Roadmap for Implementation of Water-Sensitive Urban Design and Planning in Odisha

RAINWATER HARVESTING IN PUBLIC PARKS AND OPEN SPACES

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Foreword

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In the wake of large influx of populace to towns and cities in search of sociocultural and economic opportunities, the urban ecosystems have been subjected to unprecedented pressure in recent times. The incessant utilization of resources is impacting the per capita availability adversely.

Water is key to the sustenance and growth of a settlement. Domestic, manufacturing, construction and many other sectors rely heavily on availability of this precious resource. No wonder that most of the urban areas are water stressed.

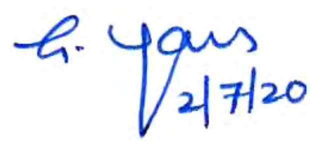
The hydro-meteorological processes are becoming increasingly unpredictable. Even though the annual rate of precipitation remains by and large the same, the distribution over space and time is becoming too uneven. To add to this, unplanned urban growth and unauthorized construction over waterbodies and water channels have seriously compromised the capacity of cities to retain rainwater and recharge groundwater. While flooding during monsoon has become a common sight in many cities, lowering of the groundwater table is reaching dangerous levels every year.

Although the situation in Odisha is not very alarming, Government of Odisha is conscious of the fact that any complacency at this stage can jeopardize the prospects of sustainability in future. It has therefore been decided to put in place a water management system in all the urban areas of the state, which will be capable of catering to the needs of the present and be sensitive to the requirements of the future.

Housing & Urban Development Department, Government of Odisha, has partnered with Centre for Science and Environment (CSE), New Delhi, in this endeavour and to lend support in various critical areas for achieving the objective of water-sensitive urban design and planning (WSUDP). The department has come up with an Advisory for the ULBs and Development Authorities to create rainwater harvesting structures in all the parks and open spaces in the first phase.

As part of the support, CSE has conducted two workshops for the administrators, engineers and planners of five Municipal Corporations and nine Development Authorities and based on studies and consultations has developed a document *Roadmap for Implementation of Water-Sensitive Urban Design and Planning in Odisha—Rainwater Harvesting in Public Parks and Open Spaces.* For this purpose a few sample parks from four cities, viz. Bhubaneswar, Cuttack, Rourkela and Berhampur, have been selected to demonstrate the prospects of some generic models of rainwater harvesting structures (RWHS) in parks and open spaces.

I acknowledge with profound appreciation the efforts of CSE to expose the administrators, planners and engineers from the cities to the best practices to achieve water-sensitive designing and planning in urban Odisha. I hope the partnership will continue to manifest in many more impactful endeavours.



(G. Mathi Vathanan)

1. Introduction

The Housing and Urban Development Department (HUDD), Government of Odisha, in collaboration with Centre for Science and Environment (CSE), aim to work towards mainstreaming Water-Sensitive Urban Design and Planning (WSUDP) in cities and towns of Odisha. In view of this, CSE and HUDD entered into a memorandum of understanding (MoU) with the objective of mainstreaming storm water management and rainwater harvesting (RWH) in towns and cities of Odisha.

Cognizant that rooftop RWH has had limited success and needs incentivization and other measures, HUDD has decided to undertake radical changes in the RWH strategies for cities. Noting that there lies immense potential of rain/ storm water harvesting via public parks, roads and flyovers, HUDD released an Advisory[1] to relevant stakeholders for the implementation of WSUDP Phase-I.

Under Phase-I, all urban local bodies (ULBs) and development authorities (DAs) need to implement RWH in all public parks and open spaces. For implementation and coordination of Phase-I, a State Level Task Force (SLTF) has been constituted with the Principal Secretary as Chairperson, Joint Secretary as Nodal Officer and CSE as Member, amongst others. The SLTF is also responsible for providing technical support to ULBs and DAs for preparation of short-, medium- and long-term strategies for RWH in public parks and open spaces.

All ULBs need to identify existing and potential projects, and retrofit and implement them within the space of 30 days, for which all cities need to constitute a City Level Task Force (CLTF). The CLTF is tasked with preparation of a Preliminary Action Plan (PAP), which shall provide necessary information on the number of parks and their physical features such as area, topography, soil type, nature of green space and use. The PAP should also provide information regarding existing RWH structures, rainfall statistics, groundwater (GW) statistics, land use, etc. Once the PAP is finalized, a Feasibility Study and Final Action Plan (FAP) needs to be prepared and implemented.

As per the advisory, CSE will act as a knowledge partner to HUDD and will lend support in the following:

- Training and capacity building
- Developing generic models for different interventions
- Development of guidelines, SOPs, advisories, etc.
- Research and assessment studies on WSUDP and RWH planning and designing, etc.

As part of knowledge support, CSE has prepared the document *Roadmap for Implementation of Water-Sensitive Urban Design and Planning in Odisha: Rainwater Harvesting in Public Parks and Open Spaces* under Phase-I of the MoU. This document showcases the potential of runoff infiltration by following the approach towards rainwater harvesting in parks and green open spaces in four cities: ***Bhubaneswar***, ***Cuttack***, ***Rourkela*** and ***Berhampur***.

The document provides a general description of these cities, providing information on rainfall pattern and statistics, urban planning and provision of public parks and open spaces. For each city, potential sites for implementation are selected. Parks and open spaces of neighbourhood scale and zonal/city scale have been selected as pilot case studies, where RWH potential has been calculated, and certain preliminary design guidelines for each of these parks have been recommended. The report also provides various options and techniques for RWH structures in public parks, with their design details, thumb rules and O&M strategies.

For RWH in parks, the rainwater/storm water is managed by controlling it from source which is the park itself, and thereby preventing the runoff to meet the urban drains which also carry domestic wastewater (black water and supernatant from on-site sanitation systems) and solid waste (due to littering and dumping) in cities. The aim of this approach is not only to capture the runoff generated in parks for infiltration and recharge but also to reduce pollution and flooding at catchment level.

The said approach can also bring multiple benefits like recreational opportunities, amenities and biodiversity. The blue and green spaces thus created not only reduces and treats storm water at its source but also delivers environmental, social and economic benefits.

The runoff generation calculations are carried via rational formula. Since the structures involve catering to recharge and infiltration, the storage calculations are not taken into consideration. Peak rainfall intensity for the cities is assumed within the range of 100–150 mm/hour

The rational formula used to predict the peak runoff generation is $Q = C X i X A$, where 'C' is a runoff coefficient, 'i' is the rainfall intensity, and 'A' is the catchment area.

The preliminary data used is from Google Earth and the open source reports available on the web by the Government of Odisha.

The rainwater harvesting systems which can be considered in context of green spaces in cities of Odisha includes rain gardens, filter strips, swales, bio-retention areas, filter drains and trenches, permeable pavements, detention basins, infiltration basins, ponds and wetlands. The relevant details of these structures are also included in this document for reference.

For Phase-I, the initial work needs to establish a demonstration project, demonstrating the effectiveness of water-sensitive project within a park which is used by community/residents and documenting the success helps to evaluate and showcase how investing in green spaces can be leveraged to improve multiple outcomes. Demonstration and awareness programmes can also help build momentum and gain stakeholder and community buy-in.

Apart from designing of structures, other strategies that can be adopted are:

- Holding a competition for 'rainwater harvesting for parks design' within local areas;
- Installing a pilot project in a highly visible community park, which illustrates and measures the benefits of integrating green storm water infrastructure into park settings;

- Involving multiple agencies and community members and partners in the pilot process;
- Building an outdoor classroom or open exhibition to provide educational materials to inform park visitors of the importance of rain/storm water harvesting practices;
- Apprising visitors of the importance of green storm-water/rainwater harvesting infrastructure practices; and
- Placing hoardings or small banners for awareness of the harvesting practices.

2. Bhubaneswar

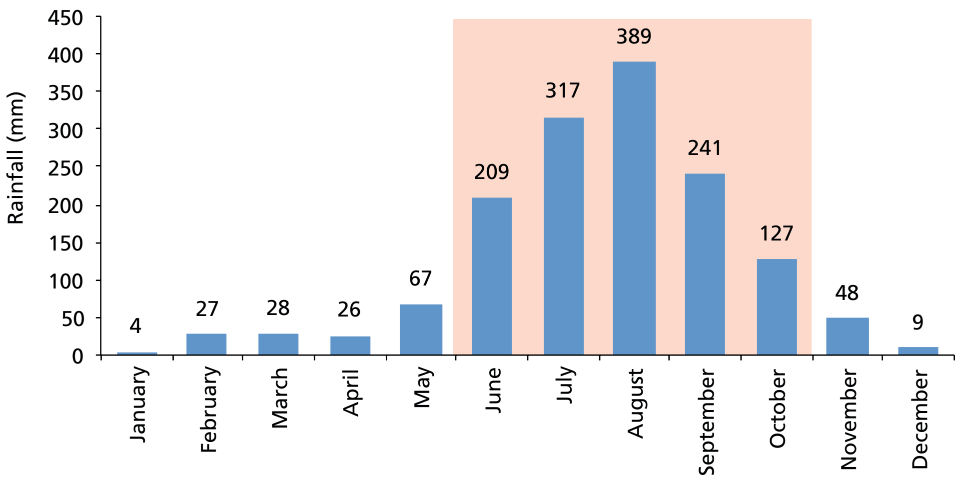
2.1 City profile

Bhubaneswar, known as the city of temples, is the state capital and the largest city of Odisha. It has various historical and culturally significant temples within the city limits. The population is 8.37 lakh (as per Census of India, 2011)[2] and the municipal area of the city (under Bhubaneswar Municipal Corporation) is spread across 148.1 sq. km. The larger Bhubaneswar Development Planning Area stretches across 422 sq. km (an addition of 173 revenue villages).

The city is located south of the Mahanadi Delta, and is bounded by the Kuakhai River on the east; the Daya River on the south, and Chandaka Wildlife Sanctuary and Nandankanam Zoo on the northern and western parts (see *Figure 2: Locational setting of Bhubaneswar)*.

The city has a tropical climate, with a maximum temperature of 45°C in May and minimum temperatures of 14°C in December. It receives an average annual rainfall of 1,492 mm, with over 80 per cent of total rainfall occurring in the monsoon season from June–October (see *Figure 1: Rainfall pattern of Bhubaneswar*).[3, 4]

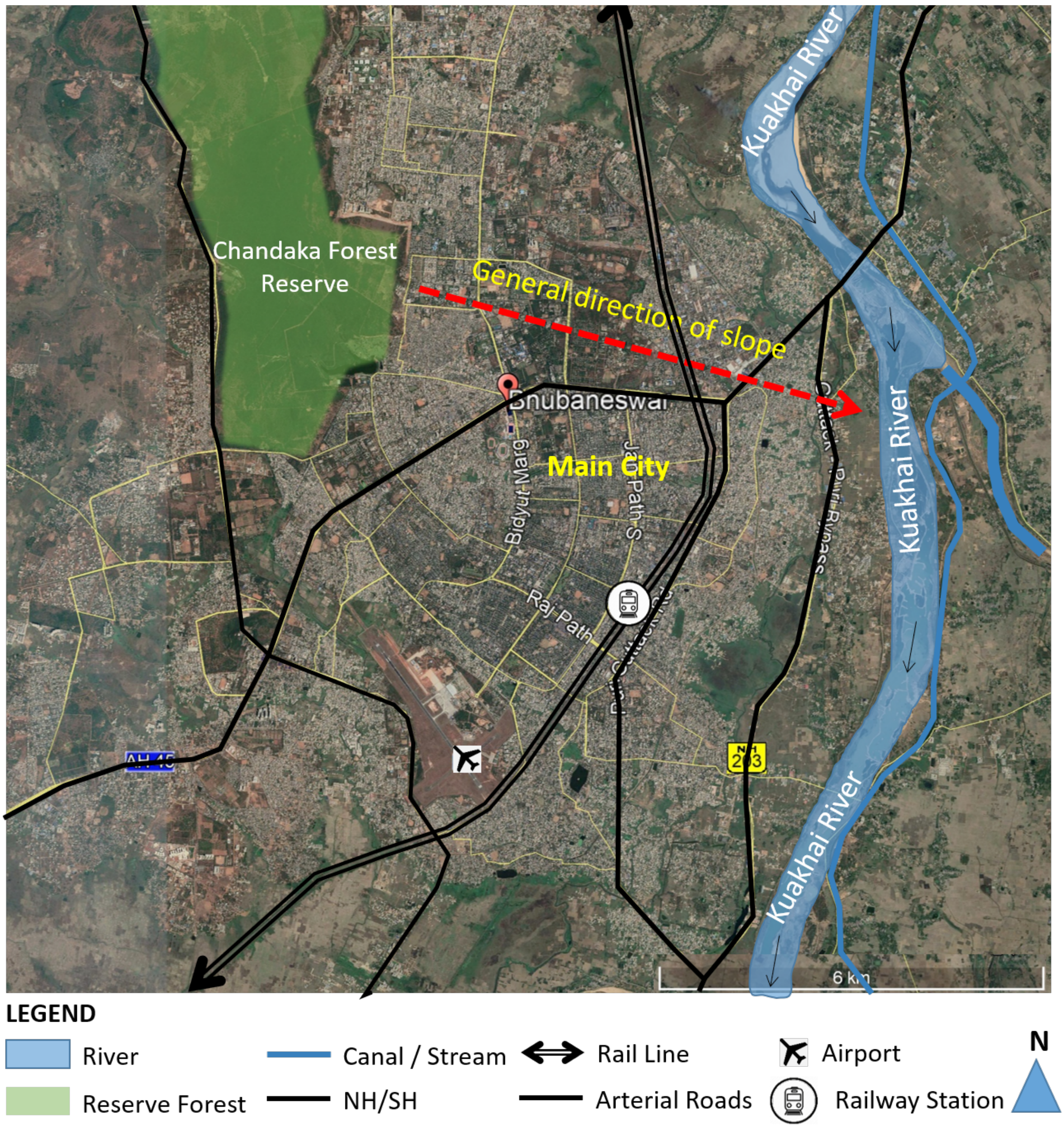
Figure 1: Rainfall pattern of Bhubaneswar



Source: CSE, 2020 (compiled from information retrieved from IMD, Government of India)

Bhubaneswar is located at an altitude of 48 m above mean sea level (AMSL). The city gently slopes from west to east, and south-east towards the rivers. It has various ponds and lakes, and major natural drains—Gangua, Buri and Chetra drains, which run west to east—of which the Gangua Nallah is the major drain of the city. Along with these, there are 10 open drainage channels, which form the drainage network of the city. As per the *Ground Water Year Book of Odisha*, the average depth of the groundwater table in the city is in the range of 5–10 m (pre-monsoon, with some areas in the city having up to 18 m depth) to 2–5 m post-monsoon.[5]

Figure 2: Locational setting of Bhubaneswar



Source: CSE, 2020 (Compiled from information retrieved from Google Maps and CDP for Bhubaneswar-2030)

The geological profile of the city exhibits western highlands on the west and north-west parts of the city, and eastern lowlands towards the eastern parts of the city. The soil type in the city varies from laterite rock and laterite morum in the western parts of the city, and alluvial ground and sand stones of varying grain sizes as we move east towards the rivers.

2.2 Urban planning in Bhubaneswar

Bhubaneswar is one of the first planned cities in India. It was built in 1949 as a modern city by German architect Otto Königsberger, known for his designs based on the neighbourhood concept, with focus on parks and open spaces in addition to connectivity. The blueprint for city design propagated the development of neighbourhood parks in the planned areas. The design principles have been carried forward with the Comprehensive Development

Plan (CDP) for Bhubaneswar, 1993, and the CDP for Bhubaneswar, 2030.

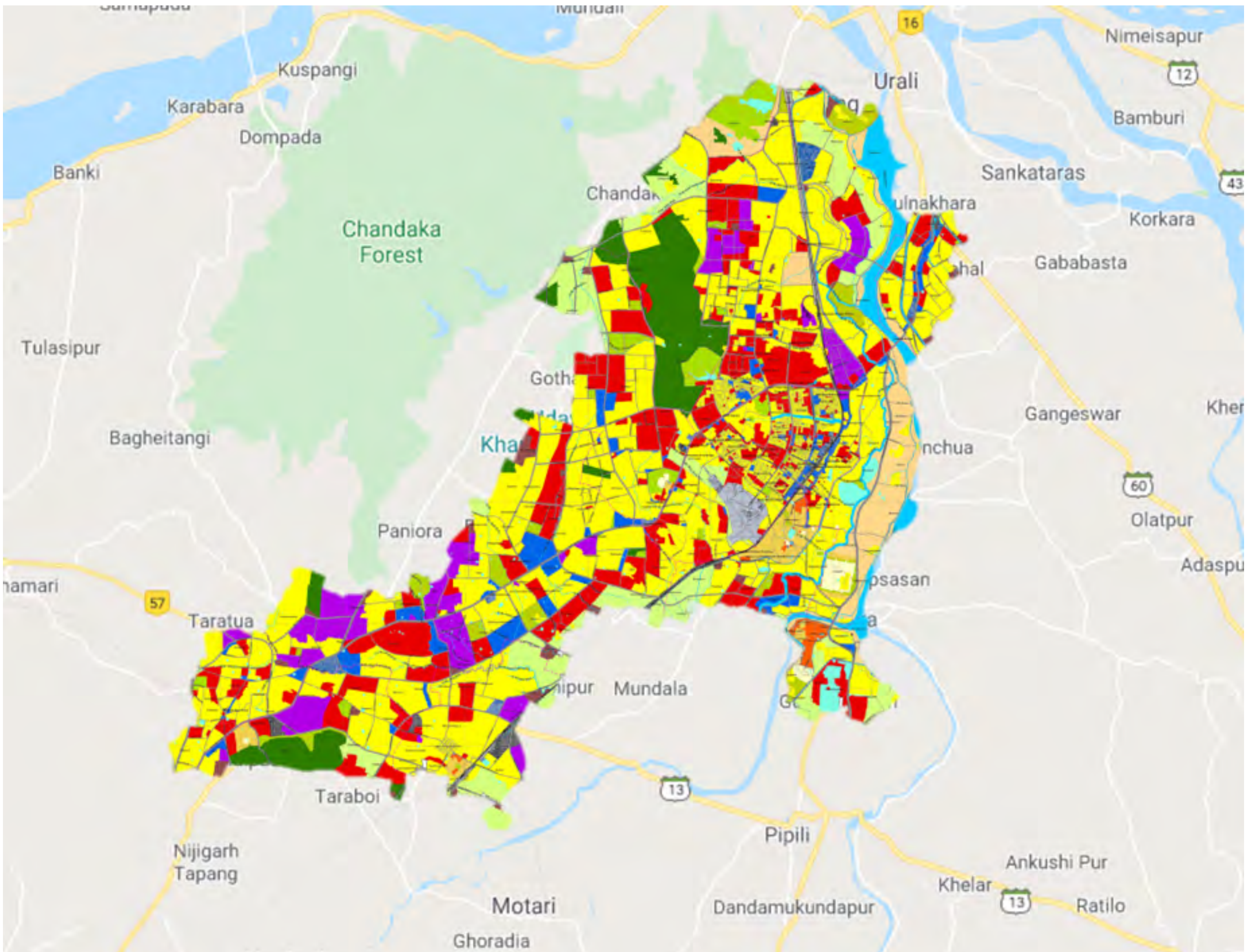
As per Comprehensive Development Plan (CDP) for Bhubaneswar, 2030, the total proposed area under ‘recreation’ is 694.40 ha, which constitutes 1.66 per cent of the Bhubaneswar Development Plan Area (BDPA; total area 419 sq. km).[6]

CDP has defined Open Space Use Zone for designating land use and permissible activities in the BDPA. The total proposed area under this category is 20.66 sq. km (4.93 per cent of total BDPA). The use zone is divided into the following four categories:

- P1: Playgrounds, stadiums, sports complex
- P2: Parks and gardens
- P3: Special recreation zone (restricted open spaces and green buffer)
- P4: Multi-purpose open space zone

In terms of hierarchy of open spaces, the city has neighbourhood parks (P2) and city-level parks. While city-level parks include the city forest areas, botanical garden, and other city-level infrastructure, neighbourhood parks are smaller, ranging from 0.5 acres to 5 acres.

Figure 3: Land Use Plan, 2030 for Bhubaneswar Development Planning Area



Source: CDP for Bhubaneswar, 2030

2.3 Rainwater harvesting (RWH) in selected public parks

Indira Gandhi Park

Coordinates: 20°16’10.05”N, 85°49’57.90”E; | Area: 54,000 sq. m (approx. from Google Maps)

Figure 4: RWH structures for Indira Gandhi Park, Bhubaneswar

Source: CSE, 2020

- Potential runoff generated: 16,114 KL annually with annual rainfall of 1,492 mm;
- Assuming peak rainfall to be within range of 100–150 mm;
- Depth of structure to be 2 m; and
- Area required for infiltration structures will be within range of 675–1,012.5 sq. m.

Hence the percentage required to be dedicated for the infiltration structure is in the range 1.5–3 per cent of the total area of the park to cater to peak rainfall over 15 minutes.

Potential infiltration systems that can be proposed:
- Swale along the footpath or desired path;
- Bio-retention areas surrounded by vegetation at nodes;
- Detention basin in centre; and
- Infiltration basin.

Biju Patnaik Park
Coordinates: 20°15’29.12’’N, 85°49’31.18’’E; | Area: 86,490 sq. m (approx. from Google Maps)

Figure 5: RWH structures for Biju Patnaik Park, Bhubaneswar

Source: Google earth, compiled by CSE, 2020

- Potential runoff generated: 25,809 KL annually with annual rainfall of 1,492 mm;
- Assuming peak rainfall to be within range of 100–150 mm;
- Depth of structure to be 2 m; and
- Area required for infiltration structures will be in the range of 1,081–1,622 sq. m.

Hence the percentage required to be dedicated for the infiltration structure is in the range of 1.5–3 per cent of the total area of the park to cater to peak rainfall over 15 minutes.

- The bio-retention areas can be located after identifying low-lying areas within the park.
- Trench with filter strips and swales can be located along the footpath.

Neighbourhood park, Unit 3
Coordinates: 20°16’18.96”N, 85°50’20.30”E; | Area: 3,736 sq. m. (approx. from Google Maps)

Figure 6: Neighbourhood park, Unit 3, Bhubaneswar

Source: CSE, 2020

- Potential runoff generated: 1,115 KL annually with annual rainfall of 1,492 mm;
- Assuming peak rainfall to be in the range of 100–150 mm;
- Depth of structure to be 2 m; and
- Area required for infiltration structures will be in the range of 47–70 sq. m.

Hence the percentage required to be dedicated for the infiltration structure is in the range of 1.5–3 per cent of the total area of the park to cater to peak rainfall over 15 minutes.

Potential infiltration systems that can be proposed:
- A small rain-garden can be proposed with provision of overflow;
- Trench with filter strips and swales can be located along the footpath;

- From these three parks, a total of 43.04 million litres of rainwater can be harvested annually.
- Assuming 15 neighbourhood-level parks implement RWH in Bhubaneswar, an additional 16.72 million litres of rainwater can be harvested.
- Therefore, a total of 59.76 million litres of rainwater can be harvested in Bhubaneswar annually.

3. Cuttack

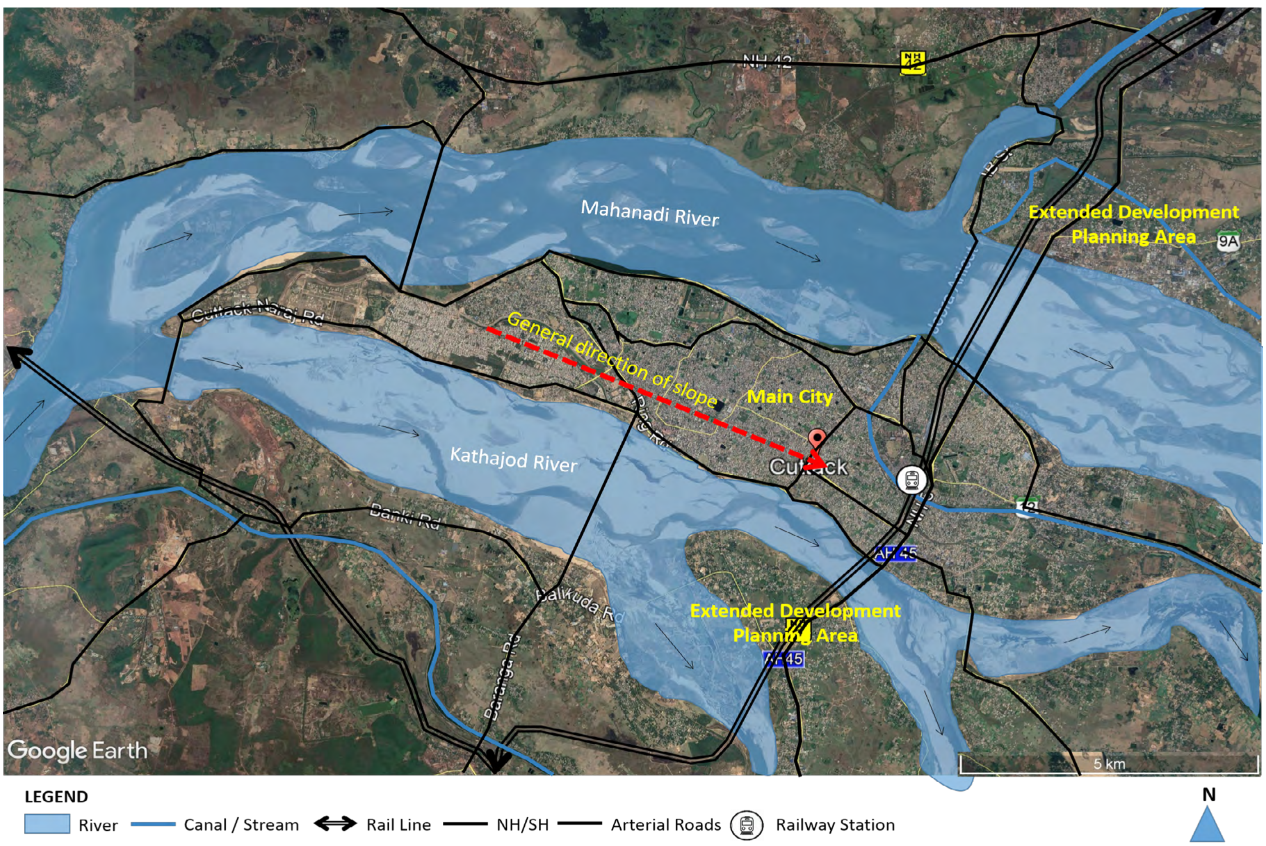
3.1 City profile

The historical city Cuttack is the former capital city of Odisha. The city has a population of 6.66 lakh (as per Census of India, 2011)[7] and the municipal area of the city (under Cuttack Municipal Corporation) is spread across 192.5 sq. km. The larger Cuttack Development Planning Area stretches across 398 sq. km.

The main city is located within the Mahanadi Delta, and is bounded by the Mahanadi River on the north and the Kathajod River on the south, with the extended development planning area north of the Mahanadi River and south of Kathajod River (see *Figure 7: Locational setting of Cuttack*). It is located at an altitude of 36 m AMSL, and gently slopes from the north-west to south-east direction. The city exhibits alluvial soil and sand stones, owing to it being located in the delta.

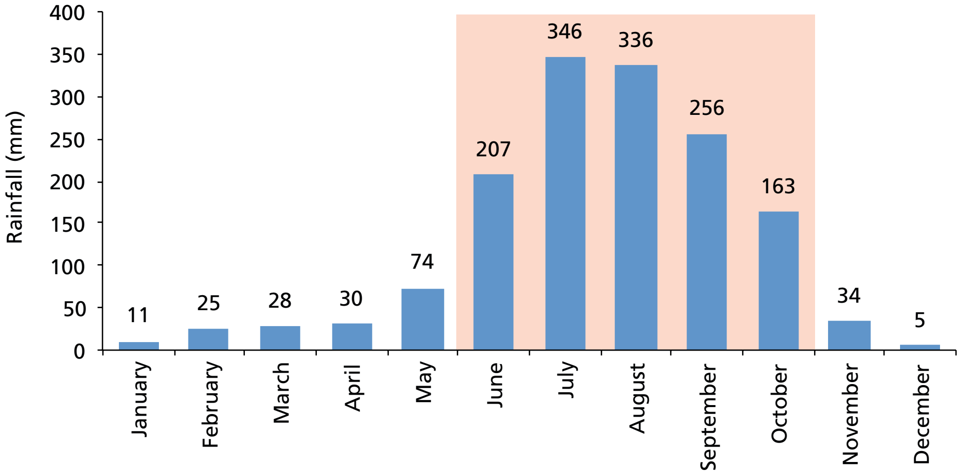
The city has a tropical wet and dry climate, with maximum temperature exceeding 45°C in May and minimum temperature of 10 °C in December. It receives an average rainfall of 1,515 mm, with over 80 per cent of total rainfall occurring in the monsoon season from June to October (see *Figure 8: Rainfall pattern of Cuttack*)

Figure 7: Locational setting of Cuttack



Source: CSE, 2020

Figure 8: Rainfall pattern of Cuttack



Source: CSE (Compiled from information retrieved from IMD, Government of India)

The city has various small ponds and lakes, and a major canal dividing the eastern part of the city. As per the *Ground Water Year Book of Odisha*, the average depth of the groundwater table in the city is in the range of 5–10 m (pre-monsoon) to 2–5 m post-monsoon.

3.2 Urban planning in Cuttack

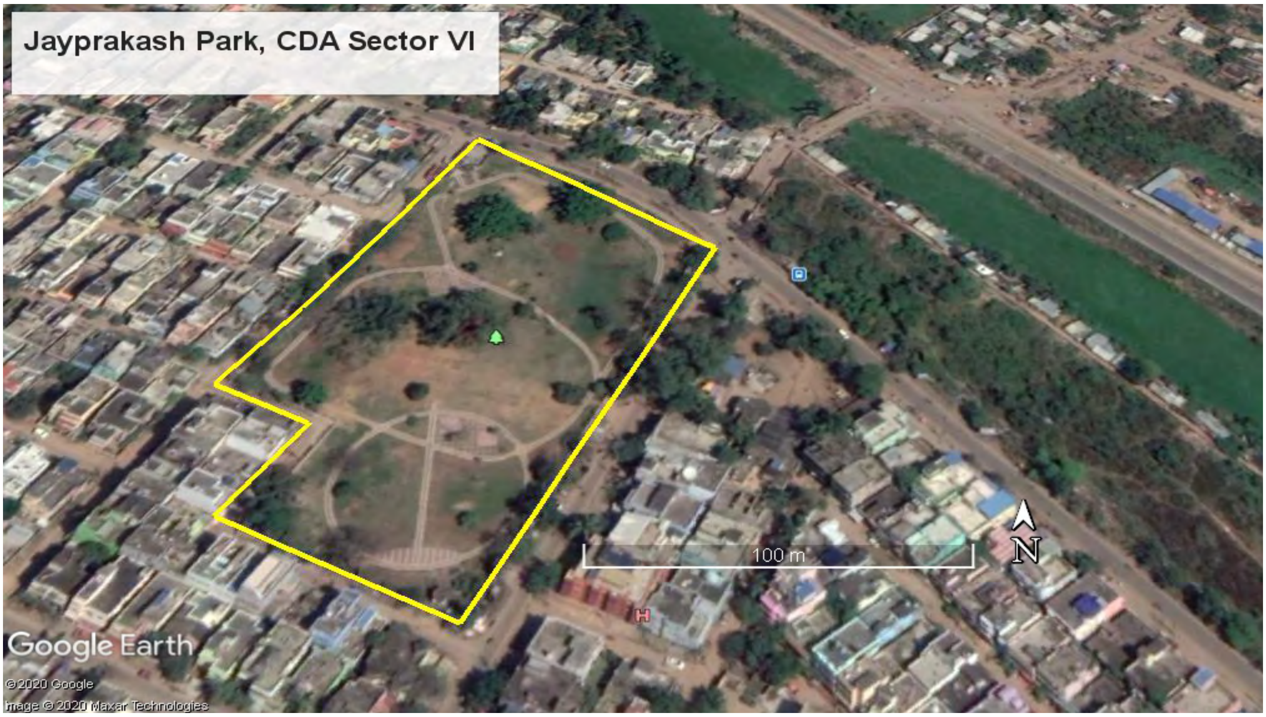
Cuttack city is a historical town, which has grown organically over time. Most of the city has high-density built-up areas. Some of the areas in the city are planned townships, developed by the Cuttack Development Authority (CDA). The Comprehensive Development Plan for Cuttack, 2030 is prepared by the CDA for the development planning area of the city.

Due to the organic nature of the city, the city has scarce neighbourhood parks. The riverfront areas provide the recreation spaces of the city. However, the city has various city-level parks and playgrounds. As per the Cuttack Municipal Corporation, there are 29 public parks in the city of various sizes.

3.3 RWH in selected public parks

Jayaprakash Park, CDA Sector VI
Coordinates: 20°28’38.30”N, 85°50’27.70”E; | Area: 12,580 sq. m (approx.)

Figure 9: RWH structures for Jayaprakash Park, Cuttack



Source: Google Earth

- Potential runoff generated: 3,812 KL annually with annual rainfall of 1,515 mm;
- Assuming peak rainfall to be in the range of 100–150 mm;
- Depth of structure to be 2 m; and
- Area required for infiltration structures will be in the range of 157–236 sq. m.

Hence the percentage required to be dedicated for the infiltration structure is in the range of 1.5–3 per cent of the total area of the park to cater to peak rainfall over 15 minutes.

Potential infiltration systems that can be proposed:

- Swale along the footpath or desired path; and
- Bio-retention areas surrounded by vegetation at nodes

Jugal Kishore Park, Sector 9
Coordinates: 20°28'46.34"N, 85°49'56.69"E; | Area: 7,000 sq. m. (approx. from Google Maps)

Figure 10: Jugal Kishore Park, Cuttack

Source: Google Earth

- Potential runoff generated: 2,121 KL annually with annual rainfall of 1,515 mm;
- Assuming peak rainfall to be in the range of 100–150 mm;
- Depth of structure to be 2 m; and
- Area required for infiltration structures will be within range of 88–131 sq. m.

Hence the percentage required to be dedicated for the infiltration structure is in the range of 1.5–3 per cent of the total area of the park to cater the peak rainfall over 15 minutes.

Potential infiltration systems that can be proposed:
- Swale along the footpath or desired path; and
- Bio-retention areas surrounded by vegetation at nodes.

Biju Patnaik Park
Coordinates: 20°29'1.39"N, 85°48'44.95"E; | Area: 111,940 sq. m (approx.)

Figure 11: RWH structures in Biju Patnaik Park, Cuttack

Source: Google Earth

- Potential runoff generated: 33,918 KL annually with annual rainfall of 1,515 mm;
- Assuming peak rainfall to be within range of 100–150 mm;
- Depth of structure to be 2 m; and
- Area required for infiltration structures will be in the range of 1,399– 2,099 sq. m.

Hence the percentage required to be dedicated for the infiltration structure is in the ranges of 1.5–3 per cent of the total area of the park to cater the peak rainfall over 15 minutes.

Potential infiltration systems that can be proposed:
- Swale along the footpath or desired path;
- Bio-retention areas surrounded by vegetation at nodes; and
- Detention basin to detain and then to infiltrate runoff.

- From these three parks, a total of 39.85 million litres of rainwater can be harvested annually.
- Assuming 15 neighbourhood-level parks implement RWH in Cuttack, an additionally 31.81 million litres of rainwater can be harvested.
- Therefore, a total of 71.66 million litres of rainwater can be harvested in Cuttack annually.

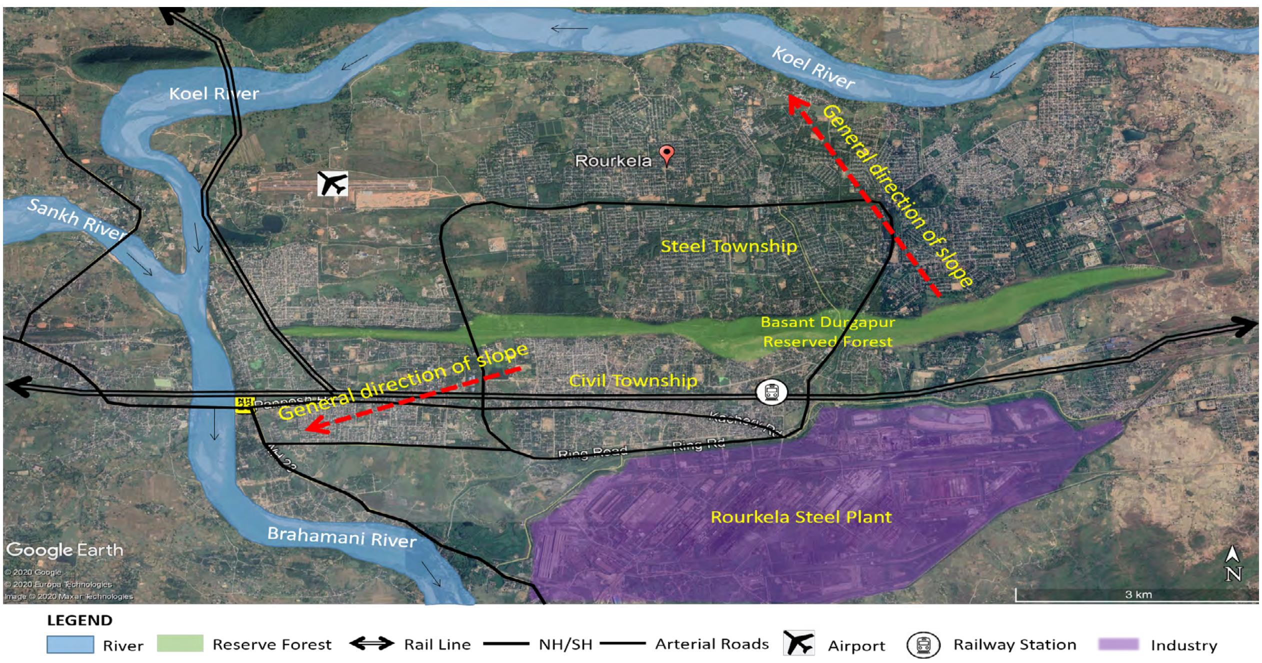
4. Rourkela

4.1 City profile

Rourkela is the third largest city of Odisha. The city was developed as a greenfield industrial township by the Steel Authority of India (SAIL) when it developed the Rourkela Steel Plant in the 1950s and 1960s. The municipal area of the city is spread across 200 sq. km and comprises Rourkela Town (Civil Township) and Rourkela Industrial Township (Steel Township). As per the Census of India, 2011, the civil township has a population of 2.7 lakh, while the steel township has a population of 2.10 lakh. The metropolitan area has a total population of 5.52 lakh.[8]

The city is surrounded by a range of hills and encircled by the Koel and Sankha Rivers, which meet at Vedvyas and flow as a single river called the Brahmani. It is located at an altitude of 219 m AMSL. The civil township and industrial township are divided by the linear Basant Durgapur Reserve Forest, and the city gently slopes from the south-east to north-west direction in the northern parts of the forest, and north-east to south-west in the southern parts of the forest (see *Figure 12: Locational setting of Rourkela*). The city exhibits alluvial soil.

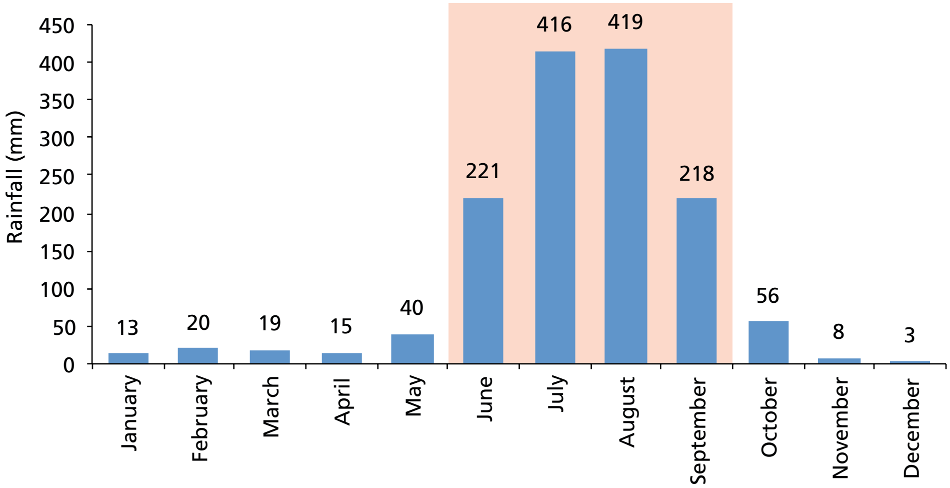
Figure 12: Locational setting of Rourkela



Source: CSE, 2020

The city has tropical climate, with a maximum temperature at 49°C in May and minimum temp of 5°C in December. The city receives an average annual rainfall of 1,448 mm, with over 80 per cent of total rainfall occurring in the monsoon season from June to September (see *Figure 13: Rainfall pattern of Rourkela*). As per the *Ground Water Year Book of Odisha*, the average depth of the groundwater table in the city is in the ranges of 10–20 m (pre-monsoon) to 5–10 m post-monsoon.

Figure 13: Rainfall pattern of Rourkela, Odisha

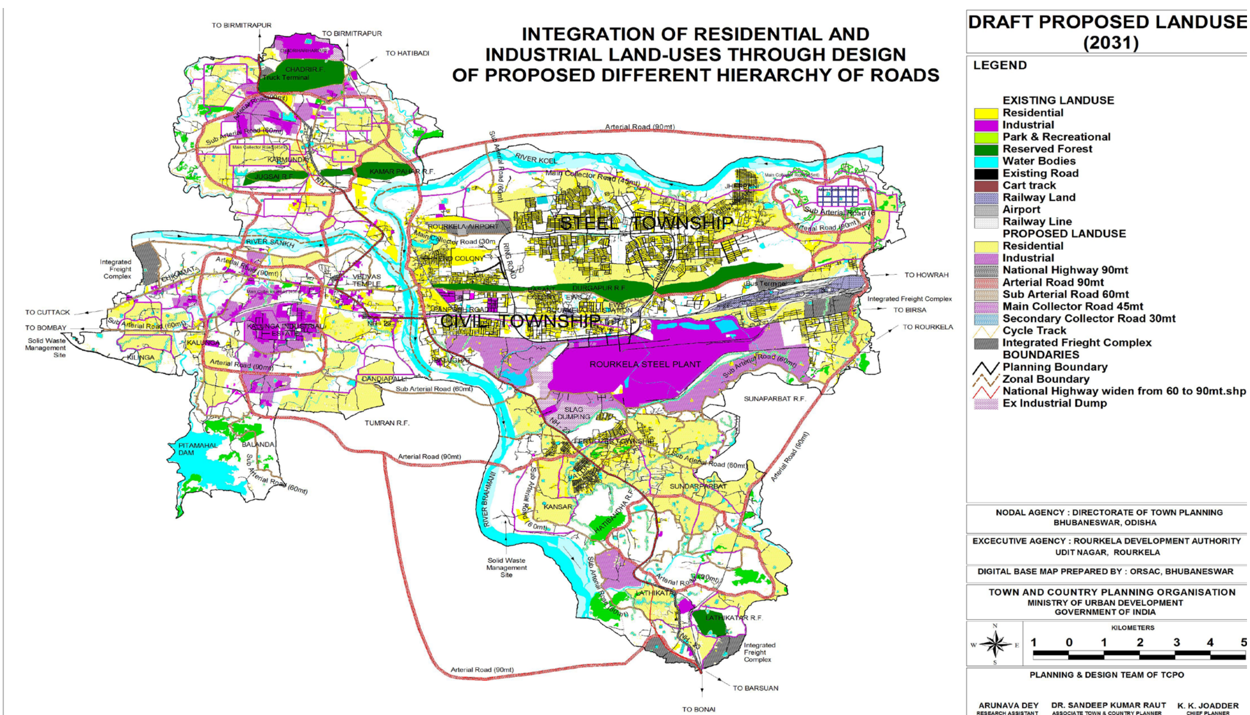


Source: CSE (Compiled from information retrieved from IMD, Govt. of India)

4.2 Urban planning in Rourkela

Rourkela is a greenfield township, which has been developed on the basis of sector planning, with each sector a self-sufficient unit (as in Chandigarh, Dwarka, Gandhinagar, etc.). Due to this, each sector has neighbourhood-level parks and playgrounds. The Industrial Township was developed by the SAIL and the civil township by the Rourkela Development Authority (RDA). The Comprehensive Development Plan for Rourkela, 2030 was prepared by the RDA for the development planning area of the city.[9]

Figure 14: Land Use Plan, 2030 for Rourkela



Source: CDP for Rourkela, 2030

4.3 RWH in selected public parks

Indira Gandhi Park

Coordinates: 22°14’25.94”N, 84°52’30.89”E; | Area: 1,74,000 sq. m. (approx.)

Figure 15: Indira Gandhi Park, Rourkela

Source: Google Earth

- Potential runoff generated: 50,390 KL annually with annual rainfall of 1,448 mm;
- Assuming peak rainfall to be in the range of 100–150 mm;
- Depth of structure to be 2 m; and
- Area required for infiltration structures will be in the range of 2,175–3,263 sq. m.

Hence the percentage required to be dedicated for the infiltration structure is in the range of 1.5–3 per cent of the total area of the park to cater peak rainfall over 15 minutes.

Potential infiltration systems that can be proposed:

- Swale along the footpath or desired path; and
- Bio-retention areas surrounded by vegetation at nodes.

Deer Park
Coordinates: 22°15’10.27”N, 84°50’26.50”E; | Area: 26,120 sq. m. (approx.)

Figure 16: RWH structures in Deer Park, Rourkela

Source: Google Earth

- Potential runoff generated: 7,564 KL annually with annual rainfall of 1,448 mm;
- Assuming peak rainfall to be in the range of 100–150 mm;
- Depth of structure to be 2 m; and
- Area required for infiltration structures will be in the range of 327–490 sq. m.

Hence the percentage required to be dedicated for the infiltration structure is in the range of 1.5–3 per cent of the total area of the park to cater the peak rainfall over 15 minutes.

Potential infiltration systems that can be proposed:
- Swale along the footpath or desired path; and
- Bio-retention areas surrounded by vegetation at nodes.

Neighbourhood Park, Sector 7
Coordinates: 22°15’5.83”N, 84°50’49.37”E; | Area: 3,170 sq. m. (approx.)

Figure 17: Neighbourhood park, Sector 7, Rourkela

Source: Google Earth

- Potential runoff generated: 1,115 KL annually with annual rainfall of 1,448 mm;
- Assuming peak rainfall to be in the range of 100–150 mm;
- Depth of structure to be 2 m; and
- Area required for infiltration structures will be in the range of 40–59 sq. m.

Hence the percentage required to be dedicated for the infiltration structure is in the range of 1.5–3 per cent of the total area of the park to cater to peak rainfall over 15 minutes.

Potential infiltration systems that can be proposed:
- A small rain-garden can be proposed with provision of overflow; and
- Trench with filter strips and swales can be located along the footpath.

- From these three parks, a total of 61.12 million litres of rainwater can be harvested annually.
- Assuming 15 neighbourhood-level parks implement RWH in Rourkela, additionally 47.55 million litres of rainwater can be harvested.
- Therefore, a total of 108.67 million litres of rainwater can be harvested in Rourkela annually.

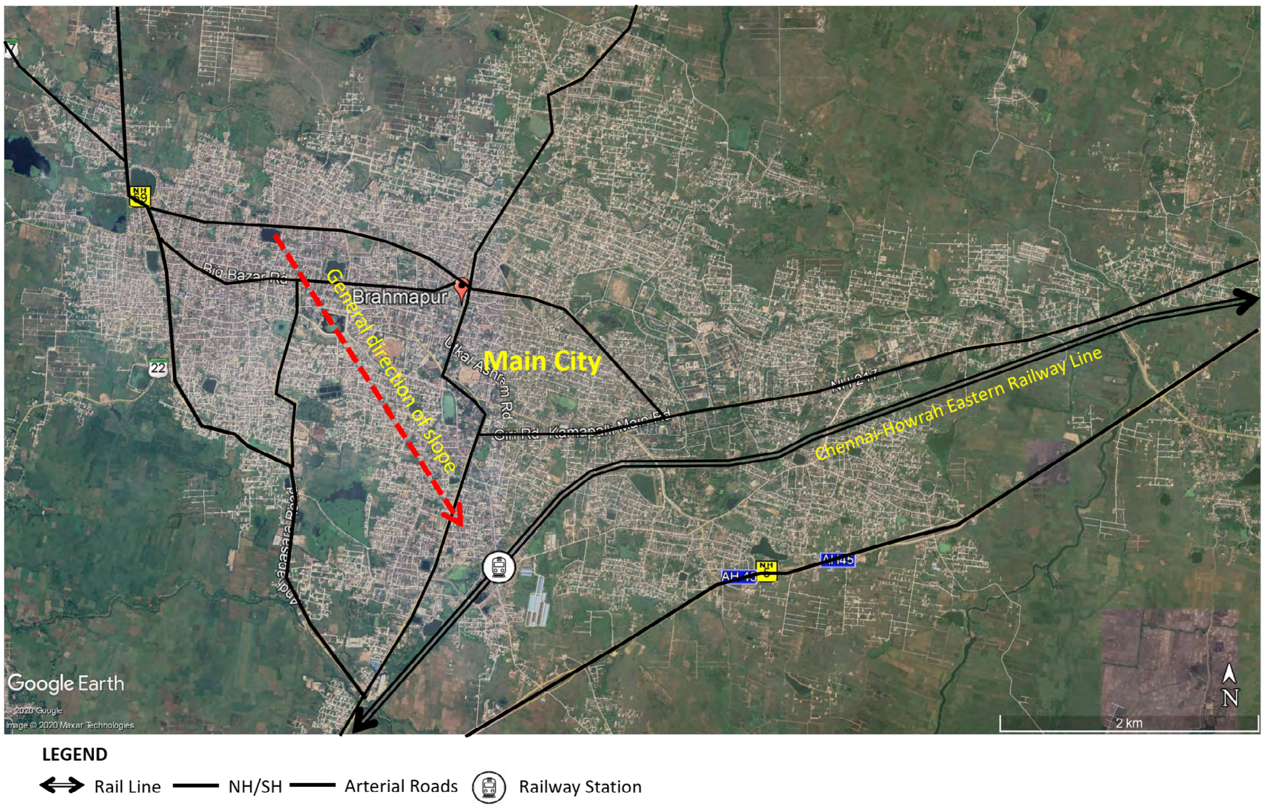
5. Berhampur

5.1 City profile

The city of Berhampur is the fourth largest city of Odisha. It has a population of 3.85 lakh (as per Census of India, 2011) and the municipal area of the city (under Berhampur Municipal Corp.) is spread across 79.8 sq. km. The larger Berhampur Development Planning Area is spread across 320.61 sq. km. It includes Gopalpur and Chatrapur Notified Area Councils and 139 villages (in addition to Berhampur Municipal Corp.) and has a population of 6.07 lakhs.

The main city is surrounded by vast cultivable plains, with the main Howrah–Chennai Railway Line and NH-16 bounding the city in the south. However, development is being observed south of the railway line and the highway. It is located at an altitude of 26 m AMSL, about 15 km from the Bay of Bengal. The city mildly slopes from the north-west to south-east direction towards the Bay of Bengal (see *Figure 18: Locational setting of Berhampur*).

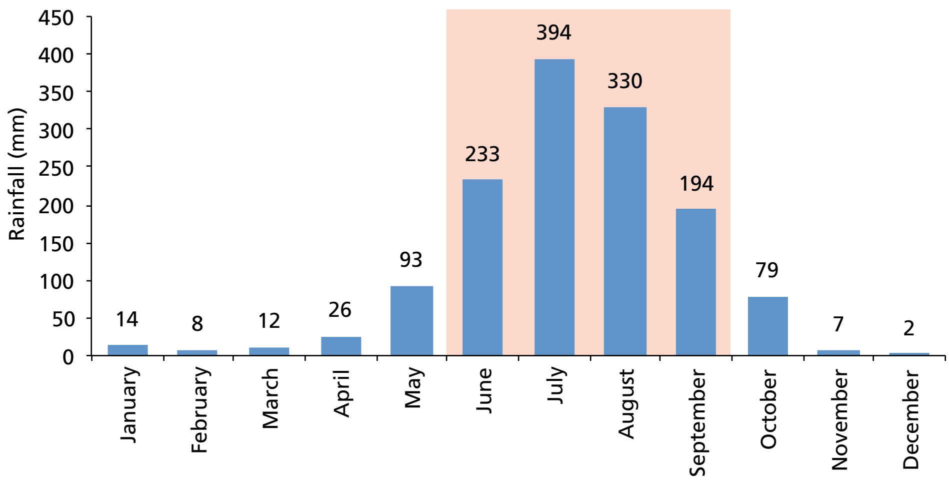
Figure 18: Locational setting of Berhampur



Source: Google Earth

The city has a typical coastal climate with high humidity and pleasant temperatures due to proximity to the Bay of Bengal. The maximum temperature is 40°C in May and minimum temperature of 22°C in December. The city receives an average annual rainfall of 1,392 mm, with over 80 per cent of total rainfall occurring in the monsoon season from June to September (see *Figure 19: Rainfall pattern of Berhampur*).

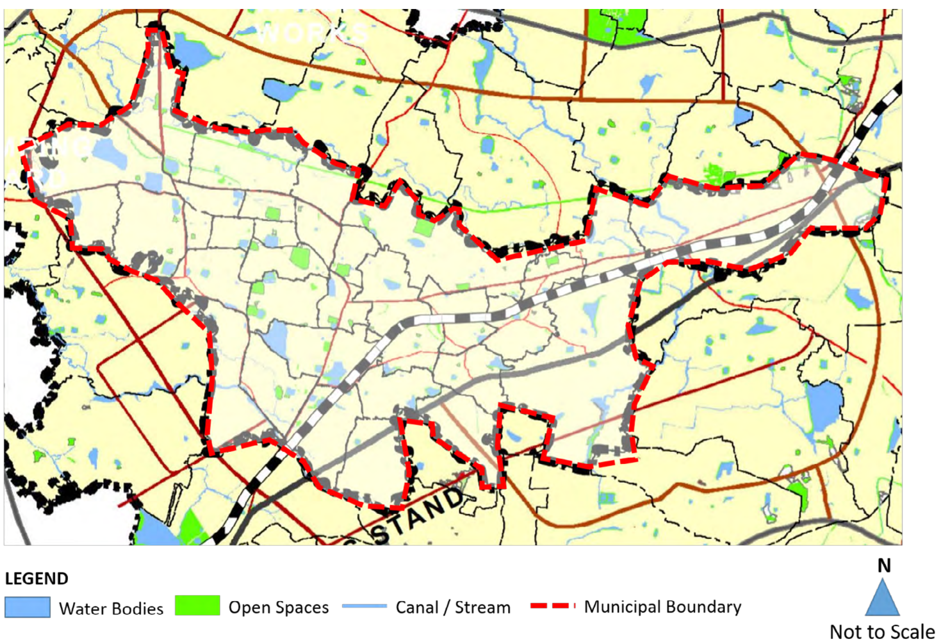
Figure 19: Rainfall pattern of Berhampur



Source: CSE (compiled from information retrieved from IMD, Government of India)

The city has various small and big ponds and lakes (see *Figure 20: Waterbodies and open spaces in Berhampur*), and two natural drains, flowing towards the Bay of Bengal. As per the *Ground Water Year Book of Odisha*, the average depth of the groundwater table in the city is in the range of 5–10 m (pre-monsoon) to 2–5 m post-monsoon.

Figure 20: Waterbodies and open spaces in Berhampur



Source: CDP for Berhampur, 2030

5.2 Urban planning in Berhampur

Berhampur is an important trading town in Odisha and has a strong connectivity via road and rail network. The nature of socioeconomic activities has shaped the development of the town. The town has grown organically with various informal settlements. It lacks planned recreational and open spaces; however, there are city-level parks (see *Figure 21: Waterbodies and open spaces in Berhampur*) and recreation spaces around the waterbodies.

Some of the areas in the city are planned townships developed by the Berhampur Development Authority (BeDA). The Comprehensive Development Plan for Berhampur, 2030 is prepared by the BeDA for the development planning area of the city.[10]

5.3 RWH in selected public parks

Nehru Park

Coordinates: 19°18’8.02”N, 84°47’45.36”E; | Area: 3,200 sq. m. (approx.)

Figure 21: Nehru Park, Berhampur

Source: Google Earth

- Potential runoff generated: 891 KL annually with annual rainfall of 1,392 mm;
- Assuming peak rainfall to be within the range of 100–150 mm;
- Depth of structure to be 2 m; and
- Area required for infiltration structures will be in the range of 40–60 sq. m.

Hence the percentage required to be dedicated for the infiltration structure is in the range of 1.5–3 per cent of the total area of the park to cater to peak rainfall over 15 minutes.

Potential infiltration systems which can be proposed:
- Swale along the footpath or desired path; and
- Bio-retention areas surrounded by vegetation at nodes.

- Assuming 15 neighbourhood-level parks implement RWH in Berhampur, a total of 13.36 million litres of rainwater can be harvested in Bhubaneswar annually.

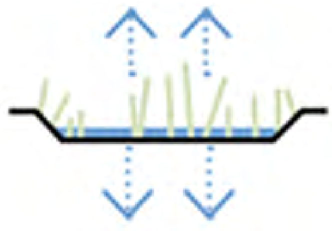
6. Options and techniques for RWH in parks

Public open spaces including playground and parks proposed for rainwater/storm-water harvesting practices are characterized by pervious land cover which are opportunity areas for increased infiltration and conveyance of surface water runoff.

This section provides the options and techniques available for implementing storm-water harvesting into the existing landscape, creating multiple use spaces in playground and parks. These techniques can be applied with an objective to augment the groundwater resources and to manage the increased volumes of storm-water runoff in cities of Odisha.

The functionality and applicability of these structures is based on existing site conditions which can be gathered from preliminary data (see *Annexure: Template for Data Requirement for Preliminary Action Plan*). Depending on characteristics of the site, the structures can be customized to gain maximum efficiency. These can be designed as a series of modules as per identified locations in the park. Moreover, the performance of these structures also depend on the regular operation and maintenance (O&M) practices along with active community participation.

6.1 Infiltration basins



Purpose: Filtration and infiltration of storm-water runoff

Location in the park: Infiltration basins require a large accessible area which is relatively flat and highly pervious.

Dimensions: The size, form and aesthetic appearance of the facility will depend on specific site characteristics.

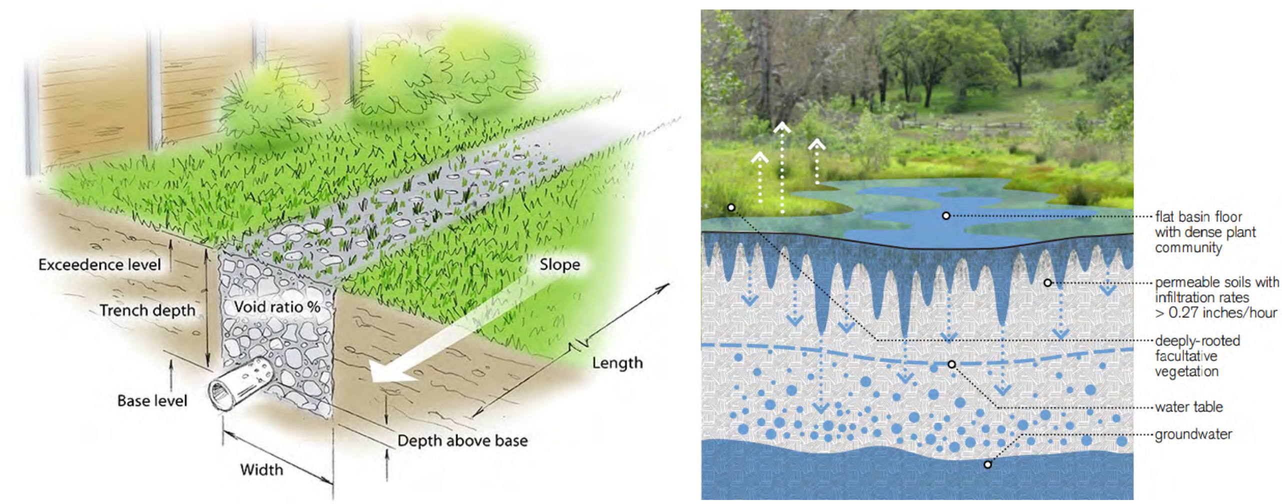
Maintenance required: Semi-annual removal of trash and sediment, and mowing;

- Regular inspections for signs of deterioration in performance, clogging and other blockages;[11]
- Removal of litter and cleaning of inlet and outlet; and
- Vegetation management.

Description: The basins collect surface water runoff from small areas and are usually off-line to prevent siltation (see *Figure: Infiltration basin plan*).[12]

Infiltration basins in playground and parks

Conceptual illustrations of infiltration basin

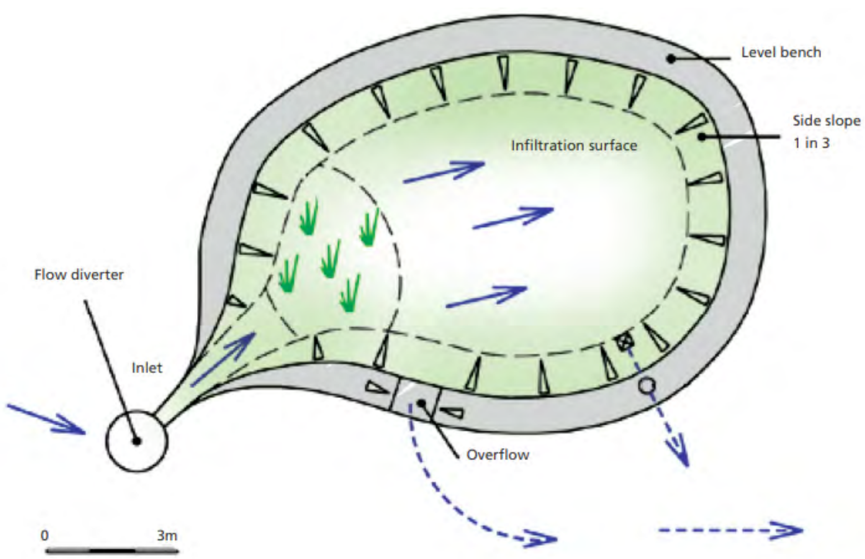


Source: https://help.innovyze.com/display/XDH2016v1/Infiltration+Trench

Key design criteria:

- Effective pre-treatment required to remove sediments and fine silts prior to infiltration;
- Designed to infiltrate the water quality treatment volume as a minimum; and
- Infiltration should not be used where groundwater is vulnerable or to drain pollution hotspots.[13]

Schematic plan of infiltration basin



Source: CSE, Practitioner's Guide for WSUDP, 2016

Thumb rule:

- The bottom of the basin should be graded as flat as possible to provide uniform ponding and infiltration of the runoff across the surface.
- The side slopes of the basin should be no steeper than 1 in 4 to allow for vegetative stabilization, mowing and access as well as for public safety.

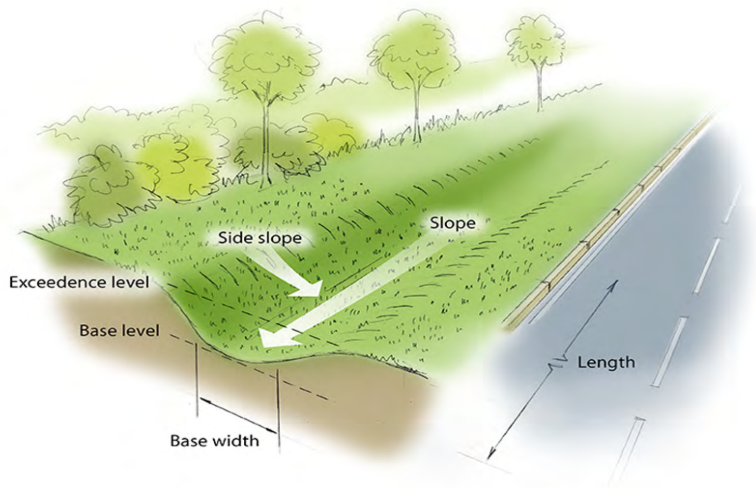
6.2 Swales

Objectives and purpose:
Conveyance, allowing infiltration at the same time

Dimension (thumb rule):
2–8 feet wide with 2–4 inches optimal water depth.

Maintenance required:
Occasional removal of trash and pruning of vegetation

Description:
Swales are linear vegetated channels with a flat base that encourage sheet flow of water through grass or other robust vegetation. They collect, convey and sometimes store surface water runoff, allowing water to soak into the ground where soil conditions are suitable (see *Figure: Conceptual illustrations of a swale*).[14]



Conceptual illustrations of swale

Key design criteria:

- Limit velocities during extreme events to 1–2 m/s, depending on soil type, to prevent erosion;
- Maintain flow height of water during frequent events below the top of the vegetation (typically 100 mm);
- Maximum side slopes of 1 in 3 (where soil conditions allow); and
- Minimum base width normally 0.5 m.[15]

Soil requirements: The swale should not be constructed in gravelly and coarse sandy soils (which cannot support vegetation).

Thumb rule 1: Soil infiltration rate greater than 0.2 mm/s (avoid compaction of the soil)

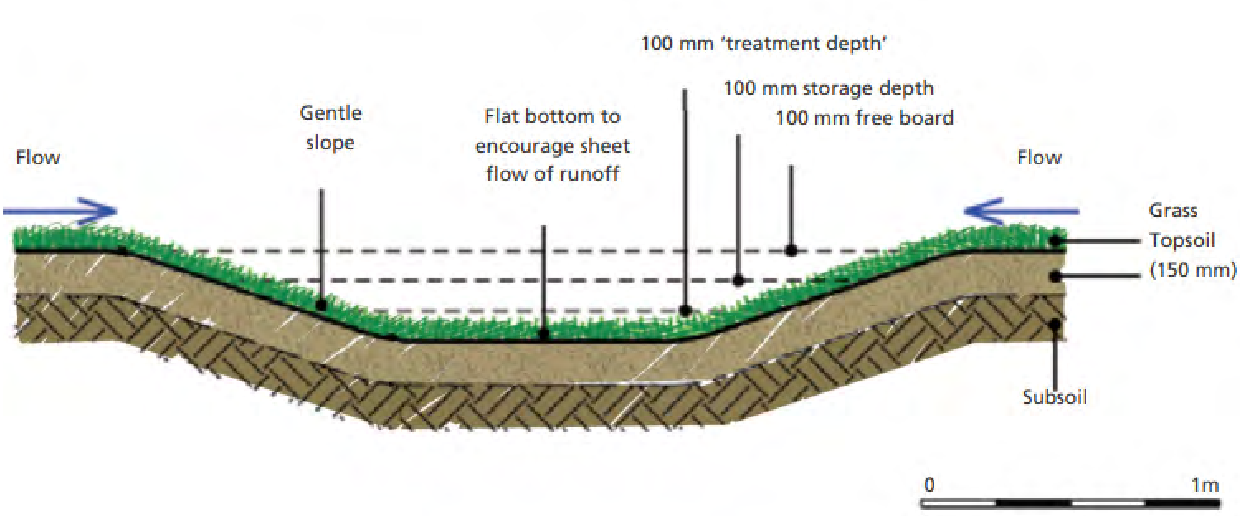
Vegetation: Fine, close-growing, water-resistant grass (more the surface area of the vegetation exposed to runoff more the effectiveness of the system), e.g. reed canary grass, grass–legume mixtures and red fescue.

Geometry: Shape—trapezoidal cross-section

Side slope: 1:3 (recommended to maximize the wetted channel perimeter of the swale)

Longitudinal slope: Should be greater than 2 per cent if drain tile is incorporated and slope greater than 4 per cent can be used if check dams are placed in the channel to reduce flow velocity.

Schematic cross-section of swale



Source: CSE Practitioner's Guide for WSUDP, 2016

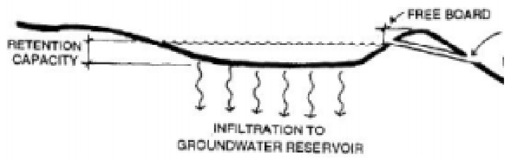
Thumb rule:

- The total surface area of the swale should be 1 per cent of the area that drains to the swale.
- The effectiveness of the swale to treat runoff, depth of the storm water should not exceed the height of the grass.

6.3 Detention basin

Purpose:

Detention of flood runoff for heavy/high peak intensity rainfall for large catchments.



Dimension (thumb rule):

Cater to watershed/catchment runoff area of 10 acres and greater with maximum depth of water to be 3 m.

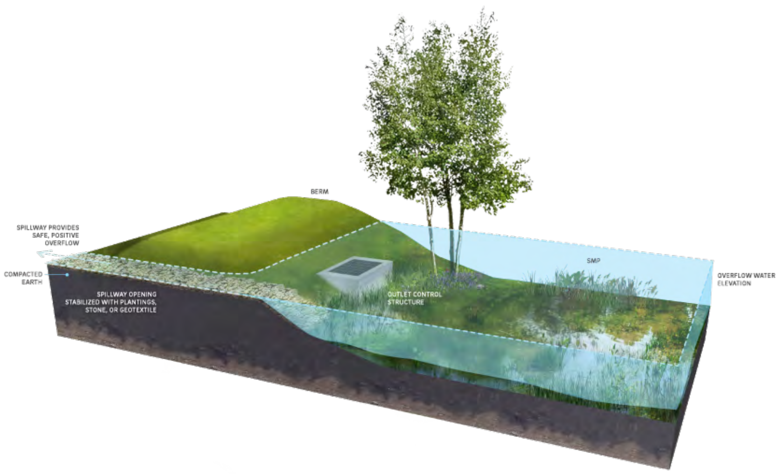
Maintenance required:

- Regular trash and intermittent sediment removal;
- Pollutants accumulate in soils and may require amendments and clean out.

Description:

Detention basins are vegetated depressions in the ground, designed to store surface water runoff and either allow it to soak into the ground or flow out at a controlled rate. Within development, these basins are usually small-grassed areas, sometimes with a micro-pool or planted areas at a low point where some standing water can accumulate (see *Figure: Detention basin plan*). It can also be used as playgrounds and recreational areas.

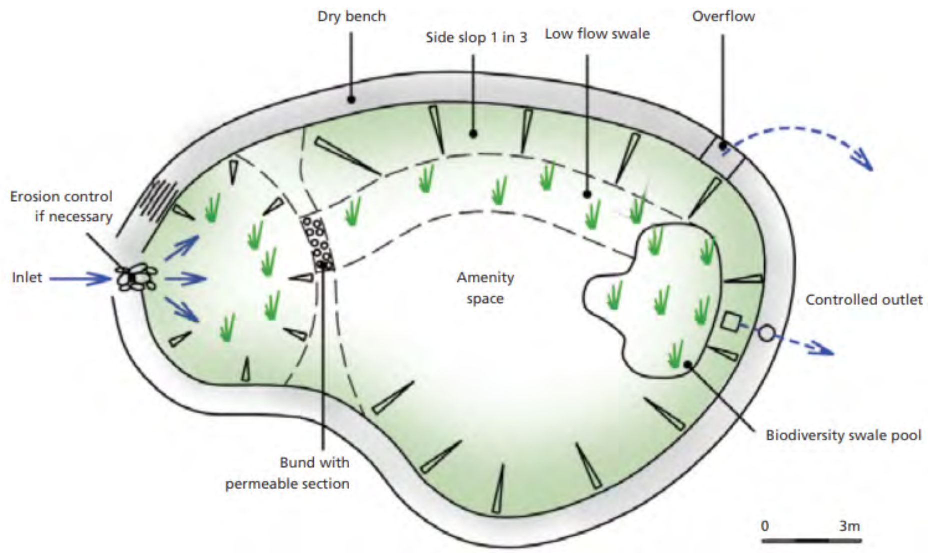
Conceptual illustration of detention basin



Key design criteria:

- Detention volume to manage design storms via constrained outflow;
- Minimum length-to-width ratio of 2:1;
- Maximum side slopes of 1:4 for maintenance and safety reasons, unless the situation allows steeper slopes to be used; and
- Bio-retention and/or wetland/micro-pools at outlets are desirable for enhanced pollution-control.[16]

Schematic plan of detention basin

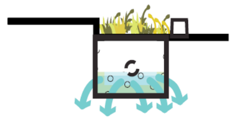


Source: CSE. Practitioner's Guide for WSUDP, 2016

Thumb rule:

- Length-to-width ratio: 2:1
- Side slopes: 1:4 (shallow and gentle slope)
- Maximum water depth: 3 m

6.4 Bio-retention areas



Purpose:
Intermittent retention and infiltration of storm-water runoff

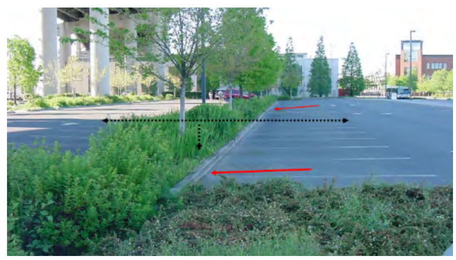
Location in the park:
Usually constructed at the lowest point of the site.

Dimension (thumb rule):
Bio-retention areas require 5–10 per cent of the overall site area. Watershed runoff areas no smaller than 10 acres depending on regional precipitation.

Maintenance required:
- Inspected semi-annually to confirm that drainage is functioning properly and to remove sediment, accumulated trash and debris.[17]
- Vegetation management soil spiking and scarifying.

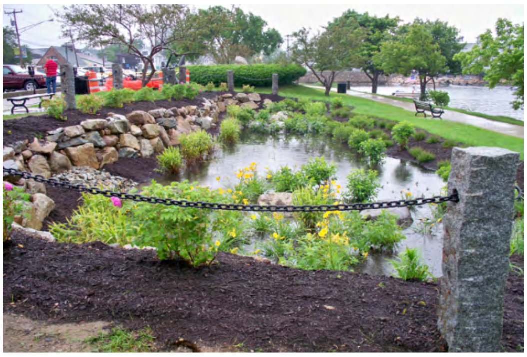
Description:
Bio-retention areas and rain gardens are planted areas that are designed to provide a drainage function as well as contribute to the soft landscape (see *Figure: Bio-retention area plan*).[18]

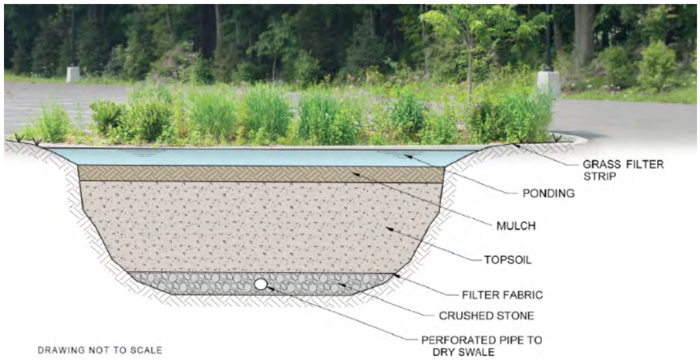
Conceptual illustration of bio-retention area



Source: https://help.innovyze.com/display/XDH2016v1/Bioretention

Cross-section of bio-retention area

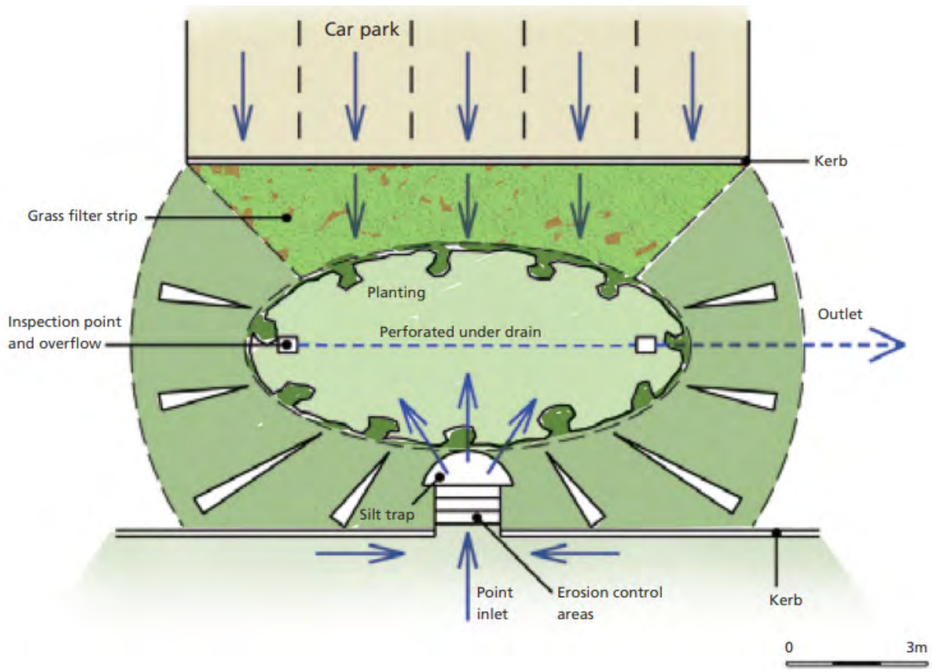




Key design criteria:

- Sufficient area to temporarily store the water quality treatment volume (Vt) at a depth less than 0.15 m on the surface;
- The water-quality treatment event should half drain within 24 hours to provide adequate capacity for multi-event scenarios;
- Minimum depth to groundwater of 1 m, if unlined; and
- Overflow/bypass facilities for extreme events.[19]

Schematic plan of bio-retention area

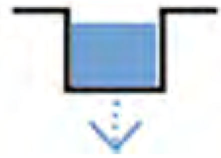


Source: CSE. Practitioner's Guide for WSUDP, 2016

Thumb rule:

The bio-retention surface area will be approximately 5–7 per cent of the contributing drainage area.

6.5 Infiltration trenches



Purpose:
Infiltration and attenuation of storm-water runoff

Dimension (thumb rule):
From a small strip to a sand field with a maximum catchment area of two acres. Trench depths should generally be 1–2 m.

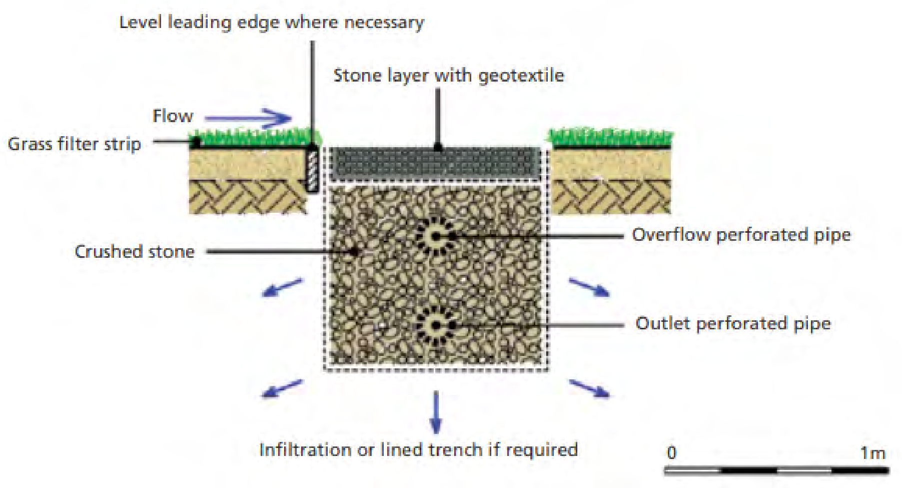
Maintenance required:
Annual removal of trash and raking to maintain permeability

Description:
Filter drains and trenches are linear excavations filled with stone that ideally collect surface water runoff laterally as sheet flow from impermeable surfaces. They filter surface water runoff as it passes through the stone allowing water to infiltrate into soil or flow (see Diagram 9: Cross section of filter drains and trenches).[20]

Conceptual model of infiltration basin

Key design criteria:
- Excavated trench 1–2 m depth filled with stone aggregate;
- Effective upstream pre-treatment to remove sediment and fine silts;
- Infiltration should not be used where groundwater is vulnerable or to drain pollution hotspots; and
- Observation wells and/or access points for maintenance of perforated pipe components.[21]

Schematic cross-section of filter drains and trenches



Source: CSE. Practitioner's Guide for WSUDP, 2016

Thumb rule:

The slowest observed infiltration rate should be used in the design calculations.

6.6 Filter strips

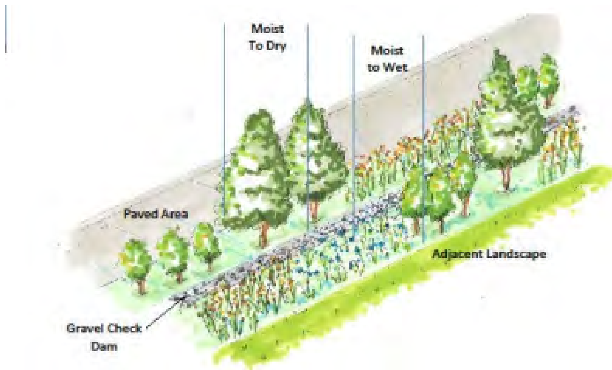
Purpose:
Filtration and infiltration of sheet flow runoff

Dimension (thumb rule):
From a small slope at street side to the size of a large field

Maintenance r equired:
Trash and sediment removal, and mowing

Description:
Filter strips are grass or other densely vegetated strips of land that collect surface water runoff as sheet flow from impermeable surfaces (see *Figure: Cross section of filter strip*).[22]

Conceptual illustration of a filter strip

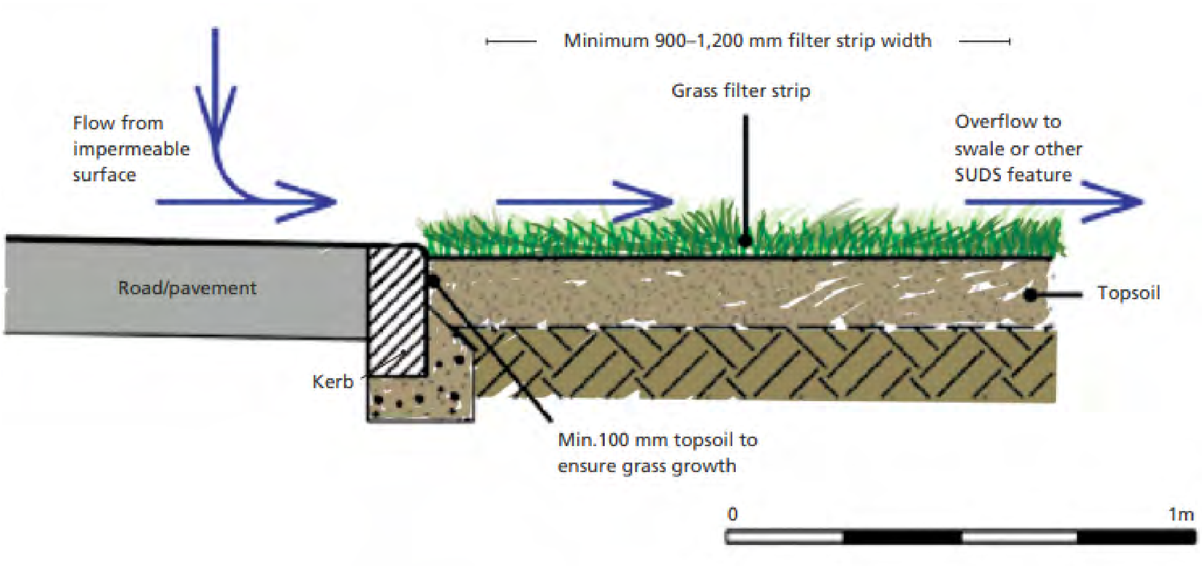


Source: BACA Architects, Luo, H. M., CHE, W., LI, J. Q., WANG, H. L., MENG, G. H., & HE, J. P. (2008). Application of rainwater garden to storm and flood control and utilization. China Water and Wastewater, 24(6), 48.

Key design criteria:

- Recommended minimum width of 6 m
- Runoff from an adjacent impervious area must be evenly distributed across the filter strip with a water depth less than 50 mm for the water quality treatment event
- Slopes not exceeding 1 in 20, minimum 1 in 50.[23]

Schematic cross-section of filter strip

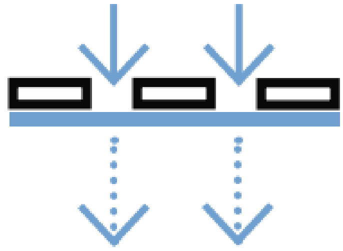


Source: CSE, *Practitioner's Guide for WSUDP*, 2016

Thumb rule:

- Filter strips should be designed with a minimum longitudinal slope (i.e. slope along the direction of flow) of 1 in 50 (to prevent ponding) and a maximum slope of 1 in 20 to prevent flow channelling.
- The top and bottom of the slope should be at the lower end of the allowable slope range to reduce flow velocities and thereby reduce the risk of erosion. The maximum berm height should be 0.3 m.
- The filter strip should extend the entire length of the area that is being drained.

6.7 Pervious pavement



Purpose:
Infiltration of sheet flow storm-water runoff

Dimension (thumb rule):
From a parking stall to a parking lot or street

Maintenance required:
- Sweeping and regular brushing;
- Vacuum-based sediment removal from paving; and
- Turf paver systems may need to be mowed and irrigated to maintain vegetation.[24]

Description:
Porous pavement can be used for streets, parking lots, sidewalks and other impervious surfaces for maintaining infiltration. It comprises porous asphalt, concrete, lattice pavers, concrete blocks or stones. The surface material is laid on a gravel sub-grade and surface voids are filled with sand or a sandy loam turf (see *Figure: Cross-section of porous pavement*). Storm water flows as well as percolates through the pavement into the underlying soil.[25]

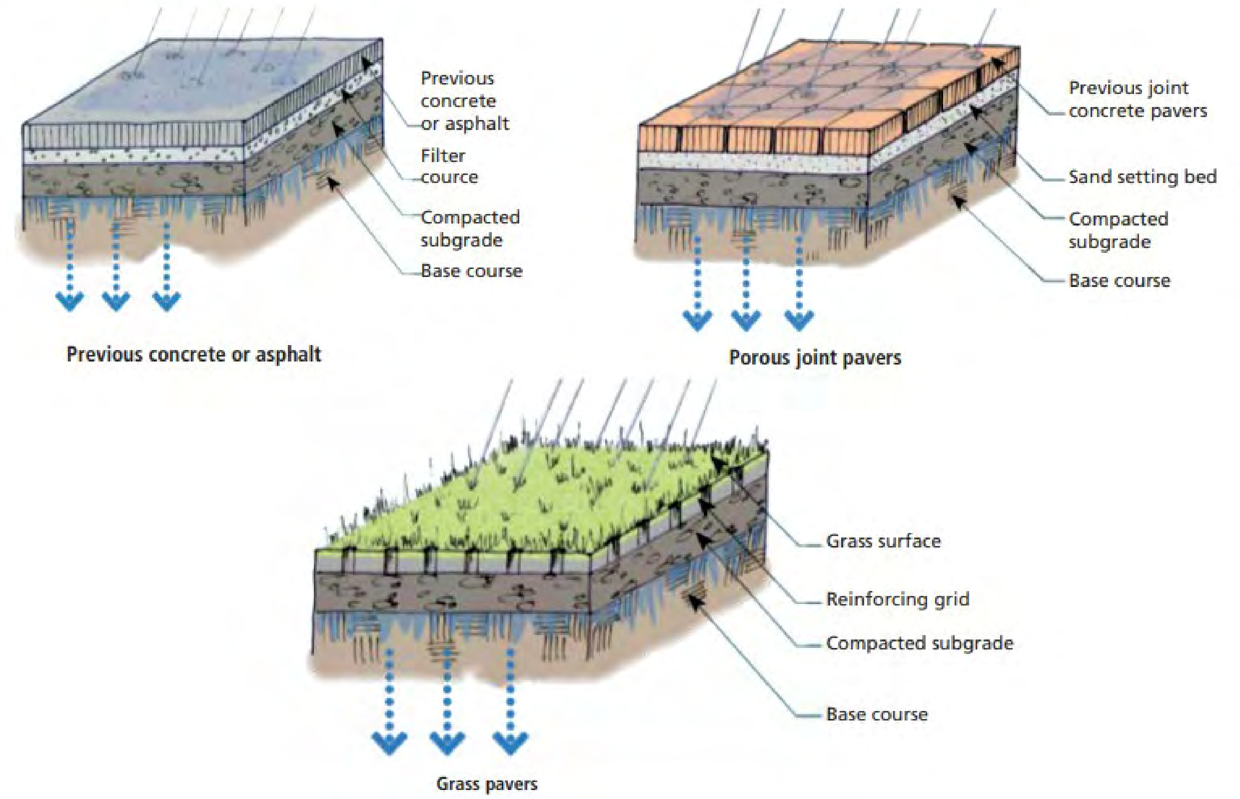
The following types of porous pavements can be adopted:
- Porous asphalt: A very small proportion of fine aggregates. Interconnected void space provides the permeability characteristics; can withstand repeated traffic
- Pervious concrete: Concrete with permeable spaces
- Single-size aggregate: Aggregates used without any binder, least expensive, high utility in areas with low-traffic conditions, such as parking stalls
- Porous turf: Used in parkings; counteracts heat is land with water transpiration

Permeable pavements

Key design criteria:

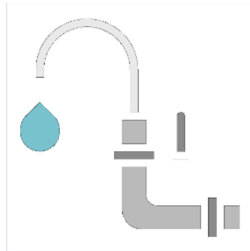
- Pervious surface and sub-base to be structurally designed for site purpose and design vehicular loading;
- Surface infiltration rate should normally be an order of magnitude greater than the design rainfall intensity;
- Temporary subsurface storage volume to meet requirements for infiltration and/or controlled discharge; and
- Geotextile may be specified as a filtration treatment component near the top of the structure.
- Soil and other material must be prevented from contaminating the pavement surface and sub-structure.[26]

Schematic cross-section of porous pavement



Source: UTTIPEC, Delhi Development Authority, Storm water management and retrofitting our urban streets for sustainable drainage, 2012, Oasis Designs Inc.

6.8 Soakaways or recharge shafts



Purpose

Infiltration and adsorption

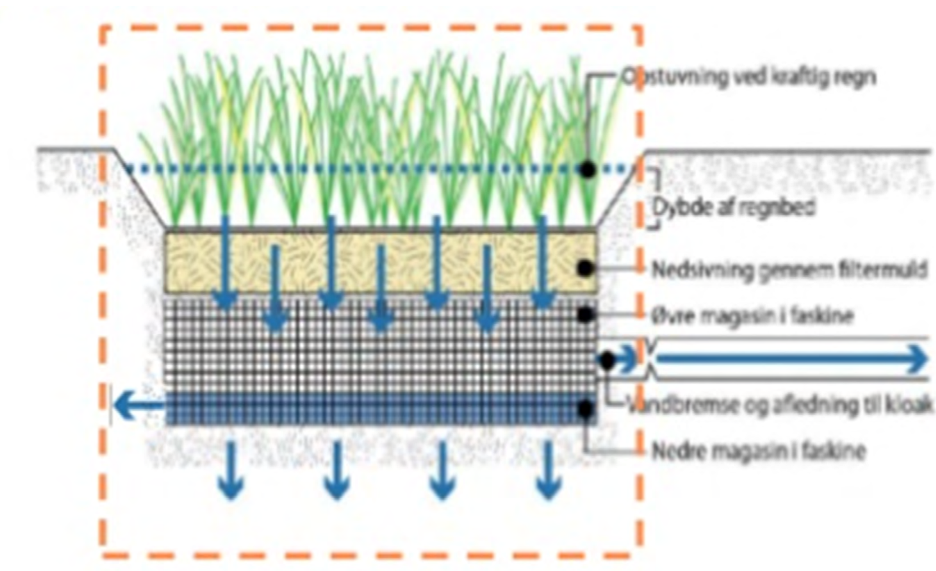
Maintenance required:

- Removal of sediments/debris from pre-treatment device; and
- Monitoring performance (using observation well).

Description:

Soakaways are square or circular excavations, either filled with rubble or lined with brickwork, pre-cast concrete or polyethylene rings/perforated storage structures surrounded by granular backfill. They can be grouped and linked together to drain large areas including highways. The supporting structure and backfill can be substituted by modular, geo-cellular units. Soakaways provide storm-water attenuation, storm-water treatment and groundwater recharge. [28]

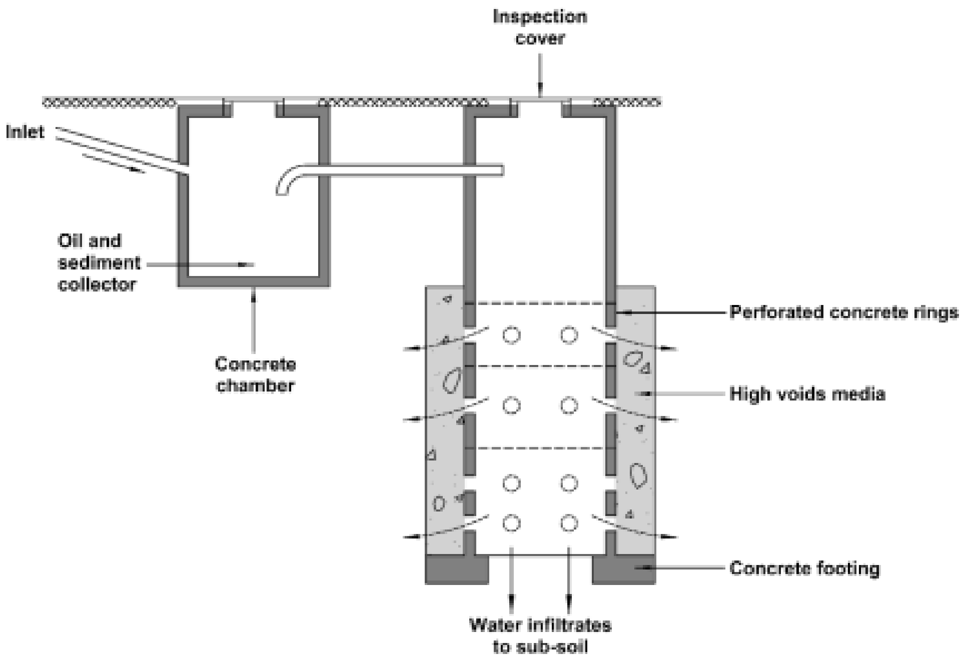
Conceptual illustration of soakaways



Key design criteria:

- Design to meet site drainage standards, generally 1 in 10 or 1 in 30 year design event;
- Site infiltration rate assumed for design should be based on appropriate site investigations and should include an appropriate factor of safety;
- Appropriate pre-treatment is required;
- If used, fill material should provide greater than 30 per cent void space;
- Minimum distance of 1 m from the base to the seasonally high groundwater table;
- Minimum distance of 5 m from foundations; and
- With adequate void support, soakaways can be designed to suit any available geometry. Deep soakaways (i.e. greater than 4 m) will require approval by the environmental regulator.[29]

Schematic cross-section of soakaway (including a pre-treatment device)



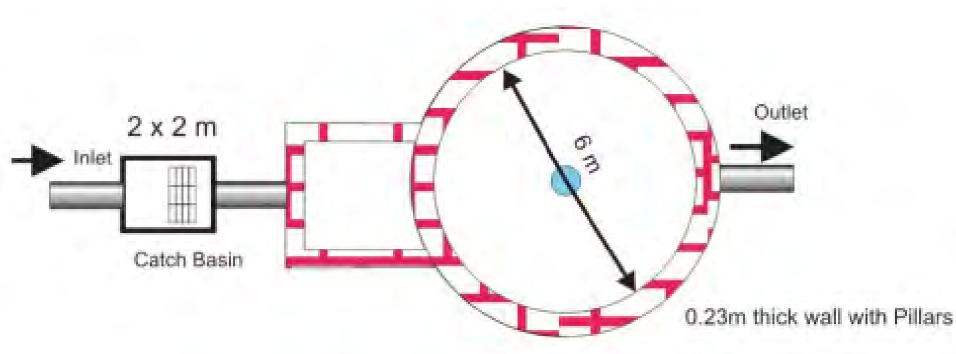
Source: Woods-Ballard, B., Kellagher, R., Martin, P., Jefferies, C., Bray, R., & Shaffer, P. (2007). The SUDS manual (Vol. 697). London: Ciria.

6.9 Recharge pits and shafts with recharge wells

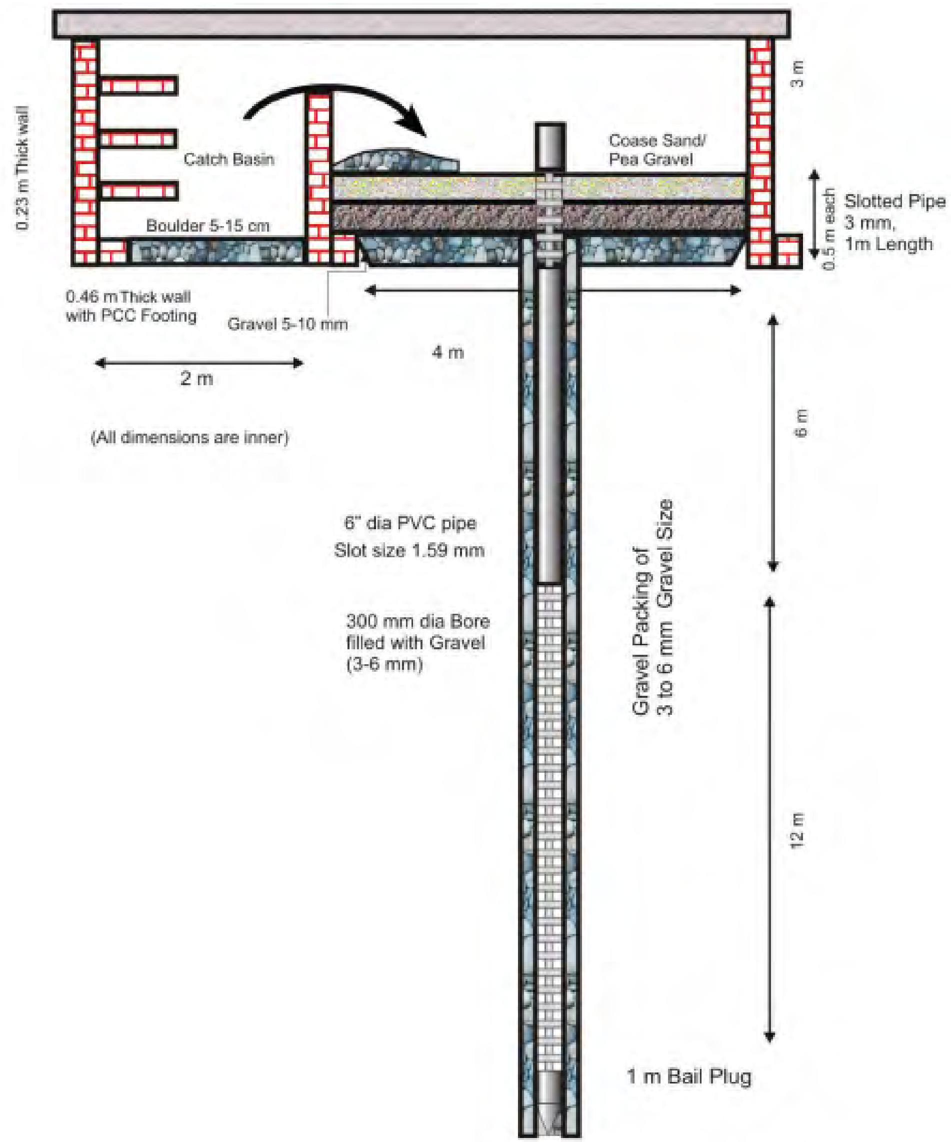
Purpose:
Groundwater recharge

Dimension (thumb rule):
Recharge shaft may be dug manually if the strata is of non-caving nature. The diameter of shaft is normally more than 2 m. Recharge pits may be of any shape and size. They are generally constructed 1–2 m wide and 2–3 m deep.[30]

Description:
Recharge shaft is an artificial recharge structure that penetrates the overlying impervious horizon and provides effective access to surface water to recharge the aquifer. These structures are ideally suited to areas with deep water levels. In areas where a low permeable sandy horizon is within shallow depths, a trench can be excavated to a depth of 3 m and back-filled with boulder and gravel. The trench can be provided with an injection well to effectively recharge deeper aquifers (see *Figure: Recharge shaft with bore well*). The diameter of shaft should normally be over 2 m to accommodate enough water. In the areas where rainwater has silt, the shaft should be filled with boulders, gravel and sand from the bottom to have an inverted filter.



Schematic plan and cross-section of recharge shaft with bore well



Source: Functional plan for ground water recharge in NCR, 2015

7. Way forward

Odisha receives more than 1,400 mm average rainfall every year; with monsoons as an asset the Government of Odisha has realised the need to include public open spaces within urban fabric in the form of storm management infrastructure. This would eventually help in transforming cities of Odisha into water-sensitive cities. Parks provide ideal opportunities for rainwater harvesting as they are often highly visible, multifunctional public spaces. Parks are a common land use feature in cities of Odisha and can be used to their maximum capacity to recharge groundwater.

It is seen in the report that rainfall can be considered as an important and manageable resource by contributing only 2–3 per cent of open public open space for RWH infrastructure. This report gives an overarching framework of potential RWH systems that can be implemented in the open areas, depending on the physical and land use features.

Implementation of RWH systems in cities of Odisha can contribute significantly to addressing the water demand supply gap, dealing with water logging/flooding and recharging depleting aquifers/groundwater.

This would be the great step by government agencies of Odisha to make deliberate efforts to make water everybody's business and work prudently towards implementation of RWH in the area.

8. Annexure: Template for data requirement for Preliminary Action Plan (PAP)

City level information

General Information	
City	
Population (with year)	
Municipal area	
No. of wards	
City-level task force (yes/no)	Attach list of CLTF members as Annexure
Name of organization preparing PAP	
Rainfall data	
Average annual rainfall (mm/year)	
Peak hour intensity rainfall (mm/hr)	
Monsoon months	
Average number of rain days	
Groundwater (GW) data	
GW table/fluctuation map	
GW quality map	
Total no. of GW monitoring structures	
Geological profile	

Information on GW monitoring structures

S. no.	**Type**	**Coordinates**	**Pre-Monsoon**	**Date**	**Post-Monsoon**	**Date**
1	Dug well					
2	Borewell					
3	Piezometer					

Information on public parks

Data on Parks and Open Spaces	
Total number of parks	
No. of neighbourhood-level parks	
No. of city-level parks	
No. of parks with installed RWH	
No. of parks with functional RWH	

Information on parks

(For parks selected for implementation of RWH under PAP)

S. no.	Area (sq. m)	Lat./ long.	Nature of use	Soil type	Existing RWH Structures (Y/N)		Horticulture		Borewell/ dug well	Depth (m b.g.l.)	
					Type(s)	Operational (Y/N)	Demand (KL)	Source		Pre-	Post-
1											
2											
3											
4											

For each park, provide layout plan / schematic drawing providing the following information:

- Park dimensions and geometry
- Location and dimensions of walkways, park furniture, etc.
- Contour levels and/or gradient with direction
- Landscape profile: Nature of green, location of trees, type of species
- Existing stormwater drains in and around the park
- Utilities commissioned inside the park: Electrical, telecommunication, solid waste, water supply, wastewater, sanitation (mention source of water)
- Waterbodies in the park (if any): Source of water, depth and size, use of water
- Location of existing RWH structures (if any) and Borewell/Dug-wells (in any)
- Surrounding land use: roads, residential area, etc.

9. Bibliography

1. Government of Odisha (2 June 2020) *Advisory on Water Sensitive Urban Design and Planning (WSUDP)—Phase-I*. Dept. of Housing and Urban Development. Odisha

2. Census of India (2011) *Primary Census Abstract for Odisha*. Registrar General and Census Commissioner for India. New Delhi

3. Pulak Guhathakurta, D.K. (2020). Observed Rainfall Variability and Changes Over. India Meteorological Department, Ministry of Earth Sciences, Government of India. Retrieved from http://imdpune.gov.in/hydrology/rainfall%20variability%20page/odisha_final.pdf

4. Laskar, S.I. (2016). India meteorological department. Proceedings of the Indian National Science Academy, 82(3), 1021–37.

5. Central Ground Water Board (2017). *Groundwater Year Book for Odisha 2016–17*. Central Ground Water Board. Faridabad, Haryana

6. Bhubaneswar Development Authority. (2010). *Comprehensive Development Plan for Bhubaneswar-2031*. Planning Department, Bhubaneswar Development Authority. Bhubaneswar, Odisha.

7. Census of India (2011). *Primary Census Abstract for Odisha*. Registrar General and Census Commissioner for India. New Delhi

8. Ibid.

9. Rourkela Development Authority. (n.d.). *Comprehensive Development Plan for Rourkela-2031*. Planning Department, Rourkela Development Authority. Rourkela, Odisha.

10. Berhampur Development Authority. (2015). *Comprehensive Development Plan for Berhampur-2031*. Planning Department, Berhampur Development Authority. Berhampur, Odisha.

11. Huber, J. (2010). *Low Impact Development: A Design Manual for Urban Areas.* Arkansas: Fayetteville.

12. Suresh Kumar Rohilla, Shivali Jainer and Mahreen Matto, 2017, *Mainstreaming rainwater harvesting in Noida*, Centre for Science and Environment, New Delhi

13. Woods-Ballard, B., Kellagher, R., Martin, P., Jefferies, C., Bray, R., & Shaffer, P. (2007). *The SUDS manual* (Vol. 697). London: Ciria.

14. Suresh Kumar Rohilla, Shivali Jainer and Mahreen Matto, 2017, *Mainstreaming rainwater harvesting in Noida*, Centre for Science and Environment, New Delhi

15. Woods-Ballard, B., Kellagher, R., Martin, P., Jefferies, C., Bray, R., & Shaffer, P. (2007). *The SUDS manual* (Vol. 697). London: Ciria.

16. Ibid.

17. Huber, J. (2010). *Low Impact Development: A Design Manual for Urban Areas*. Arkansas: Fayetteville.

18. Suresh Kumar Rohilla, Shivali Jainer and Mahreen Matto, 2017, *Mainstreaming Rainwater Harvesting in Noida*, Centre for Science and Environment, New Delhi

19. Woods-Ballard, B., Kellagher, R., Martin, P., Jefferies, C., Bray, R., & Shaffer, P. (2007). *The SUDS Manual* (Vol. 697). London: Ciria.

20. Suresh Kumar Rohilla, Shivali Jainer and Mahreen Matto, 2017, *Mainstreaming rainwater harvesting in Noida*, Centre for Science and Environment, New Delhi

21. Woods-Ballard, B., Kellagher, R., Martin, P., Jefferies, C., Bray, R., & Shaffer, P. (2007). *The SUDS manual* (Vol. 697). London: Ciria.

22. Suresh Kumar Rohilla, Shivali Jainer and Mahreen Matto, 2017, *Mainstreaming rainwater harvesting in Noida*, Centre for Science and Environment, New Delhi

23. Woods-Ballard, B., Kellagher, R., Martin, P., Jefferies, C., Bray, R., & Shaffer, P. (2007). *The SUDS manual* (Vol. 697). London: Ciria.

24. Huber, J. (2010). *Low Impact Development: A Design Manual for Urban Areas*. Arkansas: Fayetteville.

25. Suresh Kumar Rohilla, Shivali Jainer and Mahreen Matto, 2017, *Mainstreaming rainwater harvesting in Noida*, Centre for Science and Environment, New Delhi

26. Woods-Ballard, B., Kellagher, R., Martin, P., Jefferies, C., Bray, R., & Shaffer, P. (2007). *The SUDS manual* (Vol. 697). London: Ciria.

27. UTTIPEC, Delhi Development Authority. (2012). *Storm water management and retrofitting our urban streets for sustainable drainage*. Oasis Designs Inc.

28. Suresh Kumar Rohilla, Shivali Jainer and Mahreen Matto (2017). *Mainstreaming rainwater harvesting in Noida*, Centre for Science and Environment, New Delhi

29. Woods-Ballard, B., Kellagher, R., Martin, P., Jefferies, C., Bray, R., & Shaffer, P. (2007). *The SUDS manual* (Vol. 697). London: Ciria.

30. Central Ground Water Board (2015). *Functional Plan for Groundwater Recharge in NCR*. Central Ground Water Board. Faridabad, Haryana

31. Rohilla, S.R., Jainer, S., and Matto, M. (2017). *Green Infrastructure: A Practitioner's Guide*. Centre for Science and Environment.

32. Rohilla, S.R., Matto, M., Jainer, S. and Sharda, C. (2017). *Water-Sensitive Urban Design and Planning: A Practitioner's Guide*. Centre for Science and Environment, New Delhi

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This report showcases the potential of runoff infiltration in rainwater harvesting (RWH) systems in parks and green open spaces in four cities—Bhubaneswar, Cuttack, Rourkela and Berhampur. It also presents city profiles, pilot case studies of selected parks for implementation of RWH strategies, and options and techniques for RWH structures in parks.

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