CLIMATE RESILIENT INFRASTRUCTURE SERVICES

CASE STUDY BRIEF: VISAKHAPATNAM

CONTENTS

PREFACE

Infrastructure plays an important role in sustaining the development of a city. Infrastructure assets provide critical social and economic services not only to the city where they are located but also to the surrounding areas. The degree to which a city is vulnerable to climate hazards depends on the frequency and intensity of climate related events as well as the local capacity to anticipate and respond to them. Quality, access, and efficiency of infrastructure services play an important role in determining this local capacity of the city as well as the magnitude of structural and economic loss that a city will have to bear in times of adversities. The vulnerability of coastal regions to climate change is an issue which has gained attention recently. Increase in the Sea- Level Rise (SLR), and the frequency and intensity of storms are two primary impacts of climate change faced by coastal communities.

This document is a result of a year long study conducted by The Energy and Resources Institute (TERI) granted by USAID as part of their Climate Change Resilient Development (CCRD) project's climate adaptation small grants program. This grant was in support of the Climate Resilient Infrastructure Services (CRIS) program within the CCRD project. The work was reviewed by ICF International and Engility which is leading USAID's small grants program under the CCRD initiative. The goal of this study was to help the cities of Panaji and Visakhapatnam to plan for and implement climate risk management strategies as an integral part of city development. The aim was to understand the kind of infrastructure that Panaji and Visakhapatnam house and their vulnerability to climate change and sea-level rise, in particular. The study focused on the following thematic components:

1. Develop and demonstrate an urban infrastructure inventory and linkages along with other considerations to support climate resilient planning efforts
2. Develop and demonstrate a rapid climate vulnerability assessment approach for infrastructure services

This case study presents the learning and project outcomes from Visakhapatnam.

INTRODUCTION: VISAKHAPATNAM CITY, ANDHRA PRADESH, INDIA

Visakhapatnam (also known as Vizag) with a land area of 515 sq km is among the five major harbours in the state (*Figure 1*). The population of Visakhapatnam Urban Agglomeration is 1,730,320 (Census 2011). The city, which appears like a small basin, is surrounded by the Yarada hill popularly known as the Dolphin's nose (358m) on the side of the Kailasgiri hills on the north, with the Bay of Bengal forming the eastern wall. Visakhapatnam is facing long-term threats in terms of sea-level rise. The city is located on the eastern coast of India, which is particularly vulnerable to climate change induced extreme events like cyclones and storm surges. The year 2013 alone witnessed the two cyclones Phailin and

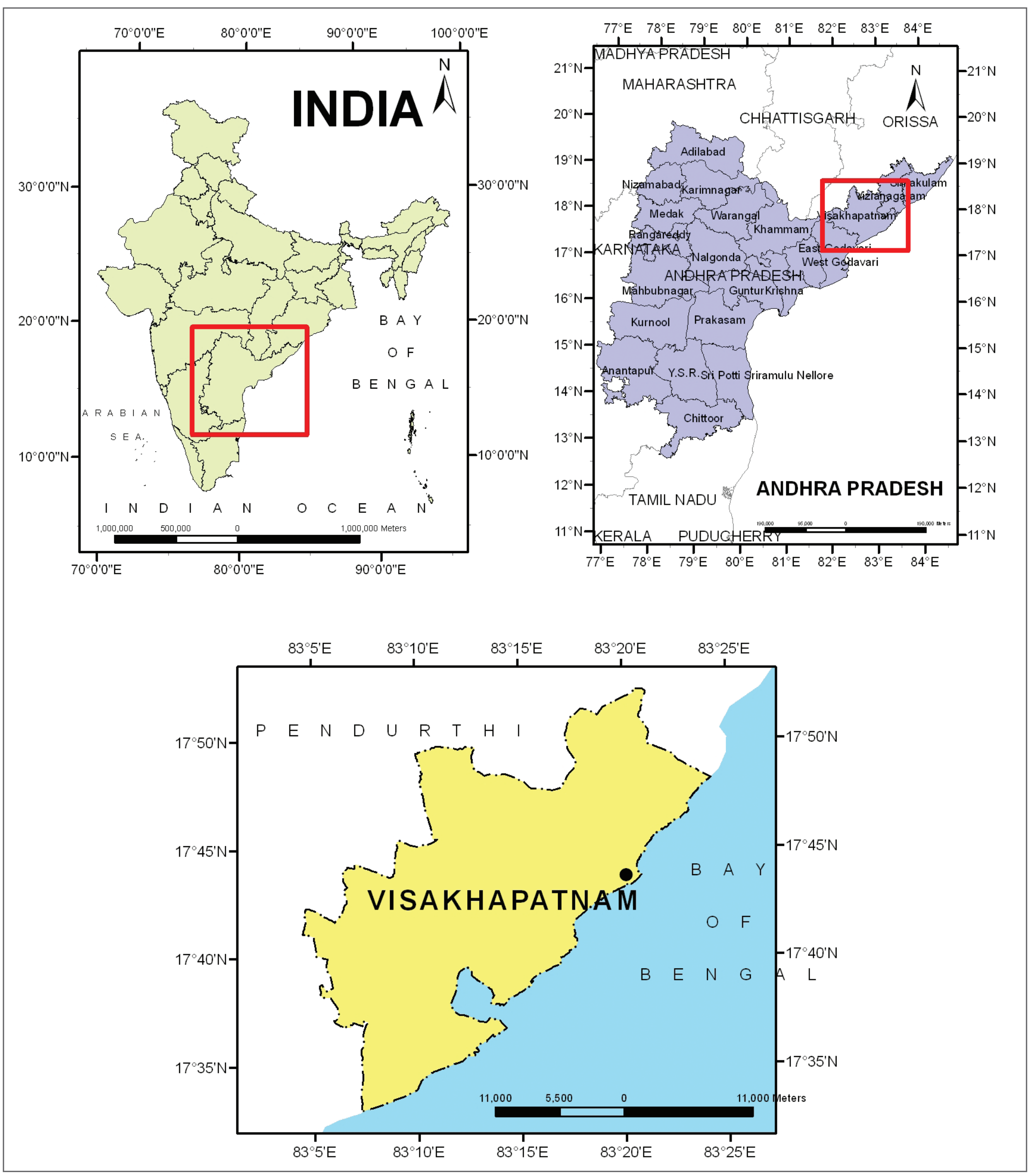


Figure 1: Location map of Visakhapatnam city

Helen, causing damage to property and infrastructure assets besides damaging the coastal structures and morphology.

Moreover, the city has experienced high population increase and rapid industrialization with the growth of major industries like steel, petroleum refining, and fertilizer (CDP, 2006). The city is also a major tourist destination which adds further pressure on the city's infrastructure. Developmental activities like offshore jetties, small ports, the maintenance of entrance channels, offshore drilling activities for hydrocarbon resources, etc., have their own impact on the shallow bathymetry, coastal and near shore processes, and on the living and non-living natural resources. As per the Organisation for Economic Co-operation and Development (OECD) study (2008)[1] Visakhapatnam is among the port cities with high exposure and vulnerability to climate extremes globally.

SCOPE OF THE STUDY

The scope of the study included developing and demonstrating a methodology for assessing the vulnerability of infrastructure services of coastal cities to sea-level rise and how this assessment can support climate resilience planning efforts. This was done by taking up case studies of two coastal cities – Panaji on the west coast and Visakhapatnam on the east coast of India. This document presents the outcomes of the case study of Visakhapatnam city.

OBJECTIVES AND OUTCOMES

Objectives

The vulnerability assessment for the city of Visakhapatnam was carried out with an objective to:

1. Understand the impact of sea-level rise and vulnerability of the city to climate change induced events like extreme precipitation, cyclones, and storm surges.
2. Identify hotspots and critical infrastructure and services.
3. Identify actions to address climate criticality and to plan for climate resilience.
4. Inform planning decisions at the level of the local government (city government) to achieve the same.

Outcomes

The study resulted in identification of vulnerable hotspots and critical infrastructure on spatial scale and a Database Management System (DBMS) to support the city government to address the impacts of sea- level rise in the city planning strategies. The study also gives broad sector-wise recommendations to the city as a starting point to initiate climate resilience planning and retrofitting of infrastructure assets and services. However, further detailed studies and expert consultation will be required to appropriately implement these actions.

Relevance of Development Goals

The purpose of the study is to inform and support the city's decision-makers in planning the infrastructure and services of the city such that the climate impacts are addressed appropriately at all levels—structural, planning, investment, and governance.

Key Stakeholders and Target Groups

1. **Stakeholders and end users:** The city government including Greater Visakhapatnam Municipal Corporation (GVMC) and Visakhapatnam Urban Development Authority (VUDA).
2. **Target groups and key sectors:** The study targets the Municipal Corporation and the concerned departments that plan, build, and manage infrastructure and basic services in the city.

Key sectors identified in the study

- Water supply
- Sewerage and drainage
- Solid waste management
- Transport
- Social infrastructure (schools and hospitals)
- Heritage and tourism
- Ecologically sensitive areas
- Energy and communications
- Disaster management

PRIMARY PROFILING OF THE CITY: ESTABLISHING BASELINE INFORMATION

Preparing an Urban Infrastructure Inventory of the City

City profiling was done through an inventorization exercise wherein both climatic as well as non-climatic information were collated. The non–climatic information on the city was restricted to infrastructure and services of the city only, considering the scope of the study. A detailed framework for inventorization of infrastructure assets in Visakhapatnam city was formulated which basically draws out the infrastructure

[1] http://www.oecd-ilibrary.org/environment/ranking-port-cities-with-high-exposure-and-vulnerability-to-climate-extremes_011766488208

specific list of information that the city is maintaining at present. The inventory prepared as a result of this activity was then developed into a Microsoft Access-based DBMS (*Figure 2*). At present, this is a stand-alone system and can easily be installed on any computer.

The objective of the DBMS is to demonstrate an urban infrastructure inventory where sector-wise forms can be accessed to record, retrieve, and update information to support urban development and climate resilience planning efforts. The baseline information collected from various city level departments is already fed into the DBMS to provide a broader overview of data available to them, while planning for climate resilience. The data fields for which data could not be procured or was not available during the duration of the study have been highlighted and can be populated by the city government at a later stage. This was done with a view that these data fields would help the cities to improve their data inventory as well as contextualize it as per their needs. The data fields, which are important from the climate resilience planning perspective, have been colour coded separately within the sectoral forms.

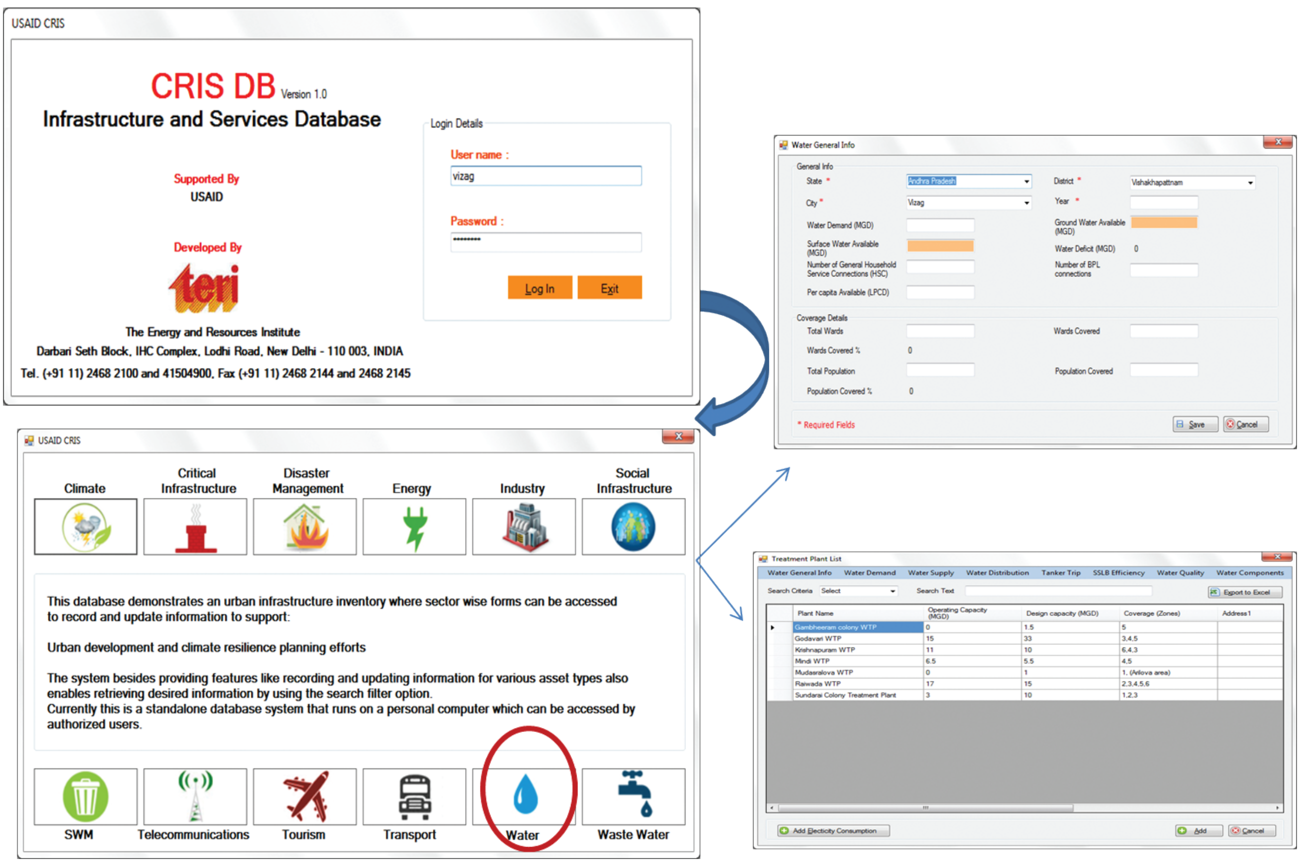


Figure 2: Snapshot of DBMS developed by TERI for Visakhapatnam city

The broad fields for the inventory include man-made infrastructure such as, transport systems, electricity, water, social infrastructure, communications systems, and industries. Detailed forms have been created for each sector in the DBMS. The next section provides an overview of the water supply sector as an example.

Overview of Water Sector in DBMS

'General Info' is the first component of the water sector in the DBMS. The form records the following details (*Figure 3*):

a) The water demand, and the groundwater and surface water share available in the city (in million litres per day, MLD). The total water available is calculated as per the sum total of these two entries.

b) Water deficit is calculated by subtracting water demand and total water available.

c) Number of domestic connections and number of BPL connections.

d) The per capita water available in that city (in litres per capita per day, LPCD).

e) Coverage details are recorded in terms of the number of wards having water supply connections and the total population having access to these connections. The percentage coverage is displayed in the form after filling the total population and total number of wards in the form.

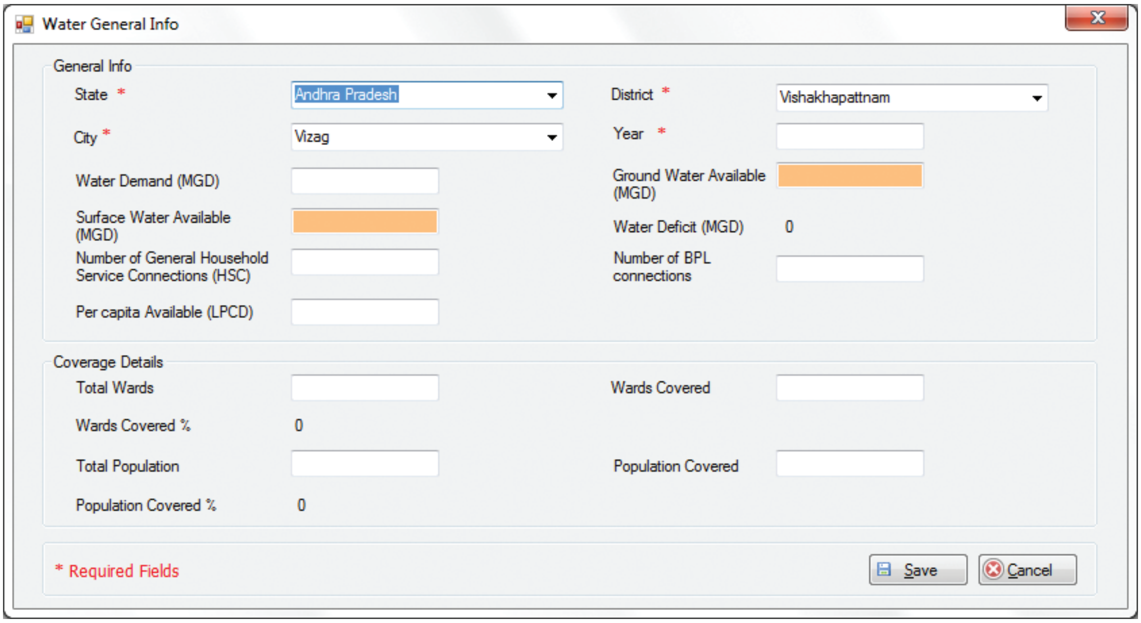


Figure 3: Snapshot of 'General Info' form for water supply sector

Water supply Sources

To enable digitization of information related to water supply sources, a form stores the basic details of the sources as mentioned below:

a) Name of the water source

b) Location of the source and its distance from the city

c) Allotted quantity of water to be supplied from that source and the actual quantity supplied

d) Full capacity of the source, and the minimum and maximum water level of each water supply source

The city of Visakhapatnam is into the practice of recording basic information about all of their water supply sources in a daily report format. For this purpose, the form enables date-wise entry to record the daily status of the water supply sources. The form contains the following details:

a) The quantity of treated water supplied from the source on that particular day

b) Share of industrial and domestic water supplied from the source

c) Water level of the source on that day

Besides the above details, the city also records data on the number of tanker trips to the under-served areas. In a separate master table, the categories of tankers (GVMC tankers, Contractor tankers, Private tankers, etc.) along with their filling points and target supply areas are recorded. A separate form has been created to record the number of tanker trips on a daily basis.

Water Treatment Plants

The treatment plant form records information under the following heads (*Figure 4*):

a) The name and location of the treatment plant

b) The raw water source of the treatment plant

c) The operating and design capacity of the treatment plant

[2] Please note that the location parameter is recorded in a uniform format in all the forms by further breaking it into Line 1 Address, Line 2 Address, and Line 3 Address

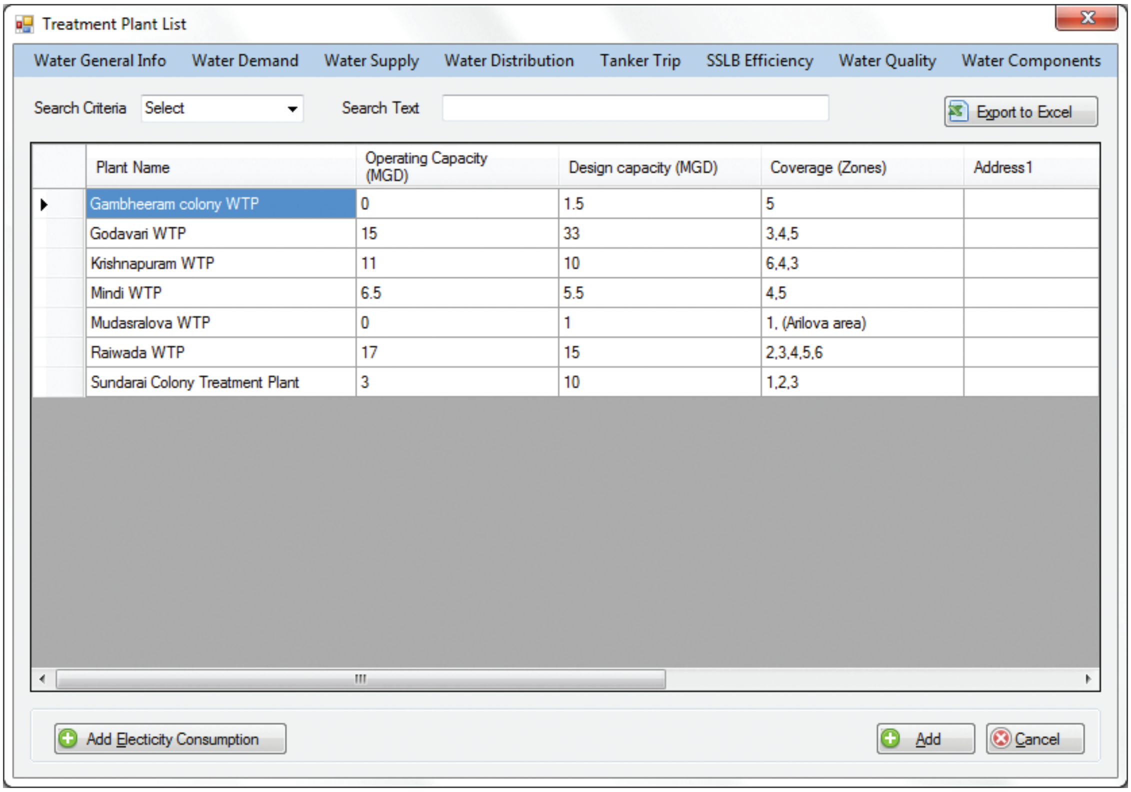


Figure 4: Snapshot of form for recording details on water treatment plants

Water distribution[3] **and consumption**

Figure 5 gives a snapshot of the form for recording information on water distribution and consumption details for different types of connections (Domestic, Bulk, Semi-bulk) and consumer categories (General, BPL, Residential, etc.). Further details on tariff and monthly charges can also be maintained in this form.

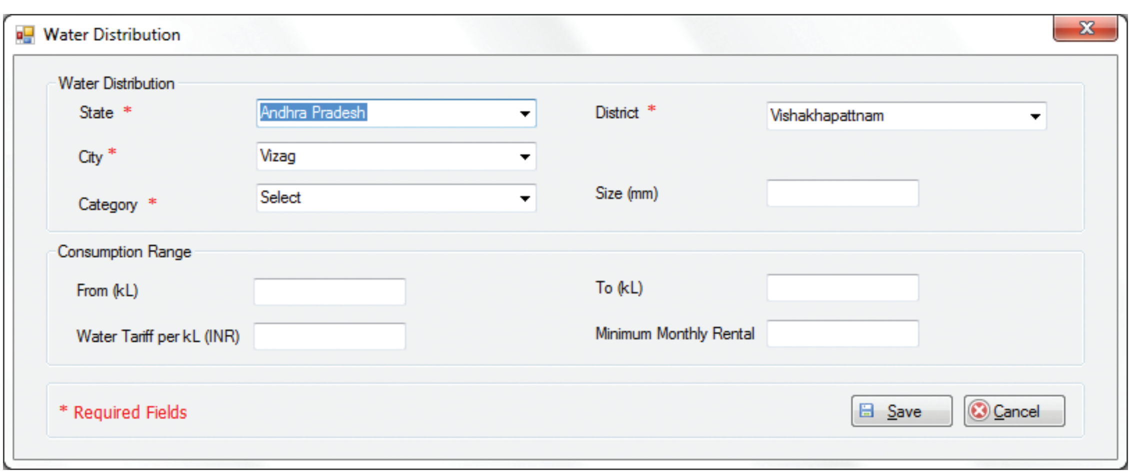


Figure 5: Snapshot of water distribution form

[3] The data heads for this sub-component have been derived from the way Visakhapatnam was recording this data.

Distribution network; Pumping station; Water storage

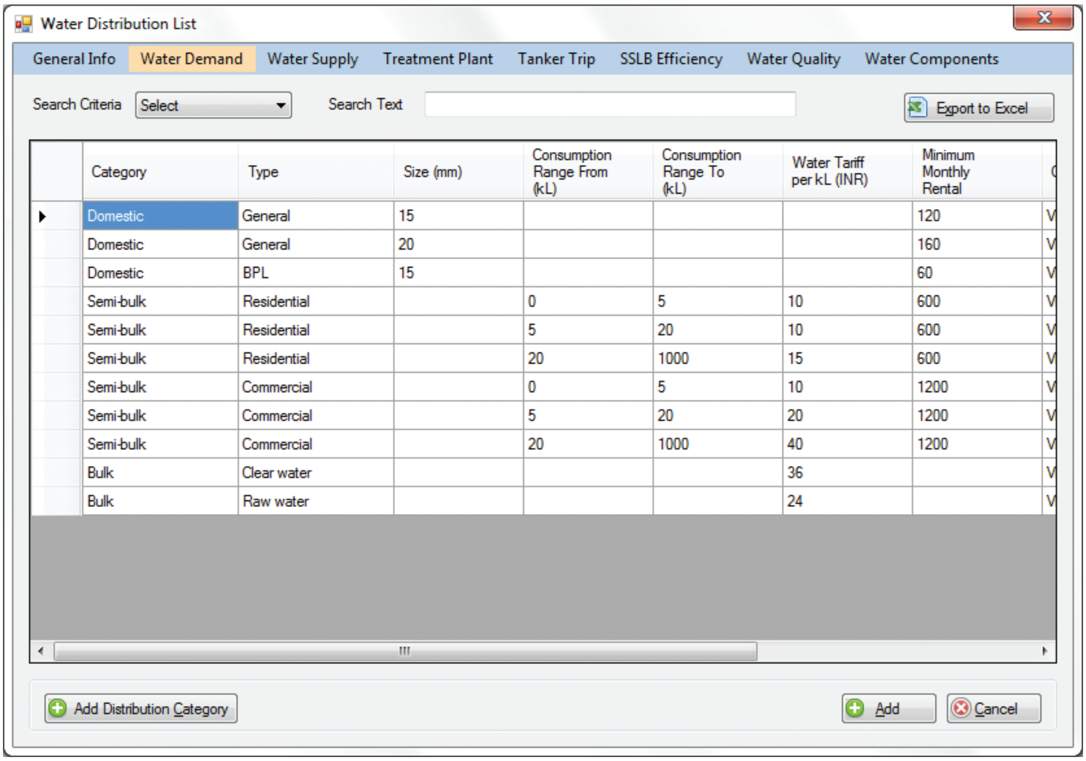
Information on the three key sub-components of the water supply sector, namely distribution network, pumping station, and water storage is proposed to be collected in the following format:

a) Recording the ward coverage of the sub-component

b) Capacity, age, expected lifetime, and material of the structure

c) Maintenance requirements and cost involved

Figure 6 gives a snapshot of the form for recording distribution network details.



Water Distribution List

General Info | Water Demand | Water Supply | Treatment Plant | Tanker Trip | SSLB Efficiency | Water Quality | Water Components

Search Criteria: Select | Search Text | Export to Excel

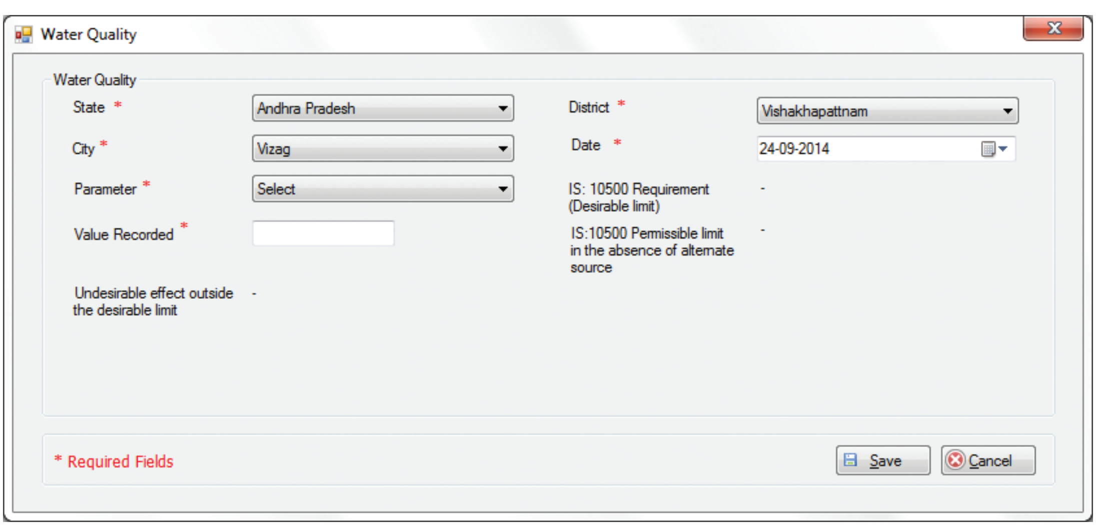
Category	Type	Size (mm)	Consumption Range From (kL)	Consumption Range To (kL)	Water Tariff per kL (INR)	Minimum Monthly Rental	(
Domestic	General	15				120	V
Domestic	General	20				160	V
Domestic	BPL	15				60	V
Semi-bulk	Residential		0	5	10	600	V
Semi-bulk	Residential		5	20	10	600	V
Semi-bulk	Residential		20	1000	15	600	V
Semi-bulk	Commercial		0	5	10	1200	V
Semi-bulk	Commercial		5	20	20	1200	V
Semi-bulk	Commercial		20	1000	40	1200	V
Bulk	Clear water				36		V
Bulk	Raw water				24		V

Add Distribution Category | Add | Cancel

Figure 6: Form on water supply distribution network

Water quality

A master table lists the water quality parameters and the required and permissible limits as per the Drinking Water Specification: IS: 10500, 1992[4]. The database form enables date-wise entry to record the value against each water quality parameter (*Figure 7*). There is an option for the city to add more measurable parameters to the master table as per their need.



Water Quality

Water Quality

State * Andhra Pradesh

District * Vishakhapattnam

City * Vizag

Date * 24-09-2014

Parameter * Select

IS: 10500 Requirement (Desirable limit) -

Value Recorded *

IS:10500 Permissible limit in the absence of alternate source -

Undesirable effect outside the desirable limit -

* Required Fields

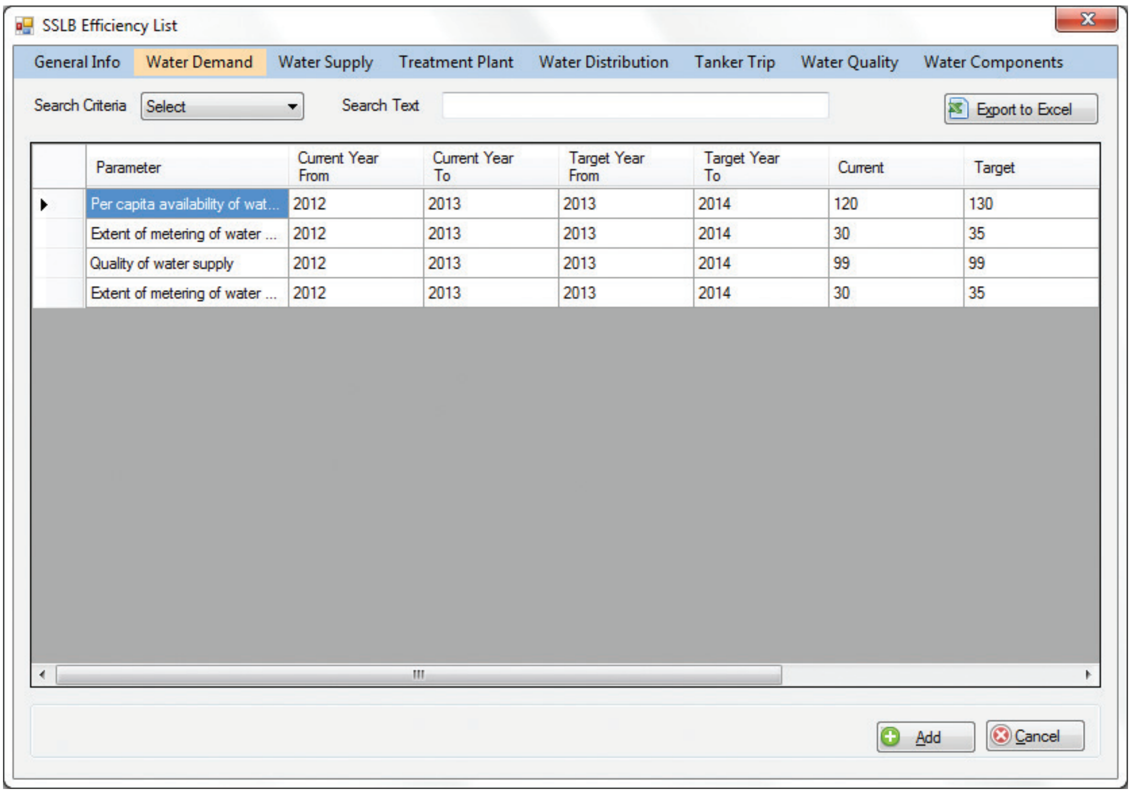
Save | Cancel

Figure 7: Snapshot of the form on water quality

[4] Specification for drinking water issued by Bureau of Indian Standard (BIS) http://www.wbphed.gov.in/main/Static_pages/bureau_of_indian.php

SSLB efficiency

In order to benchmark and improve the service delivery in Urban Local Bodies (ULBs), the Mission Directorate, **Jawaharlal Nehru National Urban Renewal Mission (JNNURM)**, under the Ministry of Urban Development (MoUD), has defined Standardized Service Level Benchmarks (SSLBs)[5]. As a result of this exercise, performance indicators were derived for the basic services sectors, such as water supply; sewerage; solid waste management; storm water drainage. The DBMS enables the recording of data on SSLB efficiency parameters for the water supply sector in the required reporting format (*Figure 8*). The user can select the performance indicator and enter the values for the current and target year. For each indicator the benchmark standard value as per Ministry of Urban Development (MoUD) has also been included in the form itself.



SSLB Efficiency List

General Info | Water Demand | Water Supply | Treatment Plant | Water Distribution | Tanker Trip | Water Quality | Water Components

Search Criteria: Select   Search Text   Export to Excel

Parameter	Current Year From	Current Year To	Target Year From	Target Year To	Current	Target
Per capita availability of wat...	2012	2013	2013	2014	120	130
Extent of metering of water ...	2012	2013	2013	2014	30	35
Quality of water supply	2012	2013	2013	2014	99	99
Extent of metering of water ...	2012	2013	2013	2014	30	35

Add   Cancel

Figure 8: Snapshot of the form for recording information on SSLB performance indicators

Preparing a spatial inventory of urban infrastructure services of the city

The second component of the DBMS was a spatial inventory of urban infrastructure services in the city, wherein sector-wise infrastructure assets and service networks in the city were mapped in Arc GIS platform. The data set used for creation of the spatial database was sourced from various city level departments including Greater Visakhapatnam Municipal Corporation (GVMC), Visakhapatnam Urban Development Authority (VUDA) and other sectoral city level and state line departments. This data set included maps obtained in Auto CAD format, images (.tiff/ .jpeg) or in hard copy. In addition to this, the locational information on different infrastructure assets was also received in form of lists of addresses and geographical coordinates. The spatial data set so received was pre-processed through geo-referencing and geometrical structuring and corrections in Arc GIS platform to come up with land use and sector-wise infrastructure maps for Visakhapatnam (*Figures 9–17*). For a ready reference to the city planners and decision-makers, these maps were integrated in the DBMS and linked to respective sector-wise inventories.

5 http://www.asci.org.in/sslb/page1.htm

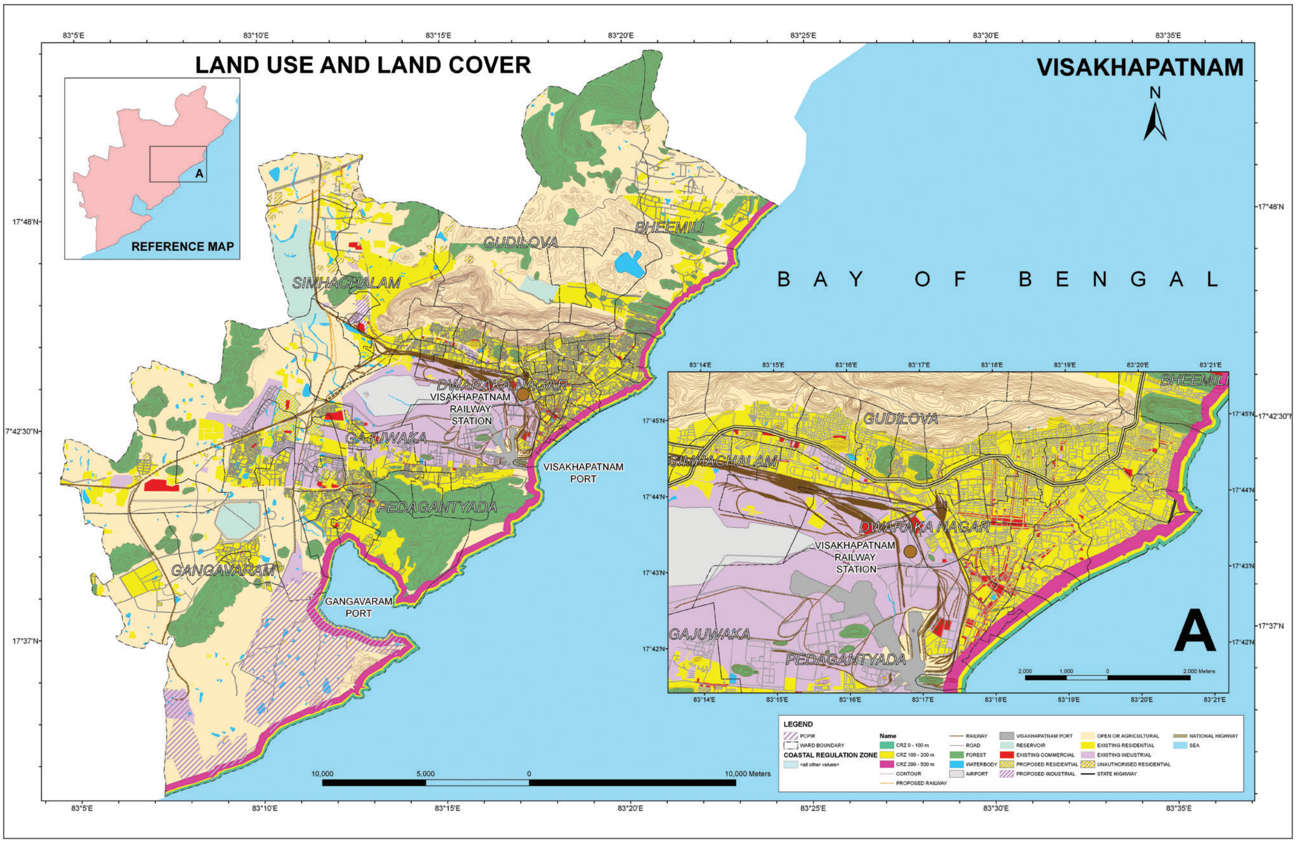


Figure 9: Land use and land cover for Visakhapatnam, 2010 – Mapped using land use plans received from VUDA in Auto CAD format

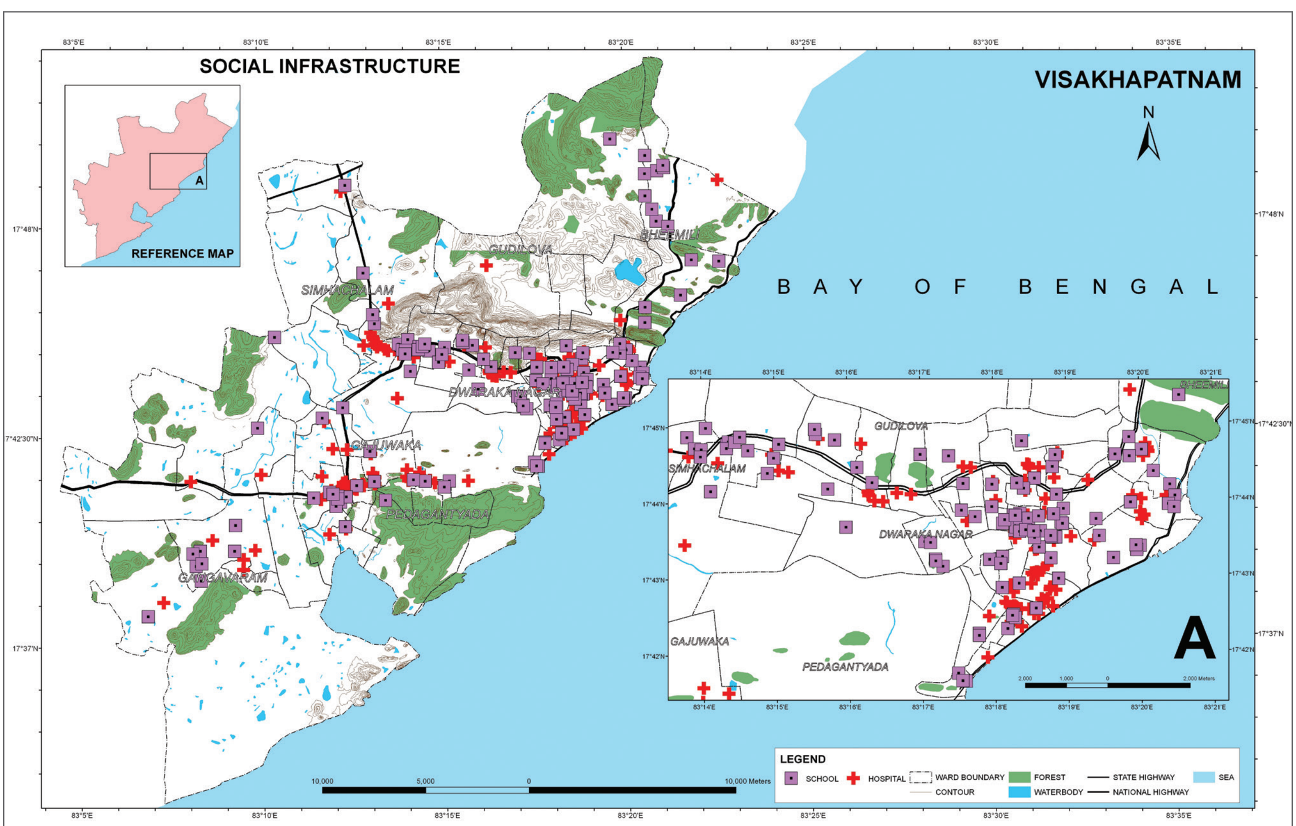


Figure 10: Social Infrastructure, Visakhapatnam– Schools and hospitals in the city were mapped using list of addresses received from GVMC and Google Earth

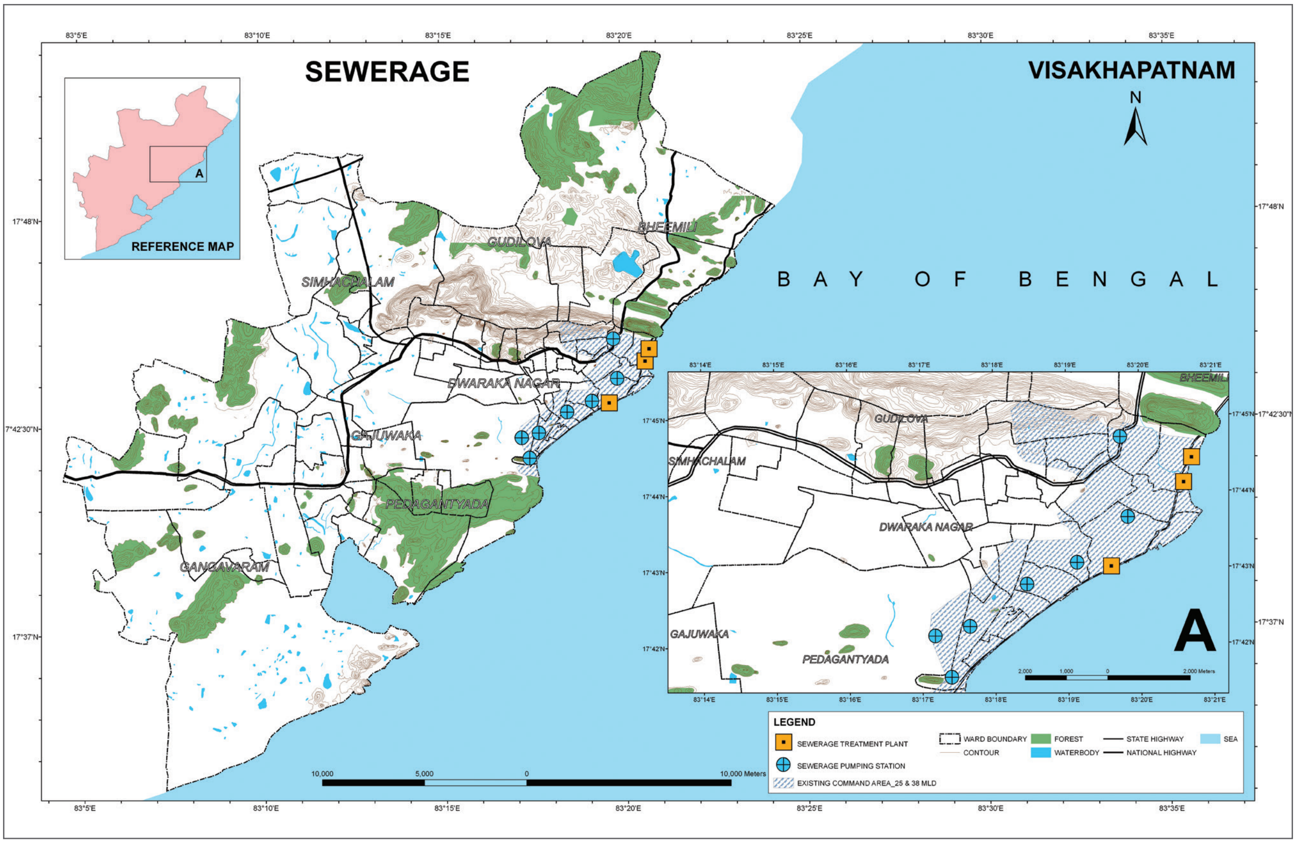


Figure 11: Sewerage Infrastructure, Visakhapatnam– Existing command area, major trunk drains, sewage treatment plants, and pumping stations mapped from the data received from GVMC and using Google Earth

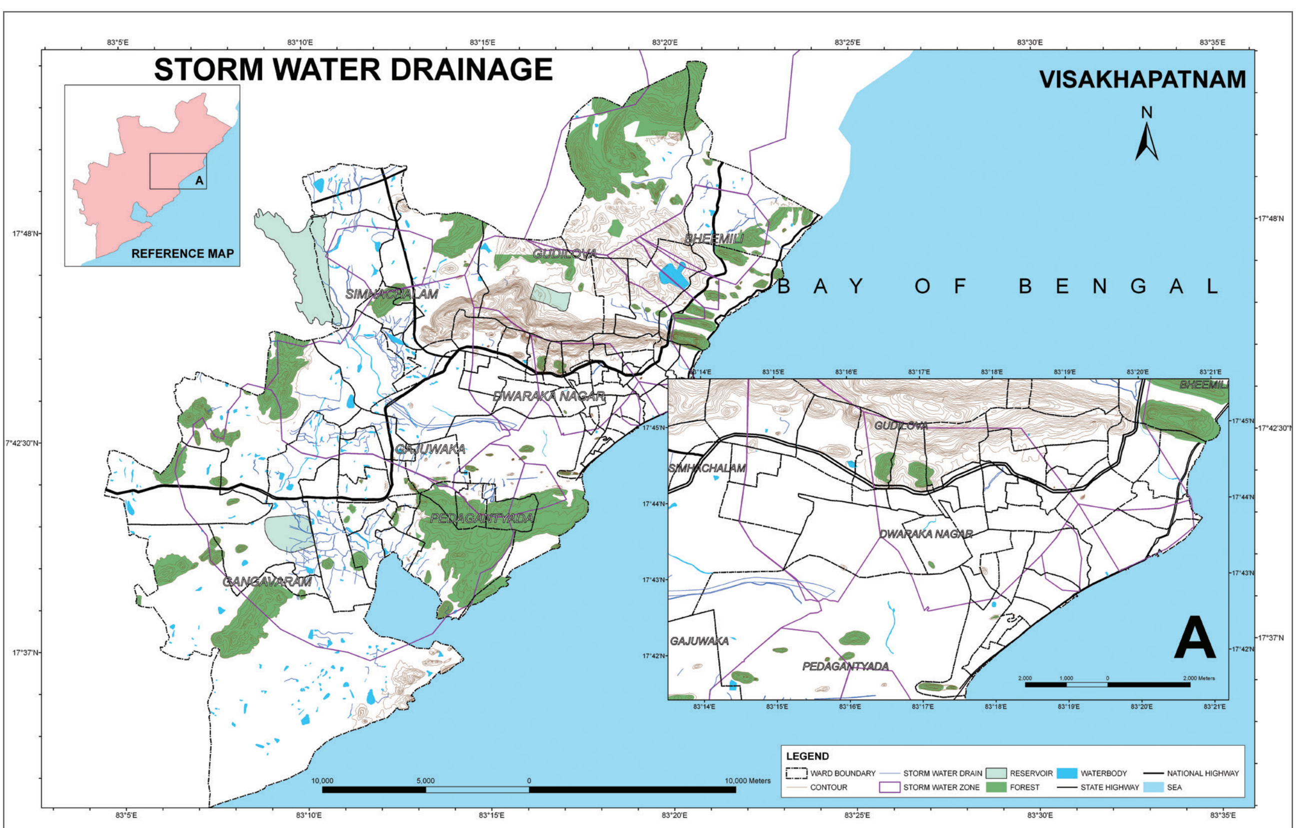


Figure 12: Storm water drainage infrastructure, Visakhapatnam– Existing catchment areas and storm water zones, major trunk drains mapped from the data received from GVMC and VUDA

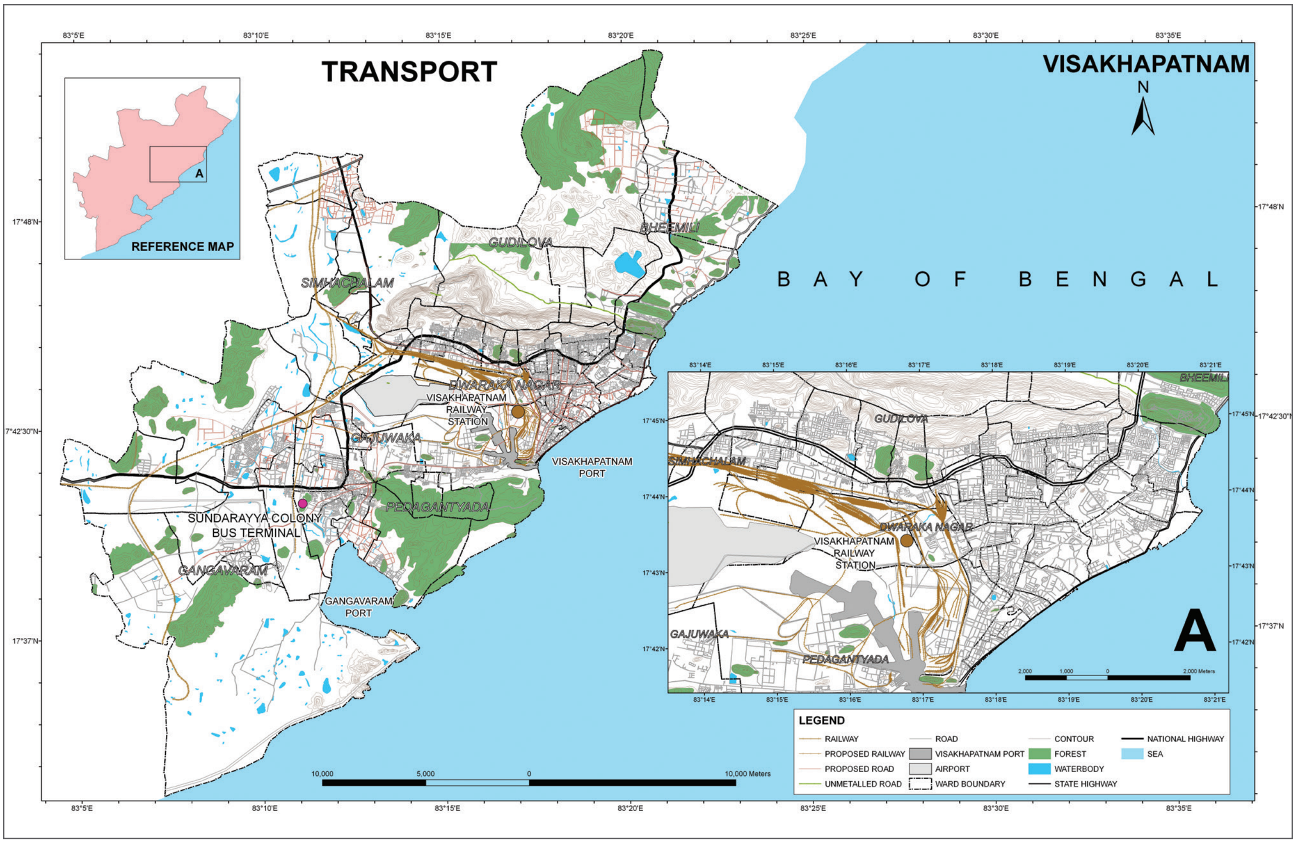


Figure 13: Transport infrastructure, Visakhapatnam– Existing and proposed roads and railway network, highways, locations of major terminals, airport, Visakhapatnam and Gangavaram Ports have been mapped.

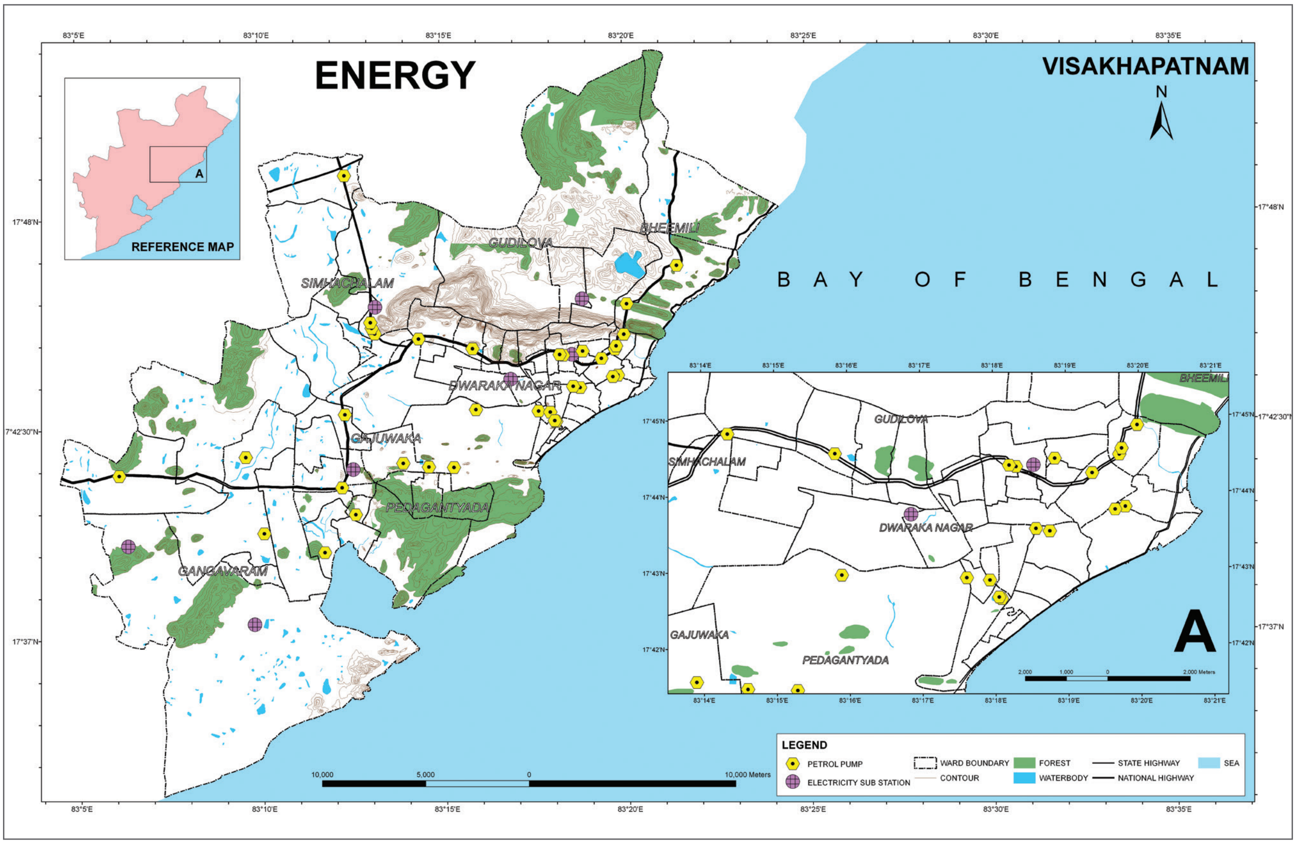


Figure 14: Energy infrastructure assets, Visakhapatnam– Electricity substations and petrol pumps have been mapped using the list of addresses received from APTRANSCO and GVMC.

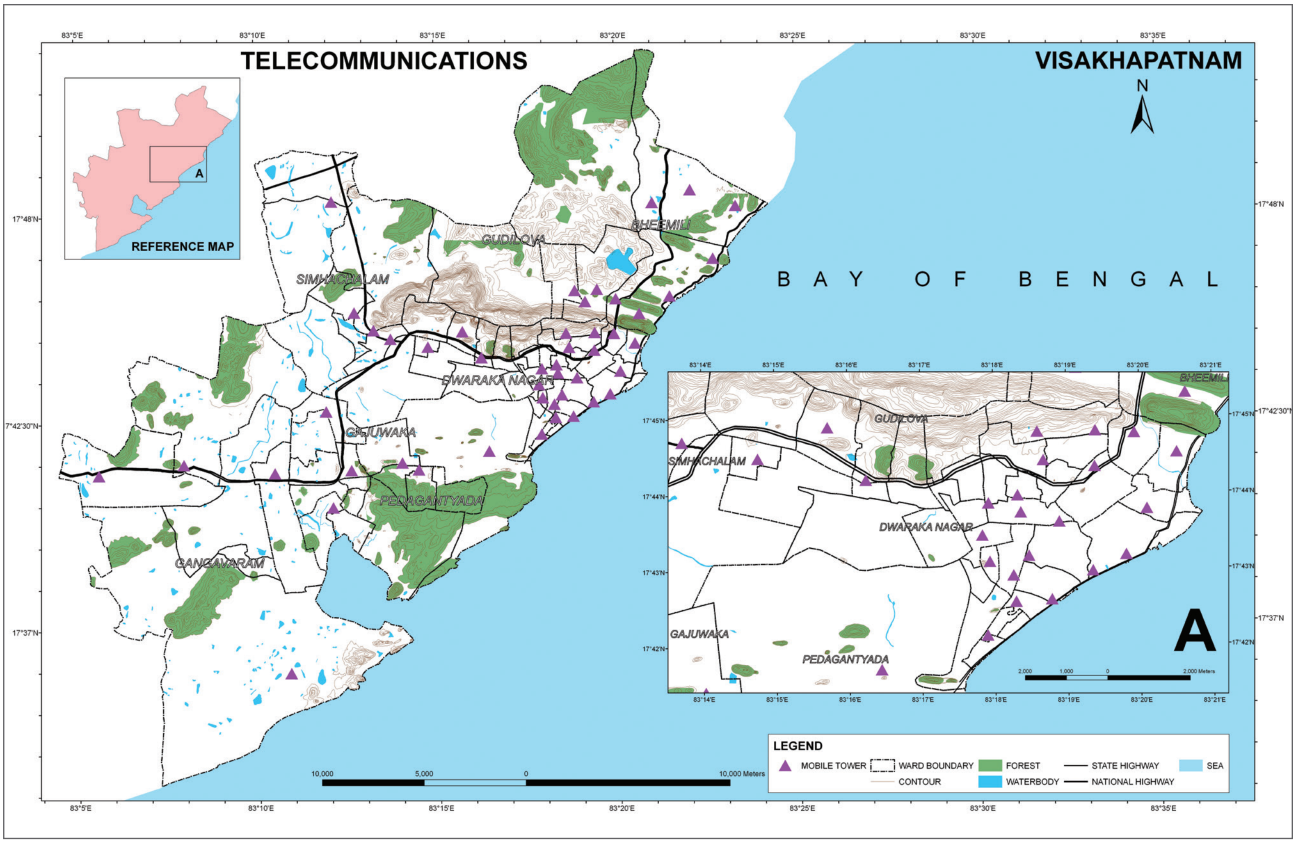


Figure 15: Telecom infrastructure, Visakhapatnam– Cell phone towers have been mapped using the list of addresses received from GVMC.

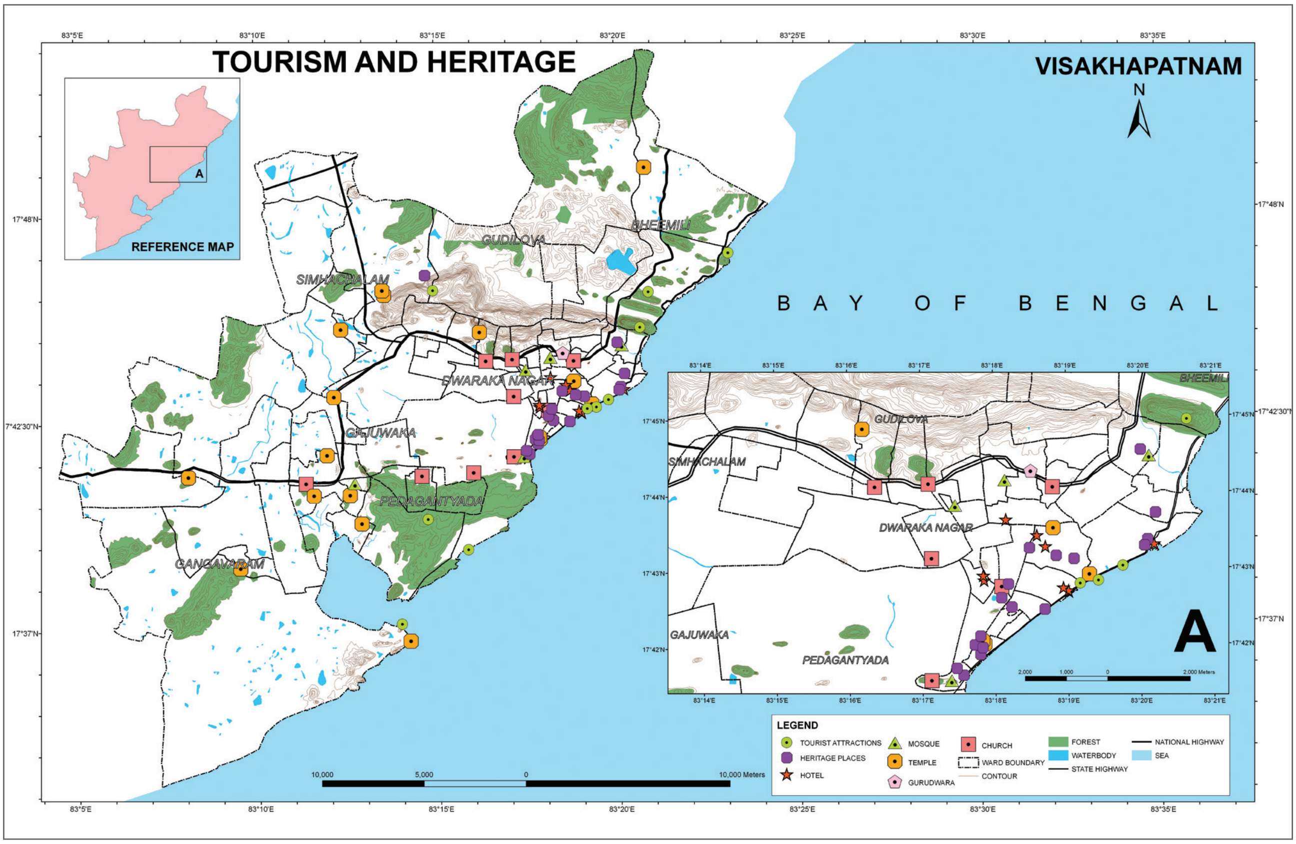


Figure 16: Tourism infrastructure, Visakhapatnam – Hotels, religious and cultural places, built, and natural heritage areas have been mapped using the list of addresses received from GVMC and maps from VUDA.

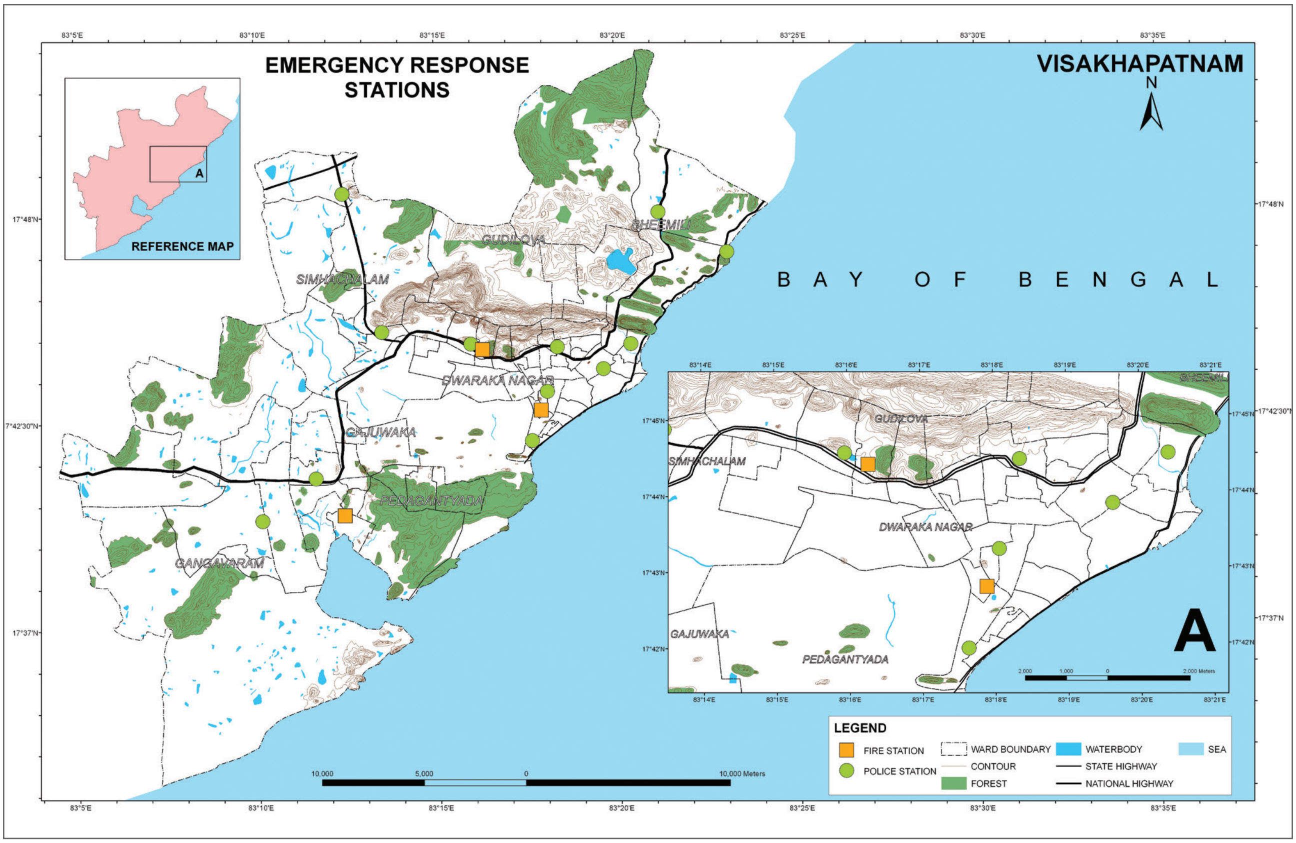


Figure 17: Emergency response stations, Visakhapatnam– Police stations and fire fighting stations have been mapped

DEVELOPING CLIMATE KNOWLEDGE

The study focuses on climate change induced SLR and other extreme events and their effect on the infrastructure and services of the city. Hence, the climatic information included broad assessment of climatic exposure, particularly precipitation and cyclone events, apart from exposure to sea-level rise.

i. **The precipitation trends** for the last three decades for Visakhapatnam were studied. The data set sourced from the Indian Meteorological Department were analysed to understand the rainfall anomalies— annual as well as for the monsoon months of June, July, August, and September (JJAS). An extreme rainfall analysis was also done to understand the trend of occurrence of extreme precipitation events which may aggravate the vulnerability of infrastructure assets. The analysis result shows a decreasing trend for total monsoonal rainfall for the period 1979–2009 (*Figure 18*). Visakhapatnam also shows an increase in the highest 24 hourly rainfall annually and for monsoon months. The observations show high rainfall in lesser number of rainy days over this period and indicate increase in extreme rainfall incidences (*Figure 19*).

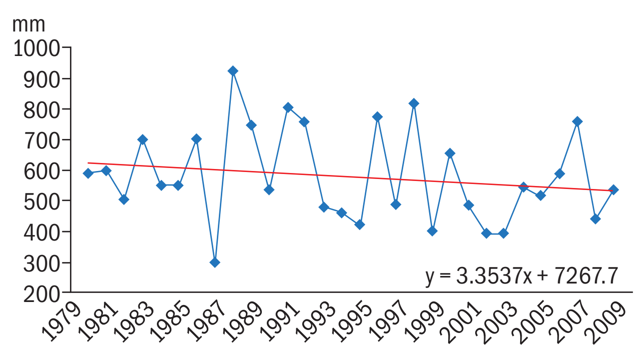


Figure 18: Trend of total annual rainfall for Visakhapatnam, 1979–2009

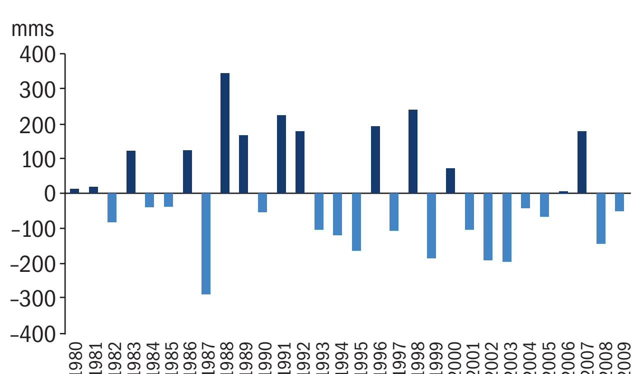


Figure 19: Total rainfall anomalies for JJAS for Visakhapatnam, 1979 –2009

ii. **The observed sea level trend** over the coast of Visakhapatnam, which is obtained by using freely available tide gauge data sourced from PSMSL[6] website for the years 1935–2010, was analysed. For the years with missing values, a smoothing filter was applied to get a good trend for the past 50-60 years. The trend for Visakhapatnam (1935–2010) shows an increase in the sea level based on the tide gauge data (*Figure 20*). The trend estimated from the data set is 0.7mm/year which after GIA correction comes out to be 1.09 mm/year.

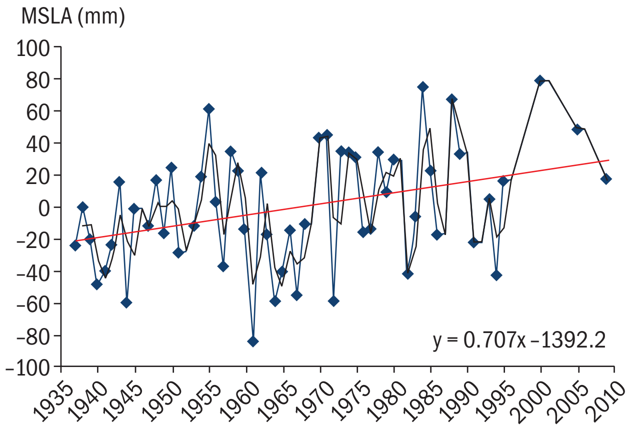


Figure 20: Annual MSL anomaly for Visakhapatnam, 1935–2010

iii. **The Mean Sea-Level (MSL) rise for future:** The CMIP3 (Meehl et al., 2007) data sets presented in IPCC Ar4 report, which are the global models having typical horizontal resolution of 1–3 degree were used. Since the domain of the study area was based on a regional scale, utilization of the relatively coarse global models and data set increases the uncertainty of the projections. Therefore an ensemble approach using six IPCC AR4 models was used. This kind of ensemble approach is globally accepted as a key measure to reduce model uncertainty. For this purpose, a total of fifteen models were analysed and the models which had over 70 years of consistent projections available for the "business as usual" scenario were selected. This ensemble mean was used to plot the trends for the future (year 2100). For Visakhapatnam coast, the models projected an increasing trend of ~0.2mm/year (*Figure 21*).

Due to the element of high uncertainty in future SLR and storm surge modelling at smaller scales using coarse global models and lack of GIA corrections, a multiple scenario approach was further applied to understand the impact of SLR on Visakhapatnam. Based on extensive literature review and results of the modelling exercise, four scenarios were considered for vulnerability assessment of the city.

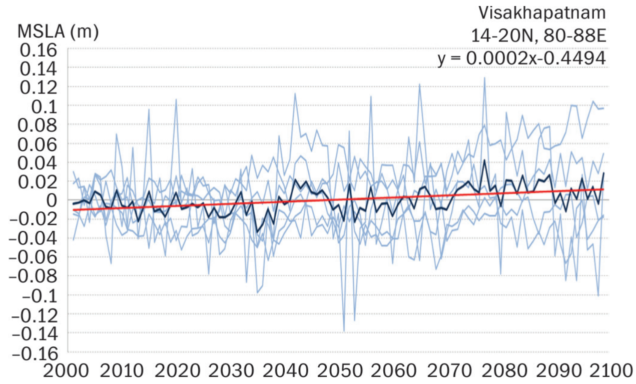


Figure 21: Projected sea level anomaly for Visakhapatnam

SLR Scenarios

- **Scenario 1: Based on TERI's SLR model projections** of 0.2mm/yr
- **Scenario 2: Based on observed SLR trend (with GIA corrections)** which was found to be 1.09mm/yr for Visakhapatnam
- **Scenario 3: Based on 1 meter sea-level rise in 100 years** (Byravan et al., 2010; MoEF 2010 and USGCRP 2009)
- **Scenario 4: In case of cyclonic events with surge height of 4m**. Literature review indicates that category five cyclones can cause a storm surge of 6m height and more depending on the speed of the winds and the past records for Visakhapatnam show storm surges with height of 2–4m (MoEF 2010). This scenario considers a moderate situation.

The MSL for the baseline scenario was calculated from the tide gauge data obtained from the PSMSL website. For Visakhapatnam, the MSL value was found to be 7.071m based on tide gauge data since 1937. The projected trend for the four scenarios was added over and above these MSL values for the year 2000 to come up with the estimated MSL for the year 2100.

VULNERABILITY ASSESSMENT

Exposure Profile

Exposure is the nature and extent of changes that a place's climate is subjected to with regard to variables, such as temperature, precipitation, extreme weather events, sea level

[6] Permanent Service for Mean Sea Level

(Brenkert and Melone 2005). This study particularly looks at SLR and extreme weather events as a component of climate change and how it affects the infrastructure and services of Visakhapatnam city. Sea-level rise coupled with extreme events like cyclones and storm surges or rainfall extremes will lead to inundation, water logging, and floods in the city.

To understand the exact spatial extent of the impact of SLR and extreme events on Visakhapatnam, the four SLR scenarios were overlayed on the Digital Elevation Model (DEM) of the city. This led to identification of hotspots, areas and assets that are likely to be affected under different SLR scenarios, providing a concise spatial exposure profile for the city of Visakhapatnam.

Ward nos. 5–7, 17, 18, 25, 26, 31, 42–46, 50–53, 55, 61, 65–68 were found to be partially vulnerable (*Figure 22*). In terms of the uses/activities that are likely to be affected, these areas have land uses ranging from residential, commercial, and institutional to heritage, conservation areas, and also ecologically sensitive areas. Areas in and around Visakhapatnam Port, railway station, HPCL Refinery, Visakhapatnam Steel Plant, NTPC Plant, Gangavaram Port are likely to be affected. Areas in the vicinity of Rushikonda beach and Jail road may also be partially affected. In case of an extreme event like a category four or category five cyclones, depending upon wind speeds and resulting storm surge heights, further inland areas may be affected. As per the vulnerability mapping done by TERI, the impact of storm surge may be felt as far inland as Gopalapatnam in the north and Srinagar, Sramikanagar in the south (*Figure 23*).

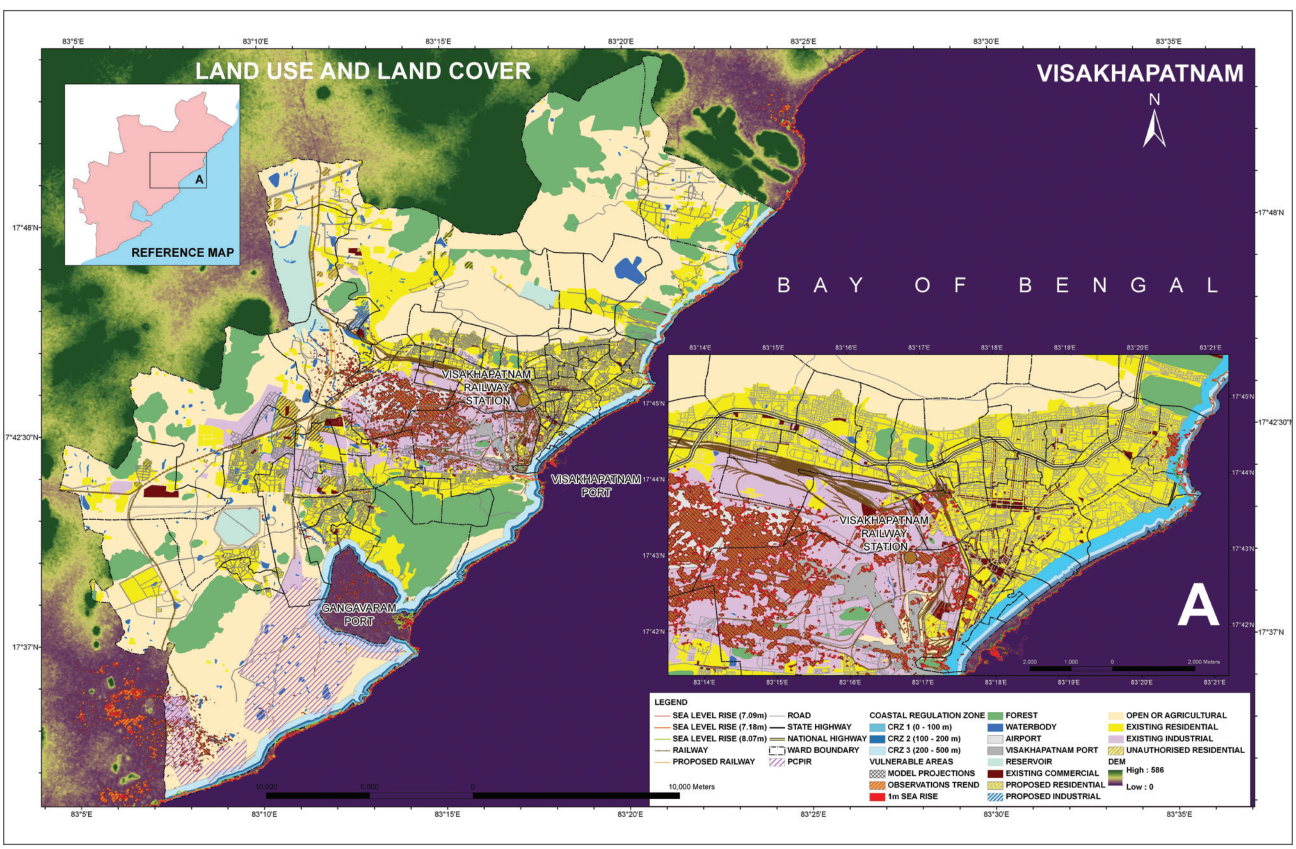


Figure 22: Exposure of Visakhapatnam under SLR scenario

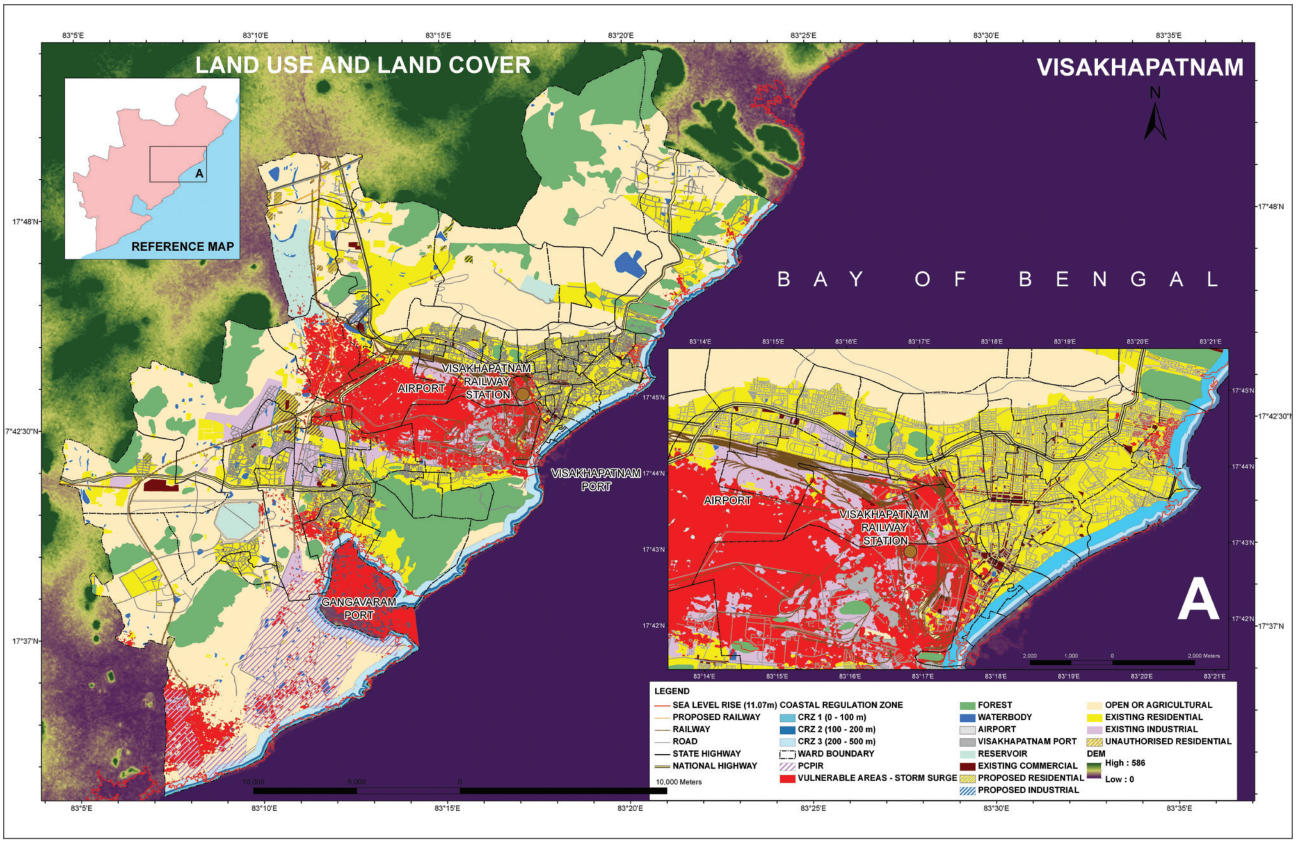


Figure 23: Exposure of Visakhapatnam under storm surge scenario

Sensitivity

Having identified and prepared the exposure profile of the city, the next step in the vulnerability assessment was to identify and assess the sensitivity of the city systems to the identified exposure levels. Sensitivity is the degree to which a system or species is affected, either adversely or beneficially, by climate stressors. The effect may be direct (for e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (for e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise) (IPCC 2014). Sensitivity analysis done as part of this study led to an understanding of sector-specific impacts in SLR scenarios.

To understand this, SLR scenarios and sector-wise infrastructure assets and services were superimposed on the DEM of the city (*Figures 24-27*). Based on this 'vulnerability mapping', the sector-wise areas and assets that are likely to be impacted by SLR or storm surge scenarios, and hence are sensitive were identified (*Table 1*).

Table 1: Sensitive areas and sectors for Visakhapatnam city

Area	Sensitive sectors	Factors causing sensitivity
Visakhapatnam Airport Area and Vicinity	Airport Infrastructure Social Infrastructure Stormwater Drainage Industries	SLR Storm surges Low elevation Flood prone

Port Areas – Visakhapatnam and Gangavaram and Vicinity	Port Infrastructure Industries including HPCL Refinery, Visakhapatnam Steel Plant, NTPC Simhadri Power Plant, Hindustan Shipyard, Naval Dockyard, Petrochemical Industries, Petroleum, Chemical and Petrochemical Investment Region (PCPIR) Heritage (Built and Natural) Energy and Telecommunication	SLR Storm surges Low elevation Flood prone
Beach Road	Sewerage Buildings Tourism Heritage (Built and Natural) Transport Infrastructure	SLR Storm surges Low elevation and High density development
Gajuwaka	Sewerage Storm Water Drainage Energy and Telecommunication	SLR Storm surges Low elevation Flood prone
Visakhapatnam Railway Station and Vicinity	Railway and Road Infrastructure Buildings Tourism Heritage (Built and Natural) Sewerage Drainage Social Infrastructure	SLR Storm surges Flood prone Low elevation and high density development

From the above table, critical infrastructure identified for resilience planning are as follows:

- **Social infrastructure:** Some specific locations have been identified in *Table 1* where the hospitals and schools will be affected by flooding either due to extreme rainfall or SLR.
- **Energy and telecommunication:** The power supply network, electric substations, petrol pumps, telecommunication lines, and cell phone towers have been mapped and identified in the vulnerable zones.
- **Transport:** Vulnerable transport infrastructure including roads, airport, and railway has been mapped.
- **Industries:** Major industrial area of the city falls under the vulnerable zone which has been mapped.
- **Buildings:** Buildings in some of the residential areas that have been found within the vulnerable zone.
- **Heritage and tourism:** These are the temples and churches that fall under the vulnerable zone.
- **Sewerage and drainage:** This includes sewerage treatment plants, pumping stations, and surface and underground storm water drains.

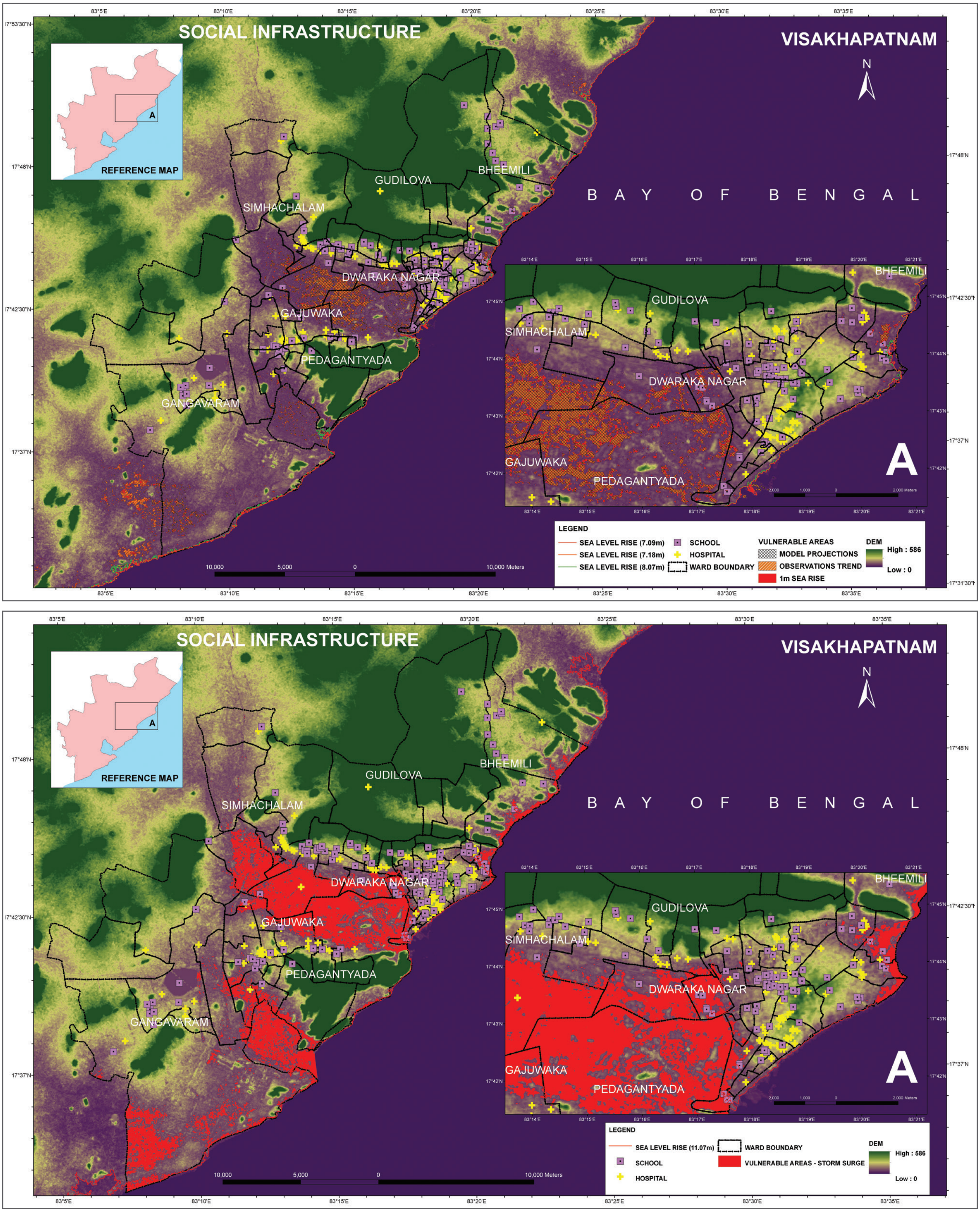
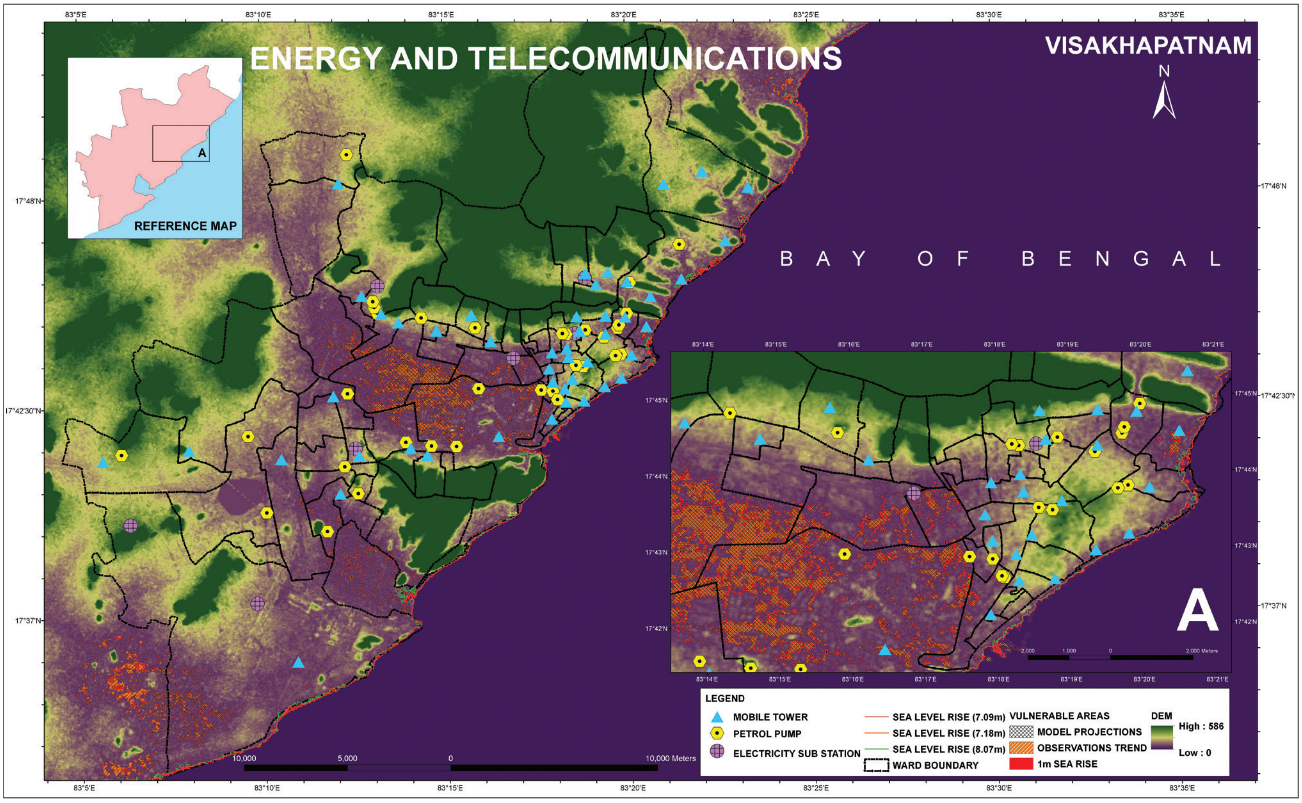


Figure 24: Social infrastructure (schools and hospitals) likely to be affected by flooding in SLR and storm surge scenario



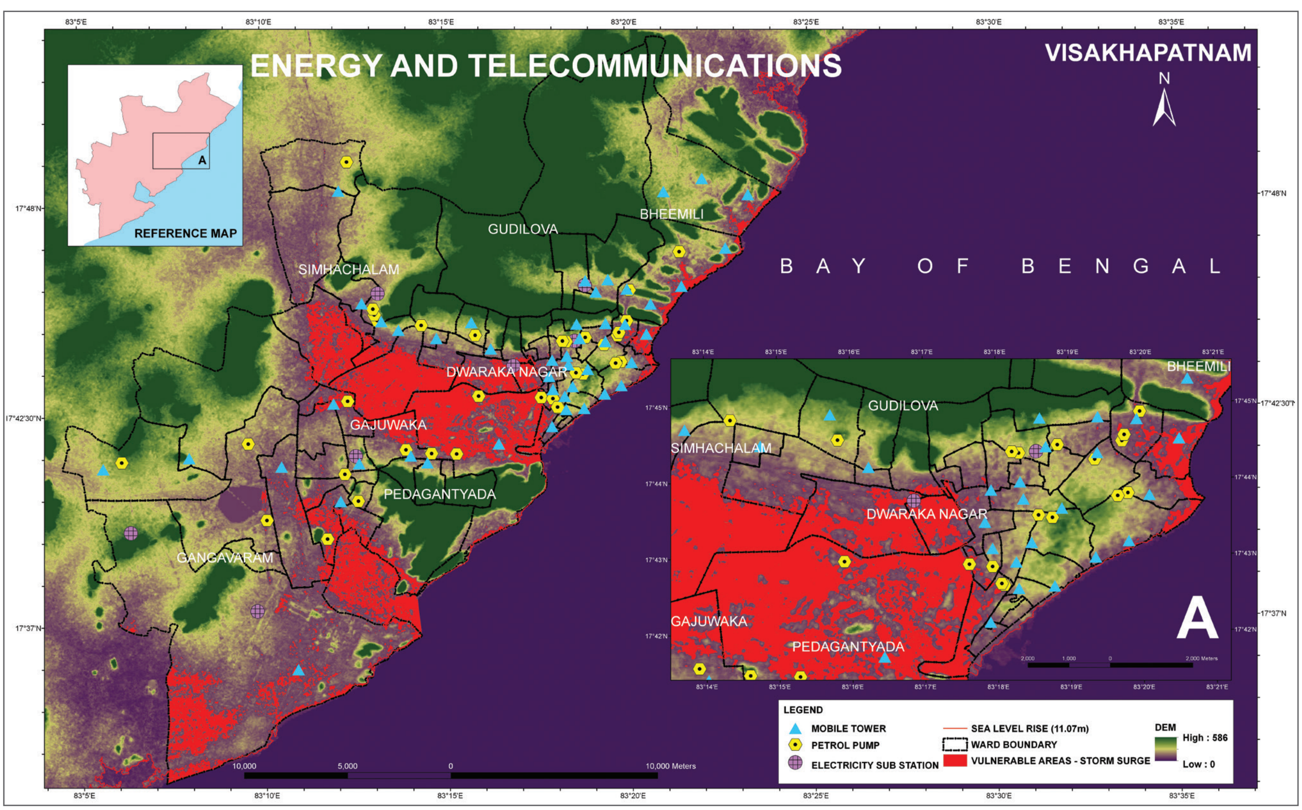


Figure 25: Energy and telecommunication infrastructure assets likely to be affected by flooding in SLR and storm surge scenario

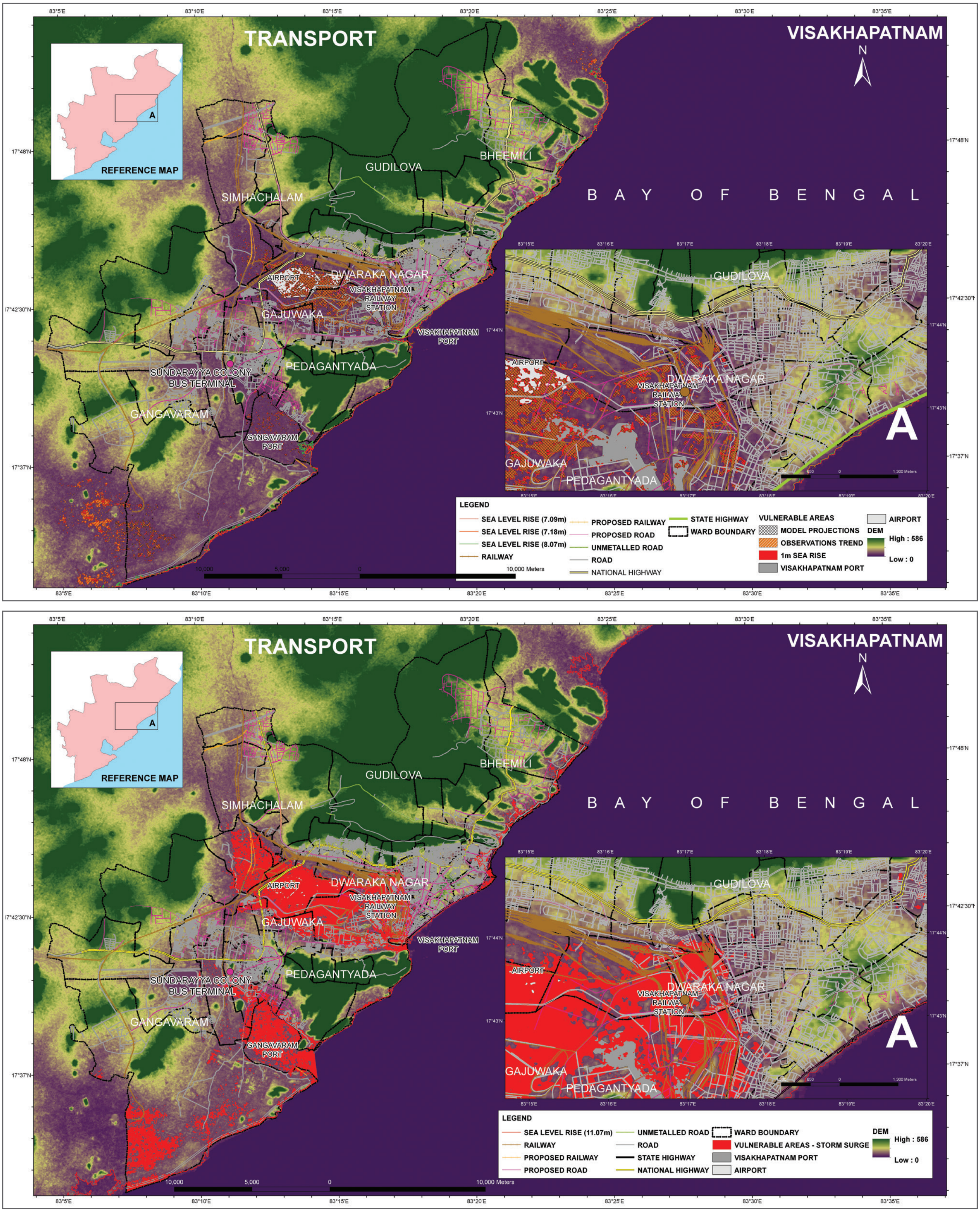


Figure 26: Transport infrastructure likely to be affected by flooding in SLR and storm surge scenario

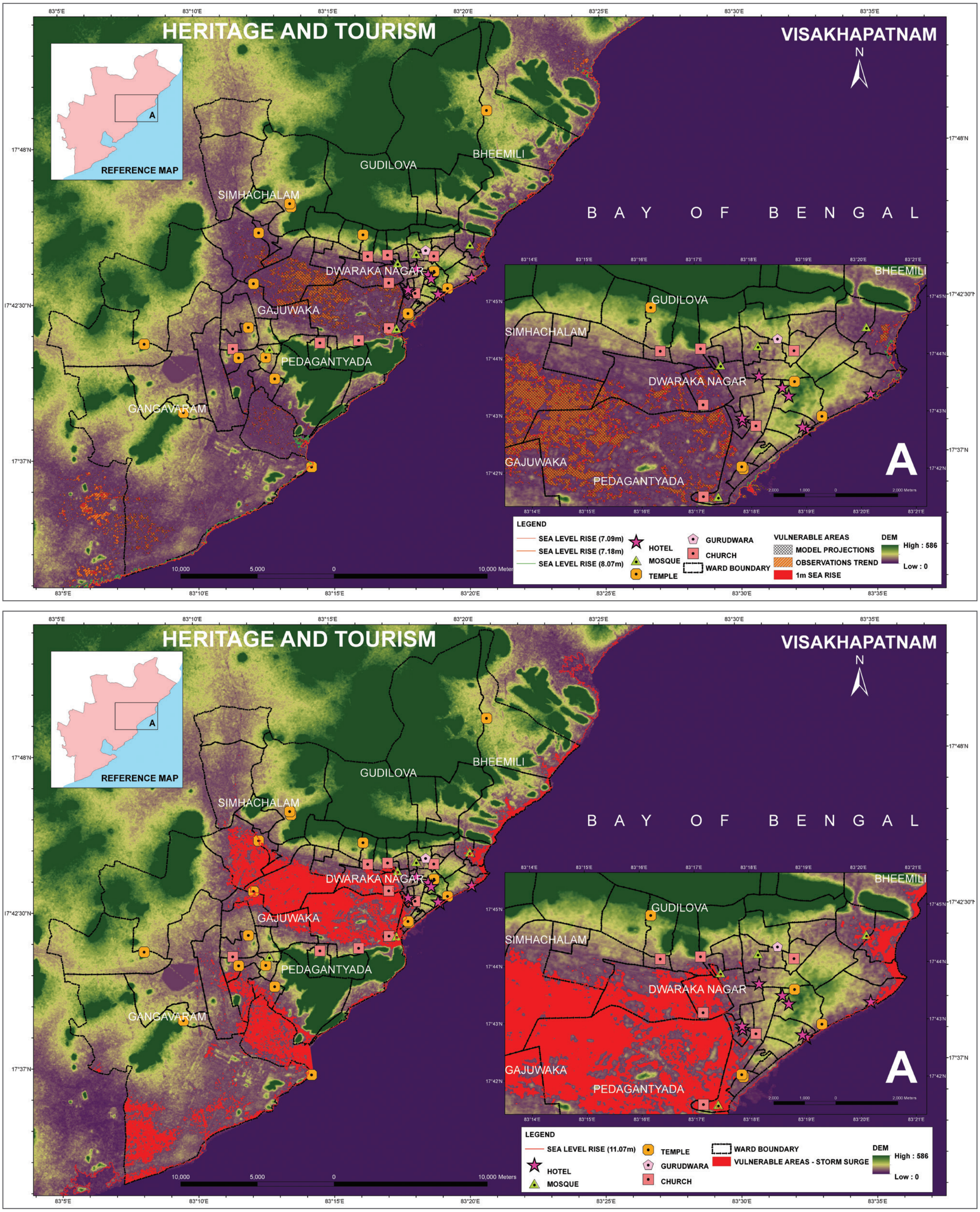


Figure 27: Heritage and tourism infrastructure and assets likely to be affected by flooding in SLR and storm surge scenario

ADAPTIVE CAPACITY

Adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes) so as to moderate potential damages, to fully utilize the opportunities, or to cope up with the adverse consequences. As part of this project, assessment of the adaptive capacity of Visakhapatnam city was a continuous process and relied mostly on review of relevant city level plan documents, state level policies, acts and rules, stakeholder consultations, and discussions with sector experts. For instance, two Expert Review Committee workshops contributed in assessing the adaptive capacity and validating the methodology and recommendations proposed in this study (See Box).

A broad assessment of institutional and policy framework, disaster preparedness, infrastructure, and services adequacy and efficiency was done in order to understand the adaptive capacity of the city. Based upon this assessment, structural recommendations, enabling policies, and institutional recommendations have been suggested for resilience planning and increasing the adaptive capacity at city level. Besides this, the DBMS developed as part of this study recommends certain 'colour coded' data fields to be maintained by the city that will help in formulating and implementing policy and engineering decisions for increasing the adaptive capacity of Visakhapatnam city. This inventory can further be refined in consultation with multiple departments/sectors to include several other infrastructure planning parameters as relevant to the particular city. The study also recommends a detailed analysis of critical infrastructure sectors to understand the obstacles, barriers, or limitations that affect the city's ability to respond to climate and non-climate stressors, disasters, or impacts to implement measures for increasing its adaptive capacity.

Box: Expert Review Consultations

An expert committee was constituted comprising a mix of experts and professionals working in the areas of coastal cities/ settlements, disaster management, climate resilience planning, urban planning, representation from USAID and officials from various sectoral departments at city level. The expert review committee met twice during the year-long project timelines to review the work performed and provide inputs for its improvement in terms of the methodology adopted for assessments and vetting the recommendations.

RECOMMENDATIONS

Having identified the vulnerable areas and sector-wise infrastructure assets and services, broad recommendations addressing specific sectors of the city have been formulated and suggested. The recommendations are said to have been 'broad' since structural adaptation interventions as well sector-specific adaptation interventions would need expert advice, planning and detailed analysis, both technical and financial, to arrive at a decision for implementation. In addition to this, the study also highlights the primary enabling and supporting considerations like institutional and regulatory frameworks, financing mechanisms and capacity building, which would be required for planning new infrastructure or retrofitting/climate proofing of existing one. *Table 2* presents the key structural and non-structural measures and key data fields suggested for addressing the future sea-level rise and current and future vulnerability associated with SLR and storm surge incidences in the city.

Addressing the safety and resilience of the critical man-made infrastructure

- Social Infrastructure
- Solid waste management
- Heritage and Tourism
- Water supply
- Transport
- Sewerage and drainage
- Energy and telecommunication

Addressing the safety and resilience of natural infrastructure

Addressing beach erosion

Supporting and enabling measures

- Planning measures
- Regulations and institutions
- Capacity building and awareness generation

Figure 27: Overview of recommendations

Table 2: Recommendations

Sector	Structural measures	Non-structural measures	Suggested data fields
Social Infrastructure	• Reducing the impact of flooding through appropriate building design solutions • Addressing the requirements after the flood has receded • Checking for building stability and efficiency	• Planning for evacuation , response, and relief in case of extreme events - Standard Operating Procedures (SOPs) • Planning new infrastructure: Avoiding low-lying vulnerable hotspots • Integrating vulnerability assessment and resilience planning in institutional framework and plans, acts, rules, bye-laws, building codes, etc.	• Health – Information on location of hospitals and health centres, ambulances, medicine stocks, doctors, nursing and paramedical personnel, yearly data on diseases, etc. • Education – Information on location of schools, number of students, available rooms and infrastructure, transport facilities, etc.
Energy and Telecommunication	• Appropriate building design solutions for reducing flood damage in vulnerable areas • Appropriate on-site drainage in production and refuelling stations • Maintaining safe heights for infrastructure assets like Electric Sub Station (ESS) and for leak-proof equipment storage.	• Planning new infrastructure: Avoiding vulnerable hotspots for siting • Integrating vulnerability assessment and resilience planning in institutional framework and plans, acts, rules, by-laws, building codes, etc.	• Location and elevation of facilities – Production sites, sub stations, etc • Details of transmission lines – Location of towers, network, underground cabling details for flood-prone and low lying areas

	• Appropriate reinforcement measures for the safety and stability of towers and cables/ lines	• Enforcing state level Renewable Portfolio Obligation (RPO) in line with the Electricity Act of 2003 for promoting smaller, distributed power generation units to minimize and manage impact on grid and develop climate resilient power infrastructure.	
Heritage and Tourism	• Reducing the impact of flooding • Addressing the requirements after the flood has receded • Checking for building stability and efficiency	• Flood proofing and conservation programmes based on expert advise • Emergency plan for the safety of the tourists, for e.g., emergency evacuation, safe transport facilities, and health facilities • Assessments regarding impact of sea level rise on tourism activities for siting of upcoming infrastructure like hotels and beach tourism, etc. • All future tourism infrastructure projects must comply with Coastal Regulation Zone (CRZ) rules.	• Data on intensity of tourist inflows in the city at a particular time of the year. • Age, condition, and last maintenance carried out in the heritage sites • An inventory of informal sector that support tourism should be maintained.
Transport	• Retrofit and adaptation of airport and sea port systems • Appropriate design of public transport systems—siting, entry and exits, drainage, manholes, considerations for safety of structures, equipment, and operations. • Building elevations and materials for structural safety • For transport networks, appropriate drainage provisions with optimum design capacity, length, depth, and the gradient are required.	• Emergency transport arrangements and alternative route planning—SOPs • Emergency operations and control measures— SOPs • Planning new infrastructure: Avoiding low-lying vulnerable hotspots • Integrating vulnerability assessment and resilience planning in institutional framework and Plans, Acts, Rules, By-aws, building codes, etc. • Enforcement of Coastal Regulation Zone (CRZ) Notification 2011 while development and siting of transport infrastructure and networks	• Road infrastructure—Location and elevation of roads, bridges, subways, tunnels, etc.; data on age, type of structures, building materials, etc.; drainage information. • Railways—Information on location and networks, maintenance plan and frequency, elevation, flood- prone areas, data on disruptions due to extreme weather phenomena, data on railway buildings • Airport—Capacity, footfalls, age, building material, elevation, plinth level, entry to runway/taxi ways, details of low-lying/flood-prone areas

	• If the parking lot is not to be used for retaining water, provision of drains, impervious surface area, and adequate slope at strategic locations to prevent flooding and water logging would be required.	• Siting of processing and industrial units in and around port areas as per the CRZ Notification 2011	• Port—Detailed mapping of port areas, assessments on precipitation, SLR and extreme events and its impact on port infrastructure and operations— berths, quays, material handling, design height of key structure, building materials, maintenance plans.
Sewerage and Drainage	• The vertical elevation of the outfall channel should be above the high tide level to avoid back flows from sea • Planning the gradual augmentation of the sewerage system—New drains to take into account the vulnerable zones of the city and appropriately inbuilt resilience features	• Identifying alternate energy sources in vulnerable zones housing pumping stations • Regular maintenance— The drains must be cleaned periodically to avoid blockages during peak time • Integrating vulnerability assessment and resilience planning in institutional framework and Plans, Acts, Rules, By-laws, building codes, etc.	• Data on flood-prone areas • Yearly data on water logged areas • Locational details of drainage • Height of outfall sewers from the mean sea level/ high tide level • Maximum capacity of pumps and treatment plants • Distance of waste water plant from sea
Industries	• Appropriate building design solutions for reducing flood damage in vulnerable areas • Appropriate on –site services like electricity, waste water drainage • Appropriate measures for the safety of machines, equipment, and production facilities • Appropriate measures for safe and leak-proof equipment and material storage	• Avoiding vulnerable hotspots for planning and siting of new infrastructure, for example in the proposed PCPIR • SOPs and early warning systems for emergency situations • Integrating vulnerability assessment and resilience planning in institutional framework and Plans, Acts, Rules, By-laws, building codes, etc.	• Location and elevation of industries— data and locations, layout plans • Common facilities like Common Effluent Treatment Plants (CETP), on-site services—Age, elevation, building materials, etc. • Mapping Connectivity
Buildings	• Reducing the impact of flooding through appropriate building design solutions • Addressing the requirements after the flood has receded • Checking for building stability and efficiency	• Planning for evacuation , response, and relief in case of extreme events— SOPs • Planning new housing: Avoiding low-lying vulnerable hotspots • Integrating vulnerability assessment and resilience planning in institutional framework and Plans, Acts, Rules, By-laws, building codes, etc.	• Buildings – Age, use, number of dwelling units/ rooms, type of structure, FAR, FSI, building material, elevation, plinth level, services on site. • Slums — Spatial location, population, number of households and dwelling units, services on site, details on livelihood/ occupations, etc.

THE WAY FORWARD

The study undertaken by TERI resulted in a factual, updated, and multi-sectoral DBMS. On the basis of this a scientific vulnerability mapping exercise and broad recommendations were suggested. However, it is only a first step in demonstrating and initiating climate action in Visakhapatnam city and for coastal cities in India in general and it is really up to the city to take this forward while envisioning and planning for a development that takes cognizance of the future shocks and stressors.

In order to implement the suggested measures and build climate resilience, the city will need to come up with detailed recommendations and action points for short, medium and long term period, based on expert advice, scientific studies, and financial considerations. Supporting and enabling mechanisms in terms of policy and regulatory frameworks, finance allocation, sensitization, and capacity building of stakeholders will be an integral part of climate resilience planning efforts. Since infrastructure development and management for a number of sectors and services is beyond the powers and functions of the ULB, an integrated multi-sectoral approach with dedicated institutional framework needs to be formulated for coordinating infrastructure development and management at city level.

ACKNOWLEDGEMENT

We are grateful to the US Agency for International Development (USAID) for granting this study to TERI as part of their Climate Change Resilient Development (CCRD) project's climate adaptation small grants program. We are particularly thankful to Mr Christopher Evans, Deputy Program Manager, CRIS Program and Manager, ICF International, Ms Michelle Colley, Senior Manager, ICF International and Ms Lana Lightle, CCRD Grant Manager for their constant involvement and support to TERI during the course of this study.

The study could not have taken place without the approval, support, and continuous participation of Greater Visakhapatnam Municipal Corporation (GVMC) and Visakhapatnam Urban Development Authority (VUDA), who formally supported the project and facilitated data collection, stakeholder consultations, and provided inputs from time to time. We are thankful to Mr N Yuvaraj, District Collector Visakhapatnam and Former Vice Chairman, VUDA for guiding and facilitating our work in Visakhapatnam city. Of particular mention is the support from Mr M V Satyanarayana, Commissioner, GVMC for extending all the support during the course of one year when the project continued in the city. We are also thankful to Ms M Janaki, Additional Commissioner, GVMC for supporting the study and steering interest and participation from the city officials during the course of the study. We would also like to thank various officials from city level and state line departments who were consulted for the study for their valuable inputs and insights. Of particular mention is the guidance and support received from Gangavaram Port Limited, Visakhapatnam Port Trust, Indian Meteorological Department's Cyclone Warning Center in Visakhapatnam, and Ms Jayashree and Mr Sohan Hattangadi.

TERI also extends its gratitude to all the participants of the two expert validation workshops and members of the Expert Review Committee formed within the project for their time, inputs, and expert advice to make this study practical and implementable for the city.

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All activities in TERI, the largest developing-country institution working towards sustainability, move from formulating local- and national-level strategies to shaping global solutions to critical issues.

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