Project Urban Living Lab

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SMART CITY DEVELOPMENT LTD.

ST. INEZ CREEK REJUVENATION PLAN

PANAJI

Green Strategic Partnership
India-Denmark

ROYAL DANISH EMBASSY
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MINISTRY OF FOREIGN AFFAIRS
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ST INEZ CREEK REJUVENATION PLAN

Executive Summary

The St Inez Creek cuts across Goa's capital city, Panaji. It originates in the marshlands in Taleigao and is fed by rainwater from the Altinho and Nagahalli hills. In Panaji, it passes through Camrabhat, Tamddi Mati Tonca; flowing behind the Military Hospital, Don Bosco School and the ESG complex. Of particular importance to the city is how both the St Inez Creek and the Fontainhas Creek (which runs along the Rua De Ourem) play a crucial role in the city's drainage during the monsoon season. Despite the importance of these creeks for the city, they has increasingly become polluted, silted and stagnant.

Several studies and projects have been prepared for the St Inez Creek development, however, for various reasons, these have not yet been implemented. One of the main challenges with its rejuvenation and restoration of the creek, is the states and city's (Goa) fragmented governance. Essentially, there is no single institutional owner of the creek, and the many government bodies, some with overlapping jurisdictions, are responsible for different aspects of its management.

The restoration and rejuvenation of the creek is not a one-off intervention. The maintenance of the creek will need to become part of the city's plan and should be incorporated in every visioning document. Considering that Panaji was built on low-lying wetlands, the importance as a water body draining the city's larger drainage network cannot be overemphasised. The important riparian urban biodiversity and associated agricultural livelihoods it supports; all makes its conservation all the more important for the sustenance of the city and the wellbeing of its citizens.

This document outlines major issues in the planning and management of the St Inez Creek and sets out a broad framework for creating a common vision for the rejuvenation of the St Inez Creek. It sets specific goals, that when achieved, will fulfil the restoration of the water body to its functional use. It emphasises a number of interventions for the body of the creek to be carried out, both in short and medium time frames, to achieve specific goals. While certain actions and interventions are to be implemented beyond the creek body into the watershed to have sustainable results in maintaining the health of the creek. In suggesting measures to rejuvenate the creek, best practices from Danish experience, as well as those that have achieved significant impact from the Indian context with the use of nature-based solutions are given importance.

Contents

List of abbreviations

ABR	Anoxic Bioremediation Technology
BOD	Biological Oxygen Demand
CCP	City Corporation of Panaji
CZMP	Coastal Zone Management Plan
DPR	Detailed Project Report
ESG	Entertainment Society of Goa
GCZMA	Goa Coastal Zone Management Authority
GMC	Goa Medical Complex
GPPDA	Greater Panaji Planning and Development Authority
GSIDC	Goa State Infrastructure Development Corporation
GSPCB	Goa State Pollution Control Board
HDSCL	Hubballi-Dharwad Smart City Limited
HMDA	Hyderabad Metropolitan Development Authority
INOX	INOX Leisure Ltd
INR	Indian Rupees
IPSCDL	Imagine Panaji Smart City Development Limited
LKS	LKS Ingenieria, S. Coop
MLD	Million Litres per Day
NBS	Nature Based Solutions
OPM	Oxford Policy Management
PULL	Project Urban Living Lab
PVC	Poly Vinyl Chloride
PWD	Public Works Department
RDE	Royal Danish Embassy
STP	Sewage Treatment Plant
SWM	Solid Waste Management
TSS	Total Suspended Solids
WAPCO	Water and Power Corporation
WRD	Water Resources Department
WRI	World Resources Institute India Ross Centre

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1
THE CONTEXT

1 The Context

The St. Inez creek cuts across the city of Panaji. It originates at the marshland in Taleigao and is fed by rainwater from the Altinho and Nagahalli hills. In Panaji, it passes through Camrabhat, Tamddi Mati, Tonca, flowing behind the Military Hospital, Don Bosco School and the ESG complex. It has two arms that open up into the Mandovi river - one opposite the old GMC/INOX complex and the other at the Indoor Stadium, Campa, both in close proximity to the point of the river's confluence with the sea.

Not only does the creek support various flora and fauna, it is also a site for tidal flushing, or the constant replacement of water as a result of tides. For instance, during the high tide, the sea water enters the city, carrying with it rich biodiversity from the Mandovi river, including a variety of fish. Tidal flushing also supports a mangrove ecosystem at Tonca.

Despite the importance of the creek for the city, it has increasingly become polluted, silted and stagnant. The reasons for the pollution include the release of sewage from the Sewage Treatment Plant in Tonca, sewage tankers from casinos, high rise buildings and informal settlements, and the dumping of trash in the creek. The problems of the creek are not limited to Panaji, and pollution from the creek affects interlinked wells and water bodies in the area.

Several government studies and projects have been prepared for the creek but, for various reasons, these have not been implemented. One of the main challenges with its rejuvenation and restoration is its fragmented governance. There is no single institutional owner of the creek, and many government bodies, some with overlapping jurisdictions, are responsible for different aspects of its management.

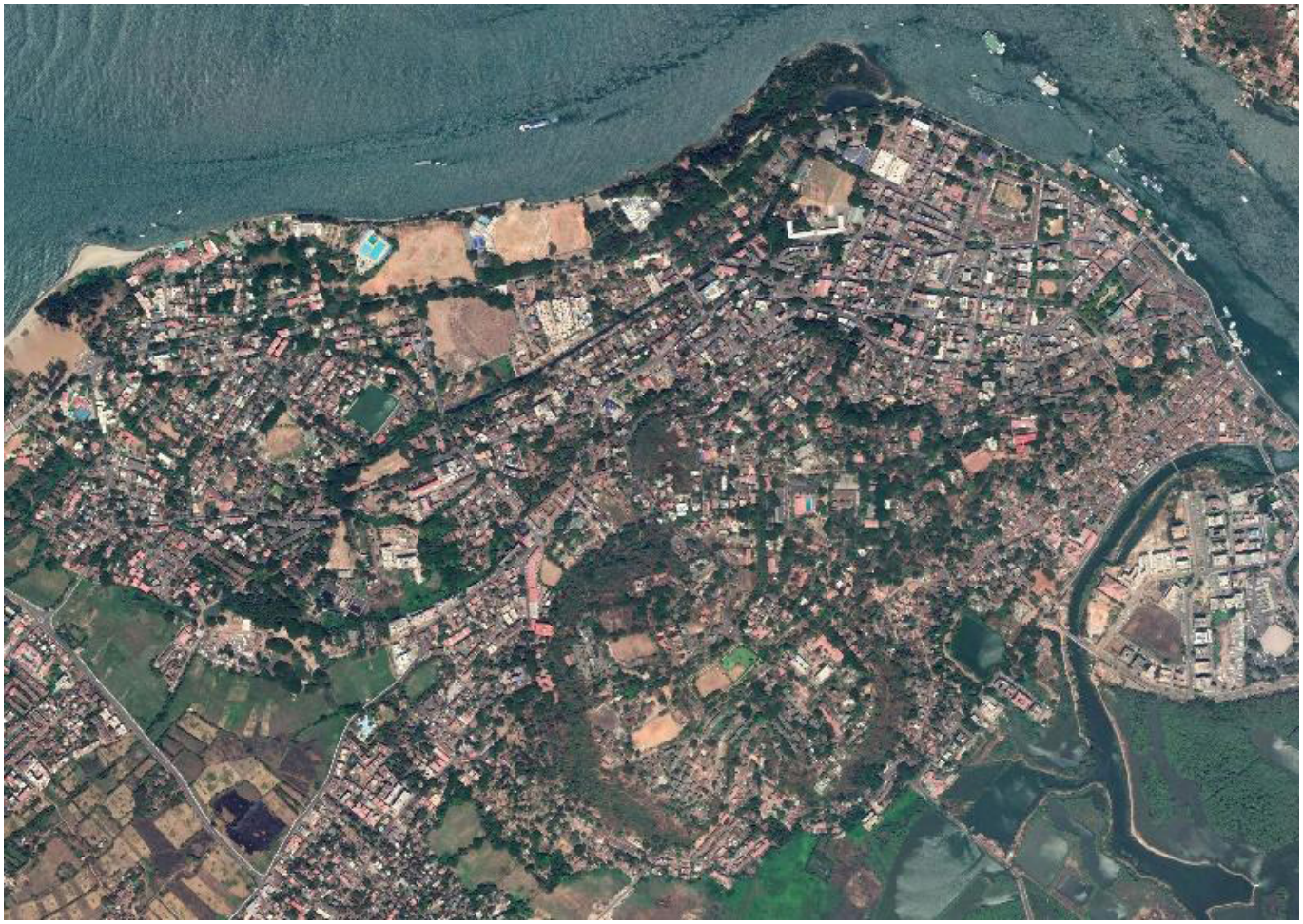
This is the first plan for the creek that will reflect multi-stakeholder government input. The plan and solutions will be reviewed by an interdepartmental committee on the creek, and their implementation arrangements discussed. In addition, the plan will be updated to reflect community visions for the creek. Community consultations have not been possible so far, because of the risks posed by the COVID-19 pandemic in Goa

1.1 Vision and goals

The vision statement for the St. Inez creek is that: **The Creek is able to support a diverse and healthy ecosystem and connect residents to nature by 2050.** To meet this vision, the following goals need to be met:

1. The creek's natural flow should be maintained by:
    a. Ensuring the creek is free of solid waste
    b. Addressing the sedimentation at the mouth of the creek
2. Improved water quality [to Class B*] through pollution management and Nature Based Solutions (NBS) by ensuring
    a. 100% sewage treatment in the city
    b. Ensuring the creek is free of solid waste
3. Communities can access the creek, and enjoy public spaces around it

Figure 01: The St. Inez Creek.



1.2 Report Structure

This rejuvenation plan summarizes the existing conditions of the creek, and presents various solutions that can be undertaken to meet the vision for the creek. The vision, goals and actions need to be further discussed and prioritized in consultation with relevant city stakeholders in government.

2
METHODOLOGY

2 Methodology

The PULL analysed primary and secondary data on the creek to understand current challenges and prepare solutions sheets. The data analysis and solutions were prepared in collaboration with Knowledge Partner Ramboll Group.

2.1 Primary and secondary data

The team consulted secondary data including earlier Detailed Project Reports (DPRs) and data on the creek collected by WAPCO, GKS consulting and Royal HasKonig, as well as data on water quality from the Goa State Pollution Control Board and Public Works Department.

2.2 Data collection and analysis

2.2.1 Primary data collection and analysis

The PULL conducted an aerial drone based Light Detection and Ranging (LiDAR) survey and a ground-based survey to collect topographic data for the city **(**Error! Reference source not found.**)** The survey collected cross sectional details of the St. Inez Creek and visible outfall pipes draining into the Creek. In addition to the survey, the PULL conducted participatory mapping exercises and recces of the creek to understand its existing conditions.

Figure 02: Survey of current challenges

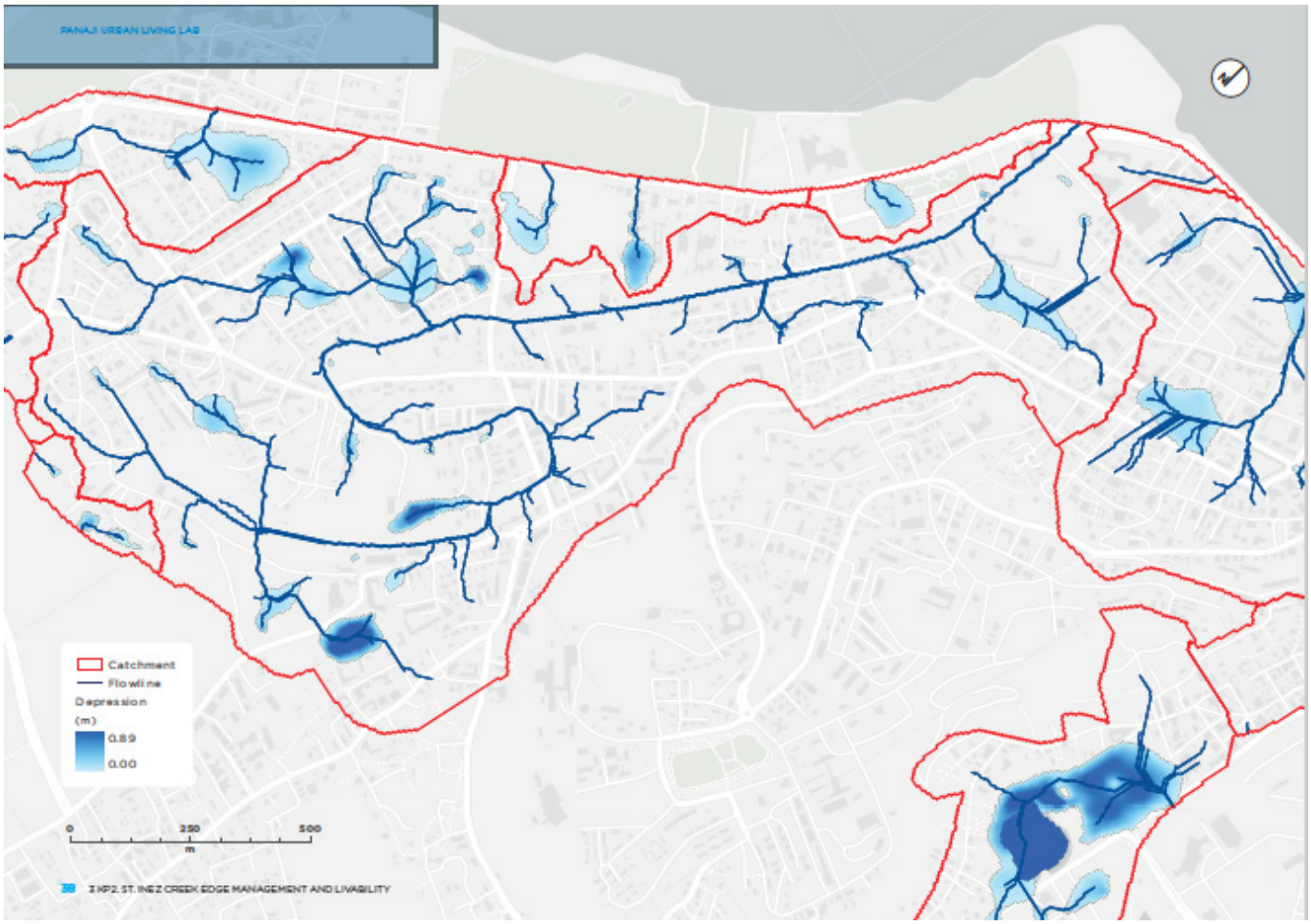
Hydraulic Analysis

Analysis of the data was led by Knowledge Partner Ramboll. The main findings of the analysis include

the following:

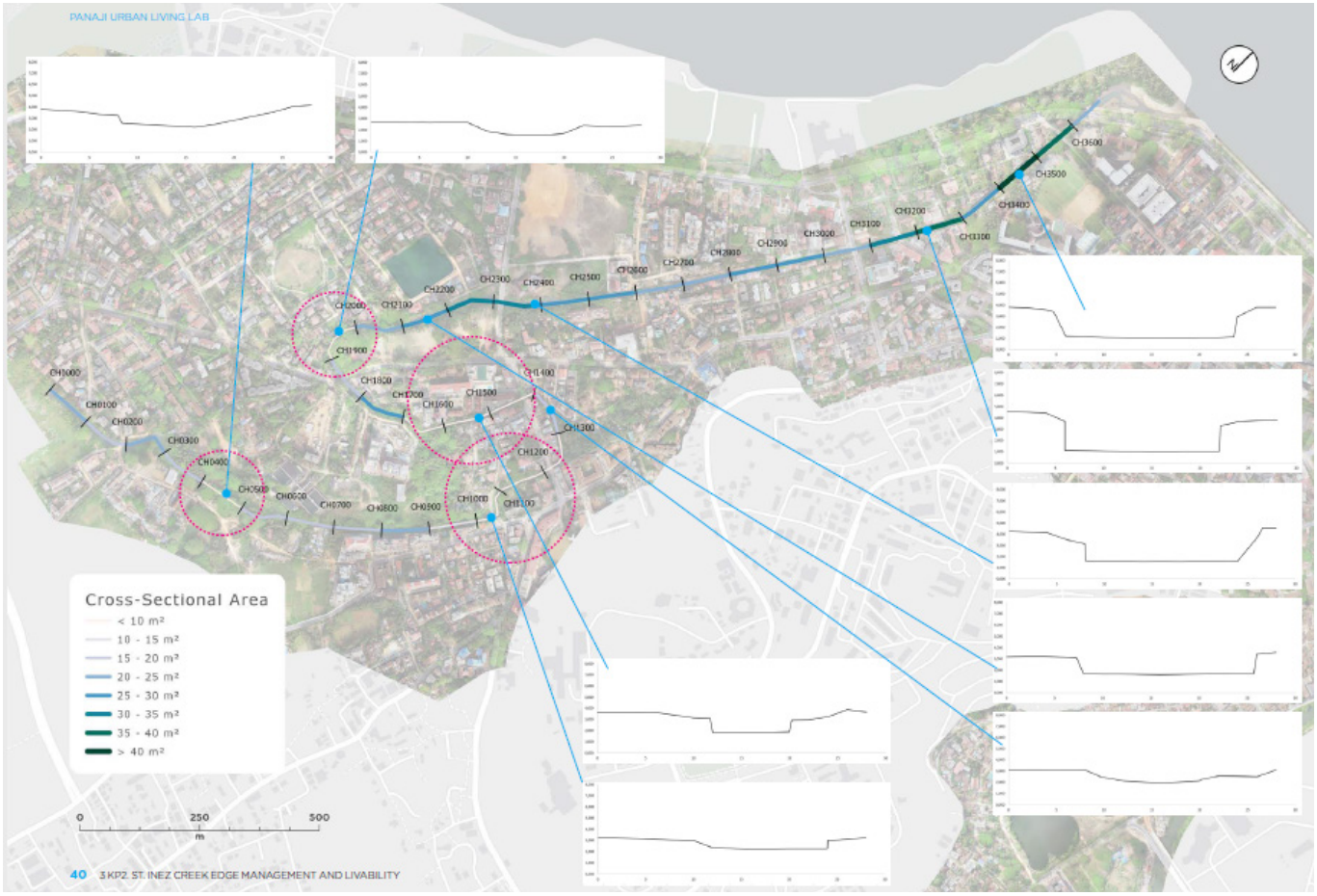
- Cross-sectional area of the creek ranges from 6 m^2 to 42 m^2. There is an increase in the cross-sectional area from upstream, moving downstream **(Figure 4).**
- Local shallow sections and encroachments have been identified
- Restricted flow:
  - The slope of the creek is limited to an average of 0.5 % and shows clear signs of siltation/ blockage and encroachment with sudden drops in cross-sectional flow areas creating unnatural bottlenecks in the flow.
  - Culvert structures and bridges/overpasses, this is expected to further restrict the flow, particularly if limited maintenance and cleaning of the creek is performed as silt, sludge and solid waste may build up in the creek and block the flow.
  - The section of the creek at chainage 1900 m () shows clear signs of blockages or encroachment with the steep decrease in the cross-section area from 18.6 m^2 at chainage 1800 m to 7.8 m at chainage 1900 m ().
  - The issue of sedimentation obstructing flows is also apparent at the outlet where the Creek meets Mandovi River, which is possibly caused by silts in the main river being deposit at the

Figure 03: Surface flow lines in the St Inez Creek area based on elevation data



Blue areas indicate where water may accumulate during intense rain events. No drainage infrastructure is considered or is assumed to be blocked or at capacity in this map. Map prepared by Knowledge Partner Ramboll.

Figure 04: Cross sectional flow area along the creek



These findings point to the importance of maintaining the natural flows by either restoring the natural cross-sectional flow area proportional to the catchment size, or engineered solutions such as lining of the creek and diversion flows to increase the overall capacity of the drainage system. Additionally, the water balance of the catchment may be supplemented with storage capacity to manage peak flows when the conveyance of the creek is surpassed or otherwise restricted by high water levels at the outlet.

A return to natural conditions would entail a restriction of peak flows reaching the creek to mimic pre-development conditions, by introducing storage volumes within the catchment, either through traditional flood management structures such as basins or through Nature based Solutions (NBS) and multi functional spaces that also provides co-benefits such as recreational spaces and improved micro-climate conditions that further mitigates the impacts of climate.

Creek recces

The PULL team conducted several mapping exercises to understand the lay of the creek and also to identify restrictions to its natural flow. The team also mapped the incidence of solid waste around the creek. This activity was paused due to the COVID- 19 enforced lockdowns in 2020.

Figure 05: St Inez Creek Field Visit and Pollution Mapping

2.2.2 Secondary data collection and analysis

A detailed secondary data review provided information on the main challenges and recommendation actions for the St Inez Creek. A summary of the findings of the review are summarised in **Table 01**

Table 01: Past studies on the St Inez Creek

Agency	Year	Description
State Pollution Control Board	2013-2014	• Survey of water quality in 22 locations in 2013 • Found raw sewage discharge at many locations, heavy growth of the invasive water hyacinth and extremely high densities of total coliform and faecal coliform bacteria.
DPR prepared by WAPCO for the CCP under the Jawaharlal Nehru National Urban Renewal Mission (JnNURM)	2014	• Highlighted problems with sewage and garbage disposal • Recommended the removal of encroachments, as well as concretising some parts of the creek. • Recommended the re-design of creek channel, use reclaimed land for parks and the promenade

DPR prepared by LKS consulting for GSIDC for Jn-NURM	2019	• Recommended the following interventions: ◦ Building of embankment walls ◦ Desilting and cleaning of main creek and branch channels ◦ Re-building of bridges and all the utility crossings ◦ Sluice gates at 3 location to inundate water, improve water quality and maintain flows The construction of a promenade along the length of the creek with public places, gardens, walkways etc.
Royal HasKoning DHV for the Smart Cities Mission	2020	• Reviewed earlier DPRs • Recommended the following interventions ◦ Land Use Master Plan for the watershed ◦ Hydraulic study for scientific analysis of desilting of the creek ◦ Design and reconstruction of bridges to consider natural environment and cultural heritage of city ◦ Prioritizing solid waste management and sewerage network works in catchment areas • Proposed an environmentally friendly approach to rejuvenation, based on youth and community engagement

3
CURRENT STATUS

3 Current status

Based on the data collection activities, the St Inez Creek was divided into five zones to better understand the current challenges facing it and the particular sections of the Creek. These are presented in Table 2 and Figure 6.

Table 02: Current challenges

Zone
• Zone 1: Mouth of the St Inez Creek
• Zone 2: Bridge on Fire Services Road; Slab on St Inez Road, in front to PWD/STP complex; Tambdi Mati areas
• Zone 2: Tambdi Mati area (side drains) • Zone 4: Upstream of Taj Vivanta • Zone 5: Camrabhatt
• Zone 3: Where the creek meanders • Zone 4: Upstream of Taj till the Fire Services Bridge is a potential area for edge management; Fire Brigade Bridge to Swimming Pool Complex (Branch channel) - connecting to new Mandovi River font/ boardwalk • Left Bank from Camrabhat till Tambidi Mati is also potential for a biking/walking trail, nature walk
• Zone 5: Camrabhatt • Zone 2: Bridge on Fire Services Road

Challenge	Possible solutions	PULL Goals
Sedimentation and siltation of St Inez Creek	Dredging to address sedimentation issues caused by natural sediment build-up	Goal 1: Maintaining the natural flow of the creek
Solid Waste	Education campaign about solid waste management practices to address dumping of household waste in creek; Trash traps and floating trash barriers	Goal 1: Maintaining the natural flow of the creek
Sewerage and sullage	Development of sanitation facilities to address lack of toilets in informal settlement Education campaign about solid waste management practices to address dumping of household waste in creek (from Settlement on Right Bank of creek)	Goal 1: Maintaining the natural flow of the creek Goal 2: Improving water quality
Edge management	Porous walls Recreational and community development solutions along edge, Rejuvenation of the park abutting creek in that area (street art, cycle paths, riparian species integration etc) Daylighting	Goal 2: Improving water quality Goal 3: Creating spaces for communities to access the creek
	Nature based solutions for bioremediation	Goal 2: Improving water quality Goal 3: Creating spaces for communities to access the creek

Figure 06: St. Inez Creek zones

3.1 Ongoing projects

At present, IPSCDL is undertaking two projects for the St Inez Creek which focuses on the stabilisation of banks and the renovation of bridges.

Rejuvenation of St Inez Creek - Development and Improvement to Hydrodynamics, Water Quality and Stabilisation of Creek Banks.

The Rejuvenation of the St Inez Creek - Development and Improvement to Hydrodynamica, Water Quality and Stabilisation of Banks, is being implemented by the state/or Panaji city Water Resources Department and is being implemented in two phases. The approximate cost of the project is INR 42.24 crores. Activities include:

- Improvement of the St Inez Creek waterway including removal of settled sediments/sludge from the creek bed by dredging for an average depth of 1.5m
- Stabilisation of the banks alongside the creek and wherever necessary by rehabilitation/ new bank protection works
- Improvement to water quality upstream of creek,near outlet of the Tonca sewage treatment plant (STP) treated effluent discharge, by providing gated structures to inundate the water, treatment through in-situ aeration and regulate the flow - based on tidal movements and water quality improvements
- Hydrodynamic and Hydrologicw Waterway survey, investigation and report by expert agencies, including a topographic survey
- Beautification of creek banks with footpath, promenade, landscaping, illumination etc. and

fencing the land boundary of creek with 2 m high chain-link fence.

This project is in line with the goals of the St Inez Rejuvenation Plan, as it will address the sedimentation at the mouth of the creek, undertake activities to improve water quality and make the creek accessible to the public.

Rejuvenation of St Inez Creek - Reconstruction and Renovation of Culverts/Bridges at Seven locations

This project, the reconstruction and renovation of culverts/bridges at seven locations, involves reconstruction and renovation of several culverts/bridges across the St Inez Creek to improve the hydraulic carrying capacity of these structures, in line with the PULLs goals of improving the flow of the creek. The project is being implemented by the Public Works Department at an estimated cost of INR 10.99 crores. The culverts and bridges that will be reconstructed or renovated include:

- Culvert near Haji Ali at St Inez
- Box culvert at Kamrabhat
- Box culvert near Gaunekar Hospital
- Box culvert near Expert Pharmacy
- Box culvert near Thomas Garage
- Minerva Bridge (near Inox) - a masonry bridge
- Ponte de Portugal Bridge (near Vivanta) - a masonry bridge

4
PREREQUISITE ACTIONS TO ACHIEVE GOALS

4 Prerequisite Actions to Achieve Goals

In this section, the PULL presents some prerequisite actions required to implement the goals of the plan. These actions include the following:

- Conducting a hydraulic and land use study to investigate the water current, quantity and pressure to propose solutions to restore the natural flow of the creek in order to make an informed selection of solutions.
- Clarifying the governance structure of the creek and determining the responsibility of the implementation of projects and maintenance of the creek with government departments
- Ensure the correct terminology is used for the creek so that it can be appropriately protected

Each of these prerequisite actions is detailed in the subsections below, and needs to be implemented before actions can be prioritised.

4.1 Land use and hydraulic study for the Creek

A land use and hydraulic study for the St Inez Creek is required to prioritise and implement proposed solutions.

Hydraulic Modeling has evolved as a tool to aid decision making when the interventions involve expensive investments for infrastructure. It aids in understanding the impacts on the system as a whole, allows for evaluating alternatives and analyzes the risks involved with each set of interventions. The hydraulics of the creek extents beyond the creek boundary into the upstream wetlands or Khazan lands, the urban drainage network of Panaji in the middle reaches and at the downstream side the Mandovi River and the tidal influence from the Arabian Sea. The urban landuse of Panaji, dependence of urban drainage network of the City draining into St. Inez creek is not so well understood and how the water level in the creek influences urban flooding instances in various areas of the creek watershed. The sedimentation at the mouth of the creek due to the morphology of Mandovi River is another less understood subject on the functioning of the creek. The influence of these parameters on the overall functioning of the creek and its restoration to natural flow regime can be studied using hydraulic study.

The key outputs of such a study will include data on:

- Flows and water levels in the drainage network during rain events
- Identify critical points of overflow in the drainage network during intense rain events
- Identify bottlenecks in the drainage network, i.e. culverts or bridge crossings with improper dimensions
- Scenarios with altered cross-sections or removal of bottlenecks to quantify benefits to illustrate hydraulic conditions in the drainage network ‘ before-and-after’ an intervention
- Climate change scenarios, including rising sea levels and increasing precipitation and how this affects the hydraulics in the creek i.e. more overflow from the creek or limited gravitational drainage capacity
- Scenarios with altered stormwater runoff patterns, i.e. changes in land cover such as reduced/ increased imperviousness
- Scenarios with changes to stormwater control structures such as storage volumes, i.e. the addition of a new stormwater basin or Blue Green infrastructure with a storage component, weirs and/or sluice-gates

A memo prepared by Knowledge Partner Ramboll A/S on the types of hydraulic models and prerequisites is found in Annex 1.

4.2 Clarity on governance structure of the St Inez Creek

PULL proposed an interdepartmental committee to discuss and take actions on projects and studies for St Inez Creek. The first agenda item for the first meeting for the proposed interdepartmental committee should be for all relevant departments to clarify their roles and responsibilities for the management of the creek's rejuvenation projects and upkeep.

The PULL conducted an institutional assessment of St Inez Creek and found that there were several government departments with overlapping jurisdictions responsible for its management **(refer to Annex 2).** These include:

At the city level, the Corporation of City of Panaji (CCP) is the urban local body charged with the upkeep and maintenance of civic facilities in Panaji. It draws its powers from the City of Panaji Corporation Act, 2002 - an outcome of the 74th Constitutional Amendment which devolves certain powers to municipal bodies1. Additionally, Imagine Smart City Development Limited has been formed as a Special Purpose Vehicle (a legal entity created for a specific purpose) by the state Government of Goa to implement the national Indian Government's Smart Cities Mission in Panaji. Although it does not, by default, have powers to manage the St Inez Creek, it has been tasked by the Government of Goa with the revitalization of the creek2.

The St Inez Creek also passes through the village of Taleigao - located on the south-western periphery of Panaji. Therefore, a section of the creek falls within the area limits of the Taleigao Village Panchayat, which regulates landuse and building permissions along that particular section of the creek. Lastly, the Greater Panaji Planning and Development Authority (GPPDA) is a statutory body formulated under the Town and Country Planning Department, Government of Goa. Its main functions include the development and implementation of plans and schemes, land use regulation, and granting development permissions for the areas under its jurisdiction - which are currently comprising of Panaji, Taleigao, Bambolim and the Kadamba plateau. With decision making powers with regards to land use over both, the city limits of Panaji and the spatial boundaries of Taleigao, it is the only body which can regulate development and land use along the entire stretch of the St Inez Creek.

As a result, there is no single institutional owner of the creek, rather several government bodies, some with overlapping jurisdictions, who are responsible for different aspects of the creek's management.

[1] Ministry of Housing and Urban Affairs, 74th Constitutional Amendment Act, <http://mohua.gov.in/upload/uploadfiles/files/74th_CAA13.pdf> [accessed 2 September 2020]
[2] Times News Network, (2018), Government asks Smart City Mission to work on reviving St Inez creek, <http://timesofindia.indiatimes.com/articleshow/62397526.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst> [accessed 24 April 2020]

4.3 The terminology used for the creek

St Inez Creek needs to be called/referred to as a creek in all official documents, in order to protect its historical and ecological significance.

The status of the St Inez Creek has changed over time. For example, before 2010, the creek was classified as a 'nullah' or drain, under control of the city government. As a 'nullah', the creek therefore could be built upon and there were even plans to concretise parts of it[3]. In 2010, a subcommittee of the urban scheme of the Jawaharlal Nehru National Urban Renewal Mission, decided to reclassify the St Inez Nullah a creek, based on evidence of tidal flushing.[4] Then In 2015, there was a workshop where the Goa State Pollution Control Board (GSPCB), members of the Member of Legislative Assembly of Panaji and other stakeholders reclassified the creek to a nullah.

In 2019, the National Green Tribunal directed the state government, specifically the Goa Coastal Zone Management Authority (GCZMA), to consider declaring the St Inez a creek by changing the classification of the St Inez Creek in the Coastal Zone Management Plan (CZMP) for the state, based on scientific findings[5].

However, as of July 2020, the status of St Inez - whether it is classified as a tidal creek or a drainage channel/ nullah - continues to remain ambiguous. The CZMP has been published for comments, but it does not contain information on the classification of the status of the creek[6].

[3] Times News Network (2019), Greed, neglect kill St. Inez creek, < https://timesofindia.indiatimes.com/city/goa/greed-neglect-kill-st-inez-creek/articleshow/70111405.cms> [accessed 24 April 2020]
[4] Times News Network, (2010), St Inez nullah now a creek, <http://timesofindia.indiatimes.com/articleshow/5764960.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst> [accessed 24 April 2020]
[5] Times News Network (2019), Declare St Inez water body as creek: NGT to Goa Government, <http://timesofindia.indiatimes.com/articleshow/71005656.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst> [accessed 24 April 2020]
[6] Draft Coastal Zones Management Plan, (as per CRZ notification, 2011), <https://czma.goa.gov.in/ViewDoc.aspx> [accessed 24 April 2020]

5
COMPENDIUM OF SOLUTIONS

5 Compendium of solutions

This chapter will present various projects the PULL, in collaboration with Ramboll, has shortlisted as possible solutions, drawing on specific examples and case studies. These projects could help the Panaji achieve its goals of the rejuvenation of St Inez Creek. These proposed solutions, presented below need to be prioritised and discussed with the city planners/departments and relevant stakeholders, showing their potential and how to be best adapted for the St Inez Creek location and then set out as a clear achievable action plan. The following solutions include the following details:

- Timeframe
- Location where the solution needs to be implemented for St Inez Creek rejuvenation plan
- Approximate cost derived from secondary literature including a case study (location where a similar project has been implemented)
- Proposed implementing agency or agencies in the city or state who have successfully implemented previous plans/projects

5.1 Goal 1: Maintaining the natural flow of the creek

Goal 1 relates to maintaining the natural flow of the creek.

5.1.1 Addressing SWM issues

Floating trash barriers

Description	• Barricades made of steel and aluminium, installed in the inlets of water bodies. These are secured to points on the creek bank or anchored to the creek bed: These barricades will • Assist with collecting all the trash in the creek including: plastic, weeds, sludge and mixed trash, which would be prevented from flowing into rivers and lakes. The arrested trash and plastics are brought to the creek banks using natural flow of water. • The barricades should be deployed where the stream is close to a road, which would make it convenient to remove and dispose with the use of land based equipment. • It is important that the barricades are built strong enough to withstand flood situations; and they are also durable in the corrosive, polluted waters that they are installed in • Currently, CCP has installed few of these traps/barricades, but these were not properly planned to trap only the floating debris and allow for bi-directional movement of fish

Implementation	• The installation of the barriers is a quick and easy process and would immediately start trapping waste/debris once installed. • However, cleaning minor and smaller channels, those of 20 to 30 meters, may be a problem since the water tends to stagnate.
Operation and Maintenance	• Dedicated resources (including a budget and workforce) required for daily raking, collection and disposal of the entrapped solids. • The collected solid waste/debris will have to be removed from the banks; the Municipal Solid Waste Management Agency has to regularlymaintain and haul away for proper resource recovery and disposal.
Financial and vendor details	• A successful case study is the Cooum River project in Chennai, Tamil Nadu. • The tender for installing trash traps in 9 locations along the 72 km Cooum River cost 85 lakhs, and further tender of 50 lakhs to install three additional traps • Vendors: AlphaMERS, DESMI, Agastya Intervention Pvt. Limited. 

Box 1: Trash barriers on the Cooum River, Chennai

Trash barriers, installed at eight places on the Cooum River in Chennai by Indian company AlphaMERs have prevented an estimated 21, 665 tonnes of waste from entering the sea. The waste is cleared out from the barriers with the help of trucks, or boats. AlphaMERS has installed these in Chennai, Tuticorin, Bengaluru and Pondicherry.

Box 2: Cleaning the Hussain Sagar lake

The Danish-based company DESMI provides unique floating barriers to clean up lakes and rivers. Under a tripartite agreement with World Resources Institute India Ross Centre (WRI) and the Hyderabad Metropolitan Development Authority (HMDA), DESMI installed a trash barrier in the Hussain Sagar Lake as a pilot demonstration project. The barrier traps up to 200-300 kgs of solid waste per day, which is then segregated and taken to recycling facilities or transfer stations. The HMDA is planning to install six more of these barriers in 2021. DESMI has a liaison office in Telangana and a production facility in Hyderabad.

5.2 Goal 2: Improving the water quality of the creek

Bioremediation/ Phytoremediation

Please note: It is crucial that the water in the St. Inez Creek is allowed to flow freely. This means that free floating aquatic vegetation, although potential effective, should not be introduced in it's waters as they could impede its flow. The aquatic vegetation will also facilitate the trapping of solid wastes, leading to further choking at the creeks bottleneck. This is likely to further exacerbate the flooding situation. Any bio remediation intervention should be done on the open banks of the Creek.

Time frame	Location	Cost	Proposed implementing agency
Short-Medium	Near Tonca PWD offices (STP) Cambrabhat – near the starting point / source of creek Downstream of STP out-let near Tambdi Mati		WRD and CCP

Description	• Bioremediation amplifies natural biological actions to remedy or remediate polluted groundwater and contaminated soil. It is a technique of the restoration of polluted water bodies by using natural and eco-friendly methods, such as use of aerobic microbes, enzymes and protozoa, which clean up the polluted water. It may also use some mechanisation, such as mechanical aeration systems, to support these natural processes. • Advantages of this method is that it can be relatively cheap since it does not require equipment, labouror energy • Contaminated soil and groundwater are treated onsite without having to dig, pump, and transport them elsewhere for treatment. Because microbes change the harmful chemicals into small amounts of water and gases, few if any, waste by products are created.
Implemen-tation	• Bioremediation can be carried out in the following two ways: a. In-situ, where all bioremediation work is done right at the contamination site. b. Ex-situ, wherein contaminated material is moved to a remote treatment location. • Several types of bioremediation techniques exist including phytoremediation, bioventing, bioleaching, landfarming, bioreactor, composting, bioaugmentation, rhizo-filtration and bio-stimulation
Operation and Maintenance	• The Operation and Maintenance depends on the method of bioremediation chosen and whether specific equipment is required.

Financial and vendor details	• The capital costs for the bioremediation project of the Haus Khaz Lake in Delhi totalled INR 5,72,500 and the operations and maintenance costs are INR 2,80,000 per acre per year. The total area under treatment is 15 acres. • Vendors: JM Enviro Technologies, Envirologic Technologies, EnoVeo,

Box 3: Treating the Haus Khaz Lake, New Delhi

Anoxic Bioremediation Technology (ABR) was used to treat the Haus Khaz Lake in New Delhi, which receives treated and untreated sewage from a nearby sewage treatment plant. Selected microbes were used to decompose sludge and break large molecules into smaller ones, reduce the Total Suspended Solids (TSS), Biological Oxygen Demand (BOD) and oil. The water is treated close to the inlet, and is treated in an alternating fashion, with high shock doses, followed by low doses.

Box 4: Feasibility of Phytoremediation for the creek

Anoxic Bioremediation Technology (ABR) was used to treat the Hauz Khas Lake in New Delhi, which receives treated and untreated sewage from a nearby sewage treatment plant. Selected microbes were used to decompose sludge and break large molecules into smaller ones, reduce the Total Suspended Solids (TSS), Biological Oxygen Demand (BOD) and oil. The water is treated close to the inlet, and is treated in an alternating fashion, with high shock doses, followed by low shock doses.

Phytoremediation is a form of in situ bioremediation that is a low cost, environmentally sustainable means of reducing contamination of soil and groundwater for both organic and heavy metal contaminants. In general, the planted areas have a significantly higher level of soil microorganisms, which are effective in enhancing the biodegradation of organic compounds into a form that can be taken up by plants. These microorganisms are primarily associated with the plant's root zone, called the rhizosphere, and generally share a symbiotic relationship with the plants.

It is crucial that the water in the St Inez Creek is allowed to flow freely. This means that free floating aquatic vegetation, although a potentially effective solution for improving the water quality, should not be introduced in its waters as it could impede the creek's water flow. Risks include the aquatic vegetation could also facilitate the trapping of solid wastes and debris, leading to further choking at any of the creek's bottlenecks, which could further exacerbate the flooding situation.

Considering these risks, any phytoremediation intervention taken up should be done along open banks of the creek. The vegetation could also effectively serve as another function, to stabilise the creek banks and prevent erosion, particularly in unstable areas.

Points to keep in mind while planning a phytoremediation intervention

- Use indigenous species as far as possible. When sites are highly contaminated, there could be a focus on planting species that are hyperaccumulators; i.e. plants that are disproportionately effective in absorbing pollutants.
- Planting of riparian species, i.e. species that thrive along waterwways
- Depending on the conditions, endophytic bacteria could be added to facilitate plants in the degradation

Phytoremediation could also be combined with other technologies such as electro kinetic remediation. This is done by transmitting electricity through the soil and can facilitate greater accumulation of the contaminants in the interstitial fluid of the rhizosphere.

Aeration

Time frame	Location	Cost	Proposed implementing agency
Short Term	Cambrabhat Near Tonca PWD offices (STP) Upstream of Vivanta Bridge		WRD

Description	• Aeration is required in water bodies that are polluted by adjacent human activities, including sewage discharges, agricultural run-off and solid waste disposal. • Aeration brings water and air in contact by exposing drops or thin sheets of water to the air; or by introducing small bubbles of air and letting them rise through the water. This helps remove dissolved metals through oxidation, the chemical combination of oxygen from the air with certain undesirable metals in the water. • There are a variety of ways to aerate water, which fall into two broad areas – surface aeration and subsurface aeration. Both types of aeration can be achieved through natural and mechanical methods.

Implementation	• Mechanical aerators can be installed in any reach of the creek; however, it is important to consider the depth of the water so that the device can function without disturbing the sediments on the bottom. It is also important to install these where there is stagnant water, which is not influenced by tidal flow. • It may be necessary to install these with floating trash barriers to remove any floating debris that would interfere with the operation of these mechanical devices. • Availability of a power source, and access to the creek edge are further considerations. The typical timeline for installation of these is between 3 to 5 months.
Operation and Maintenance	• Very low operating and maintenance costs; and can be installed by one person. • Periodic monitoring of the mechanical aerators is required to clean out floating materials trapped in the absence of floating trash barriers.
Financial and vendor details	• According to research articles, the annual maintenance cost for the cascade aeration in Hauz Khas L ake is approximately 6 lakhs per year. • Vendors: Hydratech Engineers and Consultants

Box 5: Aerators for Hebbal Lake, Mysore

In an effort to tackle fish deaths in Mysore's Hebbal Lake, six aerators were installed inside the lake by the Infosys Foundation under the Public Private Partnership(PPP) model by the State. As well as oxygenating the lake and enhancing fish habitats, the aeration system provided several other benefits to the Lake's ecosystem such as breaking down unwanted bacteria, reducing foul odours and algae etc., therefore ultimately improving the overall health of Hebbal Lake.

Bio frames

Time frame	Location	Cost	Proposed implementing agency
Short Term	On side drains discharging to St Inez Creek - Cambrabhat inlet drains - Tambdi Mati - St Inez Road (opp PWD offices)	INR 5 Lakhs / location without structural interven-tions	WRD

Description	• Bioframes, or suspended growth media, are designed for wastewater treatment. These are made of an inert object that provides large surface areas for the microorganisms to attach themselves to and multiply. These colonies of microorganisms improve the efficiency of uptake of biological material (food) from the flowing water. The support frames or suspended growth media provide protection for the microorganisms from being washed away. • The microbes efficiently treat the sewage, and ensure a high quality of treated water. Bioframes are recognised as a promising water treatment tool and can be installed in existing drains at culverts or similar openings.
Implementation	• These frames require little to low maintenance and are easy to install. They can be installed in existing drains at culverts or similar openings. The installation of these might require some changes for the drain/ opening of the drain cover etc., based on site specific condition. Overall, these can be implemented with in a few weeks time period.
Operation and Maintenance	• Bioframes provide a symbiotic culture bed for a wide spectrum of microbes including bacteria, protozoans and algae. The proliferating microbes efficiently treat the sewage and ensure a high quality of treated water. Anaerobes consume the excreta of the aerobes, so the system becomes a balanced food chain in itself. Bioframes have been recognised as a promising water treatment tool, can work effectively in either large or small size water bodies and can be installed in existing drains at culverts or such openings. The only maintenance they require is removal of any foreign materials, like plastic or other large items, which can hinder the surface contact of fibers with the flowing water.
Financial and vendor details	• First phase, worth INRs 15 crores spent by HDSCL

Ecological bridge filters

Time frame	Location	Cost	Proposed implementing agency
Medium Term	Areas where side walls are being re-habilitated - Near Don Bosco School - Upstream of Tonca PWD works - Near Tambdi Mati along the park edge		WRD

Description	• Ecological filter beds mainly consist of gabion baffle walls installed, along with fibrous media, to provide a favourable space for microorganisms to purify the water quality of contaminated water. A galvanic iron wire or a galvanic wire mesh structure is made by twisting PVC-coated iron wire after galvanization and filled with a pebble or crushed stone in the gabion. • When filling a structure with pebble or crushed stone, a plurality of fibrous media having a large microbial adhesion area are arranged at regular intervals in a vertical or horizontal direction and then filled with the pebble or crushed stone, thereby fixing the fibrous media between the stones. All the floatable and suspended solids are trapped in this biological bridge and the turbidity of flowing water is reduced substantially. These gabion structures also provide for structural side walls for the creeks to demarcate the banks and assist in preventing erosion.
Implementation	• Two metal screens are installed at upstream of the filter bridges to prevent the solid waste entering into the system. • Green bridge filter is prepared with a combination of coconut coir mats, sand, gravel and boulders. • The floatable and suspended solids are trapped which substantially reduces the turbidity of flowing water. • Microbial bioremediation process reduces the organic and inorganic content present in the untreated water • Plantation of local grasses,for example lemon grass and Typha, is done to aid the treatment process

Operation and Maintenance	• The installation can be carried out by local resources. The microbial and plantation would take 2-3 months for establishment. Overall, the Green Filter Bridge can be installed in 4-6 weeks. • These can be deployed on the main creek downstream of the pollution sources. These are also effective in treating the flows discharging from side drains. The bridge acts as a barrier, capturing the floating materials and the impurities in the water, which are then screened and treated while it passes through the natural filter bed. Due to potential for ponding of water in the creek, the site will require an area which can allow or accommodate such ponding. • This is not suitable where the tidal flow is prevalent as it disturbs the filter media due to bi-directional flow. The salinity also will have an adverse impact on the biotic environment which grows in these filter media and enables treatment of organic matter.
Financial and vendor details	• F or the revival of the Ahar R iver in Udaipur, Green B ridge technology is being used and has been operational since 2010. The actual capital cost for that project totalled INR 2-5 lakhs. • Designed Capacity of Ahar River project: 100 MLD • The capital cost of the project was INR 33 lakhs (This cost denotes the amount incurred by Udaipur, with Operation and Maintenance costs totally between INR 2-3 Lakhs per year

5.3 Goal 3: Ensuring that communities can access St Inez Creek

Currently access to St Inez Creek is not available/possible for the community. This further creates a distance between the community and the water body, and therefore any rejuvenation plans for the creek must include the creation of community spaces that the neighbourhoods can access. Including the ability to use it as a community space for recreation and outdoor activities. As well as the development of park spaces along the creek front, all plans should also include goals that further should enhance the land use along the creek, including those that develop a natural ecosystem. Such a natural system is essential to preserve and increase the biodiversity of Panaji and to create a system that preserves the creek.

Access along the length of the St Inez Creek can be created by a continuous natural trail along the creek incorporating a cycle-only and/or pedestrian paths to encourage interaction of public with the creek. As the creek revitalization and clean up gains in popularity, the community will further benefit from increased livability, a cleaner environment and from a natural recreation environment which in turn promote community measures and engagement to preserve the creek.

6
INSTITUTIONAL ENGAGEMENT

6 Institutional engagement

The St Inez Creek cuts across the Goa state captial city of Panaji. It originates in the marshlands in Taleigao and is fed by rainwater from the Altinho and Nagahalli hills. In Panaji, it passes through Camrabhat, Tamidi Mati, Tonca, flowing behind the Military Hospital, Don Bosco School and the ESG complex. Despite the importance of the creek for the city, it has increasingly become polluted, silted and stagnant.

One of the main challenges with its rejuvenation and restoration is its fragmented governance. There is no single institutional owner of the creek, and many government bodies, some with overlapping jurisdictions, are responsible for different aspects of its management. The overlapping jurisdictions of the various government bodies have several implications for the management of the creek. Some of these include:

- Plans for revival of the creek made by various agencies: Proposals for revival of the creek have been commissioned by several agencies including the Corporation of City of Panaji, the Goa State Infrastructure Development Corporation and Imagine Panaji Smart City Development Limited.
- Role of the Sewage Treatment Plant in Tonca: A significant dry weather flow in the creek is from the treated effluent from the Sewage Treatment Plant at Tonca. Though the STP is managed and operated by the Public Health Division of the Public Works Department, there seems to be ambiguity with stakeholders on the quantity and quality of the treated effluent discharged from this STP into the Nala. Under the Smart City projects, a project is envisaged by PWD to utilise the treated effluent for irrigation of all parks and green spaces in Panaji City. In parallel, the WRD has proposed an element under its St Inez Rejuvenation Plan to build a water retaining structure and place aerators to improve the water quality of the treated effluent being discharged into the creek. Although both projects are being taken under the aegis of the Smart City proposals, there appears to be lack of coordination on the planning of utilisation of the treated effluent from the STP. A cursory review of the treated effluent quality indicates that the treatment standard meets receiving water quality set out by Goa State Pollution Control Board.
- Overlapping jurisdictions in desilting the creek: The Water Resource Department is in charge of desilting the creek, but needs permission from the GCZMA to do so. Most recently, the Goa Coastal Zone Management Authority (GCZMA) has cautioned the Water Resources Department (WRD) against over desilting the mouth of the creek to protect sandbars and mangroves. In addition, to dispose of the sand on forest land, the WRD has to be granted a no-objection certificate by the state Forest Department. Further, dredging/ desiltation at the mouth of the St Inez Creek, which flows into the Mandovi River falls within the jurisdiction of the Captain of Ports Department, Government of Goa. The constriction at the mouth of the river is planted and maintained by the Forest Department and any change in the nose formation has to be with the permission of the Forest Department. These kinds of inter-departmental dependencies cannot be resolved by a single implementing department and require very close coordination among all the departments involved in the jurisdiction of the St Inez Creek.

In light of the multi-departmental jurisdiction on the planning, management and operation of the St Inez Creek, it is recommended that an inter departmental coordination committee be set up for planning and management of the St Inez Creek.

Bibliography

1. Correia, F.N., Da graça saraiva, M., Da Silva, F.N. et al. 1999. "Floodplain Management in Urban Developing Areas. Part I. Urban Growth Scenarios and Land-Use Controls." Water Resources Management 13 1-21. doi:https://doi.org/10.1023/A:1008097403587.
2. CPHEEO. 2013. Manual on Sewerage and Sewage Treatment Systems. New Delhi: MoUD.
3. CPHEEO. 2019. Manual on Stormwater Drainage Systems Volume-1, Part A: Engineering Design, First Edition. Ministry of Housing and Urban Affairs, Govt. of India, Central Public Health Environmental Engineering Organisation. http://cpheeo.gov.in.
4. CRISIL Risk and Infrastructure Solutions Limited. 2015. Revised City Development Plan for Panaji, 2041. Panaji: Corporation of the City of Panaji.
5. LKS INGENIERIA, S.COOP. 2017. Detailed Project Report Hydraulic and Environmental Regeneration of Santa Inez Creek. Panaji: Goa State Infrastructure Development Corporation.
6. MoEF&CC. 2017. "Environment Protection Amemdment Rules." GSR 1265 (E). New Delhi, 13 10.
7. Ramboll and Ramboll Studio Dreiseitl. n.d. The Copenhagen Cloudburst Formula: A Strategic Process for Planning and Designing Blue-Green Interventions. Copenhagen, Denmark: Municipality of Copenhagen.
8. T.Sundarmoorthy, Lalitha Ramadurai and N.G.Anuthaman. 2009. "Urban Floods: Case Study of Chennai." Disaster & Development Vol. 3 No. 1 April 2009 105-181, April: 105-181.
9. Vishwanath, S. n.d. Rainwater Harvesting, Case Studies, Jakkur Lake - Urban Lake Management. Accessed April 14, 2020. https://www.cseindia.org/jakkur-lake-urban-lake-management-6402.
10. WAPCOS. 2014. Final Detailed Project Report for Development of Santa Inez Creek. Gurgaon: Corporation of the City of Panaji.

ANNEXURES

Annexure 1 Hydraulic Modelling Approach For Panaji

This memo is prepared by Knowledge Partner Ramboll for various approaches to hydraulic modelling of urban stormwater management.

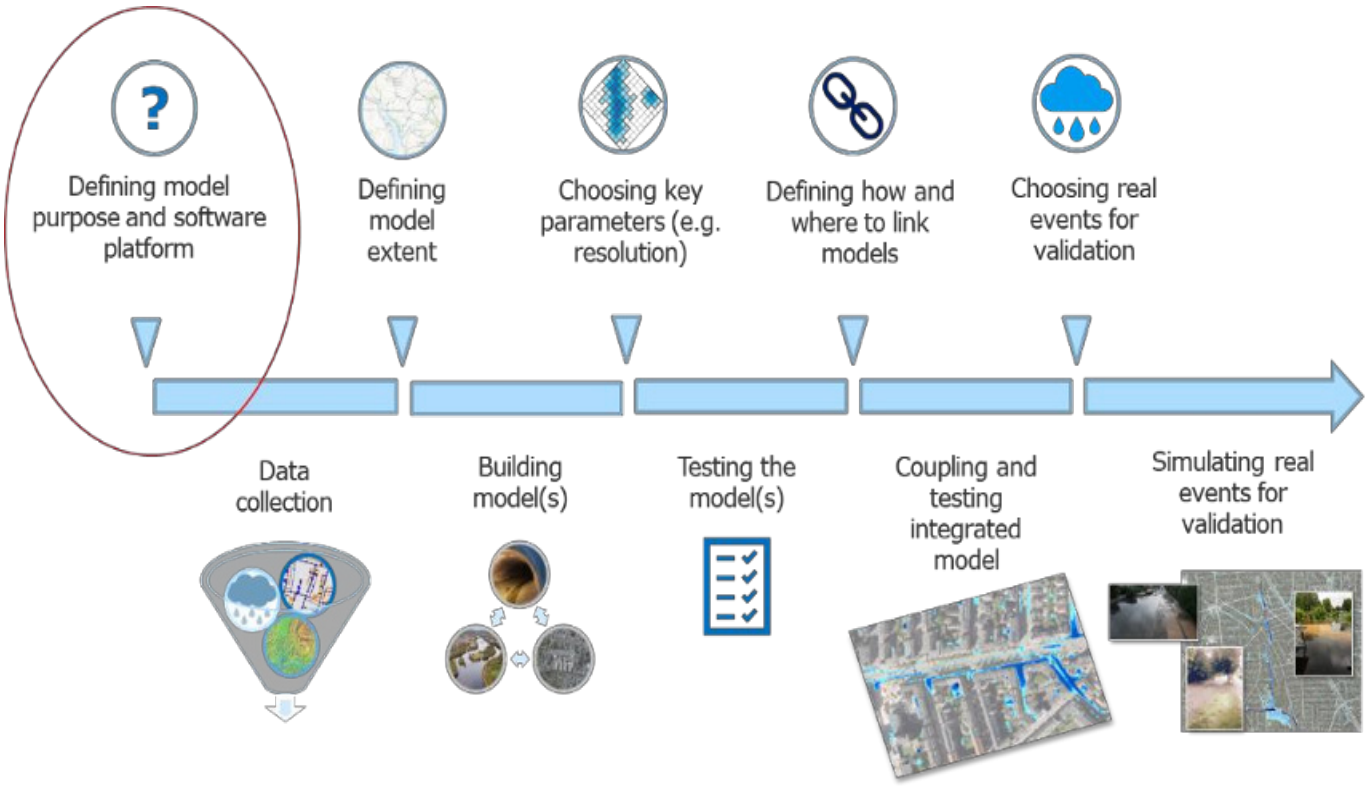
1.1 Background

This memo describes potential approaches to building a hydraulic model for Panaji covering the St Inez Creek, with the purpose of facilitating further discussions and workshops to define the best approach, considering the short-and long-term needs as well as the available resources. The memo is based on conversations about the state of St Inez Creek between IPSCDL, PULL and Ramboll as knowledge partne,r as well as, the report describing in the rejuvenation plan for the creek by Royal Haskonig DHV (August 2019).

To provide understanding of the available options in terms of model uses and different levels of detail, three modelling approaches are presented; each with increasing data requirements and level of detail. These should not be seen as the only options available, as there will be intermediary stages or other approaches available, but the three options are considered to provide an understanding of the typical approaches applied when building hydraulic models.

The typical process for selecting, building, and testing hydraulic models is illustrated on Figure 1 below, ranging from the initial definition of the model purpose to the simulation of real rain events. The process is in the first step of the process and this document will support the decisions that are necessary to proceed along this process.

Figure 01: Typical process of selecting and developing a hydraulic model



1.2 Modelling Approach

The following sections will provide details on model outputs, data requirements and assumptions for three modelling approaches at increasing levels of detail. Important considerations when deciding which modelling approach is more beneficial include:

- The purpose of the model should be considered and defined before settling on a specific approach, to ensure that the model provides the necessary outputs while not spending valuable resource building models that are more complicated and detailed than what are necessary to meet the demand.
- The available data (or possibility of collecting additional data) should match the level of detail expected from the model. The accuracy of any hydraulic model is, for the most part, is determined solely by the quality of the data which the model is based on. Therefore, if limited data is available, a simple model may be the optimal choice.
- Consider who is going to be using the model, and if there are any limitations to the technical capacity of the end-users.

The three model approaches presented in the following sections include both one-dimensional models (1D models) and a two-dimensional model (2D model). The key difference between a 1D model and a 2D model is in the data requirement and available model outputs. A 2D model relies on a detailed terrain model, and while this is often one of the more challenging data items to obtain, it provides the option to produce flood maps that show the extent and depth of flooding and indicate which assets (houses, roads, infrastructure etc.) that would be exposed to flood damages.

1.3 Model Approach 1: St. Inez Creek – 1D model

The first approach considers the hydraulics of the St Inez Creek and relies on simplifications and assumptions to model the runoff and conveyance in the urban drainage network. This model would be relatively simple to produce and does not require significant surveys or measurements to make a functioning model. The available model outputs are limited however, and potential model scenarios would include changing the cross-section i.e. remove obstructions caused by bridges and culverts, testing simple control structures such as weirs and stormwater detention and run scenarios that considers a changing climate and urban development and how this affect the hydraulic dynamics in the creek.

1.3.1 Key Model Outputs

- Flows and water levels in the river during rain events
- Identify critical points of overflow along the banks of the creek
- Identify bottlenecks in the river, i.e. culverts or bridge crossings with improper dimensions
- Scenarios with altered cross-sections or removal of bottlenecks to quantify benefits and illustrate hydraulic conditions in the river 'before and after' a proposed intervention
- Climate change scenarios, including rising sea levels and increasing precipitation and how this affects the hydraulics in the creek i.e. more overflow from the creek or limited gravitational drainage capacity
- Scenarios with altered stormwater runoff patterns, i.e. changes in land cover such as reduced/increased imperviousness
- Scenarios with changes to stormwater control structures such as storage volumes, i.e. the addition of a new stormwater basin or Blue Green Infrastructure with a storage

component, weirs and/ or sluice gates

1.3.2 Data requirements:

Figure 01: Typical process of selecting and developing a hydraulic model

- River cross-sections, the number of cross-sections will depend on the bathymetry of the creek but capturing significant cross-sectional change i.e. culverts or bridges is of key importance.
- Existing stormwater control structures, such as stormwater detention, pumping stations, weirs and sluice gates in the creek
- Water level time series at the point of discharge (at the mouth of the Mandovi River)
- Land cover data (used to estimate runoff coefficients within the catchment)
- Catchment delineation for the creek

1.3.3 Key Assumptions:

- All runoff from the creek catchment reaches the creek, without obstruction (locations of overflows and limited capacity of the secondary and tertiary drainage network is not captured in this model)
- The condition of the creek is reflected in the cross-section data, hence local obstructions due to collapsed retention walls between cross-sections will not be captured in the model unless specifically added as a unique feature in the model
- The river is free of solid waste and siltation
    - Scenarios with partially blocked cross-sections may be tested.

1.4 Model approach 2: All Drainage Infrastructure – 1D model

In addition, to Model Approach 1 of the creek itself, the urban drainage system may be added to the model to represent the dynamics of the urban drainage conditions more accurately. While this would require information on dimensions and levels of the drainage networks, it provides the opportunity to more accurately represent the dynamics of the drainage system and capture local flooding issues caused by insufficient conveyance or storage in the secondary and tertiary drainage system.

1.4.1 Key Model Outputs

- Flows and water levels in the drainage network during rain events
- Identify critical points of overflow in the drainage network during intense rain events
- Identify bottlenecks in the drainage network, i.e. culverts or bridge crossings with improper dimensions
- Scenarios with altered cross-sections or removal of bottlenecks to quantify benefits to illustrate hydraulic conditions in the drainage network 'before and after' an intervention
- Climate change scenarios, including rising sea levels and increasing precipitation and how this affects the hydraulics in the creek i.e. more overflow from the creek or limited gravitational drainage capacity
- Scenarios with altered stormwater runoff patterns, i.e. changes in land cover such as reduced/increased imperviousness
- Scenarios with changes to stormwater control structures such as storage volumes, i.e. the addition of a new stormwater basin or blue-green-infrastructure with a storage component, weirs, or sluice-gates

1.4.2 Data requirements:

- River cross-sections, the number of cross-sections will depend on the bathymetry of the creek but importantly it would be required to capture significant cross-sectional change i.e. culverts or bridges.
- Existing stormwater control structures, such as stormwater detention, pumping stations, weirs, and sluice-gates in the drainage network
- Water level time series at the point of discharge (at the mouth of the Mandovi River)
- Drainage network layout
    - Must be fully connected i.e. no gaps in the drainage network
- Dimensions of all drains and pipes
- Invert levels for all drains and pipes
- Land cover data (used to estimate runoff coefficients)
- Drainage network catchment delineation

1.4.3 Data requirements: Key assumptions

- All runoff reaches the drainage network, without obstruction
- The condition of the drainage network is reflected in the cross-sections and drain/pipe dimensions. Local obstructions due to collapsed drains, shifted pipes etc. will not be captured in the model unless specifically added as a unique feature in the model
- The drainage network is free of solid waste and siltation

- Scenarios with partially blocked cross-sections may be tested

Figure 01: Modelling approach that includes the drainage system, relying on simplifications and assumption to simulate the hydrology and hydraulics of surface flows.

1.5 Combined Flood Model – 2D model

Combining the 1D flood model with 2D model simulating flows on terrain will allow the user to map the extent and depth of flood events, and potentially quantify damages and more accurately target improvements at the areas where the highest risk is observed. As this type of model simulates flows across the terrain (considering each 'cell' of the terrain model in the simulation) the accuracy of the terrain model is critical to obtain results that accurately represent real conditions. Further detailing may include accurate representation of infiltration by including groundwater levels and soil types, evaporation and base flows. However, this is not considered feasible or necessary for the expected purpose of the model in Panaji.

Figure 01: Modelling approach that includes the drainage system and terrain relying on simplifications and assumptions to simulate hydrological conditions such as infiltration and evaporation

1.5.1 Key Model Outputs

- Flood maps showing the extent and depth of flooding
- Identification of exposed assets and damages
    - This may be quantified in monetary terms if damage curves are available and sufficient model accuracy is obtained. If damages are quantified in monetary terms, a cost-benefit assessment may be used to justify or discard proposed interventions by weighing the reduced flood damages against the cost of the intervention
- Flows and water levels in the drainage network during rain events
- Identify critical points of overflow in the drainage network during intense rain events
- Identify bottlenecks in the drainage network, i.e. culverts or bridge crossings with improper dimensions
- Scenarios with altered cross-sections or removal of bottlenecks to quantify benefits illustrate
- Hydraulic conditions in the drainage network 'before and after' an intervention
- Climate change scenarios, including rising sea levels and increasing precipitation and how this affects the hydraulics in the creek i.e. more overflow from the creek or limited gravitational drainage capacity
- Scenarios with altered stormwater runoff patterns, i.e. changes in land

cover such as reduced/increased imperviousness
- Scenarios with altered terrain
- Scenarios with changes to stormwater control structures such as storage volumes, i.e. the addition of a new stormwater basin or blue green Infrastructure with a storage component, weirs or sluice gates

Figure 01: Modelling approach that includes the drainage system, relying on simplifications and assumption to simulate the hydrology and hydraulics of surface flows.

Exposed areas
Example: Copenhagen

Exposed buildings and infrastructure
Example: Oslo

Testing proposed solutions
Example: New York City

1.5.2 Data requirements:

- Detailed terrain model, ideally in a 5 x 5 m grid size or less, but larger cell sizes may be used at the cost of model accuracy
    - The elevation model should only include the terrain surface and should not include features that does not affect the surface flows significantly e.g. tree canopies or other vegetation
    - The terrain model may include buildings, or these can be raised in post-processing if the buildings are digitalis ed (usually provided as polygons in CAD or GIS)
- River cross-sections, the number of cross-sections will depend on the bathymetry of the creek but importantly it would be required to capture significant cross-sectional change i.e. culverts or bridges.
- Existing stormwater storage infrastructure, both location and dimensions
- Water level time series at the point of discharge (at the mouth of the Mandovi River)
- Drainage network layout
    - Ideally the network should be connected i.e. no gaps in the drainage network
- Dimensions of all drains and pipes
- Invert levels for all drains and pipes
- Land cover data (used to estimate runoff coefficients)
- Drainage network catchment delineation

1.5.3 Key assumptions:

- The drainage network is free of solid waste and siltation
    - Scenarios with partially blocked cross-sections may be tested, but specific obstructions will not be captured
- Ideally, the drainage network and terrain must be aligned to allow for flows between the network and the surface
    - Where the two are not aligned along the z-axis, the network will typically be fitted to the terrain model, thereby artificially changing the invert levels, and decreasing model accuracy
    - Where the drainage network is not aligned with the 2D surface the network would be manually fitted to the 2D surface, or you would allow for some inaccuracies in the model

1.6 Next Steps / Additional Considerations

The purpose of this document is to provide a baseline to discuss the specific needs of scenario based modelling in Panaji, to facilitate the discussions and workshops and finally select the optimal model setup. This will be an ongoing process that will take place following the production of this document. Further data gap analysis will be necessary/required to identify any missing data will be required in order to design and build the optimal model. As well it is crucial that there is an alignment of expectations that consider the resources that will be allocated to close the potential data gaps and meets the demands of the hydraulic model.

Finally, to build confidence in the results of any of the three modelling approaches a calibration/ validation process is required. This may be done running simulations of real events and comparing the results with real conditions. This will require historical rain data as the input to the model and measured water-levels/discharge/flood extent to validate the results.

2 Annexure 2: Institutional Assessment of St. Inez Creek Management

2.1 Introduction

The St Inez Creek cuts across the Goa state captial city of Panaji. It originates at the marshland in Taleigao and is fed by rainwater from the Altinho and Nagahalli hills[7]. In Panaji, it passes through Camrabhat, Tamddi Mati, Tonca, flowing behind the Military Hospital, Don Bosco School and the ESG complex[8]. Despite the importance of the creek for the city, it has increasingly become polluted, silted and stagnant.

One of the main challenges with its rejuvenation and restoration is its fragmented governance. There is no single institutional owner of the creek, and many government bodies, some with overlapping jurisdictions, are responsible for different aspects of its management.

This note summarises the institutional landscape of the creek. Section 1.2 summarises the institutional landscape at the national, state and city level. Section 1.3 describes the implications of fragmented governance, using examples from recent news articles on the creek. The note builds upon the institutional mapping prepared in the background paper.

2.1 Institutional framework

2.1.1 Background

India has three tiers of government, the central, state and village/city level. The Indian Constitution specifies three lists that demarcate functions across these tiers. The union or central list contains the subjects on which the Parliament can legislate on, while the state legislatures legislate on the state; the concurrent list has subjects where both the state and centre have jurisdiction. Policy is framed at the centre and the state depending on the subject and its place in the central, state or concurrent list. Line departments of ministries at the centre and state are charged with implementing these policies.

Water is a state subject, which means that states have the exclusive power to regulate water supplies, irrigation and canals, drainage and embankments, water storage, waterpower and fisheries. The central government may provide financial resources to states for the management of water resources. States can devolve some functions related to minor irrigation, water management, supply and solid waste management to local governments.

Coastal areas, such as creeks, estuaries and beaches, come under a Coastal Regulation Zone (CRZs) as per a Coastal Zone Regulation notification of 1991. Under this notification, areas are demarcated into various zones; zones that denote the level of economic activity allowed. CRZ rules are made by the Union and implemented by the state and are intended to protect coastal and estuarine ecosystems.

[7] Mission Green Goa, State of the St. Inez Creek – A reconnaissance visit with the GSPCB, Available: http://missiongreengoa.blogspot.com/2013/09/state-of-st-inez-creek-reconnaissance.html [accessed 22 April 2020]
[8] Royal HasKonig DHV, Review of the DPR Report, St. Inez Creek – not publicly available

2.1.2 Current status of the St Inez Creek

In the past, the status of the St Inez Creek has changed, ostensibly for political reasons. For instance, before 2010 the creek was classified as a 'nullah' or drain, under control of the city government. In 2010, a subcommittee of the urban scheme, the Jawaharlal Nehru National Urban Renewal Mission, decided to classify the St Inez Nullah as a creek, based on evidence of tidal flushing. As a 'nullah', the creek could be built upon and there were plans under the JnNURM to concretise parts of it. These plans were later abandoned.

In 2015, there was a workshop in which the Goa State Pollution Control Board (GSPCB), the Members of Legislative Assembly of Panaji and other stakeholders, to reclassify the creek to a nullah. Citizen groups allege that this reclassification was politically motivated to allow builders to continue to build in and around the creek. In 2019, the National Green Tribunal directed the state government, specifically the Goa Coastal Zone Management Authority (GCZMA), to consider declaring the St Inez a creek by changing the classification of the St Inez Creek in the Coastal Zone Management Plan (CZMP) for the state - based on scientific findings which were discussed during the 119th meeting of the GCZMA in August, 2015.9 As of July 2020, the status of the St Inez Creek - whether it is a tidal creek or a drainage channel/ nullah - remains ambiguous since the GCZMA has not concluded the CZMP for Goa.[10]

2.1.3 National

At the national level, the following Ministries are relevant

Institutional framework

Government body	Functions with respect to the St Inez Creek
Ministry of Environment and Forests	Conducts
Department of Ocean Development	Conduct
Central Pollution Control Board	Conduct

[9] https://timesofindia.indiatimes.com/city/goa/declare-st-inez-water-body-as-creek-ngt-to-goa-government/articleshow/71005656.cms
[10] https://www.heraldgoa.in/Goa/Deadline-missed-still-months-to-go-to-finalise-CZMP/163428

2.1.4 State level institutional arrangements

At the State level, the following departments and government bodies are responsible for management of activities and resources associated with water bodies in Goa, including the St Inez Creek:

Government body	Website	Legislation	Functions with respect to the St Inez Creek
Department of Water Resources, Government of Goa	https://goawrd.gov.in/	Earlier known as the Irrigation Department, it was re-named as Department of Water Resources Governwwment Notification No. 23/1/87/GA & D (i), dated 12/12/2000	• - • Engage in flood control, anti-sea erosion and drainage works • Other works by the department include conservation of water resources, watershed development and development of water resources for domestic and industrial use • For St Inez Creek - Responsible for water network infrastructure (Treatment Plants, etc.)
Goa State Pollution Control Board	http://goaspcb.gov.in/Functions	Constituted on 1 July 1988, under the Water (Prevention & Control of Pollution) Act, 1974	• Monitoring water quality for water bodies in the city • Monitoring and regulation of wastewater discharged by industries and establishments • For c reek - Monitoring water quality and discharge from activities along the creek
Public Works Department (Public Health Engineering division includes Water Supply & Sanitation schemes/ programmes)	https://pwd.goa.gov.in/programmes-projects-and-schemes/water-supply	--	• Provide water supply to tourist, commercial, industrial, and residential areas • Extend sewerage facilities in the uncovered urban areas • For c reek - Tonca wastewater treatment management and maintenance, management of water supply infrastructure

Goa Coastal Zone Management Authority	https://czma.goa.gov.in/	Constituted by the Ministry of Environment and Forest, Government of India, in exercise of power conferred by sub-section (1) and (3) of section 3 Environment (Protection) Act, 1986	• Mandate is to take measures for protecting and improving the quality of coastal environment • Preventing, abating, and controlling environmental pollution in the coastal areas • Enforces Coastal Regulation Zone (CRZ) notifications • For c reek- Regulating developments along the creek, both manmade and natural
Department of Forest, Government of Goa	https://www.forest.goa.gov.in/#	Set up under the Indian Forest Act, 1927	• Implement policies and programmes of the state government for protection, development and management of forest and wildlife resources • To protect and improve mangrove ecosystems • Conservation and protection of the endangered flora and fauna of the state • For c reek - Manage vegetation adjacent to the creek and along the banks
Directorate of Agriculture, Government of Goa	https://www.goa.gov.in/department/agriculture/	--	• Planning, execution, and monitoring of agricultural development programmes in accordance with state and central sector policies on agriculture • Provide suitable measures for welfare of the farmers in the state of Goa • For c reek - Activities related to irrigation along the creek and ancillary water channels
Town and Country Planning Department, Government of Goa	https://tcp.goa.gov.in/	Statutory under the Town & Country Planning Act 1974	• Implement different plans for urban and regional areas, such as - regional plan, development plans/ zoning plans, conservation area plans • Provide consultancy and technical services for government agencies, such as the development of rehabilitation/layout plans for residential and industrial developments

Captain of Ports Department, Government of Goa	http://www.ports.goa.gov.in/en/	Implements the Indian Ports Act, Inland Vessels Act, Goa Daman and Diu Barge/ Goods Taxation Acts, etc.	Responsible for developmental works of inland waterways and minor ports of Goa, by way of periodical hydrographic surveys, dredging of rivers, and maintenance of lighthouses and beacons
Department of Urban Development (Municipal Administration), Government of Goa	https://urban.goa.gov.in/	Deals with various functions as envisaged under the Goa Municipalities Act, 1968, and the City of Panaji Corporation Act, 2002 and Rules	Exercises administrative control over the 13 Municipal Councils and one Corporation of the City of Panaji in the State of Goa Administers/implements State and Central Government Schemes and grants are also provided
Goa State Urban Development Agency (GSUDA)	https://www.gsuda.org/	Society registered under the Societies Registration Act 1860 under the administrative control of the Directorate of Municipal Administration, Urban Development Department, Govt. of Goa	Nodal Agency for coordination, monitoring, and implementation of various centrally-sponsored schemes implemented by the Ministry of Urban Development and the Ministry of Housing and Urban Poverty Alleviation, Government of India Engaged in infrastructural development activities in urban areas in the state under Integrated Development of Major Towns, which is a state-sponsored scheme

2.1.5 City-level institutional arrangements

The Corporation of City of Panaji (CCP) is the urban local body charged with the upkeep and maintenance of civic facilities in Panaji. It draws its powers from the City of Panaji Corporation Act, 2002 - an outcome of the 74th Constitutional Amendment which devolves certain powers to municipal bodies. Its main functions with regards to the St Inez Creek include regulating land use along the creek, maintaining storm water channels leading up to the creek and ensuring adequate management of solid waste and sanitation facilities. Additionally, Imagine Smart City Development Limited has been formed as a Special Purpose Vehicle (a legal entity created for a specific purpose) by the Government of Goa to implement the Indian Government's Smart Cities Mission in Panaji. Although it does not, by default, have powers to manage the St Inez Creek, it has been tasked by the Government of Goa with the revitalisation of the creek[11].

The St Inez Creek also passes through the village of Taleigao, located on the south western periphery of Panaji. Due to this, a section of the creek falls within the area limits of the Taleigao Village Panchayat, which regulates land use and building permissions along that particular section of the creek.

Lastly, the Greater Panaji Planning and Development Authority (GPPDA) is a statutory body formulated under the Town and Country Planning Department, Government of Goa. Its main functions include the development and implementation of plans and schemes, land use regulation, and granting development permissions for the areas under its jurisdiction; currently comprising Panaji, Taleigao, Bambolim and the Kadamba plateau. With decision-making powers with regards to land use over both, the city limits of Panaji and the spatial boundaries of Taleigao, it is the only body which can regulate development and land use along the entire stretch of the St Inez Creek.

Table 01: Institutions responsible for the St Inez Creek[12]

Government body	Website	Functions with respect to the St Inez Creek
Corporation of City of Panaji	http://ccpgoa.com/about-us	• Urban local body (ULB) for the city of Panaji. • Responsible for land use around the creek, sanitation, solid waste management, and maintenance of storm water drains leading into the creek.
Imagine Panaji Smart City Development Limited	https://imaginepanaji.com/	• Special Purpose Vehicle for the implementation of the Smart Cities Mission in Panaji.
Taleigao Village Panchayat	n/a	• Regulates land-use and building permissions pertaining to the section of the creek which passes through the village of Taleigao.

[11] https://timesofindia.indiatimes.com/city/goa/govt-asks-smart-city-mission-to-work-on-reviving-st-inez-creek/articleshow/62397526.cms

[12] Based on information in Royal HasKonig DHV, Review of the DPR Report, St. Inez Creek – not publicly available

Greater Panaji Planning and Development Authority (GP-PDA)	n/a	• Preparation of development plans. • Prescribe use of land within its area. • Implementation of development plans and schemes. • Schemes of development and undertake their implementation. • Development regulation including granting permissions. • Enforcement of prohibition on cutting of hilly land and filling up of low lying areas.

2.2 Implications of management of the St Inez Creek

The overlapping jurisdictions of the various government bodies have several implications for the management of the creek. Some of these include:

- Plans for revival of the creek made by various agencies: Proposals for revival of the creek have been commissioned by several agencies including the Corporation of City of Panaji, the Goa State Infrastructure Development Corporation, and Imagine Panaji Smart City Development Limited.
- Role of the Sewage Treatment Plant in Tonca: In March 2019 there were reports that the creek had been encroached upon by the government Sewage Treatment Plant at Tonca. Based on the reports, the city government was not aware and had not provided permission for this encroachment.
- Overlapping jurisdictions in desilting the creek: The Water Resource Department is in charge of desilting the creek, but needs permission from the GCZMA to do so. Most recently, the Goa Coastal Zone Management Authority (GCZMA) has cautioned the Water Resources Department (WRD) against over desilting the mouth of the creek in order to protect sandbars and mangroves. In addition, to dispose of the sand on forest land, the WRD has to be granted a no-objection certificate by the state Forest Department. Further, dredging/ desiltation at the mouth of the St Inez Creek, which flows into the Mandovi River falls within the jurisdiction of the Captain of Ports Department, Government of Goa.

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