Program Management & Implementation Unit (PM&IU), Punjab Affordable Housing Program (PAHP)

Technical Study on Wastewater Treatment Options for Housing Schemes

DRAFT FEASIBILITY REPORT

January 2025

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List of Abbreviation

ABR	Anaerobic Baffled Reactor
ASP	Activated Sludge Process
AT	Aeration Tank
BDA	Bahawalpur Development Authority
BOD	Biochemical Oxygen Demand
BR	Blower Room
CAPEX	Capital Expenditure
COD	Chemical Oxygen Demand
CST	Communal Septic Tank
DT	Disinfection Tank
ESCF	Environmental and Social Compliance Framework
EP&CCD.	Environmental Protection and Climate Change Department
ESSF	Environmental and Social Systems Framework
FDC	Flow Distribution Chamber
GDP	Gross Domestic Product
GIS	Geographic Information System
GoP	Government of Punjab
HUD & PHE	Housing Urban Development & Public Health Engineering Department
IPF	Investment Project Financing
LG&CDD	Local Government and Community Development Department
LGs	Local Governments
MC	Municipal Corporation
MoU	Memorandum of Understanding
NESPAK	National Engineering Services Pakistan (Pvt.) Ltd.
NGO	Non- Government Organization
NOC	No Objection Certificate
NSL	Natural Surface Level
O&M	Operation and Maintenance
OPEX	Operational Expenditure
PAHP	Punjab Affordable Housing Program
PAHP-TA	Punjab Affordable Housing Program Technical Assistance
PATS	Pakistan Approach to Total Sanitation
PDO	Program Development Objective
PEQS	Punjab Environmental Quality Standards
PM&IU	Program Management and Implementation Unit
PST	Primary Settling Tank
RDA	Rawalpindi Development Authority
R-WASA	Rawalpindi Water and Sanitation Agency
SFS	Sludge Filter Shed
SHPS	Sludge Holding Pumping Station
SHT	Sludge Holding Tank
SP	Soakage Pit

SST	Secondary Sedimentation Tank
ST	Sludge Thickener
STPS	Sludge Thickener Pumping Station
TSS	Total Suspended Solids
UASB	Up Flow Anaerobic Sludge Blanket
WASA	Water and Sanitation Agencies
WSP	Waste Stabilization Ponds
WWTP	Wastewater Treatment Plant

Executive Summary

1. Introduction

The World Bank is supporting the Punjab Affordable Housing Program - Technical Assistance (PAHP-TA). This Program will be executed by a Program Management & Implementation Unit (PM&IU) of the Housing Urban Development and Public Health Engineering Department (HUD& PHED), Government of Punjab with the Urban Unit and Punjab Housing and Town Planning Agency (PHATA) as the co-implementing agencies.

The program will be implemented under the following three windows:

Window-1: Program for Results (P4R)
Window-2: Investment Project Financing (IPF) Support to strengthen housing policy, enabling environment, & institutions
Window 3: IPF - Program Management and Implementation Unit (PM&IU)

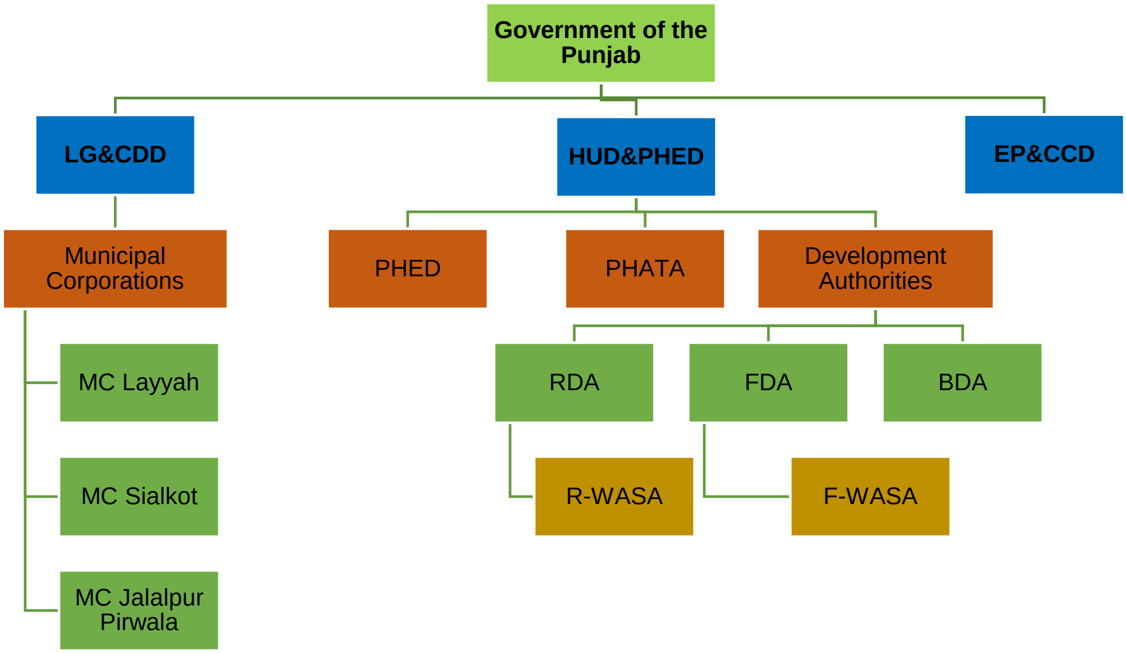
The current study evaluates and recommends feasible wastewater treatment options for PAHP by analyzing various treatment technologies and considering factors such as pollution load, land use, financial viability, etc. The recommendations of the current study will be made part of the Environmental and Social Compliance Framework (ESCF) proposed under the Environmental and Social Systems Assessment (ESSA) of the Program.

2. Institutional Arrangement and Regulatory Framework

Three key departments of the Government of Punjab manage sewage disposal and treatment including HUD&PHED, the Local Government and Community Development Department (LG&CDD), and the Environmental Protection and Climate Change Department (EP&CCD). However, these departments have broader roles but they will have program-specific roles i.e., HUD&PHE will assist in formulating policies related to proposed PAHP Housing Schemes, LG&CDD will manage, operate, maintain, and improve the municipal infrastructure and services and EP&CCD will regulate the management of wastewater, solid waste and all other types of pollution through regulation and enforcement.

Among the other departments Punjab Housing and Town Planning Agency (PHATA) will act as a regulator throughout the project implementation. The Municipal Corporations (MCs) are responsible for implementing local sewage management systems, including operating and maintaining sewage treatment facilities and Water and Sanitation Agencies (WASAs) provide clean water and sanitation services to urban areas in various cities across Pakistan.

The organogram of the functionaries involved in the project is given hereunder:



The applicable environmental regulatory framework and standards are National Sanitation Policy, 2006, Pakistan Approach to Total Sanitation (PATS) 2010, National Climate Change Policy, 2021, Punjab Urban Water and Sanitation Policy, 2007, WASA Regulations Faisalabad 2015, Punjab Municipal Corporation Act, 1976, Punjab Environmental Quality Standards (PEQS), 2016, and Punjab Environmental Protection Act 1997 (Amended 2022).

3. Field Visits and Investigations

The field visits were intended to select wastewater sampling points and to assess the present status of wastewater treatment needs of the housing scheme based on the sewage network disposal and characteristics. The Consultants initially identified various housing schemes through Geographic Information System (GIS) tools in the selected cities for wastewater sampling and conducted the field visits in the month of September 2024. Following on-site evaluations, several housing schemes were removed from the list, and new schemes were identified due to unavailability of sewerage network and not complying with the requirements of TORs. Additionally, the socioeconomic conditions of the identified schemes were also assessed to aid decision making.

4. Wastewater Characterization & Analysis

Wastewater characterization is a matter of primary importance in the planning and designing of wastewater treatment systems. Though it is important to test the wastewater of the actual source at the time of planning, currently there are no functional housing schemes under the program. However, PMIU has initially identified nine (09) potential sites for the proposed interventions. Therefore, the wastewater characterization was performed from similar schemes in the vicinity of identified sites.

24-hour composite sampling were carried out to present a better picture of wastewater characteristics. Each sample collected is combined into a single composite sample, providing an average representation of wastewater characteristics throughout the day. The sampling and testing were conducted in September and October 2024 by M/S SGS and M/s Pak Green Enviro Engineering Pvt. Ltd.

The statistical analysis was conducted for key wastewater quality parameters, i.e., Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Suspended Solids (TSS). On a broader scale the samples were segregated on the bases of geographical region i.e., South, Central and North Punjab as well as socio-economic status of the communities i.e., High-income, Medium-income and Low-income communities.

The mean and median values of the key parameters are well within the permissible limits; however, these values are observed to be higher in the south region as compared to others. This could be due to varying standards of living and the availability of water in the region. In the case of medium income communities, the values were observed to be slightly higher in the North region. This is the specific case of Rawalpindi where there is acute shortage of water, and the dilution of wastewater is minimum. The values in the low-income communities are higher irrespective of the geographical location. The primary reason is the limited availability of water.

In addition to the measurement of key parameters from raw samples, the samples were also subject to settling and then the filtered samples were analyzed. It was concluded that the wastewater if subject to primary settling, then 30% of the pollution load is reduced.

Overall, the wastewater is characterized as low strength, with a significant proportion of pollution coming from settleable solids.

5. Wastewater Management Options

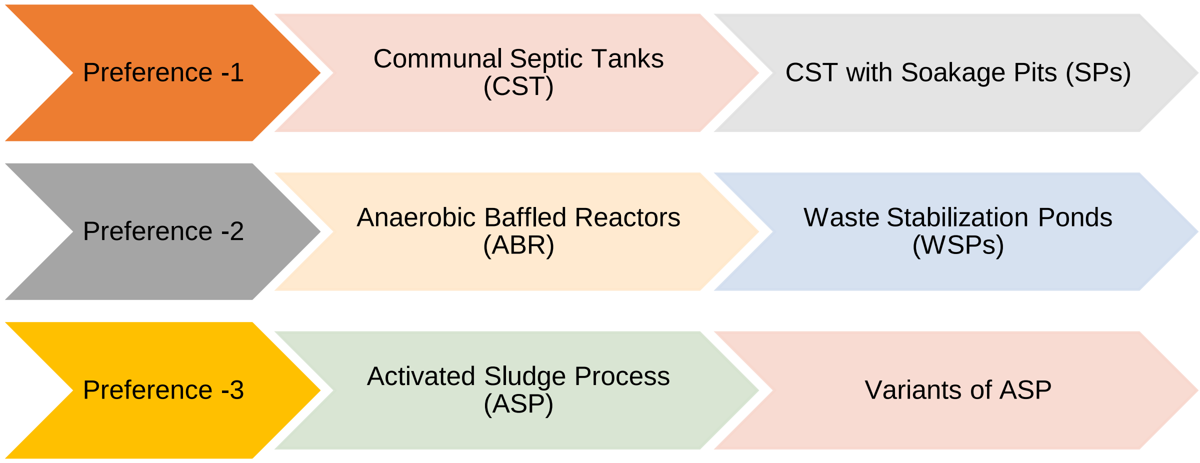
Wastewater treatment is complex and costly, typically managed at the municipality's final collection and disposal site. Once wastewater from a housing or commercial area connects to the municipal sewer system, it becomes the municipality's responsibility. Therefore, the program focuses on conveying sewage into the existing community network while ensuring regulatory compliance and meeting institutional requirements.

There could be the following four (04) scenarios in terms of the connectivity of sewage:

Scenario – 1: The municipality sewer will be adjacent to the housing scheme.
Scenario – 2: The municipality's sewer line is available but situated at a considerable distance. The project will construct a new sewage conveyance channel for connection.
Scenario – 3: There could be cases where the municipality WWTP is available.
Scenario – 4: Lastly, if it is not possible to make a connection with the existing municipality sewer, the program will provide a wastewater treatment plant (WWTP) as the last resort.

Preferences of Wastewater Treatment Options

In the light of wastewater characterization, the following preferences have been defined in terms of selection of wastewater treatment methods.

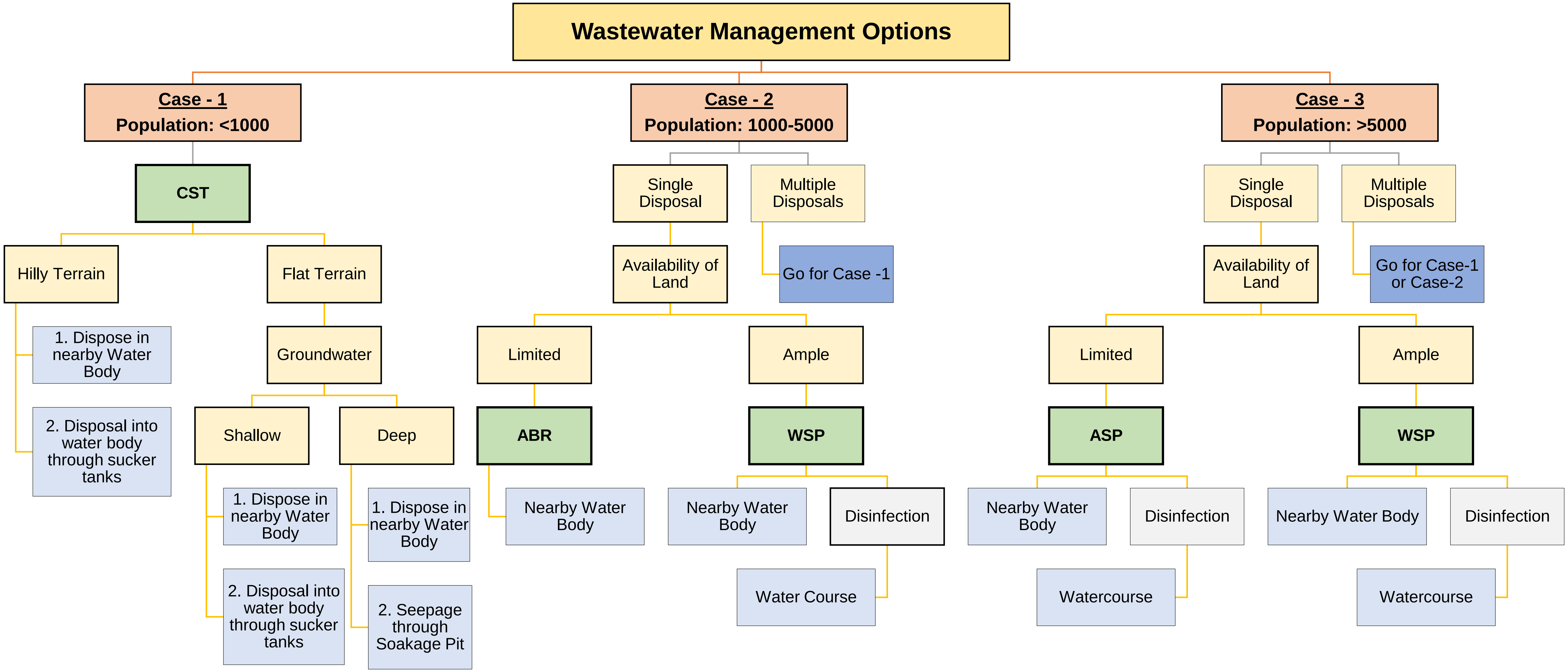


Wastewater Management Options

Based on population, three distinct scenarios have been established, each corresponding to a tailored approach for wastewater management. Detailed explanations of each scenario are provided below:

Case – 1: Population < 1000
Case – 2: Population 1000 - 5000
Case – 3: Population > 5000

The chart below presents all three cases discussed above.


Wastewater Management Options
Case - 1
Population: <1000
Case - 2
Population: 1000-5000
Case - 3
Population: >5000
CST
Single Disposal
Multiple Disposals
Single Disposal
Multiple Disposals
Hilly Terrain
Flat Terrain
Availability of Land
Go for Case -1
Availability of Land
Go for Case-1 or Case-2
1. Dispose in nearby Water Body
Groundwater
Limited
Ample
Limited
Ample
2. Disposal into water body through sucker tanks
Shallow
Deep
ABR
WSP
ASP
WSP
1. Dispose in nearby Water Body
1. Dispose in nearby Water Body
Nearby Water Body
Nearby Water Body
Disinfection
Nearby Water Body
Disinfection
Nearby Water Body
Disinfection
2. Disposal into water body through sucker tanks
2. Seepage through Soakage Pit
Water Course
Watercourse
Watercourse

6. Proposed Wastewater Treatment Systems

Based on the wastewater characterization the following four (04) wastewater treatment systems have been proposed.

i. Communal Septic Tank (CST)

The septic tank is a water-tight container usually made of concrete, fiberglass, or polyethylene to hold the wastewater long enough to allow solids to settle down to the bottom forming sludge, while the oil and grease floats to the top as scum. A septic tank when receiving the flow from multiple Houses of a community or the entire population is called a communal septic tank (CST).

ii. Anaerobic Baffled Reactor (ABR)

Anaerobic Baffled Reactor (ABR) is an improved form of septic tank which is divided into series of compartments. It is a rectangular anaerobic digester. ABR combines the characteristics of septic tank and more sophisticated digesters models such as Up Flow Anaerobic Sludge Blanket (UASB) reactors etc. ABR works on the principle of anaerobic digestion in which sludge blanket of granules of bacteria is developed. Contact of organic matter with the granules of bacteria enhances the digestion rate.

iii. Waste Stabilization Ponds (WSP)/ Natural Lagoons

Waste Stabilization Ponds are among the common systems adopted around the world, especially in developing countries. Low construction and operating cost make this option a financially attractive alternative compared to other treatment systems. WSP comprise a single series of anaerobic, facultative and maturation ponds or several such series in parallel.

iv. Activated Sludge Process (ASP)

Activated sludge process is a mechanized treatment technology employed to reduce the colloidal BOD which remains after PSTs. In an activated sludge process, microorganisms (MO) are mixed with organic matter so that they can grow and stabilize the influent organic matter.

7. Environmental and Social Impacts

Communal septic tanks, anaerobic baffled reactors (ABRs), waste stabilization ponds (WSPs), and activated sludge processes (ASP) vary in climate resilience. Septic tanks and WSPs are simple and adaptable but vulnerable to flooding. ABRs tolerate variable inflows but are less effective in cold climates, while ASPs offer high efficiency but are energy-dependent and sensitive to disruptions. Climate-resilient designs and hybrid approaches can enhance their performance.

8. Conclusion And Recommendations

The conclusions and recommendations have been drawn from the current study with respect to selection of the most feasible wastewater management options for proposed PAHP Housing Schemes.

Conclusions

1. The wastewater characterization results from a total of 40 wastewater samples in six (06) cities reveal that the tested wastewater is of low strength irrespective of the socioeconomic status of the selected schemes and the geographical location. Most of the values were observed to be within the prescribed limits of Punjab Environmental Quality Standards (PEQS), either from the household sample or the end-of-pipe sample.
2. No major fluctuations have been observed in the values of key parameters, i.e., BOD, COD and TSS except for a sample from a low-income scheme in the south region and two samples from Rawalpindi. It is pertinent to mention that the corresponding samples in Rawalpindi are from the areas where there is acute water shortage, and the community is dependent on water tanks for potable needs. The less usage of water undermines the dilution of waste, hence higher values have been observed.
3. The key wastewater quality parameters were tested from the raw sample as well as from the filtered sample which was allowed to settle for 1 hour in an Imhoff cone to analyze the settleable pollution. Interestingly, a sufficient reduction was observed in the settled sample indicating the presence of settleable solids/pollution in the wastewater samples. This indicates that the wastewater if subject to primary settling, then 30% of the pollution load is reduced, which further strengthens the stance that only simple treatment technologies can serve the purpose of meeting the PEQS.

Recommendations

1. The statistical analysis of the wastewater characterization results reveals that the wastewater is low-strength and mostly comprises settleable pollutants, which if allowed sufficient settling, clears out most of the pollution. Hence the wastewater treatment technologies for the proposed PAHP Housing Schemes do not need to be complex or cutting-edge technologies, rather they need to be simple yet efficient systems to serve the primary objective of meeting the PEQS while keeping the construction and operation expenses to the minimum.
2. The most suitable technologies to be adopted for the proposed PAHP Housing Schemes in terms of preference of selection are as follows:

1 INTRODUCTION

1.1 Overview

The World Bank is supporting the Punjab Affordable Housing Program - Technical Assistance (PAHP-TA). This Program will be executed by a Program Management & Implementation Unit (PM&IU) of Housing Urban Development and Public Health Engineering Department HUD & PHE Department, Government of Punjab with the Urban Unit and Punjab Housing and Town Planning Agency (PHATA) as the co-implementing agencies.

The Program Development Objective (PDO) is to support the Government of Punjab in strengthening its housing institutions, processes, and systems while enhancing the quantity and quality of affordable housing. In collaboration with the World Bank, the PAHP will be implemented during the span of five years (i.e., 2022-27).

PAHP will support climate resilience in the future and planned affordable housing schemes through adaptation measures, which may include green stormwater infrastructure with a high capacity to capture and absorb rainwater on-site, permeable pavement materials on roads to slow runoff, solid waste collection points to discourage dumping in open drains and sewerage system.

The program will be implemented under the following three windows:

Window-1: Program for Results (P4R)
Window-2: Investment Project Financing (IPF) Support to strengthen housing policy, enabling environment, & institutions
Window 3: IPF - Program Management and Implementation Unit (PM&IU)

PM&IU - PAHP has hired the services of National Engineering Services Pakistan (Pvt.) Ltd. (NESPAK) for the project titled “Technical Study on Wastewater Treatment Options for Housing Schemes”.

The assessment and findings of the study will form a theory of change that will ultimately help PHATA for the adoption of technically and financially viable solutions for wastewater treatment in its future housing schemes. The study will provide a list of alternative wastewater treatment systems with safe disposal arrangements for PAHP Housing Schemes with preliminary design level details to establish Punjab Environmental Quality Standards (PEQS) compliance, engineering estimates per household for capital and O&M costs, institutional arrangements at implementation and operational stages, for the PAHP Housing Schemes.

1.2 Need and Purpose of Study

The current study evaluates and recommends feasible wastewater treatment options for PAHP by analyzing various treatment technologies and considering factors such as pollution load, land use, financial viability, etc. The recommendations of the current study will be made part of the Environmental and Social Compliance Framework (ESCF) proposed under the Environmental and Social Systems Assessment (ESSA) of the Program.

1.3 Program Background

Islamic Republic of Pakistan is urbanizing at the rate of 3 percent per annum, which is the highest urbanization rate in South Asia. Its population is also expected to reach between 270 and 300 million people by 2050 as per World Bank estimates. Over the next 20 years, annual urban population increase is expected to be 2.3 million per year (around 360,000 Houses if they remain at 6.5 individuals per household).

Punjab Province is the most populous province with a population of 110 million and represents 46 percent share of Pakistan's population. 36.7 percent of the Punjab's population lives in urban areas. Urban population growth in the Punjab is primarily driven by migration from rural areas (60 percent of all recent migrants to Punjab's urban centers came from rural areas). The five major cities of Punjab Province have half of the urban population of the whole province. The demand for urban housing is particularly strong in the largest urban agglomerations. Growing urbanization is putting constraints on the government's efforts to provide affordable housing, infrastructure and services, and economic opportunities. Housing investment and construction make up 12.8 percent of Pakistan's GDP in 2019, while construction and real estate sectors counted for 7.6 percent of urban employment during 2017–18.

Over the past decade, the private sector supply of affordable housing in Punjab Province has been minimal and it has predominantly catered for the richer segments of the population. The housing market in Punjab Province is divided between formal and informal. The formal market primarily targets high-income groups and speculators and is beyond the reach of most of the population. The informal market encompasses unapproved developments and slums or Katchi Abadis. Such informal housing, along with regularized Katchi Abadis with rented and self-occupied units, provides the de facto "affordable housing" for the low- and lower-middle income population in Punjab Province.

The current program is being supported by the World Bank to elevate the housing issues in a financially affordable, environmentally sustainable and socially acceptable manner.

1.4 Objectives of the Consultancy

The overall objectives of this study are as follows:

- Establishing the expected characteristics of wastewater of PAHP Housing schemes based on the wastewater characterization of similar housing schemes in Punjab.
- Analyzing, evaluating, and recommending alternative wastewater treatment methods and technologies along with sludge treatment and its final disposal in an environmentally friendly way. This will be based on pollution loading, land requirements, site and geotechnical conditions, simplicity/complexity, energy and related resources demand,

sensitive environmental and social receptors, and equipment and material demands, while drawing on the lessons learnt and other good international best practices and examples.

- Developing designs and specifications and suggesting institutional arrangements for the management of treatment and disposal of wastewater from PAHP Housing Schemes to existing sewerage and drainage system of Water and Sanitation Agencies (WASAs), Municipal Corporations (MCs) and committees, Local Governments etc. in compliance with the applicable environmental regulatory framework (provincial/national) and Core Principles of World Bank (WB) Policy Program for Results (PforR) and standards.
- Proposing preferred options for wastewater treatment systems including disposal for PAHP Housing schemes located at sites which will not be able to connect with existing sewerage and drainage infrastructure, in line with technical, financial and environment and social (E&S) considerations.
- Developing per Household capital and operations and maintenance (O&M) cost estimates of alternative wastewater systems and sludge treatment options for housing schemes.

1.5 Program Area

The program will be implemented in major cities across Punjab province, covering the northern, central, and southern regions. A list of cities for the proposed housing schemes has been provided by PM&IU-PAHP via email dated 15.08.2024.

Table 1.1: List of Selected cities for study

Location	Large Cities	Medium Cities
Northern Punjab	Rawalpindi	Sialkot
Central Punjab	Faisalabad	Layyah
Southern Punjab	Bahawalpur	Jalalpur Pirwala

1.6 Scope of the Consultant

The study will provide a list of alternative wastewater treatment systems with safe disposal arrangements/options for PAHP Housing Schemes with preliminary design level details to establish PEQS compliance, engineering estimates per household for capital and O&M costs, institutional arrangements at implementation and operational stages, for the PAHP Housing Schemes. The scope, duties, and responsibilities of the consultant will include the following tasks to undertake the stated objectives:

- Collection and analysis of relevant data on sources and volumes of wastewater, and establish the characteristics of wastewater (physical, chemical, and biological) as per PEQS of existing similar housing schemes included in the program from at least six (06) cities of Punjab based on their size (large and medium) and location (north, center and south). At least 05 schemes will be studied and evaluated in each city based on income level, size of households and spread across the city in different zones (for example, near industrial zone, in the densely populated zone, near commercial zone, and away from the main city centers etc.). The samples of wastewater will be collected for testing from following locations:

- Near individual houses.
- At boundary of target scheme/settlement.

- Comparative analysis of different alternative wastewater treatment processes/ technologies suitable for PAHP housing schemes including green infrastructure options based on the factors including but not limited to pollution loading, land requirements, per Household capital and operation & maintenance costs, treatment efficiency, sludge production, energy demand and efficiency, simplicity/complexity, comparison of merits and demerits, design age, ease of operation & maintenance, labor qualification, equipment and material demand, and environmental and social sustainability etc. to reach at a most suitable treatment technology.

- Recommend the most feasible optimal technologies as per the size and location of the city as well as the category of the housing schemes in the program with respect to population / number of unit (at least three categories).

- Identify and analyze relevant laws, rules, regulations, and standards applicable on the wastewater treatment of PAHP Housing Schemes and recommend modifications if required for the selected alternatives. Carry out the economic / financial, environmental, social and legal framework analysis of the alternative of the wastewater treatment options and recommend design mechanisms and institutional terms and conditions for the disposal of wastewater from PAHP housing scheme to the existing city sewerage and drainage network (WASAs, Local Governments etc.) and for those schemes which will not be connected with existing sewerage and drainage network in line with technical, financial and E&S considerations.

- Preparation of Conceptual Designs, Specifications and per Household Capital and O&M Cost estimates of preferred options including treated wastewater quality (as per PEQS), sludge management for WWTPs and its final disposal. Moreover, assessment of environment & social impacts including but not limited to identification of possible environmental and social risks, impacts, and mitigation measures for the recommended options should be included.

- Develop institutional responsibilities for constructing and operating the recommended wastewater treatment systems in liaise with all concerned entities (Water & Sanitation Agencies / Local Governments, HUD & PHE Departments and NGOs) working in the sector to ensure coordination and compatibility of solutions. In addition, support the Client to develop inter-institutional terms and conditions for transporting wastewater from PAHP Housing Schemes to existing infrastructure networks of WASAs, MCs, and LGs and coordinate with Punjab EPA.

- Organize technical consultations with stakeholders including the World Bank, PHATA, The Urban Unit, other relevant Government Departments, Water and Sanitation Agencies, Developers, end users etc. to review the findings of the draft report and gather feedback to be incorporated in the final output. The final deliverable will take into account the feedback and comments received on the draft report.

1.7 Structure of Report

- Chapter 1: Introduction
- Chapter 2: Regulatory Framework and Institutional Arrangement
- Chapter 3: Field Visits and Investigations
- Chapter 4: Wastewater Characterization and Statistical Analysis
- Chapter 5: Wastewater Management Options
- Chapter 6: Proposed Wastewater Treatment Systems
- Chapter 7: Conclusion and Recommendation

1.8 Study Team

Sr #	Study Team	Designation
1.	Mr. Ali Hamid	Project Manger
2.	Mr. Saeed Husain	Social Development Expert
3.	Ms. Saba	Senior Design Engineer
4.	Mr. Syed Zeeshan Abbas	Senior Environmental Engineer
5.	Mr. Malik Tariq Mahmood	Senior Design Engineer
6.	Mr. Abdul Manan	Senior Design Engineer
7.	Mr. Muhammad Ali	Design Engineer
8.	Mr. Muhammad Anns	Design Engineer
9.	Mr. Tahir Sajjad	Design Engineer

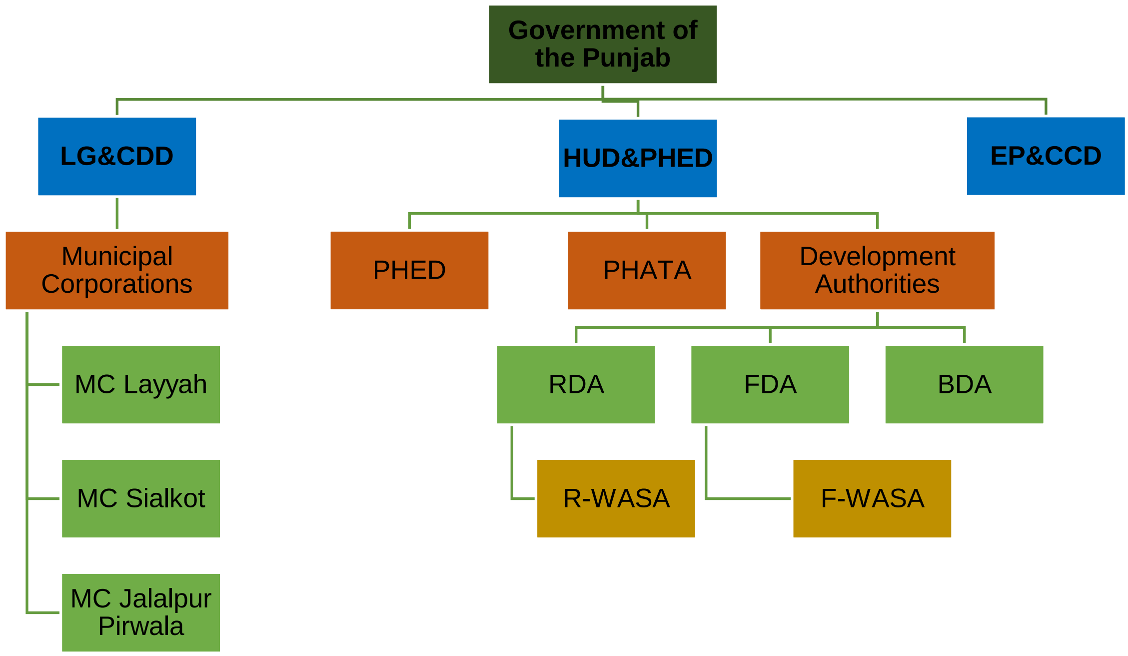
2 INSTITUTIONAL ARRANGEMENT AND REGULATORY FRAMEWORK

2.1 General

There are several functionaries involved in the implementation of the PAHP. However, the disposal, management, and treatment of wastewater (section 5- scenario 1, 2, 3 and 4) are dealt with separately, hence the relevant institutions need to be brought on board for successful implementation of the project. This section overviews the institutional arrangements and applicable environmental regulatory framework and standards.

2.2 Institutional Functionaries

Three apex departments of the Government of Punjab (GoP) mainly deal with sewage disposal and treatment, namely the Housing, Urban Development and Public Health Engineering (HUD&PHE) Department, Local Government and Community Development Department (LG&CDD), and Environmental Protection and Climate Change Department (EP&CCD). These departments have several other responsibilities as well as various offices involved, but the program-specific organogram is given hereunder:



Legends:

RDA:	Rawalpindi Development Authority
FDA:	Faisalabad Development Authority
BDA:	Bahawalpur Development Authority
F-WASA:	Faisalabad Water and Sanitation Agency
R-WASA:	Rawalpindi Water and Sanitation Agency

Figure 2.1: Organogram of Institutional Arrangements

PHED is responsible for planning, designing, constructing, and maintaining water supply and sanitation infrastructure, primarily in rural and peri-urban areas, ensuring access to safe drinking water and sanitation services. PHATA focuses on urban planning and housing development in Punjab, overseeing low-cost housing schemes and ensuring affordable housing options. The Development Authorities, such as Rawalpindi Development Authority (RDA) and Faisalabad Development Authority (FDA), manage urban development, infrastructure, and regulatory oversight in their respective cities. Both authorities have theirown Water and Sanitation Agencies i.e., R-WASA and F-WASA, which handle water supply, sewage, and sanitation services.

2.3 Roles and Responsibilities

The roles and duties of each department are given hereunder.

i. Housing, Urban Development and Public Health Engineering (HUD&PHE) Department

Scope: State-level jurisdiction overseeing urban development and housing projects across Punjab.

Responsibilities:

- Formulating policies related to urban planning, housing, and infrastructure development.
- Setting state-wide standards for sewage management and environmental sustainability.
- Planning and implementing large-scale infrastructure projects, including sewage treatment plants.
- Coordinating with other state departments and agencies for integrated urban development.

ii. Punjab Housing and Town Planning Agency

Scope:

Responsibilities:

Rejuvenating the housing sector in general and provision of shelter to shelter-less low-income groups in particular.

- Implementing parameters of the national housing policy, coordinating and liaising with the Federal Government, District Governments, Tehsil Municipal Administrations, concerned departments and agencies.
- Identifying state and other lands for developing low-income and low-cost housing schemes.
- Providing affordable, cost-efficient housing schemes, especially for low-income groups and families out of the Revolving Fund.

- Promoting an environment for friendly and standardized construction activities (Cluster Housing).
- Facilitating land availability through various innovative measures, develop a comprehensive land information system (Land Bank) to cater for the planning and development requirements for a period of five to ten years (Forward Planning).
- Formulating provincial land use policy, plan and prepare regional development plans (Inter district spatial planning – Master plans) for an integrated, coordinated and systematic planning to ensure orderly growth and development of physical infrastructure such as highways, railways, industrial zones, conservation of forest reserves and provision of electricity, telephone, sui gas, etc.
- Developing land disposal systems that are unified, transparent and market-oriented with open auction policy and exceptions for special needs.

iii. Municipal Corporations

Scope: Local-level jurisdiction within specific urban areas (cities and towns) in Punjab.

Responsibilities:

- Implementing local sewage management systems, including operating and maintaining sewage treatment facilities.
- Regulating and managing the collection, treatment, and disposal of sewage within their jurisdiction.
- Ensuring compliance with state and national sewage treatment standards.
- Conducting public awareness campaigns and community engagement related to sewage disposal and sanitation.

iv. Local Government & Community Development Department (LG&CD)

Scope: Local-level jurisdiction within specific urban areas (cities and towns) in Punjab.

Responsibilities:

- Provide, manage, operate, maintain, and improve the municipal infrastructure and services
- Manage properties and assets vested in local governments
- Enforcement of municipal laws and regulations
- Perform functions within the provincial framework
- Frame bye-laws to regulate municipal services
- Take cognizance of municipal offenses and enforcement

2.1 Interrelationship Between HUD&PHED & MC

The jurisdictions of HUD&PHED and MCs are distinct yet interconnected, particularly regarding urban planning and sewage management.

Collaboration: While HUD&PHE sets broader policies and standards, Municipal Corporations are responsible for executing those policies at the local level.

Regulatory Oversight: HUD&PHE monitors the performance of Municipal Corporations to ensure adherence to state policies and standards.

v. Environmental Protection and Climate Change Department (EP&CCD)

EP&CCD plays a key role in managing wastewater through regulation and enforcement. It ensures compliance with environmental laws, particularly the treatment of wastewater by industries and municipalities before discharge. The department promotes the construction of wastewater treatment plants, monitors water quality, and raises public awareness about sustainable wastewater practices.

vi. Water and Sanitation Agencies (WASAs)

The Water and Sanitation Agencies (WASAs) provide clean water and sanitation services to urban areas in various cities across Pakistan. Its main responsibilities include the supply, treatment, and distribution of potable water, as well as the collection, treatment, and disposal of wastewater. WASAs play a critical role in maintaining and expanding water infrastructure, ensuring that residents have access to clean drinking water, and managing effective drainage and sanitation systems to prevent pollution and maintain public health.

vii. Role of District Councils (DCs)

Scope: Pakistan, manage local governance, infrastructure development, and public services in rural areas, focusing on community welfare and regulatory functions.

Responsibilities:

- District Councils (DCs) will manage and supervise the wastewater treatment plants in their respective domains.
- DCs work closely with local stakeholders to identify sustainable solutions and manage resources effectively in the PAHP.

2.4 Roles of Institutions in PAHP

i. Development Authorities (RDA, BDA and FDA)

Among the selected cities for the proposed PAHP Housing Schemes, the development authorities are functional in three (03) cities i.e., FDA, RDA and BDA. Regarding wastewater disposal; connections to main trunks; and treatment, the development authorities are responsible for issuing NOCs to the new housing schemes after necessary documentation, fieldwork, and investigations.

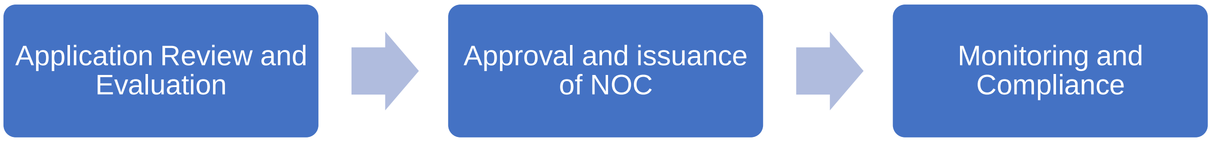
In the present case, BDA will be approached to seek approval for the disposal/ management/ treatment of wastewater from the proposed Housing Schemes. However, in Rawalpindi and Faisalabad, the powers have been devolved to the WASAs, who do the needful on their part, in terms of sewage disposal and management.

Recommendation

In addition to the initial approval, the development authorities and WASAs are also responsible for the operation and maintenance of sewerage lines and wastewater treatment plants. Thus, they need to be taken on board and the MoU needs to be signed with them for the O&M. Further, adequate funds should be allocated for the capacity building and trainings of the personnel involved in the O&M of WWTPs.

ii. Water and Sanitation Agencies (WASAs)

R-WASA and F-WASA have a systematic procedure for the issuance of NOCs to the housing schemes for wastewater disposal which is discussed hereunder:



iii. Municipal Corporations (MCs)

Municipal Corporations (MCs) will be involved in Sialkot, Layyah and Jalalpur Pirwala. Being municipal services providers, MCs will ensure that the proposed housing schemes are managing their wastewater adequately. They will provide technical support and relevant data to the project for adhering to the municipal services delivery standards.

2.5 Applicable Environmental Regulatory Framework and Standards

The applicable environmental regulatory framework and standards are given in the Table below:

Table 2.1: Key National /Provincial and International Acts and Policies

Sr. No.	Regulatory Instrument	Brief Coverage	Relevance to project
National Regulations/Policies/Acts			
1	National Sanitation Policy, 2006	The National Sanitation Policy of Pakistan, 2006, stresses the safe disposal of excreta away from the dwellings, the creation of an open defecation-free environment, and	The project will ensure compliance with the policy and ensure that the wastewater from the proposed housing schemes is managed safely in an environmentally friendly manner.

Sr. No.	Regulatory Instrument	Brief Coverage	Relevance to project
		the promotion of health and hygienic practices in the country.	
2	Pakistan Approach to Total Sanitation (PATS) 2010	The PATS is aimed towards achieving and sustaining an open defecation-free environment both in rural and urban contexts with a clear emphasis towards behavioral change and social mobilization enhancing the demand side of sanitation. It contains several branded total sanitation models, having a key role in communities, which include: • Community Led Total Sanitation • School Led Total Sanitation • Component Sharing • Sanitation Marketing • Disaster Response The above models may be adopted by the provincial and local governments in accordance with what suits best in their local context and in accordance with the reinforcement values of PATS.	The applicable model of Community Led Total Sanitation under PATS will be adopted in the proposed housing schemes.
3	National Climate Change Policy, 2021	The National Climate Change Policy provides a framework for addressing the issues that Pakistan faces or will face in the future due to the changing climate. Given Pakistan's high vulnerability to the adverse impacts of climate change, particularly extreme events, adaptation effort is the focus of this policy document. The vulnerabilities of various sectors to climate change have been highlighted and appropriate adaptation measures spelled out.	The climate-resilient infrastructure will be provided to adapt to environmental challenges. Wastewater treatment plants will be able to withstand the effects of climate change, such as extreme weather events, flooding, and droughts. Furthermore, carbon emissions will be minimized from the project.
Provincial Regulations/Policies/Acts			
1	Punjab Urban Water and Sanitation Policy, 2007	The Punjab Urban Water and Sanitation Policy of the Government of Punjab is intended to guide and support provincial institutions, District Governments, Tehsil Municipal Administrations, Water Utilities and communities for improving water and sanitation services.	The project will comply with Punjab urban water and sanitation policy.
2	WASA Regulations	WASA Regulations govern water supply, sewerage, and drainage systems in urban areas. Provision of	The project will follow WASA Regulations while making connections with the existing

Sr. No.	Regulatory Instrument	Brief Coverage	Relevance to project
	Faisalabad 2015	this regulation is safe drinking water, efficient wastewater management, and proper stormwater drainage. Housing schemes must obtain No Objection Certificates (NOCs) for connections to WASA's sewer lines and water supply. WASA enforces compliance with effluent quality standards for wastewater disposal. It also regulates water tariffs, monitors infrastructure maintenance, and imposes penalties for non-compliance.	sewerage network or in case of construction and O&M of wastewater treatment plants.
3	Punjab Municipal Corporation Act, 1976	The Punjab Municipal Corporation Act, 1976 provides the legal framework for the establishment and functioning of municipal corporations in Punjab. It outlines the powers and responsibilities of municipal bodies in areas such as urban planning, infrastructure development, and public service delivery. The Act provides essential services like water supply, sanitation, waste management, and public health. Municipal corporations are responsible for imposing taxes, maintaining civic amenities, and enforcing environmental and public health standards. The Act allows for penalties and corrective actions for non-compliance with municipal regulations.	The provisions of this act will be complied with, and the municipal services delivery standards will be followed.
4	Punjab Environmental Quality Standards (PEQS), 2016	PEQS endows information on the permissible limits for discharges of municipal and industrial effluent parameters and industrial gaseous emissions to regulate environmental pollution. Results of environmental monitoring (ambient air, water and noise) conceded out at different locations in study area are compared with PEQS values and are conversed in Section 4 of the report.	The wastewater treatment plants for the proposed housing schemes will produce the effluent that will comply with the PEQS.
5	Punjab Environmental Protection Act 1997	The Punjab Environmental Protection Act, 1997 (as Amended up to 2022) is comprehensive legislation and provides the legislative framework for protection,	The proposed housing schemes will be environmentally friendly, and the wastewater treatment

Sr. No.	Regulatory Instrument	Brief Coverage	Relevance to project
	(Amended 2022)	conservation, rehabilitation and improvement of the environment.	plants will ensure the protection of the environment.
6	Sustainable Development Goal (SDG-6)	SDG 6 aims to ensure the accessibility and sustainable management of water and sanitation for all. It focuses on improving water quality, increasing water use efficiency, and protecting water ecosystems. The goal seeks to provide universal access to safe drinking water and sanitation, promoting long-term sustainability.	Targets 6.3, 6.5, and 6.6 of SDG 6 are directly relevant to our program, which focuses on improving water quality, implementing integrated water resource management, and protecting water ecosystems respectively. The program aims to deliver sustainable wastewater treatment systems that ensure no harm to natural water bodies at final effluent discharge.

3 FIELD VISITS AND INVESTIGATIONS

3.1 General

This section presents the findings from the field visits and details an action plan developed from the analysis of the collected data.

3.2 Schedule of Field Visits

The finalized list of cities to be included in the program, along with the proposed sites for housing schemes, was communicated by PM&IU-PAHP via email on August 15, 2024. After conducting comprehensive desk studies, the consultants identified multiple housing schemes in each city for wastewater sample collection and analysis of existing sanitation systems. Based on this information, a detailed schedule for site visits and data collection was developed.

Table 3. 1: Schedule of site visit

Sr. No.	Teams	Members	Cities	Date of Visit
1	Team-1	Mr. Ali Hamid Mr. Abdul Manan	Rawalpindi, Bahawalpur, Jalalpur Pirwala	03.09.2024 to 04.09.2024 & 19.09.2024 to 20.09.2024
2	Team-2	Ms. Saba Gull Mr. Malik Tariq	Sialkot	03.09.2024 to 04.09.2024
3	Team-3	Mr. Syed Zeeshan Abbas Mr. Tahir Sajjad	Faisalabad, Layyah	04.09.2024 to 06.09.2024

3.3 List of Housing Schemes

The list of housing schemes to be studied under the current assignment was included in the inception report after the consent of PM&IU-PAHP. The rationale behind the selection of schemes and the location maps are part of the inception report. However, the list has been reproduced hereunder for reference.

Table 3.2:List of Housing Schemes for Wastewater Sampling

Sr No.	Housing Scheme Names (Region wise)	GPS Coordinates	
		Latitude	Longitude
South Punjab			
Bahawalpur			
1.	Model Avenue	29.338633°	71.610861°
2.	Maqbool Colony	29.377694°	71.721944°
3.	Zaman Villas	29.409472°	71.707331°
4.	Paragon Ideal Homes	29.392767°	71.637039°
5.	Muslim Town	29.396261°	71.704864°
6.	Sadiq Colony	29.383386°	71.662458°
7.	Qasim Town	29.400028°	71.690928°

Sr No.	Housing Scheme Names (Region wise)	GPS Coordinates	
		Latitude	Longitude
Jalalpur Pirwala			
1.	Mohalla Abbasia	29.5162°	71.226194°
Central Punjab			
Faisalabad			
1.	Mehboob Town	31.485743°	73.055174°
2.	Shahbaz Nagar	31.480181°	73.052451°
3.	Awaisia Colony	31.387878°	73.192227°
4.	Rana Town	31.383491°	73.165897°
5.	Faisal Town	31.393638°	73.173818°
Layyah			
1.	Housing Colony	30.976472°	70.958355°
2.	Al Madni City	30.965576°	70.979503°
3.	TDA Colony	30.962733°	70.958558°
4.	Rehman Abad	30.979094°	70.941266°
5.	Al Janat City	30.967158°	70.979597°
6.	Qureshi Housing Scheme	30.950743°	70.971031°
North Punjab			
Sialkot			
1.	Chand Bagh Society	32.527561°	74.472380°
2.	Mag Town	32.499423°	74.501649°
3.	Ghansar Pur	32.528795°	74.478771°
4.	Punjab Colony	32.514627°	74.523146°
5.	Umer Town	32.482839°	74.513314°
Rawalpindi			
1.	Citi Villas	33.55983611°	73.09770000°
2.	Ghori Town Phase-V	33.61191389°	73.13274722°
3.	Ameen Town	33.64257778°	73.05116944°
4.	PWD Housing Society	33.57087222°	73.14527500°
5.	Millat Colony	33.613612°	73.069280°

3.4 Objectives of Field Visits

The following were the objectives of field visits:

- To select wastewater sampling points.
- To get a general idea of the project area and assess the general topography.
- To assess the present status of wastewater treatment needs of the housing scheme based on the sewage network disposal and characteristics.

3.5 Findings of Field Visits

Targeted field visits were conducted to gather project-specific information. A customized data collection form was employed to collect the necessary data (refer to **Annex -- I**). As previously noted in this report, the initial selection of existing housing schemes was based on desk studies using Geographic Information System (GIS) tools. However, following on-site evaluations, several housing schemes were removed from the list, and new schemes were identified for the following reasons:

- Unavailability of sewerage network
- Not complying with the requirements of TORs

The city-wise details of the field visits and the findings are discussed hereunder:

3.6 Bahawalpur

Bahawalpur is a historically significant city known for its rich cultural heritage and architectural landmarks, including palaces and forts from its time as a princely state. The city plays a vital role in the economy of southern Punjab, serving as a center for trade, agriculture, and education. The region is largely agricultural, with vast tracts of arable land that benefit from the Sutlej River and extensive irrigation systems. Key crops include wheat, cotton, sugarcane, and various fruits, which contribute significantly to the local and national economy.

Bahawalpur is strategically located near the Cholistan Desert, and its proximity to major road networks connects it to larger urban centers such as Multan and Lahore. This enhances its role as a trade and logistics hub for the southern regions of Punjab. Additionally, the city's growing population and ongoing urban development projects have increased its importance as a center for education and healthcare, with several reputable institutions and hospitals serving the region. Given Bahawalpur's economic and strategic significance, it was included in the program.

3.6.1. Model Avenue

Model Avenue is a mixed-income residential society located on the outskirts of the city, near the industrial zone on Ahmed Pur Link Road. The Society is a planned development with an operational sewage collection system. All wastewater generated within the society is collected through the sewer network to a disposal station situated in the society. The wastewater from the disposal station is then discharged into fields outside the society.

Water supply distribution system is available in the society. Groundwater is available at a depth of 80 to 90 feet below the ground and it is supplied through the water distribution system in the society. During the site visit, residents reported that the groundwater quality is good. The society comprises approximately 250 Houses.

Further details are summarized in the **Table 3.3** below:

Table 3.3:Summary of finding in Model Avenue

Locality	Near industrial area
Plot size distribution	5,10 marla
No. of houses	250
Household size	7 (approximately)
Sewerage network	Sewage network system and disposal station available in the society
Trunk sewer	Available within the society

The glimpses of the scheme are shown in **Plate – 3.1** below:

Plate - 3.1: Photolog of Model Avenue

3.6.2. Government Employee Cooperative Housing Society

The Government Employee Cooperative Housing Society is a high-income residential development located on the outskirts of the city along Bahawalpur-Bahawalnagar Road. The society is a well-planned residential area with a fully functional sewage collection system. All wastewater generated within the society is conveyed through a sewer network to an on-site disposal station. From the disposal station, the wastewater is directed to a communal septic tank before being discharged into surrounding fields.

Water supply distribution system is available in the society. Groundwater is available at a depth of 70 feet and is supplied through a water supply distribution network and utilized for both domestic and drinking purposes. During the site visit, residents reported that the groundwater quality is good. The society comprises approximately 1,500 Houses.

Further details are summarized in the **Table - 3.4** below:

Table 3.4:Summary of finding in Government Employee Cooperative Housing Society

Locality	Outskirt of city
Plot size distribution	5,10, 20marla
No. of Houses	1500
Household size	6 (approximately)
Sewerage network	Sewer network and disposal station available
Trunk sewer	Available within the society

The glimpses of the scheme are shown in **Plate 3.2** below:

Plate - 3.2: Photolog of Government Employee Cooperative Housing Society

3.6.3. Qasim Town

Qasim Town is a low-income residential area located in the commercial zone of the city, along Sadiq Egerton College Road. It is a partially planned, densely populated town with a functional sewage network. All wastewater generated in the town is collected at the Municipal Corporation (MC) disposal station via MC trunk line and is further discharged into the Sutlej River.

The town lacks water supply distribution system. Groundwater, available at a depth of 110 feet below natural surface level (NSL) and it is used for both drinking and domestic purposes. During the site visit, local residents reported that the groundwater quality is good. The town comprises approximately 600 Houses.

Further details are summarized in the **Table 3.5** below:

Table 3.5:Summary of finding in Qasim Town

Locality	Near commercial area
Plot size distribution	5,10,20 marla
No. of Houses	600
Household size	6 (approximately)
Sewerage network	Sewer network is available in the society
Trunk sewer	MC Trunk sewer is available outside of society

The glimpses of the scheme are shown in **Plate 3.3** below:

Plate - 3. 3: Photolog of Qasim Town

3.6.4. Sadiq Colony

Sadiq Colony is a low-income residential area located on the outskirts of the city along Ahmed Pur Road. The colony is a planned, densely populated area with a functional sewage network. All wastewater generated in the area is collected at the Municipal Corporation (MC) disposal station via the MC trunk line. At the disposal station, wastewater from various housing societies is collected and discharged into the nearest water body.

There is no water supply distribution system in the colony. Groundwater is available at a depth of 80 feet below the natural surface level (NSL) and is used for both drinking and domestic purposes. According to local residents, the groundwater quality is reported to be good. The colony consists of approximately 1,600 Houses.

Further details are summarized in the **Table 3.6** below:

Table 3. 6:Summary of finding in Sadiq Colony

Locality	In densely populated area
Plot size distribution	3,5,10 marla
No. of Houses	1600
Household size	7.5 (approximately)
Sewerage network	Sewer network available in the colony
Trunk sewer	MC Trunk sewer is available outside of society

The glimpses of the scheme are shown in **Plate – 3.4** below:

Plate - 3.4: Photolog of Sadiq Colony

3.6.5. Paragon Ideal Homes

Paragon Ideal Homes is a high-income residential development located on the outskirts of the city, along the N5 Link Road (Samma Satta Road). The society features a well-planned housing scheme with a functional sewage network. All wastewater generated within the society is conveyed to the municipal corporation (MC) disposal station via the MC trunk line, from where it is discharged into the nearest water body.

The society lacks water supply distribution system. Groundwater, available at a depth of 80 feet is utilized for both drinking and domestic purposes. During the site visit, local residents reported that the groundwater quality is considered good. The housing society consists of approximately 300 Houses.

Further details are summarized in the **Table 3.7** below:

Table 3.7:Summary of finding in Paragon Ideal Homes

Locality	On outskirt of city
Plot size distribution	5,10,20,40 marla
No. of Houses	300
Household size	7 (approximately)
Sewerage network	Sewer network available in the society
Trunk sewer	MC Trunk sewer is available outside of society

The glimpses of the scheme are shown in **Plate – 3.5** below:

Plate - 3.5: Photolog of Paragon Ideal Homes

i. Final List of Housing Schemes for Bahawalpur

As per TORs, five (05) Nos. housing schemes were initially selected in Bahawalpur for wastewater sampling and analysis. The list of schemes, after the approval from PM&IU, was made part of the Inception Report. However, when the sites were physically visited, the following schemes don't meet the TORs criteria.

- Muslim Town
- Maqbool Colony
- Zaman Villas

Since the previously mentioned scheme does not meet the required criteria, it has been deemed unsuitable for further evaluation. Consequently, an alternative scheme was identified during the field study and has been selected for further analysis.

- Government Employee Cooperative Housing Society

The updated list of housing schemes in Bahawalpur are given hereunder:

Table 3.8: List of Selected Housing Schemes in Bahawalpur

Sr. No.	City/District	Selected Housing Schemes
1	Bahawalpur	Model Avenue
2		Government Employee Cooperative Housing Society
3		Qasim Town
4		Sadiq Colony
5		Paragon Ideal Homes

The updated location maps are given in **Figure 3.1**.

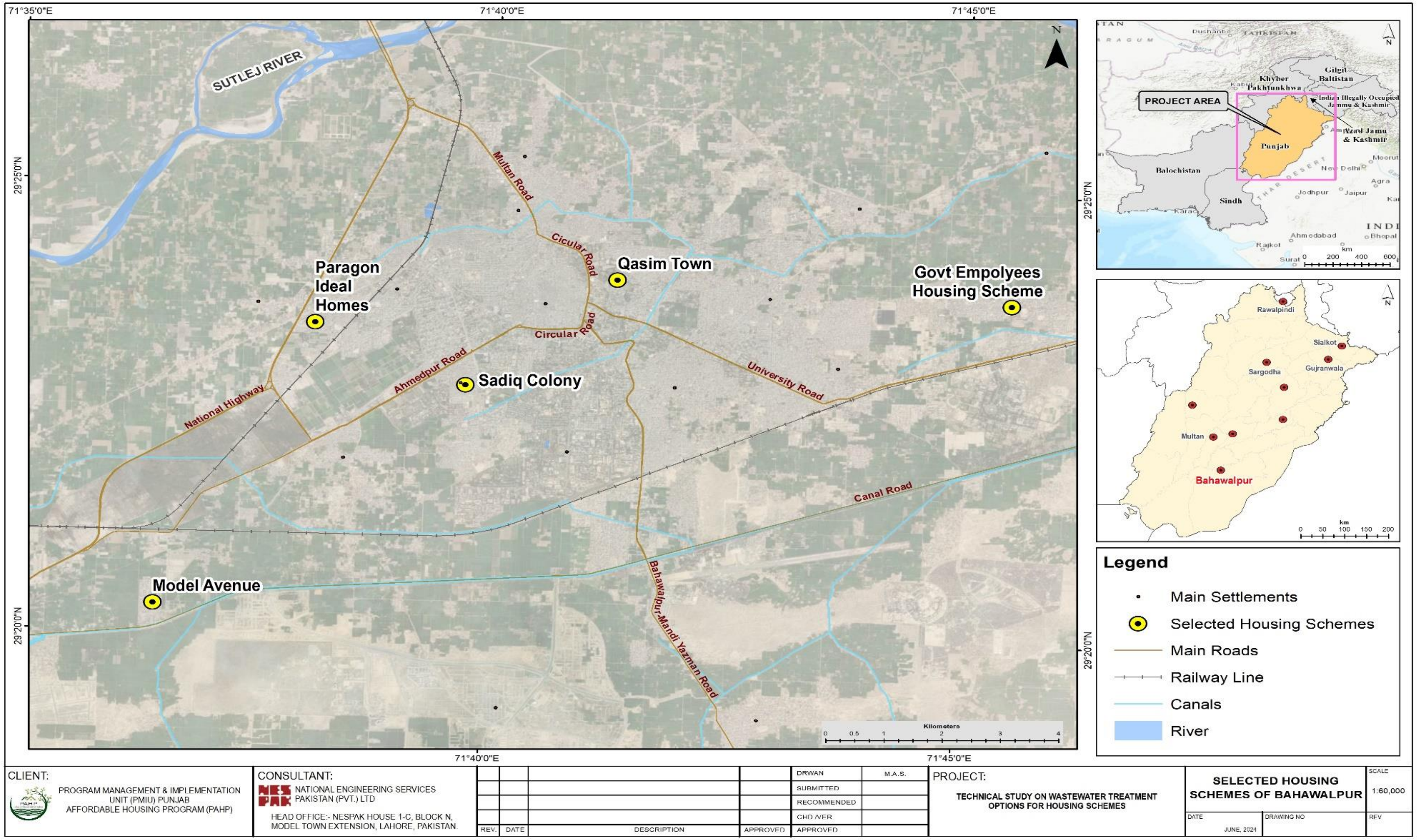


Figure 3.1: Location Map of Selected Housing Schemes of Bahawalpur

3.7 *Jalal Pur Pirwala*

Jalal Pur Pirwala, a key agricultural town in southern Punjab, is included in the Punjab Affordable Housing Program (PAHP) due to its growing population and economic significance. The town's economy revolves around agriculture, with crops like wheat, cotton, and sugarcane, supported by irrigation systems from the Sutlej River.

Strategically located near Multan, Jalal Pur Pirwala benefits from strong road connectivity i.e., from Motorway M5, making it a vital part of the region's logistics and trade networks. Under the PAHP, the town will see improved housing regulations, expand residential infrastructure, and increase private investment, helping to boost the local economy. The program also emphasizes energy-efficient, climate-resilient designs, ensuring that new housing projects are sustainable and adaptive to environmental challenges.

3.7.1. Punjab Housing Scheme

The Punjab Housing Scheme is a mixed-income residential development located near the city, along the Jalalpur Pirwala–Uch Sharif Highway, approximately 2.8 km north of the M5 Jalalpur Pirwala interchange. It is a planned housing project with 10% of the area developed and features a functional sewage collection system. All wastewater generated within the scheme is conveyed through the sewerage network to the Municipal Corporation (MC) trunk line located outside the housing scheme. The wastewater is then collected at the MC disposal station and pumped to a wastewater treatment plant (WWTP), where it is treated using wastewater stabilization ponds. The treated effluent is subsequently sold to farmers for irrigation purposes at a rate of 1,000 PKR per hour.

The society has a functioning water supply system, with groundwater available at a depth of 40 feet below the natural surface level (NSL). However, local reports during a site visit indicated that the groundwater is saline and unsuitable for consumption. Despite this, some houses are utilizing the groundwater for domestic purposes, while filtered water is used for drinking. There are 70 Houses approximately.

Further details are summarized in the **Table 3.9** below:

Table 3.9: Summary of finding in Punjab Housing Scheme

Locality	Near residential area
Plot size distribution	3,5 marla
No. of Houses	70
Household size	7 (approximately)
Sewerage network	Sewage network system available in the society
Trunk sewer	MC trunk line outside the society

The glimpses of the scheme are shown in **Plate – 3.6** below:

Plate - 3. 6: Photolog of Punjab Housing Scheme

i. Final List of Housing Schemes for Jalalpur Pirwala

The selected schemes for Jalalpur Pirwala remain unchanged after the field visits.

Table 3.10: List of Selected Housing Schemes in Jalalpur Pirwala

Sr. No.	City/District	Selected Housing Schemes
1	Jalalpur Pirwala	Punjab Housing Scheme

The location map is given in **Figure 3.2.**

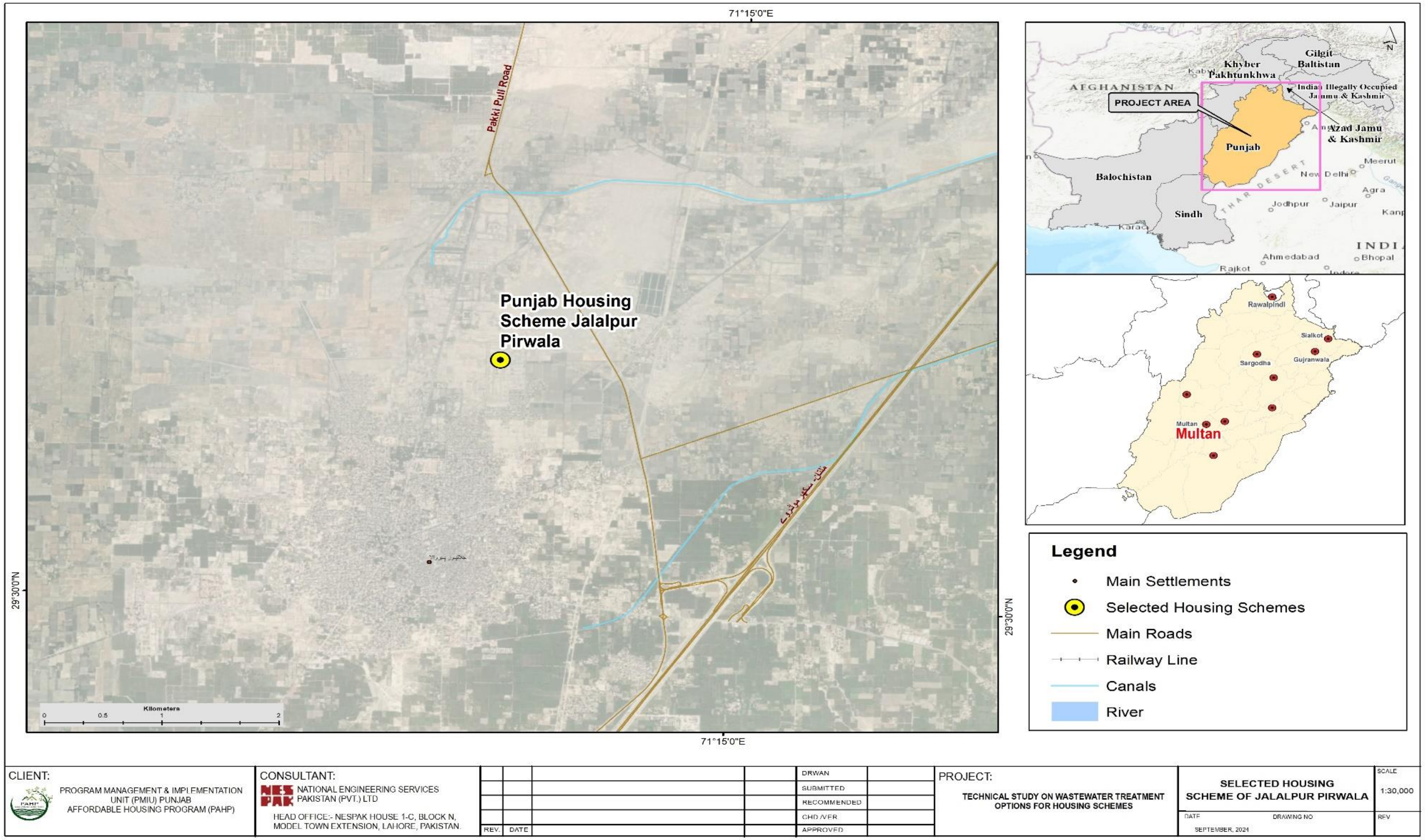


Figure 3.2: Location Map of Selected Housing Schemes of Jalal Pur Pirwala

3.8 Faisalabad

Faisalabad, often referred to as the "Manchester of Pakistan," is a vital economic hub known for its thriving textile industry, which significantly contributes to the country's export earnings. The city serves as a major agricultural center, benefiting from its fertile land and advanced irrigation systems. Additionally, Faisalabad's strategic location enhances its role as a key trade and transportation junction, facilitating commerce throughout the region. Its growing population and urban development also position Faisalabad as an important center for education and healthcare in Pakistan.

The aforementioned qualifications make Faisalabad an attractive city to live in, therefore, it was included in the program. The initially identified schemes were strategically located in various parts of the city. However, more preference was given to the housing schemes near the proposed program sites. Each of the schemes was physically visited and evaluated based on the project criteria. The following are the scheme-wise details:

3.8.1. Mehboob Town

Mehboob Town is a low-income town on the city's outskirts near Motorway M-4. The area is residential and lacks basic civic amenities. The sanitation conditions are deplorable as the wastewater could be seen overflowing in the open drains. The residents informed that the area is inundated in the rainy season and stormwater finds its way into the houses. There are a couple of disposal points where the open drains terminate in the open areas which are further directed to the watercourses.

There is no water supply system, and the town relies on groundwater from boreholes that extract the groundwater from 110 feet depth. The groundwater was reported to be unfit as a few Hepatitis cases were reported in the area.

There are 1400-1500 Houses, and the residents are of the low-income group earning an average of PKR 25,000 to 30,000 per month.

Further details are summarized in the **Table 3.11** below:

Table 3.11:Summary of finding in Mehboob Town

Locality	Away from the city center
Plot size distribution	2,3,4,5,7 & 10 marla
No. of Houses	1400-1500
Household size	7 (approximately)
Sewerage network	Open drains and open disposal
Trunk sewer	Available at a distance of 0.5 km on main road and Seam Nullah available at a distance of 1.5 km

The glimpses of the scheme are shown in **Plate - 3.7** below:

Plate - 3.7: Photolog of Mehboob Town

3.8.2. Shahbaz Nagar

Shahbaz Nagar is a low-income community located on the city's outskirts, near Motorway M-4. The area is a planned residential settlement with a functional sewage collection system. Most of the wastewater is conveyed via a sewer network to a F-WASA's disposal station located on the boundary of the settlement. Some of the Housess discharge their sewage directly into nearby fields. At the disposal station, wastewater is pumped for irrigation purposes using a diesel-operated engine installed by local farmers.

The water supply network is laid in many streets, but it was reported to be non-functional. The community relies on groundwater extracted from boreholes at a depth of 110 feet for domestic usage, while for drinking purposes commercially available filtered water is being used. The groundwater was reported to be unfit, with several cases of Hepatitis, diarrhea, and gastro-intestinal illnesses.

There are 450Houses, and the residents are of the low-income group earning an average of PKR 25,000 to 30,000 per month.

Further details are summarized in the **Table 3.12** below:

Table 3. 12:Summary of finding in Shahbaz Nagar

Locality	Away from the city center
Plot size distribution	2 & 4 Marla
No. of Houses	450
Household size	7 (approximately)

Sewerage network	WASA, Sewage Network and Disposal Station available
Trunk sewer	Available at 0.7 km on the main road and Seam Nullah is available at 2 km

The glimpses of the scheme are shown in **Plate - 3.8** below:

Plate - 3.8: Photolog of Shahbaz Nagar

3.8.3. Awaisia Colony

Awaisia Colony is a low-income colony located on Jaranwala-Faisalabad Road. The area is residential and lacks basic civic amenities. The sanitation conditions are deplorable, and the wastewater is disposed off haphazardly via multiple disposal points in nearby fields and open land. The lack of an adequate sewerage network and disposal facilities makes this scheme an unlikely option to be studied under the project.

Further details are summarized in the **Table 3.13** below:

Table 3.13:Summary of finding in Awaisia Colony

Locality	Away from city center
Plot size distribution	No information available
No. of Houses	
Household size	
Sewerage network	No Sewage Network and Disposal Station available

The glimpses of the scheme are shown in **Plate – 3.9** below:

Plate - 3.9: Photolog of Awaisia Colony

3.8.4. Ashiana Housing Scheme

The Ashiana Housing Scheme is a high-income residential scheme located along Jaranwala-Faisalabad Road. The scheme is well-planned, having adequate civic infrastructure and equipped with a functional sewage collection system. All wastewater generated within the housing scheme is conveyed through an underground sewer network to a disposal station built within the premises. The wastewater is pumped and discharged into a minor canal outside the society's boundary.

Groundwater is available at a depth of 60-70 feet and is utilized for domestic purposes and distributed through the society's water supply network. For drinking water, a Reverse Osmosis (RO) plant has been installed within the housing society to ensure safe drinking water.

There are 102 Houses, and the residents are of the low to medium income i.e., 35,000-40,000 PKR group.

Further details are summarized in the **Table 3.14** below:

Table 3.14:Summary of finding in Ashiana Housing Scheme

Locality	Away from city center
Plot size distribution	3, 5 Marla
No. of Houses	102
Household size	4 (approximately)
Sewerage network	Sewage Network and Disposal Station Available
Trunk sewer	No trunk sewer available

The glimpses of the scheme are shown in **Plate - 3.10** below:

Plate - 3.10: Photolog of Ashiana Housing Scheme

3.8.5. Faisal Town

Faisal town is a mixed-income town located near the center of the city, on Jaranwala-Faisalabad Road. The area is residential and lacks basic civic amenities. The sanitation conditions are deplorable as the wastewater could be seen overflowing in the open drains. There are no sewage lines and disposal stations.

Further details are summarized in the **Table 3.15** below:

Table 3.15:Summary of finding in Faisal town

<table>
<tr><td>Locality</td><td>Near city center</td></tr>
<tr><td>Plot size distribution</td><td rowspan="3">No information available</td></tr>
<tr><td>No. of Houses</td></tr>
<tr><td>Household size</td></tr>
<tr><td>Sewerage network</td><td>No Sewage Network and Disposal Station available</td></tr>
</table>

The glimpses of the scheme are shown in **Plate – 3.11** below:

Plate - 3.11: Photolog of Faisal town

3.8.6. Rana Town

Rana Town is a mixed-income town (i.e., population range from 30,000 – 50,000 PKR) situated near the city center, along Jaranwala-Faisalabad Road (opposite Faisal Town). The area is primarily residential and lacks essential civic amenities. The sanitation conditions are poor as there are no sewage lines and disposal stations and the wastewater could be seen overflowing in the streets.

Further details are summarized in the **Table 3.16** below:

Table 3.16:Summary of finding in Rana Town

Locality	near city center
Plot size distribution	
No. of Houses	No information available
Household size	
Sewerage network	No Sewage Network and Disposal Station available

The glimpses of the scheme are shown in **Plate – 3.12**below:

Plate - 3. 12: Photolog of Rana Town

3.8.7. Imtiaz Town

Imtiaz Town is a mixed-income housing scheme located near Jaranwala Road, Dhudiwala, Faisalabad, in a densely populated area. It is a planned residential development with an operational sewage collection system. The wastewater generated within the housing scheme is collected via the local sewer network to a trunk line located 350 meters southeast of the society along Kahlon Road.

No water supply system is available in the town, underground water is available at a depth of 120 feet which is used for domestic purposes while filter water is used for drinking purposes. There are 150 Houses, and the residents are of the mixed-income group earning 35,000 to 55,000 PKR a month.

Further details are summarized in the **Table 3.17** below:

Table 3.17:Summary of finding in Imtiaz Town

Locality	City Center
Plot size distribution	2,2.5,3,5 Marla
No. of Houses	150
Household size	7.5 (approximately)
Sewerage network	Sewage Network Available
Trunk sewer	A Trunk line passing 350 meters away

The glimpses of the scheme are shown in **Plate – 3.13** below:

Plate - 3.13: Photolog of Imtiaz Town

3.8.8. Abdullah Pur

Abdullah Pur is a mixed-income housing scheme centrally located on Canal Road, Faisalabad. It is a planned area comprising residential, industrial, and commercial blocks, all served by a functional sewage collection system. The wastewater generated within the scheme is collected via a trunk sewer to the WASA disposal station, located approximately 50 meters southwest of Abdullah Pur.

WASA Water supply system is available in this area which is used for domestic purposes while for drinking purposes most of the people use filter water, furthermore underground water is available at a depth of 100-110 feet which is not used as the groundwater was reported to be unfit as a few Hepatitis cases were reported in the area.

There are 3,350 Houses, and the residents are of the Mix-Income group earning on an average of PKR 30,000 to 35,000 per month.

Further details are summarized in the **Table 3.18** below:

Table 3.18:Summary of finding in Abdullah Pur

Locality	City Center,
Plot size distribution	1.5,2,2.5,4,5,6,7,8 Marla
No. of Houses	3350
Household size	7.5 (approximately)
Sewerage network	Sewage Network and Disposal Station is Available
Trunk sewer	WASA Trunk line passing 50 meters away

The glimpses of the scheme are shown in **Plate - 3.14** below:

Plate - 3.14: Photolog of Abdullah Pur

3.8.9. Steam Power Colony

Steam Power Colony is a high-income residential area near the city center along Canal Road, Faisalabad. It is a planned colony comprising residential zones, an industrial section featuring a steam power plant, and the WAPDA Engineering Academy. Wastewater generated within the colony is collected at eight designated disposal points and is pumped to open fields through a disposal station.

The colony has a water supply system that fulfills domestic needs, while most residents rely on filtered water from an on-site filtration plant for drinking purposes. Although groundwater is available at a depth of 100–110 feet, it is not utilized for drinking due to its reported unsuitability for consumption. There are 388 Houses. The residents earn of 50,000 PKR a month.

Further details are summarized in the **Table 3.19** below:

Table 3.19:Summary of finding in Steam Power Colony

Locality	City Center,
Plot size distribution	2.5,3,5,7,10,20,25 Marla
No. of Houses	388
Household size	4.5 (approximately)
Sewerage network	Sewage network and disposal stations is available
Trunk sewer	A trunk line is available within the colony

The glimpses of the scheme are shown in **Plate – 3.15** below:

Plate - 3.15: Photolog of Steam Power Colony

i. Final List of Housing Schemes for Faisalabad

As per TORs, five (05) Nos. housing schemes were initially selected in Faisalabad for wastewater sampling and analysis. The list of schemes, after the approval from PM&IU, was made part of the Inception Report. However, when the sites were physically visited, the following schemes were reported to have no sewerage collection and disposal system.

- Awaisia Colony
- Rana Town
- Faisal Town

The absence of a sewerage network makes these housing schemes unfit for further studies therefore the following additional schemes were identified in the field and have been considered for further studies.

- Imitiaz Town
- Abdullah Pur
- Steam Power Colony

Furthermore, Mehboob Town and Shahbaz Nagar share similar characteristics and are located adjacent to one another. The only difference between the two is the availability of a disposal station in Shahbaz Town. Therefore, Shahbaz Town has been selected among them.

The updated list of housing schemes in Faisalabad are given hereunder:

Table 3.20:List of Selected Housing Schemes in Faisalabad

Sr. No.	City/District	Selected Housing Schemes
1	Faisalabad	Shahbaz Nagar
2		Ashiana Housing Scheme
3		Imitiaz Town
4		Abdullah Pur
5		Steam Power Colony

The updated location maps are given in **Figure -3.3.**

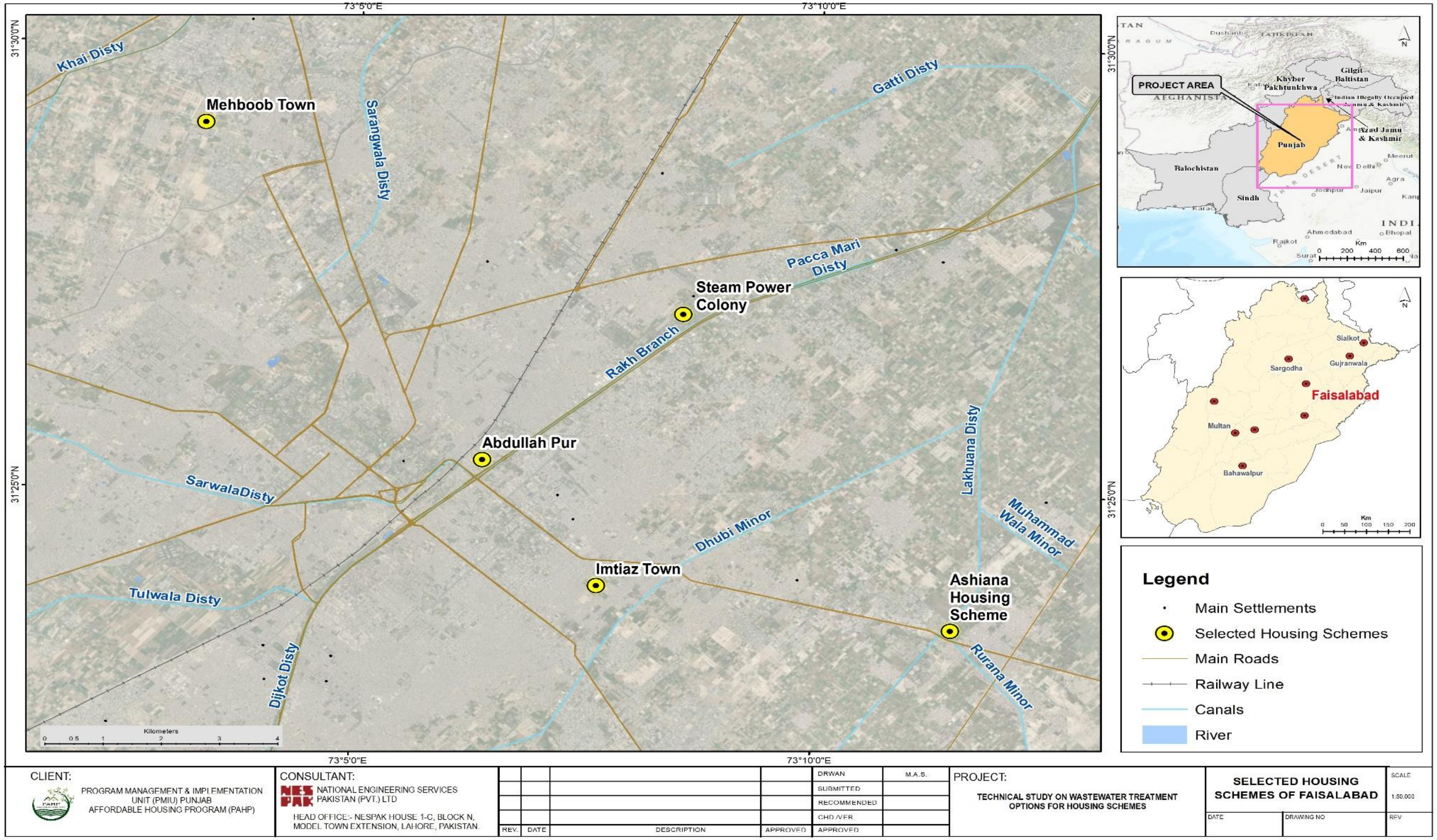


Figure 3.3: Location Map of Selected Housing Schemes of Faisalabad

3.9 Layyah

Layyah City is an emerging urban center situated within the agricultural heartland of Punjab, Pakistan. Known for its rich, fertile lands, Layyah plays a significant role in the country's agricultural output, particularly in the production of wheat, sugarcane, and cotton. The region benefits from a well-established canal irrigation system, which supports its agricultural base. Layyah's economy is gradually diversifying, with small-scale industries and services emerging to support its growing population. The city's strategic location near the Indus River further enhances its agricultural potential and provides connectivity to other parts of southern Punjab.

Layyah's urban development is on the rise, with increasing investments in infrastructure, healthcare, and education. The city's modest yet growing population makes it a focus area for rural-to-urban migration, further stimulating the need for housing development.

Housing schemes in Layyah have been emerging in line with the city's urban expansion. These schemes are often situated near key agricultural zones and along transportation routes, taking advantage of the city's strategic location. The evaluated housing schemes for potential projects would likely be selected based on proximity to key urban amenities, agricultural fields, and major transportation routes. This makes Layyah an attractive location for new development programs aimed at enhancing the urban infrastructure while supporting its agricultural economy.

3.9.1. Housing Colony-I

Housing Colony-I is a mixed-income society in the center of the city on College Road Layyah. The area is a planned residential colony with a functional sewage collection system. All the wastewater generated in the colony is collected through trunk line at disposal station located 100 meters away from the colony in east direction. The income range varies from 30,000 to 50,000 PKR.

Both water supply and groundwater sources are available in the society. Groundwater is accessible at a depth of 100 feet and is utilized for both drinking and domestic purposes. During a site visit, locals reported that the groundwater quality is good. There are 600 Houses.

Further details are summarized in the **Table 3.21** below:

Table 3.21:Summary of finding in Housing Colony-I

Locality	Within the city center
Plot size distribution	3,5,7,20 marla
No. of Houses	600
Household size	7 (approximately)
Sewerage network	Local government Sewage Network & disposal station available
Trunk sewer	Available at a distance of 100 m away from the colony

The glimpses of the scheme are shown in **Plate – 3.16** below:

Plate - 3.16: Photolog of Housing Colony-I

3.9.2. Rehman Abad

Rehman Abad is a low-income area located near the center of city on Karor-Layyah Road. It is an unplanned, densely populated residential area with an open sewage drain connected to the municipal trunk sewer via a manhole situated along Karor Layyah Road.

No water supply system is available in this area as most of the Houses have their own boreholes. Groundwater is accessible at a depth of 100 to 110 feet, and residents utilize this underground water for both drinking and domestic purposes because during a site visit it was reported by the locals that the underground water quality is good. The income range is 35,000 to 45,000 PKR. There are 250 Houses.
Further details are summarized in the **Table 3.22** below:

Table 3.22:Summary of finding in Rehman Abad

Locality	Near city center
Plot size distribution	5, 7.5, 10
No. of Houses	250
Household size	7.5 (approximately)
Sewerage network	Open drain connected with MC sewer
Trunk sewer	MC Sewer available on Karor Layyah road

The glimpses of the scheme are shown in **Plate – 3.17** below:

Plate - 3.17: Photolog of Rehman Abad

3.9.3. TDA Colony

TDA colony is a high-income society in the center of the city on Layyah-Chobara Road. The colony is a planned residential settlement with a functional sewage collection system. All the wastewater produced in the colony is collected through trunk line at disposal station located 800 meters away from the colony in south direction.

Both water supply and groundwater sources are available in the society. Groundwater is accessible at a depth of 100-120 feet and is utilized for both drinking and domestic purposes. During a site visit, locals reported that the groundwater quality is good. There are 202 Houses.

Further details are summarized in the **Table 3.23** below:

Table 3.23:Summary of finding in TDA colony

Locality	City center
Plot size distribution	8,12,20 marla
No. of Houses	202
Household size	6 (approximately)
Sewerage network	Local government Sewage Network & disposal station available
Trunk sewer	Available at a distance of 250m away from the colony

The glimpses of the scheme are shown in **Plate – 3.18** below:

Plate - 3.18: Photolog of TDA colony

3.9.4. Qureshi Housing

Qureshi housing is a mixed income housing society on the outskirts of city on Layyah Bypass Link Road. The housing is a planned residential area with a functional sewage collection system. All the wastewater produced in the colony is collected through a trunk sewer at a disposal station located within the society. The effluent of disposal station is disposed to open area near housing society.

Water supply system is not available in the colony, underground water is available at a depth of 100-120 feet, and it is used for both drinking & domestic purpose. During the site visit it was reported by the locals the underground water quality is good. There are 60 Houses. The income range is 40,000 -50,000 PKR.

Further details are summarized in the **Table 3.24** below:

Table 3.24:Summary of finding in Qureshi housing

Locality	Out skirt of city
Plot size distribution	5,6 marla
No. of Houses	60
Household size	6 (approximately)
Sewerage network	Sewage Network & disposal station available within society
Trunk sewer	Available with in society

The glimpses of the scheme are shown in **Plate – 3.19** below:

Plate - 3. 19: Photolog of Qureshi housing

3.9.5. Al-Janat City

Al-Janat city is a high-income housing society on the outskirts of city on Layyah-Chowk Azam Road. The housing scheme is a planned residential area with a functional sewage collection system. All the wastewater produced in the colony is collected through a trunk sewer in an open area located within the society and disposed to open area within housing society.

Water supply system is not available in the colony, underground water is available is available at a depth of 100-120 feet and it is used for both drinking & domestic purposes. During the site visit it was reported by the locals the underground water quality is good. There are 90 Houses. The income range is 70,000 PKR and above.

Further details are summarized in the **Table 3.25** below:

Table 3.25:Summary of finding in Al-Janat city

Locality	Out skirt of city
Plot size distribution	2,3,5,10,20 marla
No. of Houses	90
Household size	6 (approximately)
Sewerage network	Sewage Network available with no Disposal Station
Trunk sewer	Available with in society

The glimpses of the scheme are shown in **Plate – 3.20** below:

Plate - 3.20: Photolog of Al-Janat city

i. Final List of Housing Schemes for Layyah

As per TORs, five (05) Nos. of housing schemes were initially selected in Layyah for wastewater sampling and analysis. The list of schemes, after the approval from PMIU, was made part of the Inception Report. During the field visit, it was observed that five (05) societies selected for the inception report comply with the TORs except the sixth Al- Madni colony.

Table 3.26: List of Selected Housing Schemes in Layyah

Sr. No.	City/District	Selected Housing Schemes
1	Layyah	Housing Colony
2		Qureshi Housing Scheme
3		TDA Colony
4		Rehman Abad
5		Al Janat City

The location maps are given in **Figure 3.4.**

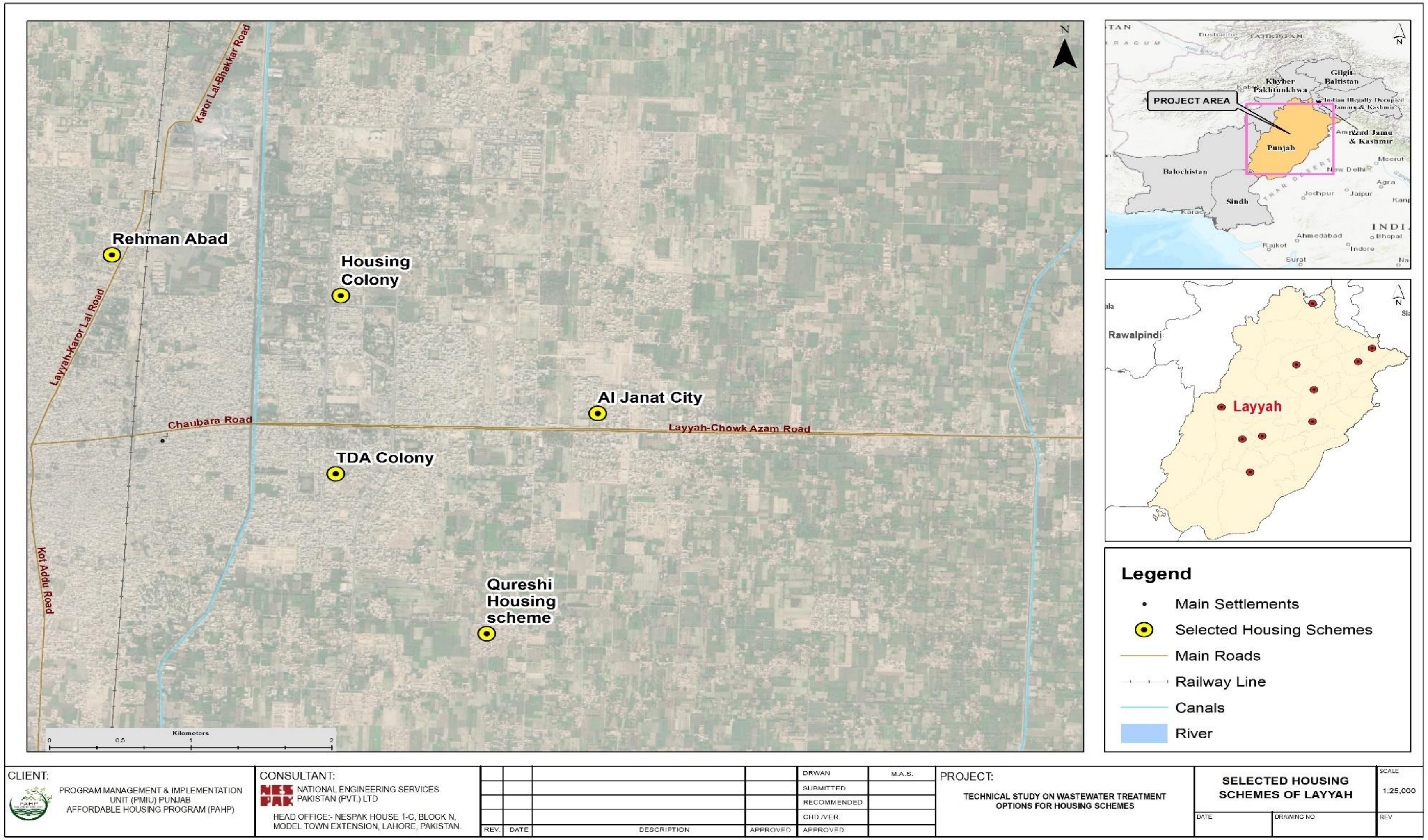


Figure 3.4: Location Map of Selected Housing Schemes of Layyah

3.10 Sialkot

Sialkot city is the 13th most populous city of Pakistan. The city has been noted for its entrepreneurial spirit and productive business climate which have made Sialkot an example of a small Pakistani city that has emerged as a "world-class manufacturing hub." Sialkot is one of the few cities of Pakistan where dry port was established in 1984 and export processing zone (EPZ) was developed in 1995. Sialkot has 8,100 industrial units which makes it the 4th largest manufacturing hub. Sialkot is the 2nd largest surgical instrument manufacturing city in the world. It is the 3rd largest sports manufacturer in the world and ranks 1st in Asia. The city has been labeled as the Football manufacturing capital of the World, as it produces over 70% of all footballs manufactured in the world. Sialkot is the sole city in Pakistan which developed its private airport which has the longest runway. Regarding the historical personalities, Allama Muhammad Iqbal (poet) was born in this city and his residence is being used as library now a days.

The aforesaid qualities make Sialkot an attractive city to live in, therefore, it was included in the program. The initially identified schemes were strategically located in various parts of the city. However, more preference was given to the housing schemes near the proposed program sites. Each of the schemes was physically visited and evaluated based on the project criteria. The following are the scheme-wise details:

3.10.1. Chand Bagh

Chand Bagh is a well-planned housing society located at the outskirts of Sialkot city on Airport Road. The residents of the society belong to medium income category. The society has basic amenities. The sanitation conditions are good, and society has a well-planned sewerage network. The wastewater generated by the Houses is collected through RCC sewer network. Society has two disposal points with final trunk sewer size of 24” & 30”. The collected sewage finally disposes of into Palkhu Nullah, passing along the boundary of the society. Palkhu Nullah is originally a stormwater drain, however, currently it is also receiving sewage from nearby areas. There are around 70 number of houses of 5 marla and 10 marlasizes, in the society.
Further details are summarized in the **Table 3.27** below:

Table 3.27:Summary of finding in Chand Bagh

Locality	Away from city center
Plot size distribution	5 & 10 marla
No. of houses	70
Household size	6 (approximately)
Sewerage network	RCC sewers
Trunk sewer	24” & 30”

The glimpses of the scheme are shown in **Plate - 3.21** below:

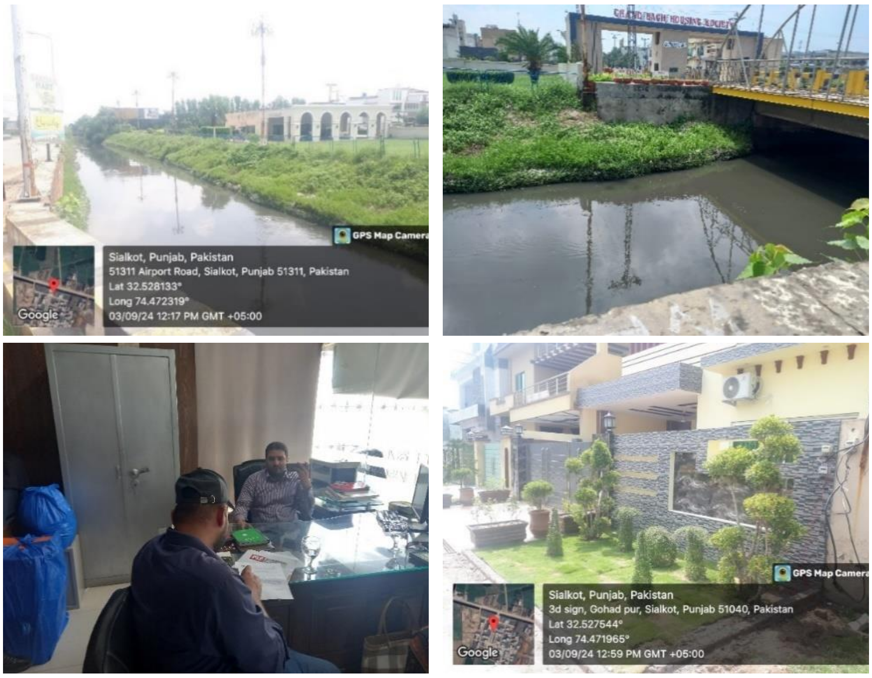


Plate - 3. 21: Photolog of Chand Bagh

3.10.2. Ghansar Pur

Ghansar Pur is low income unplanned densely populated area located at outskirts of city. Ghansarpur has no sewer network, rather it has a network of open drains of size 1'x1 ½' for collection of sewage and there is no disposal station in the area. The sewage generated by the Houses goes to the open drains directly. The drains ultimately connect into the MC conduit, at different points, passing near the boundary of the area. The sizes of houses vary from 3 marla to 5 marla. The income range is 30,000 to 50,000 PKR.

Further details are summarized in the **Table 3.28** below:

Table 3.28:Summary of finding in Ghansar Pur

Locality	Away from city center
Plot size distribution	3 & 5 marla
Household size	6 - 7 (approximately)
Sewerage network	Open drains
Size	1' x 1 ½'

The glimpses of the scheme are shown in **Plate 3.22** below:

Plate - 3. 22: Photolog of Ghansar Pur

3.10.3. MAG Town

Mag town is a well-planned housing society, with an area of around 452 kanals, located at Kashmir Road in center of Sialkot city near commercial zone. The residents of the society belong to medium to high income category. The society has basic amenities. The sanitation conditions are good, and society has a well-planned sewer network along with disposal station. The wastewater generated by the Houses is collected through well-planned RCC sewer network and goes to disposal station. After preliminary treatment through disposal station the wastewater pumped to Bedh Nullah. There are approximately 600 number of houses with plot size of 5 marla and 10 marla. The income range is 40,000 to 60,000 PKR.

Further details are summarized in the **Table 3.29** below:

Table 3.29:Summary of Findings in Mag town

Locality	In city center near commercial zone
Plot size distribution	5 & 10 marla
No. of houses	600
Household size	6 (approximately)
Sewerage network	RCC sewers
Trunk sewer	36” & 48”
Disposal Station	01 (2 pumps of 7.5 HP each)

The glimpses of the scheme are shown in **Plate – 3.23** below:

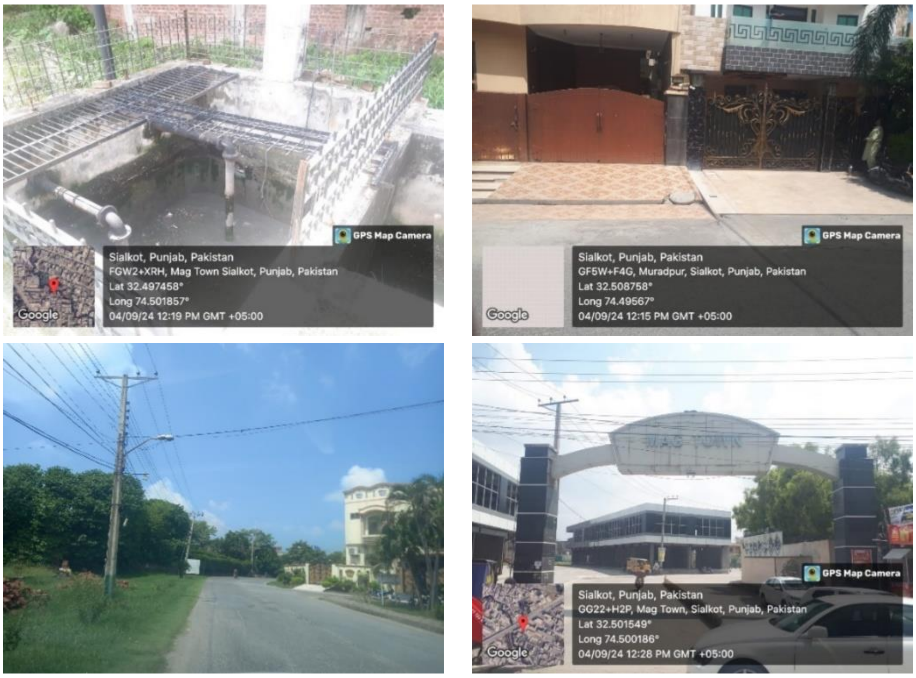


Plate - 3. 23: Photolog of Mag town

3.10.4. Umar Town

Umar town is a small densely populated housing scheme located near small industrial area and commercial zone at Defence Road. It has 200 – 250 number of housing units with plot size mainly of 5 marla and 10 marla with a few houses of size 16 to 20 marla. The residents of the society belong to different income categories ranging from low income to high income category. The society has basic amenities. The sanitation conditions are good and society has a well-planned sewer network with trunk sewer size of 24” dia. The wastewater generated by the Houses is collected through RCC sewer and goes to MC Conduit passing near the scheme. The income range is 30,000 – 45,000 PKR.

Further details are summarized in the **Table 3.30** below:

Table 3. 30:Summary of finding in Umar town

Locality	In city center near commercial zone and small industrial area
Plot size distribution	3, 5,10,16, 20 marla
No. of houses	200 – 250
Household size	7 (approximately)
Sewerage network	RCC sewers
Trunk sewer	24”

The glimpses of the scheme are shown in **Plate – 3.24** below:

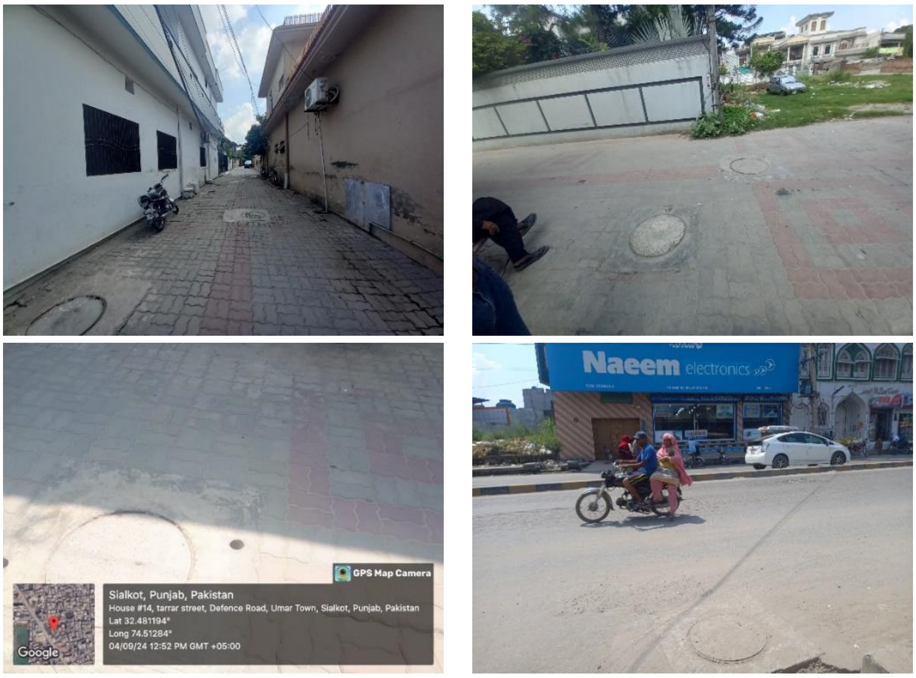


Plate - 3. 24: Photolog of Umar town

3.10.5. Punjab Colony

Punjab Colony is a densely populated housing scheme located in center of city near commercial area at Cantt Road. It has 200 – 250 number of housing units with plot size mainly of 5 marla. The residents of the society belong to medium income category. The society has open and covered drains network for collection of sewage. There is no disposal station in the scheme. The wastewater generated by the Houses is collected through drains and goes to MC Conduit passing near the scheme. The average income is around 40,000 PKR.

Further details are summarized in the **Table 3.31** below:

Table 3.31:Summary of finding in Punjab Colony

Locality	In city center near commercial zone
Plot size distribution	5 marla
No. of houses	200 – 250
Household size	6-7 (approximately)
Sewerage network	Open & covered drains

The glimpses of the scheme are shown in **Plate – 3.25** below:

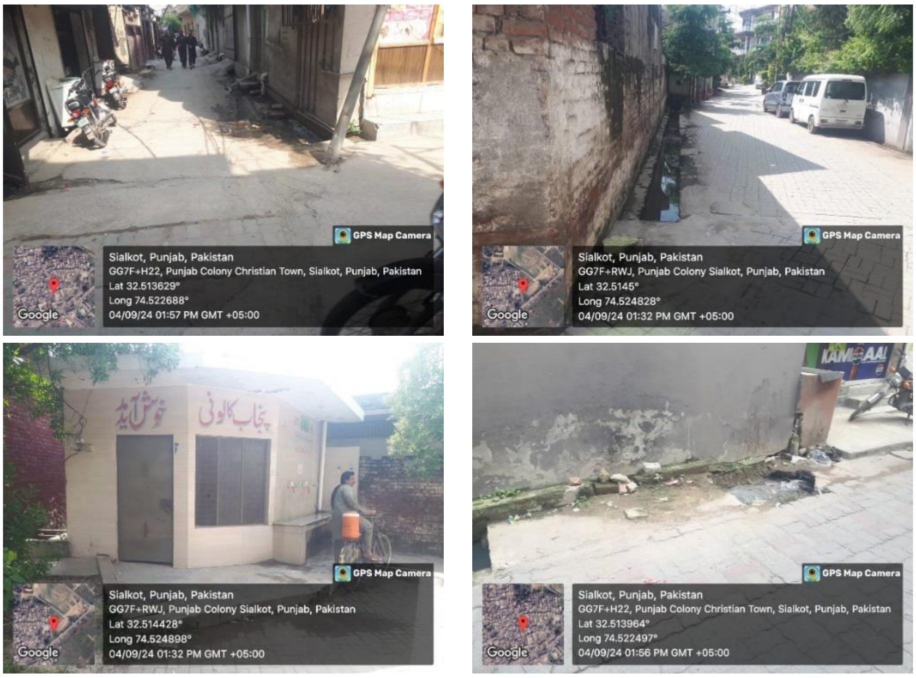


Plate - 3.25: Photolog ofPunjab Colony

i. Final List of Housing Schemes for Sialkot

As per TORs, five (05) Nos. housing schemes were initially selected in Sialkot for wastewater sampling and analysis. The list of schemes, after the approval from PMIU, was made part of the Inception Report. After site visit it is evaluated that the visited societies in Sialkot meet the TORs, criteria for Wastewater sampling and analysis.

Table 3.32: List of Selected Housing Schemes in Sialkot

Sr. No.	City/District	Selected Housing Schemes
1	Sialkot	Chand Bagh Society
2		Mag Town
3		Ghansar Pur
4		Punjab Colony
5		Umer Town

The location maps are given in **Figure 3.5.**

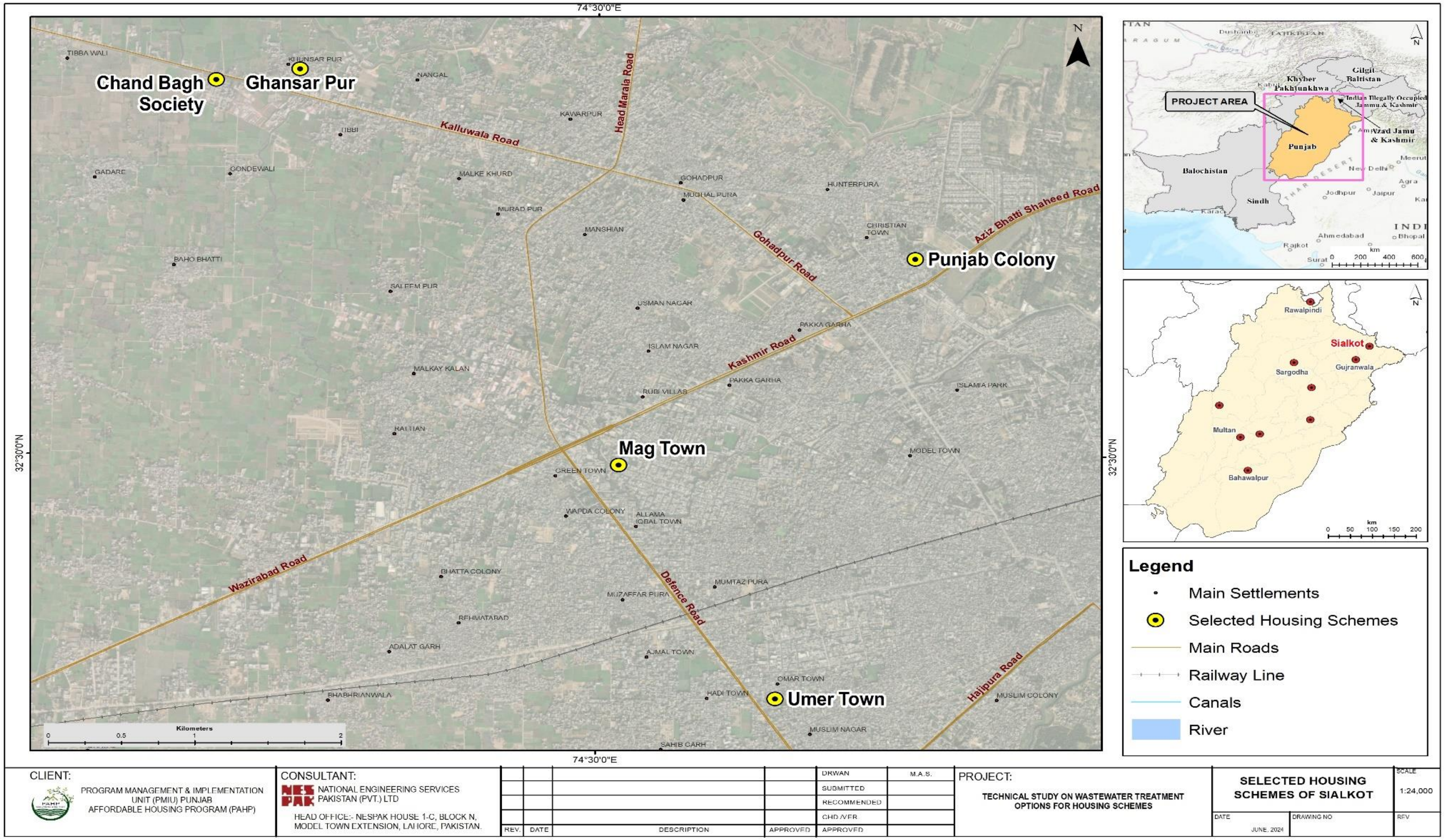


Figure 3.5: Location Map of Selected Housing Schemes of Sialkot

3.11 Rawalpindi

Rawalpindi, often regarded as a gateway to the northern regions of Pakistan, plays a critical role as both a historical and economic hub. The city is closely linked to the capital, Islamabad, and serves as a twin city, contributing to its significance in trade, government, and military affairs. Rawalpindi has a diverse economy, with industries such as textiles, pharmaceuticals, food processing, and electronics playing an important part in the city's economic landscape. Agriculturally, the surrounding region benefits from the Potohar Plateau, which supports rain-fed crops, fruit orchards, and livestock farming.

The city's strategic location along major highways and rail networks enhances its role as a transportation center, facilitating trade and travel across northern Pakistan. Additionally, Rawalpindi is home to numerous healthcare and educational institutions, further solidifying its importance as a service and administrative center in the region. The combination of its strategic importance, economic diversity, and proximity to the capital makes Rawalpindi an attractive place to live and work, which is why it was included in the program.

3.11.1. Ameen Town

Ameen Town is a mixed-income residential area located near the commercial zone of city on the edge of Rawalpindi-Islamabad Territory on Karnal Sher Khan shaheed Road. The housing scheme is densely populated, with an operational sewage collection system. All wastewater generated in the town is conveyed through the sewerage network and directly discharged into Nullah Lai. The town comprises 11 streets, each with its sewage system directly connected to Nullah Lai.

The town is fed by an R-WASA water distribution system, as groundwater is inaccessible due to its considerable depth (i.e., 250 feet). Consequently, most residents utilize the municipal water supply for domestic purposes, while filtered water is used for drinking purposes. There are 800 Houses.

Further details are summarized in the **Table 3.33** below:

Table 3.33:Summary of finding in Ameen Town

Locality	Commercial area of city
Plot size distribution	5,10 marla
No. of Houses	800
Household size	6 (approximately)
Sewerage network	Sewage Network System available but no disposal station is present.
Trunk sewer	Lateral sewer directly connected with Nullah

The glimpses of the scheme are shown in **Plate 3.26** below:

Plate - 3.26: Photolog of Ameen Town

3.11.2. Chaklala Phase-III

Chaklala Phase-III is a high-income residential community centrally located on the service road of Islamabad Expressway. The area is a planned, densely populated neighborhood situated near an industrial zone, with a fully operational sewage collection system. All wastewater generated in the community is conveyed via a trunk line to an open drain, which ultimately discharges into Nullah Lai.

Water supply system is available in the society, as groundwater is inaccessible due to its significant depth (200-250 feet). Consequently, most residents rely on the municipal water supply and tanker services for domestic purposes, while filtered water is used for drinking. There are 1000 Houses. The average income is above 70,000.

Further details are summarized in the **Table 3.34** below:

Table 3.34:Summary of finding in Chaklala Phase-III

Locality	Near city center
Plot size distribution	10,20 marla
No. of Houses	1000
Household size	7 (approximately)
Sewerage network	Community sewer and Main drain is available
Trunk sewer	Trunk sewer available

The glimpses of the scheme are shown in **Plate - 3.27** below:

Plate - 3.27: Photolog of Chaklala Phase-III

3.11.3. City Villas

City Villas is a high-income residential society located in the center of city near the commercial zone on Chaudhry Bostan Khan Road. The area is a planned, densely populated residential community with a partially combined sewerage system. All wastewater generated in the society is collected through lateral sewers into an open drain, which ultimately discharges into Nullah Lai.

The society does not have a municipal water supply system. Groundwater is available at a depth of 250 feet and is used by 8-10% of the residents for both drinking and domestic purposes, while the majority of the population relies on water tankers.

The area is a planned populated residential area located near the commercial zone with partial combined sewerage system. All the wastewater produced in the society is collected through lateral line to open drain and further it is disposed to Nullah Lai. There are 700 Houses. The average income is 50,000 PKR and above.

Further details are summarized in the **Table 3.35** below:

Table 3.35:Summary of finding in City Villas

Locality	Near city center
Plot size distribution	5,10 marla
No. of Houses	700
Household size	7 (approximately)
Sewerage network	Community sewer is available but no disposal station
Trunk sewer	Trunk sewer is available

The glimpses of the scheme are shown in **Plate – 3.28** below:

Plate - 3.28: Photolog of City Villas

3.11.4. Gulrez-II

Gulrez-II is a mixed-income housing society located in a densely populated area. The area features a partially combined sewerage system. All wastewater generated within the society is collected via a trunk sewer and discharged directly into the Korang River.

Water supply system is not available in the society. Groundwater is accessible at depths of 300 to 400 feet, with a few Houses using bore water, while the majority of residents rely on tanker-supplied water for domestic purposes while for drinking purposes filter is being used. There are 900 Houses. The average income is 40,000 – 50,000 PKR.

Further details are summarized in the **Table 3.36** below:

Table 3.36:Summary of finding in Gulrez-II

Locality	Densely populated area
Plot size distribution	5,10 marla
No. of Houses	900
Household size	7 (approximately)
Sewerage network	Community sewer is available but no disposal station
Trunk sewer	Trunk sewer is available

The glimpses of the scheme are shown in **Plate - 3.29** below:

Plate - 3.29: Photolog of Gulrez-II

3.11.5. Milat Colony

Milat Colony is a low-income residential area located near the city center on Chaklala Road. The colony is an unplanned, densely populated area with an open drainage system. Wastewater generated in the colony is collected through open drains and discharged into a WASA trunk sewer running adjacent to the colony. This trunk line connects to an open drain, which eventually discharges into the Korang River.

A municipal water supply system is available in the colony. During a site visit, locals reported that most residents use the water supply for domestic purposes, while filtered water is used for drinking. There are 1000 Houses. The income range is around 35,800 PKR.

Further details are summarized in the **Table 3.37** below:

Table 3.37:Summary of finding in Milat Colony

Locality	Densely populated near the city center
Plot size distribution	3,5 marla
No. of Houses	1000
Household size	7.5 (approximately)
Sewerage network	Open drains connected with trunk sewer
Trunk sewer	WASA Trunk sewer is available

The glimpses of the scheme are shown in **Plate - 3.30** below:

Plate - 3.30: Photolog of Milat Colony

i. Final List of Housing Schemes for Rawalpindi

As per TORs, five (05) Nos. housing schemes were initially selected in Rawalpindi for wastewater sampling and analysis. The list of schemes, after the approval from PMIU, was made part of the Inception Report. However, when the sites were physically visited, the following schemes did not meet the TORs criteria.

- Ghori Town Phase-V
- PWD Housing

Since the aforementioned schemes do not meet the required criteria, they have been deemed unsuitable for further study. Consequently, the following additional schemes were identified in the field and have been selected for further analysis.

- Chaklala Phase-III
- Gulrez-II

The updated list of housing schemes in Rawalpindi are given hereunder:

Table 3. 38:List of Selected Housing Schemes in Rawalpindi

Sr. No.	City/District	Selected Housing Schemes
1	Rawalpindi	Ameen Town
2		Chaklala Phase-III
3		City VIlas
4		Gulrez-II
5		Milat Colony

The updated location maps are given in **Figure 3.6.**

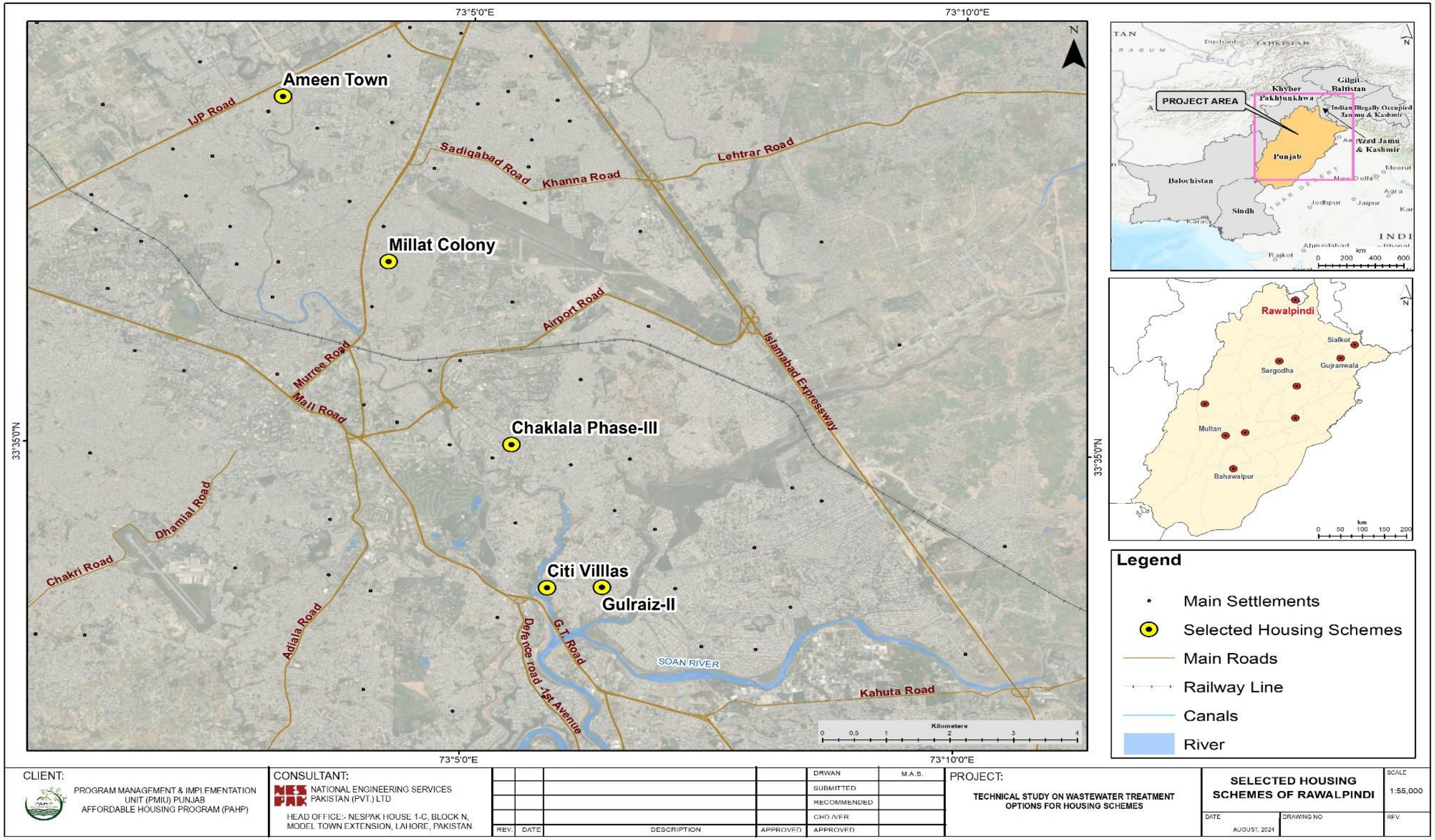


Figure 3.6: Location Map of Selected Housing Schemes of Rawalpindi

3.12 List of Selected Housing Scheme

The list of housing schemes is finalized after completing site visits. During this evaluation process, schemes that did not meet the established TOR criteria were identified and excluded from the list. This process ensured that only those schemes are selected in the final list that comply with the technical requirements. The final list of selected housing schemes are given in the **Table 3.39.**

Table 3.39:List of Selected Housing Schemes

Sr No.	Scheme Names (Region wise)	GPS Coordinates	
		Latitude	Longitude
South Punjab			
Bahawalpur			
1.	Model Avenue	29.338633°	71.610861°
2.	Government Employee Cooperative Housing Society	29.393327°	71.752469°
3.	Qasim Town	29.400028°	71.690928°
4.	Sadiq Colony	29.383386°	71.662458°
5.	Paragon Ideal Homes	29.392767°	71.637039°
Jalalpur Pirwala			
2.	Punjab Housing Scheme	29.521532°	71.229619°
Central Punjab			
Faisalabad			
1.	Shahbaz Nagar	31.480178°	73.052451°
2.	Ashiana Housing Scheme	31.39096°	73.187959°
3.	Imitiaz Town	31.399309°	73.129436°
4.	Abdullah Pur	31.420548°	73.105568°
5.	Steam Power Colony	31.446517°	73.140593°
Layyah			
1.	Housing Colony	30.976472°	70.958355°
2.	TDA Colony	30.962733°	70.958558°
3.	Rehman Abad	30.979094°	70.941266°
4.	Al Janat City	30.967158°	70.979597°
5.	Qureshi Housing Scheme	30.950743°	70.971031°
North Punjab			
Sialkot			
1.	Chand Bagh Society	32.527561°	74.472380°
2.	Mag Town	32.499423°	74.501649°
3.	Ghansar Pur	32.528795°	74.478771°
4.	Punjab Colony	32.514627°	74.523146°
5.	Umer Town	32.482839°	74.513314°
Rawalpindi			
1.	Ameen Town	33.64257778°	73.05116944°
2.	Chaklala Phase-III	33.585560°	73.0972540°
3.	Citi Villas	33.55983611°	73.09770000°
4.	Gulrez-II	33.560182°	73.10701°
5.	Millat Colony	33.613612°	73.069280°

4 WASTEWATER CHARACTERIZATION & ANALYSIS

4.1 General

Wastewater characterization is crucial for understanding the composition of wastewater, helping to identify key contaminants such as organic matter, inorganic matter, nutrients, and solids. It enables the selection of appropriate treatment methods prior to discharge in any existing effluent drain ensuring compliance with environmental standards such as Punjab Environmental Quality standards (PEQS). Accurate characterization ensures efficient resource management and regulatory compliance in wastewater treatment. This section presents the results and analysis of wastewater characterization conducted in the selected schemes finalized in the preceding section.

4.2 Objectives of Wastewater Characterization

- To assess the quality and composition of wastewater in various locations.
- To identify key pollutants and their concentration.
- To determine the appropriate treatment technologies and level of treatment required, based on the characterization.
- To compare wastewater characteristics against PEQS.

4.3 Wastewater Characterization

Wastewater characterization is a matter of primary importance in the planning and designing of wastewater treatment systems. Though it is important to test the wastewater of the actual source at the time of planning, currently there are no functional housing schemes under the program from where the samples could be collected. However, PMIU has initially identified nine (09) potential sites for the proposed interventions. Therefore, the wastewater characterization was performed from similar schemes in the vicinity of identified sites.

Section – 3 of the current report presents a detailed assessment of the similar housing schemes in the vicinity of the proposed locations and identifies the potential wastewater sampling points for further consideration into WWTP planning. The list of selected sampling points is given in **Section-3, Table 3.36**.

Owing to a greater number of sampling locations and keeping in view the time constraints, two different EPA-certified laboratories were hired to do the needful i.e., M/S SGS and M/s Pakgreen Enviro Engineering Pvt. The scope of work of the laboratories is given hereunder:

Laboratory	Cities Assigned
M/s SGS	1. Jalalpur Pirwala 2. Bahawalpur
M/s Pakgreen Enviro Engineering Pvt. Ltd.	1. Faisalabad 2. Sialkot 3. Rawalpindi 4. Layyah

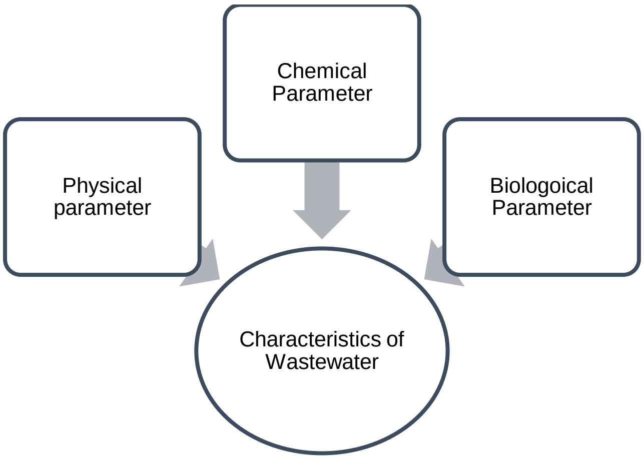
The sampling and testing were conducted in September and October 2024.

4.3.1 Sampling Technique (Composite Sampling)

24-hour composite sampling were carried out to present a better picture of wastewater characteristics. Each sample collected is combined into a single composite sample, providing an average representation of wastewater characteristics throughout the day. This method accounts for fluctuations in flow and pollutant concentrations, making it ideal for accurate monitoring.

4.4 Key Parameters in Wastewater Characterization

The following are the key parameters of wastewater;



1. **Physical Parameter:** e.g., Temperature, TSS
2. **Chemical Parameter:** e.g., BOD, COD, TDS, Nutrients
3. **Biological Parameter:** e.g., Total Coliform, Fecal Coliform, E-Coli

4.5 Wastewater Quality Standards

PEQS are the prevailing standards in Punjab for wastewater quality. However, there are two different sets of standards with respect to the ultimate disposal i.e., disposal into inland water and disposal into sewage treatment. . The PEQS are attached as **Annex - II**.

It is pertinent to mention that the effluent from the selected sampling points is either being discharged into the inland water bodies i.e., rivers, canals and watercourses as well as the municipality sewers. Therefore, the test results will be compared with respect to the final disposal for each of the sampling locations.

4.6 Wastewater Characterization Results and Analysis

The findings of wastewater characterization and analysis of the results for each selected housing scheme in selected cities are given hereunder. The detailed reports are provided in **Annex-III.**

4.6.1 Jalalpur Pirwala

The wastewater testing results for Jalalpur Pirwala are given in **Table 4.1**.

Table 4.1: Wastewater Laboratory Results in Jalalpur Pirwala

Sr. No.	Measuring Parameter	Units	PEQS Limits		Disposal Station	Imam Baksh (Manhole)	Hassan Bakhsh Colony (Manhole)	WWTP Inlet	WWTP Outlet
			Inland Waters	Sewage Treatment					
1	Temperature	◦C	---		30.3	32.5	32.5	32	31.9
2	PH (at respective temperature)	pH	6.5 to 8.5	6.5 to 8.5	6.85	6.90	6.91	6.83	7.01
3	Oil & Grease	(mg/L)	10	10	<5	<5	<5	<5	<5
4	Total Dissolve Solids (TDS)	(mg/L)	3500	3500	960	2220	1070	1204	1210
5	Total Suspended Solids (TSS) (RAW)	(mg/L)	200	400	314	418	28	20	16
6	Total Suspended Solids (TSS) (Settleable)	(mg/L)	-	-	91	106	09	09	05
7	Biological Oxygen Demand (RAW)	(mg/L)	80	250	241	245	45	93	47
8	Biological Oxygen Demand (Settleable)	(mg/L)	-	-	95	145	39	81	34
9	Biological Oxygen Demand (Filter)	(mg/L)	-	-	62	106	37	50	27
10	Chemical Oxygen Demand (RAW)	(mg/L)	150	400	521	525	134	283	137
11	Chemical Oxygen Demand (Settleable)	(mg/L)	-	-	261	422	120	260	110
12	Chemical Oxygen Demand (Filter)	(mg/L)	-	-	185	295	104	176	84

Sr. No.	Measuring Parameter	Units	PEQS Limits		Disposal Station	Imam Baksh (Manhole)	Hassan Bakhsh Colony (Manhole)	WWTP Inlet	WWTP Outlet
			Inland Waters	Sewage Treatment					
13	Ammonia	NH_3(mg/L)	40	40	60.76	52.13	79.57	<5	<5
14	Total Phosphate	(mg/L)	-	-	8.63	7.86	6.34	6.45	6.34
15	Volume Stealable Solids (45 min)	ml/L	-	-	2.6	1.9	0.3	0.1	0.4
16	Total Toxic Metals	(mg/L)	2.0	2.0	0.526	0.652	0.44	0.767	0.443
17	Arsenic	As (mg/L)	1.0	1.0	<0.005	<0.005	<0.005	<0.005	<0.005
18	Chromium	Cr (mg/L)	1.0	1.0	0.029	0.012	0.040	0.047	0.033

The wastewater from the sampling locations is discharged either into municipality sewerage system or into inland waters i.e., Rivers, Canals or water courses etc., therefore, the results have been compared separately with the standards for disposal into sewage treatment system and disposal into inland waters respectively.

The Total Suspended Solids (TSS) in raw form in Imam Baksh colony sample are higher than prescribed wastewater sewage treatment PEQS limit, while TSS (settleable)are remarkably lower, indicating that significant portion of the settleable solids is present in wastewater sample. Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) is a key indicator of organic pollution, and measuring it in different forms (raw, settleable, and filtered) provides insight into the composition of the wastewater. In Imam Baksh colony manhole and Disposal Station sample, the raw COD is significantly higher than prescribed limit, indicating a relatively high organic load in untreated wastewater. The COD (settleable) is showing that a significant portion of the organic matter can settle out of suspension. The filtered COD represents the dissolved organic matter that remains after settleable solids are removed. The difference between these values highlights the presence of particulate and dissolved organic pollutants. Ammonia levels at higher side further suggest a considerable presence of nitrogenous waste. The wastewater sample is of low strength.

As discussed in Section 3.7, the area selected for the sampling is a rural setting that barely gets a certain amount of potable water. Therefore, the wastewater does not get diluted much and presents high concentrations in certain manholes and disposal stations. However, the lower concentrations at the inlet of WWTP are due to settling in the force main, which is around 1 km long. It is thus concluded that the reason behind high concentrations is the lesser availability of water and that behind the lower concentrations is settling in the conveyance system.

4.6.2 Bahawalpur

The wastewater testing results for Bahawalpur are given in **Table 4.2**.

Table 4.2: Wastewater Laboratory Results in Bahawalpur

Sr #	Measuring Parameter	Unit	PEQS Limits		Qasim Town Manhole	Govt. Employee Housing Society Manhole	Govt. Employee Housing Society Disp. Station	Manhole Near House 144 B	Manhole Infront of Disposal Station	Sadiq Colony Manhole	Sadiq Colony Manhole Infront Public School	Ideal Homes Manhole	Ideal Homes Manhole Water Filtration Plant
			PEQS Limit	Sewage Treatment									
1	Temperature	◦C	---		31.8	32.4	32.2	32.8	33.6	31.6	31.3	31.1	31.2
2	PH	pH	6.5 to 8.5	6.5 to 8.5	6.83	6.96	7.13	7.22	7.20	6.90	6.75	7.31	7.24
3	Oil & Grease	mg/L	10	10	<5	<5	<5	<5	<5	<5	<5	<5	<5
4	Total Dissolve Solids	mg/L	3500	3500	880	1248	1583	814	876	882	872	1101	1052
5	Total Suspended Solids (TSS) (RAW)	mg/L	200	400	39	80	68	24	14	208	244	28	18
6	Total Suspended Solids (TSS) (Settleable)	mg/L	-	-	26	34	25	10	05	96	120	06	06
7	Biological Oxygen Demand (RAW)	mg/L	80	250	180	192	94	35	40	150	180	80	74
8	Biological Oxygen	mg/L	-	-	130	160	75	31	38	110	108	78	57

Sr #	Measuring Parameter	Unit	PEQS Limits		Qasim Town Manhole	Govt. Employee Housing Society Manhole	Govt. Employee Housing Society Disp. Station	Manhole Near House 144 B	Manhole Infront of Disposal Station	Sadiq Colony Manhole	Sadiq Colony Manhole Infront Public School	Ideal Homes Manhole	Ideal Homes Manhole Water Filtration Plant
			PEQS Limit	Sewage Treatment									
	Demand (Settleable)												
9	Biological Oxygen Demand (Filter)	mg/L	-	-	106	130	66	31	30	92	93	70	44
10	Chemical Oxygen Demand (RAW)	mg/L	150	400	474	491	242	107	120	425	472	226	190
11	Chemical Oxygen Demand (Settleable)	mg/L	-	-	370	430	213	97	119	296	264	218	152
12	Chemical Oxygen Demand (Filter)	mg/L	-	-	322	385	180	96	97	264	236	186	132
13	Ammonia	mg/L	40	40	79.18	59.19	58.4	38.8	55.27	55.66	39.98	53.70	43.90
14	Total Phosphate	mg/L	-	-	4.34	5.52	6.18	3.24	3.10	3.11	3.12	5.14	4.62
15	Stealable Solids	mg/L	-	-	0.5	0.6	0.4	0.1	0.1	0.3	0.4	0.1	0.1
16	Total Toxic Metals	mg/L	2.0	2.0	0.408	0.495	0.549	0.717	0.589	0.46	0.501	0.71	0.395
17	Arsenic	mg/L	1.0	1.0	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
18	Chromium	mg/L	1.0	1.0	0.008	0.045	0.039	<0.005	0.009	<0.005	0.011	<0.005	0.015

Raw BOD levels in Manhole and disposal station of Govt. Employee Housing Society is significantly higher than the prescribed limit, indicating a relatively high organic load in untreated wastewater. COD in Govt. Employee Housing Society and at Sadiq colony samples are also not in compliance with PEQS. The BOD and COD (settleable) is showing that a significant portion of the organic matter can settle out of suspension. The reason behind high concentrations is the lower dilution of wastewater due to limited water supply in the project area. The filtered samples represent the dissolved organic matter that remains after settleable solids are removed. The difference between these values highlights the presence of particulate and dissolved organic pollutants. It is thus concluded that there is a significant percentage of settleable pollution in sampled wastewater which gets cleared when allows sufficient settling. Furthermore, ammonia levels are high which suggest a considerable presence of nitrogenous waste. Overall, the wastewater sample is of low strength.

4.6.3 Faisalabad

The wastewater testing results for Faisalabad are given in **Table 4.3**.

Table 4.3: Wastewater Laboratory Results in Faisalabad

Sr #	Measuring Parameter	Units	PEQS Limits		Ashiana Housing Scheme (Disp. Station)	Ashiana Housing Scheme (Manhole)	Abdullah Pur FSD. (Disp. Station)	Abdullah Pur FSD. (Manhole)	Shahbaz Nagar (Disp. Station)	Imtiaz Town (Manhole)	SPC-I (Disposal Station)
			PEQS Limit	Sewage Treatment							
1	Temperature	◦C	---		23.9	23.8	24	24.5	23.8	24	24
2	PH	pH	6.5 to 8.5	6.5 to 8.5	8.1	7.85	7.72	7.4	8.042	8.73	8.040
3	Oil & Grease	(mg/L)	10	10	BDL	BDL	BDL	BDL	BDL	BDL	BDL
4	Total Dissolve Solids (TDS)	(mg/L)	3500	3500	920	890	2090	680	2270	2810	630
5	Total Suspended Solids (TSS) (RAW)	(mg/L)	200	400	72	92	64	240	62	180	52
6	Total Suspended Solids (TSS) (Settleable)	(mg/L)	-	-	65	65	27	154	40	150	40
7	Biological Oxygen Demand (RAW)	(mg/L)	80	250	48	58	78	184	158	138	68
8	Biological Oxygen Demand (Settleable)	(mg/L)	-	-	38	42	68	138	108	124	58
9	Biological Oxygen Demand (Filter)	(mg/L)	-	-	28	38	68	118	98	108	38
10	Chemical Oxygen Demand (RAW)	(mg/L)	150	400	78	96	128	294	252	224	112
11	Chemical Oxygen Demand (Settleable)	(mg/L)	-	-	56	64	112	216	172	192	98
12	Chemical Oxygen Demand (Filter)	(mg/L)	-	-	48	56	112	192	154	168	56

Sr #	Measuring Parameter	Units	PEQS Limits		Ashiana Housing Scheme (Disp. Station)	Ashiana Housing Scheme (Manhole)	Abdullah Pur FSD. (Disp. Station)	Abdullah Pur FSD. (Manhole)	Shahbaz Nagar (Disp. Station)	Imtiaz Town (Manhole)	SPC-I (Disposal Station)
			PEQS Limit	Sewage Treatment							
13	Ammonia	NH3(mg/L)	40	40	5.5	7.4	17.6	27.4	22.4	19.9	11.9
14	Total Phosphate	(mg/L)	-	-	2.271	2.461	4.899	8.88	5.59	5.444	5.49
15	Stealable Solids	(mg/L)	-	-	65	64.5	27	154	40	150	40
16	Total Toxic Metals	(mg/L)	2.0	2.0	0.1285	0.1477	0.2011	0.1941	0.3572	0.2318	0.3249
17	Arsenic	As (mg/L)	1.0	1.0	BDL	BDL	BDL	BDL	BDL	BDL	BDL
18	Chromium	Cr (mg/L)	1.0	1.0	0.1285	0.1477	0.201	0.1941	0.3572	0.2318	0.3249

The sampling site is a rural settlement with less availability of water. Raw BOD and COD levels in disposal station of Shahbaz Nagar and at Manhole of Imtiaz colony are significantly higher than the prescribed limit, indicating a relatively high organic load in untreated wastewater. The BOD and COD (settleable) suggest that a significant portion of the organic matter can settle-out of suspension. The higher values are because of the reason that the sample was collected directly from the outlet of a household in the manhole. The high values in disposal station could be due to the reason that the sample was collected from the incoming sewage without allowing the settling.

The filtered samples represent the dissolved organic matter that remains after settleable solids are removed. The difference between these values highlights the presence of particulate and dissolved organic pollutants. Overall, the wastewater is of low strength and most of the samples were within the permissible limits.

4.6.4 Layyah

The wastewater testing results for Layyah are given in **Table 4.4**.

Table 4.4: Wastewater Laboratory Results in Layyah

Sr #	Measuring Parameter	Units	PEQS Limits		Housing Colony 1 (Manhole)	Housing Colony 1 (Disposal Station)	Al Jannat City (Disposal Station)	Qureshi Colony (Disposal Station)	Rehman Abad (Open Drain)	TDA Colony (Disposal Station)	TDA Colony (Manhole)
			PEQS Limit	Sewage Treatment							
1	Temperature	◦C	---		22.5	22	22	22.8	22.8	22.7	24.9
2	PH	pH	6.5 to 8.5	6.5 to 8.5	7.575	7.716	7.774	7.856	7.025	7.430	7.649
3	Oil & Grease	(mg/L)	10	10	BDL	BDL	BDL	BDL	BDL	BDL	BDL
4	Total Dissolve Solids	(mg/L)	3500	3500	950	990	1020	1040	1080	780	710
5	TSS (RAW)	(mg/L)	200	400	100	50	50	30	350	18	83
6	Total Suspended Solids (Settleable)	(mg/L)	-	-	75	36	40	20	210	6	67
7	Biological Oxygen Demand (RAW)	(mg/L)	80	250	58	68	38	24	328	28	26
8	Biological Oxygen Demand (Settleable)	(mg/L)	-	-	40	53	36	14	208	24	22
9	Biological Oxygen Demand (Filter)	(mg/L)	-	-	32	44	18	6	178	18	16
10	Chemical Oxygen Demand (RAW)	(mg/L)	150	400	88	108	64	40	524	48	40

Sr #	Measuring Parameter	Units	PEQS Limits		Housing Colony 1 (Manhole)	Housing Colony 1 (Disposal Station)	Al Jannat City (Disposal Station)	Qureshi Colony (Disposal Station)	Rehman Abad (Open Drain)	TDA Colony (Disposal Station)	TDA Colony (Manhole)
			PEQS Limit	Sewage Treatment							
11	Chemical Oxygen Demand (Settleable)	(mg/L)	-	-	64	80	56	18	320	32	32
12	Chemical Oxygen Demand (Filter)	(mg/L)	-	-	48	64	32	8	280	28	24
13	Ammonia	NH3(mg/L)	40	40	18.5	4.0	4.3	3.5	23.6	1.1	10.9
14	Total Phosphate	(mg/L)	-	-	2.525	2.158	14.83	10.84	4.935	11.67	9.824
15	Stealable Solids	(mg/L)	-	-	75	36	400	20	210	06	67
16	Total Toxic Metals	(mg/L)	2.0	2.0	0.0561	0.0552	0.0583	0.0547	0.2629	0.0633	0.0574
17	Arsenic	As (mg/L)	1.0	1.0	BDL	BDL	BDL	BDL	0.0142	BDL	BDL
18	Chromium	Cr (mg/L)	1.0	1.0	0.0561	0.0552	0.0583	0.0547	0.0838	0.0633	0.0574

Raw BOD and COD levels in disposal station of Rehman Abad Colony is significantly higher than the prescribed limit, indicating a relatively high organic load in untreated wastewater. The reason in higher concentrations in comparison to other samples could be open dumping of solid waste i.e., silt or could be due to mixing of industrial wastewater. The BOD and COD (settleable) shows that a significant portion of the organic matter can settle out of suspension. The filtered samples represent the dissolved organic matter that remains after settleable solids are removed. The difference between these values highlights the presence of particulate and dissolved solids are present in the sample. The overall strength of wastewater is low.

4.6.5 Sialkot

The wastewater testing results for Sialkot are given in **Table 4.5**.

Table 4.5: Wastewater Laboratory Results in Sialkot

Sr #	Measuring Parameter	Units	PEQS Limits		Ghanaspur Main Trunk Sewer	Ghanaspur Manhole	Chandbagh Main Trunk Sewer	Punjab Colony Manhole	Umer Town Main Trunk Sewer	Mag Town Manhole	Mag Town Disposal Station
			PEQS Limit	Sewage Treatment							
1	Temperature	◦C	---		24.7	24.3	24.7	23.9	24.7	23.7	23.2
2	PH	pH	6.5 to 8.5	6.5 to 8.5	7.715	7.345	7.485	7.257	7.34	7.006	7.295
3	Oil & Grease	(mg/L)	10	10	BDL	BDL	BDL	BDL	BDL	BDL	BDL
4	Total Dissolve Solids	(mg/L)	3500	3500	1010	1040	740	820	580	448	590
5	Total Suspended Solids (TSS) (RAW)	(mg/L)	200	400	47	97	95	64	542	83	43
6	Total Suspended Solids (Settleable)	(mg/L)	-	-	26	79	61	32	432	60	17
7	Biological Oxygen Demand (RAW)	(mg/L)	80	250	46	178	68	58	188	48	40
8	Biological Oxygen Demand (Settleable)	(mg/L)	-	-	28	44	48	38	58	36	58
9	Biological Oxygen Demand (Filter)	(mg/L)	-	-	24	38	28	28	48	24	38
10	Chemical Oxygen Demand (RAW)	(mg/L)	150	400	72	280	112	88	294	80	96

Sr #	Measuring Parameter	Units	PEQS Limits		Ghanaspur Main Trunk Sewer	Ghanaspur Manhole	Chandbagh Main Trunk Sewer	Punjab Colony Manhole	Umer Town Main Trunk Sewer	Mag Town Manhole	Mag Town Disposal Station
			PEQS Limit	Sewage Treatment							
11	Chemical Oxygen Demand (Settleable)	(mg/L)	-	-	48	64	72	56	96	56	72
12	Chemical Oxygen Demand (Filter)	(mg/L)	-	-	40	56	40	48	80	40	64
13	Ammonia	NH3(mg/L)	40	40	4.6	29.1	9.1	7.7	32.6	7.6	4.1
14	Total Phosphate	(mg/L)	-	-	7.09	6.539	6.277	7.493	7.380	5.027	8.150
15	Stealable Solids	(mg/L)	-	-	26	79	61	32	432	60	17
16	Total Toxic Metals	(mg/L)	2.0	2.0	BDL	BDL	BDL	BDL	BDL	BDL	BDL
17	Arsenic	As (mg/L)	1.0	1.0	BDL	BDL	BDL	BDL	BDL	BDL	BDL
18	Chromium	Cr (mg/L)	1.0	1.0	BDL	BDL	BDL	BDL	0.1084	BDL	BDL

The wastewater from the above sampling locations is discharged either into the municipality sewers or the wastewater drains, thus the results have been compared with the standards for disposal into sewage treatment facility. It has been observed that all the parameters are within the prescribed limit for disposal into sewage treatment. However, the only sample of Umar Town Main Trunk Sewer represents higher TSS concentrations. The possible reasons could be the silt deposition in the trunk sewer. Furthermore, the greater depth of sample could also be the cause of hthe higher concentrations.

4.6.6 Rawalpindi

The wastewater testing results for Rawalpindi are given in **Table 4.6**.

Table 4.6: Wastewater Laboratory Results in Rawalpindi

Sr #	Measuring Parameter	Units	PEQS Limits		Gulraiz 2 Colony (Disposal)	Millat Colony (Drain)	Millat Colony (House Outlet Pipe)	Chaklala-3 (Nullah)	Ameen Town (Pipe Near Nullah)
			PEQS Limit	Sewage Treatment					
1	Temperature	◦C	---		23.4	23.0	23.6	22.9	22.9
2	PH	pH	6.5 to 8.5	6.5 to 8.5	7.433	8.212	7.492	7.515	7.304
3	Oil & Grease	(mg/L)	10	10	BDL	BDL	BDL	BDL	BDL
4	Total Dissolve Solids	(mg/L)	3500	3500	1120	990	910	590	1280
5	TSS (RAW)	(mg/L)	200	400	480	160	200	15	880
6	TSS (Settleable)	(mg/L)	-	-	260	100	110	06	580
7	Biological Oxygen Demand (RAW)	(mg/L)	80	250	128	128	148	18	408
8	Biological Oxygen Demand (Settleable)	(mg/L)	-	-	108	88	108	08	218
9	Biological Oxygen Demand (Filter)	(mg/L)	-	-	80	58	88	06	188
10	Chemical Oxygen Demand (RAW)	(mg/L)	150	400	210	196	230	28	648
11	Chemical Oxygen Demand (Settleable)	(mg/L)	-	-	168	144	178	16	348
12	Chemical Oxygen Demand (Filter)	(mg/L)	-	-	132	96	144	10	298
13	Ammonia	NH3(mg/L)	40	40	27.6	26.3	29.1	3.1	35.6
14	Total Phosphate	(mg/L)	-	-	3.953	2.073	2.080	0.709	5.380
15	Stealable Solids	(mg/L)	-	-	260	100	110	06	580
16	Total Toxic Metals	(mg/L)	2.0	2.0	0.1114	0.1047	0.2258	0.1415	0.2732
17	Arsenic	As (mg/L)	1.0	1.0	BDL	BDL	BDL	BDL	BDL

Sr #	Measuring Parameter	Units	PEQS Limits		Gulraiz 2 Colony (Disposal)	Millat Colony (Drain)	Millat Colony (House Outlet Pipe)	Chaklala-3 (Nullah)	Ameen Town (Pipe Near Nullah)
			PEQS Limit	Sewage Treatment					
18	Chromium	Cr (mg/L)	1.0	1.0	0.0688	0.1047	0.1277	0.1415	0.1534

The TSS in raw form at Gulraiz Townand at Ameen Townare higher than prescribed PEQS limit, while TSS (settleable) are relatively lower, indicating that significant portion of the settleable solids is present in wastewater sample. At Gulraiz Town, Millat Colony (2 samples) and Ameen Townsample, the raw BOD is significantly higher than prescribed limit, indicating a relatively high organic load in untreated wastewater. The sample was collected from the area which is suffering from water crises and receives very limited amount of water. Thus there is very little dilution and the strength of wastewater is high.

The BOD (settleable) is showing that a significant portion of the organic matter is settleable. The filtered BOD represents the dissolved organic matter that remains after settleable solids are removed. The difference between these values highlights the presence of particulate and dissolved organic pollutants. However, in the remaining sample collected BOD and COD are complying with PEQs level which indicates Houses sewage typically has more consistent composition and many solids are in settleable solids form. The wastewater sample is of low strength.

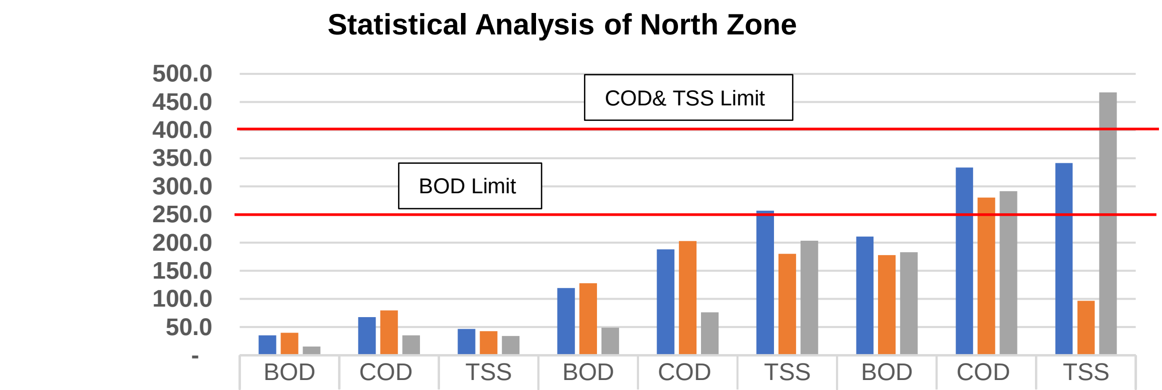
In Ameen Town, the BOD levels are notably high due to the lack of a proper water supply system in the area. Water is typically available for only one hour per day, leading residents to rely on commercial water tankers. This limited water availability results in low dilution, contributing to a higher BOD and COD load in the wastewater.

4.7 Statistical Analysis of Wastewater Characterization Results

The preceding section presents a comprehensive analysis of the wastewater testing results and the justification for certain parameters. However, a statistical analysis has been conducted to enhance decision-making for selection of the most suitable wastewater management option. Only the key wastewater quality parameters, i.e., BOD, COD and TSS have been included in the statistical analysis. On a broader scale the samples were segregated on the bases of geographical region i.e., South, Central and Noth Punjab as well as socio-economic status of the communities i.e., High-income, Medium-income and Low-income communities.

4.7.1 Statistical Analysis Based on Geographical Location

Geographically, the samples were collected from South, Central and North Punjab and their Mean, Medians and Standard Deviations are presented hereunder:

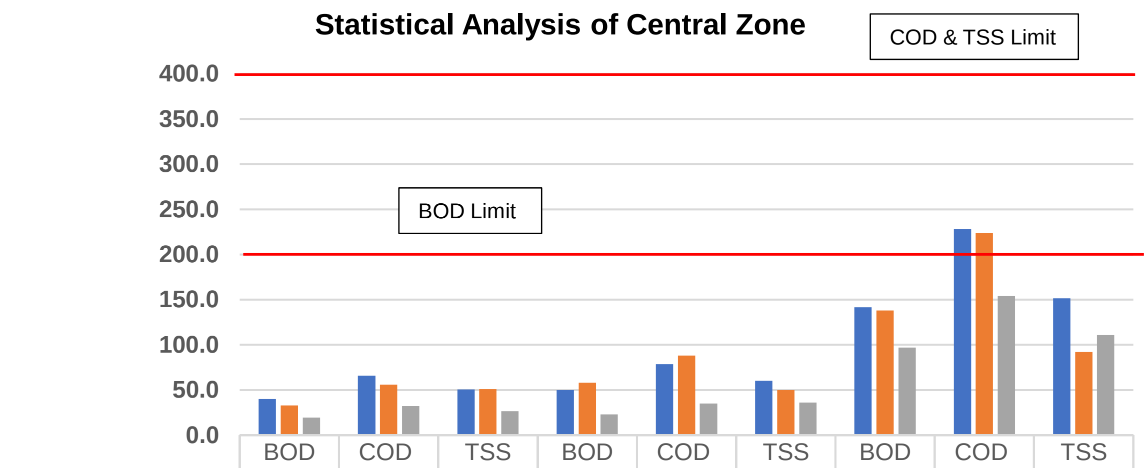


	High Income			Medium Income			Low Income		
	BOD	COD	TSS	BOD	COD	TSS	BOD	COD	TSS
Mean	35.3	68.0	47.0	119.7	188.3	256.8	210.7	333.3	341.3
Median	40.0	80.0	43.0	128.0	203.0	180.0	178.0	280.0	97.0
Standard Deviation	15.5	35.6	34.2	49.2	76.6	203.5	183.2	291.7	467.2

Mean Median Standard Deviation

Figure 4.1: Statistical Analysis of North Zone

The statistical analysis reveals that as we move from high income to low-income communities in the North region (i.e., Rawalpindi and Sialkot), an increasing trend is observed in terms of mean and median values of the key parameters. The reason behind this increasing trend is that the high-income communities receive high volumes of water per capita, and the availability of water reduces for the medium-income communities and is least for the low-income areas. The higher quantities of water in the high-income groups dilute the wastewater which is observed less in the other groups. However, the value of the parameters is not significantly high and is within the PEQS limits as shown in **Figure 4.1**.

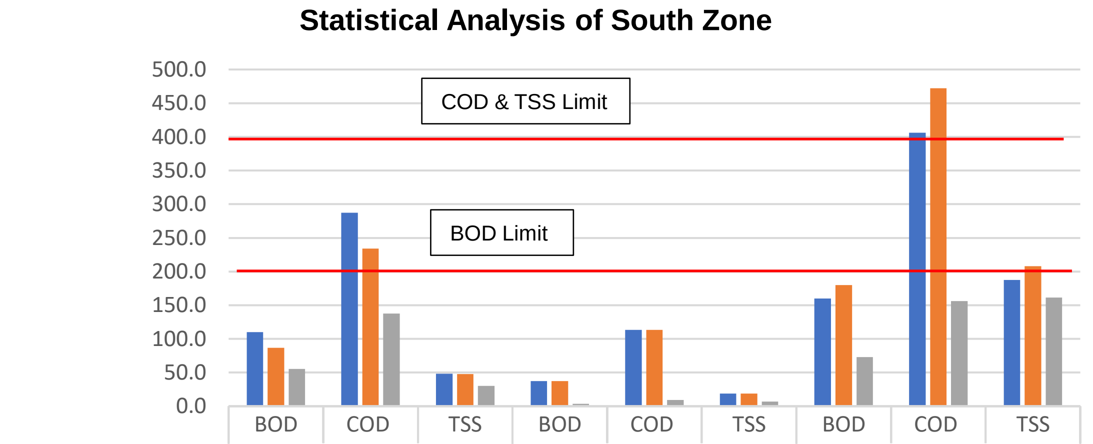


	BOD (High Income)	COD (High Income)	TSS (High Income)	BOD (Medium Income)	COD (Medium Income)	TSS (Medium Income)	BOD (Low Income)	COD (Low Income)	TSS (Low Income)
Mean	40.0	66.0	50.8	50.0	78.7	60.0	141.7	228.0	151.4
Median	33.0	56.0	51.0	58.0	88.0	50.0	138.0	224.0	92.0
Standard Deviation	19.4	32.2	26.6	23.1	34.9	36.1	97.1	154.1	110.7

■ Mean ■ Median ■ Standard Deviation

Figure 4. 2: Statistical Analysis of Central Zone

Likewise North, the same trend was observed in the central region (i.e., Faisalabad and Layyah). The mean and median values of the BOD, COD and TSS are slightly higher in low-income communities, but within the PEQS limits as shown in **Figure 4.2**.



	BOD (High Income)	COD (High Income)	TSS (High Income)	BOD (Medium Income)	COD (Medium Income)	TSS (Medium Income)	BOD (Low Income)	COD (Low Income)	TSS (Low Income)
Mean	110.0	287.3	48.5	37.5	113.5	19.0	160.0	406.0	187.4
Median	87.0	234.0	48.0	37.5	113.5	19.0	180.0	472.0	208.0
Standard Deviation	55.3	137.6	30.1	3.5	9.2	7.1	73.1	156.1	161.4

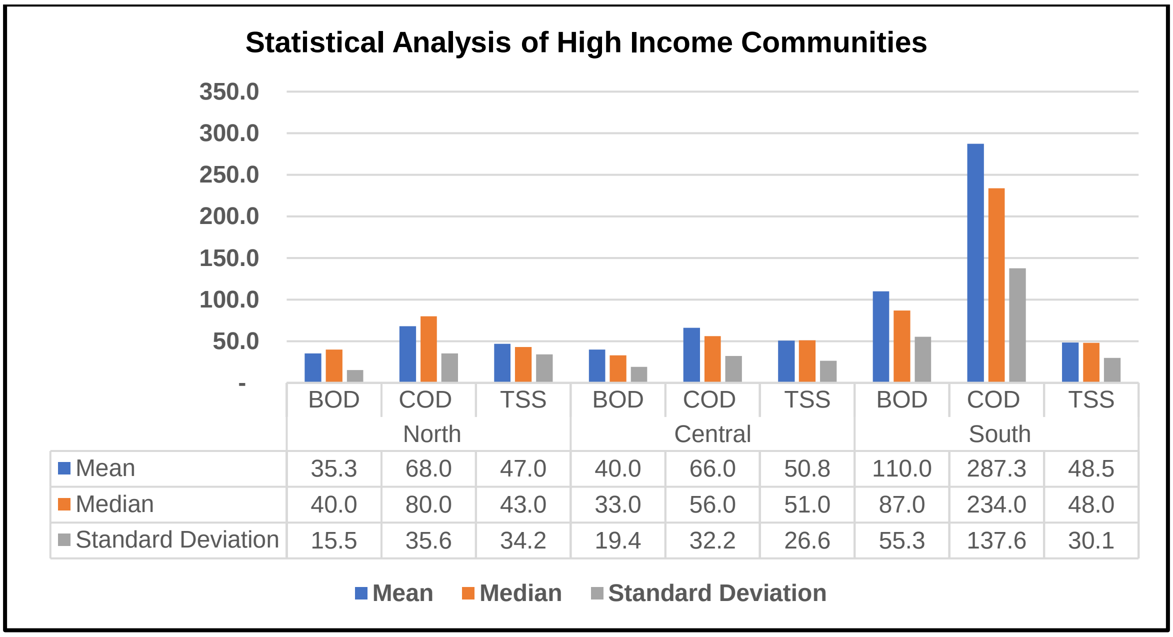
■ Mean ■ Median ■ Standard Deviation

Figure 4.3: Statistical Analysis of South Zone

The case of South (i.e., Bahawalpur and Jalalpur Pirwala) is not different from the ongoing trend and the low-income groups impart higher BOD, COD and TSS. More importantly, these values do not surpass PEQS as shown in **Figure 4.3**.

4.7.2 Statistical Analysis Based on Socioeconomic Status

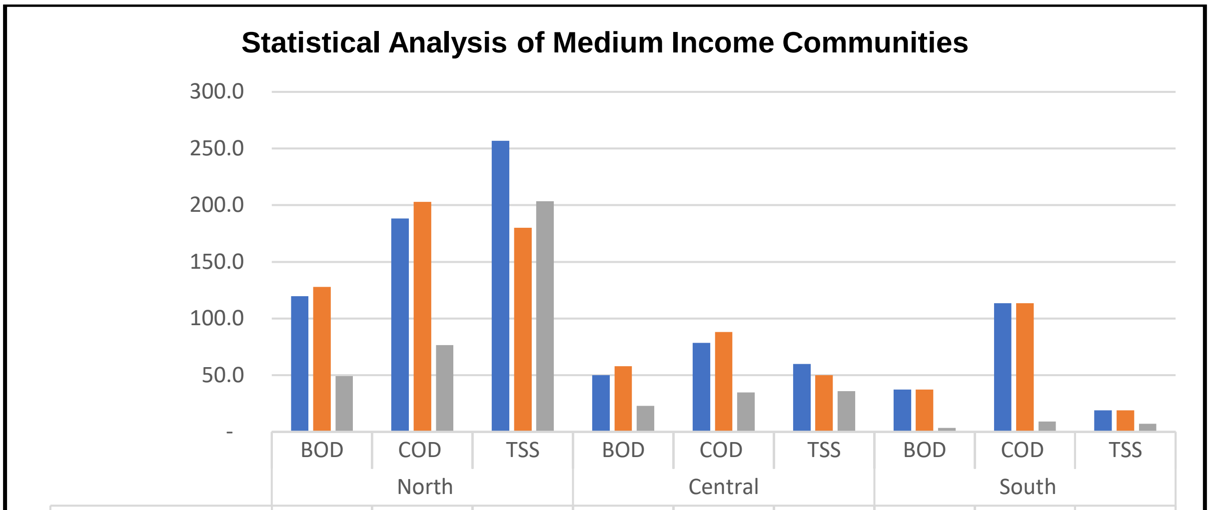
It has been observed that the values of BOD, COD and TSS do vary with respect to the socioeconomic status of the communities. Therefore, an individual analysis with respect to socioeconomic status was also conducted and is presented hereunder.



	North			Central			South		
	BOD	COD	TSS	BOD	COD	TSS	BOD	COD	TSS
Mean	35.3	68.0	47.0	40.0	66.0	50.8	110.0	287.3	48.5
Median	40.0	80.0	43.0	33.0	56.0	51.0	87.0	234.0	48.0
Standard Deviation	15.5	35.6	34.2	19.4	32.2	26.6	55.3	137.6	30.1

Figure 4.4: Statistical Analysis of High Income Communities

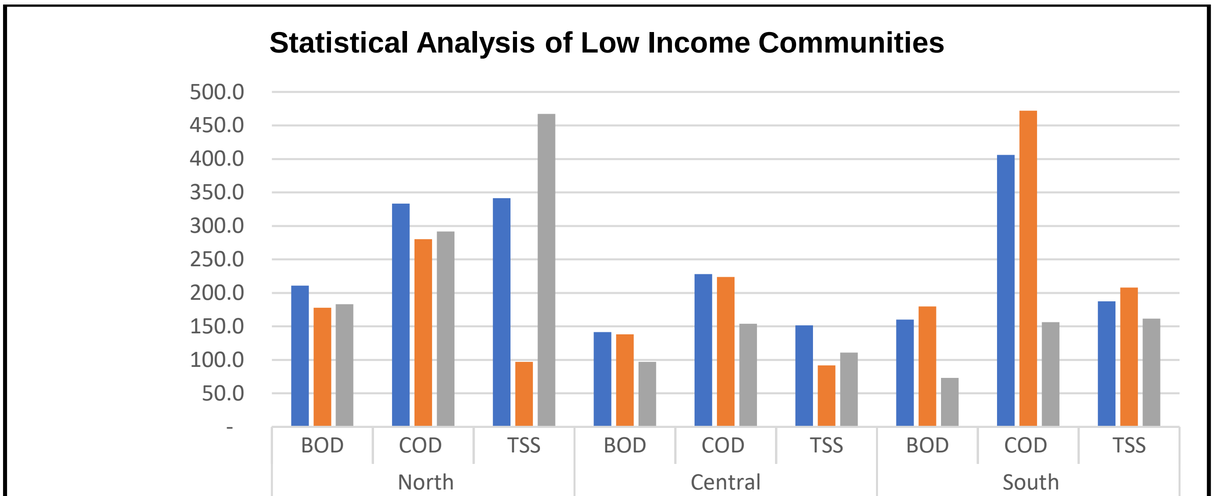
The mean and median values of the key parameters are well within the permissible limits; however, these values are observed to be higher in the south region as compared to others. This could be due to varying standards of living and the availability of water in the region as represented in **Figure 4.4**.



	BOD	COD	TSS	BOD	COD	TSS	BOD	COD	TSS
	North			Central			South		
Mean	119.7	188.3	256.8	50.0	78.7	60.0	37.5	113.5	19.0
Median	128.0	203.0	180.0	58.0	88.0	50.0	37.5	113.5	19.0
Standard Deviation	49.2	76.6	203.5	23.1	34.9	36.1	3.5	9.2	7.1

Figure 4.5: Statistical Analysis of MediumIncome Communities

In the case of medium income communities, the values were observed to be slightly higher in the North region. This is the specific case of Rawalpindi where there is acute shortage of water, and the dilution of wastewater is minimum. However, all the values are within the PEQS limits as shown in **Figure 4.5**.



	BOD	COD	TSS	BOD	COD	TSS	BOD	COD	TSS
	North			Central			South		
Mean	210.7	333.3	341.3	141.7	228.0	151.4	160.0	406.0	187.4
Median	178.0	280.0	97.0	138.0	224.0	92.0	180.0	472.0	208.0
Standard Deviation	183.2	291.7	467.2	97.1	154.1	110.7	73.1	156.1	161.4

Figure 4.6: Statistical Analysis of Low-Income Communities

The values in the low-income communities are higher irrespective of the geographical location. The primary reason is the limited availability of water. However, the values are not beyond the permissible standards as shown in **Figure 4.6**.

4.8 Percentage Reduction through Settling

In addition to the measurement of key parameters from raw samples, the samples were also subject to settling and then the filtered samples were analyzed. The holistic comparison of the mean values of all forty (40) samples in raw and settled form along with their percentage reduction through settling is given in **Table 4.7** below and shown in **Figure 4.7**:

Table 4.7: Percentage Reduction Through Settling

Parameters	Mean Value of 40 Samples (Raw)	Mean Value of 40 Samples (Settled)	Percentage Reduction (%)
BOD	104	72	31
COD	200	143	29
TSS	137	83	39

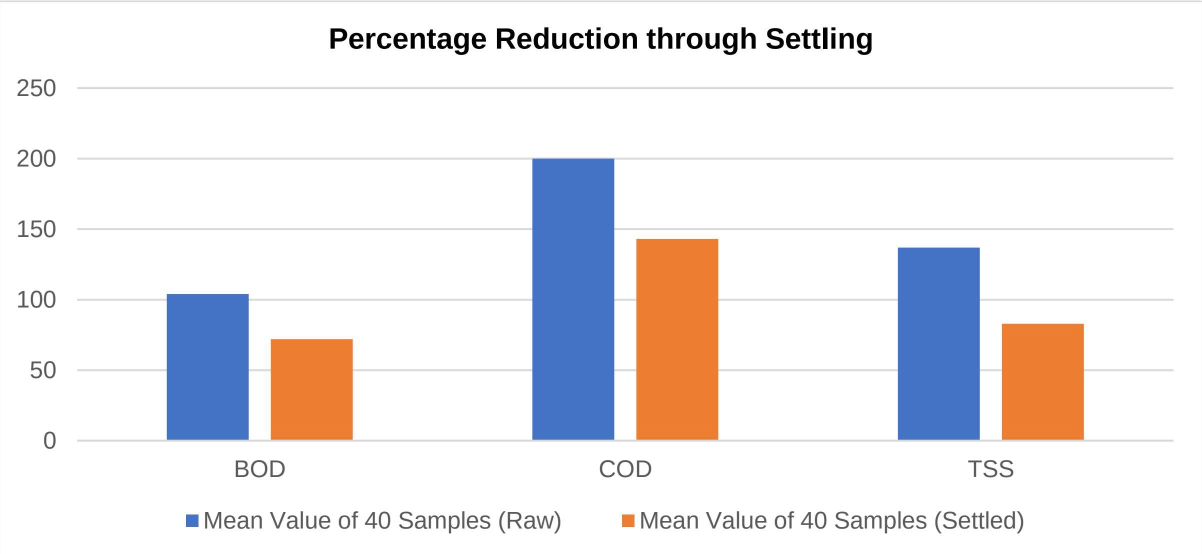


Figure 4.7: Percentage Reduction through Settling

This indicates that the wastewater if subject to primary settling, then 30% of the pollution load is reduced.

4.9 Conclusion of Wastewater Characterization

Based on the above analysis, it is declared that the wastewater is of low strength and a significant proportion of the pollution corresponds to the settleable solids. Therefore, for future planning of wastewater treatment systems, the following parameters will be adopted as given in **Table 4.8**.

Table 4.8: Proposed Parameters for wastewater treatment option selection

Parameters	Values
BOD	100-140 mg/L
TSS	100-200 mg/L
Water Demand	30 Gallons per capita per day (GPCD)
Sewage Generation	85% of water demand (25.5 GPCD)

5 WASTEWATER MANAGEMENT OPTIONS

Wastewater treatment is a complex and costly endeavor, ideally carried out at the end of the pipeline, specifically at the municipality's final collection and disposal site. Once wastewater from a housing scheme or commercial area is linked to the municipality's sewer system, it becomes the municipality's responsibility to manage that wastewater. Consequently, the program's primary focus is to convey the sewage into the existing community network, ensuring compliance with necessary regulations and meeting institutional requirements. A symbolic diagram of connecting the sewage to the municipality sewer is shown in **Figure 5.1** below:

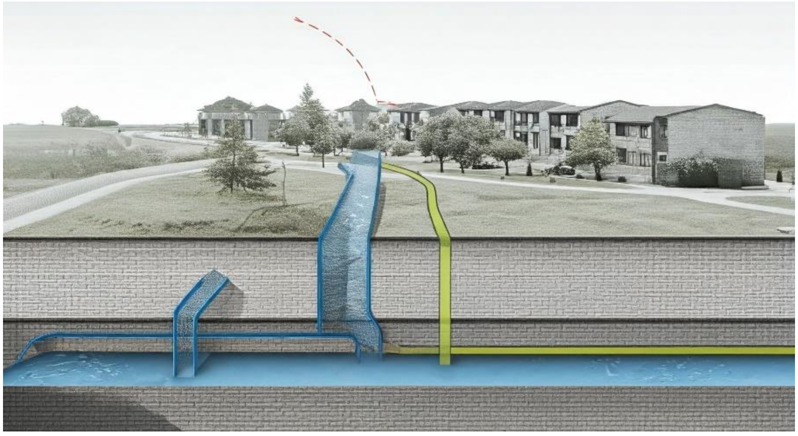


Figure 5.1: Symbolic Diagram of the Sewage Connecting to the Municipality Sewer

However, there could be the following four (04) scenarios in terms of the connectivity of sewage:

Scenario – 1:

In the first scenario, the municipality sewer will be adjacent to the housing scheme. PAHP will ensure the preliminary treatment of the domestic wastewater at the household level, i.e., through Houses septic tanks, and then convey it to the municipality sewerage network. The schematic diagram is shown in **Figure 5.2**:

Figure 5.2: Schematic Diagram of Scenario – 1

Scenario – 2:

If the municipality's sewer line is available but situated at a considerable distance from the proposed PAHP housing scheme, the project will construct a new sewage conveyance channel for connection. This option involves several technical, social, and environmental factors. Technical considerations include the depth of the groundwater table, soil types, topography, and potential road and canal crossings. Environmental factors may involve the proximity of water bodies and the need for tree removal, if necessary. Social considerations could address land issues, connectivity, and crossings in relation to other housing schemes and commercial areas. Once all these factors have been evaluated, and the construction of sewerage line is declared feasible in the site-specific study, then sewer line will be installed from the community's collection point to the municipality. It's important to emphasize that having septic tanks in Houses is essential. Furthermore, if the construction of the sewerage line is not feasible then the construction of in-house treatment facility (WWTP) will be considered (see Scenario-4).

The schematic of the Scenario-2 is shown in **Figure 5.3**.

Figure 5.3: Schematic Diagram of Scenario – 2

Scenario – 3:

There could be cases where the municipality WWTP is available. In this case the sewage from the proposed PAHP Housing Schemes will be conveyed to WWTP. However, likewise Sceanrio-2, if the WWTP is located at a considerable distance from the proposed housing scheme, all the technical, environmental and social considerations will come into play and the feasibility would decide if the connection to the WWTP is possible or not. If it is rendered unfeasible, thenan in-house treatment facility will be provided in the proposed housing scheme.The schematic of Scenario-3 is given hereunder in **Figure 5.4**:

Figure 5.4: Schematic *Diagram of* Scenario –3

Scenario – 4:

Lastly, if it is not possible to make a connection with the existing municipality sewer, the program will provide a wastewater treatment plant (WWTP) as the last resort. The WWTP will ensure adequate treatment of the wastewater prior to final discharge into the nearby water body or agricultural fields. The schematic is shown in **Figure 5.5** below:

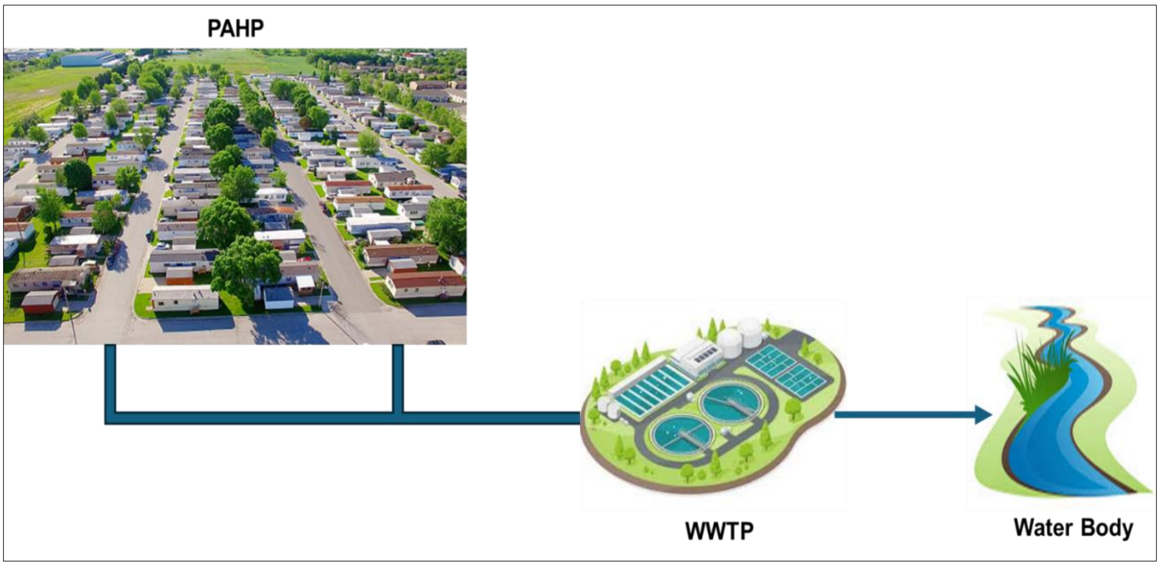


Figure 5.5: Schematic Diagram of Scenario –4

5.1. Wastewater Treatment Options

Once the construction of the WWTP is rendered inevitable, various factors will be considered to select the type of wastewater treatment system and the level of treatment required, based on the intended reuse of the wastewater. The primary factors governing the selection of wastewater treatment technology include the following:

Population	No. of Houses	Wastewater Characterization	Topography
Depth of groundwater table	No. of disposal points	Availability of land	Depth of sewer at the final disposal point

The statistical analysis of the wastewater characterization results in the preceding section reveals that the wastewater is low-strength and mostly comprises settleable pollutants, which if allowed sufficient settling, clears out most of the pollution. Hence the wastewater treatment technologies for the proposed PAHP Housing Schemes do

not need to be complex or cutting-edge technologies, rather they need to be simple yet efficient systems to serve the primary objective of meeting the PEQS while keeping the construction and operation expenses to the minimum.

The available literature on wastewater treatment also suggests adopting easy-to-operate and low-cost technologies wherever it is possible.

The same approach is also in line with the recommendations provided in the book "*Rural by Design: Planning for Town and Country" (second edition) by Randall Arendt*, which explores alternative sewage treatment methods suited for rural settings. It evaluates various sewage treatment solutions, such as decentralized systems, which can be more appropriate for low-density and environmentally sensitive areas compared to conventional centralized sewage systems.

5.1.1. Preferences of Wastewater Treatment Options

In the light of wastewater characterization, the following preferences have been defined in terms of selection of wastewater treatment methods.

Preference -1	Communal Septic Tanks (CST)	CST with Soakage Pits (SPs)
Preference -2	Anaerobic Baffled Reactors (ABR)	Waste Stabilization Ponds (WSPs)
Preference -3	Activated Sludge Process (ASP)	Variants of ASP

5.1.2. Rationale for Sequence of Preferences

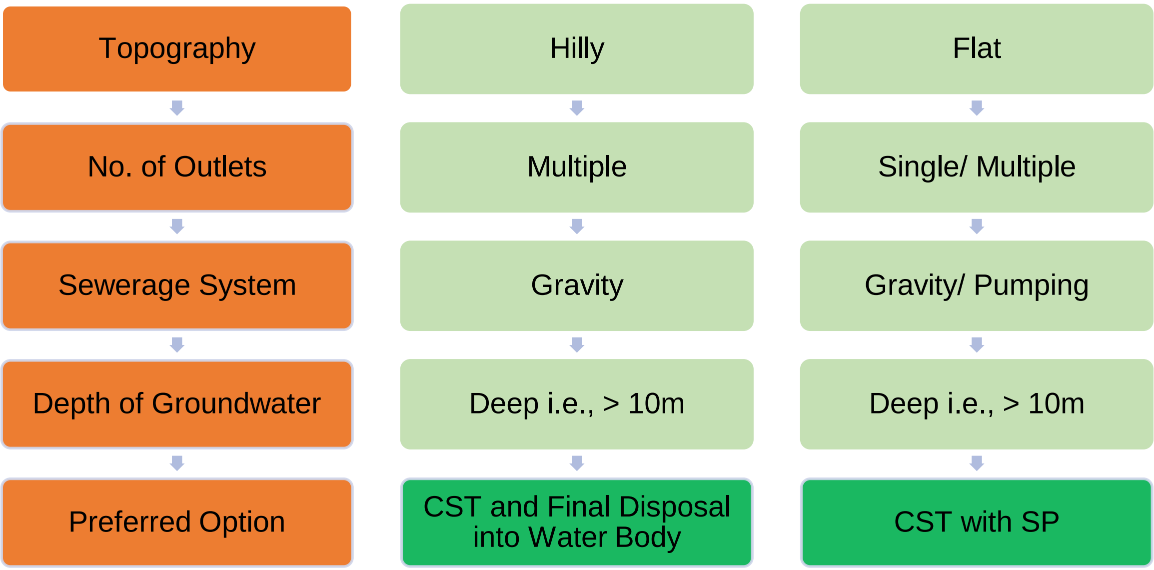
The rationale for the sequence of preferences of the possible WWTP options is given hereunder:

I. Preference – 1

The septic tanks are the basic wastewater treatment units provided at the household levels for the preliminary treatment of wastewater. These septic tanks when receiving wastewater from various Houses or the entire community as called Communal Septic Tanks (CSTs). The CSTs are the ideal solution for the low-strength wastewater streams from limited numbers of Houses and populations. For PAHP housing schemes, when the number of Houses is less than 150 and the population is less than 1000, then CSTs will be provided for wastewater treatment. Beyond these thresholds, the CSTs would require a large volume not sufficientfor effective wastewater treatment.

In large housing schemes having multiple wastewater disposal points, this option can also be adopted as the number of Houses and population will remain within the prescribed limits. In hilly areas particularly, the number of disposal points are multiple, and the sewage flows under gravity, then CSTs will be provided. However, for flat areas either with single or multiple disposal points with gravity sewage flow, CSTs may be provided. In case the groundwater table is greater than 10 meters deep, then CST can be coupled with soakage pits (SPs).

Primary Factors for CSTs	
No. of Houses:	<150
Population:	<1000
Strength of Wastewater:	BOD: 100-140 mg/L TSS: 100-250 mg/L



ii. Preference – 2

If the conditions for providing CSTs are not feasible (HHs numbers and population greater than prescribed limits i.e. 150 and 1,000 respectively), the next preferred options would be Anaerobic Baffled Reactors (ABRs). ABRs are suitable for communities with 150 to 750 Houses, or populations between 1,000 and 5,000. Beyond a population of 5,000 and relatively large flows, multiple units of ABRs would be required and may not be technically and financially feasible to perform adequately. Additionally, ABRs are optimal for treating low-strength domestic wastewater in areas with limited space. However, if ample space is available, Waste Stabilization Ponds (WSPs) will also be provided. Both ABRs and WSPs are the natural wastewater treatment methods and do not require any mechanical equipment and energy cost.

Primary Factors for ABRs/Afs	
No. of Houses:	150 – 750
Population:	1000 – 5000
Strength of Wastewater:	BOD: 100-140 mg/L TSS: 100-250 mg/L

The options between ABR and WSP can be decided based on the following:

No. of Outlets	Single	Single
Sewerage System	Gravity/ Pumping	Gravity/ Pumping
Availability of Land	Limited	Ample
Cost of Land	High	Low
Preferred Option	ABR	WSP

III. Preference – 3

In large housing schemes (population greater than 5,000 and Houses greater than 750), relatively large wastewater flows will be generated. For treatment of large flows, CSTs or ABRs would not be the feasible option to get the required degree of wastewater treatment. For such large housing projects, the mechanized wastewater treatment system will be provided where limited space is available. The most suitable mechanized system for domestic wastewater is Activated Sludge Process (ASP). There are multiple variants of ASP and can be utilized in the proposed housing schemes depending upon the construction and operational expenses. Where ample space is available for wastewater water treatment, WSPs can also be considered.

Primary Factors for ASP & WSP	
No. of Houses:	>750
Population:	>5000
Strength of Wastewater:	BOD: 100-140 mg/L TSS: 100-250 mg/L

The options between ABR and WSP can be decided based on the following:

No. of Outlets	Single	Single
Sewerage System	Gravity with Pumping	Gravity with Pumping
Availability of Land	Limited	Ample
Cost of Land	High	Low
Preferred Option	ASP	WSP

5.2. Wastewater Management Options

The preferences set in the previous section have streamlined the selection process for wastewater treatment and management options. With a focus on optimal outcomes, population size has been identified as the primary criterion for determining the most effective solution. Based on population, three distinct scenarios have been established, each corresponding to a tailored approach for wastewater management. Detailed explanations of each scenario are provided below:

Case – 1: Population < 1000
Case – 2: Population 1000 - 5000
Case – 3: Population > 5000

5.2.1. Case – 1 (Population < 1000)

When the population is less than 1000 people, the primary target is to provide a CST. However, there could be cases where the terrain is either hilly or flat. In the case of hilly terrain, the effluent from CST will be discharged into the nearest water body. However, if the water body is at a sufficient distance, the effluent treated from CST can be transported to the water body through suction trucks.

In flat terrains, the depth of groundwater will further be checked. For the shallow groundwater table i.e., < 10 meters deep, CST will be provided and the treated effluent will be disposed off into nearby water body. However, if the water body is at a sufficient distance, the effluent treated from CST can be transported to the water body through suction trucks. In case, for the deeper groundwater table i.e., > 10 meters deep[1], the effluent can either be disposed off into the nearest water body or the soakage pits could be provided after the CST to allow the treated water to infiltrate into the ground strata[2].

[1] PICIIP- Wastewater Treatment Plant (WWTP), North Zone Sahiwal (Stage-1), Third Party Validation Report, Prof. Dr. Sajjad H. Sheikh, UET Lahore.
[2] Indian Practical Civil Engineers' Handbook, P.N. Khanna, Engineers' Publishers, New Dehli, Punjab, 1995

5.2.2. Case – 2 (Population 1000-5000)

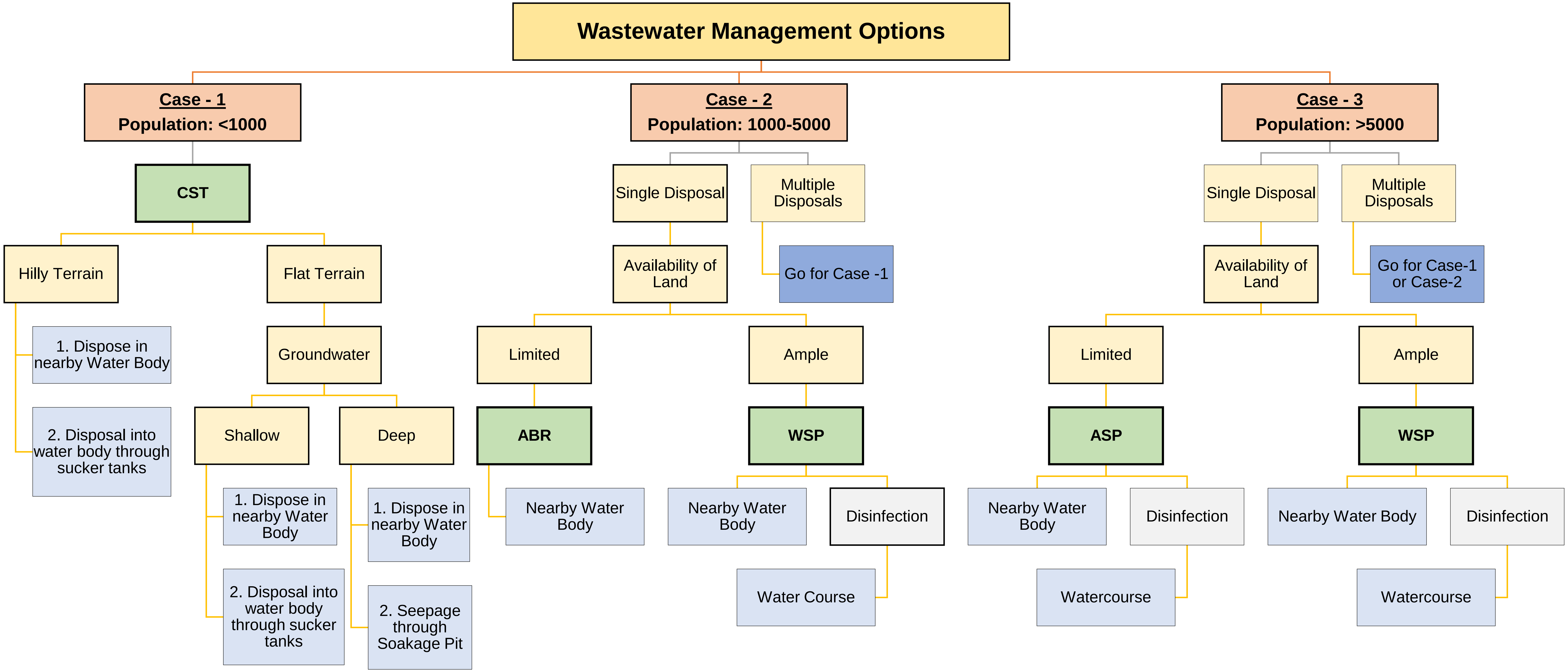
For population between 1000-5000, the sewage collection system would be checked if there are multiple or single disposal points. In case of multiple disposal points, the flow could be fragmented, and Case-1 may be considered. However, for a single disposal point, the availability of land will be checked. If limited land is available, the ABRs will be provided, and the treated effluent will be disposed off into nearby water bodies. If the treated effluent is to be reused for agricultural purposes, the wastewater after adequate disinfection will be discharged into the nearby watercourses.

If land is not a constraint, the best possible treatment solution would be WSP, which provides natural treatment for wastewater. The treated effluent from WSP can be discharged directly into the water bodies, or it can be disinfected through maturation ponds if it is to be reused for agricultural purposes.

5.2.3. Case – 3 (Population >5000)

The mechanized wastewater treatment options will come into play when the population of the proposed housing schemes exceed 5000 persons. However, if there are multiple wastewater disposal points of the sewage, then either of Case-1 and Case-2 may be considered. But before opting the mechanized technology i.e., ASP, the availability of land will be assessed and if ample land is available, then WSP can be adopted as an option owing to its minimal operational expenditures and good treatment efficiency.

The chart below presents all three cases discussed above.


Wastewater Management Options
Case - 1
Population: <1000
Case - 2
Population: 1000-5000
Case - 3
Population: >5000
CST
Hilly Terrain
Flat Terrain
1. Dispose in nearby Water Body
2. Disposal into water body through sucker tanks
Groundwater
Shallow
Deep
1. Dispose in nearby Water Body
2. Disposal into water body through sucker tanks
1. Dispose in nearby Water Body
2. Seepage through Soakage Pit
Single Disposal
Multiple Disposals
Availability of Land
Go for Case -1
Limited
Ample
ABR
WSP
Nearby Water Body
Nearby Water Body
Disinfection
Water Course
Single Disposal
Multiple Disposals
Availability of Land
Go for Case-1 or Case-2
Limited
Ample
ASP
WSP
Nearby Water Body
Disinfection
Watercourse
Nearby Water Body
Disinfection
Watercourse

The chart above provides an overview of the available wastewater management options, while the matrix below offers a detailed comparison across key selection parameters. In addition to population, factors such as terrain/topography, groundwater depth, number of and locations for disposal points, land availability, and land cost have been thoroughly analyzed. Based on this analysis, twelve different options have been developed. By inputting these factors in the following matrix, the possible wastewater management option can be opted for any of the proposed housing schemes.

Population	<1000				1000-5000				>5000			
Options	**Option -1**	**Option -2**	**Option -3**	**Option -4**	**Option -5**	**Option -6**	**Option -7**	**Option -8**	**Option -9**	**Option-10**	**Option-11**	**Option -12**
Terrain	Hilly/	Hilly	Flat	Flat	Hilly/Flat	Hilly/Flat	Hilly/Flat	Hilly/Flat	Hilly/Flat	Hilly/Flat	Hilly/Flat	Hilly/Flat
Depth of Groundwater	Shallow	Deep	Shallow	Deep	Shallow/Deep	Shallow/Deep	Deep	Deep	Deep	Deep	Shallow/Deep	Shallow/Deep
No. of Disposal Points	Multiple	Multiple	Single/Multiple	Single/Multiple	Single	Single	Single	Single	Single	Single	Single	Single
Final Disposal	Water Body	Groundwater Seepage	Water Body	Groundwater Seepage	Water Body	Watercourse	Water Body	Watercourse	Water Body	Watercourse	Water Body	Watercourse
Availability of Land					Limited	Limited	Ample	Ample	Ample	Ample	Limited	Limited
Cost of Land					Low/High	Low/High	Low	Low	Low	Low	High	High
Suitable Technology	**CST**	**CST with SP**	**CST**	**CST with SP**	**ABR**	**ABR with Disinfection**	**WSP**	**WSP with DT**	**WSP**	**WSP with DT**	**ASP and its variants**	**ASP with Disinfection**

6 PROPOSED WASTEWATER TREATMENT SYSTEMS

6.1 General

This section provides a comprehensive overview of various Wastewater Treatment Systems, examining their respective merits and demerits. Each system is analyzed for its functional efficiency, cost-effectiveness, and maintenance requirements, with the goal of aiding in the selection of the most suitable treatment method based on specific needs. To facilitate a deeper understanding of the operational mechanisms, flow diagrams and functional drawings are included for each system.

6.2 Description of Proposed Wastewater Treatment Systems

The description of different wastewater treatment systems is given below:

6.2.1 Communal Septic Tank (CST)

The septic tank is a water-tight container usually made of concrete, fiberglass, or polyethylene to hold the wastewater long enough to allow solids to settle down to the bottom forming sludge, while the oil and grease floats to the top as scum. A septic tank when receiving the flow from multiple Houses of a community or the entire population is called a communal septic tank (CST).

The CST comprised compartments and a T-shaped outlet which prevents the sludge and scum from leaving the tank. The treatment process in the CST is based on anaerobic treatment which reduces BOD and COD pollution up to 40-60%. Solids settling inside the septic tank are anaerobically digested thus reducing the sludge volume. Desludging is required after 2-3 years. Schematic diagram of septic tank is shown in **Figure 6.1**.

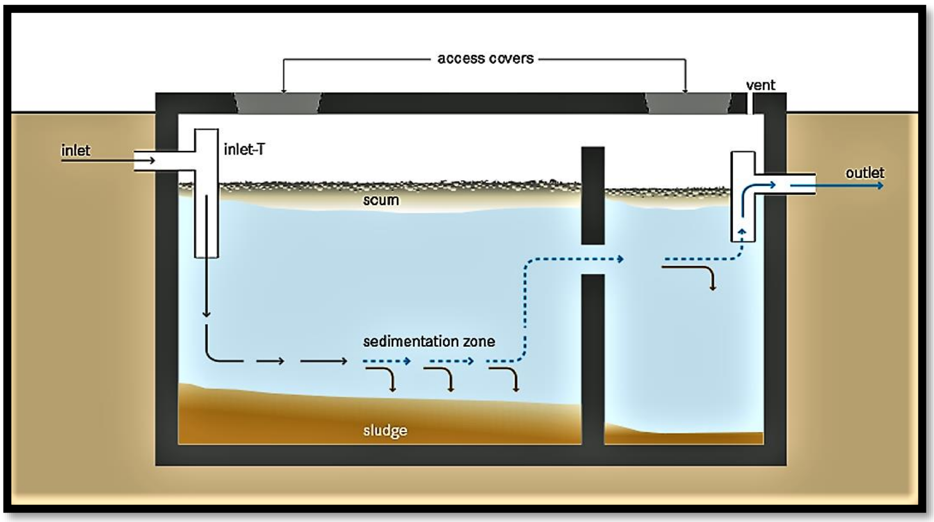


Figure 6.1:Schematic Diagram of Septic Tank

The functional drawings of community septic tank with soakage pit and without soakage pit are given below in **Figure 6.2** and **Figure 6.3.**

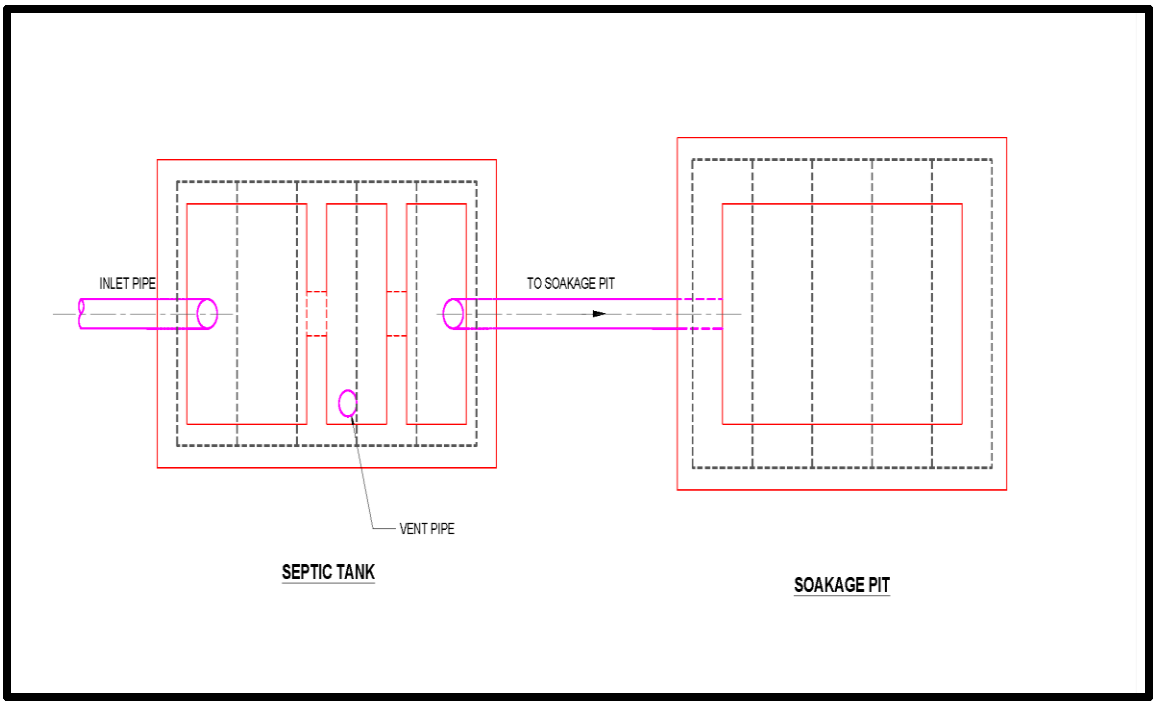


Figure 6.2:Functional Drawing of Community Septic Tank with Soakage Pit

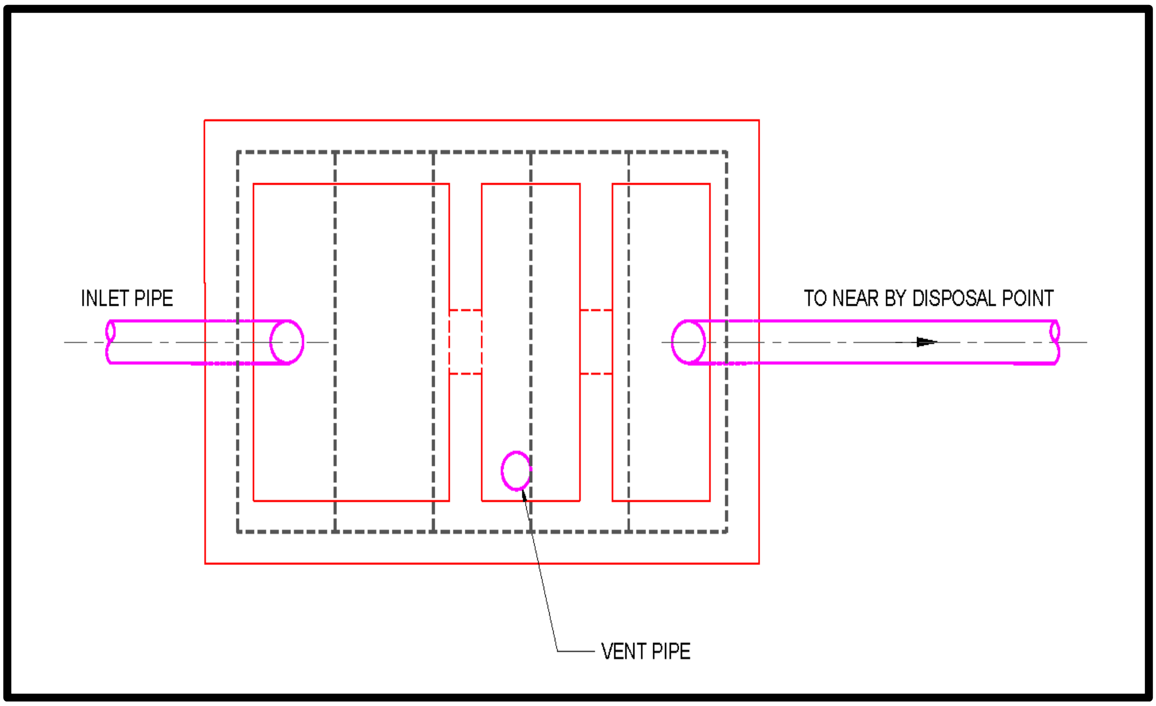


Figure 6.3:Functional Drawing of Community Septic Tank without Soakage Pit

i. Environmental and Social Aspects of CST

Environmental Aspects

- If the CST is not properly constructed or maintained, the effluent can percolate into the soil, potentially contaminating groundwater resources.
- Leaks or overflows from CSTs could result in harmful substances like pathogens, nitrogen compounds, and heavy metals leaching into the environment.
- CSTs, if not designed or managed properly, may emit unpleasant odors due to anaerobic decomposition of waste.
- High concentrations of methane, hydrogen sulfide, or other gases can pose a risk to air quality.

Social Aspects

- Successful implementation of CSTs requires community acceptance and awareness about the importance of regular maintenance and wastewater management.
- The location of the CST must be carefully chosen to avoid encroaching on residential spaces, agricultural land, or areas with high cultural significance.
- CST systems depend on local or community involvement for maintenance and monitoring; without it, they quickly degrade, causing poor performance and dissatisfaction.
- Community health can be impacted if there are leaks, blockages, or poor maintenance leading to contamination of drinking water sources.
- Well-managed CST systems can contribute to community development by providing a reliable and sustainable sanitation solution.

6.2.2 Anaerobic Baffled Reactor (ABR)

Anaerobic Baffled Reactor (ABR) is an improved form of septic tank which is divided into series of compartments. It is a rectangular anaerobic digester. ABR combines the characteristics of septic tank and more sophisticated digesters models such as Up Flow Anaerobic Sludge Blanket (UASB) reactors etc. ABR works on the principle of anaerobic digestion in which sludge blanket of granules of bacteria is developed. Contact of organic matter with the granules of bacteria enhances the digestion rate.

In ABR, by means of baffles or down flow pipes, wastewater is forced to move up through sludge blanket of anaerobic bacteria located at the bottom of the tanks. Close contact of organic matter in wastewater with the granules of bacteria enhances the digestion rate. Some turbulence is needed; however, a limited-up flow velocity is required to keep the sludge within the ABR. If the up velocity is too high, the water will pass through quickly, reducing the efficiency of the treatment and flushing out the bacteria.

A settler must be provided before an ABR to avoid accumulation of heavy solids in the baffles. The settler could either be included in the same structure or be a separate construction, as a septic tank. **Figure 6.4** and **Figure 6.5** shows schematic and flow diagramsof Anaerobic Baffled Reactor (ABR).

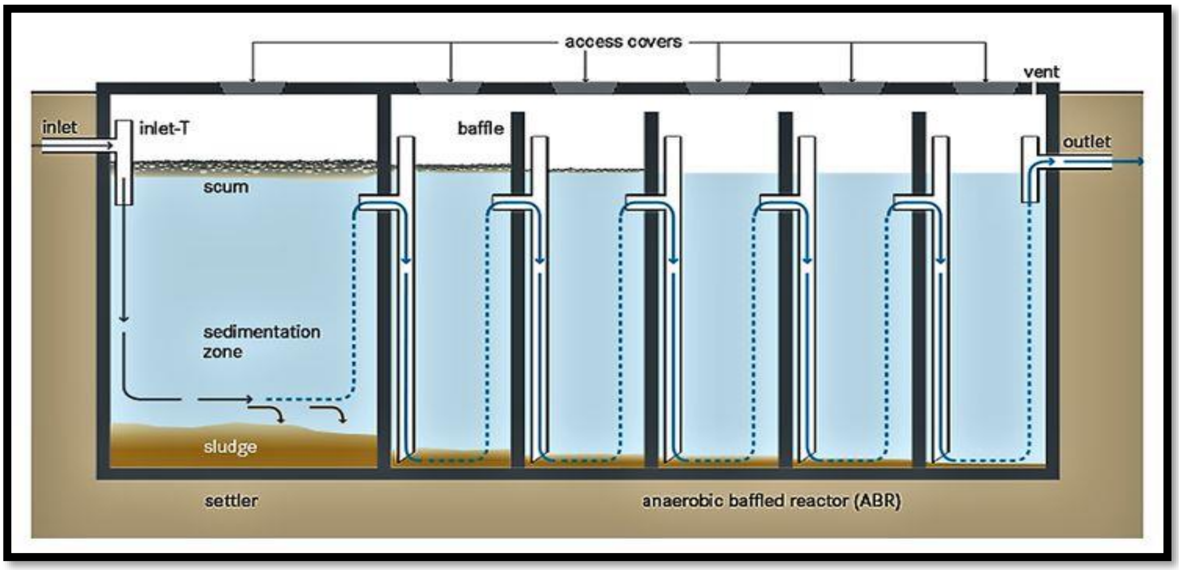


Figure 6.4: Schematic Diagram of ABR

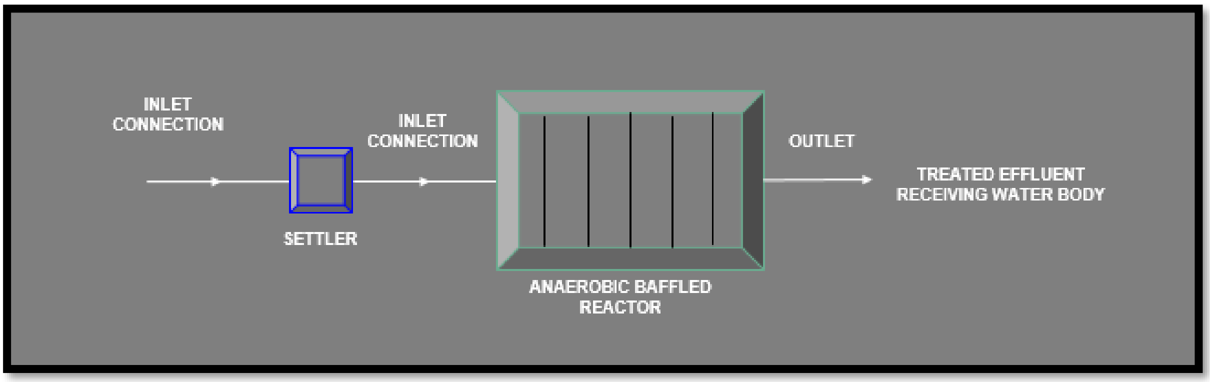


Figure 6.5: Flow Diagram of ABR

The functional drawings of ABR with disinfection and without disinfection are given **Figure 6.6 and Figure 6.7.**

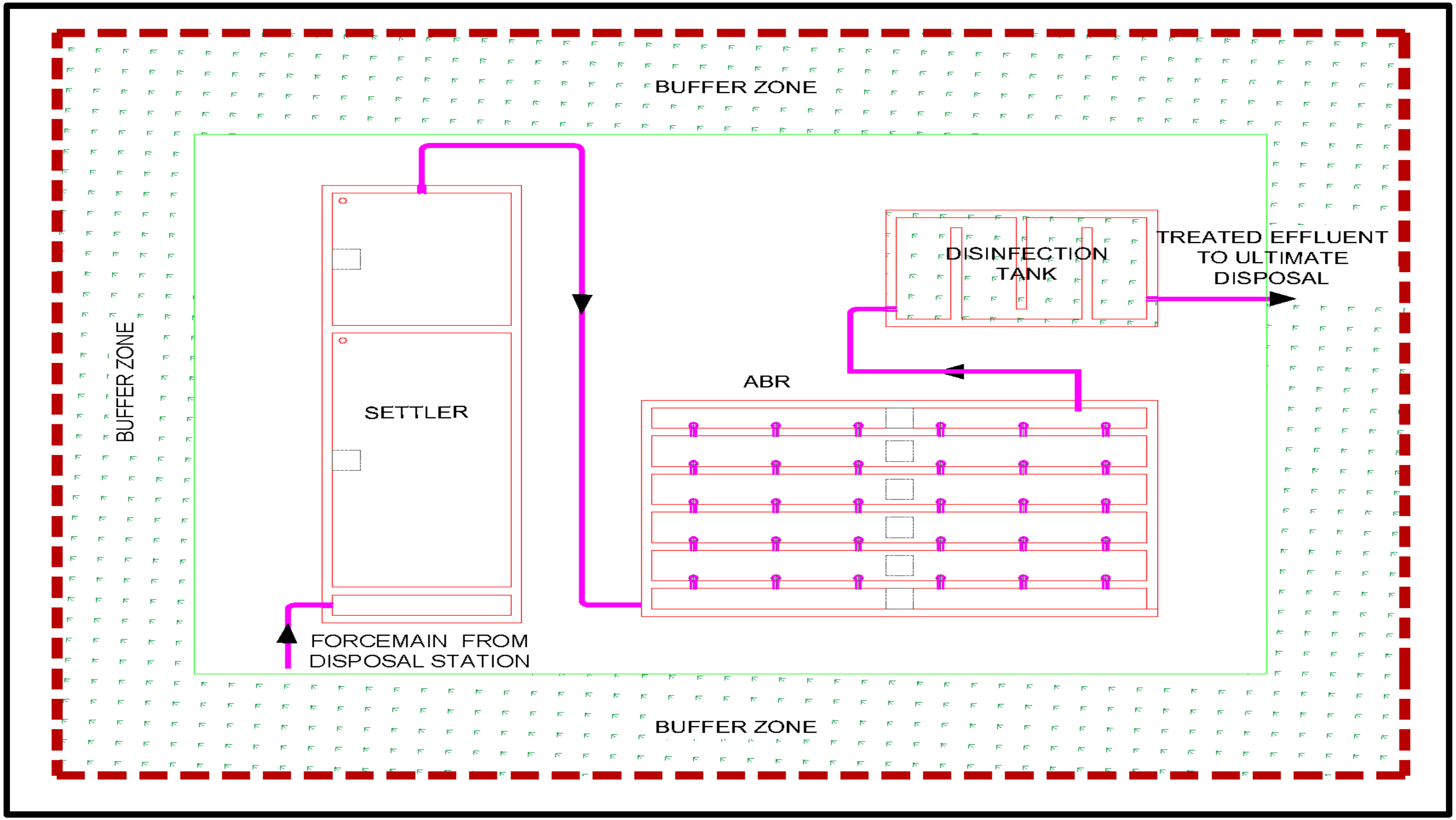


Figure 6.6: Functional Drawing of ABR with Disinfection Tank

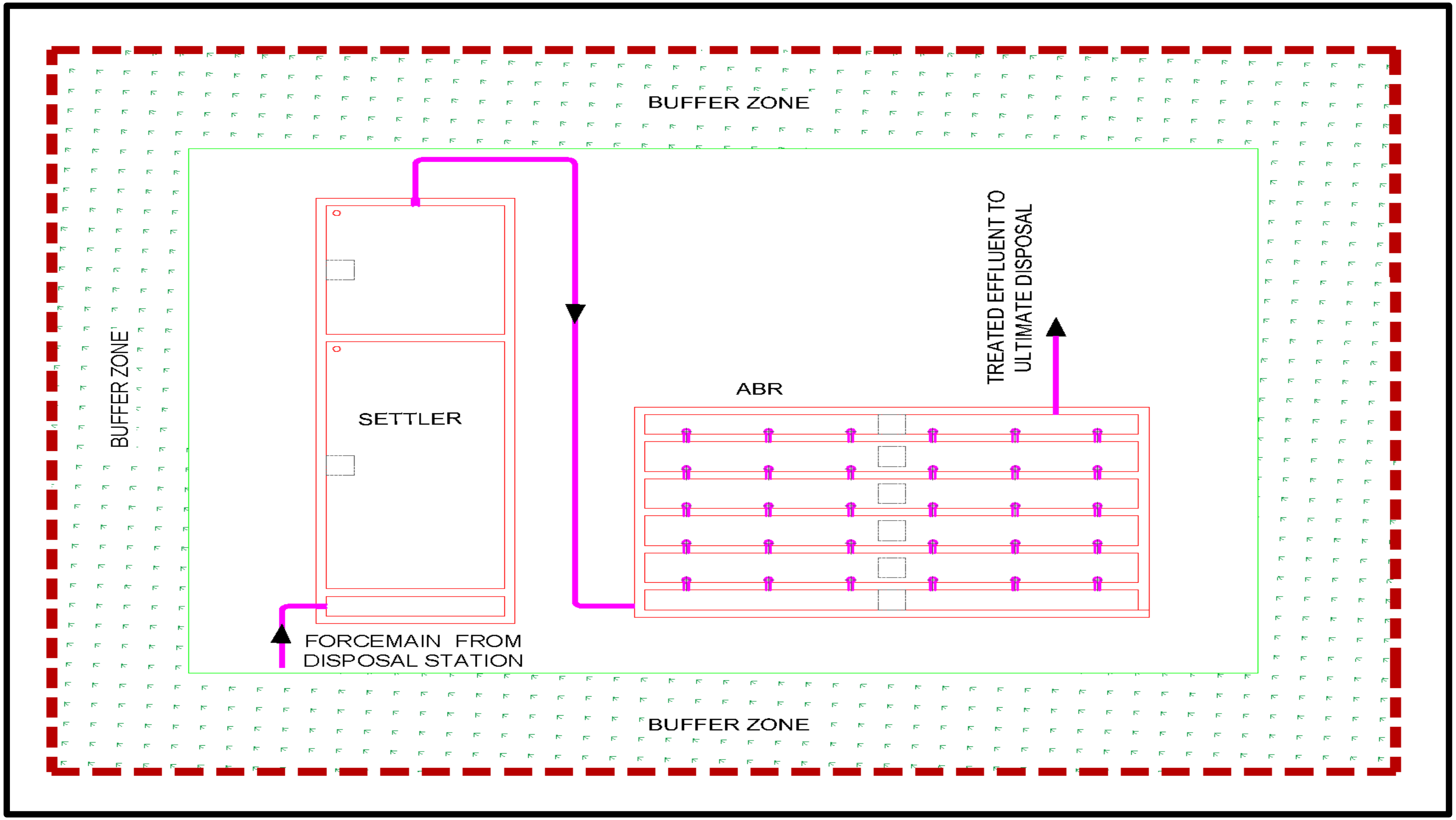


Figure 6.7: Functional Drawing of ABR Without Disinfection Tank

i. Environmental and Social Aspects of ABR

Environmental Aspects

- ABRs effectively remove organic matter and reduce biochemical oxygen demand (BOD) and chemical oxygen demand (COD) in wastewater, improving water quality in receiving water bodies.
- ABRs can contribute to removing nutrients like nitrogen and phosphorus.
- ABRs generally produce less sludge compared to aerobic processes, minimizing the need for sludge disposal and associated environmental impacts
- High concentrations of methane, hydrogen sulfide, or other gases can pose a risk to air quality.

Social Aspects

- Through effective treatment, ABRs can contribute to improved public health by reducing the spread of waterborne diseases.
- In rural and remote areas, ABRs can provide decentralized wastewater treatment solutions, promoting sustainable development and improving living conditions
- The biogas produced by ABRs can be used for cooking, heating, or electricity generation, providing economic benefits to communities, especially in areas with limited access to traditional energy sources.

6.2.3 Waste Stabilization Ponds (WSP)/ Natural Lagoons

Waste Stabilization Ponds are among the common systems adopted around the world, especially in developing countries. Low construction and operating cost make this option a financially attractive alternative compared to other treatment systems.

WSP comprises a single series of anaerobic, facultative and maturation ponds or several such series in parallel.

Anaerobic Ponds are designed for high organic loads which favor the anaerobic process. Anaerobic bacteria grow under such conditions through utilizing organic matter. Anaerobic ponds are the first component of WSPs.
Facultative Ponds are employed for medium organic loadings where a mutual relationship prevails between algae, which provide oxygen, and facultative bacteria, which provide nutrients for algal growth. Organic matter is consumed primarily by facultative bacteria. Resulting effluent, thus, have very less BOD. Facultative ponds are provided after anaerobic ponds.

Primarily, Anaerobic and facultative ponds are designed for BOD removal and maturation ponds are designed for pathogens removal. Although, some BOD removal occurs in maturation ponds and some pathogen removal in anaerobic and facultative ponds. In many instances only anaerobic and facultative ponds will be required when relatively weak wastewater is to be treated prior to surface water discharge.

Waste Stabilization Ponds have a number of advantages as compared to other wastewater treatment technologies including rapid stabilization of strong organic wastes, the least operational and maintenance cost and requirement of relatively un-skilled labour. Disadvantages of the WSPs include very large area requirements, sensitivity to variation in temperature and chances of ground water pollution. **Figure 6.8** shows flow diagram of Waste Stabilization Ponds.

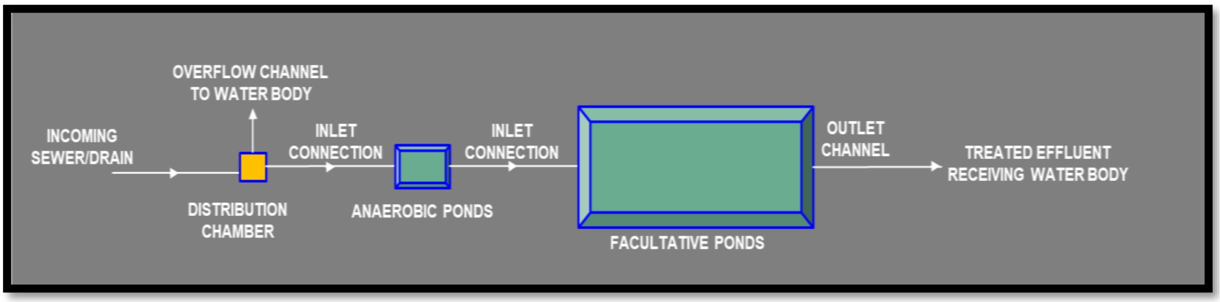


Figure 6.8: Flow Diagram of Waste Stabilization Ponds

The functional drawings of WSP with disinfection and without disinfection are given **Figure 6.9 and Figure 6.10.**

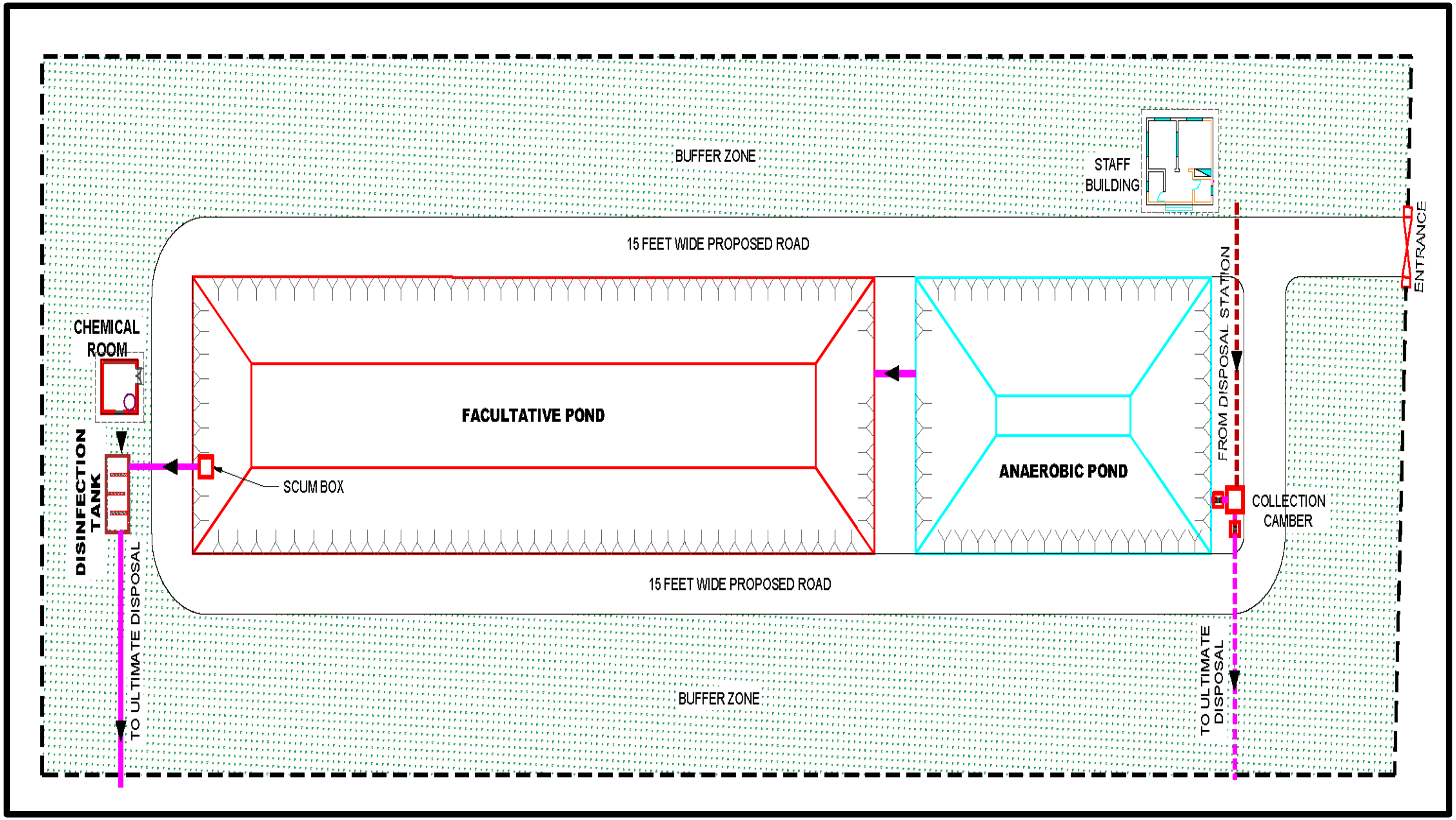


Figure 6.9: Functional Drawing of WSP With Disinfection Tank

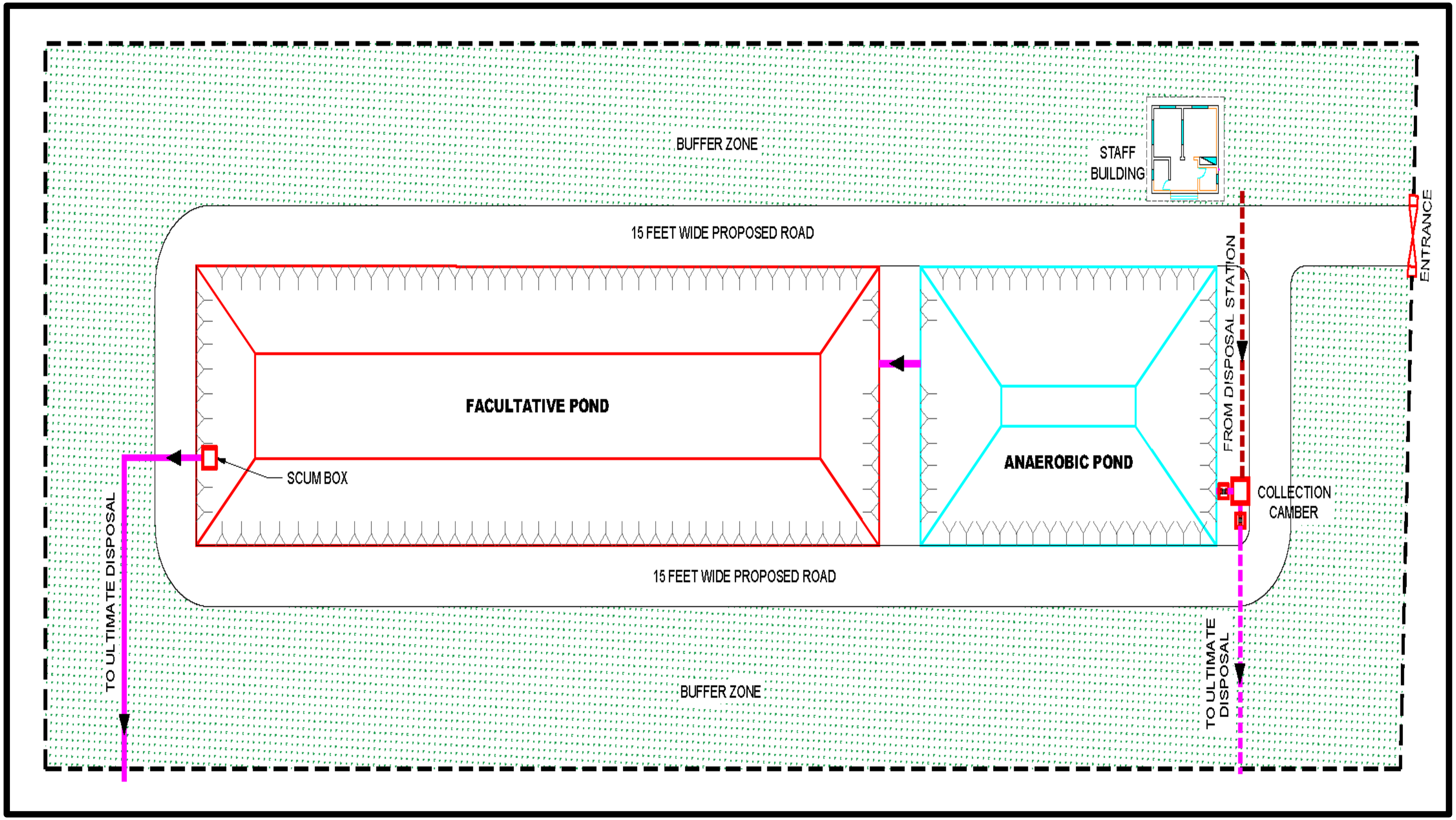


Figure 6.10: Functional Drawing of WSP Without Disinfection Tank

i. **Environmental and Social Aspects of WSP**

Environmental Aspects

- WSPs can release nutrients like nitrogen and phosphorus into the environment, potentially contaminating nearby water bodies.
- WSPs can release greenhouse gases like methane and nitrous oxide, contributing to climate change.
- WSPs can produce unpleasant odors, especially during periods of high organic load or temperature fluctuations
- Improperly managed WSPs can attract vectors like mosquitoes, and flies, which can transmit diseases.

Social Aspects

- WSPs can be perceived negatively due to their appearance and potential odors, leading to social resistance.
- Improperly managed WSPs can pose health risks to communities, especially through the transmission of waterborne diseases.
- WSPs can limit recreational activities in nearby areas due to aesthetic concerns and potential health risks
- The presence of WSPs can negatively impact property values in surrounding areas.

6.2.4 Activated Sludge Process (ASP)

Activated sludge process is a mechanized treatment technology employed to reduce the colloidal BOD which remains after PSTs. In an activated sludge process, microorganisms (MO) are mixed with organic matter so that they can grow and stabilize the influent organic matter. As the microorganisms, recirculated from secondary clarifier, are mixed with incoming wastewater and oxygen is supplied by aeration, the individual organisms flocculate to form an active mass of microbial floc called activated sludge. The mixture of activated sludge and wastewater is aerated in an aeration tank for a specified detention time and flows to the secondary clarifier where it is settled. The treated effluent is separated from the settled solids in the secondary clarifier and carried for either further treatment or disposal. The principal types of biological reactors are plug flow, complete mix and arbitrary flow. Completely mix ASPs are more commonly used. **Figure 6.11** presents a typical process flow diagram of ASP.

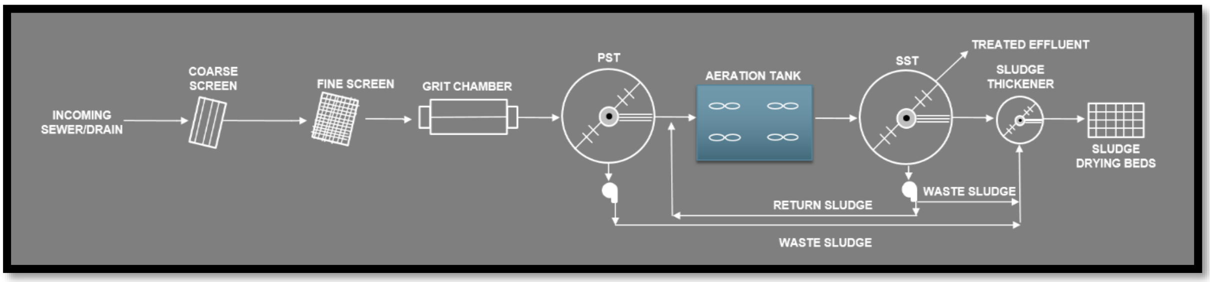


Figure 6.11: Flow Diagram of Activated Sludge Process

The functional drawing of ASP is given **Figure 6.12.**

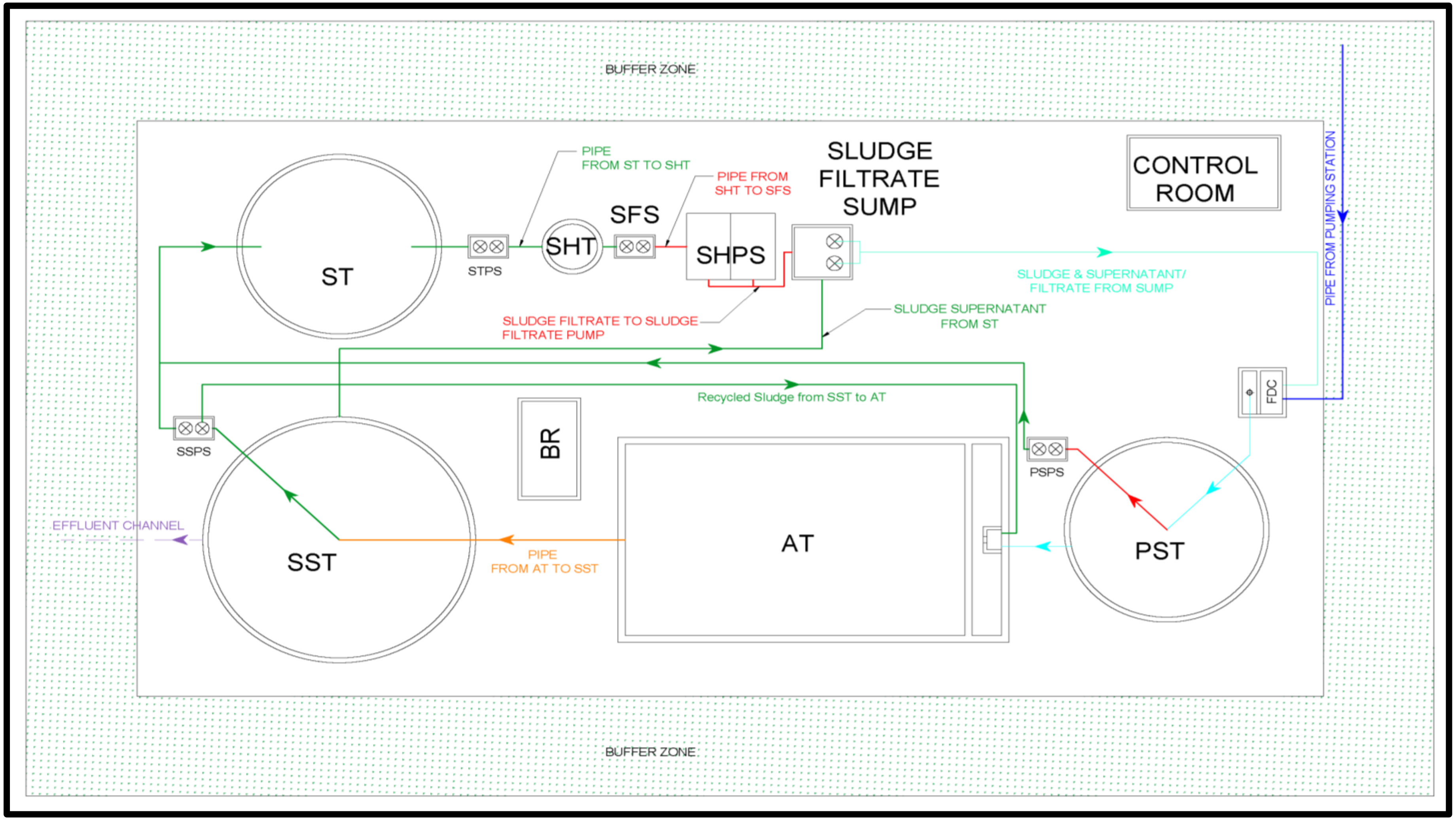


Figure 6.12: Functional Drawing of Activated Sludge Process (ASP)

i. **Environmental and Social Aspects of ASP**

Environmental Aspects

- ASP removes organic matter (BOD, COD), suspended solids from wastewater and removes pathogens improves water quality in receiving water bodies.
- ASP requires significant energy for aeration, pumping, and sludge treatment
- ASP generates large quantities of sludge, which requires proper disposal or treatment to avoid environmental pollution.
- Improper sludge disposal can lead to soil and water contamination

Social Aspects

- The treated wastewater can be used for irrigation or industrial purposes after tertiary treatment.
- It requires less area as compared to other wastewater treatment technologies.

6.3 Unit Cost of Wastewater Treatment Systems

The unit cost for various treatment systems has been estimated based on previous experiences and comparable projects of similar scope, and nature. Using standard unit flow rates as a basis, these cost estimations provide a reliable benchmark for evaluating the cost of each treatment system option. This approach ensures that the cost calculations align with realistic operational scenarios, enhancing the accuracy of the project's financial planning. The per unit CAPEX and OPEX for different systems is given hereunder:

Table 6.1: CAPEX for Scenario-1

Sr.#	Treatment Technology	Population	Number of Houses*1	Capital Cost*2	Cost/ House
1	Communal Septic Tank	1,000	155	3,825,660	24,680
2	Communal Septic Tank with Soakage Pit	1,000	155	3,925,660	25,326
3	Communal Septic Tank with Sewer Suction Truck*3	1,000	155	2,910,000	18,774

NOTE:

1: Number of houses calculated while considering a household size of 6.5 persons.

2: The capital cost is calculated based on projects of a similar size or nature and may vary according to site conditions. Land cost is not included in it.

3: Sewer suction truck cost 21,150,000/-PKR, having capacity of 7,000 litres is not included in Capital cost.

4: The cost in Sr. #1 includes the cost of sludge drying beds while in Sr. #3 the cost of transportation and disposal through suction tanks is involved.

Table 6.2: CAPEX for Scenario-2

Sr. #	Treatment Technology	Population	Number of Houses*1	Capital Cost*2	Cost/ House
1	ABR with DT	5,000	770	70,746,980	91,880
2	ABR without DT	5,000	770	61,662,640	80,000
3	WSP with DT	5,000	770	88,915,660	115,475
4	WSP without DT	5,000	770	81,915,660	106,384

NOTE:

1: Number of houses calculated while considering a household size of 6.5 persons.

2: The capital cost is calculated based on projects of a similar size or nature and may vary according to site conditions. Land cost is not included in it.

Table 6.3: CAPEX for Scenario-3

Sr. #	Treatment Technology	Population	Number of Houses*1	Capital Cost*2	Cost/ House
1	ASP with DT	7,000	1080	151,400,000	140,185
2	ASP without DT	7,000	1080	141,600,000	131,111
3	WSP with DT	7,000	1080	120,915,660	111,959
4	WSP without DT	7,000	1080	111,115,660	102,885

NOTE:

1: Number of houses calculated while considering a household size of 6.5 persons.

2: The capital cost is calculated based on projects of a similar size or nature and may vary according to site conditions. Land cost is not included in it.

Table 6.4: OPEX for Scenario-1

Sr. #	Treatment Technology	Population	Number of Houses*1	Annual O&M Cost	Annual O&M Cost/m3	Monthly O&M Cost/House
1	Communal Septic Tank	1,000	155	157,300	675	85
2	Communal Septic Tank with Soakage Pit	1,000	155	157,300	675	85
3	Communal Septic Tank with Sewer Suction Truck*2	1,000	155	198,200	851	107

Note:

1: Number of houses calculated while considering a household size of 6.5 persons.

2: Travel cost of the sewer suction truck is included.

Table 6.5: OPEX for Scenario-2

Sr. #	Treatment Technology	Population	Number of Houses*1	Annual O&M Cost	Annual O&M Cost/m3	Monthly O&M Cost/House
1	ABR with DT	5,000	770	5,265,124	9047	570
2	ABR without DT	5,000	770	697,000	1198	75
3	WSP with DT	5,000	770	5,265124	9047	570
4	WSP without DT	5,000	770	775624	1333	84

Note:

1: Number of houses calculated while considering a household size of 6.5 persons.

Table 6.6: OPEX for Scenario-3

Sr. #	Treatment Technology	Population	Number of Houses*[1]	Annual O&M Cost	Annual O&M Cost/m^3	Monthly O&M Cost/House
1	ASP with DT	7,000	1080	46,886,017	57529	3,618
2	ASP without DT	7,000	1080	40,589,767	49803	3,132
3	WSP with DT	7,000	1080	7,071,874	8677	546
4	WSP without DT	7,000	1080	775,624	952	60

Note:

1: Number of houses calculated while considering a household size of 6.5 persons.

2: The WSP with disinfection has a substantially higher O&M cost due to the involvement of a high quantity of chemicals i.e., sodium hypochlorite.

6.4 Land Requirement for Proposed Treatment Systems

The unit land requirement against each technology is given in Table 6.7 below:

Table 6.7: Unit Land Requirements

Sr.#	Treatment Technology	Population	Flow (m3/day)	Land/Flow (acres)	Total Land (acres)	Total Land (sq.ft)
1	Communal Septic Tank	1,000	233	0.000482	0.112	4,896
2	Communal Septic Tank with Soakage Pit	1,000	233	0.000545	0.127	5,533
3	Communal Septic Tank with Sewer Suction Truck	1,000	233	0.000482	0.112	4,896
4	ABR with DT	5,000	582	0.000899	0.523	22,798
5	ABR without DT	5,000	582	0.000824	0.480	20,901
6	WSP with DT	5,000	582	0.008379	4.877	212,432
7	WSP without DT	5,000	582	0.008305	4.865	211,919
8	ASP with DT	7,000	815	0.000678	0.553	24,081
9	ASP without DT	7,000	815	0.000209	0.545	23,740
10	WSP with DT	7,000	815	0.008379	6.829	297,477
11	WSP without DT	7,000	815	0.008305	6.768	294,822

7 ENVIRONMENTAL AND SOCIAL IMPACTS

The environmental impacts of the proposed wastewater treatment systems along with the relevant mitigation measures are given in **Table 7.1**:

7.1 Climate Resilience

Climate change is a harsh reality that needs to be looked into for any development to ensure sustainability. Wastewater treatment systems are a necessity for adequate treatment of wastewater, reducing the pollution load into freshwater streams. The climate resilience of wastewater treatment systems depends on their ability to adapt to and withstand the impacts of climate change, including increased precipitation, flooding, droughts, and temperature variability. Below is an overview of the climate resilience of communal septic tanks, anaerobic baffled reactors (ABRs), waste stabilization ponds (WSPs), and the activated sludge process (ASP).

7.1.1 *Communal Septic Tanks*

Resilience Strengths

- Simple design and operation, requiring minimal energy and technology, making them adaptable to remote or resource-scarce areas.
- Functionality is generally robust under moderate temperature variations.

Vulnerabilities

- Susceptible to overflow and failure during heavy rainfall or flooding, leading to contamination.
- Sludge management may become challenging under extreme weather conditions if desludging services are disrupted.
- Poor performance in areas with high groundwater tables, which may worsen with rising sea levels.

7.1.2 *Anaerobic Baffled Reactors (ABRs)*

Resilience Strengths

- High resilience to variable influent quality and moderate hydraulic shocks caused by fluctuating inflows.
- Low energy requirements and reliance on biological processes, making them sustainable under energy shortages.
- Effective even in regions with moderate temperature ranges, as anaerobic bacteria can tolerate some variations.

Vulnerabilities

- Efficiency may decrease in cold climates or during sudden temperature drops, as anaerobic processes slow down.
- Risk of clogging if high solids or non-biodegradable materials enter the system.
- Overflows during extreme rain events can compromise treatment performance.

7.1.3 *Waste Stabilization Ponds (WSPs)*

Resilience Strengths

- Highly adaptable to a wide range of climates, especially in warm and sunny regions, where high temperatures enhance pathogen removal and biological processes.
- Can buffer hydraulic shocks, such as high inflows from heavy rains.
- Simplicity in design and operation makes them resilient to resource limitations and disruptions.

Vulnerabilities

- Efficiency can decline in colder climates due to reduced biological activity.
- Large land requirements make them vulnerable to land-use changes and flooding.
- Risk of overflow and contamination during extreme weather events.

7.1.4 *Activate Sludge Process*

Resilience Strengths

- Can achieve high treatment efficiencies under controlled conditions, even with variable inflow and load.
- Suitable for urban areas with adequate infrastructure and stable electricity supply.

Vulnerabilities

- High energy dependence makes it vulnerable to power outages during extreme weather events.
- Sudden hydraulic or organic shocks (e.g., due to heavy rain or flooding) can disrupt microbial balance and efficiency.
- Requires skilled operation and maintenance, which may become challenging in emergencies or resource-scarce contexts.

Table 7. 1: Environmental and Social Impacts of Wastewater Treatment Systems

Sr. No.	Aspects	Technology				Mitigation
		CST	ABR	WSP	ASP	
1	Groundwater pollution	It can significantly impact groundwater quality if not properly maintained, as it may allow contaminants like pathogens, nutrients and chemicals to seep into the soil causing contamination of the groundwater sources. This poses health risks to people who rely on groundwater and can lead to environmental issues.	ABR has a limited impact on groundwater if operated and maintained properly. Leakage, although a potential risk, can lead to the leaching of residual pollutants.	Properly designed and maintained WSP have a limited impact on groundwater. Potential risks include seepage, which can allow untreated or partially treated wastewater to seep into the surrounding soil and contaminate groundwater. This can lead to the leaching of nutrients, pathogens, and other pollutants into groundwater sources.	ASPs have a limited impact on groundwater if properly designed, operated, and maintained. Potential risks include leaks from the sludge holding tanks or the effluent discharge pipe. These leaks can introduce nutrients, pathogens, and potentially harmful chemicals into the surrounding soil and contaminate groundwater.	• The tanks of CST, ABR and ASP should be leakproof. • WSPs should be provided with proper liners and geomembranes to avoid infiltration. • Frequent inspections should be carried out for all the treatment technologies to ensure proper working.
2	Surface water pollution	Communal septic tanks can have a significant impact on surface water quality. Leakage or overflowing of septic tanks can discharge untreated or partially treated wastewater directly into surface waters. This can lead to contamination with pathogens, nutrients, and other pollutants.	ABRs generally have a limited impact on surface water quality. Properly designed and maintained ABRs minimize the risk of untreated wastewater discharge into surface waters. However, potential risks include accidental spills or leaks, which could release of pollutants into nearby streams or rivers.	WSPs can have a significant impact on surface water quality. Leakage in ponds can result discharge of untreated or partially treated wastewater directly into surface waters. This can lead to contamination with pathogens, nutrients, and other pollutants.	ASP can impact surface water if the treated effluent contains residual nutrients, pathogens, or organic pollutants due to insufficient treatment or system failure. These contaminants can lead to water quality degradation, which harm aquatic life and posing risk to human health relying on the surface water.	• Routine inspections should be conduct to identify and address any leakage or malfunctions of CST. • In WSPs, monitor pond levels and water quality to address any issues promptly. • In ASPs, conduct regular inspections of all components, including pipes, tanks, and pumps, to identify and address any leaks or malfunctions promptly. • Bypass arrangements should be provided in case of flooding.
3	Soil contamination	Over flow and leakage can lead to the seepage of untreated or partially treated wastewater into the soil, causing soil contamination. This can introduce harmful pathogens, nutrients like nitrogen and phosphorus in the soil. Thus, results in degrading the soil quality and potentially affecting plant health.	ABRs generally have a limited impact on soil contamination. Properly designed and maintained ABRs minimize the risk of soil infiltration by treated effluent. Soil contamination may occur if the effluent is not adequately treated or discharged. Inadequate treatment may result in the release of residual organic matter, nutrients and pathogens, which can seep into the soil, degrading the quality of the quality.	WSPs can cause the soil contamination if the treated effluent is not managed properly or ponds overflow, allowing untreated or inadequately treated wastewater to seep into the soil. This may introduce pathogens, nutrients, and organic matter, which can degrade soil health and affect plant growth.	ASPs can have a limited impact on soil contamination. Properly designed and operated ASPs minimize the risk of soil contamination by treated effluent. However, potential risks include leaks from the sludge holding tanks or the effluent discharge pipe. These leaks can introduce nutrients, pathogens, and potentially harmful chemicals into the surrounding soil. If the sludge is not adequately treated or disposed of, its residual toxins, heavy metals, or pathogens that can degrade soil quality and pose environmental risks.	• In CST, ensure periodic cleaning of the septic tanks to prevent overflow and leakage of untreated waste into the soil. • Proper sludge handling and disposal systems are crucial in ASPs to prevent soil contamination.
4	Sludge management	CSTs have minimal sludge generation. However, their improper management or non-periodic or infrequent removal of the sludge, can lead to system failure.	ABRs are effective in sludge management by promoting the stabilization and reduction of organic matter. The baffled design ensures enhanced retention time and efficient microbial activity, leading to improved	WSPs effect sludge generation by facilitating the natural treatment of wastewater through microbial activity in anaerobic, facultative, and aerobic ponds. Over time, the organic matter in	ASPs have a significant impact on sludge generation and management. ASPs produce a significant amount of excess sludge during the treatment process. This sludge requires proper handling, dewatering, and disposal.	• Proper and frequent cleaning of WSPs and CSTs is essential to avoid the deposition of sludge at the bottom • In ASPs, it is crucial to ensure the proper movement of liquid sludge

Sr. No.	Aspects	Technology				Mitigation
		CST	ABR	WSP	ASP	
			digestion of sludge. This results in reduced sludge volume,	the sludge is partially decomposed, leading to a decrease in volume. The gradual decomposition of organic matter in wastewater, leading to the accumulation of sludge at the pond bottom.		from the process tanks to the sludge drying beds and subsequently from the drying beds to the disposal site. This is essential for preventing contamination and ensuring proper sludge handling.
5	Solid waste management	CSTs have a limited direct impact on solid waste management. However, their improper functioning can indirectly contribute to increased solid waste generation. Leakage of septic tanks release wastewater contaminating soil and groundwater. Thus, generating additional solid waste in the form of contaminated soil that needs to be disposed of properly.	ABRs significantly enhance solid waste management by efficiently treating organic waste through a series of interconnected chambers that facilitate anaerobic digestion. ABR systems contribute to more sustainable waste management practices, lowering environmental impact and reducing landfill dependency.	WSPs can have a significant impact on solid waste management, particularly in wastewater treatment. WSPs help reduce the volume of solid waste, especially organic matter, while also producing treated effluent that can be safely discharged or reused.	ASPs have a significant impact on solid waste management. They generate substantial amounts of excess sludge as a byproduct of the treatment process. This sludge requires proper handling, dewatering, and disposal, which contributes significantly to the overall solid waste management burden.	• Ensure the regular removal and transport of sludge extracted from CSTs, ABRs, WSPs, and ASPs to designated disposal sites
6	Climate Change	Properly maintained septic tanks can reduce greenhouse gas emissions. However, leaking septic tanks can release methane, a potent greenhouse gas, into the atmosphere.	The ABR minimizes the need for external energy inputs, reducing greenhouse gas emissions compared to conventional treatment systems. It reduces the greenhouse gas emissions through methane capture and utilization, improving nutrient removal, and potentially generating renewable energy.	WSPs provide a low-energy, passive wastewater treatment solution that adapts well to varying environmental conditions. WSPs also contribute to climate change, by producing methane - a potent greenhouse gas.	ASPs typically require significant energy input for aeration, pumping, and sludge processing. This contributes to greenhouse gas emissions. The excess sludge generated by ASPs requires careful management. If not handled properly, it can decompose and release methane.	• In ASPs, renewable energy sources such as solar should be utilized to reduce carbon footprints. • Methane capture measures may be provided if feasible.

8 CONCLUSION AND RECOMMENDATIONS

8.1 General

The following conclusions and recommendations have been drawn from the current study with respect to selection of the most feasible wastewater management options for proposed PAHP Housing Schemes.

8.1.1 Conclusions

1. The wastewater characterization results from a total of 40 wastewater samples in six (06) cities reveal that the tested wastewater is of low strength irrespective of the socioeconomic status of the selected schemes and the geographical location. Most of the values were observed to be within the prescribed limits of PEQS, either from the household sample or the end-of-pipe sample.

Parameters	Mean Value of 40 Samples
BOD	104
COD	200
TSS	137

2. No major fluctuations have been observed in the values of key parameters, i.e., BOD, COD and TSS except for a sample from a low-income scheme in the south region and two samples from Rawalpindi. It is pertinent to mention that the corresponding samples in Rawalpindi are from the areas where there is acute water shortage, and the community is dependent on water tanks for potable needs. The less usage of water undermines the dilution of waste, hence higher values have been observed.

3. The key wastewater quality parameters were tested from the raw sample as well as from the filtered sample which was allowed to settle for 1 hour in an Imhoff cone to analyze the settleable pollution. Interestingly, a sufficient reduction was observed in the settled sample indicating the presence of settleable solids/pollution in the wastewater samples.

Parameters	Mean Value of 40 Samples (Raw)	Mean Value of 40 Samples (Settled)	Percentage Reduction (%)
BOD	104	72	31
COD	200	143	29
TSS	137	83	39

This indicates that the wastewater if subject to primary settling, then 30% of the pollution load is reduced, which further strengthens the stance that only simple treatment technologies can serve the purpose of meeting the PEQS.

8.1.2 Recommendations

1. The statistical analysis of the wastewater characterization results reveals that the wastewater is low-strength and mostly comprises settleable pollutants, which if allowed

sufficient settling, clears out most of the pollution. Hence the wastewater treatment technologies for the proposed PAHP Housing Schemes do not need to be complex or cutting-edge technologies, rather they need to be simple yet efficient systems to serve the primary objective of meeting the PEQS while keeping the construction and operation expenses to the minimum.

2. The most suitable technologies to be adopted for the proposed PAHP Housing Schemes in terms of preference of selection are as follows: