MANUAL OF PLANTING AND LANDSCAPING OF URBAN ROADS

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GLOSSARY

Applied Water: A portion of water supplied by the irrigation system to the landscape.

Automatic Irrigation Controller: An automatic timing device used to remotely control valves that operate an irrigation system. Automatic irrigation controllers shall schedule irrigation events using either evapotranspiration (ETo)/weather–based, or moisture sensor data.

Avenue: A wide road or pathway lined with trees on either side.

Backfill: Soil that is replaced in a hole or trench after excavation and placement of irrigation lines or plant materials.

Backflow Prevention Device: A safety device used to prevent pollution or contamination of the water supply due to the reverse flow of water from the irrigation system.

Buffer: The use of landscape to curtail view, sound or dust with plants or earth berms, wall, or any such element.

Canopy: The uppermost branches of trees in the forest, forming more or less a continuous layer of foliage.

Clear height: It is measured as the height from the ground to the general level of bottom of branching, which is clear and uninterrupted.

Climber (Creeper/Vine): A non-supporting plant, woody or herbaceous, which clings to a wall, trellis or other structures as it grows upward.

Columnar: A slender, upright plant form.

Compaction: Compression of the soil structure or texture by any means that creates an upper layer that is impermeable. Compaction is injurious to roots and the health of a tree.

Compost: Safe and stable product of controlled biological decomposition of organic material that is beneficial to plant growth.

Critical Root Zone (CRZ): CRZ is the area around the trunk of the tree where most of its roots are present. Typically, the CRZ is represented as a circle with diameter equal to 12 times the diameter of the tree's trunk.

Dangerous/Hazardous tree: A tree that due to structural defect poses an imminent danger to people or vehicles passing by.

Dead Tree: A tree that is dead or that has been damaged beyond repair or is in an advanced state of decline (where an insufficient amount of live tissue, green leaves, limbs or branches, exists to sustain life) and has been determined to be such by a certified botanist.

Deciduous Tree: Tree that sheds all its leaves in the dry season.

Distribution Uniformity: The measure of uniformity of irrigation water over a defined area.

Disturbance: All of the various activities from construction or development that may damage trees.

Drip Irrigation: Low volume, low pressure irrigation systems that generally deliver water directly to the root area of plants; includes drip line, micro–spray emitter, bubbler, and point–to–point systems.

Drought Tolerant Plant: Plants that can survive drought conditions for limited periods of time.

Effective Precipitation: or "Usable rainfall" means the portion of total precipitation which becomes available for plant growth.

Elevation: A contour line or notation of relative altitude, useful in plotting existing or proposed feature.

Emitter: A drip irrigation emission device that delivers water slowly from the system to the soil.

Erosion: The transportation of soil particles, or mass movement of soil (mass wasting), by water, wind, or mechanical means.

Estimated Annual Water Use (EAWU): The estimated water use in litres per year for a landscaped area.

ET Adjustment Factor (ETAF): A factor that when applied to reference ETo, adjusts for plant water requirements and irrigation efficiency, two major influences on the amount of water that is required for a healthy landscape.

Evapotranspiration (ETo): The quantity of water evaporated from adjacent soil and other surfaces and transpired by plants during a specified time period.

Evapotranspiration Rate: The quantity of water evaporated from adjacent soil and other surfaces and transpired by the plants in a given time.

Evergreen Tree: Tree that remains green for most part of the year and sheds leaves slowly throughout the year.

Excessive Pruning: Removing in excess, one-fourth (25 per cent) or greater, of the functioning leaf, stem or root area. Pruning in excess of 25 per cent is injurious to the tree. Excessive pruning typically results in the tree appearing as a 'bonsai', 'lion's-tailed', 'lolly-popped' or overly thinned.

Exotic: A plant that is not native to the area in which it is planted. It may or may not be invasive.

Fencing: A barrier of plant or construction material used to set off the boundary of an area and to restrict visual or physical passage in or out of it.

Finished Grade: Grade accomplished after landscape features are installed and completed as shown on plan as proposed contours.

Flow Rate: The rate at which water flows through pipes, valves and emission devices, measured in litres per minute, or cubic metres per second.

Flow Sensor: An in-line device installed at the supply point of the irrigation system that produces a repeatable signal proportional to flow rate. Flow sensors must be connected to an automatic irrigation controller, or flow monitor capable of receiving flow signals and operating master valves. This combination flow sensor/controller may also function as a landscape water meter or submeter.

Foliage: The collective leaves of a plant or plants.

Formal Landscaping: Formal landscapes consist of landscaping around buildings, intensive and passive outdoor use areas, and high impact and visibility areas. Formal landscapes can consist of irrigated lawns and nonindigenous planting beds around buildings or non-irrigated indigenous plantings.

Friable: A soil condition that is easily crumbled or loosely compacted down to a minimum depth per planting material requirements, whereby the root structure of newly planted material will be allowed to spread unimpeded.

Geo-textile: Any permeable textile (natural or synthetic) used with foundation, soil, rock, earth or any other geotechnical engineering-related material as an integral part of a human made project, structure or system.

Grade: The slope or lay of the land as indicated by a related series of elevations.

Gradient: The degree of slope of a pipe invert or road or land surface. The gradient is a measure of the slope height as related to its base. The slope is expressed in terms of percentage or ratio.

Grading: The cutting and/or filling of earth to establish smooth finish contours. Grading facilitates good drainage and sculpts land to suit the intent of landscape design.

Graywater: Untreated wastewater that has not been contaminated by toilet discharge, has not been affected by infectious, contaminated, or unhealthy bodily wastes, and does not present a threat from unhealthful processing, manufacturing or operating wastes.

Grasses: Plants that characteristically have joint stems, sheaths and narrow blades (leaves).

Greenbelt: An area specifically planted to buffer differing uses; i.e., a landscaped easement along the side of a major road may buffer adjacent uses from traffic noise and fumes.

Groundcover: The planting material that forms a carpet of low height; these low-growing plants are usually installed as the final part of landscape construction.

GRIHA (Green Rating for Integrated Habitat Assessment): A National Rating System that evaluates the environmental performance of a building holistically over its entire life cycle, thereby providing a definitive standard for what constitutes a ‘green building’.

Invasive Species: Any species of plant not historically found in an area that spreads outside cultivated areas and may damage environmental or economic resources.

Hardscape: Civil work component of landscape architecture such as pavement, walkways, roads, retaining walls, sculpture, street amenities, fountains and other built environment.

Hardy Plant: Plants that can withstand harsh temperature variations, pollution, dust, extreme soil conditions, and minimal water requirements and the likes. These plants have ability to remain dormant in such conditions and survive.

Hedge: Number of shrubs or trees (often similar species) planted closely together in a line. A hedge may be pruned to shape or allowed to grow to assume its natural shape.

Herb: An annual plant with a non-woody or fleshy structure. Certain herbs are highly useful for cooking or of high medicinal value.

Hydro zone: A portion of the landscape area having plants with similar water needs. A hydrozone may be irrigated or non–irrigated.

Indigenous: Originating or occurring naturally in a particular place.

Injury: A wound resulting from any activity, including but not limited to 'excessive pruning', cutting, trenching, excavating, altering the grade, paving or compaction within the tree protection zone of a tree. Injury shall include bruising, scarring, tearing or breaking of roots, bark, trunk, branches or foliage, herbicide or poisoning, or any other action foreseeably leading to the death or permanent damage to tree health.

Invert: The low point inside a pipe, culvert, or channel.

Irrigation Audit: An inspection which includes an in-depth evaluation of the performance of an irrigation system conducted by a certified irrigation auditor. An irrigation audit may include, but is not limited to, inspection, system tune up, system test with distribution uniformity or emission uniformity, reporting overspray or runoff that causes overland flow, and preparation of an irrigation schedule.

Irrigation Efficiency: The measurement of the amount of water beneficially used divided by the water applied. Irrigation efficiency is derived from measurements and estimates of irrigation system characteristics and management practices.

Kerb: A concrete or stone edging along a pathway or road often constructed with a channel to guide the flow of storm water and thereby serving dual purpose of soil retention and channelization of storm water.

Landscape Architect: An architect trained in the science of designing of open spaces using hardscape and plant material among others.

Landscape Contractor: Contractor skilled in the planting and construction of landscapes.

Lateral Line: The water delivery pipeline that supplies water to the emitters or sprinklers from the valve.

Low Head Drainage: A sprinkler head or other irrigation device that continues to emit water after the water to the zone in which the device is located has shut off.

Low Volume Irrigation: The application of irrigation water at low pressure through a system of tubing or lateral lines with low volume emitters such as drip lines or bubblers.

Main line: The pressurized pipeline that delivers water from the water source to the valve or outlet.

Median: An area between opposing lanes of traffic that may or may not be planted with trees, shrubs, perennials and ornamental grasses.

Microclimate: The climate of a small, specific area that may contrast with the climate of the overall landscape area due to factors such as wind, sun exposure, plant density or proximity to reflective surfaces.

Mound: A small hill or bank of earth, developed as a characteristic feature in landscape.

Mulch: An organic material such as leaves, bark, straw left loose and applied to the soil surface to reduce evaporation, suppress weeds, moderate soil temperature or prevent soil erosion.

Multi Functional Zones: Multi-Functional Zones (MFZ) are organized strips of space that are to be provided on either side of the carriageway – to consolidate various street components/ amenities in an organized and streamlined manner, which would otherwise be located in a haphazard way within the ROW and often found encroaching on carriageway or footpath space.

Native: A plant indigenous to a particular locale.

Nativized: Plants that have adapted well to a new environment or landscape condition which they originally do not belong to.

Natural Grade: A naturally occurring grade consisting of contours that have not been modified for any purpose.

Natural Landscapes: Native, or "natural", landscapes consist of undisturbed areas that consist of naturally occurring plants, rocks, water, and a host of natural elements in varying compositions.

Operating Pressure: The pressure at which the parts of an irrigation system are designed by the manufacturer to operate.

Open Space: Areas set aside for resource conservation or recreational use. Many of these areas are natural and undisturbed. Many are parks and/or recreational facilities.

Ornamental Plants: Plants that are nursery–cultivated for use in ornamental landscapes.

Overspray: The water from irrigation that is delivered outside an area targeted for the irrigation and makes contact with a surface not intended to be irrigated.

Pervious/Permeable: Any surface or material that allows the passage of water through it and into underlying soil.

Plant Factor: or "Plant water use factor" is a factor when multiplied by ETo, estimates the amount of water needed by plants.

Plant factor for Xeriscape or Very low water use plants: 0-0.1

Plant factor for Low water use plants: 0.1-0.3

Plant factor for Moderate water use plants: 0.4-0.6

Plant factor for High water use plants: 0.7-1.0

Protective Tree Fencing: A temporary enclosure erected around a tree to be protected at the boundary of the tree protection zone. The fence serves three primary functions: 1) to keep the foliage crown, branch structure and trunk clear from direct contact and damage by equipment, materials or disturbances; 2) to preserve roots and soil in an intact and non-compacted state; and 3) to identify the tree protection zone in which no soil disturbance is permitted and activities are restricted.

Recreational Area: Areas, excluding private landscapes or gardens, designated for active play, recreation or public assembly in parks, sports fields, picnic grounds, amphitheatres or greens.

Recycled Water: Waste water that has been treated at the highest level for water not intended for human consumption. "Tertiary treated recycled water" means water that has been through three levels of treatment including filtration and disinfection.

Revegetation: Restoration or re-creation of a self–sufficient and self–regenerating plant community on a disturbed site, with native and naturalized plant species.

Root Buffer: A temporary layer of material to protect the soil texture and roots. The buffer shall consist of a base course of tree chips or mulch spread over the root area to a minimum of 15 cm depth.

Runoff: Water that is not absorbed by the soil or by plants, that is flowing from landscaped areas or the development site.

Screen: A vegetative or constructed hedge or fence used to block wind, undesirable views, noise, glare and the like, as part of landscape design; also known as ‘screen planting’ and ‘buffer plantation’.

Sediment: The product of erosion processes; the solid material, both mineral and organic, that is in suspension, is being transported or has been moved from its site of origin by air, water, gravity or ice.

Shrub: A woody plant of low to medium height, deciduous or evergreen, generally having many stems.

Site Planning Drawings: A set of drawings (e.g. preliminary drawings, site plan, grading, demolition, building, utilities, landscape, irrigation, tree survey, etc.) that show existing site conditions and proposed landscape improvements, including trees to be removed, relocated or to be retained. Site plans shall include the following minimum information that may impact trees:

Surveyed tree location, species, size, dripline area (including trees located on neighbouring property that overhang the project site) and protected trees within 10 m of the project site. Paving, concrete, trenching or grade change located within the tree protection zone.

Existing and proposed utility pathways.

Surface and subsurface drainage and aeration systems to be used.

Walls, tree wells, retaining walls and grade change barriers, both temporary and permanent.

Landscaping, irrigation and lighting within dripline of trees, including all lines, valves, etc.

Location of other landscaping and significant features.

All of the final approved site plan sheets shall reference tree protection instructions.

Slope: A gradient in land.

Sloping Landscape: An expanse of rising or falling land, especially on a hillside.

Soft Landscaping: The natural elements in landscape design, such as plant materials and the soil itself.

Soil Compaction: The compression of soil particles that may result from the movement of heavy machinery and trucks, storage of construction materials, structures, paving, etc. within the tree protection zone. Soil compaction can result in atrophy of roots and potential death of the tree, with symptoms often taking 3 to 10-years to manifest.

Soil Moisture: The amount of water in a given portion of soil at a given time.

Soil Moisture Sensing Device: A device that measures the amount of water in the soil. The device may also suspend or initiate an irrigation event.

Soil Test: Test to determine soil fertility, texture, pH, salinity, and alkalinity; generally includes recommendations for soil amendments.

Spot Elevation: In surveying and contour layout, an existing or proposed elevation noted as a dot/cross on the plan.

Sprinkler Head: Or 'Spray head' is a device that delivers water through a nozzle.

Static Water Pressure: The pipeline or municipal water supply pressure when water is not flowing.

Street/Outdoor Furniture: Items of furnishing in outdoor landscape.

Street Trees: Trees planted along city streets for environmental and aesthetic benefit of the general public.

Structural Defect: Any structural weakness or deformity of a tree or its parts.

Subsurface Irrigation: An irrigation device with a delivery line and water emitters installed below the soil surface that slowly and frequently emit small amounts of water into the soil to irrigate plant roots.

Succulent: Succulent plants, also known as succulents, are plants having some parts that are fleshy and are thickened to store water. Such plants are normally found in arid climates or such soil conditions.

Swale: A linear wide and shallow depression used to temporarily store, route or filter runoff. A swale may be grassed or lined.

Swing Joint: means an irrigation component that provides a flexible, leak-free connection between the emission device and lateral pipeline to allow movement in any direction and to prevent equipment damage.

Topsoil: Soil that is within the upper horizon of a soil profile, containing organic matter, nutrients, and the micro organisms necessary for normal plant growth. The uppermost layer of the soil.

Transitional Area: A portion of a landscaped area that is adjacent to a natural or undisturbed area and is designated to ensure that the natural area remains unaffected by plantings and irrigation installed.

Transplantation: Transplantation is the process of bodily lifting of mature and large plants from their planted position to a new position.

Tree: A woody plant, generally taller than 2.00 m, with a well-distinguished trunk below the leaf crown.

Tree Grate: A metal or concrete grille, installed at the base of a tree otherwise surrounded by pavement that allows the free passage of air, water, and nutrients to the tree root, without allowing the foot traffic to interfere with the soil.

Tree/Plant Guard: The protection constructed around a tree to deter vandalism and help to prevent damage. It could be made of metal, bamboo or concrete or the like.

Trenching: Any excavation to provide irrigation, install foundations, utility lines, services, pipe, drainage or other property improvements below grade. Trenching within the CRZ is injurious to roots and tree health and is prohibited, unless approved.

Turf: A surface cover of mowed grass.

Unbalanced Crown: Excessive pruning also includes removal of the leaf or stem area predominantly on one side, topping, or excessive tree canopy or crown raising. Exceptions are when clearance from overhead utilities or public improvements is required or to abate a hazardous condition or a public nuisance.

Water Conservation: Water management procedures, including design and maintenance procedures, which direct their result to saving water.

Water Conserving Plant Species: A plant species identified as having a very low or low plant factor.

Water Feature: A design element where open water serves an aesthetic or recreational function. A water feature includes a pond, lake, waterfall, fountain, artificial streams. Constructed wetlands used for on–site wastewater treatment or stormwater best management practices are not water features.

Wildlife: Indigenous or naturalized bird, reptilian, mammalian, fish, or invertebrate life found outdoors.

Working Drawings: A set of precise plans and details with written specifications used for the construction of a landscape project.

Xeriscape: Xeriscaping is a technique of landscape design that uses negligible amounts of water for irrigation.

INTRODUCTION

The Guidelines on Landscaping and Tree Plantation, First Revision (IRC:SP:21-2009) published in November, 2009 provides comprehensive guidance on landscaping and roadside arboriculture along highways. As the focus of the current publication appears to be more towards roads of higher categories, IRC prepared and published another document titled Guidelines on Tree Plantation along Rural Roads (IRC:SP:103-2014) on request of National Rural Road Agency (NRRDA), Ministry of Rural Development (MoRD).

Catering the need of Urban Roads, the task to prepare a separate document on "Manual for Planting and Landscaping of Urban Roads" was taken up by the Urban Roads and Streets (H-8) Committee. The H-8 Committee in its meeting held on 20.05.2017 entrusted the work of preparation of initial draft to the sub-group under the chairmanship of Ms. Paromita Roy comprising Ms. Nidhi Madan and Shri Anuj Malhotra. The initial draft was discussed in various meetings and valuable inputs were received from members of H-8 Committee. The H-8 Committee approved the document in its meeting held on 18.08.2017 for placing before the HSS Committee.

The composition of the H-8 Committee is given below:

Pawar, A.B.	……..	Convenor
Parida, Prof. (Dr.) M.	……..	Co-Convenor
Thakar, Vikas	……..	Member-Secretary

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Director General (Road Development) & Special Secretary to Govt. of India	(Kumar, Manoj), Ministry of Road Transport & Highways
Secretary General, Indian Roads Congress	Nirmal, Sanjay Kumar

The Highways Specifications & Standards Committee (HSS) considered and approved the draft document in its meeting held on 24th October, 2017. The inputs were also received from officers of S&R Zone of Ministry of Road Transport and Highways. The Executive Committee in its meeting held on 2nd November, 2017 considered and approved the same document for placing it before the Council. The Council in its 213th meeting held at Bengaluru on 3rd November, 2017 considered and approved the draft for printing.

HOW TO USE THIS MANUAL

Urban Roads are important corridors for integrating sustainable landscapes to improve air quality, reduce urban flooding; improve liveability; protect natural ecosystems; promote efficient use of water; minimize soil erosion; and provide a comfortable transit environment. This Manual provides the requisite landscape standards and guidelines to successfully achieve these goals.

Landscaping when integrated with geometric design elements of roads as well as provision of amenities for all road users, is often termed as Streetscaping. It is a multi-disciplinary subject encompassing various expertise/fields such as transport planning, traffic/road engineering, urban design, landscape architecture, utility engineering and traffic management.

The focus of this Manual is on the landscaping elements of road design/streetscaping. While other aspects of road design is covered in various chapters of the Urban Roads Manual and related IRC documents.

Landscaping, integrated with roadways, must be designed and detailed with specifications by qualified technical experts, including civil engineers, architects, landscape architects and horticulture experts.

This manual is structured to comprehensively address the role of planting and landscape through i) critical considerations of all hierarchies of urban roads, ii) integrated design with landscape and planting, iii) implementation details and specifications for horticulture practice, and, iv) maintenance requirements. It is a comprehensive resource that can be consulted on a chapter-wise basis by any category of user.

Although all chapters encompass aspects that concern all three primary users of the document, certain chapters are more relevant to one than the other and the same is outlines in the **Table 1** below:

Table 1 Relevance of this Manual to Various Professionals

Sr. No.	Chapter	Primary relevance to:	Also relevant to:
1	Paradigm Change in Landscaping of Roads	Designers and Engineers	All
2	Design Methodology with Landscape and Planting	Designers and Engineers	Planners, Landscape Architects, Monitoring Agencies
3	Implementation Details	Implementing Engineers; Designers	Civil Contractors, Monitoring Agencies
4	Maintenance	Horticulture Departments	Horticulture Contractors, Monitoring Agencies

Each chapter includes important criteria to be addressed, mandatory codes and minimum standards of practice, and recommendations for best management practices. These Landscape Standards are applicable to all Right of Ways as defined by IRC for Urban Roads. It includes Greenfield developments, Public Improvement Projects and ROW retrofits.

Chapter 1: Paradigm Change highlights the overarching landscape strategies required in Streetscaping.

Chapter 2: Design Methodology with Landscape and Planting provides guidelines for planting standards, landscape design and plant selection in the Right-Of-Way (ROW).

Chapter 3: Implementation Details includes specifications for planting, tree protection, transplantation, special project conditions and installation, as well as landscape irrigation/water management,

Chapter 4: Maintenance provides post construction procedures and maintenance standards for protection, pruning, and maintenance of planting and landscaped areas.

Fig. 1 below illustrates how each of the above chapter related to various stages of street design/ planning/engineering and implementation and maintenance.

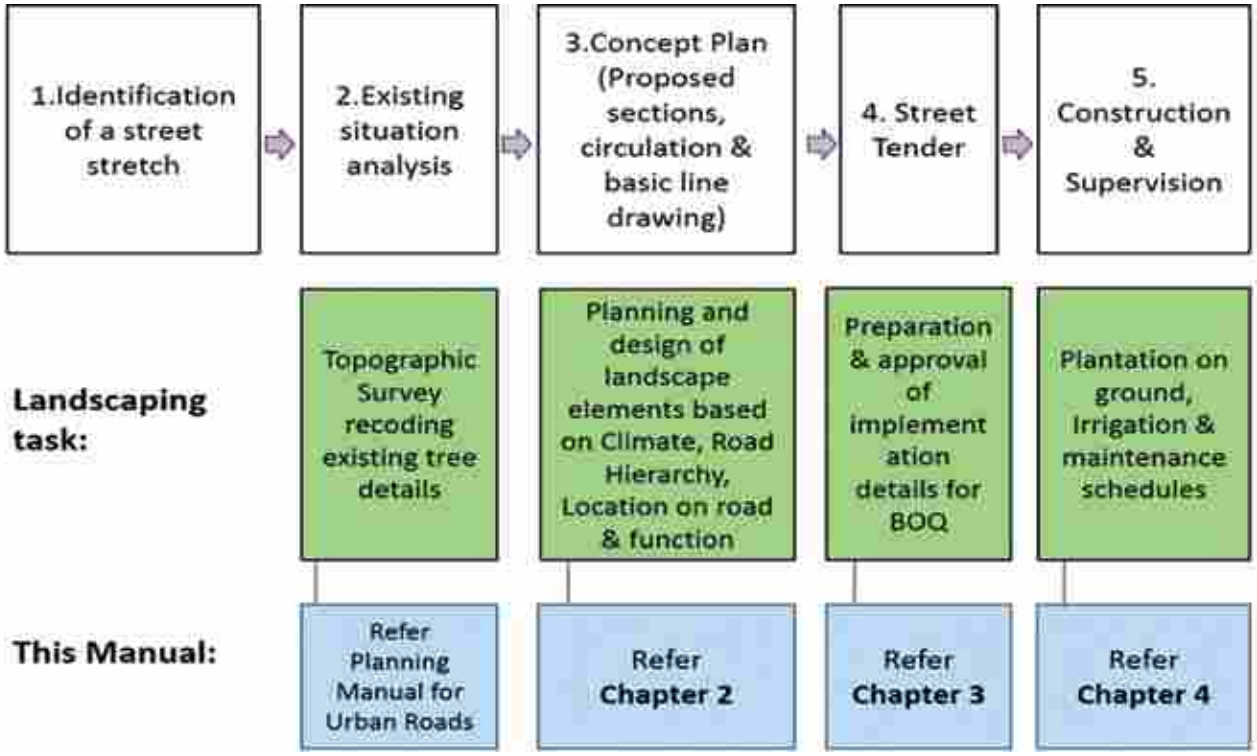


Fig. 1 Process of Roadway Design and Integration of Landscape

The guidelines do not dictate certain designs nor are overly specific. They are intended to provide a general design framework for the various types of planting applications to ensure high quality, well designed spaces.

CHAPTER 1
PARADIGM CHANGE IN LANDSCAPING OF ROADS AND STREETS

In recent years, the paradigm of landscaping of roads is meant to take on a significant role in the context of increased air pollution, urban flooding and global warming. Issues such as the following have come to the forefront of planning and engineering of urban roads in the context of landscaping:

- Seasonal flooding and mixing of untreated waste water with storm-water
- Extreme spikes in temperature and frequent formation of heat islands, negatively affecting walkability of a place
- Shortage and use of potable water for irrigation
- Road damage due to frequent repairs and subgrade damage due to trees
- Damage to trees in heavy footfall areas; destruction of tree cover during road widening, repairs and storms;
- Increase in air pollution, dust and noise levels
- Soil erosion

A paradigm change is envisaged in the Landscaping of Roads and Streets in sync with other related IRC codes, in order to address the above issues, as follows:

Issue 1. Air Pollution, Heat Island Effect and their Mitigation

Rapid urbanization and increasing loss of green cover is leading to higher ambient temperatures than normal and contributing to dust-re-suspension and accentuated air-pollution issues in urban areas. Lack of shading and green cover on roads is making them unfriendly for pedestrians and cyclists and leading to an induced modal shift towards private vehicles and unsustainable development trend.

To address the above, trees need to be incorporated as an indispensable element of streets given the predominantly hot weather of Indian cities. Trees help in providing shade during hot months and reducing ambient air temperatures.

A major role is also played by trees and green cover in combating air pollution by absorbing pollutants, increasing humidity and minimizing soil erosion/dust re-suspension.

Existing urban spaces/roads should therefore be planted with sufficient amount of trees, shrubs and ground cover for a comfortable microclimate and ambient air quality (refer **Fig. 2** below).

Trees are not to be placed on a footpath in an ad-hoc manner in left-over spaces as an “after-thought”. Trees must be planted in the specifically allocated Multi-Functional Zone (MFZ) which has been proposed as an essential requirement on all categories of streets. Details of the design and implementation of MFZ are given in Chapters 2 and 3 (in addition to IRC:103-2012, IRC:SP:50-2013).

UNDESIRABLE: without MFZ | **DESIRABLE: with planted MFZ**

a. Parking, utilities in haphazard way within ROW

b. All utilities, parking and tree line within MFZ

c. Stormwater running off into drains without infiltration

d. Bio-swales for water treatment within MFZ

e. Trees occupying footpath space within ROW

f. Consolidated space for trees, utilities within MFZ

Fig. 2 The Desirable and Undesirable Practices on Urban Roads with and without the Designated Multi-Functional Zone (MFZ)

In addition, this manual provides standards and guidelines for mandatory plantation along roads and streets, based on various types of road hierarchy, functional requirements, road space availability and planning/design criteria.

Stage 1: ROW without appropriate tree plantation for shading

Stage 2: ROW with shade trees planted but with additional temporary shading device during growth period

Stage 3: ROW well shaded with full grown trees

Fig. 3 (Refer all figures above) During Retrofitting of Existing Roads, Various Methods of Temporary Shading Devices can be used at Various Stages of Tree Plantation, till the Tree Attains its Full Growth.

Issue 2. Urban Flooding and Natural Storm Water Management to reduce runoff and Seasonal Flooding

Fig. 4 Impact of Rain on Urban Roads.
Shown above, a street in Ahmedabad after rains

Fig. 4, above represents a common scenario in urban areas, caused by just a few inches of rain. As more and more areas develop, they get covered by impervious surfaces, which do not let water infiltrate. Due to limited capacity and interconnectivity of storm water lines, they get choked. The water floods the streets and neighborhoods. Low-lying areas sometimes record standing water up to a few days but with minimal infiltration, causing long term water issues and loss of green cover. It is therefore, extremely important, that storm water is allowed to infiltrate the soil and reach aquifer.

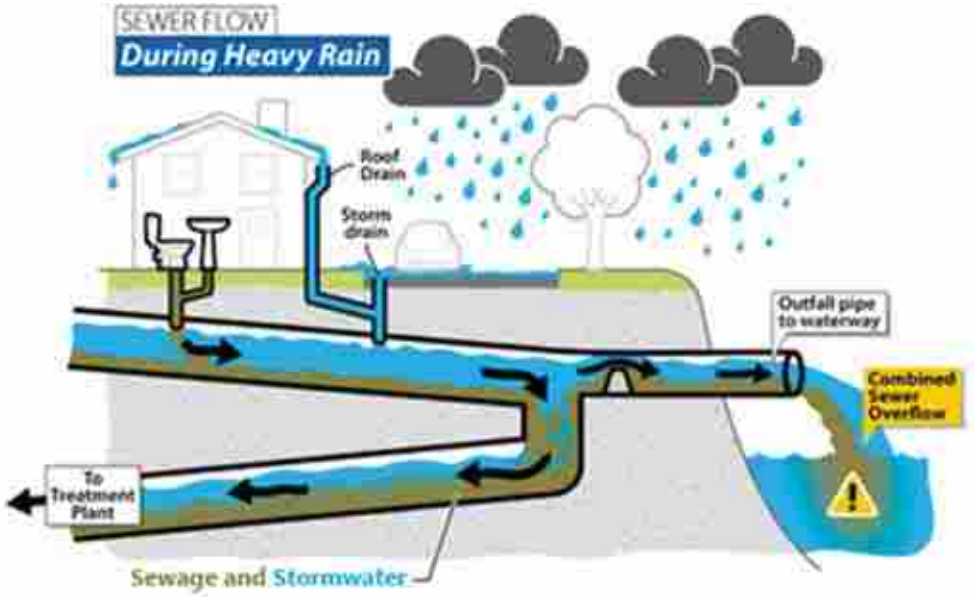


Fig. 5 Sewer and Storm Water flows during Heavy Rains

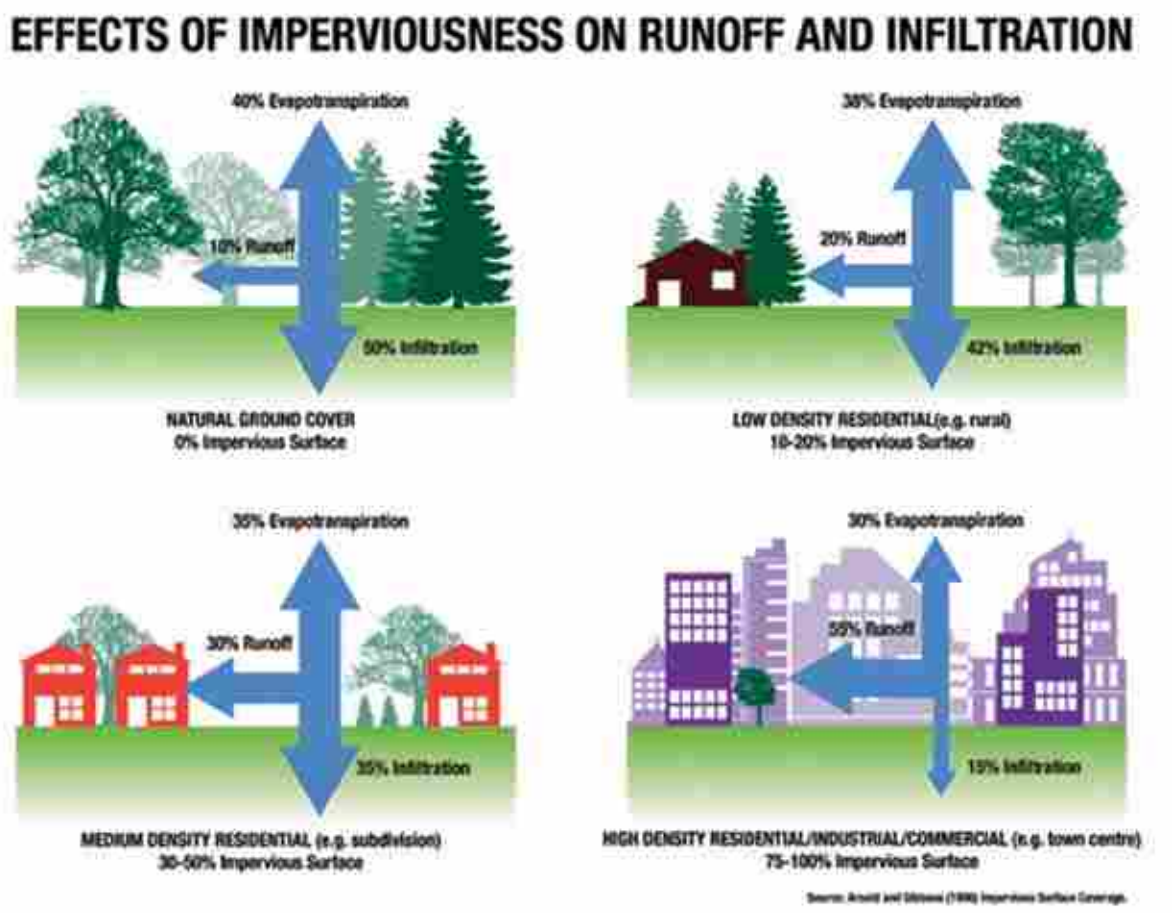


Fig. 6 Effect of Imperviousness on Runoff and Infiltration

To overcome urban flooding and mixing of storm water with sewage, the following measures are effective:

1. Retrofitting the existing roads and new roads to decentralize storm water systems and achieve maximum treatment and infiltration in sub-soil before it leaves the area through the structured system.
2. Increase porous, pervious surfaces (especially in walking, cycling and parking areas) so that storm water is soaked in soil and by plants before it runs off to water body.
3. Direct storm water to nearby parks and gardens so that it gets a larger area to get filtered and infiltrated.
4. Create retention structures, that are interconnected, that help absorb storm water.

The above had been introduced in IRC:SP:50-2013 and have been further enhanced within this Manual in Section 2.6 and 3.7.

Fig. 7 Flooding of Roads affecting Vulnerable Users

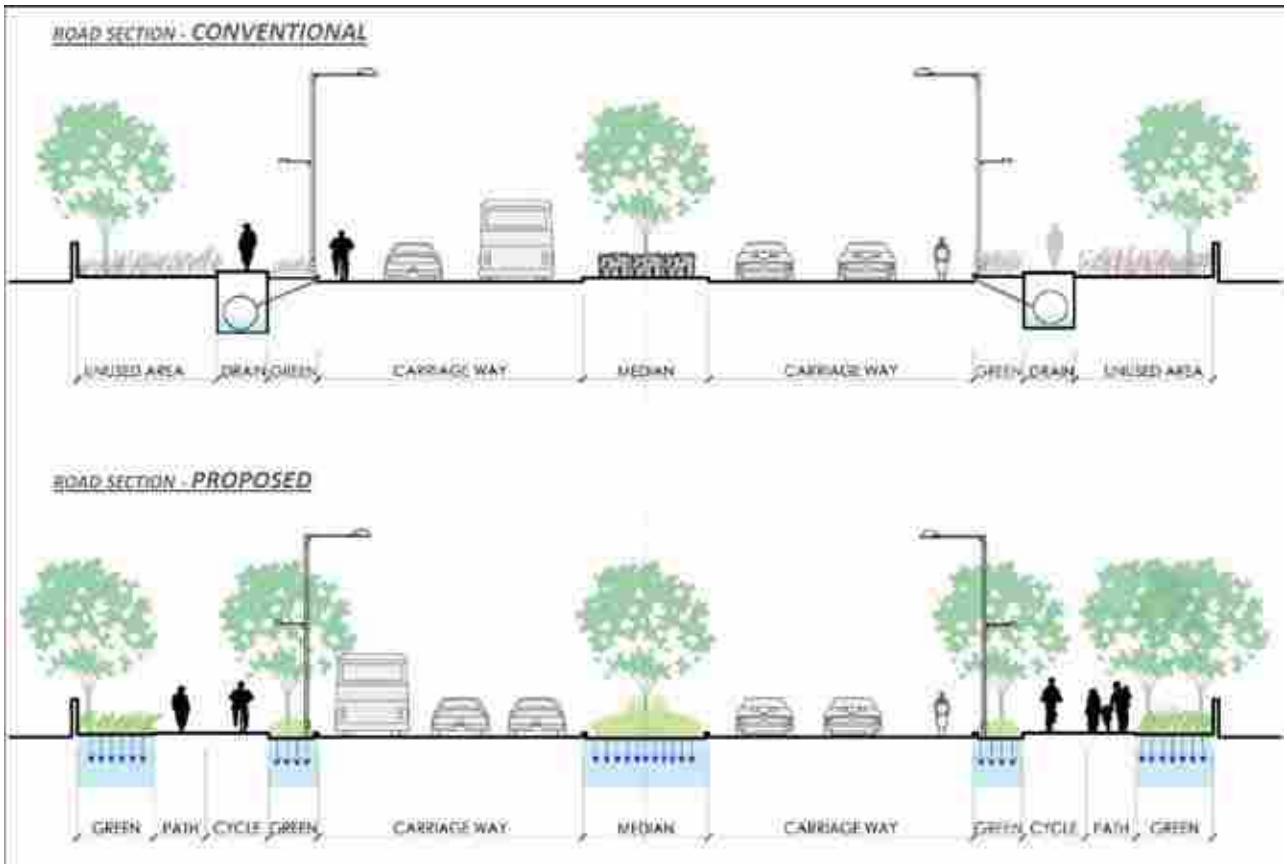


Fig. 8 The Conventional and the New Approach to managing Storm Water on Urban Roads (Source: IRC:SP:50-2013)

Issue 3. Water Scarcity and Progressive Irrigation Techniques (Drip Irrigation, Recycled Water, Xeriscaping)

With increase in green cover within roads and streets, comes an induced requirement of additional water for irrigation. Most cities have inadequate amount of water to spare for irrigating roadway planation and therefore innovative techniques such as drip irrigation and use of local recycled water needs to become the norm. This manual provides recommendations and technical details for drip irrigation planning and other decentralized systems of irrigating roadside plantation in Section 3.7 and 4.2.

Xeriscaping is a technique of landscape design that uses negligible amounts of water for irrigation. (Please refer Glossary – Xeriscape and Plant Factor). By encouraging this landscape technique one can reduce water usage while still have beautiful landscapes adorning public spaces. Xeriscaping is particularly recommended for water scarce regions and places that receive excessive sunlight. Xeriscaping plants are typically, all species of cactus, yucca and succulants.

Issue 4. Protection of Existing Trees and Green Cover

With increasing urbanization, infrastructure development projects such as new road construction, road widening, flyovers, mass transit corridors, etc. have become common features of city development. Most often, trees become the first casualty of this or come as an after thought.

Section 2.2 and Section 3.5 of this manual provides strategies and technical specifications for preserving trees during road widening/new road alignment; scientific process for planting, sub-grade protection, tree protection and transplantation to save valuable mature trees; tree protection and co-exiting with human interface; and storm protection.

Issue 5. Erosion Control – Roads in Water-Logged Areas; Bio-Diversity Zones

Erosion in hilly areas is a major cause of natural disasters, and blockages of essential roadways and arterials during emergencies. Therefore, erosion control measures are essential for maintaining safety and access in such areas. A spectrum of erosion control measures while utilizing trees and ground cover effectively for the purpose, have been suggested in Section 3.10 and **Annexure C**.

Annexure-A provides a matrix of Tree Properties based on Climatic Zones, so that appropriate trees can be selected by designers/horticulturists based on the criteria and guidance provided in this document.

CHAPTER 2
DESIGN METHODOLOGY FOR LANDSCAPING AND PLANTATION

Documenting the Context

2.1 Survey Requirements

At the start of every project, all existing trees must be identified, numbered and marked on a Survey Plan. Requirements for various types of Surveys have been provided in **Annexure-B**. The following information should be marked on a Survey Plan:

(i) Adjoining public parks.(any open areas within or adjacent to the public ROW where seasonal storm water can be diverted to)
(ii) Residential area or mixed-use commercial area with heavy footfall
(iii) Soil type and water table
(iv) Sloped or Hilly
(v) Predominant climate and side of road likely to remain least shaded
(vi) Existing trees within ROW

Locations of trees with girth more than 30 cm (measured at 1 m height from the ground level) should be indicated in the survey plans and also in a separate CAD layer. A table, showing location, type, their species, and girth diameter and reference number duly shown on the plan shall be made. The trees at site to be numbered and marked with paint including the identification of trees, which can be saved (without cutting), or including in median or where found unavoidable.

The following additional aspects should be considered during the Context Analysis of the roadway/street design project:

- Landscape Impact of the proposed road alignment/retrofitting/widening project.

- Existing tree inventory including quantity, species, caliper size and height as mentioned above.
- Drainage ways, inlets, outlets, area drains and overflow areas.
- Existing and proposed location of above and below grade site utilities and service connections.
- Fire tender pathway and access requirements.
- Location and direction of service openings on above grade utilities such as transformers, telephone, and utility boxes and clearance/safety zones required.
- Existing landscape fixtures such as seating, planters, street lighting, signage, paving, pervious emergency vehicle access, etc.
- Existing landscape irrigation/water management system.

Design Approach

2.2 Design Approach Based on Project type

2.2.1 *New roads*

Decision on where to put drains and bio-swales and where to put plantation keeping in mind future widening:

(i) In new roads, planting shall be done in a way that no movement, cutting or transplantation is necessary. To ensure this, the entire RoW should be planned to keep future requirements so that no displacement of trees is necessary.

(ii) For new roads, the two critical aspects to be considered are the location of the storm water drain (deciding slopes of the carriageway) and the location of the tree lines, such that, future widening of roads and footpaths, etc. is not hampered.

(iii) One row of trees could be planted along the central median, on roads having medians of 2.1 m and above,while ensuring clear sight distance and clear height as per **Fig. 85**, with adequate sub-grade protection as per this manual. The width shall also be helpful in having refuge space for wheelchairs.

(iv) As shown in **Fig. 9**, in Phase 1 of road-building for 60 m roads and above, widening provision can be kept as part of a wider median and the second row of trees can be planted approx. 13 m from the center-line. For 45 m, it should be 11.5 m. In case of roads wider than 45 m, the second row could consist of a double row of trees, or a third row could be added.

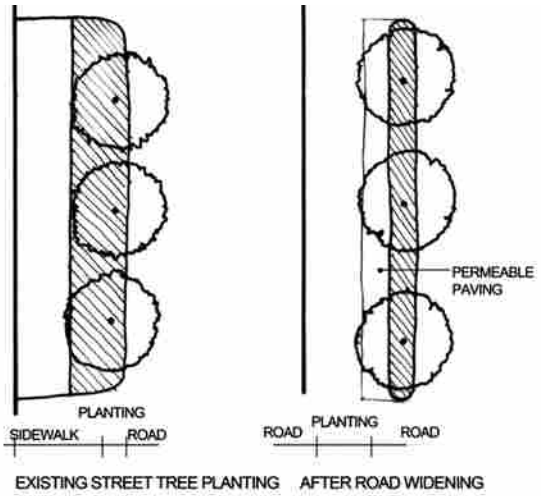


Fig. 9 Tree Protection in Median

(v) Structured and/or decentralized drainage lines should be incorporated along the tree lines. Multi-Functional Zones can house tree line and drainage/infiltration systems. For various classes and widths of roads, **Table 2** provides the location of the Multi-Functional Zone which can have the tree line, plantation, etc.

(vi) The location of the infiltration units/bio-swales/detention areas should be such that the run-off from roads reaches them first before entering the structured drain system. Overflow from the infiltration units/bio-swales could be connected to the structured underground drainage system or could be directed to a nearby open space for recharge by sheet flow of water. Section 3.7.2 provides guidance on the various type of infiltration modules that can be provided for various conditions of widths of sidewalks and medians.

(vii) Shading of footpaths, cycle tracks and carriageway could be achieved by planning trees next to the kerbs and in the medians.

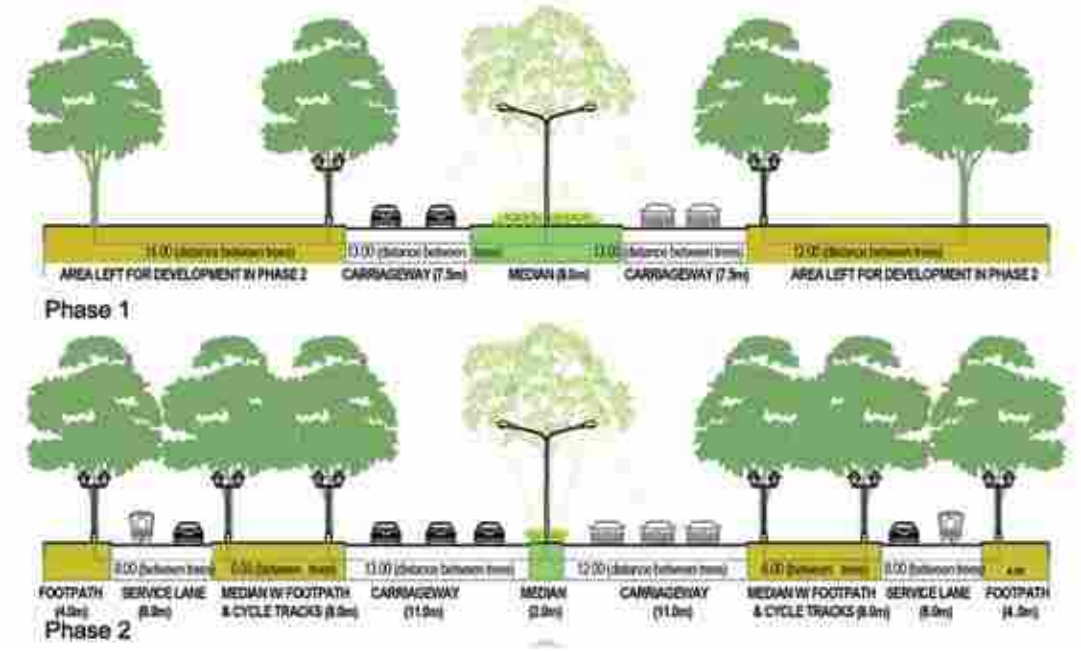


Fig. 10 Illustrative Sections of a proposed Arterial Road showing Tree Plantation – Keeping Future Widening Provisions.

2.2.2 *Retrofitting of existing roads*

How to decide where/how to retrofit for adding local recharge and decentralized treatment:

(i) The streets having existing drains can be retrofitted with adding local recharge as over-flow module or pre-infiltration module as per the site conditions. The **Fig. 10** (top) shows adding of an overflow module to the existing drain. The **Fig. 10** (bottom) shows adding of an infiltration module so that water infiltrates before overflowing into existing drain.

(ii) Decentralized sewage treatment systems should be designed within a width not more than 1.8 m so that they can be positioned within the Multi-Functional Zone, as shown in **Fig. 12**. The length of these systems should be shorter than the centre-to-centre distance between the trees. **Fig. 12** illustrates this condition.

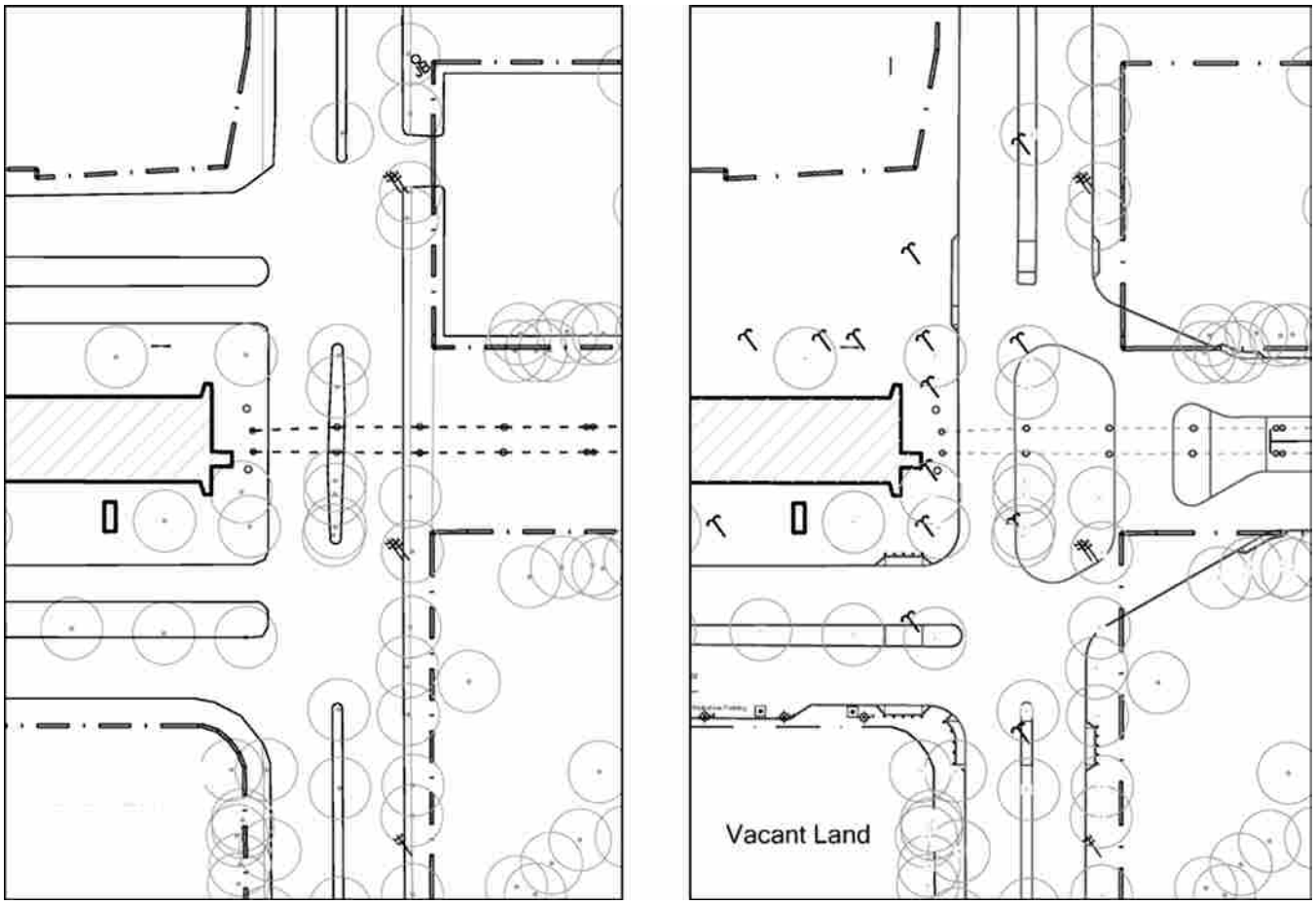


Fig. 11 An Existing and Proposed Alignment Plan of a Junction Showing how all Existing Trees can be kept Intact during Junction Design

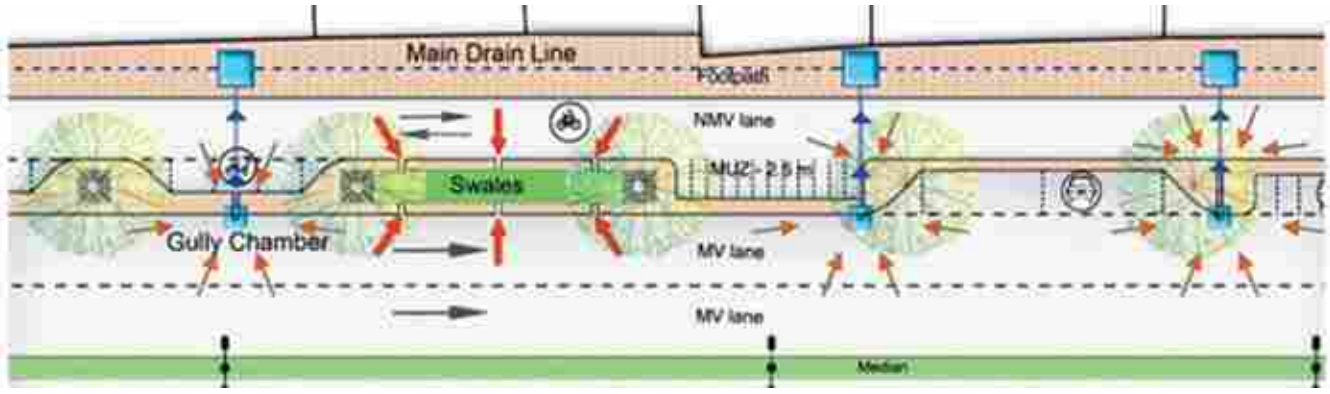


Fig. 12 Plan showing Typical Road Edge with MFZ having Tree-Planting, Bio-Swales, Vehicular and NMV Parking (refer Chapter 3 for typical details)

2.2.3 *Road widening*

Criteria to be considered during road widening projects incorporating existing tree lines and drain locations:

(i) Existing tree lines should be retained as far as possible and the road design should be adapted to their locations. Transplantation of trees should be avoided

and should be the last choice during road widening decisions, although it may be preferred over cutting, as shown in **Fig. 11** above.

(ii) Pedestrian zones, cycling lanes and resting spots can be developed around existing trees or they could be incorporated into medians so as to avoid their cutting or transplantation. **Fig. 13** and **14** illustrate how existing tree line was retained as a median during road widening for BRTS.

(iii) The top of existing drains can be readjusted to meet the top height of the footpath, such that their top surface can be utilized as a walking surface. Trees can be planted on the sides to shade the walking surface.

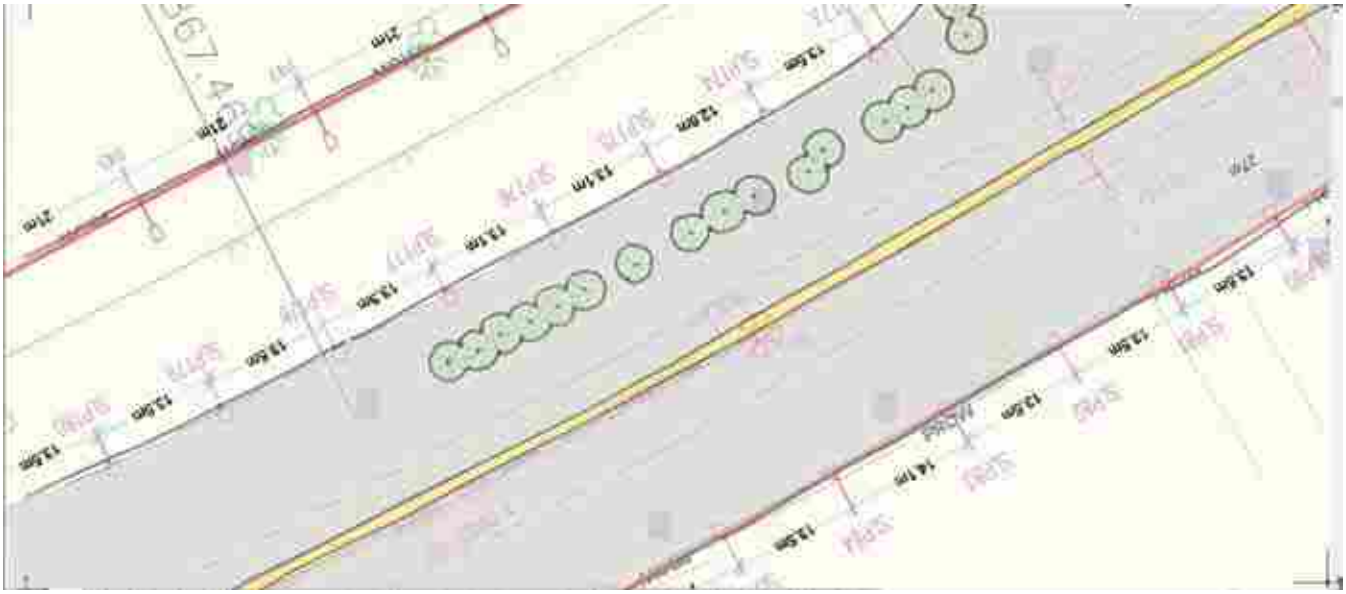


Fig. 13 Ahmedabad BRTS Corridor Implementation: Protection of Tree Line by Carving Out a Median by Separating Travel Lanes (Before Condition)

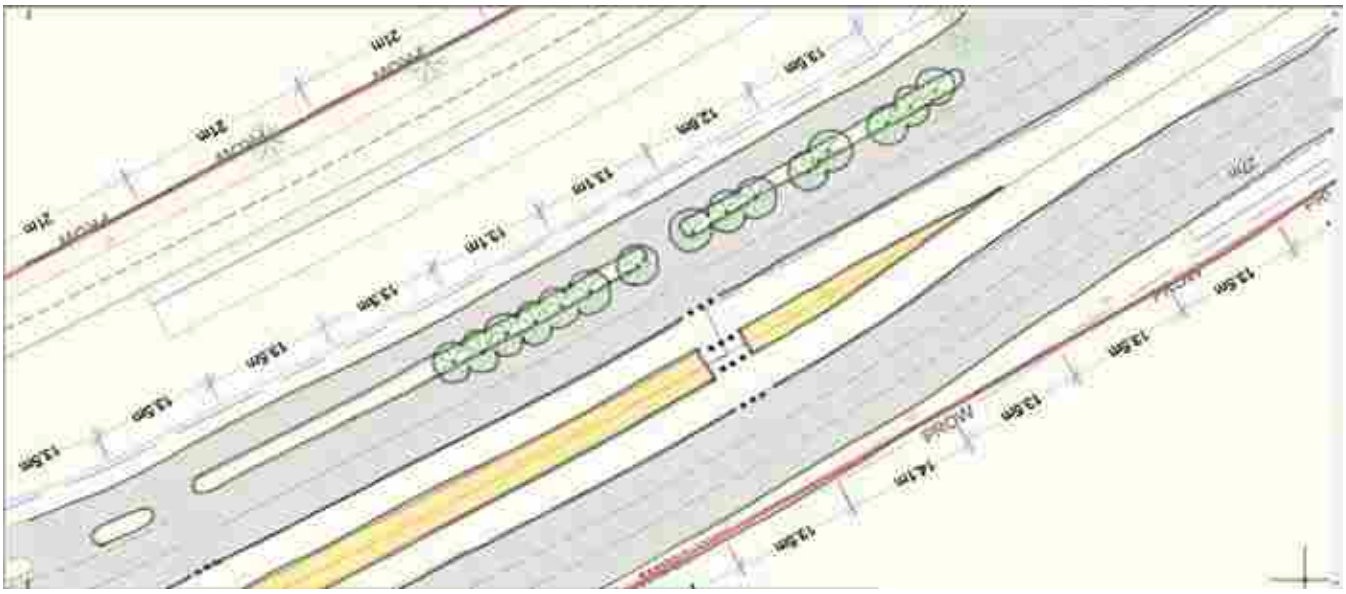
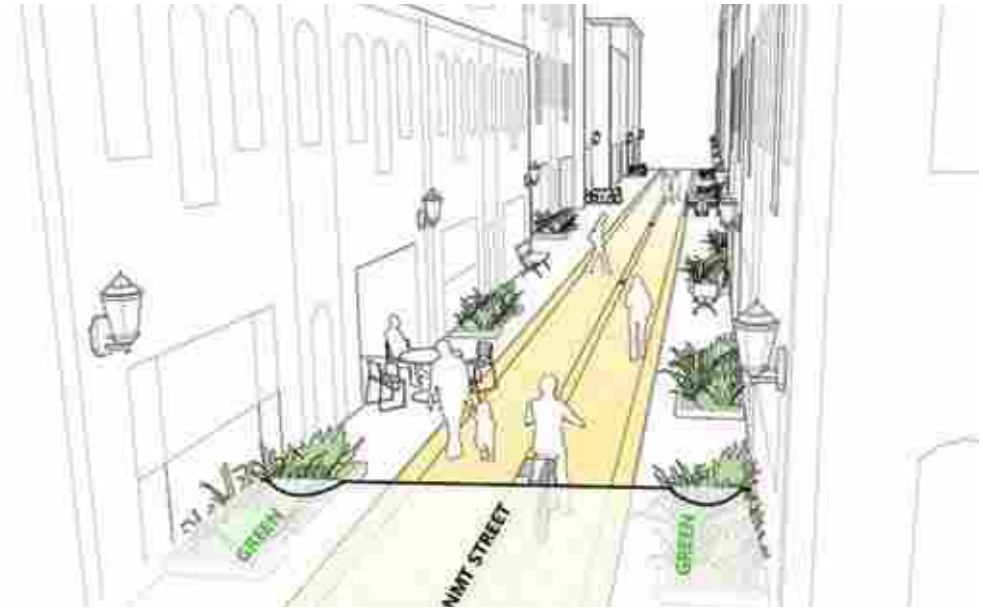
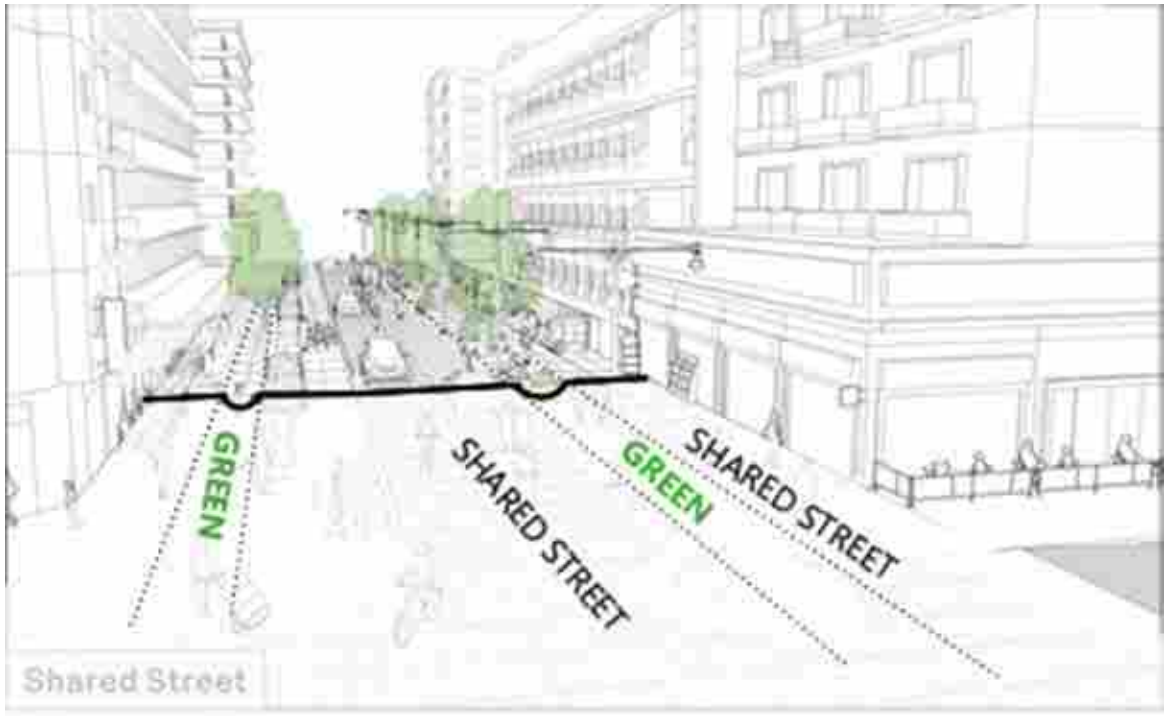


Fig. 14 Ahmedabad BRTS Corridor Implementation: Protection of Tree Line by Carving Out a Median by Separating Travel Lanes (After Condition)

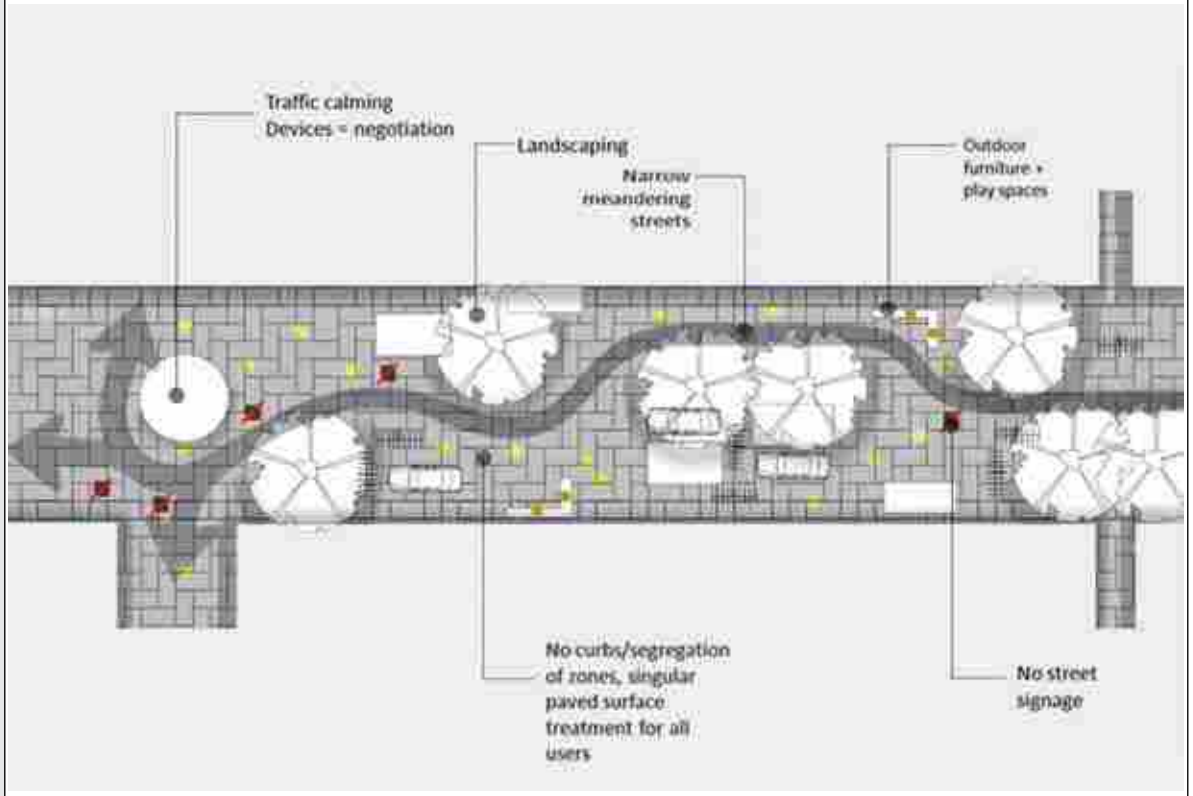
2.3 Design Approach Based on Road Hierarchy

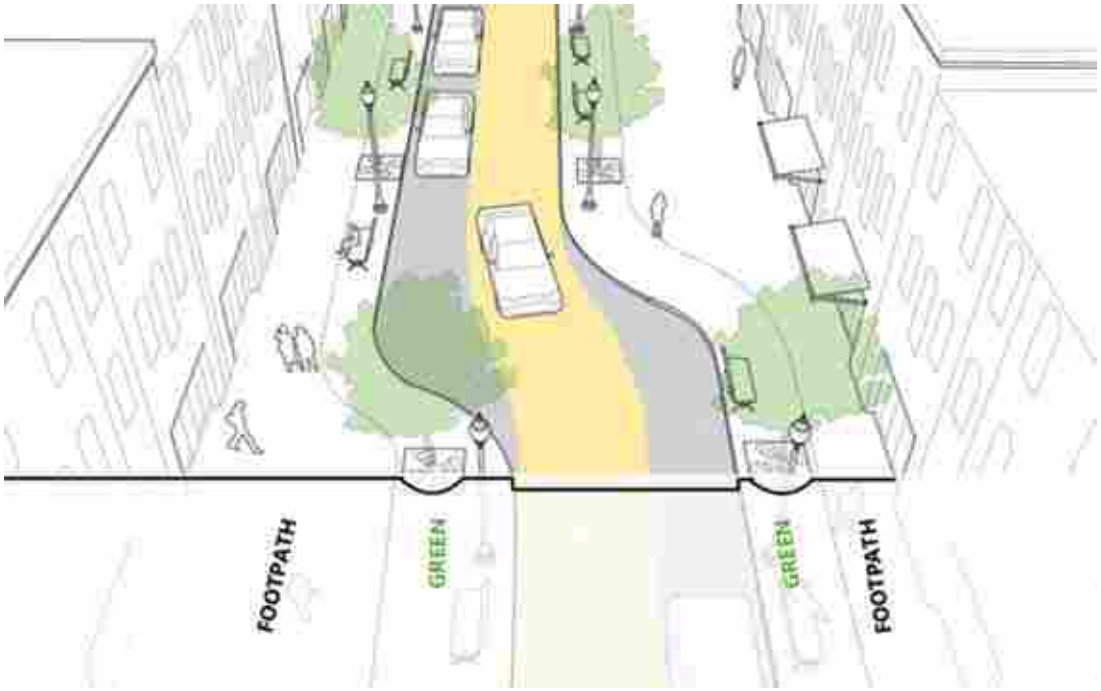
Table 2 Space Distribution in RoW Based on Road Hierarchy

Road Hierarchy	Important aspects to consider	Aspects to look for in plant selection
(i) Local Streets: can be designed in the following ways - • *Neighbour-hood Streets* • *Shared Streets* • *Non-Motorized Transport (NMT) Streets* • *Greenways* • *Woonerfs*	• Shade providing – medium high canopy trees for reducing urban heat island effect, dust prevention and humidity control • Traffic calming through plantation design. • Shading of pedestrian walkways and cycle tracks or cycle lanes and resting spots. • Urban drainage, ground water recharge, bio-swales. • Anti-skid, less jointed surface for walking and cycling. • Pervious surfaces at resting spots, parking, pick-up drop-off locations, etc. • Slope protection and stabilization through plantation and structural means to reduce events of subsistence and erosion.  **Fig. 15 An Example of Local NMT Street with Plantation**	• Function: Shade-giving • Branching: High • Root depth: Deep • Water consumption: Low

Road Hierarchy	Important aspects to consider	Aspects to look for in plant selection
	 **Fig. 16 An Example of Local Shared Street**	

Road Hierarchy	Important aspects to consider	Aspects to look for in plant selection
	 **Fig. 17 An Example of Local Avenue Street**	

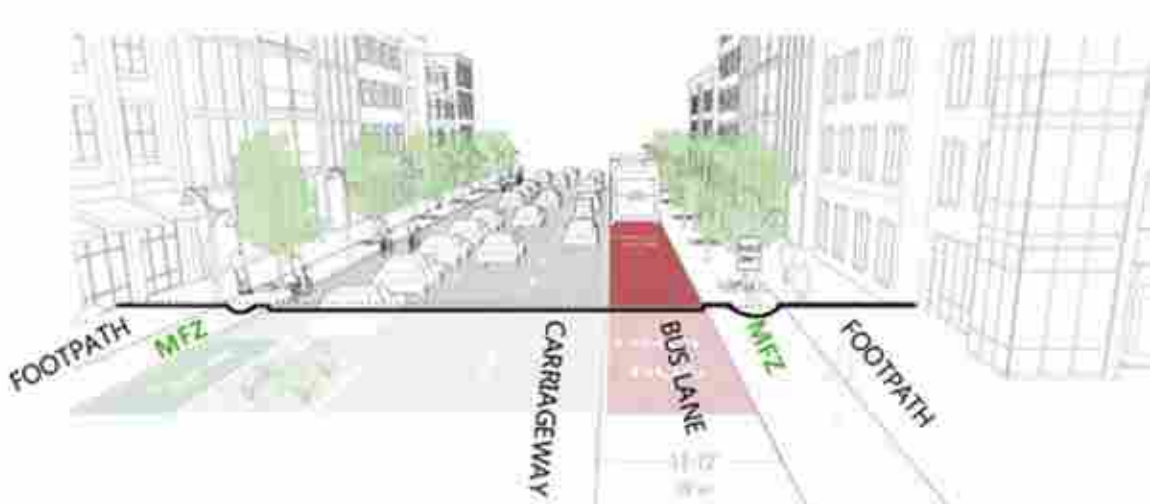
	Woonerf (type of local street) - Additional requirements: • Traffic calming through plantation design and design of resting spots, parking spots. • Urban drainage, ground water recharge, bio-swales.	
	 **Fig. 18 An Example of Woonerf with Traffic Calming and Landscaping**	

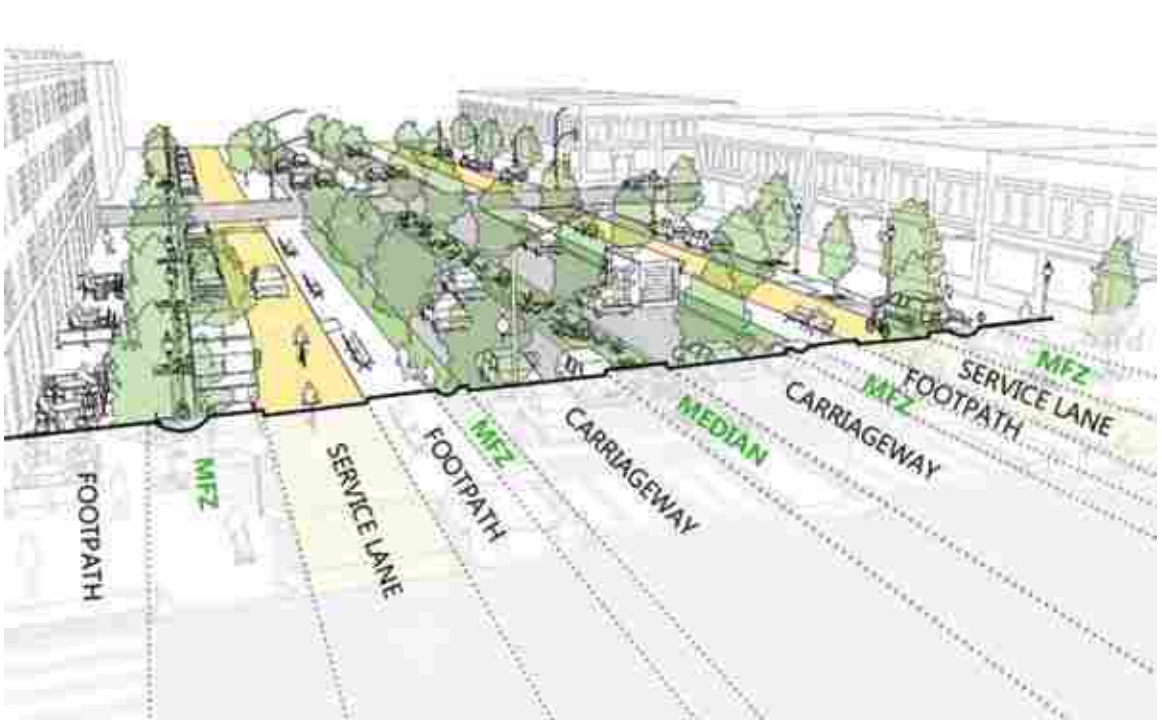
	 **Fig. 19 An Example of Local Woonerf**	
(ii) Collector Roads: can be as any of the following - • Boulevards • Promenades • Elevated Roads with Metro Viaducts • BRT Corridors	• Screening for dust and noise mitigation • Shade providing – high canopy trees for reducing urban heat island effect, dust prevention and humidity control • View-cutters, if required. • Shading of pedestrian walkways and cycle tracks and resting spots. • Urban drainage, ground water recharge, rain gardens, bio-swales. • Pervious surfaces at resting spots, parking, pick-up drop-off locations, etc. • Slope protection and stabilization through plantation and structural means to reduce events of subsistence and erosion. • Safety through clear line of sight for pedestrians, cyclists and vehicles. • Aesthetics.	• Function: Shade-giving • Branching: High • Root depth: Deep • Water consumption: Low

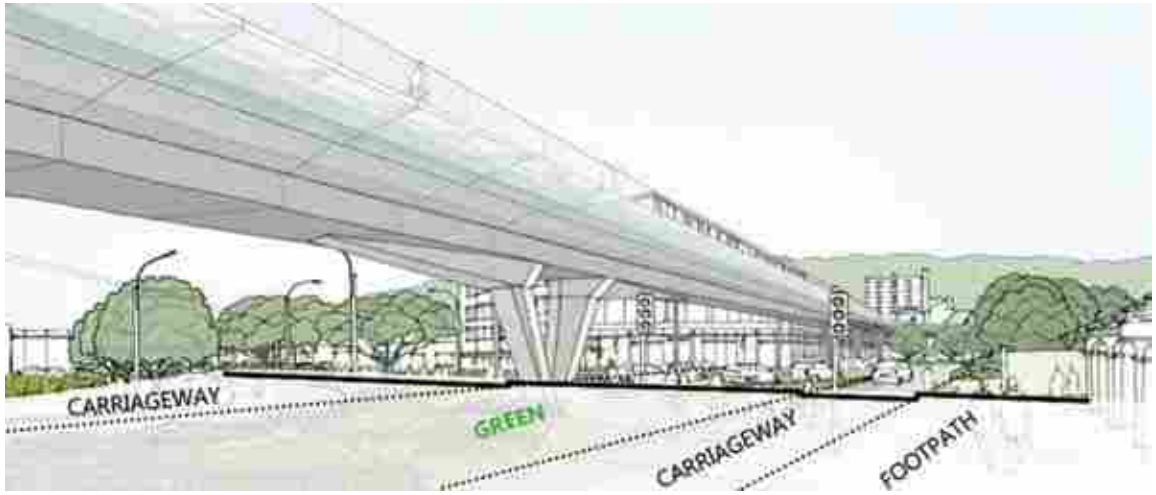
	Collector Road as Boulevard – Additional requirements: • Regular uniform canopy trees to frame view corridors, road curves, etc. • High canopy trees are preferred in continuous planting area. Understory trees may be used when limited planter width and conflicts with utilities exist. • Screening shrub plantation for noise and dust mitigation and as buffer plantation. • Storm water recharge details, bio-swale, rain gardens, etc.	• Water consumption: Low
	 **Fig. 20 An Example of a Collector Road Boulevard with Multiple Rows of Tree Plantation and Bio-swales**	

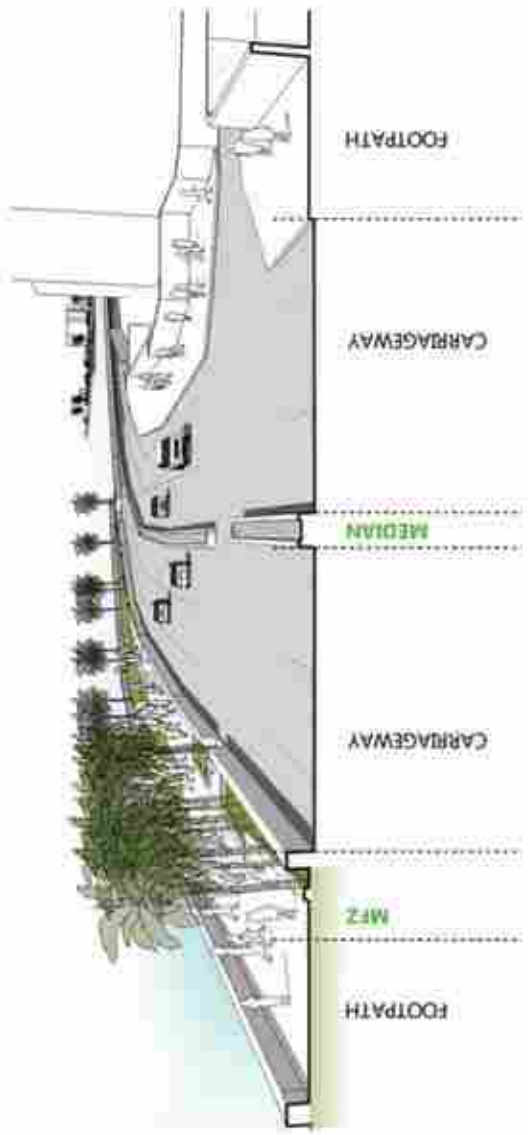
	Collector Road as Promenades – Additional requirements: • Shade providing – medium to high canopy trees for clear sight vision and shade along the water edge. • Pervious surfaces for maximizing rainwater infiltration. • Aesthetics and pleasing environment. Accent trees and plants.	• Water consumption: Low
	 **Fig. 21 An Example of a Collector Level Avenue**	

	Collector Roads with elevated Metro viaducts: Additional requirements: • Urban drainage – storm water conduits to at-grade water recharging details. • Mini-forest, rain gardens, botanical gardens, community gardens, resting spaces, on-street parking spaces, vending areas, under the viaducts.	• Water consumption: Low
	 **Fig. 22 An Example of Landscape along Collector Road with Elevated Metro Viaduct**	

	Collector Roads as BRT corridors – Additional requirements: • High canopy trees are preferred in continuous planting area. Understorey trees may be used when limited planter width and conflicts with utilities exist. • Traffic calming; Shading of pedestrian walkways, cycle tracks and resting spots. • Urban drainage, ground water recharge, rain gardens, bio-swales	
	 **Fig. 23 An example of Tree Plantation along Collector Road BRT corridor**	
(iii) **Arterial Roads:** *can be designed with/as any of the following --* • *Boulevard* • *Flyovers* • *Promenades* • *Footover-Bridges (FOB)* • *Metro Viaducts* • *BRT Corridors*	• Screening for dust and noise mitigation • Shade providing – high canopy trees for reducing urban heat island effect, dust prevention and humidity control • View-cutters, if required. • Shading of pedestrian walkways and cycle tracks and resting spots. • Urban drainage, ground water recharge, rain gardens, bio-swales. • Pervious surfaces at resting spots, parking, pick-up drop-off locations, etc.	• Function: Shade-giving • Branching: High • Root depth: Deep • Water consumption: Low

	Arterial Road designed as Boulevard – Additional requirements: • Double row of trees wherever possible of different species. • Regular uniform canopy trees to frame view corridors, road curves, etc.	• Water consumption: Low
	 **Fig. 24 An Example of Boulevard within an Arterial Road with Multiple Rows of Tree Plantation and Bio-Swales**	

	Arterial Roads with Flyovers – Additional requirements: • Creepers in suspended planters along railing or along and columns for reducing Urban Heat Island. • Shading by structural elements. • Urban drainage – storm water conduits to at-grade water recharging details. • Mini-forest, rain gardens, botanical gardens, community gardens, community spaces, on-street parking spaces, shops, if permitted, vending areas, under the flyovers. • Permeable paving in walkways and public spaces under flyovers.	• Water consumption: Low
	 **Fig. 25 An Example of Flyover with Plantation and Green Public Spaces under Viaduct in an Arterial Road**	

Arterial Roads designed as Promenades – Additional requirements: • Pervious surfaces for maximizing rainwater infiltration. • Aesthetics and pleasing environment. Accent trees and plants.	 **Fig. 26 An Example of a Arterial Road Waterfront Promenade**

	Arterial Roads with Foot over-bridges (FOB) – Additional requirements: • Shade providing – shading by structural elements or plantation, if possible. • Urban drainage – storm water conduits to at-grade water recharging details. • Maintaining humidity and aroma through plants.	• Water consumption: High
	 **Fig. 27 An Example of Plantation along Foot-over Bridge within an Arterial Road**	

	Arterial Roads with Metro Viaducts – Additional requirements: • Creepers in suspended planters along railing or along and columns for reducing Urban Heat Island. • Urban drainage – storm water conduits to at-grade water recharging details. • Mini-forest, rain gardens, botanical gardens, Vertical plantation on columns, community gardens, community spaces, on-street parking spaces, shops, if permitted, vending areas, under the flyovers.	• Water consumption: High
	 **Fig. 28 An Example of Landscape along Metro Viaduct within an Arterial Road**	

	Arterial Roads as BRT Corridors – Additional requirements: • Traffic calming; View-cutters, if required. • Pervious surfaces at resting spots, parking, pick-up drop-off locations, etc.	• Water consumption: Low
	 **Fig. 29 An Example of Arterial Road BRT Corridor**	

(iv) **Urban Expressways:** *are considered Arterial roads when within urban areas/ They can also be grade-separated Elevated Roads.*	• Wide canopy trees that provide shade for both carriageway and footpaths, cycle tracks. • Urban drainage, ground water recharge, rain gardens, bio-swales. • Pervious surfaces at resting spots, parking, etc. • Slope protection and stabilization through plantation and structural means to reduce events of subsistence and erosion, where required.	• Function: Shade-giving • Branching: High • Root depth: Deep • Water consumption: Low
	Elevated roads/viaducts (including columns) – Additional requirements: • Creepers in suspended planters along railing or along and columns for reducing Urban Heat Island. • Vertical plantation on columns. • Mini-forest, rain gardens, botanical gardens, gardens, community spaces, on-street parking spaces, under the flyovers. • Permeable paving in walkways and public spaces under viaduct.  **Fig. 30 An Example of Plantation along Column of Viaducts**	Creepers generally have more water demand than trees at the time of maturity, but experience reduction from the initial months.

Planting and Other Elements of Streetscaping

Streetscaping is an increasingly popular term being used in recent times by municipalities around the country to improve roads which not only includes landscaping and plantation, but also, provision of Street Furniture and various street amenities as part of the road design. Various components of Streetscape design are indicated below.

2.4 Street Furniture

Street furniture is one of the most important component of any street, as it helps in providing essential resting space 'pause points' and public utility, and helps make the streets more enjoyable and safe. All street furniture should be placed in the Multi-Functional Zone and should be clear of the designated walking and NMT space, or in resting islands made within the street edge, where there is more space available, as shown in **Fig. 31** and **32** below.

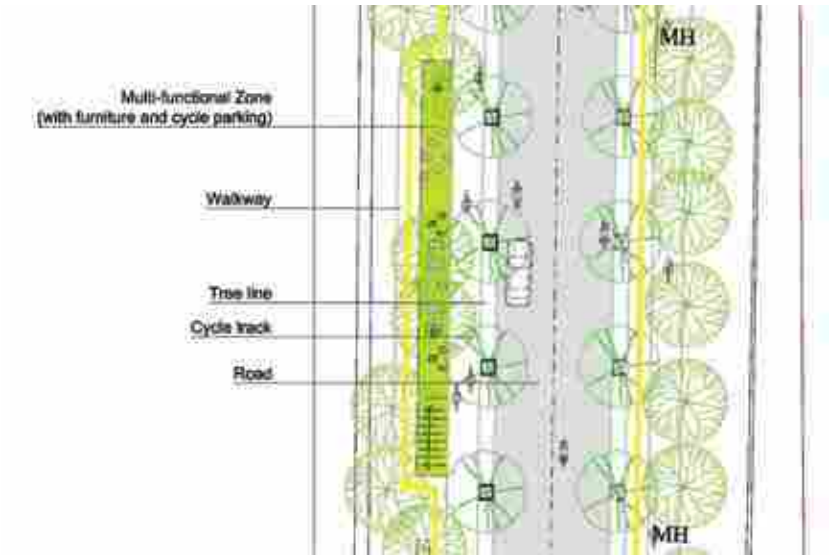


Fig. 31 Part Alignment Plan of a Road showing Multi-Functional Zone with Street Furniture, as Resting Island within the Street

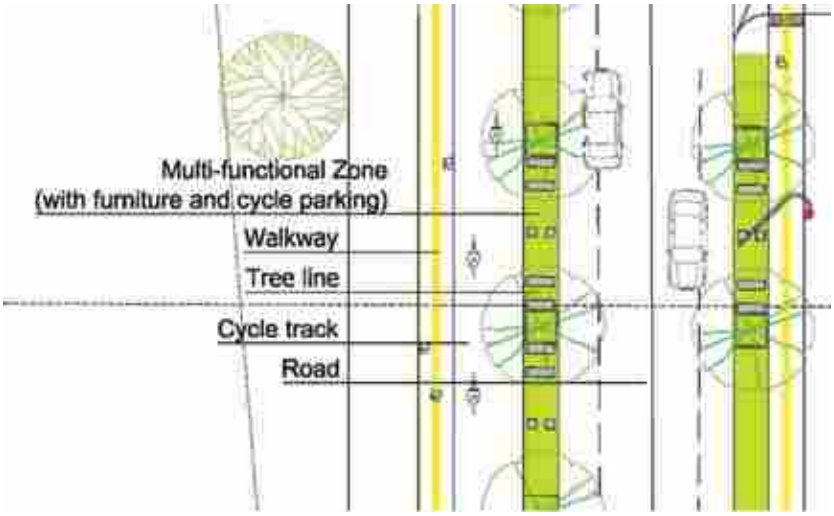


Fig. 32 Part Alignment Plan of a Road showing Multi-Functional Zone with Street Furniture, Integrated with the Tree Line

The Multi-Functional Zone can house the benches and the dustbins, apart from signage, tree pits, kiosks, parking and other important utilities. The benches (**Fig. 35-37**) and dustbins should be placed every 50 m on the street to have ample facility for the pedestrians and cyclists (**Fig. 38-39**). At every 300-500 m a toilet block should also be provided. Bollards should be placed to define the division between two different use of spaces & to enhance safety, between street and footpath, or between cycle track and walkway or between MFZ and cycle track, as shown in **Fig. 33** and **34** below. Bollards, should preferably be of sitting height 450 mm (**Fig. 106**) where resting spots are developed or of 750 mm (**Fig. 105**) to provide barrier to vehicles from entering the NMT zone. The distance between bollards could be varying from 600 mm to 1100 mm (for wheelchair access). Please refer Section 3.6 for construction details.

Fig. 33 Use of Bollards to Separate Road from Walking Area.

Fig. 34: Use of Bollards to Restrict Intrusion of Vehicles in Pedestrian Refuge Area

Fig. 35 Bench around Planter facing the Walkway

Fig. 36 Benches can be Creatively used Pieces of Art that bring Joy and Color to the Street

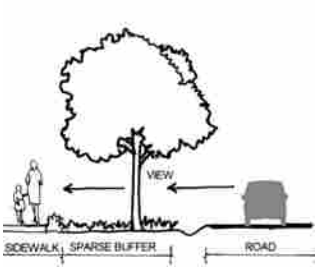
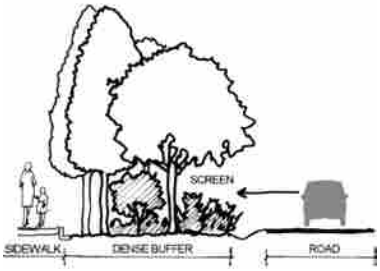
Fig. 37 Benches around Trees in MFZ

Fig. 38 Bench and Dustbins Integrated within the MFZ

Fig. 39 Dustbins, Public Toilets, Cycle Parking all Integrated within MFZ

2.5 Planting Strategy for Various Components of Roads

This Section provides guidance on the type of trees/plantation that may be provided within various parts of a Streetscape:

Location criteria	What to do	What not to do	Plant Choice
Requirement for all Streetscapes	 • Preferably plant trees in simple straight lines signifying the movement direction; • In hot climates, provide for shade giving trees, with other criteria as per the tables below. • Incorporate storm-water management techniques based on local soil type; • Use native plantings to increase longevity and minimize maintenance.	 • Trees if not pruned become an impediment. • Lack of street tree planting makes roads uncomfortable to all road users, increases heat island effect and increase runoff and erosion. • Monocultures are to be avoided by breaking the single species planting with alternative planting at regular intervals.	**Native:** Species common throughout India include Terminalia arjuna (Arjun), Tamarindus indica (Imli), Syzynium cuminii (Jamun), Madhuca indica (Mahua), Ficus religiosa (Peepal), Mangifera indica (Mango) Azadirachta indica (Neem), Ficus infectoria (Paker) and Dalberjia sissoo(Sheesam); Sargooro, Kankero, Kharo jall, Roheda, Kummath and Khejadi.
Along Footpaths, cycle tracks (within MFZ)	• High - canopy / high-branching trees with shrubs/ groundcovers as per requirement (refer **Fig. 69**). • Wide spread (min. 6-8 m or more) with dense foliage; • Ensuring visibility of safety and surveillance by regular pruning of shrubs/growing/ grown trees to maintain clear walking zone (2.4 m) 	• Do not plant large shrubs near signages; trees need to be pruned to keep signages and lighting clear; • Plantation must occur outside of required sight lines as per IRC:SP:66 • Planting should not block sight lines from roadside and active uses along the edges. 	• Branching: High • Evergreen • Fast-growing • Native

Location criteria	What to do	What not to do	Plant Choice
Medians; all unpaved areas	• **To prevent jaywalking and minimize headlight glare from reverse direction:** Shrubs upto 1.5 m height to be planted. • **To prevent dust re-suspension:** native grasses or hedges should be planted within all tree-pits, unpaved areas and medians;  • **Median less than 1 m wide** should be planted with ground cover with a line of shrubs in the center not more than 0.6 m high, and pruned from sides. (refer **Fig. 99**) • **Medians 1 m-2 m wide** should be planted with two rows of shrubs not more than 1.5 m high with additional row of ground cover or low height shrub near the edge of median. (refer **Fig. 100**). • **Medians 2.1 m-3 m wide** should be planted with at least 3 rows of shrubs not more than 1.5 m high, The median can also have a row of trees of medium to short height. (refer **Fig. 101**), • **Medians more than 3 m wide** can be planted with a variety of shrubbery, not more than 1.5 m high and with a row of medium to	• Avoid low-branching tree species on medians. • **Soil shall not be exposed;** must be covered with plantation or mulch. • Avoid monocultures, mix of species would increase disease resistance.  • Species planted should be able to withstand dust, fumes, high air speed, and full sun.	• Thorny; • Flowering; **Shrubs:** E.g. Bougainvillea and Thevetia nerifolia (Kaner) **Ground Cover:** E.g. Cynodon dactylon, Cythocline perpurea, Solanum nigrum, Alternanthera, Chlorophytum, Eupatorium, Wedelia, Duranta, Portulacca, Ipomea, Pelia cadrii, Beleprone oblongata, Tradescantia, Asparagus, Opheopogon grass etc. **Bio-swales:** Refer section 2.6.2

Location criteria	What to do	What not to do	Plant Choice
	large trees in the middle (refer **Fig. 102**), • **Medians with existing trees** should be retained with regular pruning of tree roots, branches and leaves such that clear height distance of 4.5 m above finished road level is maintained (refer **Fig. 103**). If required, sub-grade protection should be constructed. • **Bioswales** can be provided in low water table areas local recharge and combat flash-floods;  • **In hilly areas,** a natural drainage swale at the top and bottom of the slope will carry the rainwater runoff and reduce formation of gullies.		
Traffic-islands	• **Bio-swales and detention systems** can be provided within roundabouts in areas with low water table, non-clayey soils and prone to flash flooding. 	• **Avoid raised landscaped mounds** in traffic islands which increase run-off over the carriageway instead of relieving seasonal flooding. 	

Location criteria	What to do	What not to do	Plant Choice
	• **Flowering shrubs** upto 1.5 m height may be planted for aesthetics. • **Public spaces** with well-shaded hawker zones, seating, cycle-parking, etc. should be provided within traffic islands which tend to be otherwise under-utilized.	• Dense clumps of low branching trees or large shrubs should be avoided. High branching well-pruned trees with clear height of 4.5 m over the carriageway, are preferable.	
Paved plazas/ piazzas	• **Function - based plantation** may be required as per para 2.7 • Paved plazas can create major runoff so infiltration and retention systems should be integrated with their design; permeable paving should be used as much as possible. • Provide seating around tree pits wherever possible (refer 3.6.2) without obstructing storm water flow into the tree-pit. 	• **Minimize tree-trunk frequency** in busy pedestrian areas/piazzas – by using wide-canopy trees (≥12 m); • **Minimize planters and shrubs** within piazzas/ plazas as they restrict pedestrian movement; • **Avoid open un-grated tree-pits** as pedestrians may trip; • **Avoid un-usable tree-seats** which block storm water flow into tree-pits. 	• **Shade Trees** • **Wide Canopy trees** • **Bio-swales:** Refer section 2.6.2 • **Permeable Paving:** Refer section **Table 3**
Open Parking lots (requiring shading)	• Parking lots generate lot of ambient heat and should be planted with evergreen shade giving trees and permeable paving used for reducing run-off. 	• Dark colored materials such as asphalt tremendously increases heat island effect; to be avoided. 	• **Shade Trees** • **Wide Canopy trees** • **Bio-swales:** Refer section 2.6.2 • **Permeable Paving:** Refer ***Table 3***

Location criteria	What to do	What not to do	Plant Choice
	• Low-albedo, light-colored pavers (light gray/beige/ tan colors), aggregates or top coats, preferably with a reflectivity of 0.29 or higher.	• Minimize storm water run-off from parking lots; Catch, treat and infiltrate the storm-water locally.	

2.6 Storm Water Management - Decentralization to Combat Seasonal Flooding

There are three main steps for a decentralized natural storm water management system in urban roads/urban areas:

(i) **Catch, slow down, treat/infiltrate storm-water at source:** using permeable paving, bio-swales, bio-planters, and other such mechanisms.

(ii) **Direct excess storm-water to local detention areas:** utilizing nearby parks and depressed open areas to accommodate run-off

(iii) **Recharge and replenish local water-bodies as perennial reservoirs/ retention ponds**

Since roads are generally the lowest points of any urban area, they play a pivotal role in overall decentralized storm water management in urban areas.

In order to increase local ground water recharge and combat seasonal flooding of roads, decentralization of storm-water management needs to be integrated in roadway design. In conjunction with IRC SP:50-2013, various new aspects such as bio-swale planting with deeper kerbs, infiltration pits and edge details have been introduced in this manual – to catch, slow down, treat and infiltrate storm water locally, and increase local recharge and enable better flash-flood management.

In a standard system as shown in **Fig. 40**: Conventional approach - storm water flows directly into the structured drain, storm water and silt flows directly into the Storm Water drain, carrying all pollutants with it. Slope of Storm Water Pipe prevents drains from being used to full capacity. Drains convey this polluted storm water in the fastest possible manner to the nearest natural drain further polluting the latter. This method causes large amount of run-off and is detrimental to decentralized management and local infiltration.

In a decentralized system as shown in **Fig. 41**, storm water flows directly into a bio-filtration pit or bio-swale/planter system. Water is to be temporarily retained and infiltrated in the bio-swale and gradually conveyed to the nearest detention pond or conventional drain system. This allows storm water to be filtered and partly treated of pollutants before entering a natural water-body or ground water table.

For heavy rain situations, provision may be made to allow storm water to overflow into the existing S.W. Drain. In such cases, bio-filtration systems can connect to the Main Storm Water Drain – either in series (connected only at the end); or in parallel – i.e. each bio-swale bed overflows directly into the Storm Water drain, in case of heavy rainfall. The Parallel Connection option is preferable. Adding organic compost or mulch to soil improves its ability to support plants and absorb storm water, as healthy soil is the backbone of such natural drainage systems.

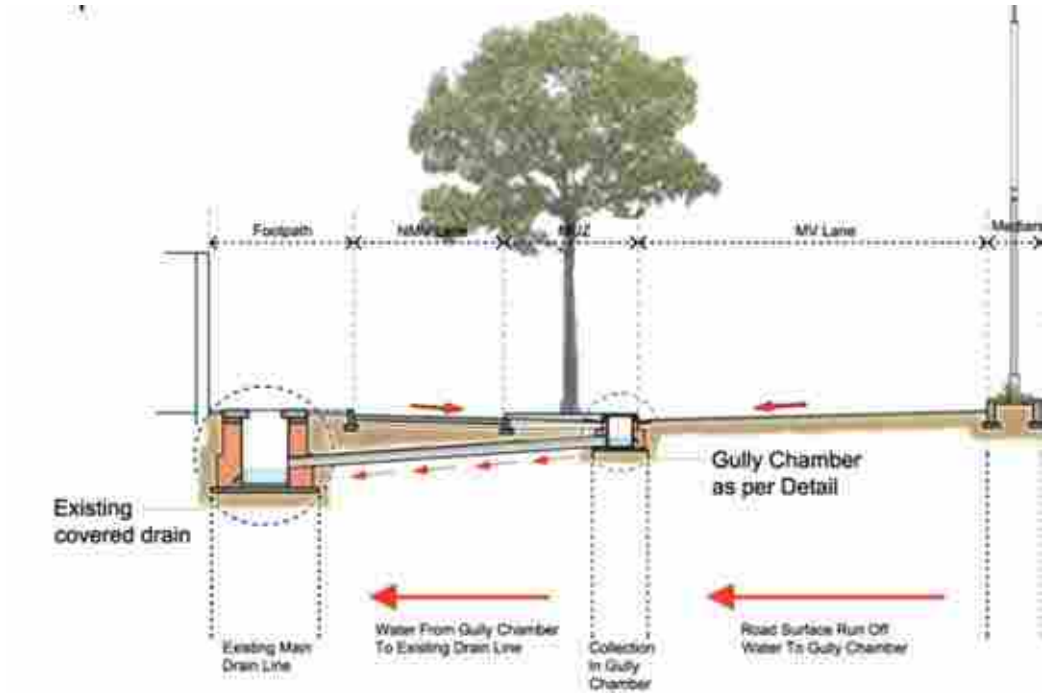


Fig. 40 Conventional Approach - Storm Water flows directly into the Structured Drain

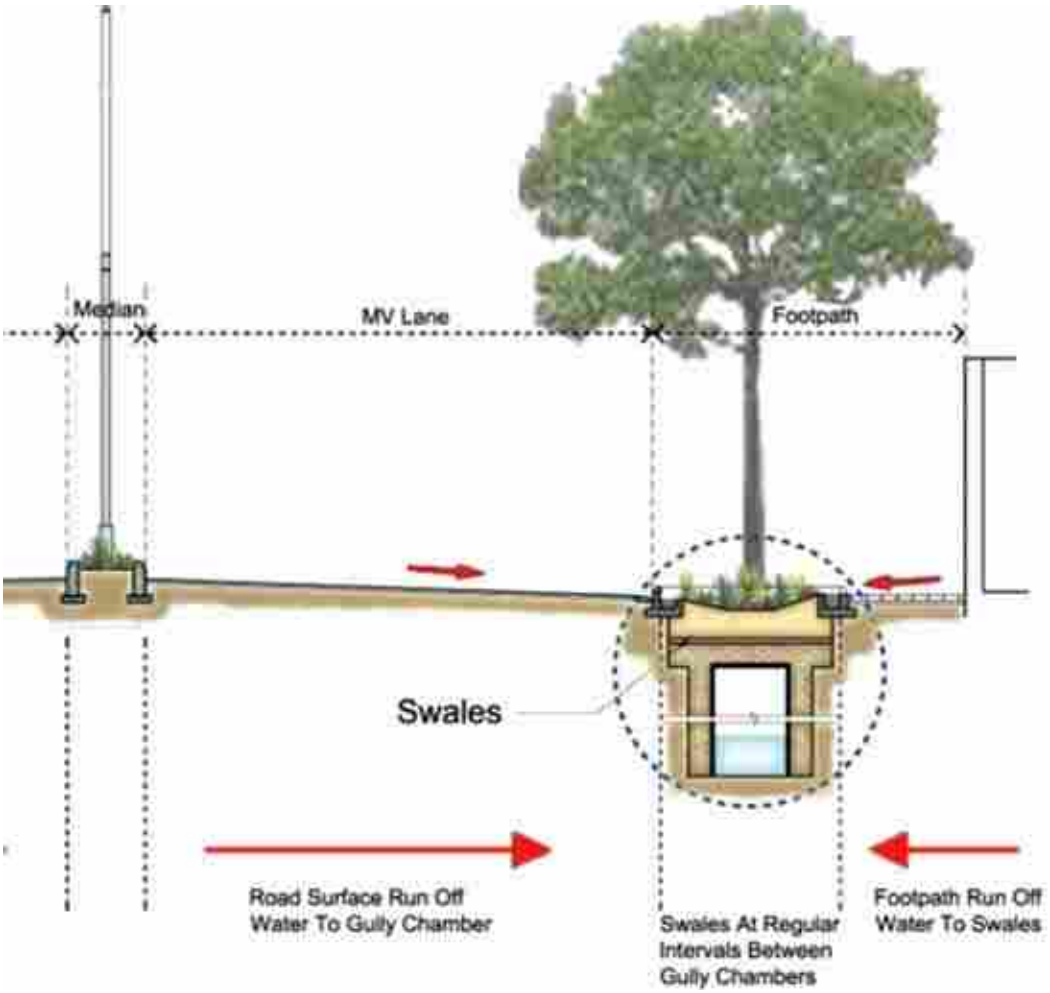


Fig. 41 MFZ with Tree Planting with an Integrated Bio-swale

In order to integrate the above strategies into city and roadway design, various techniques to improve storm-water management along roads are proposed, as follows:

2.6.1 *Bio-filtration systems within ROW:gravel filters/vegetated filters/green gutters/ permeable paving*

Gravel filter: is a depressed planter bed (below finished road level) which has an impervious bottom or is placed on an impervious surface and a filter basin or pit where gravel is used as the filter media to oxygenate or trap pollutants from water (**Fig. 42**). Pollutant reduction is achieved as/when the water gradually filters through the gravel and sand. Following are the guidelines for the same:

(i) Filters may be constructed in-ground with a waterproof lining.

(ii) Gravel filters can be used next to road kerb or foundation walls, adjacent to property lines (if less than 750 mm in height), or on slopes. An overflow to an approved conveyance and disposal method will be required.

(iii) Irrigation facilities to be given for non-monsoon season.

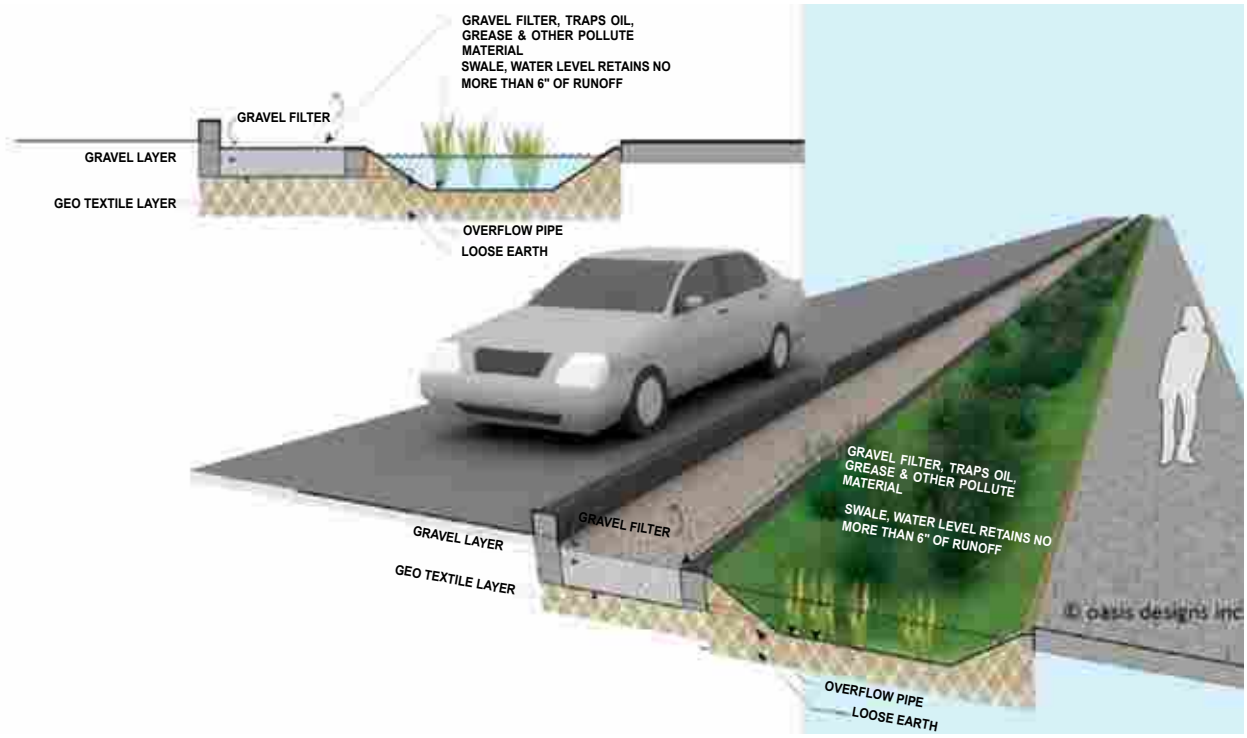


Fig. 42 Gravel Filter to deliver Water to Green Area within ROW

Vegetated Filter: is a filter basin or pit where roots of plants are the primary filter media to filter the water (**Fig. 43**). Following are the guidelines for the vegetated filter:

(i) Vegetated filter strips, or vegetated filters, are gently sloping areas used to filter, slow, and infiltrate storm-water flows. Storm-water enters the filter as sheet flow from an impervious surface. Flow control is achieved using the relatively large surface area, for slopes greater than 5 per cent check dams or berms shall be provided.

(ii) Pollutants are removed through filtration and sedimentation.

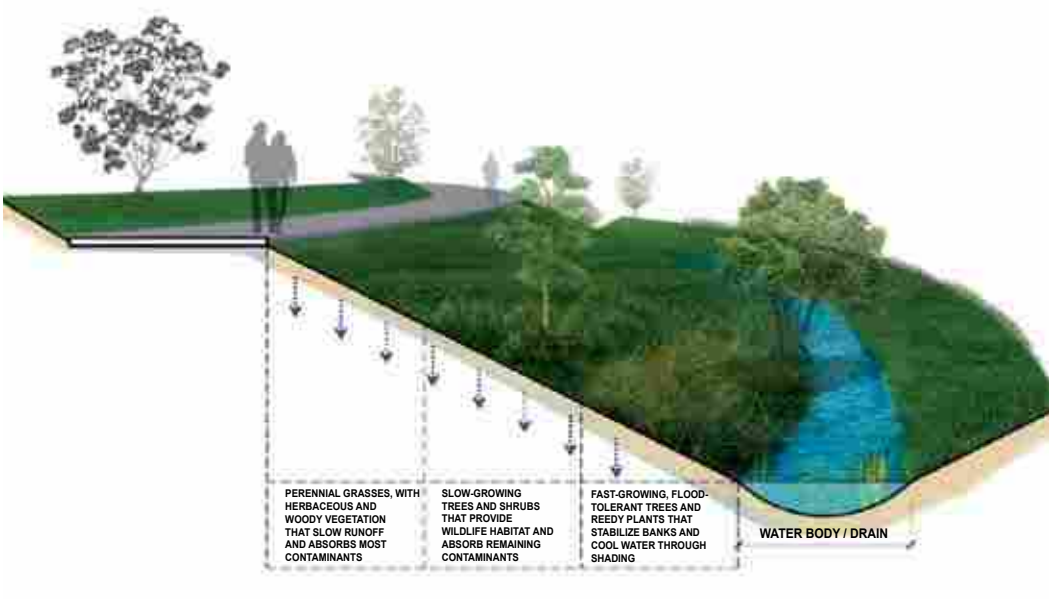


Fig. 43 Vegetated Filter in a Riparian Area next to ROW or within ROW

Permeable Pavement: is a paving system which allows the waterto percolate into an underlying soil or aggregate storage reservoir, where storm-water is stored and infiltrated to underlying subgrade, or removed by an overflow drainage system (**Fig. 44, 45**). Permeable pavements provide ground water recharge and reduce pollutants in storm-water runoff into rivers and nallahs.

(i) Permeable paving is most suitable for large paved areas e.g. within the Multi-Functional Zone, parking lots, driveway kerb-cuts, large plazas, hawker zones, etc. without heavy foot traffic or any fast vehicle movement.

(ii) The sub-grade of porous paving surfaces must be porous to a minimum depth of 150 mm in order to achieve the desired level of permeability.

(iii) A number of permeable materials are available for use: like, permeable asphalt, concrete, interlocking concrete block, open-celled paving grid, open-celled paving grid with gravel, as shown in **Table 3**.

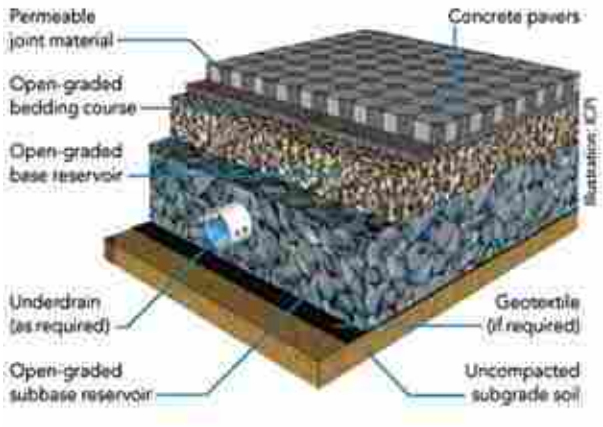


Fig. 44 Typical Section of Permeable Concrete Pavers

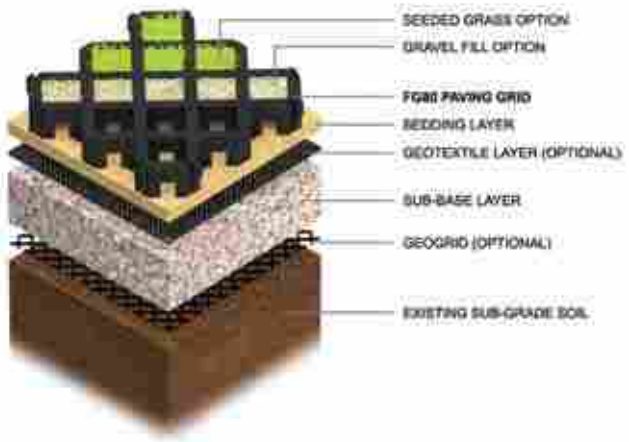


Fig. 45 Typical Section of Open Cell Pavers

Application and Design Considerations: In general, sites where pervious pavement will be installed needs to meet the following criteria:

(i) Soils need to have a permeability of at least 12 mm per hour.

(ii) Areas that have high potential for contamination such as transfer stations, gas stations, or highly industrial areas may not be suitable for permeable pavements due to the increased risk of ground water contamination (**Fig. 46**).

(iii) The bottom of the stone reservoir should be flat, so that runoff can infiltrate through the entire surface.

(iv) The seasonal high water-table should be at least 1 m below grade.

(v) It should be installed at least 30 m away from drinking water wells.

(vi) Pervious pavements should not be used in areas with a slope >15%, as erosion of the fill material may occur. **Table 3** explains materials for pervious pavements.

Fig. 46 Example of Permeable Paving used within the Parking Area within MFZ

Table 3 Table for Selection of Permeable Pavers

Permeable Asphalt	Permeable Concrete	Interlocking concrete pavers	Open-celled paving grid with vegetation	Open-celled paving grid with gravel
				

Permeable Asphalt	Permeable Concrete	Interlocking concrete pavers	Open-celled paving grid with vegetation	Open-celled paving grid with gravel
Fundamentally the same as regular asphalt, but it does not contain the fine particles that asphalt does, hence, creating porosity. • It needs to be cleaned 2 to 4 times a year to avoid buildup of debris. • It does not require special training and can easily be supplied by conventional asphalt batch plants	This is a variation of traditional concrete, but without the fine particles in the mix. • Installation is quite different from the traditional method, and requires experienced installers both in the mixing and laying of the product. • Proper maintenance includes periodic vacuuming of the surface to prevent clogging with sediment or organic material.	Themselves are not always permeable, but they are typically installed with gaps between them to allow infiltration into the subsurface. The gaps, typically 10% of the surface area, are filled with a permeable material, usually small clean stone. • They have a long useable life, are relatively easy to install and provide good infiltration. • However, they are sensitive to deformation in the base and do require a thick base to prevent "heaving."	Open-celled paving grids consist of a rigid grid composed of concrete or a durable plastic that is filled with a mix of sand, gravel, and topsoil for planting vegetation. • The plastic grid pavers are also flexible, allowing them to be used on uneven sites. • They do not require another drainage facility and are competitively priced to asphalt and concrete paving, when their required drainage costs are factored in.	The same open-celled grid structure is employed but the voids in the rings are filled with a mix of gravel. • With the gravel in place this grid system does provide additional structural support. And since most gridcell material is plastic, hence flexible, it can adapt well to shrink/swell and freeze/thaw conditions.

Percolation/Infiltration Pit and Trench: A percolation or infiltration pit is a confined pit dug into the ground that receives rain water (storm water) and through filtration media, delivers water into the sub-soil for percolation and infiltration. A percolation pit stretched over a long distance, is termed as a percolation trench (**Fig. 49**). Percolation pits and trenches have a pervious bottom and allow water to seep through into the sub-soil through filter media. **Fig. 47** below shows a typical Percolation pit and **Fig. 50** shows the construction detail of trench.

Percolation pits/trenches should be made as an integral part of plaza and public space designs to help infiltrate rain water, recharge ground water - thereby reduce run-off and seasonal flooding. The area around the pits can be landscaped as shown in **Fig. 45** below. Existing storm water drains can be retrofitted to receive overflow into the infiltration trenches, as shown in **Fig. 48**.

Fig. 47 Percolation/Infiltration Trench in the Median. (Right) A Typical Percolation Pit Detail

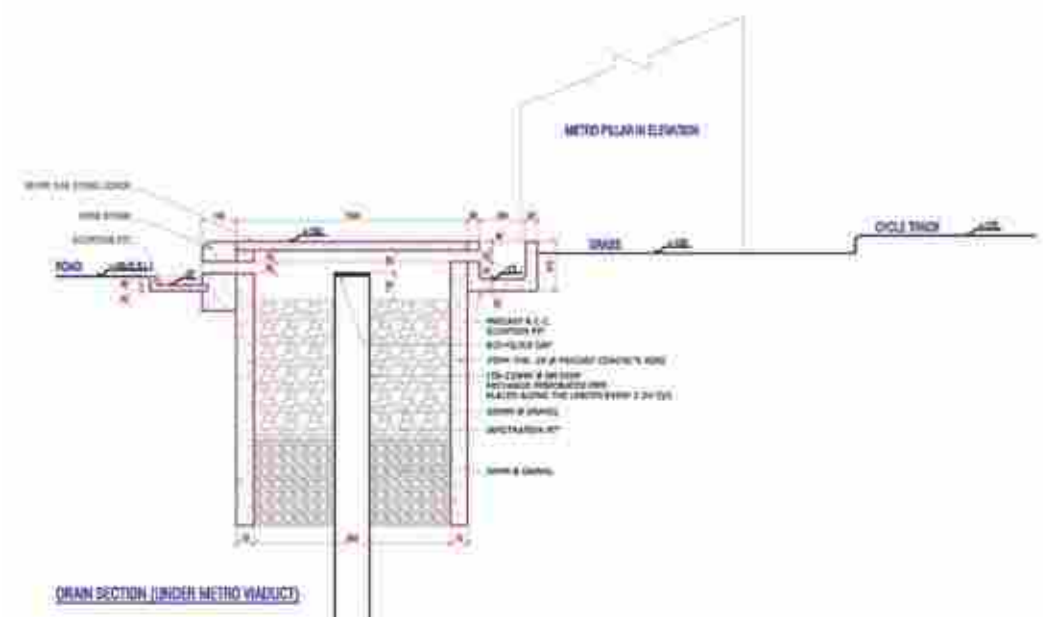


Fig. 48 Detail of the Percolation/Infiltration Trench

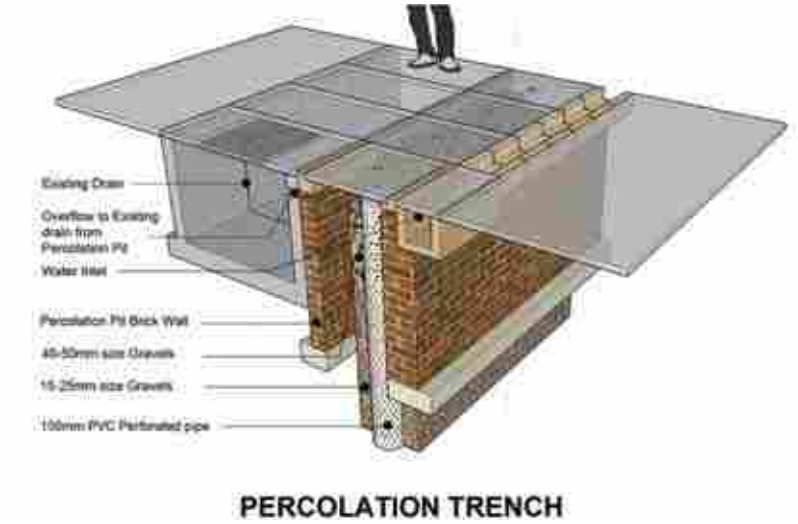


Fig. 49 View of a typical Percolation Trench

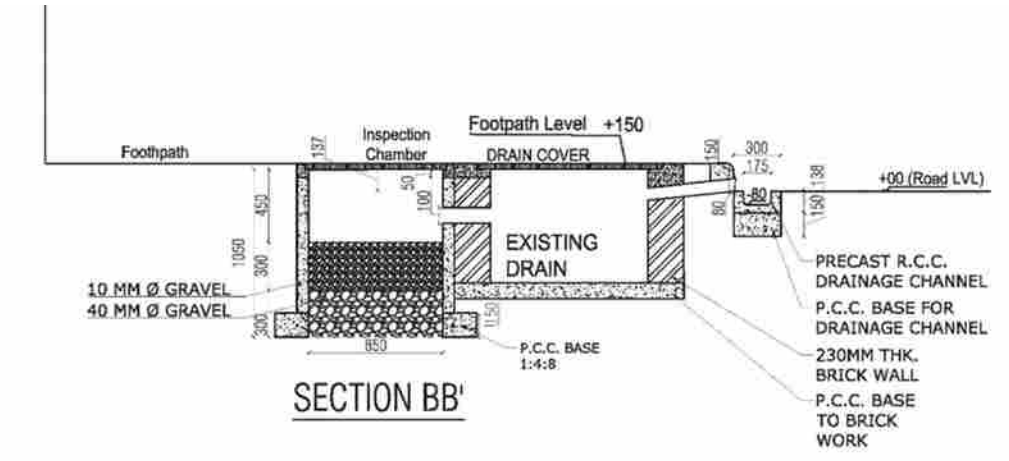


Fig. 50 Figure showing Retrofitting of Existing Drain with Percolation Trench

2.6.2 *Conveyance: through bio-swales and planters, green gutters.*

Bio-swales are landscaped shallow troughs comprised of natural materials such as native plants, rocks and soil, which is used as an alternative form of water drainage that filters and absorbs polluted water (**Fig. 51, 52**)

- A bio-swale uses bio-filtration media such as gravel, plantation, geo-textiles, etc. to filter pollutants, soak excess run-off thus reducing its volume and modulating the peak runoff rate. They are also adequately sloped towards a detention or detention area or a structures system, so as to facilitate gradual conveyance of excess runoff.
- A bio-swale has natural edges which are retained through appropriate plantation and slope stabilization measures.
- Bio-swales are particularly suitable for areas with low water table and absorbent/ permeable soil types.
- Suggestive plant selection table for bio-swales is given at **Table 12.**

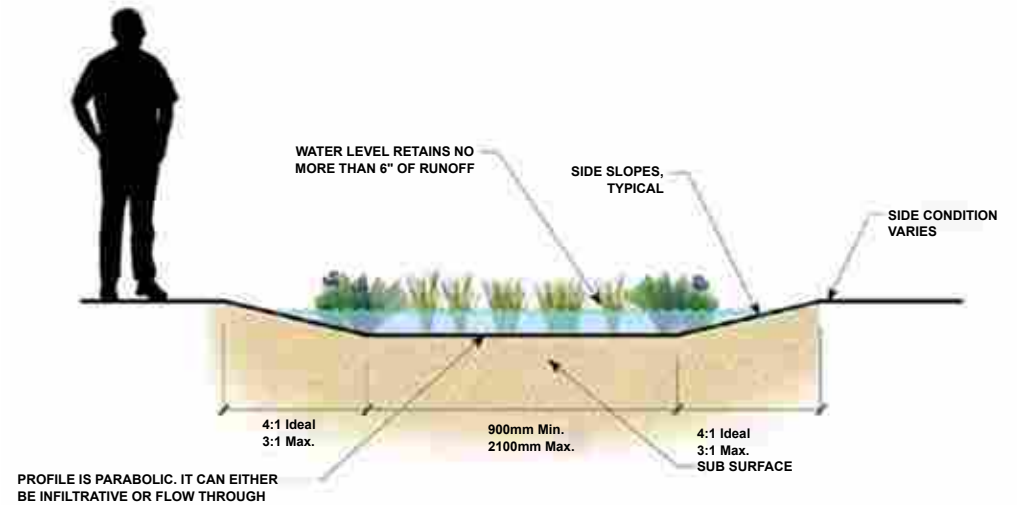


Fig. 51 Bio-swale

Fig. 52 Examples of Bio-swales along Roads

Following are the guidelines for the bio-swales:

(i) The bio swale typically has water tolerant vegetation permanently growing in the retained body of water. It uses biological process to remove a variety of pollutants;

(ii) Provides storm water treatment and conveyance;

(iii) Can be part of infrastructure within transportation ROW, can be an aesthetic feature;

(iv) Check dams, weirs, or stepped cells need to be used in areas with steep slopes.

Bio-Planters are structured landscaped reservoirs filled and planted with natural materials such as native plants, rocks and soil, etc. used to collect, filter, and infiltrate storm-water runoff. They allow pollutants to settle and filter out as the water percolates through the planter soil and infiltrates into the ground, or gets conveyed to the nearest detention/retention area, as shown in **Figs. 53-54**.

Following are the guidelines for the bio-planters:

- A bio-planter shave structured edges such as in concrete/brick/stone/etc. so as to retain the subgrade on the outer edges as well as retaining storm-water;
- Bio-planters can be of two types – **Infiltration bio-planters** (as shown in **Fig. 53**) are suitable for areas with low water table and absorbent/permeable soil types; while **Flow-through bio-planters** (as shown in **Fig. 54**) are particularly suitable for areas with high water table and clayey/non-permeable soil types;
- In road retrofitting projects; bio-planters can be created within existing storm-water drains, to create infiltration facilities within the same area.
- Flow rates and volumes can also be managed with adequate sloping of infiltration planters.

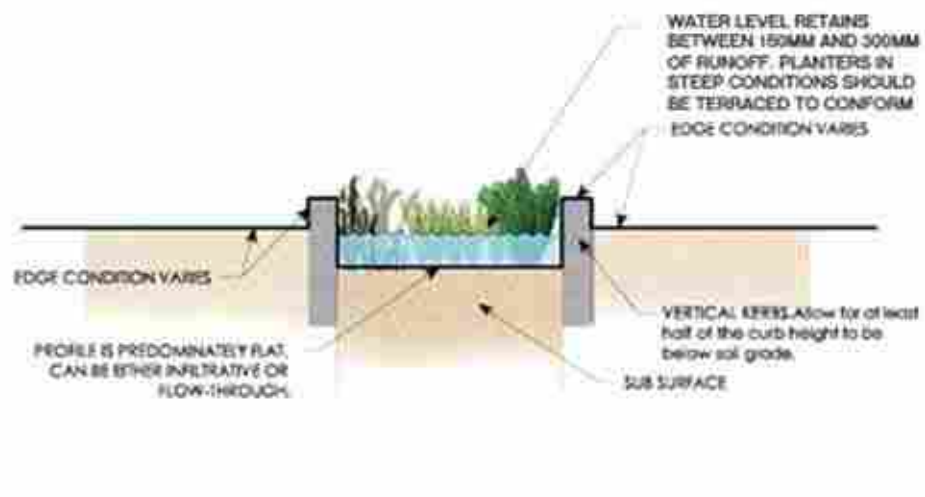


Fig. 53 Infiltration Bio-planters

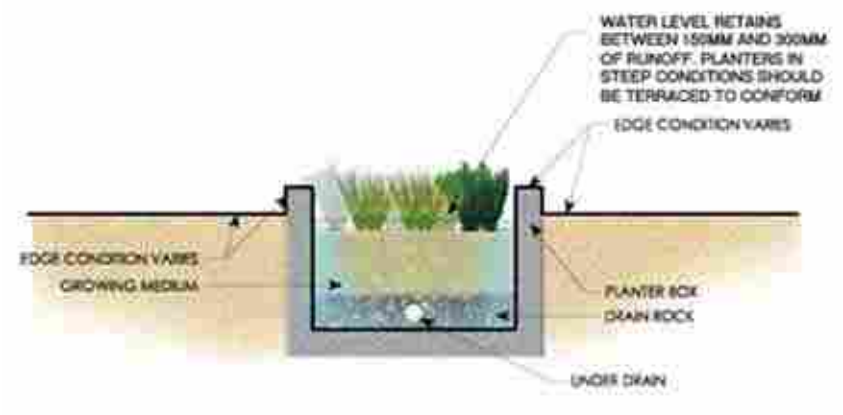


Fig. 54 Flow-through Bio-planters

Green gutters are narrow strip of green along the walkway or road edge that traps pollutants and delivers good water to sub soil surfaces. These being narrow have lower efficiency to clarify water.

They should be long and continuous to effectively filter pollutants, as shown in **Figs. 55-56**.

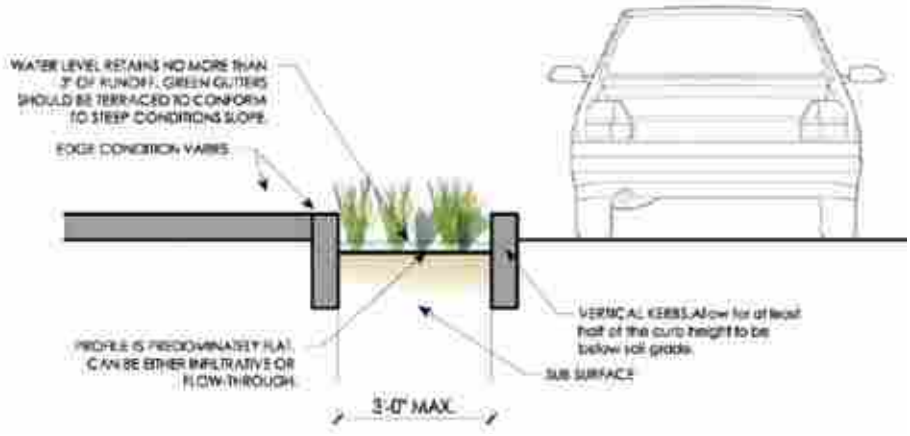


Fig. 55 Green Gutters

Fig. 56 Existing and Proposed: Green Gutters, although Narrow, can increase Infiltration

Fig. 57 The pictures above show few Typical Bio-planters with Reeds and other Plantation as per Table 12

Special Kerbs: Since bio-filtration beds would require deeper pits and planters within the MFZ, deeper kerbs with openings, as shown in **Fig. 58**, would be required to allow storm-water to flow into the planted beds while protecting the sub-grade of the footpaths and carriageways. Details of several such kerb types available are provided in **Fig. 57**: Kerbs with cuts can help storm water reach infiltration pits and bio-swales and in Section 3.

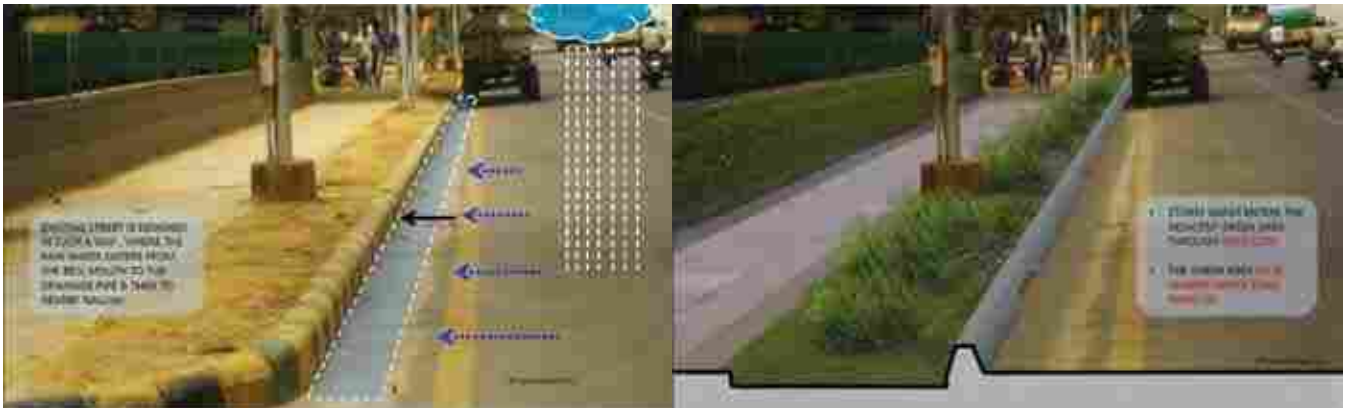


Fig. 58 Existing and Desirable Condition showing Modified Kerb Cuts which allow Storm-Water to Flow into the Bio-filtration Beds

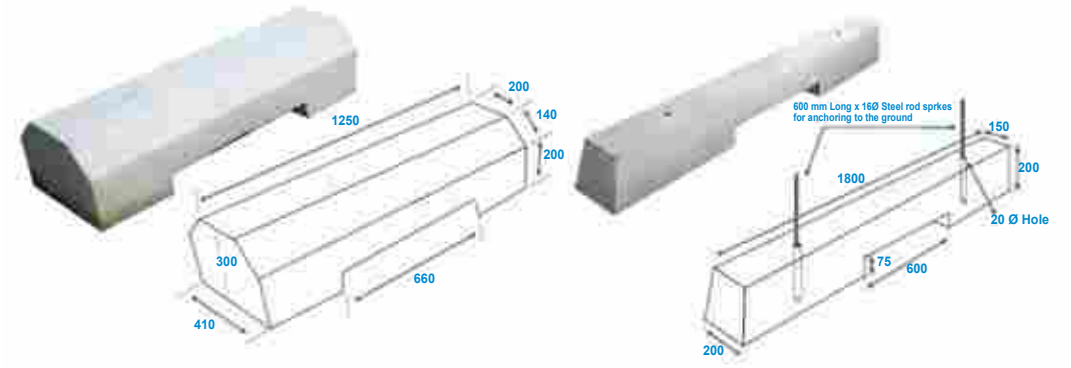


Fig. 59 Kerbs with Cuts can help Storm Water reach Infiltration Pits and Bio-swales

All planted bio-filtration systems such as bio-swales/bio-planters/green-gutters can also play a major role in reducing heat-island effect and preventing dust re-suspension within the ROW and are therefore multi-functional features which are also aesthetically pleasing. There are various locations within the ROW where such features can be incorporated (refer **Fig. 59**).

Fig. 60 Areas that could be used for Localized Storm Water Management on Roads: include Roadside Planting Strips (MFZ), Landscaped Medians, Underside of Flyovers and Viaducts, etc.

2.6.3 *Detention and retention structures – detention ponds, constructed wetlands, underground water tanks or rainwater harvesting structures*

Detention systems are primarily designed to store storm water temporarily and then release it gradually. The primary purpose of detention basins is to control storm-water runoff.

(i) Storage capacity is dependent on available site area.
(ii) Regular maintenance of vegetation and sediment removal required.
(iii) Suitable for relatively impermeable soils or impermeable filter media.

Retention systems, on the other hand, can store water for a longer duration or be always filled with storm water. It's ideal for handling large volumes of storm water runoff, recharge it and moderate peak infiltration rate. In case of high-water table, the wetlands may require de-watering.

(i) Flexible in size and filtration.
(ii) Higher maintenance until vegetation is established.
(iii) Limited impervious drainage area.

Detention ponds are temporary holding areas for storm water that store peak flows and slowly release them, reducing the demand on treatment facilities during storm events and preventing

flooding (**Fig. 61**).

(i) Detention ponds are designed to fill and empty within 48 hours of a rain fall and could reduce peak flows and runoff volumes. They can be used to provide flood control by including additional flood detention storage.

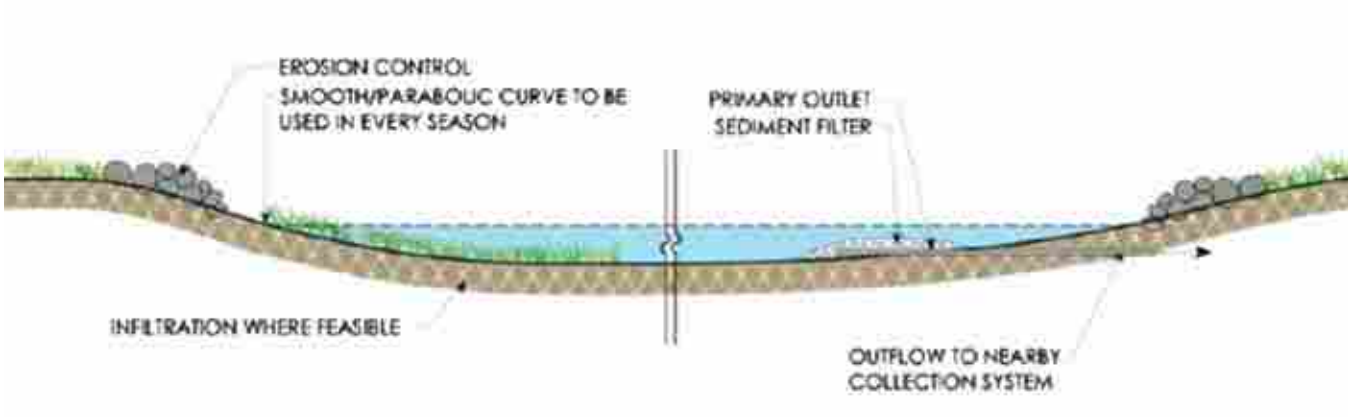


Fig. 61 Typical Detention Pond

Dry swales are simple drainage and grassed channels that primarily served to transport storm water runoff away from roadways and rights-of-way (**Fig. 62**).

(ii) This provides both quantity (volume) and quality control by facilitating storm water detention.

(iii) Dry swales are used at low density residential projects or for very small impervious areas.

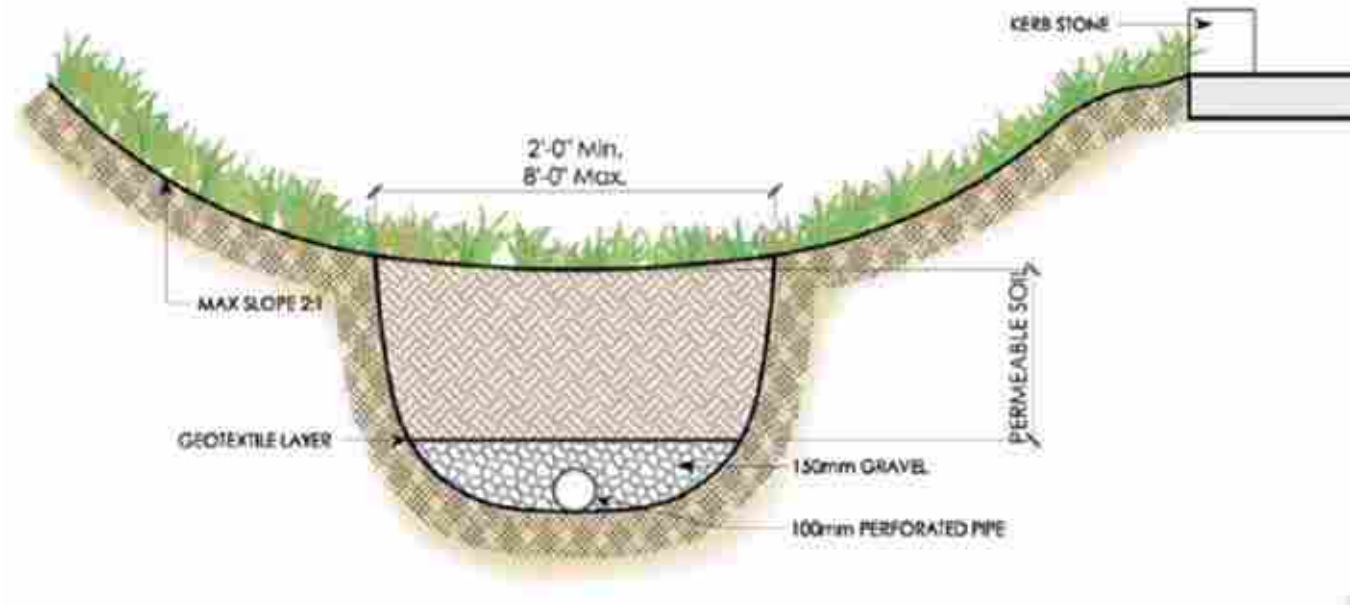


Fig. 62 Dry Swales

Retention ponds maintain a permanent pool of water in addition to temporarily detaining storm water. These ponds fill with storm water and release most of it over of a few days, slowly returning to its normal depth of water (**Fig. 63**).

(iv) As these have to maintain a permanent pool, they can't be constructed in areas with insufficient precipitation or highly permeable soils.

(v) Retention ponds can have aquatic habitat if properly planted and maintained. Regular cleaning and maintenance is needed to ensure proper drainage.

(vi) Areas of possible application: Unused open areas, maidens. Open spaces in the city parks.

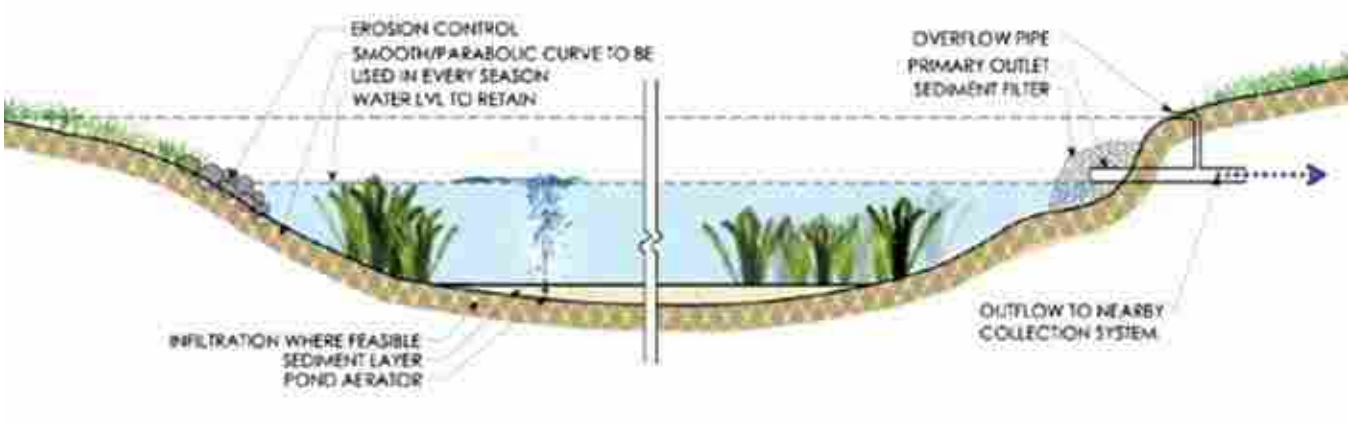


Fig. 63 Typical Retention Pond

Constructed wetlands are shallow, man-made pool with vegetated systems designed to provide storm water retention and pollutant removal. Can be designed for enhanced nitrogen removal by creating aerobic and anaerobic zones (**Fig. 64**).

(vii) Reduces runoff temperature

(viii) Creates habitat. Plants and wetland helps to reduce storm water speed and allows sediment to settle out. These can be applied to the areas those were wetland once or low line areas of any site.

These are different from retention ponds in their shallower depths and large vegetation coverage.

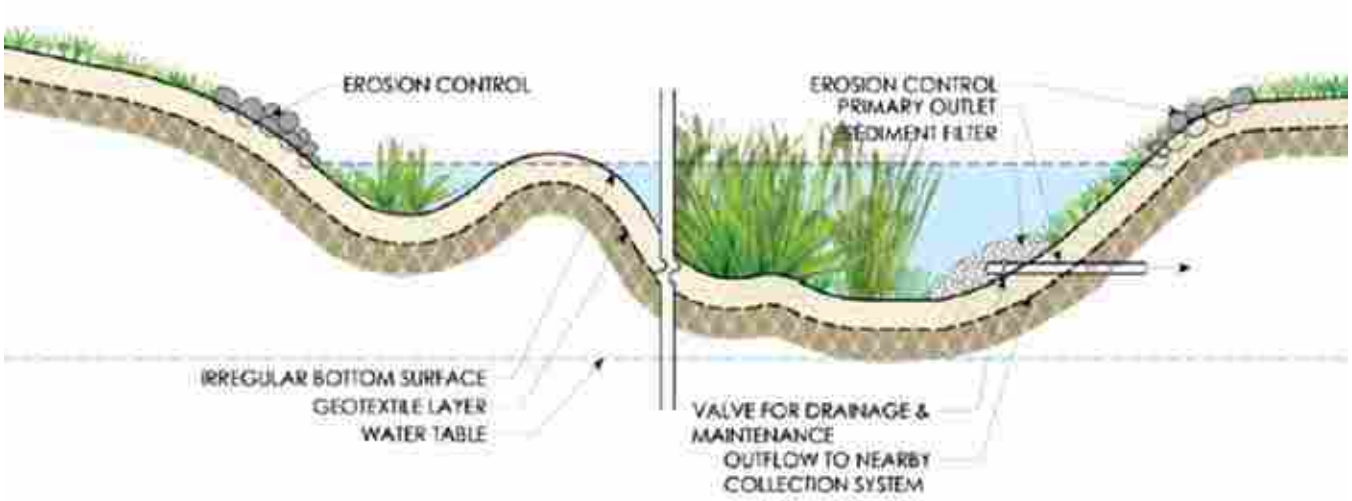


Fig. 64 Constructed Wetlands

2.6.4 *Infiltration: through infiltration trench or basin, rain gardens, etc.*

Infiltration system are natural or constructed land areas located in permeable soils that capture, store, and infiltrate the volume of storm-water runoff into surrounding soil.

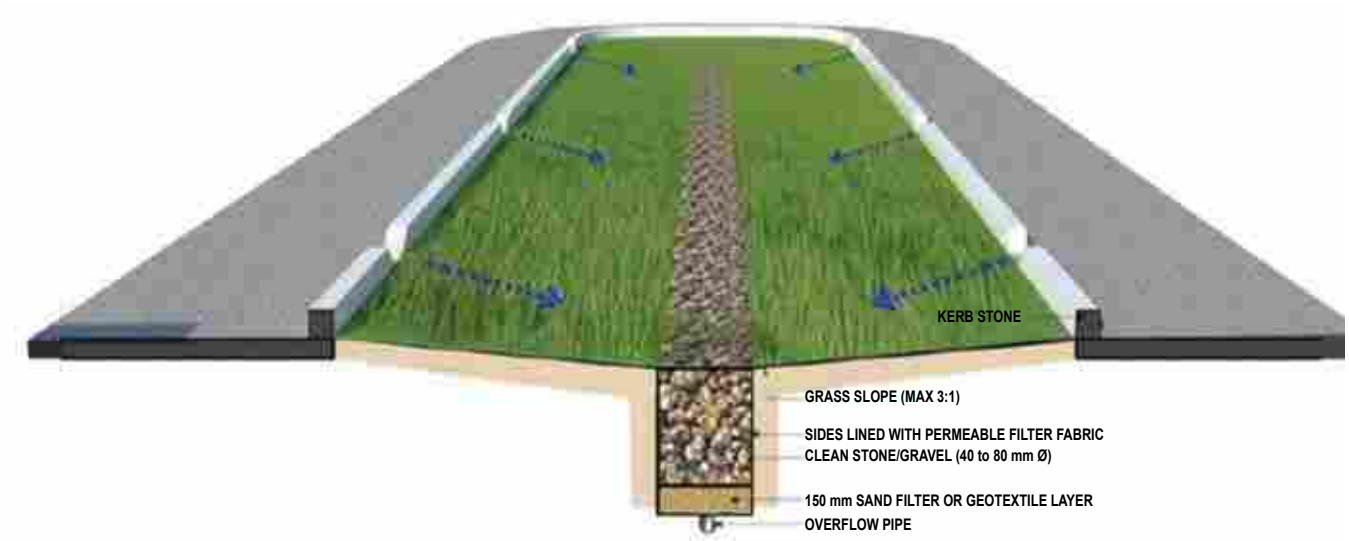


Fig. 65 Infiltration Trench

Infiltration trenches help storm water infiltrate the sub-soil slowly.Storm-water runoff is diverted to the trench and stored until it infiltrates, usually over several days (**Fig. 65**).

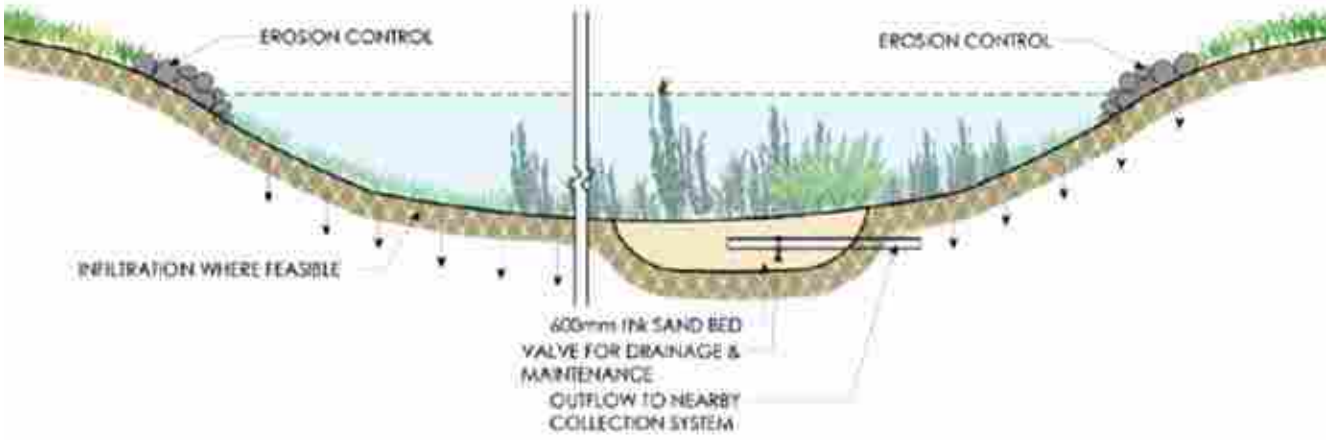


Fig. 66 Infiltration Basin

An **infiltration basin** is a shallow pond over permeable soil that captures storm water, stores it, and allows it to infiltrate, using the natural filtering ability of the soil to remove storm water pollutants (**Fig. 66**).

(i) A vegetated swale, before the basin, can help to stop coarse sediments and soil to enter the basin, thereby increasing its longevity and reducing maintenance costs.

(ii) Deep-rooted plants on the basin's bottom reduce the risk of clogging and increase infiltration capacity by creating small conduits through which water can infiltrate.

(iii) Existing drains can also be retrofitted with infiltration trenches, as shown in **Fig. 67**.

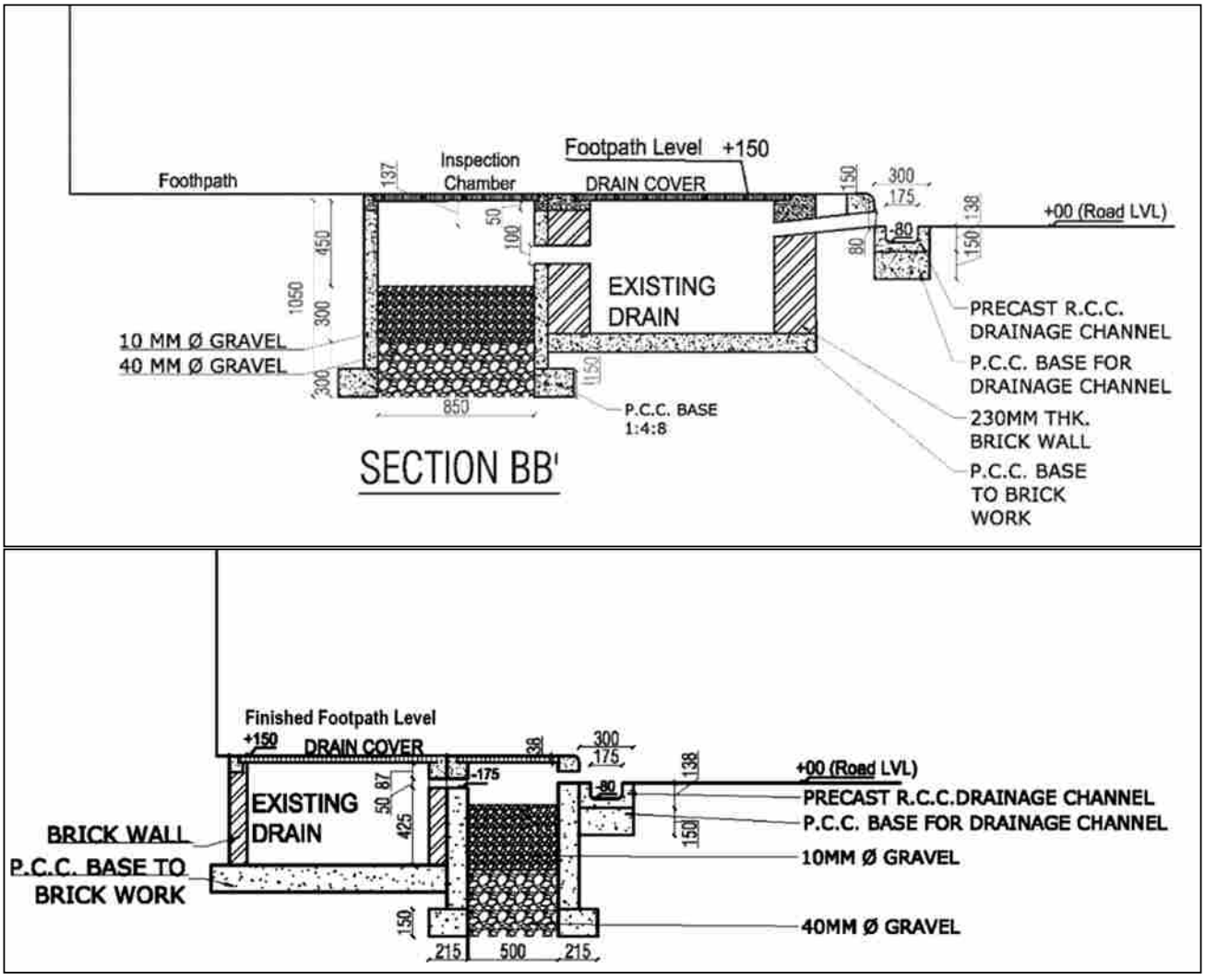


Fig. 67 Illustrations of how Existing Drains can be Retrofitted with Infiltration Units

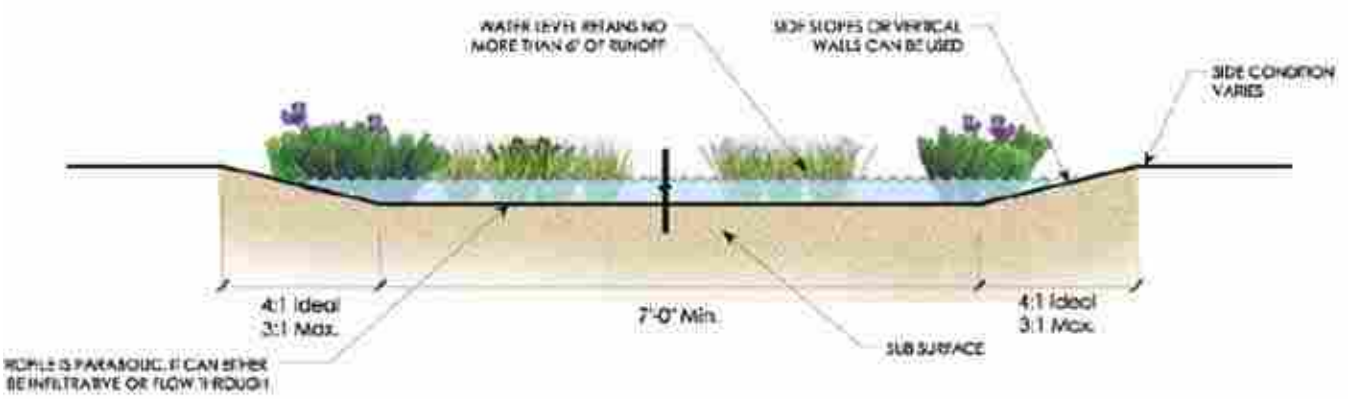


Fig. 68 Rain Garden

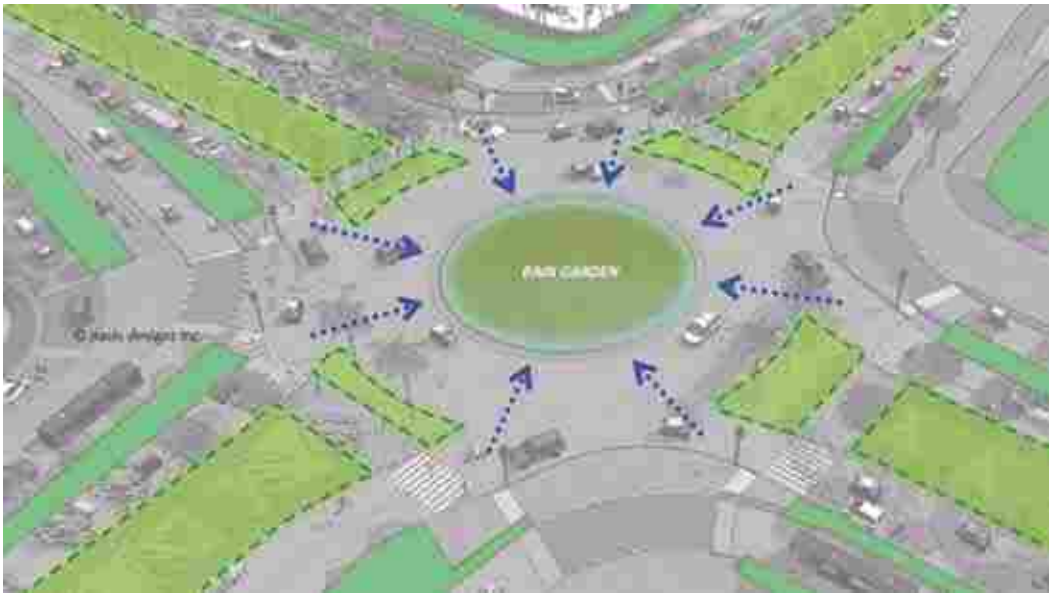


Fig. 69 Rain Gardens can be Integrated into Roundabouts

Rain gardens retain storm water, thereby reducing flow rate and volume of run off.They can also allow for infiltration, depending on the capacity of native soil, as shown in **Figs. 68–70**.

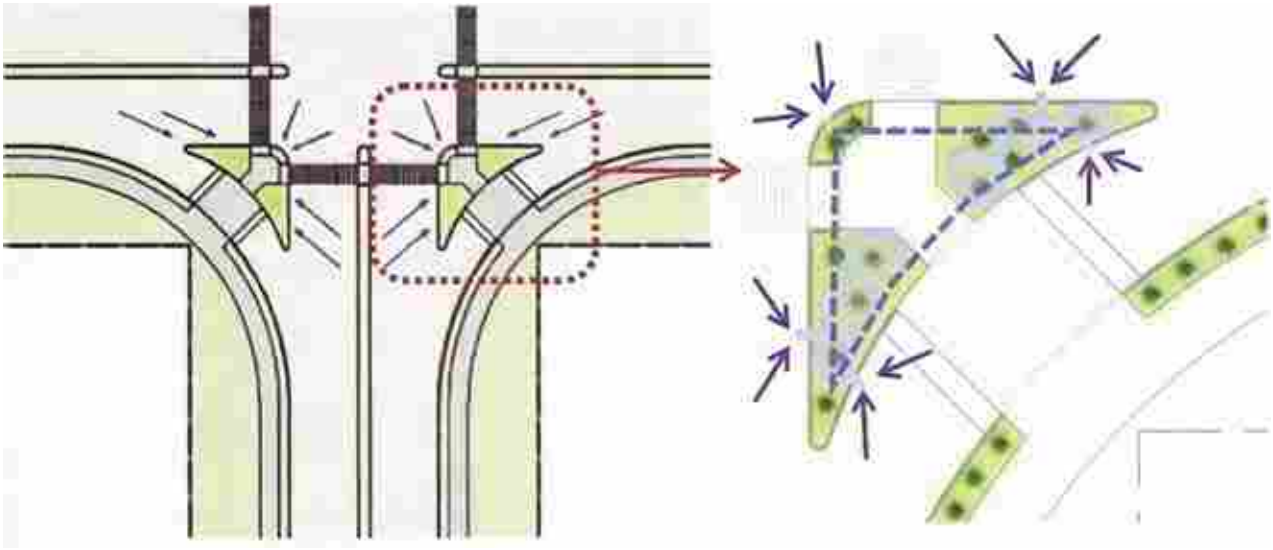


Fig. 70 Rain Gardens can be Integrated into Traffic Islands through Kerb Cuts

2.7 Functional Design

This Section provides guidance on what plantation type may be selected for performing various contextual functions along a street, based on the surrounding context in which the roadway/ street is located.

2.7.1 *Street design near retail/commercial frontages (requiring shade with visibility)*

(i) High branching trees should be preferred allowing visual transparency till at least first floor level (**Fig. 71**). Trees to be pruned regularly to maintain visual

transparency, in addition to providing adequate shade for comfort of pedestrians, as shown in **Fig. 72**. Low foliage density preferable. Deciduous preferable (in areas with seasonal variation).

Fig. 71 Continuous Planting Zones within MFZ are suitable where High-Speed Traffic is expected in off-peak hours and Pedestrians need to be contained within the Walking Zone.

Fig. 72 In Retail/Commercial Areas, MFZ should have trees in Tree-Guards (and not continuous planting strips) – to allow more Space for Pedestrians to walk over, as well as flexibility to disembark from various modes near the Kerb-Edge.

(ii) Spaces between trees to have sitting areas, amenities, utilities, lighting, parking, pick-up drop-off points, etc. within the Multi-Functional Zone (MFZ).

Fig. 73 Bus-Stops, Toilets, Drinking Water Stations, Hawking Zones and other Public Utilities should have Trees on both sides to provide maximum comfort and shade.

2.7.2 *Near high-density residential frontages*

High density residential frontages require dense tree plantation to provide shade and comfort to local pedestrians as well as walkers, children, people of all ages. A well shaded and well-designed street fosters community interaction and helps build resilient cities, (**Fig. 74**). Residential streets could be programmed with various types of activities like children play areas, chess-tables, play-courts; hawker plazas, etc. as shown in **Fig. 75** below.

Fig. 74 Kids playing on the Road in a Residential Colony lacking proper Facilities

Fig. 75 Well-designed Interactive Public Space along Carter Road Promenade in Mumbai

2.7.3. *Noise and view cutters*
(near schools, hospitals, low-density residential frontages)

Residential edges may have more than one row of trees to act as view cutters from the main carriageway, as shown in **Fig. 76**. Trees in parallel rows should alternate to provide maximum shade. Mixed plantation – high and low branching is preferred, to provide both shade and privacy. Fruit trees near residential edges that attract birds and provide food, are preferable. Local storm water should drain into the landscaped MFZ or landscaped pits. Soil should not remain exposed at any time in the pits.

Fig. 76 Noise and view cutting Plantation next to Buildings

Trees like Pongamia sp.. Acacia auriculiformis, Plumeria species and Gravillea robusta; tall shrubs like Casia biflora, hamelia patens etc. are appropriate for visual and noise screening.

2.7.4 *Water edges providing public access*

(i) Water edges should be planted with buffer plantation that holds the soil near the water edge, about 1 m high. Slopes should be stabilized with ground covers and shrubs that hold the soil. Plants to be planted close to each other at 30 cm apart. Prefer shrubs that can take submergence.

(ii) Promenades to have accent trees/specimen plantation of avenues or single trees to provide visual delight and comfort – drooping leaves trees appear attractive. (**Fig. 77**)

(iii) High branching shade giving plants with a mix of species shall provide for bio-diverse region along the water body.

Fig. 77 Promenade along the Water Edge. Shown above, Hussain Sagar Lake, Hyderabad

2.7.5 *Response air pollution mitigation (near industrial areas, busy arterials)*

Industrialized areas, places of critical bio-diversity and schools and hospitals require dust prevention, noise mitigation and pollution mitigation, which is achieved through dense buffer plantation.

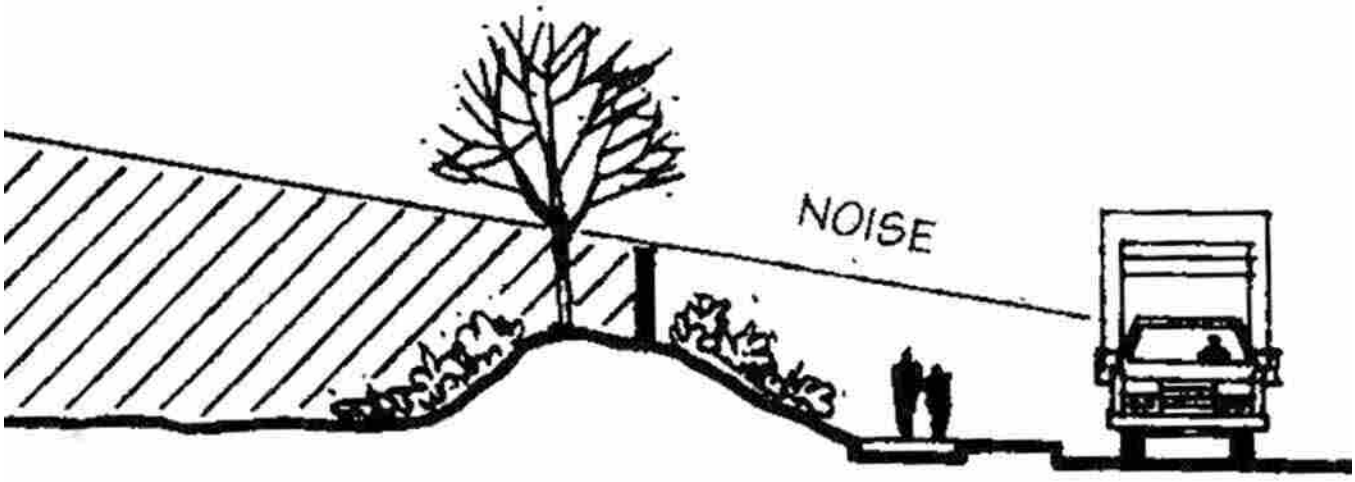


Fig. 78 Planting Typology to Mitigate Air and Noise Pollution

(i) Buffer to consist of at least two rows of plantation, 6 m apart with trees of various heights. First row to consist of high branching, high canopy trees with small leaves to help trap pollution and dust, as shown in **Fig. 78**.

(ii) Second row to be medium to high trees with dense foliage to prevent noise and pollution. Lower-storey plantation by high shrubs can further screen and prevent noise but should be avoided for reasons of safety. Prefer shrubs that offer some visual transparency.

(iii) Native species with low water use is preferable.

Neem (Azadirachta Indica), Mango (Mangifera Indica), Shisham (Dalbergia Sisso), Imli (Tamarindus Indica), Karanj (Pongamia sp.), and some flowering trees like Amaltas, Gulmohar, Kachnar etc. are good for filtering air from pollutants, and act as noise barrier.

2.7.6 *Odour mitigation:* e.g. near Sewage treat Plants, drains, landfill sites, cremation grounds/factories/industrial sites, etc.

(i) Buffer plantation can be used with aromatic plants having inflorescence that attract birds and bees.

(ii) Aromatic flowering plants should be planted in multiple layers, with the medium height shrubs having aromatic inflorescence nearest to the walking zone/ pedestrian areas, as shown in **Fig. 79**.

(iii) **Table 4** provides a suggestive list of aromatic plants that may be used.

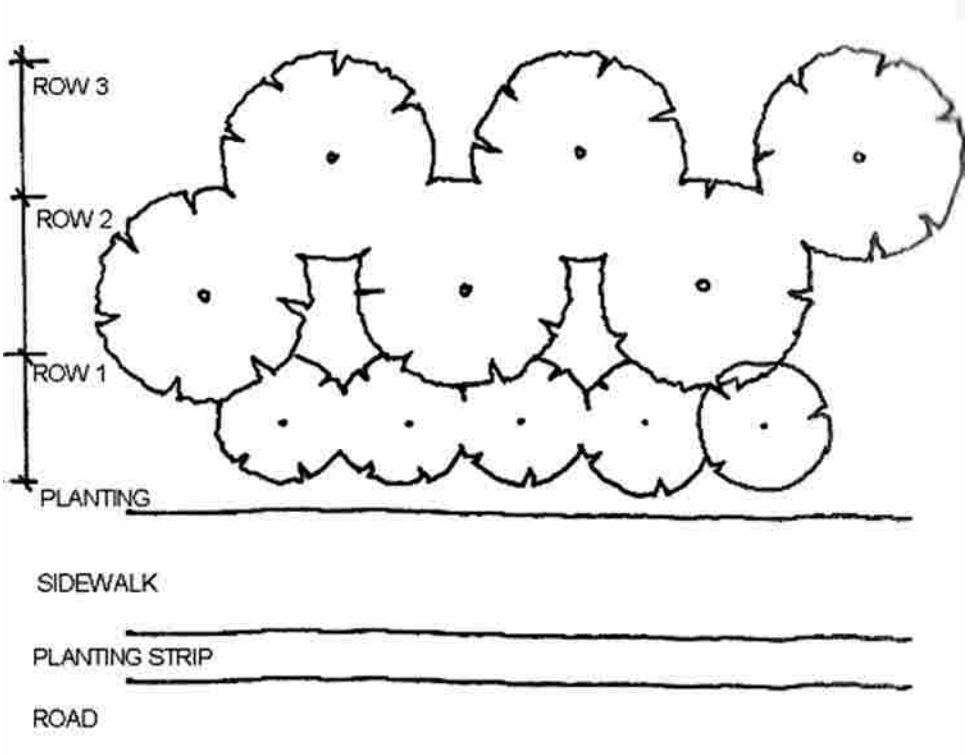


Fig. 79 Planting Typology for Odour Mitigation

Table 4 Palette of Aromatic Plants

Golden Champa – Michalia Champaca

Magnolia

Plumeria rubra

Plumeria alba

Citrus sinensis

Citrus limetta

Tabernaemontana CORONARIA

Jasmine walk

Clerodendrum fragrans

MurrayaExotica

Gardenia jasminoides

Jasminum rubescens

Clemati

Jasminum pubscence

Jasminum samb

Scented creeper garden

Cestrum Nocturnum

Spider lily

White & Pink Lily

Pandanus

Rajnigandha

Lavandula angustifolia 'Alba'

Lavandula angustifolia 'Munstead'

Lavandula 'Goodwin Greek Grey'

Lavandula intermedia 'Du Provence'

Lavandula spicca 'Rosea'

Lavandula intermedia 'Fred Boutin'

Lavandula X intermedia 'Alba'

lavandula intermedia 'Grosso'

Rosa hybrid- Red climbing rose

Rosa tea hybrid 'Orange Surprise'

Rosa 'Santana'

Rosa chinensis 'Mutabilis'

Rosa hybrid 'Wild Spice'

Rosa hybrid 'Glamis Castle'

Rosa hybrid 'Moondance'

Rosa hybrid 'Iceberg'

Rosa hybrid 'Strike It Rich'

Rosa hybrid 'Graham Thomas''

Rosa Grandiflora 'Honey Dijon'

Rosa hybrid 'Gypsy Dancer'

Rosa banksiae 'Lutea''

2.7.7 *Animal-grazing resistance*

Fig. 80 Planting near Junctions and on Medians should be resistant to Grazing

(i) Shrubs and groundcovers used may include thorny and non-toxic plants to repel stray animals and damage, particularly close to intersections and in long stretches and medians with no access. (**Fig. 80**)

(ii) Bougainvillea, Karonda, Didonia and Kaner are most popular and effective for preventing cattle from grazing on median and roadside shrub plantation.

2.7.8 *Prevention of jaywalking*

Dense plantation up to 1.5 m height may be planted all along the median to prevent jaywalking between the designated crossings. Grazing-resistant plantation such as Bougainvillea or Kaner can be used, with additional fencing if required, as shown in **Fig. 81**.

Fig. 81 Median Planting to prevent Jaywalking

2.7.9 *Low-water table and low-rain areas*
(plantation having zero irrigation requirements)

(i) Deep rooted plants/trees, trees with small leaves should be preferred.

(ii) Avoid ground covers and grasses in particular. Soil surface should be covered with mulch at all times to preserve humidity and to prevent dust.

2.7.10 *Water treating plants*

Details of Water-treating plants are given in **Table 12**.

2.7.11 *Bio-diversity areas, ecologically sensitive areas*

The plant selection should be based on the study of the current bio-diverse region and ecological areas where intervention needs to be made. The plants shall be strictly native and no foreign or exotic species should be planted. **Fig. 82** shows a bio-diverse region.

The following aspects should be considered:

(i) Plantation should meet with the existing hydrozone. Introduction of new hydrozones should be avoided.

(ii) Lighting has to be carefully planned.

(iii) For biologically diverse regions close to human habitation or urban areas, buffer regions should be planned such that urban activities can be contained to these regions and penetration of these activities into the bio-diverse regions avoided. These buffer regions should also be landscaped with native species and not exotic ones while also considering the activities planned in the zone – like trekking/camping, explorations, edible gardening, etc.

Fig. 82 Bio-Diverse Regions should be carefully planned with Native Species

2.7.12 *Areas affected with floods, storms and hurricanes*

(i) Trees be planted close to each other to form a shelter belt. Spacing should be less than 6 m c/c. Arrange trees in clusters than in rows.

(ii) Prefer trees that have small and thin leaves, do not prefer large leaved trees.

(iii) Deep rooted trees should be preferred. Prefer slow growing native trees as they weather the storm best, as evident from **Fig. 83** below.

(iv) For uprooted trees, stakes should be provided from at least 3 directions, for proper guying of the tree till the tree is re-established.

(v) As far as possible, trees should not be metaled close to its trunk. A tree pit diameter or pit size should be maintained for proper watering of the tree. It helps the tree in holding onto the soil and withstanding wind and water pressures.

Fig. 83 Deep Rooted Plants Weather the Storm better than Shallow Rooted Ones

2.7.13 *Roads in water-logged and/or sandy areas*

(i) Species shall be selected based on local conditions in the region where the plants that can take submergence easily and that can stand the same for long periods of time.

(ii) Various varieties of grasses and legumes are ideal for such conditions which have the capability to survive long submergence rates while also have the ability to clarify water.

(iii) Water loving trees can also be planted like Salix, Tamarix and Barringtonia. These trees transpire huge amounts of water and therefore maintain their growth.

(iv) In areas of high salinity/alkalinity/sodicity, the plants selected should have tubular root systems.

(v) T. Arjuna, Jamun, Eucalyptus, Bamboo and tall local grasses are usually recommended for waterlogged areas.

2.7.14 *Roads in hilly areas*

Minimize disturbance by retaining natural topography, with a balance of cut and fill or cut in areas of unstable slopes. Avoid grading under the drip-line of trees. During construction, top soil should be stripped and stockpiled for later use at the time of planting.

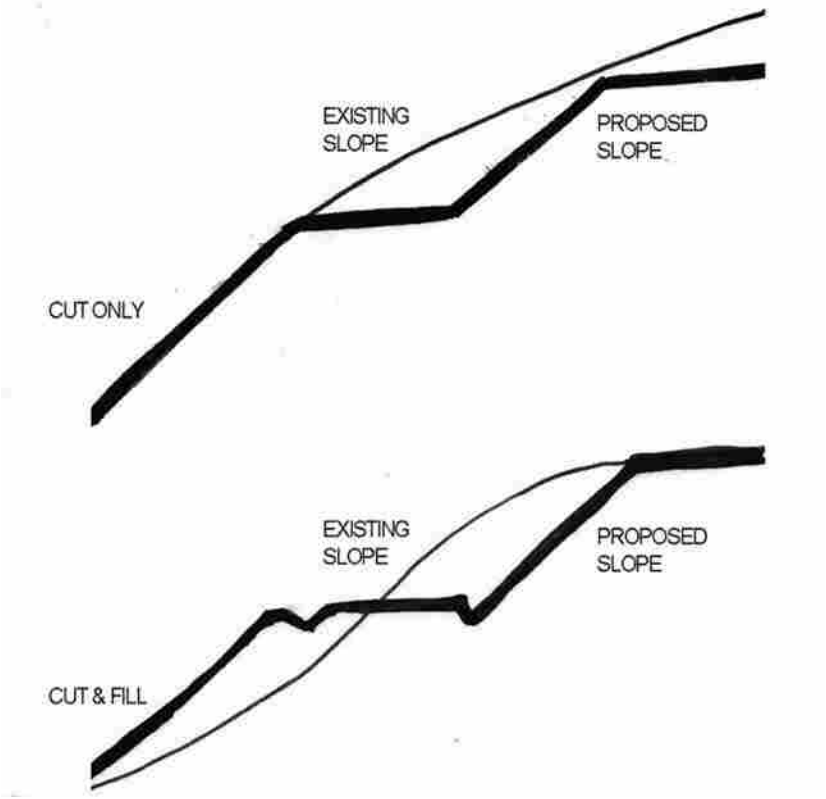


Fig. 84 Along Stable Slopes, Cut and Fill should be Balanced; for Unstable Slopes, Cut only

For sloped embankments, gentler vegetated slopes are preferred for soil stability and to prevent erosion. The impact of the rod runoff should be minimized by grass swales along the road and at the top and bottom of the slope to check surface runoff (refer **Fig. 84** above). Surface water along roads should be directed via natural swales or interceptor drains to existing or designed water bodies or rainwater filtration and groundwater recharge areas to avoid ponding on roads. For erosion and sedimentation control, slopes should be stabilized with native grasses, shrubs and ground covers. For steeper slopes, terraces can be created or retaining walls can be used.

CHAPTER 3
STANDARDS AND IMPLEMENTATION DETAILS

3.1 Standards

3.1.1 *Plantation standards*

(i) At least 100[1] trees shall be planted, per planting row, per side within one-kilometer distance. If trees are existing, then they shall be counted, and number of planted trees shall be that much less. If median is planted with trees, then median plantation shall be counted as a row. Trees that are planted in pots shall not be counted. Total number of trees per kilometer shall be as per **Table 5**.

[1] Exceptions are flyovers, elevated roads and underpasses.

Table 5 Minimum Number of Trees per km

Sr. No.	RoW	Min. number of trees per km (inclusive of existing trees)
1	Less than 35 m	200
2	35 m – 45 m	300
3	46 m – 60 m	500
4	61 m – 120 m	700

(ii) Pedestrian and cycle tracks shall be under 70-85%[2] shade, by way of plantation or shading devices or through shade line of buildings, between 11am to 4pm, especially in hot climates.

(iii) Tree pits shall be a minimum of 3.3 sqm area with a minimum dimension of 1.8 m. in any direction and minimum depth of 1.2 m. However, for medians, small to medium height trees should be planted in a pit that's retained on all sides with a minimum internal dimension of 1 m in any direction (refer details in 3.5.1).

(iv) Tree line should be decided as per the orientation of the street. In case of narrower streets where double rows of trees may not be possible, the sunnier side of the street should be considered for tree plantation, (e.g. where space is) limited for planting, preference is to be given to tree planting on the South/West facing side of the road, especially in hot climates.

(v) Trees and shrubs should be grouped together so that they correspond to a single hydrozone, for optimizing water requirements.

(vi) In order to minimize air pollution through dust re-suspension, tree pits, planters or any unpaved areas within the ROW shall not have exposed soil and shall be covered by ground covers, shrubs, mulch or any other kind of plantation. Soil spaces between shrubs shall always be filled with mulch, such that soil is not left exposed.

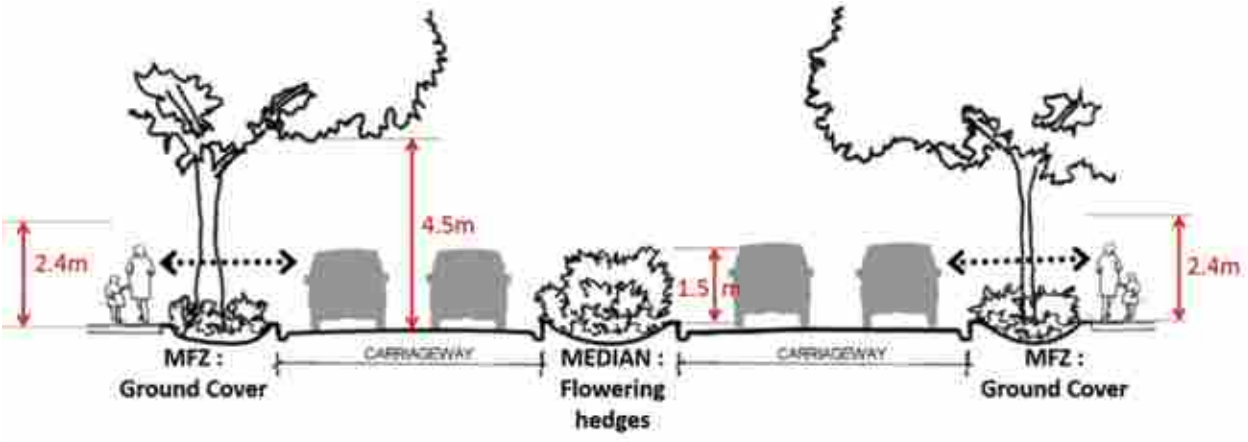


Fig. 85 A Typical Section showing Height of Tree Foliage and Height of Median Plantation

(vii) **Table 6:** Clearance of trees to utilities gives clearances of the tree trunk to various utilities/fixtures. Exception to this rule are the existing trees, where the utilities shall be adjusted to them.

[2] Percentage can be judged by measuring total surface area that is alays under shade, at any given time.

Table 6 Clearance of Trees to Utilities

S. No.	Utility	Distance to tree trunk
1	Bus Stop	3 m
2	Face of kerb	1.2 m
3	Light pole	3 m
4	Utility pole	3 m
5	Underground utility pipe or duct	1.5 m
6	Electric cable	0.6 m
7	Communication cable	0.6 m
8	Boundary wall	1 m

(viii) In medians, the shrubs shall be maintained at a height of 1-1.5 m to cut off headlight glare from the opposing traffic.

(ix) Pruning of leaf, stem or root area, shall never be in excess of 25%, to preserve the trees from adversely affecting them. Itis an approximate measure taken by eye/photographic evidence to ascertain nearly a quarter percentage of pruning.

(x) Avoid overcrowding or sparse plantation - To allow individual trees to have a full mature canopy, minimize competition for resources and provide more shade and usable space beneath.

(xi) Tree spacing should be based on the species selected for plantation and in due coordination with the lighting and signage plan. As a thumb-rule:

- Large trees: plant >15 meter c/c
- Medium trees: plant >10 meters c/c
- Small trees: plant >6 meters c/c

3.1.2 *Multi-functional zone*

(i) Multi-Functional Zones (MFZ) are organized strips of space that are to be provided on either side of the carriageway – to consolidate various street components/ amenities in an organized and streamlined manner, which would otherwise be located in a haphazard way within the ROW and often found encroaching on carriageway or footpath space.

(ii) MFZs integrate various functions/amenities such as bus-stops, street lights and poles, utility boxes, NMV stands, taxi drop-offs, hawker zones, paid private vehicle parking, street furniture as well as tree plantation and natural storm water management, as shown in **Fig. 86**. The plantation within the MFZ can also function as natural storm water catchment and filtration systems, aiding in ground water recharge, preventing seasonal flooding and reducing pressure on piped storm water infrastructure.

(iii) Multi-functional zones within any road/street should preferably be a minimum of 1.8 m wide so as to house a tree pit. This width canalso to accommodate single row of parking, bio-swale bed, bus-stop, etc.

(iv) Common Utility Ducts and Duct Banks should not be located under the MFZ as there may be interference due to trees.

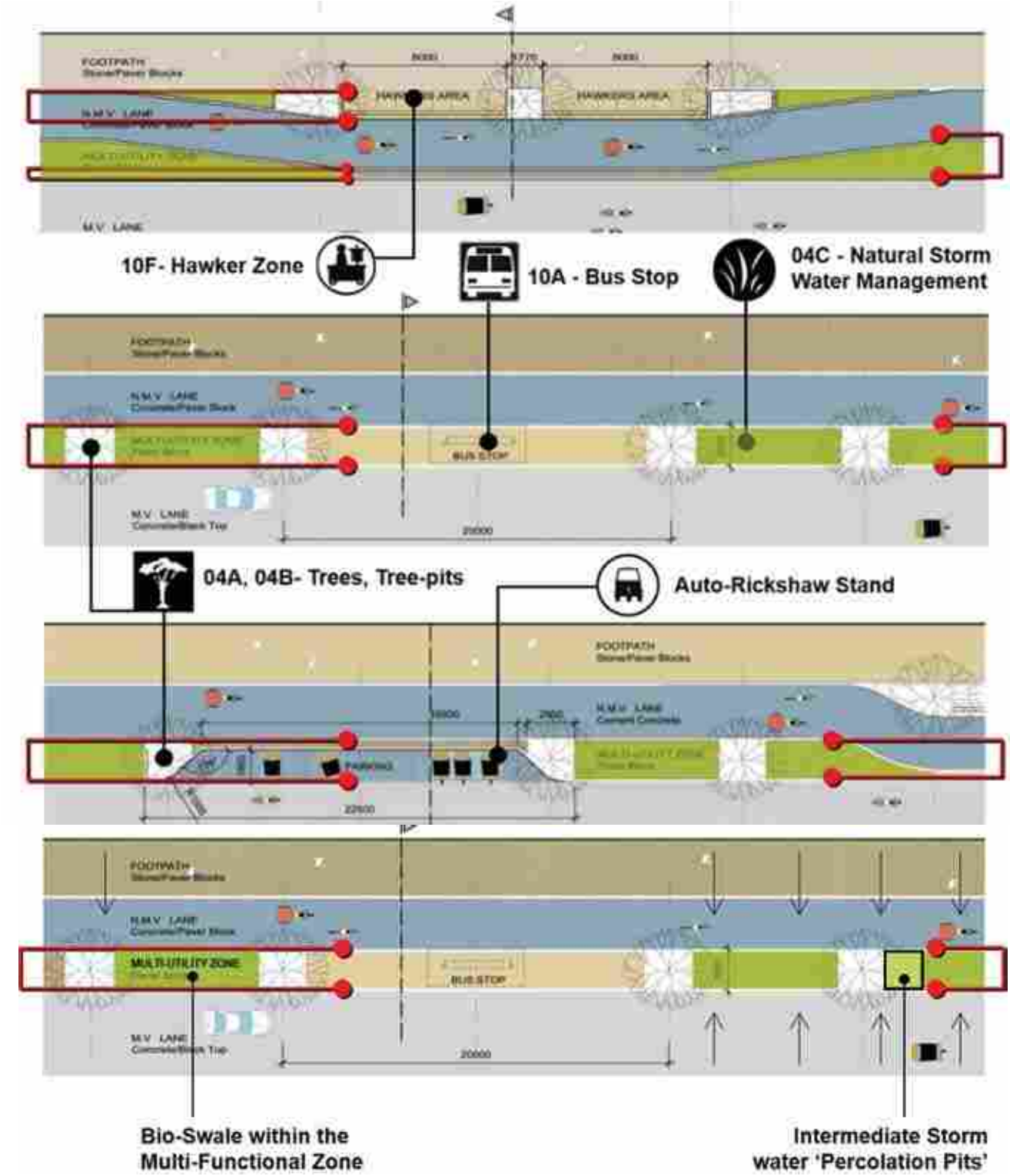


Fig. 86 Layout of typical Multi-Functional Zone and location of Bio-filtration Beds with MFZ
[Source: IRC 103:2012]

3.1.2.1 Locating bio-filtration beds within MFZ

Infiltration beds are best placed along the road sides, within the MFZ, such that they can directly receive the run off from the road/pavement/footpath, before the over flow reaches the structured drains. They can be integrated within the MFZ as shown in the **Figs. 87, 88** below:

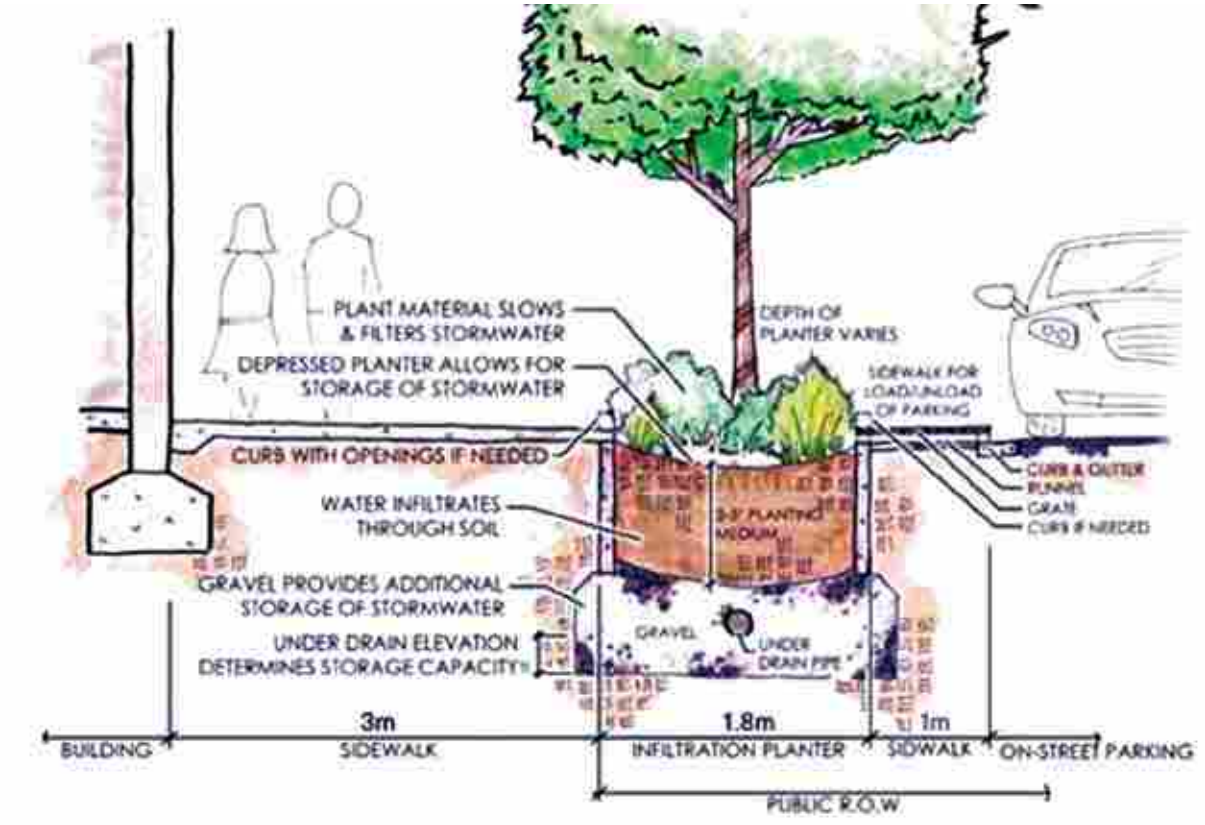


Fig. 87 Bio-planters in MFZ

Fig. 88 Bio-planters can be located within the Multi-Functional Zone

3.1.2.2 Storm-water management techniques as per spatial criteria

Storm water management systems can be well integrated with streets as per the available width. The following table provides the list as per space required from the edge of carriageway to boundary wall and for medians.

Table 7 Infiltration Modules for various conditions of Sidewalks and Medians

Sr. No.	Width/ Area	Filtration	Conveyance	Detention	Retention	Infiltration
A	For roads draining away from centre					
1	Less than 3 m	• Gravel Filter Chamber	• Storm water pipes • Flow through planters	-	-	-
2	3 – 5 m	• Gravel Filter strip	• Swale • Flow through planters	• Dry Swale • Underground storage tank	-	• Infiltration trench
3	5 – 10 m	• Gravel filter strip • Vegetated filter	• Swale • Flow through planters	• Underground storage tank • Detention pond	• Retention pond	• Infiltration trench
4	More than 10 m	• Vegetated filter	• Swale	• Underground storage tank • Detention pond	• Retention pond • Constructed wetland	• Rain garden • Infiltration basin
5	Median	• Gravel Filter strip	• Green gutter/Flow through planters	-	-	• Infiltration trench
B	For Centre-draining roads					
6	Median	• Gravel filter strip	• Swale	-	-	• Rain garden • Infiltration trench

3.1.3 *No plantation zone*

Tree plantation should not be carried out in the following areas:

(i) Within 5 m of a median cut, kerb cuts/entries and grade separators;

(ii) Within 25 m of a major traffic intersection having at least one arterial road;

(iii) To prevent damage to carriageway, sub-grades and other utilities from long-rooted plants, sub-grade protection measures should be undertaken. See Chapter 3 for details.

(iv) No tree plantation should be done within areas which can hinder sight distances within roads, as per Section 3.1.3.1 and IRC:66.

3.1.3.1 Clear sight distance

Experience has been that growth of thick vegetation close to the formation on inside of horizontal curve leads to serious reduction of sight distance and causes avoidable accidents with cattle/ children suddenly emerging from the side. Uncontrolled trees/vegetation may also affect visibility of traffic control devices and road signs. To ensure visibility in critical areas:

(i) Tree canopy should be pruned to a clear height of minimum 4.5 m over carriageway and 2.4 m above the pedestrian walkway and cycle tracks (measured from finished surface level).

(ii) Minimum visibility distance along roads at priority intersections are given in **Table 8**.

Table 8 Minimum Visibility Distance along Arterial Roads and Priority Intersections

Sr. No.	Design speed (km/hr)	Minimum visibility distance (m)
1	80	180
2	60	135
3	50	110
4	40	80

(iii) IRC:66 gives calculation of sight distance criteria, which should be considered for planting of trees.

(iv) At junctions, low height shrubs and ground covers should be planted at least 1 m away from kerb-edge and high canopy trees planted at least 2.5 m away from the edge of the carriageway so as to not to obstruct movement and sight lines.

3.1.3.2 Plantation plan coordinated with lighting, utilities and signage

Landscaping and plantation shall be well integrated with utilities and services. The following to be considered where utilities and tree plantation are close to each other:

(i) Utilities to be planned as stacked banks and to be implemented under the roadside such that all utilities pack themselves close to each other, resulting in better management and maintenance.

(ii) Where utilities are not planned as banks, provision of ducts should be made that encase cables and offer no hindrance to adjoining trees/root systems and can be easily maintained.

(iii) Where electric cables and other cables run close to rooting system of trees and plants, the same should be sleeved in PVC sleeves such that the plantation does not cause harm to cables.

(iv) Where drainage pipes and water lines pass, the trees should be planned at safe clearance of 0.6 m so that the roots steer clear of the drainage systems.

(v) The Clear Pedestrian Zone (minimum 1.8 m wide) and Utility Easements/ Common Utility Ducts/Duct Banks must be placed separately from the Tree Planting Zone/MFZ, as in **Fig. 90**.

(vi) Trees must be placed such that they do not obstruct street lighting as well as visibility of traffic signals. Therefore, the Tree Planting Plan must be prepared in conjunction with the Street Lighting Plan, as shown in **Figs. 89** and **91**.

(vii) Trees must be pruned from the bottom such that all safety devices, signage and traffic signals are clearly visible to all road users.

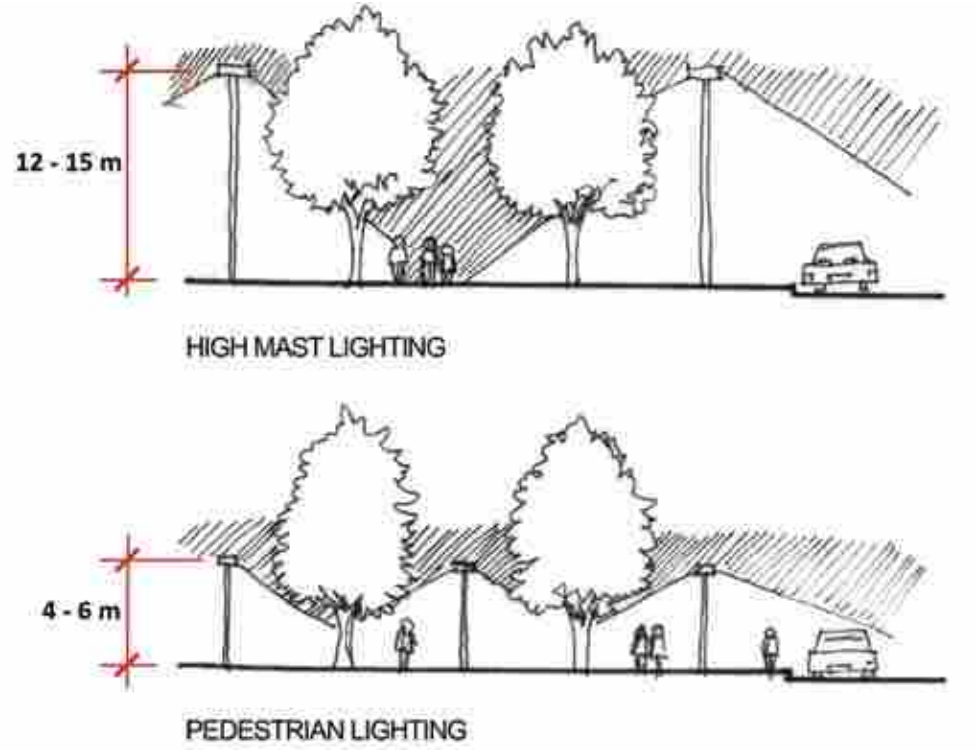


Fig. 89 Planning of Lighting with regards to Tree Plantation on Street

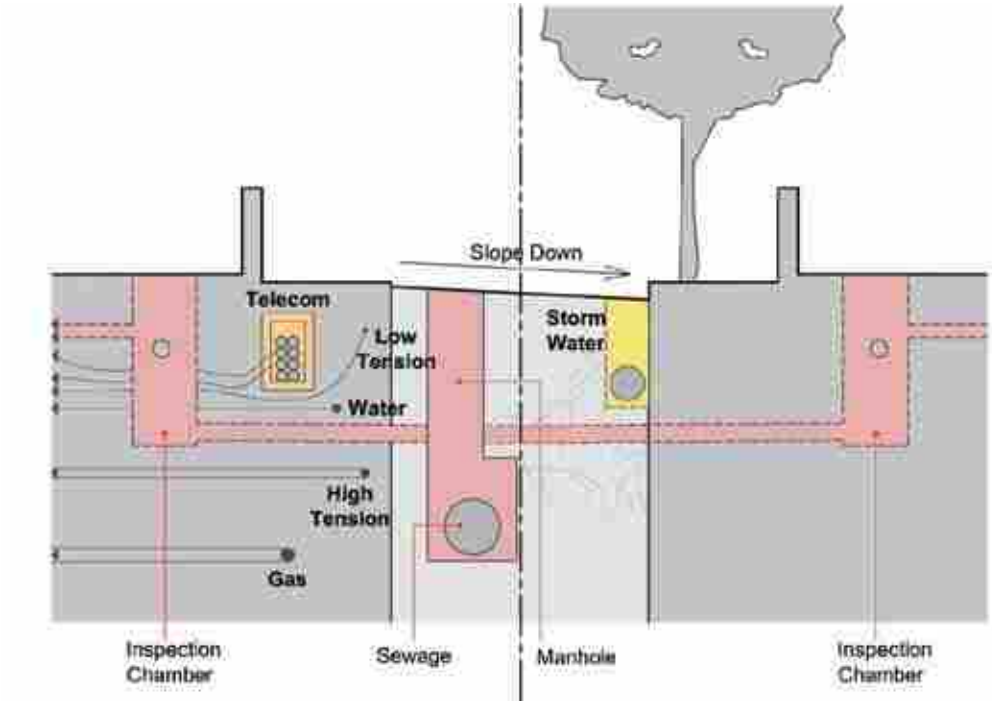


Fig. 90 Tree Alignment in Conjunction of Services

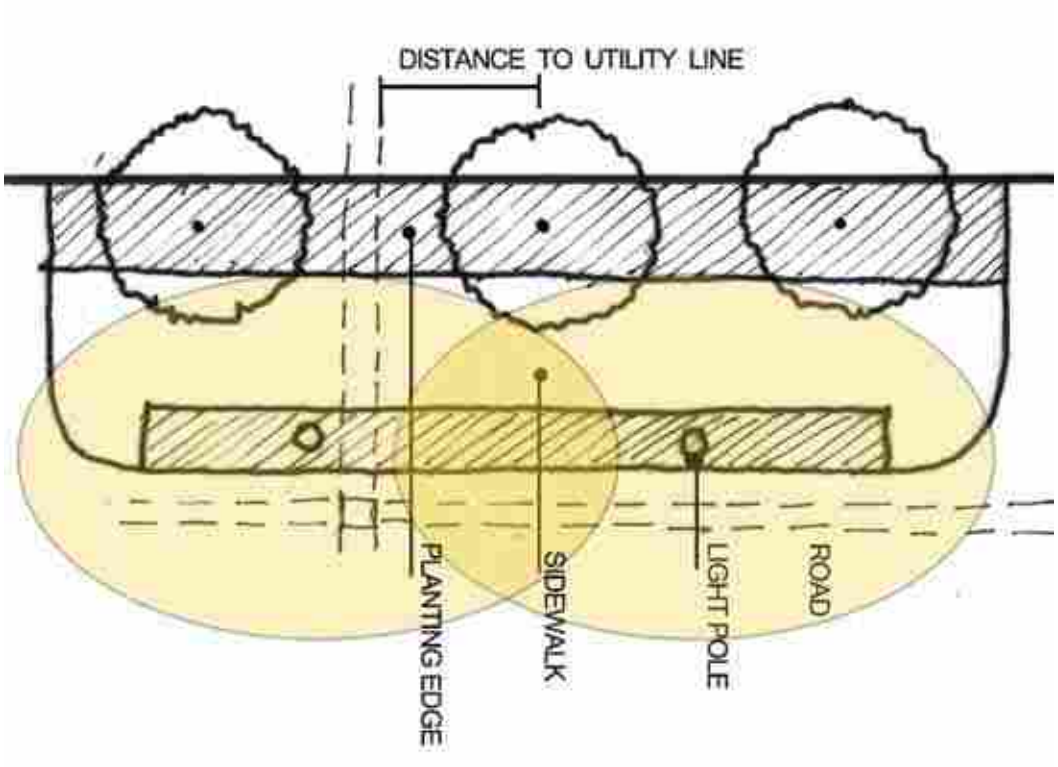


Fig. 91 Tree Alignment in Conjunction of Lighting

3.1.3.3 Other guidelines

(i) Preferably, Native trees should be planted on streets in order to minimize irrigation requirements, preserving bio-diversity and prolonging tree life.

(ii) In case of limited space for planting, preference is to be given to tree planting on the South/West facing side of the road, especially in hot climates.

(iii) Hedges should not block walking desire lines and should respond to them and enhance movement lines and facilitate spaces for rest and movement spaces.

(iv) Spacing between trees to be 3 m for dense buffer and 5-8 m for visibility through the trees.

(v) For narrow roads, smaller species can be used with smaller canopy.

(vi) Shrubs and groundcovers used may include thorny and toxic plants to repel stray animals and damage, particularly in long stretches and medians with no access.

Plants that obstruct movement, create extensive leaf and fruit litter should be avoided in pedestrian areas.

3.1.4 *What not to plant*

(i) Trees that are not native to the country like Eucalyptus, Australian Acacia, Lantana, Luceana, Mast tree (False Ashoka) should be avoided.

(ii) Native shrubs, grasses and groundcover recommended for understorey and slope stabilization can be locally sourced, require little maintenance and enhance

the biodiversity benefits. Turf, meanwhile, requires intensive maintenance, watering, weeding, pesticides and limits indigenous plant and animal habitat, and should be planted sparingly.

(iii) In areas of degraded landscapes and wetlands, pioneer grasses to be introduced to create functioning wetlands which will then fix the soil pH and allow the growth of the entire planting structure of trees, shrubs and groundcovers required to sustain bio-diverse plant and animal species.

Table 9 Trees to Avoid

Sr. No.		Location to Avoid	Location to Use	Example
1	**Invasive**	Everywhere	None	*Proposis julifolia, Parthenium hysterophorus*
2	**Toxic or Noxious Plants**	Along pedestrian corridors	Along vehicular corridors, as buffers, where contact is minimal	*Thevetia neriifolia, Ricinus communis L*
3	**Debris: Fruit, Seed Pods/Nuts**	Along pedestrian and vehicular areas	In open areas, away from hardscape	*Morus rubra, Syzygium cumini*
4	**Thorns and spikes**	Along pedestrian corridors	Along vehicular corridors, as buffers, where contact is minimal	*Proposis julifolia,*
5	**Allergen**	Close to pedestrian routes	Can be used in areas of less occupancy/ movement	*Ailanthus, Holoptelea, Artemesia*
6	**Odour**	Along pedestrian corridors	In open area	
7	**Shallow roots**	Along pedestrian and vehicular corridors	In open areas, away from hardscape	*Ficus Benjamina, Ficus virens*
8	**Drooping Branches**	Along pedestrian and vehicular corridors	In open areas, away from hardscape	*Callistemon*
9	**Fruit trees w/ Insect and Pests**	Along pedestrian corridors	In open areas, away from hardscape	*Mangifera indica, Morus rubra*

3.1.4.1 Alien/invasive species

An alien species is one which becomes established in natural or semi natural ecosystems or habitat, an agent of change, and threatens native biological diversity. Invasive species cause

loss of biodiversity including species extinctions, and changes in hydrology and ecosystem. Differences between native and exotic plant species in their requirements and modes of resource acquisition and consumption may cause a change in soil structure, its profile, decomposition, nutrient content of soil, moisture availability, etc. Invasive species are thus a serious hindrance to conservation and sustainable use of biodiversity, with significant undesirable impacts on the goods and services provided by ecosystems.

3.1.4.2 Mono-cultures

Homogeneous stretches developed based on corridor available, topography, climate, and soil conditions should be limited in the use of a single species to avoid the possibility of high casualty in case of disease or low tolerance to site specific conditions.

For example, monoculture street tree plantations of Elm trees saw catastrophic losses of over 25 million trees in Britain and over 40 million in the US due to the Dutch elm disease in the mid- 20th century. They devastated the landscapes of cities across the Northern Hemisphere, where there were planted along roads, walkways and hedges because of their overarching form and shade.

A rule of thumb recommendation for street tree plantation is that no more than 10% of any 1 species, no more than 20% of any one genus, and no more than 30% of any one family are planted in a single stretch.

Minimum Species Diversity: To help prevent insect or disease susceptibility and eventual uniform senescence on a development site or in the adjacent area, species diversity is required and extensive monocultures are prohibited. No more than twelve (12) trees shall be used consecutively, and frequent alternation of different species is necessary. Existing trees may be included when determining species diversity. **Table 10** below shows the desired mix of species.

Table 10 Maximum Percentage of any one Species to be Planted

Sr. No.	Number of trees on site	Maximum percentage of any one species
1	10 – 19	50%
2	20 – 39	33%
3	40 – 59	25%
4	60 or more	15%

3.1.5 *Critical root zone*

Each tree to be retained shall have a designated Critical Root Zone (CRZ) identifying the area sufficiently large enough to protect the tree and roots from disturbance. **Table 11** gives various strategies for tree protection.

Table 11 Tree Protection Strategies

Sr. No.		Likely damage from	Impact	Mitigating Strategy
1	**During Construction/ Utility work**	Equipment	Stress, damage	Tree protection fences, Hand digging around tree
		Stacking of Construction Material	Dust Accumulation, lack of topsoil	Regular watering, No exposed soil/ groundcover planting
		Grade changes	Soil Compaction	Aeration system for roots
			Alters drainage patterns, cuts roots	Retaining wall
	During Establishment/ First two years	Pavement/ Conflict with existing/new built structures	Breakage, Tripping Hazard	Avoid planting shallow rooted trees, root pruning Permeable paving/Tree grates in paved areas
		Small size, subject to vandalism	Breakage/Injury	Tree Guard
2	**Lifecycle of Tree**	Vehicles	Mechanical Injury	Raised curb/edge
		Animals	Grazing	Plant toxic/thorny plants around
		Pedestrians	Compaction	Tree Grates
3	**During Transplantation**	Root injury, shock	Exposed roots, root damage	Cut back roots and backfill Protect root ball and keep moist
4	**Damage**	Extensive pruning; Branch/canopy injury; Weak trunk		Max. 25% pruning Pruning as required; Staking and Guying

3.2 Specifications for Plantation – Trees

(i) Trees saplings shall be carefully handled at site with the root bulbs properly protected in polybags, to be stacked and stored appropriately. For delay in planting time, regular water sprinkling should be carried out.

(ii) Tree pit shall be 1.8 m x 1.8 m with a minimum depth of 1.2 m, filled with a mix of backfill and compost in proportion of 18% organic compost and 10% clay. For medians, however, a retained pit of 1 m internal width should be made and short

or medium height trees (up to 12 m height) should be planted. A typical tree planting detail is shown in **Fig. 92**.

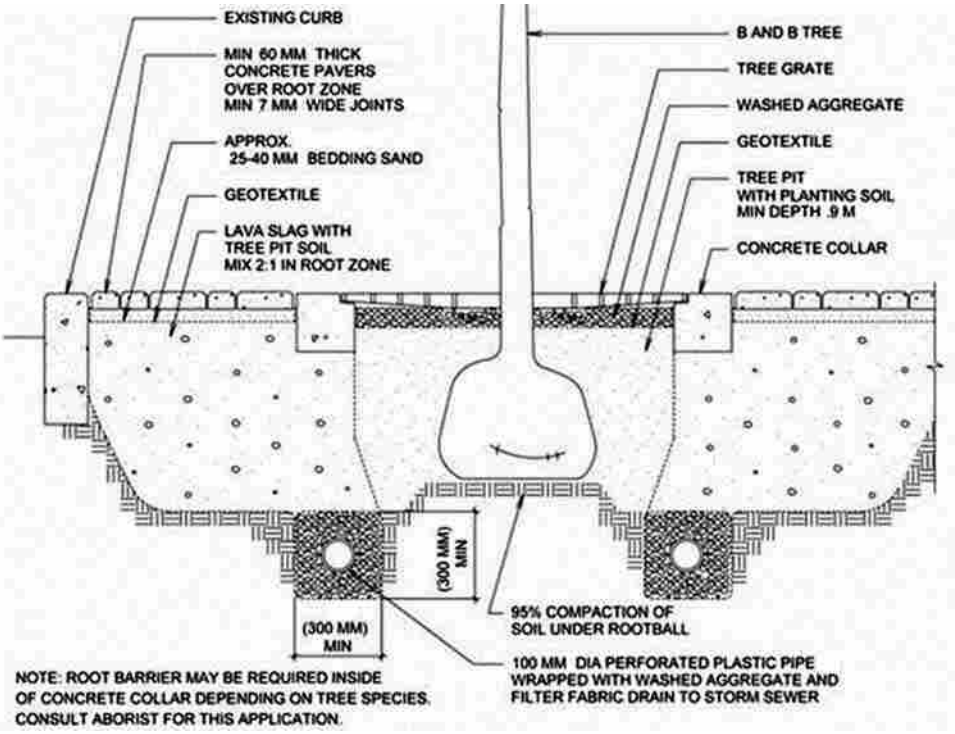


Fig. 92 Typical Tree-pit Detail with Protection

(iii) Sub-grade protection detail should be implemented for tree pits, for trees planted in medians or next to footpath.

(iv) Tree pit shall be excavated and backfill stored in proper place so that it does not cause obstruction to pedestrians. Excavated tree pit shall be exposed to sun and weather for one day and filled with water to clear out the weeds. The pit shall be made with concrete, brick or stone wall masonry in case it is next to sub-grade for its protection.

(v) If during excavation, the sub-soil is found to have poor drainage, then it must be treated with 3 parts of manure + 2 parts of sweet earth and + 1 part of sand, to improve its drainage. A well-drained and porous soil shall support growth of new roots and contribute to the health of the tree.

(vi) Tree shall be provided protection in terms of staking, guard and grating for adequate growth and prevention of interference.

(vii) Tree sapling shall be of various heights depending on species, but as a rule, small saplings should be preferred over large saplings for better adaptability and longer life. If seeding is possible, then it should be preferred over saplings.

(viii) Transplantation shall be avoided as far as possible, and existing trees to be accommodated in road design. If it has to be carried out, then a scientific process shall be followed to ensure maximum survival of trees.

3.3 Specifications for Plantation – Shrubs

(i) The species to be planted in median should be of low or medium height with ornamental value to enhance the visual experience of the road corridor. It will also act as a screen to prevent glare from the incoming vehicles.

(ii) One or two rows of flowering shrubs are recommended. In accordance with the varying width of the median in different sections. In sections where median width is less than 1.5 m, low height shrubs are recommended with low to medium height trees, the branches of which are pruned at 4.5 m height. On medians of upto 3 m width, 2-3 rows of shrubs of various varieties and medium height trees can also be planted. For medians, more than 3 m wide, trees with high canopies mixed with low to medium height shrubs can be planted. The trees, if planted, should be in a single row along the centerline of the median.

(iii) The shrubs should be at spacing of 0.45 m c/c and size of the pits for planting should be 0.6 m x 0.6 m x 0.6 m.

(iv) For shrub planting in medians, the kerbs shall be 150 mm high and at least 450 mm deep to retain good soil inside the adjacent walls of the kerb.

(v) The species recommended for median are ones which can withstand pollution, dust, wind speeds and drought conditions and are unattractive to cattle. There are many varieties that can be planted and usually Bouganvillea, Karonda, Didonia and Kaner are most popular. However, other species (listed in the Appendices) may also be used.

(vi) The surface for the median plantation should be well prepared. The masses of loose debris on the median and any convexities should be removed. Similarly, any concavities should be filled with good soil. The surface should have sufficient layer of good quality soil so as to have a better growth and survival of grasses and shrubs. No part of the median should have exposed soil. It should either be planted or have a layer of mulch on it.

(vii) The height of the shrubs will not be more than 1.5 m and need to be in polythene bags until the planting is completed. All plants supplied must be planted within three days of removal from the nursery. The plantation should be watered in case of insufficient rains after planting.

(viii) Use of compost and manure - 1/3 of volume of pit mixed with soil, and refilled.

3.4 Specifications for Ground Cover

Dust re-suspension from unpaved surfaces is one of the major causes for air pollution, as seen in **Fig. 93** below. Plantation in the form of shrubs and ground cover is essential to ensure that there is no exposed earth along/within the road right of way.

Fig. 93 Exposed Dust Surfaces should not be provided to avoid Pollution through Re-suspension. All Unpaved Surfaces must be Planted with Green Cover

(i) The soil surface is to be prepared for grass sowing. The grass and shrub planting is done to provide a strong surface cover but needs a well-prepared surface. All masses of loose debris should be removed. Any convexities should be removed and similarly any concavities are to be filled with good soil. The surface should have sufficient layer of good quality soil [upto 45 cm] so as to have better growth and survival of grasses and shrubs.

(ii) Grass lines are used to provide a strong surface cover but need a well-prepared surface in which to be planted. If grass is to be in effective form, then it must be allowed to establish properly on a slope which does not subject it to undue stress from erosion and mass movement in its initial stages. A few more measures required are given below:

(iii) Sowing of grasses is intended to create a strengthened surface that is resistant to erosion,

(iv) It is necessary to ensure that the condition of the site is good enough for the successful establishment of grasses.

(v) It is necessary to supervise all field operations like preparation of surface, sowing of grasses and quality of grass seeds used.

(vi) A cover of 25 gram of grass seed per square meter of surface should be achieved.

(vii) The timing of sowing is of utmost importance. The seed sowing must be carried out before the onset of monsoon [May & June] so that they yield desired results. The watering of the surface will be done by tankers till the onset of the monsoon.

(viii) After sowing, mulch of prepared and dried out herbs should be laid over the entire seeded area in a thin layer so that the direct sunlight and transpiration loss may not affect the grasses

3.5 Specifications for Tree-Protection

3.5.1 *Tree pits*

(i) Tree pits shall be a minimum of 3.3 sq.m. area with a minimum dimension of 1.8 m. in any direction and minimum depth of 1.2 m. A typical tree pit is shown in **Fig. 94**.

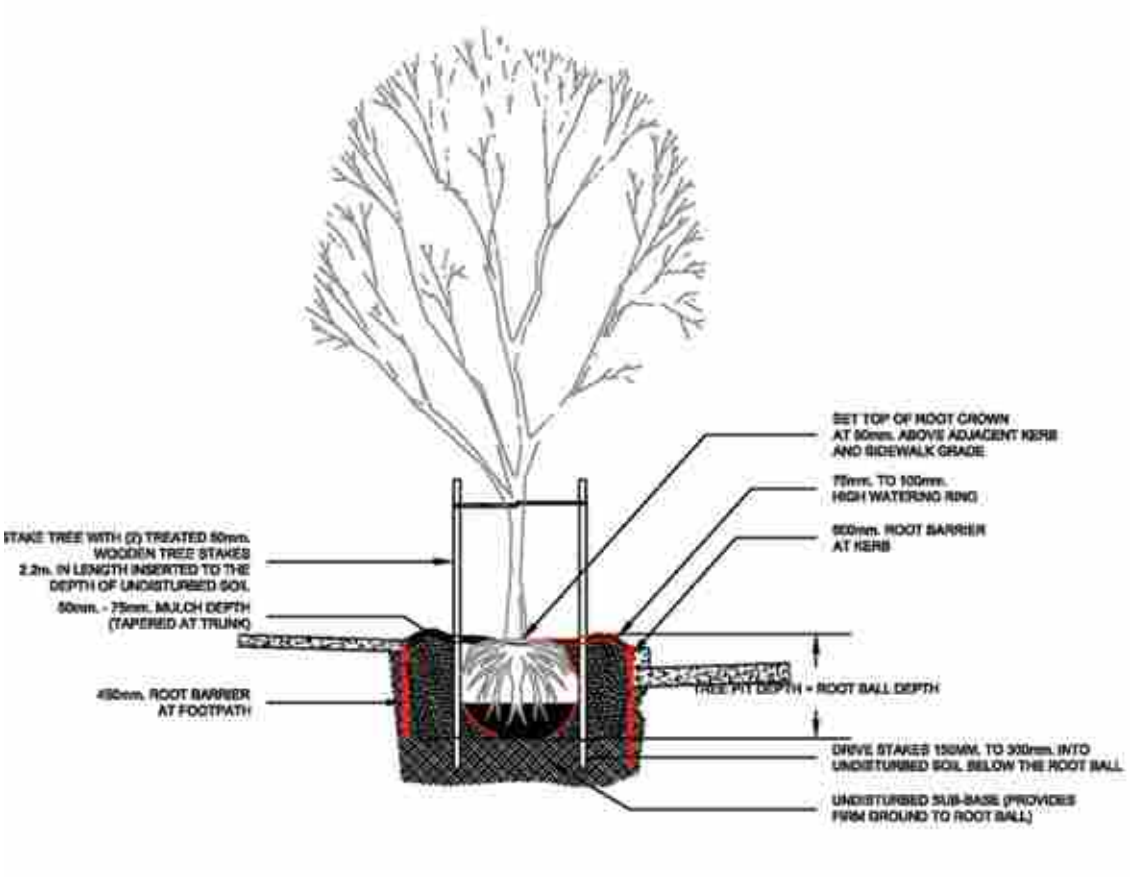
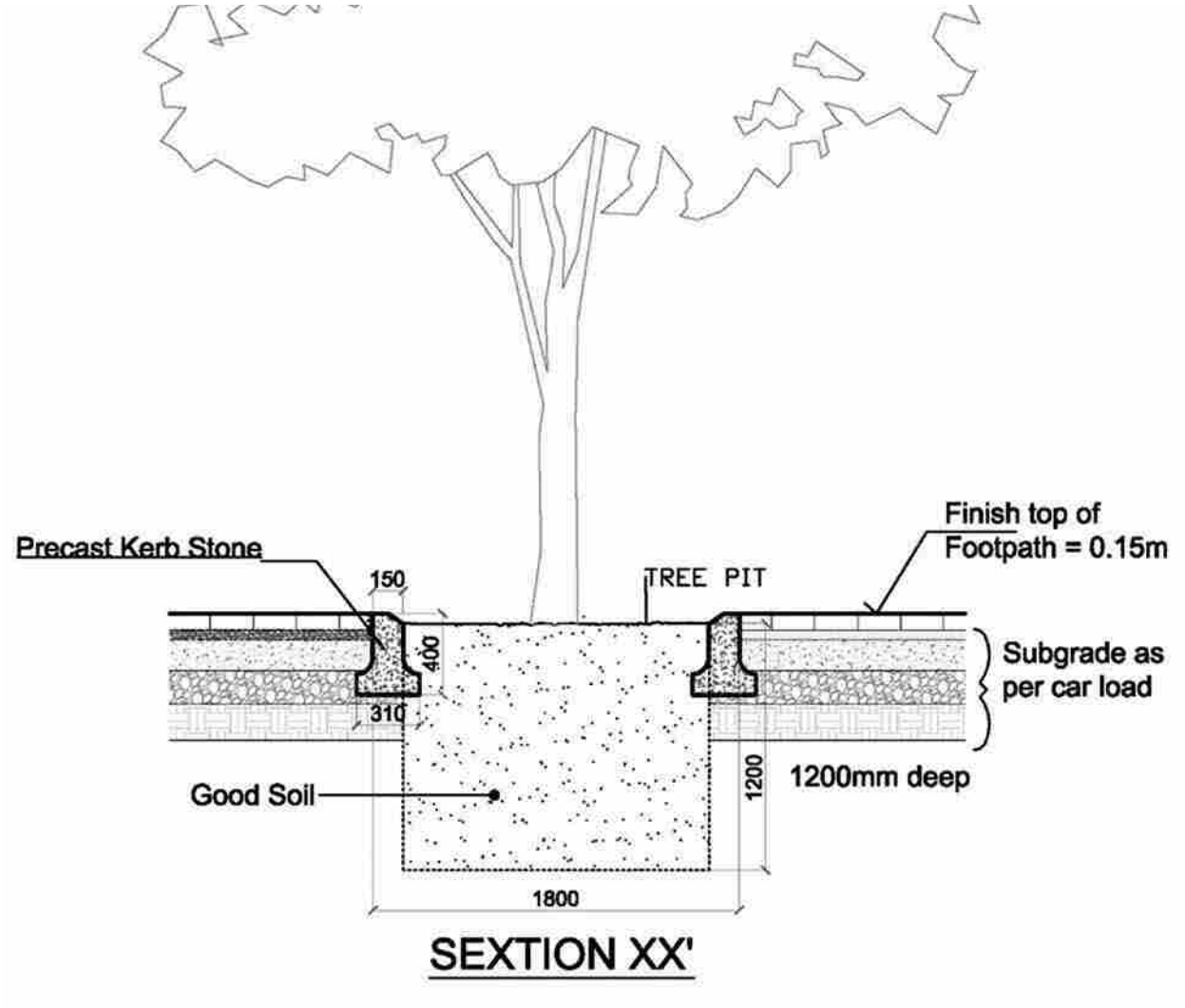


Fig. 94 A Typical Tree Pit

(ii) For medians, a pit of minimum internal width of 1 m in any direction can be provided, that's appropriately retained so as to not cause damage to road sub-grade. The pit can be retained by providing a 230 mm thick brick wall or a concrete wall of 75 mm thickness.

(iii) A tree pit shall have a min. excavated depth of 1.2 m which shall be filled with good garden soil.

(iv) Tree pit shall be lined with toe wall not less than 150 mm wide or with concrete kerb of 150 mm top width, both of which shall be at least 450 mm. deep and with their top flushed with the level of the footpath, as shown in **Fig. 95** below. Any wall of the tree pit lining shall not project out of the level of the footpath.



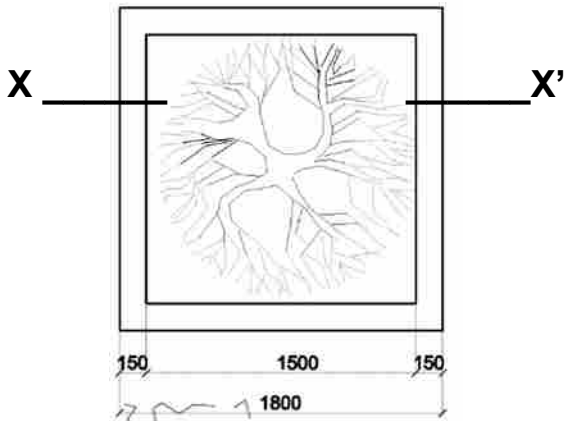
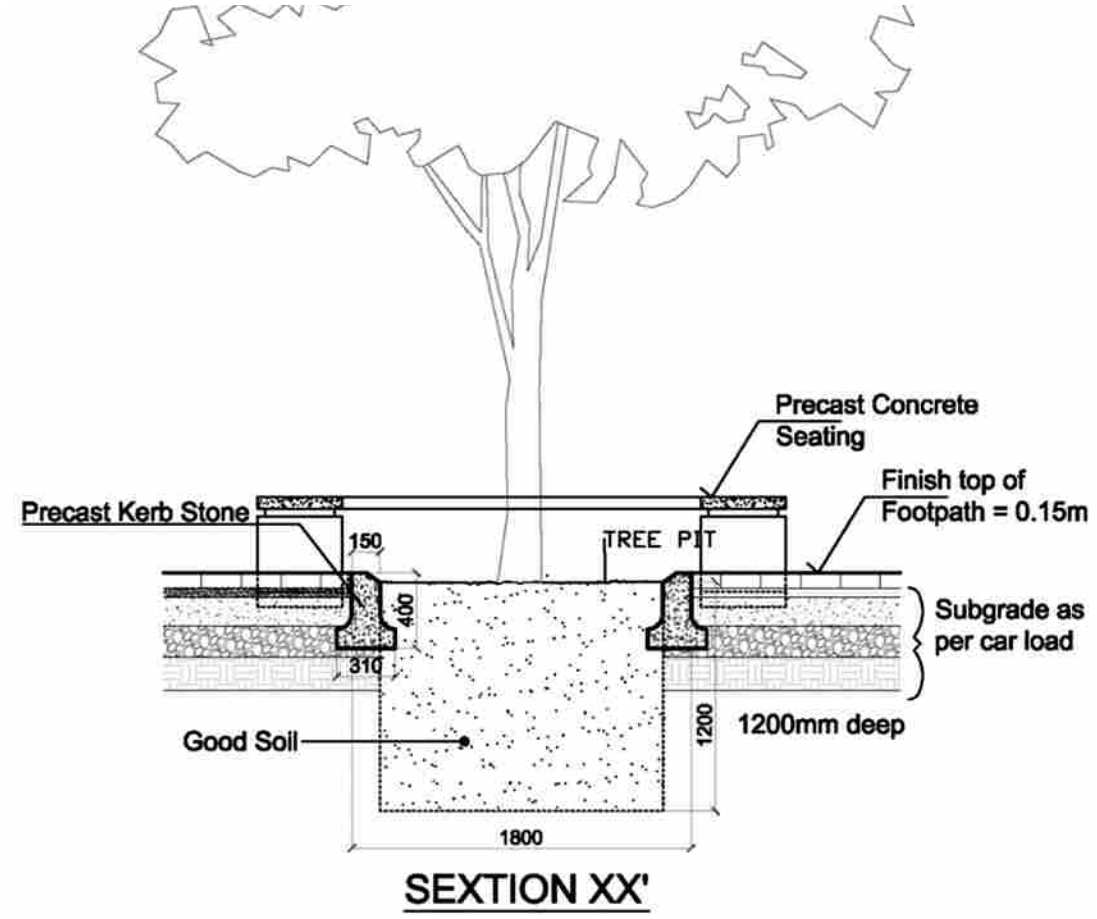


Fig. 95 Tree-pit Detail without Seating (note: unplanted tree-pits are not recommended)

(v) Tree pits can be protected very effectively by putting a bench around them, as it provides a barricade to damaging the trunk but at the same time allows water under the bench to flow to the pit, as shown in **Fig. 96** below.



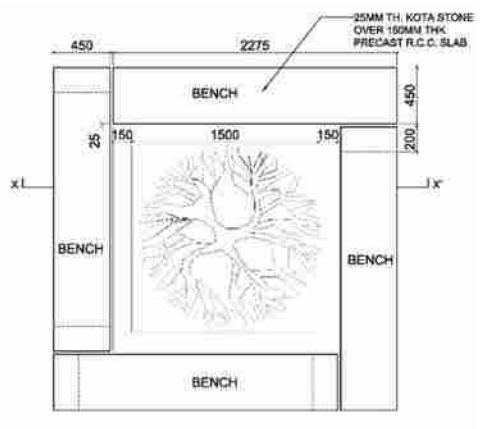


Fig. 96 Tree-pit Detail with Seating

(vi) In case the tree pit being adjacent to the road edge, for sub-grade protection, tree pit shall have 230 mm thick brick wall or concrete wall of min 75 mm thickness till the depth of 1.2 m, the top of which should not project out of adjacent footpath level. Garden soil shall be filled in this constructed pit. Under no circumstances, the bottom of the tree pit will be lined or sealed with any material.

(vii) Before filling the excavated or constructed pit with garden soil, the tree pit shall be sprayed with natural anti-termite solution and tree pit exposed to weather for a day.

3.5.2 *Tree pits within medians*

(i) **Median less than 1 m wide** should be planted with ground cover with a line of shrubs in the center not more than 0.6 m high and pruned from sides. (refer **Fig. 97**)

(ii) **Medians 1 m-2 m wide** should be planted with two rows of shrubs not more than 1.5 m high with additional row of ground cover or low height shrub near the edge of median.(refer **Fig. 98**). The plantation shall be two rows of shrubs with spacing of 1 m c/c pruned up to 1.5 m height.

(iii) **Medians 2.1 m-3 m wide** should be planted with at least 3 rows of shrubs not more than 1.5 m high, with additional rows of short height shrubs or ground cover near the edge. The median can also have a row of trees of medium to short height (refer **Fig. 99**), however clear sight distance should be ensured by regular pruning of branches up to 4.5 m clear height above finished road level (refer **Fig. 85**). The plantation shall be four rows of shrubs with large shrubs at spacing of 1 m c/c and small shrubs at spacing of 0.6 m c/c along with single row of tree spaced according to species selected (between 6 m - 10 m c/c).

(iv) **Medians more than 3 m wide** can be planted with a variety of shrubbery, not more than 1.5 m high and with a row of medium to large trees in the middle (refer **Fig.100**), however clear sight distance should be ensured by regular pruning of branches up to 4.5 m clear height above finished road level (refer **Fig. 85**). The plantation shall be six rows of shrubs with large shrubs at spacing of 1.5 m c/c, medium height at 1 m c/c & small shrubs at spacing of 0.6 m c/c. Single row of tree spaced according to species selected (between 6 m - 10 m c/c).

(v) **Medians with existing trees** should be retained with regular pruning of tree roots, branches and leaves such that clear height distance of 4.5 m above finished road level is maintained (refer **Fig. 101**). If required, sub-grade protection should be constructed.

(vi) **Bio-swales** can be provided in low water table areas for local recharge and to combat flash-floods;

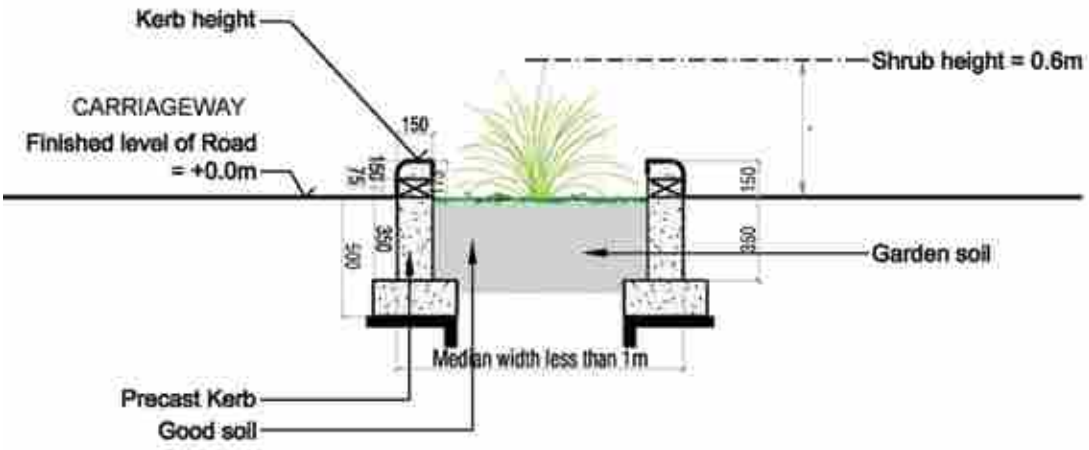


Fig. 97 Median Plantation for Widths less than 1 m should be limited to Shrubs only

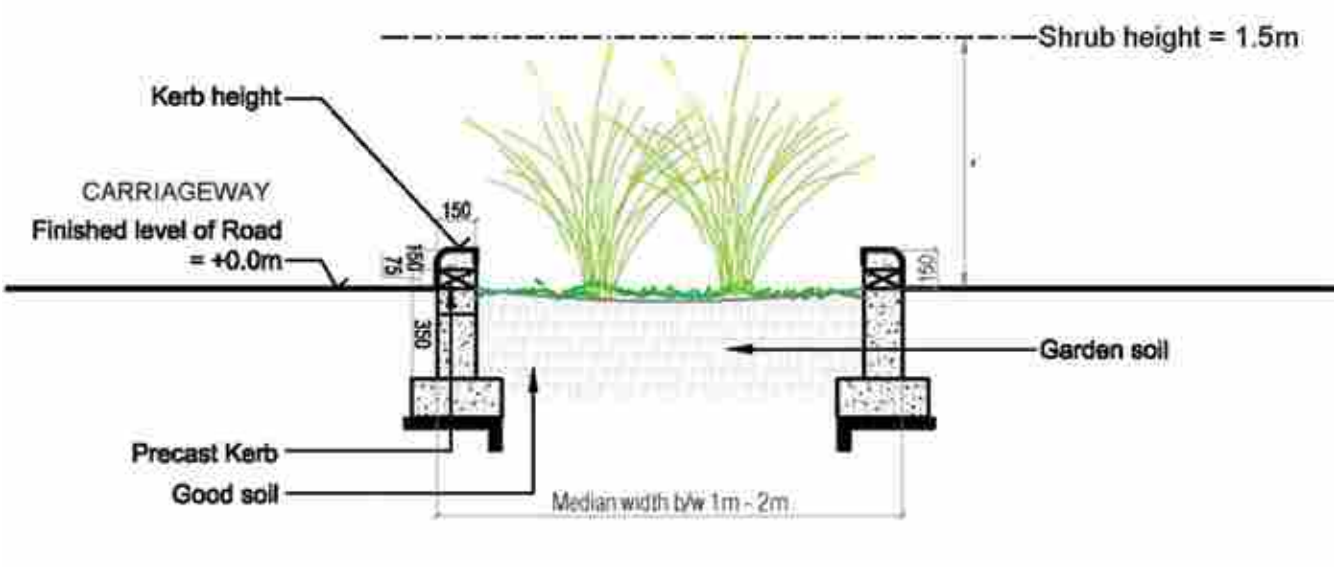


Fig. 98 Median Plantation for Width between 1 m - 2 m

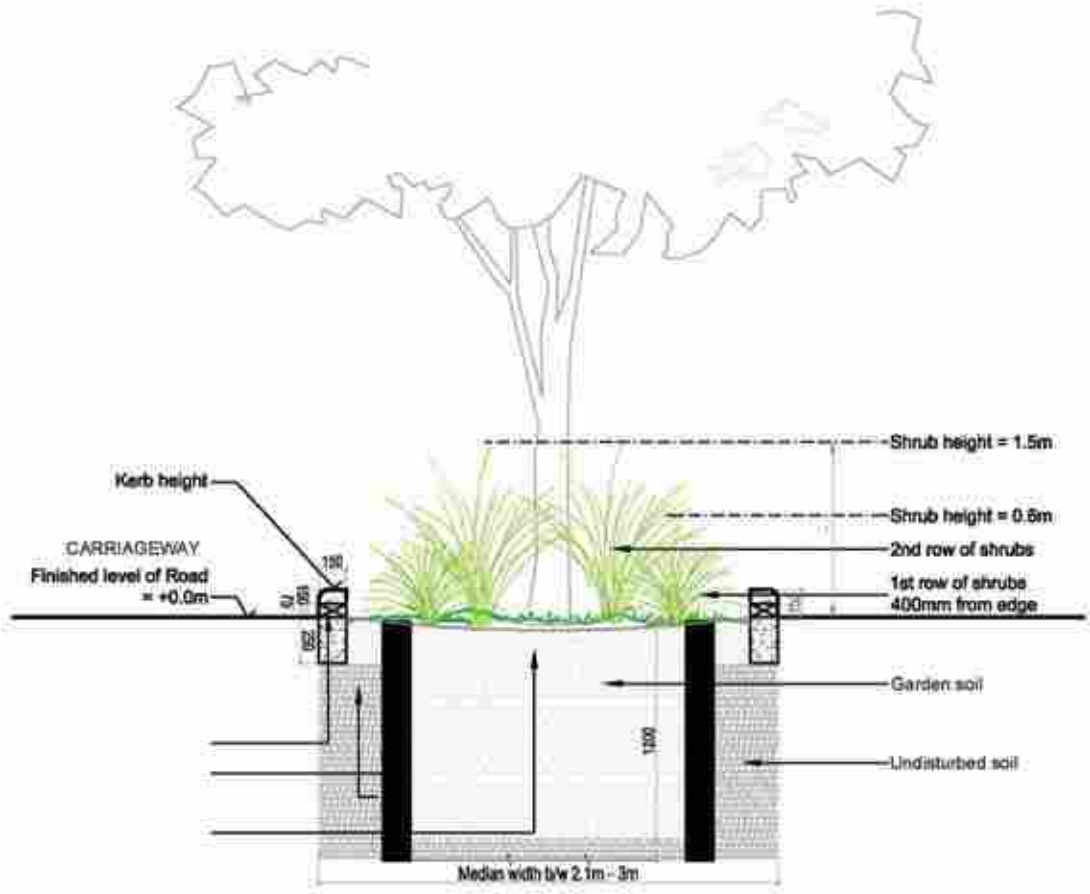


Fig. 99 Median Plantation for Width between 2.1 m - 3 m

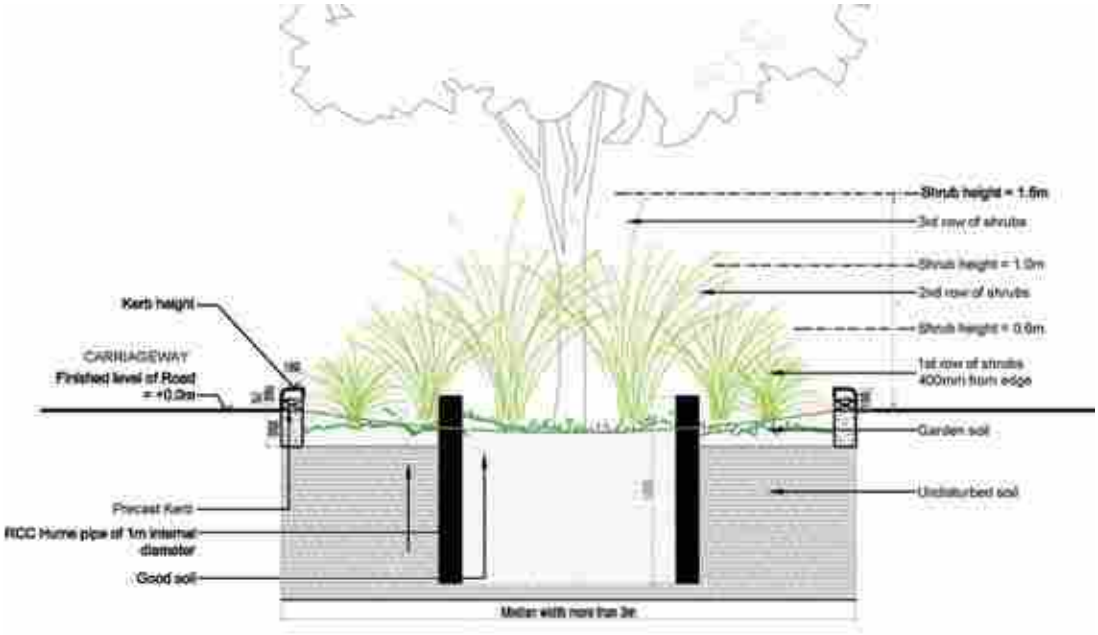


Fig. 100 Median Plantation for Width more than 3 m

Fig. 101 Medians with Existing Trees should be Retained and Pruned from Time to Time Example: Lodhi Road, New Delhi

3.5.3 *Tree guards*

(i) The diameter of tree guard shall be 75 mm minimum.

(ii) MS angle section or flats or rectangular section of minimum 1 m height and driven inside the ground 0.5 m minimum and fixed to place by concrete stubs buried inside the ground.

(iii) MS bars of 6 mm diameter minimum or square mesh of 50 mm x 50 mm dimension welded to main verticals and with 200 mm clearance above ground.

(iv) The tree guard shall have welded frame and fixed to place by buried concrete stubs and fixed to place with level meter for levelling with ground.

(v) Tree guard can also be fixed to tree gratings and fixed in place by bolts over the tree grate. Tree guard shall be designed to be removable after 2 years of tree planting.

(vi) Care shall be taken that the tree guard shall not cause any injury to the plant while fixing or welding and therefore, it should be manufactured in two halves and then welded to whole on site or bolted to whole on site.

(vii) Tree guard if made of any other material, organic and recycled (example: bamboo as in **Fig. 102**), shall be preferred over MS, fixing of the same shall be ensured to tree grate and with enough strengthening of the members by way of ties and horizontals.

Fig. 102 Bamboo Tree Guard

(viii) At the time of establishment, tree plantations require protection from extreme climates and vandalism using removable iron/brick tree guards, as shown in **Fig. 103**. Locally available bamboo guards or thorn fencing may also be used where protection can be ensured through these guards. Once it is established with caliper of 150 mm or more, and able to support itself, the tree guard must be removed.

(ix) Post establishment, trees need to be protected during road widening and/or pavement repair and work. Tree guards can be used, as shown in **Fig. 104** and **105**. No construction debris, or equipment should be stacked near the tree, to avoid strangulation. They need protection till maturity, an example is shown in **Fig. 106**.

Fig. 103 Installation of Tree Protection. Right: Example of Tree-pit with Skirting Around – acts as an Impediment for Pedestrians, prevents Rainwater from reaching the Roots and is not advisable

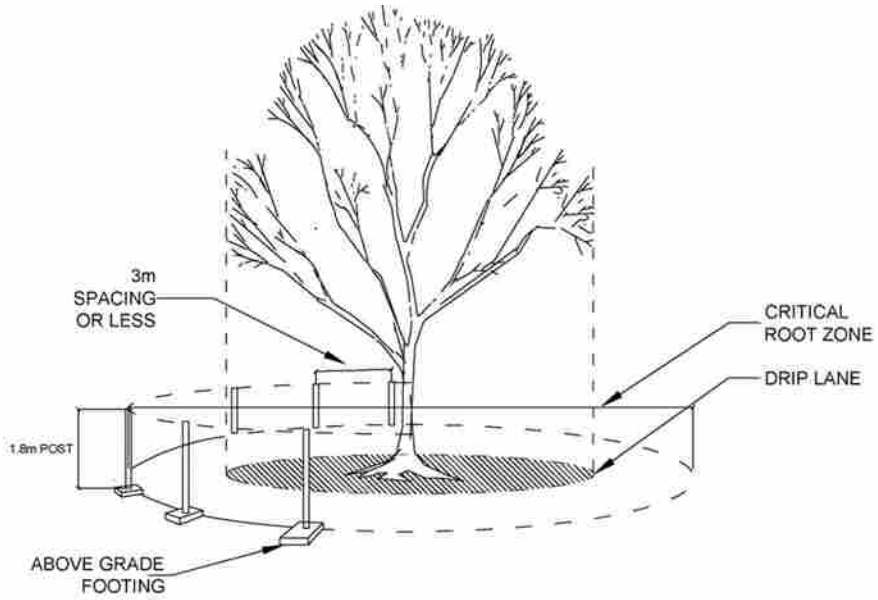


Fig. 104 Tree Protection Detail during Construction, Widening or Repairs

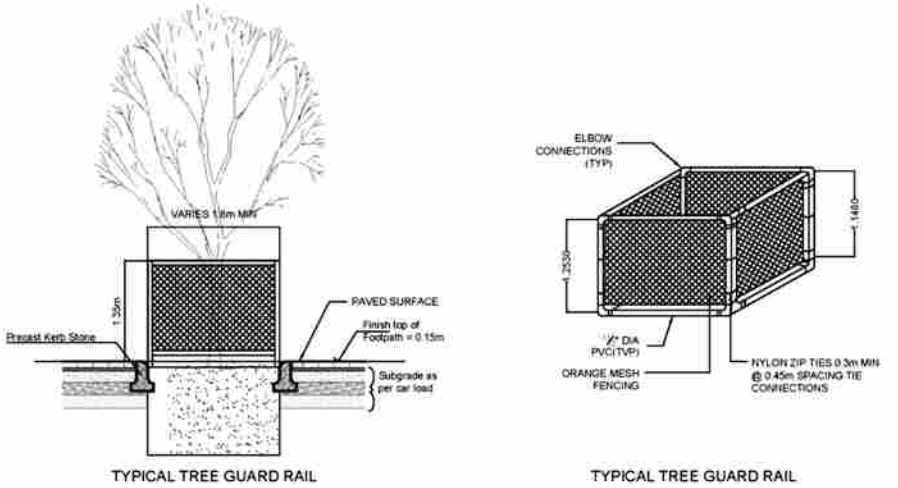


Fig. 105 Tree Guard for Young Trees or during Construction

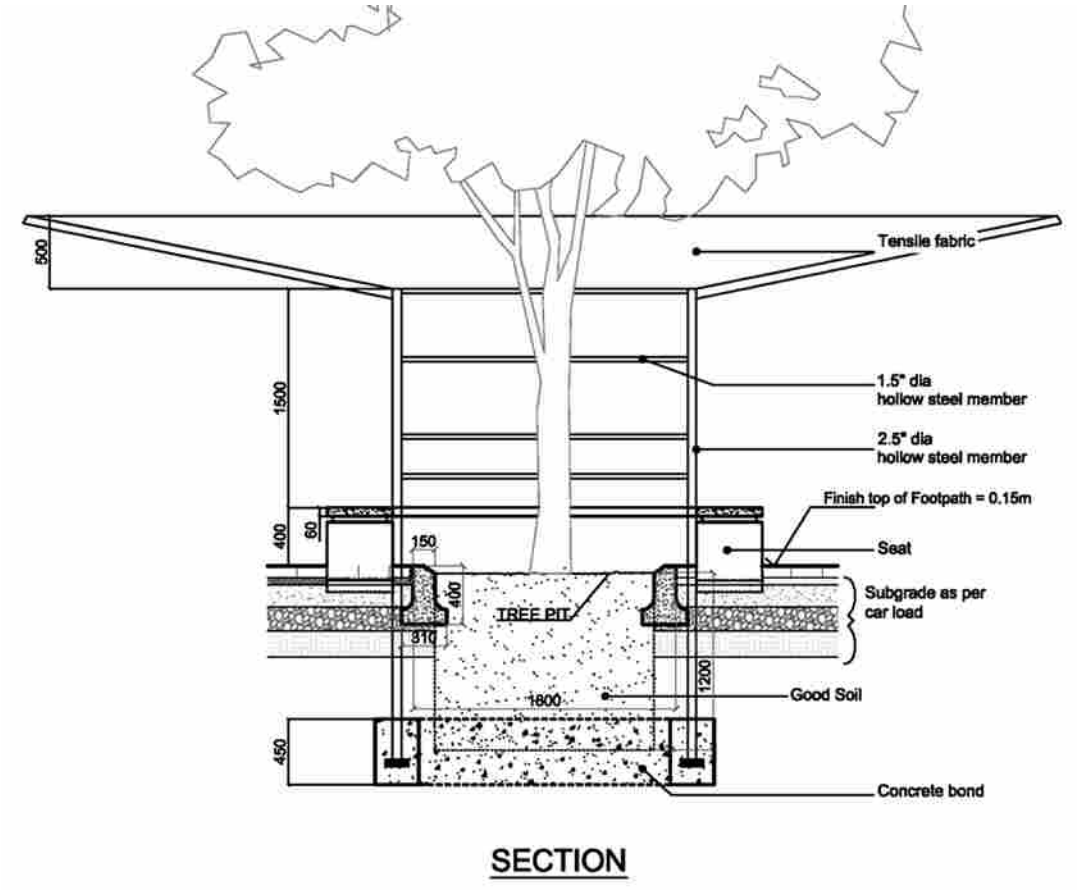


Fig. 106 Tree Guard Detail with Tensile Structure to Protect Trees when they are yet to Mature

3.5.4 *Tree grates*

(i) Heavy foot traffic can compact the soil limiting tree access to nutrients, oxygen and water, and can reduce the longevity of plants. Porous paving, tree grates and/or planting at the ground level and aeration to the roots are required for sustainability.

(ii) Tree grates or porous paving may be used to facilitate pedestrian movement, without causing soil compacting, as shown in **Fig. 107**.

(iii) Tree grate shall be made of concrete or cast iron or any similar material. Tree grates shall be of a minimum size of 1.8 m x 1.8 m or as per the dimensions of the tree pit.

(iv) The tree grate, if made of concrete, shall be 60 mm thick with all members in the design of the grate not less than 40 mm thickness. Cast Iron tree grate shall be not less than 15 mm thick.

(v) The level of tree grate shall be matched with the top level of the adjacent footpath level, such that the tree grate shall not project out of the footpath level after fixing.

(vi) Concrete tree grate shall be placed over the lining of the tree pit and fixed to place by bolts 150 mm long at three places per grate piece. Housing for bolts shall be kept during the construction of the tree pit lining, as shown in **Fig. 108**.

(vii) It shall be ensured during the design of the concrete tree grate that it is rubber molded with M20 grade concrete and without cracks and joints. Monolithic tree gratings shall be cast with enough holes kept for air and water to pass.

(viii) Cast Iron tree grate shall be fixed with vertical pegs cast into the corners of the grate and inserted into the soil for 150 mm deep and fixed in place by concrete stubs 150 mm x 150 mm at corners and buried deep to get the grating bolts driven through it for fixing.

Fig. 107 Tree Grating that allows Water to seep through and Plants to peep through, while allowing People to Walk Over

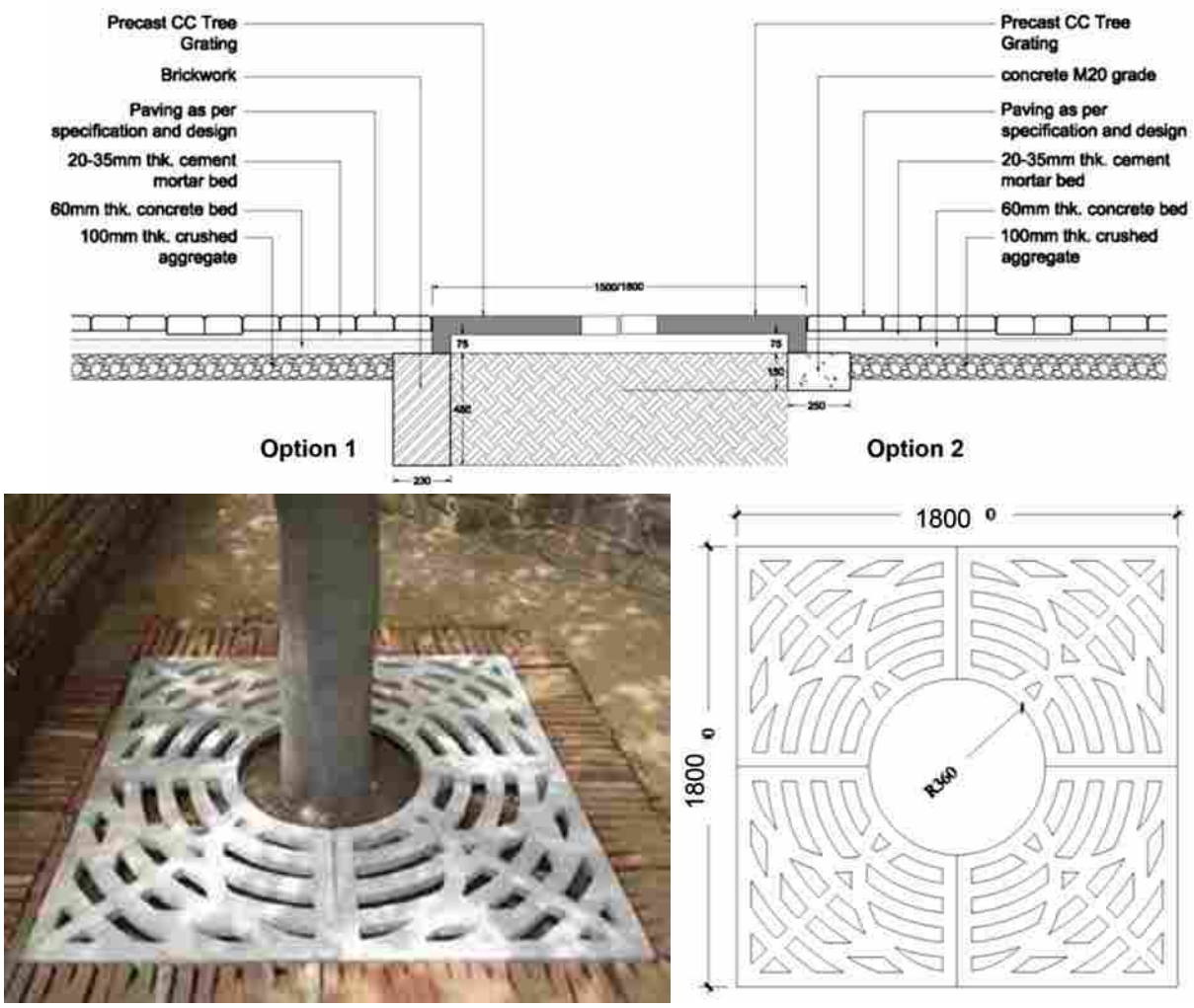


Fig. 108 Typical Concrete Tree-Grating Detail that allows Pedestrians to Walk Over them, without harming Tree-Roots or Over-Compacting the Soil

3.5.5 *Storm protection*

(i) In case of storm or cyclone areas with likelihood of uprooted trees or slipperiness during rains, tree plantation to be avoided. Trees with shallow roots and columnar habit should not be considered.

(ii) Staking to be done for new trees and for uprooted trees only, to add to its stability. Staking should be such that it prevents swaying of the truck, as shown in **Fig. 109**.

(iii) Staking shall be done by driving vertically inside the soil, three stakes of 2 m length and 60 mm diameter or 50 mm x 50 mm section made of wood and buried inside the soil for at last 50 cm.

(iv) The stakes shall be tied to tree trunk by means of cotton ties strong enough to not let the tree trunk sway. Another method is to drive the stakes inclined into the soil with its other end meeting other stakes at the trunk and then tying all together by means of cotton tie.

(v) All stakes shall be removed within one year of their fixing.

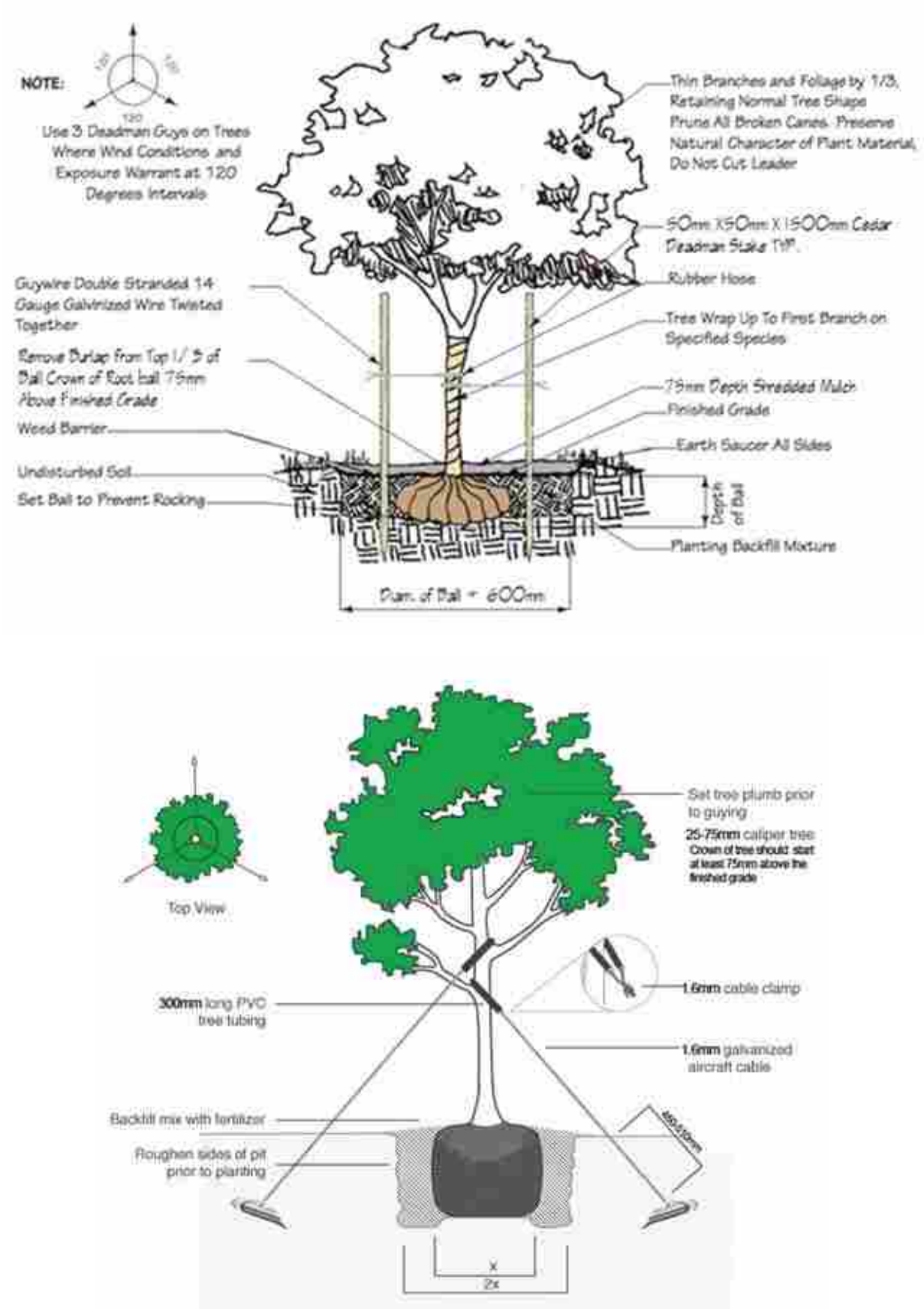


Fig. 109 Staking the Tree for Stability Post Storms or during Planting (above and below)

3.6 Typical Details for Street Landscape Elements

There are many commonly-used Street Landscape Elements such as Bollards, Benches, Paving and Boundary Walls. This section provides a few details of the same.

3.6.1 *Bollards*

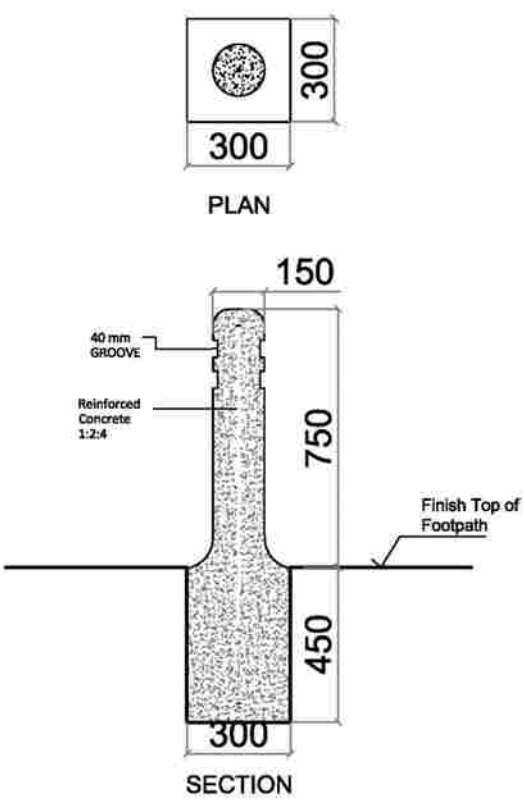


Fig. 110 Bollard Type 1

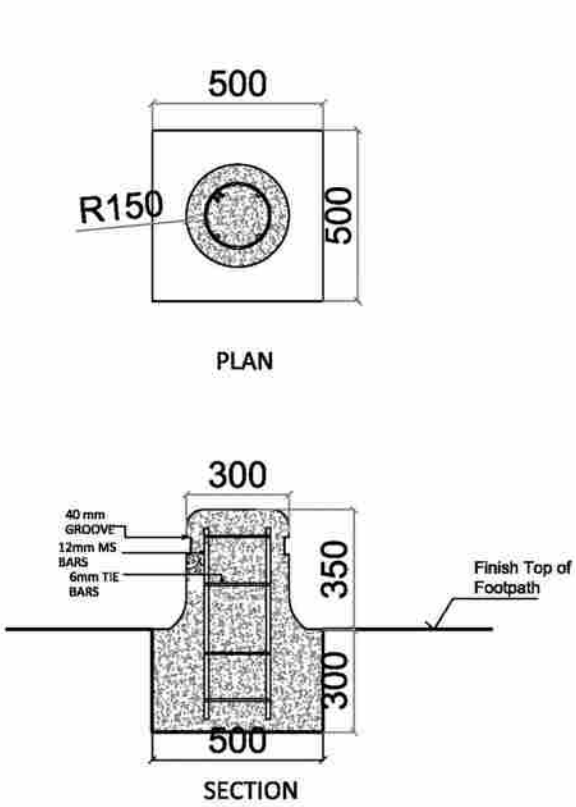


Fig. 111 Bollard Type 2

3.6.2 *Benches*

The bench shown in **Fig. 112** is made with the following specifications:

(i) Precast M30 concrete 100 mm thick and 2275 mm long and 450 mm wide, monolith seat perforated, transported in one piece to pre-prepared location.

(ii) The seat to rest on 1:2:4 PCC base 115 mm thick laid over rammed rubble soling on rammed earth up to depth of 200 mm.

(iii) Seat laid to position with level meter and backfill on all sides and finished with floor finish on all sides.

(iv) Curing as required.

The bench shown in **Fig. 113** is made with the following specifications:

(i) Precast M30 concrete 100 mm thick and 2275 mm long and 450 mm wide, monolith seat perforated, transported in one piece to pre-prepared location.

(ii) The seat to rest on 1.5 mm thick MS box section 50 mm x 100 mm dimension, bolted on concrete leg with foundation 300 mm high which shall rest on 1:2:4

PCC base 115 mm thick laid over rammed rubble soling on rammed earth up to depth of 200 mm.

(iii) Seat laid to position with level meter and backfill on all sides and finished with floor finish on all sides.

(iv) Curing as required.

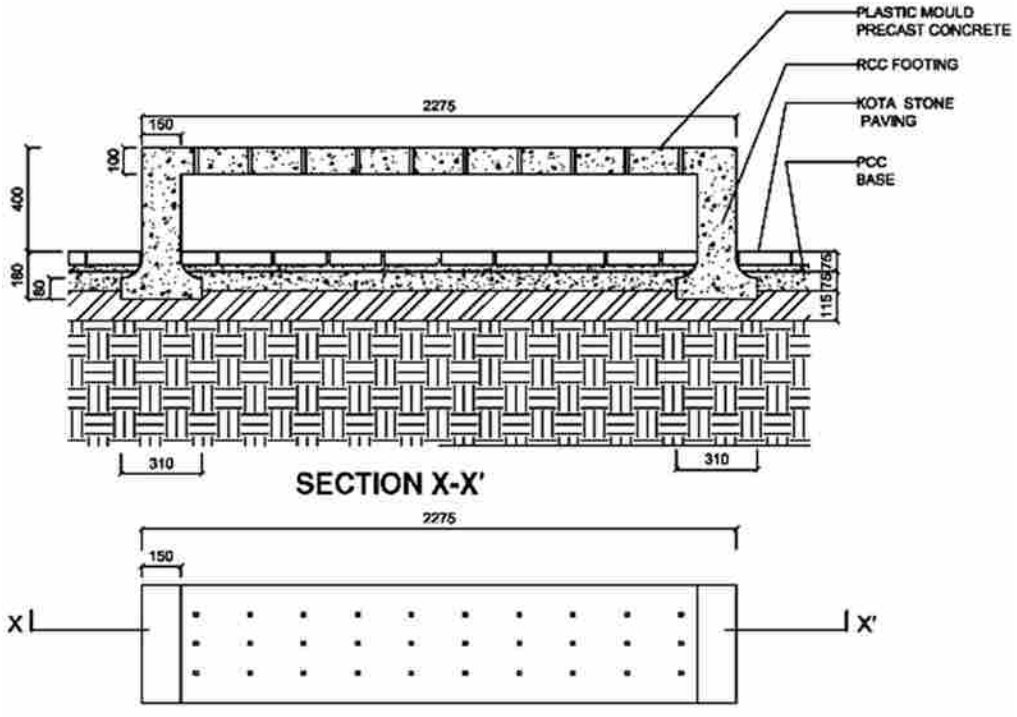


Fig. 112 Bench Type 1 - with Precast Concrete Material

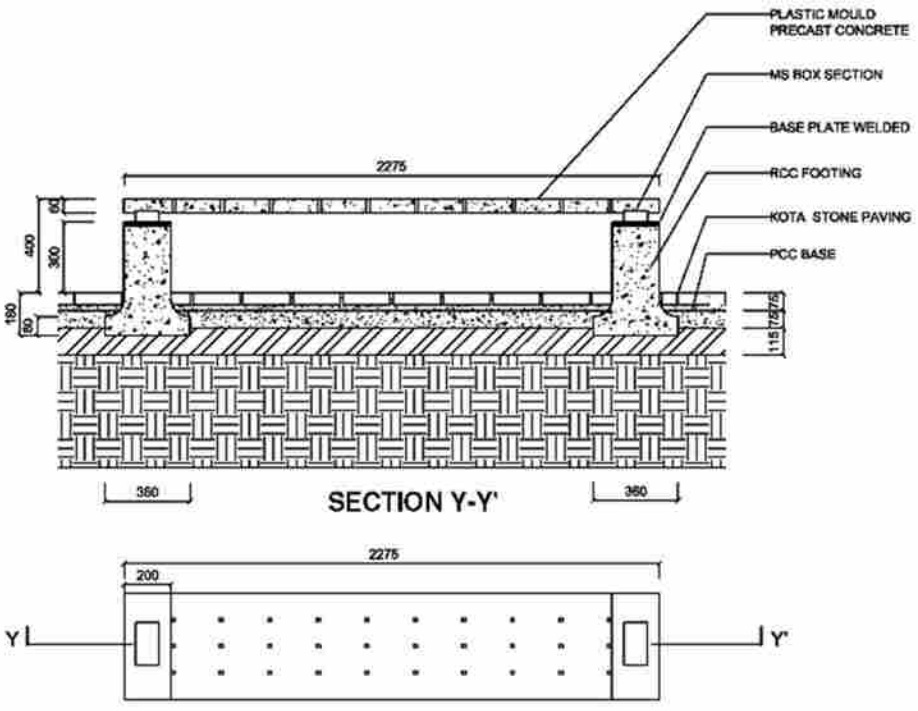


Fig. 113 Bench Type 2 - with Precast Concrete Seat Resting on Metal Section

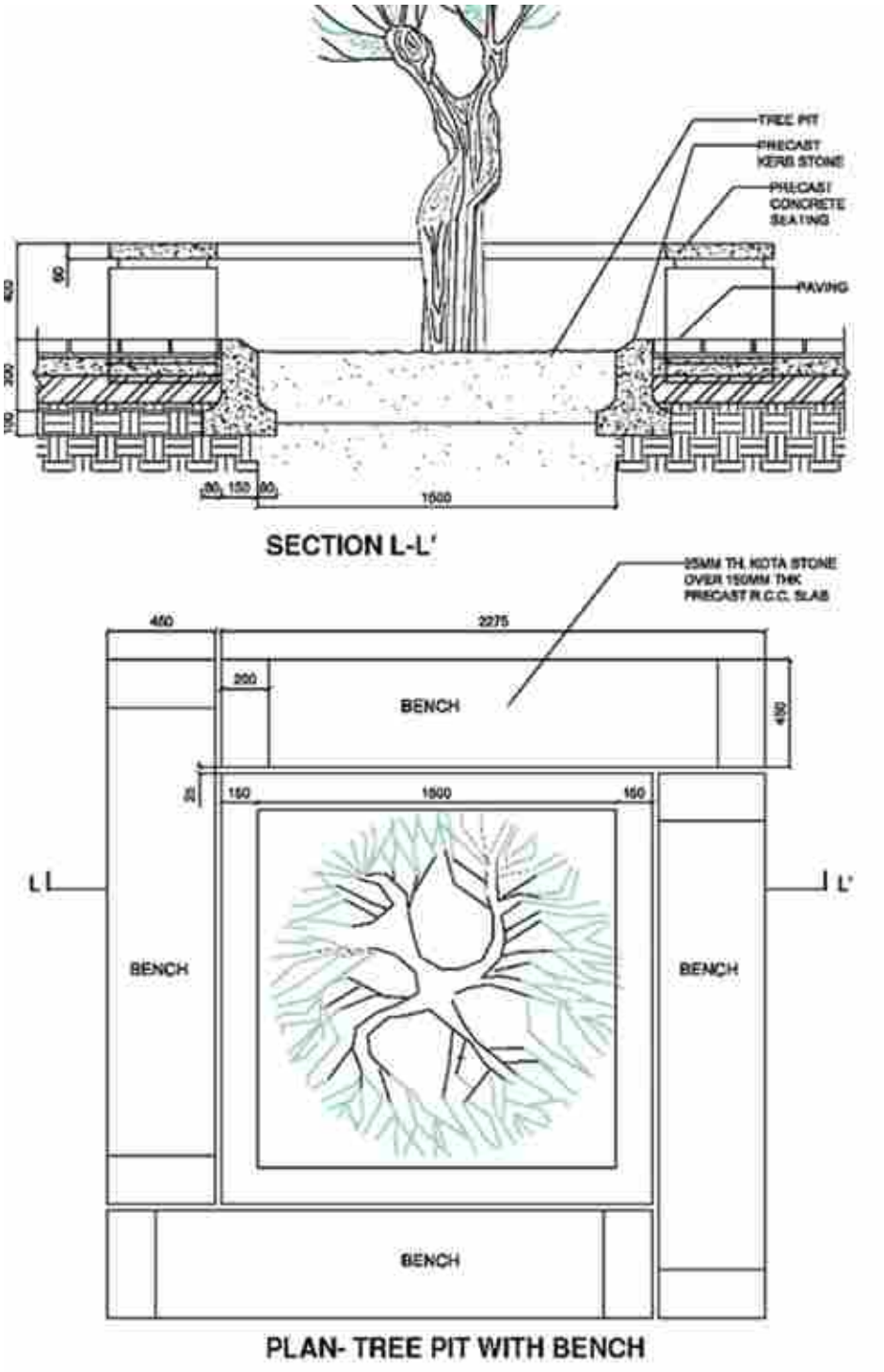


Fig. 114 Bench Type 3 - with Kota Stone Top (Also refer to 3.5.1 Point (v) for details)

3.6.3 *Paving*

Paving of footpaths must have adequate subgrade so as to prevent frequent damage, dislocation of paver blocks and need for repairs and replacement. A proper sub-grade also provides a comfortable and hindrance free walking environment especially to the differently abled, small children and older persons. The typical paving sub-grade detail is given in **Fig. 115** below which may be modified based on site and sub-soil conditions.

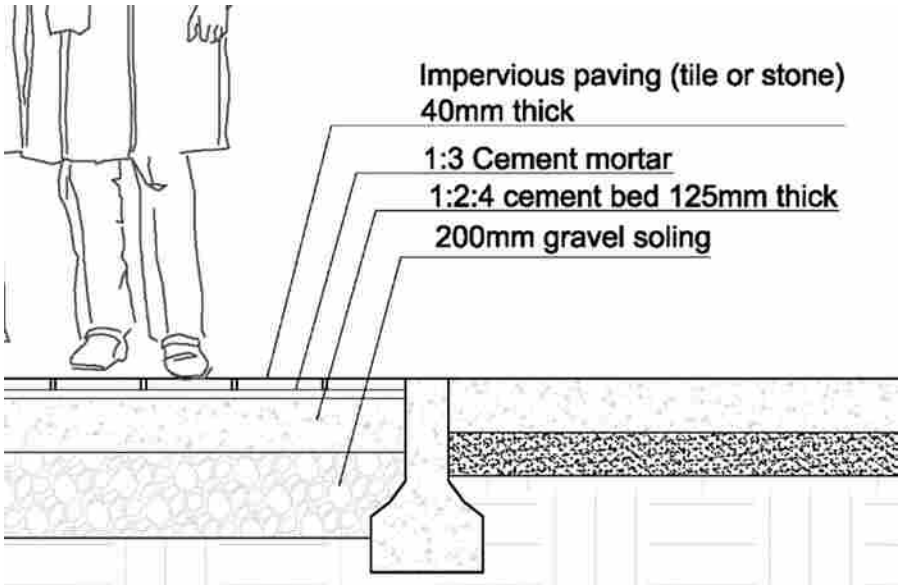


Fig. 115 Paving with Adequate Subgrade is required to provide Universal Accessibility and less need for Frequent Repairs

Permeable paving may be used in various areas within the ROW as explained in 2.6.1.

A typical detail is given in **Fig. 116** below, showing the porous sub-grade which is essential to allow percolation.

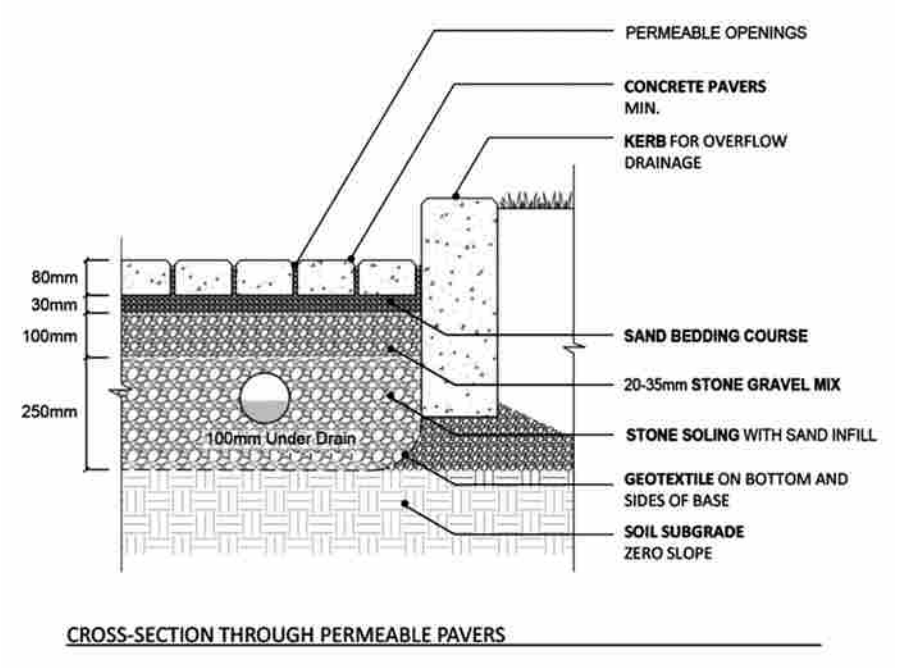


Fig. 116 Typical Permeable Paving Detail showing Porous Sub-Grade Layers

3.6.4 *Typical boundary/edge condition details*

The boundary wall can be modified in certain cases to a bench or seat which can double up as social space while rendering required porosity to the site. Typically, having such low seat-height boundary walls make the street safer and more inviting for a user, as shown in **Fig. 117**.

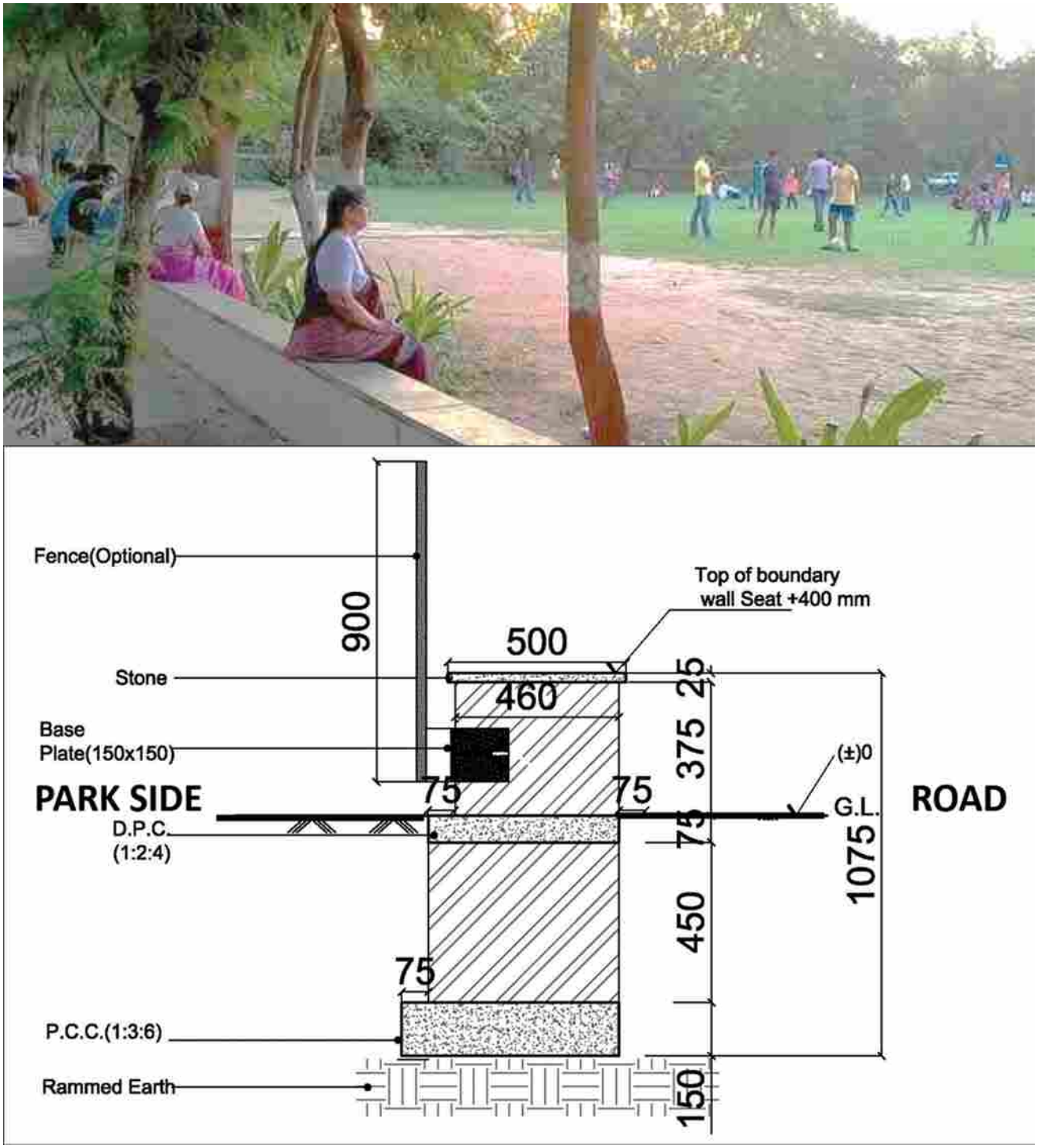


Fig. 117 A Typical Detail of Boundary Wall next to Park Edge. (Top) Boundary Wall in Use

3.7 Specifications for Storm Water Management

Landscape design can play a vital role in Storm Water Management. With appropriate construction detail, MFZ and landscape areas can be used for water percolation before the overflow goes to structured drains, thereby improving the ground water condition of the area as well as reducing load on the structured storm water drainage system, as shown in **Fig. 118**.

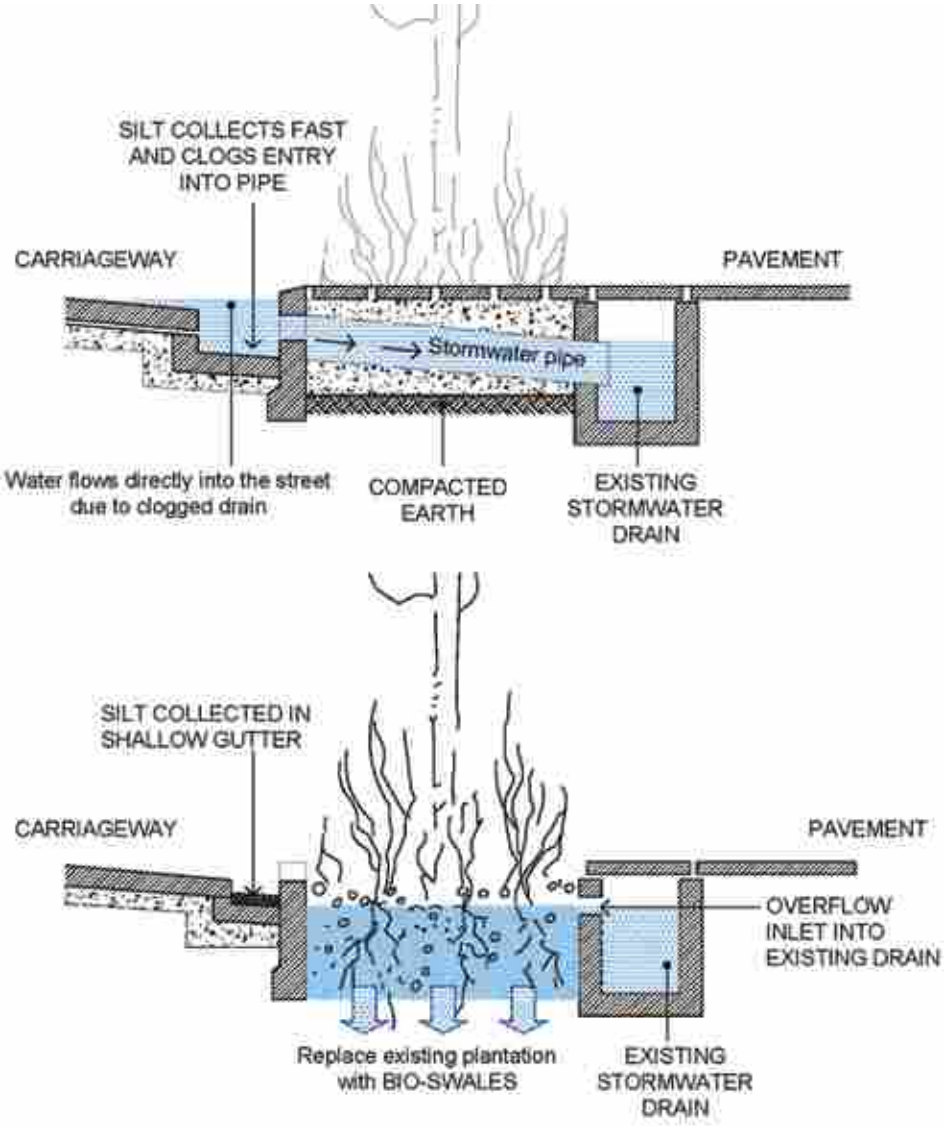


Fig. 118 Conventional System (above) and Decentralized System (below) of Road Drainage and Storm Water Treatment within ROW

(i) As shown in **Fig. 118**, in a standard system, storm-waterflows into the Storm Waterdrain, carrying all pollutants with it. Slope of Storm Water Pipe prevents drains from being used to full capacity. Drains convey this polluted storm water in the fastest possible manner to the nearest natural drain further polluting the latter. Over time, due to siltation of the gully chamber and drain itself, the overall capacity of the system decreases, leading to flowing of the roads, during rainy season.

(ii) In a decentralized system, storm-water flows directly into a bio-filtration pit or bio-swale system. Water is to be temporarily retained and infiltrated in the bio-swale and gradually conveyed to the nearest detention pond or conventional drain system. This allows storm water to be filtered and partly treated of pollutants before entering a natural water-body or ground water table.

(iii) For heavy rain situations, provisions may be made to allow overflow storm-water to overflow into the existing Storm Water Drain.

(iv) Bio-swales can connect to the Main Storm Water Drain – either in series (connected only at the end); or in parallel – i.e. each bio-swale bed overflows directly into the Storm Water drain, in case of heavy rainfall. The Parallel Connection option is preferable.

(v) Adding organic compost or mulch to soil improves its ability to support plants and absorb storm-water. Healthy soil is the backbone of natural drainage systems.

3.7.1 *Kerb details: for implementing bio-infiltration zones within MFZ*

Kerb cuts and placing of special types of kerbs or lowering of kerbs are essential to help storm water reach the infiltration basin. Several design options for such kerbs are shown in the **Figs. 119-122** below:

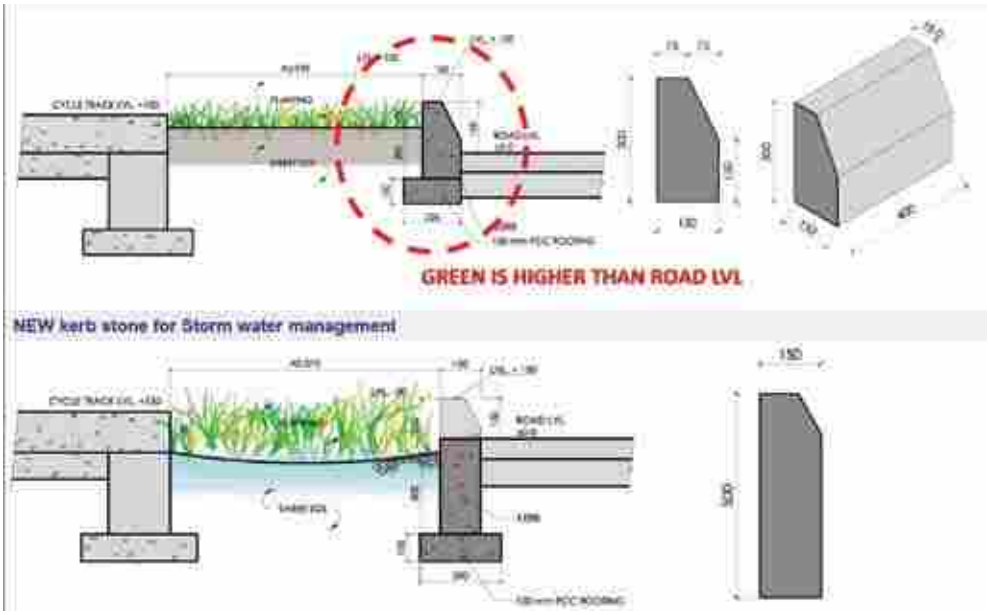


Fig. 119 Top: Conventional Method. Below: Kerb-cuts for Letting Water Flow

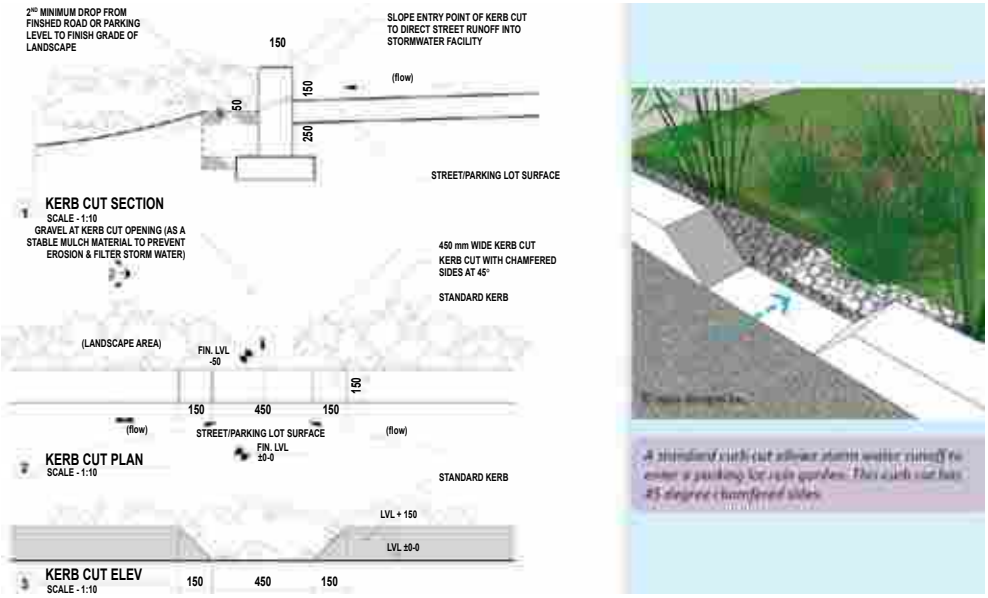


Fig. 120 Kerb Type 1: Standard Kerb Type

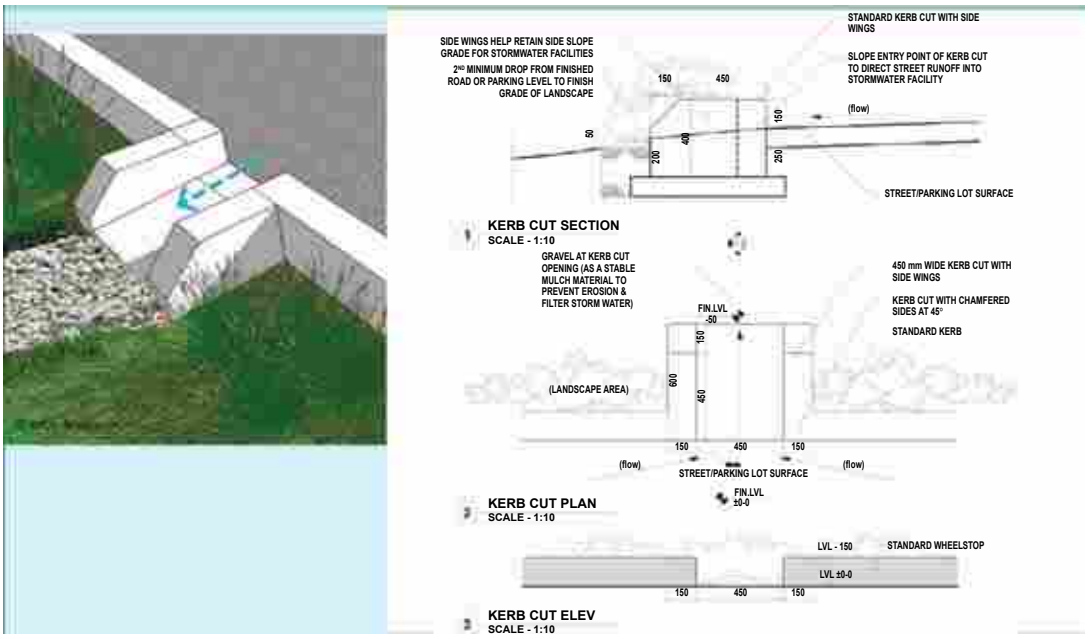


Fig. 121 Kerb Type 2: Kerb with Wings

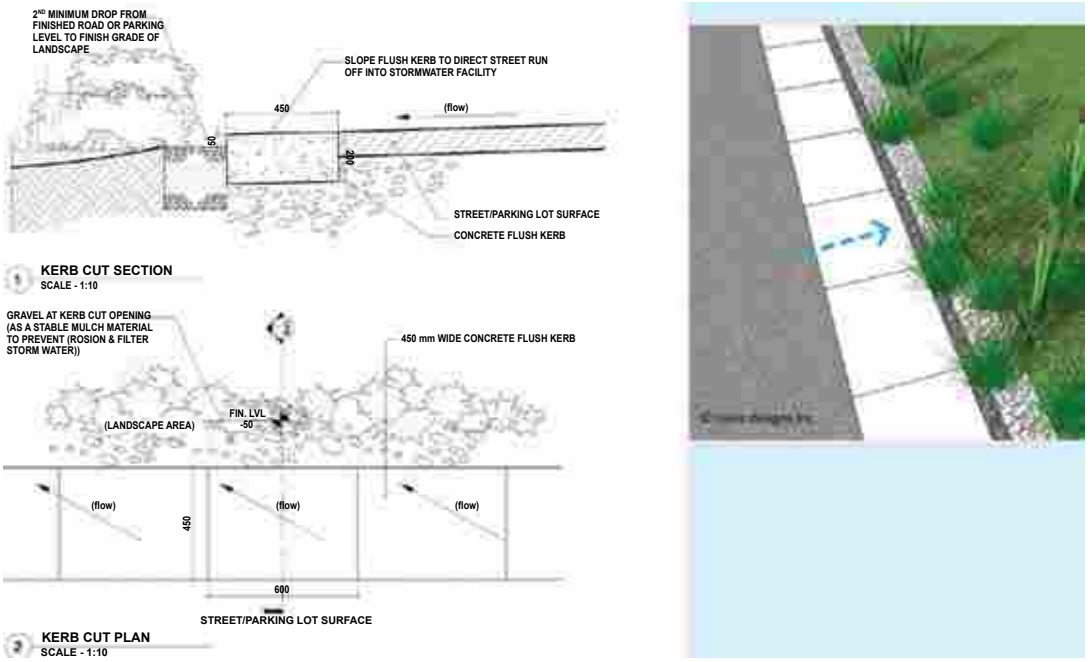


Fig. 122 Kerb Type 3: Flush Kerb

3.7.2 *Bio-swale details*

a) Typical Bio-swale typical detail within MFZ

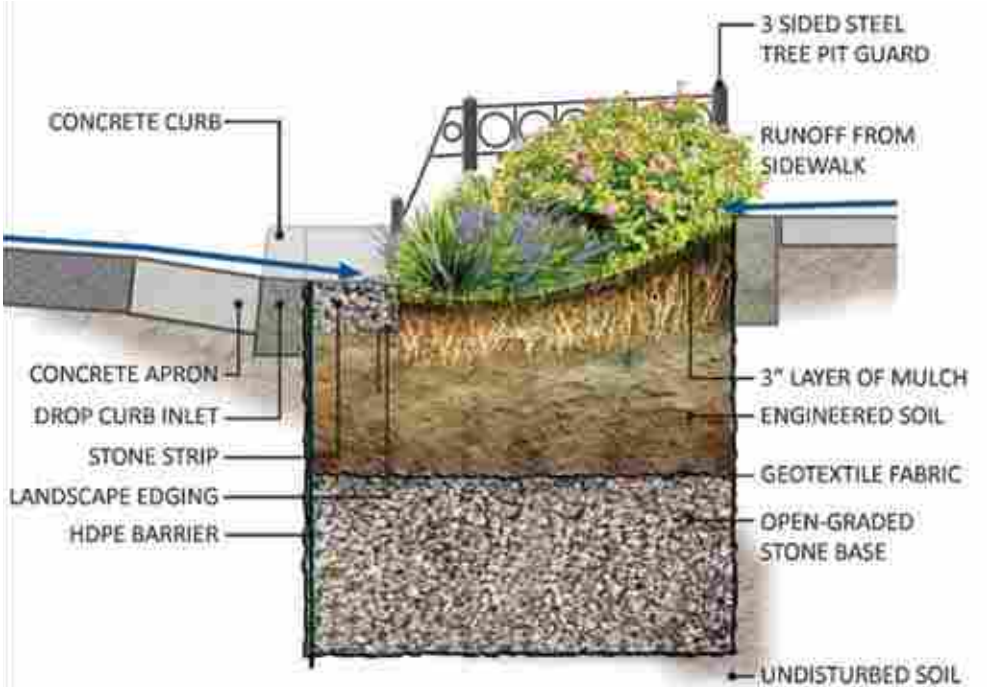
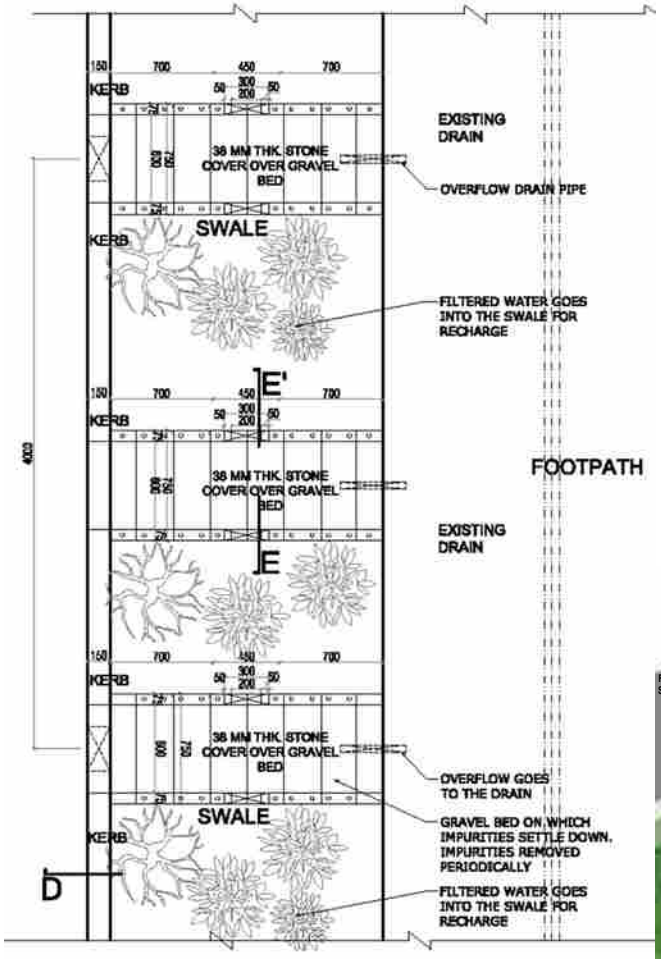
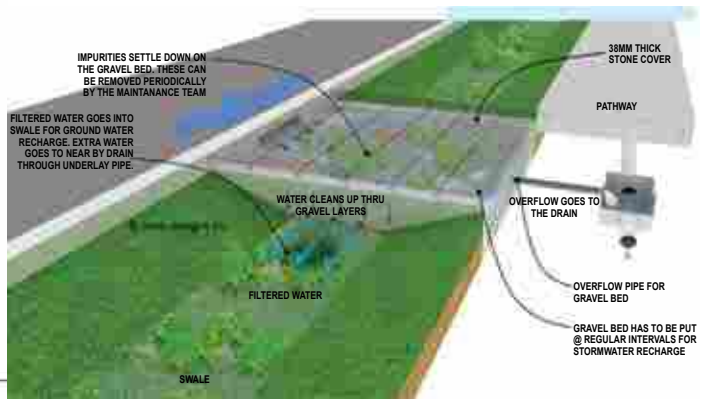


Fig. 123 Typical Bio-swale detail within MFZ

b) Typical bio-swale and local infiltration details within MFZ: for areas with low water table and non-clayey soils





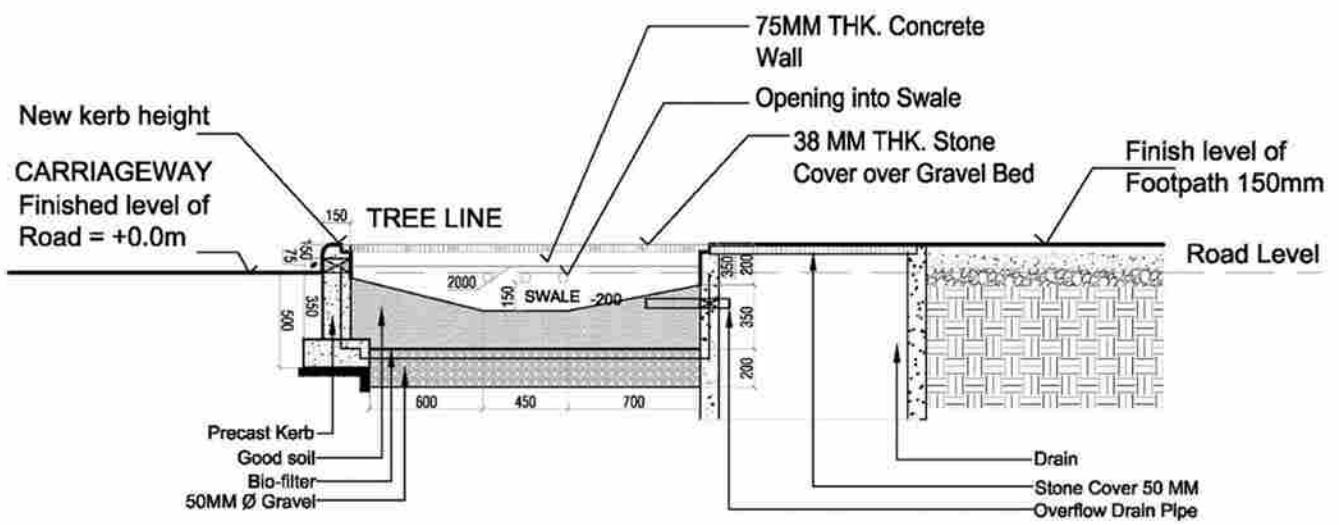


Fig. 124 Bio-swale in Plan (top left), View (top right) and Section (above)

c) Typical bio-swale and local infiltration details within MFZ: for areas with clayey soils

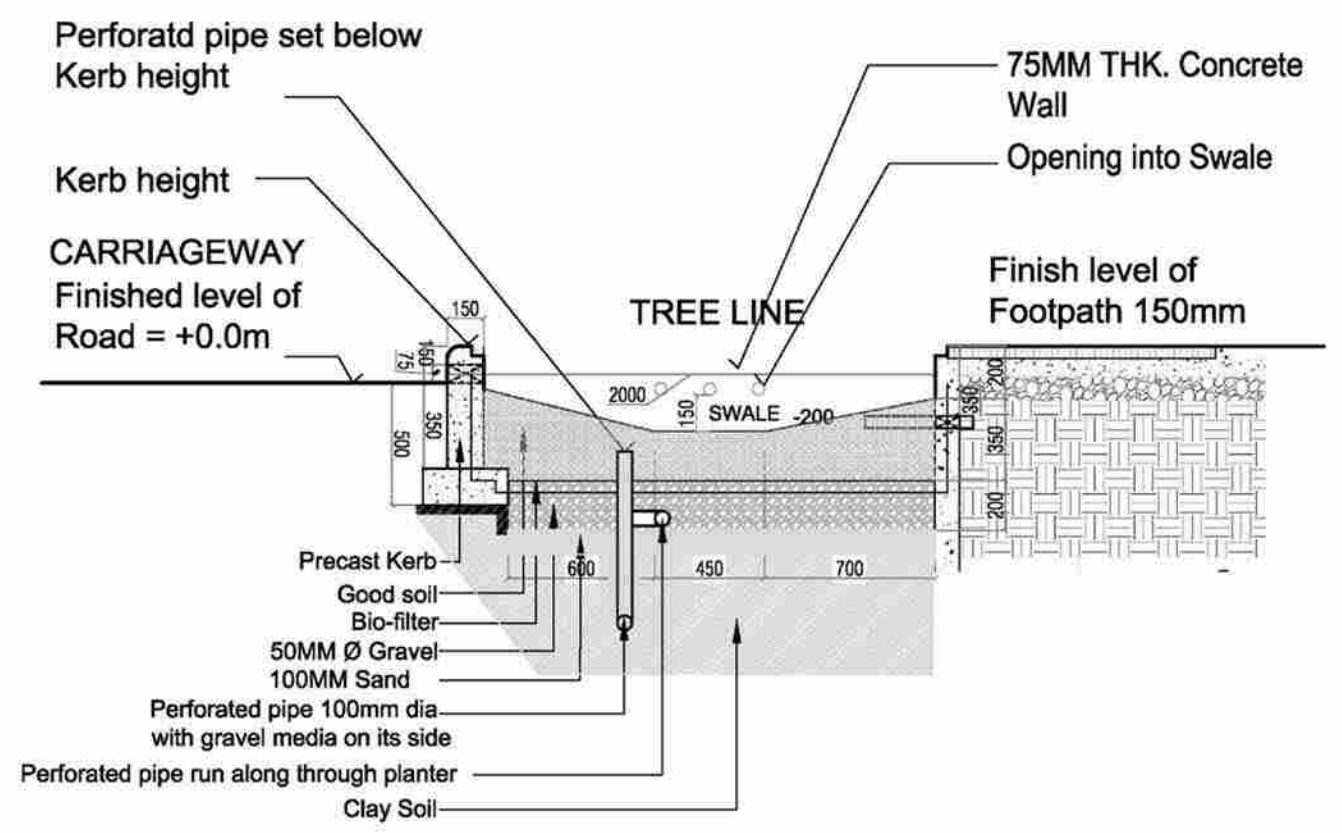


Fig. 125 Typical Bio-swale and Local Infiltration details within MFZ: for areas with clayey soils

d) Storm water pit for clayey soils

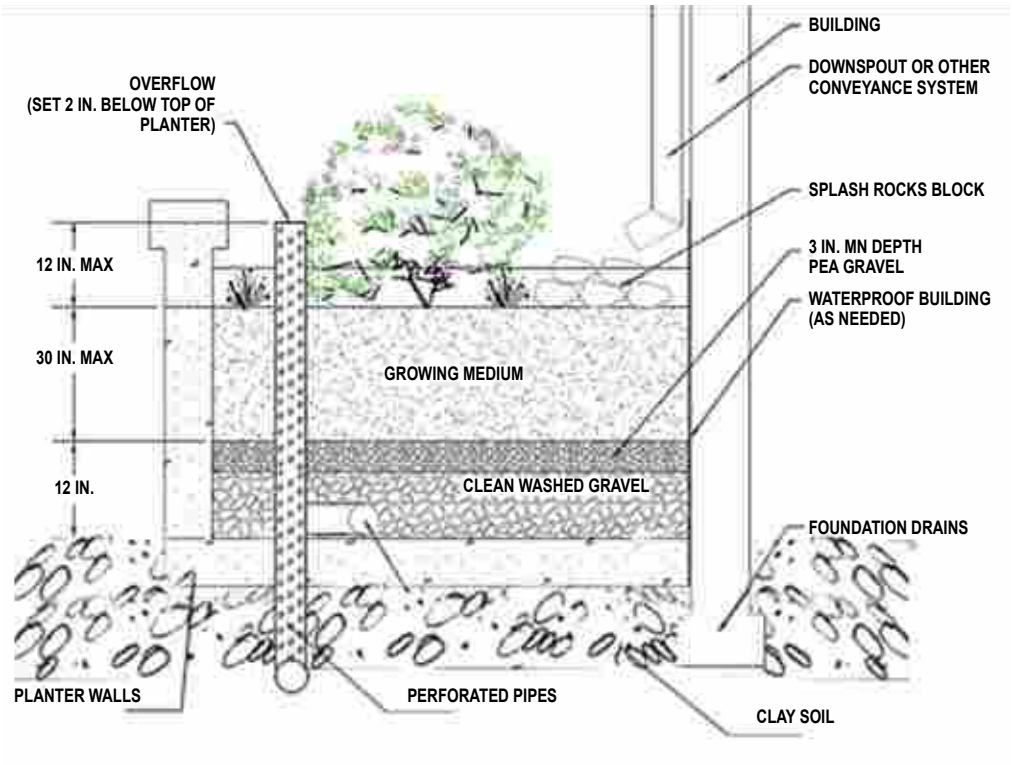


Fig.126 Storm Water Pit for Clayey Soils

3.7.3 *Storm-water management construction details*

a) Draining overflow rain into parks in new roads and exiting areas

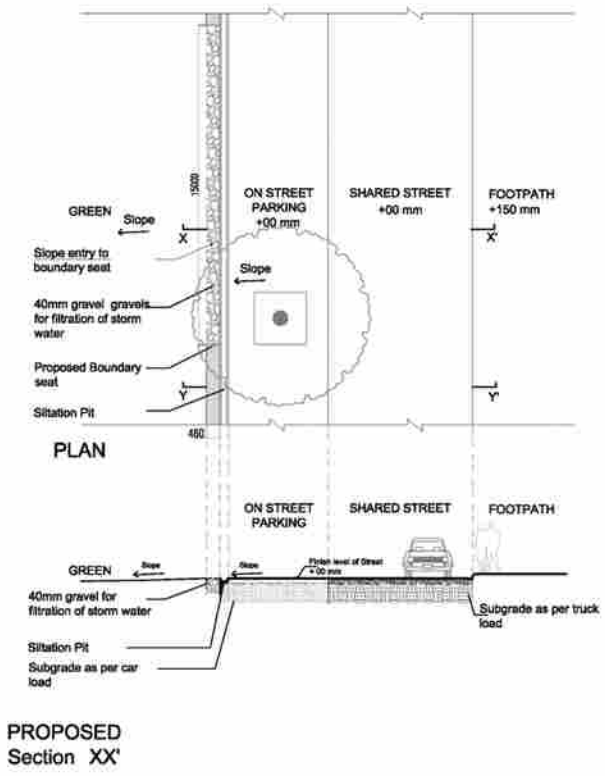


Fig. 127 Without Boundary Wall, a detail for Excess Storm-Water to Drain into nearby Park

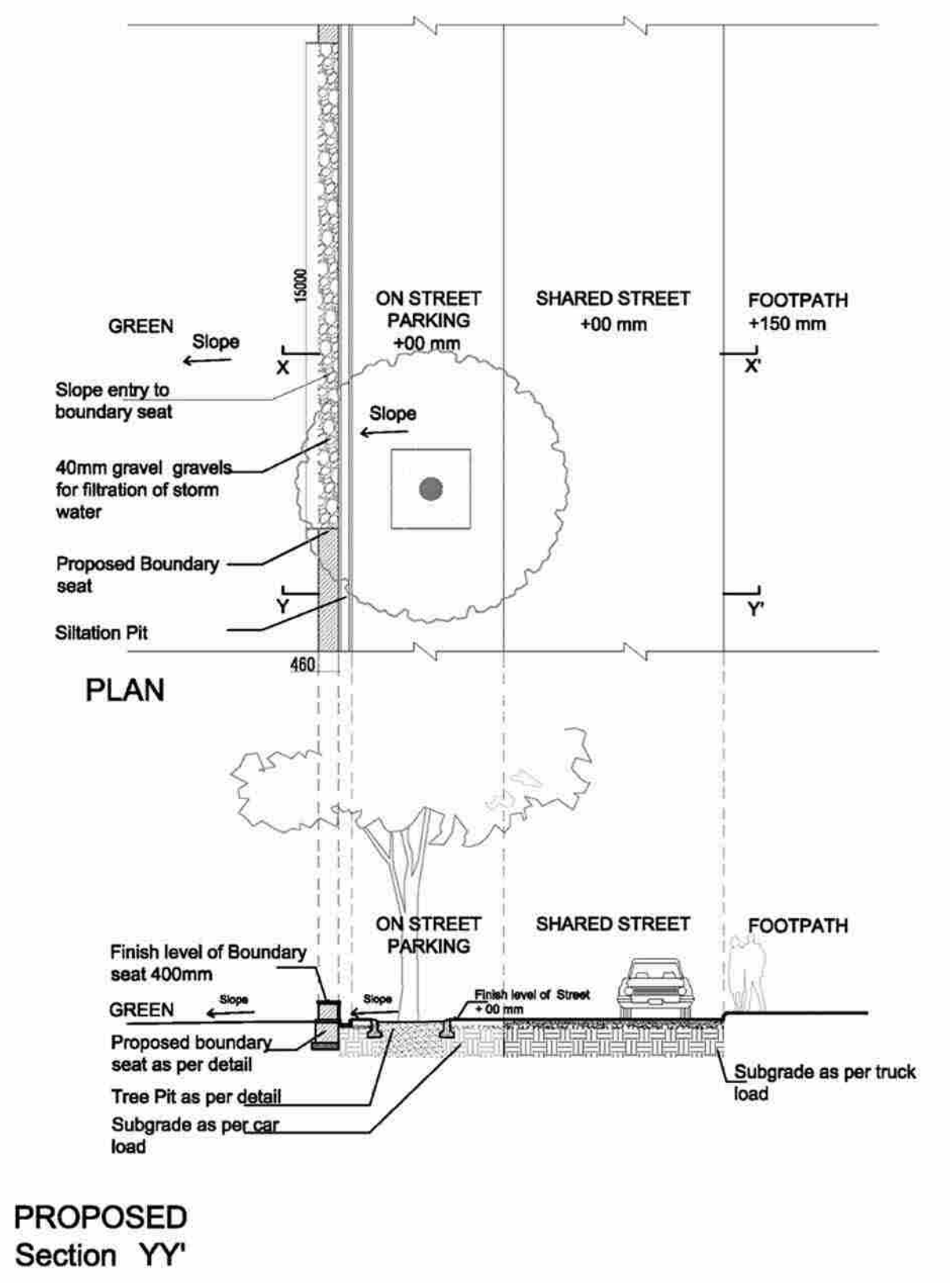


Fig. 128 With Boundary Wall, a detail for Excess Storm-Water to Drain into nearby Park

b) Centre-draining roads and streets

c) Retrofitting existing streets with SWM systems

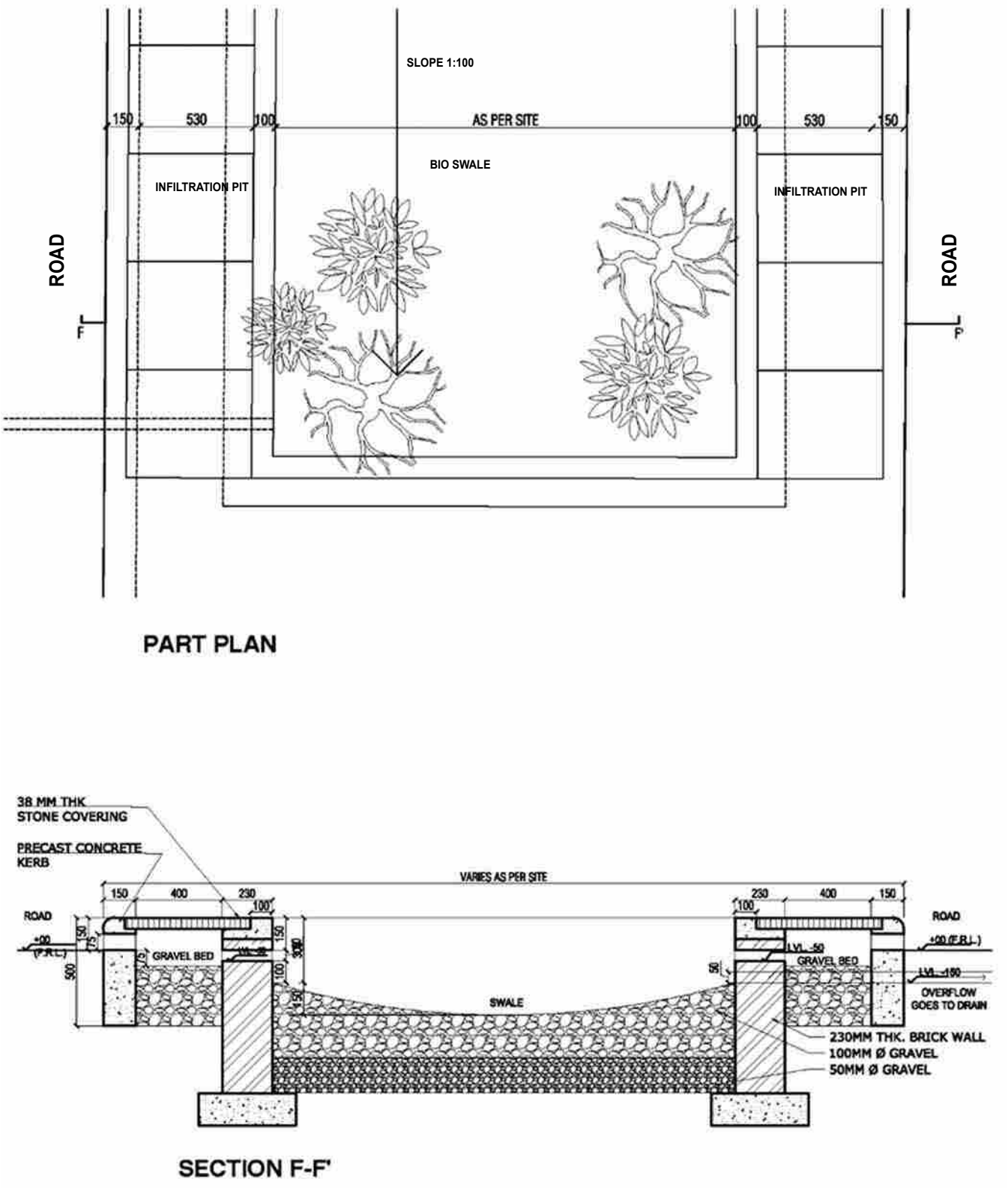


Fig. 129 Typical Detail of Centre-Draining Roads and Streets having Infiltration Basin

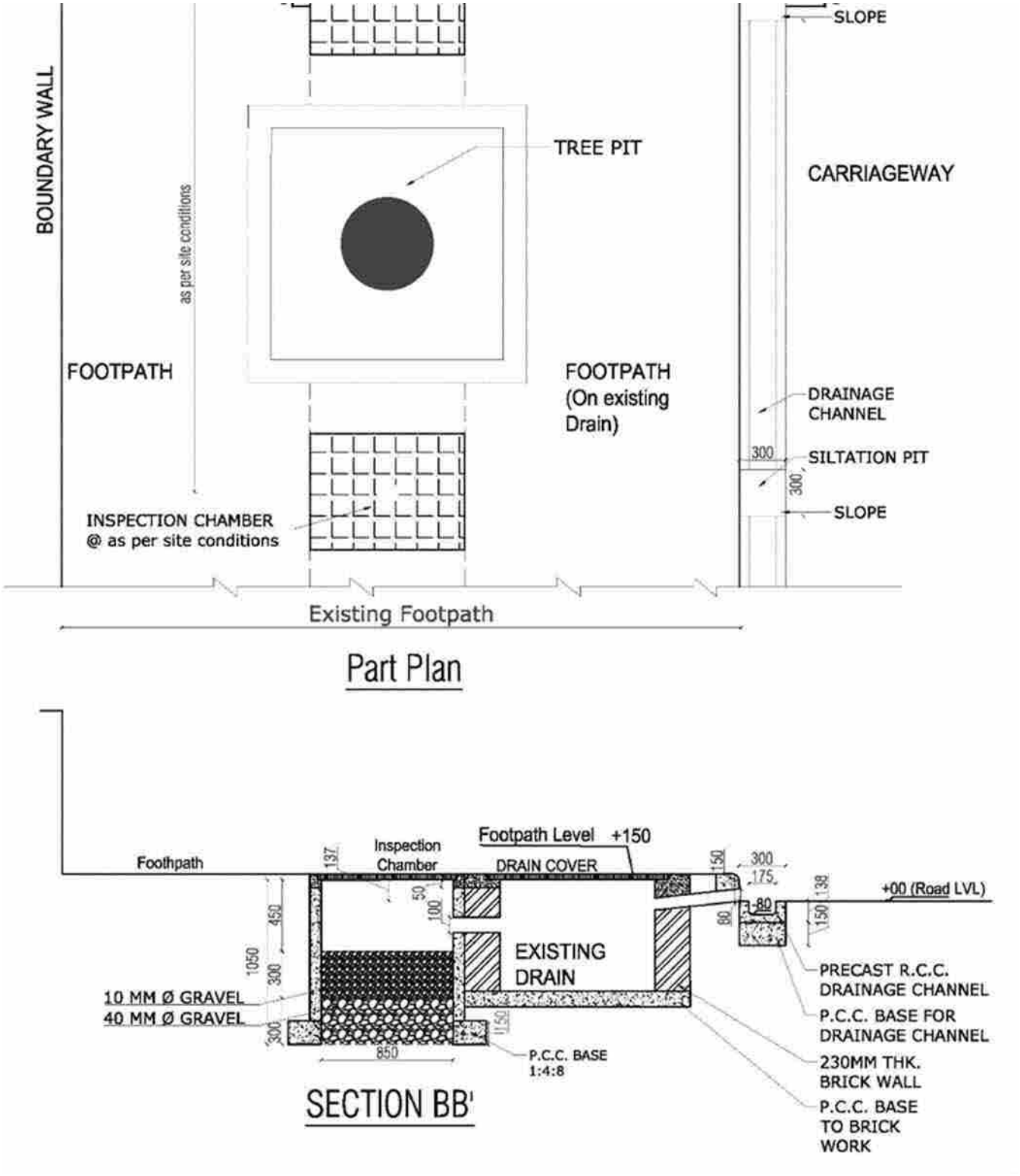


Fig. 130 Retrofitting Existing Streets with Storm-Water Management Systems and creating Local Recharge in Existing Roads

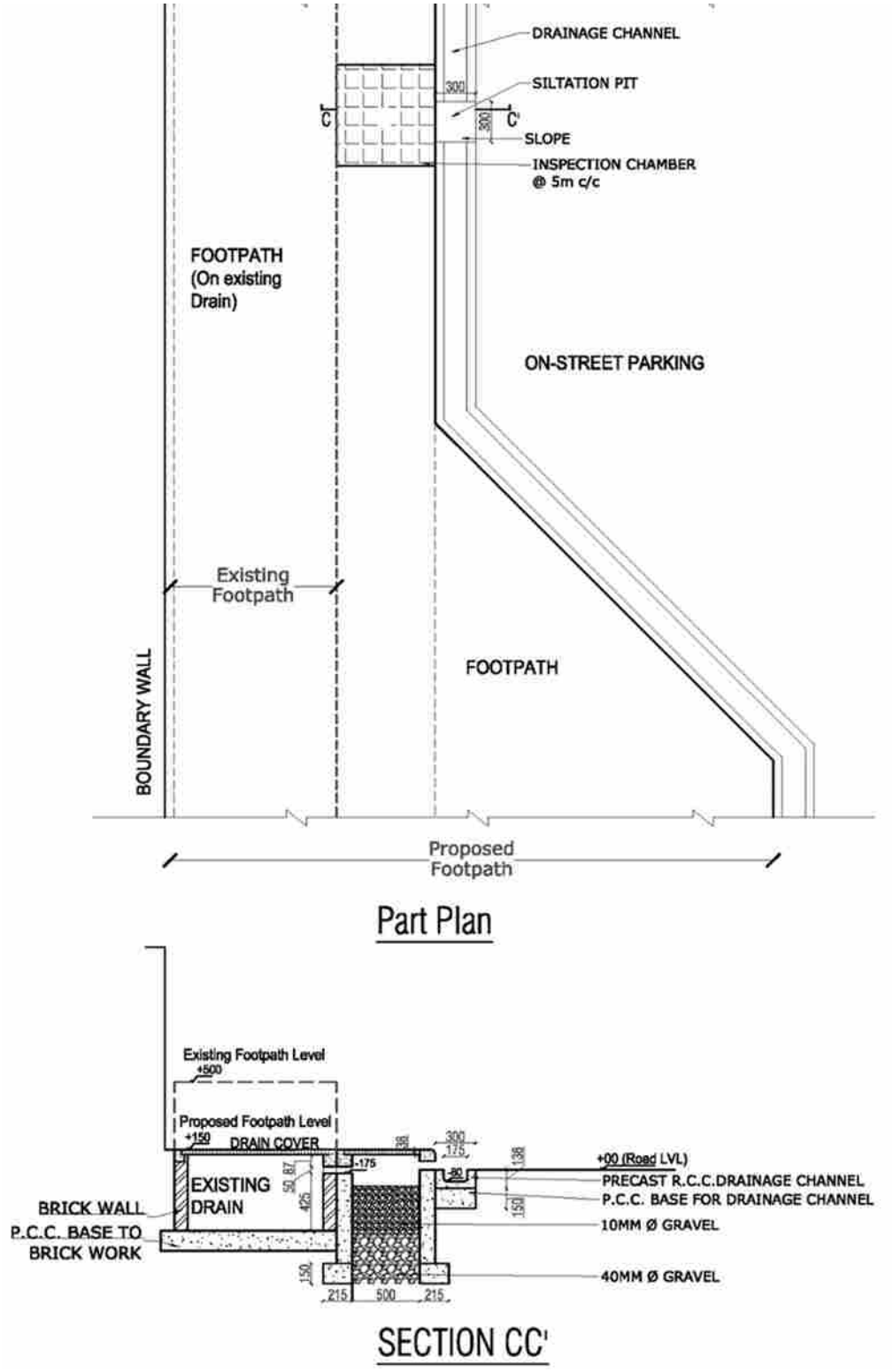


Fig. 131 Retrofitting Existing Streets with Storm-Water Management Systems and Creating Local Recharge in Existing Roads

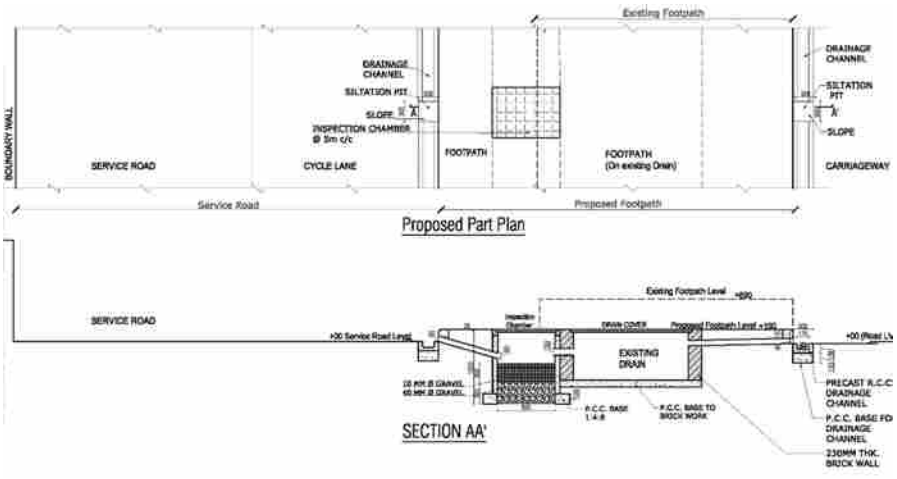


Fig. 132 Storm Water Drain with Infiltration Pit for Overflow – e.g. 45 m RoW

3.7.4 *Plant palette for bio-swales*

Bio-filtration beds need to be planted with specialized local plants/reeds/grasses, etc. which help in filtering and treating pollutants before the water enters the sub-soil or is conveyed away. Such plants help cut down costs of localized rainwater harvesting/water treatment and also contribute to reduction of heat island effect and air pollution.

The process of the working of such plants is illustrated in **Fig. 133**. Such landscapes which incorporate plants of this palate are aptly termed as “working landscapes”.

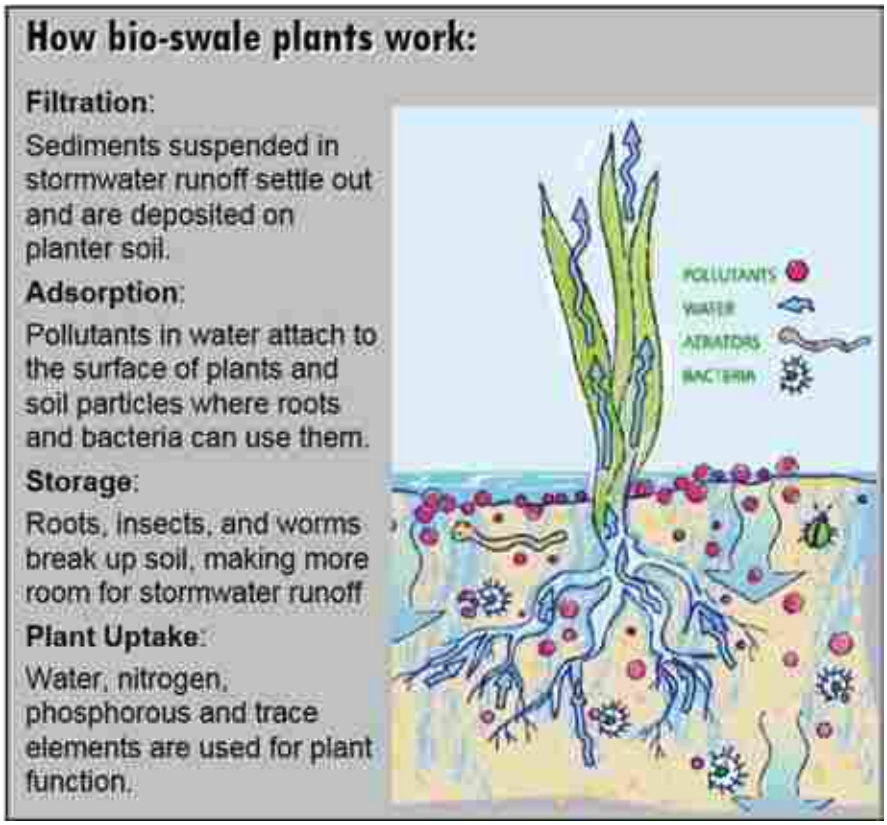


Fig. 133 Working Process of a Bio-filtration Plant

Table 12 Table of Selection of Plants for Bio-swale

Yellow Canna

Red Canna

Pampas Grass

Cyperus Spp.

Spider Lily

Canna Verigated

Typha Spp.

Soft Rush/Bull Rush Spp.

Elephant Ear

Phragmites australis/spp.

Scirpus

Eichhornia crassipes

Potamogeton nodosus

Sagittaria latifolia

Ceratophyllum demersum

Bioswale Plant Palette (For colder region)

Iris

Bergnia Ciliata

Hydreangea

Fern

3.8 Specifications for Irrigation

(i) Irrigation system should be designed to prevent run-off, low head drainage, over-watering, or other similar conditions where irrigation water flows onto non-targeted areas, such as adjacent property, non-irrigated areas, hardscapes, roadways or structures.

(ii) Every irrigation system shall necessarily have water meter attached to the mains and water record shall be maintained on a daily basis.

(iii) Water Use Estimate (WUE) should be calculated on seasonal basis and on the factors such as: local climate, soil type, plant selection (evapotranspiration rate) and irrigation method used.

(iv) As far as possible, recycled water should be used for irrigation.

(v) Irrigation systems must be designed in a manner that precipitation rate of 19 mm/hr is not exceeded in any part of landscape/planter beds.

(vi) Sprinklers, drip irrigation and bubblers must be on separate valves.

(vii) Low head drainage is not recommended. Anti-drain valves or check valves in sprinkler heads and drip emitter devices are required as necessary to prevent low-head drainage.

(viii) Overhead irrigation is not to be permitted within 0.6 m of any non-permeable surface.

(ix) While planning, high water use plants should be clubbed together and separated from low water use plants so that irrigation system can be efficiently planned. Each water use area (referred to as hydrozone) shall correspond to total WUE on a street.

(x) Irrigation pipes should be embedded under soil at 0.3 m-0.6 m from finish level, to avoid vandalism or accidental punctures.

(xi) Drip irrigation system should be preferred over sprinkler or hose-flooding system to appropriately conserve water and to avoid maintenance issues associated with sprinklers.

(xii) Irrigation systems should be designed with manual over-rides.

(xiii) Regular checks to ascertain soil moisture content should be made to avoid over-watering and re-calibrating the irrigation schedule.

(xiv) The following backfill coverage to finished grade is required over the piping:

a. For street sides, medians, open areas, planter beds: 300-400 mm

b. For sleeving under carriageways: 450-600 mm

Irrigation design shall contain:

(i) Location and size of separate water meters for landscape;

(ii) Location, type and size of all components of the irrigation system, including controllers, main and lateral lines, valves, sprinkler heads, moisture sensing devices, rain switches, quick couplers, pressure regulators, and backflow prevention devices;

(iii) Static water pressure at the point of connection to the public water supply;

(iv) Flow rate (litres per minute), application rate (litres per hour), and design operating pressure (pressure per square cm) for each station;

(v) Recycled water irrigation systems.

Calculating Water Use Estimate (WUE)

Water Use Estimate for each plant or Hydrozone can be calculated as cumulative of total water requirement by all the plants in a specific area or in a planter. It can be calculated as follows:

Water requirement of plant (liters per day) = (2.36 x A_c x ET_P x F_P)/IE

Where,

A_c = Canopy area of the plant (plan-view size)

ET_P = Potential Evapotranspiration Rate (of a plant in a region)

F_P = Plant factor that measures the resistance of plants to stress conditions

IE = Irrigation Efficiency

Table 13 Potential Evapotranspiration Rates

Sr. No.	Climate Type	ETP
1	Cool Humid	3-4 mm per day
2	Cool Dry	4-5 mm per day
3	Warm Humid	4-5 mm per day
4	Warm Dry	5-6 mm per day
5	Hot Humid	6-8 mm per day
6	Hot Dry	8-11 mm per day

Cool = under 21˚C as an average midsummer high

Warm = between 21˚C and 32˚C as midsummer high

Hot = over 32˚C

Humid = over 50% as average midsummer relative humidity [dry = under 50%]

Table 14 Plant Factor

Sr. No.	FP	Types of Plants
1	1.0	Evergreen, Fruit trees, small shrubs, vines, perennials, and lush ground cover
2	0.7	Newly shaded native plants in semi-arid and arid regions; ornamental or shade trees and shrubs native to humid areas
3	0.4	Established plants native to area

Table 15 Irrigation Efficiency

Sr. No.	Climate Type	Factor
1	Hot, dry and high desert	0.85
2	Moderate and hot	0.90
3	Cool and very cool	0.95

3.8.1 *Soil characteristics determining irrigation*

The soil type on the site is a factor in determining how fast and how often water can be applied to the plant material. Soil absorbs and holds water in much the same way as a sponge. A given texture and volume of soil will hold a given amount of moisture. The intake rate of the soil will influence the precipitation rate and type of sprinkler that can be utilized. The ability of soil to hold moisture, and the amount of moisture it can hold, will greatly affect the irrigation operational schedule.

Table 16 Water Intake for various Soil Types

Sr. No.	Soil type	Soil texture	Soil components	Intake Rate	Water retention	Drainage Erosion
1	Sandy Soil	Coarse texture	Sand	Very high	Very low	Good drainage Low erosion
			Loamy Sand	High	Low	
2	Loamy Soil	Moderately Coarse	Sandy, Fine	Medium	Moderately Low	Good drainage Low erosion
		Medium Texture	Fine loam, Loam, Silty loam, Silt	Medium	Moderately high	Moderate drainage
		Moderately fine	Clay loam, sandy loam	Moderately low	High	
3	Clay Soil	Fine texture	Sandy clay, Silty clay, Clay	Low	High	Drainage Severe erosion

3.8.2 *Hydrozone*

"Hydrozone" means a portion of the landscaped area having plants with similar water needs and rooting depth. A hydrozone may be irrigated or non-irrigated. The design of the irrigation system should conform to the hydrozone of the landscape design plan. While planning for irrigation or designing an irrigation system, the following shall be considered:

(i) Each valve shall irrigate a hydrozone with similar site, slope, sun exposure, soil conditions, and plant materials with similar water use.

(ii) Sprinkler heads and other emission devices shall be selected based on what is appropriate for the plant type within that hydrozone.

(iii) Where feasible, trees shall be placed on separate valves from shrubs, groundcovers, and turf to facilitate the appropriate irrigation of trees. The mature size and extent of the root zone shall be considered when designing irrigation for the tree.

(iv) Individual hydrozones that mix high and low water use plants shall not be permitted.

(v) On the landscape design plan and irrigation design plan, hydrozone areas shall be designated by number, letter, or other designation.

3.8.3 *Components of an irrigation system*

All irrigation systems use all or some of the following components in various combinations to deliver water to the plant beds. A typical irrigation system will have the following components associated with them.

(i) Automatic Irrigation Controllers

(ii) Irrigation emitters

(iii) Solenoid cables and connectors

(iv) Irrigation system sensors

(v) Filters

(vi) Valve Boxes

(vii) Valves

(viii) Backflow prevention devices

(ix) Mainlines, Laterals, Sub-mains

(x) Flow and Water pressure

(xi) Hose pipes

3.8.4 *Types of irrigation emitters/systems*

The following irrigation emitters/systems employ one or more of the components listed above, in various combinations.

(i) Drip

(ii) Sprinkler

(iii) Flooding

a) Drip Irrigation

Drip irrigation system can offer more efficient method of watering compared to other systems, particularly on road side and for planters, and therefore should be preferred choice for irrigation of urban roads, as shown in **Fig. 134**. Installation can be cheap and, with maintenance, a drip system can last as long as or more than other irrigation systems. Drip irrigation applies water to the soil slowly. The water flows under low pressure through drippers/emitters, bubblers, or spray heads placed at intervals. Because drip irrigation systems distribute water slowly, the run time may be significantly longer than that for a traditional sprinkler system. However, there will be less evaporation and loss due to runoff.

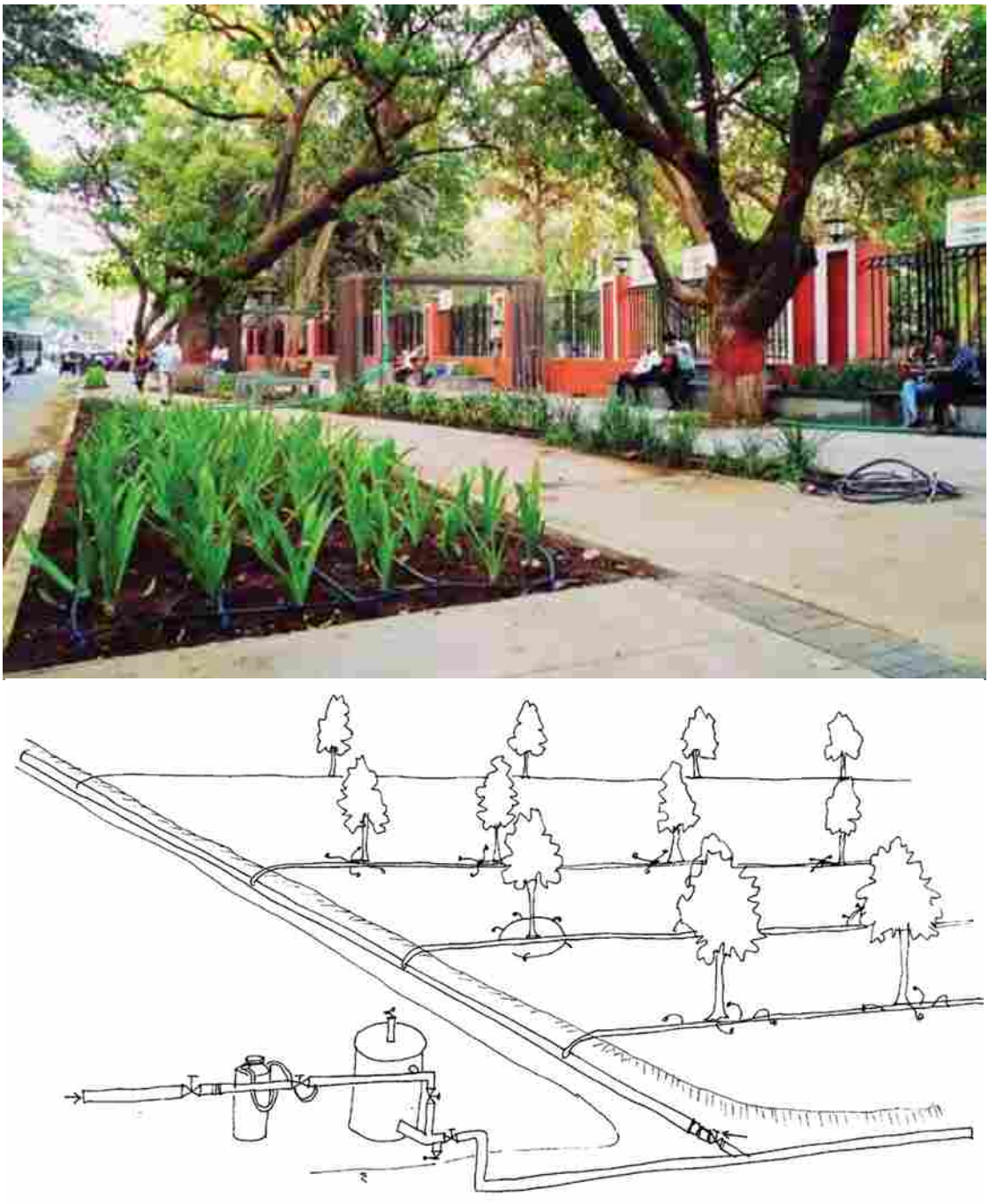


Fig. 134 Drip Irrigation Laterals to Irrigate Rows of Trees: Typically, a Street Condition

There are many benefits to using drip irrigation:

(i) With proper management, drip irrigation reduces water loss by 60 per cent or ore, compared with traditional watering methods. Because drip irrigation applies water just where it is needed, there is little chance of waste through evaporation or runoff.

(ii) The soil moisture remains relatively constant. Water contact with the leaves, stems, and fruit of plants is minimized, preventing disease. Rows between plants remain dry, which reduces weed growth.

(iii) Once installed, there is little labor required to operate or maintain a drip irrigation system.

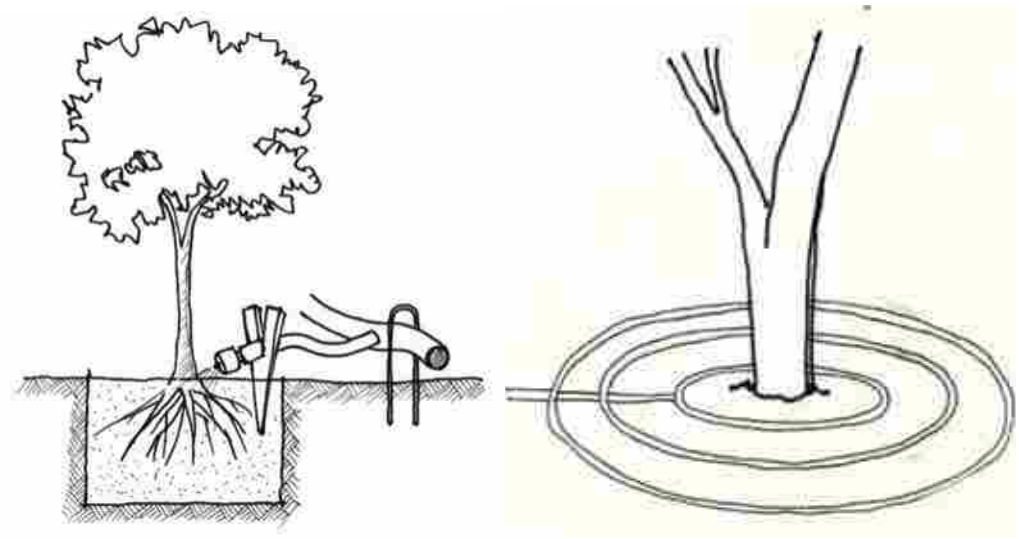


Fig. 135 Drip Irrigation Arrangement for Irrigating a Tree

The following is to be considered with Drip Irrigation method:

(i) Drip irrigation shall have a minimum operational lower quarter emission uniformity of 80%. A precipitation rate of 19 mm per hour cannot be exceeded.

(ii) Trees shall be irrigated on a separate valve.

(iii) Drip irrigation emitters shall emit no more than 3.5 litres per hour. Multi-outlet emitters are prohibited.

Container Plantings and Raised Planters may use 3.5 mm & 7 mm solid tubing (also referred to as “spaghetti” tubing,) nowhere else may 3.5 mm & 7 mm solid tubing be used for irrigation.

Drip irrigation valve assemblies are required for each drip zone and must include:

(i) Anti-siphon valve if a master backflow protection device is not specified;

(ii) pressure regulator;

(iii) Filter with a 150 – 200 mesh, wye or tee filter with a stainless-steel screen;

(iv) “Twist-lock” type fittings are prohibited.

(v) Wire stakes shall be U-shaped galvanized steel wire stakes and shall be installed at minimum every 1 m.

(vi) Drip tubing shall be made of polyethylene.

b) Sprinkler Irrigation

Sprinkler irrigation is a common watering method. Sprinkler systems can consist of “hose-end” sprinklers that one can set up and move around the yard, or can consist of built-in irrigation systems. The following types can be generally used:

(i) Pop Up Sprinkler Bodies

Pop up sprinklers ‘pop up’ when in operation. This ‘pop up’ action helps conceal the sprinkler when not in use and reduces potential vandalism. Pop up bodies can be used with fixed radius heads, gear drives and rotary nozzle types, as seen in **Fig. 136**. They come in a variety of sizes and models However, they are best used in turf areas due to vegetation blocking the spray path when used in garden beds. If these types are used in garden beds, it is important that vegetation is kept clear of all sprays.

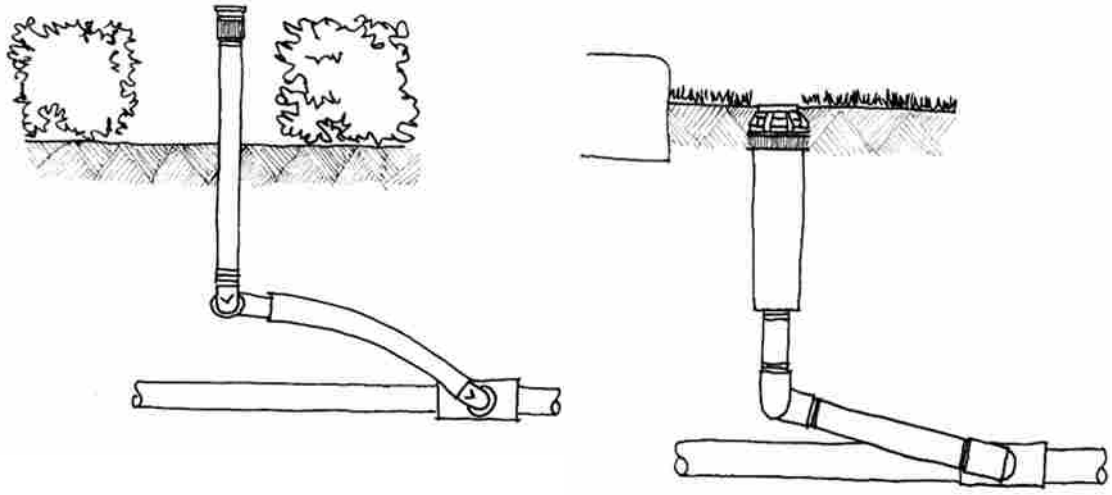


Fig. 136 Sprinklers Embedded in Ground

(ii) Fixed Spray Sprinklers

Fixed spray sprinklers are sprinkler heads that are installed onto a riser in garden bed situations. The sprinkler heads are either fixed radius heads set at a pre-set arc and radius or rotary action.

(iii) Rotator Nozzles

Rotator nozzles can operate at relatively low pressures and rotate in a sweeping arc up to 360 degrees providing relatively even water distribution in calm conditions. As with all spray irrigation, significant amounts of water can be lost through evaporation and wind drift due to the large spraying distance. Spray patterns are significantly disrupted in garden beds as plants mature and obstruct the spray pattern.

(iv) Gear Drive Sprinklers

Gear drive sprinklers rotate up to 360 degrees and operate via water driven gears. Water moving through the sprinkler spins a turbine which then turns a set of gears and the nozzle. These generally require more water pressure to

operate than rotary, spray or drip types of irrigation and deliver larger volumes of water per minute.

The following are to be considered with Sprinkler Irrigation method:

(i) Sprinkler system should be designed for Head-to-Head coverage. Head to head coverage means that the placement of the sprinklers allows the spray of one sprinkler (or the radius) to completely meet the head of the next sprinkler. Sprinkler heads must have a minimum of head-to-head coverage (minimum of 50% of diameter).

(ii) Pop up sprinklers should be 150 mm tall for the most efficient delivery of water. Tall lawns are most common and before mowing day can easily get tall enough to get in the way of the spray pattern of shorter sprinklers.

(iii) Sprinkler spacing shall be designed to achieve the highest possible distribution uniformity.

(iv) Sprinklers shall not be used for areas less than 3 m in width in any direction. They shall be irrigated with subsurface irrigation or other means that produces no runoff or overspray.

(v) Sprinklers shall have a minimum operational lower quarter distribution uniformity of 71%.

(vi) No sprinklers shall be located within 600 mm of any trees or impermeable hardscape, including but not limited to sidewalks, carriageways, streets, walkways, fencing/boundary walls.

(vii) Irrigation shall not runoff nor overspray onto impermeable surfaces including but not limited to buildings, fencing, property line, public right-of-way.

(viii) Sprinkler heads on the same valve shall have matched precipitation rates. The precipitation rate shall not exceed 19 mm per hour.

(ix) Spray heads with or without multi-stream, multi-trajectory rotating nozzles, shall have built-in pressure regulation in the body or stem or shall have pressure regulating swing joints.

(x) Sprinkler heads shall have swing joints or other riser-protection components.

c) Flooding

Flooding is the most common type of irrigation method, which is inexpensive but at the same time, is wasteful of water resources in most cases. Flooding is carried out through water mains having a tap through which a flexible hose is connected, that is normally spread around in planter beds and timed manually for the amount of water discharged. On urban roads, where the water mains for irrigation are not present, flooding is carried out by a movable water tanker which has the flexible hose attached to deliver water to planter beds or tree pits, as it moves slowly along the edge of the road.

Disadvantages of Flood-type irrigation:

(i) Since the water spreads through the movement on the ground, areas closer to the source of water outlet tend to get over-irrigated than the ones far from it, causing water imbalance and ultimately wasting of the resource.

(ii) Flooding is checked manually for its timing of discharge, and therefore is subject to inefficiencies.

(iii) Since over-irrigation is a common phenomenon of this method, low-water landscapes are difficult to maintain or irrigate.

(iv) For the same amount of water discharge, the water spread is much less as compared to drip or sprinkler irrigation systems.

3.8.5 *Water source for irrigation*

Source of water is an important and critical component of irrigation and can have important maintenance considerations. As far as possible, greywater or recycled water should be used for irrigation. A cost to benefit analysis should take real costs for brining both types of water, recycled and potable, to the site. Use of groundwater for irrigation is prohibited. The following shall be the criteria for selecting water source:

(i) Priority one: Use Recycled water

a. To be sourced from a nearby Sewage Treatment Plant, from public or private facility, and stored on site or directly pumped when required; or

b. To be sourced by constructing a road-side Sewage Treatment Plant, where feasible, by treating domestic waste from underground sewer line, and local irrigation system to be setup; or

c. To be sourced from treating sewage from public toilets.

(ii) Priority two: Potable water

a. To be sourced through water mains, hydrant lines, or by tankers.

b. In special cases where costs of laying lines and constructing sewage treatment plants are expensive and a water body is present nearby, water can be sourced from drilling a tube well within 25 m distance from the edge of water body, and not directly from the water body.

c. Recycling saline water.

3.9 Integration with Utilities and Protection to Sub-grade

Landscape and planting shall be well integrated with utilities and services. Refer **Fig. 137** and clause 3.1.3.2 for details on coordinating landscape with services. The following to be considered where utilities and come too close to tree planting are close to each other:

(i) Utilities to be planned as stacked banks and to be implemented under the roadside such that all utilities pack themselves close to each other, resulting in better management and maintenance.

(ii) Where utilities are not planned as banks, provision of ducts should be made that encase cables and offer no hindrance to adjoining trees/root systems and can be easily maintained.

(iii) Where electric cables and other cables run close to rooting system of trees and plants, the same should be sleeved in PVC sleeves such that the plantation does not cause harm to cables.

(iv) Where drainage pipes and water lines pass, the trees should be planned at safe clearance of 0.6 m so that the roots steer clear of the drainage systems.

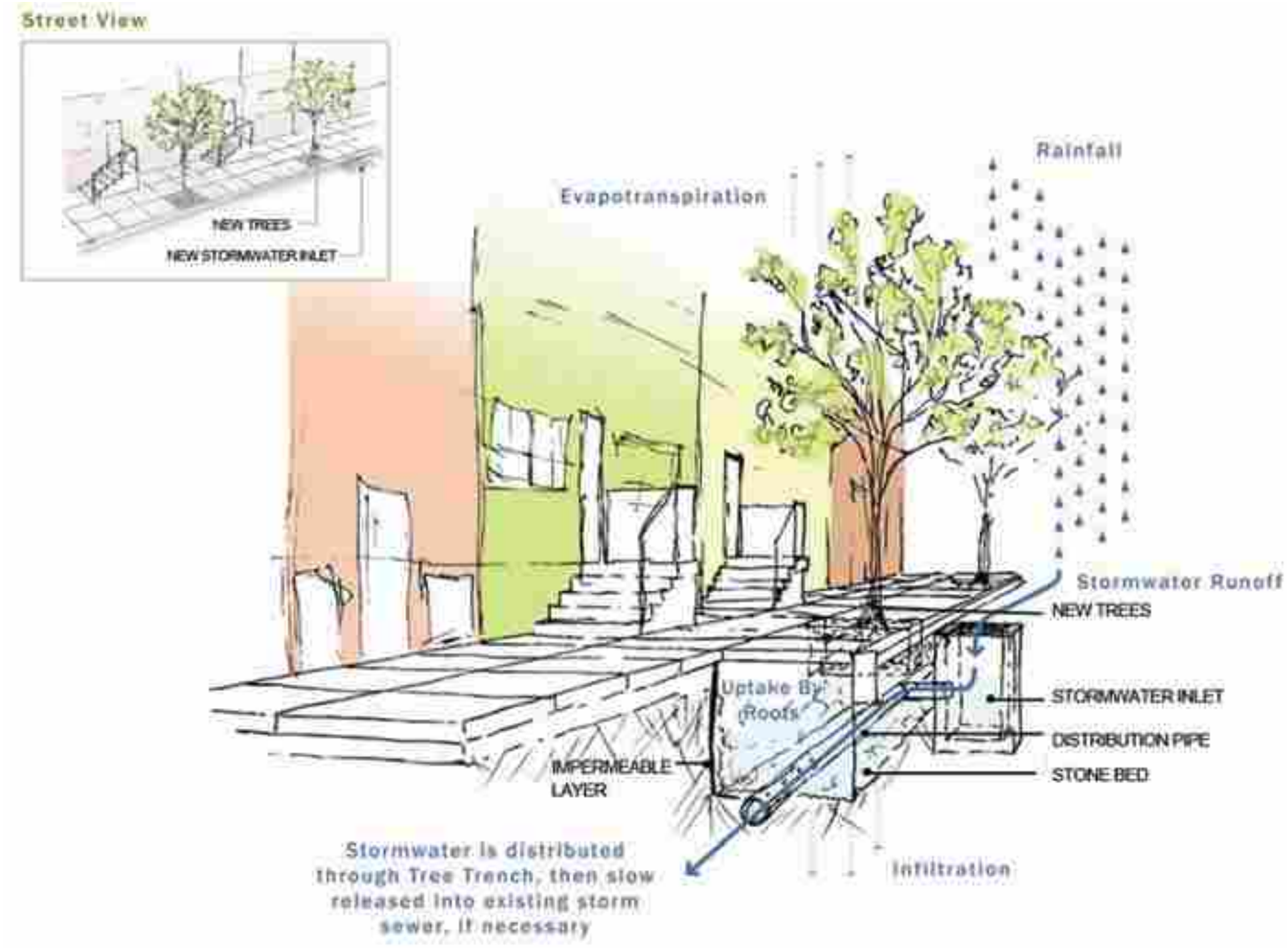


Fig. 137 Integration of services with plantation

3.9.1 *Subgrade protection from median plantation*

For details of sub-grade protection from median plantation, kindly refer 3.5.2. **Fig. 97-101**.

3.9.2 *Specifications of sub-grade protection from trees (for roads/plazas)*

This is one of the most usual issues faced by engineers where tree shade is important to provide, but at the same time, sub-grade protection is of utmost importance as tree roots can easily deliver water to sub-grade and also enter the region and cause subsistence of the surface. For such conditions, the trees should be planned in a cylindrical pipe such that the roots go deeper before penetrating the sides. This ensures good and long-lasting protection to sub-grade while also being beneficial to the plant. Refer **Fig. 138** below.

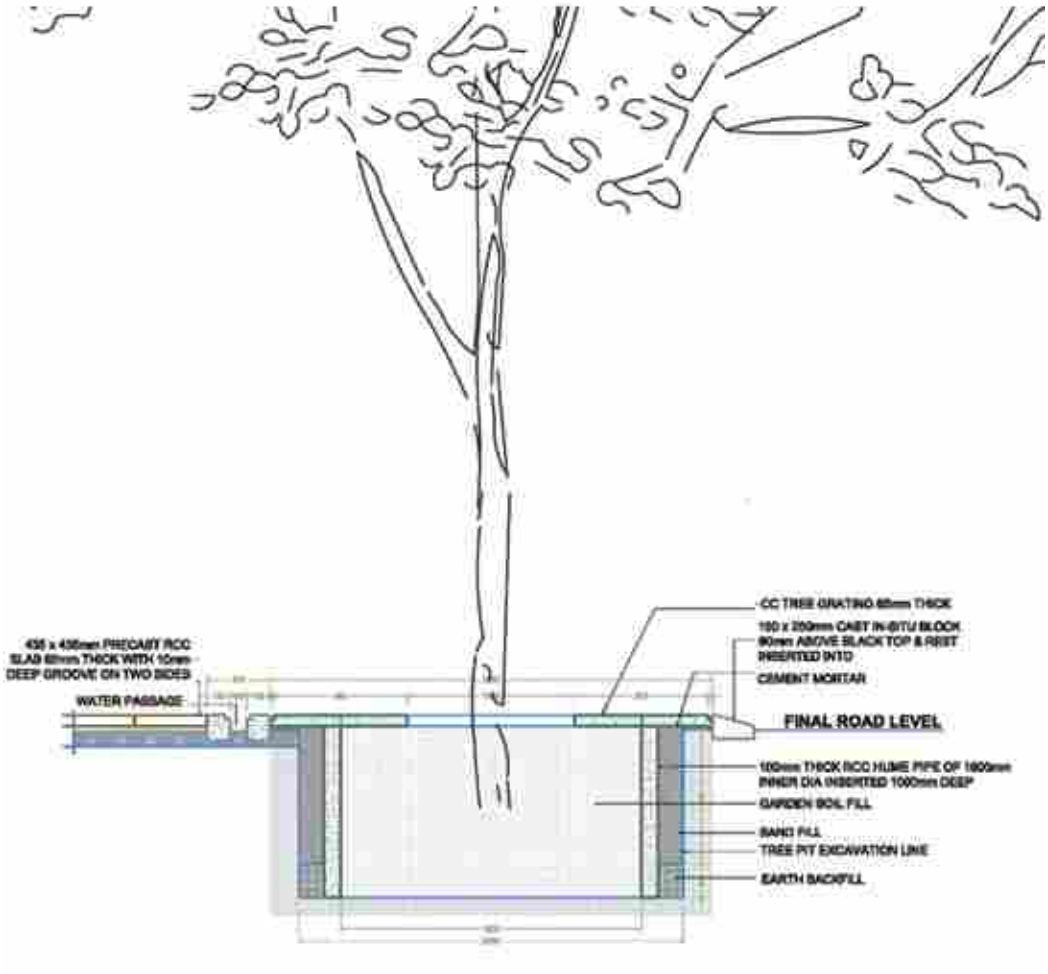


Fig. 138 Sub-grade Protection Detail for Tree Pit

3.10 Specifications for Erosion Control Measures

(i) For sloped embankments, gentler vegetated slopes are preferred for soil stability and to prevent erosion. Refer **Annexure C**.

(ii) The impact of the road runoff should be minimized by grass swales along the road and at the top and bottom of the slope to check surface runoff Surface water along roads should be directed via natural swales or interceptor drains to existing or designed water bodies or rainwater filtration and groundwater recharge areas to avoid ponding on roads.

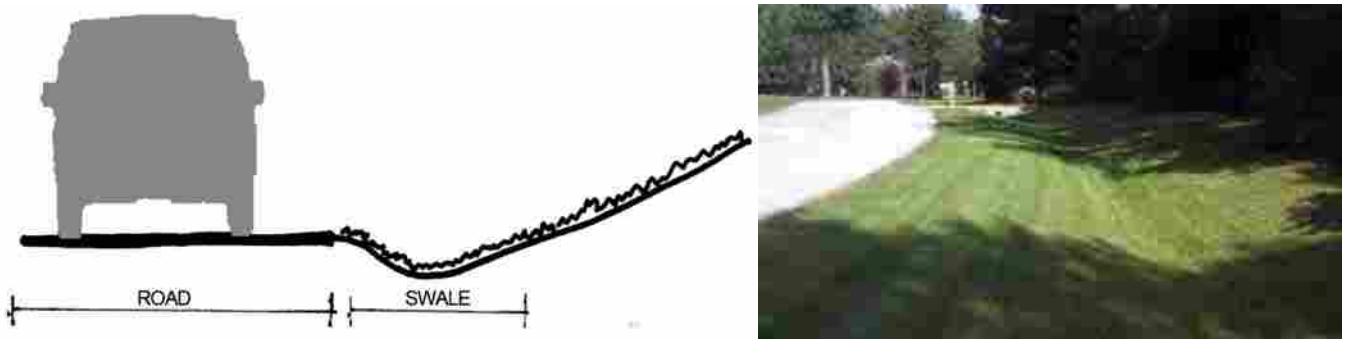


Fig. 139 Planted Slopes help check Soil Erosion as well as help in Infiltration

(iii) For erosion and sedimentation control, slopes should be stabilized with native grasses, shrubs and ground covers, as shown in **Fig. 139**. For steeper slopes, terraces can be created or retaining walls can be used, as shown in **Fig. 140**.

(iv) Protect existing vegetation – Tree felling should be at a minimum, with greater emphasis on protection of older mature trees with wide canopies to protect the biodiversity it supports. Invasive, non-native trees can be replaced, preferably in a phased manner, to prevent total loss of tree cover. Compliance to Forest Conservation Act and local laws Conservation Act and local laws is required. Refer **Annexure C**.

(v) Waterlogged Areas and Sandy/Desert Areas require site appropriate treatment. Aquatic plants in water logged area with successive plants for wetland areas along the low areas and drainage runoff to be directed towards these low-lying areas. Around water bodies, to prevent erosion, soil stabilization planting is essential.

(vi) Desert planting to be minimal with use of xerophytic planting and key areas.

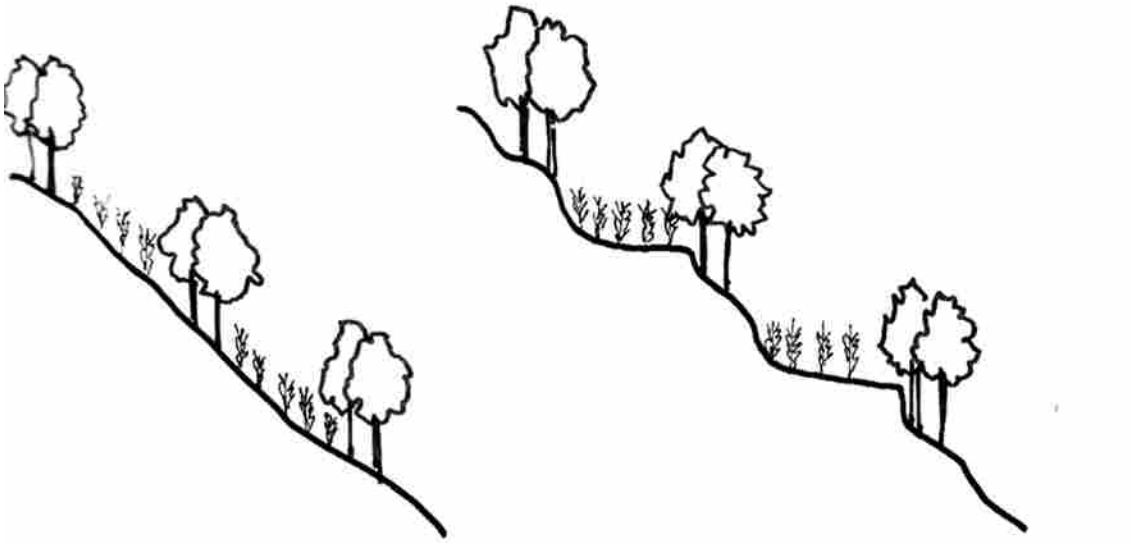


Fig. 140 Slope Stabilization by Terrace Cuttings and Plantation on Edges to hold Soil

3.10.1 *Bio-engineering of slopes*

Various methods are available for hillside and slope stabilizing. Often used methods of seeding are dry-seeding and hydroseeding. On exposed areas, the seed will be protected with straw in combination with bitumen or meshes of jute and wire. After revegetation with seeding, the stabilization can be increased through transplanting stump sprout deciduous trees. With different types of brush layering, loose rock slopes can be stabilized. If the plants are rooted, they are called hedge layer. If they are unrooted, they are called brush layer. A combination of both is a hedge brush layer. A useful method for dewatering and stabilization of wet slopes is the use of drain and slope fascines. The fascines consist of live branches of willows that are tied together with wire. There are numerous different hillside and slope stabilization methods which utilize plants in combination with constructions of wood, stone and wire such as planted pole walls, live slope grids, live wooden crib walls, vegetated stone walls and vegetated gabions, as shown in

Fig. 141. Choosing the right method depends on various factors such as the position of slope, ground and available material. Refer **Annexure C** for more details.

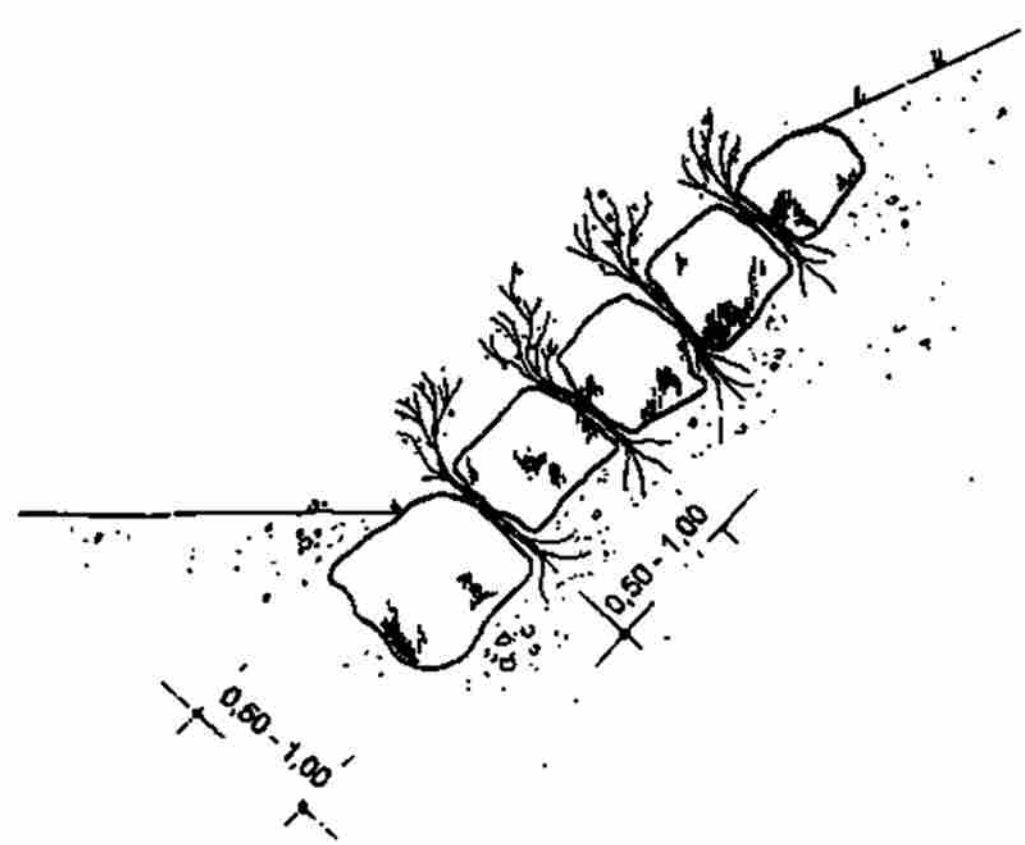


Fig. 141 Stabilization of Rocky Slope by Hydroseeding

3.10.2 *Soil erosion control blankets*

Erosion Control blankets protects soil and seed from erosion by providing a cover against the erosive forces of overland storm water flow and the effect of rainfall, as shown in **Fig. 142**. Erosion control blankets act as non- deteriorating mulch that promotes seed germination beneath the mat. Vegetation easily grows through it because of its high porosity.

Fig. 142 Coir Blankets used for Erosion Control

Benefits of using Coir, please see **Table 17** below:

(i) Coir is natural and 100% biodegradable. Coir is one of nature's strongest fibers and will maintain its tensile strength under soil and water. It is also highly UV resistant.

(ii) Coir has the best content of lignin and is resistant to mold and rot. Coir is biodegradable slowly over a 5-10 year period.

(iii) Coir retains moisture, acts as mulch and provides an excellent microclimate for faster growth of plant and root system.

(iv) Re vegetation measures using coir encourage the restoration of terrestrial and aquatic habitat.

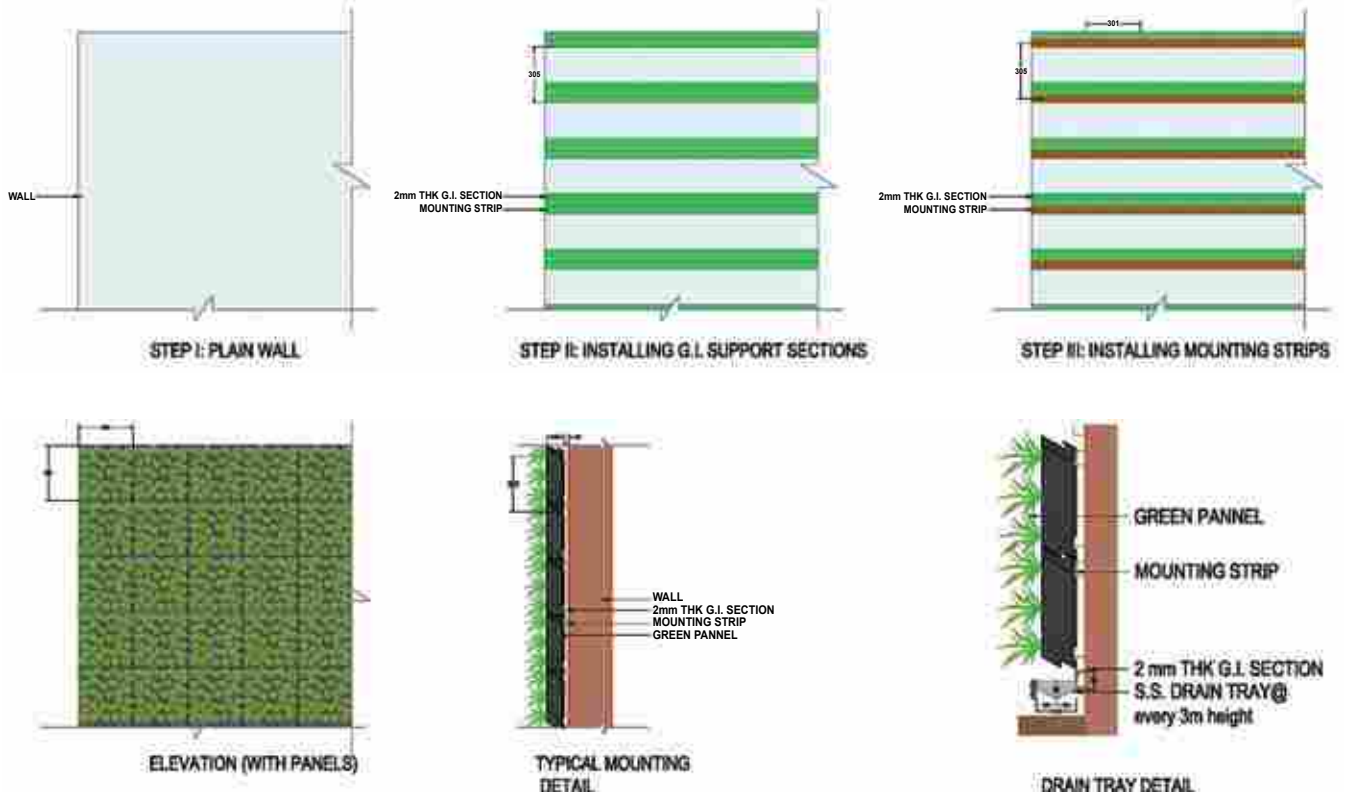
Table 17 Benefits of Coir

S. No.	Naturalization	Hard Armoring
1	Naturalization also called bio engineering, involves, working with Natural materials such as live vegetation with help of coco-peat erosion control blankets	It refers to solid installations of concrete, rip rap or metal pilings
2	Immediate stabilization that strengthens over time	Immediate stabilization
3	Economical	Expensive
4	Provides fish and wildlife habitat	Destroys fish and wildlife habitat
5	Decrease water velocities	Increases water velocities
6	Provides shading and decreases water temperature	Warms stream water
7	Works with natural forces rather than fighting them	More likely to cause downstream erosion
8	Aesthetically pleasing	Aesthetically unpleasant

3.10.3 *Vertical gardens*

Fig. 143 Vertical Plantation on Walls and Columns to green the Concrete Surfaces and reduce Heat Island Effect while greening them

Planting vertical surfaces is termed as vertical gardens. These are made possible by a grid of metal joists that can hold the pots which would have the plants rooted in. The same steel frame is utilized to run the drip irrigation pipe for irrigation purposes. Since the surface being vertical, there are maintenance issues that have to be dealt with and the upkeep of plants shall be much greater than the ordinary ground plantation. Vertical gardens are expensive to build, but they reduce the glare, heat island effect and give a pleasing look to an otherwise sterile concrete and road environment. Ideal for underpasses and flyovers, as shown in **Fig. 143** and **144**.



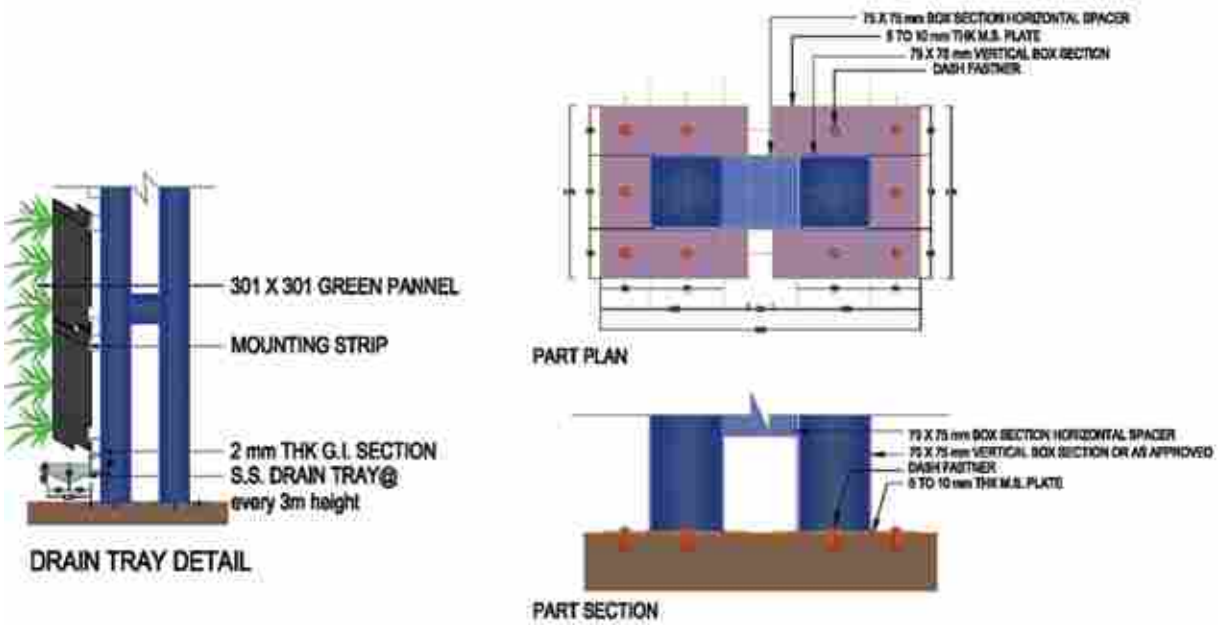


Fig. 144 Vertical Garden Construction Details. It is advisable to follow Structural Advise by a Structural Design Consultant during design of the details

3.11 Specifications for Transplantation

Transplantation of trees may be carried out to save mature trees along existing ROW, within a viable distance of its existing location. Transplantation should be scheduled based on the season, expertise and specialized equipment with adequate and careful planning, execution and post-transplantation care.

3.11.1 *Transplantation of large tree*

Occasion may arise when a grown-up tree has to be cut for making room for constructing a road, a building or other structure. It would be desirable to save this plant by transplanting it at a suitable site. In winter when the tree is dormant or less active, it should be pruned heavily leaving a bare framework of the large branches. A 40 to 50 cm wide trench 1 to 2 m deep should be dug around the stem as much distance away from it, depending upon the stature of the specimen, cutting all the roots, big and small, in the process.

The trench should then be compacted with dry leaf, straw or any such material followed by heavy irrigation which would be repeated from time to time according to necessity. In spring, new shoots will come out along with a new set of fibrous roots. In the beginning of rainy season, the trench would be reopened by removing the packing materials, thereby exposing the new roots. The big earth ball at the base of the tree would be wrapped firmly with burlap. The trunk should simultaneously be covered with several rounds of gunny on which a strong iron chain will be tied like a belt. Now a crane would be summoned and the tree securely attached to it through the iron chain. The basal roots would then be cut to free the tree from the ground and carried on a vehicle to the new site where a suitable pit has already been dug to receive the huge earth ball.

Transplanting large trees is difficult, expensive, and requires expertise and equipment. **Table 18** highlights the issues to be considers for providing a successful transplanting. As far as possible,

it should be the last choice to be considered and adapting road design to existing trees should be prioritized.

Table 18 Key Aspects of Transplantation

Sr. No.	Aspect	Recommendations	Success Rate
1	**Age and Size**	High casualty of trees over 200 mm	Younger plant > Older tree Smaller girth > Large girth Smaller root ball > Larger root ball
2	**Site**	Relocation site should match the conditions of the existing site	Preplanning of site selection and treatments done in time
3	**Timing**	Dormant season recommended; minimum 3 months preparation time	July- August: Most Suitable September-March: Suitable April- June: Adverse
4	**Health**	There should be no major defects in its trunk branch structure or disease	
5	**Survival**	Different species have different survival rates based on • species, • tree height, • trunk diameter, • health, • form, • structural soundness, and location	Shrubs >Trees Deciduous Plants> Evergreen Plants Palms> Trees Shallow rooted species > Deep rooted species
6	**Expertise**	Specialized process requires arboriculture expert	
7	**Transportation**	Tree crown to be covered to protect the tree from drying out and windburn Root Ball kept moist and compact	Careful handling
8	**Equipment Required**	Smaller trees - using a tree spade or other specialty equipment/ techniques Larger trees -mechanical digging equipment and appropriate hoists and heavy equipment	
9	**After transplanting**	Create and implement a multi-year aftercare program, providing adequate moisture to the root ball	Adequate watering and follow up care required

CHAPTER 4
PLANTATION AND MAINTENANCE PROCEDURES

4.1 Arboriculture and Maintenance Schedule

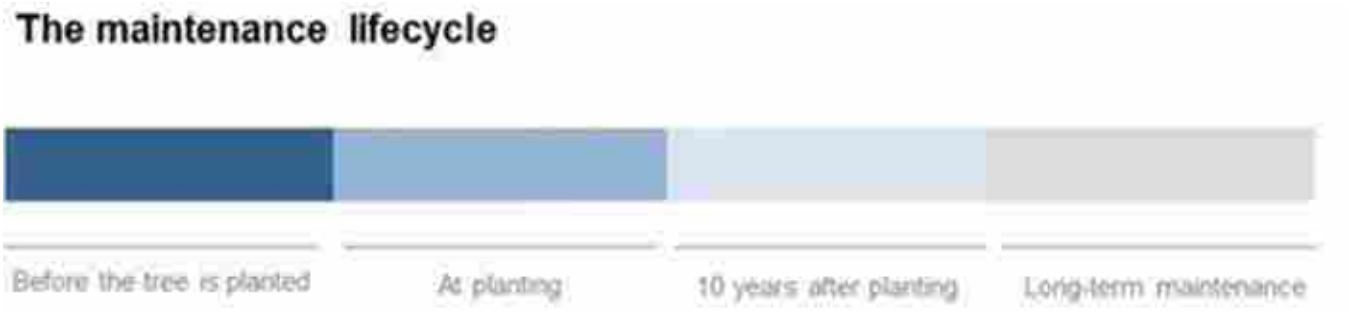
Plantation activities are highly time specific, as the plants respond to the seasonal variations in climatic conditions. Even in highly mechanized irrigated plantations, the growth of plants is not uniform throughout the year and is governed by the atmospheric factors. It is therefore, vital to plan the planting activities in advance as per the prevailing climatic conditions of the area, especially the time and duration of monsoon. A suggestive Arboriculture regime is provided in **Table 19** below. Plantations works are usually started with the onset of monsoon. However, if it is possible to provide irrigation,it is advisable to utilize the high temperatures of summers. Plants respond well to Irrigation during peak summer seasons, as the conditions are favourable for growth if moisture Is not the limiting factor.

Table 19 Arboriculture Regime (Ref: IRC:SP:103)

Year	Month		Activities to be done
1st year	January-March	1	Surveying and cleaning of the area
		2	Digging of Pits as per code
		3	Procurement of brushwood and live fencing
2nd year	April-June	1	Purchase of Farm yard manure
		2	Fencing
		3	Plantation along the road
		4	Filling up of pits with farm yard manure and soil
	July-August	1	Transportation of plants
		2	Planting of saplings
		3	Watering
		4	Weeding and hoeing
	September-November	1	Weeding and hoeing
		2	Watering 4 times a month
	December-February	1	Watering and hoeing; Tending saplings of trees and plants till they can stand by themselves
		2	Maintenance
	March	1	Watering 4 times a month
3rd year	April-June	1	Watering 6 times a month
	July-August	1	Causality replacement (20% of the total plants)
		2	Weeding
		3	Maintenance by Mali
	September-November	1	Watering 2 times a month
		2	Maintenance by Mali
	December-February	1	Maintenance by Mali
	March	1	Watering 4 times a month
		2	Maintenance by Mali

Year	Month		Activities to be done
4th year	April-March	1	Watering
		2	Causality replacement (10% of the total plants)
		3	Maintenance by Mali

4.2 Details of Activities



4.2.1 *Watering of plants/Irrigation*

The quantity of water requirement depends largely on the nature of species, soil quality, depth of the aquifer and on the climatic condition of that area. The relative humidity, temperature, wind speed and wind direction have major role in this regard. About 450 to 650 litres of water is required per plant per year since the very beginning of the plantation till it attains its normal safe size and growth i.e. about 6-7 years from the date of plantation. The external supply of water is to be continued till the roots of that species may be able to absorb the required quantity of water from the soil strata.

The requirement of irrigation based on various criteria are to be as per **Table 16** and as per the schedule above.

a) Street tree watering guidelines

(i) All young trees, need to be watered in the first two years, even if they are drought tolerant and/or native, till they become established. Mature trees require less consistent care, but during droughts need to be monitored and watered as required.

(ii) The complete extent of young tree roots in the first few years after planting is limited to the soil volume that the tree was last grown in (for example, a pot or container). Mature, established trees generally require less consistent care, but during droughts every tree must be monitored and watered adjusted accordingly.

(iii) For young trees, roots around the trunk need to be watered (not the trunk) and not the area outside the root ball. A 1.0 m wide and 2.5 cm to 7.5 cm deep organic mulch ring around the trunk for its entire life, will help maintain soil moisture.

(iv) For mature trees (>25 years), or those with a trunk more than 30 cm in diameter, water deep and occasionally.

b) Irrigate street trees with storm water

(i) Cities need to pro-actively design streets, roofs, parking lots, sidewalks and other impervious parts of the urban landscape to drain towards trees and planted areas. Cities with over 635 mm annual precipitation should use every 93 sqm, of impervious surface to water large shade trees for long-term health. In arid cities with 200 mm to 380 mm annual precipitation, 372 sqm, of impervious surface can irrigate a large street tree. The urban landscape can be graded to create berms, mounds, and slopes to turn the entire pervious area into a tool for draining water towards tree/planting areas.

(ii) Trees that have access to larger volumes of loamy soil will then be able to withstand dry periods better because of the water reserves the soil can contain.

4.2.2 *Irrigation system maintenance*

A few important things to consider for maintaining the irrigation system:

(i) The irrigation systems must be maintained according to the manufacturer's specifications and in accordance with all local, state and central laws and regulations.

(ii) Irrigation issues that may be observed will be:

a. Controller malfunctioning. Remedy: regular checks.

b. Pipe leakage. Remedy: Patching or changing piping on immediate basis.

c. Choked emitters. Remedy: Passing recommended solvents at prescribed intervals through the system to clean up depositions and salts.

d. Changes in pressure. Remedy: Change irrigation timing or check pressure meter and rectify.

e. Broken pipe. Remedy: Sink the pipe till appropriate depth so that to lessen effect of walking, mowing or traffic.

(iii) Licensed and trained contractors should be employed to conduct regular checks to the system to maintain its integrity.

4.2.3 *Training and pruning of shrubs*

By nature of their growth, shrubs tend to take extra growth or unbalanced growth. Thus, regular training and pruning by cutting and removal of undesired parts of twigs is required.

a) Training

The process of providing desired form and size to a shrub plant is training. This is done by cutting away all growth that does not come in the desired frame, shape and size. Training of plants is started when they are still young. 3-4 branches are allowed to grow from main stem near the ground, radially to different directions. These are further divided into 2-3 branches each making oval shape of 3 m diameter in spread near the ground and 1.5 to 2 m high. This process is completed in 3-4 operations of cutting and pruning in first 2 years of growth. When the plants take their final size and shape, they are annually cut to this shape by pruning extra growth once or twice a year.

b) Pruning

(i) During first 4 years of growth, regular pruning is a must for maintaining the clear walking zone within footpaths and from considerations of traffic operations and safety.

(ii) Selective pruning or cutting of trees and shrubs will be required at situations where these (i) interfere with sight distance, (ii) come in the way of effective street illumination, (iii) are too close to the carriageway so as to be hazardous, (iv) conceal desirable views and scenic vistas and (v) have become too old or dead.

(iii) Excessive Pruning: Removing more than ¼ (25 per cent) of the functioning leaf, stem, or root area. Pruning in excess of 25 per cent may be injurious to the tree and needs to be avoided, as shown in **Fig. 145**.

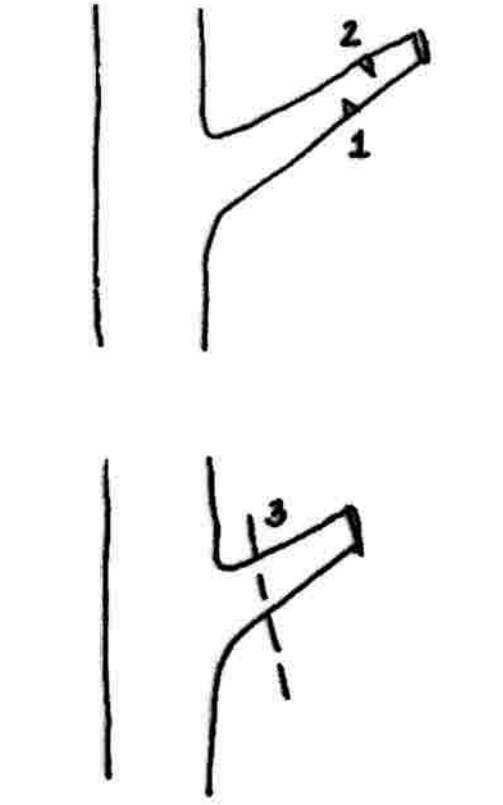


Fig. 145 Branch Pruning Process

(iv) Removal of tree branches obstructing smooth traffic movement and good view should be carried out judiciously. Similarly, old tree stumps should be removed and the area made presentable by suitable means.

(v) Care should be taken that bark of the plants is not damaged, ruptured, or peeled off.

(vi) Time of pruning is important and it should be done only in the season of dormancy i.e. when the plant is not in active growth. However, light pruning and pinching of tips can be done any time when it becomes necessary due to other emergent reasons of safety visibility of signs, signals and sanitation etc.

(vii) Maintenance of ground cover through weeding, watering and trimming is important to keep the surface usable and easy to maintain.

(viii) Keeping the rest of the areas neat and clean.

The trees and plants should be maintained under the supervision of horticulture staff and new plants put up, wherever necessary, in adequate time, especially to replace the dead and old trees. Proper working plans should be prepared where the work involves felling of mature trees/ plantation.

4.2.4 *Composting and recycling*

Collecting and composting leaf litter create valuable sources of nitrogen and phosphorus for soil amendments. Done on a regular basis it avoids the clogging drains and pipes.

4.2.5 *Monitoring requirements*

The monitoring schedule, parameters for monitoring the progress and status of plantation are given in **Table 20**.

Table 20 Monitoring Parameters

Sr. No.	Phase	Monitoring parameter
1	1st year (Advance Soil Work)	Number of pits
2	2nd year (Plantation of Saplings)	Survival percentage of saplings
3	3rd year (Maintenance of Plantation)	Survival percentage before and after. Casualty replacement. Height of plants
4	4th year (Maintenance of Plantation)	Survival percentage before and after, Casualty replacement. Height of plants

4.3 Plant/Tree Installation Criteria

4.3.1 *Minimize damage during plantation*

Plant material shall be handled in a manner so as to cause the least amount of damage during the planting process.

(i) Inspect trees or shrubs before, during and after they are planted.

(ii) Plant pits should be dug or prepared on approval of their location.

(iii) Balled and burlapped and container plants shall always be handled by the soil ball. Under no circumstances should they be dragged, lifted or pulled by the trunk or foliage in a manner that will loosen the roots in the ball.

(iv) During transportation, plants should be handled, secured or covered so as to prevent damage from wind or vibration. Plants should never be thrown or bounced off a truck or loader to the ground.

(v) Plant material shall be planted the day it is delivered to the planting site or it shall be watered and covered with mulch or soil or placed in a shady area to prevent dehydration.

(vi) In cases where trees are likely to have their trunks scarred during the planting operation, the trunks should be protected with non-abrasive wrap or padding. Any bark abrasions or broken limbs caused in the planting operation should be treated or corrected immediately.

(vii) Trees and shrubs should not be dug, balled and burlapped, or moved during the active growing period unless the ball is large enough to ensure a reasonable chance of survival.

(viii) Evergreen trees with an excessively bushy growth form shall have the boughs tied up with rope or twine during transport and planting to avoid damage to the foliage and branches. After planting, the boughs should be released, and all twine removed.

4.3.2 *Prevent public hazards during plantation*

(i) Clean up of any soil, branches, or other debris resulting from any tree or shrub planting shall be promptly completed following planting. The work area shall be kept safe at all times until the clean-up operation is completed. Under no circumstances shall the accumulation of soil, branches, or other debris be allowed in such a manner as to result in a public hazard.

(ii) Excavated pits that will be left open when work is not in progress or pose an immediate and considerable hazard to pedestrian or vehicular traffic shall be adequately barricaded with warning devices.

4.4 General Guidelines for Planting

(i) Maintain minimum tree opening in paved areas:

a. To avoid choking root systems, and compaction, minimum tree opening size of 1.8 m x1.8 m to be maintained. This may be covered by tree grates, porous pavers or planting, but must be outside of heavy vehicular routes. Where compaction occurs, aeration strategies for root systems to be added.

b. Tree roots should be visible. If only the trunk is visible, then the tree is too deep. The primary root structure should be visible, i.e. the trunk flair.

c. Single strong leader - Where all branching starts from the same point, there is a higher chance of fatality. Dominant branches should start at varying heights, to avoid lop-sidedness in case of breakage.

(ii) Tree Pits

a. Tree pits should be dug in a ratio of 1: 2 or 3 heights to width.

b. Circular pits with sloping sides shall be excavated for all balled and burlapped and container plants. Trees should be planted so that the trunk flair is approximately 50 mm above grade. The pits should be at least 2 to 3 times wider and slightly shallower than the depth of the soil ball. All plants should be centered in the pit.

(iii) Check services

a. All underground electric or telephone lines, gas lines, water lines or any other improvements, public or private, shall be re-checked before planting is done.

(iv) Planting under Trees

a. Tree can be subject to root damage (caused by planting and removing flowers) and water competition for that temporary beauty for seasonal planting. Where required care must be taken to plant understorey seasonal with minimal impact to the tree roots.

4.5 Urban Tree Planting Issues and Remedies

Planting in urban areas can present its challenges. **Table 21** summarizes the mitigation measures of various constraints that the situation may present, while planting trees.

Table 21 Mitigation Measures in Tree Plantation

Sr. No.	Potential Impact	Potential Resolution
1	Limited Soil Volume	• Provide 4 cum of rootable soil volume per tree. • Use planting arrangements that allow shared rooting space. A minimum of 3 cum of rootable soil volume must be provided for each tree in shared rooting space arrangements.
2	Poor Soil Quality	• Test soil and perform appropriate restoration. • Select species tolerant of soil pH, compaction, drainage, etc. • Replace very poor soils, if necessary, and replace with garden soil with 20% natural compost and 10% clay.
3	Air Pollution	• Select species tolerant of air pollutants
4	Soil Erosion/resuspension	• Use mulch to prevent erosion • Plant shrubs/ground cover in all unpaved areas to check soil displacement by wind • Keep soil moist
5	Damage from vandalism	• Use tree cages or benches to protect trees • Select species with inconspicuous bark or thorns • Install lighting nearby to discourage vandalism
6	Damage from vehicles	• Provide minimum 1 m setback between vehicle parking/movement spaces and trees; planted thorny buffers can also be used up to 60 cm height.

Annexure – A

TREE PROPERTIES FOR GUIDANCE ON PLANTING ALONG ROADS AS PER CLIMATE ZONE

TREE	B. NAME	SEASONAL	FUNCTION	BRANCHING	SPREAD	HEIGHT	ROOT-DEPTH	WATER CONSUMPTION	LIFE	WHERE TO PLANT	FLOWERING COLOUR	FLOWERING SEASON	FRAGRANCE
NATIVE TREES IN THE HIMALAYAN REGION (Uttarakhand)													
Dodimma, Jhilla, West-Himalayan Silver Fir	*Abies pindrow*	*Evergreen*	Shade/Wind break	Low	2.4m	50 m	Deep	Low	>75	Clusters along hills/ Avenues	Red	April - May	Acidic/Neutral fragrance
Himalayan Silver Fir, East Himalayan Fir	*Abies spectabilis*	*Evergreen*	Shade/Wind break	Low	2.4m	50 m and more	Deep	Low	>75	Clusters along hills/ Avenues	Dark purple flowers	April - June	Acidic/Neutral fragrance
Khair	*Acacia catechu*	*Deciduous*	Medicinal/Fuel wood, fodder	Low	3m	15m	Moderate	Low	15-30	Open Patches	White or Pale Yellow flowers	February - May	Fragrant
Ronjh, Phulai	*Acacia leucophloea*	*Deciduous*	Ornamental, fuel wood, reforestation	Low	3m	35m	Moderate	Low	15-30	On slopes, Open patches, in clusters	Pale yellow or cream flowers	July -Nov	Fragrant
Kanchiro	*Acer acuminatum*	*Deciduous*	ornamental, shade, soil protection	High	10m	25m	Shallow	Moderate	40-200	understorey trees	Greenish flowers	March - April	>
Tarkanna	*Acer caesium*	*Deciduous*	ornamental, shade, soil protection	High	10m	25 m	Shallow	Moderate	40-200	Accent	white flowers	March - May	>
Bael	*Aegle marmelos*	*Evergreen*	Shade/Food/Medicinal	Low	3m	15m	Deep	Low	>20	Accent	Greenish white flowers	February - May	Fragrant
Indian Horse Chestnut	*Aesculus indica*	*Deciduous*	Ornamental/Shade/ Windbreak	Low	11-15m	20-30m	Deep	Low	>75	For slope stabilization, Accent/ Avenue	White pinkish flowers	May - June	>
Kala Siris	*Albizia chinensis & A julibrissin*	*Deciduous/ Semi evergreen*	Wind break/ Ornamental/Shade/ Green manure/Erosion control	Low	4m	30m	Shallow	low	>50	Avenue/Tea Plantation	Yellowish white flowers/ Red fls.	Feb -Mar, Sept - Oct	Fragrant
Chhal	*Anogeissus latifolia*	*Deciduous*	Medicinal/Ornamental/ Timber/Fodder		4m	20-36m	Deep	Low	>75	Forest tree/	White or Pale Yellow flowers	June -Sept	Fragrant
Bidi Leaf Tree	*Bauhinia racemosa*	*Deciduous*	Flowering/Ornamental	Low	2m	3m	Shallow	High	>10	Understorey shrub	White Flowers	February - May, Aug - Oct	>
Kachnar	*Bauhinia variegata*	*Deciduous*	Flowering/Medicinal/ Ornamental	Low	3-6m	12m	Shallow	High	>12	Understorey tree/ Accent/Mass plantation	Magenta, lavender, purplish blue or even white	February-April	Fragrant
Silk Cotton Tree, Kapok Tree	*Bombax ceiba*	*Deciduous*	Shade/ornamental/Fuel/ Timber	High	18 m	30m	Deep	Low	>75	Specimen/Avenue	Red flowers	Feb-April	>
Salai	*Boswellia serrata*	*Deciduous*	Medicinal/Ornamental	High	3-5m	3-5m	Deep	Low		Avenue/Slope stabilization	Creamish pink flowers	January	
Dhak	*Butea monosperma*	*Deciduous*	Shade/ornamental/ Medicinal/Timber/Dye/ host for Lac insect	Low	3-8m	8-15m	Deep	Low	>50	Forest tree/Mass plantation/Accent	Orange and Vermilion Flowers	January - March	Scentless

TREE	B. NAME	SEASONAL	FUNCTION	BRANCHING	SPREAD	HEIGHT	ROOT-DEPTH	WATER CONSUMPTION	LIFE	WHERE TO PLANT	FLOWERING COLOUR	FLOWERING SEASON	FRAGRANCE
Wild Guava	*Careya arborea*	*Deciduous*	Ornamental	3M	6-10m	20m	Shallow - Deep	Medium	>10	Forest edge/ Grasslands	Pink white	March- April	Bad odour
Devdar, Himalayan Cedar, Deodar cedar	*Cedrus deodara*	*Evergreen*	Ornamental/food/Forest	High	9- 15m	50m	Deep	High	>1000	Forest/Cluster planting/Avenue		Sept- Oct	
Eastern Nettle Tree	*Celtis tetrandra*	*Deciduous*	Ornamental/drought resistant/Forest	Low	5m	30m	Deep	Low	>100	Forest/Cluster planting/Avenue	male flowers white, female Pale green	March - April	
Shisham	*Dalbergia sissoo*	*Deciduous*	Shade/Medicinal/ Aforestation/Timber	High	14 m	25m	Deep	Moderate	>100	Avenue	Whitish to pink flowers	March - April	Fragrant
Himalayan Spindle Tree	*Euonymus hamiltonianus*	*Deciduous*	Ornamental	Low	2m	3m	Deep	Moderate	>10	Hedging & Screens Low Maintenance Cottage & Informal Garden Wildlife GardensOpen Patches	White flowers	April - July	
Indian Spindle Tree	*Euonymus indicus*	*Evergreen*		Low	2-3m	5-10m	Deep	Moderate	>11	Understorey	Reddish flowers	April - July	
Tiger's Milk Spruce, Chinese Tallow	*Falconeria insignis*	*Deciduous*		Low		5-10m		Moderate		Open patches,Forest	Green flowers	December - January	
Goolar	*Ficus racemosa*	*Evergreen/ Deciduous*	Shade/food/Medicine	High	5-8m	20-30m	Deep	Low	<100	Shade in coffee plantation,Open patches, Forest, River banks, NHs, Gardens	Red figs	Jul -Aug	Fragrant figs
Drooping Fig	*Ficus semicordata*	*Deciduous*	Shade/food/Fodder/ Medicine	Low	2-3m	3-10m	Deep	Low	<50	Forest edge,understorey, slope protection, river and stream banks	Red Figs		
Small-Flowered Himalayan Ash	*Fraxinus micrantha*	*Deciduous*	Ornamental/Shade/ Timber	Low	10m	45m	Deep	Moderate	<100	Gardens, Avenue, Slope stabilization	White flowers	April - May	
Kekra	*Garuga pinnata*	*Deciduous*	Food	Low		25m	Moderate	Low	<15	Reclaimed lands/ Fire resistant	creamy white or yellow flowers	Jan	Edible fruits
Haldu	*Haldina cordifolia syn Adina cordifolia*	*Deciduous*	Timber	High	10m	20-30m	Deep	Low	<100	Slope Stabilization, Field border, Avenue	Yellow to Pink flowers	June - Sep	
Kanju	*Holoptelea integrifolia*	*Deciduous*	Shade/Ornamental/ Fodder	High	15m	30m	Deep	Low	<100	Avenue on NHs/ Open areas, Forests	Greenish-brown	March-April	
Bridal Couch Tree	*Hymenodictyon orixense*	*Deciduous*	Shade/Ornamental	High	15	25m	Deep	Moderate	<100	Open Patches/Soil Stabilization	White	January - February	
Walnut	*Juglans regia*	*Deciduous*	Shade/Ornamental/ Nuts/oil/medicinal	High	20m	25 - 35m	Deep	Low	<100	Large gardens/ Accent/Orchards unsuitable as avenue tree	yellowish Green	May - June	Leaves Fragrant, Edible fruits

TREE	B. NAME	SEASONAL	FUNCTION	BRANCHING	SPREAD	HEIGHT	ROOT-DEPTH	WATER CONSUMPTION	LIFE	WHERE TO PLANT	FLOWERING COLOUR	FLOWERING SEASON	FRAGRANCE
Small Flowered Crape Myrtle	*Lagerstroemia parviflora*	*Deciduous*	Timber/Ornamental	High	5m	30m	Deep	High	<100	Avenue, Cluster planting	White flowers	April - June	Scentless
Thick Leaved Oak	*Lithocarpus pachyphyllus*	*Evergreen*	Timber,Shade,soil conservation	Low	4m	25m	Deep	Low	<100	Avenue, Cluster planting	White cream flowers	May - June	
Oval Leaved Lyonia	*Lyonia ovalifolia*	*Deciduous*	Medicinal/Slope protection		2m	10m	Deep	Moderate	<15	Open Patches	White flowers	April- June	
Kaim	*Mitragyna parvifolia*	*Deciduous*	Shade/Food/Hardy	Low	4.5m	15m	Deep	Medium	<100	Avenue on NHs/ Open areas/Forests/ Accent/Temple & Gardens	Yellow flowers	August-September	Fragrant
Sonjna	*Moringa oleifera*	*Deciduous*	Ornamental/Hardy	Low	2m	3m	Shallow	Moderate	>25	Hedges/ Windbreaks/Avenue on narrow lanes	White flowers	March- April	Fragrant
Balsena	*Naringi crenulata*	*Deciduous*	Ornamental/Medicinal/ Fodder	Low	2m	8m	Shallow	Moderate	>15	Hedges/Accent/ Mass plantation	Creamish white flowers	Apr - May	
Rose Sandalwood	*Olea dioica*	*Evergreen*	Food	Low	4m	15m	Deep	Moderate	<100	Mass plantation/ Forest	Greenish white flowers	December - March	Fragrant
Pharrai	*Oroxylum indicum*	*Deciduous*	Ornamental/Food/ Medicinal	High	3m	8-12m	Deep	Moderate	<15	Mass plantation/ Forest	Flowers with reddish-purple outside and pale, spinkish-yellow within	June - July	
Wild Date Palm	*Phoenix sylvestris*	*Evergreen*	Food/Ornamental	N/A	2m	4-8m	Shallow	Low	<20	Avenues/Plaza/ Mass plantation	Yellow	January - February	
Amla, Indian gooseberry	*Phyllanthus emblica*	*Deciduous*	Food/Medicinal/Shade	High, Spreading	4 m	8-18m	Deep	Low	<30	Orchard, Mass plantation, gardens	Greenish yellow	Feb - Mar	
Himalayan Spruce, Morinda Spruce, West Himalayan Spruce	*Picea smithiana*	*Evergreen*	Ornamental, Shade, Timber, Paper	Low, pendulous	6m	40 - 55 m	Deep	High	<100	Avenue, Garden, Accent, Forest	<	<	<100
Chir pine	*Pinus roxburghii*	*Evergreen*	Shade, Timber, Oil	High	10m	30-50m	Deep	Low	<100	Avenues/Plaza/ Mass plantation	Cones	Apr-Jun	Fragrance due to resins
Himalayan Blue Pine	*Pinus wallichiana*	*Evergreen*	Shade, Timber, Oil	High	10m	50 m +	Deep	Low	<100	Avenues/Plaza/ Mass plantation		April - June	Fragrant
Karang	*Pongamia pinnata*	*Evergreen*	Shade/Wind break/ Medicinal/Fodder	Low	10m-25m	25m	Deep	Low -High	<50	Shade/Wind break/ To check soil erosion & bind sand dunes/Avenue/ Riverbanks	White or pinkish	Mar - Apr	Fragrant
Himalayan Poplar	*Populus ciliata*	*Deciduous*	Wind break/ Ornamental/Shade/ Fodder/Medicine/Paper/ Erosion control		4m	20m	Shallow-Deep	High	<50	Avenues/Plaza/ Mass plantation/ Wind break/Tall screen	Green	March - April	

TREE	B. NAME	SEASONAL	FUNCTION	BRANCHING	SPREAD	HEIGHT	ROOT-DEPTH	WATER CONSUMPTION	LIFE	WHERE TO PLANT	FLOWERING COLOUR	FLOWERING SEASON	FRAGRANCE
Dusky Fire-Brand Mark	*Premna mollissima*	*Deciduous*	Food,Fuel wood	Low	2m	8m	Shallow-Deep	High	<20	Open patches, Mass plantation	Greenish white flowers	November - February	Strong overwhelming odour
Himalayan Bird Cherry	*Prunus comuta*	*Deciduous*	Ornamental, Fruit, Seed, Medicine, Dye,Wood	High	4m	15m	Shallow	High	<50	Avenue,Mass plantation,Erosion control on slopes	White flowers	Feb-Mar	Scentless
Himalayan Pear, Indian wild pear, Wild pear	*Pyrus pashia*	*Deciduous*	Ornamental small tree or shrub,Fruit, wood, Fodder	Low	6m	6-10m	Shallow	Low	<20	Specimen, Mass plantation, Aforestation	White flowers	March - April	Scentless
Glaucous Oak, Ring-cupped Oak, Japanese Blue Oak	*Quercus glauca*	*Evergreen*	Shade, Timber, Fuel, Wood	High	6m	18m	Deep	Low	<100	Specimen/Avenue	White flowers	Mar - May	
Layered Acorn Oak	*Quercus lamellosa*	*Evergreen*	Ornamental, Fruit, Seed, Medicine, Dye,Wood	High	10m	40m	Deep	Low	<100	Gardens, Avenue, Slope stabilization	Greenish white	April - May	
Blackjack Oak, Grey Oak	*Quercus leucotrichophora*	*Evergreen*	Ornamental, Fruit, Seed, Medicine, Dye,Wood	High	10m	15-25m	Deep	Low	<100	Gardens, Avenue, Slope stabilization	Greenish white	April - May	
Burans	*Rhododendron arboreum*	*Evergreen/ Deciduous*	Shade/Ornamental/food	High	3m	12-20m	Deep	High	<100	Clusters along hills/ Accent	Showy scarlet red flowers	March-November	Scentless
Kusum	*Scheleichera oleosa*	*Deciduous*	Shade/Ornamental/ Religious/Medicinal	High	16 m	20m	Deep	High	<100	Accent	Greenish Yellow	Mar-Apr	
Sal	*Shorea robusta*	*Evergreen/ Deciduous*	Ornamental/Avenue/ Shade/Timber	High	15m	40m	Deep	High	<100	Avenue, NHs/ Cluster planting, Accent	Whitish flowers	Mar - May	Fragrant
Hairy Rowan, Hairy Rowan	*Sorbus lanata*	*Deciduous*	Ornamental	Low	3m	10m	Deep	Moderate	<20	Pastures, Cluster planting	White flowers	April - May	Fragrant
Baringa	*Sterculia villosa*	*Deciduous*	Ornamental/Shade/ firewood/Gum	High	4m	10m	Deep	High	<20	Open patches, Cluster planting	Yellow with Pinkish throat flowers	December - March	Fragrant
Fragrant Padri Tree	*Stereospermum chelonoides*	*Deciduous*	Ornamental/Medicine/ Food	High	3m	10-20m	Deep	Low	<20	Forest edges	Pinkish flowers	Feb - Mar	Fragrant
Jamun	*Syzygium cumini*	*Evergreen*	Shade/Medicinal	High	10m	15-30m	deep	Medium	<100	Avenue/Wind break, Aforestation in problem soils	White	Mar -April	Fragrant
Arjun	*Terminalia arjuna*	*Deciduous*	Shade/Wind break/ Medicinal	Low	10m	35m	Deep	High-Low	<100	ACCENT,Avenue, Plaza, river banks	Creamy yellow	April-May	Fragrant
Baheda	*Terminalia bellirica*	*Deciduous*	Shade/Timber/ Medicinal	Low	23 m	40m	Deep	Moderate	<100	Plaza/Avenue/ Accent/Aforestation	Greenish Yellow	Apr	
Asan	*Terminalia elliptica*	*Deciduous*	Timber	High	10m	30m	Deep	Low	<100	Cluster	Creamish yellow flowers	April-May	
Indian mahogany, Red cedar, Surian	*Toona ciliata*	*Deciduous*	Ornamental/Shade/ Timber	High	5m	35m	Deep	Low	<100	Avenue/Aforestation	White flowers	Mar - Apr	Fragrant

TREE	B. NAME	SEASONAL	FUNCTION	BRANCHING	SPREAD	HEIGHT	ROOT-DEPTH	WATER CONSUMPTION	LIFE	WHERE TO PLANT	FLOWERING COLOUR	FLOWERING SEASON	FRAGRANCE
Chinese Toon	*Toona sinensis*	*Evergreen*	Ornamental/Timber	High	10m	40m	deep	Low	<100	Slopes/Disturbed areas	White or pale pink flowers	May - June	Fragrant
Ber	*Zyzyphus mauritiana*	*Deciduous*	Shade/Wind break/ Medicinal	Low	3m	8m	Deep	Low	<15	Orchard	Pale Greenish	July-October	Fragrant
NATIVE TREES FOR HOT AND HUMID													
	Adansonia digitata		Ornamental										
Bael	*Aegle marmelos*	*Evergreen*	Shade/Food/Medicinal	Low	3m	15m	Deep	Low	>20	Accent	Greenish white flowers	February - May	Fragrant
Siris	*Albizzia lebbek*	*Deciduous*	Shade/fodder/green manure	High	17 m	12m	Shallow	High	<20	not wind firm/Good for garden & Parks	Creamy-white	April-June	Fragrant
Chatium	*Alstonia scholaris*	*Evergreen*	Shade/Ornamental	High	9m	20m	Deep	Moderate	<75	ACCENT,Avenue, Mass plantation, Aforestation	Greenish-white	October-December	Fragrant
Tree of Heaven	*Millingtonia hortensis*	*Deciduous*	Ornamental/Medicinal (Mosquito larvicidal properties)	High	11m	25m	Deep	High	<40	Plaza, Avenue gardens,mass plantation	white	Sept - Dec	Fragrant
Chilla	*Casearia graveolens*	*Deciduous*	Ornamental	Low	2m	6-8m	Deep	Moderate	<15	Accent cluster, understorey	Pale green flowers	February - March	Orange yellow capsule
Bread fruit	*Artocarpus altilis*	*Evergreen*	Shade, Food, Ornamental	High	3m	26m	Deep	High	<100	Accent, Plaza, Mass plantation	multiple fused perianths	Through out the year	
Fanas	*Artocarpus heterophyllus*	*Evergreen*	Shade/Ornamental/ Fruits	High	8m	12m	Deep	High	<100	Orchard/Shade plant for coffee & peper/Accent	Greenish	Through out the year, heaviest in Jan - Feb	Fragrant
Neem	*Azadirachta indica*	*Evergreen*	Shade/Medicinal/ Aforestation	High	5 m	16m	Deep	High	<100	ACCENT,Avenue, Mass plantation, Aforestation	White	April	Fragrant
	Barringtonia asiatica		Shade										
Kachnar	*Bauhinia variegata*	*Deciduous*	Flowering/Medicinal/ Ornamental	Low	3-6m	12m	Shallow	High	>12	Understorey tree/ Accent/Mass plantation	Magenta, lavender, purplish blue or even white	February-April	Fragrant
Amaltas	*Cassia fistula*	*Deciduous*	Shade-giving/ Ornamental/Timber/ Medicinal	Low	5 m	10m	Deep	Low	<100	Plaza + accent/ Avenue/Aforestation	Yellow	April	Scentless
Gharmalo (Pink)/ Java Cassia	*Cassia javanica*	*Evergreen*	Shade/Ornamental/ Flowering	High	4m	10m	Shallow	High	<30	Accent/Avenue/ Mass plantation	Pink petals, fading to white	June	
Gharmalo (Dark Pink)Pink Cassia	*Cassia nodosa*	*Evergreen*	Shade/Ornamental/ Flowering	High	10m	12-16m	Shallow	High	<30	Accent/Avenue/ Mass plantation/	Dark Pink petals	June	
Safed Semal, Kapok	*Ceiba pentandra*	*Deciduous*	Shade/Ornamental	High	10m		Deep	low	<100	ACCENT,Avenue, Mass plantation, Aforestation	Pink -Red	March -April	Scentless

TREE	B. NAME	SEASONAL	FUNCTION	BRANCHING	SPREAD	HEIGHT	ROOT-DEPTH	WATER CONSUMPTION	LIFE	WHERE TO PLANT	FLOWERING COLOUR	FLOWERING SEASON	FRAGRANCE
Yellow silk cotton	*Cochlospermum religiosum*	*Deciduous*	Ornamental/Medicinal	High	2M	10m	Deep	High	<15	Specimen/Mass plantation/in Temples	Yellow	February-April	Fragrant
Gondi	*Cordia dichotoma*	*Deciduous*	Fodder/Food/Medicinal	Low	2M	8m	Deep	Moderate	>20	Mass plantation, Aforestation	White	Feb - Mar	Fragrant
Cordia	*Cordia sebastena*	*Evergreen*	Ornamental	Low	3m	6m	Moderate	Moderate	<10	Specimen, Mass plantation, Aforestation	Scarlet - Orange	Through out the year	Slightly Fragrant
Gab	*Diospyros embryopteris syn D malabaricum*	*Evergreen*	Shade/Food/Medicinal/ Timber	Low	4-6m	6-8m	Moderate	Moderate	<100	As screen, Specimen, Avenue, Good for seaside	Ochre yellow, inconspicuous	Jan - Feb	Fragrant
Putranjiva	*Putranjiva roxburghii syn Drypetes roxburghii*	*Evergreen*	Shade/Wind break/ Medicinal	Low	10m	25M	Deep	Moderate	<100	ACCENT,Avenue, Mass plantation, Aforestation/ Riverbanks	Yellow,Green	March-April	Fragrant
Pangara	*Erythrina variegata*	*Deciduous*	Shade/Flowering	High	6m	15m	Shallow	Moderate	<20	ACCENT,Avenue, Mass plantation, Aforestation	Red	February-March	Scentless
Rubber Tree	*Ficus elastica*	*Evergreen*		High	15m	30m	Deep	High	<100	Avenue on narrow lanes, Specimen, Along river fronts	Reddish figs	Apr - May	Figs are Fragrant on ripening
Goolar	*Ficus racemosa*	*Evergreen*	Shade/food	High	5-8m	22m	Deep	Low	<100	Specimen, Mass plantation, Aforestation	Reddish figs	Apr - May	Figs are Fragrant on ripening
Kekra	*Garuga pinnata*	*Deciduous*	Food	Low		25m	Moderate	Low	<15	Reclaimed lands/ Fire resistant	creamy white or yellow flowers	Jan	Edible fruits
Madre tree	*Gliricidia sepium*	*Deciduous*	Ornamental/shade in coffee plantations, fodder, firewood, fencing, green manure, rat poison	Low	2m	10-12m	Shallow	Low	<20	Reclaimed lands/ Fences	Bright pink to lilac	Feb - Apr	Scentless
Guest tree	*Kleinhovia hospita*	*evergreen*	Shade/Ornamental	High	5m	20m	Deep	Moderate	<20	Accent/Mass plantation	Pale pink	Through out the year	<
Jarul	*Lagerstroemia speciosa*	*Deciduous*	Ornamental/Flowering	Low	3m	30m	Shallow	High	<20	Accent/Avenue/ Mass plantation/ River banks	Purple/Pink/ Mauve	Apr -Jun,Jul -Aug	Scentless
Bollywood	*Litsea chinensis*		Shade										
Aamba	*Mangifera indica*	*Evergreen*	Shade/Food	Low	10m	35m	Deep	Moderate	<100	Orchard, Mass plantation, gardens,NHs, River banks	Yellowish green	Dec - Feb	Fragrant
Bakul	*Mimusops elengi*	*Evergreen*	Shade/Medicinal/ Timber	Low	10m	10-15m	Deep	Moderate	<100	Plaza, Avenue trees, gardens,Temples, mass plantation	White	May-June	Fragrant

TREE	B. NAME	SEASONAL	FUNCTION	BRANCHING	SPREAD	HEIGHT	ROOT-DEPTH	WATER CONSUMPTION	LIFE	WHERE TO PLANT	FLOWERING COLOUR	FLOWERING SEASON	FRAGRANCE
Kaim	*Mitragyna parvifolia*	*Deciduous*	Shade/Food/Hardy	High	4.5m	15m	Deep	Moderate	<100	Plaza, Avenue trees, gardens, Temples, mass plantation	Yellow flowers	August-September	Fragrant
Wild Date Palm	*Phoenix sylvestris*	*Evergreen*	Food	No branching	2m	4-8m	Shallow	Low	<50	Plaza, Avenue trees, gardens,mass plantation	Yellow flowers	January - February	Fragrant
Indian Mast Tree, False Ashok	*Polyalthia longifolia*	*Evergreen*	Shade/Wind break/ Medicinal	High	3m	25m	Deep	High	<100	ACCENT,Avenue, Mass plantation, Aforestation	Pale green	March-April	Fragrant
Karanj	*Pongamia pinnata*	*Evergreen*	Shade/Wind break/ Medicinal/Fodder	Low	10m-25m	25m	Deep	Low -High	<50	Shade/Wind break/ To check soil erosion & bind sand dunes/Avenue/ Riverbanks	White or pinkish	Mar - Apr	Fragrant
	Pterocarpus indicus		Ornamental										
Buddha's coconut	*Pterygota alata*	*Deciduous*	Shade/Wind break/ Medicinal	High	5m	30-35m	Deep	Moderate	<100	ACCENT,Avenue, Mass plantation, Aforestation	Rusty Brown tomentose	March-April	
Safed Chandan	*Santalum album*	*Evergreen*	Shade	Low	2M	4-9M	Moderate	Low	<100	Mass plantation/ Forest	White turning to red orange	<	Fragrant
Kusum	*Scheleichera oleosa*	*Deciduous*	Shade/Ornamental/ Religious/Medicinal	High	16 m	20m	Deep	High	<100	Accent	Greenish Yellow	Mar-Apr	
Java olive	*Sterculia foetida*	*Evergreen*	Shade/timber	High	15m	35m	deep	Low	<100	Forest, Open areas	Green/Purple	Mar	Foul smell
Sandpaper	*Streblus asper*	*Evergreen*	Shade	Low	3m	4 - 10m	Moderate	High	,10	Mass plantation/ Forest	Yellowish Green		
Jamun	*Syzygium cumini*	*Evergreen*	Shade/Wind break/ Medicinal	High	10m	30m	deep	Medium	<100	Avenue/Wind break, Aforestation in problem soils	White	Mar -April	Fragrant
Indian mahogany, Red cedar, Surian	*Toona ciliata*	*Deciduous*	Ornamental/Shade/ Timber	High	5m	35m	Deep	Low	<100	Avenue/Aforestation	White flowers	Mar - Apr	Fragrant
Indian Tulip Tree	*Thespesia populnea*	*Evergreen*	Ornamental	Low	5m	10m	shallow	High	<15	Accent, Plaza, Mass plantation	Lemon-Yellow	Mar - Apr	Scentless
NATIVE TREES FOR HOT AND DRY													
Kadam	*Anthocephalus cadamba*	*Evergreen*	Ornamental/Medicinal/ Religious/Shade	High	5m	20m	Deep	High	<50	ACCENT,Avenue, Mass plantation, Aforestation	creamy orange	Jun	Fragrant
Bael	*Aegle marmelos*	*Evergreen*	Shade/Food/Medicinal	Low	3m	15m	Deep	Low	>20	Accent	Greenish white flowers	February - May	Fragrant
Black siris	*Albizzia lebbek*	*Deciduous*	Shade/fodder/green manure	High	17 m	12m	Shallow	High	<20	not wind firm/Good for garden & Parks	Creamy-white	April-June	Fragrant

TREE	B. NAME	SEASONAL	FUNCTION	BRANCHING	SPREAD	HEIGHT	ROOT-DEPTH	WATER CONSUMPTION	LIFE	WHERE TO PLANT	FLOWERING COLOUR	FLOWERING SEASON	FRAGRANCE
White siris	*Albizzia procera*	*Evergreen*	Shade/fodder/green manure	High	8m	10m	Shallow	Low	<30	Avenue,Aforestation	White	May-September	Fragrant
Saptparni	*Alstonia scholaris*	*Evergreen*	Shade/Ornamental	High	9m	20m	Deep	Moderate	<75	ACCENT,Avenue, Mass plantation, Aforestation	Greenish-white	October-December	Fragrant
Dhau	*Anogessus sericea*	*Deciduous*	Shade/Ornamental/ Religious	Low	10m	20m	Deep	Low	<100	ACCENT,Avenue, Mass plantation, Aforestation	Yellowish	March-April	
Fanas	*Artocarpus heterophyllus*	*Evergreen*	Shade/Ornamental/ Fruits	High	8m	12m	Deep	High	<100	Orchard/Shade plant for coffee & peper/Accent	Greenish	Through out the year, heaviest in Jan - Feb	Fragrant
Kamrakh	*Avrrhoea carambola*	*Evergreen*	Shade/Ornamental/ Fruits	High	9m	12m	Deep	Low	<30	Orchard/Mass plantation	White with lilac on pink stalks	Through out the year	
Neem	*Azadirachta indica*	*Evergreen*	Shade/Medicinal/ Aforestation	High	5 m	16m	Deep	High	<100	ACCENT,Avenue, Mass plantation, Aforestation	White	April	Fragrant
Kaniar	*Bauhinia purpurea*	*Evergreen*	Ornamental, Medicinal,vegetable	Low	5m	10 - 16m	Moderate	Low	<20	Avenue on narrow roads, Mass plantation, Aforestation	Rose pink or lilac	October-December	Fragrant
Kachnar	*Bauhinia variegata*	*Deciduous*	Flowering/Medicinal/ Ornamental	Low	3-6m	12m	Shallow	High	>12	Understorey tree/ Accent/Mass plantation	Magenta, lavender, purplish blue or even white	February-April	Fragrant
semal	*Bombax ceiba*	*Deciduous*	Shade/Ornamental/Fuel wood	High	18 m	30m	Deep	Low	<100	Accent/Avenue/ Mass plantation/ Aforestation	Deep red,Coral or yellow petals	February-March	Scentless
Dhak, Kesuda	*Butea monosperma*	*Deciduous*	Shade/ornamental/ Medicinal/Timber/Dye/ host for Lac insect	Low	3-8m	8-15m	Deep	Low	>50	Forest tree/Mass plantation/Accent	Orange and Vermilion Flowers	January - March	Scentless
Amaltas	*Cassia fistula*	*Deciduous*	Shade-giving/ Ornamental/Timber/ Medicinal	Low	5 m	10m	Deep	Low	<100	Plaza + accent/ Avenue/Aforestation	Yellow	April	Scentless
Saru	*Casuarina equisetifolia*	*Evergreen*	Shade/Fuel wood/ Timber/Medicinal	High	5m	40m	Deep	High	>50	Hedges/ Windbreaks/Avenue on narrow lanes/ aforestion of riverine tracks, sea fronts	Pink		
Chikrassy	*Chukrasia tabularis*	*Deciduous*	Shade/Timber	High	10m	40m	Deep	Moderate	<100	Plaza + accent/ Avenue/Aforestation	White	Apr - May	Fragrant

TREE	B. NAME	SEASONAL	FUNCTION	BRANCHING	SPREAD	HEIGHT	ROOT-DEPTH	WATER CONSUMPTION	LIFE	WHERE TO PLANT	FLOWERING COLOUR	FLOWERING SEASON	FRAGRANCE
Nimbu	*Citrus lemon*	*Evergreen*	Food/Ornamental	Low	2m	3m	shallow	Moderate	>15	Orchard/Specimen/ Mass plantation	White	Feb -Apr, Jul - Aug & Sept -Oct.	Fragrant
Gondi	*Cordia dichotoma*	*Deciduous*	Fodder/Food/Medicinal	Low	2M	8m	Deep	Moderate	>20	Mass plantation, Aforestation	White	Feb - Mar	Fragrant
Cordia	*Cordia sebastena*	*Evergreen*	Ornamental	Low	3m	6m	Moderate	Moderate	<10	Specimen, Mass plantation, Aforestation	Scarlet - Orange	Through out the year	Fragrant
Barna	*Crataeva religiosa*	*Deciduous*	Ornamental/Medicinal	Low	2.5M	4-5m	Deep	Low	<20	ACCENT,Avenue, Mass plantation, Aforestation	Greenish yellow	November-December	
River ebony	*Diospyros peregrina syn D malabaricum*	*Evergreen*	Shade/Food/Medicinal/ Timber	Low	4-6m	6-8m	Moderate	Moderate	<100	As screen, Specimen, Avenue, Good for seaside	Ochre yellow, inconspicuous	Jan - Feb	Fragrant
Amla	*Emblica officinalis*	*Deciduous*			5m	10m	Deep	Low	<50	Orchard/Specimen/ Mass plantation	Pink or greenish	March-April	Fragrant
Pangara	*Erythrina variegata*	*Deciduous*	Shade/Flowering	High	6m	15m	Shallow	Moderate	<20	ACCENT,Avenue, Mass plantation, Aforestation	Red	February-March	Scentless
Wood Apple/ Elephant Apple	*Feronia elephantum*	*Evergreen*	Field edges and village roads, medicinal, Wood, Gum,Pectin	Low	3m	9m	Deep	Moderate	<20	On slopes, Open patches, in clusters, Aforestation in dry tracts	Reddish green flowers	February-March	
Vad	*Ficus bengalensis*	*Deciduous*	Shade	Low	20 m	30m	Deep	low	<100	Avenue on NHs/ Open areas, Forests	Reddish figs	Jan - Feb	Figs are fragrant on ripening
Weeping fig	*Ficus benjamina*	*Evergreen*		Low	10m	12m	Deep	Moderate	<100	Avenue/Wind break, Aforestation/Tall hedge/Topiery	Reddish figs	Jan - Feb	Figs are fragrant on ripening
Rubber Tree	*Ficus elastica*	*Evergreen*		High	15m	30m	Deep	High	<100	Avenue on narrow lanes, Specimen, Along river fronts	Reddish figs	Apr - May	Figs are fragrant on ripening
Peepal	*Ficus religiosa*	*Deciduous*	Shade	High	18m	35M	Deep	High	<100	Avenue on NHs/ Open areas, Forests		Mar - Apr	Figs are fragrant on ripening
Sewan	*Gmelina arborea*	*Deciduous*	Shade/Ornamental/ Timber/Medicinal/Dye/ Silkworm culture	High	10m	40m	Deep	High	<50	Avenue/Specimen/ Aforestation	Yellow-brown	Feb - Apr	Fragrant
Kanju	*Holoptolia integrifolia*	*Deciduous*	Shade/Ornamental/ Fodder	High	15m	30m	Deep	Low	<100	Avenue on NHs/ Open areas, Forests	Greenish-brown	March-April	
Small Flowered Crape Myrtle	*Lagerstroemia parviflora*	*Deciduous*	Flowering	Low	5m	20m	Deep	High	<50	Avenue on narrow lanes, Specimen, Along river fronts	White	April-May	Scentless

TREE	B. NAME	SEASONAL	FUNCTION	BRANCHING	SPREAD	HEIGHT	ROOT-DEPTH	WATER CONSUMPTION	LIFE	WHERE TO PLANT	FLOWERING COLOUR	FLOWERING SEASON	FRAGRANCE
Aamba	*Mangifera indica*	*Evergreen*	Shade/Food	Low	10m	35m	Deep	Moderate	<100	Orchard, Mass plantation, gardens,NHs, River banks	Yellowish green	Dec - Feb	Fragrant
Rayan	*Manilkara hexandra*	*Evergreen*	Shade, Food	High	10m	25m	Deep	Low	<100	Avenue on NHs/ Open areas, Forests	White or cream	Sept-Dec	Fragrant
Bakam Neem	*Meila azedarach*	*Deciduous*	Shade	High	10m	14m	Moderate	Moderate	<50	Plaza, narrow roads, gardens,mass plantation	Light purple/ Lilac	March-April	Fragrant
Akash Neem	*Millingtonia hortensis*	*Deciduous*	Ornamental/Medicinal (Mosquito larvicidal properties)	High	11m	25m	Deep	High	<40	Plaza, Avenue gardens,mass plantation	white	Sept - Dec	Fragrant
Bakul	*Mimusops elengi*	*Evergreen*	Shade/Medicinal/ Timber	Low	10m	10-15m	Deep	Moderate	<100	Plaza, Avenue trees, gardens, Temples, mass plantation	White	May-June	Fragrant
Sonjana	*Moringa oleifera*	*Deciduous*	Shade/Food	Low	10m	15m	Shallow	High	<15	Plaza/Avenue trees for narrow roads/ Wind break - hedge/ Gardens/Temples/ Aforestation	White	February-March	Fragrant
Shetur	*Morrus alba*	*Deciduous*	Shade/Food	Low	3m	6m	Moderate	Low	<20	Orchard and Farm edges, Gardens, slopes	Greenish	February-March	
	Morus indica	*Deciduous*	Shade/Food	Low	3m	9m	Moderate	Low	<21	Orchard and Farm edges, Gardens, slopes	Greenish	February-March	
Yellow Gulmohar	*Peltophorum pterocarpum*	*Deciduous*	Shade/Ornamental/ Flowering	High	7m	14m15-25M	Deep	Low	<100	ACCENT,Avenue, Mass plantation, Aforestation	Bright yellow	May-June	Fragrant
Indian Mast Tree, False Ashok	*Polyalthia longifolia*	*Evergreen*	Shade/Wind break/ Medicinal	High	3m	25m	Deep	High	<100	ACCENT,Avenue, Mass plantation, Aforestation	Pale green	March-April	Fragrant
Karanj	*Pongamia pinnata*	*Evergreen*	Shade/Wind break/ Medicinal/Fodder	Low	10m-25m	25m	Deep	Low -High	<50	Shade/Wind break/ To check soil erosion & bind sand dunes/Avenue/ Riverbanks	White or pinkish	Mar - Apr	Fragrant
Jhand	*Prosopis cineraria*	*Evergreen to Deciduous*	Shade/Wind break/ Medicinal/Fodder/ Nitrogen fixing in soil	Low	5m	12m	Deep	Low	<400	Shade/Wind break/ To check soil erosion & bind sand dunes/Afforestation	Yellow	Mar - Apr	Fragrant
Almand	*Prunus amygdalus*	*Deciduous*	Shade/Wind break/ Medicinal	Low	3m	6m	Deep	Low	<100	Stunted in Delhi	Pink	Feb - Mar	

TREE	B. NAME	SEASONAL	FUNCTION	BRANCHING	SPREAD	HEIGHT	ROOT-DEPTH	WATER CONSUMPTION	LIFE	WHERE TO PLANT	FLOWERING COLOUR	FLOWERING SEASON	FRAGRANCE
Kanak Champa	*Pterospermum acerifolium*	*Deciduous*	Shade/Wind break/ Medicinal	High	10m	16m	Moderate	Moderate	<50	ACCENT,Avenue, Mass plantation, Aforestation	White-YELLOW	March	Fragrant
Buddha□s coconut	*Pterygota alata*	*Deciduous*	Shade/Wind break/ Medicinal	High	5m	30-35m	Deep	Moderate	<100	ACCENT,Avenue, Mass plantation, Aforestation	Rusty Brown tomentose	March-April	
Wild Olive	*Putranjiva roxburghii*	*Evergreen*	Shade/Wind break/ Medicinal	Low	10m	25M	Deep	Moderate	<100	ACCENT,Avenue, Mass plantation, Aforestation/ Riverbanks	Yellow,Green	March-April	Fragrant
Peelu	*Salvadora persica*	*Evergreen*	Medicinal/wind break/ reclamation of saline and sandy soils	Low	6m	7m	Deep	Low		Ornamental/Farm edges/Tall Hedge	Greenish or Yellow	December & April	Aromatic fruits
Sita-Ashok	*Saracca asoka*	*Evergreen*	Shade/Wind break/ Medicinal	Low	6m	12m	Deep	High	<100	ACCENT,Avenue, Mass plantation, Aforestation/ Riverbanks	Orange-red	Feb-Apr	Fragrant
Kosam	*Scheleichera oleosa*	*Deciduous*	Shade/Ornamental/ Religious/Medicinal	High	16 m	20m	Deep	High	<100	Accent	Greenish Yellow	Mar-Apr	
Jamun	*Syzygium cumini*	*Evergreen*	Shade/Wind break/ Medicinal	High	10m	30m	deep	Medium	<100	Avenue/Wind break, Aforestation in problem soils	White	Mar -April	Fragrant
Rai Jamun	*Syzygium jambolana*	*Evergreen*	Shade/Wind break/ Medicinal	High	10m	25m	Deep	High	<100	Avenue/Wind break, Aforestation in problem soils	White	May	Fragrant
Arjun	*Terminalia arjuna*	*Deciduous*	Shade/Wind break/ Medicinal	Low	10m	35m	Deep	High-Low	<100	ACCENT,Avenue, Plaza, river banks	Creamy yellow	April-May	Fragrant
Badaam	*Terminalia catappa*	*Deciduous*	Shade/Food/Medicinal	High	5m	35m	Deep	High	<50	ACCENT,Avenue, Plaza	Greenish white	Feb - Mar	
Baheda	*Terminalia bellirica*	*Deciduous*	Shade/Timber/ Medicinal	Low	23 m	40m	Deep	Moderate	<100	Plaza/Avenue/ Accent/Aforestation	Greenish Yellow	Apr	
Indian Tulip Tree	*Thespesia populnea*	*Evergreen*	Ornamental	Low	5m	10m	shallow	High	<15	Accent, Plaza, Mass plantation	Lemon-Yellow	Mar - Apr	Scentless
Ber	*Zyzyphus mauritiana*	*Deciduous*	Shade/Wind break/ Medicinal	Low	3m	8m	Deep	Low	<15	Orchard	Pale Greenish	July-October	Fragrant
Indian mahogany, Red cedar, Surian	*Toona ciliata*	*Deciduous*	Ornamental/Shade/ Timber	High	5m	35m	Deep	Low	<100	Avenue/Aforestation	White flowers	Mar - Apr	Fragrant

SURVEY REQUIREMENTS FOR ROAD/STREET RETROFITTING AND DESIGN

Type of Survey	Requirements may include:
Topographical/Total Station Survey of demarcated Right-of-Way (including a 50 m offset from edge of R/W):	i. The roads marked in Blue in the key plan provided for survey estimate, are to be surveyed and documented including locations of trees (with girth more than 30 cm measured at 1 m height from the ground level) & their species, locations of zebra crossings, street furniture, traffic lights, height of footpaths (above finished road level), locations of bus stops, lamp posts and all above-ground utilities like manholes, electric line, telephone line, H.T, L.T transmission lines (along with their capacities). Information regarding traffic signal, light posts, bus stops, junction boxes (telephone & power), wire and water hydrants (fire-fighting and others), transformers, telephone posts, street lights etc. ii. Tree Survey to be done as per enclosed **"Tree Survey Data Sheet"** iii. Location of utilities like manholes, sewers, pipelines etc. are to be shown along with any other structure or details which may be relevant. iv. Location, sizing, height (above finished road level) and invert levels of storm water drains to be marked. v. Plotting of spot/Ground levels at 0.5 meters Intervals (with grid) and at sudden changes in levels with all features and spotting all utilities. vi. All temporary/permanent activities and encroachments taking place within the Road R/W including on footpaths, to be shown with Legend. vii. Edge conditions within 50 m from Edge of Right-of-Way to be marked, including nearest boundary wall/entry gate and/or building footprint and the use-premise; Landmarks if any. viii. Centrelines of Rights-of-Way to be marked. ix. Sample Drawing is provided in Column 1 of Figure x. Panoramic photo documentation must be carried at every 25 m

	ADDITIONAL & OPTIONAL: **(a) Activity Survey within Right-of-Way:** xi. All temporary/permanent activities and encroachments taking place along with a small description of their types within the Road R/W including footpaths, to be shown with Legend. xii. Location of hawkers, unauthorized markets, garages and utility areas are to be marked. xiii. Location of all types of temporary and permanent parking areas, along with vehicle counts (peak hour) and their types is to be specified. Parking counts to be done in day and night time and also on weekend. xiv. Plot/building entries are to be demarcated. xv. The activity survey should be overlaid on the Total Station Survey drawing of the Right-of-Way. xvi. Location of social gathering spaces in the public ROW, as well as the number of people engaged in activities in such spaces in the study area. This information will inform the placement of street furniture and other elements in the final design xvii. Sample Drawing shown in Figure…. below.
Traffic Survey of roads/junctions (if required):	**Primary Traffic Surveys (if required):** **1. Record movement pattern of vehicular, pedestrian and NMV traffic:** The surveys can be done by various methods including video-recordings, on-site counts, interviews, etc and will include: • Speed and delay survey - For private vehicles, the survey can be done by using test-car method both in peak and off-peak periods along all major routes in the Study Area. For public transport speed survey shall be carried out on board both in peak and off-peak periods along all major routes in the Study Area. • A detailed inventory of existing transport system network in the study area including all intersections and type of control • Inventory of existing traffic management measures in the study area • 16 hrs. classified traffic volume survey at a maximum of about 25 mid-block locations on major roads as well as feeder roads falling in the Study Area, to be identified in consultation with stakeholders. • 16 hrs. classified turning volume count at a maximum of about 25 identified junctions in the study area to assess the quantum of direction wise traffic at each intersection. Final location and number of junctions to be identified in consultation with stakeholders. • Signal time & Queue Length survey will also be carried out at these identified intersections.

	• Road side Origin-Destination and opinion survey (if required) to assess the traffic movement pattern (including the through traffic) by interviewing the passengers at intersections during red phase of the signal at all major intersections. About maximum of 25 such locations could be surveyed, to be identified in consultation with stakeholders. The survey must include peak hours. • Understand broad pedestrian and cyclist movement within the study area using lines - Pedestrian counts for 'along' and 'across' movement at maximum of about 25 indentified mid-block/intersection locations, for 16 hour duration on a typical week day (including the peak hours), as per locations identified in consultation with stakeholders. • Parking accumulation and duration survey (if required) at locations identified in consultation with stakeholders.
Secondary Data	• Information regarding ongoing and proposed projects for the road stretch shall be collated and analysed. The data includes but is not limited to public or mass transit improvements, road widening proposals, beautification projects within the study area and is likely to impact the road stretch. • Accident Data – Collect data on accident hot spots from the Traffic Police along road stretch and within 50 m of all junctions.
Perception Surveys through workshops/ design charrettes and Stakeholder Interviews (if required)	• Perceptions of different users on the use and experience of using the road/street and suggested improvements (e.g. Residents, visitors, formal and informal businesses and service providers along the road stretch as well as all types of commuters) • Workshops and design charettes can be organized to involve local stakeholders and understand their expectations from the project • Stakeholder interviews with Zonal Traffic Police, Roads Department, Resident Welfare Association, Industry Associations and Utility Providers.

Parking Surveys	To identify parking patterns and occupancy rates along the road stretch and along roads within 250 m of all intersections, the following are required:
	• Classicization of Parking based on:
	  • Type of Mode
	  • Informal viz. formal
	  • Location of parking (on-street/off-street/multi-level)

	• **Parking Duration/Occupancy Survey –** Manual count of number of parked vehicles at least 3 or 4 different time periods during the day and night (including all times with peak demand) for at least 2 working days and 1 non-working day - to establish peak and off-peak demand for different zones within the study area and establish short-term and long-term parkers; • **Pricing** (with hourly, weekly variation if any) • **Demand projection** based on future development proposals • **Willingness to Shift/Stated Preference Survey** (if required) based on criteria such as increase in pricing, provision of public transport or circulator services, etc. • **Parking Origin-Destination Survey** (if required) to establish long-distance and short-distance commuters.

Annexure B

TREE SURVEY DATA SHEET

Surveying Agency
Name:
Address:
Contact Number:

Date of Survey:
Time of Survey:
Street Name:
Area:

Sr. No.	Tree Number (<prefix street number/name> Numerical)	Coordinates (Lat/ Long)	Existing Locational Condition (check box)					Physical Properties					Obervation (about tree condition)					Name of Species (if known to surveying agency)
			On Road	On Walkway	On Median	Inside Property	Any other	Diameter on ground	Width of stem/ trunk (measured 1.2m above ground)	Overall Height of tree (in meters)	Height of first branch from ground	Foliage diameter	Healthy	Satisfactory	Declining	Poor	Dead	

EDGE CONDITIONS BOOKLET

1 INTRODUCTION

Importance of River Bank

The river banks are not only environmentally sensitive areas and habitats for local flora and fauna but also desirable places that people want to visit, explore and enjoy. As the river banks are at a risk to erosion, prior to any development of the islands, it is critical that the river banks are protected and the island edges are preserved.

There are number of strategies that have been successfully employed to preserve river banks these can be broken into two major categories; natural and built.

Natural

The root systems of trees, shrubs, and grasses along the river bank bind and hold the it together. The vegetation helps absorb the force of the flow and reduce the water's capacity to erode the banks. Trees and shrubs on the banks also provide shade and shelter for aquatic and terrestrial fauna. Grasses and other ground cover plants help filter sediments, nutrients and pollutants from run-off before they enter the stream.

The natural strategy attempts to mimic nature by reconstructing a river bank with riparian flora that helps maintain the structural integrity of the bank and also serving as a habitat for the fauna.

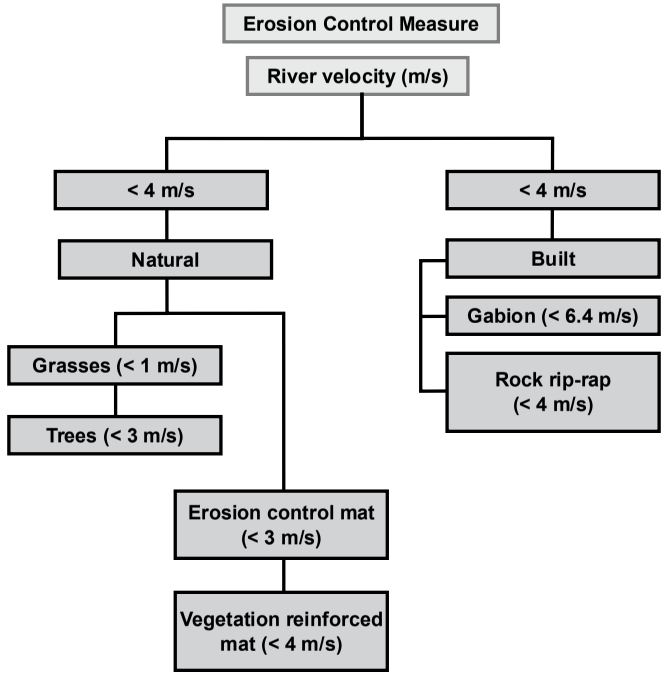
Built

Rivers bank areas provide people with much needed open space and offer people a place away from stresses and strains of urban life. Programme along the river edge such as walking & cycle trails, shops and restaurants and park areas helps in creating an active and vibrant area.

To develop activity zones abutting the river edge requires a more engineered or harder edge solution involving the construction of retaining structures that can increase the structural stability of the edge, provide safe and easy access to the water front and prevent the erosion of the river bank.

Natural Vs. Built Edge

Natural erosion control solutions such as planting of vegetation, grasses and erosion control mats are used when the maximum velocity the river bank experiences is less than 3 m/s. For river bank areas experiencing higher velocities built solutions such as rip-rap and gabion walls.



2 EDGE STABILIZING STRATEGIES

Some basic principles of shoreline protection

- Imitate nature - The native vegetation usually found at the shoreline strengthens its structural integrity and prevents the land from breaking apart.
- Keep slopes gentle - The gradual slope of a natural shoreline absorbs the energy of waves. A steep, eroded slope or retaining wall allows waves to crash into the shore, drastically increasing erosion and causing that wave energy to cause damage on adjacent shorelines.
- Employ “soft armouring” whenever possible. - By “soft armoring” refer to live plants, logs, root wads, vegetative mats, and other methods Soft armor is alive and so can adapt to changes in its environment as well as reproduce and multiply. It also provides habitat for fish and wildlife.
- Mix it up - Regardless of the type of natural shoreline encountered, you will undoubtedly see a wide diversity of materials: live trees, dead branches, stumps, rocks of many shapes and sizes, silt, sand, cattails, grasses, flowering plants, etc.
- The edge stabilization strategies can be divided into two categories

Natural Edge

- Coconut Fiber Roll
- Vegitated Geogrids
- Live Stakes
- Boulder Stabilization
- Branch Packing
- Live cribwall
- Live Fascine
- Green grid System
- Log Revetment

Built Edge

- Vegitated Gabion wall
- Rock Rip-Rap
- Terraced Stabilization

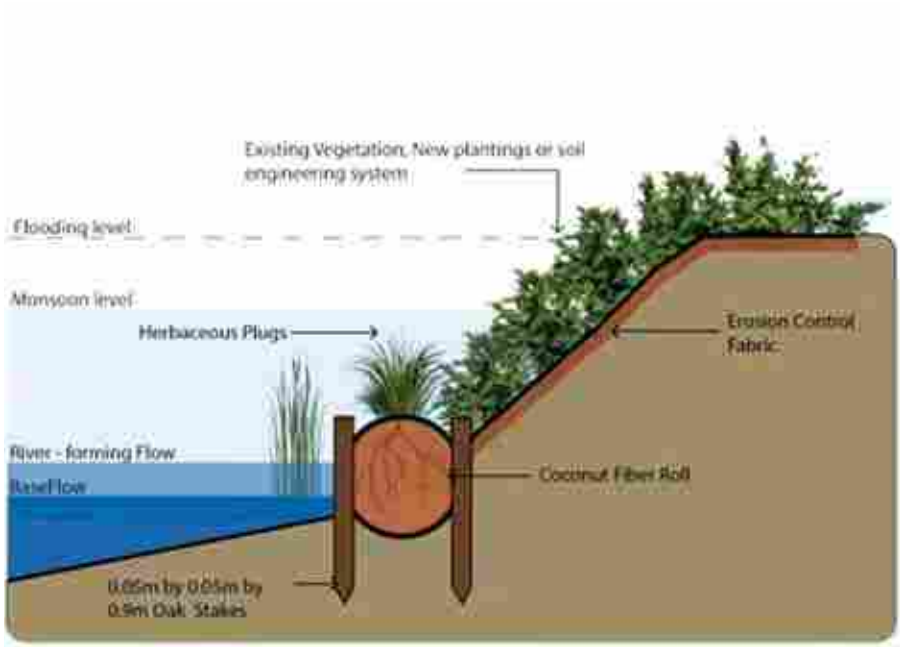
2.1 Natural Edge

Coconut Fibre Roll

Basic idea: Coconut fibre rolls are cylindrical structures made of coconut husk fibres bound together with coconut husk twine. The roll is staked to the toe of the slope. Rolls are about 12 inches in diameter and up to 20 feet long.

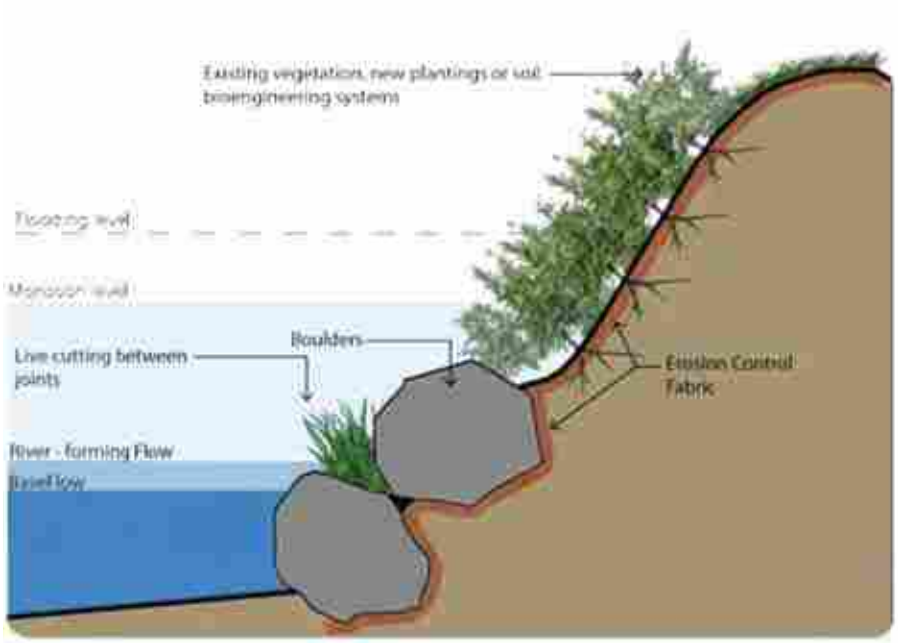
Where it works: Slopes of 6H:1V with light erosion

Cost: Low Difficulty: Easy



Advantages and disadvantages

- Shallow earth slips are prevented.
- Undermining at the toe of a streambank is prevented.
- Plants can grow in the roll.
- A flexible roll allows the roll to conform to the bank.
- Disturbance to the streambank is limited.
- Sediment is trapped in the fibres.
- The roll provides erosion control for 6 to 10 years.
- The materials are relatively expensive.



Boulder Stabilization

Basic idea: To Place considerably big stones as toe protection with sparse vegitation along with the stone and proper vegetation on the slope.

Where it works: On badly eroded slope - 4H:1V

Cost: Low; Difficulty: Moderate

Advantages and disadvantages

- Boulder stabilization can be used where the bank cannot be pulled back to a gentle slope.
- Boulder stabilization can be used where a bank has low erosion
- A large amount of soil and rock must be available to fill against the bank.
- Rapid vegetation growth is allowed from the live cuttings, which slows water during high water stages.

Live Stakes

Basic idea: Lay live bundles of stems and branches in trenches on the shoreline, and cover them with soil. They are held in place with both wooden and live stakes. They will sprout roots and grow.

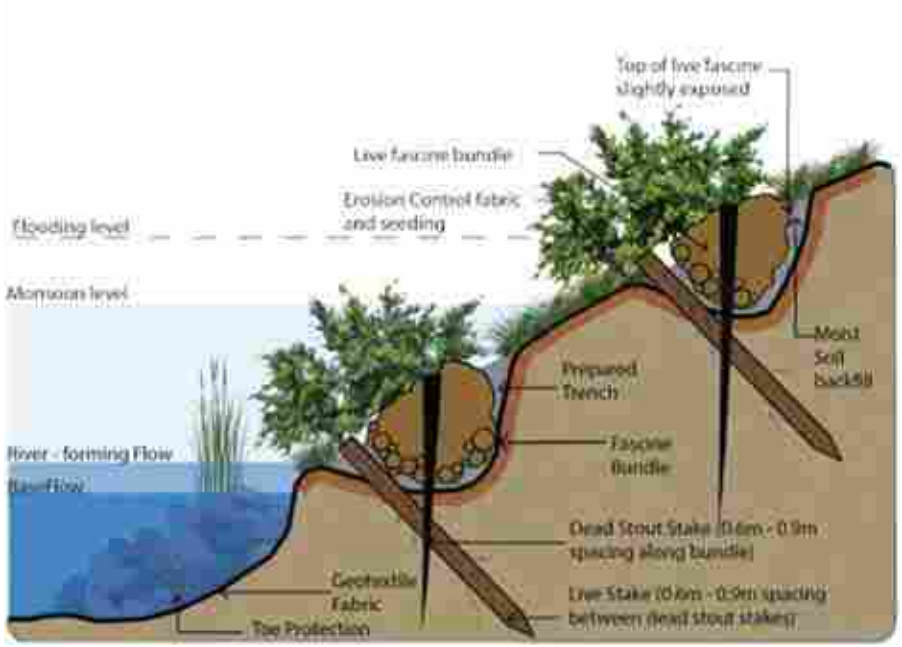
Where it works: Slope - 2H:1V with light erosion

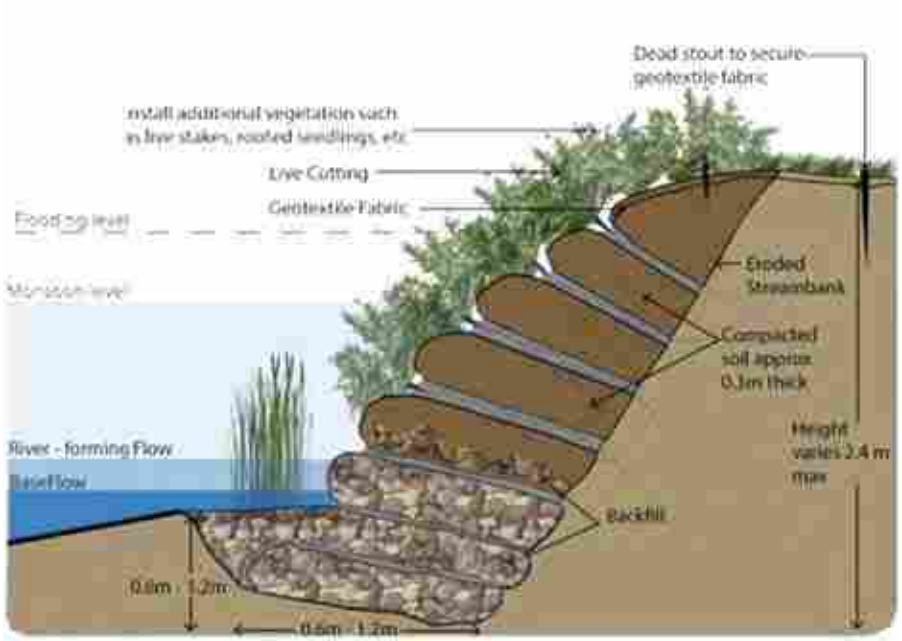
Cost: Low

Difficulty: Easy to moderate depending on level of site prep needed.

Advantages and disadvantages

- To increase the resistance to erosion immediately after placement, erosion control fabric can be used to protect the slope and still allow the cuttings to grow.
- This method is effective where there is an adequate supply of live cuttings and frequent heavy stream flows.
- Staking is also useful in conjunction with other more complex erosion control methods.
- This method should not be used if immediate stabilization is required.





Vegetated Geogrids

Basic idea: The erosion control fabric is secured by tucking it into the slope. Live cuttings are placed between the geogrids, and a root structure is established to bind the soil within and behind the geogrids.

Where it works: On badly eroded slopes of 3H:1V

Cost: Moderate Difficulty: Moderate

Advantages and disadvantages

- Vegetated geogrids can be used where the bank cannot be pulled back to a gentle slope.
- Vegetated geogrids can be used where a bank has severely eroded.
- A large amount of soil and rock must be available to fill against the bank.
- Rapid vegetation growth is allowed from the live cuttings, which slows water during high water stages.

Branch Packing

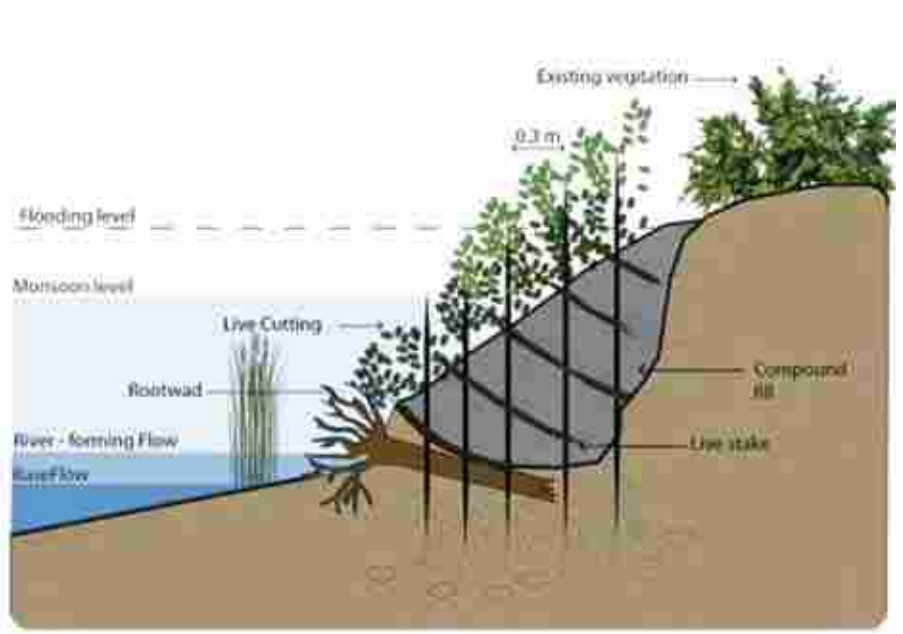
Basic idea: Branchpacking is the layering of live branch cuttings and compacted soil to fill small holes and slumps in a streambank.

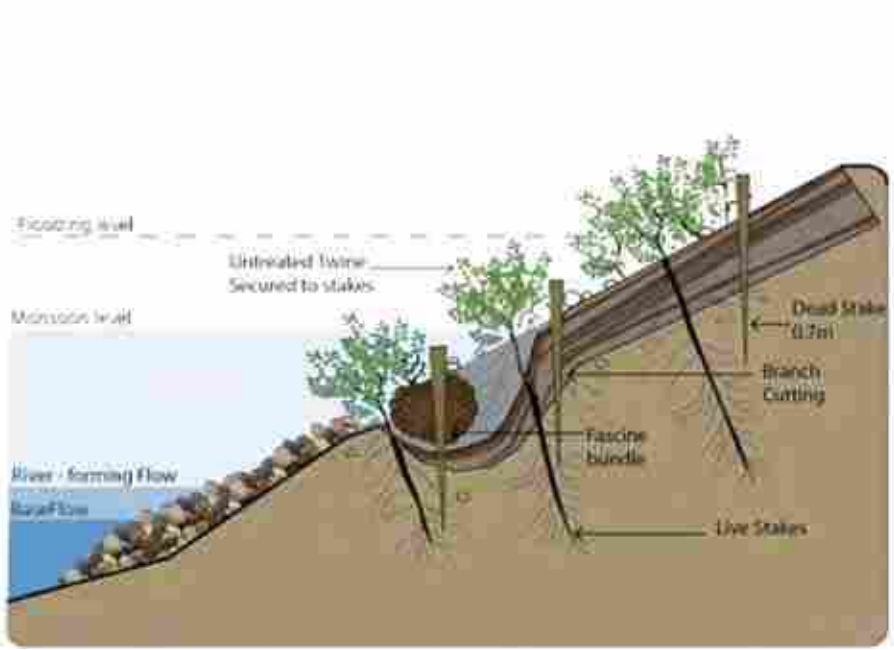
Where it works: Slope - 2H:1V with light erosion

Cost: Low Difficulty: Easy

Advantages and disadvantages

- Branchpacking is used to fill holes or gullies (two to four feet in height and depth).
- The branches root and stabilize the soil to the bank.
- An immediate barrier is provided to reinforce the bank and prevent bank erosion from overland flow.
- Branchpacking is an effective and inexpensive method on small projects.
- Branchpacking should not be used on an eroded bank with holes greater than four feet in depth and four feet in width.





Live Fascine

Basic idea: Lay live bundles of stems and branches in trenches on the shoreline, and cover them with soil. They are held in place with both wooden and live stakes. They will sprout roots and grow.

Where it works: Slopes with light erosion

Cost: Moderate

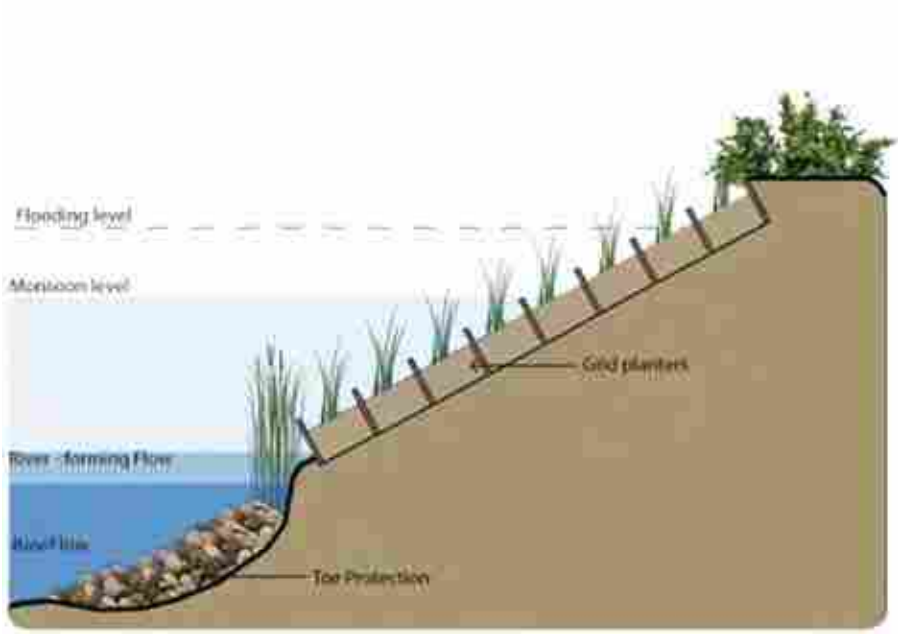
Difficulty: Easy to moderate depending on level of site prep needed.

Advantages and disadvantages

- Live fascine is most effective when combined with live staking and riprap.
- The fascine is placed above the stream-forming flow and causes minimal site disturbance.
- A tiered streambank creates shorter slopes to slow overland flow.
- Angled fascines create drainage paths in the slope.
- Successful fascines require a large supply of long branches.

Green Grid Sysytem

Basic idea: Root guards protect tree roots by spreading force from the ground laterally instead of downwards, preventing compaction of the soil and undue damaging pressure on tree roots. They come in honeycomb like panels which are filled with porous material. The cell honeycomb structures prevent the infill from spreading downwards under pressure loads from above.



Where it works: Gradual Slope with low erosion

Cost: Low Difficulty: Easy

Advantages and disadvantages

- Shallow earth slips are prevented.
- Undermining at the toe of a streambank is prevented.
- Plants can grow inside the grid
- Disturbance to the streambank is limited.
- The materials are relatively expensive.

Log Revetment

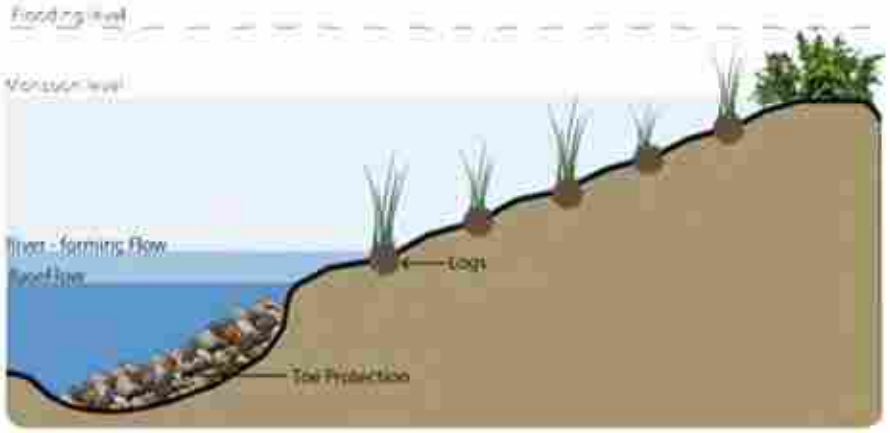
Basic idea: Holes are dug into the side of the slope, and plant cuttings are inserted at an angle, and grow outward, while the roots grow into the slope.

Where it works: On badly eroded slopes

Cost: Low Difficulty: Moderate

Advantages and disadvantages

- Vegetated geogrids can be used where the bank cannot be pulled back to a gentle slope.
- Vegetated geogrids can be used where a bank has severely eroded.
- A large amount of soil and rock must be available to fill against the bank.
- Rapid vegetation growth is allowed from the live cuttings, which slows water during high water stages.



Seeding of Stream Bank

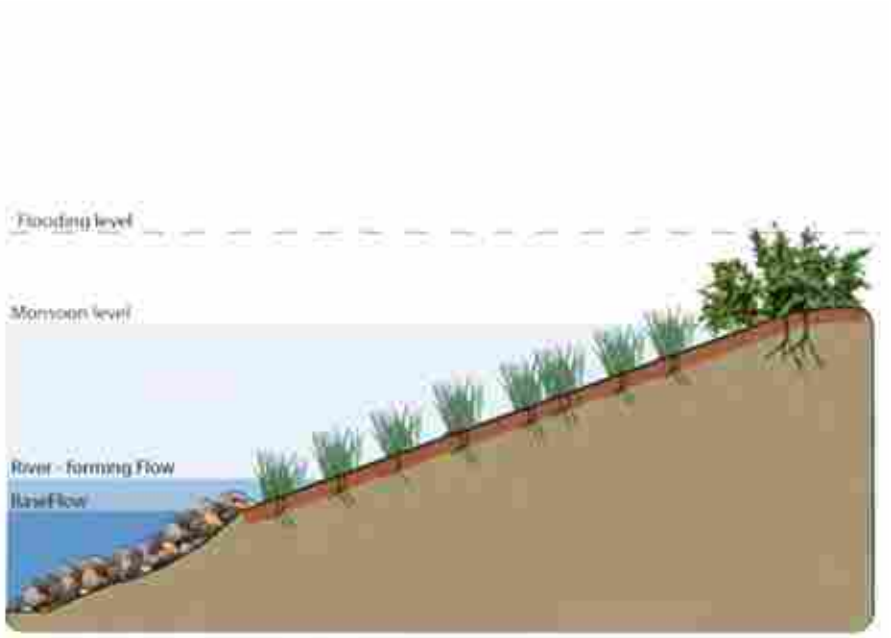
Basic idea: A sheet of special three-dimensional biodegradable erosion-control geotextile fabric is laid down over the exposed slope of the shoreline. The grass becomes intertwined with the mat or blanket and stabilizes the shore.

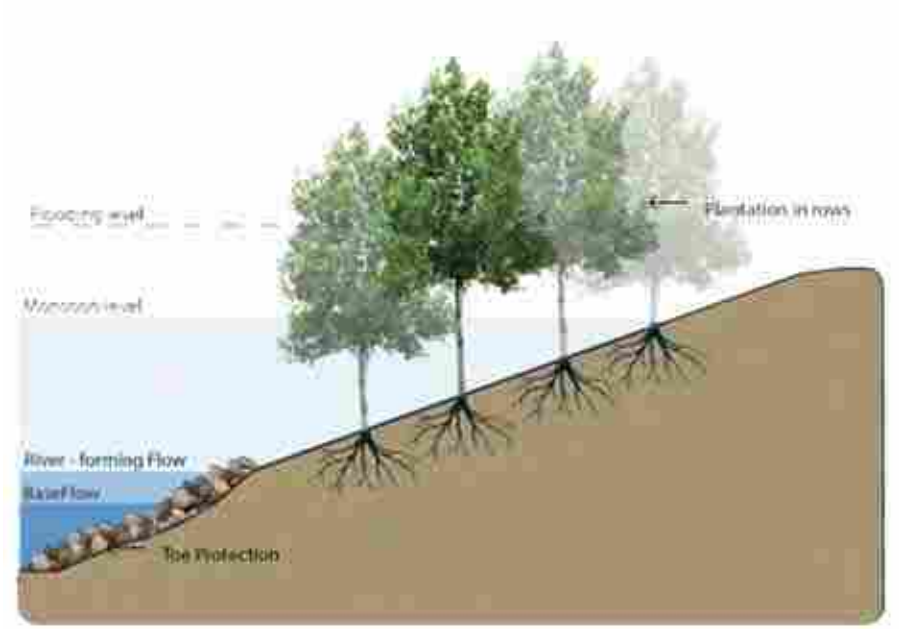
Where it works: Moderate slopes up to 1 vertical to 2 horizontal slopes along waterways.

Cost: Moderate, Difficulty: Moderate to difficult

Advantages and disadvantages

- Seeding is useful when rich topsoil is readily available.
- Vegetation improves the appearance of streambanks.
- Seeding is low-cost, particularly when compared to structural erosion control methods.
- If used alone, seeding may not be adequate to control bank erosion, especially when erosion is severe.
- Seeding must be done during low flow conditions, and vegetation must have sufficient time to grow before high flow conditions occur.





Dormant Post Planting

Basic idea: Holes are dug into the side of the slope, and plant cuttings are inserted at an angle, and grow outward, while the roots grow into the slope.

Where it works: On badly eroded slopes

Cost: Low, Difficulty: Moderate

Advantages and disadvantages

- Vegetation is established on the streambank.
- Dormant post planting slows the stream, especially in high water flows, and catches sediment.
- Dormant post planting is best used on small, non-gravel streams.
- Dormant post planting can be damaged by ice flows.
- Some heavy equipment is required to install the stabilization.
- The moisture of the slope is reduced by the roots of the trees.

2.2 Built Edge

Terraced Strategy

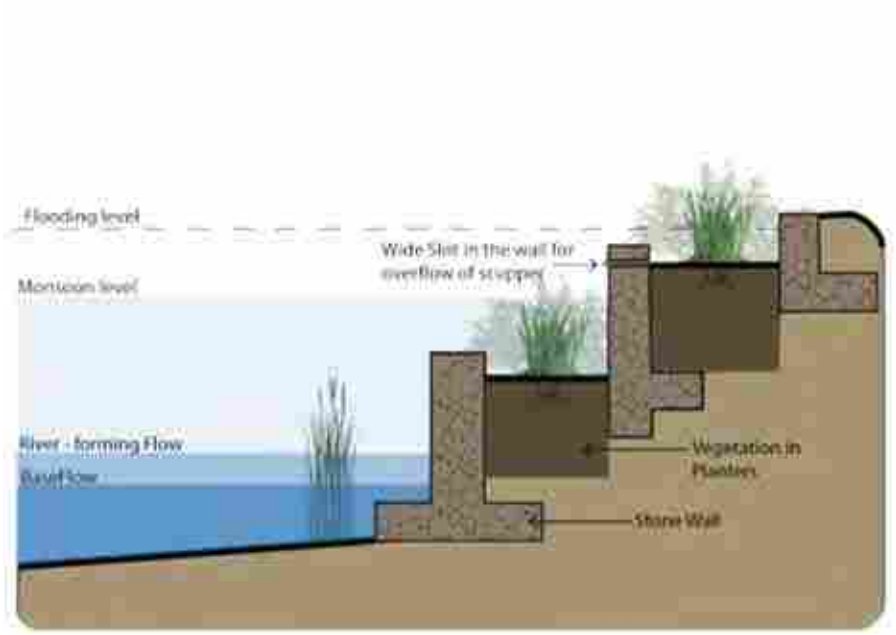
Basic idea: Terraced by building stone wall and filling with compound fill and planting native vegitation or poviding with seating space

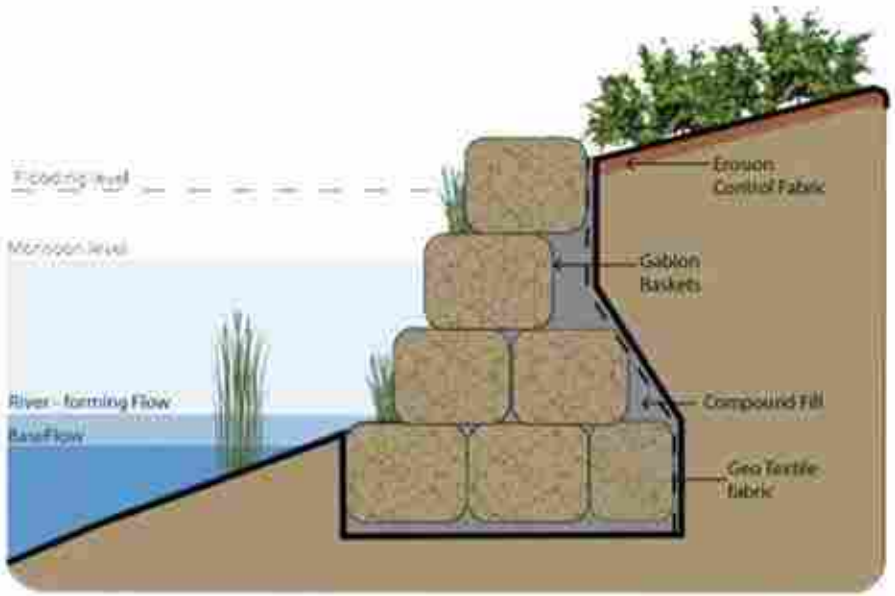
Where it works: Steep slopes prone to extreme erosion

Cost: High Difficulty: Difficult

Advantages and disadvantages

- Shallow earth slips are prevented.
- Undermining at the toe of a streambank is prevented.
- Plants can grow in the roll.
- A flexible roll allows the roll to conform to the bank.
- Disturbance to the streambank is limited.
- Sediment is trapped in the fibres.
- The roll provides erosion control for 6 to 10 years.
- The materials are relatively expensive.





Vegitated Gabion Mattress

Basic idea: A gabion mattress is an elongated, mattress shaped cage filled with rocks. Vegetated gabion mattresses involved branches or cuttings inserted through rocks in the cage.

Where it works: Moderate slopes to resist wave action, ice and surface erosion.

Cost: High, Difficulty: High.

Advantages and disadvantages

- Vegetated geogrids can be used where the bank cannot be pulled back to a gentle slope.
- Vegetated geogrids can be used where a bank has severely eroded.
- A large amount of soil and rock must be available to fill against the bank.
- Rapid vegetation growth is allowed from the live cuttings, which slows water during high water stages.

Live Cribwall

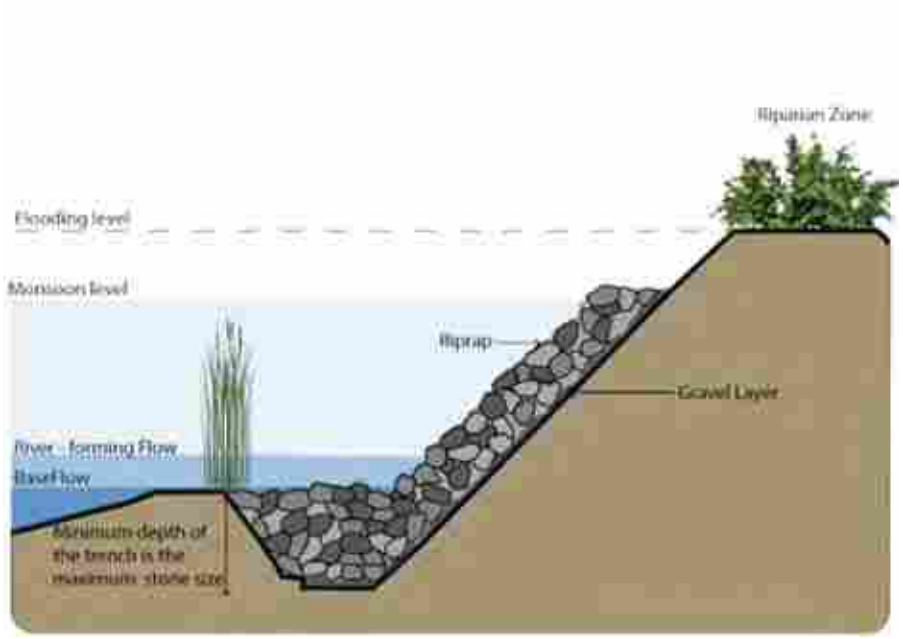
Basic idea: Interlocking planks of wood act as a sort of live retaining wall, but with less of an environmental impact. Vegetation is planted between the planks. This does not work well on high banks with heavy wave action.

Where it works: Unvegetated slopes with a lot of backfill and little wave action

Cost: Moderate to high, Difficulty: Moderate.

Advantages and disadvantages

- The structure can be filled to form a vertical wall.
- A live cribwall requires minimal space.
- Stability above and below the water level is provided.
- The toe of the slope is stabilized.
- Live cribwalls can provide a natural habitat for riparian wildlife.
- Immediate sloe protection is provided.
- The height of the cribwall should not exceed 7 feet.
- The width of cribwall should not exceed 20 feet.



Rock Riprap

Basic idea: A layer of stones is laid along a slope face or bank and prevents erosion caused by wave action.

Where it works: Shorelines where underlying soil is stable.

Cost: Moderate to high

Difficulty: Moderate

Advantages and disadvantages

- Riprap is effective because the rock can adjust to the contours of the streambank and vegetation can grow among the rocks to provide habitat for wildlife in and above the stream.
- Riprap is easy to install and repair, has a natural appearance, and does not harm the environment.

(The Official amendments to this document would be published by the IRC in its periodical, 'Indian Highways' which shall be considered as effective and as part of the Code/Guidelines/Manual, etc. from the date specified therein)