KOCHI SMART CANAL

FINAL REPORT

(1 April 2022 – 31 January 2023)

SUPPORTED BY

IMPORTANT NOTICE

The project was undertaken with financial support from Swiss Re Foundation.

Table of Contents

List of Abbreviations

MCD	Municipal Corporation of Delhi
FSTP	Faecal Sludge Treatment Plant
HEC-HMS	Hydrologic Engineering Center- Hydrologic Modelling System
HEC-RAS	Hydrologic Engineering Center- River Analysis System
KLD	Kilo Liters per Day (= cubic meters per day)
LiDAR	Light Detection and Ranging
MBBR	Moving Bed Biofilm Reactor
MLD	Million Liters per Day
NEERI	National Environmental Engineering Research Institute
NRSC	National Remote Sensing Centre
NBS	Nature Based Solutions
PPP	Public Private Partnership
STP	Sewage Treatment Plant
SBR	Sequenced Batch Reactor
USGS	United States Geological Survey

1 Executive Summary

The project was aimed at undertaking a feasibility study for canal restoration using green grey infrastructure in Kochi. The canals in Fort Kochi were the project focus. These canals served as a major source of transportation, livelihood, and infrastructure for flood resilience since times immemorial. However, they are highly degraded due to pollution, solid waste dumping, unplanned infrastructure development, population pressure. As a result, these canals, which once used to build the flood resilience of the city, are now vulnerable to floods. There is an urgent need to restore and rejuvenate the canals to build climate resilience in the city.

With the aim of undertaking the pilot study on use of green grey infrastructure for canal restoration, with the aim of building flood resilience, ICLEI-Local Governments for Sustainability, South Asia, Bechtel.org and Swiss Re joined forces. The assignment was funded by Swiss Re Foundation. Kochi Municipal Corporation extended support and Centre for Heritage, Environment and Development was the local partner. The report presents a pilot model, focussing on green grey infrastructure, for canal restoration. This is a replicable model. The next phase of the project will aim at implementation of the pilot with the aim that the same is then up-scaled as well as out-scaled with support from the relevant city and state authorities.

A detailed baseline assessment was carried out for canal selection (Refer Attachment 2). Through the baseline assessment, Pandarachirathodu canal was identified as the study site. This report presents the broad conceptual design of the green grey infrastructure. The report concentrates on six aspects- Canal Works (civil work), Sewage Treatment, Waste Management, Green Infrastructure and Others and Financial Stability and describes detailed actions that need to be taken up under each of them. Figure 1-1 indicates the key components of the execution framework.

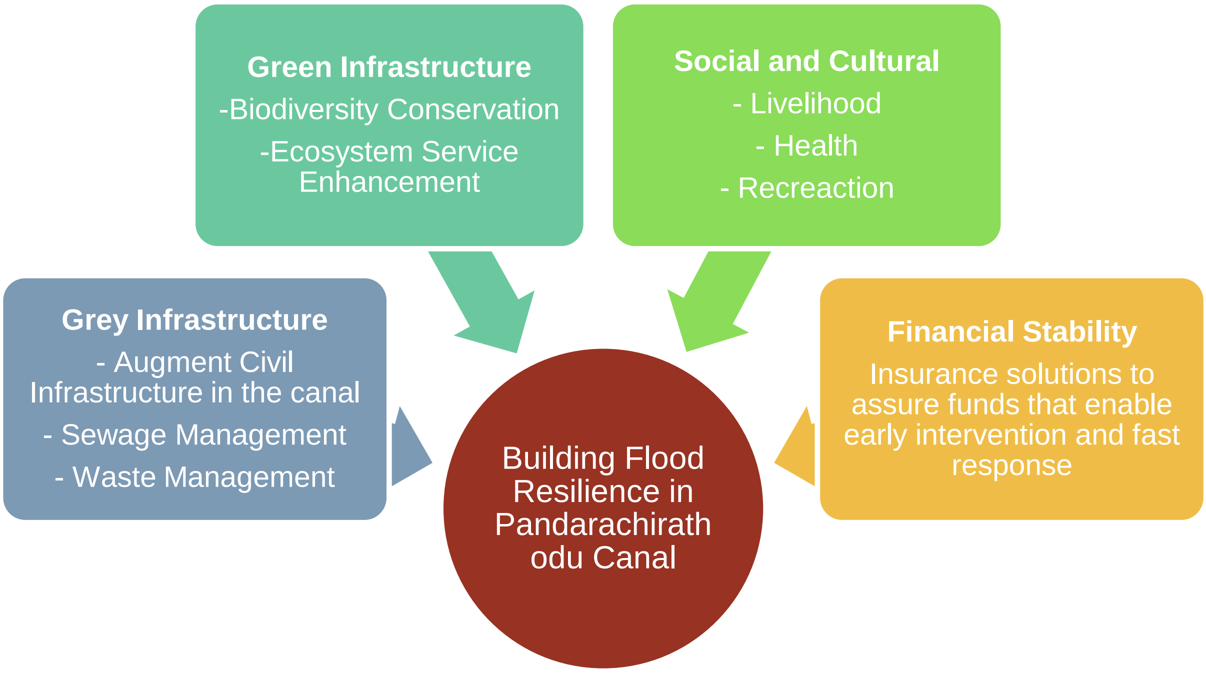


Figure 1-1 Key components of the execution framework

Through a detailed analysis and expert consultations, the report has suggested a basket of recommendation, across the six aspects mentioned above. The recommendations have also been categorised into the timelines of short, medium and long term. The basket of recommendations comprises of both soft and hard interventions. The short-term interventions would require a budget of USD 5 million. The project consortia has the ambition to secure grant funding to help catalyse short term interventions, on priority basis. This will then serve as a pilot case for building flood resilience in Pandarachiathodu canal. The Kochi Municipal Corporation, a partner in the project, will facilitate the implementation of these short-term measures in the pilot case and would need to take ahead the medium- and long-term interventions. Regular maintenance of the interventions will also be need to be carried out, in order to augment the flood resilience capacity of Pandarachirathodu canal.

2 Introduction to Pandarachirathodu Canal

Pandarachirathodu canal is situated near Palluruthy in Kochi in Ernakulam district. The canal passes through wards 22 and 24 of Kochi Municipal Corporation. This canal facilitates drainage of water to Chirakkal river and Rameswaram canal and vice-versa. The canal is approximately 2.4km long. The Pandarachirathodu canal flows between 9.939250° N and 76.255028°E and 9.922048° N and Longitude 76.263235° E.

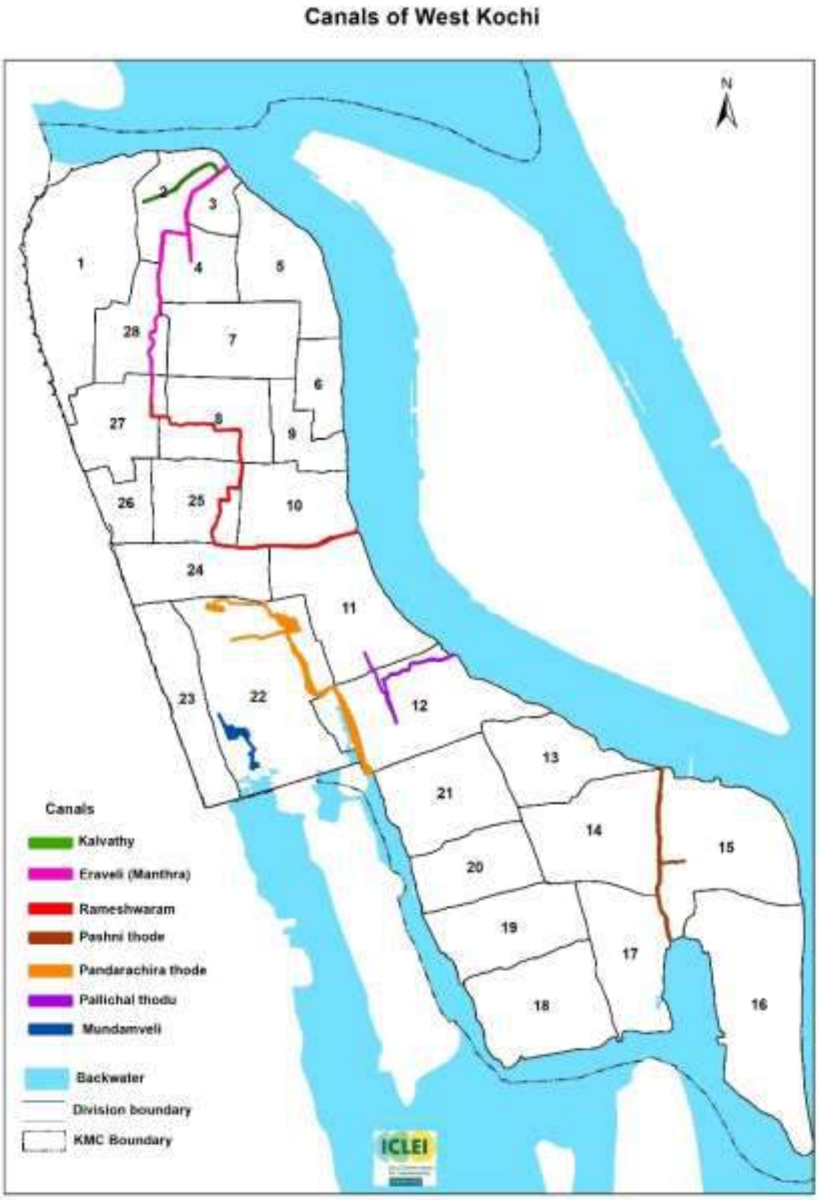


Figure 2-1 Canals of Fort Kochi

Pandarachirathodu is a natural canal and was once used by the Kochi Maharaja and his family to travel through West Kochi. This canal was also used for transporting goods in large country boats to various parts of Fort Kochi. Goods were transported mostly through a network of three canals in the south *viz* Pashni canal, Pallichal canal and Pandarachirathodu canal, which were interconnected, leading to the Rameshwaram canal in the north. However, most of the connections and network cannot be seen today due to rampant urbanisation and unplanned infrastructure growth.

Figure 2-2: Vintage photo of a canal market
(*Source https://pazhayathu.blogspot.com/2011/12/more-old-pictures-of-kerala.html)*

The lands adjoining Pandarachirathodu canal were highly fertile and used for agriculture. Water from the canal was the source of irrigation. In 1965 the Irrigation Department built side protection walls using rubble to protect Pandarachirathodu canal.

Pandarachirathodu canal was once a bustling lifeline of the city. Like other canals this canal has lost its importance and fallen prey to rapid urbanisation and large-scale infrastructure growth. The salient features of Pandarachirathodu Canal are summarised in Table 1. Even though the canal is facing high levels of degradation, it still harbours the highest biodiversity among all the five canals in Fort Kochi that were surveyed (refer Attachment 2 for details of species sighted in Pandarachirathodu canal during the biodiversity survey).

Table 1: Pandarachirathodu Canal at a glimpse

Features	Description
Name	Pandarachirathodu
Division Nos (the canal passes through)	22 and 24
Canal wall	Stone Masonry
Length (Approx.)	2364 m
Width (varies)	2m to 56m
Depth (varies)	0.8m to 2.5m
Number of floral species recorded in the survey	79
Number of faunal species recorded in the survey	67

3 Grey Infrastructure Suggestions- Survey Methodology

In order to develop the grey infrastructure solutions, an in-depth survey and gap analysis was carried out. This focussed on understanding the prevailing socio-economic conditions and status of flood mitigation, sewage treatment and waste management.

3.1 Methodology

The methodology comprised of undertaking site survey, community consultations, questionnaire surveys. The data collected was then analysed, based on which grey infrastructure solutions have been designed. Figure 3-1 summarises the methodology.

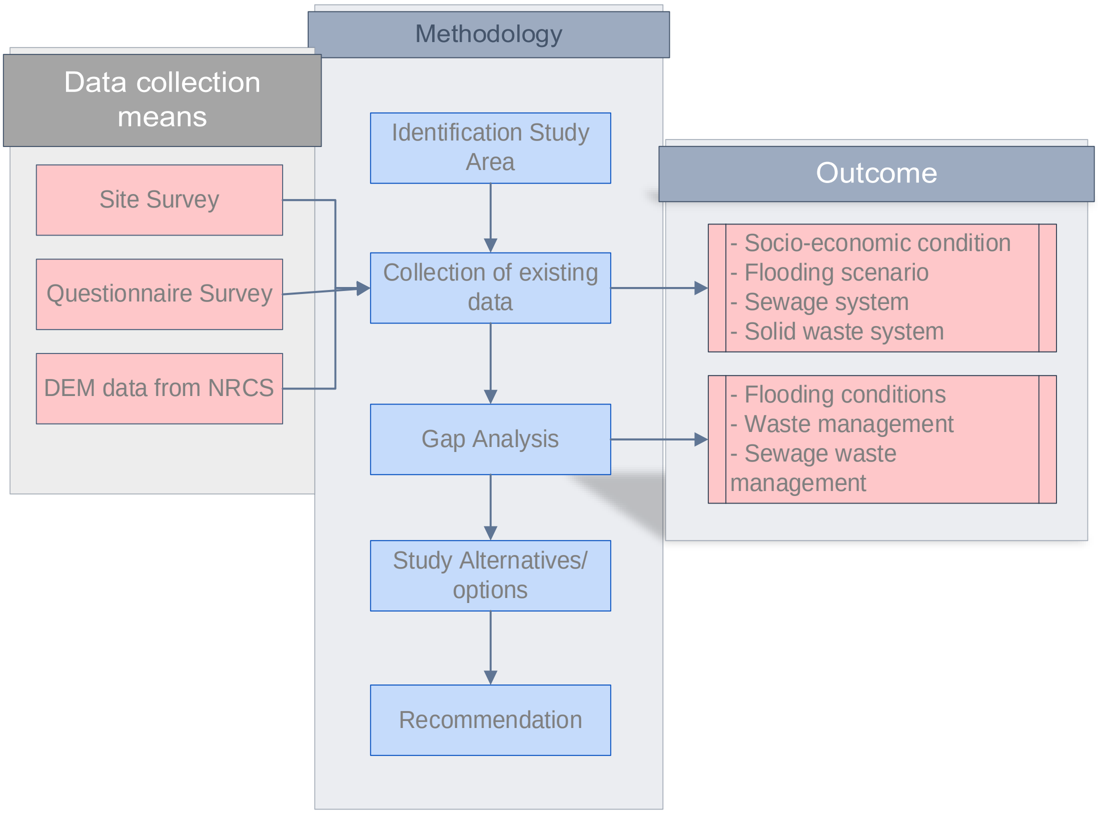


Figure 3-1 Methodology

3.2 Intervention Site

A 2 km stretch of Pandarachirathodu canal and an area up to 250 m on either side of the canal were identified as the area of interest for this study. Following are the start and end coordinates of the identified stretch:

Start: Latitude 9.934930° and Longitude 76.255267°

End: Latitude 9.922048° and Longitude 76.263235°

Figure 3-2 Location of Pandarachirathodu Canal

An initial site survey had revealed that the two major challenges for restoration of the canal were:

1. High levels of pollution in the canal due to dumping of waste and lack of sewage system
2. Constant flooding of areas near the canal during heavy rainfall due to chocking of culverts with waste inhibiting free flow of water and lack of regular desilting.

3.3 Collection of existing Data

To gain deeper insights and understand issues of waste management as well as flooding patterns in the area, an onsite survey and a door-to-door survey of households near to the canal were conducted. A detailed questionnaire was designed for the survey with the following objectives:

- To understand the socio-economic condition of the area
- To identify locations of monsoon and tidal flooding in the area
- To map current infrastructure, services & practices in solid waste and sanitation at household levels.

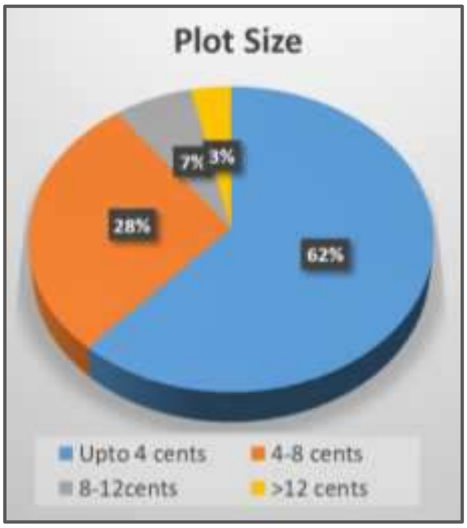
Thirty students from St Theresa's College Kochi were engaged to carry out this survey, which covered over 300 households on both sides of Pandarachirathodu canal. The survey was designed and carried out using an open source android based application Epicollect5 and responses analyzed using ArcGIS and Google Earth. Households situated within 250 m on both sides of the canal were surveyed. This included houses in ward 11 as well. Though the canal did not directly flow here, but it came within the 250 m zone of influence. In all, the survey was conducted in 3 wards- 11, 12 and 22 (Figure 3-3). Topography data was obtained from open sources such as USGS and Google Earth. Additionally, data from NRSC (DEM) and KMRL (lidar survey) was used to validate the accuracy of data from the open sources. The topography data was used to determine the natural subbasins and their runoff contribution to each part of Pandarachirathodu canal.

Figure 3-3: Location of the households surveyed

4 Grey Infrastructure Suggestions- Survey Findings

4.1 Socio-economic conditions

Most of the people living along Pandarachirathodu canal belong to low- income group. 47% of the population living around the canal have a monthly income up to Rs 10,000. 62% of the households have a plot size of 4 cents[1] or less. 75% of those surveyed were house owners and only 25% were living on rent. The survey also identified that 49% of the households had 3-5 members with the average family size of 3.8 per household.



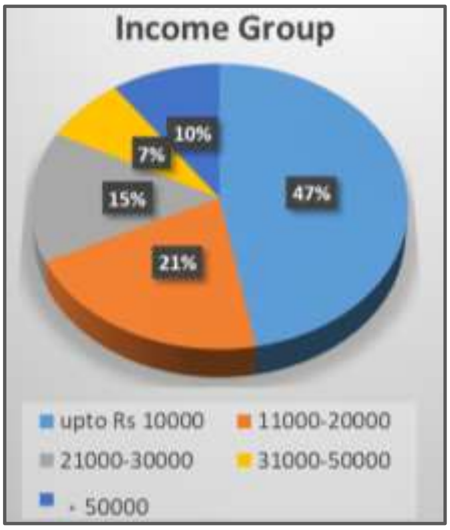


Figure 4-1: Survey findings - Socio-economic conditions of the household

4.2 Waste Management

Rapid urbanization and lack of proper waste management has caused heavy pollution in the canal. Solid waste was found to be dumped both in the canal as well as its banks. Around 45% of those surveyed across wards 11, 12 and 22 agreed that waste management was a huge issue in the area. In many places, the canal was found to be emanating foul smell, which was also reiterated in the survey with more than 40% responding having experienced foul smell.

[1] A cent is one hundredth of an acre, i.e., 40.5 m^2

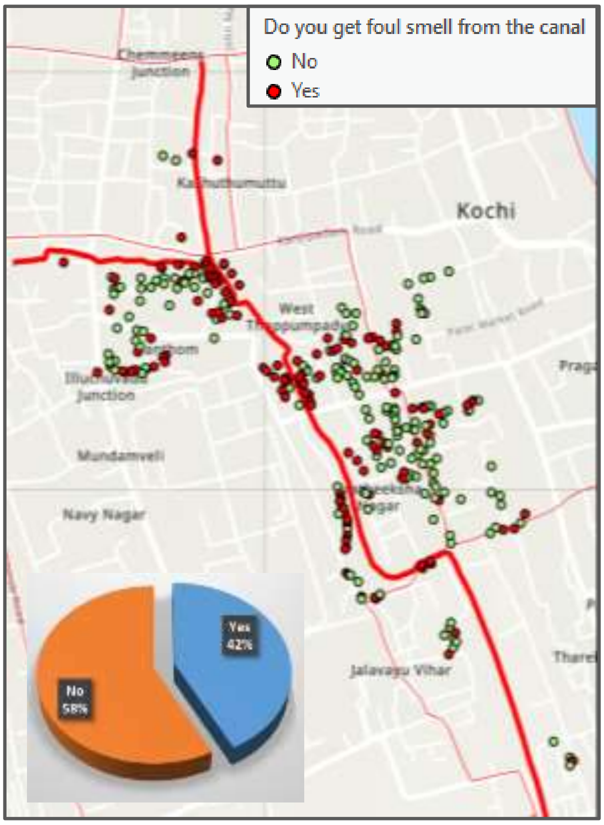


Figure 4-2: Location indicating people experiencing foul smell

Although, 66% of the total population subscribe to garbage collection, 45% of them have expressed dissatisfaction with the garbage collection system. Only 6% of the surveyed households informed that daily collection of waste happens. The survey also showed that not all types of waste are collected from households.

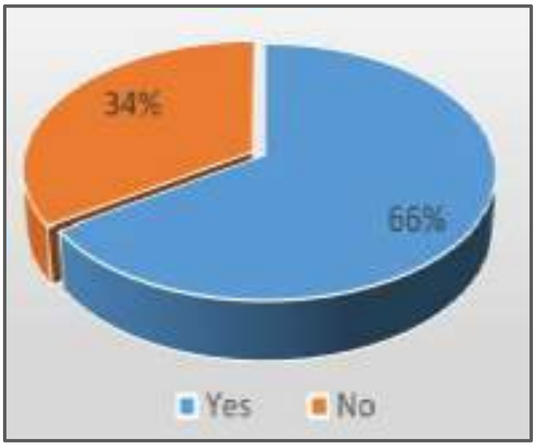


Figure 4-3: Waste collection subscription

Figure 4-4: Frequency of waste collection

Among households that did not have waste collected, 17% reported to disposing their waste in the canal or elsewhere. Disposal of waste in the canal can be seen with canals overflowing with solid waste in many places, choking and clogging culverts. This hinders free flow of water, causing stagnation of water and overflowing of canal and drains. Further, the stagnant water makes the canal a perfect breeding ground for mosquitoes. 30% have reported to burning the waste, which again has adverse environmental implications.

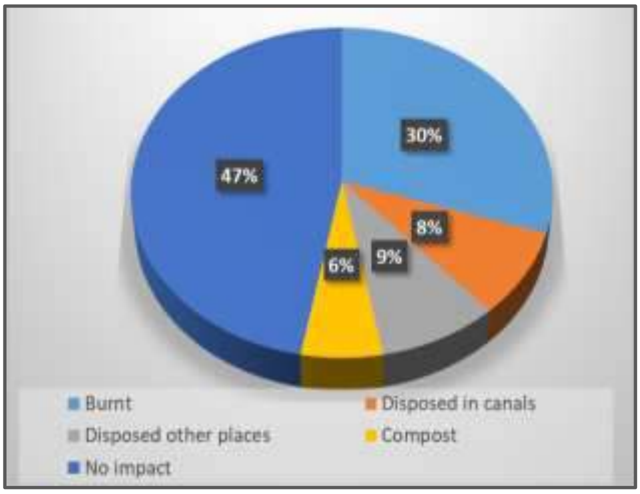


Figure 4-5: Disposal means for waste

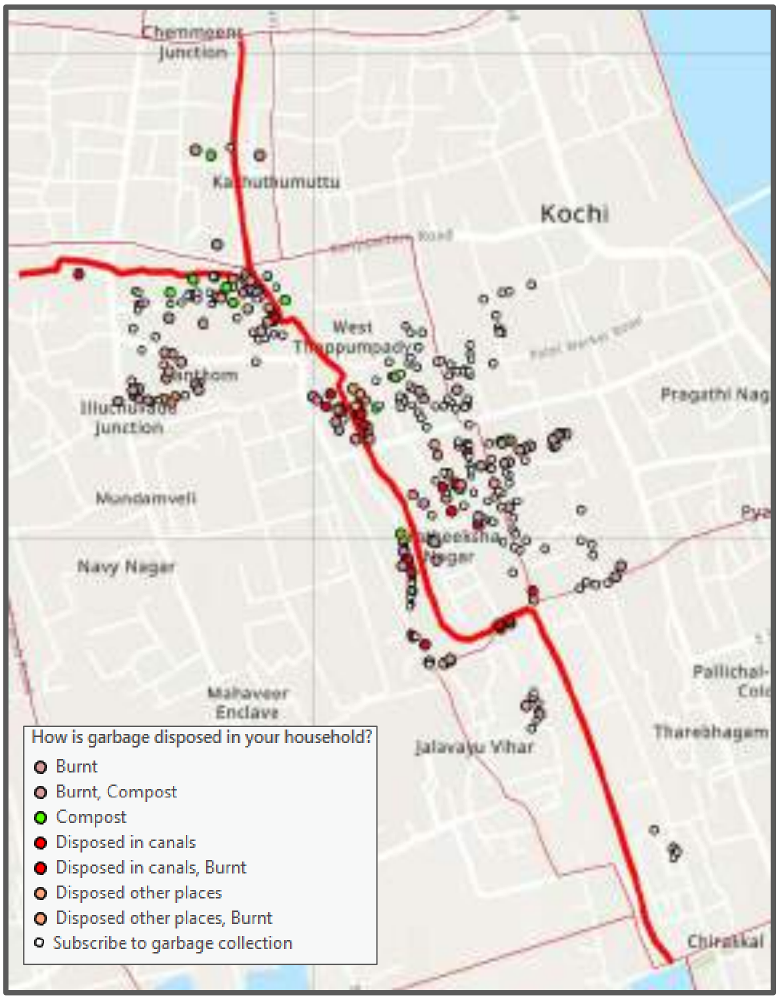


Figure 4-6: Pattern of disposal of waste by households

4.3 Canal route and flooding conditions

Pandarachirathodu canal has two main branches, Pandarachira branch canal and Athipozhi canal. 480 m length of the initial stretch of the main canal is only 2 m wide. It was observed that this stretch of the canal is now reclaimed and covered with precast concrete slabs. Approximately, 520 m long branch canal meets the main Pandarachirathodu canal near the Thoppumady village office. At this junction, huge accumulation of trash is seen causing stagnation on the upper reaches of Pandarachirathodu canal and over considerable length of the branch canal.

Figure 4-7:Garbage seen in the canal

Approximately 320m of the canal flows adjacent to the Santhom colony, where the residents reported flooding during monsoon and high tides due to overflow from the canal. All the houses along this stretch have encroached and sit almost directly above the canal and were found to discharge their grey and black effluents directly into the canals.

Unlined canal banks leads to easy flooding of adjacent lands and erosion of side walls.

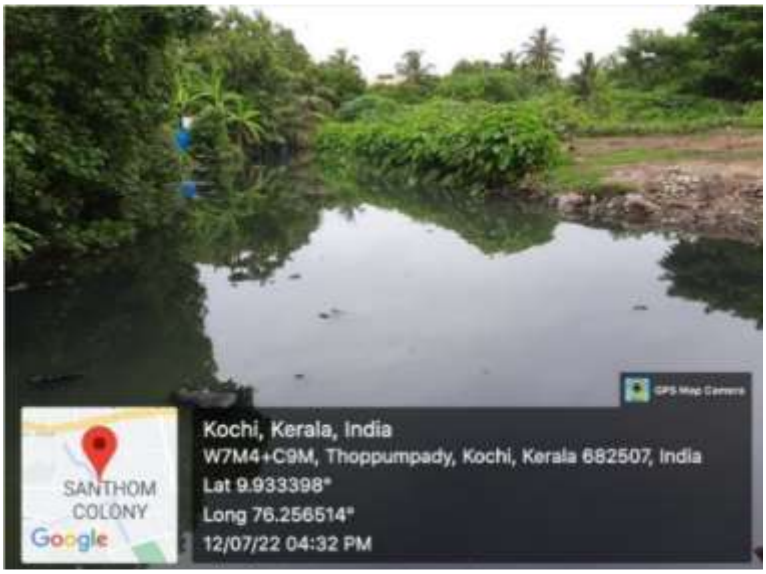


Figure 4-8: Unlined canal banks

The depth of water in this stretch ranges from 0.6m to 0.7m (Department of Irrigation). This stretch of the canal is not lined and is without any freeboard.

The canal then crosses Kochupally road via two existing culverts of 1.5 m diameter (Report on flood mitigation Kochi, Irrigation Department, Ernakulam, 2021) where the depth is reportedly 2 m. This variation of depth over a small distance is due to silting of canal. The inlet and outlet of these culverts were seen to be heavily clogged with garbage due to which the flow upstream of the culverts had visibly stagnated.

Solid waste accumulated at the mouth of the culvert restricts the flow through the culvert and causes flooding on the upstream.

Figure 4-9: Blockage due to accumulation of solid waste

The stretch of the canal between Kochupally road culvert and Valummel road bridge is covered with dense proliferation of water hyacinth.

Figure 4-10: Water hyacinth spread in the canal

The stretch of the canal between Valummel road bridge and the Chirakkal bridge was found to be relatively cleaner, and the depth ranged between 1 m to 2.5 m (Department of Irrigation). At this stretch the canal has an average width of 50 m, except near the Norul Eeman Sunni Juma Masjid where the canal width is reduced to only 20 m due to encroachment. However, this stretch has considerable freeboard.

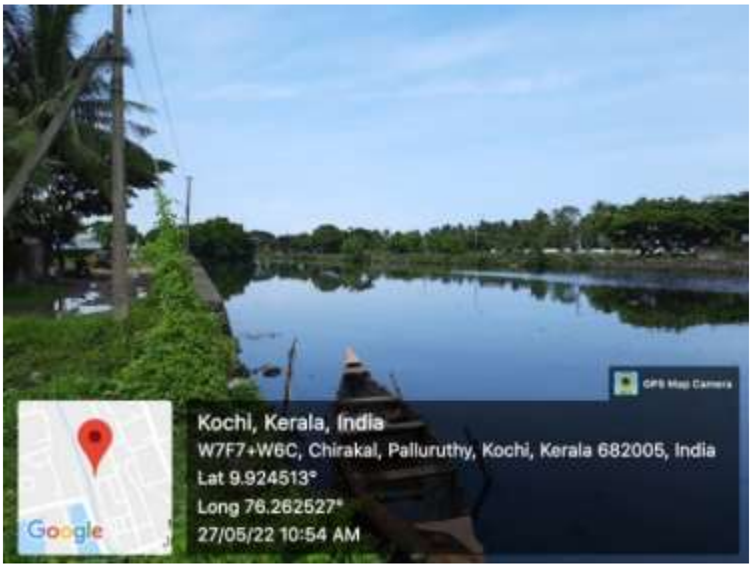


Figure 4-11 Clean stretch of the canal near Chirakkal river

In general, in the stretch of the canal upstream of Valummel road bridge, it was seen that the canal banks have been encroached, reducing the canal width. Silting has also led to the reduction in depth in the canal. These conditions make this stretch and the houses therein vulnerable to floods. There are several drains that carry water from adjacent areas to the canal along the entire stretch of the canal, most of which are clogged. Therefore, they may not have enough capacity to handle any back flow during high tides. These internal drains have not yet been mapped. They will need to be mapped before the pilot project implementation is initiated in the next phase of the project. The canal width varies from 2 m at the start and 56m at the end. However, the width increase is not gradual or linear, the canal width varies in many places along the length of the canal. Additionally, where there is a bridge over the canal, the canal is considerably restricted because the span of the bridge is smaller than the width of the canal upstream of the bridge. This causes higher water levels upstream of the bridge, resulting in flooding of the adjoining areas during heavy rainfall.

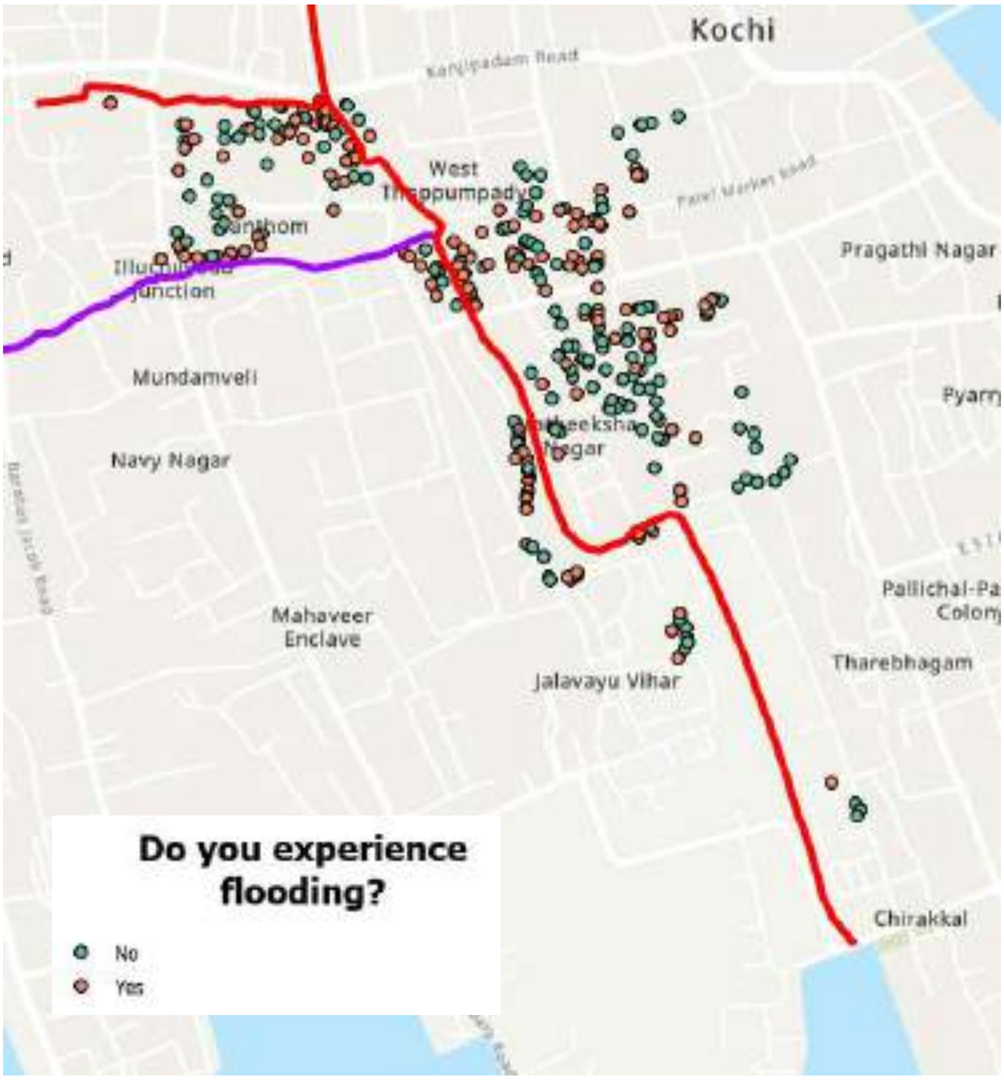


Figure 4-12: Locations where people have experienced flooding

44 % respondents reported flooding during heavy rainfall across all the three wards. Kerala being a coastal state is particularly vulnerable to climate change. As per the Indian Meteorological Department, there has been a threefold increase in incidences of heavy rainfall across all districts of Kerala since 2015. In 2021, the state experienced 115 heavy rainfall events as compared to 43 such events in 2015. Very heavy rainfall events are categorised as days that experience rainfall between 115.6 and 204.4 mm [11].

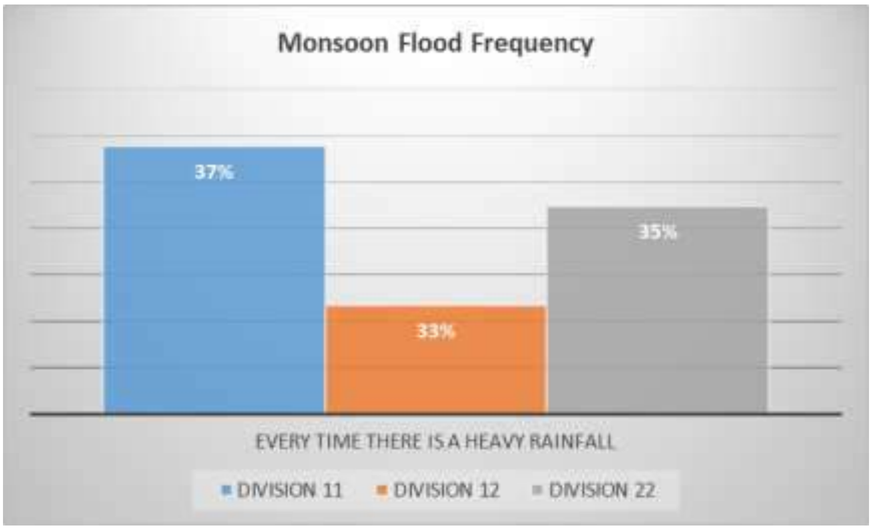


Figure 4-13: Ward wise distribution of monsoon flooding

Other than monsoon flooding, approximately 39% of the respondents reported incidences of tidal flooding across all three wards.

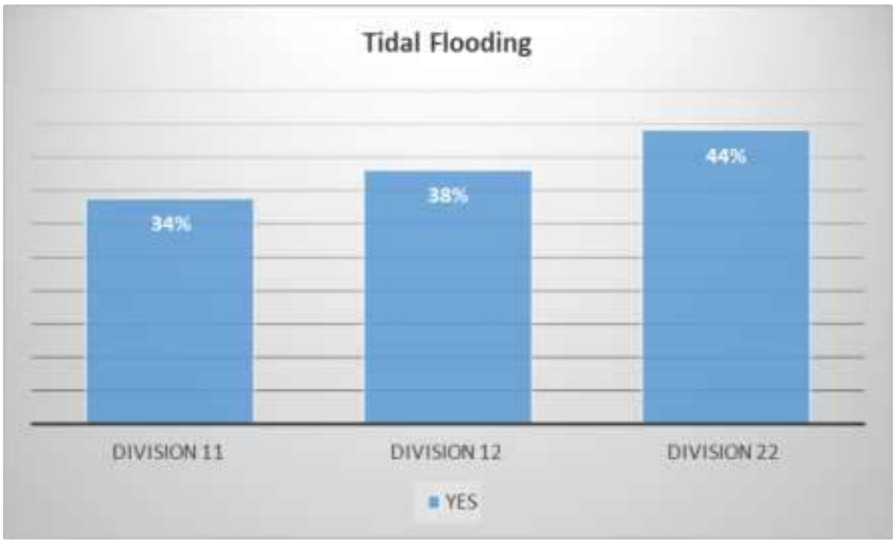


Figure 4-14: Ward wise reporting of tidal flooding

Figure 4-15: Locations where people have experienced tidal flooding

All the three wards experience tidal flooding at least once a year.44% of the respondents have confirmed to the event in ward 22. 34% and 38% of the respondents have confirmed to the event in wards 11 and 12. Tidal flood occurring more than once a year was confirmed by less than 10% of the respondents in each of the 3 wards. Seasonal distribution of tidal flood event revealed that 54% of the respondents experienced tidal flooding during the winter months, while 46% said that the tidal flooding occurred during the monsoon months (May through August).

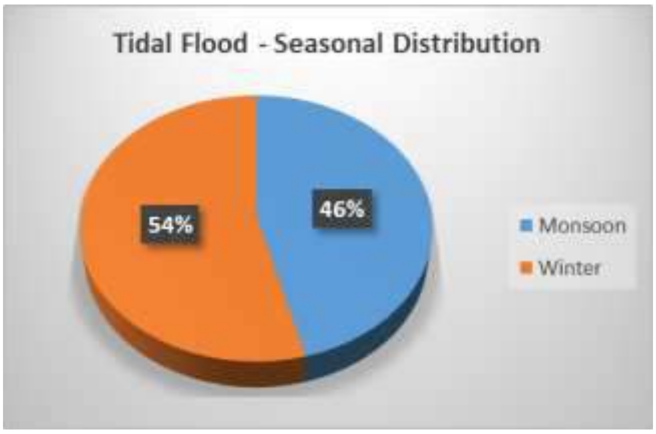


Figure 4-16: Seasonal distribution of tidal flooding incidences

The survey showed that the areas adjacent to the canal are subjected to flooding due to canal overflowing, predominantly at Santhom colony, where there is practically no freeboard, and the canal water is almost at the same level as the bank. Lesser flooding of the canal banks occurs during monsoons at the canal stretch between Kochupally road crossing and Valummel road crossing. The survey data also showed that minor flooding occurs in this area due to tidal effects.

4.4 Sanitation system

There is absence of an integrated sewage collection infrastructure in Fort Kochi. Almost every household has a toilet which is dependent on an on-site sanitation facility. These sanitation facilities are limited to septic tank systems that often show signs of malfunctioning due to aging systems and lack of proper maintenance.

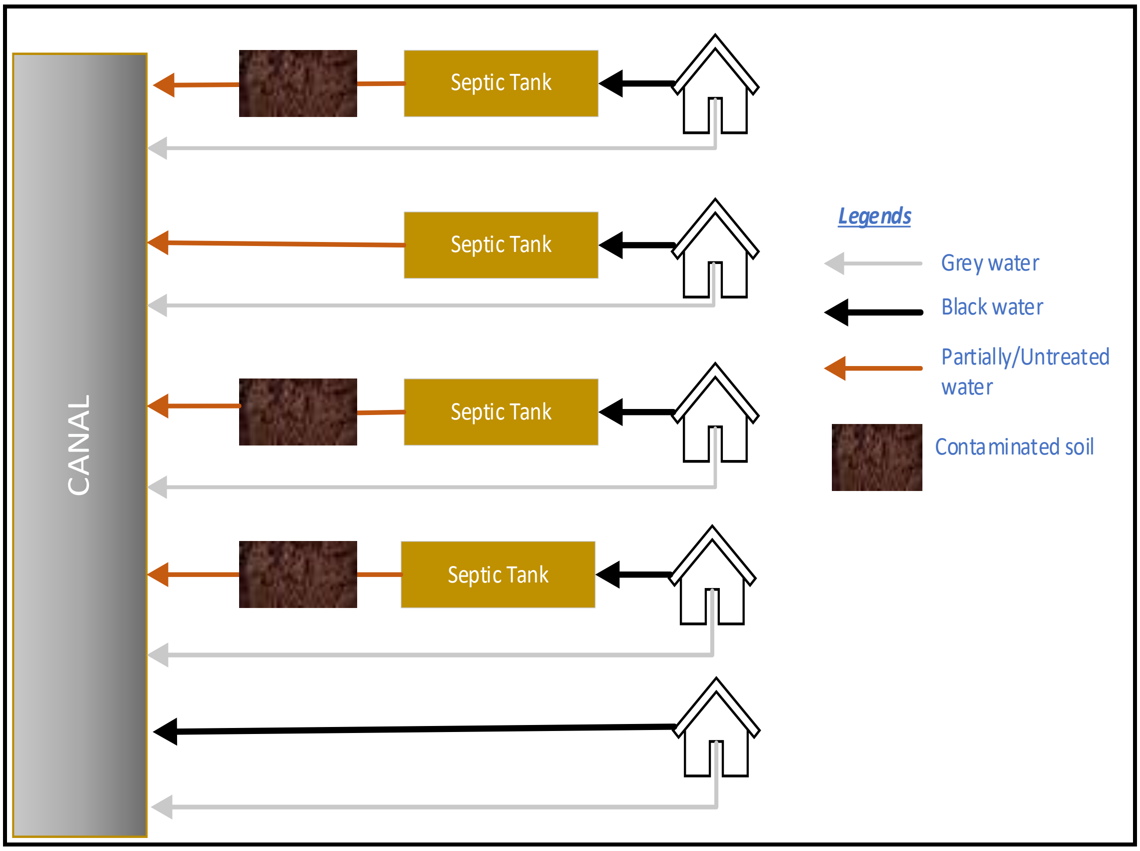


Figure 4-17: Wastewater discharge into canals in Fort Kochi

The survey also corroborated this finding with nearly 85% of the respondents reporting to have septic tank in their households. However, 34% have reported these septic tanks to have been constructed more than 15 years back and around 48% were constructed less than 10 years old. The survey also showed that most households without septic tanks belong to representatives from the very low-income group. Around 25 % respondents indicated that they had never cleaned their septic tanks (which seems to suggest that there is a likely chance of either percolation or leakage into adjacent drains). 43 % indicated a cleaning frequency of once in three years. Around 25% have indicated a cleaning frequency of once in two years.

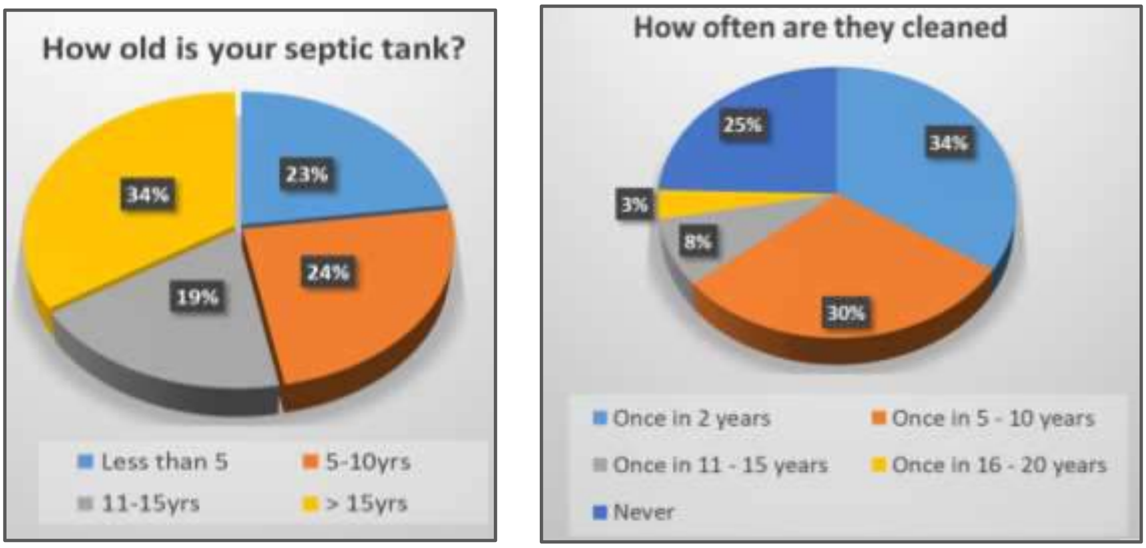


Figure 4-18: Condition of the septic tanks in houses along Pandarachirathodu canal

Direct discharge of black and grey water into the canal was noticed from many households, especially from those houses which were present directly atop the canal bank.

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Figure 4-19: Direct discharge into the canal from toilet blocks

Apart from sewage, it was observed that leachate from septage dumping also enters into the canal and contributes to deterioration of water quality in the canal. 15% of the respondents reported absence of septic tank in their houses.

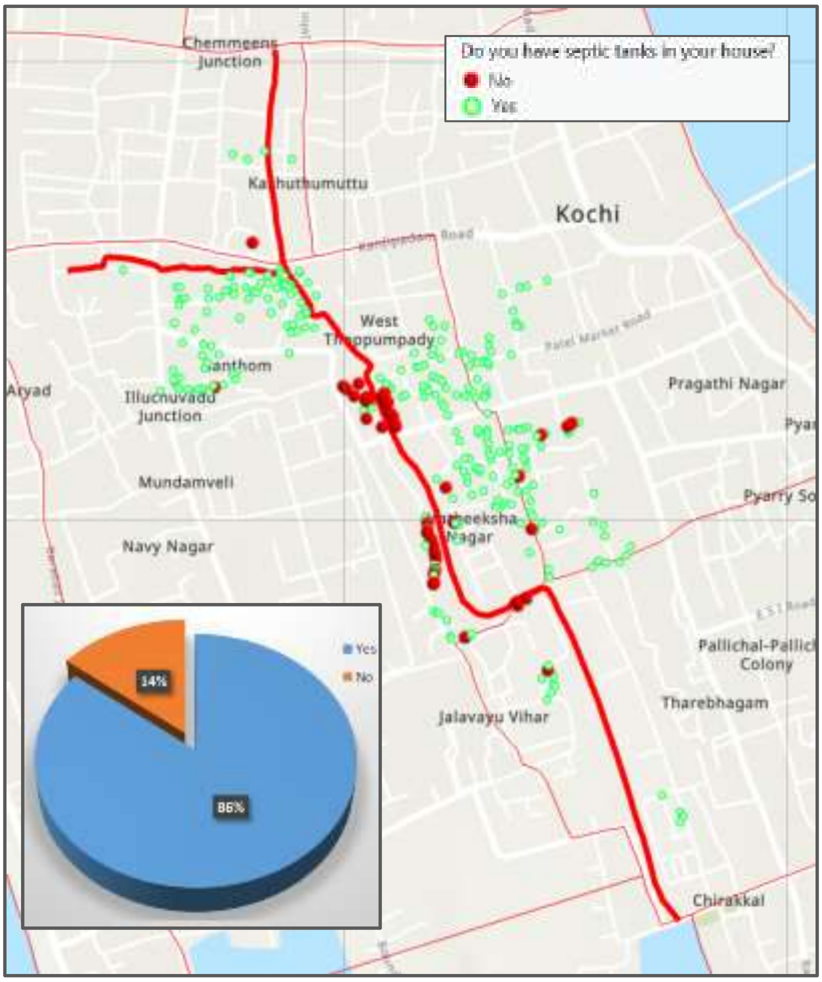


Figure 4-20: Households with and without septic tanks

4.5 Drinking water

The primary source of drinking water is Kerela Water Authority (KWA). However, few people have also indicated that they are using ground water or water from tankers.

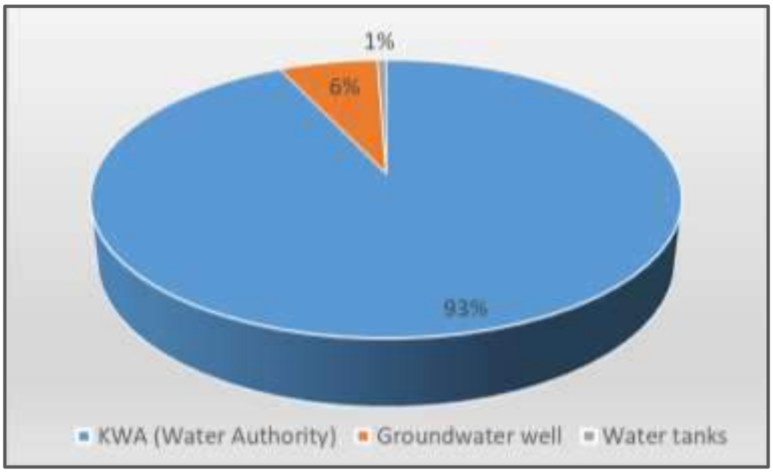


Figure 4-21: Sources of drinking water

Around 7% of the survey respondents reported of illnesses due to poor water quality. Irregularity of water supply is also an issue. The respondents of the survey also stated that water being salty during monsoons, indicating contamination of water lines.

4.6 Summary of findings

From the site visits and survey, it was ascertained that the flooding of the areas adjacent to the canal is due to several factors, such as lack of periodic dredging, building of smaller span bridges at the canal road crossing locations causing the canal width to decrease, dumping of solid waste into the canal that get accumulated at the culvert entrances and restrict smooth flow and spread of invasives like water hyacinth. Additionally, discharge of untreated sewage waste has led to deterioration of water quality in the canal.

5 Flood Mitigation

A hydrologic and hydraulic study of the canal and its subbasins was carried out to determine the extent and depth of flooding, in order to propose various appropriate flood mitigation measures. The study for Pandarachirathodu canal was carried out using HEC-HMS, HEC-RAS and Global Mapper software. The detailed methodology, considerations, assumptions, and results are provided in Attachment 1. Figure 5-1 shows the delineation of the subbasins within the area drained by Pandarachirathodu canal. Figure 5-2 is a schematic representation of the HEC-HMS model used to estimate runoff from the subbasins within Pandarachirathodu drainage area during different rainfall events. Figure 5-3 shows the location of the cross sections used to describe the geometry of Pandarachirathodu canal in the HEC-RAS hydraulic model for the flow simulation during different monsoon and high tide events.

Figure 5-1: Subbasin delineation

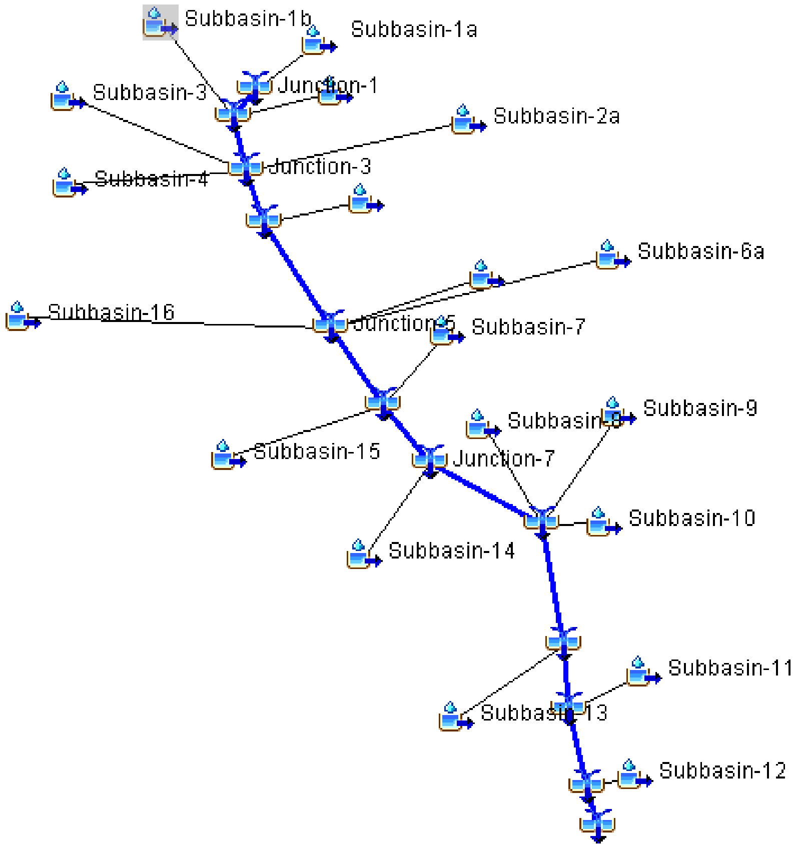


Figure 5-2: Schematic of the HEC-HMS hydrologic model used to estimate runoff

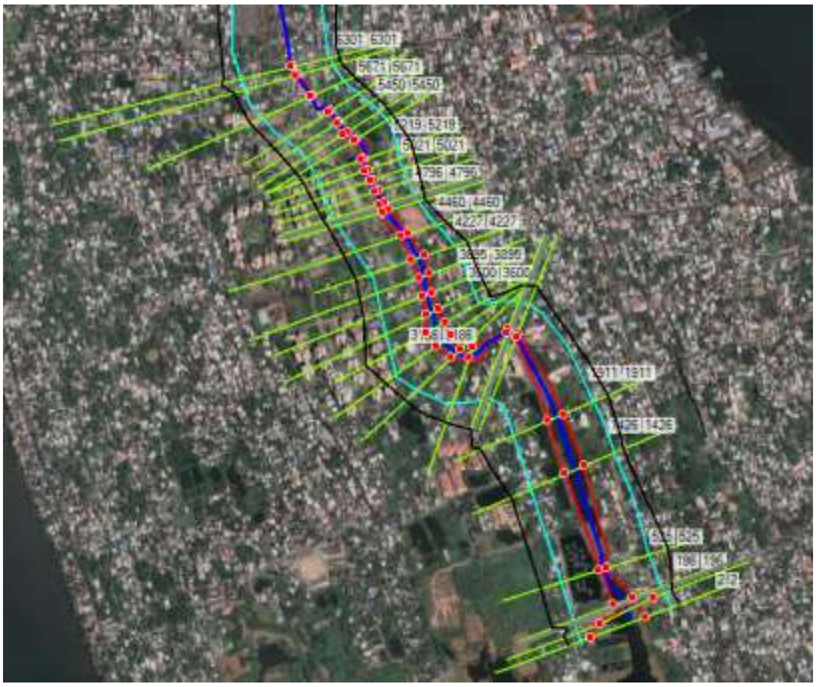


Figure 5-3: HEC- RAS Model Location of cross sections used to describe geometry of Pandarachirathodu canal in the HEC- RAS model used to simulate the flow in the canal during different events

5.1 Findings

The results from the study largely corroborated with the survey data. However, since the topographical and geometry data of the canal used in the study were obtained from open sources, it becomes necessary that the input data be verified through a thorough ground survey.

Figure 5-1 shows the simulated water surface profiles for resulting from 24-hour storms of five different ARIs (2, 5, 10, 50 and 100 years). The bridges at Valummel Road and Kochupally Road restrict the flow, resulting in higher water levels on their upstream side. The water level difference between the upstream and the downstream side of the bridge is especially pronounced at Kochupally Road.

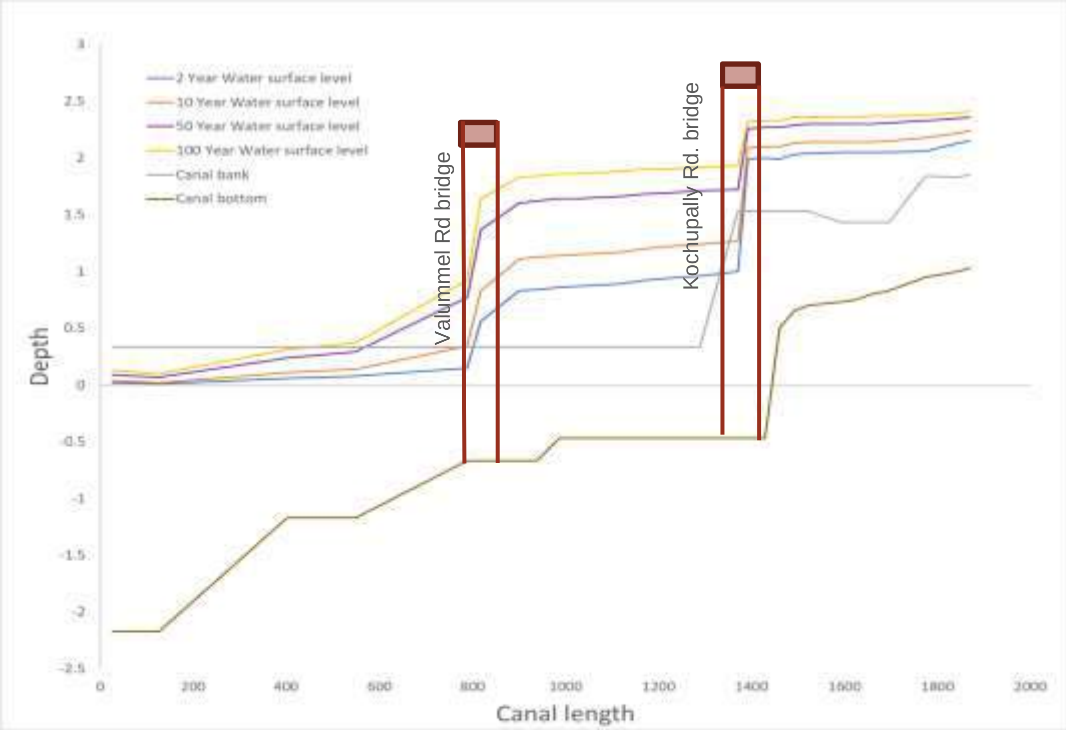


Figure 5-4: Steady state water surface profiles for 24-hour storm of 2, 5, 10, 50 and 100-year ARI

Figure 5-5 shows the maximum water surface profile from a simulation of a 24-hour cycle during the highest spring tide of the year. This simulation shows that some low-lying areas are flooded during such a high tide.

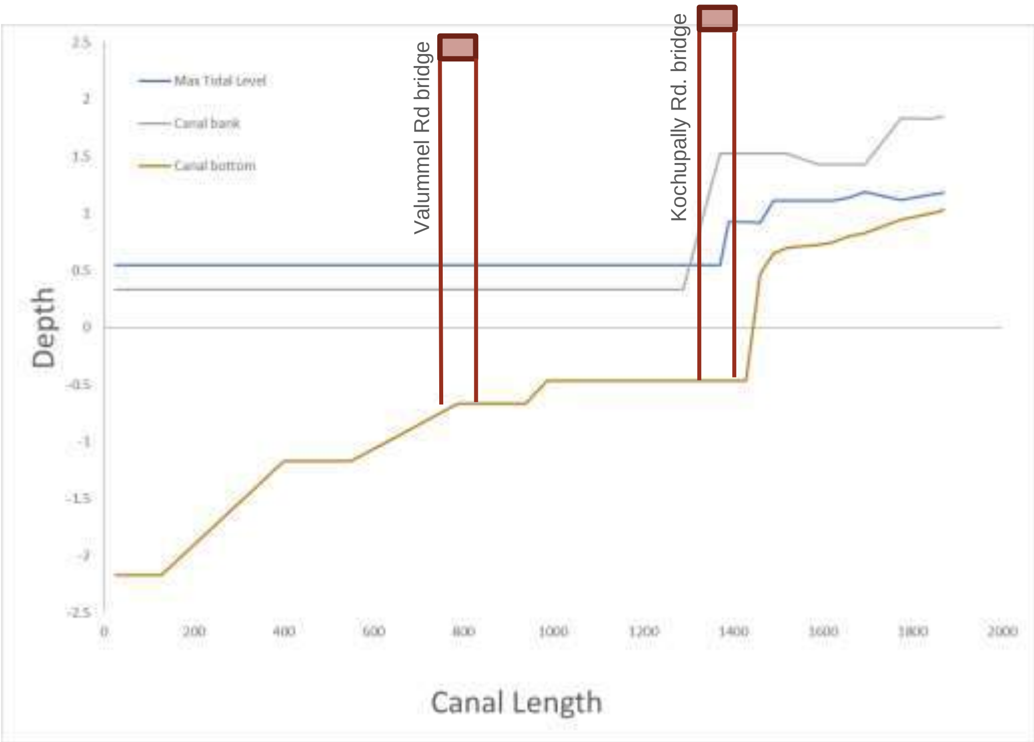


Figure 5-5: Water surface profile variation during Spring Tide

The model was used to evaluate two options of canal improvement. Option 1 includes adding one culvert under Kochupally bridge. Option 2 consists of removing the two existing culverts from under Kochupally bridge and create a free flow path under the bridges (Valummel road bridge and Chirakkal bridge). Both options also include deepening the canal by a minimum 0.5 m at Santhom Colony stretch and increasing the slope of the canal bed downstream of Kochupally bridge by deepening the canal point at various locations. Figure 5-6 and Figure 5-7 highlight the maximum water surface profile during the 2-year, 24-hour storm for options 1 and 2 respectively. Simulated water surface profiles for other ARIs are presented in Attachment 1. The flooded area are expected to reduce considerably if the recommendations were adopted.

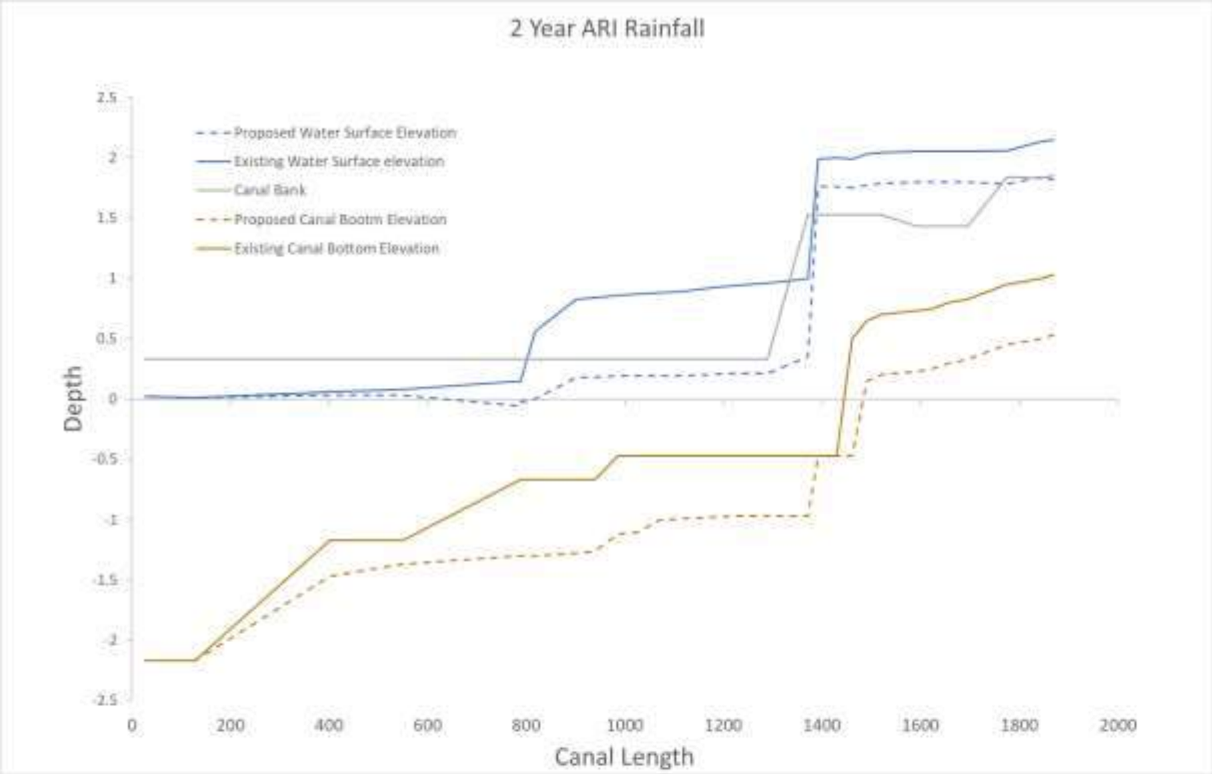


Figure 5-6: Comparison of the water surface profile between the existing conditions and after implementation of option 1 – 2-year ARI rainfall

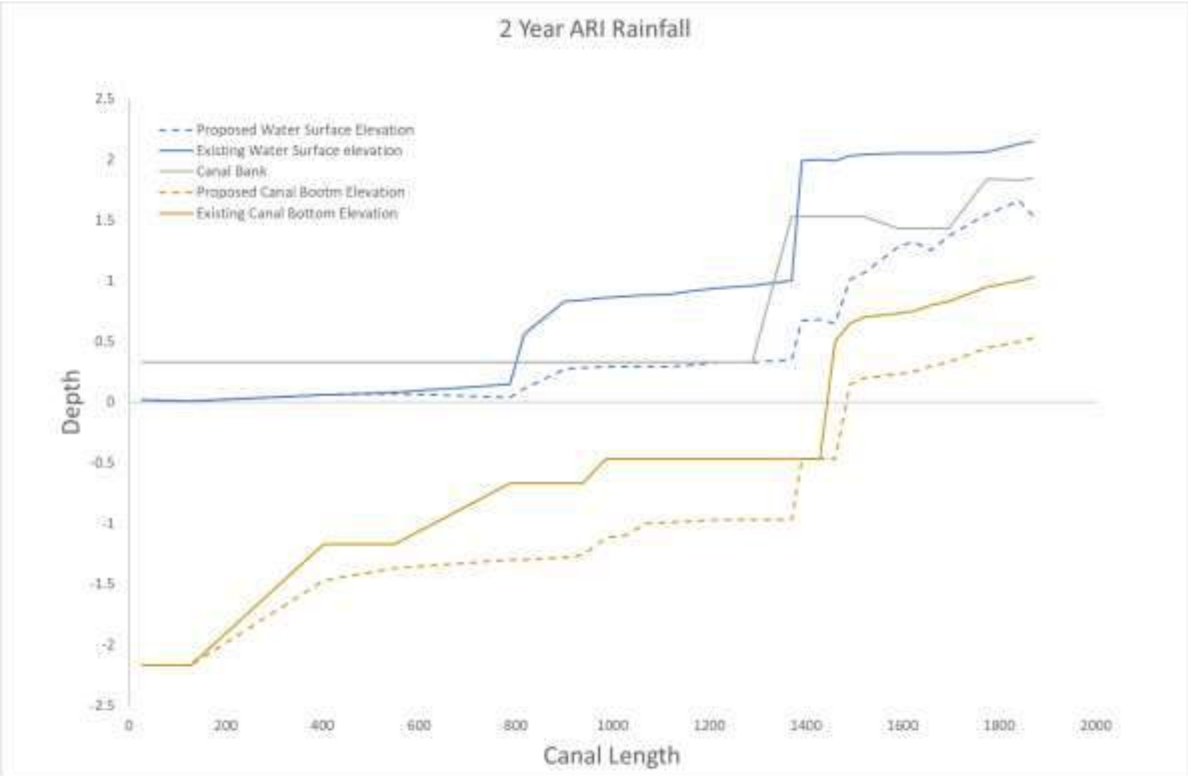


Figure 5-7: Comparison of the water surface profile between the existing conditions and after implementation of option 2 – 2-year ARI rainfall

The model simulations suggests that both options would reduce the flooded area considerably

Figure 5-8 compares the extent of flooded area for storms of different ARIs under the present condition with that under the proposed options.

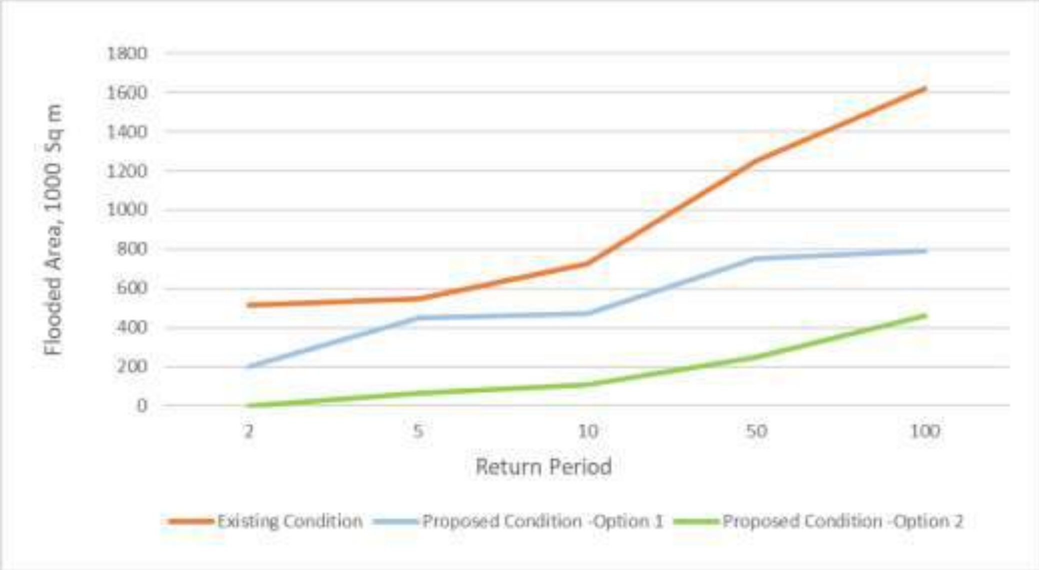


Figure 5-8: Extent of flooding

5.2 Recommendations

- Periodic cleaning and dredging of canal and internal drain networks should be made mandatory to help drain the flood waters effectively. It was reported by the residents that the cleaning and desilting of the canal is irregular, with cleaning intervals exceeding a year. Periodic cleaning helps the canal to maintain its original geometry, thereby ensuring no reduction in its capacity. Properly maintained internal drains can carry the storm runoff efficiently into the canals and also help absorb tidal backflows in the canal.

Figure 5-9 Canal cleaning activities

- Building canal banks 800 mm higher than the current canal banks for option 1 and 400 mm higher than the current canal banks for option 2 at Santhom Colony. For proposed bank heights at other locations please refer Attachment 1. The proposed bank height is the outcome of the hydraulic analysis of the canal which can be referred in Attachment 1. From the visual inspection it was seen that the high-water levels in this area can be mostly attributed to the shallow canal depths, which in turn are the result of silting and garbage dumping into the canal.

- Lining the canal banks with rubble masonry at locations where there are no linings or damaged linings. Lining the canal banks would protect the canal banks from erosion over time and creates a defined water passage.
- Installing bar screens upstream of culverts. This would help arrest entry of solid waste into the culverts. Cleaning the bar screens would be an easier option than cleaning the inside of the culverts. The bar screens can be installed at certain intervals so that there is no heavy trash collection at a single point.

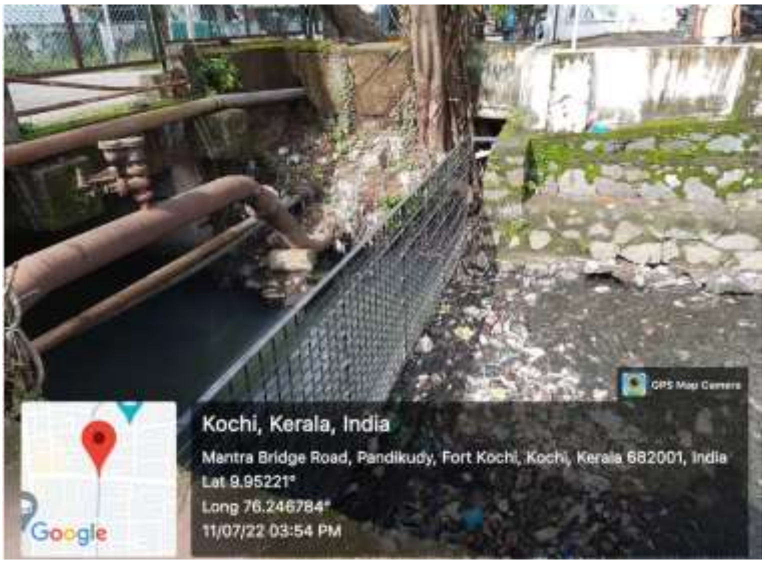


Figure 5-10: Newly installed bar screen installed at the culvert entry location

- Keeping the canal banks free from encroachments. This will ensure that the canal can be widened to its original width, which would increase the capacity of the canal, thus allowing to quickly drain flood waters from larger areas.
- To reduce canal flooding the following two options are proposed. The choice between these options can be made based on cost consideration, as both options would result in about the same level of flood reduction.

Option 1

- Adding one culvert under Kochupally bridge
- Deepening the canal by a minimum 500 mm at Santhom Colony stretch and increase the slope of the canal bed downstream of the Kochupally bridge by deepening the canal point at various locations
- Building protective walls along the canal, maintaining the top of the wall 800mm (including 200mm freeboard) above the existing ground for reach passing through Santhom Colony

Option 2

- Removing the two existing culverts from under Kochupally bridge and creating a free flow path under the bridges (Valummel road bridge and Chirakkal bridge)
- Deepening the canal by a minimum 500 mm in Santhom Colony stretch and increasing the slope of the canal bed downstream of Kochupally bridge by deepening the canal point at various locations
- Build protective walls along the canal maintaining the top of the wall 400 mm (including 200 mm freeboard) above the existing ground for reach passing through Santhom Colony

Figure 5-11 Chirakkal Bridge

6 Sewage Management

Currently, partially treated or untreated waste is discharged into the canal/drain due to direct discharge from toilet blocks and poorly maintained septic tanks. This problem is further amplified by high ground water table. Untreated sewage carries pathogens and other contaminants. Polluted and stagnant canal waters have also become breeding ground for mosquitoes.

6.1 Addressing the situation

6.1.1 Proposed Scheme

As already stated, existing septic tanks are old and inefficient. Hence, discharge from the septic tanks will require further treatment. The proposed system comprises of existing septic tanks, which will be first used to remove settleable and floating solids from the wastewater from each house before it flows into a network of collector mains (typically 6 inches, in diameter). Since the settleable solids will be removed in the septic tanks, the discharge will not carry grit and sewage solids. Therefore, pipes of smaller diameter, placed at reduced slopes or gradients can be used. This will further minimize trench excavation costs. Households which do not have septic tanks, will need to be identified and be provided with septic tanks. Waste collected from septic tanks is then treated in sewage treatment plant before being discharged into the canal. Figure 6-1 provides details of the proposed schematic of sanitary connections.

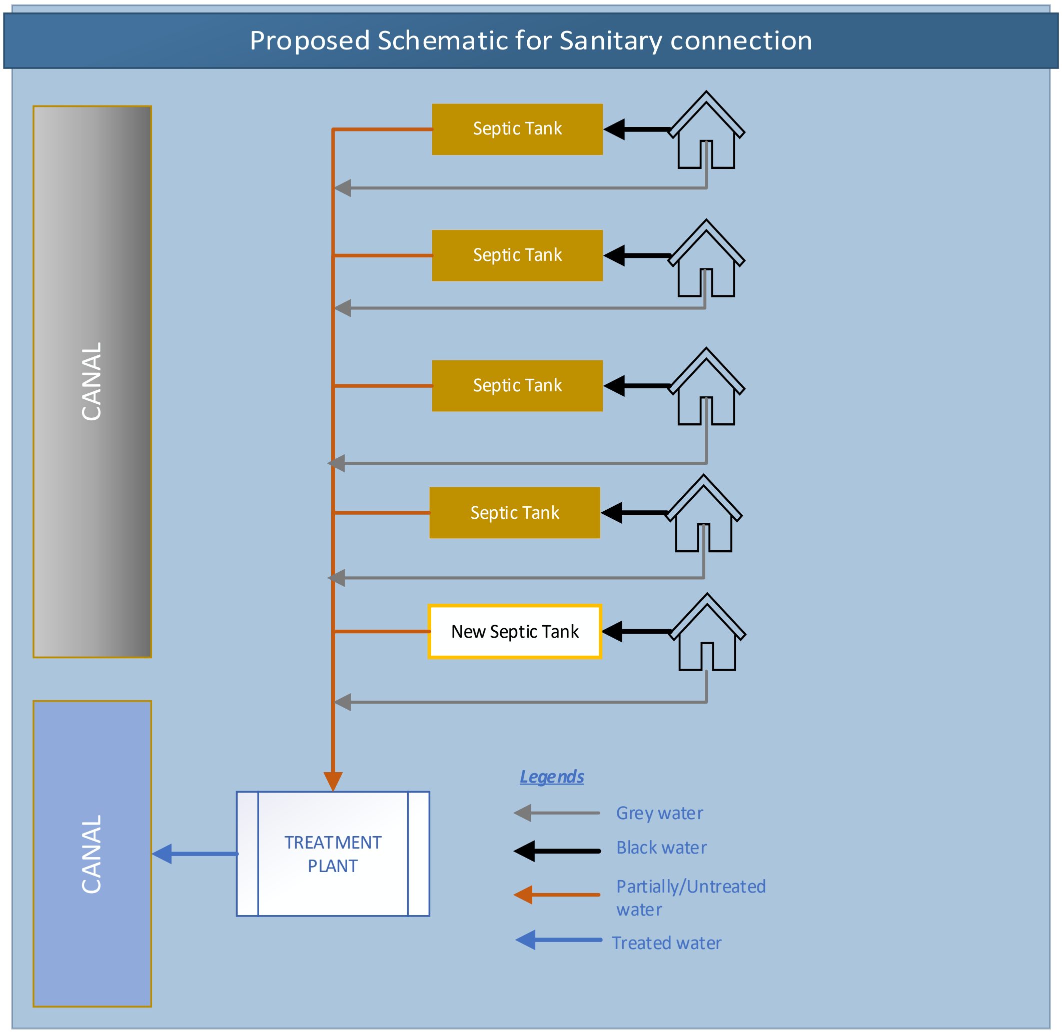


Figure 6-1: Schematic of existing sewage system

6.1.2 Sewage Treatment Plant

A number of alternative wastewater treatment techniques exist, including secondary and tertiary treatment, trickling filter or activated sludge. Each method has its advantages and disadvantages in terms of capital and operation costs, requirement of land, suitability for the area etc. For finalization of STP following criteria was considered

- Ease of implementation
- Cost effectiveness
- Reliability
- Operation and maintenance requirements
- Environmental Impacts

6.1.2.1 Sewage treatment plant alternatives

The following STPs which are commonly used were studied for above criteria

1) Moving Bio Bed Reactor (MBBR)
2) Sequential Bio Reactor (SBR)
3) Treatment plant based on phytorid technology (constructed wetland)

Refer to Annexure 2 for detailed comparison.

Conventional sewage treatment plants require considerable operation and maintenance costs owing to regular power supply and skilled man force for maintenance. Phytorid technologies such as the Integrated Wetland Technology (IWT) on the other hand are innovative natural treatment systems for treatment of sewage naturally. This techonology, also known as constructed wetlands, is an example of green infrastructure used in conjunction with grey infrastructure.

A constructed wetland or phytorid technology is an organic wastewater treatment system that mimics and improves the effectiveness of the processes that help to purify water similar to naturally occurring wetlands. The system uses water, aquatic plants (i.e.: reeds, duckweed), naturally occurring microorganisms and a filter bed (usually of sand, soils and/or gravel).

> Phytorid is a self-sustainable technology for wastewater treatment that leverages green-grey infrastructure and works on the principle of natural wetland. It uses certain specific plants that carry out bio-remediation. This is an example of green infrastructure, being used in conjunction with grey infrastructure.

The components of the Integrated Wetland Technology include:

1. Coarse, Fine Screens: Floating matter, rags, plastic, sanitary waste, etc. in the sewage is separated by using bar screens.

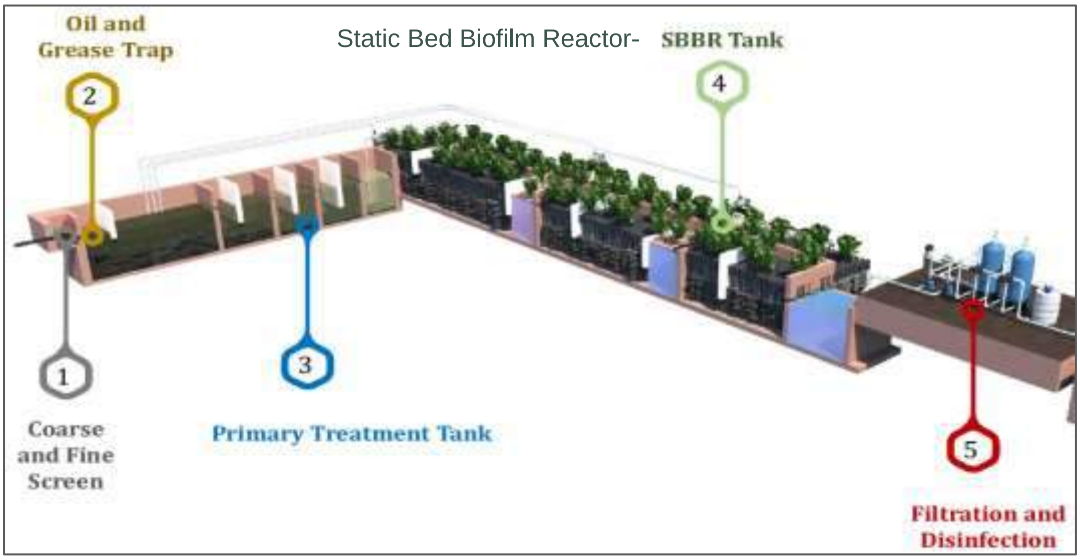
2. Oil and Grease Trap: Used to separate oil and grease with the help of baffel wall.

3. Primary Treatment Tank: Used to remove suspended solids from wastewater.

4. Secondary treatment tank or Static Bed Biofilm Reactor (SBBR): Consists of a layer of gravel/stones/pebbles and plants like *Pennisetum purpureum*, *Typha* sp., *Phragmites* sp., *Canna* sp., Alternanthera sp., that are normally found in natural wetlands with filtration and treatment capability.

5. Tertiary Activated Carbon Filter (ACF): Acts as final treatment after which treated water is disinfected and discharged into the canal.

This technology is now being used successfully in several places in the country. For example, Shahdara Jheel, in Delhi has been rejuvenated using a phytorid technology based STP (capacity - 3.0 MLD) by Municpal Corporation of Delhi. This STP has been constructed with the support of National Environmental Engineering Research Institute (NEERI). It includes tanks for sedimentation of the sewage water and its purification through screens, gravels and boulders, and an ultra-violet (UV) filter. The STP was developed as part of a lake revival project. Apart from STP, this complex is planned to house an amphitheatre, administrative blocks, boating and other facilities. The park is open to the public and currently has jogging and cycling tracks. MCD has proposed to make it a tourist hub [14]. Other exmaples of successful use of this technology also include Neela Hauz in Delhi and Neknampur Lake in Hyderabad.



(Source: Emergy Enviro Private Limited, Mumbai)

Figure 6-2: Typical schematic of Phytorid bet STP

(Source: https://www.hindustantimes.com/delhi-news/in-east-delhi-s-shahdara-a-sewage-filled-dying-lake-is-all-set-for-a-grand-makeover/story-bugdSmMJRyncq3OG522RlN.html)

Figure 6-3: Image of lake revival plan with phytorid bed at of STP at Shahdara, Delhi

6.1.2.2 Technology provider for Phytorid

This technology has been patented by NEERI. The detailed design can only be developed by NEERI approved vendors.

The following vendors are approved by NEERI for licenses for Phytorid wastewater treatment technology [https://www.neeri.res.in/abouts/details/list-of-licenses]

- M/s Technogreen Environmental Solutions, Pune
- M/s Ecologique Science Technik (India) Pvt. Ltd., Mumbai
- M/s Alaknanda Technologies Pvt Ltd, Nagpur
- M/s S.S. Engineering, Uttar Pradesh
- M/s Ayyappa Infra Projects Pvt. Ltd, Hyderabad
- M/s Emergy Enviro Pvt. Ltd, Mumbai
- Scientific Precision Pvt. Ltd, Mumbai

6.1.3 Implementation Plan at Pandarachirathodu Canal

For the pilot implementation, households along the canal were considered, as they have a direct impact on the canal. Based on the catchment basin delineation, the demographic distribution, and the topography features of the project area, the following options can be considered for the wastewater network:

- Option 1: Centralized layout
- Option 2: Decentralized layout

Option 1 – Centralized system

The first option for the layout calls for one sewerage network for the entire area. The collected wastewater would then be conveyed to one large centralized Sewage Treatment Plant (STP). Main sewage conveyances and pumping stations will convey the collected wastewater from a number of colonies to central treatment plant.

The advantage of this approach is that the operation and maintenance of the regional sewage treatment plant is centralized.

This option however has several constraints and barriers that limit its applicability, including:

- Additional pumping stations required as depth will increase for collector lines.
- Canal crossing to be considered
- High water table
- The investment cost required for the main sewage collector/rising main

Option 2: Decentralized system

Another option is construction of sewerage networks in small areas. The collected wastewater would then be conveyed to small scale STPs in each micro-basin, such that one plant is connected to each colony.

Decentralized wastewater treatment can provide a long-term and cost-effective solution for communities by: avoiding large capital costs, using land wisely, reducing depth of piping, reducing operation and maintenance costs.

This technical option has the advantage of ease of operation and maintenance, as the plant is very small. This option also defers the problem of constructing large collectors and expropriating service roads for the collectors. This option also avoids the delay in resolving the water resources pollution problems at the source level.

Refer to Annexure 2 for detailed comparison between above options.

Considering the above advantages, a decentralized system is recommended for houses along the canal.

Figure 6-4: Tentative proposed locations of STPs

Table 2: Tentative location of proposed STPs

	Location	
	Latitude	**Longitude**
STP - 1	9.933765°	76.256951°
STP - 2	9.931822°	76.257604°
STP - 3	9.930429°	76.257933°
STP - 4	9.929710°	76.258577°
STP - 5	9.925546°	76.261305°
STP - 6	9.923600°	76.262884°

These tentative locations have been identified based on google imagery. Actual number of STPs will be determined during the pilot implementation phase.

6.1.4 Proposed STP capacities

Sewage flows have been developed based on residential water usage of 135 litres per capita per day. High rises have not been considered in the pilot phase, as these are mandated by the City Government to have their own treatment plants. Commercial average daily flows have also not been considered in this feasibility study. Contributions from these sources will be analysed during the pilot implementation phase. Residential average daily flows were estimated by accounting for 80% of anticipated water demand.

Population has been calculated based on average household members of 4 persons per household. Future growth factor of 2.5 has also been considered. Table 3 indicates the capacity and location of the STPs.

Table 3 : Tentative capacities of STPs

	Number of houses#	Total Number of persons	STP Capacity (KLD)	Capacity considered (KLD
STP - 1	34	136	45.90	**50**
STP - 2	44	176	59.40	**100**
STP - 3	70	280	94.50	**100**
STP - 4	52	208	70.20	**100**
STP - 5	30	120	40.50	**50**
STP - 6	22	88	29.70	**50**

Total number of houses are calculated based on google earth

6.2 Recommendations

- **Construction of new decentralized sewage treatment plant (using green grey infrastructure):** To improve the quality of water in the canal, it is imperative to provide for a wastewater collection network and treatment facility or facilities. Six decentralised STPs are proposed. For details of location refer to Figure 6.4, Table 2 and Table 3.
- **Closing the outlets opening to the canals:** The sewage outlets from household discharging into the canals need to be plugged.
- **New STPs:** It was found during the survey that about 15% of the houses require new septic tanks. Houses without septic tanks along the canal to be identified and septic tanks need to be provided.
- **Septage management system:** The effluent from the septic tank can be collected in a network of drains and/or sewers and treated in treatment plants designed appropriately. The sludge accumulating at the bottom of the septic tanks should be removed and treated once it has reached the designed depth or at the end of the designed desludging period whichever occurs earlier. Such a removal is possible only by trucks. While sucking out the sludge, the liquid in the septic tank will also be sucked out. With most toilets connected to septic tanks, periodic emptying of septic tanks is essential. If the septage is not safely disposed and is dumped into open streams/rivers, paddy fields and other areas, it will lead to contamination of the canal and drinking

water sources. To combat this situation, it is recommended to have a Faecal Sludge Treatment Plant (FSTP).

- One such example is an FSTP built in Devanahalli, Karnataka. The plant efficiently converts the toilet waste of a town of 30,000 into compost for farmers. It has low operational and maintenance costs, as it runs on gravity and does not use electricity or any chemical additives.

***(Source:** https://swachhindia.ndtv.com/faecal-sludge-treatment-plant-in-devanahalli-near-bengaluru-earns-praise-from-ministry-of-drinking-water-and-sanitation-18161/)*

Figure 6-5: FSTP at Devanahalli, Karnataka

Control on dumping by spot fines/penalties: These are also likely to minimize the waste being dumped into the canal.

- Enforce fines/penalty for discharging untreated wastewater in the canal from houses and buildings
- All trucks carrying septage should be registered with the Kochi Municipal Corporation. These trucks should be equipped with GPS device so that the movement of the trucks can be monitored.

6.3 Challenges and Mitigation

High water table in Kochi

- Due to high water table, ground water levels even with normal rainfall cause many septic tanks in low lying areas to become waterlogged or temporarily flooded. As a result, drains in the house may run slow, toilets may not flush properly and water may back up into floor drains in the basement. Low lying toilets are mainly found in unauthorized low-income group colonies, where the toilet is separate from the main household. These will need to be raised to avoid infiltration of ground water during pilot implementation. Due to the high water table, during construction, laying of pipe network will pose problems. These need to be mitigated during construction through regular dewatering of trenches while laying pipes. Manholes will need to be designed for high water table.
- Septic tank leakages with high water table cause untreated sewage to leak into the groundwater and thereby into the canal without being visible, leading to groundwater and canal pollution. Old and malfunctioning septic tanks will need to be replaced during pilot implementation.

Disposal of Septage

- There is absence of well-defined system for disposal of septage. This system needs to be properly streamlined, in absence of which there is a high risk of contamination of the canal waters.

7 Waste Management

Kochi faces the challenge of not having 100 percent at source segregation and waste collection. Dumping of waste into the canal was observed frequently. This on one hand increases the pollution level in the canal waters, and on the other hand leads to clogging of the canal, leading to increased frequency of flooding. It is imperative that a sustainable waste management system be adopted.

7.1 Recommendations

Waste collection

- Strengthening the on-going efforts of door-to-door collection and segregation at source.
- Presently, all types of waste are not collected and hence, they end up polluting the canal. Collection of all types of waste including rubber, plastic, glass, and electronic items needs to be regularly carried out.
- Effective community wide sensitization programmes against dumping of solid waste in the canals.

Community level wase collection

- Bins for collection of waste should be placed at strategic locations to effectively reduce roadside littering and dumping of waste in the canal. It is recommended to have bins that can be easily lifted by the garbage collection trucks. These bins should be located in areas that are easily accessible by collection vehicles.

Figure 7-1: Images of bins that can be placed at key location (Photo credit:bechtel.org)

- Providing truck mounted refuse compactors: Emptying of waste bins is a challenging task. Often, they end up becoming the dumping site. To avoid this it is recommended to provide automated collecting and dumping equipment.
- One such example is truck mounted refuse compactor. The Refuse Compactor Vehicles are the solid waste collection equipment designed for lifting and unloading the garbage from garbage bins/containers, compaction transportation to dumping ground/transfer stations/processing plants.

(Source: https://www.tpsmfg.com/solid-waste-management-machinery-equipments.php)

Figure 7-2: Truck mounted refuse compactor

- Bio Bins: Bio Bins are designed for treating biodegradable waste at the community level. These bins use an aerobic microbial composting technique. With the exception of paper, plastic, coconut shells and diapers, the bio bins can be used for composting any kind of organic waste. The bins are already in operation in Kochi and have been working successfully for the last five years [15].

(Source: **https://www.indiamart.com/hitechbiofertilizersindia/waste-to-compost.html** *and https://www.cleanindiajournal.com/kerala-to-adopt-bio-bin-to-treat-waste/#:~:text=These%20bins%20use%20aerobic%20microbial,would%20have%20turned%20into%20compost.)*

Figure 7-3: Bio bins

Fencing along Pandarachirathodu canal

To prevent dumping of solid wastes into the canal by residents and commercial establishments, canals can be fenced at critical locations. Along Rameshwaram stretch at few locations fences have already been provided. This needs to be replicated at critical stretches along Pandarachirathodu canal.

Figure 7-4: Fencing at Rameshwaram canal (Photo credit: bechtel.org)

CCTV cameras at strategic locations

Use of surveillance cameras to detect littering violations is a preventive step. This would help authorities to identify the violators and also deter potential violations.

CHENNAI,TAMIL NADU, 26/07/2019 : FOR DOWNTOWN : The residents of Bhai garden have turned an ugly spot in their street into a garden and also installed a camera with a loudspeaker to monitor and warn those who dump garbage and abuse the space at Selayur, East Tambaram in chennai on Friday.Photo : B. Velankanni Raj

(Source: https://www.thehindu.com/news/cities/chennai/residents-tap-into-technology-to-put-an-end-to-littering/article28731799.ece)

Figure 7-5: CCTVs in Chennai

Spot fines/penalties for dumping waste: This practice, though not new to Kochi Municipal Corporation, needs to be strictly implemented.

7.2 Challenges and Mitigation

- **Increased volume of waste**: Rapid urbanization, population growth, and changing consumption patterns with economic growth have contributed to an increase in the amount of waste generated. Strengthening the waste collection system and segregation at source will go a long way to mitigate this challenge.
- **Limited space for storing and transferring waste**: Increased population density has led to decrease in the space available for community bins and transfer stations. Compact transfer station and increase in frequency of waste collection are recommended mitigation measures.

8 Green Infrastructure

The rejuvenation of the canal also needs green infrastructure solutions. The following solutions have been identified.

8.1 Removal of *Eichhornia crassipes*

The canal, at several portions (eg Kochupally road crossing and Valummel road crossing) is infested with water hyacinth. This needs to be removed on priority basis. The presence of water hyacinth on the water surface leads to reduction in the dissolved oxygen availability. This in turn impacts the aquatic flora and fauna. Water hyacinth will need to be manually removed by raking and skimming. Aquatic weed harvester (refer Figure 8.1) can also be used for removal of water hyacinth. Since water hyacinth is the main food source for the *Neochetina beetle* (Figure 8.2), they are commonly used as a biological management factor for the plant.

The screens, that have been proposed in the above sections, once established, will help to keep those areas clean from water hyacinth infestation, once the initial removal of the weed is carried out. The water hyacinth that is removed can be composted.

(Photo Source - https://aquaplant.tamu.edu/management-options/water-hyacinth/)

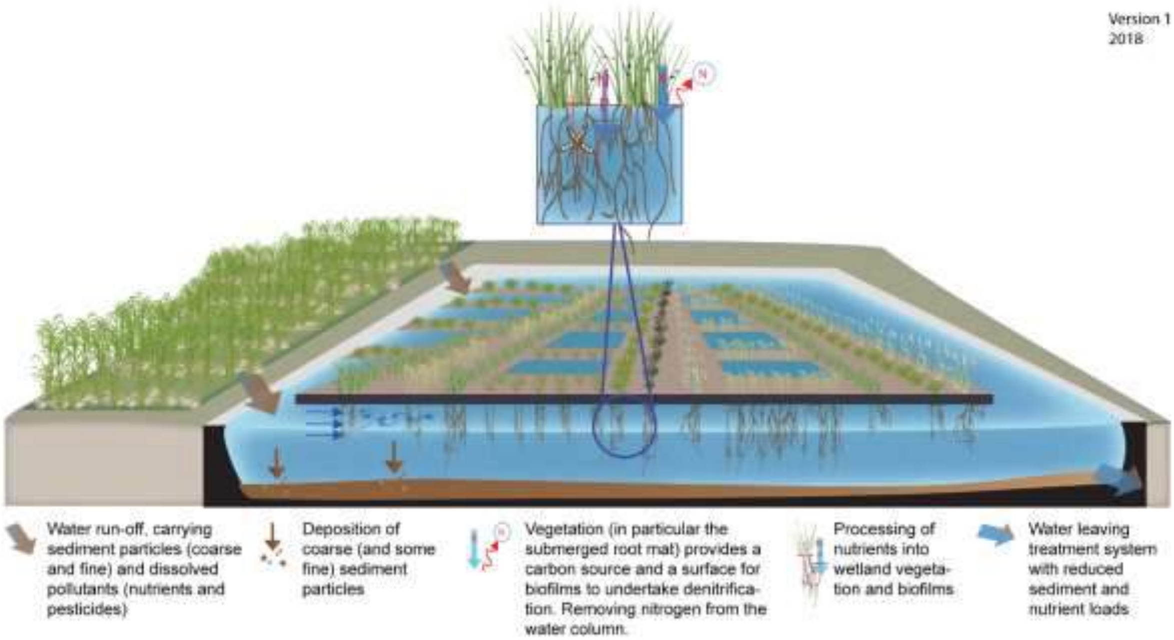
Figure 8-1: Aquatic Weed Harvester being used for removal of water hyacinth

Figure 8-2: Neochetina eichhorniae has been used to successfully control water hyacinth in Hebbal Lake (Photo Source: Google)

8.2 Floating Wetlands

Floating wetlands consist of a suspended matrix planted with wetland plants. This facilitates microbiological and plant processing of nutrients. Floating wetlands work by encouraging settling and biological processing of suspended sediments, particulate and dissolved nutrients and pollutants and also by directing the water through the suspended root mass.

Floating wetlands can be established in the entire selected 2 km stretch of Pandarachirathodu Canal. Since the canal has brackish water, plant species that are able to grow in salt water need to be selected. These include *Aegiceras corniculatum, Avicennia marina, Avicennia officinalis, Bruguiera cylindrica, Bruguiera gymnorhiza, Bruguiera sexangula, Ceriops tagal, Excoecaria agallocha, Excoecaria indica, Kandelia candel, Lumnitzera racemosa, Rhizophora apiculata*, along with *Canna* sp, and duck weed etc. Each floating island will be of the size of 6ft*ft. 3-4 floating islands need to be established, every 500 m, along the entire stretch of the canal. In order to improve the aeration in the canal, around 10 floating fountains also need to be established.



(Source: https://wetlandinfo.des.qld.gov.au/wetlands/management/treatment-systems/for-agriculture/treatment-sys-nav-page/floating-wetlands/)

Figure 8-3: Diagrammatic representation of a Floating Wetland

Figure 8-4: A Floating Wetland in Neknampur Lake (Photo Credit: Madhulika Choudhary)

(Source: https://in.pinterest.com/pin/AfPs_eITHV-LxVuYLTWY_0ltjs-S16RiDhS0C2N2prl8IOBN5SJKYno/)

Figure 8-5: Mechanism behind a floating island

8.3 Mangroves

Centuries back, mangroves used to be present along the canal banks and this entire area. Mangroves act as a natural defence against the impacts of climate change and also provide livelihood. A significant proportion of the fishermen population of Kochi is dependent on mangroves. A study carried out by ICLEI South Asia (2020) shows that regular inland fishermen of the area receive an average benefit of ₹124,000 per annum from mangrove ecosystem. An overall estimation, using data from samples across the mangrove areas of 2.47 km^2 (247 hectares) within Kochi Municipal Corporation and adjacent areas, show a total fisheries ecosystem services generation worth ₹1.7 million per annum per ha ($24,100/ha/yr) from mangroves.

The study has identified areas along the canal where mangrove plantation needs to be undertaken. This will also help to stabilise the banks and prevent soil erosion, along with other benefits. All areas along the canal which have a width of more than 20 m have been selected. Thus, the selected area on the eastern side of the canal accumulates to 1004.23 m and that along the western side of the canal is 1060.16 m. In total, an area of 2064.4 m, along both sides of the canal has been identified for undertaking mangrove plantation (Figure 8-6).

Figure 8-6: Stretches (marked in red) along Pandarachirathodu Canal where mangrove plantation can be undertaken

8.4 Hydraulic Pavers

During the survey, it was noticed that land on both sides, adjacent to the canal is all concretised. This does not allow for the percolation of rain water and the entire rain water rushes into the Pandarachirathodu Canal, thereby aggravating the flooding issue. There is thus a need to promote percolation of rain water in the land areas next to the canal (on which buildings have not been constructed). Though such area is limited, it will still contribute to reducing the water flow into Pandachirathodu and also support ground water recharge. The Table 4 below highlights the advantages of using paver blocks, as compared to Reinforced Cement Concrete or Bitumen.

In order to calculate the area that can be covered using paver blocks, a rough estimation has been carried out. An area of 25 m on both sides of Pandarachirathodu Canal has been taken into consideration Considering 25 m on both sides of the canal, shows a total area of 11.94 ha (5.9 ha on the east side and 6.04 ha on the right side), where paver blocks can be established (though before pilot implementation, detailed ground survey needs to be done as some of this area is already under constructed buildings and will thus have to be left without paver blocks).

Table 4: Comparison between Paver Blocks, RCC and Bitumen

Features	Paver Blocks	Reinforced Cement Concrete	Bitumen
Life Expectancy	>10 years	>10 years	3-5 years (with frequent resurfacing)
Initial Cost	Medium	High	Low
Construction Time	Medium as pavers are laid manually. After construction, immediate use is possible	Very high as after construction 15-20 days required for curing	Low. After construction, use possible within 1-2 days
Rainwater Drainage	Permeable pavers allow water to pass through to the base thereby reduce pooling or flooding in heavy rain	Surface is impermeable and drainage must be achieved by proper surface camber and slope	Surface is impermeable and drainage must be achieved by proper surface camber and slope
Safety	Good slip and skid resistance, helps reduce braking distances	Prone to slippage and skidding during rain and due to spills	Good traction and skid resistance
Surface Cracks	Not affected by rainwater or thermal heat of expansion (due to small unit size and mass)	Prone to cracks due to large thermal mass (which requires provision of expansion joints) and due to poor base preparation	Heavy rains and extreme temperatures leading to potholes
Repairs	Easy, fast and inexpensive as even a single paver block can be removed and re-laid/replaced. Repaired area is available for immediate use	Difficult, time consuming and expensive as whole concrete slab may have to be replaced and re-cast	Cracks, potholes can be repaired inexpensively and quickly by patch work. But repaired area is often not durable due to poor work quality
Reuse	Same blocks can be removed and reinstated after repairs	Cannot be reused but can be crushed for recycling	Cannot be reused but can be crushed for recycling
Quality	Factory produced in large volumes to meet stringent specifications and Indian Standards for strength, water absorption, abrasion resistance and dimensional tolerances	Cast at site and hence dependent on quality of concrete and compaction at the site	Since asphalt is a flexible pavement, its strength relies heavily on the subgrade, subbase and base materials being well compacted
Environmental Issues	Paver block usage has no harmful effects on the environment	Concrete pavement construction has no harmful effects on the environment	Process of melting bitumen creates greenhouse gases that contribute to environmental pollution

8.5 Establishment of Biodiversity Park

Biodiversity parks are a conservation approach that both bring back lost natural heritage specific to an area, and also conserve vanishing ecosystems, communities and species (flora and fauna) on marginal/ degraded vacant lands in and around urban centres. This approach is based on the principle of ecosystem restoration, which promotes assisted recovery of degraded, damaged or destroyed ecological assemblages of species into communities/ecosystems. A biodiversity park is the end product of ecosystem restoration. It preserves natural heritage, and has educational, conservation and cultural value. This approach is different from all other forms of ex-situ and serve as a nature reserve. The underlying principle of the biodiversity parks is to recreate self-sustaining ecosystems with native flora and fauna of the area, for enhancing the quality of the environment. They provide a wide range of ecological services that contribute to human well-being. Some of the ecological services rendered include:

- **Improved public health:** A biodiversity park has diverse natural ecosystems that harbour a rich environmental microbiome which, in turn, are a source for enriching people's microbiomes, can enhance their immunity and thereby reduce health risks and the public health burden.
- **Air pollution mitigation:** The diverse assemblages of tree and other plant species act as effective and efficient filters for both point and non-point sources of air pollution, thereby mitigating air pollution hazards and improving the local air quality.
- **Water recharge and stormwater retention:** The wetlands and associated plant communities of biodiversity parks store millions of cubic metres of floodwater every year and recharge groundwater, which is rapidly depleting due to heavy extraction.
- **Carbon sink:** The biodiversity parks serve as major sinks for carbon dioxide and store huge carbon stocks, both above- and below-ground biomass, contributing to climate change mitigation and adaptation, thus enhancing the city's resilience.
- **Improving micro-climate:** A biodiversity park with diverse forest cover influences local climate conditions particularly ambient temperature. There is scientific evidence that on a large enough scale, forest and vegetation cover can drive local cloud formation, resulting in localised precipitation.
- **Habitat for wildlife:** The diverse ecological niches in biodiversity parks are ideal habitats for certain species of flora and fauna that are otherwise disappearing from the area, and hence serve as nature reserves, harbouring natural heritage.
- **Education and research values:** Biodiversity parks serve as living museums/ laboratories for undertaking research on ecosystem processes and functions. They represent the tools for promoting practical environmental and nature conservation education among students and environment awareness among the public.
- **Recreation value:** Biodiversity parks provide recreation to the public and promote ecotourism.
- **Livelihood value:** Biodiversity parks generate livelihoods for local communities by engaging locals as tourist guides for nature walks and for imparting nature education to visitors.
- **Medicinal value:** The rich plant resources of biodiversity parks provide a myriad of products/ medications that can be used through the Ayurveda, Yoga, Naturopathy, Unani, Siddha, Sowa-Rigpa and Homoeopathy (AYUSH) modalities in treating health disorders, and thereby contributing to the human health care system.
- **Treatment of wastewater:** Biodiversity parks can also contribute to the rejuvenation of canals, rivers and lakes through the use of natural and/or constructed wetlands for the treatment of wastewater before it enters into natural waterbodies.

During the survey, an area has been identified that can be developed into a biodiversity park. This will help augment ecosystem services and also provide green jobs to the local community. The various components that can form part of the biodiversity park include:

1. Butterfly corner
2. Herbal garden
3. Bambusetum
4. Nature Interpretation Centre having exhibits of representative ecosystems in the area
5. Mangrove Board Walk (along the canal edges where mangroves are planted as part of the green infrastructure)
6. Species specific arboreta
7. Amphitheatre
8. Camping Facilities for school children

9 Financial Stability

Competing priorities for public utilities limit the focus on funding for waste management, which presents challenges in maintaining a stable source of funding and servicing. Insurance can help stabilize income streams and mitigate investment risks for this holistic canal restoration approach.

Insurance is an efficient financial instrument and risk management tool that can enhance resilience and improve sustainable management of infrastructure and natural ecosystems, and the economies and communities that depend on them.

As risk carriers, re/insurers protect households, business and governments by absorbing financial shocks from events such as cyclones, floods, droughts, earthquakes, accidents and illnesses. As risk managers, insurers help communities understand, prevent and reduce risk through research and analytics, catastrophe risk models and loss prevention. Insurers also advocate proper land-use planning, ecosystem-based disaster risk reduction, healthy lifestyles, and disaster preparedness.

The traditional role of insurance is one of compensation, providing indemnity after significant loss or damage to property, or disruption of services. However, insurance also transfers risk to a third party, so it can reduce uncertainties, make investment more attractive and accelerate projects. Some of the traditional and more innovation applications are outlined below.

Guaranteeing replacement for loss or damage - Traditional indemnity-based insurance provides a payout after losses have been incurred after a significant weather event, natural catastrophe or other shock. The benefit of insurance is that it provides stability, replacing volatility with planned cash flows. So with insurance coverage, the policy holder doesn't need to hold cash or a capital buffer 'just in case' there is a future loss, which frees up funds for potential investment.

Supporting fast recovery and building resilience - Rather than wait for the loss to be fully assessed and quantified, index-based, or parametric insurance is a pre-agreed contract to pay out a defined amount in a specified circumstance. The claim is automatically triggered by reliable and objective data indices – such as weather, satellite and remote sensing data, and hence payouts can be much faster, proving funds for emergency response, early intervention and recovery activities. Note these types of insurance products carry 'basis risk' where the payout may be higher or lower than the actual incurred loss.

Insurance to enable lending - Insurance purchases at the planning and design phase can help provide assurance and attract investment. Whether indemnity or index based, knowledge that the cover is in place provides peace of mind to lenders and investors. This means that is the project is hindered by catastrophic events, it can be quickly restarted or supported through delays.

Such risk transfer solutions can facilitate efficient, effective and sustainable canal restoration works for the Fort Kochi community:

Stage	**Problem**	**Insurable Risks and Perils**	**Risk transfer Solutions**
Repair and Restoration	De-risking project investment, ensuring and ensuring target outcomes, on time and on budget	• Weather delays and damages • Man-made damages • Operating failures	• Contractors cover for liability and damages • Cover against delays, machinery breakdown, weather events and shortfalls
Residual Risk Management	Damages to property and lives due to excessive flooding – canal overflow	• Excessive rain, storms and related flooding	• Parametric covers to support emergency response • Indemnity property covers
Transfer of transition risk	Effectiveness of restoration outcomes hindered by external factors	• Index-based events – such as water level rising to pre-agreed threshold/s	• Parametric covers to support early intervention

10 Summary of Recommendations

Table 5 below lists key recommendations that need to be implemented in Pandarachirathodu Canal in order to build flood resilience.

Table 5: Building Flood Resilience in Pandarachirathodu Canal

S. No.	Recommendation	Outcome	Timeline
1.0	Canal works (Civil work)		
1.1	Periodic cleaning and dredging of canal and internal drain	• Periodic cleaning and dredging of the canal would help maintain the original geometry of the canal thereby maintaining its original flow capacity. • Cleaning and maintaining the internal drains that outfall into the water will ensure a clear passage of the storm runoff into the canals during monsoons. Clean internal drains also partly absorb the tidal back flows that occur in the canal during high tides, thus reducing flood hazards.	Short term
1.2	Build canal banks at least 0.6 m higher than the current bank elevation	Will help address regular flooding in low-income group houses in Santhom Colony, which are built directly on the top of the unlined canal banks.	Short term
1.3	Line the canal banks with rubble masonry	• Lining the canal banks would protect the canal banks from erosion. • Lining the canal banks would help create a defined boundary of the canal which, if designed accordingly, could act as a retaining wall for small tracks/roads along the canal banks.	Medium term
1.4	Removal of existing culverts at Kochupally road crossing and rebuilding new bridge with increased span	Will allow free passage for canal water and would help reduce the upstream flooded area by 25%.	Medium term

S. No.	Recommendation	Outcome	Timeline
1.5	Removal of hyacinths between Kochupally road crossing and Valummel road	Will increase the flow velocity in the canal thereby allowing faster draining of flood waters.	Short term
1.6	Installation of bar screens at canal entry locations and upstream of culverts	Will arrest entry of solid waste into the canal, thereby preventing clogging of the canal. Additionally, bar screens can also be installed at regular intervals, along the canal stretch to avoid high levels of solid waste accumulating in one stretch in the canal.	Short term
2.0	Sewage treatment		
2.1	Construction of decentralized sewage treatment plant	Will help to control canal water pollution and improve water quality	Medium term
2.2	Closing the wastewater outlets discharging into the canal	Will help to control canal water pollution and improve water quality	Medium term
2.3	Installation of septic tanks for houses without septic tank	Will help to control canal water pollution and improve water quality	Medium term
2.4	Regular inspection of septic tanks for proper functioning with respect to leakages and regular cleaning	Will help to control canal water pollution and improve water quality in the canal as well as groundwater quality	Short term
2.5	Constant monitoring of discharge from high rise apartments, situated along the canal	Will help to control canal water pollution and improve water quality	Short term
2.6	Strict enforcement of fines/penalty for discharging untreated waste in the canal	Will deter people from discharging untreated waste into the canal and thus control canal water pollution and improve water quality	Short term

S. No.	Recommendation	Outcome	Timeline
2.7	Establishment of a Faecal Sludge Treatment Plant	• Will help to control canal water pollution and improve water quality • Compost generated can be used in agriculture	Long term
3.0	Waste Management		
3.1	Installation of Community Bins at Strategic Locations	Minimise waste dumping and clogging of the canal	Medium term
3.2	Adopting Truck Mounted Refuse Compactors	Minimise waste dumping and clogging of the canal	Medium term
3.3	Installation of Bio Bins	Minimise waste dumping and clogging of the canal; Compost availability	Medium term
3.4	Fencing along Panadarachirathodu canal	Minimise waste dumping and clogging of the canal	Medium term
3.5	Strict enforcement of fines/penalty for dumping waste	Minimise waste dumping and clogging of the canal	Short term
3.6	Installation of CCTV camaras at strategic locations	Minimise waste dumping and clogging of the canal	Medium term
3.7	Effective door to door waste collection and segregation at source	Minimise waste dumping and clogging of the canal	Medium
4.0	Green Infrastructure		
4.1	Removal of *Eichhornia crassipes*	Cleaning the canal (manual and mechanic) and improvement in the dissolved oxygen levels	Short term
4.2	Floating Wetlands	Bio-remediation and improvement of water quality	Short term

S. No.	Recommendation	Outcome	Timeline
4.3	Floating Fountains	Improved aeration and water quality	Short term
4.4	Mangrove Nursery	Improved ecosystem services, stabilization of banks, improved livelihood benefits, improved green cover, connectivity corridor establishment which will further enhance overall biodiversity	Short term
4.5	Mangrove Plantation	Improved ecosystem services, stabilization of banks, improved livelihood benefits, improved green cover, connectivity corridor establishment which will further enhance overall biodiversity	Medium and Long term
4.6	Hydraulic Pavers	Rain water percolation, reduction in water flow into the canal, reduction in flooding	Medium term
5.0	Others		
5.1	Development of Biodiversity Park, including Mangrove Board Walk	Several ecosystem service benefits including canal restoration, ground water recharge, augmenting pollinator diversity, ecotourism, green jobs, among others	Long term
6.0	Financial stability		
6.1	Engineering and contract work coverage to be taken out on all construction works	Financial compensation in the event of (1) collapse of design, (2) events breaching and exceeding design limits and (3) human interference (i.e. wrongdoing) – to support rework and project completion	Short term
6.2	Designing and implementation of a parametric excess rainfall residual risk cover	Payouts triggered by pre-agreed rainfall amounts, to support fast response and preparation for flooding	Short term – with opportunity for this cover to start at a higher level then scale down, once the

S. No.	Recommendation	Outcome	Timeline
			green components have matured to optimal effectiveness
6.3	Exploring 'replant guarantee' and solutions to preserve additional green design components	If green components are damaged, insurance solutions provide funds to enable replanting	Short – Medium term
6.4	Exploring solutions to fund early intervention during transition phase – eg: a) using sensors in the canals to trigger the need for early intervention activity b) setting up and managing early intervention funds (pre-funded capital solutions)	When defined events are triggered (such as water rising to a certain level), payouts enable municipal services to take early action, educate and clear potential blockages	Short term – this solution to be in place to support transition to new services and behavior, then be obsolete

Note –

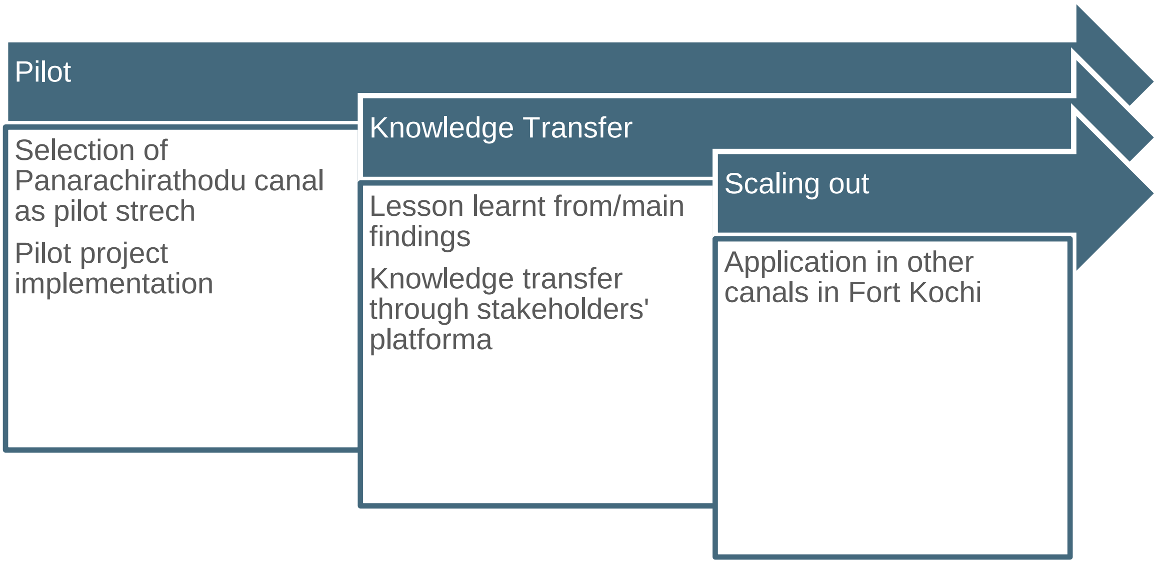
1) These recommendations need to be implemented through Public Private Partnership (PPP)
2) Timeline definition:
   a. Short term – up to 6 months
   b. Medium term – 6 months to 24 months
   c. Long term – beyond 24 months

3) The ball park cost estimate for the above-mentioned short term recommendations is USD 5 million (no price escalation has been considered). The role of Kochi Municipal Corporation will be pivotal in the implementation of the medium and long term recommendations.

11 Path Forward and Scaling up strategy

There are numerous internal drains that outfall into the canal along the entire stretch of the canal, most of which are clogged. Hence, they may not have enough capacity to absorb the back flow during high tides. These internal drains have not yet been mapped. Mapping of the drains during the execution phase is required. There are several wetlands that are connected to Pandarachirathodu canal. Those wetlands need to be maintained and no land use change should be allowed for the same. These wetlands act as buffer and help to retain a significant amount of water. Reduction in the size, number or depth of the wetlands will increase chances of flooding in the canal.

11.1 Scaling-up strategy



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13 Annexures

Annexure 1	Comparison Chart between different STPs
Annexure 2	Sewage layout system comparison
Annexure 3	Drawings for Sanitary treatment
Annexure 4	Pictures

14 Attachments

Attachment 1	Hydrology and hydraulics report
Attachment 2	Third Progress Report (Baseline Report)

ANNEXURE 1

COMPARISON BETWEEN

DIFFERENT TYPE OF STPs

Annexure 1 - Comparison between various Sewage Treatment Plants

Particulars	Moving Bed Biofilm Reactor (MBBR)	Sequencing Batch Reactor (SBR)	Phytorid Technology STP
Principle	Floating high-Capacity Micro Organism Bio Chips media within the aeration and anoxic tanks. The microorganisms breakdown organic material. The media provides increased surface area for the biological microorganisms to attach and grow.	Fills and draws activated sludge system for wastewater treatment. SBR uses a single batch reactor/single tank to process the equalization, aeration, and clarification compared to other technologies that use different batch reactors for various processes.	Constructed wetland. It uses certain specific plants that carry out the process of bioremediation
Process	Electro-Mechanical and Complex	Electro-Mechanical and Complex	Gravity based treatment (one pump for 4 hours /15 days)
Mechanical Equipment	Aerators, recycle pumps, scrappers, thickeners, digesters, dryers gas equipment	Aerators, recycle pumps, scrappers, thickeners, digesters, dryers' gas equipment	Recycle pumps
Electrical Equipment	Yes	Yes	Optional
Electrical Consumption	Very High - 24X7 operation	Very High 24X7 operation	Minimal
Sludge Handling	Daily	Daily	Once in a year
Aeration	Electricity based	Electricity based	100% Natural

Particulars	Moving Bed Biofilm Reactor (MBBR)	Sequencing Batch Reactor (SBR)	Phytorid Technology STP
Tertiary Treatment & Pumps	Required	Required	Single Small pump required
Aesthetic	Not Good	Not Good	Good
Manpower for O&M	24X7 skilled manpower	24X7 skilled manpower	Unskilled manpower non-dedicated
Space required	Low	Low	High
Land Re-Use for recreation or any other purpose	No	No	Yes
Use of Chemical	Yes	Yes	No

Annexure 2

SEWAGE LAYOUT OPTIONS

Annexure 2 –Sewage layout options

	Decentralized	Centralized	Remarks
Description	Includes construction of multiple sewerage networks in small areas. The collected wastewater would then be conveyed to small scale Sewage treatment plants (STPs)	Centralized system will include using one sewage treatment plants instead of several treatment plants	
Economies of scale	Decentralized STPs brings right-sized treatment to where it's needed, with much lower set up costs.	Large-scale, centralized desalination or wastewater treatment plants, use widespread collection and distribution networks	
Scalability and Resilience	Decentralized systems can be scaled up or down and they respond quickly to changing needs.	Large-scale infrastructure can deliver massive capacity, but it's less scalable and less resilient.	
Conveyance structure	In decentralized systems the treatment and disposal or reuse of the effluent is close to the source of generation. This leads to small diameter pipes. The depth of the pipe is also reduced which is useful in places with high water table	This option calls for constructing sewer networks throughout the pilot stretch, with large diameters. The depth and diameter of pipe will increase as the collection system will be catering to larger population	
Capital and Operating Expenditures	A significant benefit of decentralized treatment is its cost savings, particularly in terms of collection and distribution networks, which can account for 75% of the capital expenditure (CAPEX) when establishing wastewater treatment plants.	Centralized system requires more CAPEX and OPEX. Pipeline operating costs are also higher in case of centralized system	
Excavation for Pipe trenches	The trench depth will be limited, and will lead to ease of construction	Due to deeper and larger diameter pipes, the trenched will be deeper and will pose problems due to high water table in Kochi. Refer remarks	Deeper excavation may lead to other serious problems, including the washout and displacement of pipes, the settlement of

	Decentralized	Centralized	Remarks
			manholes, the breakage of sewer lines, the high infiltration rates during the wet season, which would lead to inefficient operation of the treatment plants), etc.
Pumping requirement	No pumping required	Additional pumping stations required as depth will increase for collector lines.	
Canal Crossing	Location of STPs shall be finalized to avoid canal crossings	Multiple canal crossings	
Land Requirement	Smaller pieces of land required at multiple locations	Require large piece of land	
Operation and Maintenance	This technical option has the advantage of ease of operation and maintenance. The plant is relatively small.	Operation and maintenance of the regional sewage treatment plants is centralized.	

Annexure 3

DRAWINGS FOR SEWAGE LAYOUT

Annexure 3 –Drawings for Sewage Layout

Annexure 3

KOCHI CANAL RESTORATION PROJECT

LEGENDS

- SEWAGE TREATMENT PLANT (STP)
- PUMP STATION (PS)
- START OF SEWER
- PUMPED SEWER LINE
- GRAVITY SEWER LINE

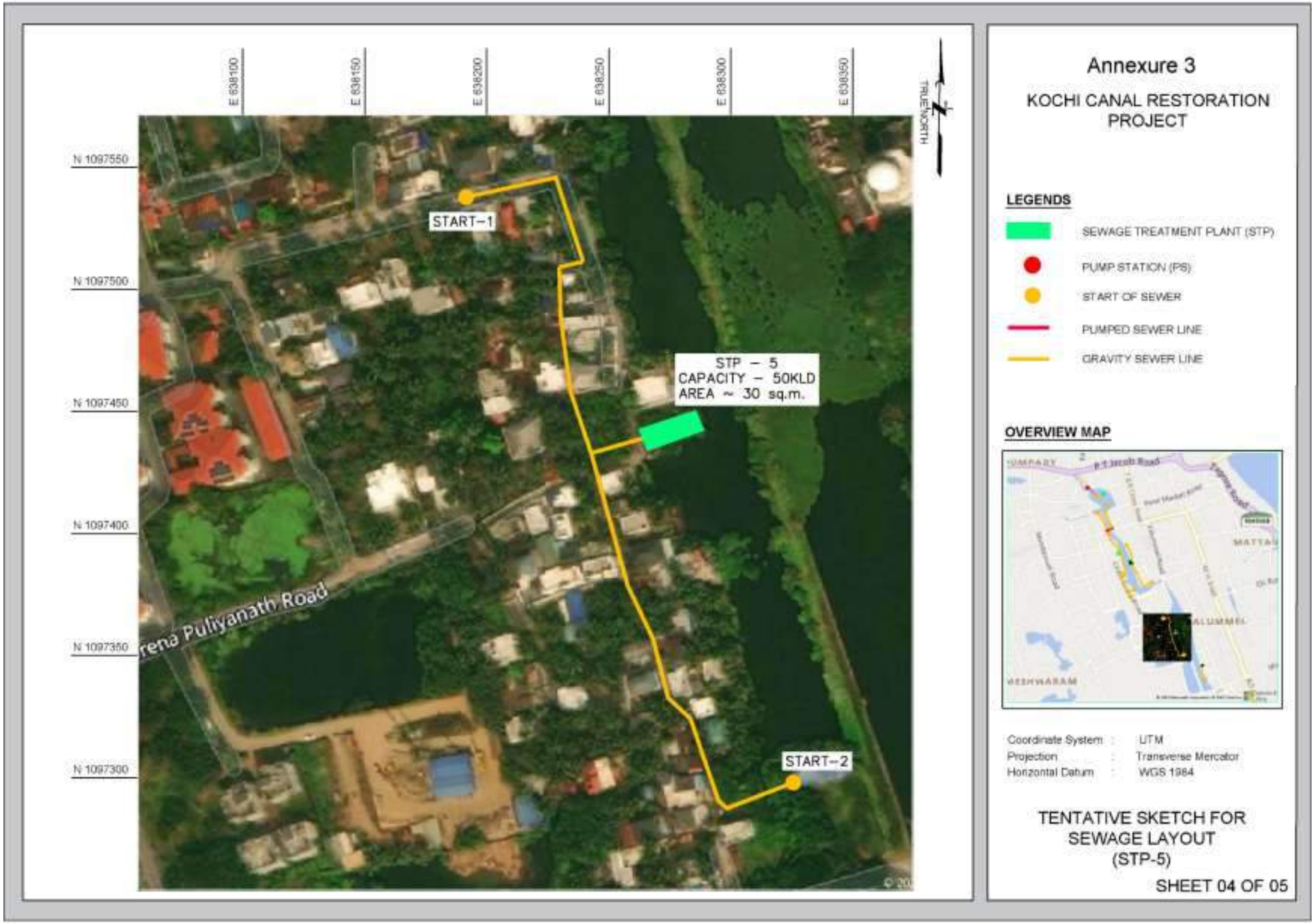
OVERVIEW MAP

Coordinate System	:	UTM
Projection	:	Transverse Mercator
Horizontal Datum	:	WGS 1984

TENTATIVE SKETCH FOR SEWAGE LAYOUT (STP-2)

SHEET 02 OF 05


Annexure 3
KOCHI CANAL RESTORATION PROJECT
LEGENDS
SEWAGE TREATMENT PLANT (STP)
PUMP STATION (PS)
START OF SEWER
PUMPED SEWER LINE
GRAVITY SEWER LINE
OVERVIEW MAP
Coordinate System : UTM
Projection : Transverse Mercator
Horizontal Datum : WGS 1984
TENTATIVE SKETCH FOR SEWAGE LAYOUT (STP-3 AND STP-4)
SHEET 03 OF 05
TRUE NORTH
E 637750
E 637800
E 637850
E 637900
E 637950
E 638000
E 638050
E 638100
E 638150
N 1098050
N 1098000
N 1097950
N 1097900
N 1097850
N 1097800
N 1097750
N 1097700
N 1097650
Kochupally Road
START–1
START–2
START–3
START–4
START–5
START–6
STP – 3
CAPACITY – 100KLD
AREA ~ 50 sq.m.
STP – 4
CAPACITY – 100KLD
AREA ~ 50 sq.m.
Coast Guard Road
Valummel Road


E 638100
E 638150
E 638200
E 638250
E 638300
E 638350
TRUE NORTH
N 1097550
N 1097500
N 1097450
N 1097400
N 1097350
N 1097300
START-1
START-2
STP - 5
CAPACITY - 50KLD
AREA ~ 30 sq.m.
rena Puliyanath Road
Annexure 3
KOCHI CANAL RESTORATION PROJECT
LEGENDS
SEWAGE TREATMENT PLANT (STP)
PUMP STATION (PS)
START OF SEWER
PUMPED SEWER LINE
GRAVITY SEWER LINE
OVERVIEW MAP
Coordinate System : UTM
Projection : Transverse Mercator
Horizontal Datum : WGS 1984
TENTATIVE SKETCH FOR SEWAGE LAYOUT (STP-5)
SHEET 04 OF 05

Annexure 3

KOCHI CANAL RESTORATION PROJECT

LEGENDS

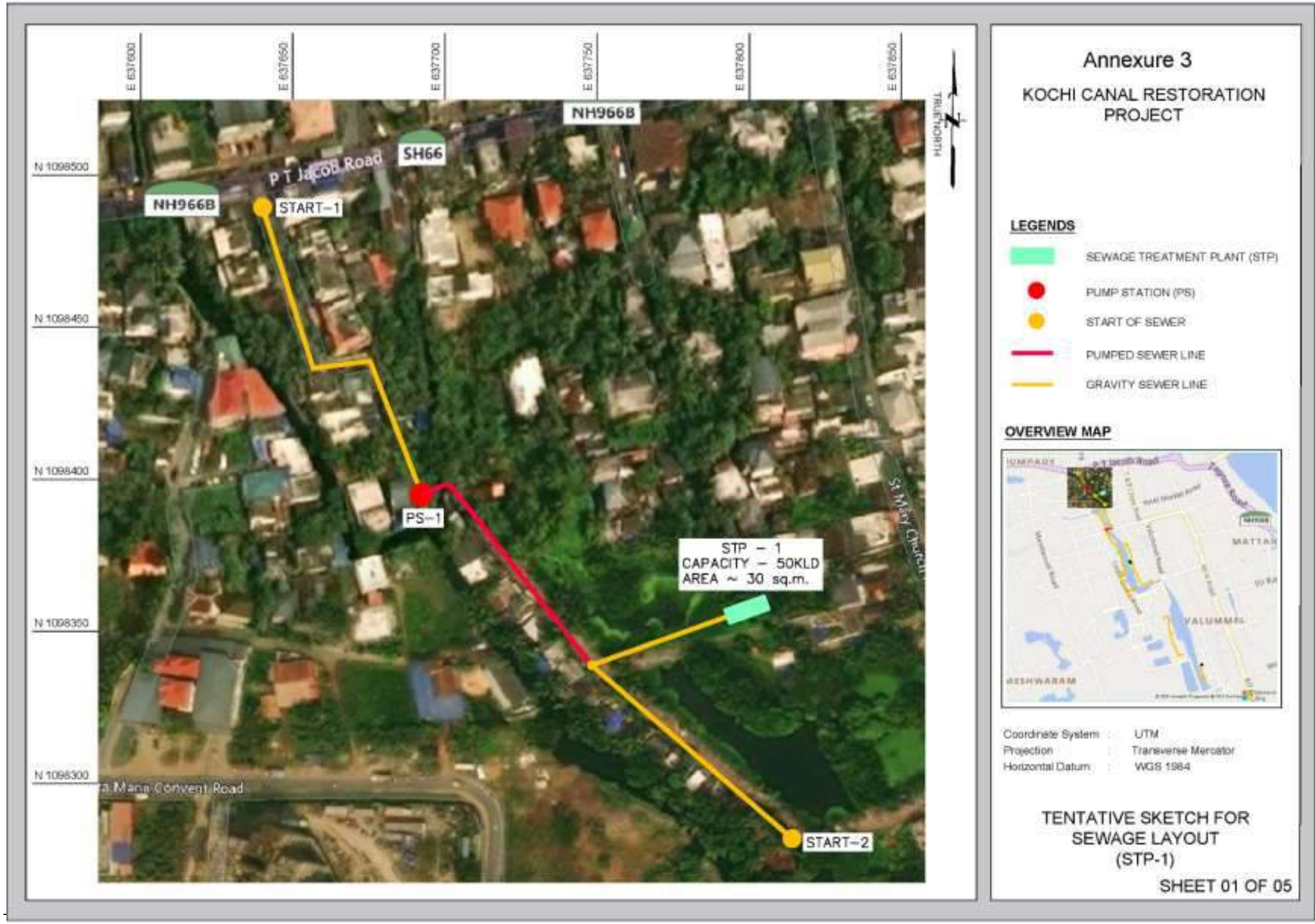
- SEWAGE TREATMENT PLANT (STP)
- PUMP STATION (PS)
- START OF SEWER
- PUMPED SEWER LINE
- GRAVITY SEWER LINE

OVERVIEW MAP

Coordinate System	:	UTM
Projection	:	Transverse Mercator
Horizontal Datum	:	WGS 1984

TENTATIVE SKETCH FOR SEWAGE LAYOUT (STP-5)

SHEET 05 OF 05


E 637600
E 637650
E 637700
E 637750
E 637800
E 637850
N 1098500
N 1098450
N 1098400
N 1098350
N 1098300
TRUE NORTH
NH966B
SH66
P T Jacob Road
NH966B
START-1
PS-1
STP - 1
CAPACITY - 50KLD
AREA ~ 30 sq.m.
St Mary Church
Maria Convent Road
START-2
Annexure 3
KOCHI CANAL RESTORATION PROJECT
LEGENDS
SEWAGE TREATMENT PLANT (STP)
PUMP STATION (PS)
START OF SEWER
PUMPED SEWER LINE
GRAVITY SEWER LINE
OVERVIEW MAP
Coordinate System : UTM
Projection : Transverse Mercator
Horizontal Datum : WGS 1984
TENTATIVE SKETCH FOR SEWAGE LAYOUT (STP-1)
SHEET 01 OF 05

Annexure 3

KOCHI CANAL RESTORATION PROJECT

LEGENDS

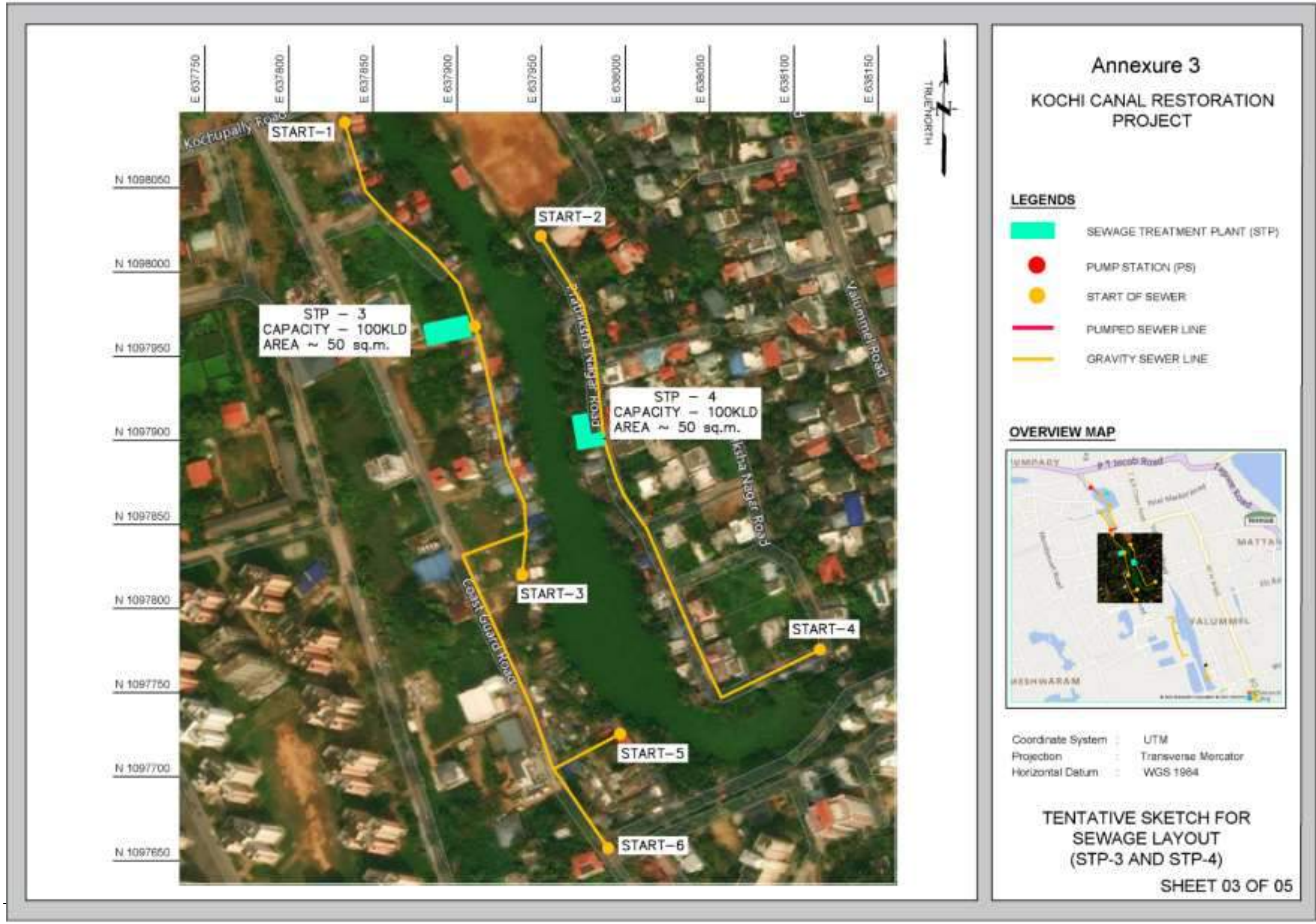
- SEWAGE TREATMENT PLANT (STP)
- PUMP STATION (PS)
- START OF SEWER
- PUMPED SEWER LINE
- GRAVITY SEWER LINE

OVERVIEW MAP

Coordinate System	:	UTM
Projection	:	Transverse Mercator
Horizontal Datum	:	WGS 1984

TENTATIVE SKETCH FOR
SEWAGE LAYOUT
(STP-2)

SHEET 02 OF 05



Annexure 3
KOCHI CANAL RESTORATION PROJECT
LEGENDS
SEWAGE TREATMENT PLANT (STP)
PUMP STATION (PS)
START OF SEWER
PUMPED SEWER LINE
GRAVITY SEWER LINE
OVERVIEW MAP
Coordinate System : UTM
Projection : Transverse Mercator
Horizontal Datum : WGS 1984
TENTATIVE SKETCH FOR SEWAGE LAYOUT (STP-3 AND STP-4)
SHEET 03 OF 05
START-1
START-2
START-3
START-4
START-5
START-6
STP - 3 CAPACITY - 100KLD AREA ~ 50 sq.m.
STP - 4 CAPACITY - 100KLD AREA ~ 50 sq.m.
Kochupally Road
Coast Guard Road
Valummel Road
TRUE NORTH
E 637750
E 637800
E 637850
E 637900
E 637950
E 638000
E 638050
E 638100
E 638150
N 1098050
N 1098000
N 1097950
N 1097900
N 1097850
N 1097800
N 1097750
N 1097700
N 1097650

Annexure 3

KOCHI CANAL RESTORATION PROJECT

LEGENDS

- SEWAGE TREATMENT PLANT (STP)
- PUMP STATION (PS)
- START OF SEWER
- PUMPED SEWER LINE
- GRAVITY SEWER LINE

OVERVIEW MAP

Coordinate System	:	UTM
Projection	:	Transverse Mercator
Horizontal Datum	:	WGS 1984

TENTATIVE SKETCH FOR SEWAGE LAYOUT (STP-5)

SHEET 04 OF 05

Annexure 3

KOCHI CANAL RESTORATION PROJECT

LEGENDS

- SEWAGE TREATMENT PLANT (STP)
- PUMP STATION (PS)
- START OF SEWER
- PUMPED SEWER LINE
- GRAVITY SEWER LINE

OVERVIEW MAP

Coordinate System	:	UTM
Projection	:	Transverse Mercator
Horizontal Datum	:	WGS 1984

TENTATIVE SKETCH FOR SEWAGE LAYOUT (STP-5)

SHEET 05 OF 05

ATTACHMENT 1

HYDROLOGIC & HYDRAULIC STUDY OF THE PANDARACHIRA CANAL

Table of Contents

List of Tables

List of Figures

1 Software

The HEC-HMS and HEC RAS models were used for the hydrologic and hydraulic analysis of the Pandarachira canal network and its catchment. Both models have been developed by the Hydrologic Engineering Center, which is a division of the United States Army Corps of Engineers.

HEC-HMS simulates the precipitation-runoff processes of dendritic drainage watersheds. It is designed to be applicable in a wide range of geographic areas for solving the widest possible range of problems. This includes large river basin water supply and flood hydrology, and small urban or natural watershed runoff. Hydrographs produced by the program are used directly or in conjunction with other software for studies of water availability, urban drainage, flow forecasting, future urbanization impact, reservoir spillway design, flood damage reduction, floodplain regulation, and systems operation.

HEC-RAS models the hydraulics of water flow through rivers and channels and is also used for flood depth and flood plain determination. It can model full networks of channels, dendritic systems, or a single river reaches with different cross section shapes and variable friction characteristics (Manning's n) along each section. It can be used for steady and unsteady flow simulations. It is capable of modelling subcritical, supercritical, and mixed flow regimes water surface profiles.

Both models are widely used across the globe.

Global Mapper was used for processing various spatially distributed data and subbasin delineations. Global Mapper is a complete Geographic Information System (GIS) software with many features that facilitate the processing of data used in hydrologic and hydraulic analysis.

The software versions used were 4.1 for HEC-HMS, 5.07 for HEC-RAS and 21 for Global Mapper.

2 General Approach

The hydrologic and hydraulic analysis was performed using the combination of the HEC-HMS and HEC-RAS models. The catchment of the Pandarachira canal and several subbasins within it were delineated based on Shuttle Radar Topography Mission (SRTM) digital elevation data. Ground cover over the area drained by the Pandarachira canal was assessed from Google Earth imagery and appropriate Manning's coefficients were assigned to various catchments and the canal reaches.

The response of the Pandarachira canal catchment to storms of different return periods was modelled in HEC-HMS. The peak discharges at the junctions of the HEC-HMS model were used as input to the upstream end of each reach in HEC-RAS to perform a steady simulation. The approach of using peak discharges from HEC-HMS in steady state analysis with HEC-RAS is conservative and is considered appropriate at the present stage of flooding potential assessment. When more detailed ground data are available, unsteady HEC-RAS simulations using as input discharge hydrographs produced by HEC-HMS can be performed. In addition, unsteady state analysis was performed to assess the response of the canal to high tides under dry weather conditions. The analysis allows to evaluate the capacity at various sections of the canals and recommend corrective measures, if required, such that the canal can adequately convey design storms and tidal flows.

3 Input Data

3.1 Topography

Two sets of topographic data were obtained for use in this study. The first is the Shuttle Radar Topography Mission (SRTM) data set available from the U.S. Geological Survey. This data has an approximate spatial resolution of 30 meters (Reference 4). These data are directly accessible through Global Mapper. The second set of topographic data CartoDEM from the National Remote Sensing Centre of India (Reference 5). According to Reference 5, the CartoDEM data have an absolute planimetric accuracy of 15 m and a posting of 10 m. In addition to these two data sets, Light Detection and Ranging (LiDAR) data along a zone extending 150 m on each side of the Rameswaram canal were obtained from the Kochi Metro Rail Department (Reference 6). These LiDAR data are very high resolution of 0.5 m and even though they cover a very small part of the area cover by the Pandarachira canal they allowed an assessment of the adequacy of the SRTM and the CartoDEM data for the hydrologic analysis of the Pandarachira canal.

Because the drainage basin of the Pandarachira canal is very flat, with the elevation difference between its highest and lowest point being less than 10 m, it is difficult to define exactly its subbasins and drainage patterns from the STRM and the CartoDEM data. A comparison of the data with the LiDAR data along the Rameswaram canal showed local differences of the order of 2 to 3 m, which is enough to affect local drainage patterns within a relatively flat area. Therefore, the delineation of the subbasins with the Pandarachira canal, even though is considered for the present preliminary study it should be revisited during the final design of mitigation measures using more accurate topographic data.

3.2 Canal Geometry

The canal geometry was provided by the Irrigation Department of Ernakulam (Reference 2). The data on the geometry of several section are listed in Table 2, which also includes information on any obstructions, flow blockages, silt accumulation and waste disposal in the canal. Additional information on the canal is provided in a 2021 report of the Irrigation Department (Reference 3).

3.3 Rainfall Data

Intensity-duration-frequency data were obtained from Reference 1. Table 1 lists the rainfall depth for different duration up to 24 hours and Average Recurrence Interval (ARI) of 2, 5,10, 25, 50 100 years.

Table 1. Rainfall Depth-Duration-Frequency data

Duration	**Depth, mm**					
hours	**2-year**	**5-year**	**10-year**	**25-year**	**50-year**	**100-year**
0.08	24.2	27.3	30.3	36.3	42.4	48.5
0.25	34.9	39.3	43.7	52.4	61.2	69.9
1	55.5	62.4	69.3	83.2	97.1	110.9
2	69.9	78.6	87.4	104.8	122.3	139.8
3	80.0	90.0	100.0	120.0	140.0	160.0
6	100.8	113.4	126.0	151.2	176.4	201.6
12	127.0	142.9	158.7	190.5	222.2	254.0
24	160.0	180.0	200.0	240.0	280.0	320.0

Figure 1 plots the Intensity-Duration-Frequency (IDF) curves for the same return periods as those listed in Table 1.

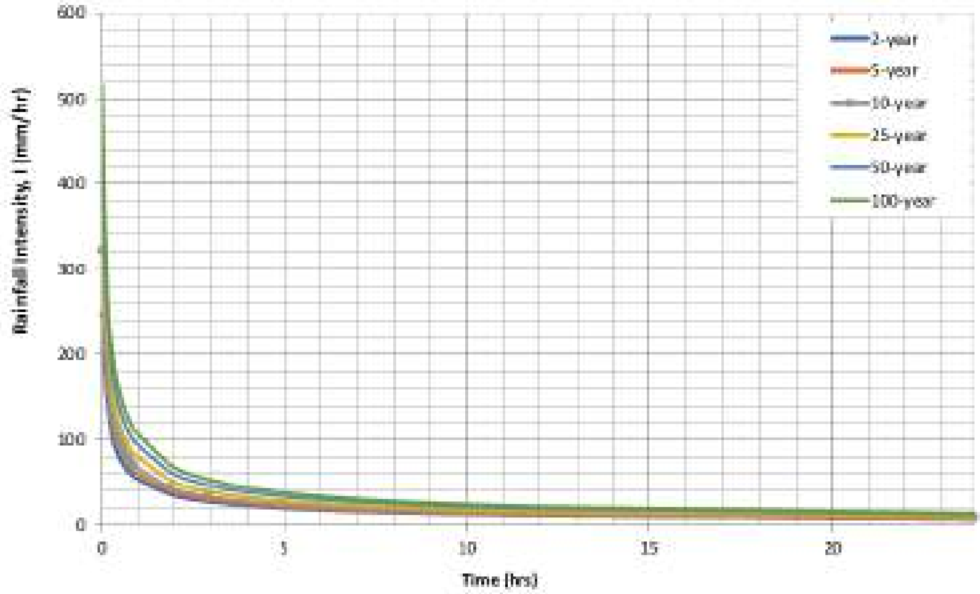


Figure 1. Intensity-Depth-Frequency Curves (reproduced from Reference 1)

Table 2. Geometry of cross sections along the Pandarachira Canal

Name of Particular Location	Latitude	Longitude	Present width	Depth w.r.t GL	Obstructions/any other details	Special identifications (Waste disposal/encroachment/ delta formations)
Starting from Rameswaram Canal	9.93925	76.25503	2	0.8	huge qty of silt deposited	Accumulated with silt and waste
Near Rameswaram Canal	9.939233	76.2551	2	0.8	huge qty of silt deposited	Accumulated with silt and waste
AD Puram byroad	9.93758	76.254847	2	0.8	Fully slab covered	1 drain 1m width at right side
Opposite KSEB	9.935942	76.25505	1.5	0.8		Accumulated with silt and waste
Road Crossed Culvert	9.935203	76.255167	1.5	0.8		Accumulated with silt and waste
Culvert at Thoppumpady FortKochi Road	9.935007	76.255237	5	0.8		Accumulated with silt and waste
Kazhuthumuttu palam	9.934823	76.255243	6	0.8		Flow stand still Waste deposited
Near Kazhuthumuttu palam	9.93478	76.255325	8	0.8		Flow stand still Waste deposited
Bent	9.933953	76.25585	5.5	0.6		Flow stand still Waste deposited
Bent 90 degree	9.934047	76.256077	5.5	0.6	Pandaraparambu thodu meeting point	Flow stand still Waste deposited
Kazhuthumuttu by lane	9.933752	76.256282	6	0.6		Flow stand still Waste deposited
Bent	9.935236	76.256421	6	0.6	Width reduced	Encroachment

Sharp bent	9.933047	76.256878	7	0.7	Side protection needed,	Encroachment, Flow stand stil, waste deposited
Near Athipozhi Thodu Junction	9.932923	76.256908	9	0.8	Athipozhi thodu meeting point,side protection required	Encroachment, Flow stand stil, waste deposited
Near Naval building SRA Rameswaram culvert left side	9.931775	76.257317	12.4	2		Only 2 pipes of dia 1.50 m provided for flow which is insufficient,Encroachment, Flow stand stil, waste deposited
Near Naval building SRA Rameswaram culvert right side	9.931495	76.257367	18.4	0.8		Encroachment, Flow stand stil, waste deposited
Sunami hall built by corporation	9.930453	76.258015	40	0.8		Encroachment left side, to be evicted strtictly
Santhom colony, ICDS Building, Ward 22	9.928093	76.258843	80	0.8		Delta formation deposited, waste deposited
Thodu at curve portion	9.927667	76.259518	23	1		Flow stand still Waste deposited,Side protection work to be done
Coast guard building	9.928192	76.259888	10	1		Encroachment
Cost guard road to East side	9.92854	76.26023	10	1	Side protection need	Encroachment left side, heavy waste deposited

Valummel bridge build by cochin corporation	9.928538	76.260538	8	1	Bridge width reduced to 8m	Small thodu at right side 2m width
NearCoast guard building	9.927727	76.260923	30	1.5	Side protection need	Huge quantity of waste accumulated
Valummel palam bylane	9.927275	76.261122	40	1.5	Side protection need in right side upto bridge	Huge quantity of waste accumulated
Near Chirakkal Fish farm	9.923955	76.262218	60	2.5		Huge quantity of waste accumulated
Right side Noorul Eeman Masjid	9.9231	76.262557	20	2.5		Encroachment
Front of Cage farm tourism plot	9.922442	76.26279	20	2.5		Encroachment
Road bent	9.922095	76.26293	57	2.5		Huge quantity of waste accumulated
Chirakkal bridge	9.921997	76.263137	57	2.5	bridge approaches damaged present width of bridge 10m	Huge quantity of waste accumulated

3.4 Tidal Data

Tidal data were obtained from Reference 7 which provides the amplitude and phase lag of 25 tidal constituents at eight stations in the Kochi backwaters. Data for the Kochi inlet were used to simulate water levels over one year. Figure 2 shows the simulated water levels during the highest spring tide cycle of the year.

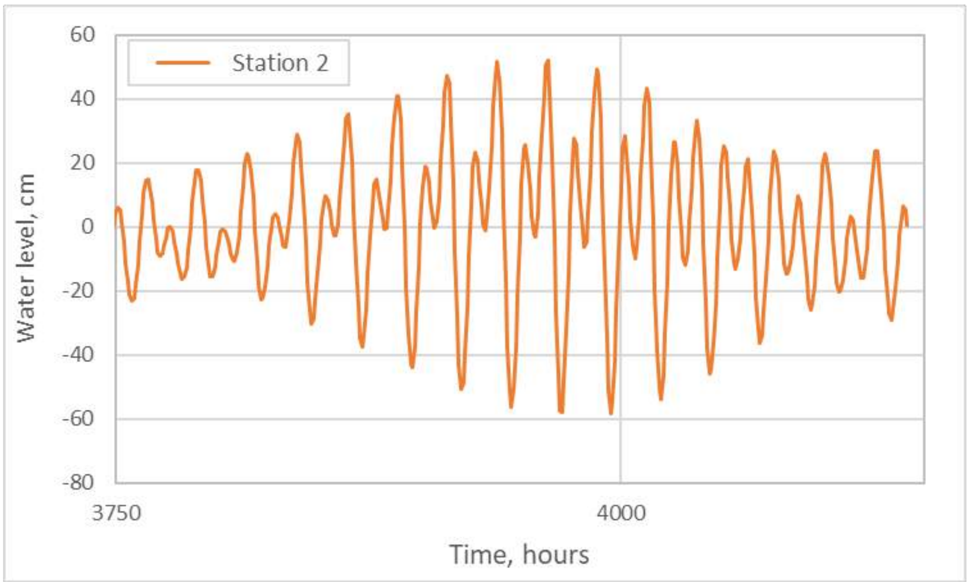


Figure 2. Simulated highest spring tide of the year.

4 Hydrologic Model

4.1 HEC-HMS model setup

The HEC-HMS hydrologic model used the rainfall intensities listed in section 3.3 for 2, 5, 10, 50 and 100 ARI. The HEC-HMS default value of 50 percent was used for the maximum rainfall intensity in the construction of the storm hyetograph. This means that in the 24-hour storm used in the present simulations the peak of the hyetograph is 12 hours after the start of the storm.

The loss method adopted in the development of the HEC-HMS model was the SCS Curve number method, with the curve number values used based on the assessment of land use from Google Earth imagery and guidance provided in Reference 12. Routing was performed with normal depth method.

Subbasin delineation was done using automated watershed delineation process in Global Mapper followed by manual delineation adjustments of subbasins based on observations during site visits. The estimated subbasin areas from Global Mapper or Google Earth were used as an input to HEC-HMS.

The lag times were calculated with the formula proposed by Ven Ven Te Chow (Reference 8), expressed in metric units:

$$t_L = 0.00116\left(\frac{L}{\sqrt{S}}\right)^{0.64}$$

t_L = Lag time, hours

L =Longest flow path in the subbasin, m

S= average slope of the subbasin

The Manning's roughness coefficient used for the canal banks was 0.020 (clean recently completed) and for the canal bottom 0.027 (for excavated canal with short grass and few weeds) (References 9, 10)

The reach length has been measured from google earth and the bottom slope of the canal has been calculated from the irrigation department report.

The geometry of the canal in HEC-HMS was modelled using eight-point option.

The left and the right bank's Manning's coefficients were adopted from the Storm Water Management Model (SWMM) Reference Manual, Table 3-5, page 75 (Reference 11). The following Manning's coefficients were used:

Suburban area - 0.055

Semi business land – 0.035

Pasture – 0.055

Figure 3 shows the subbasin and reach layout of the Pandarachira HEC HMS model.

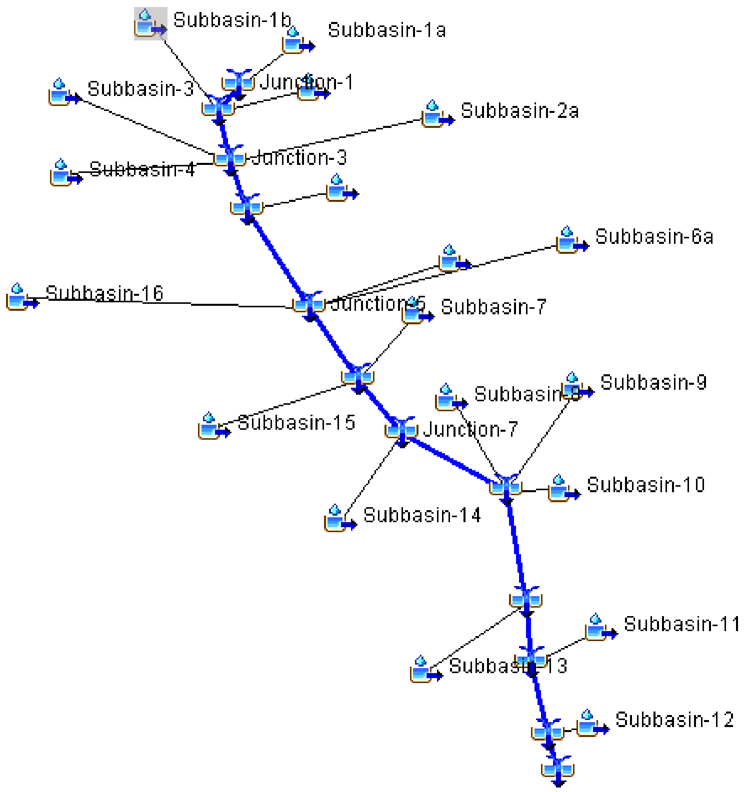


Figure 3. Schematic representation of the Pandarachira HEC-HMS model

4.2 HEC-HMS Model Results

Table 3 summarizes the peak discharge at the junctions of the HEC-HMS model. The relative location of the junctions within the Pandarachira canal basin is shown in the schematic diagram of Figure 3.

Table 3. Peak HEC-HMS discharges different return period 24-hour storms

Hydrologic Element	Drainage Area, km^2	Peak Discharge, m^3/s				
		2-year	5-year	10-year	50-year	100-year
Junction 1	0.04	1.0	1.1	1.3	2	2.3
Junction 2	0.11	1.9	2.2	2.6	4	4.8
Junction 3	0.51	8.5	10.1	11.7	18.4	21.7
Junction 4	0.55	6.9	7.8	8.7	12.8	15.1
Junction 5	1.02	12.4	14.5	16.7	25.1	29.2
Junction 6	1.47	19.4	23.1	26.7	41.2	48
Junction 7	1.58	20.8	24.7	28.7	44.3	51.5
Junction 8	1.84	23.2	27.6	31.7	48.5	56.5
Junction 9	1.95	23.9	28.5	32.7	50.1	58
Junction 10	2.00	24.3	28.9	33.2	51	58.9
Junction 11	2.06	24.5	29.1	33.5	51.5	59.7
Junction 12	2.06	24.2	28.9	33.3	51.3	59.5

4.3 HEC-RAS Hydraulic Model

The hydraulic modelling of the canal was performed in HEC-RAS. The reach and the banks were delineated using RAS Mapper by overlaying the google satellite imagery. This helped to easily identify the canal banks. The cross-sections were drawn at appropriate intervals to capture changes in the geometry of the canal. More closely spaced cross-sections were used at parts of the canal where local residents had complained about flooding.

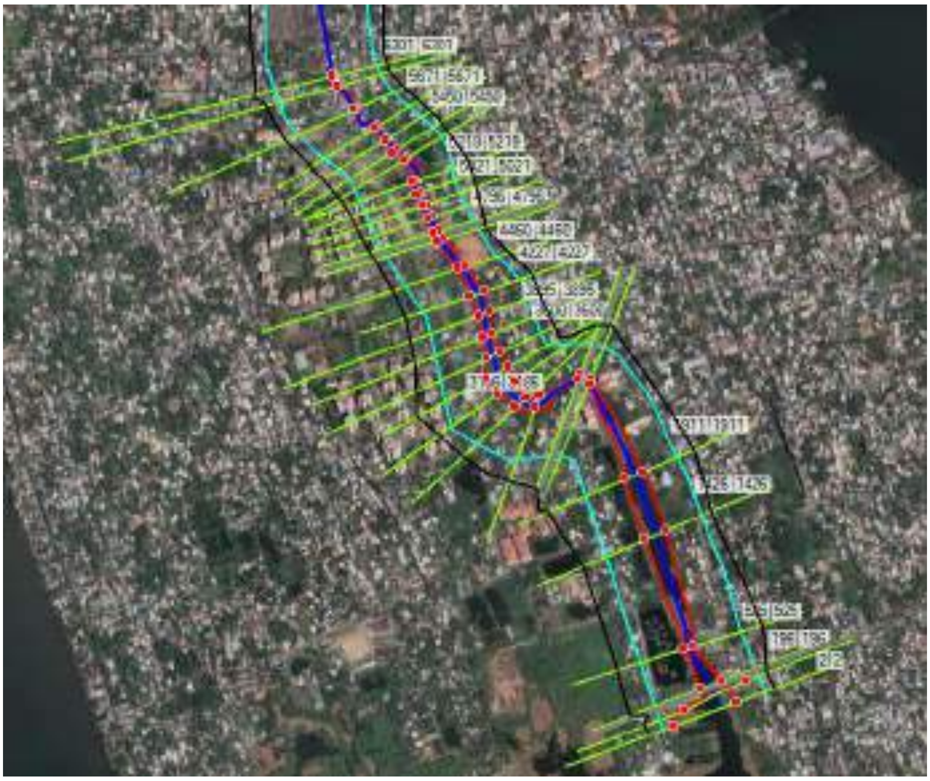


Figure 4. HEC-RAS model layout and location of cross section

The geometry of the cross-sections was based on the geometry data provided by the Irrigation Department discussed in Section **Error! Reference source not found.**. but the w idth of the canal south of the Kochupally road crossing up to the Chirakkal bridge has been reduced by 2m on the stretch where the canal width is greater than 20m. This 2m wide space is the space allocated for mangrove plantation which is a green measure to improve the canal water quality.

Culverts and bridge structures were modelled based on the information and data from Irrigation Department.

The Manning's roughness coefficient n for each part of the canal was adopted from Chow 1959 Table 5-6, however the values have been corrected using several correction factors to account for actual conditions in the canal and also for the proposed mangrove plantation along the side walls of the canal wherever applicable.

Following Reference 13, the value of n was computed by following formula

$$n = (n_b + n_1 + n_2 + n_3 + n_4)m$$

where

- n_b is a base value of n for a straight, uniform, smooth channel in natural materials
- n_1 is a correction factor for the effect of surface irregularities,
- n_2 is a value for variations in shape and size of the channel cross section,
- n_3 is a value for obstructions,
- n_4 is a value for vegetation and flow conditions, and
- m is a correction factor for meandering of the channel.

Recommended values for these correction factors based on channel conditions are given in Table 2 of Reference 13.

The values of Manning's roughness coefficient for overland flow beyond the banks of the canal were adopted from Table 3-5 on page 75 of Reference 11. Based on land use assessment from Google Earth imagery, for parts of the area beyond the banks of the canal, a Manning's n value of 0.055 was used for suburban residential areas and for pasture, and a value of 0.035 for semi-business land use.

HEC-RAS allows dividing the overbank areas into segments and defining a different Manning's n value in each segment (Reference 14). Table 4 lists the Manning's n values used at the cross sections defining the HEC-RAS model. Where mangroves are envisaged the canal wall Manning's co-efficient has been considered as 0.100 (channels with dense brush, high stage)

Table 4. Manning's n values at the cross sections of the HEC-RAS model

Cross Section	Canal		Overbank Area	
	Bottom	Sides	Left	Right
6301	0.027	0.020	0.055	0.055
6275	0.027	0.020	0.055	0.055
6053	0.027	0.020	0.055	0.035
5791	0.027	0.027	0.055	0.035
5671	0.027	0.027	0.055	0.035
5554	0.027	0.027	0.055	0.035
5450	0.027	0.027	0.055	0.035
5219	0.027	0.027	0.055	0.035
5121	0.027	0.027	0.055	0.035
5021	0.027	0.02	0.055	0.035
4918	0.027	0.02	0.045	0.035
4796	0.027	0.02	0.045	0.035
4728	0.027	0.1	0.055	0.035
4460	0.027	0.1	0.055	0.035
4227	0.027	0.1	0.055	0.035
4060	0.027	0.1	0.055	0.035
3895	0.027	0.1	0.055	0.035
3740	0.027	0.1	0.055	0.035
3600	0.027	0.1	0.055	0.035
3466	0.027	0.1	0.055	0.035
3309	0.027	0.1	0.055	0.055
3186	0.027	0.02	0.055	0.035
2790	0.027	0.02	0.055	0.055

2693	0.027	0.02	0.045	0.055
1911	0.027	0.1	0.045	0.055
1426	0.027	0.1	0.045	0.045
525	0.027	0.1	0.045	0.045
196	0.027	0.1	0.045	0.045

Table 5 lists the discharge assigned as input at selected sections in the steady flow simulation of different ARI storms. These sections are located at the points of the junctions in the HEC-HMS, which are also listed in Table 5.

Table 5. Steady flow data input to HEC-RAS from the HEC-HMS output:

ARI, years		2	5	10	50	100
HEC-HMS Junction	HEC-RAS Section	Discharge, m^3/s				
3	6301	8.5	10.1	11.7	18.4	21.7
4	5554	6.9	7.8	8.7	12.8	15.1
5	5219	12.4	14.5	16.7	25.1	29.2
6	4227	19.4	23.1	26.7	41.2	48
7	3600	20.8	24.7	28.7	44.3	51.5
8	2790	23.2	27.6	31.7	48.5	56.5
9	1911	23.9	28.5	32.7	50.1	58
10	1426	24.3	28.9	33.2	51	58.9
11	525	24.5	29.1	33.5	51.5	59.7
12	196	24.2	28.9	33.3	51.3	59.5

The downstream boundary condition in the steady state flow simulation of different storms was constant water surface level set equal to mean sea level (MSL).

There culvert crossing at Kochupally road crossing currently consists of 2 nos precast concrete circular pipes of 1.5m diameter. The same has been modelled in HEC RAS.

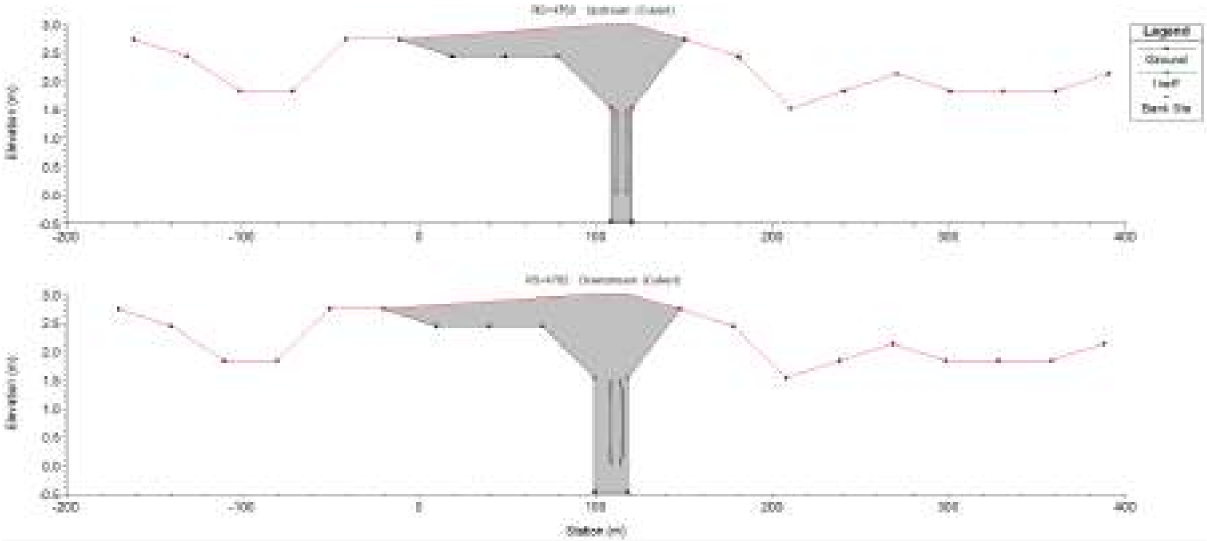


Figure 5. Culvert modelled in HEC-RAS to simulate existing conditions

Table 6. Culvert parameters for existing condition

Length	10m
No. of Barrels	2
Entrance Loss Co-efficient	0.5
Exit Loss Co-efficient	1.0
Manning's n	0.029

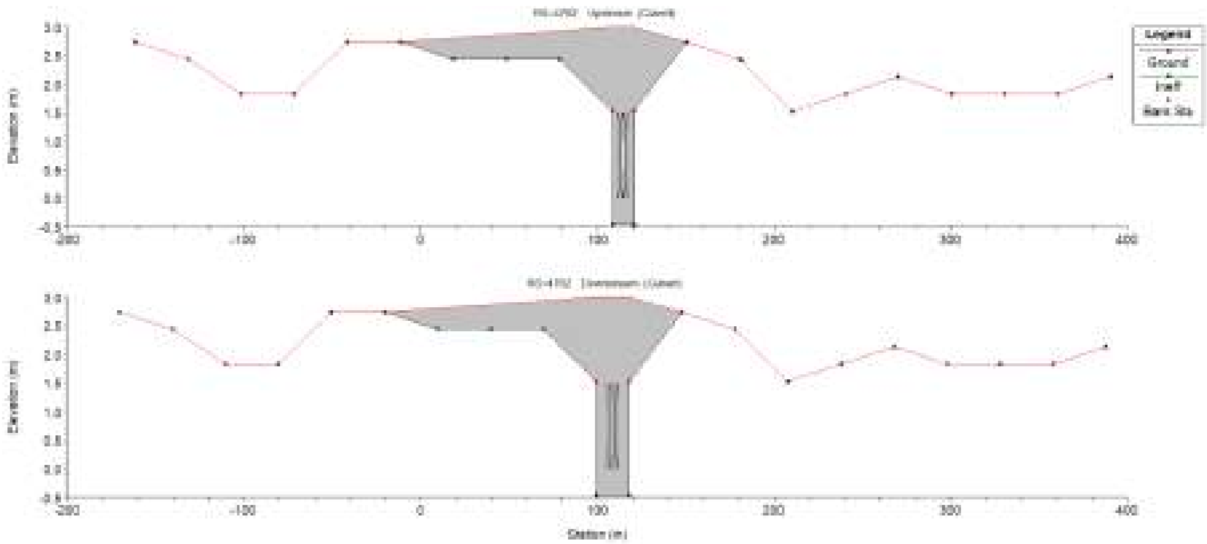


Figure 6. Culvert modelled in HEC-RAS with 3 pipe culverts

Table 7. Culvert parameters for proposed condition

Length	10m
No. of Barrels	3
Entrance Loss Co-efficient	0.5
Exit Loss Co-efficient	1.0
Manning’s n	0.013

A scenario was also modelled wherein the 2 existing culverts were removed and a wide passage equal to the span of the bridge is created.

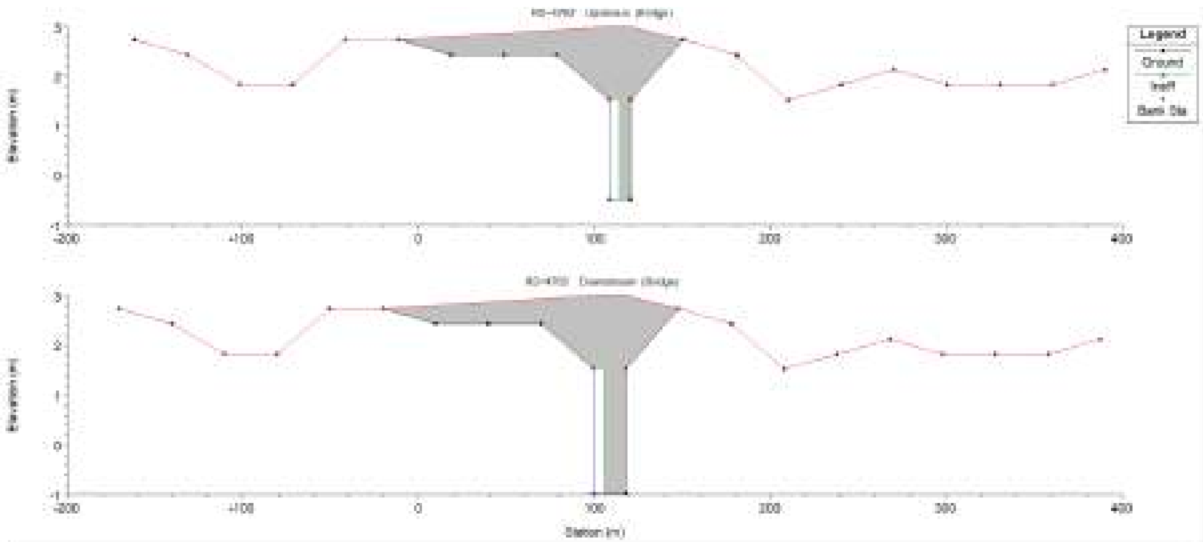


Figure 7. 2nos existing culverts removed under the Kochupally road bridge.

4.4 HEC-RAS Model Results

4.4.1 **Simulation of 24-hour monsoon events**

Figure 8 shows the simulated water surface profiles for resulting from 24-hour storms of five different ARIs (2, 5, 10, 50 and 100 years). As can be seen in Figure 8, the bridges at the Valummel Road and the Kochupally Road restrict the flow resulting in higher water levels on their upstream side. The water level difference between the upstream and the downstream side of the bridge is especially pronounced at Kochupally Road. Figure 9 shows this bridge and its two culverts.

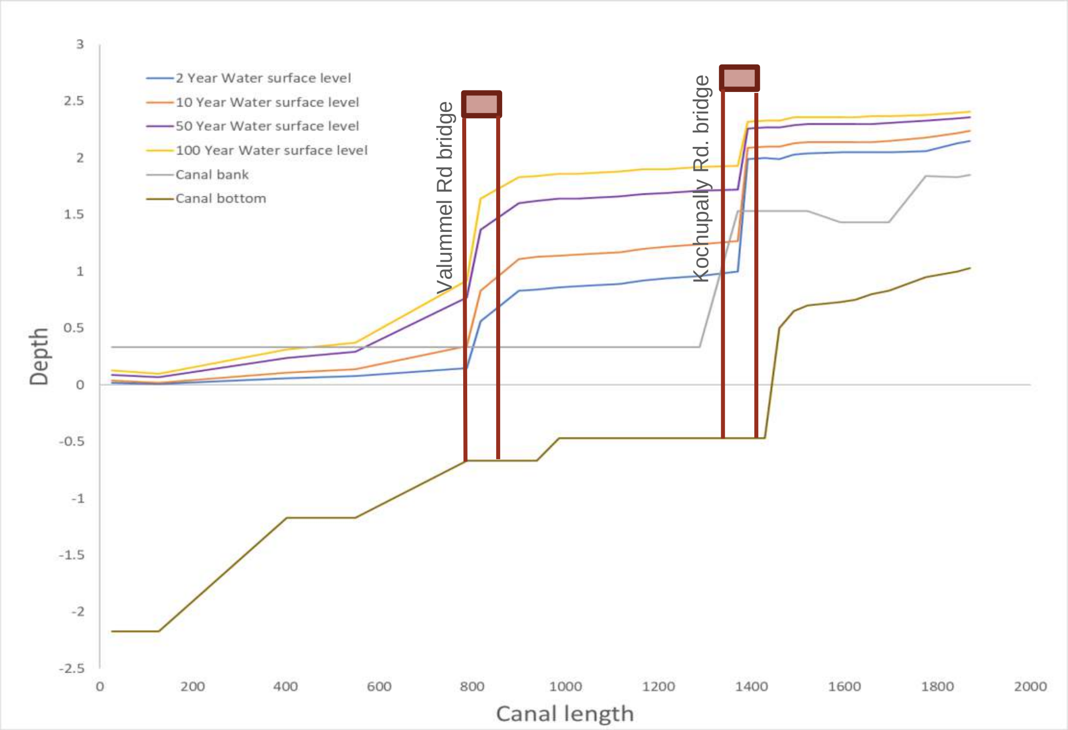
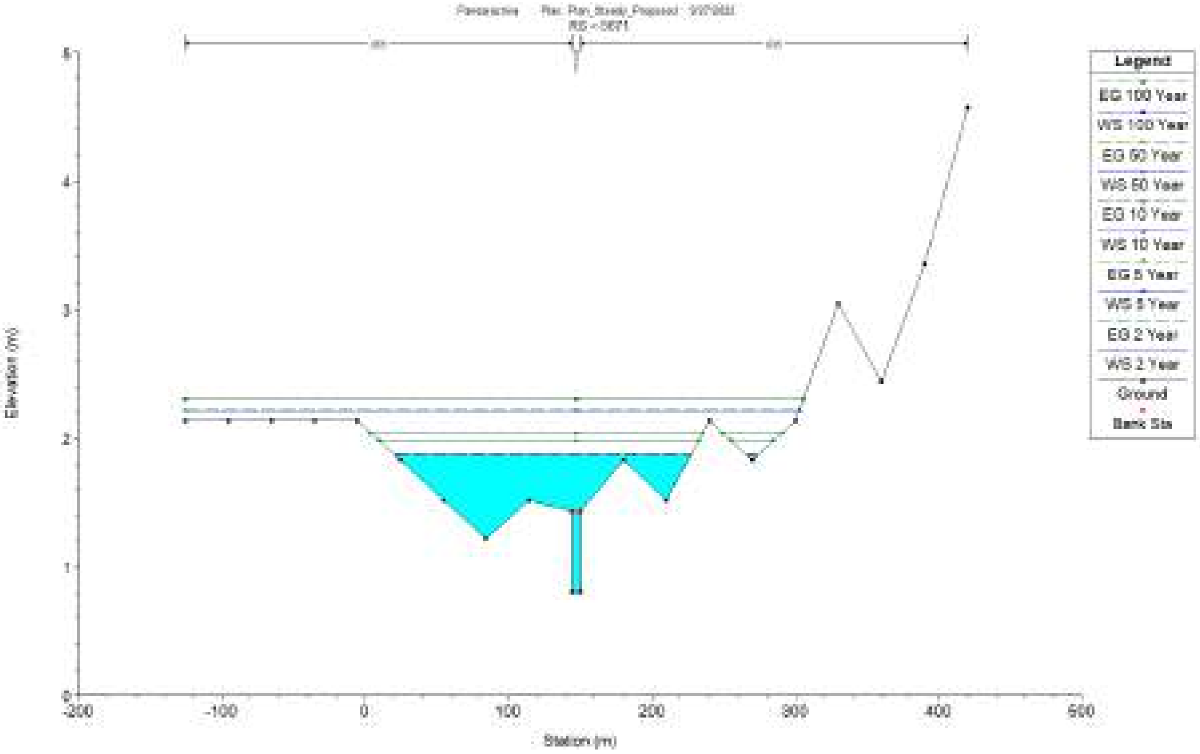


Figure 8. Steady state water surface profiles for 24-hour storm of 2, 5, 10, 50 and 100-year ARI

Figure 9. The bridge at Kochupally Road and the two culverts under the bridge.



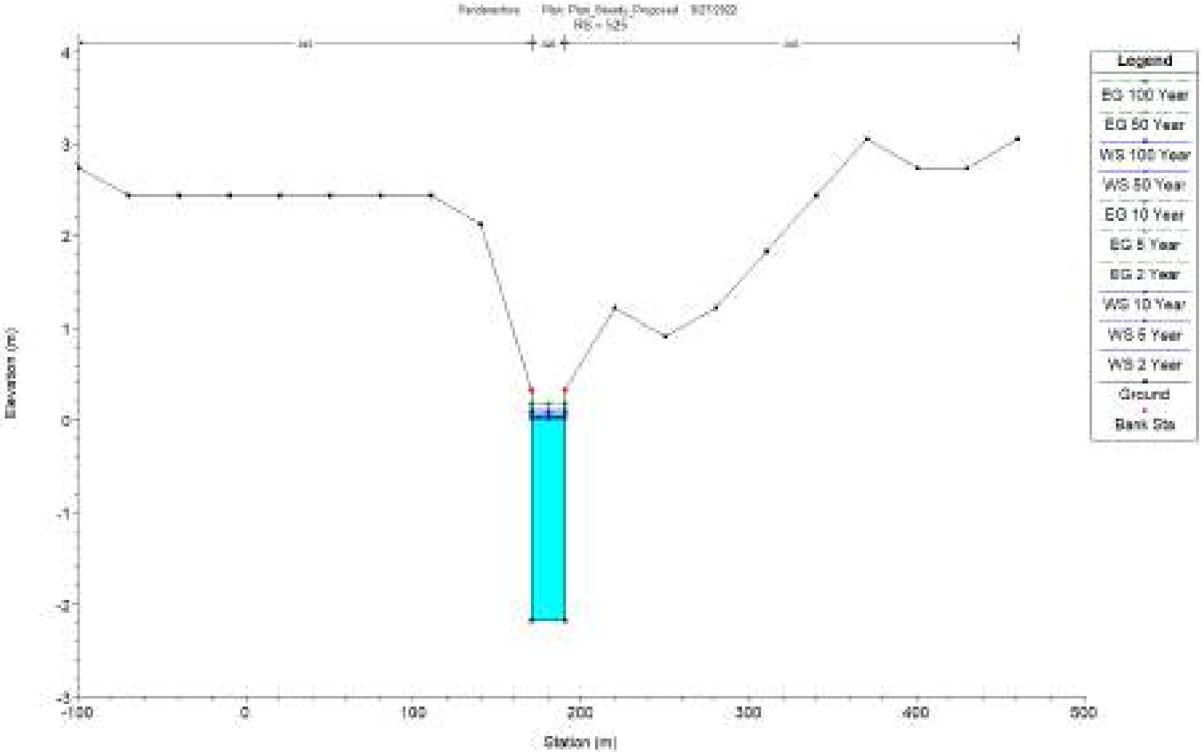


Figure 10. Steady state water surface at typical cross sections for 24-hour storm of 2, 5, 10, 50 and 100-year ARI

Figure 11 shows an approximate estimate the extent of the area beyond the banks of the Pandarachira canal that is flooded for different ARI 24-hour storms.

Figure 11. Extent of flooded areas as a function of the storm ARI.

4.4.2 Simulation of high tide events with no rainfall

Figure 12 shows the maximum water surface level during high spring tide with no rainfall. As can be seen in Figure 12, the water level in the Pandarachira canal from its downstream end to the Kochupally Road bridge (Section 4796 in the model) respond quickly to tidal fluctuations with the maximum water level along this part of the canal being practically identical to the maximum sea level, which in the case of this simulation is about 0.5 m MSL. Therefore, areas adjacent to the canal at an elevation below 0.5 m MSL would tend to be flooded during high tide. As explained in Section 3.4, the sea levels during high tides used in this analysis are simulated values based on estimates of 25 harmonic tide constituents. Measured water levels should be used for better assessment of the areas flooded during high tides.

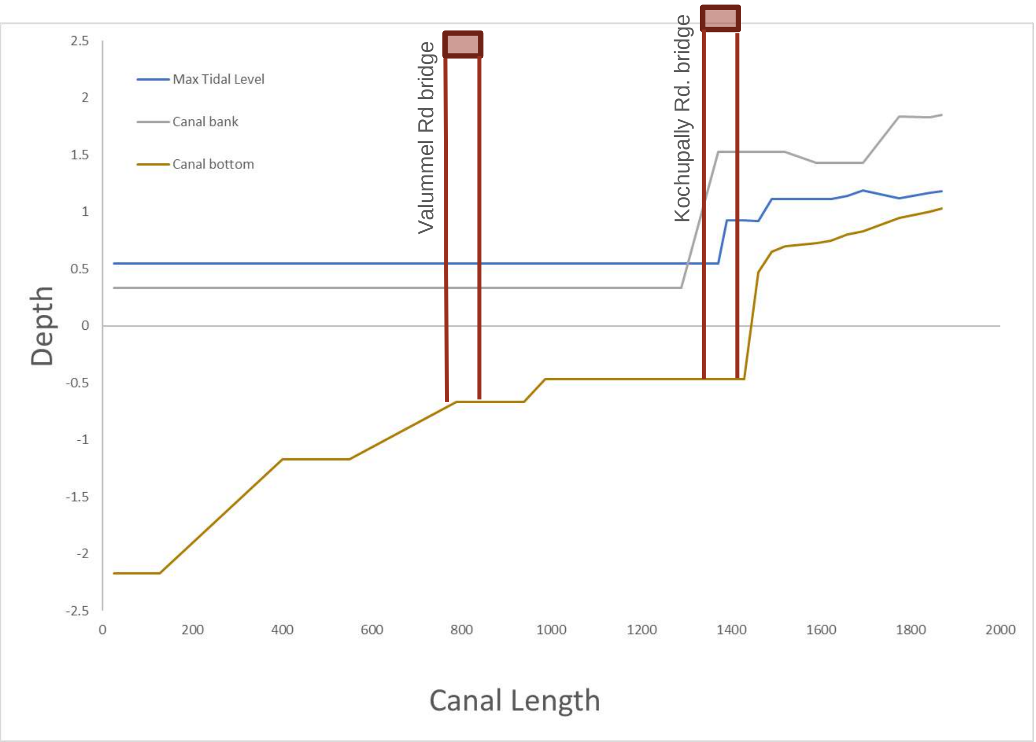


Figure 12. Maximum water surface level during high spring tide with no rainfall

It is noted that based on information from a survey of local residents, during spring tides Santhom Colony is subjected to considerable flooding. The survey report indicated that other areas also get flooded due to tidal effects. Refer Section 4.3 of the main report for details of survey. This can be due to the fact that there are numerous lateral drains connected to the main canal. During high tides the water from the canal can flow back into these smaller drains causing flooding where the drains are clogged.

Therefore, it is important to survey the lateral drains and study their effect of tidal flooding at a considerable distance from the canal.
In general, the hydraulic model showed that the effects of tidal flooding are much lesser than monsoon flooding.

5 Grey infrastructure mitigation measures

The following mitigation measures would improve flow conditions in the canal and reduce the frequency and extent of flooding in adjacent areas:

- Trash and debris removal/cleaning the canals
- Installation of trash racks in front of culverts/bridges, which should be followed by regular removal of trash trapped by the trash racks. Without such regular removal of trash, the trash racks may have the opposite of the intended effect by blocking the flow through the culverts and under the bridges.
- Dredging of portions of the canal
- To reduce flooding due to canal overtopping, following of the two options may be adopted depending upon the cost effectiveness and technical feasibility:

- Option 1
  - Add one culvert under the Kochupally bridge
  - Deepen the canal by a minimum 500mm in the Santhome Colony stretch and increase the slope of the canal bed downstream of the Kochupally bridge by deepening the canal point at various locations,
  - Build protective walls along the canal maintaining the top of the wall 800mm (including 200mm freeboard) above the existing ground for reach passing through the Santhom Colony,
- Option 2
  - Remove the 2 existing culverts from under the Kochupally bridge and create a free flow path under the bridges same as in Valummel road bridge and Chirakkal bridge
  - Deepen the canal by a minimum 500mm in the Santhome Colony stretch and increase the slope of the canal bed downstream of the Kochupally bridge by deepening the canal point at various locations
  - Build protective walls along the canal maintaining the top of the wall 400mm (including 200mm freeboard) above the existing ground for reach passing through the Santhom Colony

- Erosion bank protection/stabilization of selected parts of the canal
  - Rubble masonry lining to be implemented at stretches of the canal where there are no linings.
  - Raising the canal banks to mitigate flooding of the adjacent areas keeping due provisions for drainage of the areas adjacent to the canal.
- It was also seen that the trash and wastes were being dumped directly into the canal in specific locations. It is recommended that such reaches of the canal to be fenced and cctv camera installed.to monitor the illegal dumping of wastes into the canal.
- Repair and restore canal banks at locations where the linings are damaged

The major actions in terms of grey infrastructure are the addition of one more culvert under the Kochupally Road or the removal of the existing 2 culverts and the lining of portions of the canal. Hydraulic analysis was performed to simulate water levels in the canal after lining of the canal banks at suitable locations, dredging the canal and implementation of option 1 and 2 as mentioned above.

Figure 13 thru 20 compares the water surface profile under present conditions with that after the implementation of the proposed grey infrastructure measures for the 2-year, 24-hour monsoon event. As can be seen in this Figure, the proposed measures reduce the maximum water levels, but in parts of the canal the water level is over the top of the canal banks, which would cause flooding.

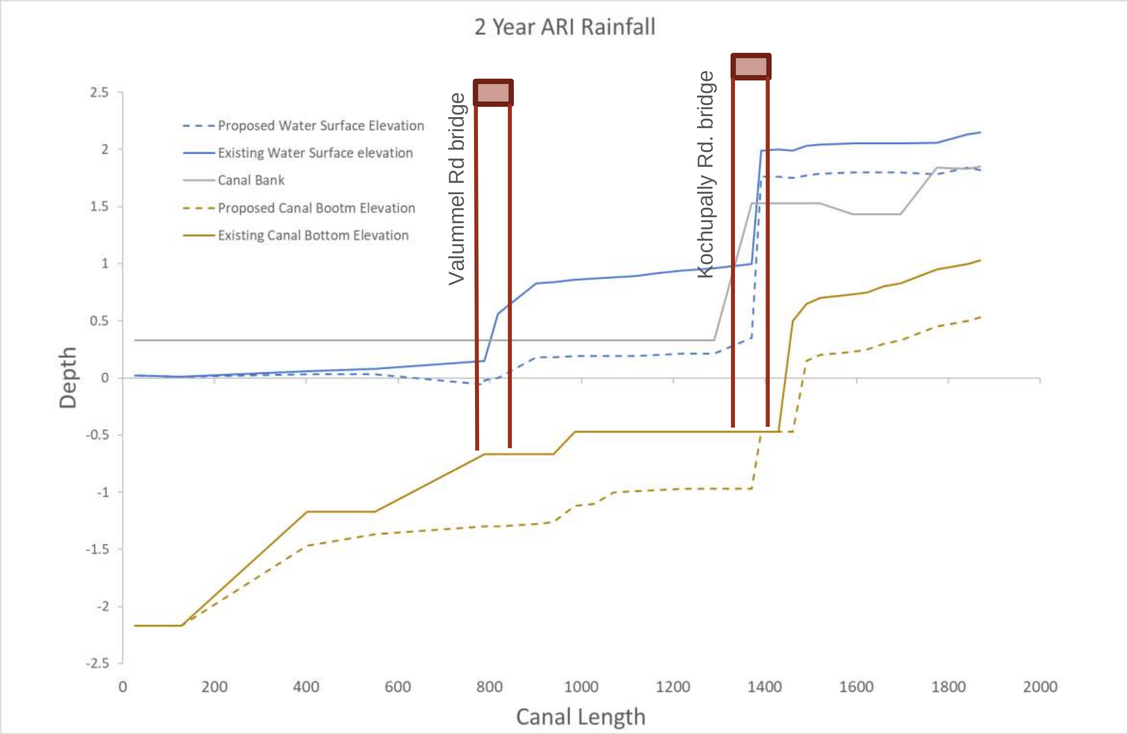


Figure 13. Comparison of the water surface profile between the existing conditions and after implementation of option 1 – 2-year ARI rainfall.

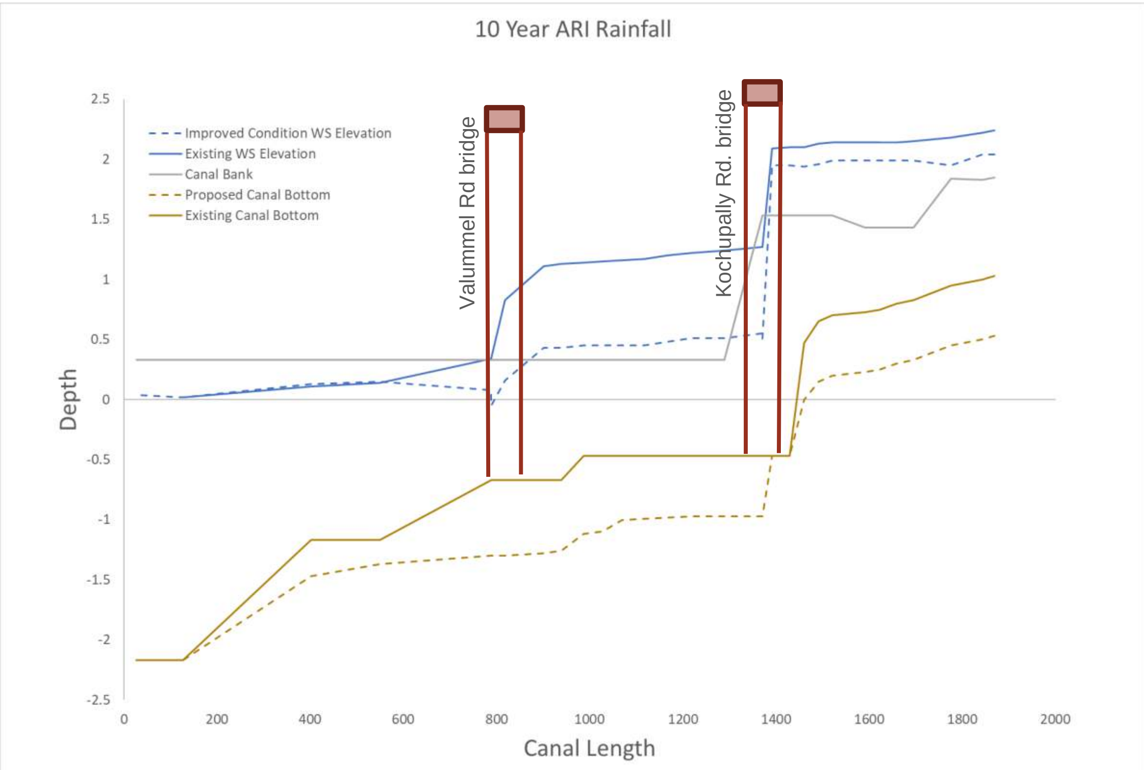


Figure 14. Comparison of the water surface profile between the existing conditions and after implementation of option 1 – 10-year ARI rainfall.

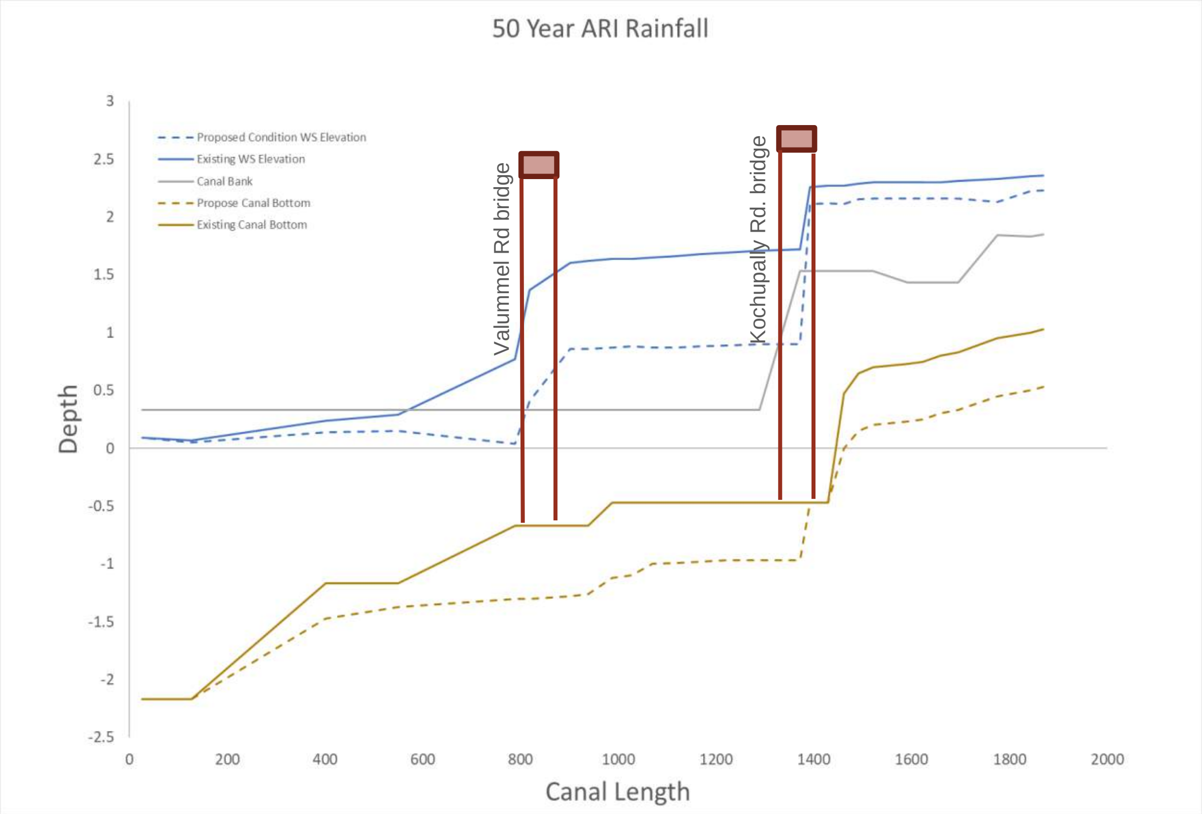


Figure 15. Comparison of the water surface profile between the existing conditions and after implementation of option 1 – 50-year ARI rainfall.

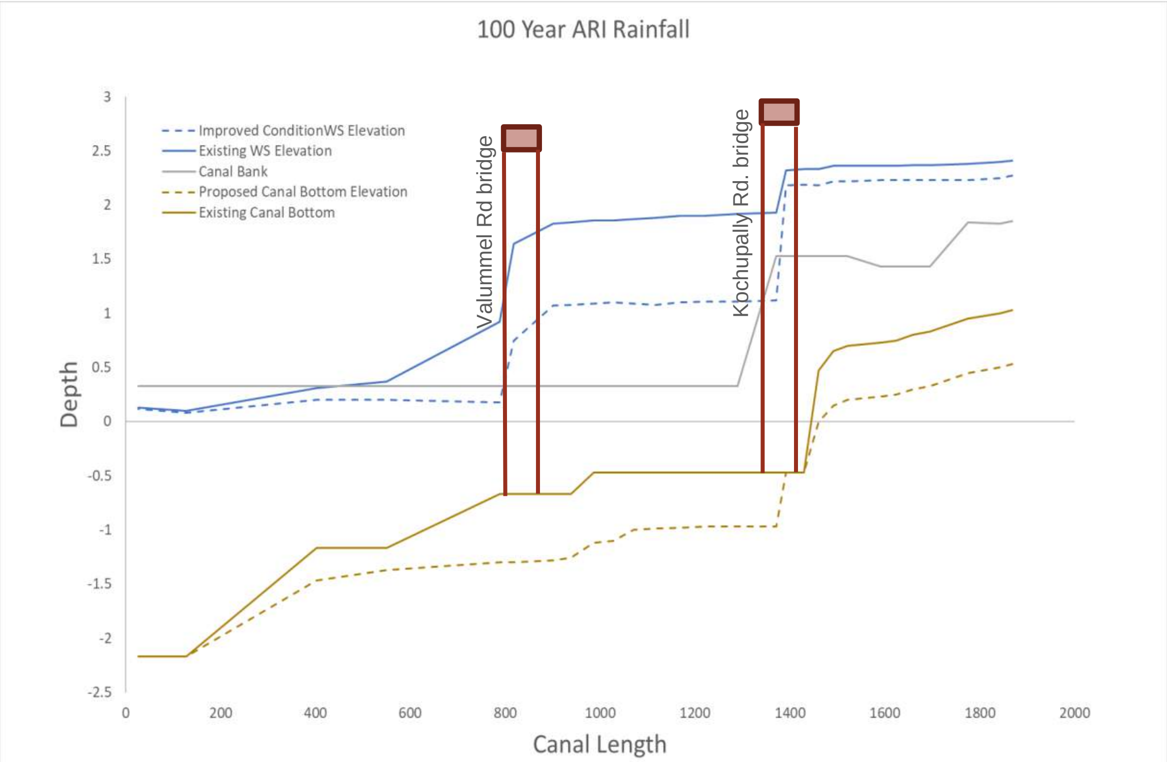


Figure 16. Comparison of the water surface profile between the existing conditions and after implementation of option 1 – 100-year ARI rainfall.

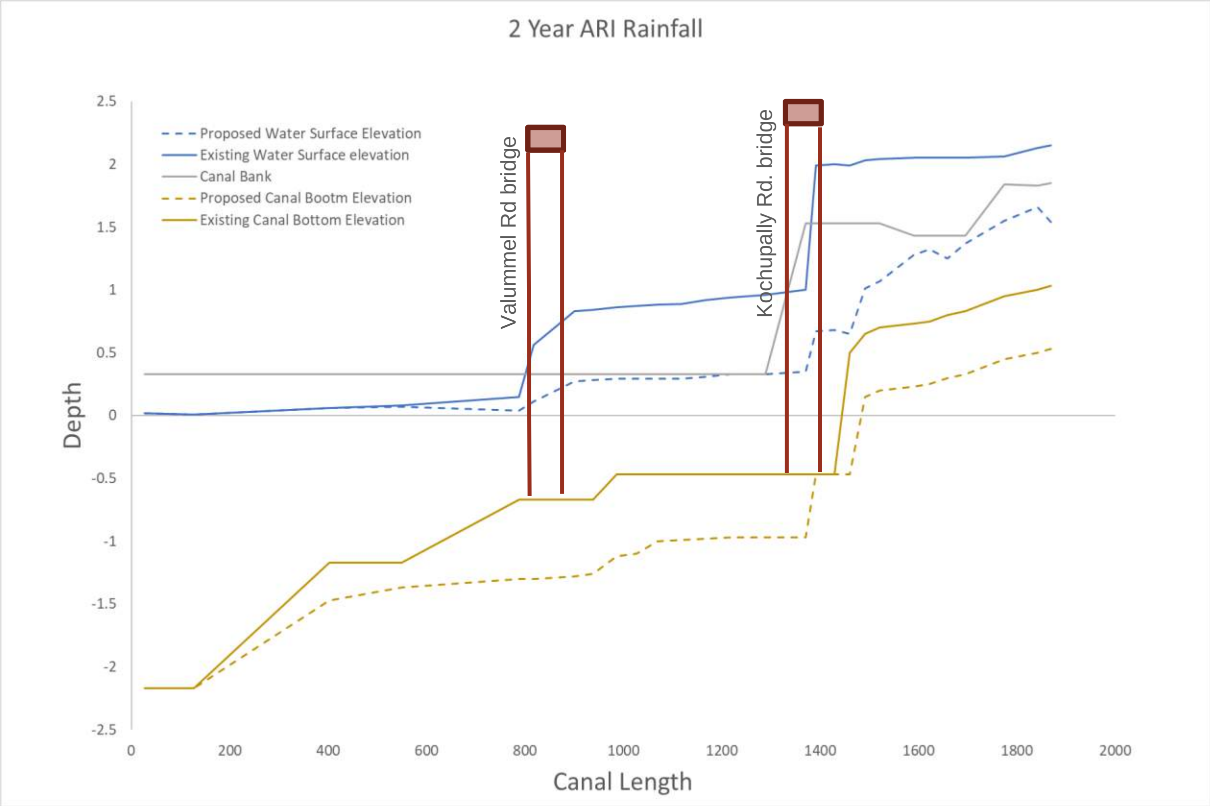


Figure 17. Comparison of the water surface profile between the existing conditions and after implementation of option 2 – 2-year ARI rainfall.

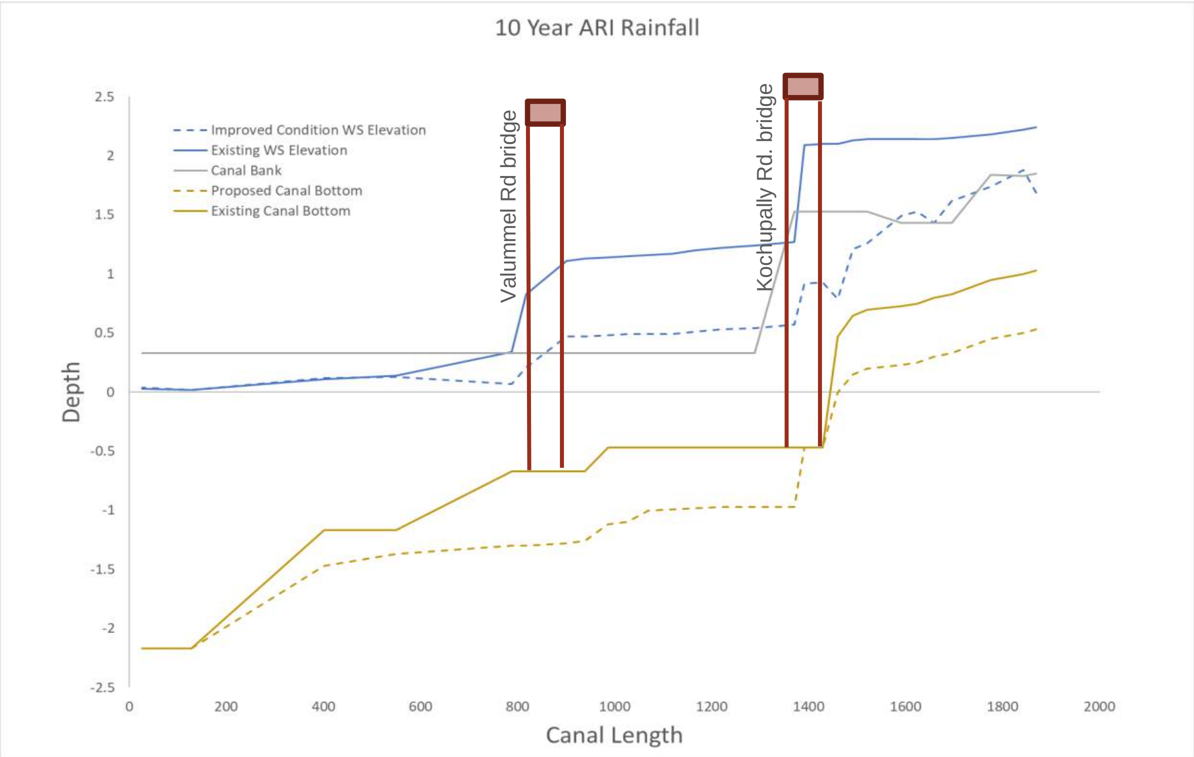


Figure 18. Comparison of the water surface profile between the existing conditions and after implementation of option 2 – 10-year ARI rainfall.

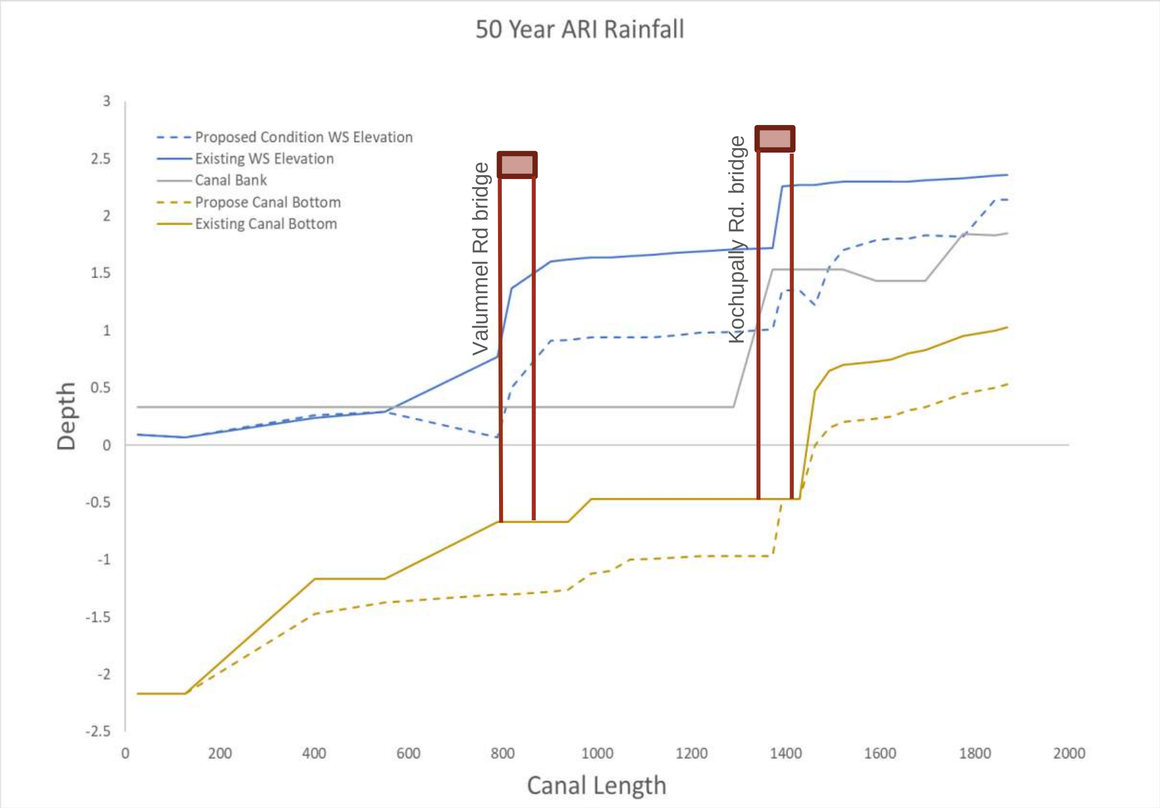


Figure 19. Comparison of the water surface profile between the existing conditions and after implementation of option 2 – 50-year ARI rainfall.

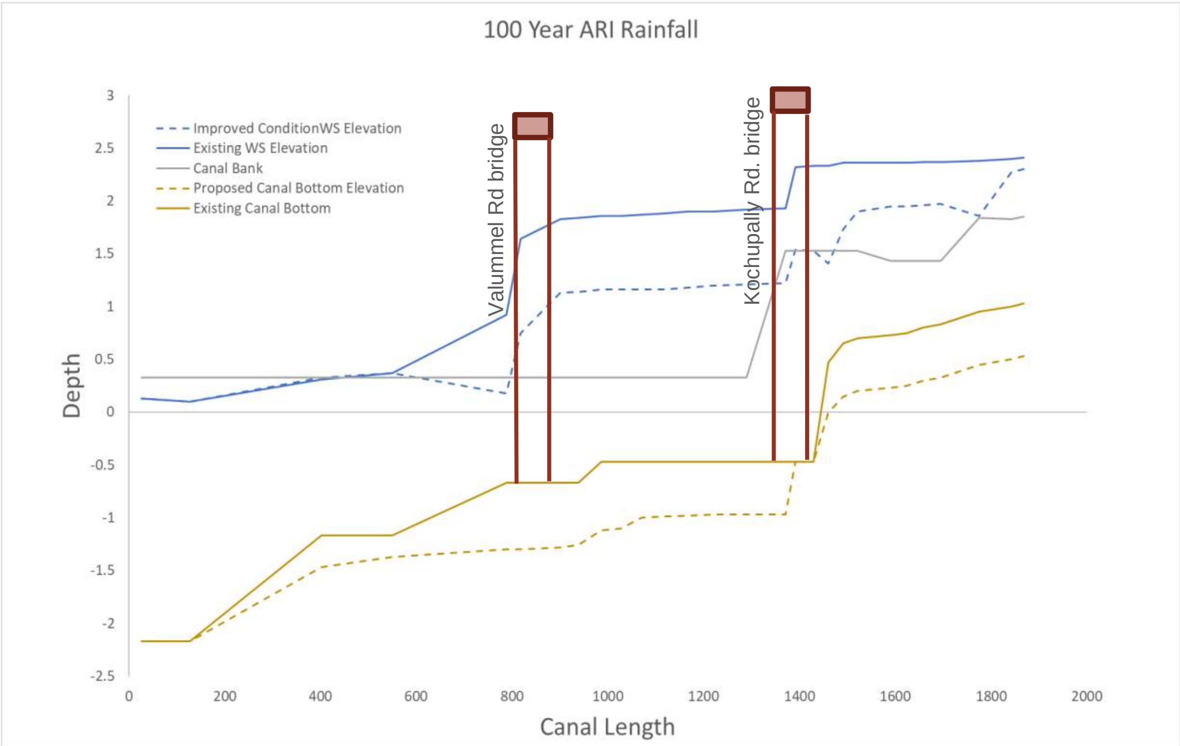


Figure 20. Comparison of the water surface profile between the existing conditions and after implementation of option 2 – 100-year ARI rainfall.

6 Conclusions

Hydrologic and hydraulic modelling was used to assess the extent of potential flooding within the area drained by the Pandarachira canal under different monsoon conditions and during high tides. The modeling results are consistent with anecdotal information about flooding and data from a survey of local residents.

The modeling showed that the two culverts under the Kochupally Rd restrict the flow causing higher water levels and flooding upstream (e.g., in the Santhom Colony area). Simulations accounting for the proposed mitigation measures showed that by adopting option 1 (Refer Section 5) considerable extent of flooding could be reduced even for 2 year ARI rainfall, but it would not completely prevent it, however if option 2 (Refer Section 5) was adopted, the extent of flooding for 2 year ARI rainfall could be well contained within the canal banks without building any protective walls whereas for 10 year and above ARI rainfalls construction of protective walls would be necessary, the details for the same have been detailed in section 5. Although it is seen that option 2 has provides better flood mitigation that option 1, the choice between them can be made based on the cost and technical feasibility considerations.

It should be noted that the results of the present modeling are conservative because they are based on steady state simulations for the peak discharge produced by different monsoon events. In reality, the peak discharge will persist over a relatively short time and it will be succeeded by lower flows. However, the conservatism used in the present analysis is justified because of many uncertainties, arising from the lack of accurate ground surface elevation data and the effect of climate change on rainfall intensity. Simulation of tidal effects shows that areas at elevation at about 0.8 m below MSL get flooded during high spring tides (winter time). The effects and extent of tidal flooding are considerably lower than those of monsoon flooding due to rainfall.

The current hydrologic and hydraulic analysis is based on data mostly from open public domain sources, The results of the present study must be confirmed when more reliable topography and canal geometry data are made available.

7 Recommendations

To reduce the exposure to flooding and protect vulnerable areas the mitigation measures described in Section 5 are recommended. The most important grey infrastructure measures are:

- Installation of an additional culvert under Kochupally Road or remove both existing culverts
- Dredging and deepening of portions of the canal
- Trash and debris removal from the canal
- Installation of trash racks in front of culverts/bridges, followed by regular maintenance/removal oil trash trapped by the racks.
- Construction of levees or walls to protect very low -lying areas

Before undertaking these actions, it is recommended to collect additional data that would allow refining the hydraulic modeling and use its results in the final design of the proposed measures. Specific data collection activities include:

- Topographic survey to obtain accurate ground surface elevations. A LiDAR survey would be desirable, but this may not be possible due government restrictions in the area of the canal.

- Mapping of lateral ditches draining in the canal. This should also include information on potential blockages or silting
- Bathymetric survey of the canal, including data on silt deposition thickness.
- Historic rainfall records from the nearest meteorological station and information on past flooding
- Tidal data and information on historic sea levels during winter months

These data should be used to update the hydrologic and hydraulic models to better asses the effectiveness of the proposed mitigation measures and support their final design.

Below is the tentative cross-sectional geometry of the proposed canal banks for option-2 condition. The geometry will be verified against a ground topographical and bathymetry survey of the canal prior to execution.

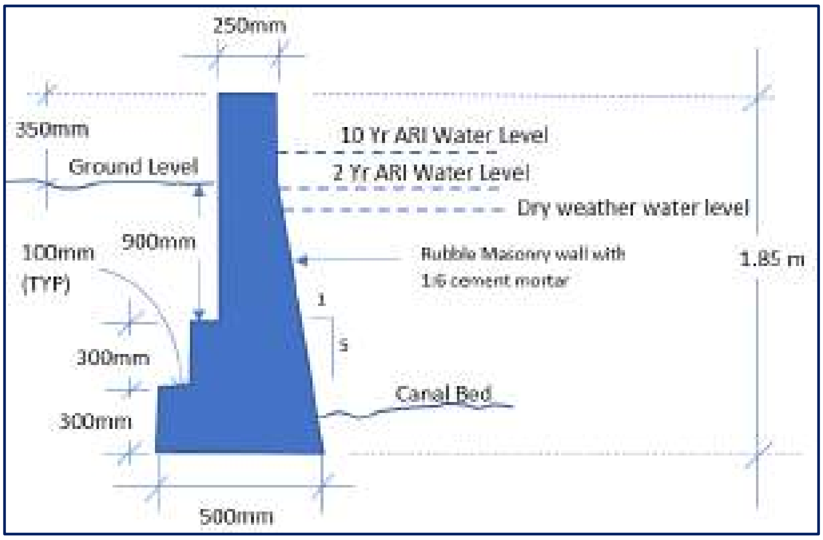


Figure 21. Proposed canal bank at Santhom colony

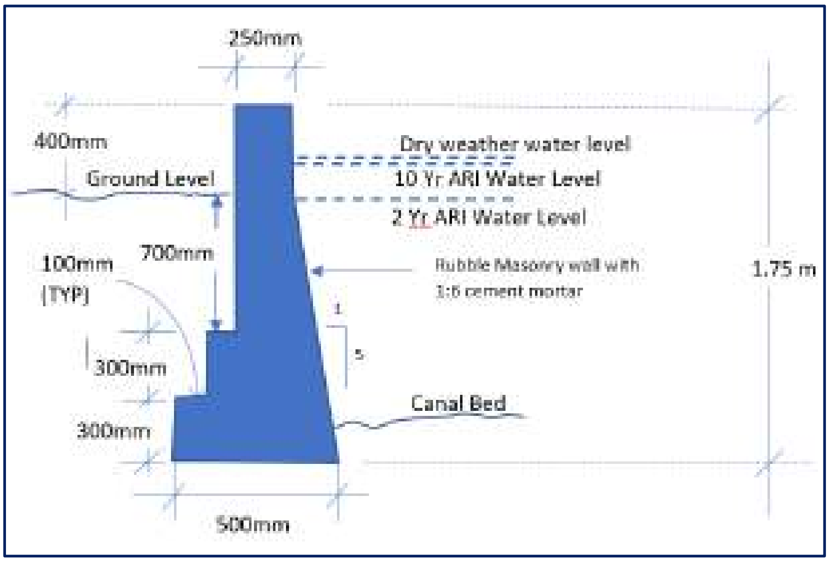


Figure 22. Proposed canal bank between Kochupally bridge & Valummel bridge

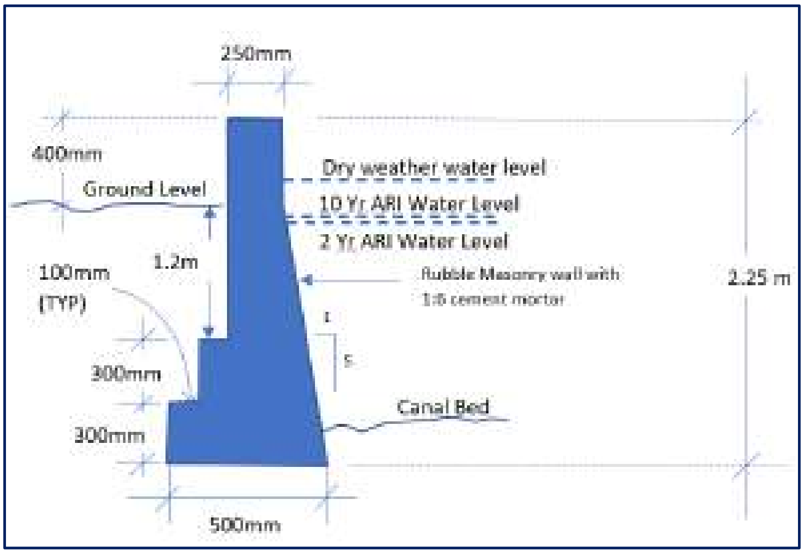


Figure 23. Proposed canal bank between Valummel bridge & Chirakkal bridge

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KOCHI SMART CANAL

PROGRESS REPORT

(1 April 2022 - 30 June 2022)

Contents

KOCHI CANAL PROJECT

Summary

This report presents the progress of the work in the project, up to 30 June 2022. The report details the methodology adopted for identification of the preferred canal for the feasibility study. Detailed analysis of five canals- Eruveli, Calvathy, Mathra, Rameshwaram and Pandarchirathodu was carried out. Scientific data, traditional knowledge and understanding community expectations formed the backbone of this analysis. The criteria that were used to identify the canal are: Flood resilience; Water quality; Transportation; Future opportunities; Financial feasibility; Vulnerability assessment; Documented biodiversity; Land use along the canal boundary; Accessibility and Existing/planned work on the canal (government or any other agency). Each suitability criterion was evaluated independently through a set of key indicators that were translated into quantifiable site characteristics and into a common suitability scale expressing preference for one site over another. The suitability scale ranged from 1 to 5, where the scale value of 1 was the lowest level of suitability (least preferable) and the scale value of 5 is the highest (most preferable). Through the detailed study undertaken, Pandarachirathodu canal was found to be the most ideal for the feasibility study. This canal also supports the highest biodiversity (amongst all five canals). Areas with higher biodiversity need to be given conservation priority. This further consolidated the need to chose Pandarachirathodu canal for the feasibility study. These findings were also presented to the Hon'ble Mayor, councillors and other stakeholders. They are also in agreement with the analysis. The report presents this analysis in detail. Some of the possible green-grey infrastructure solutions have also been highlighted upon in this report.

Canal Selection

The primary activity that was undertaken in this period is the selection of the canal for the detailed feasibility study. The selection was carried out through assessment of criteria for green and grey infrastructure. The activities related to the grey infrastructure were led by bechtel.org, while the ones related to the green infrastructure were led by ICLEI-Local Governments for Sustainability, South Asia.

Selection Criteria:

Canal selection is one of the most critical steps in the feasibility study. Scientific data, traditional knowledge and understanding community expectations are essential for the same. The pilot project needs to be designed in a manner where it would be possible to achieve the canal restoration objectives in a cost effective and time bound manner, to support the overarching goal of building flood resilience.

The criteria listed below were used to assess the present condition of the canals and identify the canal for the feasibility study.

- Flood resilience
- Water quality
- Transportation
- Future opportunities
- Financial feasibility
- Vulnerability assessment

- Documented biodiversity
- Land use along the canal boundary
- Accessibility
- Existing/planned work on the canal (government or any other agency)

The following canals were studied:

- Rameshwaram
- Manthra
- Kalvathy
- Eraveli
- Pandarachirathodu

Primary and secondary data was collected through the following:

- Discussions with different authorities, consultants, and relevant agencies
- Open- sources
- Field Surveys and interviews with stakeholders
- Existing reports
- Various photographs and imagery
- GIS mapping

Annexure 1 provides further details on the same.

Canal Selection based on Suitability for Grey Infrastructure based Solutions:

A. Methodology

The following methodology was adopted for the activity.

1) The criteria to evaluate suitability of each potential sites was developed after an in-house brainstorming.
   This included
   - Flood resilience
   - Water quality
   - Transportation
   - Future opportunities
   - Feasibility
2) Each suitability criterion was evaluated independently through a set of key indicators that were translated into quantifiable site characteristics and into a common suitability scale expressing preference for one site over another. The suitability scale ranged from 1 to 5, where the scale value of 1 was the lowest level of suitability (least preferable) and the scale value of 5 is the highest (most preferable). Annexure 2 provides details of scores allocated to each indicator and criteria.
3) In addition to defining the key indicators and associated suitability scale for each suitability criterion, a weighting factor for each suitability criterion was used to account of its relative importance.

For selecting a canal for the feasibility study, the current condition of each canal and the future possibilities and community expectations were studied and understood. The latter was analysed to set clear restoration goals for the canal. Field trips were undertaken to have an in-depth understanding of the canals and the surrounding areas.

The criteria listed in section D were used to assess the present conditions of the canals and future possibilities. These criteria led to the identification of the pilot canal, the restoration of which would bring the maximum benefit to the local community and environment.

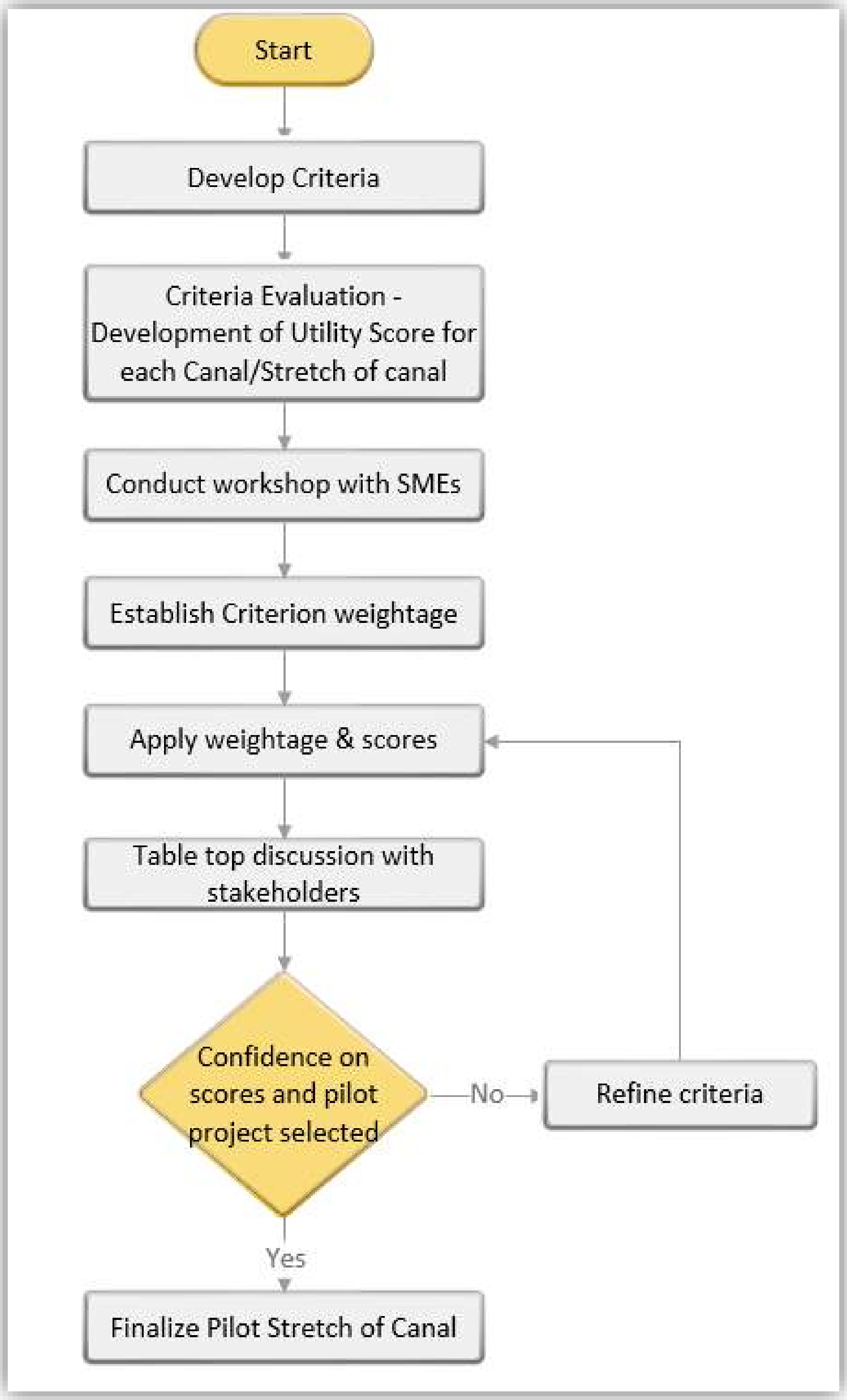


Figure 1: Flow Chart Indicating Methodology for Scoring

B. Data Collection and Site Visit

Data was collected from the following sources:

- Discussions held with various stakeholders to gain better insights into issues faced by the community. Annexure 3 provides details of the same.
- Open- sources such as Google Earth and other websites
  - o Demographic data, focussing on people residing in the wards along four canals in Fort Kochi (Kalvathy, Eraveli, Manthra, Rameshwaram and Pandarachirathodu) was collected from the Census of India (https://censusindia.gov.in/2011-common/censusdata2011.html).
    Refer Annexure 4 for details.
  - o Kochi flood map for assessment of flooding in low lying areas: https://www.floodmap.net/?gi=1273874 Refer Annexure 4 for details.
  - o Kerala State Disaster Management Authority, flood hazard maps https://sdma.kerala.gov.in/hazard-maps/ Refer Annexure 4 for details.
- Field visual surveys and interviews with the stakeholders during site visit – Annexure 5 provides all the details.
- Existing reports – Several existing reports were referred to. Details of the same are provided in Annexure 6.
- Annexure 7 provides a visual overview of the present condition of the canals.

Listed below are the major sources of data and assumptions considered for scoring of pilot canal selection:

1) **Number of households and other population sources data**
   Ward-wise household data from Census 2011 was used. Refer to https://censusindia.gov.in/2011-common/censusdata2011.html

   Households within 250m on both sides from the centre line of each canal were assumed to be subject to the maximum impact due to flooding from the canal. The number of houses affected were determined based on the density of the households.
   The number of households along the bank of each canal was identified and counted using the Google Earth pro software.
   Fish markets, meat markets & other commercial establishment were identified from Google Earth and validated through a site field survey.

2) **Images of areas susceptible to flooding** by virtue of it being low lying were sourced from https://www.floodmap.net/?gi=1273874. The areas captured in these images were redrawn using polygons in Google Earth pro and the final flood area was determined. The flood elevation from mean sea level was considered as +3m level (Refer https://sdma.kerala.gov.in/hazard-maps/)

3) **Transportation**
   The use of each canal for transportation was inferred from the presence of boats in the canal, which were seen during the site visit.

4) **Potential for creation of recreational places, fishing, ecotourism**
   Stretches of vacant land alongside the canal were identified based on Google Earth imagery. The availability of vacant land and ownership pattern needs further validation and approval from Kochi Municipal Corporation.

5) **Accessibility for cleaning and area available along the canal**
   Data was gathered during site visit and from Google Earth imagery.

6) **Footbridges constructed along the bank of the canal**: The data for this parameter was collected during the site visit and from Google Earth imagery.

7) **Dredging Timeline**
This data was obtained during the discussion with the Department of Irrigation, and is provided in Annexure 3.

C. Present Status of the Canals

An overview of the existing conditions in the canals and their historic significance has been provided in the second progress report. This section builds on from there. Additional information on the existing status, presented here, has been substantiated from the site visits, discussions and secondary literature review. Figure 2 provides an overview of the canals that have been studied.

Figure 2: Position of the canals (Photo Credit: bechtel.org)

It was noticed that all the canals are plagued by several common issues. These include:

- Direct disposal of solid waste in the canals
- Direct discharge of grey and black water into the canals
- Reduction in width of canal banks due to encroachment
- Private construction of low foot bridges across the canals
- Poor maintenance of canal lining
- Silting of canal beds

Rameshwaram Canal

The Rameshwaram canal starts approximately at Latitude 9.949082°N and Longitude 76.246662°E and ends approximately at Latitude 9.940437° N and Longitude 76.262441° E.
The canal was initially 15m wide all along its length, but presently it has been reduced to as low as 4m width at certain locations (Irrigation Department, 2021).

Ward Nos (the canal passes through)	8,10,11,24,25
Length (Approx.)	3,254 m
No. of Households along the canal	3,956
Width (varies)	4.5 m to 10 m
Depth (varies)	1.2 m to 3.0 m
Length of canal impacted by other canals - Upstream - Downstream	 233 m NA

The principal problem identified was the reduced width of the canal due to rampant encroachment. This does not leave sufficient freeboard at existing bridges and culvert locations. Hence reconstruction of these bridges is required to maintain sufficient freeboard.
Kerala Water Authority (KWA) pipelines which cross the canals at near surface water levels in the canal, trap the trash floating in the canal This impedes the flow in the canal, which at certain locations leads to potential stagnancy in the canal.
Silting of the canal bed has caused the canal bed levels to rise, so the high and low tide water does not flow through the canal.

Manthra Canal

The Manthra canal starts approximately at Latitude 9.949082° N and Longitude 76.246662° E and ends approximately at Latitude 9.962910° N and Longitude 76.249571° E.

Ward Nos (the canal passes through)	2,4,7,8,27,28
Length (Approx.)	1,848 m
No. of Households along the canal	2,718

Width (varies)	6m to 12m
Depth (varies)	1.2m to 2m
Length of canal impacted by other canals - Upstream - Downstream	 580 m 1,740 m

The Manthra canal has similar problems as the Rameshwaram canal. The canal width has been drastically reduced and there are numerous vehicular bridges and foot bridges, which makes maintenance and navigation in the canal difficult.

Eruveli Canal

The Eruveli canal starts approximately at Latitude 9.960855° N and Longitude 76.249728° E and ends approximately at Latitude 9.968109° N and Longitude 76.252487° E.

Ward Nos (the canal passes through)	2,3,4
Length (Approx.)	980 m
No. of Households along the canal	948
Width (varies)	10m to 16m
Depth (varies)	1.2m to 3.0m
Length of canal impacted by other canals - Upstream - Downstream	 2,608 m NA

Nine vehicular/foot bridges cross the canal. The major stretch of the canal is accessible from both banks due to the presence of roads on both sides of the canal. Few boats were seen at the end stretch of the cana,l indicating that the canal is still used by small scale fishermen.
Manthra and Kalvathy canal both flow into Eruveli canal before they drain into Vembanad backwaters.

Kalvathy Canal

The Kalvathy canal starts approximately at Latitude 9.965346° N and Longitude 76.246008° E and ends approximately at Latitude 9.967552° N and Longitude 76.251836° E.
Kalvathy canal has historic significance and played a crucial role in trade. The degradation of this canal started when the canal started losing its importance as a means of transportation.
.

Ward Nos (the canal passes through)	2
Length (Approx.)	760 m
No. of Households along the canal	630

Width (varies)	7m to 10m
Depth (varies)	1.2m to 3.0m
Length of canal impacted by other canals - Upstream - Downstream	 NA 95 m

This canal has good access from one side. There are fewer footbridges across the canal, but the canal side walls are not well maintained. There is a sizable population living along the canal banks which makes it prone to garbage dumping. Household effluents are being discharged into the canal.

Pandarachirathodu Canal

The Pandarachirathodu canal starts approximately at Latitude 9.939241°N and Longitude 76.255001° E and ends approximately at Latitude 9.922041°N and Longitude 76.263230°E.
The Pandarachirathodu canal is situated near Palluruthy in Kochi taluk of Ernakulam district. This canal facilitates drainage of water to the Chirakal river and the Rameswaram canal and vice versa.

Ward Nos (the canal passes through)	11,12,22,24
Length (Approx.)	2,364 m
No. of Households along the canal	3,288
Width (varies)	0.8m to 2.5m
Depth (varies)	2m to 57m
Length of canal impacted by other canals - Upstream - Downstream	 2,381 m NA

The Pandarachirathodu canal has only two bridges crossing it, which makes the canal far more accessible compared to the other canals in the area. Under one of the bridges there are two existing 1.5 m diameter circular culverts that become a bottleneck due to their relatively small size. They need complete replacement with a larger diameter culvert.
There is an approximately 150 m long stretch of the Pandarachirathodu canal which passes through the Santhom colony. There are about 10 to 15 houses built right on the banks of the canal and the residents there reported that the canal water overflows into their houses during monsoon up to 3ft height. The canal banks along those houses are unlined.
The canal is accessible from the roads in the area and the southernmost stretch is over 57 m wide, which can easily facilitate dredging using pontoon mounted dredgers.
There is ample space for fish farming and development of recreation facilities which would help improve the socio-economic condition of the community.

D. Criteria and Key Indicators

As already stated earlier, the following criteria were developed to identify the canal for the feasibility study. In parallel, a scoring system was developed with different weightage given to various key indicators, in order to help determine the canal most suited to be selected for the feasibility study. The criteria are: Flood resilience; Water quality; Transportation; Future opportunities and Feasibility. Annexure 8 provides more details.

Flooding

Two key indicators were considered to ascertain flooding scores

- **Key indicator 1 -** Probability of flooding due to canal/drain clogging during monsoon.
  This indicator was based on the number of households likely to be flooded during the monsoon. This was computed from the density of households obtained from Census data. It was observed during the site visit that most of these canals were clogged and were not functional at their full capacity. The clogging of the main canal implies that there is a high probability of storm water backflowing into the upstream internal drains, causing flooding. However, further survey and analysis will be required to establish these details. Scoring was done based on the calculated number of households within 250m of the canals.

- **Key indicator 2 -** Low lying areas impacted due to storm surge/monsoon flooding within 250 m of canal
  For data collection details refer to point number 2 in the section on Data Collection and Site Visit.

Figure 3: Image highlighting low lying areas that are susceptible to flooding (Photo Credit: bechtel.org)

Scoring was done based on the extent of the areas that are below elevation +3m, which are assumed to get flooded, and within 250 m from the canal.

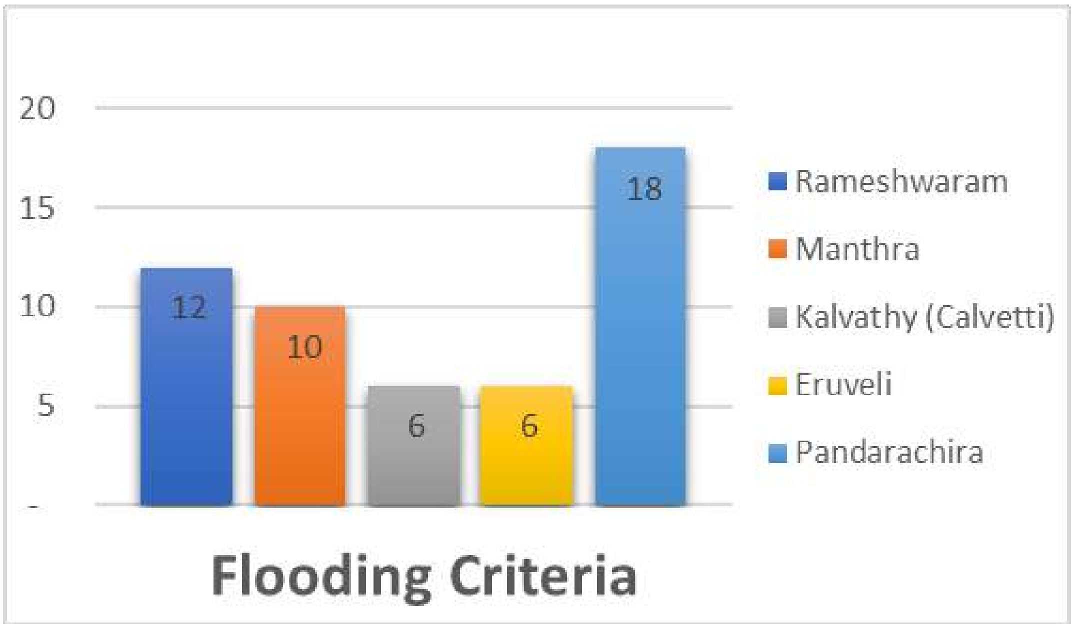


Figure 4: Scoring for flooding criteria

<u>Pollution</u>

The canals were evaluated for the extent of pollution. The canals have been contaminated with domestic wastewater and discharge from commercial operations (car wash shops, slaughterhouses, fish and meat markets, and others), and potentially by unlined septic tanks in households close to the canals.

Different indicators were considered to identify the pollution levels.

- <u>**Key indicator 1 -** Solid waste management by the houses along the canal.</u>
  This is an indicator of the probability of pollution caused by households along the bank of the canals.
  It was assumed that the houses built right on the bank are more likely to dispose off solid waste into the canal. Further it is assumed that high- and middle-income group households are less likely to throw solid waste in the canal due to accessibility to a waste management system compared to lower income group households.
  Scoring was based on the calculated number of households. Refer Annexure 8 for the basis of this calculation.

- <u>**Key indicator 2 -** Sewage management by the houses along the canal</u>
  This is an indication of direct/indirect sewage discharge by the households along the canal. Two aspects were considered for this indicator
  i. Probability of direct discharge of sewage into the canal
  ii. Discharge of wastewater due to dysfunctional septic tanks

  It was assumed that low-income households along the canal are more likely to discharge sewage directly to the canal due to absence of septic tanks or indirectly through dysfunctional septic tanks, as opposed to middle or high income group households with better maintained septic tanks.

Figure 5: Direct disposal of sewage into a canal (Photo Credit: bechtel.org)

- **Key indicator 3 -** Probability of grey water being discharged into the canal
  It was observed during the site visits that most of the households have a discharge pipe opening into the canal. Hence 90% of the households along the canals are assumed to discharge wastewater into the canals. Scoring was based on calculated number of households.

- **Key indicator 4 -** Probability of pollutants from sources other than households entering the canals
  This indicator was considered to account for pollutants other than those from households entering the canals. Scoring was based on the number of waste discharge points from small meat shops and carwashes within 250 m of the canal.
  All the above assumptions will be validated with an onsite survey to be carried out later.

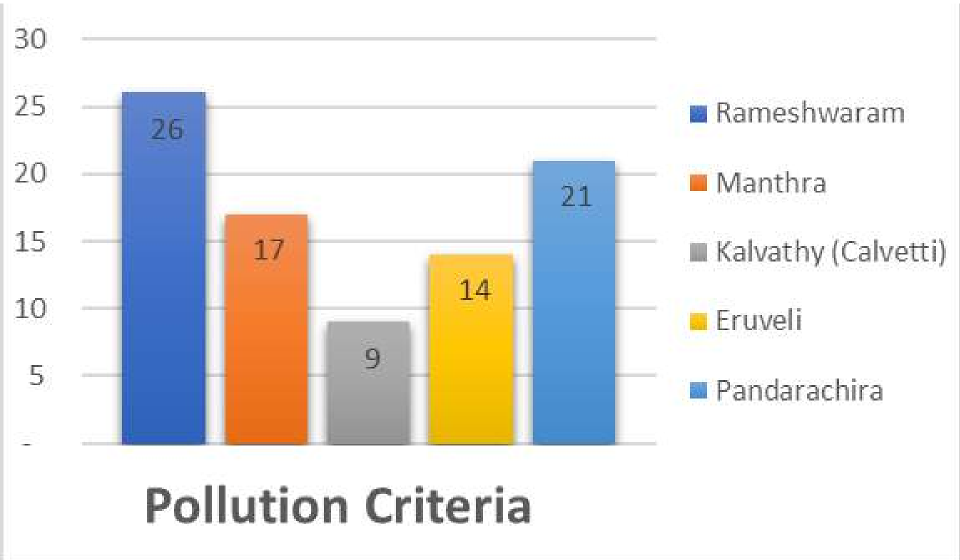


Figure 6: Scoring for pollution criteria

Transportation

The canals were evaluated for their significance with regard to transportation. The depth of the canals has been reduced by silting and different objects dumped in the canals impede the movement of boats along the canals.

Figure 7: Boats in a canal (Photo Credit: bechtel.org)

The canals were evaluated for their opportunities to improve the movement of boats by dredging them and removing objects blocking navigation.

- **Key indicator 1 -** Transportation of people – probability
  The following aspects were considered for determining scoring under this indicator
  i. People using boats to move along the canal daily
  ii. Fishermen moving daily from their houses to the sea

  The data for this indicator was assumed based on visual observations during a site visit and the number of boats present in each canal.

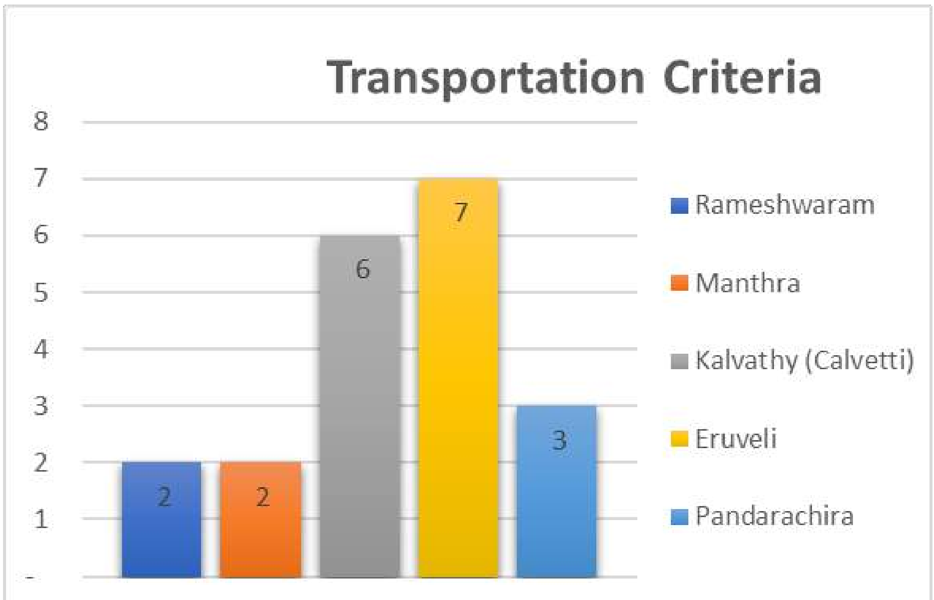


Figure 8: Scoring for transportation criteria

Future Opportunities

The canals were evaluated for potential opportunities to contribute to the local economy. They can be used to showcase points of historic or local cultural significance, as well as the local flora and fauna of interest to ecotourists. Opportunities they offer for tourist and other development were also evaluated.

- **Key indicator 1 -** Tourist points of interest along the canal
  The following aspects were considered for scoring under this indicator
  i. Historic or local cultural points of interest - No places of historical or cultural point of interest were identified along any of the canals.
  ii. Ecotourism points of interest - No eco-tourism points could be identified in any of the canals, except at the Panadarachirathodu canal, where fishponds and wetlands were identified.

- **Key indicator 2 -** Potential for recreational places
  The following aspects and parameters were considered for scoring under this indicator
  - Length of canal (m) that have widening scope for footpath from10m to 20m i.e., length of the canal with adjacent open land, with 10m to 20m width available for the development of footpaths
  - Length of canal (m) that have widening scope for recreation activities >50m i.e., length of the canal with adjacent open land with width greater than 50m available for recreational activities

  Vacant land parcels with widths between 10m to 20m and width greater than 50m, along the canal banks were identified from Google Earth imagery. The available width of land parcels so determined was used as parameters to analyse each of the canals.

- **<u>Key indicator 3 -</u>** <u>Potential for fishing</u>
  Potential length (m) of canal that can be used for fishing.
  Stretches of canal were identified from Google Earth imagery and each of the canal was rated based on the length of uninterrupted such stretches. The highest rating was given to the canal with the longest uninterrupted stretch and lowest rating to the canal having the least amount of uninterrupted stretch.

Figure 9: Fish Farm (Photo Credit: bechtel.org)

- **<u>Key indicator 4 -</u>** <u>Potential for Eco Tourism</u>
  Stretch of canal(km) with potential for boating/eco-tourism was used in the indicator, similar to key indicator 3.

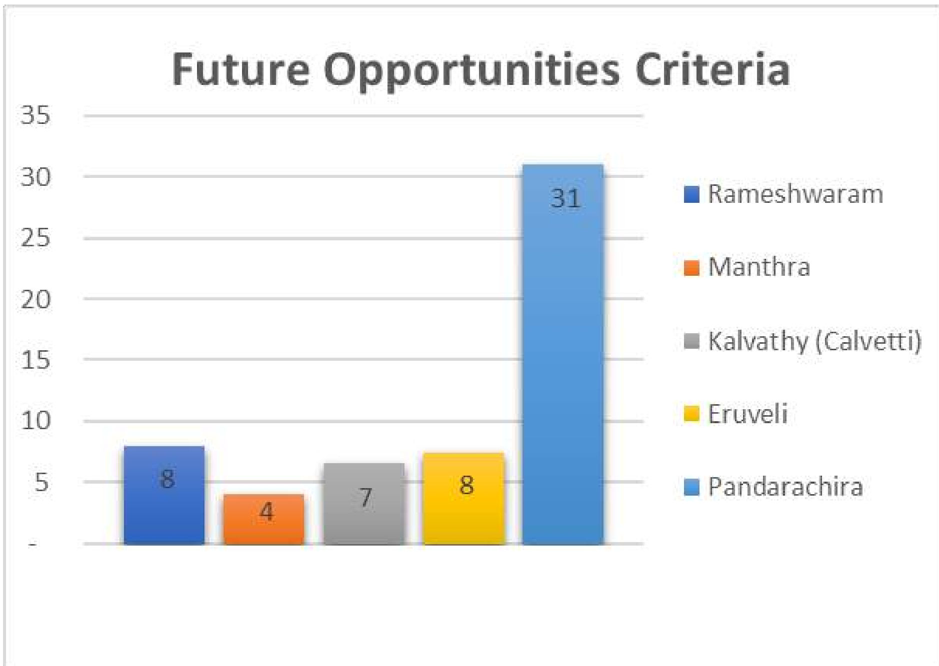


Figure 10: Scoring for future opportunities criteria

Feasibility

The canals were evaluated for feasibility as a pilot canal project based on the following indicators.

- **Key indicator 1 -** Probability of canal dredging
  Once dredging and waste removal is carried out by the city government, GGI can be implemented to address extreme flooding and improve quality of water, while promoting sustainable livelihoods.
  It has been confirmed by the Department of Irrigation that dredging was done recently for the stretch from Kalvathy to Manthra and the rest of the stretch to Rameshwaram was to be done by the first week of June, which is presumed to have been completed.

- **Key indicator 2 -** Demonstrable
  This indicator assumes demonstrability of the grey-green infrastructure within an assumed time frame of 8-12months, 12-18 months and above 18 months. The time frame for each of the canal was assumed based on the complexity, accessibility, and feasibility.

- **Key indicator 3 -** Land around canal
  Following aspects and parameters were considered for scoring under this indicator
  i. Canal accessibility - The ease of accessibility in terms of the canal length, formed the basis of rating for each canal. The highest rating was given to the canal with longest easily accessible length and the lowest rating to the canal with the shortest accessible length.
  ii. Availability of land for decentralized sewage treatment plant - The data for the availability of treatment plant was taken from Google Earth imagery wherein vacant land parcels were identified. Based on the area, rating for each canal was done with highest rating for more vacant lands available and least rating for least availability of lands for each canal. Some of these lands may be private and some under public ownership.
  iii. Possibilities for widening - The data for this parameter was obtained from site visits and from Google Earth imagery, wherein the highest rating was provided to the canal which had the longest length of canal bank free from encroachments and lowest rating to the canal with the shortest length of canal bank free from encroachments.

- **Key indicator 4 -** Length of the canal where pontoon mounted dredgers can be deployed
  The longest and the widest canal was rated highest, since manoeuvring the pontoon requires considerable width of the canal.

- **Key indicator 5 -** Requirement for reconstruction/demolition
  Extent of reconstruction/demolition required for number of footbridges across its width to be demolished was considered. The canal with the least number of footbridges was rated highest, and the canal with the most number was rated the lowest.

- **Key indicator 6 -** Impact from connecting canal
  The impact of connecting canals, both upstream and downstream of the pilot stretch is extremely critical for sustaining its water quality and flow condition for two reasons:

i. Waste material, erosion, and sediment transport into the canal from upstream of adjacent canal and areas
ii. Flow getting blocked due to clogging in downstream of the canal.

The length of such canal stretches (in km), both upstream and downstream of the canals was measured, and considered as a determinant for finalizing the pilot stretch. The canal having the longest branch canals upstream or downstream was rated the lowest and the one with the shortest or no branch canals was rated the highest.

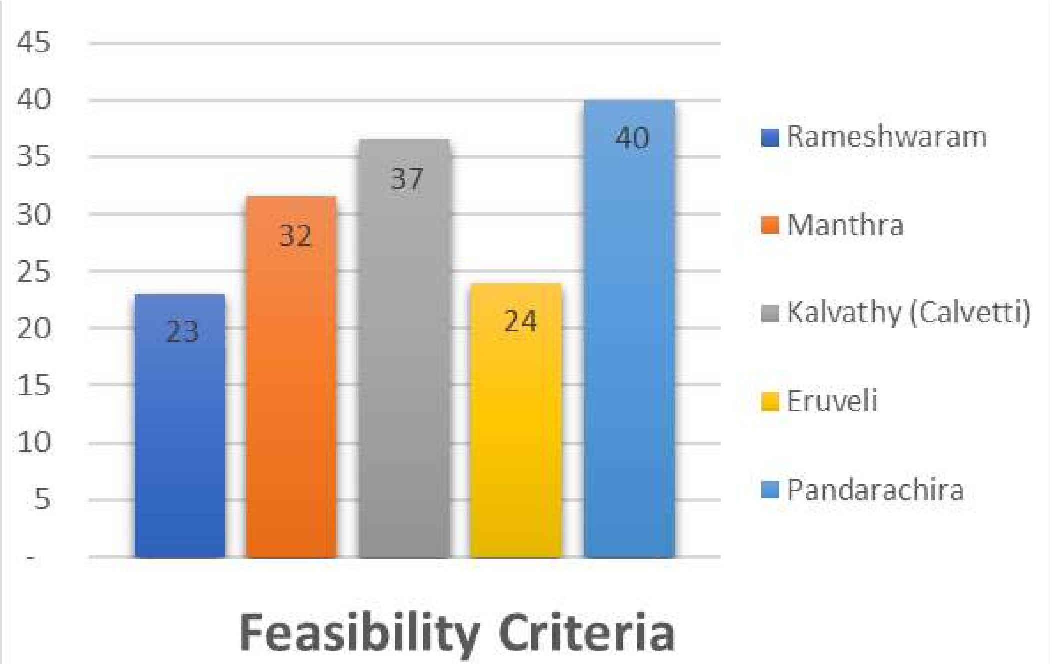


Figure 11: Scoring for feasibility criteria

E. Evaluation Summary for Suitability for Grey Infrastructure based Solutions

The detailed scoring for each criterion has been explained in the above section. Table 1 provides a summary of the same.

Table 1: Scoring of Canals

Criteria No	Criterion	Rameshwaram	Manthra	Kalvathy (Calvetti)	Eruveli	Pandar achirathodu
1	Flooding	12	10	6	6	18
2	Pollution	26	17	9	14	21
3	Transportation	2	2	6	7	3
4	Future opportunities	8	4	7	8	31

Criteria No	Criterion	Rameshwaram	Manthra	Kalvathy (Calvetti)	Eruveli	Pandar achirathodu
5	Feasibility	23	32	37	24	40
	Overall score	**71**	**65**	**64**	**59**	**113**

From the scores it is evident that the Pandarachirathodu Canal scored the highest, followed by Kalvathy, Rameshwaram, Manthra and Eruveli.

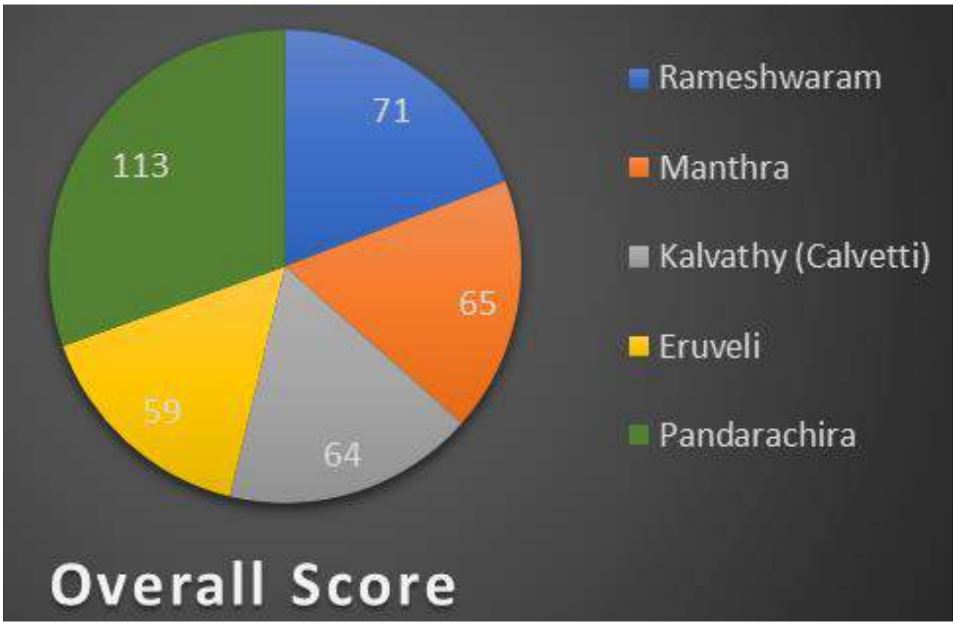


Figure 12: Overall Score of each Canal

Pandarachirathodu scores lesser than the others in transportation and pollution criteria, however it scores highest in the flooding, future opportunities, and feasibility criteria.
It has comparatively greater land availability along the banks for widening and construction of recreational spots. There are no footbridges along this canal unlike the other canals that would impede dredging and implementation of grey-green infrastructure. It also has the potential for setting up fish farming.

Canal Selection based on Suitability for Green Infrastructure based Solutions:

A. Methodology

Before initiating any ecological restoration activity, it is imperative to first document the existing biodiversity. Regions with higher biodiversity (in the form of higher diversity and presence of rare, endangered and threatened species) are prioritised for conservation and undertaking restoration activities. The canals with higher number of native species were preferred for undertaking restoration. In order to document the existing biodiversity in each of the canals, opportunistic surveys were undertaken. Floral and faunal surveys were undertaken to document trees, shrubs, herbs, mammals, birds, fishes, butterflies, dragonflies and ants. Digital documentation of the same was also carried out, to the extent possible, without capturing any individual. Species that were not identifiable at the time of survey were identified later using the photographs, with support from subject matter experts. The presence of native and non-native species was also documented for the floral species.

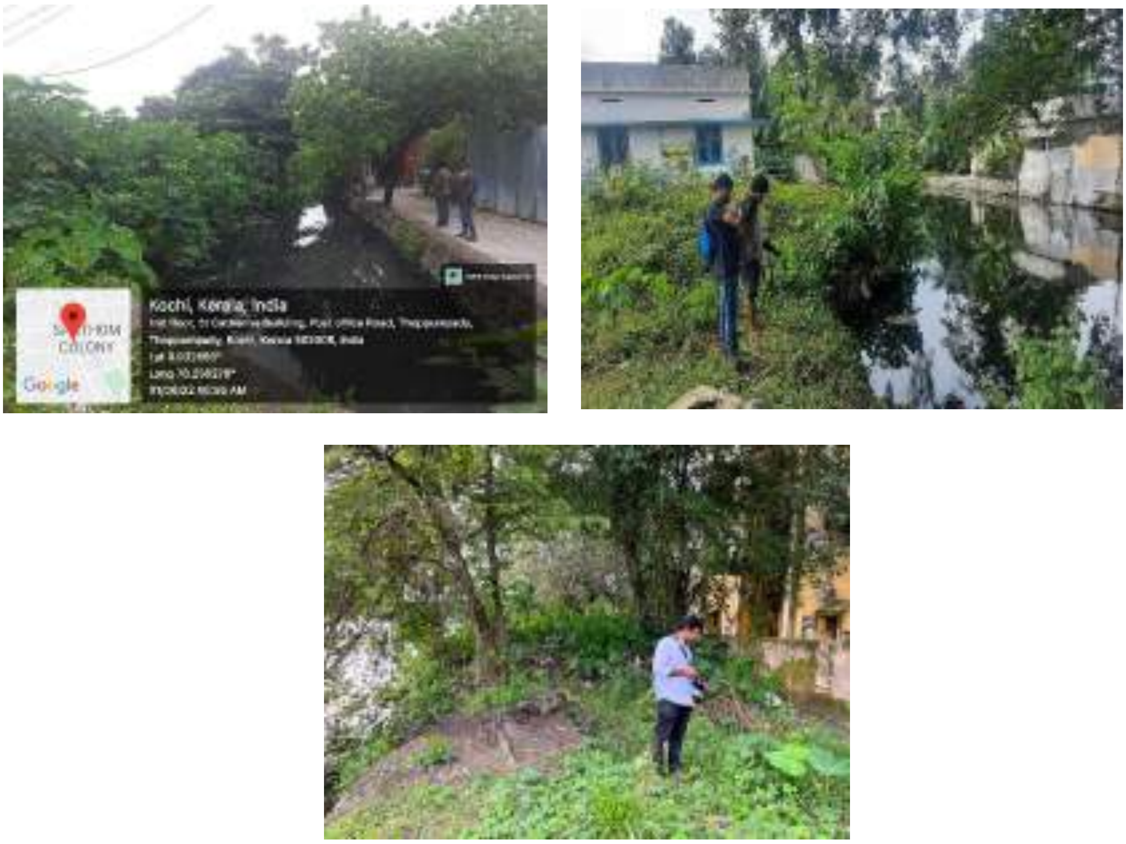


Figure 13: Documenting the Biodiversity in the Canals (Photo Credit: ICLEI South Asia)

B. Canal-wise Floral Diversity

Calvathy Canal

A total of 31 floral species have been recorded. Of these 19 are herbs, 7 shrubs and 5 tree species. A classification of the recorded species into native and exotic shows that 15 out of the documented species are exotic and 16 are native. 9 of the species are invasive and the rest are non-invasive. Table 2 provides the detailed species list.

Table 2: Floral Diversity recorded from Calvathy Canal

S.No.	Scientific Name	Common Name	Family	Habit	Native / Exotic	Invasive status
1	*Alternanthera bettzickiana*	Alternanthera	Amaranthaceae	Herb	Exotic	Invasive
2	*Amaranthus spinosus*	Prickly amaranth	Amaranthaceae	Shrub	Exotic	
3	*Colocasia esculenta*	Cocoyam	Araceae	Herb	Native	
4	*Mikania micrantha*	Mikenia	Asteraceae	Herb	Exotic	Invasive
5	*Blumea laevis*		Asteraceae	Herb	Native	
6	*Eleutheranthera ruderalis*		Asteraceae	Herb	Exotic	
7	*Wedelia trilobata*	Singapore daisy	Asteraceae	Herb	Exotic	Invasive
8	*Chromolaena odorata*	Siam weed	Asteraceae	Shrub	Exotic	Invasive
9	*Cleome burmannii*		Capparacea	Herb	Native	
10	*Ipomoea violacea*	Heavenly Blue Morning Glory	Convolvulaceae	Herb	Native	
11	*Coccinia grandis*	Ivy gourd	Cucurbitaceae	Herb	Native	
12	*Dioscorea sp.*		Dioscoreaceae	Herb	Native	
13	*Muntingia calabura*	Bird's cherry	Elaeocarpaceae	Tree	Exotic	
14	*Euphorbia hirta*	Asthma herb	Euphorbiaceae	Herb	Exotic	
15	*Phyllanthus amarus*	Phyllanthus	Euphorbiaceae	Herb	Native	
16	*Ricinus communis*	Castor oil plant	Euphorbiaceae	Shrub	Exotic	Invasive
17	*Mimosa pudica*		Fabaceae	Herb	Exotic	Invasive
18	*Lawsonia inermis*	Henna plant	Lytharaceae	Shrub	Native	
19	*Sida rhombifolia*	Sida	Malvaceae	Herb	Native	
20	*Urena lobata*	Aramina Fibre	Malvaceae	Shrub	Exotic	
21	*Thespesia populnea*	Bhendi tree	Malvaceae	Tree	Native	
22	*Ficus hispida*		Moraceae	Shrub	Native	
23	*Ficus tinctoria*		Moraceae	Tree	Native	
24	*Boerhavia diffusa*	Hogweed	Nyctaginaceae	Herb	Native	
25	*Passiflora foetida*		Passifloraceae	Herb	Exotic	Invasive
26	*Eichhornia crassipes*	Water hyacinth	Pontederiaceae	Herb	Exotic	Invasive
27	*Morinda citrifolia*	Indian Mulberry	Rubiaceae	Tree	Native	
28	*Scoparia dulcis*	Sweet broomweed	Scrophulariaceae	Herb	Exotic	
29	*Trema orientalis*	Charcoal tree	Ulmaceae	Tree	Native	
30	*Lantana camara*	Lantana	Verbinaceae	Shrub	Exotic	Invasive
31	*Cayratia trifolia*	Cayratia	Vitaceae	Herb	Native	

Eraveli Canal

A total of 44 floral species have been recorded. Of these 28 are herbs, 9 shrubs and 7 tree species. A classification of the recorded species into native and exotic shows that 21 out of the documented species are exotic and 23 are native. 11 of the species are invasive and the rest are non-invasive. Table 3 provides the detailed species list.

Table 3: Floral Diversity recorded from Eraveli Canal

S.No.	Scientific Name	Common Name	Family	Habit	Native / Exotic	Invasive status
1	*Aerva lanata*	Polpala	Amaranthaceae	Herb	Native	
2	*Alternanthera bettzickiana*	Alternanthera	Amaranthaceae	Herb	Exotic	Invasive
3	*Amaranthus spinosus*	Prickly amaranth	Amaranthaceae	Shrub	Exotic	
4	*Colocasia esculenta*	Cocoyam	Araceae	Herb	Native	
5	*Mikania micrantha*	Mikenia	Asteraceae	Herb	Exotic	Invasive
6	*Blumea laevis*		Asteraceae	Herb	Native	
7	*Eclipta prostrata*	False daisy	Asteraceae	Herb	Native	
8	*Eleutheranthera ruderalis*		Asteraceae	Herb	Exotic	
9	*Wedelia trilobata*	Singpore daisy	Asteraceae	Herb	Exotic	Invasive
10	*Chromolaena odorata*	Siam weed	Asteraceae	Shrub	Exotic	Invasive
11	*Heliotropium sp.*		Boraginaceae	Herb	Native	
12	*Cleome burmannii*		Capparacea	Herb	Native	
13	*Cleome viscosa*		Capparacea	Herb	Exotic	
14	*Ipomoea carnea*	Shrub Ipomoea	Convolvulaceae	Herb	Exotic	
15	*Ipomoea marginata*		Convolvulaceae	Herb	Native	
16	*Ipomoea violacea*	Heavenly Blue Morning Glory	Convolvulaceae	Herb	Native	
17	*Coccinia grandis*	Ivy gourd	Cucurbitaceae	Herb	Native	
18	*Dioscorea sp.*		Dioscoreaceae	Herb	Native	
19	*Muntingia calabura*	Bird's cherry	Elaeocarpaceae	Tree	Exotic	
20	*Euphorbia hirta*	Asthma herb	Euphorbiaceae	Herb	Exotic	
21	*Phyllanthus amarus*	Phyllanthus	Euphorbiaceae	Herb	Native	
22	*Ricinus communis*	Castor oil plant	Euphorbiaceae	Shrub	Exotic	Invasive
23	*Mimosa pudica*		Fabaceae	Herb	Exotic	Invasive
24	*Senna tora*		Fabaceae	Shrub	Exotic	Invasive
25	*Sesbania bispinosa*	Prickly sesban	Fabaceae	Shrub	Exotic	
26	*Leucaena leucocephala*	Lead tree	Fabaceae	Tree	Exotic	Invasive
27	*Lawsonia inermis*	Henna plant	Lytharaceae	Shrub	Native	
28	*Sida rhombifolia*	Sida	Malvaceae	Herb	Native	
29	*Urena lobata*	Aramina Fibre	Malvaceae	Shrub	Exotic	
30	*Thespesia populnea*	Bhendi tree	Malvaceae	Tree	Native	
31	*Ficus hispida*		Moraceae	Shrub	Native	
32	*Ficus religiosa*	Peepal tree	Moraceae	Tree	Exotic	
33	*Ficus tinctoria*		Moraceae	Tree	Native	
34	*Boerhavia diffusa*	Hogweed	Nyctaginaceae	Herb	Native	

S.No.	Scientific Name	Common Name	Family	Habit	Native / Exotic	Invasive status
35	*Passiflora foetida*		Passifloraceae	Herb	Exotic	Invasive
36	*Cynodon dactylon*		Poaceae	Herb	Native	
37	*Persicaria barbata*		Polygonaceae	Herb	Native	
38	*Eichhornia crassipes*	Water hyacinth	Pontederiaceae	Herb	Exotic	Invasive
39	*Morinda citrifolia*	Indian Mulberry	Rubiaceae	Tree	Native	
40	*Scoparia dulcis*	Sweet broomweed	Scrophulariaceae	Herb	Exotic	
41	*Trema orientalis*	Charcoal tree	Ulmaceae	Tree	Native	
42	*Laportea interrupta*		Urticaceae	Herb	Native	
43	*Lantana camara*	Lantana	Verbinaceae	Shrub	Exotic	Invasive
44	*Cayratia trifolia*	Cayratia	Vitaceae	Herb	Native	

Manthra Canal

A total of 40 floral species have been recorded. Of these 26 are herbs, 7 shrubs and 7 tree species. A classification of the recorded species into native and exotic shows that 19 out of the documented species are exotic and 21 are native. 10 of the species are invasive and the rest are non-invasive. Table 4 provides the detailed species list.

Table 4: Floral Diversity recorded from Manthra Canal

S.No.	Scientific Name	Common Name	Family	Habit	Native / Exotic	Invasive status
1	*Alternanthera bettzickiana*	Alternanthera	Amaranthaceae	Herb	Exotic	Invasive
2	*Amaranthus spinosus*	Prickly amaranth	Amaranthaceae	Shrub	Exotic	
3	*Colocasia esculenta*	Cocoyam	Araceae	Herb	Native	
4	*Mikania micrantha*	Mikenia	Asteraceae	Herb	Exotic	Invasive
5	*Blumea laevis*		Asteraceae	Herb	Native	
6	*Eclipta prostrata*	False daisy	Asteraceae	Herb	Native	
7	*Eleutheranthera ruderalis*		Asteraceae	Herb	Exotic	
8	*Wedelia trilobata*	Singapore daisy	Asteraceae	Herb	Exotic	Invasive
9	*Chromolaena odorata*	Siam weed	Asteraceae	Shrub	Exotic	Invasive
10	*Heliotropium sp.*		Boraginaceae	Herb	Native	
11	*Cleome burmannii*		Capparacea	Herb	Native	
12	*Cleome viscosa*		Capparacea	Herb	Exotic	
13	*Ipomoea carnea*	Shrub Ipomoea	Convolvulaceae	Herb	Exotic	
14	*Ipomoea marginata*		Convolvulaceae	Herb	Native	
15	*Ipomoea violacea*	Heavenly Blue Morning Glory	Convolvulaceae	Herb	Native	
16	*Coccinia grandis*	Ivy gourd	Cucurbitaceae	Herb	Native	
17	*Dioscorea sp.*		Dioscoreaceae	Herb	Native	
18	*Muntingia calabura*	Bird's cherry	Elaeocarpaceae	Tree	Exotic	
19	*Euphorbia hirta*	Asthma herb	Euphorbiaceae	Herb	Exotic	
20	*Phyllanthus amarus*	Phyllanthus	Euphorbiaceae	Herb	Native	
21	*Ricinus communis*	Castor oil plant	Euphorbiaceae	Shrub	Exotic	Invasive

S.No.	Scientific Name	Common Name	Family	Habit	Native / Exotic	Invasive status
22	*Mimosa pudica*		Fabaceae	Herb	Exotic	Invasive
23	*Leucaena leucocephala*	Lead tree	Fabaceae	Tree	Exotic	Invasive
24	*Lawsonia inermis*	Henna plant	Lytharaceae	Shrub	Native	
25	*Sida rhombifolia*	Sida	Malvaceae	Herb	Native	
26	*Urena lobata*	Aramina Fibre	Malvaceae	Shrub	Exotic	
27	*Thespesia populnea*	Bhendi tree	Malvaceae	Tree	Native	
28	*Ficus hispida*		Moraceae	Shrub	Native	
29	*Ficus religiosa*	Peepal tree	Moraceae	Tree	Exotic	
30	*Ficus tinctoria*		Moraceae	Tree	Native	
31	*Boerhavia diffusa*	Hogweed	Nyctaginaceae	Herb	Native	
32	*Passiflora foetida*		Passifloraceae	Herb	Exotic	Invasive
33	*Cynodon dactylon*		Poaceae	Herb	Native	
34	*Eichhornia crassipes*	Water hyacinth	Pontederiaceae	Herb	Exotic	Invasive
35	*Morinda citrifolia*	Indian Mulberry	Rubiaceae	Tree	Native	
36	*Scoparia dulcis*	Sweet broomweed	Scrophulariaceae	Herb	Exotic	
37	*Trema orientalis*	Charcoal tree	Ulmaceae	Tree	Native	
38	*Laportea interrupta*		Urticaceae	Herb	Native	
39	*Lantana camara*	Lantana	Verbinaceae	Shrub	Exotic	Invasive
40	*Cayratia trifolia*	Cayratia	Vitaceae	Herb	Native	

Rameshwaram Canal

A total of 57 floral species have been recorded. Of these 30 are herbs, 11 shrubs and 16 tree species. A classification of the recorded species into native and exotic shows that 27 out of the documented species are exotic and 30 are native. 14 of the species are invasive and the rest are non-invasive. Table 5 provides the detailed species list.

Table 5: Floral Diversity recorded from Rameshwaram Canal

S.No.	Scientific Name	Common Name	Family	Habit	Native / Exotic	Invasive status
1	*Aerva lanata*	Polpala	Amaranthaceae	Herb	Native	
2	*Alternanthera bettzickiana*	Alternanthera	Amaranthaceae	Herb	Exotic	Invasive
3	*Amaranthus spinosus*	Prickly amaranth	Amaranthaceae	Shrub	Exotic	
4	*Colocasia esculenta*	Cocoyam	Araceae	Herb	Native	
5	*Caryota urens*		Arecaceae	Tree	Native	
6	*Calotropis gigantea*	Bowstring hemp	Asclepidaceae	Shrub	Native	
7	*Mikania micrantha*	Mikenia	Asteraceae	Herb	Exotic	Invasive
8	*Blumea laevis*		Asteraceae	Herb	Native	
9	*Eclipta prostrata*	False daisy	Asteraceae	Herb	Native	
10	*Eleutheranthera ruderalis*		Asteraceae	Herb	Exotic	
11	*Wedelia trilobata*	Singapore daisy	Asteraceae	Herb	Exotic	Invasive
12	*Chromolaena odorata*	Siam weed	Asteraceae	Shrub	Exotic	Invasive
13	*Heliotropium sp.*		Boraginaceae	Herb	Native	
14	*Cleome burmannii*		Capparacea	Herb	Native	

S.No.	Scientific Name	Common Name	Family	Habit	Native / Exotic	Invasive status
15	*Cleome viscosa*		Capparacea	Herb	Exotic	
16	*Terminalia catappa*		Combertaceae	Tree	Exotic	
17	*Quisqualis indica*		Combretaceae	Herb	Exotic	Invasive
18	*Ipomoea carnea*	Shrub Ipomoea	Convolvulaceae	Herb	Exotic	
19	*Ipomoea marginata*		Convolvulaceae	Herb	Native	
20	*Ipomoea violacea*	Heavenly Blue Morning Glory	Convolvulaceae	Herb	Native	
21	*Coccinia grandis*	Ivy gourd	Cucurbitaceae	Herb	Native	
22	*Dioscorea sp.*		Dioscoreaceae	Herb	Native	
23	*Muntingia calabura*	Bird's cherry	Elaeocarpaceae	Tree	Exotic	
24	*Euphorbia hirta*	Asthma herb	Euphorbiaceae	Herb	Exotic	
25	*Phyllanthus amarus*	Phyllanthus	Euphorbiaceae	Herb	Native	
26	*Ricinus communis*	Castor oil plant	Euphorbiaceae	Shrub	Exotic	Invasive
27	*Excoecaria agallocha*	Blinding tree	Euphorbiaceae	Tree	Native	
28	*Centrosema molle*		Fabaceae	Herb	Exotic	Invasive
29	*Mimosa pudica*		Fabaceae	Herb	Exotic	Invasive
30	*Senna tora*		Fabaceae	Shrub	Exotic	Invasive
31	*Sesbania bispinosa*	Prickly sesban	Fabaceae	Shrub	Exotic	
32	*Albizia saman*	Rain tree	Fabaceae	Tree	Exotic	
33	*Cassia fistula*	Golden shower	Fabaceae	Tree	Native	
34	*Leucaena leucocephala*	Lead tree	Fabaceae	Tree	Exotic	Invasive
35	*Peltophorum pterocarpum*	Copperpode	Fabaceae	Tree	Exotic	
36	*Racosperma auriculiforme*	Acasia	Fabaceae	Tree	Exotic	Invasive
37	*Ocimum tenuiflorum*	Sacred basil	Lamiaceae	Shrub	Native	
38	*Lawsonia inermis*	Henna plant	Lytharaceae	Shrub	Native	
39	*Sida rhombifolia*	sida	Malvaceae	Herb	Native	
40	*Urena lobata*	Aramina Fibre	Malvaceae	Shrub	Exotic	
41	*Thespesia populnea*	Bhendi tree	Malvaceae	Tree	Native	
42	*Ficus hispida*		Moraceae	Shrub	Native	
43	*Ficus benghalensis*	Benyan tree	Moraceae	Tree	Native	
44	*Ficus religiosa*	Peepal tree	Moraceae	Tree	Exotic	
45	*Ficus tinctoria*		Moraceae	Tree	Native	
46	*Syzygium cumini*	Black plum	Myrtaceae	Tree	Native	
47	*Boerhavia diffusa*	Hogweed	Nyctaginaceae	Herb	Native	
48	*Passiflora foetida*		Passifloraceae	Herb	Exotic	Invasive
49	*Cynodon dactylon*		Poaceae	Herb	Native	
50	*Persicaria barbata*		Polygonaceae	Herb	Native	
51	*Eichhornia crassipes*	Water hyacinth	Pontederiaceae	Herb	Exotic	Invasive
52	*Morinda citrifolia*	Indian Mulberry	Rubiaceae	Tree	Native	
53	*Scoparia dulcis*	Sweet broomweed	Scrophulariaceae	Herb	Exotic	
54	*Trema orientalis*	Charcoal tree	Ulmaceae	Tree	Native	
55	*Laportea interrupta*		Urticaceae	Herb	Native	
56	*Lantana camara*	Lantana	Verbinaceae	Shrub	Exotic	Invasive
57	*Cayratia trifolia*	Cayratia	Vitaceae	Herb	Native	

Pandarachirathodu Canal

A total of 79 floral species have been recorded. Of these 40 are herbs, 19 shrubs and 20 tree species. A classification of the recorded species into native and exotic shows that 45 out of the documented species are exotic and 34 are native. 16 of the species are invasive and the rest are non-invasive. Table 6 provides the detailed species list.

Table 6: Floral Diversity recorded from Pandarachirathodu Canal

S.No.	Scientific Name	Common Name	Family	Habit	Native / Exotic	Invasive status
1	*Aerva lanata*	Polpala	Amaranthaceae	Herb	Native	
2	*Alternanthera bettzickiana*	Alternanthera	Amaranthaceae	Herb	Exotic	Invasive
3	*Alternanthera philoxeroides*	Alligatorweed	Amaranthaceae	Herb	Exotic	
4	*Amaranthus spinosus*	Prickly amaranth	Amaranthaceae	Shrub	Exotic	
5	*Colocasia esculenta*	Cocoyam	Araceae	Herb	Native	
6	*Caryota urens*		Arecaceae	Tree	Native	
7	*Mikania micrantha*	Mikenia	Asteraceae	Herb	Exotic	Invasive
8	*Acmella uliginosa*	Acmella	Asteraceae	Herb	Exotic	
9	*Ageratum conyzoides*		Asteraceae	Herb	Exotic	Invasive
10	*Blumea laevis*		Asteraceae	Herb	Native	
11	*Eclipta prostrata*	False daisy	Asteraceae	Herb	Native	
12	*Eleutheranthera ruderalis*		Asteraceae	Herb	Exotic	
13	*Spilanthes ciliata*		Asteraceae	Herb	exotic	
14	*Wedelia trilobata*	Singpore daisy	Asteraceae	Herb	Exotic	Invasive
15	*Chromolaena odorata*	Siam weed	Asteraceae	Shrub	Exotic	Invasive
16	*Heliotropium sp.*		Boraginaceae	Herb	Native	
17	*Cleome burmannii*		Capparacea	Herb	Native	
18	*Cleome viscosa*		Capparacea	Herb	Exotic	
19	*Carica papaya*	Pappaya	Caricaceae	Shrub	Exotic	
20	*Terminalia catappa*		Combertaceae	Tree	Exotic	
21	*Ipomoea carnea*	Shrub Ipomoea	Convolvulaceae	Herb	Exotic	
22	*Ipomoea marginata*		Convolvulaceae	Herb	Native	
23	*Ipomoea violacea*	Heavenly Blue Morning Glory	Convolvulaceae	Herb	Native	
24	*Coccinia grandis*	Ivy gourd	Cucurbitaceae	Herb	Native	
25	*Cyperus sp.*		Cyperaceae	Herb	Native	
26	*Fimbristylis sp.*		Cyperaceae	Herb	Native	
27	*Muntingia calabura*	Bird's cherry	Elaeocarpaceae	Tree	Exotic	
28	*Euphorbia hirta*	Asthma herb	Euphorbiaceae	Herb	Exotic	
29	*Phyllanthus amarus*	Phyllanthus	Euphorbiaceae	Herb	Native	
30	*Phyllanthus reticulatus*		Euphorbiaceae	Shrub	Native	
31	*Ricinus communis*	Castor oil plant	Euphorbiaceae	Shrub	Exotic	Invasive
32	*Excoecaria agallocha*	Blinding tree	Euphorbiaceae	Tree	Native	
33	*Macaranga peltata*		Euphorbiaceae	Tree	Native	
34	*Centrosema molle*		Fabaceae	Herb	Exotic	Invasive

S.No.	Scientific Name	Common Name	Family	Habit	Native / Exotic	Invasive status
35	*Derris trifoliata*	Derris	Fabaceae	Herb	Native	
36	*Pueraria phaseoloides*		Fabaceae	Herb	Exotic	Invasive
37	*Crotalaria quinquefolia*	Sen	Fabaceae	Herb	Native	
38	*Mimosa pudica*		Fabaceae	Herb	Exotic	Invasive
39	*Senna alata*	candle bush	Fabaceae	Shrub	Exotic	Invasive
40	*Senna tora*		Fabaceae	Shrub	Exotic	Invasive
41	*Sesbania bispinosa*	Prickly sesban	Fabaceae	Shrub	Exotic	
42	*Albizia saman*	Rain tree	Fabaceae	Tree	Exotic	
43	*Cassia fistula*	Golden shower	Fabaceae	Tree	Native	
44	*Leucaena leucocephala*	Lead tree	Fabaceae	Tree	Exotic	Invasive
45	*Racosperma auriculiforme*	Acasia	Fabaceae	Tree	Exotic	Invasive
46	*Tamarindus indica*	Tamarind	Fabaceae	Tree	Native	
47	*Hyptis suaveolens*		Lamiaceae	Shrub	Exotic	
48	*Ocimum tenuiflorum*	Sacred basil	Lamiaceae	Shrub	Native	
49	*Leea indica*	Bandicoot Berry	leeaceae	Shrub	Native	
50	*Lawsonia inermis*	Henna plant	Lytharaceae	Shrub	Native	
51	*Sida acuta*	Sida	Malvaceae	Herb	Native	
52	*Sida rhombifolia*	Broomjute sida	Malvaceae	Shrub	Native	
53	*Urena lobata*	Aramina Fibre	Malvaceae	Shrub	Exotic	
54	*Thespesia populnea*	Bhendi tree	Malvaceae	Tree	Native	
55	*Ficus hispida*		Moraceae	Shrub	Native	
56	*Ficus benghalensis*	Benyan tree	Moraceae	Tree	Native	
57	*Ficus benjamina*	Benjamin	Moraceae	Tree	Exotic	
58	*Ficus racemosa*	Cluster fig	Moraceae	Tree	Native	
59	*Ficus religiosa*	Peepal tree	Moraceae	Tree	Exotic	
60	*Syzygium cumini*	Black plum	Myrtaceae	Tree	Native	
61	*Boerhavia diffusa*	Hogweed	Nyctaginaceae	Herb	Native	
62	*Passiflora foetida*		Passifloraceae	Herb	Exotic	Invasive
63	*Cynodon dactylon*		Poaceae	Herb	Native	
64	*Paspalum distichum*		Poaceae	Herb	Native	
65	*Zoysia matrella*		Poaceae	Herb	Native	
66	*Persicaria barbata*		Polygonaceae	Herb	Native	
67	*Eichhornia crassipes*	Water hyacinth	Pontederiaceae	Herb	Exotic	Invasive
68	*Bruguiera gymnorrhiza*	Mangrove	Rhizophoraceae	Tree	Native	
69	*Morinda citrifolia*	Indian Mulberry	Rubiaceae	Tree	Native	
70	*Murraya koenigii*	curry leaf tree	Rutaceae	Tree	Native	
71	*Lindernia tenuifolia*		Scrophularaceae	Herb	Native	
72	*Scoparia dulcis*	Sweet broomweed	Scrophulariaceae	Herb	Exotic	
73	*Solanum violaceum*		Solanaceae	Shrub	Native	
74	*Trema orientalis*	Charcoal tree	Ulmaceae	Tree	Native	
75	*Laportea interrupta*		Urticaceae	Herb	Native	
76	*Lantana camara*	Lantana	Verbinaceae	Shrub	Exotic	Invasive

S.No.	Scientific Name	Common Name	Family	Habit	Native / Exotic	Invasive status
77	*Premna serratifolia*		Verbinaceae	Shrub	Native	
78	*Cayratia trifolia*	Cayratia	Vitaceae	Herb	Native	
79	*Curcuma sp.*		Zingiberaceae	Shrub	Native	

C. Canal-wise Faunal Diversity

Calvathy Canal

A total of 27 faunal species have been recorded from Calvathy Canal. Out of these 4 are dragonflies, 2 ants, 16 birds and 5 butterflies. Table 7 below provides the detailed list.

Table 7: Faunal Diversity recorded from Calvathy Canal

Sr. No.	Taxa	Scientific Name	Common name	IUCN Status
1	Dragonfly	*Pseudagrion microcephalum*	Blue Grass Dart	LC
2		*Diplacodes trivialis*	Ground Skimmer	LC
3		*Brachythemis contaminata*	Ditch Jewel	LC
4		*Pantala flavescens*	Wondering Glider	LC
5	Ant	*Tapimoma melanocephalum*	Odor Ant	Not evaluated
6		*Monomorium pharaonis*	Pharaoh Ant	Not evaluated
7	Bird	*Ardeola grayii*	Indian Pond-Heron	LC
8		*Corvus splendens*	House Crow	LC
9		*Dicaeum erythrorhynchos*	Pale-billed Flowerpecker	LC
10		*Columba livia*	Rock Pigeon	LC
11		*Eudynamys scolopaceus*	Asian Koel	LC
12		*Acridotheres tristis*	Common Myna	LC
13		*Copsychus saularis*	Oriental Magpie-Robin	LC
14		*Haliastur indus*	Brahminy Kite	LC
15		*Orthotomus sutorius*	Common Tailorbird	LC
16		*Dicrurus macrocercus*	Black Drongo	LC
17		*Passer domesticus*	House Sparrow	LC
18		*Halcyon smyrnensis*	White-throated Kingfisher	LC
19		*Milvus migrans*	Black Kite	LC
20		*Leptocoma zeylonica*	Purple-rumped Sunbird	LC
21		*Nycticorax Nycticorax*	Black-crowned Night-heron	LC
22		*Cinnyris lotenius*	Loten's Sunbird	LC
23	Butterfly	*Euploea core*	Common Crow	LC
24		*Catopsilia pomona*	Common Emigrant	Not evaluated
25		*Papilio polytes*	Common Mormon	Not evaluated
26		*Leptosia nina*	Psyche	Not evaluated
27		*Pseudozizeeria maha*	Pale Grass Blue	Not evaluated

Eraveli Canal

A total of 41 faunal species have been recorded from Eraveli Canal. Out of these 7 are dragonflies, 3 ants, 18 birds and 13 butterflies. Table 8 below provides the detailed list.

Table 8: Faunal Diversity recorded from Eraveli Canal

Sr. No.	Taxa	Scientific Name	Common name	IUCN Status
1		*Pseudagrion microcephalum*	Blue Grass Dart	LC
2		*Brachydiplax chalybea*	Rufous-backed Marsh Dart	LC
3		*Diplacodes trivialis*	Ground Skimmer	LC
4		*Brachythemis contaminata*	Ditch Jewel	LC
5		*Neurothemis tullia*	Paddy Pied Skimmer	LC
6		*Pantala flavescens*	Wondering Glider	LC
7	Dragonfly	Rhyothemis variegata	Common Picture Wing	LC
8		*Paratrachina longicornis*		Not evaluated
9		*Anoplolepis gracilipes*	Yellow Crazy Ant	Not evaluated
10	Ant	*Tapimoma melanocephalum*	Odor Ant	Not evaluated
11		*Ardeola grayii*	Indian Pond-Heron	LC
12		*Corvus splendens*	House Crow	LC
13		*Dicaeum erythrorhynchos*	Pale-billed Flowerpecker	LC
14		*Columba livia*	Rock Pigeon	LC
15		*Eudynamys scolopaceus*	Asian Koel	LC
16		*Acridotheres tristis*	Common Myna	LC
17		*Copsychus saularis*	Oriental Magpie-Robin	LC
18		*Haliastur indus*	Brahminy Kite	LC
19		*Orthotomus sutorius*	Common Tailorbird	LC
20		*Phalacrocorax niger*	Little Cormorant	LC
21		*Dicrurus macrocercus*	Black Drongo	LC
22		*Passer domesticus*	House Sparrow	LC
23		*Halcyon smyrnensis*	White-throated Kingfisher	LC
24		*Pycnonotus cafer*	Red-vented Bulbul	LC
25		*Milvus migrans*	Black Kite	LC
26		*Cinnyris asiaticus*	Purple Sunbird	LC
27		*Leptocoma zeylonica*	Purple-rumped Sunbird	LC
28	Bird	*Nycticorax nycticorax*	Black-crowned Night-heron	LC
29		*Ariadne merione*	Common Castor	Not evaluated
30		*Euploea core*	Common Crow	LC
31		*Catopsilia pomona*	Common Emigrant	Not evaluated
32		*Danaus chrysippus*	Plain Tiger	LC
33		*Papilio polytes*	Common Mormon	Not evaluated
34		*Acraea violae*	Tawny Coster	Not evaluated
35		*Junonia atlites*	Grey Pansy	Not evaluated
36		*Parantica aglea*	Glassy Tiger	Not evaluated
37		*Leptosia nina*	Psyche	Not evaluated
38		*Eurema hecabe*	Common Grass yellow	Not evaluated
39	Butterfly	*Pseudozizeeria maha*	Pale Grass Blue	Not evaluated

Sr. No.	Taxa	Scientific Name	Common name	IUCN Status
40		*Borbo cinnara*	Rice Swift	Not evaluated
41		*Graphium agamemnon*	Tailed Jay	Not evaluated

Manthra Canal

A total of 38 faunal species have been recorded from Manthra Canal. Out of these 4 are dragonflies, 3 ants, 19 birds and 12 butterflies. Table 9 below provides the detailed list.

Table 9: Faunal Diversity recorded from Manthra Canal

S.No.	Taxa	Scientific Name	Common Name	IUCN status
1		*Brachithemis contaminata*	Ditch Jewel	LC
2		*Neurothemis tullia*	Pied Paddy Skimmer	LC
3		*Pseudagrion microcephalum*	Blue Grass Dart	LC
4	Dragonfly	*Pantala flavescens*	Wondering Glider	LC
5		*Paratrachina longicornis*	Longhorn Ant	Not evaluated
6		*Anoplolepis gracilipes*	Yellow Crazy Ant	Not evaluated
7	Ant	*Diacamma indicum*		Not evaluated
8		*Ardeola grayii*	Indian Pond-Heron	LC
9		*Corvus splendens*	House Crow	LC
10		*Dicaeum erythrorhynchos*	Pale-billed Flowerpecker	LC
11		*Columba livia*	Rock Pigeon	LC
12		*Eudynamys scolopaceus*	Asian Koel	LC
13		*Acridotheres tristis*	Common Myna	LC
14		*Copsychus saularis*	Oriental Magpie-Robin	LC
15		*Haliastur indus*	Brahminy Kite	LC
16		*Orthotomus sutorius*	Common Tailorbird	LC
17		*Phalacrocorax niger*	Little Cormorant	LC
18		*Dinopium benghalense*	Black-rumped Flameback	LC
19		*Dicrurus macrocercus*	Black Drongo	LC
20		*Passer domesticus*	House Sparrow	LC
21		*Halcyon smyrnensis*	White-throated Kingfisher	LC
22		*Megalaima viridis*	White-cheeked Barbet	LC
23		*Pycnonotus cafer*	Red-vented Bulbul	LC
24		*Milvus migrans*	Black Kite	LC
25		*Cinnyris asiaticus*	Purple Sunbird	LC
26	Bird	*Leptocoma zeylonica*	Purple-rumped Sunbird	LC
27		*Ariadne merione*	Common Castor	Not evaluated
28		*Euploea core*	Common Crow	LC
29		*Catopsilia pomona*	Common Emigrant	Not evaluated
30		*Hasora Bandra*	Common Awl	Not evaluated
31		*Danaus chrysippus*	Plain Tiger	LC
32		*Papilio polytes*	Common Mormon	Not evaluated
33	Butterfly	*Acraea violae*	Tawny Coster	Not evaluated

S.No.	Taxa	Scientific Name	Common Name	IUCN status
34		*Junonia atlites*	Grey Pansy	Not evaluated
35		*Leptosia nina*	Psyche	Not evaluated
36		*Pseudozizeeria maha*	Pale Grass Blue	Not evaluated
37		*Appias lyncida*	Chocolate Albatross	Not evaluated
38		*Athyma perius*	Common Sergeant	Not evaluated

Rameshwaram Canal

A total of 30 faunal species have been recorded from Rameshwaram Canal. Out of these 2 are dragonflies, 4 ants, 17 birds and 7 butterflies. Table 10 below provides the detailed list.

Table 10: Faunal Diversity recorded from Rameshwaram Canal

Sr. No.	Taxa	Scientific Name	Common name	IUCN Status
1		*Pseudagrion microcephalum*	Blue Grass Dart	LC
2	Dragonfly	*Brachythemis contaminata*	Ditch Jewel	LC
3		*Paratrachina longicornis*		Not evaluated
4		*Oecophylla smaragdina*	Asian Weaver Ant	LC
5		*Tapimoma melanocephalum*	Odor Ant	Not evaluated
6	Ant	*Camponotus irritans*	Giant Honey Ant	Not evaluated
7		*Ardeola grayii*	Indian Pond-Heron	LC
8		*Corvus splendens*	House Crow	LC
9		*Dicaeum erythrorhynchos*	Pale-billed Flowerpecker	LC
10		*Columba livia*	Rock Pigeon	LC
11		*Eudynamys scolopaceus*	Asian Koel	LC
12		*Acridotheres tristis*	Common Myna	LC
13		*Copsychus saularis*	Oriental Magpie-Robin	LC
14		*Haliastur indus*	Brahminy Kite	LC
15		*Orthotomus sutorius*	Common Tailorbird	LC
16		*Phalacrocorax niger*	Little Cormorant	LC
17		*Dinopium benghalense*	Black-rumped Flameback	LC
18		*Dicrurus macrocercus*	Black Drongo	LC
19		*Passer domesticus*	House Sparrow	LC
20		*Halcyon smyrnensis*	White-throated Kingfisher	LC
21		*Milvus migrans*	Black Kite	LC
22		*Leptocoma zeylonica*	Purple-rumped Sunbird	LC
23	Bird	Nycticorax nycticorax	Black-crowned Night-heron	LC
24		*Euploea core*	Common Crow	LC
25		*Catopsilia pomona*	Common Emigrant	Not evaluated
26		*Danaus chrysippus*	Plain Tiger	LC
27		*Papilio polytes*	Common Mormon	Not evaluated
28		*Junonia atlites*	Grey Pansy	Not evaluated
29		*Leptosia nina*	Psyche	Not evaluated
30	Butterfly	*Eurema hecabe*	Common Grass yellow	Not evaluated

Pandarachirathodu Canal

A total of 67 faunal species have been recorded from Pandarachirathodu Canal. Out of these 8 are dragonflies, 3 ants, 39 birds, 14 butterflies, 2 fishes and 1 mammal. Table 11 below provides the detailed list.

Table 11: Faunal Diversity recorded from Pandarachirathodu Canal

Sr.No.	Taxa	Scientific Name	Common Name	IUCN status
1		*Bradinopyga geminata*	Granite Ghost	LC
2		*Brachithemis contaminata*	Ditch Jewel	LC
3		*Neurothemis tullia*	Pied Paddy Skimmer	LC
4		*Orthretrum sabina*	Green Marsh Hawk	LC
5		*Gynacantha dravida*	Brown Darner	DD
6		*Ischnura senegalensis*	Senegal Golden Dartlet	LC
7		*Pseudagrion microcephalum*	Blue Grass Dart	LC
8	Dragonfly	*Agriocnemis sp.*		
9		*Paratrachina longicornis*		Not evaluated
10		*Crematogaster sp.*		
11	Ant	*Oecophylla smaragdina*	Asian Weaver Ant	LC
12		*Ardeola grayii*	Indian Pond-Heron	LC
13		*Corvus splendens*	House Crow	LC
14		*Dicaeum erythrorhynchos*	Pale-billed Flowerpecker	LC
15		*Columba livia*	Rock Pigeon	LC
16		*Eudynamys scolopaceus*	Asian Koel	LC
17		*Acridotheres tristis*	Common Myna	LC
18		*Copsychus saularis*	Oriental Magpie-Robin	LC
19		*Haliastur indus*	Brahminy Kite	LC
20		*Orthotomus sutorius*	Common Tailorbird	LC
21		*Phalacrocorax niger*	Little Cormorant	LC
22		*Dinopium benghalense*	Black-rumped Flameback	LC
23		*Dicrurus macrocercus*	Black Drongo	LC
24		*Passer domesticus*	House Sparrow	LC
25		*Psittacula cyanocephala*	Plum-headed Parakeet	LC
26		*Halcyon smyrnensis*	White-throated Kingfisher	LC
27		*Psittacula krameri*	Rose-ringed Parakeet	LC
28		*Megalaima viridis*	White-cheeked Barbet	LC
29		*Cypsiurus balasiensis*	Asian Palm-Swift	LC
30		*Prinia socialis*	Ashy Prinia	LC
31		*Pycnonotus cafer*	Red-vented Bulbul	LC
32		*Vanellus indicus*	Red-wattled Lapwing	LC
33		*Threskiornis melanocephalus*	Black-headed Ibis	NT
34		*Micropternus brachyurus*	Rufous Woodpecker	LC
35		*Apus affinis*	Little Swift	LC
36		*Ardea purpurea*	Purple Heron	LC
37	Bird	*Tachybaptus ruficollis*	Little grebe	LC

Sr.No.	Taxa	Scientific Name	Common Name	IUCN status
38		*Amaurornis phoenicurus*	White-breasted Waterhen	LC
39		*Bubulcus ibis*	Cattle Egret	LC
40		*Egretta garzetta*	Little Egret	LC
41		*Anhinga melanogaster*	Oriental Darter	NT
42		*Phalacrocorax fuscicollis*	Indian Cormorant	LC
43		*Alcedo atthis*	Common Kingfisher	LC
44		*Dendrocygna javanica*	Lesser Whistling-Duck	LC
45		*Acridotheres fuscus*	Jungle Myna	LC
46		*Pelargopsis capensis*	Stork-billed Kingfisher	LC
47		*Milvus migrans*	Black Kite	LC
48		*Cinnyris asiaticus*	Purple Sunbird	LC
49		*Leptocoma zeylonica*	Purple-rumped Sunbird	LC
50		*Cinnyris lotenius*	Loten's Sunbird	LC
51		*Ariadne merione*	Common Castor	Not evaluated
52		*Euploea core*	Common Crow	LC
53		*Appias albina*	Common albatross	Not evaluated
54		*Catopsilia pomona*	Common Emigrant	Not evaluated
55		*Hasora Bandra*	Common Awl	Not evaluated
56		*Danaus chrysippus*	Plain Tiger	LC
57		*Papilio polytes*	Common Mormon	Not evaluated
58		*Acraea violae*	Tawny Coster	Not evaluated
59		*Pareronia valeria*	Common wanderer	Not evaluated
60		*Tirumala limniace*	Blue Tiger	Not evaluated
61		*Junonia atlites*	Grey Pansy	Not evaluated
62		*Parantica aglea*	Glassy Tiger	Not evaluated
63		*Junonia almana*	Peacock pansy	LC
64	Butterfly	*Leptosia nina*	Psyche	Not evaluated
65		*Panchax sp.*		
66	Fish	*Oreochromis mossambicus*	Tilapia	LC
67	Mammal	*Funambulus palmarum*	Three-striped palm squirrel	LC

D. Evaluation Summary for Suitability for Green Infrastructure based Solutions

An overall analysis of the floral diversity shows that the maximum number of species and the minimum proportion of invasives has been documented from Pandarachirathodu (Figure 14).

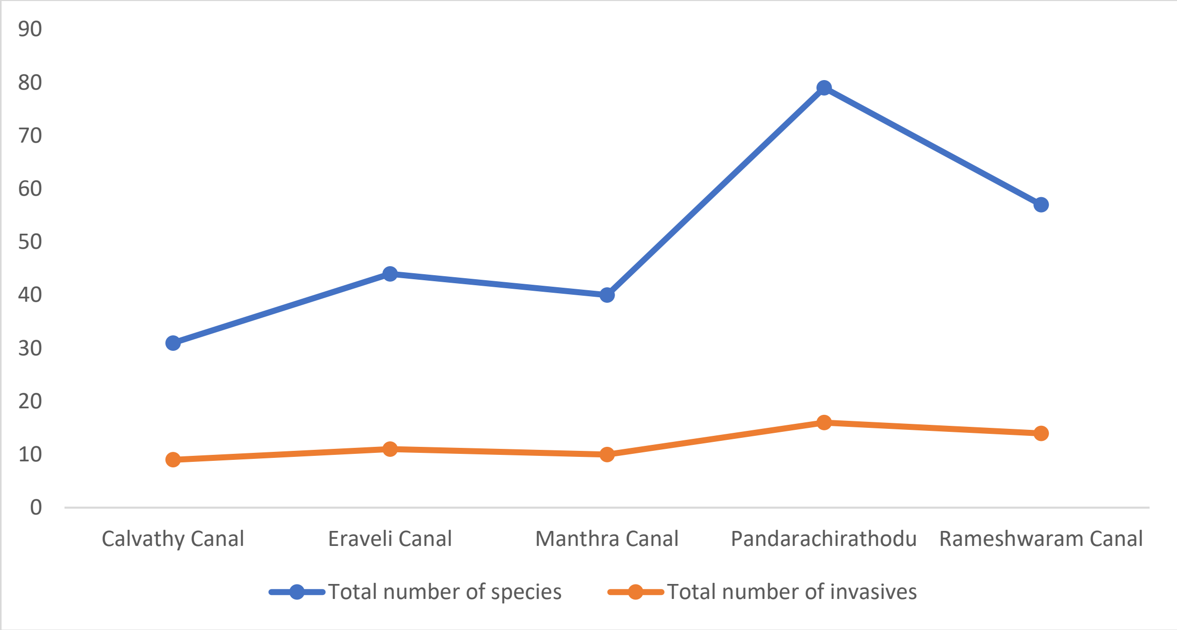


Figure 14: Flora across all canals

In addition, the total number of faunal species recorded from the canals is the highest in Pandarachirathodu canal. Infact, taxa-wise distribution analysis also shows the highest number of species per taxa at Pandarachirathodu canal (Figure 15).

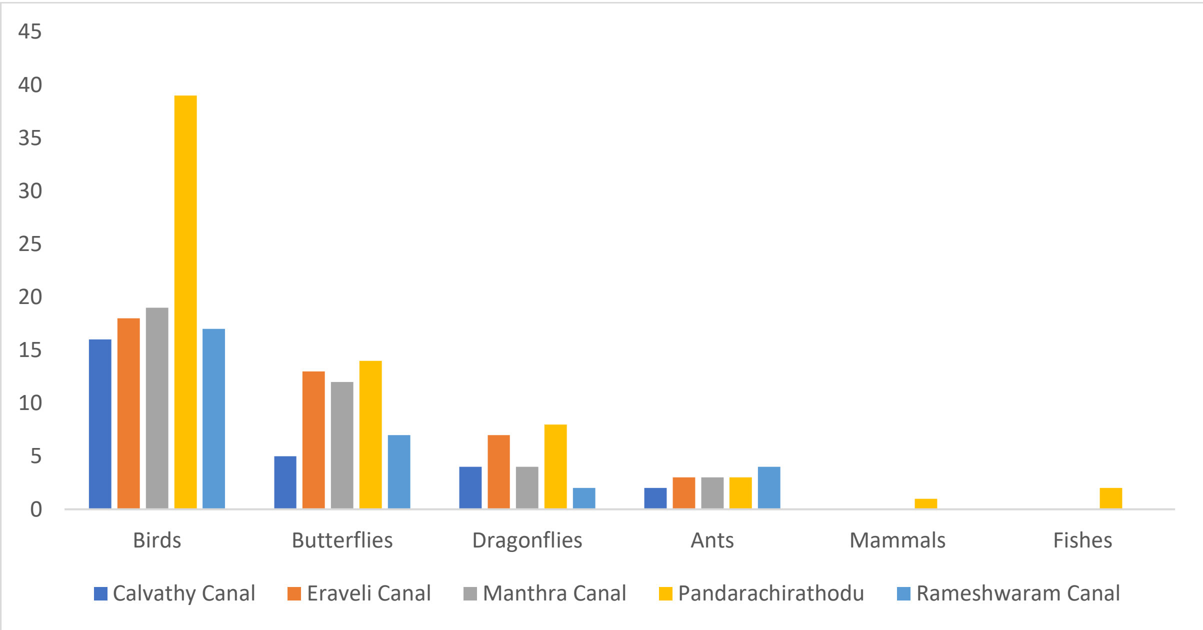


Figure 15: Fauna recorded across all canals

Thus, the detailed biodiversity survey also brings forth Pandarachirathodu canal as the most preferred one for the feasibility study.

High Level GGI Approach

Possible Grey Infrastructure Solutions:

Various options have been identified for the pilot project in Pandarachirathodu canal, based on the site assessment. They include the following:

- Installing a decentralized sewage network and treatment system for a cluster of houses along the bank of the canal so that the current practice of direct disposal of grey wastewater into the canal is stopped. The network can be coupled with a green sewage treatment facility. Phytorid treatment plant is one such promising treatment technique.

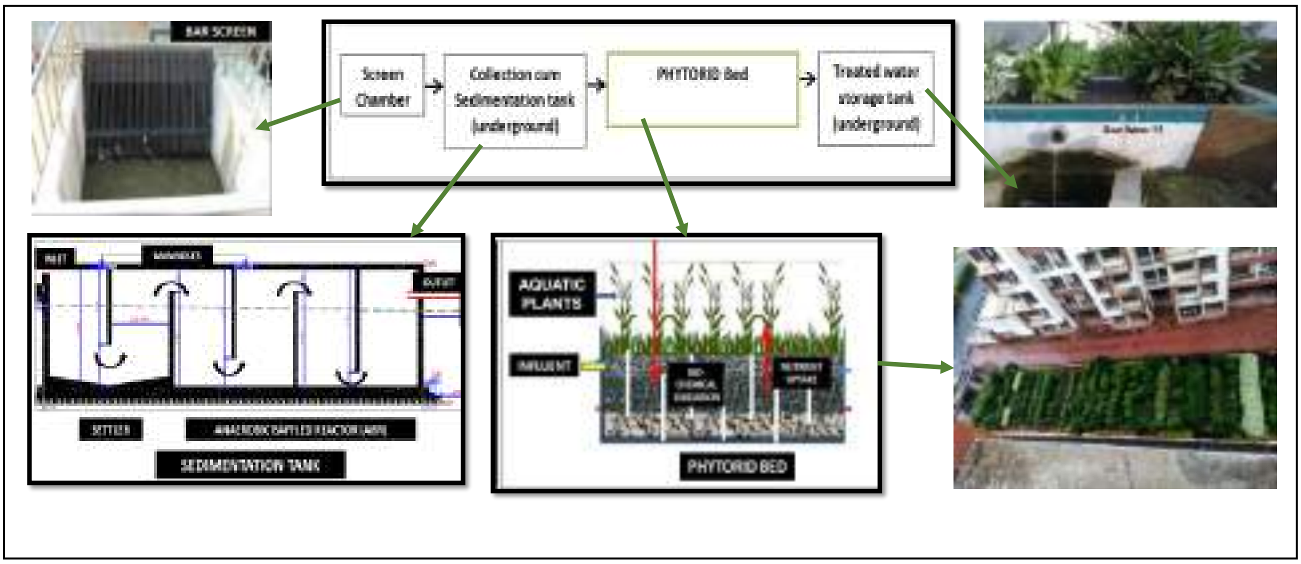


Figure 16: Phytorid technology (Photo Credit: bechtel.org)

The benefits of the Phytorid technology include:

- Cost-effectiveness
- Negligible operation and maintenance cost
- Minimum electricity requirement.
- Smaller footprint with respect to conventional STP
- Facilitates recycle and reuse of water
- No foul odour and no mosquito nuisance.

Almost all individual houses are equipped with septic tanks. However, most of them are potentially dysfunctional and can contaminate ground water. It was also noticed that the grey and the black water is discharged into a single septic tank. Grey water has detergents and is likely to kill the bacteria responsible for aerobic digestion of the sanitary wastes. Hence, it is proposed to have a separate sewage network for grey wastewater as mentioned above and to change the existing septic tanks to anaerobic bio-digester tanks.

- Installation of bar screens/trash screens at the outfall location of the tributary canals so that the solid waste is trapped in the bar screen and does not flow into the pilot canal. The bar screens can be installed at regular intervals of the tributary canal so that it does not flow downstream and can be intermittently cleaned.

Figure 17: Trash Screens (Photo Credit: bechtel.org)

- Installation of separate waste bins for bio-degradable and non-biodegradable waste outside a cluster of houses. The Municipal Corporation is expected to dispose the segregated waste as per Government of India regulations. Suggestions on treatment of bio-degradable waste is provided in the next section.

Figure 18: Solid Waste Management (Photo Credit: bechtel.org)

- Lining of the canals with cement-rubble masonry will provide immediate flood relief on the canal stretch along the Santhom Colony which does not have any lining. This will also improve the canal linings in general along the length of the canal and the canal banks can be used for walkways and other appropriate recreational activities.

Figure 19: Relining of canals (Photo Credit: bechtel.org)

- Replacing lower capacity pipe culverts with higher diameter culverts such that the adequate flow along the culvert is maintained, without causing flow build-up at upstream locations, due to less capacity of the current culverts.

- Development along canal for ecotourism, transportation, fishing etc

- Installation of fence at areas prone to solid waste dumping.

Possible Green Infrastructure Solutions:

- Constructed Wetlands: A constructed wetland is an organic wastewater treatment system that mimics and improves the effectiveness of the processes that help to purify water similar to naturally occurring wetlands. The system uses water, aquatic plants (i.e.: reeds, duckweed), naturally occurring microorganisms and a filter bed (usually of sand, soils and/or gravel). Constructed wetlands can be used for either secondary or tertiary wastewater treatment. Many different designs exist including vertical wetlands, which require less land, but more energy for operations like pumping or siphoning than horizontal wetlands, which can instead rely on gravity and topography. The extensive options in design, materials and technology allow the constructed wetland to be adapted to local conditions and land availability. Costs are dependent on the price of land and materials, but where land is cheaper and widely available, constructed wetlands are a very cost-effective method of wastewater treatment. The general concept is that the plants, microorganisms and substrates together act as a filter and purification system. First, water is slowed as it enters the wetland, allowing for the sedimentation of solids. Through the process of water flow through the constructed wetland, plant roots and the substrate remove the larger particles present in the wastewater. Pollutants and nutrients present in the wastewater are then naturally broken down and taken up by the bacteria and plants, thereby removing them from the water. The retention time in the wetland, which varies depending on the design and desired quality level, along with UV radiation and plant secretion of antibiotics will also kill the pathogens present in wastewater. After treatment in a constructed wetland, water can be safely released into surface waters or used various purposes.

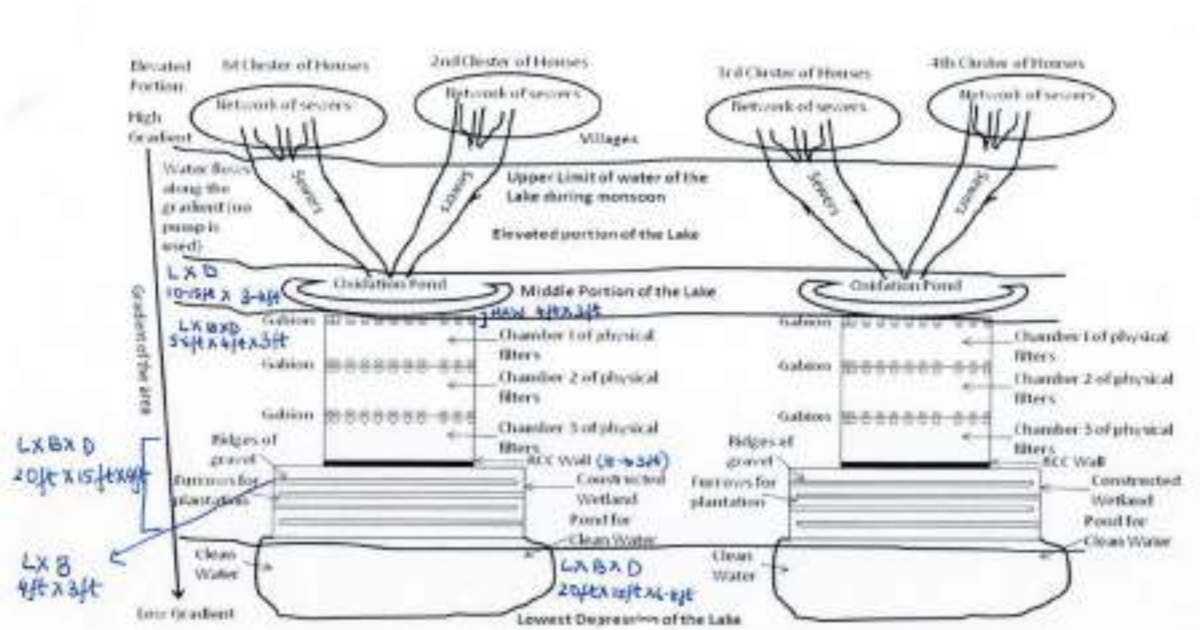


Figure 20: Schematic layout of a Constructed Wetland developed by ICLEI South Asia (Photo Credit: ICLEI South Asia)

Figure 21: Constructed Wetland developed by ICLEI South Asia (Photo Credit: ICLEI South Asia)

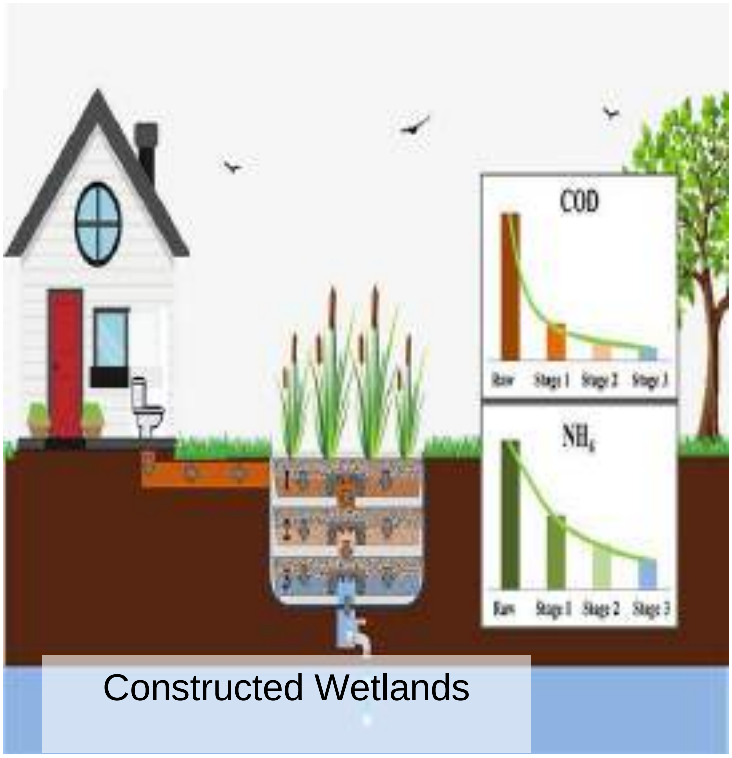


Figure 21: Diagrammatic representation of a Constructed Wetland

- Floating Wetlands: Floating wetlands consist of a suspended matrix planted with wetland plants. This facilitates microbiological and plant processing of nutrients. Floating wetlands work by encouraging settling and biological processing of suspended sediments, particulate and dissolved nutrients and pollutants and also by directing the water through the suspended root mass.

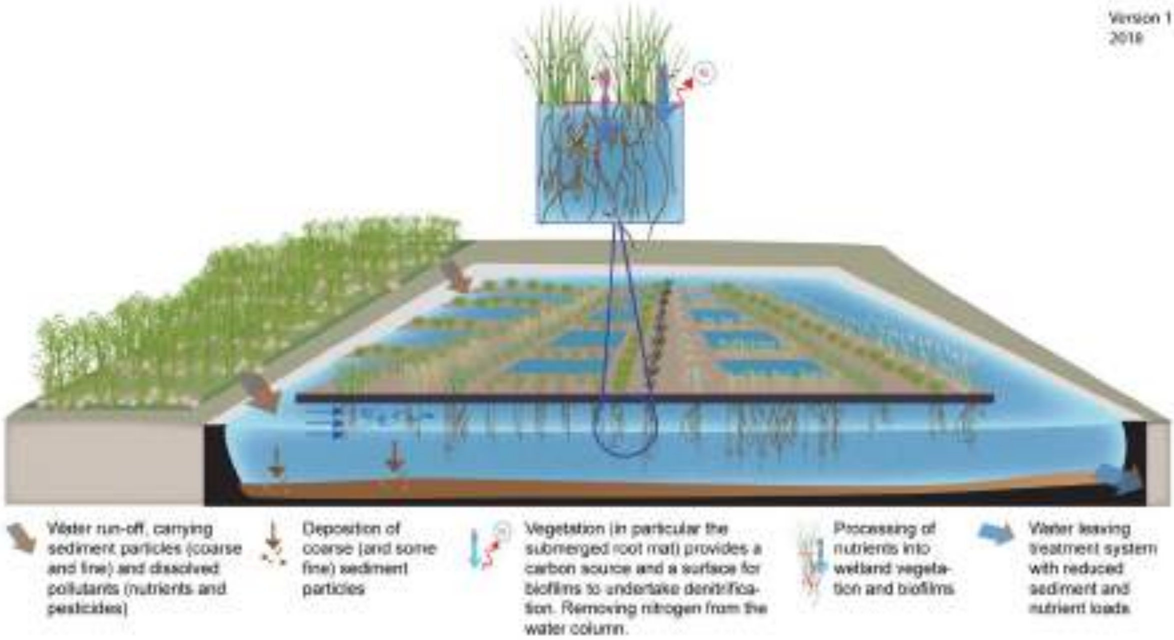


Figure 22: Diagrammatic representation of a Floating Wetland (Source: https://wetlandinfo.des.qld.gov.au/wetlands/management/treatment-systems/for-agriculture/treatment-sys-nav-page/floating-wetlands/)

Figure 23: A Floating Wetland in Neknampur Lake (Photo Credit: Madhulika Choudhary)

- Biological Treatment of Weeds: There are known methods of biological treatment of weeds and invasives. *Eichhornia crassipes,* water hyacinth ranks first among the noxious floating macrophytic hydrophytes. *Neochetina eichhorniae* and *N. bruchi* are reported to be effective bio-control agents against water hyacinth.

Figure 23: Neochetina eichhorniae has been used to successfully control water hyacinth in Hebbal Lake (Photo Source: Google)

- Bioremediation: This technique employs the use of living organisms, like microbes and plants, for the removal of contaminants, pollutants, and toxins from soil, water, and other environments. Several plants like *Canna* sp. have been successfully used for bioremediation of water bodies.

Figure 24: Canna sp. has been used successfully for bioremediation (Photo Source: Google)

- Treatment of biodegradable waste: Compositing and biomethanation are two successful techniques to treat the biodegradable waste. ICLEI South Asia has successfully developed several wards in many cities (like Siliguri, Coimbatore, Udaipur, Gangtok, Rajkot) as zero waste wards through household level segregation of waste. The biodegradable waste generated is processed through biomethanation or through development of compost using an organic waste composter.

- Establishment of mangroves along the canal banks: Centuries back, mangroves used to be present along the canal banks and this entire area. Mangroves act as a natural defence against the impacts of climate change and also provide livelihood. A significant proportion of the fishermen population of Kochi is dependent on mangroves. A study carried out by ICLEI South Asia (2020) shows that regular inland fishermen of the area receive an average benefit of ₹124,000 per annum from mangrove ecosystem. An overall estimation, using data from samples across the mangrove areas of 2.47 km^2 (247 hectares) within Kochi Municipal Corporation and adjacent areas, show a total fisheries ecosystem services generation worth ₹1.7 million per annum per ha ($24,100/ha/yr) from mangroves. ICLEI South Asia is also developing an investment case on mangrove in Kochi.

Figure 25: Locations like these along the canals are ideal spots for mangrove plantation (Photo Credit: ICLEI South Asia)

Discussions with City Council and Other Stakeholders

The methodology followed, framework, data collected and the analysis thus carried out was presented to the Hon'ble Mayor, relevant ward councillors and other stakeholders (refer Annexure 10) in a meeting on 13th June 2022 at Kochi Municipal Corporation. The meeting was highly interactive. The Hon'ble Mayor and other dignitaries agreed to the work carried out and the results obtained and gave their consent to initiate the feasibility study for Pandarachirathodu Canal.

Figure 26: Presentation made at Kochi Municipal Corporation (Photo Credit: ICLEI South Asia)

Way Forward

The canal for the feasibility study has been identified. The immediate next steps include the selection of a site, within Pandarachirathodu Canal, for where the pilot high level Green Grey Infrastructure solution will be developed. In order to identify the pilot section, some more detailed field studies, ward level community consultations, household level survey (focussing on solid waste management and sewage management), chemical analysis of the water (BOD, COD, pH, nitrate, turbidity, phosphate etc) will be carried out. Once the pilot section in identified, the high level Green Grey Infrastructure design will then be developed for the same and the detailed feasibility study will be undertaken.

Annexure 1: Selection Critieria

<table>
<tr><th>CRITERIA</th><th>PARAMETERS AND DATA FOR SELECTION CRITERIA</th></tr>
<tr><td>FLOOD RESILIENCE</td><td>Topography and land use
Will include different land use topology such as urban, suburban, and rural.
Drainage area (part of the adjacent residential and other areas draining in the canal)
Hydrology - Information on past flooding events
Rainfall data
Flooding from monsoon rains
Flooding from cyclone storm surge in combination with high tide
Hydraulics
Minimum water depth and width (by section as it may vary along the length of the canal)
Information on any obstructions (large objects, trash etc.) blocking water flow
Capacity of the canal to convey the 1, 5 and 10-year runoff
If the canal cannot carry the 1, 5 and 10-year runoff without overflowing, calculate the required minimum depth and width by section, so the canal can carry these flows
Estimate dredging requirements
Sedimentation
Erosion and sediment transport into the canal from adjacent areas - Explore erosion control measures to avoid future siltation of the canal
Demography
Number of people benefitting from reduced flood risk for a 1-, 5- and 10-year return period.</td></tr>
<tr><td>WATER QUALITY</td><td>Parameters
Water quality data
Any analytical data from water samples
Information on odors
Information on algae
Aquatic life - Fish and other species
Have there been any incidents of waterborne diseases along the canal
Demography
A social characterization of the population living along the canal (the area of direct project influence will be considered as part of the criteria for selection of pilot project.
Do any people living close to the canal depend on groundwater for different household uses</td></tr>
</table>

CRITERIA	PARAMETERS AND DATA FOR SELECTION CRITERIA
	Liquid waste disposal • Map points of wastewater discharge (if any) into the canal • Identify small shops and other operations along or near the canal using any hazardous or toxic chemicals and document how they dispose of them
TRANSPORTATION	• Usage for movement of people and/or goods along its length • Type and size of boats using the canal (now and in the future)
FUTURE OPPORTUNITIES	• Potential for other uses (e.g., eco-tourism) • Fishing (people's livelihood)
FINANCIAL FEASIBILITY	Cost- benefit analysis with regard to the business-as-usual scenario.
VULNERABILITY ASSESSMENT	ICLEI has a well-defined process (ICLEI ACCCRN Process) for vulnerability assessment.
BIODIVERSITY DOCUMENTATION	Survey along each canal to document various taxa (plants, birds, fish, butterflies, spiders etc). These will then be classified as native and non-native. The presence of any RET (Rare, Endangered and Threatened) species will also be documented.
LAND USE	Remote Sensing and GIS analysis (LULC analysis)
ACCESSIBLITY	Primary data collection; Discussions with officials and stakeholders
ONGOING/PLANNED SCHEMES	Discussions with officials of the city corporation and other relevant line departments
DEMOGRAPHY	Data on population density, household density (from municipal records and Census)- will help to identify land with more open area (for the GGI) available

Annexure 2: Evaluation Criteria

Criterion 1	Flooding
Description	The canals to be evaluated for their potential to reduce flooding in the community.
Basis	The capacity of the canals to carry runoff from adjacent areas to the sea has been reduced due to siltation and the disposal of solid waste and other materials. This can cause overflow and flooding of the surrounding areas during storms. The canals must be dredged and cleaned to increase their discharge capacity. The required depth and width of the canals will be determined based on the desired level of flood risk reduction in the community.
Utility Function	The canals will be evaluated for their probable maximum flood potential reduction using historical rainfall and storm surge data from local and international sources, as well from information on historic flooding in the area. The drainage area of each canal will be delineated and the extent of flooding under present conditions will be assessed for the maximum annual, 2-year and 5-year event. The number of households within the flooded zone for each of these events will estimated.
Component 1 - Monsoon flooding	
5	>3.5K houses affected by flood
4	2K-3.5K houses affected by flood
3	1K-2K houses affected by flood
2	< 1K houses affected by flood
1	No houses affected
Component 2 - Strom Surge/Monsoon flooding due to low lying area for an avergae flood depth of 1m	
5	> 15 Ha of land flooded
4	10 Ha - 15 Ha of land flooded
3	5 Ha - 10Ha of land flooded
2	1 Ha - 15Ha of land flooded
1	< 1 Ha of land flooded

Criterion 2	**Pollution**
Description	The canals will be evaluated for the extent of pollution.
Basis	The canals have been contaminated by domestic wastewater and discharges from commercial operations (car wash shops, slaughterhouse, fish and meat markets, and others), and potentially by unlined septic tanks in households close to the canals
Utility Function	The canals will be evaluated for their probable potential to reduce pollution effects. The water quality in each canals will be assessed in terms of different pollutants, such as heavy metals, hydrocarbons, the pH of the water, the level of dissolved oxygen and the frequency of algal blooms caused by higher levels of nutrients (nitrogen and phosphorus) in the water. In addition potential pollution source swill be identified.
Component 1 - How is the solid waste managed by the houses along the canal	
5	>250 houses dumping solid wastes directly into the canal
4	200 to 250 houses dumping solid wastes directly into the canal
3	150 to 200 houses dumping solid wastes directly into the canal
2	50 to 150 houses dumping solid wastes directly into the canal
1	<50 houses dumping solid wastes directly into the canal
Component 2 - How is sewage managed by houses along the canal: Direct Discharging	
5	>250 houses dumping solid wastes directly into the canal
4	200 to 250 houses dumping solid wastes directly into the canal
3	150 to 200 houses dumping solid wastes directly into the canal
2	50 to 150 houses dumping solid wastes directly into the canal
1	<50 houses dumping solid wastes directly into the canal
Component 3 - How is sewage managed by houses along the canal: Probable leakage through disfunctional septic tank	
5	>750 houses having disfunctional septic tanks
4	600 to 750 houses having disfunctional septic tanks
3	450 to 600 houses having disfunctional septic tanks
2	150 to 450 houses having disfunctional septic tanks
1	<150 houses having disfunctional septic tanks
Component 4 - Probability of grey waste being discharged in the canal	
5	>1000 houses probability of discharging grey wastes directly into the canal
4	800 to 1000 probability of discharging grey wastes directly into the canal
3	600 to 800 probability of discharging grey wastes directly into the canal
2	200 to 600 probability of discharging grey wastes directly into the canal
1	<200 probability of discharging grey wastes directly into the canal
Component 5 - Probability of pollutants entering into the canals other than households: Fish & Meat Markets/Other Markets	
3	>5 establishments
2	2 to 5 establishments
1	1 establishment
Component 6 - Probability of pollutants entering into the canals other than households: Car washes	
3	>3 establishments
2	2 establishments
1	1 establishment

Criterion 3	Transportation
Description	The canals will be evaluated for their importance in transporting goods and people.
Basis	The depth of the canals has been reduced by silting and different objects dumped in the canals make it difficult for boats to move along.
Utility Function	The canals will be evaluated for their opportunities to improve the movement of boats by dredging them and removing objects blocking navigation.
Component 1 - Transportation of people	
4	More than 20 people use boats to move along the canal every day; more than 20 fishermen use the canal to go from their homes to the ocean every day
3	11 to 20 people use boats to move along the canal every day; 11 to 20 fishermen use the canal to go from their homes to the ocean every day
2	6 to 10 people use boats to move along the canal every day; 6 to 10 fishermen use the canal to go from their homes to the ocean every day
1	1 to 5 people use boats to move along the canal every day; 1 to 5 fishermen use the canal to go from their homes to the ocean every day
0	Nobody uses the canal for transportation; no fishermen use the canal to go from their homes to the ocean
Component 2 - Fishermen moving daily from their houses to the ocean	
5	Above 20 small fishing boats
4	Between 11 to 20 small fishing boats
3	Between 6 to 10 small fishing boats
2	Between1 to 5 small fishing boats
1	0 small fishing boats

Criterion 4	Future opportunities
Description	The canals will be evaluated for potential opportunities to contribute to the local economy
Basis	The canals could be used to showcase points of historic or local culture interest, as well as the local flora and fauna of interest to ecotourists
Utility Function	The canals will be evaluated for their opportunities they offer for tourist development
Component 1 - Tourist points of interest along the canal	
5	More than 4 points of historic or local culture interest along the rout of the canal and more than 4 points of ecotourism interest
4	3 points of historic or local culture interest along the route of the canal, and/or 3 points of ecotourism interest
3	2 points of historic or local culture interest along the route of the canal, and/or 2 points of ecotourism interest
2	1 point of historic or local culture interest along the route of the canal, and/or 1 point of ecotourism interest
0	No points of historic or local culture interest along the route of the canal, and/or no points of ecotourism interest
Component 2 - Potential for footpath creation (10m to 20m width required)	
5	Potential length of canal that can be used for new footpath (width of 10 to 20m) or parks ≥ 1000 m
4	Potential length of canal that can be used for new footpath (width of 10 to 20m) or parks between 500 m to 1000 m
3	Potential length of canal that can be used for footpath (width of 10 to 20m) or parks between 250 m to 500 m
2	Potential length of canal that can be used for footpath (width of 10 to 20m) or parks between 100 to 250 m

1	Potential length of canal that can be used for footpath (width of 10 to 20m) or parks < 100 m
Component 3 - Potential for recreational area creations (50m minimum width required)	
5	Potential length of canal that can be used for creation of recreation spots (50m width minimum) or parks ≥ 250 m
4	Potential length of canal that can be used for creation of recreation spots (50m width minimum) or parks 150 m - 250 m
3	Potential length of canal that can be used for creation of recreation spots (50m width minimum) or parks between 100 m to 150 m
2	Potential length of canal that can be used for creation of recreation spots (50m width minimum) or parks between 50 m to 100 m
1	Potential length of canal that can be used for creation of recreation spots (50m width minimum) or parks <50
Component 4 - Potential for Fishing	
5	Potential length of canal that can be used for fishing ≥ 1000 m
4	Potential length of canal that can be used for fishing 500 m - 1000 m
3	Potential length of canal that can be used for fishing 250 m - 500 m
2	Potential length of canal that can be used for fishing 100 m to 250 m
1	Potential length of canal that can be used for fishing <100 m
Component 5 - Potential for Eco Tourism	
5	Potential length of canal that can be used as potential for ecotourism ≥ 1000 m
4	Potential length of canal that can be used as potential for ecotourism 500 m - 1000 m
3	Potential length of canal that can be used as potential for ecotourism 250 m - 500 m
2	Potential length of canal that can be used as potential for ecotourism 100 m - 250 m

Criterion 5	Feasibility
Description	The canals will be evaluated in terms of the feasibility of a restoration project
Basis	The success of a canal restoration project depends on the support of the municipality for dredging, community support for the project and the availability of financing for its execution
Utility Function	The canals will be evaluated for their opportunities they offer for tourist development
Component 1 - Probability of canal dredging	
5	It highly likely that the Kochi Municipal Corporation will dredge the selected canal to the extent determined by the restoration study.
4	It likely that the Kochi Municipal Corporation will dredge the selected canal to the extent determined by the restoration study.
3	It is somewhat likely that the Kochi Municipal Corporation will dredge the selected canal to the extent determined by the restoration study.
2	It is somewhat unlikely that the Kochi Municipal Corporation will dredge the selected canal to the extent determined by the restoration study.
1	It highly unlikely that the Kochi Municipal Corporation will dredge the selected canal to the extent determined by the restoration study.
Component 2 - What is the demonstrability time frame?	
5	Demostrable within 8 to 12 months
3	Demostrablewithin 12 to 18 months
1	Demonstrable beyond 18 months
Component 3.1 - Land around canal	
5	80%-100% of length of canal is accessible from the road for cleaning purposes
4	60%-80% of length of canal is accessible from the road for cleaning purposes

3	40%-60% of length of canal is accessible from the road for cleaning purposes
2	20%-40% of length of canal is accessible from the road for cleaning purposes
1	0%-20% of length of canal is accessible from the road for cleaning purposes
Component 3.2 - Availability of land for treatment plant	
5	Available above 5 ha of free land at a considerable distance from settlement
4	Available between 4ha- 5ha of free land at a considerable distance from settlement
3	Available between 3ha- 4ha of free land at a considerable distance from settlement
2	Available between 2ha- 3ha of free land at a considerable distance from settlement
1	Available between 1ha- 2ha of free land at a considerable distance from settlement
Component 3.3 - Percentage of length where widening of canal is possible	
5	80%-100% of length of canal where widening of canal is possible
4	60%-80% of length of canal where widening of canal is possible
3	40%-60% of length of canal where widening of canal is possible
2	20%-40% of length of canal where widening of canal is possible
1	<20% of length of canal where widening of canal is possible
Component 4 - Length of the canal where pontoon mounted dredgers can be deployed	
5	Above 1.0 kM of length available for pontoon deployment
3	0.5 to 1.0 kM of length available for pontoon deployment
Component 5 - Requirement for foot bridges demolition or reconstruction	
5	0 to 10 foot bridges to be demolished or reconstructed.
4	10 to 20 foot bridges to be demolished or reconstructed.
3	20 to 30 foot bridges to be demolished or reconstructed.
2	30 to 40 foot bridges to be demolished or reconstructed.
1	Above 40 foot bridges to be demolished or reconstructed.
Component 6 - Impact for connecting Canal on Upstream and downstream side	
5	Above 2.5 kM of connecting canal
4	1 to 2 kM of connecting canal
3	0.5 to 1 kM of connecting canal
2	0 to 0.5 kM of connceting canal
1	No connecting Canal

Annexure 3: Stakeholder Discussions

Discussions with Ms Sindhu Kumari, Assistant Executive Engineer, Department of Irrigation

Date: 25th May 2022; Venue: Office of the Department of Irrigation

Ms Sindhu and her team had undertaken a survey of Rameshwaram-Manthra-Kalvathy canals and shared the survey data with the team. The depth, as reflected in the survey data was calculated up to the top of silt deposit of the canals. The discussions revealed that dredging in the stretch from Manthra bridge to Rameshwaram was carried out in the first week of July 2021. Dredging in the rest of the stretch from Manthra bridge to Eruveli was due to start by 2nd week of June 2022. Desilting was carried out using earthmover vehicles mounted on pontoons. However, the same could not be conducted at locations where there was no road access or in stretches which lay in between houses. The Department of Irrigation stated that 70% of the silt has been removed. The major challenge in desilting was found in the Manthra region, due to the high density of houses, making the canal inaccessible. The canal, as far as the records of the Department of Irrigation state, has never overflowed.

Meeting with Ms Sindhu Kumari and other officials (Photo Credit: bechtel.org)

Discussions with Mr. Ajith Nair, General Manager, Kochi Metro Rail Limited

Date: 26th May 2022; Venue: KMRL Office

A survey of the canals in Kochi has been carried out by Mr Ajith Nair and his team. They have the Lidar data for Rameshwaram, Manthra and Kalvathy canals and are willing to share the same, once a formal request letter from the city is sent to them. The discussions revealed that the present Sewage Treatment Plant has a capacity of 3 MLD and the city needs STPs which can all together handle 112 MLD of sewage. Mr Nair also stated that the canals date back to the 16th century and lithomaps indicating the original size of the canals in Fort Kochi may be available at the state archival, located at Trivandrum. The soffit level of these canals is now below sea level, due to sea level rise. This is also a reason for the flooding of the canals. The existence of a city drainage master plan could not be confirmed by Mr Nair.

Meeting with Mr Ajith Nair (Photo Credit: ICLEI South Asia)

Discussions with Ms. Raji R., General Manager, Cochin Smart Mission Limited

Date: 26th May 2022; Venue: CSML Office

The discussions revealed that a Sewage Treatment Plant (with an overall project cost of INR 1,660 million) was proposed near Kalvathy canal but could not be implemented due to community protests. Media reports state that the protests were made by the community due to non-agreement on the site for the establishment of the STP. She agreed to share the proposed schematic for sanitary waste network of Fort Kochi. The proposed STP plan was prepared for wards 1 to 5, to cater to round 5,000 houses. A vacuum sewerage system with four pump stations was proposed as part of this STP.

Discussions with Mr Praveen Lal, Assistant Executive Engineer, Department of Irrigation

Date: 27th May 2022; Venue: Telephonic Discussion

Mr Praveen Lal stated that the Department of Irrigation had conducted a survey of the Pandarachirathodu canal. He shared the details of the same and pointed out three major points of clogging in the canal which will need to be cleared during implementation of the project.

Discussions with Dr Sunny George, Director, SCMS Water Institute

Date: 16th May 2022; Venue: Telephonic Discussion

Dr Sunny George had led survey and mapping activities at Thevara – Perandoor canal in Kochi. He provided valuable insights into general issues with regard to the canals in Kochi.

Discussions with Community Members

Date: 25th May 2022; Venue: Santhom Colony

Discussions with some of the community members, residing in Santhom Colony revealed that frequent flooding of their houses (with the water level rising to as high as 2 feet above ground level) during incidences of heavy rain is the major issue. This colony also has several critically ill patients (suffering from cancer, having undergone open heart surgery) residing. Frequent flooding adds to their hardships.

Discussions with some Community Members (Photo Credit: bechtel.org)

Annexure 4: Relevant Canal Information

Table 1: Houses within 250m of Canal						
Canal	**Passing through Ward**	**Total Area of Ward (sq.m)**	**250m wide Influence Area of Canal (sq.m) (Measured in Google Earth)**	**Total Household in the Ward (Ref. Second Project Progress Report & Census 2011)**	**No. of Household coming within 250m Influence (Ward Wise)**	**Total Affected Houses Canal Wise**
Kalvathy	2	3,82,069	1,45,662	1,652	630	**630**
Eruveli	2	3,82,069	33,323	1,652	144	**948**
	3	2,47,060	1,13,107	1,282	587	
	4	4,85,115	52,599	2,003	217	
Manthra	2	3,82,069	12,050	1,652	52	**2,718**
	4	4,85,115	1,09,828	2,003	453	
	7	6,12,301	82,423	2,012	271	
	8	7,16,129	79,257	2,810	311	
	27	7,61,619	1,94,658	1,754	448	
	28	4,89,426	2,44,713	2,364	1,182	
Rameshwaram	8	7,16,129	3,18,436	2,810	1,250	**3,956**
	10	5,85,789	2,92,895	1,815	908	
	11	9,49,931	1,91,543	2,342	472	
	24	5,74,630	1,71,104	2,041	608	
	25	4,34,273	1,88,945	1,653	719	
Pandarachira	11	9,49,931	1,45,620	2,342	359	**3,288**
	12	15,21,961	1,16,250	2,201	168	
	22	8,49,004	5,11,500	3,899	2,349	
	24	5,74,630	1,16,000	2,041	412	

Table 2: Houses along the length of the canal										
Canal	**No. of houses right on the bank of the canal having high potential to dump solid & liquid wastes directly into the canal (nos)**			**90% of the household**	**Canal Length (m)**	**Hospitals / Institutions**	**Fish/ Meat Market**	**Carwash**	**Market / shopping mall**	**High Rises**
	Mid to high income group houses	**Low income group houses**	**Total No. of household discharging into the canal**							
Kalvathy	26.00	42.00	44.00	**61.20**	760.00	**3.00**				**1.00**
Eruveli	14.00	118.00	100.00	**118.80**	980.00					**2.00**
Manthra	33.00	227.00	194.80	**234.00**	1,848.00	**1.00**			**2.00**	
Rameshwaram	42.00	325.00	276.80	**330.30**	3,254.00	**3.00**	**2.00**	**2.00**	**4.00**	**1.00**
Pandarachirathodu	18.00	206.00	172.00	**201.60**	2,364.00	**1.00**				**11.00**

Table 3: Potential Flood Area			
Canal	**Area adjacent to the canal that can come under flooding for a flood elevation of 3m (hectares)**		**Canal Length (m)**
Kalvathy	-		760.00
Eruveli	**0.50**		980.00
Manthra	-		1,848.00
Rameshwaram	**0.75**		3,254.00
Pandarachirathodu	**18.58**		2,364.00

Table 4: Land available adjacent to Canal Banks												
Canal	**Length of the canal having 10m space abutting the canal bank**		**Length of the canal having 20m space abutting the canal bank**	**Length of the canal having 50m space abutting the canal bank**		**Length of the canal having 100m space abutting the canal bank**		**Canal Length (m)**	**Total**	**% Canal length where a free space is available abutting the canal banks**	**Length of Canal not Accessible (m)**	**% of Canal length Accessible from road**
	One Side of the Canal	**Both side of the canal**	**One Side of the Canal**	**One Side of the Canal**	**Both side of the canal**	**One Side of the Canal**	**Both side of the canal**					
Kalvathy	-	-	-	-	-	-	-	760	-	**-**	139	**82**
Eruveli	48	-	48	48	-	-	-	980	144	**0**	196	**80**
Manthra	46	-	46	-	-	-	-	1,848	92	**0**	870	**53**
Rameshwaram	270	-	195	-	-	-	-	3,254	465	**0**	2,024	**38**
Pandarachira	503	-	279	128	-	-	-	2,364	910	**0**	479	**80**

Table 5: Space Available for Utilities				
Canal	**Potential Length - fishing (m)**	**Length of Canal where Pontoons can be deployed (m)**	**Availability of Space for installing STP**	
			Ward No.	**Available Area (Ha)**
Kalvathy	**35**	-	NA	NA
Eruveli	**423**	-	NA	NA
Manthra	**-**	-	27	**3**
Rameshwaram	**255**	-	NA	NA
Pandarachirathodu	**1,312**	**1,312**	22	**5**

Table 6: No of foot bridges to be demolished/ reconstructed	
Canal	**No. of Foot Bridges**
Kalvathy	**2**
Eruveli	**7**
Manthra	**25**
Rameshwaram	**30**
Pandarachirathodu	-

Table 7: Impact of Connecting Canals					
Canal	Length of connecting canal impacting U/S of the concerned canal		Length of connecting canal impacting D/S of the concerned canal		Canal Length (m)
	Canal Name	Length (m)	Canal Name	Length (m)	
Kalvathy	NA	NA	Eruveli	95	760
Eruveli	Manthra	**1,848**	NA	NA	980
	Kalvathy	**760**	NA	NA	
Manthra	Kuriplavu Branch Canal	**580**	Eruveli	980	1,848
			Kalvati	760	
Rameshwaram	Part of Pandarachirathodu Canal	**233**	NA	NA	3,254
Pandarachirathodu	Pandarachirathodu (Half conecting to Rameshwaram)	**231**	NA	NA	2,364
	Pandarachirathodu Branch Canal	**520**	NA	NA	
	Athipohzi Canal	**1,630**	NA	NA	

ERNAKULAM DISTRICT

KOCHI TALUK

1 in 10 YEAR (Historic)			
Sl No	LSG	Flood Inundation Area (Km2)	Max. Flood Level (m)
1	Chellanam	14.62	3.12
2	Cochin Corporation	3.88	3.09
3	Edavanakkad	3.34	2.39
4	Elankunnapuzha	3.08	2.24
5	Kadamakudy	11.10	4.33
6	Kumbalanghi	3.44	3.12
7	Kuzhuppilly	2.94	4.93
8	Mulavukad	9.61	2.51
9	Narakal	2.75	1.18
10	Nayarambalam	5.51	1.16
11	Pallippuram	5.37	6.73

1 in 25 YEAR (Historic)			
Sl No	LSG	Flood Inundation Area (Km2)	Max. Flood Level (m)
1	Chellanam	15.25	3.5
2	Cochin Corporation	4.08	3.5
3	Edavanakkad	4.33	3.27
4	Elankunnapuzha	3.42	2.54
5	Kadamakudy	13.02	8.09
6	Kumbalanghi	3.69	3.5
7	Kuzhuppilly	3.28	5.66
8	Mulavukad	9.82	2.83
9	Narakal	2.81	1.29
10	Nayarambalam	5.54	2.33
11	Pallippuram	5.75	7.12

1 in 50 YEAR (Historic)			
Sl No	LSG	Flood Inundation Area (Km2)	Max. Flood Level (m)
1	Chellanam	15.59	3.59
2	Cochin Corporation	4.17	3.6
3	Edavanakkad	5.34	3.93
4	Elankunnapuzha	3.62	2.75
5	Kadamakudy	13.94	8.2
6	Kumbalanghi	3.71	3.6
7	Kuzhuppilly	3.51	6.17
8	Mulavukad	10.01	3.86
9	Narakal	2.85	1.37
10	Nayarambalam	6.01	2.87
11	Pallippuram	5.99	7.31

1 in 100 YEAR (Historic)			
Sl No	LSG	Flood Inundation Area (Km2)	Max. Flood Level (m)
1	Chellanam	19.35	5.15
2	Cochin Corporation	4.24	3.7
3	Edavanakkad	6.22	5.17
4	Elankunnapuzha	3.76	2.86
5	Kadamakudy	14.69	8.31
6	Kumbalanghi	3.90	3.87
7	Kuzhuppilly	3.78	6.55
8	Mulavukad	10.23	5.23
9	Narakal	2.87	1.47
10	Nayarambalam	7.25	3.44
11	Pallippuram	6.77	7.57

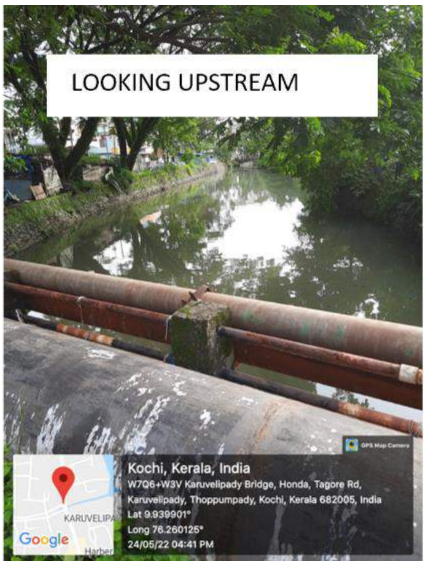
1 in 200 YEAR (Historic)			
Sl No	LSG	Flood Inundation Area (Km2)	Max. Flood Level (m)
1	Chellanam	19.73	5.33
2	Cochin Corporation	4.30	3.8
3	Edavanakkad	6.54	5.52
4	Elankunnapuzha	3.96	2.91
5	Kadamakudy	15.26	8.42
6	Kumbalanghi	4.08	4.18
7	Kuzhuppilly	3.90	6.75
8	Mulavukad	10.56	6.01
9	Narakal	3.13	2.24
10	Nayarambalam	7.93	3.82
11	Pallippuram	6.87	7.65

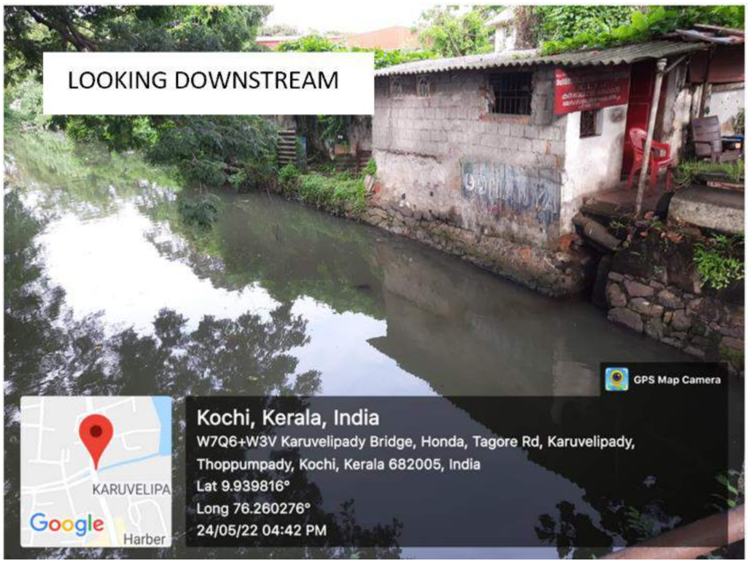
1 in 500 YEAR (Historic)			
Sl No	LSG	Flood Inundation Area (Km2)	Max. Flood Level (m)
1	Chellanam	20.19	5.62
2	Cochin Corporation	4.31	3.9
3	Edavanakkad	6.90	6.13
4	Elankunnapuzha	4.26	3.11
5	Kadamakudy	15.62	8.76
6	Kumbalanghi	4.20	4.45
7	Kuzhuppilly	4.01	7.16
8	Mulavukad	10.68	6.36
9	Narakal	3.16	2.86
10	Nayarambalam	8.21	4.23
11	Pallippuram	7.00	7.77

Annexure 5: Field Survey

24th May 2022

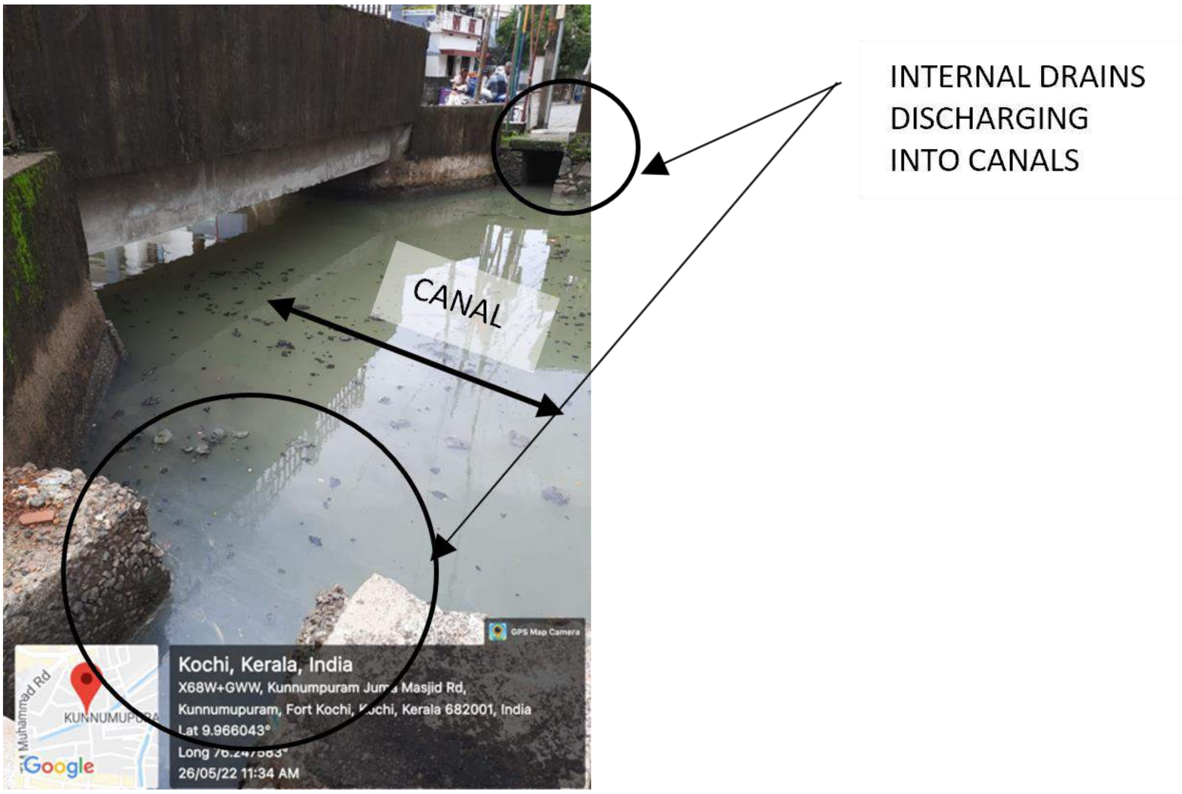
- Karuvelipady, near the mouth of Rameshwaram canal was visited first.





- Submerged drinking water pipes were found to be running along and across the canals and in some places, plastic waste in the canal was found wrapped around these pipes blocking the flow through the canal thereby making it stagnant. As these pipes carry drinking water, potential contamination is also possible.

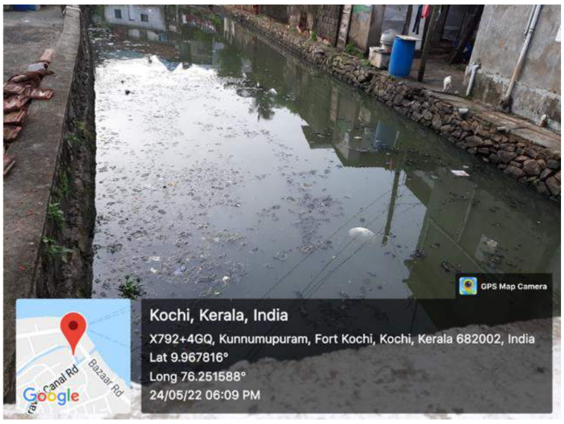
- Encroachments along the canal was also very clearly seen at various places, leading to reduced width of the canal thereby decreasing the discharge capacity.
- At all places along the length of the canal, grey water was seen being directly discharged into the canals from households adjoining the canals.
- Considerable amount of waste was seen floating in the canal and the colour of the water was black.
- Storm water drains were seen on either side of the of main roads. On narrower roads the drains were provided only on one side. These drains were trenches covered with precast slabs. These storm water drains appeared to be clogged at most places.
- While engaging with some of the local people to understand their issues, we were told that every heavy rainfall leads to their houses being flooded due to water not being able to flow down through the drain. As per the local community, overflowing from canals had not occurred.
- All storm water drains were found to be connected to the canal.



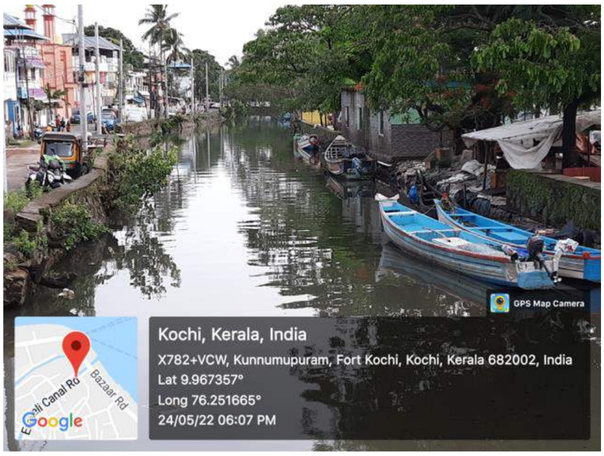
- Carwash and workshop were seen along Rameshwaram canal.
- There are numerous unauthorized low lying foot bridges constructed across the canal throughout its length which could potentially create hinderance/blockages to the flow during heavy rains.

- Fences were found to be provided along the length of the canal at Rameshwaram at few locations

- A spot near the mouth of Kalvathy/Eruveli canal was visited last. This area had a stretch of slum like houses next to the canal. The toilet and kitchen discharge outlet pipes from these were seen to be discharging directly into the canal.



- Small boats were seen parked along the Eruveli-Kalvathy canal confluence zone hinting that some stretch of Eruveli and Kalvathy canals are used by small scale fishermen.



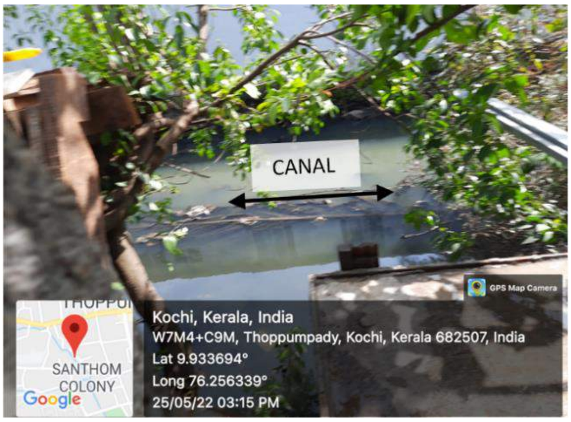
25th May 2022

Visit to Santham colony – Lying in between wetland (paddy field converted to wetland) and Pandarachira canal

- This colony consists of over two dozen houses belonging to economically weaker section. Each house is constructed over 120 sq m of plot size on encroached land next to the canal. These houses were built by a religious charity organization (Amritanandamayi) over 30 years back. The colony is sandwiched between the wetland and the canal. During heavy monsoon these houses are flooded due to overspill from both the Pandarachira canal running behind their houses and the wetland in front of their houses.

- We also found a covered drain running in front of these houses parallel to the Pandarachira canal running behind the houses. However, the drains appeared to be dry, most likely as a result of blockages.
- Large patches of wetland overgrown with water hyacinths are found in front of these houses. Some mangroves were also found growing in the wetland.

- The wetland is naturally connected to the drain at a point and then flows in to the canal.
- The Pandarachira canal running behind the houses were found to be unlined.



- While some of the houses had septic tanks, there were others without any septic tank. All the grey water and in some places the black water were observed to be directly discharged into the canal.
- Municipal drinking water supply was available to the houses in the colony through public taps (not piped directly to each house).

- Further downstream is a culvert where the canal width is reduced to around 8m which is further constricted due to two of 1.5m dia concrete pipes. The reduced width at this culvert impedes the flow of water through the canal. The constriction of flow was later also confirmed by AEE Praveen of Irrigation department who had surveyed the Pandarachira canal. The irrigation department has proposed a new wider culvert to mitigate the flow constriction at the current culvert. He also informed us about clogging of canal at the upstream stretch of Pandarachira canal which are now covered by concrete slabs and runs through highly congested colony of houses. We were also informed of a small fish market upstream where waste from fish is discarded into the canal.

- After the culvert the canal joins a wetland, extending upto approx.500m, overgrown with water hyacinth. This ”chira” as it is known in Malayalam, is a water holding area for paddy cultivation which over years of disuse have become a wetland. Due to the nature of “chira”, the water is stagnant and does not flow out to the canal.

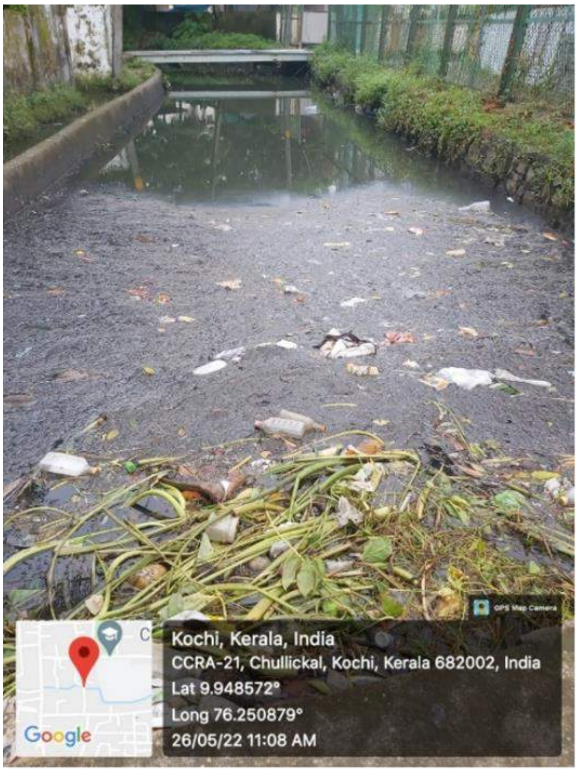
Engagement with community

- We found very articulate residents in this colony who expressed their grievances to us. Their chief complaint was the frequent flooding of their houses which would reach upto 2 ft from ground level during heavy rainfall.

- Many of these households had seriously ill patients with illness like cancer and patients who have had open heart surgery. These residents were subject to flooding of their houses during heavy downpour.

26th May 2022

- Visit to the rest of the stretch of Rameshwaram Manthra Kalvathy canal was carried out.
- Stagnant water was seen at the Kochi college stretch as indicated by the irrigation department. Other similar issues as in other parts of the canal such as encroachment, unauthorized footbridges, waste thrown in the canal resulting in clogging of canal was also seen.


Kochi, Kerala, India
CCRA-21, Chullickal, Kochi, Kerala 682002, India
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Long 76.250879°
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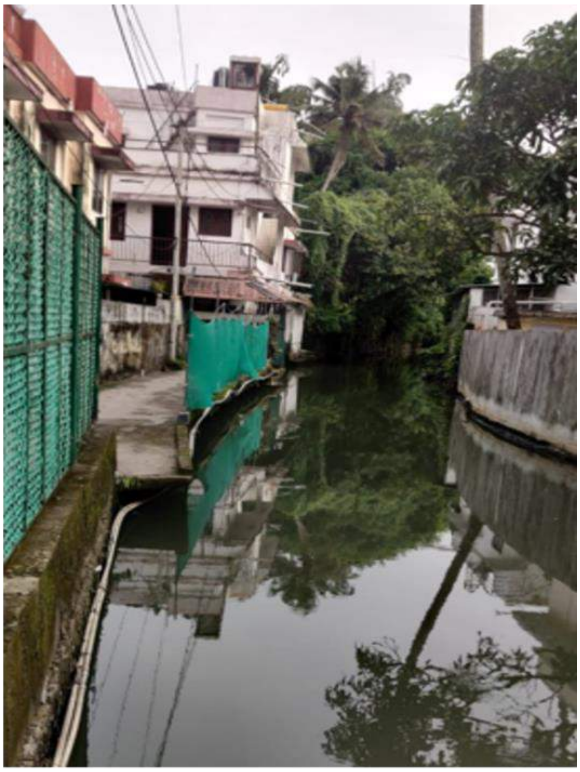


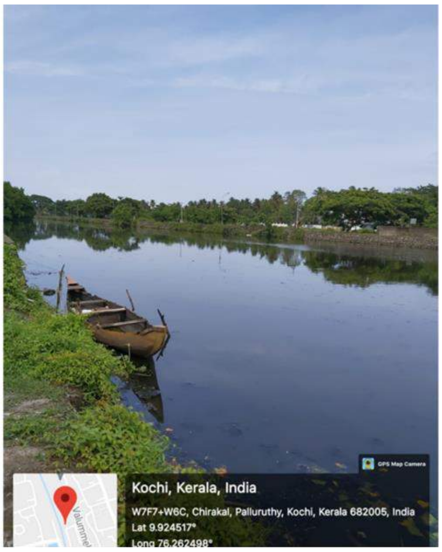
- There is a solid waste management system in the city where solid waste is being collected by agencies working for the corporation. At the start of Kalvathy stretch, we found number of trucks being filled with solid waste. management system practiced in the city.

- However, not all households subscribe to waste being collected as there is a payment attached to the collection.

27th May 2022

Visit to the outlet of Pandarachira canal

- On the last day, we visited downstream of Pandarachira canal where it was observed that the canal was wider indicating less encroachment of the canal banks and relatively less densely populated areas. It was also observed that the water was visibly cleaner and not infested with water hyacinths.
- The canal banks were visibly lined with rubble masonry.
- Presence of small boats indicated that the canal stretch south of Valummel road is being used by small scale fishermen. No indicators of the canal being used for transportation was observed.
- We found many areas where fish farming was actively being practiced towards the end of the Pandarachira canal and at the mouth of Chirakkal river.


GPS Map Camera
Kochi, Kerala, India
W7F7+W6C, Chirakal, Palluruthy, Kochi, Kerala 682005, India
Lat 9.924517°


GPS Map Camera
Google
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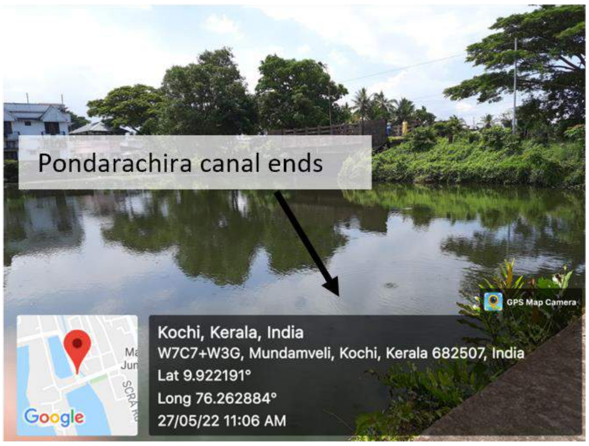
Pondarachira canal ends
GPS Map Camera
Google
Kochi, Kerala, India
W7C7+W3G, Mundamveli, Kochi, Kerala 682507, India
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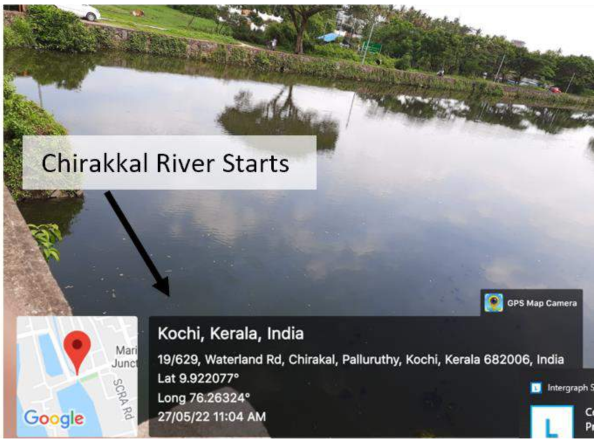
Chirakkal River Starts
GPS Map Camera
Google
Kochi, Kerala, India
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Lat 9.922077°
Long 76.26324°
27/05/22 11:04 AM


Chirakkal River flows South to the backwaters
GPS Map Camera
Google
Kochi, Kerala, India
Chirakkal Bridge, Pandara Chira, Mundamveli, Kochi, Kerala 682507, India
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Long 76.262981°
27/05/22 11:07 AM


Fish farming area
GPS Map Camera
Google
Kochi, Kerala, India
W7C7+W3G, Mundamveli, Kochi, Kerala 682507, India
Lat 9.922537°
Long 76.26268°
27/05/22 11:11 AM

Annexure 6: Existing Reports

[1]. Report on flood mitigation Kochi, Irrigation Department, Ernakulam, 2021

[2]. Draft City Sanitation plan for Kochi, Volume I - GIZ, Ministry of Housing & Urban Affairs, August 2011

[3]. Kochi Taluk, Ernakulam district flood map by Kerela Disaster Management Authority, 2020

[4]. Integrated Urban Regeneration and Water Transport System in Kochi, Kochi Metro Rail Limited February 2020

[5]. Comprehensive Water and Sanitation Assessment for Alappuzha Town by CTARA-IITB & Kerela Institute of Local Administration, May 2018

[6]. Thevara Perandoor Canal survey, Kochi Municipal Corporation by SCMS Water Institute, November 2016

[7]. Kochi Smart Canal, Progress Report (1st Feb 2022- 31st March 2022), ICLEI South Asia

[8]. Feasibility Report - Sewerage System for West Kochi,1565/M2/2.1/SWT/FR/R1, Cochin Smart Mission Limited, CSML, September 2018

[9]. Thevara Perandoor Canal Survey - Kochi Municipal Corporation, November 2016

[10]. Feasibility Report Kochi Smart City - Restoration of Canals, Kochi: Part C – Kalvathy-Rameshwaram Canal (1565/M9/9.3/CR/FR/R0), February 2019

Annexure 7: Present Condition of the Canals

Trees growing on the banks of the canal (Photo Credit: bechtel.org)

Garbage dumping area near the canal (Photo Credit: bechtel.org)

Footbridges built by each individual houses across the canal without ample headroom impedes the flow and cleaning operations (Photo Credit: bechtel.org)

KWA Water pipeline aligned across the canal. At high flood levels in the canal the water pipeline can come in direct contact with the polluted canal water (Photo Credit: bechtel.org)

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Garbage dumping area in the canal (Photo Credit: bechtel.org)

Presence of boats near the mouth of the Eruveli Canal indicating small fishermen still using the canal for navigation purposes (Photo Credit: bechtel.org)

Grey and black wastewater getting discharged directly into the canal (Photo Credit: bechtel.org)

Unlined Canal behind Santhom Colony (Photo Credit: bechtel.org)

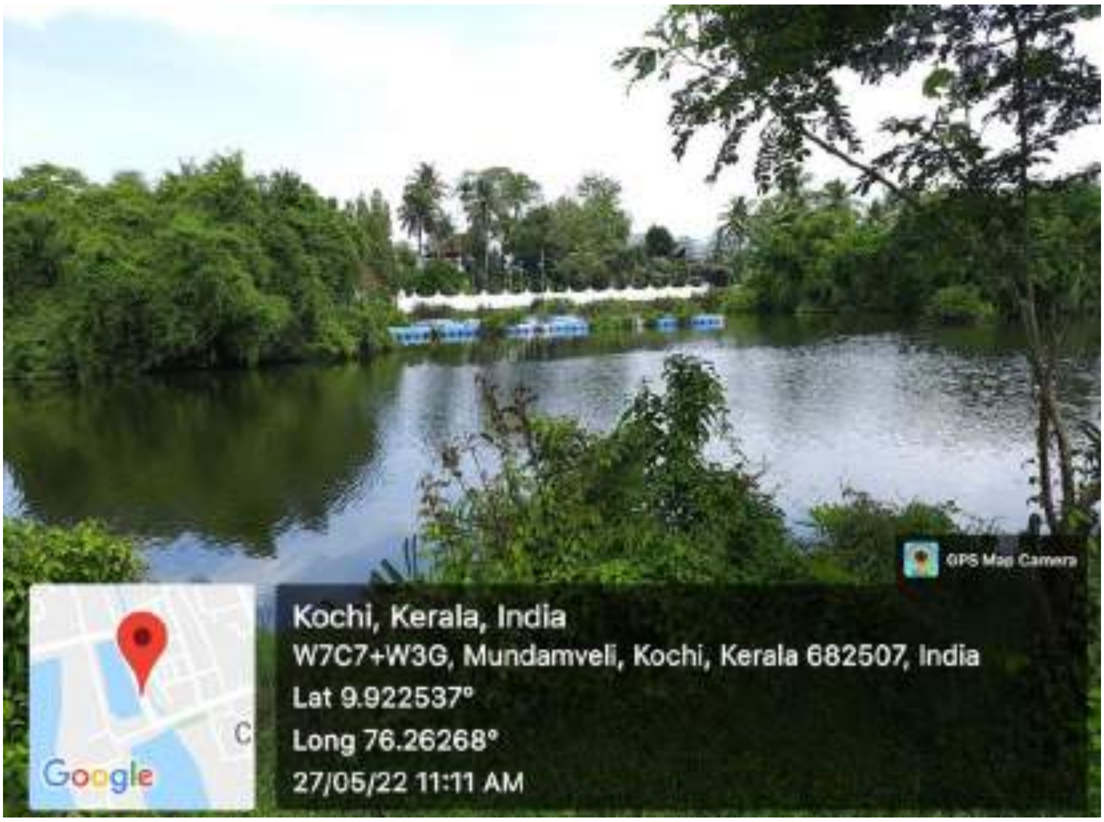
Stagnant stretch of Rameshwaram Canal near Cochin University (Photo Credit: bechtel.org)

Starting Stretch of Kalvathy Canal (Photo Credit: bechtel.org)

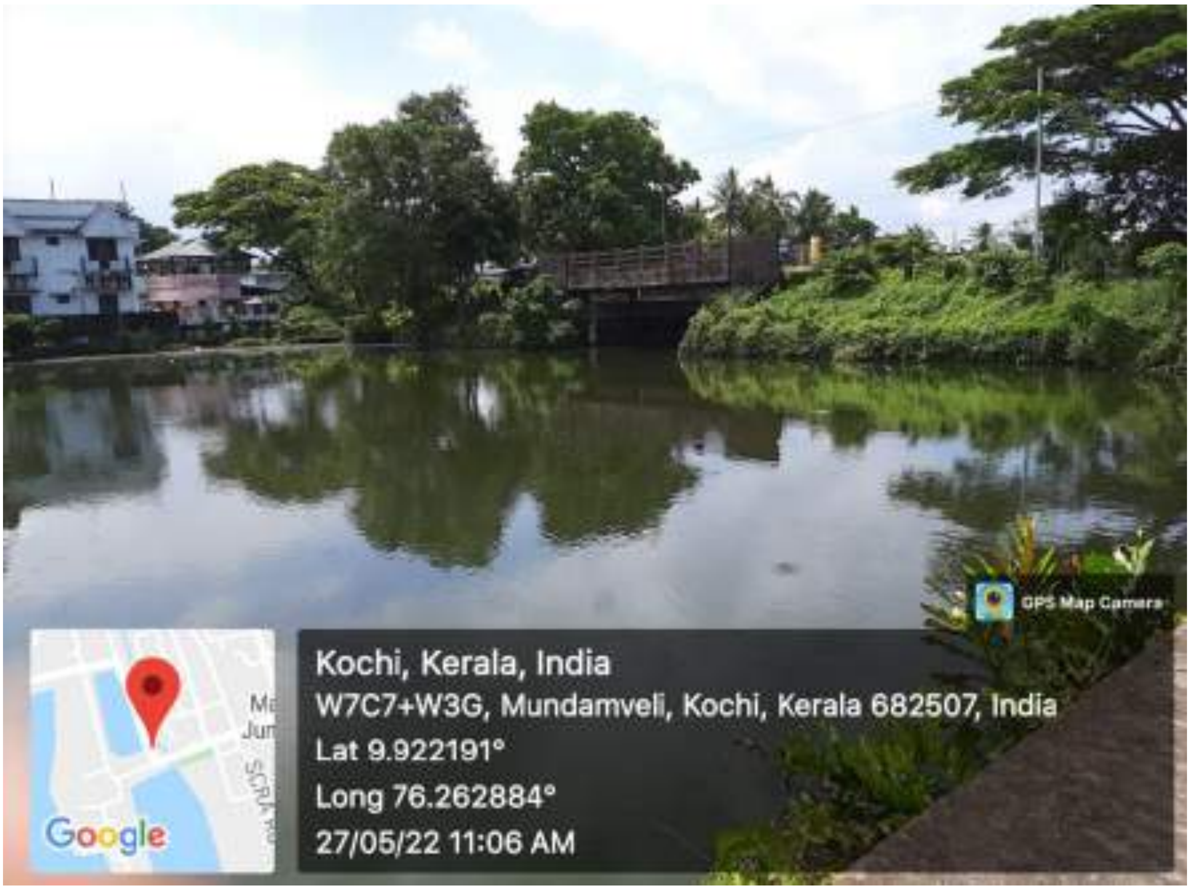
Canal Lining to be repaired (Photo Credit: bechtel.org)

Single boat sighted at Pandachirathodu canal (Photo Credit: bechtel.org)

Pandarachirathodu canal covered with water hyacinth for a considerable length (Photo Credit: bechtel.org)



Fish farm located towards the end of Pandarachirathodu canal (Photo Credit: bechtel.org)



Outfall location of Pandarachirathodu canal (Photo Credit: bechtel.org)

Annexure 8: Selection Criteria Scores

Criterion 1 - Flooding													Score						Score						Score						Score						Score
S.No.	Weight	Category	Score Criteria					Rameshwaram					33.0	Manthra					25.0	Kalvathy (Calvetti)					12.0	Eruveli					15.0	Pandarachira					36.0
1.1	**2**	**Probability of flooding due to canal/drain clogging during monsoon**	**5**	**4**	**3**	**2**	**1**	5	4	3	2	1	**5**	5	4	3	2	1	**4**	5	4	3	2	1	**2**	5	4	3	2	1	**2**	5	4	3	2	1	**4**
		Households flooded in max annual rainfall	> 3.5K	3.5K - 2K	2K-1K	<1K	0	x							x								x						x				x				
		Refer Note 1 and 2 for criteria 1.1																																			
1.2	**2**	**Low lying area impacted due to storm surge/Monsoon flooding**	**5**	**4**	**3**	**2**	**1**	5	4	3	2	1	**1**	5	4	3	2	1	**1**	5	4	3	2	1	**1**	5	4	3	2	1	**1**	5	4	3	2	1	**5**
		Area impacted - with 1m average flood depth	>15Ha	10 Ha to 15Ha	5Ha to 10Ha	1 Ha to 5 Ha	<1 Ha					x						x						x						x		x					
		Refer Note 1 and 2 for criteria 1.2																																			

Notes -

1 Number of households within 250 m of the canal

2 The values are based on the current condition of the canal as they are clogged and not running to its full capacity. The clogging of the main canal implies that there is a high probability of storm water backflowing into the U/s internal drains and causing flood. However, further survey and analysis will be required to establish this.

3 "This criteria is attributed to the low lying areas within 250m of canals only. Furhter analysis will be required to determine the actual impact. Reference - https://www.floodmap.net/?gi=1273874"

Criterion 2 - Pollution Criteria													Score						Score						Score						Score						Score
S.No.	Weight	Category	Score Criteria					Rameshwaram					26.0	Manthra					17.0	Kalvathy (Calvetti)					9.0	Eraveli					14.0	Pandarachira					21.0
2.1	**1.5**	**Solid waste management by the houses along the canal**	**5**	**4**	**3**	**2**	**1**	5	4	3	2	1	**5**	5	4	3	2	1	**3**	5	4	3	2	1	**1**	5	4	3	2	1	**2**	5	4	3	2	1	**4**
		Number of low income households discharging waste into the canal	>250	200 - 250	150-200	50-150	<50	x								x								x					x				x				
		Refer Note 1 and 2 for criteria 2.1																																			
2.2	**1.5**	**Sewage management by the houses along the canal**	**5**	**4**	**3**	**2**	**1**	5	4	3	2	1	**7**	5	4	3	2	1	**5**	5	4	3	2	1	**2**	5	4	3	2	1	**3**	5	4	3	2	1	**6**
		Probability of direct discharge of sewage into the canal	>250	200 - 250	150-200	50-150	<50	x								x								x					x				x				
		Wastewater due to dysfunctional Septic tank	>750	600-750	450-600	150-450	<150				x						x							x						x					x		
		Refer Note 3 for criteria 2.2																																			

Criterion 2 - Pollution Criteria														Score						Score						Score						Score						Score
S.No.	**Weight**	**Category**	**Score Criteria**					Rameshwaram					**26.0**	Manthra					**17.0**	Kalvathy (Calvetti)					**9.0**	Eraveli					**14.0**	Pandarachira					**21.0**
2.3	**1.5**	**Probability of grey waste being discharged into the canal**	**5**	**4**	**3**	**2**	**1**	5	4	3	2	1	**2**	5	4	3	2	1	**2**	5	4	3	2	1	**1**	5	4	3	2	1	**1**	5	4	3	2	1	**2**
		Households	>1000	800-1000	600-800	200-600	<200				x						x							x						x					x		
		Refer Note 4 for criteria 2.3																																			
2.4	**1**	**Probability of pollutants other than households entering into the canals**	**5**	**4**	**3**	**2**	**1**	5	4	3	2	1	**5**	5	4	3	2	1	**2**	5	4	3	2	1	**3**	5	4	3	2	1	**5**	5	4	3	2	1	**3**
		Fish/meat shops			>5	2 to 5	1			x							x											x						x			
		Car wash			>3	2	1				x											x							x								
		Refer Note 5 for criteria 2.4																																			

Notes -

1 Number of households considered built directly over the canal bank or very near to canal bank.

2 It is assumed that the number of households with high and middle income group are less likely to throw solid waste in the canal. Hence multiplier of 0.4 is considered and low income group are highly likely to discharge into canal hence multiplier of 0.8 is considered

3 It is assumed that the number of households along the canal with low income group are more likely to discharge sewage waste matter directly to canal or indirectly through dysfunctional Septic Tank whereas middle-high income group households have been assumed to majorly discharge the sewage through their personal septic tanks which are functional well maintained.

4 90% of the households along the canals are considered

5 Pollutants from these small shops within 250m are entering into the canal

Criterion 3 - Transportation														Score						Score						Score						Score						Score
S.No.	**Weight**	**Category**	**Score Criteria**					Rameshwaram					**2.0**	Manthra					**2.0**	Kalvathy (Calvetti)					**6.0**	Eraveli					**7.0**	Pandarachira					**3.0**
3.1	**1**	**Transportation of people - probability**	**5**	**4**	**3**	**2**	**1**	5	4	3	2	1	**2**	5	4	3	2	1	**2**	5	4	3	2	1	**6**	5	4	3	2	1	**7**	5	4	3	2	1	**3**
		People using boats to move along the canal daily	>20	11 - 20	6 - 10	1 - 5	0					x						x				x					x									x	
		Fishermen moving daily from their houses to the ocean	>20	11 - 20	6 - 10	1 - 5	0					x						x				x						x							x		
		Refer Note 1 for criteria 3.1																																			

Notes -

1 The data for above indicator is assumed based on visual inscpection during site visit and number of boats present in the canal.

Criterion 4 - Future opportunities														Score						Score						Score						Score						Score
S.No.	**Weight**	**Category**	**Score Criteria**					Rameshwaram					**8.0**	Manthra					**4.0**	Kalvathy (Calvetti)					**6.5**	Eruveli					**7.5**	Pandarachira					**31.0**
4.1	**2**	**Tourist points of interest along the canal**	**5**	**4**	**3**	**2**	**1**	5	4	3	2	1	**0**	5	4	3	2	1	**0**	5	4	3	2	1	**0**	5	4	3	2	1	**0**	5	4	3	2	1	**5**
		Historic or local culture points of interest [1]	^{3} 4	3	2	1																															
		Ecotourism points of interest [2]	^{3} 4	3	2	1																										x					
4.2	**1**	**Potential for Recreational places [3]**	**5**	**4**	**3**	**2**	**1**	5	4	3	2	1	**2**	5	4	3	2	1	**1**	5	4	3	2	1	**2**	5	4	3	2	1	**3**	5	4	3	2	1	**6**
		Length of canal (m) that have widening scope for footpath 10 to 20m	^{3} 1000	500-1000	250-500	100-250	<100				x							x					x						x				x				
		Length of canal that have widening scope for recreation activities >50m	^{3} 250	150 - 250	100-150	50-100	<50																							x					x		
4.3	**1.5**	**Potential for Fishing**	**5**	**4**	**3**	**2**	**1**	5	4	3	2	1	**2**	5	4	3	2	1	**0**	5	4	3	2	1	**1**	5	4	3	2	1	**2**	5	4	3	2	1	**5**
		Potential length (m) of that can be used for fishing	^{3} 1000	500-1000	250-500	100-250	<100				x													x					x			x					
4.4	**1.5**	**Potential for Eco Tourism**	**5**	**4**	**3**	**2**	**1**	5	4	3	2	1	**2**	5	4	3	2	1	**2**	5	4	3	2	1	**2**	5	4	3	2	1	**1**	5	4	3	2	1	**5**
		Possibility of boat travelling/eco tourism for length (km)	^{3} 1000	500-1000	250-500	100-250	<100				x						x						x							x		x					

Notes :

1. No places of historical or cultural point of interest was identified along any of the canals. Which will be further validated by on-ground survey of each of the canals.
2. No potential for development of eco tourism could be identified in any of the canals except panadarachira canal
3. The available space along the canal banks were identified from google earth imagery

Criterion 5 - Feasibility														Score						Score						Score						Score						Score
S.No.	**Weight**	**Category**	**Score**					Rameshwaram					**23.0**	Manthra					**31.5**	Kalvathy (Calvetti)					**36.5**	Eruveli					**24.0**	Pandarachira					**40.0**
5.1	**1**	**Probability of canal dredging**	**5**	**4**	**3**	**2**	**1**	5	4	3	2	1	**5**	5	4	3	2	1	**5**	5	4	3	2	1	**5**	5	4	3	2	1	**4**	5	4	3	2	1	**4**
		Probability of canal dredging by the municipality [1]	in scale 1 to 5					x						x						x							x						x				
5.2	**1.5**	**Demonstrable**	**5**	**4**	**3**	**2**	**1**	5	4	3	2	1	**1**	5	4	3	2	1	**1**	5	4	3	2	1	**3**	5	4	3	2	1	**1**	5	4	3	2	1	**5**
		Time period (in months) [2]	8-12		12-18		>18					x						x				x								x		x					
5.3	**1.5**	**Land around canal [3]**	**5**	**4**	**3**	**2**	**1**	5	4	3	2	1	**4**	5	4	3	2	1	**9**	5	4	3	2	1	**10**	5	4	3	2	1	**7**	5	4	3	2	1	**10**
		Percentage length of canal accessible	>80%	60% to 80%	40%-60%	20%-40%	<20%				x					x				x						x								x			
		Availability of land for Treatment plant													x							x										x					
		Percentage length where widening is possible	>80%	60% to 80%	40%-60%	20%-40%	<20%				x						x						x						x						x		

Criterion 5 - Feasibility													Score						Score						Score						Score						Score
S.No.	**Weight**	**Category**	**Score**					Rameshwaram					**23.0**	Manthra					**31.5**	Kalvathy (Calvetti)					**36.5**	Eruveli					**24.0**	Pandarachira					**40.0**
5.4	**1**	**Length of the canal where pontoon mounted dredgers can be deployed**	**5**	**4**	**3**	**2**	**1**	5	4	3	2	1	**1**	5	4	3	2	1	**1**	5	4	3	2	1	**1**	5	4	3	2	1	**1**	5	4	3	2	1	**5**
		Canal Length [4]	>1 km		0.5 to 1 km		0					x						x						x						x		x					
5.5	**1.5**	**Requirement for rehabilitation/demolition [5]**	**5**	**4**	**3**	**2**	**1**	5	4	3	2	1	**3**	5	4	3	2	1	**3**	5	4	3	2	1	**4**	5	4	3	2	1	**4**	5	4	3	2	1	**5**
		No. of footbridge to be demolished	0	1- 10	11 - 30	31- 40	>40			x						x					x						x					x					
5.6	**1**	**Impact from connecting canal**	**5**	**4**	**3**	**2**	**1**	5	4	3	2	1	**5**	5	4	3	2	1	**6**	5	4	3	2	1	**5**	5	4	3	2	1	**1**	5	4	3	2	1	**1**
		U/S length (km)	<0.5 km	0.5km - 1km	1 km - 2 km	2.1 km - 2.5 km	>2.5 km	x							x															x						x	
		D/S length (km)	<0.5 km	0.5km - 1km	1 km - 1.5 km	1.6 km - 2 km	>2 km										x			x																	

Notes:

1. Dredging as confirmed by the Irrigation department has been done for the stretch from Kalvethy to Manthra the rest of the stretch to Rameshwaram is to be done by 1st week of June.
2. Demonstration time period is assumed.
3. Land around canal has been estimated from google earth imagery.
4. Pontoons have been assumed to be deployed on accessible and wider stretches of the canal.
5. Requirement of rehabilitation and demolition of foot bridge has been observed from site visit and google imagery.

Annexure 9: A Glimpse of the Biodiversity in the Canals

Calvathy Canal

House Crow with Tilapia catch (Photo credit: ICLEI South Asia)

Pale-billed Flowerpecker (Photo credit: ICLEI South Asia)

Eraveli Canal

Blue grass Dart (Photo Credit: ICLEI South Asia)

Ditch Jewel (Photo Credit: ICLEI South Asia)

Rice Swift (Photo Credit: ICLEI South Asia)

White throated Kingfisher (Photo Credit: ICLEI South Asia)

Manthra Canal

Black-rumped Flameback (Photo Credit: ICLEI South Asia)

Plain Cupid (Photo Credit: ICLEI South Asia)

Pandarachirathodu Canal

Cattle Egret (Photo Credit: ICLEI South Asia)

Passiflora foetida (Photo Credit: ICLEI South Asia)

Black Drongo (Photo Credit: ICLEI South Asia)

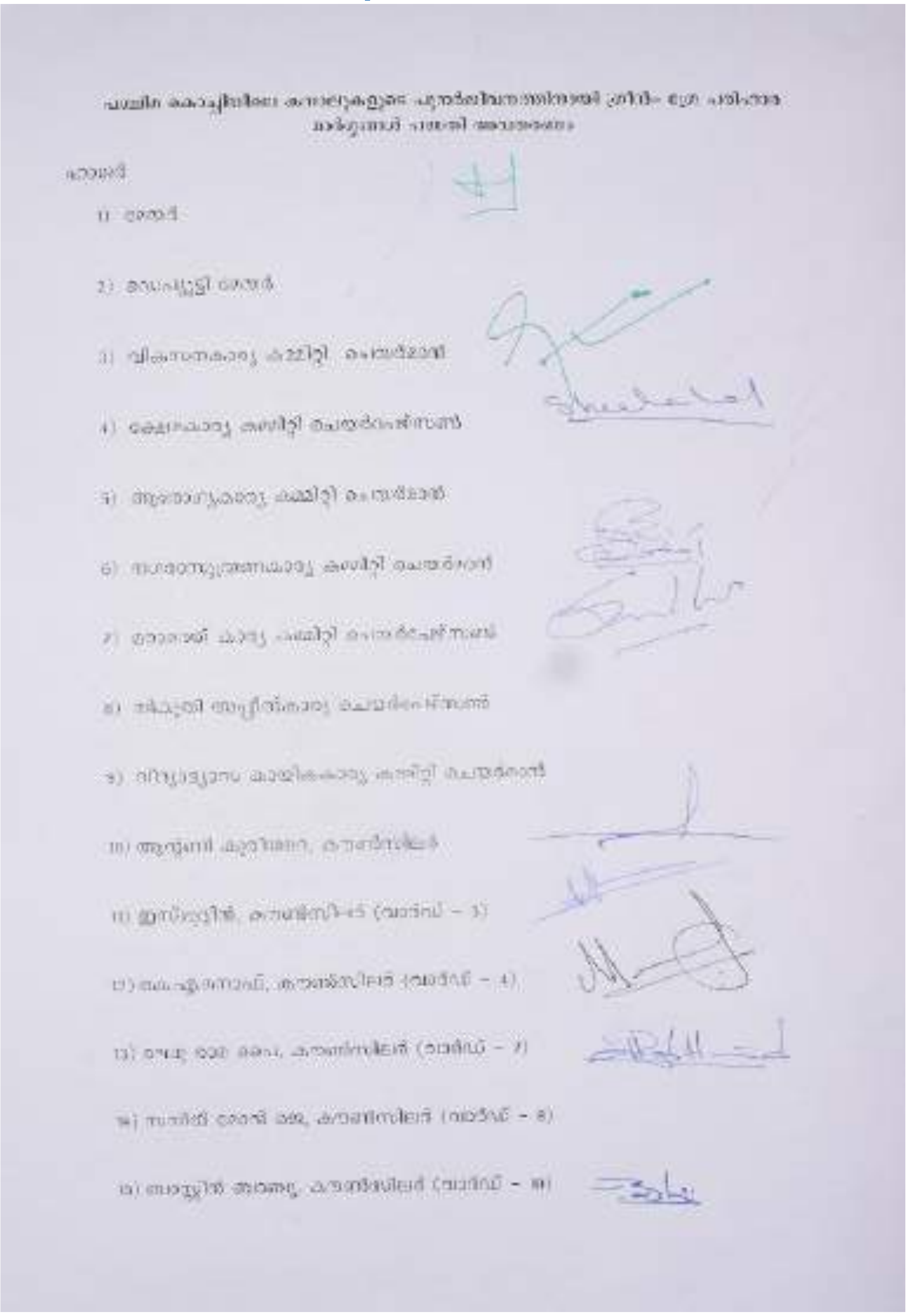
Tawny Castor (Photo Credit: ICLEI South Asia)

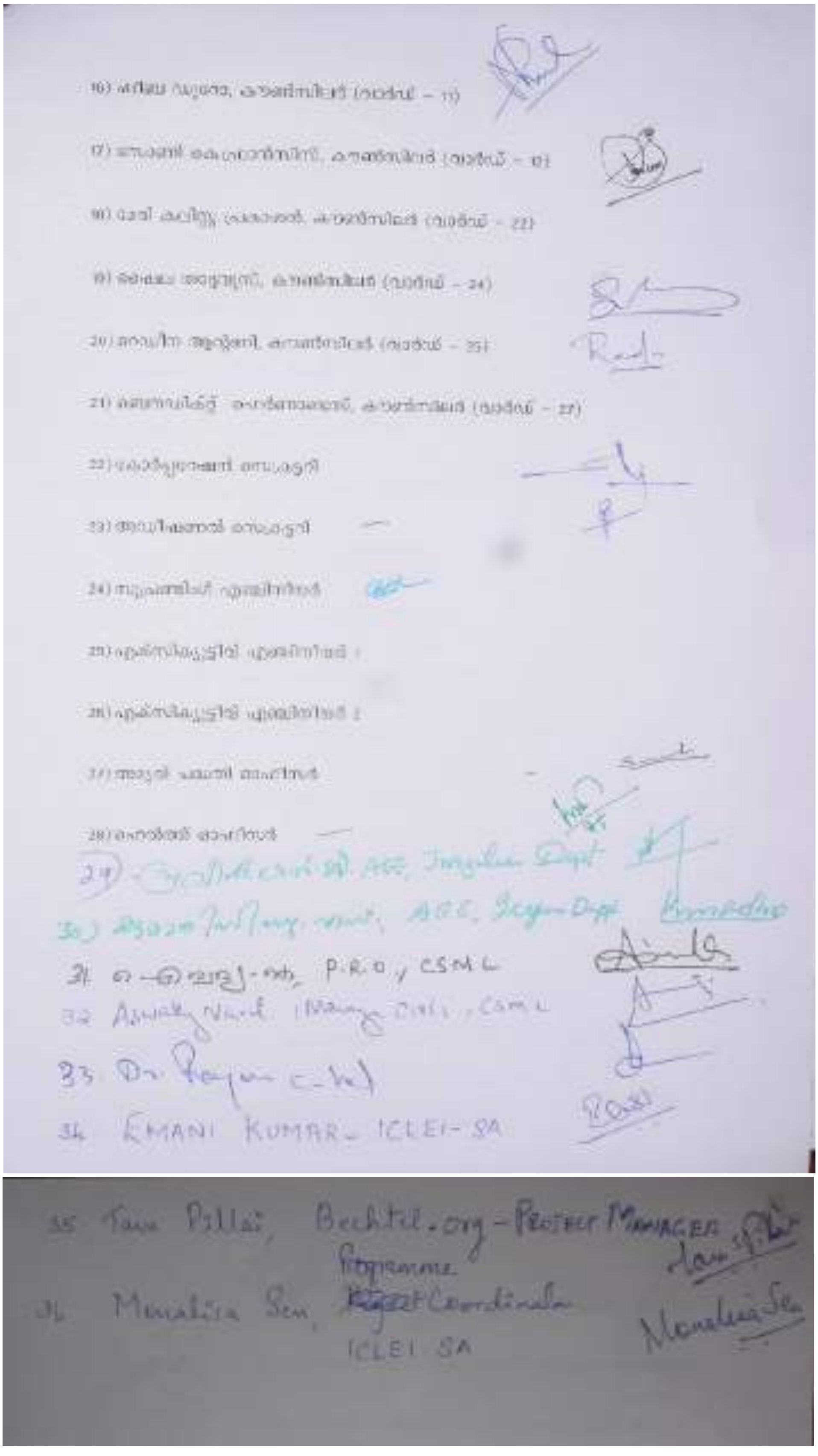
Rameshwaram Canal

Black Crowned Night Heron (Photo Credit: ICLEI South Asia)

Grey Pansy (Photo Credit: ICLEI South Asia)

Annexure 10: Participants list





16) [illegible] (വാർഡ് – 11)
17) [illegible] (വാർഡ് – 17)
18) [illegible] (വാർഡ് – 22)
19) [illegible] (വാർഡ് – 24)
20) [illegible] (വാർഡ് – 25)
21) [illegible] (വാർഡ് – 27)
22) [illegible]
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27) [illegible]
28) [illegible]
29) [illegible] AEE, [illegible] Dept
30) [illegible] AEE, [illegible] Dept
31 [illegible] P.R.O, CSML
32 [illegible] CSML
33 Dr. [illegible]
34 EMANI KUMAR – ICLEI-SA
35 Tanu Pillai, Bechtel.org – Project Manager
36 Manalisa Sen, Programme Coordinator ICLEI SA