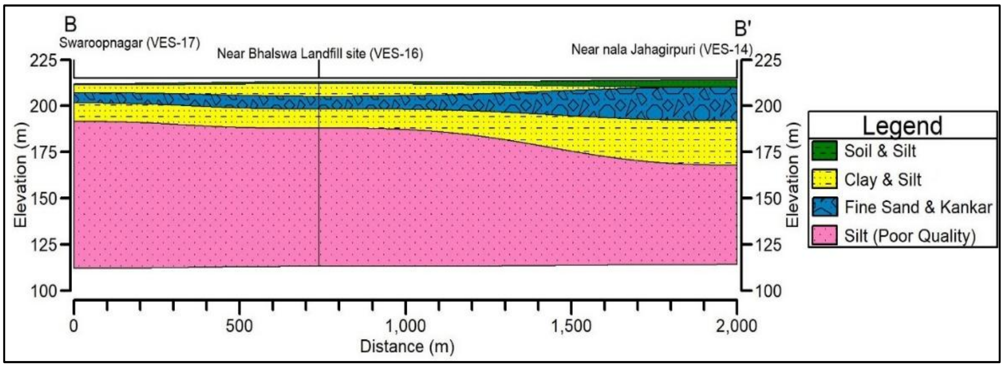


Figure 18: VES Cross-sections BB'

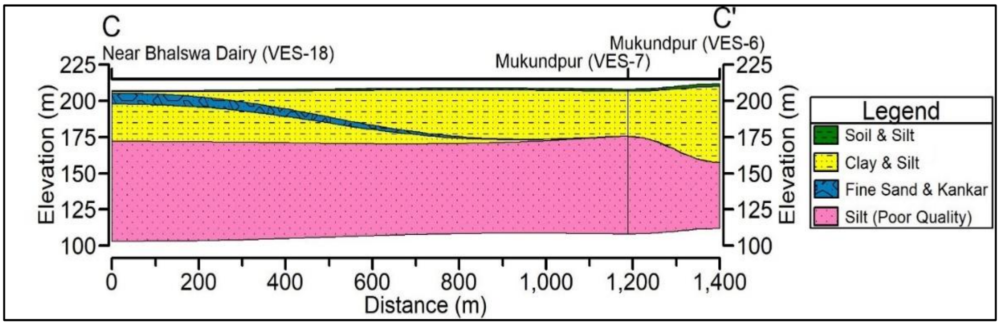


Figure 19: VES Cross-sections CC'

2.10 Ground Water Levels

Water levels have been monitored through a network of 25 monitoring wells distributed throughout the study area. Water levels were monitored during Pre-monsoon (June) and Post-monsoon (November). Locations of monitoring wells are shown in ***Fig 20.***

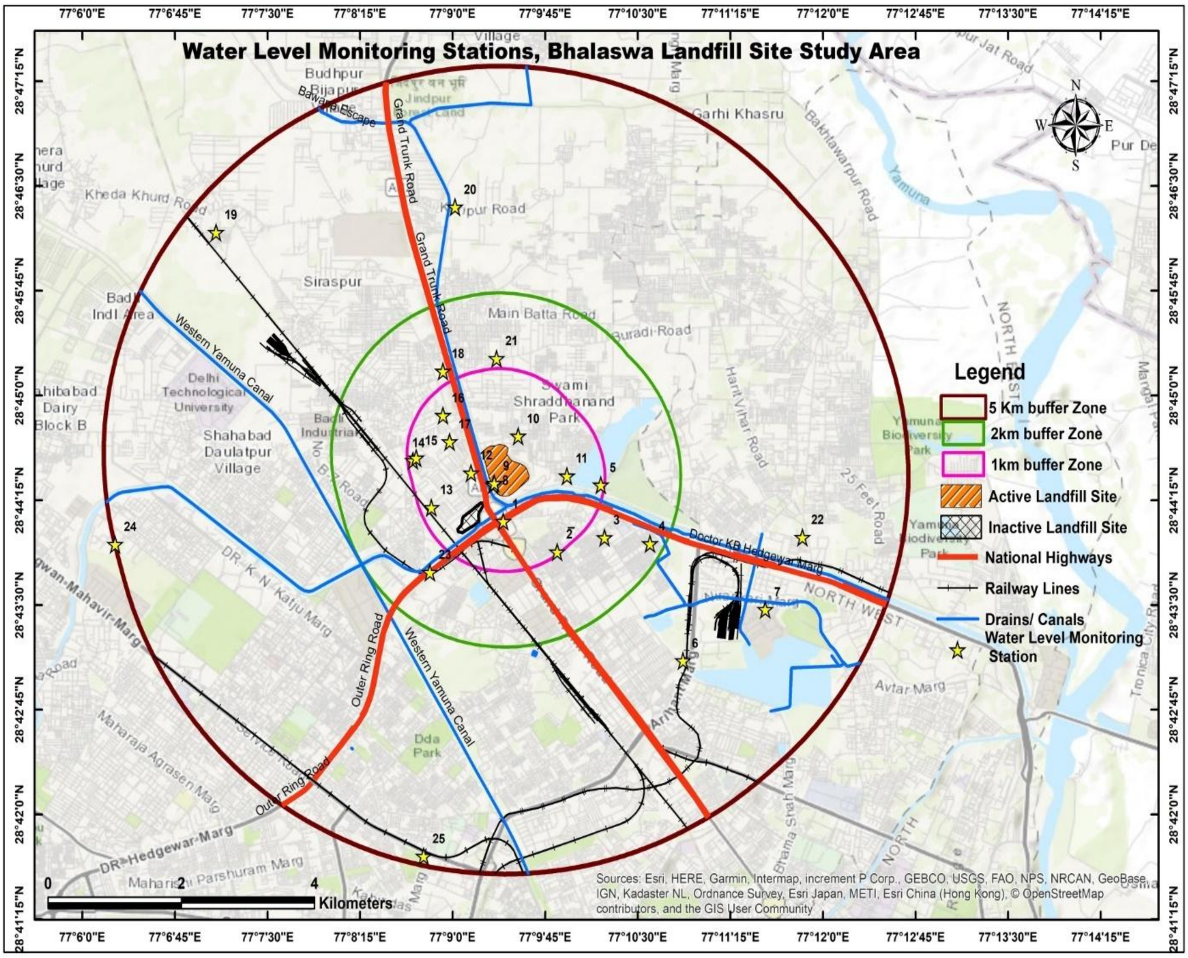


Figure 20: Water level monitoring stations

2.11 Depth to water level during Pre-monsoon (June, 2023)

The Depth to water level recorded in the study area during June, 2023 ranges from 3.56 (Bhalaswa lake Tw besides Lake) to 12.88meters below ground level (mbgl) at Haiderpur Pz. Ground water level data of a total of 14 monitoring wells have been analyzed. It is observed that 35% wells have shown water level less than 5mbgl and 35% wells had water level in the range of 5 to 10 mbgl. 30% wells have shown water level more than 10 mbgl ***Fig.21.*** Shallow water levels are observed in Bhalaswa Lake TW, Kewal Park Pz, Coronation Piller Pz, Burari DJB Ex. Engg Office Pz, Sandesh Vihar Pz, Rohini Sec-11 Pz and MCD Dispensary. Deeper water levels are observed in Toilets, CTC no. 154, SGTN TW, Khera Kalan Pz, JJ Cluster Toilets TW and Haiderpur Pz.

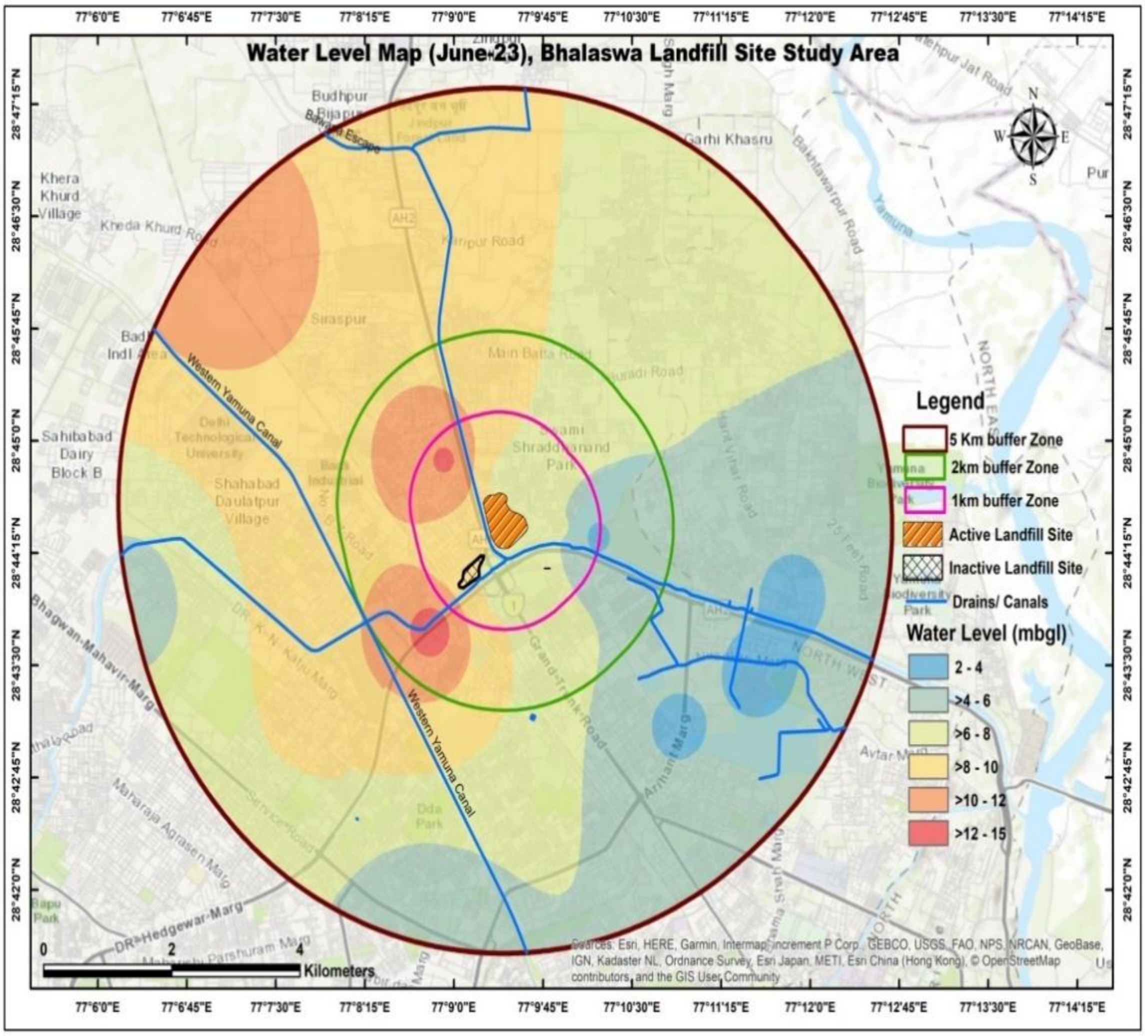


Figure 21: Depth to water level map, June 2023

2.12 Depth to water level during Post-monsoon (November, 2023)

The Depth to water level recorded in the study area during November, 2023 ranges from 2.86 to 14.90 meters below ground level (mbgl). Ground water level data of a total of 18 monitoring wells have been analyzed. It is observed that 28% wells have shown water level less than 5 mbgl and 50% wells had water level in the range of 5 to 10 mbgl. 22% wells have shown water level more than 10 mbgl ***Fig.22.***

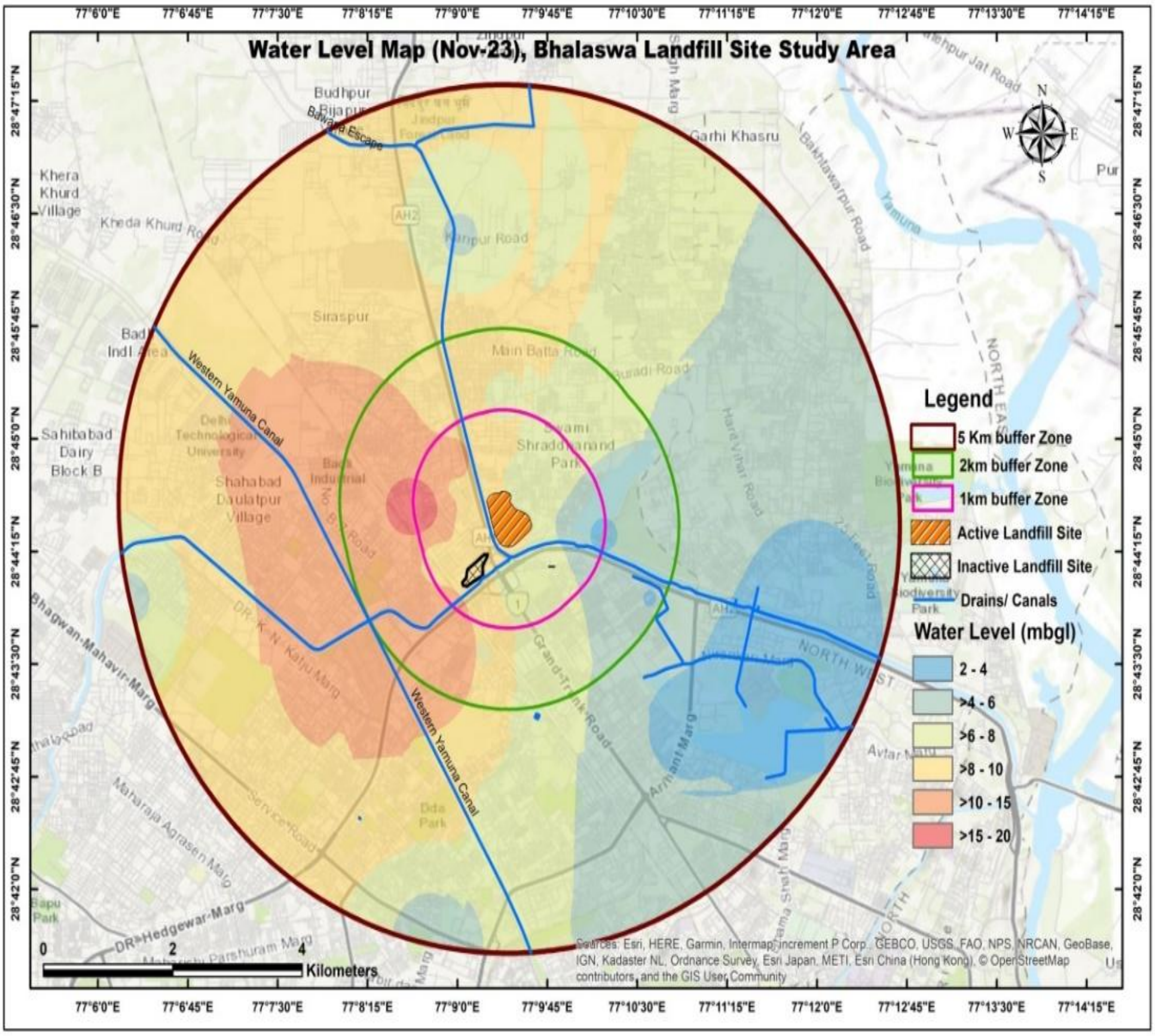


Figure 22: Depth to water level map, November 2023

2.13 Seasonal water level fluctuation (June, 2023-Nov, 2023)

The fluctuation of water levels between Pre-monsoon (June, 2023) and Post Monsoon (November, 2023) shows 0.02 to 2.02 m fall in 30% of the wells. Most parts of the study area have registered rise in water levels, which varies from 0.2 to 0.77 m ***Fig.23.***

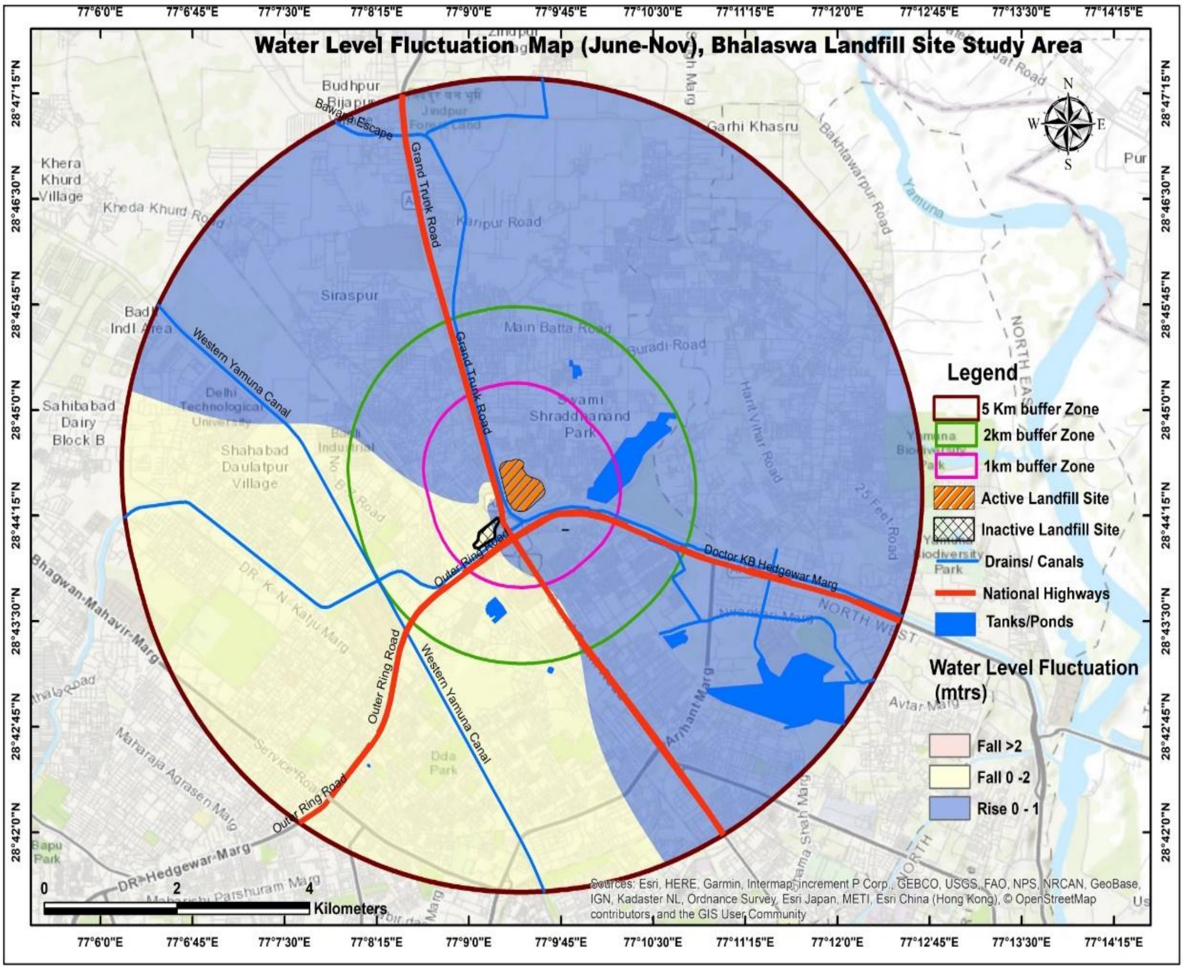


Figure 23: Water level fluctuation map, June-Nov, 2023

2.14 Long Term Water Level Fluctuation

Long term pre-monsoon data of two piezometers is available. The Haiderpur Piezometer ***Fig.24*** which is present about 3 Km from Landfill site is showing declining trend with 0.27 m/annum and the Bhalaswa Lake Piezometer ***Fig.25*** which is about 500 mt from landfill site is showing raising trend of 0.053 m/annum. Based on some existing piezometers within the study area, few hydrographs are given below.

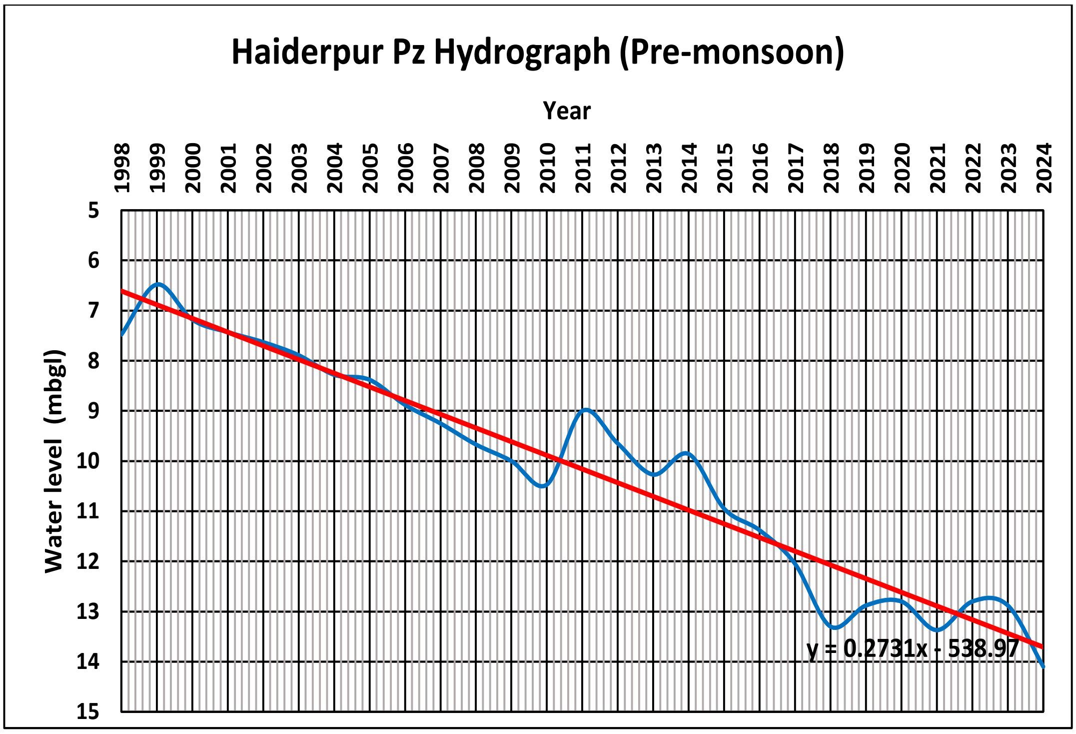


Figure 24: Hydrograph of Haiderpur Pz

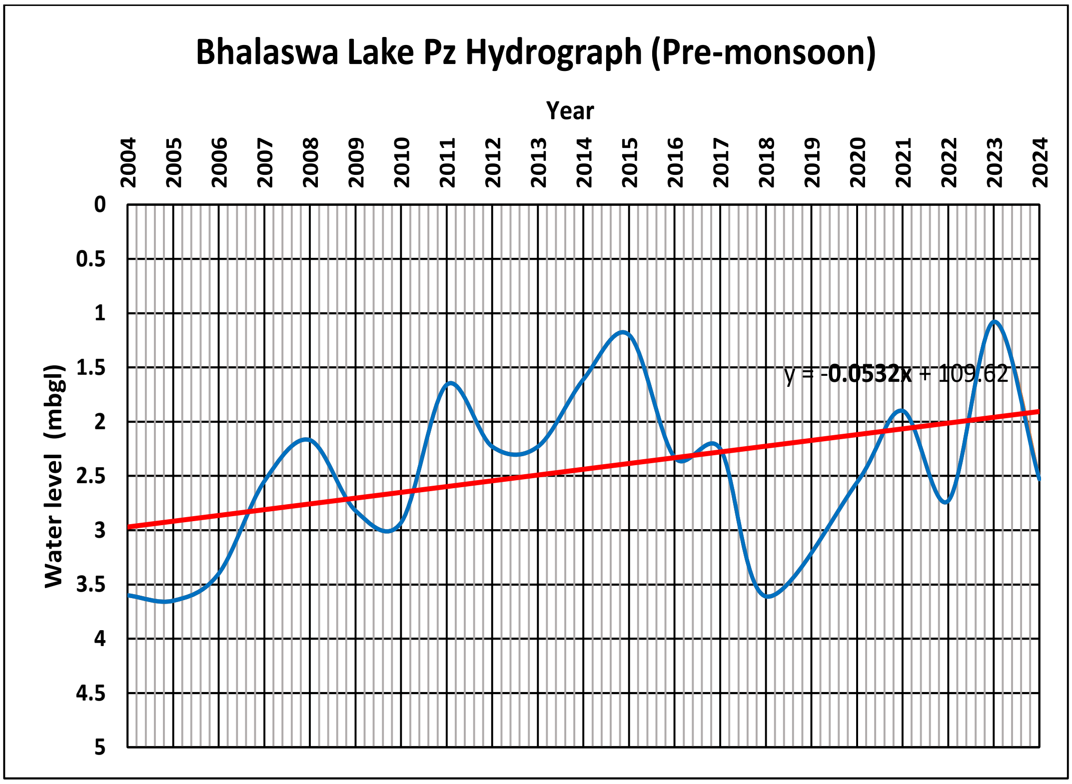


Figure 25: Hydrograph of Bhalaswa Lake Pz

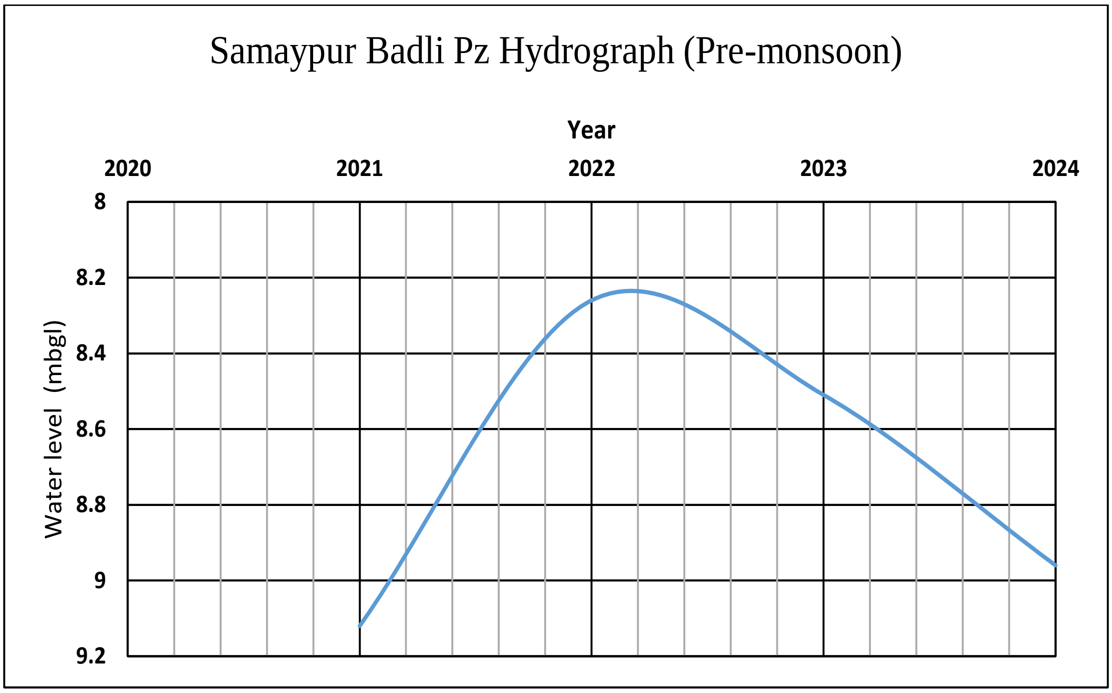


Figure 26: Hydrograph of Samaypur Badli Pz

2.15 Ground water flow

Water table contour map of June, 2023and November, 2023 is presented in ***Fig. 27 & Fig.28.*** The perusal of the map shows that the water table elevation follows the topography of the area and overall ground water flow direction is towards Yamuna River. Internal ground water flow direction is different. In the western part of the study area flow direction is towards a trough north of landfill area (JJ Cluster Toilets, Opp. Vashudev Transport) and in southern part the ground water flow direction is towards north i.e., from Sandesh Vihar area to Haiderpur area. Bhalaswa Lake acting as divider regarding ground water flow. Minor variations in flow pattern is observed during pre & post monsoon seasons.

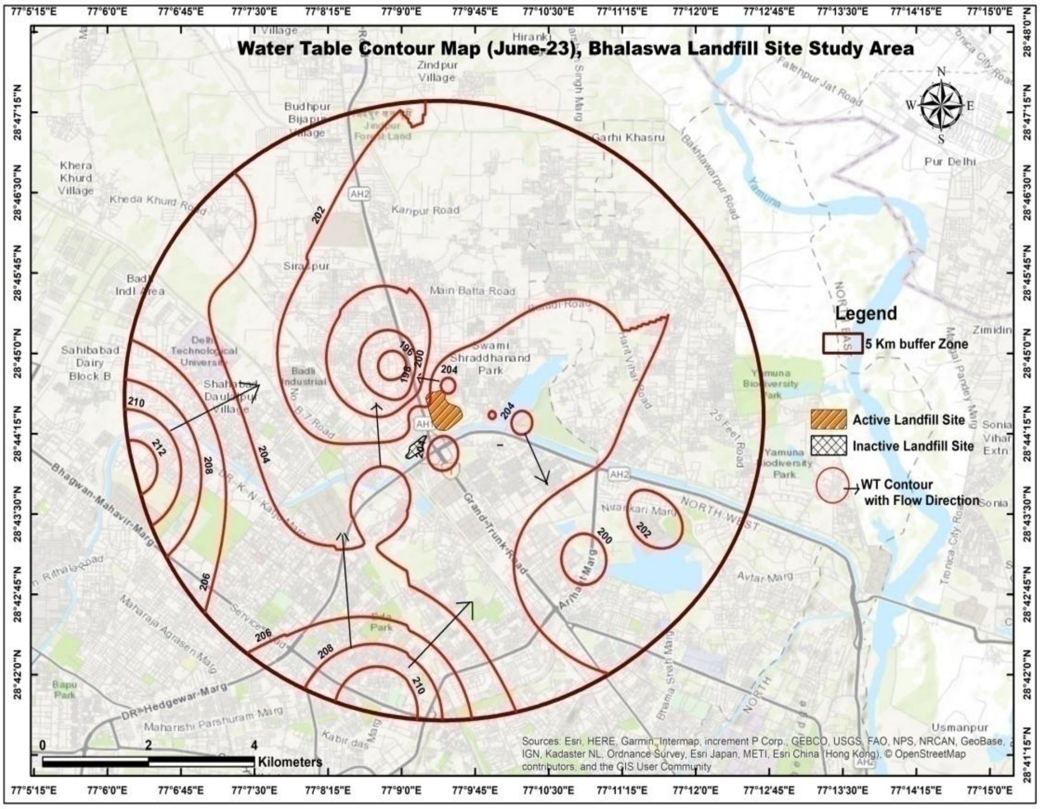


Figure 27: Water table fluctuation map, June-2023

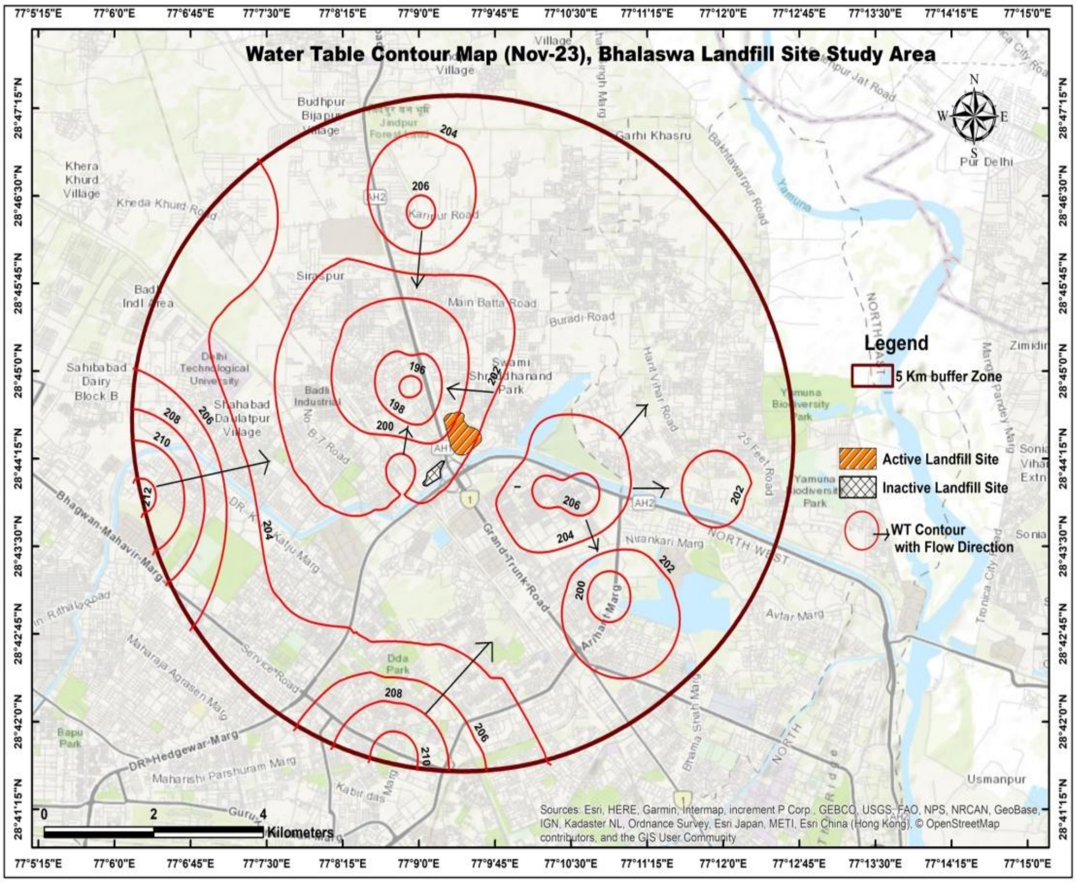


Figure 28: Water table fluctuation map, November-2023

2.16 Aquifer Parameters and Yield Characteristics

Detailed hydrogeological survey of the area has revealed that most of the tube wells present within the vicinity of SLF are tapping the aquifer in the depth range of 12 to 20 m except few tube wells, which are of 30 m depth tapping 20 to 30 m depth aquifer system. Thus both the shallow hand pumps and tube wells are tapping the same aquifer system. As per the exploratory drilling, the marginal water and saline water interface is about 40 m in Bhalaswa landfill area. The ground water in Bhalaswa and surrounding areas is brackish from the surface itself. This is mainly due to a discharge area where ground water stagnation is being taking place and no flushing is happening, to make the ground water fresh through recharge of fresh rain water. Long duration pumping test was conducted in this exploratory tube well (Singhu Village, near Bhalaswa) for calculation of aquifer parameters. It is calculated from the pumping test data, the transmissivity is 176 m^2/day and hydraulic conductivity is 9 m/day.

2.17 Leachate Generation from Bhalaswa Landfill

Leachate is highly polluted and complex wastewater containing high amounts of dissolved and suspended matter generated from percolated water through the waste in landfills. In Bhalaswa landfill site there is no leachate treatment plant.. Leachate treatment is very important as it could threaten the surrounding ecosystem when discharged and mixed with groundwater. The leachate generation mainly depends on the precipitation and the moisture contained by the waste. Various methods are implemented for quantifying the amount of leachate generated by a landfill such as the standard method, rational method, and many other conventional methods.

Here standard method has been used for calculation of leachate. A standard method is a simple mathematical model to estimate the amount of leachate generated from municipal solid waste (MSW). It is one of the most used methods or models to estimate the leachate generated in municipal landfills even these days. Many countries in the world adopted this method as it is simple and also has been used for a long time. The equation of standard method is given below

$$V = 0.15 \times R \times A$$

Where;

V is the volume of leachate discharge in a year (m3/year).

R is annual rainfall (m).

A is the surface area of the landfill (m2).

0.15 is the coefficient

The leachate generated in the Bhalaswa landfill site using standard methodis 31356.36 m3/Year from the dumped waste area of 280000 m^2 with rainfall of 746.58 mm in the year 2023. Month wise Leachate generation was calculated using rainfall data for the year 2023.

The following are the main source for the production of leachate generation:

- Higher precipitation leads to higher leachate generation as we can see in ***Fig.29***

- When the moisture content of the waste is high it causes higher leachate production.
- Larger the landfill area higher the leachate generation.
- Directly proportional to waste generation and type of waste.
- The field capacity of the waste.
- Leachate generation over time increases as the waste generation increases.

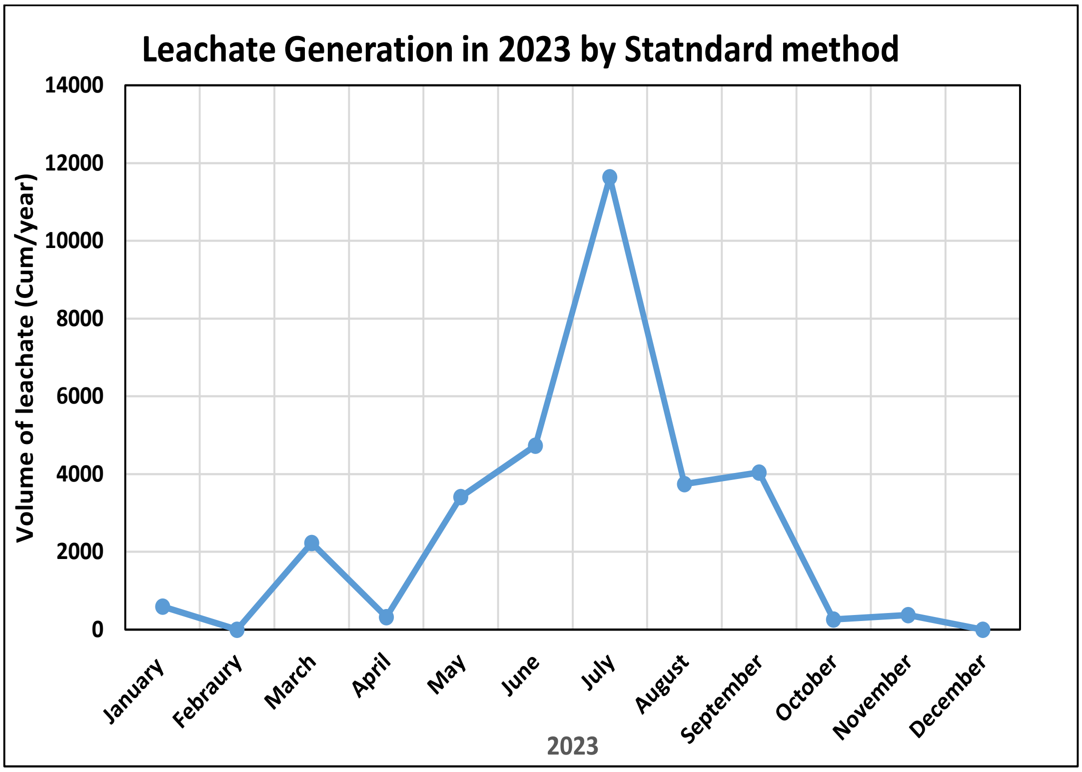


Figure 29: Leachate generation in 2023 by standard method

3 Ground Water Quality

The ground water quality samples were collected under NAQUIM 2.0 Programme from shallow depth tubewells, handpumps and leachate from landfill site. In the pre-monsoon, a total 16 ground water samples and 2 leachate samples were collected and in the post monsoon 38 ground water samples and 3 leachate samples were collected. Summarized data of basic parameters is furnished in ***Table 12***

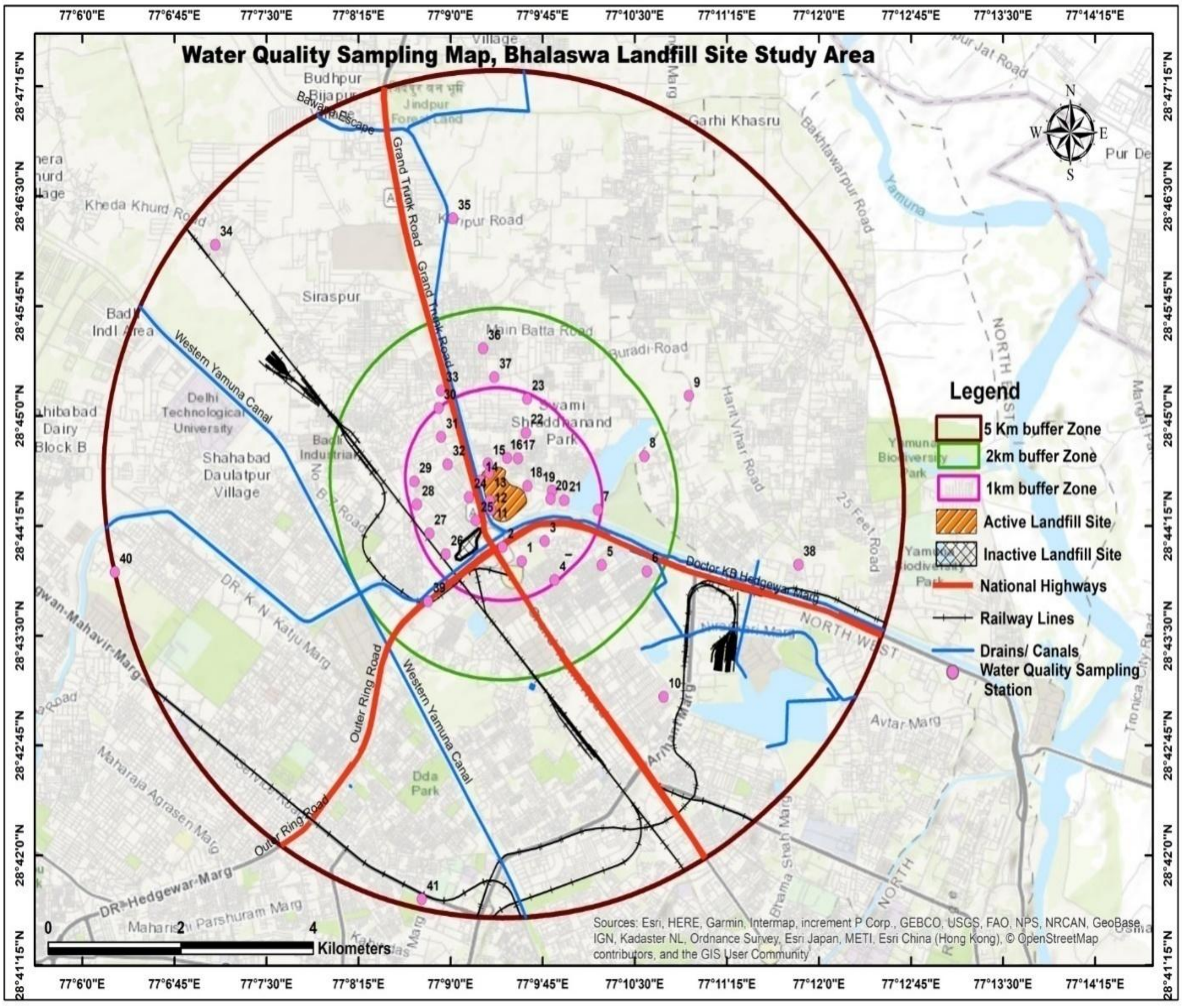


Figure 30: Ground water sample location map

3.1 Basic Parameters

Table 12: Summarized data of basic parameters

S. No	Parameters		Range	Pre-Monsoon samples			Post-Monsoon Samples		
				No.	%	leachate	No.	%	Leachate
1	Electrical Conductivity µs/cm at 25ºC	Fresh	< 750	2	12.5		1	2.64	
		Moderate	750- 2250	1	6.5		8	21.05	
		Slightly mineralized	2251- 3000	5	31.25		8	21.05	
		Highly mineralized	> 3000	8	50	2	21	55.27	3
2	Chloride mg/L	Desirable limit	< 250	3	18.75		6	15.79	
		Permissible limit	251-1000	7	43.75		25	65.79	
		Beyond permissible limit	> 1000	6	37.5	2	7	18.42	NA
3	Fluoride mg/L	Desirable limit	< 1.0	9	56.25		29	76.31	1
		Permissible limit	1.0 - 1.5	6	37.5		4	10.53	2
		Beyond permissible limit	>1.5	1	6.25	2	5	13.15	
4	Nitrate mg/L	Permissible limit	< 45	16	100		28	73.69	3
		Beyond permissible limit	> 45			2	10	26.31	

3.1.1 pH

The pH of the analyzed samples varies from 7.19-8.95 in pre monsoon & 6.85 – 8.20 in post monsoon indicating mildly acidic to alkaline nature of the ground water. Only one ground water sample in the pre-monsoon has shown pH more than 8.5 (Khera Kalan). Leachate samples in pre-monsoon have shown pH values 8.11 & 8.53 and in the post-monsoon varies from 7.68-8.06. The pH values are of remaining wells within the safe limit of 6.5 - 8.5, prescribed by BIS for drinking water (IS 10500:2012).

3.1.2 Electrical Conductivity (EC)

Electrical conductivity is a measure of total mineral contents of dissolved solids in water. It depends upon the ionic strength of the solution. An increase in dissolved solids causes a proportional increase in electrical conductivity. The electrical conductivity value of ground water in study area in pre-monsoon has been found to vary from 330-8755 µS/cm at 25ºC and in the post monsoon vary from 680 -10890 µS/cm at 25ºC. In Pre-monsoon maximum concentration of 8755 µS/ cm has been reported from Mahashiv Car Washing Centre & in post-monsoon maximum concentration of 10890 µS/ cm has been reported from MCD School, Jahangirpur. Leachate samples in pre-monsoon have shown 38845 & 39000µS/cm at 25ºC and in post-monsoon EC varies from 28170-31400 µS/cm at 25ºC. The spatial variation of EC shows relatively higher value at some sites. EC in excess of 3000 µS/cm value has been observed in 50% of the study area ***Fig.31.*** Because of finer sediments in the aquifer, flushing of ground water is not proper and longer residence time of water in the aquifer results in dissolution of salts from the aquifer material, which leads to higher TDS content and in turn higher EC.

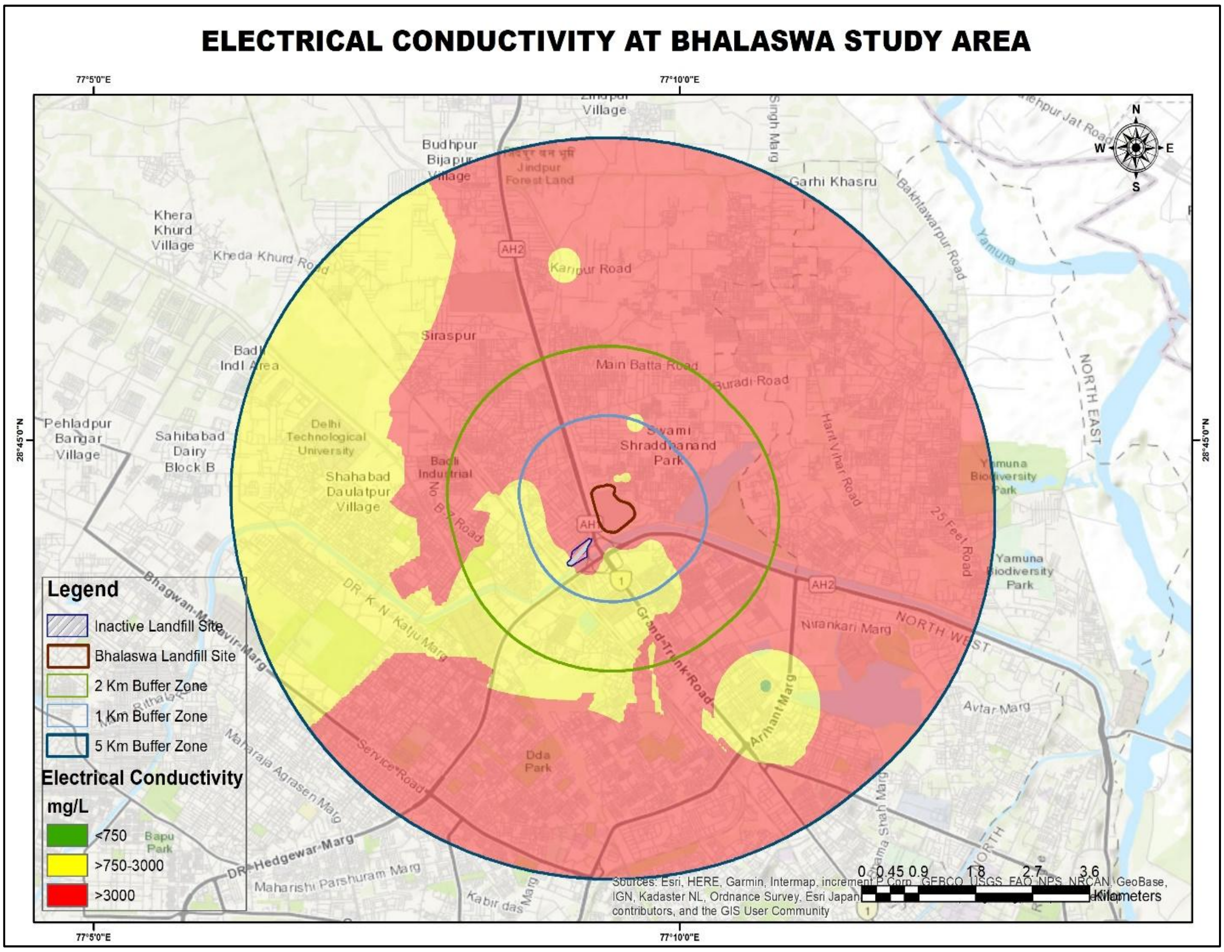


Figure 31: Electrical conductivity at Bhalaswa Study area for post-monsoon

3.1.3 Total Hardness (TH)

Classification of ground water samples based on Total Hardness is given in ***Table 13***. In pre-monsoon, TH has been found to vary from 130 mg/l (Khera Kalan) to 1790 mg/l (Mahashiv Car Washing Centre) and in post monsoon vary from 90 mg/l (Rohini Sec-11) to 1980 mg/l (MCD School, Jahangirpur), indicating hard to very hard types of ground water. High hardness may cause precipitation of calcium carbonate and encrustation on water supply distribution systems. Long term consumption of extremely hard water might lead to an increased incidence of urolithiasis, anencephaly, parental mortality and cardio-vascular disorders. In Study area, Total Hardness exceeds the recommended maximum permissible limit of 600 mg/l (IS-10500: 2012) in 50% of total analyzed ground water samples both in pre & post monsoon. Leachate samples have shown TH in pre-monsoon is 4500 mg/l & 5000 mg/l and in the post monsoon samples cannot be analyzed due to instrumental limitations.

Table 13: Hardness Classification of water

Hardness (mg/l)	Water Class	Pre-monsoon Sample (%)	Post-monsoon Sample (%)
0-75	Soft	0	0
75-150	Moderately Hard	6..25	5.27
150-300	Hard	12.5	2.63
>300	Very Hard	81.25	92.10

3.1.4 Major Anions (F^-, Cl^-, HCO_3^-, SO_4^{2-} and NO_3^-)

The anion chemistry of the analyzed samples shows that HCO_3^- and Cl^- are the dominant anions in shallow aquifer and follow the abundance order of $Cl^- > HCO_3^- > SO_4^{2-} > NO_3^- > F^-$ in majority of the groundwater samples.

In pre-monsoon, Chloride (Cl^-) concentration varies from 28 mg/l (Haiderpur) to 2840 mg/l (Mahashiv Car Washing Centre) and in post-monsoon varies from 21 mg/l (Khera Kalan) to 2623 mg/l (Sandesh Vihar). The large lateral variation in the chloride concentration and observed high concentration in some samples indicate local recharge and may be attributed to contamination by landfill site. Higher concentration of Cl^- in drinking water gives a salty taste and has a laxative effect in people not accustomed to it. In Pre-monsoon, concentration of Cl^- exceeds the desirable limit of 250 mg/l (IS-10500: 2012) in 43.8% of analysed samples and maximum permissible limit of 1000 mg/l in 37.5% of analysed samples. In Post-monsoon, concentration of Cl^- exceeds the desirable limit of 250 mg/l (IS-10500: 2012) in 65.8%of analysed samples and maximum permissible limit of 1000 mg/l in 18.4% of analysed samples ***Fig.32.*** Both the leachate samples have shown 5680 mg/l and 7810 mg/l in pre-monsoon. Leachate samples could not be monitored due to the limitations of instrument in post-monsoon.

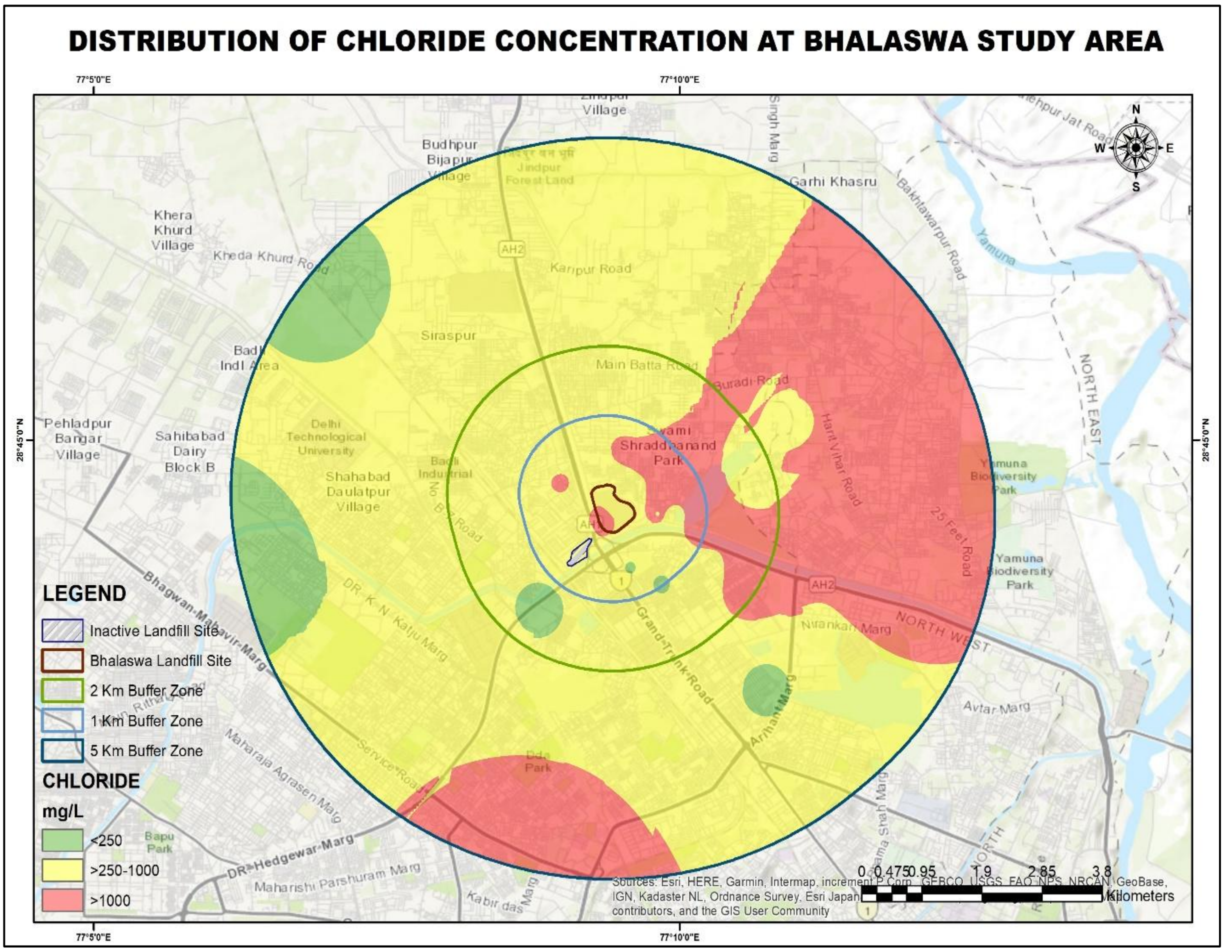


Figure 32: Distribution of Chloride concentration at Bhalaswa study area for post-monsoon

Bicarbonate (HCO_3^-) is the most dominant anion. In pre-monsoon, Concentration of bicarbonate varies from 73 mg/l (Haiderpur) to 1318 mg/l (TW LFS Entry gate)) and in post-monsoon 85 mg/l (Cremation Ground) to 1013 mg/l (Field HP, Mukundpur Road). Bicarbonate concentrations of leachate samples are 7320 mg/l and 8845 mg/l in pre-monsoon. Bicarbonates are derived mainly from the soil zone CO_2 and at the time of weathering of parent minerals or from dissolution of carbonates and/or silicate minerals by the carbonic acid. Concentration of sulphate varies from 24 mg/l to 432 mg/l in pre-monsoon and 13 mg/l to 3118 mg/l in post-monsoon. Sulphate concentration exceeded the desirable and maximum permissible drinking water limits of 200 mg/l and 400 mg/l values respectively (per IS-10500:2012) in 37.5% and 6.25% (pre-monsoon), in 31.6% and 52.6% (post-monsoon) of total analyzed samples. Both the leachate samples have shown Sulphate concentration are within the desirable limit. The observed high concentration in some samples may be the effect of landfill site. High sulphate concentration may have a laxative effect with excess of Mg in water. Waters with 200 - 400 mg/l of sulphate have bitter taste and those with 1000 mg/lor more of sulphate may cause intestinal disorder and respiratory problems. Sulphate may also cause corrosion of metals in the distribution system, particularly in water having low alkalinity.

Concentration of nitrate has been found to vary from 2 mg/l to 28 mg/l (pre-monsoon) and 1 to 260 mg/l (post-monsoon). Nitrate concentration exceeds the maximum permissible limit of 45 mg/l in drinking water prescribed by BIS (IS-10500:2012) in around 24% (post-monsoon) of the total ground water samples. Nitrate concentration is within permissible limit in pre-monsoon water samples. Leachate samples have shown 156 mg/l & 204 mg/l in pre-monsoon. Nitrate in excess of maximum permissible limit has been reported from western side of the landfill site ***Fig.33.***Higher nitrate concentration in ground water may be contamination from landfill site. Excess nitrate in drinking water can cause methaemoglobinaemia in infants, gastric cancer, goiter, birth malformations and hypertensions.

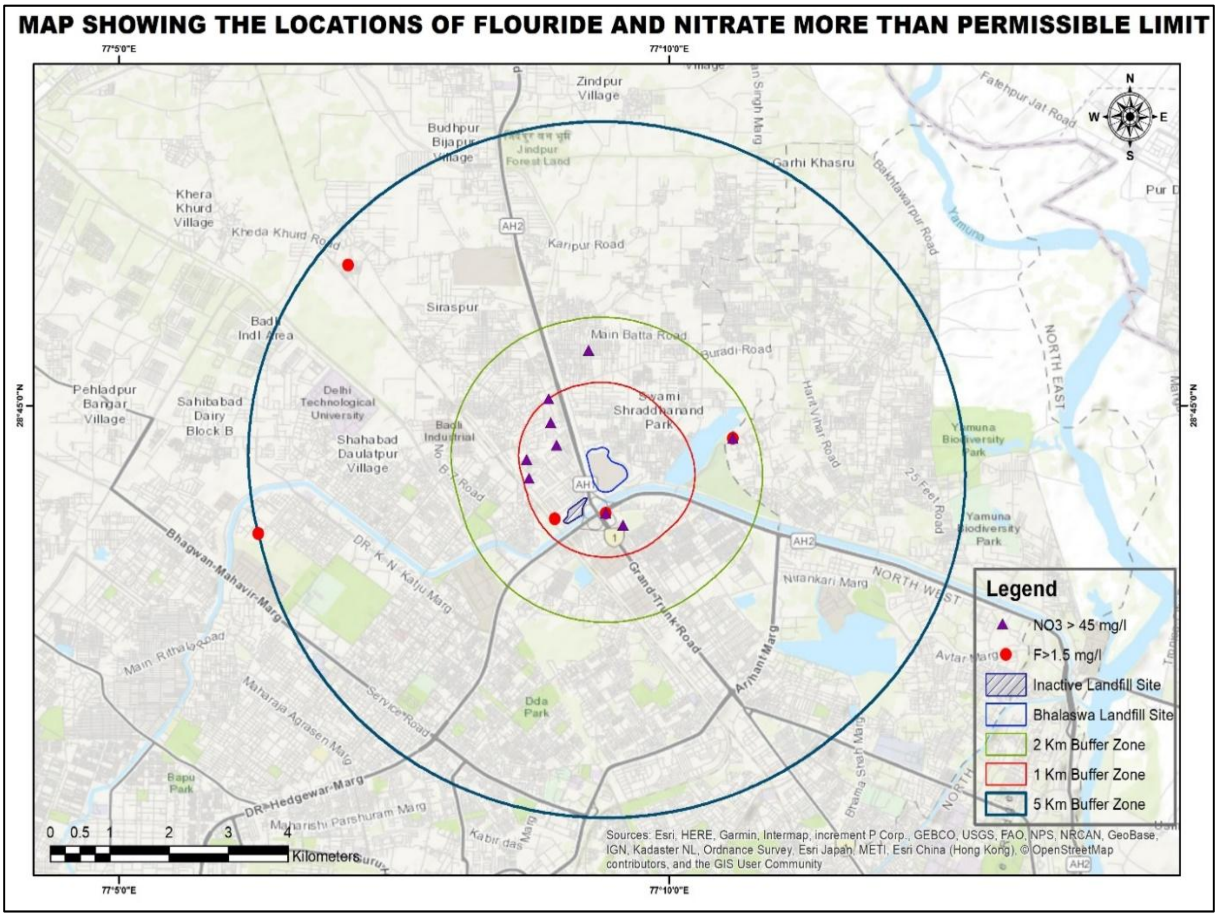


Figure 33: Fluoride and Nitrate map

Fluoride is an essential element for maintaining normal development of healthy teeth and bones. However, higher F^- concentration causes dental and skeletal fluorosis such as mottling of teeth, deformation of ligaments and bending of spinal cord. Concentration of fluoride in ground water samples has been found to vary from 0.32to2.5 mg/l (pre-monsoon) and 0.05 to 5.2 mg/l (post-monsoon). Concentration of F^- exceeds the maximum permissible limit of 1.5 mg/l (IS-10500: 2012) in 6.25% (pre-monsoon) and in 13.2% (post-monsoon) of the total analyzed samples. Excess Fluoride has been reported from isolated pockets of study area, those are Rohini Sec-11, PWD Electrical office, Khera Kalan, Field HP & Sulabh Comp Opp. Sewage Pump Stn). The fluoride contamination in ground water may be either due to landfill or due to excessive use of phosphatic fertilizers and fluoride containing insecticides and herbicides in agricultural fields.

3.1.5 Major Cations (Ca, Mg, Na, K)

The major cations include Ca, Mg, Na and K. The water chemistry of the study area is marginally dominated by alkali (Na + K) metals over the alkaline earths (Ca +Mg). The cation chemistry indicates that in general ground water belongs to Na>Ca>Mg>K water type. The weathering and cation exchange processes normally control the levels of these cations in the ground water.

Sodium (Na^+) is the most dominant cation in ground water in study area. Concentration of sodium has been found to vary from 5 to 1297 mg/l (pre-monsoon) and 42 to 1760 mg/l (post-monsoon). Leachate samples have shown 4200mg/l and 4670 mg/l in pre-monsoon. Sodium is the most important ion for human health. A higher sodium intake may cause hypertension, congenial heart diseases, and nervous disorder and kidney problems. Contamination of ground water by Na and Cl is common in growing urban areas. Sources of these ions are related to mainly leachate from Bhalaswa landfill.

Concentration of potassium ranges from 2.1 mg/l to 196 mg/l (pre-monsoon) and 3.6 mg/l to 270 mg/l (post-monsoon). Leachate samples have shown potassium concentration is 3250 mg/l and 3872 mg/l in pre-monsoon. Potassium is accounting for very less percentage of the total cationic mass balance.

Calcium (Ca) is an essential element for bone, nervous system and cell development. Ca^{2+} and Mg^{2+} are the main contributors towards hardness. Possible adverse effect from ingesting high concentration of Ca for long periods may be an increased risk of kidney stones. Concentrations of Ca^{2+} and Mg^{2+} are exceeding the drinking water desirable levels (IS-10500:2012) of 75 mg/l and 30 mg/l respectively in about 37.5 % and 18.8% of the analyzed pre-monsoon samples and for post-monsoon samples in about 58% and 55%. However, concentrations of both these ions are exceeding the maximum permissible levels of 200 and 100 mg/l respectively in 12.5% and 50% of the pre-monsoon samples and for post-monsoon 13.2% & 31.6%. Concentration of Ca in ground water varied from 20 mg/l to 352 mg/l in pre-monsoon and in post-monsoon it varies from 16 mg/l to 392 mg/l. Leachate samples have shown 800 mg/l. Concentration of Mg varies from 19 mg/l to 270 mg/l in pre-monsoon and in post-monsoon varies from 7 mg/l to 258 mg/l. Leachate samples of Mg is 730mg/l and 608 mg/l.

3.2 Water Type and Hydrochemical Facies

The Hill and Piper plot is very useful in determining relationships of different dissolved constituents and classification of water on the basis of its chemical characters. The triangular cationic field of Piper diagram reveals that the groundwater samples fall into no dominant and Na + K class, whereas in anionic triangle majority of the samples fall into bicarbonate, chloride and no dominant fields ***Fig. 34.*** The plot of chemical data on diamond shaped central field, which relates the cation and anion triangles revealed that the major water types in Bhalaswa study area were Na-K-Cl, Ca-Mg-HCO_3, and of mixed chemical character i.e. Ca-Mg-Cl-SO_4, Na-K-HCO_3-

Cl. In majority of the ground water samples, alkali metal cations (Na^{+}+K^{+}) are slightly exceeding the alkaline earth metals (Ca^{2+}+Mg^{2+}). In general, the groundwater exhibits the dominance of SO_4^{2-} +Cl^{-} (strong acid) over weak (HCO_3^{-}) acid. The facies mapping approach applied to the present study shows that Ca-Mg-HCO_3, Na-K-Cl, Ca-Mg-Cl-SO_4 and Na-K-HCO_3-Cl are the dominant hydrogeochemical facies in the groundwater.

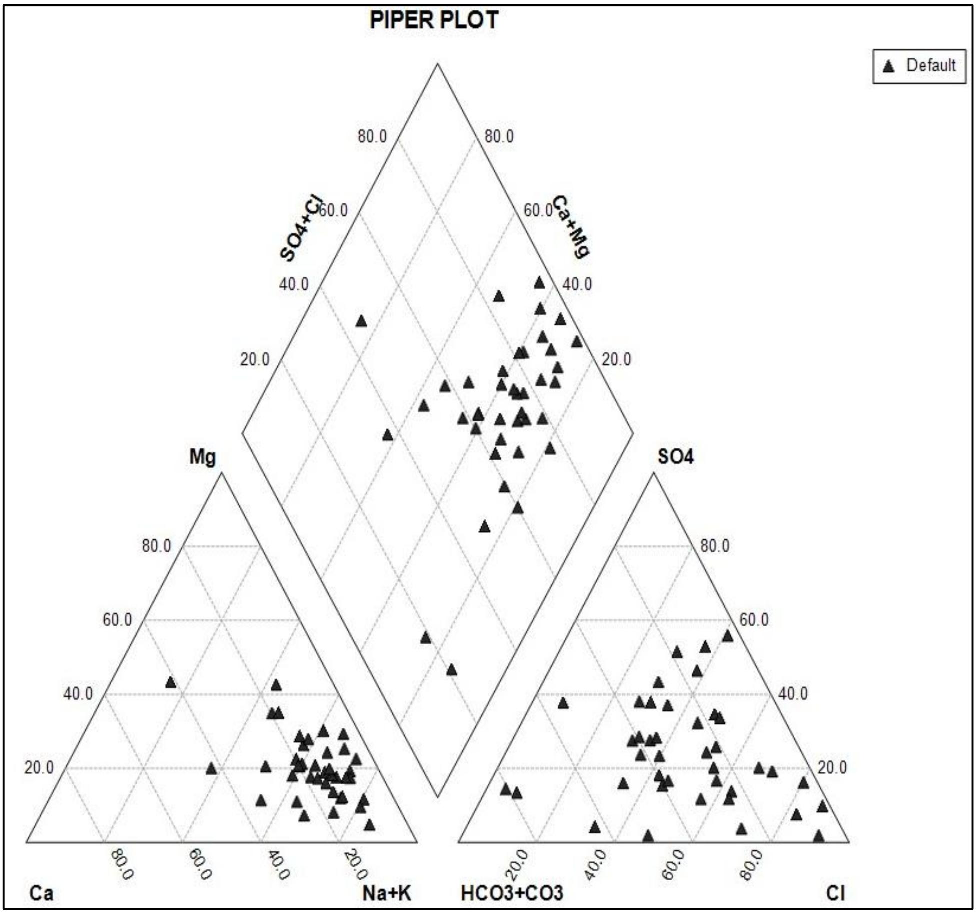


Figure 34: Hill and Piper plot showing water type and hydro chemical facies

3.3 Heavy/Trace Metal Distribution

Summarized data of chemical analysis results in respect of heavy metals is furnished in ***Table 14.***

Table 14: Summary of Heavy Metal analysis data

(Units in mg/l)	Range		Maximum Permissible Limit as prescribed by BIS (IS-10500:2012)	Samples having heavy metals in excess of Maximum Permissible Limit (%)	
	Pre-monsoon	**Post-monsoon**	**(Mg/l)**	**Pre-monsoon**	**Post-monsoon**
Fe	*BDL-6.714	0.075-9.753	1.0	12.5	21
Mn	BDL-0.904	BDL-2.324	0.3	31	45
Zn	BDL-2.835	0.054-2.74	15	Nil	Nil
Cu	BDL-0.008	BDL	1.5	Nil	Nil
Cr	BDL-0.003	0.001-0.005	0.05	Nil	Nil
Ni	0.000-0.012	--	0.02	Nil	--
Cd	0.000073-0.0006	---	0.003	Nil	---
As	BDL-0.055	BDL-0.129	0.01	6.2	13
Se	0.0000028-0.000063	---	0.01	Nil	---
Pb	BDL-0.0016	0.001-0.011	0.01	Nil	2.6
U	BDL-0.03	0.003-0.035	0.03	Nil	2.6
Two leachate samples have shown more than permissible limit for Fe, Cr, As and Ni. Only one leachate sample has shown more than permissible limit for U, Mn, Pb and Cd. Leachate samples analyzed only in pre-monsoon. *BDL=Below Detective Level					

Concentration of Iron (Fe) has been found to range from BDL to 6.7mg/land exceeded the maximum permissible limit of 1 mg/l in 12.5% of the total analysed pre-monsoon groundwater samples. For post-monsoon, concentration of Iron (Fe) has been found to range from 0.075mg/l to 9.75mg/l and exceeded the maximum permissible limit of 1 mg/l in 21%. The concentration of iron in natural water is controlled by both physico chemical and microbiological factors.

For pre-monsoon, Manganese (Mn) concentration in groundwater was found to vary from BDL to 0.904 mg/l and concentration of Mn exceeds the prescribed maximum permissible limit of 0.3 mg/l(IS-10500:2012) in 31% groundwater samples. For post-monsoon, Manganese (Mn) concentration in groundwater was found to vary from BDL to 2.324 mg/l and cconcentration of Mn exceeds the prescribed maximum permissible limit of 0.3 mg/l (IS-10500:2012) in 45% groundwater samples. Most common sources of iron and manganese in groundwater are naturally occurring, for example from weathering of iron and manganese bearing minerals and rocks. Industrial effluent, sewage and landfill leachate may also contribute iron and manganese to local groundwater.

Zinc (Zn) concentration in ground water varies from BDL to 2.835 mg/l in pre-monsoon and in post monsoon it varies from 0.054 mg/l to 2.74mg/l, which is well within the maximum permissible limit of 15 mg/l as prescribed by BIS Drinking Water Standards (IS-10500:2012).

In pre-monsoon, concentrations of Copper (Cu) and Chromium (Cr) varied from BDL to 0.008 mg/land BDL to 0.003 mg/l respectively in the analyzed groundwater samples. In post-monsoon, concentrations of Copper (Cu) is below detectable limit and concentration of Chromium (Cr) varied from BDL to 0.005mg/l in the analyzed groundwater samples. Concentration of both Cu and Cr have been found to be well within the maximum permissible limit of 1.5 mg/l and 0.05 mg/l (IS-10500:2012) respectively.

In Pre-monsoon, concentrations of Nickel (Ni) varied from 0.000 mg/l to 0.012 mg/l in the analyzed groundwater samples. Concentration of Ni has been found to be well within the maximum permissible limit 0.02 mg/l (IS-10500:2012). In post-monsoon samples could not be analysed for this element.

Concentration of Cadmium (Cd) in the analysed samples in pre-monsoon has been found to vary from 0.000073 to 0.0006 mg/l. Cd concentration has been found to be well within the maximum permissible limit of 0.003 mg/l. In post-monsoon samples could not be analysed for this element.

In pre-monsoon, concentration of Arsenic (As) in ground water has been found to vary from BDL to 0.038 mg/l. In post-monsoon, concentration of As varies from Below Detection Limit to 0.129mg/l. 6.2% of pre-monsoon samples and 13% of post-monsoon samples exceeds the maximum permissible limit of 0.01 mg/l prescribed by BIS in drinking water (IS-10500:2012).

Concentration of Selenium (Se) has been found to range between 0.0000028 to 0.000063 mg/l in pre-monsoon ground water samples. Se concentration has been found to be well within maximum permissible limit of 0.01 mg/l (IS-10500:2012).

Lead (Pb) concentration has been reported to vary from BDL to 0.0016 mg/l in pre-monsoon and it varies from 0.001-0.011 mg/l in post-monsoon. Sporadic occurrence of Pb in excess of the maximum permissible limit of 0.01 mg/l (IS-10500:2012) has been reported in 2.6% of post-monsoon samples. Excess Lead in ground water may be due pollution from industries and landfill sites.

Concentration of Uranium (U) has been found to varies from BDL to 0.01769 mg/l in pre-monsoon and it varies from 0.003 to 0.035 mg/l in post-monsoon. Concentration of Uranium 2.6% of post-monsoon samples exceeds the maximum permissible limit of 0.03 mg/l prescribed by BIS in drinking water (IS-10500:2012).

3.4 Bacteriological Contamination

The bacteriological test carried out in eight groundwater samples and 2 leachate samples of Bhalaswa study area- shows presence of total coliform and fecal coliform in all eight ground water samples and 2 leachate samples ***Table 15.*** As per BIS (IS-10500:2012), coliforms should not be detectable in any 100 ml sample. Groundwater contamination from fecal-coliform bacteria is generally caused by water percolation into the aquifer from a contamination source like domestic sewage, drains, waste from Dairy farms and septic tanks. The poor sanitation around the source water also causes bacteriological contamination. Shallow wells are particularly susceptible to such contamination. In Bhalaswa landfill site, the bacteriological contamination is due to leakage of leachate into groundwater and contamination due to Bhalaswa Dairy which is present adjacent to SLF site.

Table 15: Bacteriological Test in groundwater samples of NCT- Delhi

S. No.	Site Name	Latitude	Longitude	Source (TW/DW)	1st time sampling		Repeated sampling	
					Total Coliform Bacteria MPN/ 100ml	Fecal Coliform Bacteria MPN/100 ml	Total Coliform Bacteria MPN/100 ml	Fecal Coliform Bacteria MPN/100 ml
1	LFS Entry Gate	28.73931	77.155504	TW	36	18	40	20
2	Leachate 01 (Khata)	28.74034	77.155314		330000	130000	1700000	1300000
3	Leachate 02	28.74349	77.155231		16000000	390000	2300000	1300000
4	R.S.Poultries	28.74456	77.15506	TW	200000	78000	11000	4500
5	Ambuja Cement	28.74158	77.15768	TW	3500000	390000	2200000	170000
6	Bhagat Properties	28.74516	77.15915	HP	2800000	170000	1100000	780000
7	NBM Toilets	28.742	77.16042	TW	460000	170000	40000	20000
8	Balaji Coaching Centre	28.74147	77.16379	HP	94000	200000	220000	110000
9	Prachin Shiv Mandir	28.74054	77.163569	HP	68000	4000	49000	22000
10	Cremation Ground	28.73929	77.17	HP	45000	20000	17000	6800

TW=Tubewell, HP=Handpump

3.5 Suitability of Groundwater for Irrigation Purpose

The chemical quality of water is an important factor to be considered in evaluating its usefulness for irrigation purposes. Plants grown by irrigation absorb and transpire water but leave nearly all the salts behind in the soil, where they accumulate and eventually prevent plant growth. Excessive concentrations of solute interfere with the osmotic process by which plant root membranes are able to assimilate water and nutrients. In areas where natural drainage is inadequate, the irrigation water infiltrating the root zone will cause water table to rise excessively. In addition to problems caused by excessive concentration of dissolved solids, certain constituents in irrigation water are especially undesirable and some may be damaging even when present in small concentrations. Irrigation indices viz. Sodium Adsorption Ratio (SAR) and Residual Sodium Carbonate (RSC) have been evaluated to assess the suitability of ground water for irrigation purposes.

3.5.1 Alkali Hazard

In the irrigation water, it is characterized by absolute and relative concentrations of cations. If the sodium concentrations are high, the alkali hazard is high and if the calcium & magnesium levels are high, this hazard is low. The alkali soils are formed by the accumulation of exchangeable sodium and are characterized by poor tilt and low permeability. The U.S. Salinity laboratory has recommended the use of sodium adsorption ratio (SAR) as it is closely related to adsorption of sodium by the soil.

SAR is derived by the following equation:

$$\boldsymbol{SAR} = \frac{\boldsymbol{Na^+}}{\sqrt{\frac{\boldsymbol{Ca^{2+}Mg^{2+}}}{\boldsymbol{2}}}}$$

The water with regard to SAR is classified into four categories

- **S_1 – Low Sodium Water** (SAR <10)

Such waters can be used on practically all kinds of soils without any risk or increase in exchangeable sodium.

- **S_2 – Medium Sodium Water** (SAR 10-18)

Such waters may produce an appreciable sodium hazard in fine textured soil having high cation exchange capacity under low leaching.

- **S_3 – High Sodium Water** (SAR >18-26)

Such waters indicate harmful concentrations of exchangeable sodium in most of the soil and would require special management, good drainage, high leaching and addition of organic matter to the soil. If such waters are used on gypsiferrous soils the exchangeable sodium could not produce harmful effects.

- **S_4 – Very High Sodium Waters** (SAR >26)

Generally, such waters are unsatisfactory for irrigation purposes except at low or perhaps at medium salinity where the solution of calcium from the soil or addition of gypsum or other amendments makes the use of such waters feasible.

The computed SAR values range from 0.17 to 17.12 in pre-monsoon and 0.79 to 19.85 in post-monsoon. The maximum SAR value has been found at HP Balaji Coaching Centre in pre-monsoon and Toilets, CTCNo.154, S.G.T.N. 68.8% samples in pre-monsoon and 57.9% in post-monsoon belong to excellent category (S_1) and none of the water samples are associated with very high sodium category (S_4). Leachate samples have shown SAR >25.

It was found that total 31.25% (pre-monsoon) & 39.5% (post-monsoon) sample fall in S2 category, while 2.6% samples in post-monsoon fall in S3 category.

3.5.2 Residual Sodium Carbonate (RSC)

If the enriched carbonate (residual) concentration becomes relatively high, carbonates get together with calcium and magnesium to form precipitates. The relative abundance of sodium in comparison to alkaline earths and the quantity of bicarbonate and carbonate in excess of alkaline earths also influences the suitability of water for irrigation. This excess is represented in terms of "Residual Sodium Carbonate" (RSC). The highly soluble sodium carbonate known as residual Sodium carbonate (RSC) is defined as;

$$\boldsymbol{RSC} = (\boldsymbol{HCO_3^-} + \boldsymbol{CO_3^-}) - (\boldsymbol{Ca^{2+}} + \boldsymbol{Mg^{2+}})$$

Waters with high RSC produces harmful effects on plant development and is not suitable for irrigation. Waters associated with RSC < 1.25 are of excellent irrigation quality and can be safely applied for irrigation for almost all crops without the risks associated with residual sodium carbonate (Wilcox et al., 1954). If the RSC values lie between 1.25 and 2.5, the water is of an acceptable quality for irrigation. Waters associated with RSC values higher than 2.5 are not acceptable for irrigation. 81.3% (pre-monsoon) & 81.6% (post-monsoon) collected water samples are associated with RSC values less than 1.25 and are safe for use in irrigation practices. Only 18.7% (pre-monsoon) & 13.2% (post-monsoon) water samples are associated with RSC values more than 2.5 and are unsuitable for irrigation. The water with high RSC values if applied for irrigation causes soil to become infertile owing to deposition of sodium.

3.5.3 Wilcox diagram

EC and sodium concentration are very important in classifying irrigation water. The Wilcox diagram (Wilcox 1948) relating EC and SAR shows ***Fig. 35*** that most of the samples are plotted in C4S2, C4S3 and C3S2 showing high to very high salinity and medium to high alkali hazard and not suitable for irrigation.

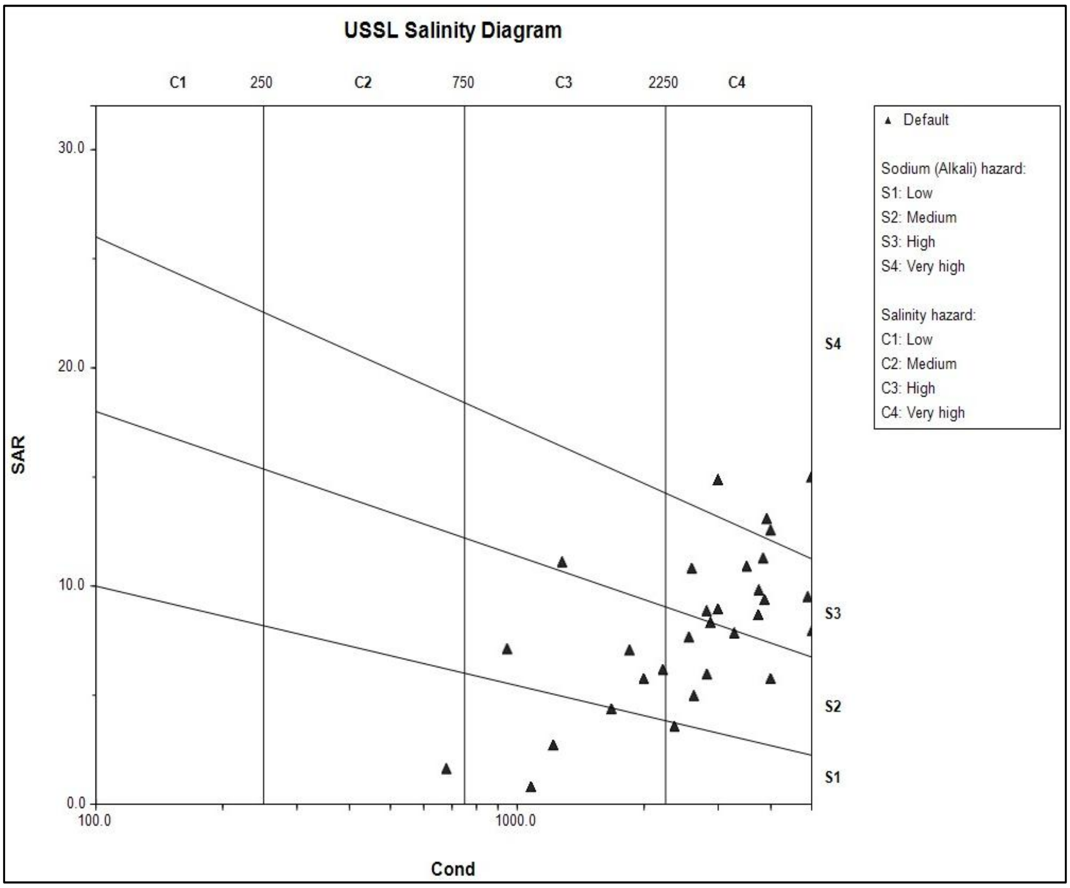


Figure 35: USSL Salinity Diagram

3.5.4 Sodium Percentage (Na %)

The sodium percentage (Na%=Na+K/ (Ca+Mg+Na+K) ×100) in the pre-monsoon groundwater of Bhalaswa study area varies from 7.47% to 80.23% and in post-monsoon it varies from 15.43% to 85.41%. Classification of ground water samples based on Na % is given in below ***Table16.***

Table 16: Water Classification based on Sodium Percent (Na %)

Na %	Water Class	% Pre-monsoon samples	% Post-monsoon samples
<20 %	Excellent	12.5	2.63
20 – 40 %	Good	0	2.63
40 – 60%	Medium	37.5	26.3
60 - 80%	Bad	43.75	60.5
>80%	Very Bad	6.25	7.9

3.5.5 Magnesium Hazard (MH)

The magnesium hazard (MH=Mg/ (Ca + Mg) ×100) in the pre-monsoon ground water of Bhalaswa study area varies from 21.96% to 88.10% and in post-monsoon 10% to 87.5%. Water is not used for irrigation if MH values exceeded the 50%. The long term application of high MH value water may reduce the crop yields and affect the agricultural productivity in the area.

4 Implementable Management Plan

4.1 Ground water pollution remedial measures at Bhalaswa SLF Site

1. It is observed that the ground water in surrounding areas of Bhalaswa SLF site is highly contaminated, it is recommended to take proper precautions to arrest further deterioration of ground water quality in the area. Total 7 Stakeholder feedback forms were collected from stakeholders during the field. Most of the Tubewells are at shallow depth as they mentioned in the stakeholder forms. Most of the tubewells/Hand Pumps are used for washing & Cleaning, Construction purposes only. For drinking purpose, they are depending on DJB supply water. Some Stake holders informed that the water colour gets transformed to yellow colour after 2-3 hours. As discussed in the field with the locals, it has been learnt that the locals does not consume the ground water for drinking purpose. Hence the health issues related due to the ground water could not be ascertained.
2. To prevent mixing of the leachate at bottom of the SLF site, number of borewells should be drilled vertically over the entire dumping yard and at the boundary of dumping yard to pump out the contaminated ground water as wells as leachate from the dumping yard. This pumped water and leachate mix shall be treated properly by putting up the ETP adjacent to the dumping yard and after proper treatment may be released to the surface water drains flowing adjacent to the dumping yard.
3. Horizontal collector wells/pipes with slotted pipes may be installed within the dumping yard and the leachate may be collected properly in the pipes and be treated in ETPs.
4. One deep trench of depth about 2 m may be constructed around the dumping yard so that the leachate is collected in the drain and transported to the ETP plant. To prevent the accumulation of storm water and rainwater over the landfill, connecting drains may be constructed criss crossing the dumping yard and connected to peripheral drain.
5. Sub-surface vertical cut-off walls may be constructed to prevent the movement of contaminated water to fresh water areas.
6. It is recommended to operate landfills appropriately at low level with restricting the height of the landfill dumping.
7. Waste Water from Bhalaswa dairy may also be collected properly and treated before releasing into the surface water drains.
8. Awareness may be created regarding contamination of ground water by putting the boarders at different locations highlighting the health risk of using contaminated ground water.

4.2 Recommendations for Future development of SLF sites

A conventional landfill is a man-made system for storing trash in specially constructed and protected cells on the ground's surface or in underground excavations. Despite the fact that more rubbish is being reused, repurposed, or energetically valorised, landfills remain an important aspect of waste management. During the degradation of waste in landfills, leachate and gases are created. These emissions have the potential to threaten human health as well as the quality of the environment. The most common greenhouse gases found in landfill gas are methane and CO2 (carbon dioxide). Landfills account approximately 20% of all anthropogenic methane emissions worldwide.

The migration of gas and leachate from the landfill body into the environment is a serious environmental concern, posing a threat to groundwater, air quality, and climate change via methane emissions, as well as significant health risks.

Scientific Landfills

A Scientific Landfill is so titled because it was built using a scientific design and approach. The seepage of solid waste leachate into the underlying soil and water, contaminating both, is one of the most critical problems with traditional landfills. Because the base layer of clay in scientific landfills successfully eliminates any seepage or leaking within the landfill, there is no possibility of garbage seeping underground. A soil drainage layer and a vegetative layer are placed on top of the base layer to avoid soil erosion. Leachate is collected before it seeps underground due to the presence of these layers ***Fig 36.***

Scientific landfills act as degassing systems by reducing methane production. Methane is produced at a slower rate than in typical landfills because the layers soak up the majority of the contaminants in the rubbish. In scientific landfills, vertical wells aid in the regular extraction of methane, which can then be used to generate energy and heat.

Components of Scientific Landfill

The following are the seven fundamental components of an MSW landfill:

1. A liner system that prevents leachate or gas from seeping into the surrounding soil at the landfill's base and sidewalls.
2. A leachate collection and control facility that collects and removes leachate from the inside and outside of the landfill before treating it.
3. A gas collection and control facility (optional for small landfills) that collects and eliminates gas from within and on top of waste before treating or recycling it.
4. A final cover system that improves surface drainage, prevents infiltration, and maintains surface vegetation at the top of the landfill.
5. A drainage system for surface water that collects and transfers all surface runoff away from the landfill.
6. An environmental monitoring system based on a landfill that collects and analyses air, surface water, soil gas, and groundwater samples on a regular basis.
7. A closure and post-closure plan that includes the methods for closing and securing a landfill once it has been filled, as well as the activities for long-term monitoring, management, and maintenance of the closed landfill.

Site selection criteria

- Responsibility of Development authorities to identify landfill sites and handover to concerned ULBs
- Nearby waste processing facility.
- Soil conditions and topography.

Table 17: Distance parameters for construction of landfill

Place	Distance Parameters
Lake or Pond	• Maximum distance 200 m • A water monitoring system should be installed if the landfill site is less than 200 m from the lake/ pond • Sites falling within wetlands are avoided
River	• Maximum distance 100 m • The distance may be reduced in some instances for non-meandering rivers but a minimum of 30m should be maintained
Flood Plains	• No landfill should be constructed within a 100 m year- flood plain
Highway	• Maximum distance 200 m
Habilitation	• Maximum distance 200 m of noticed habituated area • Site falling within forest area and national parks are avoided • A distance of 100 m must be maintained from the residential areas
Public Parks	• Maximum distance 200 m
Ground Water Table	• No landfill should be constructed in the area where water table is less than 2 m below ground surface
Airport	• A distance of 20 km the nearby airport must be maintained • Can be set up between 10-20 km by obtaining NOC from the civil aviation authority / Air Force

- Large enough to last for 20-25 years
- No development zone around landfill area
- Temporary storage facility for solid waste shall be established in each landfill

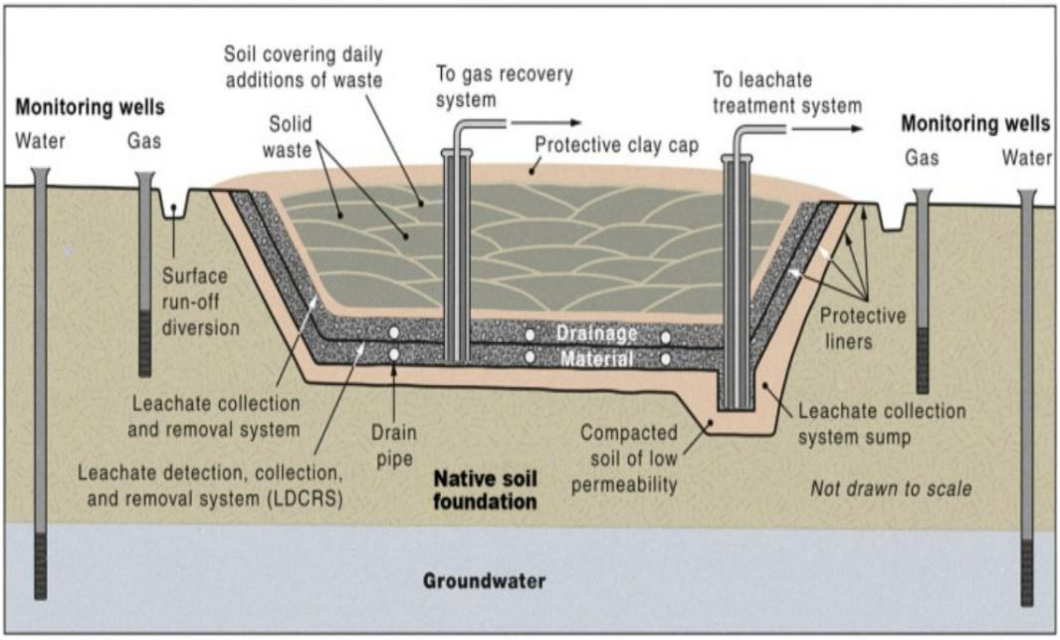


Figure 36: Schematic diagram of scientific landfill site

5 Summary and Recommendations

5.1 Summary

1. The study area covering an area is about 20 Sq. km is occupied by unconsolidated sediments of Quaternary to Recent age.
2. The landfill is not scientifically lined as the pit is only used as a dump site. It has only got a layer of malba topped with soil, instead of having a layer of plastic or a special type of clay layer required for a secure landfill. About 2500 MT/day solid waste is being dumped at this site and the filling of this site is commissioned in 1994. This landfill site is not designed as per the schedule 3 of MSWs rules which came into effect in year 2000. The solid waste received at the site is levelled, restructuring and compacted by the hydraulic bulldozers. The height of the dump is about 62 metres in 2019 from surrounding ground level. The landfill is owned by the Municipal Corporation of Delhi.
3. The ground water in the area around the Bhalaswa landfill is being contaminated due to leachate from the landfill and there is no leachate treatment in this site. Most of the people in the area are depends on Delhi Jal Board supply water for drinking purpose. Ground water is being used for domestic use such as bathing, washing utensils and clothes which has led to skin diseases of the people.
4. VES data indicates that fresh water sediments are followed by the saline water sediments. The thickness of fresh water sediments is bare minimal in Bhalaswa Study area. The depth to fresh – saline water interface varies from 22 mbgl to 65mbgl. Ground water quality below fresh saline water interface is saline all through up to the bedrock.
5. As per hydrographs of Haiderpur Piezometer Pre-monsoon water level during (1998 – 2015) indicates declining trend of ground water level, near to landfill site and Bhalaswa lake water level is rising.
6. Electrical conductivity value of pre-monsoon ground water samples in Bhalaswa study area has been found to vary from 330 to 8755 µS/cm at 25ºC and in post-monsoon it varies from 680-10890 µS/cm at 25ºC. Electrical Conductivity in excess of 3000 µS/cm value has been observed more than 50% of study area. Nitrate in excess of maximum permissible limit has been reported from 24% of post-monsoon samples.
7. All the available data as well as data generated during the course of present study were integrated and aquifer disposition maps were prepared. Fine to medium sand layer is present below the landfill site and Clay with silt also abundant in study area. In alluvium, sand and silt with kankar form the potential aquifer zones.
8. Southern and South Eastern parts of the study area shows shallow water level and western, north western parts of study area shows deep water levels.
9. In heavy metal analysis, two leachate samples have shown more than permissible limit for Fe, Cr, As and Ni. Only one leachate sample has shown more than permissible limit for Uranium, Manganese, Lead and Cadmium. In Basic analysis, Leachate samples have shown exceed the permissible limit for EC, Cl, Fluoride and Nitrate. For Bacteriological analysis both the leachate samples have shown total and fecal coliform.

10. In Basic analysis 37.5% of wells showing Chloride and 6.25% of wells are showing Fluoride beyond the permissible limit in pre-monsoon. And 18.42%, 13.15% and 26.31% of wells are showing Cl, F & No_3 beyond permissible limits. Excess Fluoride has been reported from isolated pockets in the study area.
11. Water table elevation follows the topography of the area and overall ground water flow direction is towards Yamuna River. Internal ground water flow direction is different. In the western part of the study area flow direction is towards a trough near landfill area and southern part ground water flow direction is towards north. Bhalaswa Lake acting as divider regarding ground water flow.

5.2 Recommendations

1. The study revealed that the landfill site is close to water bodies, highway. The development of new landfills should be sited not too close to natural features, residential areas and institutions in order to have minimal negative impact on them.
2. Encourage households, businesses, and industries to segregate waste at the source into recyclables, organic waste, and non-recyclables. Provide separate bins or containers for different types of waste.
3. The waste should be minimized at the source. Proper segregation would lead to better options and opportunities for scientific disposal of waste. The recyclable materials should be recovered from the wastes. Invest in research and development of innovative technologies and practices for waste management, such as waste-to-energy technologies, sustainable materials recovery, and improved recycling processes.
4. Use appropriate treatment methods for different types of waste, such as landfilling for non-recyclable and non-compostable waste, composting for organic waste, and advanced treatment technologies for hazardous waste.
5. The Bhalaswa landfill is nearing its closure date, develop a closure and aftercare plan to rehabilitate the landfill site once it reaches capacity. This includes covering the site, landscaping, and ongoing monitoring to ensure environmental protection.
6. CPCB and DPCC should take responsibility to implement the rules and policies given by Ministry of Environment, Forests and Climate Change (MoEFCC). Implement and enforce solid waste management policies and regulations at local levels. Establish incentives and penalties to encourage compliance with waste management guidelines and promote responsible waste handling practices.
7. Foster collaboration among government agencies, private sector stakeholders, NGOs, and the community to address solid waste management challenges collectively. The involvement of people and private sector through NGOs could improve the efficiency of SWM.
8. Public awareness should be created among masses to inculcate the health hazards of the wastes. Conduct public awareness campaigns to educate communities about the importance of proper waste management practices, including recycling, composting, and waste segregation. Provide clear guidelines and information on how residents can participate in waste reduction efforts.

9. Bhalswa landfill site influenced the groundwater quality of the shallow aquifers close to the site. To control/or minimize the impact of leachate on groundwater resources around the landfill sites, construction of lined engineered dumping site and leachate collection ponds are the best way to protect the movement of the leachate into the shallow groundwater of the study area. A new site for dumping should be selected as an alternative away from any residential settlement, river and agricultural field to minimize the environmental impact.
10. Ground water is highly polluted and is not fit for drinking and irrigation purposes around landfill site. It is recommended that ground water should be used only after proper treatment. Site selection and design of landfill sites should be based on sound scientific considerations. There should be strict monitoring of waste disposal in industrial belts.
11. Construct a scientific/Engineered landfill for future newly constructed landfills for better solid waste management as well as leachate management.
12. A thick column of fresh water aquifer system exists down to depth of 50 m in the vicinity of Western Yamuna Canal and its thickness decreases away from the canal. The existence of thick column of fresh ground water aquifers beneath Western Yamuna Canal is due to infiltration of fresh water from the canal and flushing of entrapped saline water from theses aquifers. These aquifers can be used by constructing tubewells of depth 40 to 50 m all along the canal. The contaminated plume may be restricted and not allowed to pollute the fresh water present under western Yamuna Canal. Pumping of fresh water present along the western Yamuna Canal may be regularized to avoid ground water contamination due to SLF site.
13. In Study area, fresh ground water is underlain by saline/ brackish water and clay is dominant in the western part giving rise to salinity due to improper flushing and long residence time of water in the formation. Over-exploitation of ground water has not only resulted in depletion of fresh ground water resources but has also led to gradual upconing of saline water. This saline water can be used after blending for uses other than drinking.

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Annexure

Annexure-I: Existing Landfill sites for Waste Management in NCT Delhi

S.No.	Location	Area (in ha.)	Remarks
1	Kailash Nagar, East Delhi	1.8	Filled up
2	Tilak Nagar, West Delhi	16	Filled up
3	Subroto Park	..	Filled up
4	PuranaQila/Bharion Road	2.7	Filled up
5	Timarpur	16	Filled up
6	Sarai Kale Khan	24	Filled up
7	Gopal Pur	4	Filled up
8	Chhaterpur	1.7	Filled up
9	S.G.T Nagar	14.4	Filled up
10	I.P. Depot	1.8	Filled up
11	Sunder Nagar	2.8	Filled up
12	Tuglakabad Extn.	2.4	Filled up
13	HaiderPur	1.6	Filled up
14	MandawaliFazilpur	2.8	Filled up
15	RohiniPh-III	4.8	Filled up
16	Near Hastal Village in West Delhi	9.6	Filled up
17	Site Near Ghazipur Dairy Farm	28	In Operation
18	Site Near Jhangirpur/ Bhalaswa	16	In Operation
19	Okhla Phase-I	12.8	In Operation
20	Crossing on G.T. Karnal Road	3.2	In Operation
21	Jaitpur/Tajpur	9.84	New
22	Near Puthkhurd	55	New
23	Bawana to Narela Road	28	New
24	Sultanpur Dabas (Bawana)	16	New

Annexure-II: Hydrogeological Data of monitoring wells around Bhalaswa Landfill Site

S.No.	Location	Latitude	Longitude	Nature of well	Depth of the well (m)	Diameter in mm	Aquifer tapped (reported)	Depth Zones Tapped (mbgl)	M.P (mbgl)	Depth to Water Level, June-23 (mbgl)	Depth to Water Level, Nov-23 (mbgl)	Use
1	MakbaraChowk	28.734954	77.156849	Tubewell	25	102	Silty Sand		0.5	7.15	6.95	Horticulture
2	MCPS Co-Ed, J-Block, Jahangirpuri	28.731316	77.164136	Tubewell	40	102	Sand & Gravel		0.3		6.93	Washing & Cleaning
3	ITI , K-Block, Jahangirpur	28.733024	77.170516	Tubewell	30	102	Silty sand		0.48		5.03	Construction & Cleaning
4	MCD School, Jahangirpur	28.732299	77.176645	Tubewell	50	204	Sand & Gravel		0.58		3.94	Washing & Cleaning
5	TW Bhalaswa lake	28.73929	77.17	Tubewell	15	153	Silty Sand	20-29	0.8	3.56	3.17	Horticulture
6	KewalparkPz	28.71833333	77.18111111	Piezometer	77	153	Silty Sand, Sand & Gravel	41-59 & 65-71	0.8	3.68	3.25	Monitoring
7	Coronation Pillar Pz	28.72444444	77.19222222	Piezometer	56	153	Silty Sand, Sand & Gravel		0.9	3.63	2.86	Monitoring
8	TW at LFS Entry Gate	28.739311	77.155504	Tubewell	50	153	Silty Sand, Sand & Gravel		0.2		10.28	Horticulture
9	TW-2 at LFS Entry Gate	28.739486	77.155622	Tubewell	50	153	Silty Sand, Sand & Gravel		0.55		9.07	Not in use
10	Shree Cements	28.745124	77.158856	Tubewell	30	102	Silty Sand		0.3		6.04	Washing & Cleaning
11	MCD Dispensary	28.74037	77.165435	Tubewell	25	153	Silty Sand		0.27	6.05	5.95	Washing & Cleaning
12	Sanjaygandhi Transport Nagar	28.7407347	77.1525009	Piezometer	69	153	Fine Sand, Sand & Gravel, Clayey Sand	15-21,39-45,60-66	0.84	8.51	8.53	Monitoring
13	MCD Toilets, Near T-Junction	28.736624	77.147134	Tubewell	40	153	Silty Sand		0.2		9.46	Cleaning
14	MCD allopathic Dispensary	28.742225	77.144652	Tubewell	50	304	Silty Sand, Sand & Gravel		0.4		19.07	Delhi Jal Board Supply Water TW
15	Shiv Mandir, MCD Office, MCD Colony	28.742526	77.145077	Tubewell	25	102	Silty Sand		0.1		17.68	Cleaning
16	JJ Cluster Toilets, Opp. Vashudev Transport	28.747596	77.148713	Tubewell	50	153	Silty Sand, Sand & Gravel		0.15	12.53	12.22	Cleaning
17	Toilets, CTC No.-154, S.G.T.N	28.744468	77.149616	Tubewell	50	153	Silty Sand, Sand & Gravel		0.32	10.98	10.65	Cleaning

18	Adarsh Sen. Sec. School Boys, G.T. Road	28.752877	77.148719	Tubewell	30	102	Silty Sand		0.97		9.91	R.O plant
19	Khera Kalan Pz	28.76944444	77.11805556	Piezometer	50	153	Silty Sand, Sand & Gravel	28-46	0.7	11.48	10.75	Monitoring
20	DJB Office, Kadipur	28.77246	77.150343	Tubewell	60	304	Silty Sand, Sand & Gravel	18-24, 28-32, 33.5-44	0.45		5.62	Delhi Jal Board Supply Water TW
21	Sawaria Traders, Azad Place	28.754397	77.155944	Tubewell	30	104	Silty Sand		0.15		6.98	Washing & Cleaning
22	Burari DJB Ex.Engg Office Pz	28.73305556	77.19722222	Piezometer	46	153	Silty Sand, Sand & Gravel	10-16,22-28,31-37,40-43	0.7	3.73	3.45	Monitoring
23	Haiderpur	28.72888889	77.14694444	Piezometer	51	153	Silty Sand, Sand & Gravel		0.75	12.88	14.9	Monitoring
24	Rohini Sec 11	28.73222222	77.10444444	Piezometer	24	104	Silty Sand, Sand & Gravel	12-16,20-24	0.58	5.26	5.7	Monitoring
25	SandeshVihar	28.695	77.14611111	Piezometer	42	153	Fine Sand, Sand & Gravel	16-18,21-27 & 36-40	0.8	4.12	5.36	Monitoring

Annexure-III: Hydrogeological Data of water Quality sampling points (post-monsoon) around Bhalaswa Landfill Site

Sample No.	Latitude	Longitude	Location	Nature of well	Depth of the well (m)	Dia in mm	Aquifer tapped (reported)	Use
1	28.733446	77.159666	Chat Ghat Jheel Wala Park	TW	30	153	Silty Sand & Fine Sand	Horticulture
2	28.735062	77.157056	PWD Electrical Office	TW	15	51	Silty Sand	Cleaning
3	28.735745	77.16277	HP Besides Jheel Park Gate	HP	15	51		Public Use
4	28.731316	77.164136	MCPS Co-Ed, J-Block, Jahangirpuri	TW	30	102		Cleaning & Washing
5	28.733024	77.170516	ITI , K-Block, Jahangirpur	TW	35	102		Cleaning & Washing, Construction
6	28.732299	77.176645	MCD School, Jahangirpur	TW	50	204	Sand & Gravel	Cleaning & Washing
7	28.73929	77.17	HP Cremation Ground	HP	15	153		Not bin daily use
8	28.745399	77.176327	Fields Handpump	HP	15	51	Silty Sand	washing
9	28.752271	77.182345	TW Mukundpur, Jheemar Village	TW	25	102		construction & Cleaning
10	28.718035	77.178927	Majlis Park, Azadpur, Opp. Kewalpark	HP	15	51		Public Use
11	28.739311	77.155504	TW at LFS Entry Gate	TW	50	153	Silty Sand , Sand & Gravel	Horticulture
12	28.740337	77.155314	Leachate-1					
13	28.743491	77.155231	Leachate-2					
14	28.742611	77.15409	Leachate-3					
15	28.74456	77.15506	R.S Poultries & Trading	TW	30	102	Silty Sand	Cleaning & Washing
16	28.74518	77.15768	Ambuja Cement	TW	20	102	Silty Sand	Cleaning & Washing
17	28.74516	77.15915	Bhagat Properties	HP	15	51		Public Use
18	28.742	77.16042	NBM Toilets	TW	40	153	Silty Sand , Sand & Gravel	Cleaning
19	28.74147	77.16379	Balaji Coaching Centre	HP	15	153	Silty Sand	Cleaning & Washing
20	28.740535	77.163569	Prachin Shiv Mandir	HP	15	153		Cleaning & Washing
21	28.74037	77.165435	MCD Dispensary	TW	25	153	Silty Sand	Cleaning & Washing
22	28.74806	77.16022	Mahashiv Car Servicing Centre	TW	20	102	Silty Sand	Cleaning & Washing
23	28.75191	77.16039	Kavya Furniture	TW	15	51	Silty Sand	Cleaning
24	28.7407347	77.1525009	Sanjaygandhi Transport Nagar toilets	TW	50	153	Fine Sand, Sand & Gravel, Clayey Sand	Cleaning
25	28.738097	77.153429	Shibu Da Dhaba	TW	35	102		Cleaning

Sample No.	Latitude	Longitude	Location	Nature of well	Depth of the well (m)	Dia in mm	Aquifer tapped (reported)	Use
26	28.73425	77.149364	Sulabh Complex, Opp. Sewage Pumping Stn.,	TW	40	153	Silty Sand , Sand & Gravel	Cleaning
27	28.736624	77.147134	MCD Toilets, Near T-Junction	TW	40	153	Silty Sand , Sand & Gravel	Cleaning
28	28.739918	77.145435	Mother Dairy House, Opp. Great Vishal Band	TW	20	102		Cleaning & Washing
29	28.742526	77.145077	Shiv Mandir, MCD Office, MCD Colony	TW	25	102	Silty Sand	Horticulture
30	28.750881	77.148404	Toilets, Sanjay Colony, Opp. Shakti Builders	TW	40	153		Cleaning
31	28.747596	77.148713	JJ Cluster Toilets, Opp. Vashudev Transport	TW	50	153	Silty Sand , Sand & Gravel	Cleaning
32	28.744468	77.149616	Toilets, CTC No.-154, S.G.T.N	TW	50	153	Silty Sand , Sand & Gravel	Cleaning
33	28.752877	77.148719	Adarsh Sen. Sec. School Boys, G.T. Road	TW	30	102	Silty Sand	R.O Plant
34	28.76944444	77.11805556	Khera Kalan Cremation ground	TW	35	102	Silty Sand	Cleaning
35	28.77246	77.150343	DJB Office, Kadipur	TW	25	102	Silty Sand	Cleaning & Washing
36	28.757651	77.154436	Vedanshi Properties	TW	20	102	Silty Sand	Cleaning & Washing
37	28.754397	77.155944	Sawaria Traders, Azad Place	TW	30	102	Silty Sand	Cleaning
38	28.73305556	77.19722222	Burari DJB Ex.Engg Office	TW	15	102	Sand &kankar	Cleaning
39	28.72888889	77.14694444	Haiderpur	TW	50	153	Silty Sand , Sand & Gravel	Horticulture
40	28.73222222	77.10444444	Rohini Sec 11	TW	45	203	Silty Sand , Sand & Gravel	Horticulture
41	28.695	77.14611111	SandeshVihar	TW	50	203	Silty Sand , Sand & Gravel	Horticulture

Annexure-IV: Pre-Monsoon Basic Chemical Analysis Results

S.No.	Tehsil Name	Latitude	Longitude	Site Name	pH	EC in µS/cm at 25^0 C	CO_3	HCO_3	Cl	SO_4	NO_3	F	Ca	Mg	Na	K	TH as $CaCO_3$
							mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/ L	mg/L
1	Alipur	28.74516	77.15915	HP Bhagat Properties	7.34	2560	nil	561	391	192	26	0.93	128	22	356	64	410
2	Alipur	28.74200	77.16042	TW SBM Toilets	7.45	3000	nil	891	490	24	27	1.20	104	29	400	196	380
3	Alipur	28.74496	77.15774	TW-4 Gayatri Gnan Mandir	7.37	2824	nil	671	419	240	27	0.85	132	63	332	104	590
4	Alipur	28.72889	77.146944	Haiderpur	8.12	330	nil	73	28	77	4.0	0.36	36	19	5.0	2.2	170
5	Alipur	28.73936	77.15547	Tubewell-1 (LFS-Entrance)	7.19	8256	nil	1318	2109	144	28	1.00	260	163	1295	78	1320
6	Alipur	28.74806	77.16022	TW Mahashiv Car Washing Centre	7.61	8755	nil	366	2840	72	4	0.58	352	221	1197	18	1790
7	Rohini	28.73222	77.1044444	Rohini Sec 11	8.19	350	nil	98	50	34	4	0.32	32	24	5.8	2.1	180
8	Alipur	28.74261	77.15413	Leachate-2	8.53	38845	2400	8845	5680	120	156	3.00	800	608	4670	3872	4500
9	Alipur	28.74039	77.15512	Leachate-1	8.11	39000	nil	7320	7810	192	204	2.20	800	730	4200	3250	5000
10	Alipur	28.76944	77.1180556	Khera Kalan	8.95	1177	30	488	71	86	0	2.50	20	19	239	5.9	130
11	Alipur	28.73306	77.1972222	Burari DJB Ex.Engg Office	7.79	2800	nil	293	682	125	3.4	1.20	84	90	364	9.2	580
12	Model Town	28.73929	77.17000	HP Cremation Ground	7.39	5628	nil	122	1598	432	0	0.46	180	199	725	16	1270
13	Model Town	28.74093	77.16397	TW Buffalo Shelter	7.46	5017	nil	756	1122	278	27	0.69	144	175	600	163	1080
14	Alipur	28.74456	77.15506	TW-3 Poultry	7.73	3916	nil	964	625	288	11	1.10	68	85	685	12	520
15	Alipur	28.75191	77.16039	Tw Kavya Furniture	7.62	2365	nil	708	284	178	25	0.65	72	126	216	41	700
16	Rohini	28.74073	77.1525009	SamaipurBadli	7.99	3722	nil	500	781	264	22	1.20	56	114	565	9.7	610
17	Model Town	28.74147	77.16379	HP Balaji Coaching centre	7.61	7470	nil	85	2272	336	2	0.32	64	202	1238	22	990
18	Saraswat iVihar	28.695	77.1461111	SandeshVihar	7.83	8380	nil	525	2343	288	11	1.20	60	270	1297	28.5	1260

Annexure-V: Post Monsoon Basic Chemical Analysis Result

S.No.	Location	Type of Wells	Lat.	Long.	pH	EC (us/cm)	Carbonate (mg/L)	Bicarbonate (mg/L)	Chloride (mg/l)	Sulphate (mg/l)	Nitrate (mg/l)	Phosphate (mg/l)	Fluoride (mg/l)	TH (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)	TDS (mg/l)
1	NBM Toilets	TW	28.742	77.16042	7.07	2950	Nil	903	432	140	16	0.50	0.54	500	180	12	390	128	1918
2	Chat GhatJheelWala Park	TW	28.73345	77.15967	6.96	1676	Nil	390	191	174	128	5.52	0.48	400	120	24	200	33	1089
3	Bhagat Properties	HP	28.74516	77.15915	7.01	2630	Nil	586	383	341	10	0.30	0.43	550	164	34	360	41.42	1710
4	Burari DJB Ex.Engg Office Pz	TW	28.73306	77.19722	7.46	5150	Nil	329	1347	490	4	0.11	0.45	970	272	71	780	17.9	3348
5	Majlis Park, Azadpur, Opp. KewalparkPz	HP	28.71804	77.17893	7.35	680	Nil	256	78	13	20	0.01	0.30	220	60	17	55	9.5	442
6	Rohini Sec 11	TW	28.73222	77.10444	8.18	1280	Nil	561	35	75	11	0.52	5.2	90	24	7	240	3.6	832
7	PWD Electrical Office	TW	28.73506	77.15706	6.85	2630	Nil	549	333	346	95	0.01	4.42	670	156	68	295	45.86	1710
8	Kavya Furniture	TW	28.75191	77.16039	7.53	2675	Nil	525	277	552	17	0.01	0.22	810	188	83	255	36	1739
9	Khera Kalan Pz	TW	28.76944	77.11806	7.96	947.9	Nil	573	21	80	1	0.20	2.2	150	32	17	200	4.7	616
10	Prachin Shiv Mandir	HP	28.74054	77.16357	7.55	6570	Nil	427	886	1716	30	0.40	0.42	960	200	112	1120	15.6	4271
11	Adarsh Sen. Sec. School Boys, G.T. Road	TW	28.75288	77.14872	7.7	5000	Nil	650	950	620	4.6	0.45	0.79	640	132	75	870	8.9	3250
12	Vedanshi Properties	TW	28.75765	77.15444	7.41	3870	Nil	708	723	201	170	0.12	1.3	700	144	83	570	11.8	2516
13	Toilets, CTC No.-154, S.G.T.N	TW	28.74447	77.14962	7.3	5740	Nil	790	1250	365	95	0.62	1.35	550	112	66	1070	6.8	3731
14	MCD School, Jahangirpur	TW	28.7323	77.17665	7.56	10890	Nil	220	1702	3118	1	0.01	0.62	1980	392	243	1760	20.45	7079
15	JJ Cluster Toilets, Opp. Vashudev Transport	TW	28.7476	77.14871	7.62	3280	Nil	549	350	690	125	0.25	0.15	710	140	88	480	13.1	2132
16	Haiderpur	TW	28.72889	77.14694	7.84	1080	Nil	403	35	220	16.8	0.13	0.78	530	104	66	42	4.2	702
17	MCD Dispensary	TW	28.74037	77.16544	7.37	4900	Nil	586	567	1298	23	0.01	0.63	1060	200	136	710	39.27	3185
18	Mother Dairy House, Opp. Great Vishal Band	TW	28.73992	77.14544	7.00	2220	Nil	512	284	298	100	0.01	0.90	510	96	66	320	7.34	1443
19	Mahashiv Car Servicing Centre	TW	28.74806	77.16022	7.37	7770	Nil	354	922	2450	3	0.01	0.44	1960	360	258	1000	10.65	5051
20	Balaji Coaching Ctr	HP	28.74147	77.16379	7.32	8050	Nil	354	1524	1820	4	0.01	0.37	1500	264	204	1300	12.9	5233
21	MCD Toilets, Near T-Junction	TW	28.73662	77.14713	7.20	2820	Nil	647	298	557	24	0.01	0.68	510	88	71	460	33.5	1833
22	DJB Office, Kadipur	TW	28.77246	77.15034	7.77	2880	Nil	476	624	305	2.8	0.11	0.4	580	100	80	460	11.4	1872
23	Sanjaygandhi Transport Nagar	TW	28.74073	77.1525	7.62	3840	Nil	403	723	652	23	0.01	1.00	630	104	90	650	7.81	2496
24	Ambuja Cement	TW	28.74158	77.15768	7.42	3000	Nil	793	376	448	2	0.31	0.80	320	52	46	610	4.86	1950
25	Sawaria Traders, Azad Place	TW	28.7544	77.15594	7.8	3510	Nil	549	723	280	3	0.32	0.41	520	84	75	570	9.8	2353

26	SandeshVihar	TW	28.695	77.14611	7.66	8610	Nil	525	2623	320	4	0.13	1.1	1440	224	214	1380	22.9	5597
27	Shiv Mandir, MCD Office, MCD Colony	TW	28.74253	77.14508	7.58	2000	Nil	427	269	212	140	0.01	0.70	450	68	68	280	7.23	1300
28	TW at LFS Entry Gate	TW	28.73931	77.1555	7.09	7500	Nil	915	1028	1708	85	0.01	0.76	1340	200	204	1220	45.42	4875
29	MCPS Co-Ed, J-Block, Jahangirpuri	TW	28.73132	77.16414	7.83	1220	Nil	329	142	170	16	0.01	0.18	360	52	56	118	35.2	793
30	TW Mukundpur, Jheemar Village	TW	28.75227	77.18235	7.72	4000	Nil	317	950	384	18	0.01	0.05	540	76	85	670	15.42	3107
31	Shibu Da Dhaba	TW	28.7381	77.15343	7.55	4000	Nil	378	532	876	38	0.20	0.90	1060	144	170	430	9.23	3315
32	HP Cremation Ground	HP	28.73929	77.17	7.32	5620	Nil	85	1574	683	1	0.01	0.41	1320	176	214	770	9	3653
33	ITI , K-Block, Jahangirpur	TW	28.73302	77.17052	7.21	3750	Nil	598	737	468	10	0.01	0.56	710	88	119	600	11.8	2438
34	Sulabh Complex, Opp. Sewage Pumping Stn.,	TW	28.73425	77.14936	7.86	2600	Nil	561	312	523	15	0.01	1.70	390	44	68	490	5.6	1690
35	Toilets, Sanjay Colony, Opp. Shakti Builders	TW	28.75088	77.1484	7.95	3740	Nil	378	624	602	260	0.01	0.20	790	72	148	560	17	2431
36	Fields Handpump	HP	28.7454	77.17633	7.46	5770	Nil	1013	744	1058	45	0.01	1.60	940	72	185	800	270	3751
37	R.S Poultries & Trading	TW	28.74456	77.15506	7.60	3750	Nil	903	596	426	12	0.42	0.40	440	28	90	730	7.4	2438
38	HP Besides Jheel Park Gate	HP	28.73575	77.16277	8.20	1850	Nil	262	305	293	5	0.23	0.83	320	16	68	290	6.31	1203
39	Leachate-1	LFS	28.74034	77.15531	7.68	2817 0	NA	NA	NA	NA	35.00	NA	0.70	NA	NA	NA	NA	NA	18311
40	Leachate-2	LFS	28.74349	77.15523	8.15	2900 0	NA	NA	NA	NA	40.50	NA	1.30	NA	NA	NA	NA	NA	18850
41	Leachate-3	LFS	28.74261	77.15409	8.06	3140 0	NA	NA	NA	NA	42.60	NA	1.42	NA	NA	NA	NA	NA	20410

***NA-** Not Analysed

Annexure-VI: Pre Monsoon Heavy metal Analysis Results

S.No.	Tehsil Name	Latitude	Longitude	Site Name	Cr	Mn	Fe	Ni	Cu	Zn	As	Se	Cd	Pb	U
					(ppm)						ppb				
1	Alipur	28.74039	77.15512	Leachate-1	2.565	0.132	6.882	0.409	0.079	0.368	565.85	0.76	1.48	8.08	6.40
2	Alipur	28.73936	77.15547	Tubewell-1 (LFS-Entrance)	0.003	0.203	0.095	0.012	0.005	0.031	2.06	0.02	0.07	0.12	12.64
3	Alipur	28.74261	77.15413	Leachate-2	1.558	0.568	21.518	0.580	0.733	0.749	103.12	0.37	4.46	122.13	37.67
4	Alipur	28.74456	77.15506	TW-3 Poultry	0.001	0.250	0.045	0.007	0.007	0.042	0.57	0.02	0.28	0.20	17.69
5	Alipur	28.74496	77.15774	TW-4 GayatriGnanMandir	0.001	0.277	0.067	0.003	0.008	0.064	0.57	0.06	0.34	0.43	5.19
6	Alipur	28.74516	77.15915	HP Bhagat Properties	0.001	0.342	0.221	0.002	0.004	0.058	0.97	0.02	0.43	0.39	5.63
7	Model Town	28.73929	77.17	HP Cremation Ground	BDL	0.325	6.714	0.000	0.001	1.493	0.13	0.00	0.30	0.10	0.54
8	Model Town	28.74093	77.16397	TW Buffalo Shelter	0.000	0.904	0.070	0.002	0.003	0.057	0.39	0.03	0.24	0.20	6.26
9	Model Town	28.74147	77.16379	HP Balaji Coaching centre	0.000	0.154	0.294	0.000	0.001	0.530	0.07	0.01	0.25	1.05	0.14
10	Alipur	28.742	77.16042	TW SBM Toilets	0.001	0.650	3.162	0.002	0.002	0.569	55.00	0.01	0.32	1.45	4.04
11	Alipur	28.74806	77.16022	TW Mahashiv Car Washing Centre	0.000	0.117	0.180	0.000	0.003	0.087	0.30	0.01	0.14	0.29	4.13
12	Alipur	28.75191	77.16039	Tw Kavya Furniture	0.000	0.666	0.097	0.002	0.003	0.615	0.42	0.03	0.59	1.59	4.27
13	Civil Lines	28.73306	77.197222	Burari DJB Ex.Engg Office Pz	BDL	1.149	0.074		BDL	0.218	5.861	0	0	3.891	BDL
14	Alipur	28.72889	77.146944	HaiderpurPz	BDL	BDL	0.195		BDL	2.623	BDL	0	0	7.818	BDL
15	Alipur	28.76944	77.118056	Khera Kalan Pz	BDL	BDL	BDL		BDL	0.263	1.823	0	0	4.167	29.687
16	Rohini	28.73222	77.104444	Rohini Sec 11 Pz	BDL	BDL	0.213		BDL	2.835	1.197	0	0	9.809	BDL
17	Rohini	28.74056	77.1525	SamaypurBadliPz	BDL	0.055	0.063		BDL	0.310	BDL	0	0	1.473	7.571
18	SaraswatiVihar	28.695	77.146111	SandeshViharPz	BDL	BDL	BDL		BDL	BDL	BDL	0	0	BDL	11.521

Annexure-VI: Post Monsoon Heavy Metal Analysis Results

S. No.	Location	Source	Latitude	Longitude	Cr	Fe	Mn	Cu	Zn	As	Pb	U
					mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1	Chat GhatJheelWala Park	TW	28.733446	77.159666	0.001	0.107	0.125	BDL	0.232	0.004	0.003	0.005
2	PWD Electrical Office	TW	28.735062	77.157056	BDL	0.154	0.459	BDL	0.096	BDL	0.001	0.007
3	HP Besides Jheel Park Gate	HP	28.735745	77.16277	BDL	4.677	0.121	BDL	0.597	BDL	0.001	0.007
4	MCPS Co-Ed, J-Block, Jahangirpuri	TW	28.731316	77.164136	BDL	2.545	0.713	BDL	0.305	0.008	0.003	BDL
5	ITI , K-Block, Jahangirpur	TW	28.733024	77.170516	BDL	0.107	0.907	BDL	1.640	BDL	0.009	0.015
6	MCD School, Jahangirpur	TW	28.732299	77.176645	BDL	0.795	0.122	BDL	0.647	BDL	0.003	BDL
7	HP Cremation Ground	HP	28.73929	77.17	BDL	3.220	0.369	BDL	2.740	BDL	0.011	BDL
8	Fields Handpump	HP	28.745399	77.176327	BDL	0.454	0.979	BDL	0.891	0.004	0.005	0.003
9	TW Mukundpur, Jheemar Village	TW	28.752271	77.182345	BDL	7.247	2.324	BDL	1.164	0.027	0.007	BDL
10	Majlis Park, Azadpur, Opp. KewalparkPz	HP	28.718035	77.178927	BDL	0.958	0.848	BDL	0.261	0.015	0.003	BDL
11	TW at LFS Entry Gate	TW	28.739311	77.155504	0.002	0.351	0.328	BDL	0.268	0.004	0.002	0.017
12	Leachate-1	LFS	28.740337	77.155314	Colored sample and not analyzed							
13	Leachate-2	LFS	28.743491	77.155231	Colored sample and not analyzed							
14	Leachate-3	LFS	28.742611	77.15409	Colored sample and not analyzed							
15	R.S Poultries & Trading	TW	28.74456	77.15506	0.002	0.127	0.310	BDL	0.739	BDL	0.005	0.020
16	Ambuja Cement	TW	28.74158	77.15768	BDL	0.757	BDL	BDL	0.872	BDL	0.006	0.012
17	Bhagat Properties	HP	28.74516	77.15915	0.001	2.203	1.259	BDL	0.323	BDL	0.002	0.007
18	NBM Toilets	TW	28.742	77.16042	0.003	5.620	0.941	BDL	0.504	0.083	0.002	0.004
19	Balaji Coaching Centre	HP	28.74147	77.16379	BDL	9.753	0.396	BDL	1.429	BDL	0.003	BDL
20	Prachin Shiv Mandir	HP	28.740535	77.163569	BDL	0.478	0.158	BDL	1.218	BDL	0.005	0.005
21	MCD Dispensary	TW	28.74037	77.165435	BDL	0.584	0.937	BDL	0.834	0.014	0.003	BDL
22	Mahashiv Car Servicing Centre	TW	28.74806	77.16022	BDL	0.437	0.208	BDL	0.176	BDL	0.001	0.005
23	Kavya Furniture	TW	28.75191	77.16039	BDL	BDL	0.994	BDL	0.251	BDL	0.002	0.007
24	Sanjaygandhi Transport Nagar	TW	28.7407347	77.1525009	BDL	0.075	0.075	BDL	0.206	BDL	0.002	0.007
25	Shibu Da Dhaba	TW	28.738097	77.153429	BDL	0.139	0.769	BDL	0.133	BDL	0.001	0.010
26	Sulabh Complex, Opp. Sewage Pumping Stn.,	TW	28.73425	77.149364	BDL	0.176	0.079	BDL	0.173	BDL	0.002	0.011

S. No.	Location	Source	Latitude	Longitude	Cr	Fe	Mn	Cu	Zn	As	Pb	U
					mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
27	MCD Toilets, Near T-Junction	TW	28.736624	77.147134	BDL	0.087	0.096	BDL	0.191	BDL	0.002	0.035
28	Mother Dairy House, Opp. Great Vishal Band	TW	28.739918	77.145435	BDL	0.125	0.114	BDL	0.196	BDL	0.002	0.014
29	Shiv Mandir, MCD Office, MCD Colony	TW	28.742526	77.145077	BDL	0.153	BDL	BDL	0.871	BDL	0.006	0.015
30	Toilets, Sanjay Colony, Opp. Shakti Builders	TW	28.750881	77.148404	BDL	0.092	0.079	BDL	0.205	BDL	0.002	0.016
31	JJ Cluster Toilets, Opp. Vashudev Transport	TW	28.747596	77.148713	BDL	0.116	0.263	BDL	0.189	BDL	0.002	0.020
32	Toilets, CTC No.-154, S.G.T.N	TW	28.744468	77.149616	0.005	1.186	0.649	BDL	0.630	0.129	0.004	0.022
33	Adarsh Sen. Sec. School Boys, G.T. Road	TW	28.752877	77.148719	BDL	0.290	0.064	BDL	0.226	BDL	0.002	0.007
34	Khera Kalan Pz	TW	28.76944444	77.11805556	BDL	0.154	BDL	BDL	1.257	0.002	0.009	0.019
35	DJB Office, Kadipur	TW	28.77246	77.150343	BDL	0.249	BDL	BDL	1.056	BDL	0.007	0.024
36	Vedanshi Properties	TW	28.757651	77.154436	BDL	0.127	BDL	BDL	0.839	BDL	0.006	0.016
37	Sawaria Traders, Azad Place	TW	28.754397	77.155944	BDL	0.196	0.056	BDL	0.367	BDL	0.003	0.014
38	Burari DJB Ex.Engg Office Piezometer	TW	28.73305556	77.19722222	BDL	0.920	0.841	BDL	0.357	0.004	0.003	BDL
39	Haiderpur	TW	28.72888889	77.14694444	BDL	0.156	BDL	BDL	0.271	BDL	0.003	0.012
40	Rohini Sec 11	TW	28.73222222	77.10444444	BDL	0.084	BDL	BDL	0.054	0.003	0.001	0.009
41	SandeshVihar	TW	28.695	77.14611111	BDL	0.119	BDL	BDL	BDL	BDL	BDL	0.008

Annexure-VII: Vertical Electrical Sounding Data

VES-01, Near Majlis Park metro station, Jahangirpuri, Delhi				
S. No.	**AB/2**	**MN/2**	**Resistance**	**Resistivity**
1	1.25	0.5	3.076	12.6888
2	2	0.5	0.06069	12.5009
3	2.5	0.5	0.69731	13.1494
4	3	0.5	0.47919	13.1779
5	4	0.5	0.2551	12.6279
6	5	0.5	0.1636	12.7261
7	6	0.5	0.10896	12.2431
8	8	0.5	0.06455	12.9335
9	10	0.5	0.3665	11.4926
10	12	0.5	0.02295	10.3722
11	16	0.5	0.01116	8.97397
12	18	0.5	0.00878	8.93322
13	20	0.5	0.00717	9.00885
14	25	0.5	0.00445	8.7562
15	25	5	0.03818	7.20031
16	30	5	0.02375	6.533217
17	35	5	0.02378	8.9701
18	40	5	0.01068	5.28785
19	45	5	0.00771	4.84979
20	50	5	0.00594	4.62396
21	60	5	0.00368	4.13714
22	80	5	0.00184	3.69048
23	100	5	0.00118	3.70036
24	120	5	0.00081	3.69345
25	150	5	0.00046	3.30887
26	180	5	0.00028	2.66752
27	200	5	0.00028	3.5839
28	230	5	0.00021	3.55551

VES-02, Mukundpur 1 near Bhalaswa				
S. No.	**AB/2**	**MN/2**	**Resistance**	**Resistivity**
1	1.25	0.5	1.58935	6.55609
2	2	0.5	0.70289	8.28412
3	2.5	0.5	0.51115	9.63885
4	3	0.5	0.39735	10.9271
5	4	0.5	0.26251	12.9907
6	5	0.5	0.18503	14.3927
7	6	0.5	0.13305	14.9471
8	8	0.5	0.07439	14.9047
9	10	0.5	0.04502	14.3666
10	12	0.5	0.03006	13.5813
11	16	0.5	0.0143	11.4941
12	20	0.5	0.00814	10.2281
13	25	0.5	0.008	9.81801
14	25	5	0.004183	7.88875
15	30	5	0.02837	7.78755
16	40	5	0.01484	7.34997
17	50	5	0.00889	6.91586
18	60	5	0.00589	6.6198
19	80	5	0.00381	6.0432
20	100	5	0.00164	3.14
21	120	5	0.02825	
22	150	5	0.00059	4.17057
23	200	5	0.00032	4.14186

Ves-03, Mukundpur2 along Bhalswa lake				
S. No.	**AB/2**	**MN/2**	**Resistance**	**Resistivity**
1	1.25	0.5	2.0065	8.27681
2	2	0.5	0.95724	11.2771
3	2.5	0.5	0.67225	12.6774
4	3	0.5	0.49432	13.594
5	4	0.5	0.27453	13.5895
6	5	0.5	0.16588	12.9009
7	6	0.5	0.10788	12.1213
8	8	0.5	0.05363	10.7464
9	10	0.5	0.03551	11.1325
10	12	0.5	0.01984	8.96854
11	16	0.5	0.00825	6.63478
12	20	0.5	0.00473	5.9503
13	25	0.5	0.0029	5.69902
14	25	5	0.0277	5.22364
15	30	5	0.01839	5.05808
16	40	5	0.01172	5.80209
17	50	5	0.00562	4.77683
18	60	5	0.00345	3.88422
19	80	5	0.00139	2.76569
20	100	5	0.00091	2.869
21	100	10	0.00331	3.16347
22	120	10	0.0021	4.74121
23	150	10	0.00123	4.34223
24	180	10	0.00082	4.1815

Ves-04, Near Bhalaswa Golf Course				
S. No.	**AB/2**	**MN/2**	**Resistance**	**Resistivity**
1	1.25	0.5	15.996	64.7661
2	2	0.5	11.926	25.2419
3	2.5	0.5	4.10592	77.426
4	3	0.5	3.00029	82.5081
5	4	0.5	1.5777	78.0965
6	5	0.5	1.02796	79.3892
7	6	0.5	0.64898	72.9181
8	8	0.5	0.22633	45.3477
9	10	0.5	0.0948	29.6274
10	12	0.5	0.04941	22.3237
11	16	0.5	0.01647	13.2447
12	20	0.5	0.00769	9.67257
13	25	0.5	0.00444	8.73288
14	25	5	0.354	6.67619
15	30	5	0.02243	6.17419
16	40	5	0.01157	5.72793
17	60	5	0.0439	4.93601
18	80	5	0.00229	4.6021
19	100	5	0.00135	4.25713
20	100	10	0.0029	4.518
21	120	10	0.00177	3.99869
22	150	10	0.00106	3.74275
23	180	10	0.00069	3.508
24	200	10	0.00053	3.3709
25	200	20	0.00105	3.28661
26	250	20	0.00069	3.3835
27	300	20	0.00044	3.09782
28	300	40	0.00091	3.18561
29	350	40	0.00076	3.64494
30	400	40	0.00056	3.54008
31	400	50	0.00045	3.60068
32	500	50	0.00026	2.54015

Ves-05, DDA Park, Bhalaswa				
S. No.	**AB/2**	**MN/2**	**Resistance**	**Resistivity**
1	1.25	0.5	41.9116	172.885
2	2	0.5	15.0808	177.739
3	2.5	0.5	9.33225	175.979
4	3	0.5	6.41255	176.345
5	4	0.5	3.3599	166.315
6	5	0.5	2.56107	199.214
7	6	0.5	1.9397	217.633
8	8	0.5	1.07987	216.36
9	10	0.5	0.70507	221.039
10	12	0.5	0.49307	222.763
11	16	0.5	0.19882	159.809
12	20	0.5	0.07979	100.248
13	25	0.5	0.0456	89.5525
14	25	5	0.43021	81.1261
15	30	5	0.23685	65.1346
16	35	5	0.13381	50.4659
17	40	5	0.07566	37.4558
18	45	5	0.04113	25.8587
19	50	5	0.0303	23.574
20	60	5	0.0132	14.835
21	70	5	0.00652	9.99973
22	80	5	0.00393	7.88977
23	90	5	0.00266	6.75193
24	100	5	0.00203	6.19459
25	100	10	0.00413	6.42567
26	120	10	0.0021	4.73008
27	150	10	0.00072	2.54608
28	180	10	0.00029	1.5062
29	200	10	0.00018	1.16385

Ves-06, Near Nala, Jahangirpuri				
S. No.	**AB/2**	**MN/2**	**Resistance**	**Resistivity**
1	1.25	0.5	3.08596	12.7295
2	2	0.5	1.59006	18.74
3	2.5	0.5	1.07699	20.3091
4	3	0.5	0.79238	21.7905
5	4	0.5	0.49571	24.5379
6	5	0.5	0.33851	26.3316
7	6	0.5	0.23679	26.6053
8	8	0.5	0.12215	24.4746
9	10	0.5	0.08107	25.418
10	12	0.5	0.05521	24.9464
11	16	0.5	0.03123	25.1074
12	20	0.5	0.0206	25.893
13	25	0.5	0.00943	18.5168
14	25	5	0.09451	17.8236
15	30	5	0.06259	17.2128
16	35	5	0.04456	16.8066
17	40	5	0.03257	16.1224
18	45	5	0.02412	15.1668
19	50	5	0.01893	14.7256
20	60	5	0.1201	13.4996
21	70	5	0.00762	11.6887
22	80	5	0.00492	9.86356
23	90	5	0.00322	8.17503
24	100	5	0.00193	6.05467
25	100	10		
26	120	10	0.0034	7.64512
26	120	10	0.0019	4.27668

VES-07, Sector -19 DDA Park Rohini				
S. No.	AB/2	MN/2	Resistance	Resistivity
1	1.25	0.5	14.5529	60.031
2	2	0.5	3.93757	46.4071
3	2.5	0.5	2.28131	43.019
4	3	0.5	1.26474	34.7805
5	4	0.5	0.54303	26.88
6	5	0.5	0.27682	21.5326
7	6	0.5	0.1661	18.6626
8	8	0.5	0.0881	17.6527
9	10	0.5		
10	12	0.5	0.04281	19.345
11	16	0.5	0.02889	23.2241
12	20	0.5	0.01862	23.3961
13	25	0.5	0.01895	37.2248
14	25	5	0.10355	19.5274
15	30	5	0.07135	19.6233
16	35	5	0.04992	18.8304
17	40	5	0.03726	18.4464
18	45	5	0.02819	17.724
19	50	5	0.02167	16.8628
20	60	5	0.01457	16.3768
21	80	5	0.00693	13.89
22	100	5	0.00326	10.2443

VES-08, Plain land opposite to Vasant Dada Nagar				
S. No.	AB/2	MN/2	Resistance	Resistivity
1	1.25	0.5	5.27799	21.7717
2	2	0.5	1.34794	15.8864
3	2.5	0.5	0.54407	10.2597
4	3	0.5	0.29039	7.98576
5	4	0.5	0.10287	5.09248
6	5	0.5	0.04785	3.7224
7	6	0.5	0.03047	3.42398
8	8	0.5	0.01392	2.79001
9	10	0.5	0.00867	2.72075
10	12	0.5	0.00695	3.1414
11	16	0.5	0.00513	4.12565
12	20	0.5	0.00397	4.99856
13	25	0.5	0.00416	8.17673
14	25	5	0.03203	6.04048
15	30	5	0.02428	6.67952
16	35	5	0.0199	7.50875
17	40	5	0.01724	8.53707
18	45	5	0.0142	8.92578
19	50	5	0.01241	9.65342
20	60	5	0.00785	8.83027
21	70	5	0.00457	7.0143
22	80	5	0.00321	6.44469
23	90	5	0.00254	6.45737
24	100	5	0.00199	6.2547
25	100	10	0.00961	7.18133
26	120	10	0.00316	7.10339
27	150	10	0.002	7.05817
28	180	10	0.00128	6.51097
29	200	10	0.00088	5.53351

VES-09, Swaroop Nagar Park, Bhalaswa				
S. No.	**AB/2**	**MN/2**	**Resistance**	**Resistivity**
1	1.25	0.5	3.50474	14.457
2	2	0.5	1.37983	16.2622
3	2.5	0.5	0.87183	16.4402
4	3	0.5	0.61478	16.9065
5	4	0.5	0.37936	18.7784
6	5	0.5	0.24596	19.1322
7	6	0.5	0.17336	19.4791
8	8	0.5	0.10723	21.4843
9	10	0.5	0.07667	24.0373
10	12	0.5	0.05863	26.4925
11	16	0.5	0.03731	29.9946
12	20	0.5	0.0266	33.4287
13	25	0.5	0.0202	39.6793
14	25	5	0.18631	35.1349
15	30	5	0.16711	32.2054
16	35	5	0.08019	30.246
17	40	5	0.04964	24.5758
18	45	5	0.03152	19.8158
19	50	5	0.0197	15.3244
20	60	5	0.01015	11.4115
21	70	5	0.00595	9.12257
22	80	5	0.00401	8.03682
23	90	5	0.00219	5.57972
24	100	5	0.00119	3.73436
25	100	10	0.00244	3.79788

VES-10, Shradhanad Park, Near Bhalaswa dairy				
S. No.	**AB/2**	**MN/2**	**Resistance**	**Resistivity**
1	1.25	0.5	4.63937	19.1374
2	2	0.5	4.40436	16.5514
3	2.5	0.5	0.90849	17.1316
4	3	0.5	0.64753	17.8071
5	4	0.5	0.43191	21.3796
6	5	0.5	0.3162	24.5964
7	6	0.5	0.2457	24.6069
8	8	0.5	0.16745	33.6111
9	10	0.5	0.11724	36.7563
10	12	0.5	0.0859	39.8164
11	16	0.5	0.04921	39.5583
12	20	0.5	0.0299	37.6656
13	25	0.5	0.02062	40.321
14	25	5	0.17676	33.3327
15	30	5	0.10196	28.9392
16	35	5	0.06217	23.4476
17	40	5	0.3643	18.0348
18	45	5	0.02682	16.8617
19	50	5	0.01923	14.9644
20	60	5	0.00896	10.0738
21	70	5	0.00488	7.48796
22	80	5	0.00373	7.48136
23	90	5	0.00312	7.92208
24	100	5	0.00306	6.54857
25	100	10	0.00355	5.53338
26	120	10	0.00217	4.89099
27	150	10	0.00122	4.31516
28	180	10	0.00077	3.93593
29	200	10	0.00044	2.70422

Annexure-VIII: Stakeholder Feedback Forms

Stakeholder Feedback Form

Name	Ankit Sharma
Village	Jahangirpuri
Tehsil	Model Town
District	NWD
Address	ITI, Jahangirpuri, K-Block
Mobile No.(optional)	
Type and Number of Structures	
Type	Tube well
Number	1
Coordinates	28.733024, 77.170516
Depth of well	30 mbgl (Reported)
Casing Depth HR	.
Slotted pipe depth SR	-
Fracture Encountered depth HR	-
Depth of installation of pump	
Average Water Level Pre-monsoon	5 - 6 mbgl
Average Water Level Post monsoon	5 - 6 mbgl
The well is used for	Building construction & cleaning purposes
Is water available throughout the Year	yes
If not for how many months water is available	-
Quality of water	slightly brackish
Common health issues in the area	

Stakeholder Feedback Form

Name	Suneel Raj
Village	Mukund pur
Tehsil	Model Town
District	Nth
Address	Near Sree Ram chowk, Jheemar village
Mobile No.(optional)	
Type and Number of Structures	
Type	TW
Number	1
Coordinates	28.752271, 77.182345
Depth of well	15 mbgl
Casing Depth HR	-
Slotted pipe depth SR	-
Fracture Encountered depth HR	-
Depth of installation of pump	12 mbgl
Average Water Level Pre-monsoon	4-5 mbgl
Average Water Level Post monsoon	4-5 mbgl
The well is used for	House construction & washing, cleaning purpose
Is water available throughout the Year	yes
If not for how many months water is available	-
Quality of water	slightly Brakish (yellowish)
Common health issues in the area	

Stakeholder Feedback Form

Name	Rampal
Village	Shradhanand colony
Tehsil	Model Town
District	North
Address	
Mobile No.(optional)	
Type and Number of Structures	
Type	Tube well
Number	1
Coordinates	28.74456, 77.15506
Depth of well	30mtr bgl (Reported)
Casing Depth HR	–
Slotted pipe depth SR	–
Fracture Encountered depth HR	–
Depth of installation of pump	28 mtrs
Average Water Level Pre-monsoon	6-7 mtrs
Average Water Level Post monsoon	5-7 mtrs
The well is used for	Washing purpose
Is water available throughout the Year	Yes
If not for how many months water is available	–
Quality of water	Not potable,
Common health issues in the area	Breathing issues

Stakeholder Feedback Form

Name	Rajender
Village	Bhalaswa Dairy (Near Durga chowk)
Tehsil	Model Town
District	North
Address	
Mobile No.(optional)	
Type and Number of Structures	
Type	Handpump
Number	1
Coordinates	28.74147, 77.16379
Depth of well	15 mtrs bgl)
Casing Depth HR	–
Slotted pipe depth SR	–
Fracture Encountered depth HR	–
Depth of installation of pump	–
Average Water Level Pre-monsoon	
Average Water Level Post monsoon	
The well is used for	Domestic purpose not for Drinking
Is water available throughout the Year	yes
If not for how many months water is available	–
Quality of water	slightly Brakish
Common health issues in the area	skin itching

Stakeholder Feedback Form

Name	Rahul singh
Village	Transport Nagar
Tehsil	Alipur
District	North
Address	
Mobile No.(optional)	
Type and Number of Structures	
Type	TW
Number	1
Coordinates	28.747596 , 77.148713
Depth of well	~~77.148713~~ 40 mbgl
Casing Depth HR	–
Slotted pipe depth SR	–
Fracture Encountered depth HR	–
Depth of installation of pump	30 mbgl
Average Water Level Pre-monsoon	12 – 13 mbgl
Average Water Level Post monsoon	11 – 13 mbgl
The well is used for	Washing & Cleaning
Is water available throughout the Year	Yes
If not for how many months water is available	–
Quality of water	Not potable for drinking
Common health issues in the area	–

Stakeholder Feedback Form

Name	Parveen Gupta
Village	Samaypur
Tehsil	Model Town
District	North
Address	Near Dispensary, MCD colony
Mobile No.(optional)	
Type and Number of Structures	
Type	TW
Number	1
Coordinates	28.742526, 77.145077
Depth of well	≈35 mbgl
Casing Depth HR	—
Slotted pipe depth SR	—
Fracture Encountered depth HR	—
Depth of installation of pump	25 mbgl
Average Water Level Pre-monsoon	16 – 18 mbgl (Reported)
Average Water Level Post monsoon	16 – 18 mbgl
The well is used for	Cleaning & Horticulture
Is water available throughout the Year	yes
If not for how many months water is available	—
Quality of water	Fresh to Saline
Common health issues in the area	

Stakeholder Feedback Form

Name	Sh. Surender Singh
Village	Bhalaswa Dairy
Tehsil	Model Town
District	NWD
Address	
Mobile No.(optional)	
Type and Number of Structures	
Type	TW
Number	2
Coordinates	28.73920, 77.15556
Depth of well	App. 80 mtrs
Casing Depth HR	–
Slotted pipe depth SR	–
Fracture Encountered depth HR	–
Depth of installation of pump	
Average Water Level Pre-monsoon	11 – 13 mbgl
Average Water Level Post monsoon	10 – 12 mbgl
The well is used for	Horticulture
Is water available throughout the Year	Yes
If not for how many months water is available	–
Quality of water	Brakish
Common health issues in the area	Breathing issues

Annexure-IX: Previous Studies Hydrogeological Data

Hydrogeological details of wells inventoried in Bhalsawa Landfill site

Sl. No.	Sample No.	Location	Nature of well	Depth of the well in (m)	Dia in mm	Aquifer tapped (reported)	Depth zones tapped (m bgl)	Depth to water level Dec, 03 (m bmp)	M.P. (m agl)	Depth to water level Dec_03 (m bgl)	Depth to water level June_04 (m bmp)	Depth to water level June_04 (m bgl)	Use
1	BH-1	Leachate location on the Western side of Sanitary land Fill in Sanjay Gandhi Transport Nagar	Leachate										
2	BH-2	In the premises of AG16, Bharat Motor transport Co., Sanjay Gandhi Transport nagar	Hand Pump	6	60	silty sand	3 to 6						Used for bathing and domestic uses
3	BH-3	Atlas Transport Corporation, AG-15, Sanjay Gandhi Nagar,	Tubewell fitted with jet pump	18	100	silty sand	12 to18	4.57	0.17	4.4	4.05	3.88	Used for washing and cleaning purpose
4	BH-4	MCD Toilet Complex, Sanjay Gandhi Transport Nagar, Adjacent to BG-234	Tubewell	60	153	silty sand		4.03	0.85	3.18	4.62	3.77	Used for toilets cleaning and flushing purpose
5	BH-5	Located infront of SLF Store, Eastern side of GT Road, about 10 m from the store	Tubewell	30	153	silty sand	18 to 30	6.09	0.5	5.59	5.8	5.3	Used for washing purpose

6	BH-6	Leachate collected from the SLF located on Eastern side of GT Road, Bhalsawa	Leachate										Leachate sample
7	BH-7	In side the complex of Vikram Poultry Farm, Shradanand Colony, 250 m from SLF, Bhalsawa	Tubewell	16	60	silty sand	13 to16	1.5	0	1.5	2.1	2.1	used for washing and bathing purpose
8	BH-7 (H.P.)	Inside the shiv temple which is located 100 m from Vikram Poultry farm	Hand Pump	12	60	silty sand	8 to 12	1.5	0	1.5	2.1	2.1	used for washing and bathing purpose
9	BH-8	In front of Raju Teastall, A-2, Durga Chowk, Bhalsawa Dairy	Hand Pump	7.6	60	silty sand	4.5 to 7.5						Used for washing and cooking purposes and some time drinking purposes
10	BH-9	10 m west of Road connecting Shradanand Colony-Saroop Nagar, D-Block of Shradanand Colony	Hand Pump	6	60	silty sand	3 to 6		1.0 m (reported)		1.5 m (Reported)		Reported water level is 1.5 m belog ground level
11	BH-10	Infront of the house of Ramji Parmal, D-I, Bhalsawa Colony, Near the intersection of Bhalsawa Dairy-Saroop Nagar Road with Burari Road	Hand Pump	20	60	silty sand	18-20	Surface Clay 0.00 to 3.00 mbgl Sand medium to coarse 3-9 m bgl, Clay yellow fine grained 9-12 m bgl, Sand yellow fine grained 12-30 m bgl with cly lenses at 18 to 20 m depth					Used for washing and cooking purposes and some time drinking purposes

12	BH-11	In the premises of shekhar Mkt, Gali No.12, Burari-Saroop Nagar Road	Hand Pump	7.6	60	silty sand	4.5 to 7.5						Used for washing and domestic uses
13	BH-12	Located in the premises of Pait makhbara, 50 m from the monument	Tubewell	30	253	Sand and kankar	21 to 29	2.94	0.16	2.88	3.6	3.44	Used for irrigational uses
14	BH-13	Beside D.S. Transport Corporation, BG-132	Hand Pump	33	100	Fine silt and kankar	24-32	4.42	0.4	4.02	5.28	4.88	Domestic uses
15	BH-14	Bhagwanpura Jhuggi, Public toilet complex	Tubewell	46	202	Fine silt and kankar	26 to 44	4.71	0.16	4.55	5.66	5.5	Drinking and domestic uses
16	BH-15	In front of Priya electrical, Bhalsawa Village,	Handpum p	7	60	Fine silt and kankar	6 to 7						Drinking and domestic uses
17	BH-16	Rajasthan Udyog Nagar, 58A car denting and painting centre	Tubewell	8	100	Fine silt and kankar	7 to 8						Drinking and domestic uses
18	BH-17	C-8, Rajasthan Udyog Nagar	Tubewell	25	100	Fine silt and kankar	18-24						Drinking and domestic uses

Annexure-X: Previous Studies Basic Chemical Quality Data

Chemical Quality of Ground Water (December, 2003) around Bhalsawa Sanitary Land Fill Sites													
			Concentrations in mg/L										
Sample-No.	pH	Electrical Conductivity µS/cm at 25 ^{o} C	CO3	HCO3	Cl	SO4	NO3	F	Ca	Mg	Na	K	Total Hardness as Ca CO3
BH-1	8.13	35100											
BH-2	7.48	2730	nil	660	282	437	37	1.25	46	36	520	89	265
BH-3	7.44	6030	nil	343	1284	1128	28	1.04	249	146	940	18	1221
BH-4	8.01	3510	nil	216	702	722	26	1.35	60	97	630	8.6	550
BH-5	7.52	8940	nil	267	2145	1763	37	1.45	329	229	1525	15	1761
BH-6	8	19600											
BH-7	7.38	4090	nil	355	924	588	1.8	0.58	148	87	680	11	730
BH-8	7.35	2430	nil	417	317	386	71	0.51	108	97	240	90	670
BH-9	7.31	10080	nil	254	2807	1686	20	1.01	489	350	1500	14	2812
BH-10	8.24	1783	nil	406	268	224	nil	1.86	32	17	365	5.4	150
BH-11	7.67	2890	nil	406	528	422	3.6	0.82	60	68	500	16	430
BH-12	7.5	2980	nil	456	525	482	4.6	0.86	80	64	530	16	465

Chemical Quality of Ground Water (June, 2004) around Bhalsawa Land Fill Site

Sample No.	pH	Electrical Conductivity (μS/cm) at 25 °C	Concentrations in mg/L									
			HCO3	Cl	SO4	NO3	F	Ca	Mg	Na	K	Total Hardness
BH-2	7.6	3020	628	400	480	50	1.5	42	54	590	2.8	327
BH-3	7.6	5850	228	1306	1230	26	1.41	179	156	930	90	1091
BH-4	7.96	4320	304	856	740	24	1.74	117	112	675	13	754
BH-5	7.8	8480	304	2123	1620	41	1.95	316	256	1500	8.1	1845
BH-7	7.73	4340	266	953	760	0.8	0.66	125	103	730	13	734
BH-8	7.5	1904	368	324	240	4.5	0.6	88	81	210	9.1	553
BH-9	7.44	10370	222	2885	1950	14	1	544	379	1500	80	2917
BH-10	8.4	2050	342	306	268	nil	2.8	42	29	385	9.9	226
BH-11	8.39	3720	305	553	720	2.1	0.2	32	54	700	15	300
BH-13	8.29	1545	46	135	456	63	1.27	32	34	183	108	220
BH-14	8.23	1770	427	255	245	2.3	0.85	40	51	298	7.8	310

Annexure-XI: Previous Studies Heavy metal Analysis Data

Heavy metal concentrations of Bhalsawa landfill site samples (December 2003)							
Sample No.	Concentrations in micrograms per litre						
	Cd	Cr	Cu	Fe	Mn	Ni	Zn
BH-1	11	7850	340	55568	308	671	832
BH-2	ND	ND	ND	233	322	ND	19
BH-3	ND	ND	6	515	397	ND	171
BH-4	ND	ND	ND	78	294	ND	282
BH-5	ND	ND	ND	40	ND	ND	49
BH-6	17	4660	1065	30969	289	678	1066
BH-7	ND	ND	ND	86	227	ND	10
BH-8	ND	ND	ND	31	5	ND	5
BH-9	ND	ND	ND	243	4000	ND	47
BH-10	ND	ND	57	504	6	ND	267
BH-11	ND	ND	ND	1403	791	ND	222
BH-12	ND	ND	ND	13155	498	ND	302

Annexure-XII: Previous Studies Isotopic Analysis Data

Isotopic analysis of Samples from Bhalsawa SLF site (December, 2003)					
S.No	**Sample No.**	**$\delta^{18}O$ (‰)**	**$\delta^{2}H$ (‰)**	**^{3}H [TU ± 1σ (0.5)]**	**$\delta^{13}C$ (‰)**
1	BH-1	-1.31	-3.06	174.48	15.6
2	BH-2	-6.46	-46	8.75	-12
3	BH-3	-6.8	-47.9	1.35	-7.03
4	BH-4	-7.39	-49.7	1.26	-14.3
5	BH-5	-6.65	-47.2	0.78	-11.4
6	BH-6	-1.49	-8.75	133.72	2.64
7	BH-7	-6.78	-45.6	0.46	-13.3
8	BH-8	-7.01	-50.5	10.18	-8.58
9	BH-9	-6.17	-45.5	4.75	-8.75
10	BH-10	-6.73	-48.4	1.6	-4.92
11	BH-11	-3.88	-35.68	10.72	
12	BH-12			1.6	-8

Isotopic analysis of samples from Bhalsawa SLF site (June 2004)					
S.No	**Sample No.**	**$\delta^{18}O$ (‰)**	**$\delta^{2}H$ (‰)**	**^{3}H [TU ± 1σ (0.5)]**	**$\delta^{13}C$ (‰)**
1	BH-2A	-5.94	-43.3	9.9	-11.35
2	BH-3A	-6.7	-45.7	6.7	-13.15
3	BH-4A	-7.12	-48.9	1.9	-11.25
4	BH-5A	-6.2	-45.7	4.84	-10.65
5	BH-7A	-6.49	-44	3.62	-12.79
6	BH-8A	-6.9	-46.9	9.9	-7.62
7	BH-9A	-6.11	-42.9	6.77	-7.82
8	BH-10A	-6.84	-46.7	4.68	-3.56
9	BH-11A	-3.78	-32.6	10.71	
10	BH-13A	-5.34	-34.9	14.41	-7.62
11	BH-14A	-6.84	-45.6	3.92	-12.61
12	BH-15A	-7.59	-48.7	11.34	-9.61
13	BH-16A	-5.99	-41.4		-11.08
14	BH-17A			11.3	

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