Environmental Impact Assessment

Project Number: 50165-002
May 2017

Bhutan: Amochhu Land Development and Township Project

Draft Report (Appendix 40)

Prepared by Construction Development Corporation Limited, Royal Government of Bhutan for the Asian Development Bank.

Environmental Impact Assessment (EIA) Report

For

Amochhu Land Development and Township Project (ALDTP), Phuentsholing, Bhutan

MAY 2017

CONSTRUCTION DEVELOPMENT CORPORATION LIMITED, BHUTAN

Appendix 40:
Landscape Assessment & Strategy

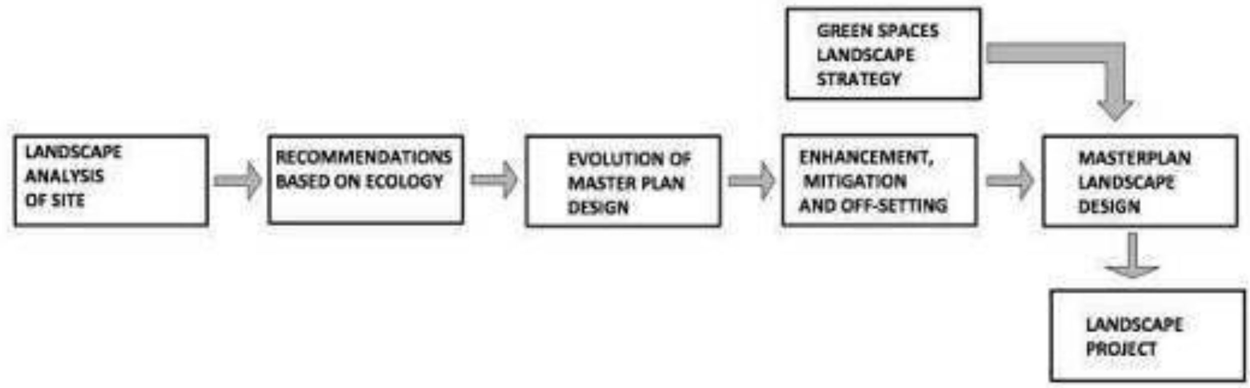
Introduction to Landscape Strategy

From the very inception of the project, it was realized, that a thorough understanding of the ecology and environment, along the riverbed hydrology, geo-technology and socio-cultural aspects of the project area, would be needed before starting any design. It was clear that the ecology of the land was going to shape the key components of the masterplan. It was clear that unless the inputs from the ecology were going to be integrated into the landscape design, the inputs from Green Spaces strategy would have little meaning in evolving a master plan that is contextual, relevant and sustainable. This masterplan then evolves into the Landscape project where landscape detailing takes place creating a tender document.

In the Landscape Strategy, the evolution of the master plan is influenced by inputs coming from two domains:

a. Ecology and environmental characteristics of the project area.
b. Green spaces strategy for urban master planning.
These together create the Landscape Project.

In this section we trace the evolution of the master plan, landscape project and landscape strategy flowcharting the following steps.



1.0 Landscape Analysis of Site:

Preceding the conceptualization of the masterplan, a landscape analysis of the site was done to understand the ecology of the site and the environmental impact of the proposed development. Broadly, based on the ecological conditions, the site can be looked at under the following headings:

1.1 **Bio-diversity** of the surrounding local areas.
1.2 **Outfalls** from valley hillsides.
1.3 **Riparian Grassland** habitat of Zone C.
1.4 **Forest Zone** at the south western international boundary.
1.5 **Eroding Slopes** on the eastern boundary below the new highway.
1.6 **Mature trees** on sand banks near the northern end of Zone B.
1.7 **Kaileshwar Hill,** a high bio-diversity zone.

1.1 **Bio-diversity** of the surrounding local areas:

Bio-diversity is especially evident on the southern and western boundary of the site adjoining Zone C.
The habitat and surrounds of the locale is "natural bio-diversity". It is this "naturalness" that needs to be brought in and highlighted as a character of ALDTP landscape. This valley has many endangered species of plants that need to be protected and preserved. List of indigenous trees found in this valley are listed in Table 1.1 of Appendix 2.

Fig. 1.1 Rich bio-diversity of peripheral habitats. (Source: HCP site photo)

Site observations show several aggressive invasive alien species that are overtaking the indigenous species. Invasive alien species, which have been observed in the ALDTP site, are listed in Table 1.2 of Appendix 2.

Fig 1.2 Invasive creeper Mikania micrantha and alien weed Lantana camara (Source: HCP site photo)

1.2 Outfalls from valley hillsides

The Amochhu valley at Phuentsholing is bounded by the Kaileshwar hill to the west and the lesser Himalayas to the north and east. The local precipitation catchment of the valleys creates a substantial volume of outflows in the valleys that empty into the river plain.

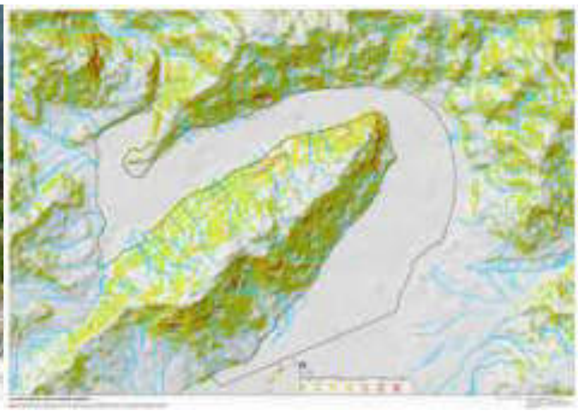


Fig. 1.3 Site photo showing outfall

Fig. 1.4 Topographical map showing outfalls

The discharge volume for storm water during peak precipitation, for 9 of the major outflows in Zones A, B and C, was estimated to understand the quantum of water flowing into the project site from catchment area.

Stream	Catchment Area in Ha.	Runoff from the premises on rainfall intensity			Proposed Area of the Retention Pond in Sq. M.
		30mm / hr	50mm/hr	75 mm/hr	
C 1	59.00	5752.96	9588.27	14382.40	3844.00
C 2	34.00	3315.27	5525.44	8288.16	2304.00
C 3	28.00	2730.22	4550.36	6825.55	1936.00
C 4	21.00	2047.66	3412.77	5119.16	1444.00
C 5	12.00	1170.09	1950.16	2925.23	802.78
C 6	15.00	1462.62	2437.70	3656.54	1024.00
C 7	26.00	2535.20	2535.20	6338.01	1764.00
C 8	35.00	3412.77	5687.96	8531.93	2304.00
C 9	24.00	2340.19	3900.31	5850.47	1600.00

Table 1.3 Estimate of outflows from streams of outfalls during peak precipitation. (Source: Annexure 7 Common urban Infra.)

As can be seen from the above estimates, the discharges range for high intensity of rain (75mm/hr/m2) from 5000 Cu.M to 44,000 Cu.M. Outfalls C01 to C04 in Zone C, discharging from the Kaileshwar Hill, are relatively at the lower end of the scale ranging from 5000 to 14,000 Cu.M. The discharge from the outfalls in Zone A and B (A02, A03 and B01) is significant being upward of 21,000 Cu.M.

Fig. 1.5 Zone wise location of Outfalls A01-A03, B01-B03 and C01-C04

1.3 Riparian Grassland habitat of Zone C:

Zone C is a large area in the ALDTP site where sediment deposition has taken place. The vast plain covering approximately 600 acres, is largely river sand mixed with clay and silt, brought down by the river. This forms an ideal habitat for the establishment of Riparian grasslands.

Fig. 1.6 Pristine riparian grassland habitat in Zone C (Source: HCP site photo)

Riparian grasslands are a repository of great ecological bio-diversity. They are flat savannahs where human settlement has happened from time immemorial. In the present day context, however, such habitats are fast disappearing from our planet.
Site observations show that at least to a depth of 600mm, loamy silt exists in this zone. The grasslands have harbored grazing animal over hundreds of years and these animal droppings have gradually improved the arable quality of such lands.
The analysis of the physical and chemical characteristics of the topsoil in Zone C grasslands is listed in Table 1.4 of the Appendix 2. It is observed that, while the physical characteristics of the soil are very suitable for plant growth, there is deficiency in the organic content and NPK nutrient. Both these can be amended at site.

1.4 Forest Zone:

At the south-western end of the project site terminating at the international boundary with India, spread over 40 acres, is the Forest Zone of Zone C. It is home to a rich palette of indigenous trees. Though there has been some amount of felling and branch cutting, once protected, these trees will grow to their original splendor.

Certain invasive species are aggressively displacing the local flora. These need to be brought under control by properly fencing and maintaining the area.

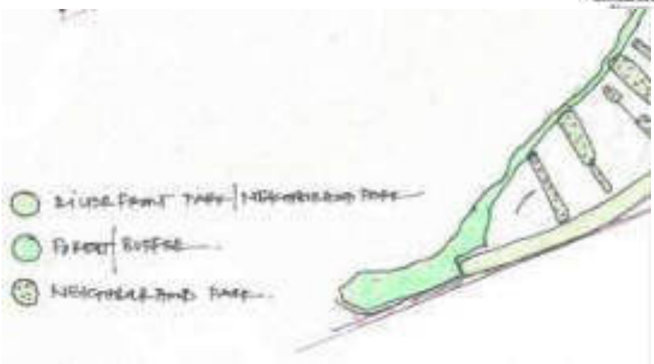


Fig. 1.7 Bio-diversity of the Forest Zone.

Fig. 1.8 Location of the Forest Zone.

The Forest zone is another area within the project boundary that is home to large mature trees. Several rare and endangered trees have been observed in this zone and listed in Table 1.1 of Appendix 2

Fig. 1.9 Boundary marker boulder demarcating the international border with India. (Source: HCP site photo)

1.5 Eroding Slopes on the eastern boundary below the new Phuentsholing-Samtse highway:

Soil erosion is a complex phenomenon governed by various natural processes, which result in decreases in soil fertility, water quality and the reduction of crop yields. Soil erosion has a high spatial variability; it is useful to obtain knowledge about where erosion is occurring, for example, for the planning of soil and water conservation measures. Rainfall is one of the primary factors contributing to soil erosion caused by water. These factors are further compounded by disturbances caused by cutting of slopes for road development. This site condition is especially evident along the eastern boundary below the new Phuentsholing-Samtse highway. The erosion seen here is continuous process that happens every monsoon. Conventional slope stabilization strategies face serious challenges in the Himalayan context due to the intrinsic nature of the soil (Sarkar and Singh 2008). Slopes fracturing by tectonic activity, subsequent weathering and erosion processes, compounded by anthropogenic factors leads to frequent slope failure in this high relief mountain system (Starkel 1972; Bartarya and Valdiya 1989; Gupta et al 1993; Virdi et al 1995).

Fig. 1.10 Boundary area erosion (Source: HCP site photos)

Fig. 1.11 Boundary area erosion (Source: HCP site photos)

Fig. 1.12 Severe erosion seen in Zone A western boundary (Source: HCP site photo)

1.6 Mature trees on sand banks near the northern end of Zone B

Site observations reveal that private plantation tree groves have been established near the northern end of Zone B. These trees are estimated to be at least 20 to 25 years old. Some of these are Accacia catechu and Albizzya lebbeck and Albizzya procera. Mature trees are an important component of the ecosystem providing perching and nesting platforms for predatory birds.

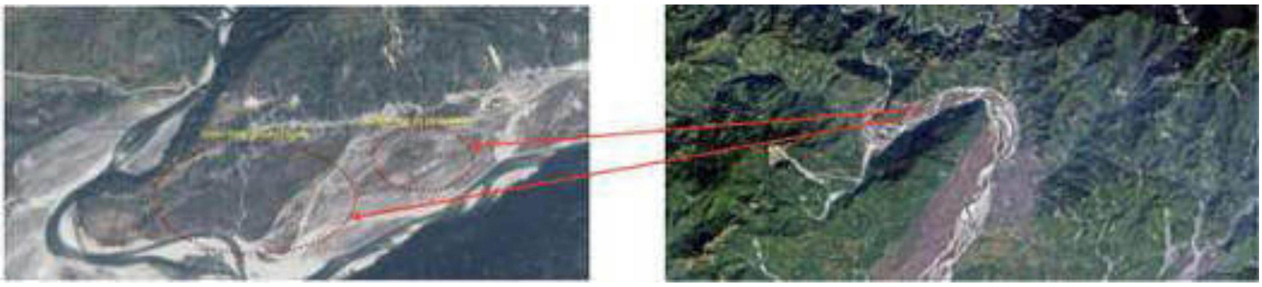


Fig. 1.13 Mature trees near the northern end of Zone B. (Source: Google Earth)

Fig. 1.14 Mature trees near the northern end of Zone B. (Source: HCP site photo)

1.7 Kaileshwar Hill, a high bio-diversity zone:

Situated at a prominent location along the western edge of Zone C, Kaileshwar Hill is bound to have a significant influence on the land-use and user experience of the proposed development. Kaileshwar Hill is a repository to large number of mature trees that are estimated to be several decades old. This hill is also home to an old temple that has a cultural significance to the local population. Kaileshwar Hill is bio-diversity rich and a vast range of endemic species of trees have been observed in this area. A representative list of endemic tree species seen at Kaileshwar Hill is listed in Table 1.4 of the Appendix 2.

Fig. 1.15 Kaileshwar Hill (Source: HCP site photo)

Kaileshwar Hill therefore signifies the forest wilderness that lies adjacent to the ALDTP site. It represents the transition from the wilderness to the ordered development.

1.8 Summary of Landscape Analysis

1. Bio-Diversity : Significant bio-diversity present all around ALDTP.
2. Outfalls : Storm water outflows in Zone A and B highly significant.
3. Riparian grasslands : Ecologically sensitive habitat. Source for softscape topsoil.
4. Forest Zone : Indigenous trees. Invasive species present.
5. Eroding hill slopes : Significant erosion due to unstable soil and road cutting.
6. Mature trees Zone B : Over 200 privately planted trees that are between 20 to 25 years old observed at tip of Zone B
7. Kaileshwar Hill : High bio-diversity Zone. Transition from wilderness to ordered development.

How these factors will affect the masterplan development will be seen in the next section where recommendations will be made on each of these ecological observations.

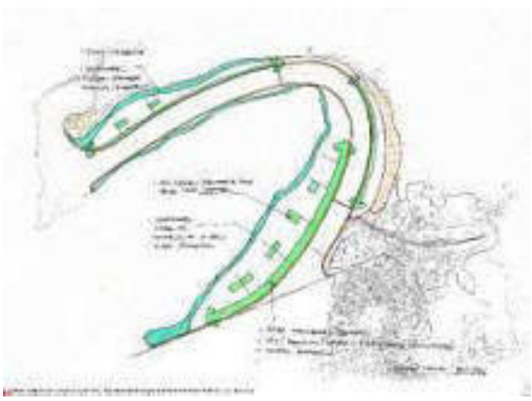
2.0 Recommendations arising from the Landscape Analysis and evolution of the Landscape Design Strategy on the Master-Plan

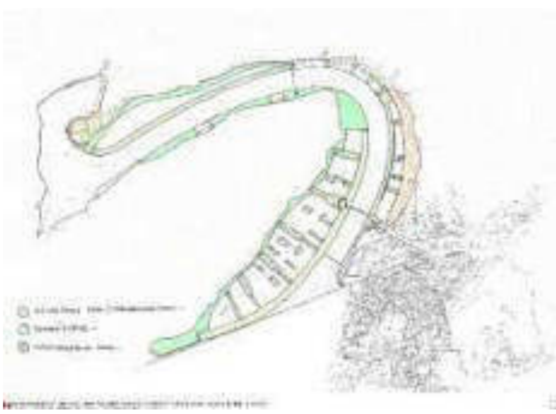
In this section, the recommendations arising from the landscape analysis of the seven ecological factors are discussed. These recommendations provide the initial basis for the Master-Plan and Landscape Design Strategy.

2.1 Bio-Diversity

Recommendations:
The habitat and surrounds of the locale is “natural”. It is this “naturalness” that needs to nurtured and highlighted as a character of ALDTP landscape. The richness of this surrounding bio-diversity requires, than an interface be created, which acts a buffer to the township development. This buffer should act as soft border that allows a smooth transition from the wilderness to ordered development. This buffer would also serve to isolate the cross migration of alien species, thus protecting and preserving the bio-diversity. Several trees in the peripheral areas of the site have been cut or whose branches have been trimmed. There are also certain invasive species that are aggressively displacing the local flora. These can be brought under control once the land is properly fenced and maintained.
Trees that are proposed for planting in the landscape design should have a high percentage of indigenous tree species. These trees should be properly labeled with the details and traditional uses. The landscape component of the masterplan should create social awareness on the importance of preserving this unique and rich bio-diversity.

Evolution of the Landscape Design Strategy
From Inception stage, the Master-Planning has incorporated a **Buffer Zone** to address the various recommendations arising from the Landscape Analysis. The following sequence of sketches of the evolution of the masterplan illustrates this principle.





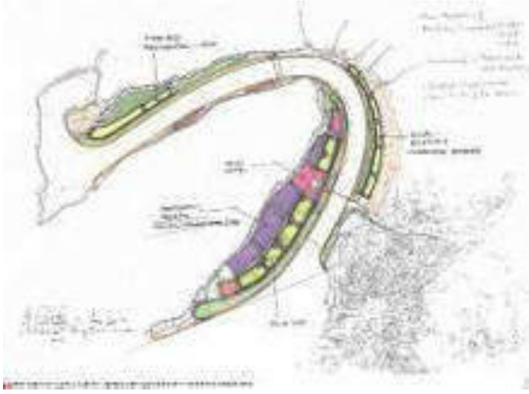
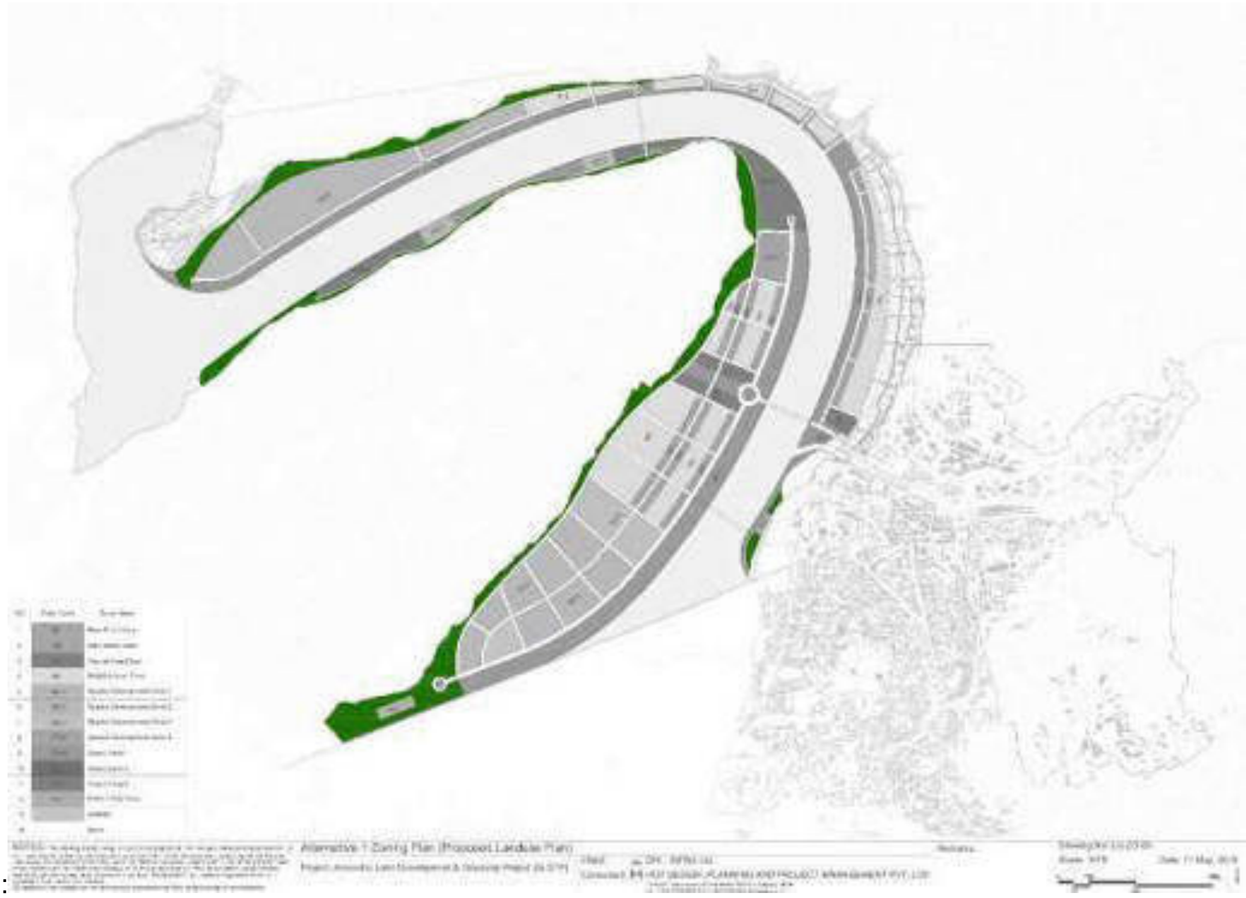


Fig 2.1 Evolution of the Buffer Zone in the masterplan design

The latest masterplan shows the following configuration for the Buffer Zone (Source – HCP)



:

Fig 2.2 Protective Buffer Zone around project boundary

These buffer zones extends almost throughout the boundary perimeter. They range from 50 mts to 300mts in width. The Buffer Zone is designed to offer a protective buffer that offers ecological and visual insulation to the project development. The buffer zones fulfill the important function of safely channeling the local precipitation from the outfalls flanking the valley. Occupying about 107 acres, the Buffer Zone constitutes an important part of the conservation plan to protect ecologically sensitive areas. In the buffer of Zone C, re-establishing seasonal wetlands and grasslands, along the detention ponds and the channels, forms a part of the mitigation and off-setting plan against the loss of riparian habitats due to project development.

The landscape design envisages over 2400 trees to be planted in the forest and buffer zone. The list of 62 species of indigenous trees are proposed for plantation are listed in Table 1.5 of Appendix 2. A representative sample of the proposed trees is given below:

Bombax ceiba

Butea monosperma

Vateria indica

Adenanthera pavonia

Anthocephalus cadamba

Mesua ferrea

:

2.2 Outfalls:

Recommendations:

There are multiple strategies that can be deployed to mitigate the damaging impact of seasonal outflows. Each of these have a significant bearing on the urban infrastructure management of the development. These strategies were examined to supplement the storm water infrastructure of the development. Two time-tested methods of mitigation are recommended:

Use of Detention ponds:

Detention Ponds are storm water basins that are seasonal in nature. Ponds include one or more fore-bays that trap course sediment and facilitate maintenance. The pond perimeter should generally be covered by a dense stand of emergent wetland vegetation. While they do not achieve significant groundwater recharge or volume reduction, they can be effective for pollutant removal and peak rate flood mitigation. Detention Ponds (DPs) can also provide aesthetic and wildlife benefits. Properly designed detention ponds, where the depths, water volume and surface area well balanced and maintained, do not support significant mosquito populations (O'Meara).

Fig. 2.3 A Typical detention Pond for flood mitigation (Source: Mays, L.W. Stormwater Collection Systems Design Handbook, McGraw-Hill Book Company, New York (2001)

It is proposed that the outflows into Zone C discharged into detention ponds.
The design of a detention pond is invariably a trade-off between the amounts of water to be retained versus the land available for the same. In this project, the size and depth of the detention ponds have been arrived at by balancing the size of the pond with the land available in Zone C buffer area. Detailed information on the design basis used to arrive at the detention pond sizes and footprints, is available in Table 1.3. At least four outfalls in Zone C are proposed to be treated as detention ponds.

Fig. 2.4 The above diagram shows the pond sizes that have been arrived for the major outfalls of Zones C

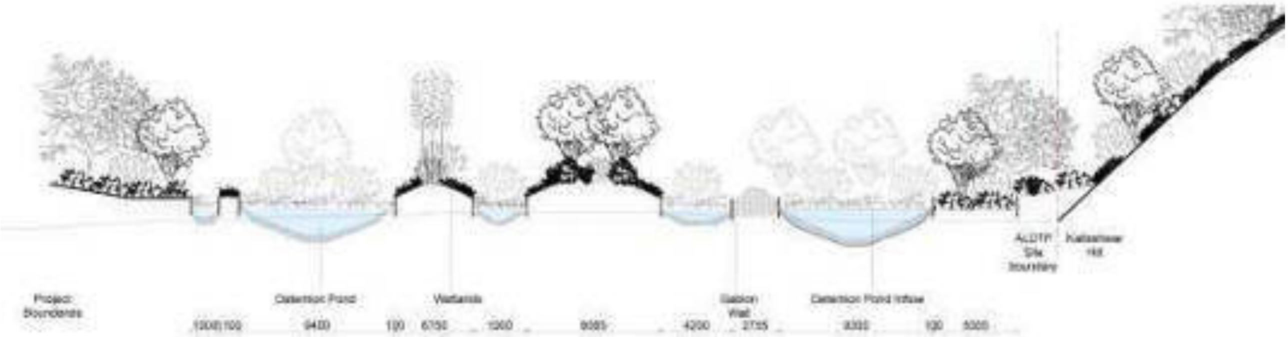


Fig. 2.5 Typical section for detention ponds in Zone C.

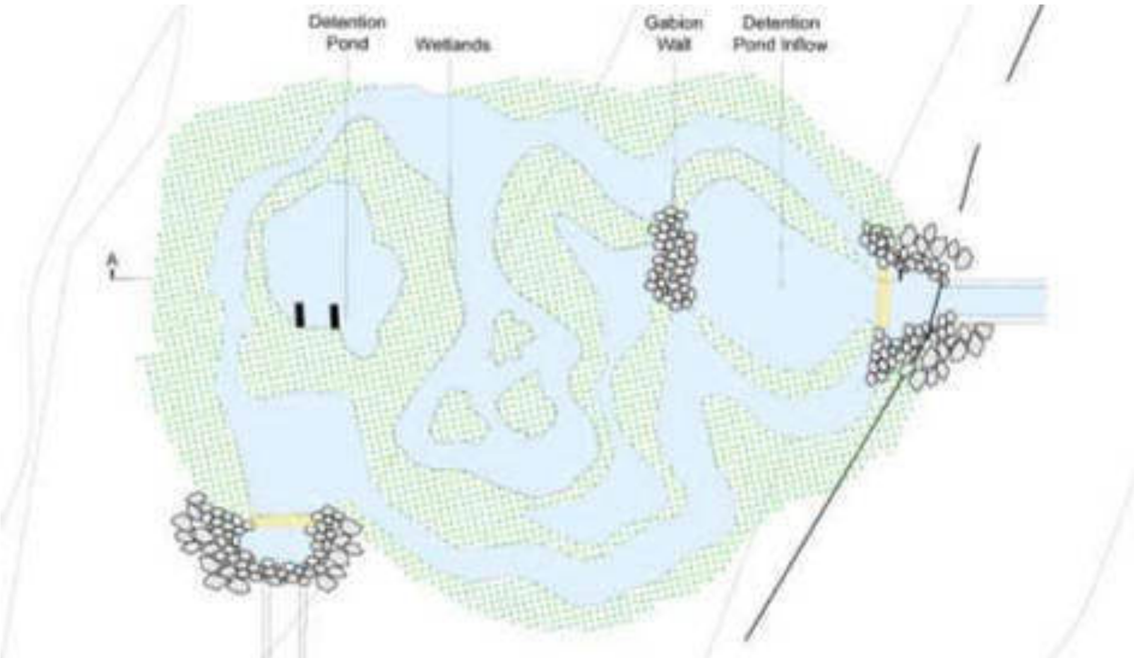


Fig. 2.6 Typical plan for detention ponds in Zone C.

Stage-wise example of construction of detention ponds:

Fig. 2.7 Example of stage-wise construction of detention ponds. (Source: The SuDS Manual (C753), Woods Ballard, B, Wilson, S. ISBN: 978-0-86017-759-3)

2.2.2. Use of storm water channels (open and ducted).

It has been estimated that large and small outfalls in Zones A and B can directly channeled to the river. This is largely due to the size of the available land being insufficient for creating a detention pond. Larger outflows will be emptied using an open channel while smaller outflows will be directed to the river using U.G. stormwater drains. Channels are usually pitched with stone rip-rap to protect against erosion. Typical sections of the channel can be V shaped or trapezoidal as shown below.

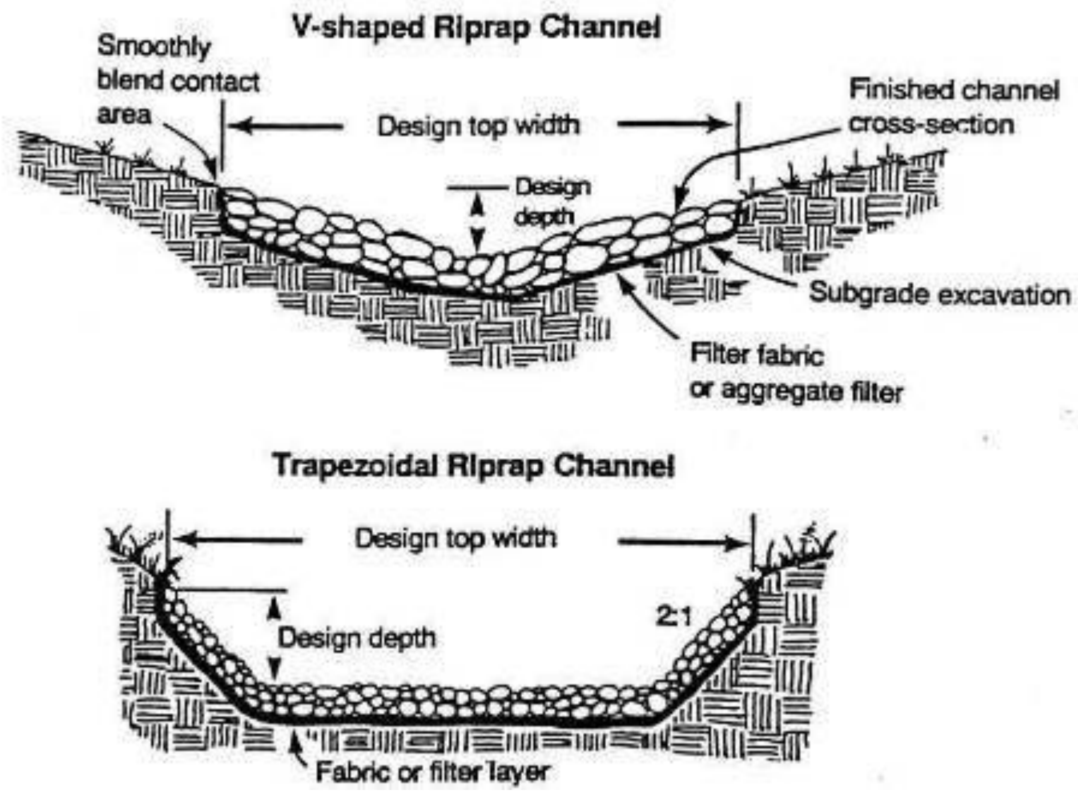


Fig. 2.8 The above diagram shows the different channel shapes for outflows directly channeled into the river.

Evolution of the Landscape Design Strategy

Based on the recommendations for managing the ecology of the outfalls, the two strategies have been incorporated into the Master Plan to safely direct the storm water from the outfalls.

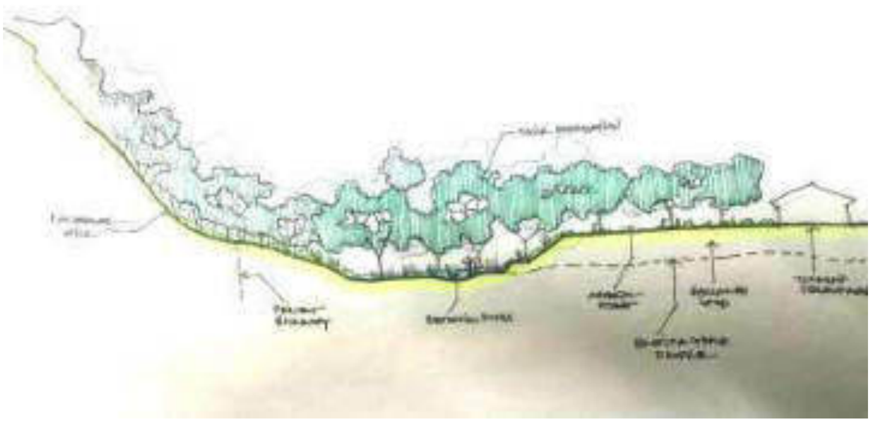


Fig 2.9 Proposed detention ponds in Zone C (section) – (Source – HCP)

The first strategy consists of creating detention ponds where the velocity of the ponds is reduced by emptying the outflows into a seasonal pond. The sizing of the ponds have been done using the hydraulic calculations passed on peak precipitation in the catchment areas as detailed in Table 1.3. The landscape design envisages the creation of four detention ponds in Zone C at the base of Kaileshwar Hill. The water collected from these will run parallel to the river and discharge into the river basin on the Indian side of the boundary.

The footprints of the estimated pond sizes are shown for Zone C are shown in the following sketch in relation to the scale of the buffer zone. It is established that the detention ponds of the estimated sizes can be accommodated within the buffer zones

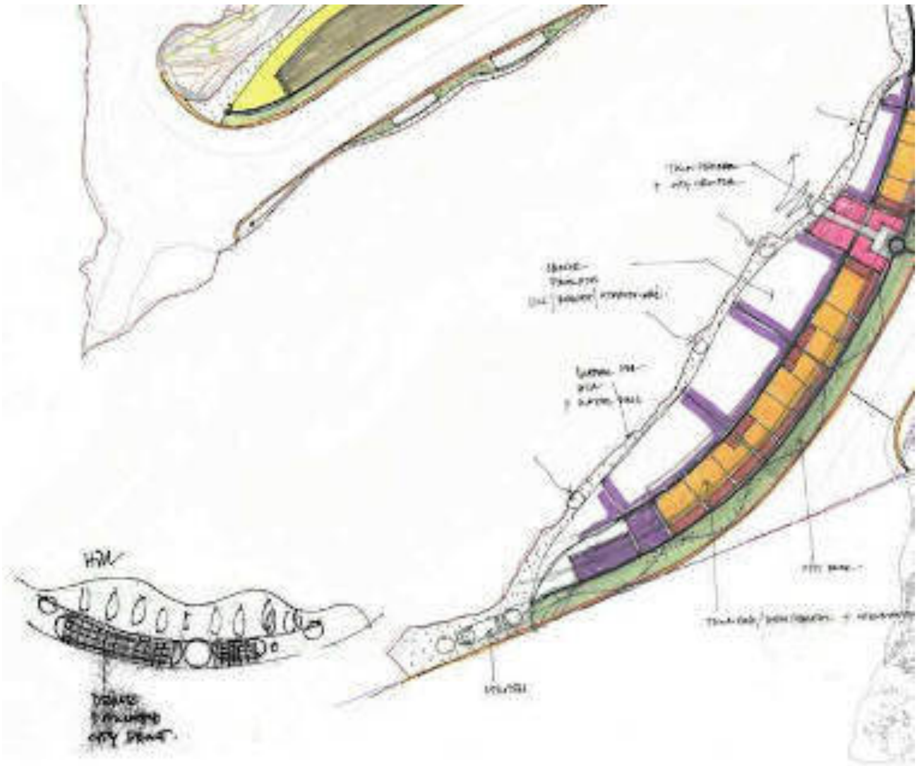


Fig 2.10 Sketches for detention ponds in Zone C (plan) (Source – HCP)

In the second strategy, the outfalls in Zones A and B are directly channeled to the river. Larger outflows will be emptied into the river using an open channel. This creates natural partitioning of the Zones A and B. The sides of these open channels will be used to recreate bio-diversity. The landscape design envisages dense plantation of native trees in the buffer area around the detention ponds. Perennial grasses and wetland flora will populate the detention ponds and the open channels directing the storm water. Smaller outflows will be directed to the river using buried ducting. This eliminates the need for channel crossings.

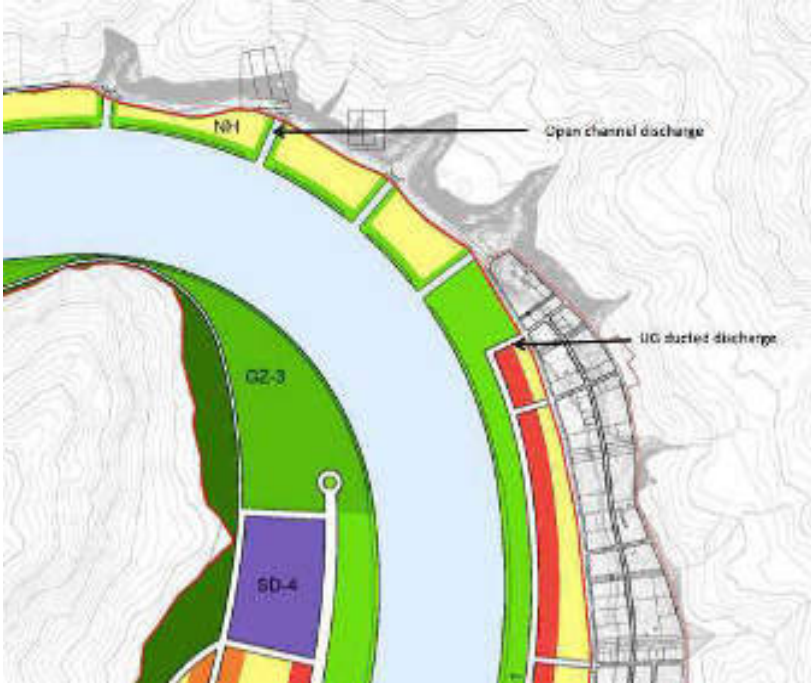


Fig. 2.11 Locations showing few open channel and ducted channel discharge in Zones A and B (Source – HCP

2.3 Riparian Grasslands:

Recommendations

"Operational Policy 4.04: Natural Habitats" (World Bank 2001), states that loss of natural habitats can be permitted only if "acceptable mitigation measures, such as compensatory protected areas, are included within the project". This is usually thirty percent of the lost habitat. Retaining portions of this riparian habitat will provide opportunity for outdoor activities among residents like bird-watching, fishing and wildlife observation.
A typical example of such preservation could be, for example, a bio-diversity park. The preserved habitat should be protected and exploration should be done only along designated trails or elevated walkways.

Zone C is an important component of the ALDTP site, as it will be the source for topsoil for all the softscape development in the project. It is recommended that the Topsoil in Zone C (excluding the Forest Zone and the area demarcated to be retained as preserved grassland) be scrapped to the depth of 400 mm. This scrapped material can be stored in the forest zone that will be largely free of construction activity. The organic matter that will be embedded in this soil will scrapping will decompose over the storage period. This soil can be then used as topsoil for landscaping once the softscape areas in the project are ready to receive it.

It is recommended that no topsoil from Zone C be exported from the site, nor topsoil required for softscape development be imported to site. This will create a positive environmental impact as material is being recycled in site, and elimination the pollution cause by transporting the material in and out of the site.

It is further recommended that this topsoil can be amended with organic compost and NPK amendments during the time of plantation.

Fig. 2.12 Zone C section showing topsoil layer

Evolution of the Landscape Design Strategy

Based on the recommendations for the riparian grasslands in Zone C, the proposed development seeks to retain about 60 acres of these grasslands to create a bio-diversity park. This will ensure the protection of the flora and fauna that is endemic to this region. The diagram below shows the location of the bio-diversity park in the context of the land-use master plan.

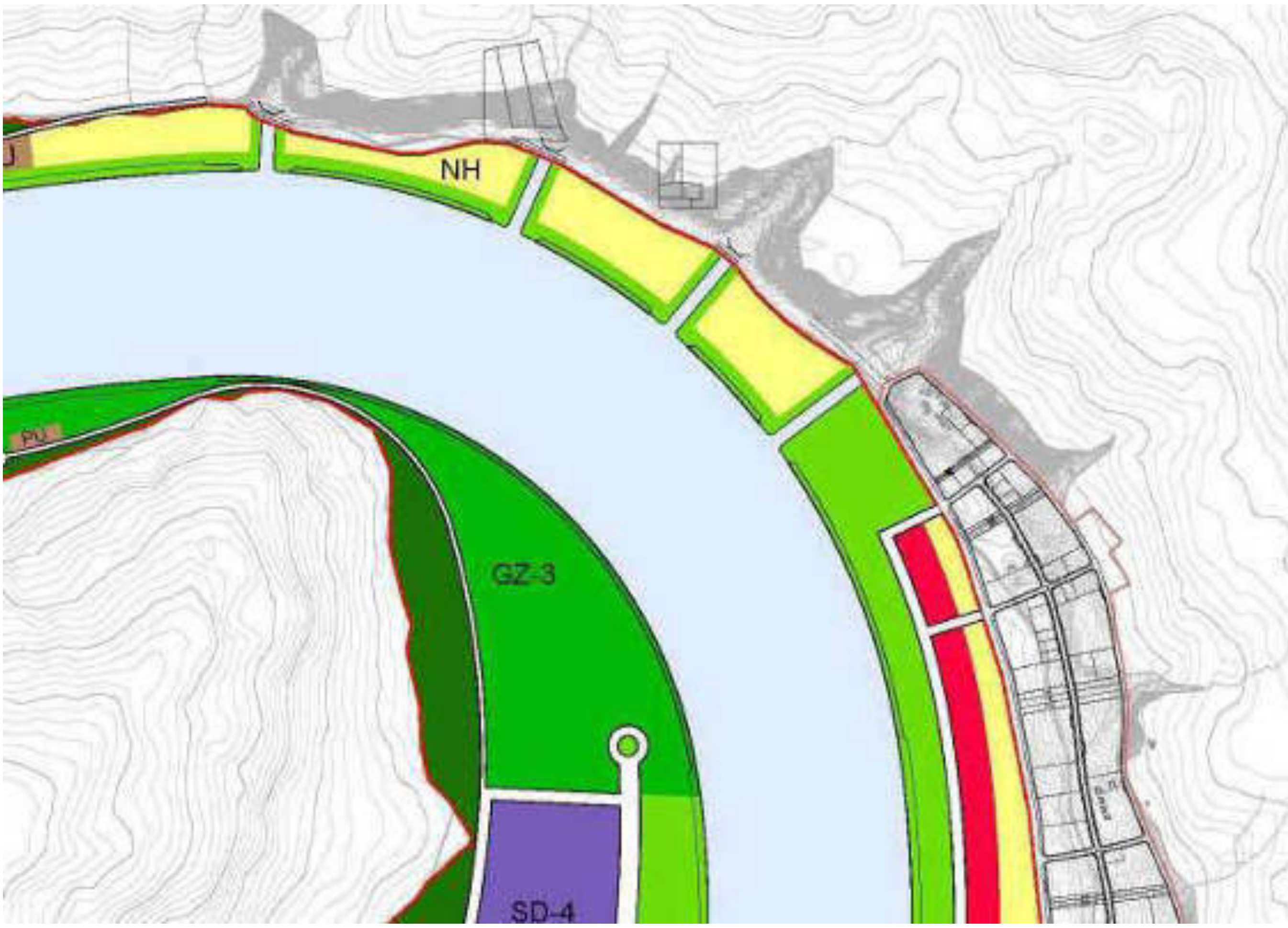


Fig 2.13 Proposed Bio-diversity park GZ-3 in Zone C (Source – HCP)

Zone C is an important component for the site, as it will be the source for topsoil for all the softscape development in the project. The table below shows the estimated requirement for topsoil in the project versus the availability of topsoil in Zone C up to 400mm depth.

Estimation for Topsoil based on Revised Land Use Plan				
Zone	Acres	Number of trees	Topsoil required per unit (M3)	Topsoil requirement (M3)
Total Landscape area excluding Buffer zones	**265.88**			
Trees				
Recreational Development (acres)	27.15	845		
Embankment (50%) (acres)	59.74	4,950		
Riverfront parks (acres)	48.55	1,510		
Detention ponds (acres)	2.42	134		
Mini golf course (acres)	71.77	2,233		
Bio-diversity parks (25%) (acres)	46.23	925		
Amusement parks (50%) (acres)	10.02	312		
Buffer and forest area (acres)	160.05	2,401		
Roads (Length in Kms)	**Kms**			
Road type 42 M Row	8.00	7,920		
Road type 36 M Row	12.50	8,250		
Road type 24 M Row	13.50	8,910		
Total Trees		**38,389**	**38,389**	**4,799**
Shrubs in Road median and planting strips in Kms	Kms	Shrubs area M2		
Road type 42 M Row	8.00	60,800		
Road type 36 M Row	12.50	82,500		
Road type 24 M Row	13.50	20,250		
Shrubs (30% of landscape area)	79.76	3,22,722		
Total Shrub area		**4,86,272**	**19,45,088**	**2,43,136**
Total Lawns (15% of landscape area excluding mini golf) M2	**39.88**	**1,61,361**	**1,61,361**	**48,408**
Total Groundcovers M2	**73.12**	**2,95,829**	**17,74,972**	**88,748.58**
Total Vetiver plantation	**63,800.00**	**5,74,200.00**	**5,74,200.00**	**15,950**
Total soil required for plantation				**4,01,041.63**
Add 12.5 % for wastage				**451171.8295**
Top soil available from Zone C scraping to depth of 400mm	**280.97**			**454818.5017**

Table 1.7 Topsoil balancing of soil scrapped and the topsoil required for softscaping.

As can be seen from Appendix 2 Table 1.7, if the project development area of Zone C (less areas for Bio-diversity Park, Forest zone and buffer areas) is scrapped to depth of 400mm, it will balance the topsoil requirement for the softscape in the entire project.

There will be no import or export of topsoil at site. This is an important requirement for environmental compliance for the landscape development. It is proposed that the scrapped soil be stored as heaps in the forest zone till the civil works of the project is completed and the softscape is started.

2.4 Forest Zone:

Recommendations
It is recommended that the Forest Zone in the south western corner of Zone C be retained in its natural state and kept largely free of development. All the trees will be retained as they are, except for invasive alien species that should be removed. This area will provide an important green buffer between the project boundary and the international boundary line.
It is recommended that the topsoil scrapped from Zone C be stored as dump heaps here, as the area will be relatively free of any construction activity.
It is recommended that the STP plant of the project be located here as it will be largely free from human interference. The abundant water and sludge from STP, can provide a favorable platform for setting up a plant nursery. An onsite nursery will be required to take care of the very large quantum of planting material that will be required for the project.
Additional tree planting of endangered medicinal trees, such as Butea monosperma, Ougeinia oojeinensis, Pterocarpus marsupium, Erythrina suberosa, and Erythrina varigata to name a few, can be taken up to eventually develop the character of this Forest Zone as a medicinal arboretum.

Evolution of the Landscape Design Strategy
As per the recommendations from the landscape analysis of this area, it is proposed that this zone will be retained as it is except for the removal of invasive alien species. The proposed masterplan design for this area incorporates an STP unit to be located here. The service buildings and ponds will be screened with dense plantation of evergreen trees.
The landscape design envisages an onsite sapling development nursery to be located. The design for this area allows for the top soil scrapped from Zone C be stored as dump heaps here, as the area will be relatively free of any construction activity.

Fig 2.14 Forest Zone in Zone C (Source – HCP)

2.5 Eroding slopes on the western boundary

Recommendations

This site condition is especially evident along the eastern boundary below the new Phuentsholing-Samtse highway. Such continuous and large-scale erosion needs to be checked if a large project such as ALDTP needs to be undertaken.

It is proposed that these slopes be stabilized using Vetiver grass planting. The Vetiver System (VS), which is based on the application of vetiver grass (*Vetiveria zizanioides* L Nash, now reclassified as *Chrysopogon zizanioides* L Roberty), was first introduced by the World Bank for soil and water conservation in India in the mid-1980s. While this application still plays a vital role in agricultural land management, R&D conducted in the last 20 years has clearly demonstrated that, due to vetiver grass' extraordinary characteristics, vetiver also has important application as a bio-engineering technique for steep slope stabilization, wastewater disposal, phyto-remediation of contaminated land and water, and other environmental protection purposes.
When vetiver roots interact with the soil in which it is grown, a new composite material comprising roots with high tensile strength and adhesion embedded in a matrix of lower tensile strength is formed. Vetiver roots reinforce the soil by transfer of shear stress in the soil matrix to tensile inclusions. In other words, the shear strength of the soil is enhanced by the root matrix (Styczen and Morgan, 1995). Vetiver roots are very strong with high mean tensile strength of 75 MPa or approximately 1/6th of strength of mild steel. When the dense and massive root networks act in unison, they resemble the behavior of soil nails normally used in civil engineering works. With its innate power to penetrate through hardpans or rocky layers, the action of vetiver roots is analogically likened to 'living soil nails' by the author (Hengchaovanich, 1998).

Detailed treatise on the use of vetiver grass for slope stabilization is detailed in Appendix 4.

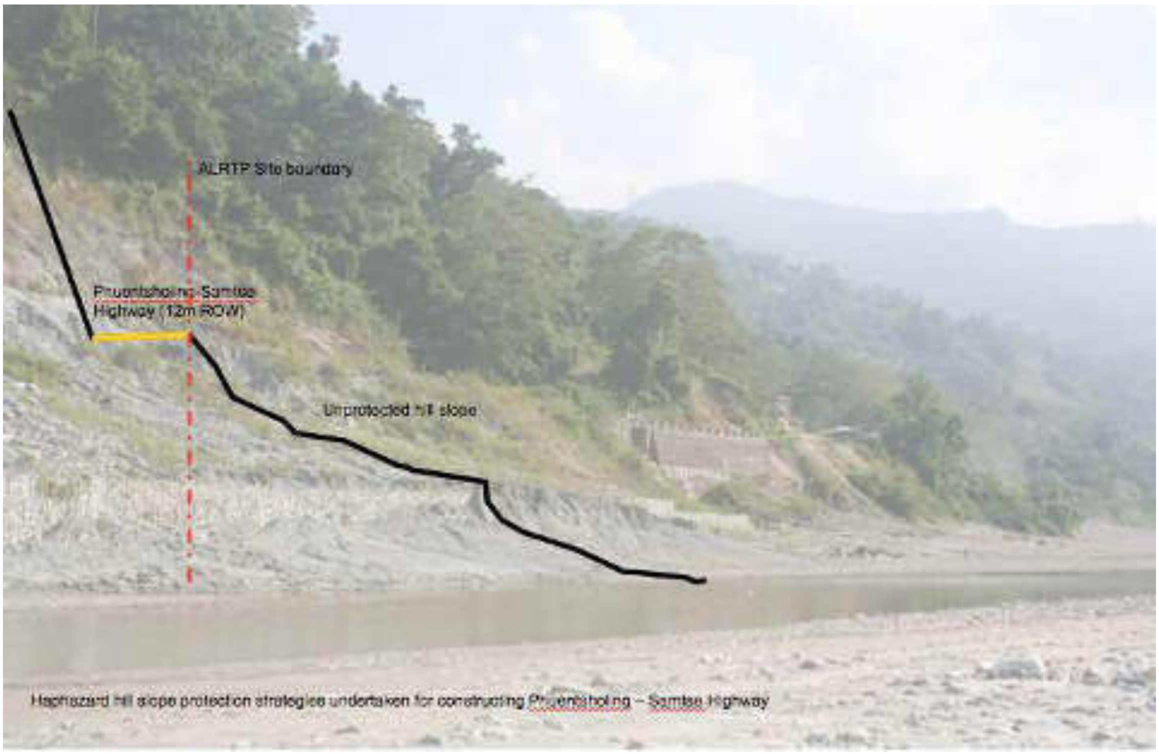


Fig. 2.15 Existing site condition requiring protection (Source: HCP photo)

Proposed treatment for hill slope stabilization:

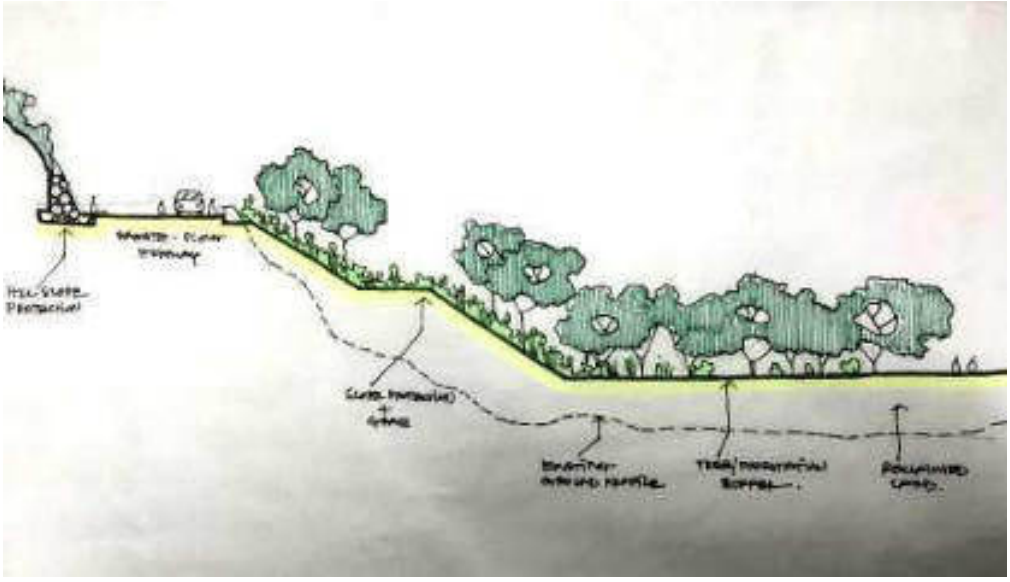


Fig. 2.16 Section through western boundary of Zone A (Source – HCP)

Evolution of the Landscape Design Strategy

The landscape design strategy involves creating terraced slopes over the existing random slopes at site. The slopes are then planted with vetiver grass which provides a very high degree of stability to the soil against erosion. Additionally, trees will be planted on the slope as well as in the terraces, creating dense bio-diversity habitats.

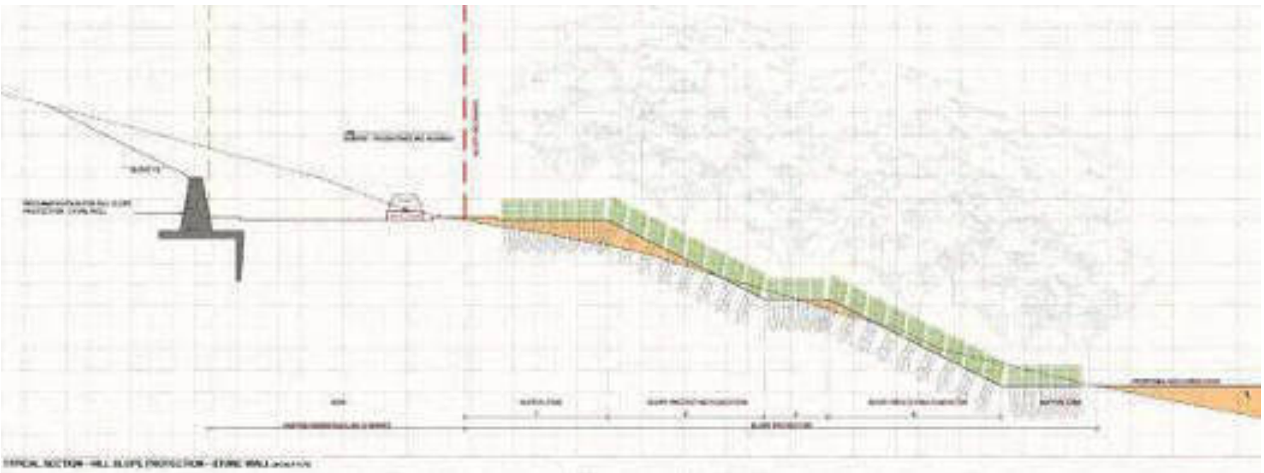


Fig 2.17 Slope stabilization using vetiver grass plantation (Source – HCP)

2.6 Landscape Strategy for the higher level sloped embankments of river training.

Although this aspect does not figure in the initial site conditions for Landscape Analysis, this input arises as a part of the ecological requirement for the stabilization of the sloped embankment of river training. The sloped embankment needs sustainable protection that is effective as well as aesthetically pleasing.

Evolution of Landscape Strategy for the embankment slope stabilization:

The initial structural design for river embankment is shown below:

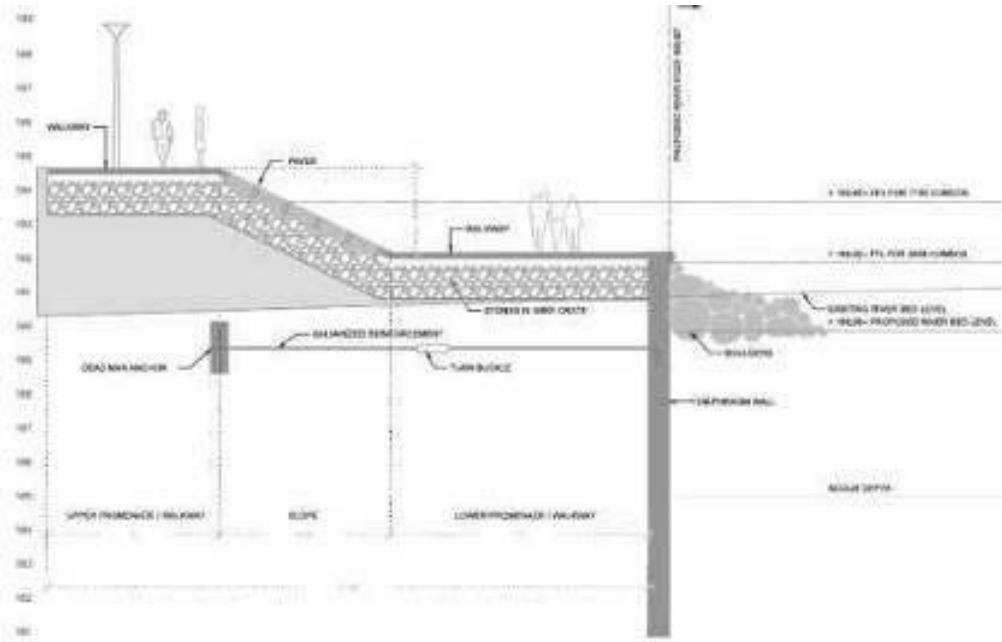


Fig 2.18 Initial structural design for river embankment (Source – HCP)

As is evident, the embankment above the FFL for 2558 cumecs (refer Fig. 3.3) has a sloped profile. It has the dual reinforcement of the gabion wire crates below and the precast concrete blocks above. However, such a large expanse of hardscape stretching on either side of the river will have limited aesthetic appeal. It will also create pocket heat islands along the river that will diminish the experience of walking along the upper and lower promenades in the summer season. Also, the logistics of handling and installing such heavy precast concrete blocks of 1000 X 1000 X 250 mm and aligning them perfectly over the gabion crates can prove particularly challenging.

In order to break the monotony of the hardscape consisting of precast concrete blocks, a second option is considered where the blocks have 800mm dia. holes in them. This will help create blocks which are lightweight, and the logistics of handling and installation will become very manageable.

These holes can be filled with large decorative pebbles ranging from 150-250 mm dia., after the precast concrete pavers have been placed over the gabion wire crates. This is indicated in the section below:

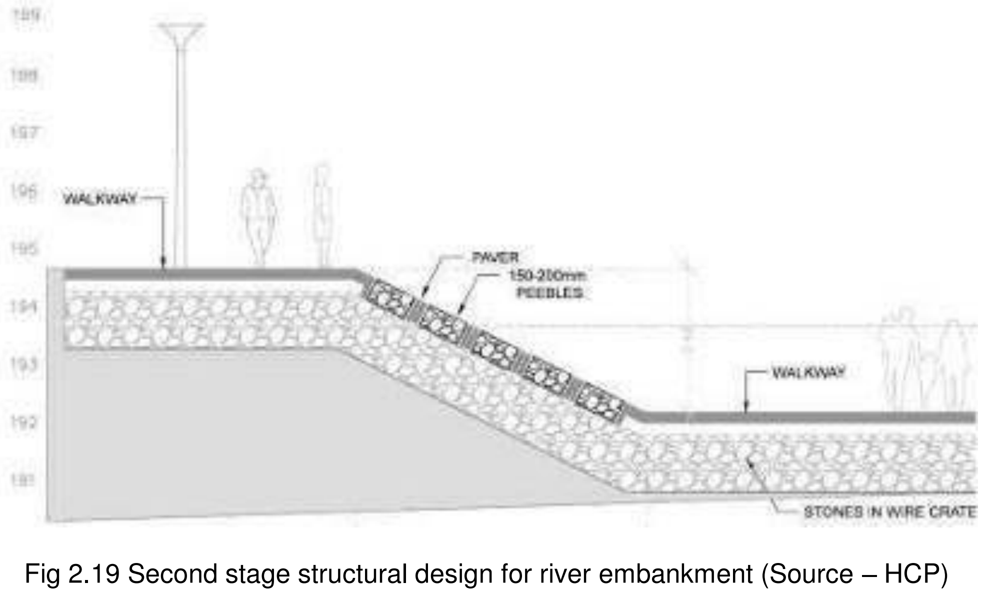


Fig 2.19 Second stage structural design for river embankment (Source – HCP)

This design will provide a break in the monotony of the texture, but will not take care of the local heat island effect. The water velocity could dislodge these decorative pebbles during such high flood conditions. This may result in periodic maintenance of replacing these dislodged decorative pebbles after high flood conditions, which is not an option.

Further enhancements, in the treatment of the sloped embankment that can take care of these shortcomings, will be required. This design, while being an improvement over the use of precast pavers with pebble infill, does not in itself, have the potential of being sustainable in the long run.

Bio-stabilization of sloped embankment:

The following special conditions will exist in the sloped embankment:

a. The precast concrete pavers sit on the gabion wire crates filled with boulders.
b. The boulders will have interstices, which will be filled with garden soil.

c. The thickness of the precast concrete pavers is only 250mm. The depth of planting in the 800mm dia. pocket in the block will be limited to 250mm.

d. Natural ground is situated only below the gabion layer, which is 1000mm below the planting layer. Planting species should have roots that penetrate to such depths.

After exploring several options for plants that can fulfill these special conditions, the Vetiver System is recommended as the ideal solution.

The Vetiver System (VS), which is based on the application of vetiver grass (Vetiveria zizanioides L Nash, now reclassified as Chrysopogon zizanioides L Roberty), is the only planting system that fulfills all the above design recommendations. The Vetiver System (VS), which is based on the application of vetiver grass (Vetiveria zizanioides L Nash, now reclassified as Chrysopogon zizanioides L Roberty), was first introduced by the World Bank for soil and water conservation in India in the mid-1980s. While this application still plays a vital role in agricultural land management, R&D conducted in the last 20 years has clearly demonstrated that, due to vetiver grass' extraordinary characteristics, VS also has important application as a bio-engineering technique for steep slope stabilization, wastewater disposal, phyto-remediation of contaminated land and water, and other environmental protection purposes.
It is proposed the Vetiver grass be used to stabilize the sloped embankment between the upper and lower walkways of the river training. Vetiver will be planted in the 800mm dia. Pockets in the 250mm thick paver blocks.

Advantages:

- Vetiver grass does not have stolon or rhizomes. Its massive finely structured root system that can grow very fast, in some applications rooting depth can reach 3-4m in the first year. This deep root system makes Vetiver plant extremely drought tolerant and difficult to dislodge by strong current..

- Stiff and erect stems, which can stand up to relatively deep water flow. Highly resistant to pests, diseases and fire.

- A dense hedge is formed when planted close together acting as a very effective sediment filter and water spreader.

- New shoots develop from the underground crown making Vetiver resistant to fire, frosts, traffic and heavy grazing pressure.
-
- New roots grow from nodes when buried by trapped sediment. Vetiver will continue to grow up with the deposited silt eventually forming terraces, if trapped sediment is not removed.

The planting of the Vetiver shoots will be done at the density of 4 per pocket of 800 mm dia. planted in the shape of a diamond as shown in the plan and section below.

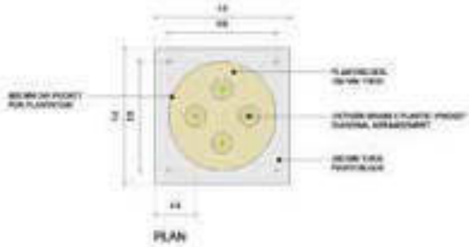


Fig 2.20 Planting layout for vetiver in the precast concrete blocks

Final design incorporating Vetiver plantation

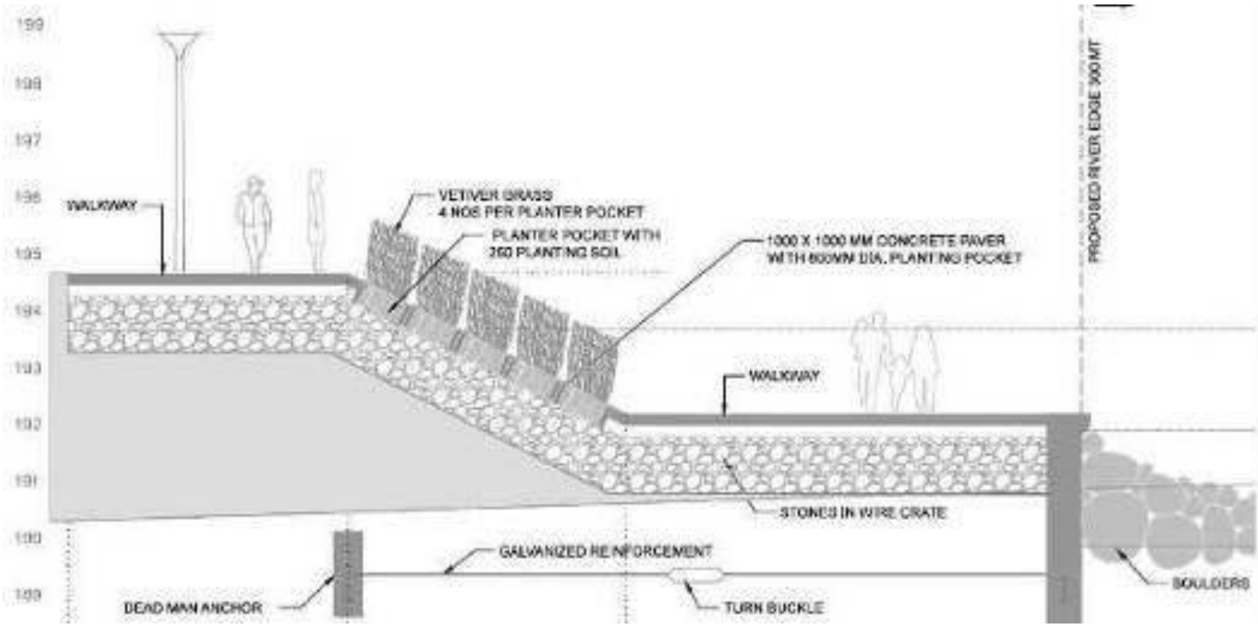


Fig 2.21 Design incorporating vetiver plantation (Source – HCP)

Examples of Vetiver use in soil stabilization.
Below are some of the examples of Vetiver use in soil stabilization

Fig. 2.22 Vetiver grass root sy   Fig. 2.23 Vetiver grass root 6 months growth
Source: Vetiver Grass: A Thin Green Line Against Erosion. National Academy Press, Washington DC, USA

Fig. 2.24 Vetiver grass planting on riverbank   Fig. 2.25 Vetiver grass one month growth
Source: Vetiver Grass: A Thin Green Line Against Erosion. National Academy Press, Washington DC, USA

2.7 Mature Trees on sand banks near the northern end of Zone B

Recommendations
Although private individuals have planted these tree groves, a small budget can be included in the project for providing compensation to them for relinquishing these trees.

It is recommended that these tree grooves, near the northern end of Zone B, be integrated into the master plan in such a way that they can be retained in the development. The tree habit is such that even if some filling is done for soil reclamation, these trees will adapt and survive.
The higher level of slit deposition in this area has allowed these trees to grow to maturity.

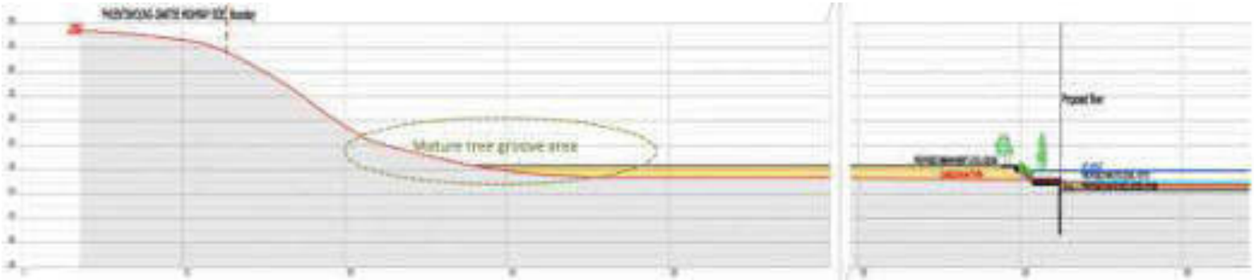


Fig. 2.26 Section showing the location of the mature tree grooves in Zone B (Source – HCP)

Fig. 2.27 Site photo showing mature tree grooves in Zone B (Source – HCP)

Evolution of the Landscape Design Strategy

The presence of these privately planted trees that are over 20-25 years old in the river banks are a landscape resource that cannot be ignored in the design of the masterplan. They require to be integrated into the landscape design so that the value they bring to the land use can be enhanced. Retaining these trees as a part of the project emphasizes ALDTP’s commitment to protecting the key elements of the existing landscape

The design of the master plan envisages an open recreational land use such as a 9 hole golf course to be developed that will integrate these trees in a meaningful manner. Any alternate land use for this area should be such that there will be minimum disruption to these trees.

Fig 2.28 Land use masterplan showing the areas allocated to Amusement park (23) and 9 hole Golf course (16)

Fig 2.29 Example of a golf course in a similar context (Source: Trail Creek Golf Course, Sun Valley, Idaho, USA)

2.8 Kaileshwar Hill

Recommendations

Kaileshwar Hill is a bio-diversity hotspot and several Rare and endangered tree species have been spotted in during site observations.

Sl No.	Species	Sl No.	Species
1	Tetrameles nudiflora	7	Knema erratica
2	Olea dioica	8	Litsea monopetala
3	Saurauia roxburghii	9	Tetradium glabrifolium
4	Ehretia laevis	10	Wenlandia coriacea
5	Chukrasia tabularis	11	Casearia graveolens
6	Phlogacanthus thyrsiflorus	12	Rhynchotechum ellipticum

Table 1.5 Representative list of endangered trees sighted at Kaileshwar Hill.
(Source: 1. Chettri, N, Sharma, E., Shakya, B., Thapa, R., Bajracharya, B., Uddin, K., Oli, K.P., & Choudhury, D. 2010: Biodiversity in the Eastern Himalayas; Status, Trends and Vulnerability to Climate Change: Climate Change Impact and Vulnerability in the Eastern Himalayas- Technical Report 2, ICIMOD. 2. Field observations)

The Hill also houses a temple that can be enhanced, reinforcing the cultural identity of the area. It is recommended that this high bio-diversity zone be retained as it is with minimum invasive development.
Eco-tourism potential can be tapped by retaining the pristine character of the hill with minimal invasive development. Guided walking tours to explore the flora and fauna can be initiated over pre-designated walking trails.

Fig. 2.30 Ariel photo of Kaileshwar Hill (Source: DHI_INFRA)

Evolution of the Landscape Design Strategy

The landscape design envisages a low impact development that has minimum invasiveness.
Eco-tourism potential can be tapped by retaining the pristine character of the hill. Guided walking tours to explore the flora and fauna can be initiated over pre-designated walking trails. The concept of a canopy walk can also be explored. Cabled walkways at the canopy level can be constructed to allow visitors to explore the

ecology and ecosystems prevalent at those heights. Ornithological tours during the migratory season could be a big attraction for visitors.

Fig 2.31 Examples of canopy walks (Source: Google images)

Eco-tourism can greatly add to the quality of lifestyle residents. It could also provide a sustainable strategy to monetize the bio-diversity of Kaileshwar Hill.

2.9 Summary of Recommendations arising from landscape analysis:

1. Bio-Diversity : Preserve and enhance bio-diversity. Indigenous trees to be included for softscape.
2. Outfalls : 4 outfalls in Zone C to be treated with detention ponds. Rest to be directed to the river either through open or ducted channels.
3. Riparian grasslands : 30% to be preserved. Use Zone C topsoil for softscape.
4. Forest Zone : Indigenous trees to be retained. STP plant location. Topsoil storage. Sapling nursery for softscape development.
5. Eroding hill slopes : Vetiver grass for slope stabilization.
6. Mature trees Zone B : Land use calls for open recreational activity that can utilize the trees.
7. Kaileshwar Hill : Minimal invasive activity. Ecotourism

Summary of evolution of landscape strategy based on the recommendations:

1. Bio-Diversity : Creation of buffer zone. 2400 indigenous trees plantation.
2. Outfalls : 4 outfalls in Zone C treated with detention ponds. Others are directed to the river either through open or ducted channels.
3. Riparian grasslands : 60 acres bio-diversity park. Use Zone C topsoil for softscape.
4. Forest Zone : Indigenous trees retained. STP plant located here. Topsoil storage and Sapling nursery for softscape development in this zone
5. Eroding hill slopes : Vetiver Strategy for slope stabilization. Creation of bio-diversity habitats.
6. Slopped embankment : Vetiver system incorporated for stabilization, aesthetics, user experience
7. Mature trees Zone B : Land use for open recreational activity utilizing the trees.
8. Kaileshwar Hill : Eoc-toursim and canopy walks.

3.0 Mitigation and Offsetting and Enhancement

In this section we shall examine, the manner in which the ecology of the site gets enhanced, its disturbance offset and mitigated, and the manner in which the design of the landscape and masterplan have evolved. Contextual pictures from similar references indicate the vision of proposed masterplan. Certain ecological zones have been clubbed in this section to read them in a holistic context.

3.1 Bio-diversity of natural and semi-natural spaces

This includes all the natural and semi-natural spaces (including, a Bio-diversity Park with grasslands, and buffer zones), that serve to enhance the user experience of these spaces.

ALDTP is a development that arises on pristine floodplains that have nurtured bio-diversity for eons. This ancient character of the land will stay preserved in various parts of the development as Natural and Semi-natural spaces. The three main zones contributing to this are the Forest zone, Buffer zones and the Bio-diversity Park.

Fig 3.1 A typical detention pond. (Source: Brian Child, Parks in Transition: Biodiversity, Rural Development and the Bottom Line Paperback – 1 Jul 2004)

The values of biodiversity in parks are legion: the value of nature for its own sake, a source of wonder and enjoyment; the value of learning about the workings of nature in places largely free of human influence, for comparison with landscapes dominated by humans; the survival value of multitudes of wild species that flourish as natural systems helping regulate climate, air quality, and cycles of carbon, nitrogen, oxygen, mineral elements, and water; all fundamental to life on Earth. There is an economic value attached to this flora. They are potential sources of food, medicine, and industrial products. Parks protect the species and their communities that underlie these values, serving if necessary as reservoirs of seed stock for restoring species lost elsewhere.

The creation and preservation of such habitats will have a large impact on the lifestyle of the residents. Outdoor activities such as biking and hiking will find more takers because of the way these pristine spaces have been designed to give an enjoyable user experience.

The following references show the proposed feel for these spaces:

Fig 3.2. Simple biking and hiking trails in forest and buffer zones (Source: Google images)

The Biodiversity Park will retain the grasslands in their original setting. As per the proposed design, these preserved grasslands will be at a lower level than the river embankment as shown in Fig. 3.2. Exploring such a bio-diversity park will require careful planning so that visitor will create the least amount of disturbance to the habitat.

The landscape design envisages elevated walking trails that will allow visitors to intimately observe nature without disturbing it significantly. The contextual pictures below are indicative of the landscape vision.

Fig. 3.3 Guided walks through the grasslands of Bio-diversity Parks (Source: Google images)

Similarly, the detention ponds can offer hours of family outing in the outdoor context.

Fig. 3.4 Family outing at the Buffer zones (Source: Google images)

The masterplan envisages the creation of an arboretum in the forest zone and a butterfly park in the bio-diversity zone. These additions will not only add to the bio-diversity but also enhance the lifestyle of its residents.

Fig. 3.5 Indoor butterfly park Source: Google images

Fig. 3.6 Walking trails in a Bio-diversity park. Source: Google images

4.0 Impact of landscape strategy on the environment across the International border:

The impact of the landscape strategy of ALDTP further downstream across the international border can be classified under the following headings:

4.1. Flows from the outfalls.

In the existing site scenario, the river opens into the Indian side of the border as a vast floodplain hosting a braided river system. Seasonal discharge from outfalls are highly variable and the continuously disrupt the course of the river. In the proposed Landscape Strategy, the flows from the outfalls will be regulated and directed to specific locations; either to the trained river or across the international boundary.

Use of four detention ponds to control the discharges from Kaileshwar Hill, and channeling the flow parallel to the hill till it exits the border will create a smaller impact on the downstream ecology.

Similarly, the channeled outflows from the outfalls bordering Zones A and B will direct all the seasonal precipitation into the trained river. This will ensure that all the catchment discharge will be safely directed into the Indian border at a single location. The will create a more predictable flow path for the river waters.

4.2. Impact of buffer zones.

The Forest Zone will be a fenced environmental buffer between ALDTP development and the Indian Border. This will minimize any ecological impact that the construction activity will have on the Indian side. The buffer zone will also ensure that there is no uncontrolled migration of the flora into the Indian side from the proposed development. The buffer zone will ensure a smooth transition from the forested areas on the Indian side to the ordered development in the ALDTP site.

4.3. Impact on sediment deposition.

Presently, there is a lot of natural debris that is arising from the erosion in the outfalls that is being carried across the international border during high flood conditions. The presence of the fore-bays in the detention ponds and the storm water channels minimize the amount of erosion debris that is being carried to the Indian side of the border. This will enhance the long term health of the ecology of the floodplain there.

5.0 Green spaces landscape strategy:

Good quality green spaces are an essential element of urban neighborhoods and make a profound contribution to the quality of life of communities. They offer many economic, social and environmental benefits. Approaching their planning and management strategically will maximize the value of capital investment and revenue expenditure.

Benefits of green strategy in ALDTP

1. Reinforcing local identity and enhancing the physical character of an area, hence shaping existing and future development. Phuentsholing valley holds a rich repository of bio-diversity. The Green strategy will seek to enhance this character by bringing into the development this "naturalness" and local bio-diversity.
2. Maintaining the visual amenity and increasing the attractiveness of a locality to create a sense of civic pride. ALDTP, when completed, will stand out as an iconic urban landscape. The creation of a planned waterfront flanking a trained river will be the pride of the country. The green strategy will seek to further this sentiment by innovative design.
3. Raising property values and aiding urban vitality. The green strategy for ALDTP will further the real estate values because it will offer more than just functionality. The green strategy seeks to create an urban ecosystem that encourages a high level of activity and interaction amongst residents.
4. Boosting the economic potential of tourism, leisure and cultural activities. The green strategy will seek to attract visitor spending. The green strategy will seek to provide spaces residents use daily, but also populate the development with sports stadia, public amphitheaters for cultural events, large public parks and gardens that attract visitors as well.
5. Securing external funding and focusing capital and revenue expenditure cost-effectively. The green strategy will create an ecosystem that is favorable for funding and investment. The creation of walking promenades, pocket parks, biking trails, and open spaces for community interaction will promote commerce and invite external investments.
6. Providing a wide variety of cultural, social and community facilities, including seasonal activities such as fairs, festivals and concerts.
7. Protecting the historical, cultural and archaeological heritage.
8. Illustrating the contribution to health agendas eg. Reducing stress levels, by providing formal and informal recreational facilities.
9. Providing popular outdoor educational facilities for schools and academic institutions.
10. Improving physical and social inclusion including accessibility, particularly for young, disabled and older people.
11. Offering alternative routes for circulation, including networks for walking and cycling and safer routes to school.
12. Raising air quality and moderating extremes of temperature.
13. Protecting and enhancing levels of biodiversity and ecological habitats
14. Providing environmental infrastructure to improve water quality and flood control.

Components of a comprehensive green space strategy:

It is proposed that the green strategy should include, the following categories of green spaces. Each of these is discussed in greater details in the later sections.

1. Community parks and public gardens.
2. Pocket parks in the urban spaces.
3. Riverside promenades and parks
4. Green corridors.
5. Outdoor sports facilities, stadia and amenity green spaces.
6. Community interaction spaces for children and young people.
7. Roadside green spaces, walking and biking trails.
8. Urban farms.
9. Ethnic village and Culture Centre.
10. Planting palette

5.1. Community parks and Public gardens

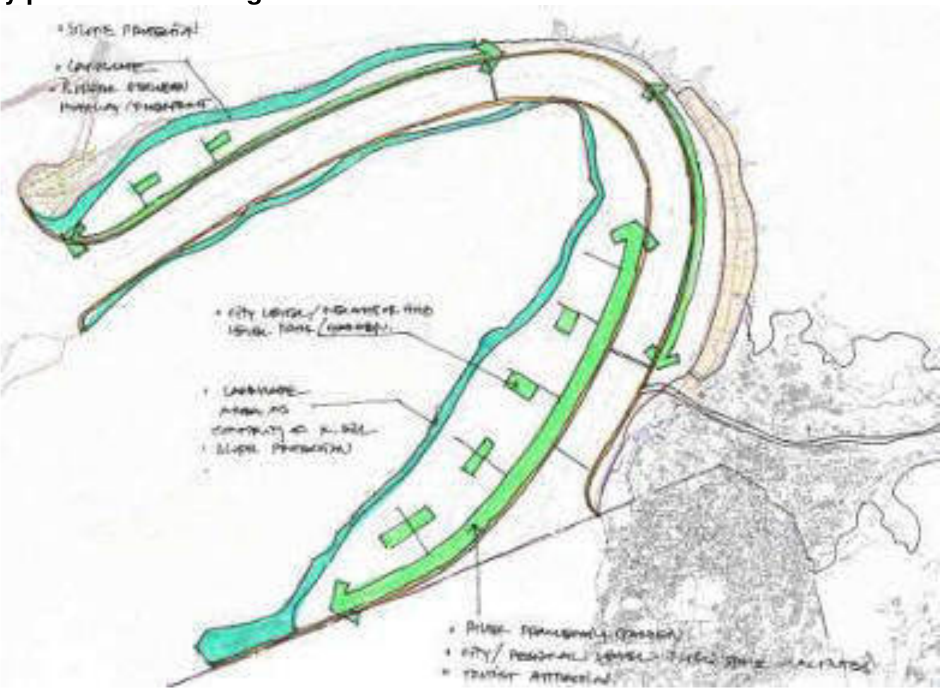


Fig. 5.1 Green Spaces within development at ALDTP (Source – HCP)

Community parks and Public Gardens are the lungs of urban development. Apart from the aesthetics and impact on the air quality, these fulfill very important functions in community interactions and lifestyle.

One of the most important but least recognized essentials to an attractive and healthy urban environment is a well-designed and well-maintained network of city parks; an essential component of any city's infrastructure. Parks support public health, the economy, the environment, education, and community cohesion. They are also critical to workforce development, particularly green career paths. Parks make our cities sustainable, livable and vibrant.

Fig. 5.2 Community Park

Source: Nassauer, J. I., 1995. Messy ecosystems, orderly frames. In: S. Swaffield, ed., Theory in landscape architecture. Part V: Ecological Design and the Aesthetics of Sustainability. Philadelphia: University of Pennsylvania Press

Exposing young people to the joys of outdoor activities in open spaces such as parks helps lower stress, improves physical and emotional health, reduces hyperactivity, and builds stronger immune systems. It also can help mold future generations into individuals who are concerned about the environment, and therefore are committed to revitalizing and enhancing the urban park system.

Fig. 5.3 City Park.

Source: Nassauer, J. I., 1995. Messy ecosystems, orderly frames. In: S. Swaffield, ed., Theory in landscape architecture. Part V: Ecological Design and the Aesthetics of Sustainability. Philadelphia: University of Pennsylvania Press

Parks of all sizes play an important role in preserving and supporting healthy environments. A network of parks and open spaces that include protected natural lands, ecological reserves, wetlands, and other green areas is critical to providing healthy habitats for humans, wildlife and plants in these densely built places.

Natural landscapes are vital to preserving regional ecosystems amid growing cities.

Fig. 5.4 Public garden.
Source: Little, Charles E. 1995. Greenways for America. Baltimore: Johns Hopkins University Press.

5.2 Pocket parks in urban spaces

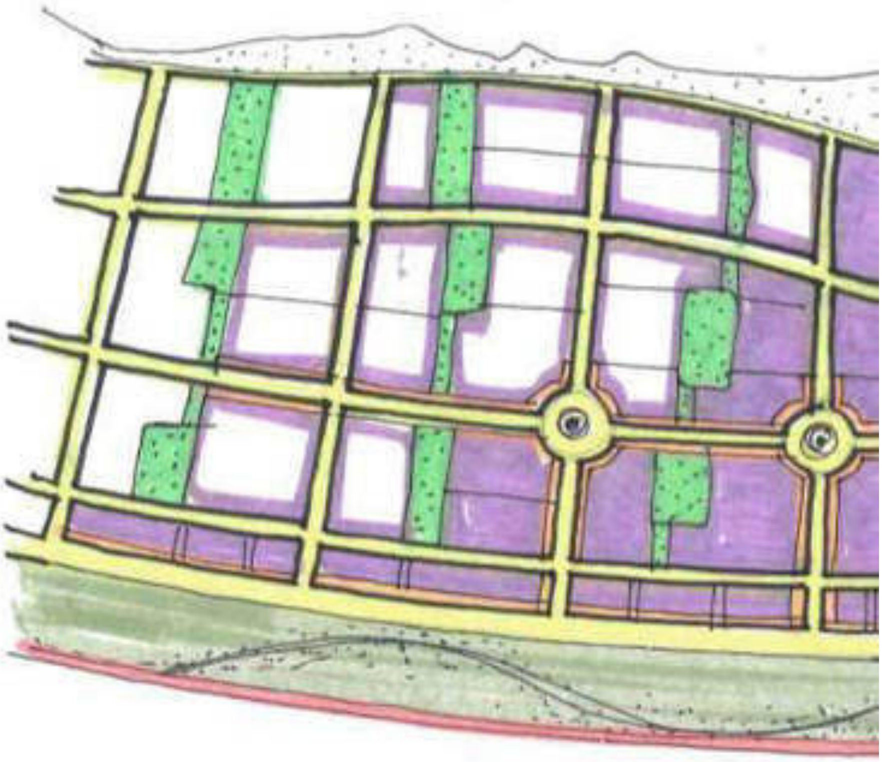


Fig. 5.5 Pocket Parks in urban spaces (Source – HCP)

Usually, pocket parks are closely tied into the neighborhoods they serve. By nature, they tend to be scattered and disconnected because they are usually created opportunistically. In ALDTP however, they will be connected. The green strategy is to place them along greenways or bike paths, while still being visible to a sufficient number of pedestrians who are also the potential users.

The establishment of pocket parks throughout the urban environment also has the potential to benefit the overall ecology of cities because communities who have parks that meet their needs within walking distance are less likely to drive far away for the same resources, thereby reducing pollution, traffic and the consumption of resources such as oil. Along these same lines, pocket parks could relieve pressure on the same larger, more distant parks. These large parks would conceivably see fewer demands for play areas (and the other needs that pocket parks can meet), allowing them more flexibility to devote larger park areas to habitat and ecological function.

Fig. 5.6 Urban Pocket Park ‘
Source: Rosemary O'Brien, BEST Pocket Parks of NYC Paperback – Import, 17 Dec 2013

These diminutive parks tend to act as scaled-down neighborhood parks, but still often try to meet a variety of needs. Functions can include small event spaces, play areas for children, spaces for relaxing or meeting friends, taking lunch breaks, etc. They can be a refuge from the bustle of surrounding urban life and offer opportunities for rest and relaxation.

5.3 Riverside parks and promenades.

ALDTP is, by its very context, a riverfront development. While most city riverfront developments have to deal with congested and poor planning that preceded them, ALDTP can plan its waterfront development from scratch. Well-planned waterfront developments, such as those in Dubai, have learnt the benefits of providing green areas alongside the river exclusively devoted to pedestrian and recreational use. This is in sharp contrast, to the way commercial establishments line and cramp every conceivable waterfront property, elsewhere in the world.

Fig. 5.7 Riverfront parks intent (Source – HCP)

The following references provide a feel of the proposed green strategy for riverfront development

Fig. 5.8 Riverfront parks.

Source: Petrillo, Joseph. 1987. Small City Waterfront Restoration. Coastal Management, Lot 15, pp. 197-212.Taylor and Francis. New York.

Fig. 5.9 Riverfront parks.

Fig. 5.10 Design intent for Dubai Waterfront Park
Source: "Advances in Landscape Architecture", book edited by Murat Özyavuz , ISBN 978-953-51-1167-2, Published: July 1, 2013

In a country like Bhutan that values "Happiness" as an index for development, such a riverfront green strategy will have a greater significance than anywhere else in the world

5.4 Roadside green spaces, walking and biking trails.

The proposed design of the Street Typologies takes into account ample opportunity for pedestrian traffic as well as biking lanes, as can be seen from the sections below:

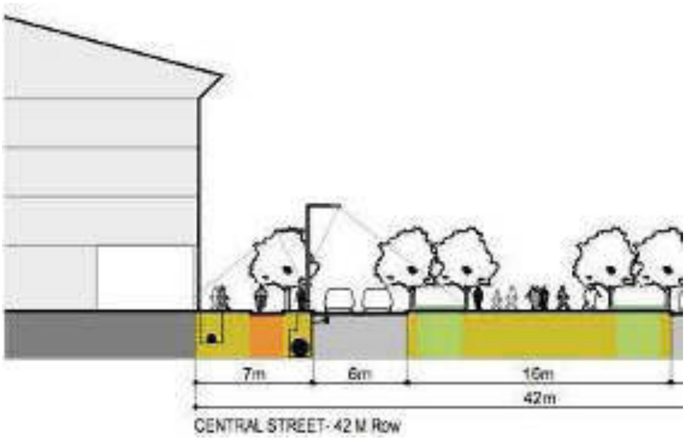


Fig. 5.11 Street Typology Source: (Source – HCP

These are in addition to dedicated biking trails and green corridors that connect the green spaces in the city discussed in earlier sections.
The references shown below provide a feel of the proposed strategy:

 Fig. 5.13 Street Typology Source : Google Images	 Fig. 5.14 Alternate circulation Source: Google images

5.5 Green corridors.

While many cities battle to link green spaces within their urban spaces due to poor vision and lack of vision preceding them, ALDTP has the opportunity to plan this from the very start. While every master-plan focuses on interlinking urban spaces with road, the Green Strategy of ALDTP seeks to link the green spaces in the development using 'Green Corridors". These could be pedestrian and/or biking trails that will allow public to engage in healthier ways of traversing the city, than using vehicles and roads.

Fig. 5.15 interconnecting urban green spaces (Source – HCP)

The corridor can become a proxy of a better city within the city. Its ripple effect can demonstrate how public spaces may be put to better use and break negative perceptions about pedestrian streets, bike lanes and public transportation. It will showcase an optimal situation where everyone, citizens, businesses and government, benefit and learn from turning "inactive" places into opportunities.
Green networks, corridors and linkages are widely seen as a key mechanism for reversing the effects of fragmentation on biodiversity. They also deliver a range of other social and environmental benefits, including enhancement of local landscape character, and greater opportunities for public access and recreational use.
Singapore is probably the one city in the world that has systematically planned green corridors throughout its urban space. The planning and the documentation of the benefits of creating urban green corridors are provided in the appendix.
The following references will give an idea of the proposed feel that is being envisaged for ALDTP by creating green corridors:

Fig. 5.16 Green corridors in Singapore. Source: Briffett, C. 1990. Master plan for the conservation of nature in Singapore. The Nature Society, Singapore.

A detailed document on the Green corridors of Singapore is included in Appendix 5

5.6 Urban Canal

Experience with several river-training projects has shown that most part of the year, the water in the river is virtually invisible to the residents from their homes, offices or shops. It is only when there is high flood level that the water in the trained river becomes prominently visible. This is due the limitations in the engineering itself that has to cater to the protection from a 100 year flood scenario.

One of the ways masterplan design works its way around this is to create a secondary waterfront by way of a canal whose connection with the trained river is only visual. The canal is always protected from flooding the use of either gates or mechanically pumping the water into the canal.

. An example of this can be seen in the Volga river training project in the city of Kazan.

Fig 5.17 Urban Canal, Kazan Source : Google Images

Fig. 5.18 Volga river training and Urban canal.

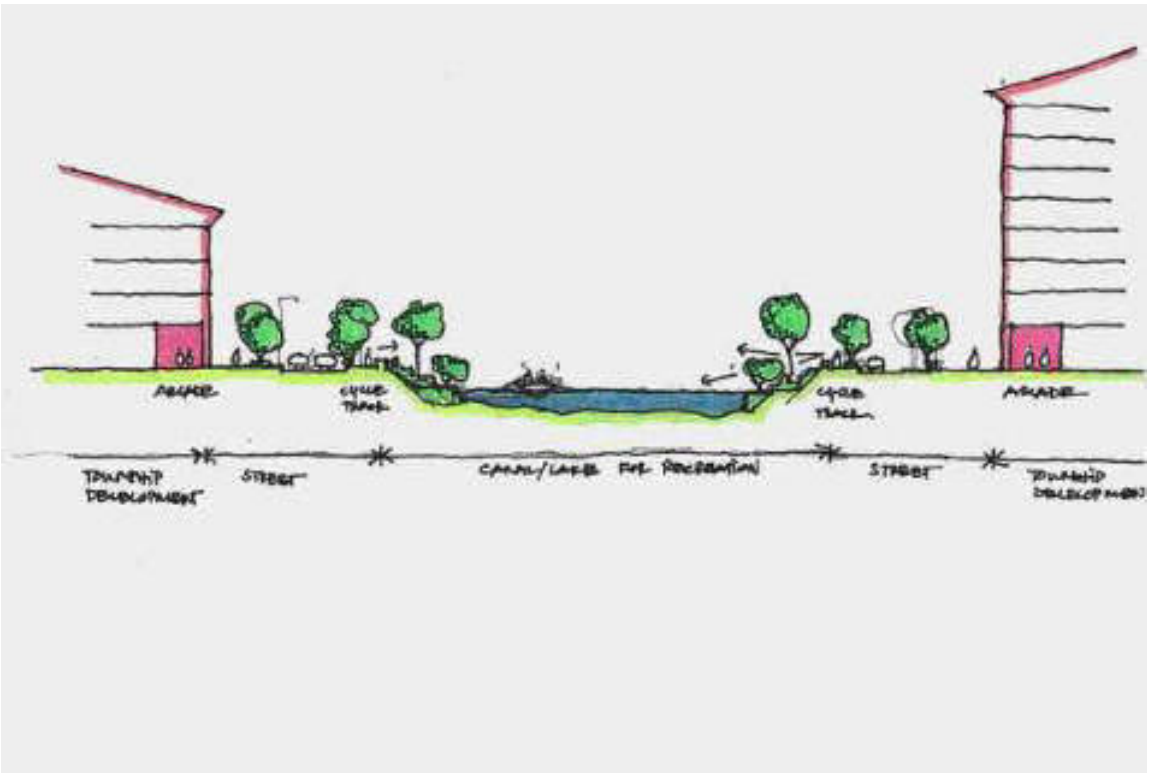


Fig. 5.19 Urban canal intent in ALDTP (Source – HCP)

5.7 Outdoor sports facilities, amenity green spaces

Archery is the national and most popular sport in Bhutan. Competitions are held regularly in most villages. Bhutanese sports include khuru, soksom, pundo, and degor.

Fig. 5.20 Archery range in Bhutan (Source: Google Images)   Archery range in amenities park

It is important to have a green strategy where all these traditional sports can be practiced in neighborhood amenities parks. Traditional sports of Bhutan need relatively less area and can be easily accommodated within urban parks. This will help provide a platform for the popularization of traditional Bhutanese sports.

Fig 5.21 Khuru practice ground
Source: Google Images

Fig. 5.22 Soksom in progress.
Source: Google Images

Fig. 5.23 Pundo (shot putt) in Bhutan
(Source: Google Images)

Fig. 5.24 Degor game in progress

Except for archery, these sports need only 20 mts length for playing. They can even be accommodated in Pocket Parks.

Amenities green spaces include children's play areas. These are proposed for neighborhood parks to take the pressure of larger parks for this function. The parks proposed for ALDTP are designed to accommodate and integrate the physically challenged.

Fig. 5.25 Amenities parks can include activities for older citizens and children. (Source: Google Images)

The Green Strategy for outdoor play areas would be to integrate them into public garden spaces rather than keep them as discrete units.

5.8 City Farms

ALDTP is a large development that will generate a huge demand for fresh fruits and vegetables. As a part of the Green Strategy, it is proposed that some area in the development will be real estate farmland that will grow chemical free farm produce for this captive market.
Urban farms are catching up fast in several cities that are fed up with the quality of farm supplies. The idea is that city farms will offer residents a reliable source for fresh organic farm produce within the development. Residents can also partake in the farming activities during their free time should they chose to do so. Although chemical free, these farms will adopt the latest agro technologies including greenhouses for year round production.

Fig. 5.26 City farms (Source: Google Images)

"City farms" is a new and innovative component of the green strategy that will add to the health and lifestyle of its residents.

Fig. 5.28 Urban greenhouse (Source: Google Images)

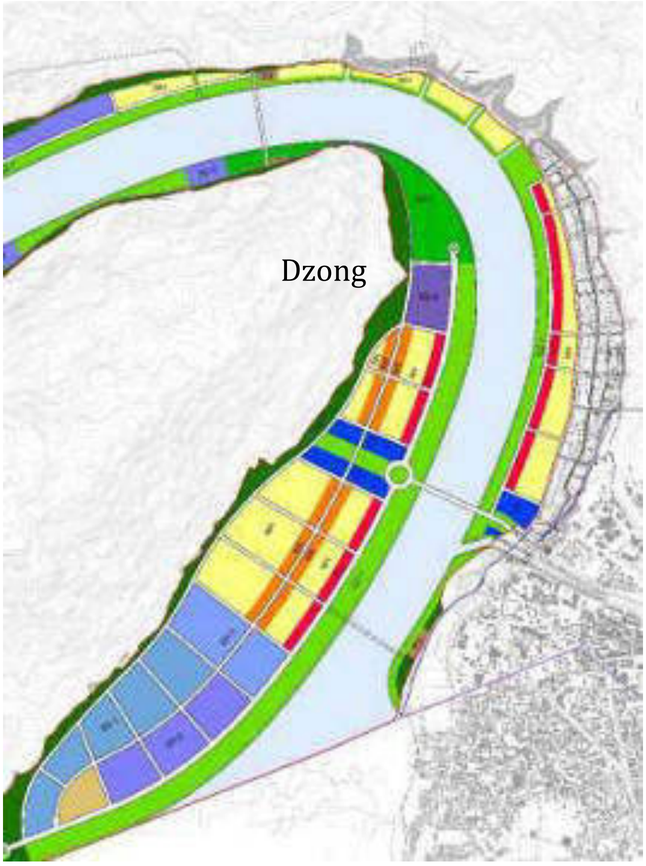
Fig. 5.29 Urban farming (Source : Google Images)

Fig. 5.30 City Farming Zone intent (Source – HCP)

5.9 Ethnic Village and Culture Center

An area around the river bend of Zone C is demarcated for Ethnic and Culture center that will showcase the diverse ethnic richness of Bhutan. It will have house architecture, arts and crafts, food and cultural shows that are representative of the various parts of the country.

Landscaped surrounds of the Dzong offer visitors tranquil surroundings to meditate and connect with their inner self. The surrounds of the Dzong offer platforms for traditional festivals and celebrations to take place. Should a Dzong be built in ALDTP, it is proposed that it can be built on the waterfront at the bend of the river. Here it will stand proud in a vantage point visible from all important locations including the entry point.



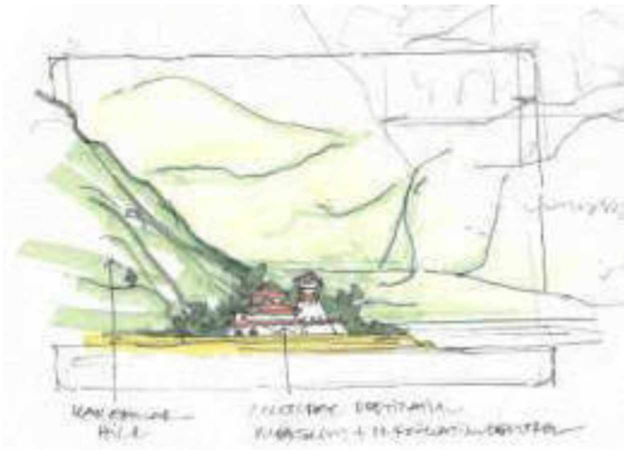


Fig. 5.32 Thumb sketch of Dzong on river bend (Source – HCP)

Fig. 5.31 Location intent for Ethnic Village and Culture center (HCP) Google Images)

Fig. 5.33 Dzong monastery (Source:

5.10 Planting Palette

On the basis of the recommendations arising from the Ecology of the region and the Green strategy for ALDTP development, an interesting mix of tree species have been identified for use in the Tree Planting Palette. The main features of this palette are:

- Predominant use of Indigenous species.
- Evergreen species given preference.
- Species already adapted to local conditions.
- Species that are easy to make saplings in on-site nursery.
- Flowering species selected on basis of adaptability to local conditions.
- Accent trees selected are hardy species.
- No invasive species.
- Mix of fruit trees included.

Preliminary planting palette includes 54 varieties of tree and palm species and is listed in Appendix 6. **All tree species will be developed in an on-site nursery located in the Forest Zone. The seeds for these will be harvested locally from the forests and obtained through the forest department nurseries.**

Representative examples of Trees form the ALDTP Tree Planting Palette:

Fig. 5.34: Planting palette Indigenous trees

Fig. 5.35: Planting palette flowering trees

Fig. 5.36: Planting palette palms

6.0 Masterplan:

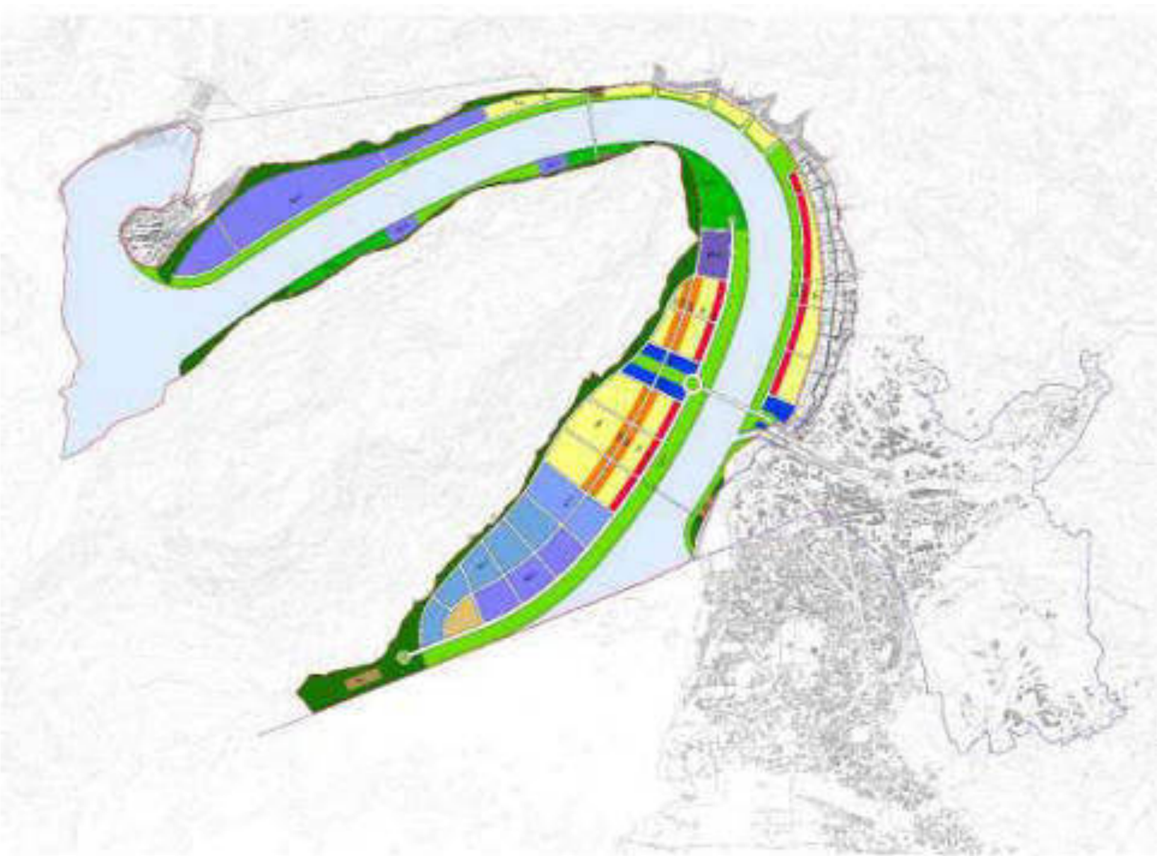


Fig. 5.37 Masterplan first draft

The above masterplan and landscape design has been arrived at using the key inputs from Land Analysis, Recommendations, Enhancements, Mitigation and Offsetting, and Evolution of the Masterplan and Landscape Design.

6.1 Summary of landscape inputs incorporated to evolve the masterplan:

Ecology:

1. Bio-diversity inputs have created the buffer zones.
2. Forest Zone retained as part of green buffer. Suitable location for plant nursery, soil storage and STP.
3. Riparian grasslands preserved up to 30% as Bio-diversity park and buffer zones.
4. Outfalls with detention ponds and channels to direct storm waters. Offsetting of bio-diversity habitat.
5. River sloped embankment treated with Vetiver grass creating aesthetic user experience.
6. Eroded slopes along boundary treated with Vetiver grass stabilization.
7. Mature trees on sandbank of Zone B incorporated into recreational spaces.
8. Kaileshwar Hill proposed for ecotourism with canopy walks.

Green Strategy:

1. Community parks and public gardens incorporated throughout the development.
2. Pocket parks in the urban spaces.
3. Riverside promenades and parks
4. Roadside green spaces, walking and biking trails.
5. Green corridors.
6. Urban canals.
7. Outdoor sports facilities, amenity green spaces.
8. City farms.
9. Ethnic Village and Culture Centre.
10. Planting palette

7.0 Landscape Project Components

The masterplan displayed at the conclusion of the 1st Draft IDPR has since evolved and the present configuration is shown below:

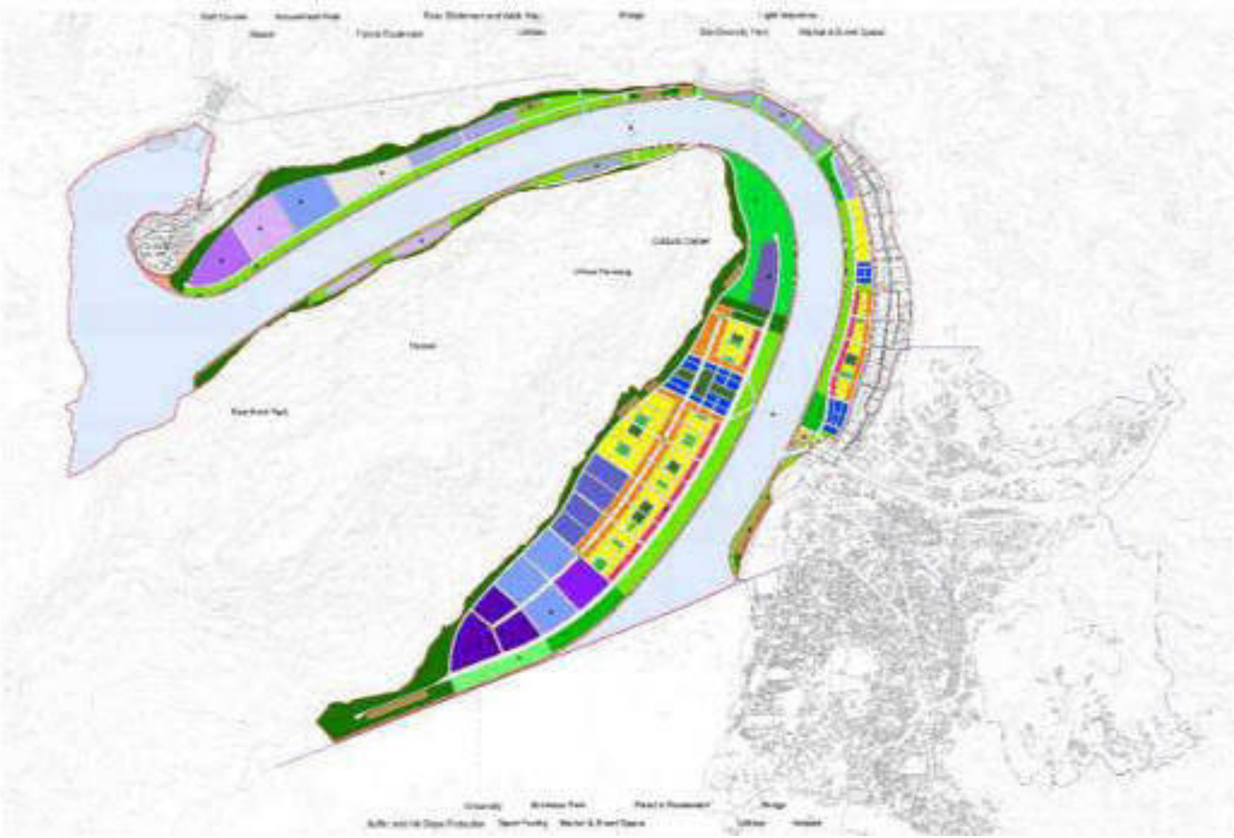


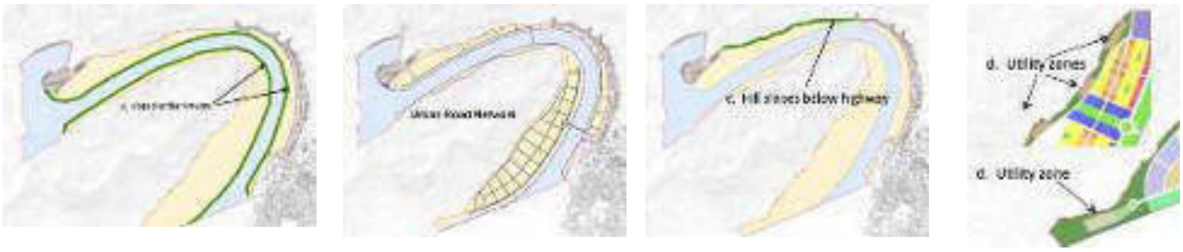
Fig. 7.01 Masterplan second draft IDPR (Source-HCP)

The masterplan has been fine tuned in terms of alignments of circulation and zoned to enhance the overall impact of the development. While the 1st draft IDPR gave the landscape strategy and intent, the present landscape document takes it to project stage when the components are actually drafted onto the masterplan to scale.

The Landscape design for the 2nd draft IDPR can be split into two sections:

Section 1- Detailed landscape design

A. Detailed landscape design for the Sloped Embankments
B. Detailed landscape design for the sloped hillsides along highway Zone A and B.
C. Detailed landscape design for the Urban Street Network.
D. Detailed landscape design for area surrounding the Infrastructure Utility Buildings in Buffer zones; the south-west forest zone as well as along the eastern edge of the Kaileshwar Hill.



a. River embankments	b. Urban street network	c. Sloped hill sides	d. Utility area

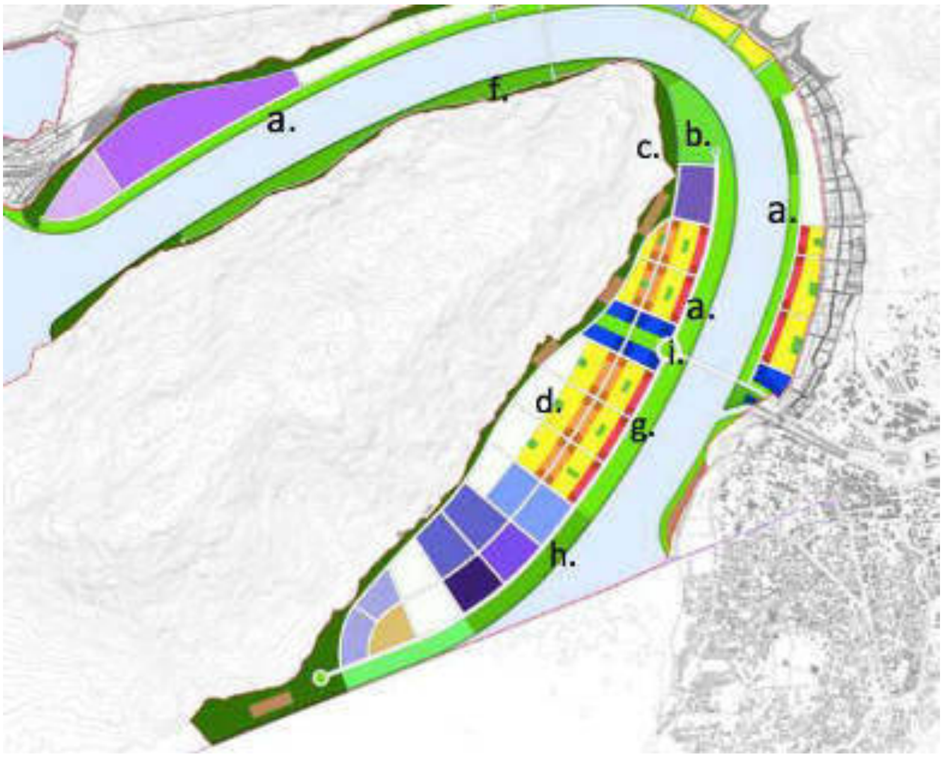
Fig. 7.02 Components for detailed landscape design in 2nd Draft IDPR

This report will contain the detailed design with relevant technical drawings, materials and planting palette.

Section 2- Landscape Guidelines

There are other common areas where landscape guidelines shall be given for tendering a design and building package. The purpose of these guidelines will be to ensure that all the aspects of the landscape vision for the masterplan will be retained, when implementation of the project shall commence.

The components which shall require set guidelines for their development are listed below:



a.	Riverside park
b.	Bio-diversity park
c.	Buffer zones
d.	Neighborhood parks
e.	Pocket parks
f.	Urban farms
g.	Market place
h.	Events plaza
i.	Town center plaza

Fig. 7.03 Components for Guidelines formulation in 2nd Draft IDPR

Section 7.10 Detailed Landscape Design

The Detailed Landscape Design is structured as follows:
- Landscape context
- Landscape objective
- Planting palette
- Planting plans
- Detailed landscape drawings

7.11 Sloped Embankments.

This section comprises of the following components:
i. Sloped embankment on riverside
ii. Lower Walkway
iii. Upper Walkway

i. Sloped Embankments on Riverside:

Landscape Context:

The riverside walk will be the iconic attraction to the ALDTP development. Nearly 14.7 kms long, it will provide a unique opportunity to experience the beauty of the river at close quarters. The lower walk is 7.5 mts wide while the upper walk is 5 mts wide. This vast expanse of hard paving needs to be softened with plantation to create the right microclimate for the users. The sloped embankment will need to have the right choice of species that will overcome the challenges of shallow soil depth and periodic river flooding.

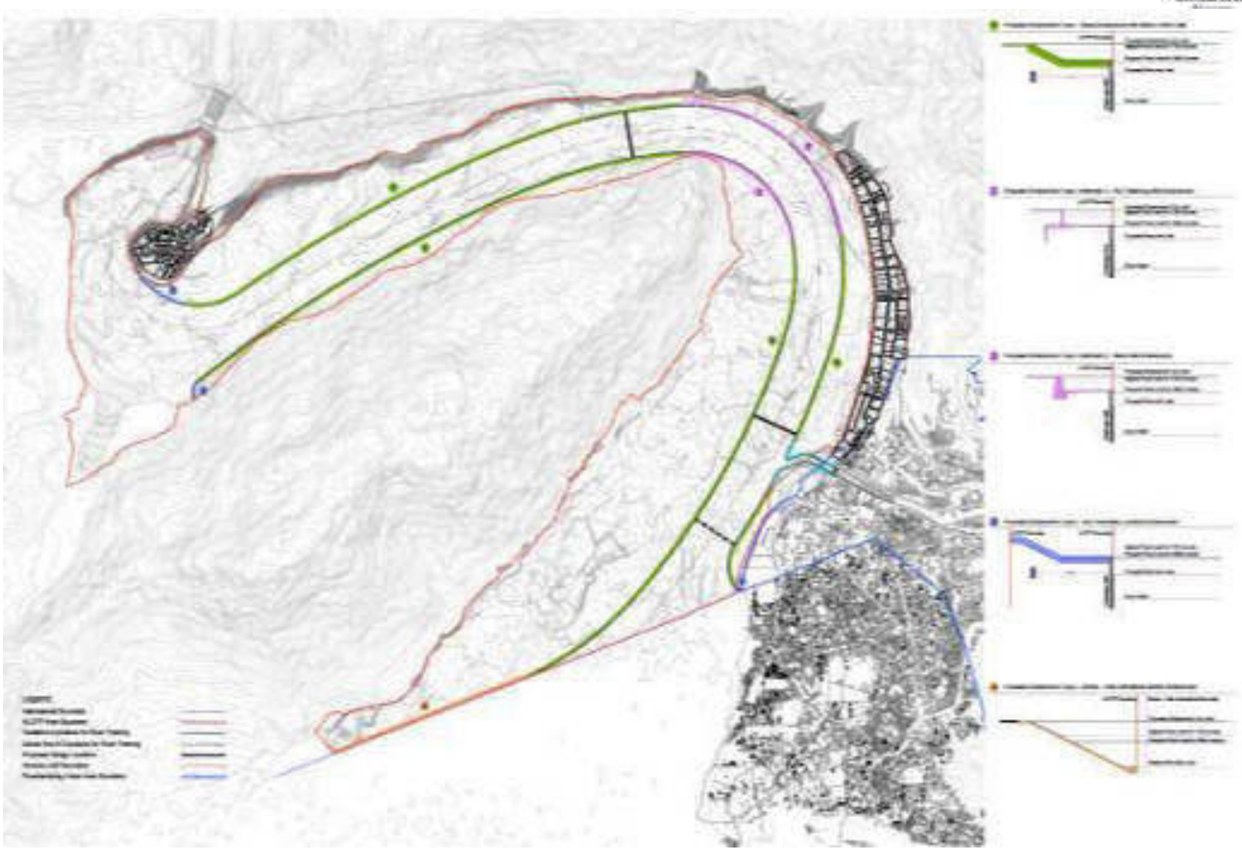
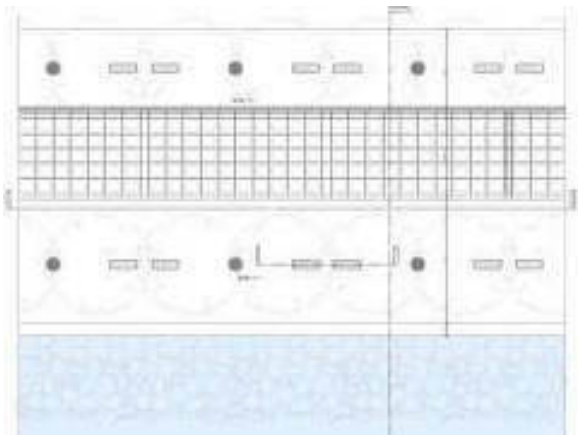


Fig. 7.04 Sloped Embankment Master Plan (Source-HCP)



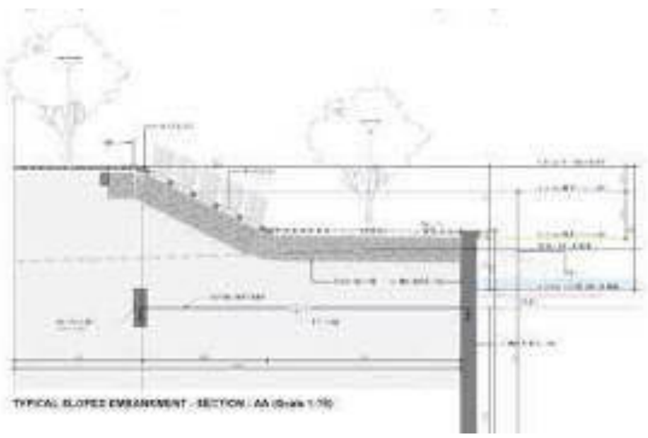


Fig. 7.05 Sloped embankment detail (plan)

Fig. 7.06 Sloped embankment detail (section)

Landscape Objective

The landscape in this section faces the following challenges:

a. The soil depth for the plantation will be 250 mm depth (thickness of pre-cast paver)
b. The species selected should be able to withstand high flood levels and the erosive power of the water.
c. The species should have vegetative growth that can be easily controlled in a sustainable manner.
d. Preferably, the roots of the plant should be able to penetrate the gabion layer providing bio revetment.

Planting Palette

Vetiveria zizanioides is the only grass that fits all the plantation requirements for the sloped embankments. the World Bank had been actively promoting vetiver as a grass that would help conserve soil (erosion control) and water (runoff retention/more infiltration).

Fig. 7.07 Vetiver grass used for erosion control

Planting Plan:

The planting pockets in the sloped embankments are created in the 800mm diameter cutouts in the precast paving blocks that sit above the gabion revetment. These are only 250 mm thick.

Four Vetiver plants are proposed for each cutout as shown below. Typically, Vetiver grass is planted as a pure stand throughout the sloped embankment.

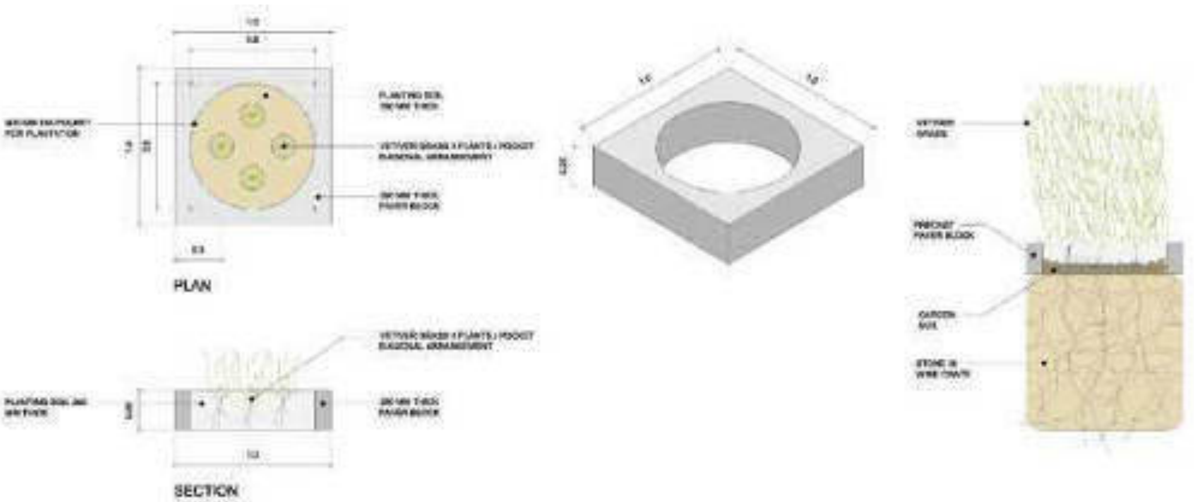


Fig. 7.08 Precast paver block with cut out and 4 vetver slip planting per cutout (Source- HCP)

The slopes before and after the river bend (on either side of the vertical RCC embankments) will have:
(i.) alternating vetiver planting in the cutouts of paver blocks
(ii) Solid paver blocks without cutouts
These shall be placed in a diamond shaped configuration as shown below:

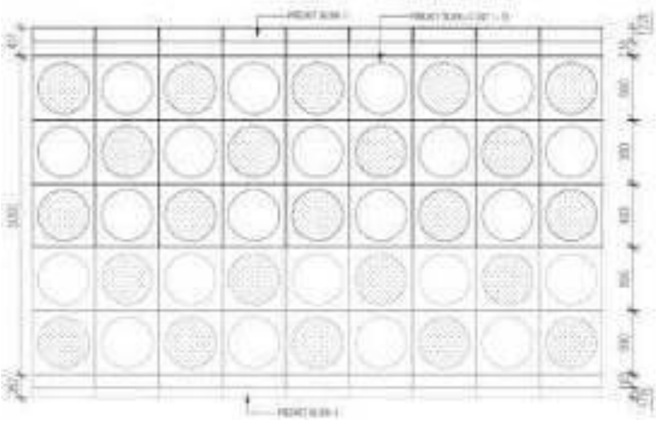


Fig. 7.09 Embankment detail showing alternate block planting

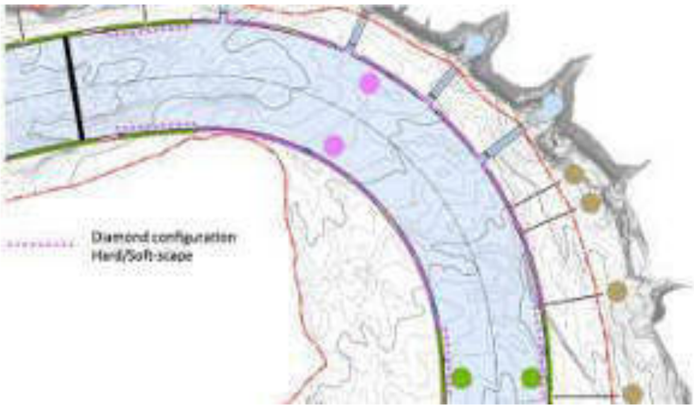


Fig. 7.10 Location of the Diamond hard and soft-scape arrangement for the sloped embankment.

Sloped Embankments with above design shall protect the current slope from damage to the slope revetment. This planting configuration will reduce velocity of water by a Manning coefficient factor by 2.5 resulting in the reduction of wave overtopping of more than 60%. This will provide extra protection to the slope from the scouring action of the water. (Vetiver system for slope stabilization: Engineer's Handbook, Paul Truong et al).

This phenomenon will only happen during High flood levels, when sloped embankments are submerged.
In frequent floods, however, sloped embankments are not submerged.

Detailed Drawings:
Refer Drawing No.: RE-LO-07
TE- SE-01

ii. Lower Walkway

Landscape Context:
This walkway allows the user to experience the riverfront from the closest quarter. The hardscape in the paving can result in creating heat islands making the experience uncomfortable. Therefore, the creation of shaded spaces assumes priority. Street furniture, including benches for users to sit and view the riverfront, are incorporated for enhanced user experience.

Landscape Objective:
The trees must provide shade suitable for walking and seating. The tree canopies should be of a spreading habit, and the canopy height and volume must not overwhelm the river embankment. The intention is to create a green canopy that has a similar volume and growth rate throughout the avenue.

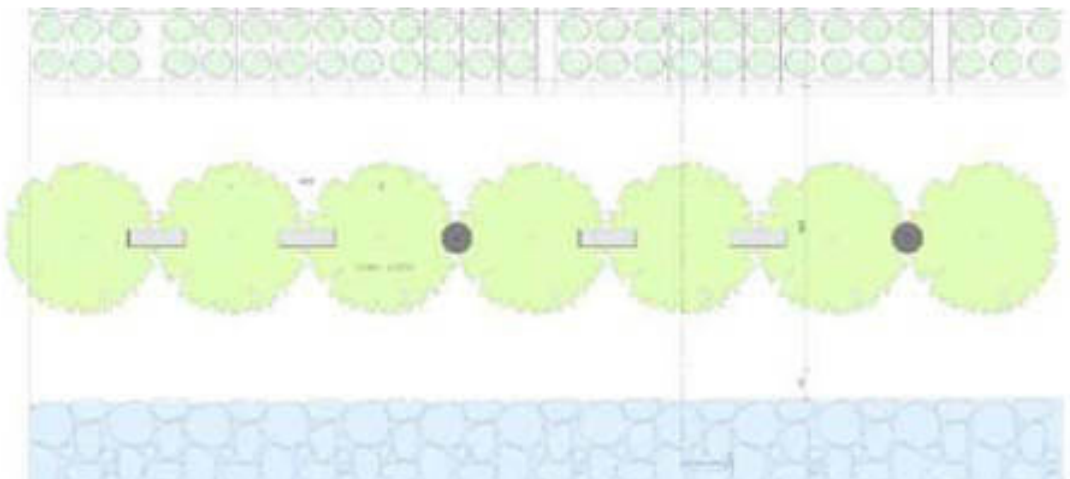


Fig. 7.11 Sketch showing the intent for uniform canopy volume and shape of the trees on the lower walkway (Source-HCP)

Planting Palette:

The lower walk will have medium trees that will grow to a maximum height of 6 to 8 mts, having a spreading canopy of 3 to 4 mts. An equitable mix, of evergreen and flowering species, has been selected. The species are mostly evergreen throughout the year. The leaf fall is generally occurring in the peak winter months when filtered sunshine is welcome to the user.

Fig.7.12 Azadiracta Indica Tree (Species A)
Canopy height 6-8 mts Canopy dia. 4-5mts

Fig. 7.13 Azadiracta Indica Flower (Species A

Fig. 7.14 Mesua ferrea Tree (Species B)
Canopy height 6-8 mts Canopy dia. 4-5mts

Fig. 7.15 Mesua ferrea Flower (Species B)

Fig. 7.16 Pongamia glabra Tree (Species C)
Canopy height 6-8 mts Canopy dia. 4-5mts

Fig. 7.17 Pongamia glabra Flower (Species C)

Fig. 7.18 Filicium decipiens Tree(Species D)
Canopy height 6-8 mts Canopy dia. 4-5mts

Fig. 7.19 Filicium decipiens Flower (Species D)

Fig. 7.20 Alsotnia scholaris Tree (Species E)
Canopy height 6-8 mts Canopy dia. 4-5mts

Fig. 7.21 Alsotnia scholaris Flower   (Species E)

Planting Plan for Lower Walkway:

The spacing of the clusters of different tree species is determined by the location of the steps/ramps that connect the upper and lower walkways. Spacing for trees in the Lower walkway is 4000mm C/C. There will be 3 trees between light poles that are 12000mm C/C. The lower walkway is typically 7500mm wide.

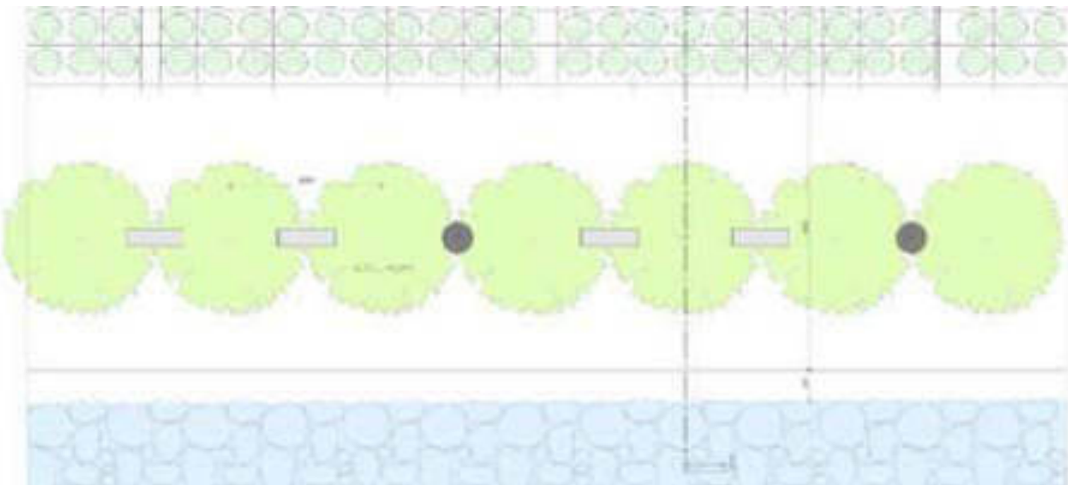


Fig. 7.22 Detail showing tree planting plan for lower walkway (Typical)

Fig. 7.22a Detail showing tree species cluster planting for lower walkway (Typical)

The detailed distribution of the tree species is given the figures below Part 1 to Part 6.

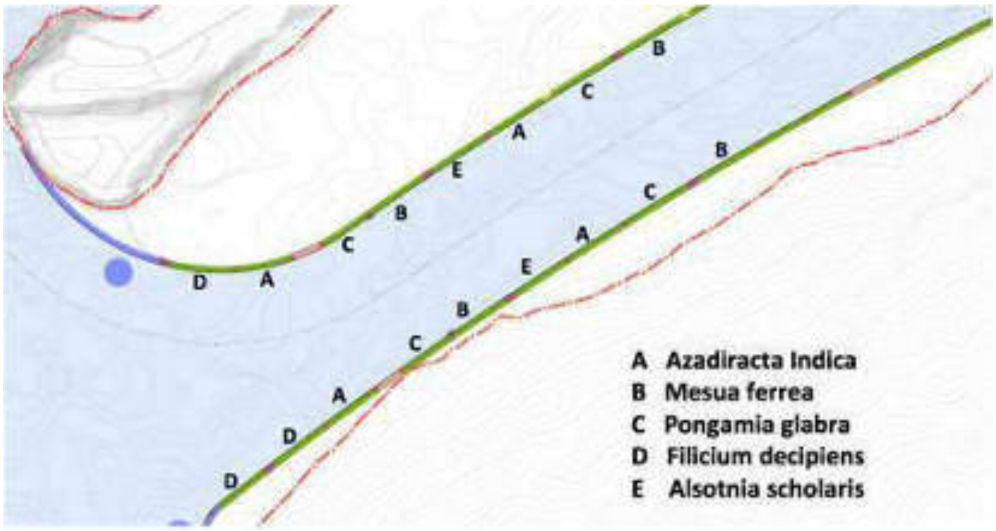


Fig. 7.23 Detail showing tree species cluster planting for lower walkway Part 1

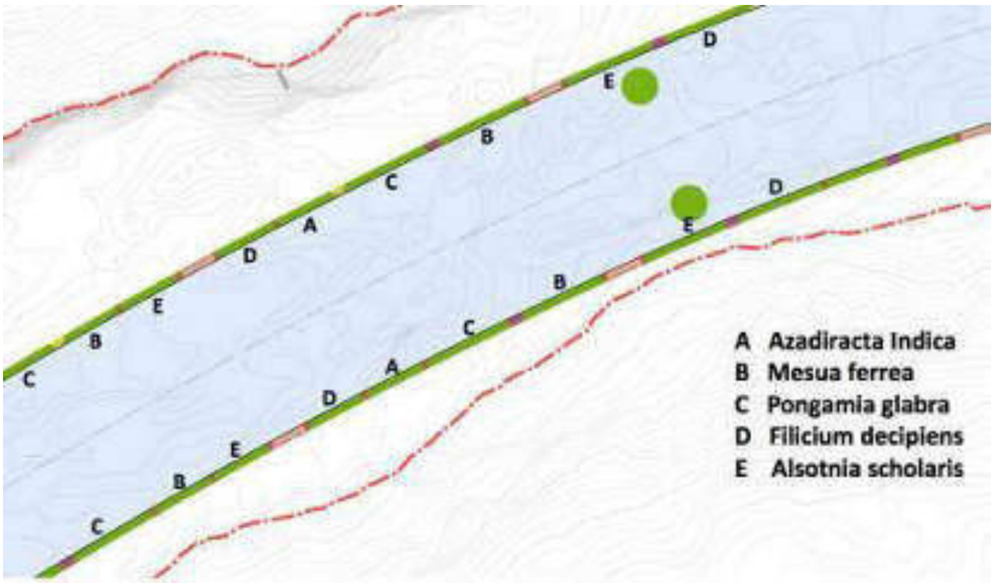


Fig. 7.24 Detail showing tree species cluster planting for lower walkway Part 2

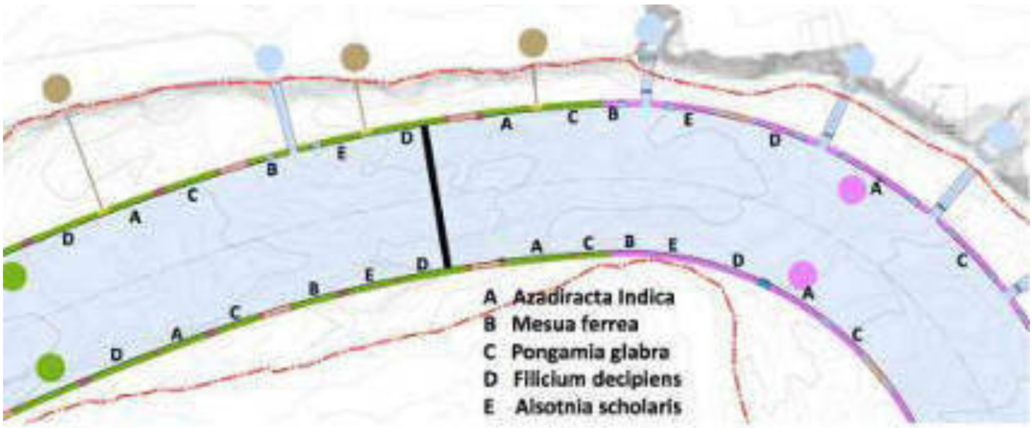


Fig. 7.25 Detail showing tree species cluster planting for lower walkway Part 3

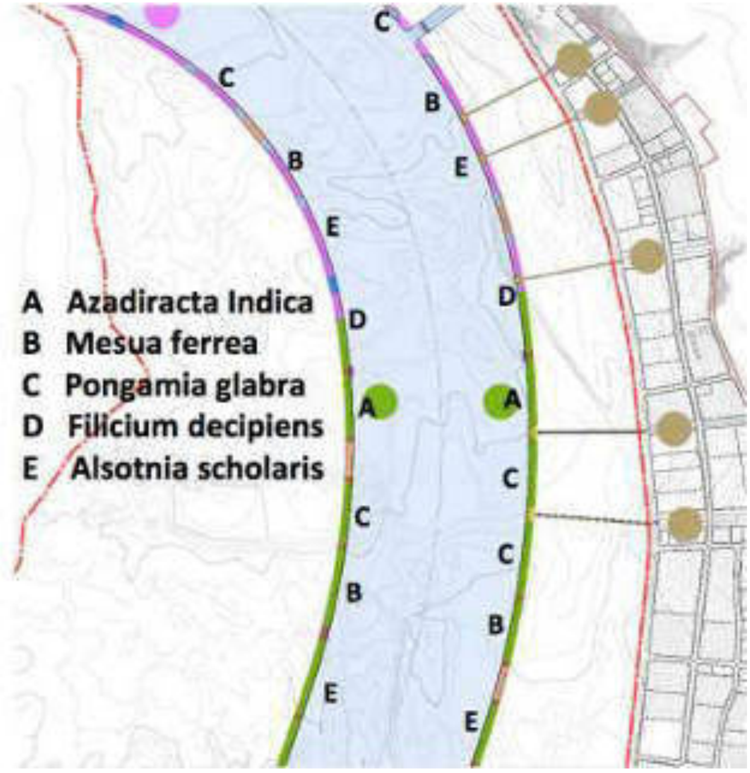


Fig. 7.26 Detail showing tree species cluster planting for lower walkway Part 4

Fig. 7.27 Detail showing tree species cluster planting for lower walkway Part 5

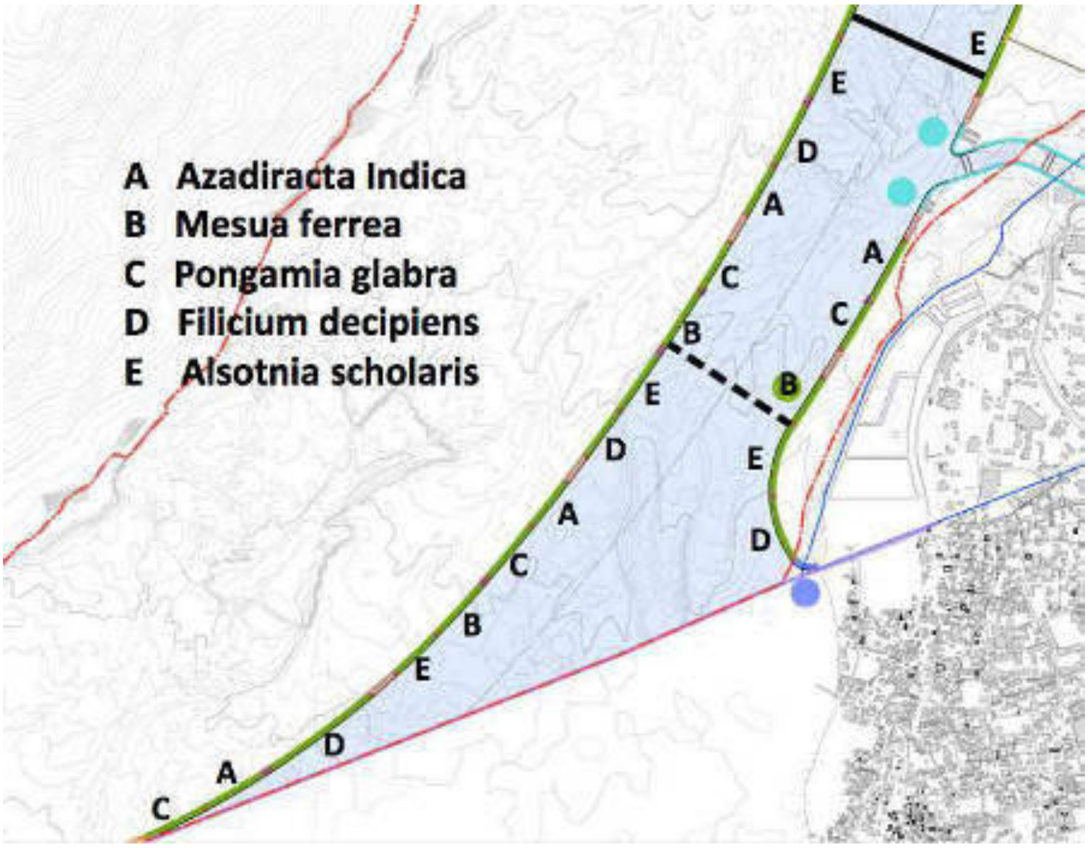
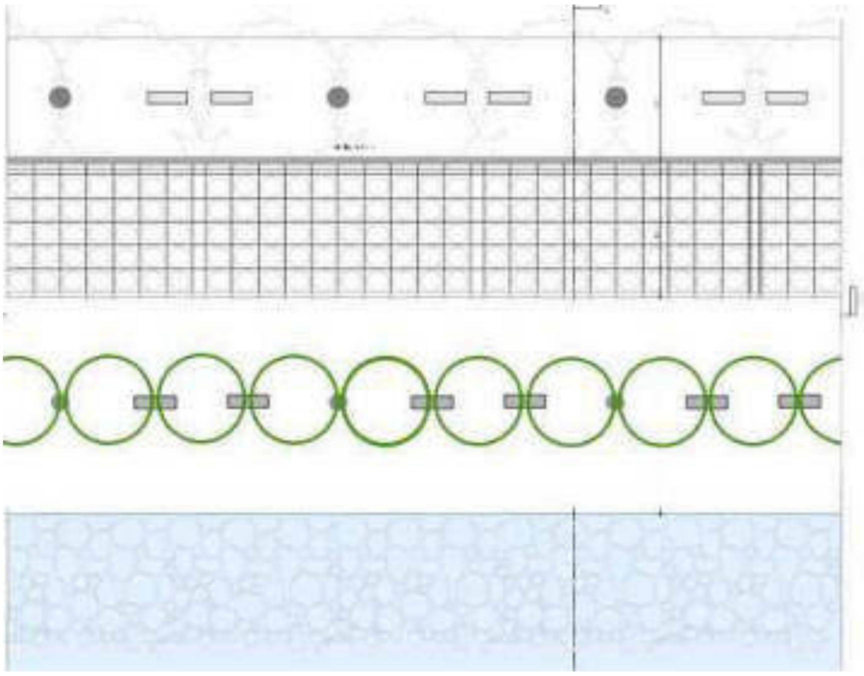


Fig. 7.28 Detail showing tree species cluster planting for lower walkway Part 6

Lower Walkway Street furniture:
The typical layout for street furniture is given below:



Lower Walkway

Tree planting	4000mm C/C
Light pole	12000mm C/C
Seating Bench	4000mm C/C

Fig. 7.29 Lower walkway street furniture (typical)

Street furniture in other site specific contexts for the lower walkway are described in Figs 7.51 to 7.54

iii. Upper Walkway:

Landscape Context:

The Upper Walkway provides scenic vistas all along the waterfront for the users. It provides entry to the river Ghats that access the lower walkway. Tree plantation is required all along the walkway as will be seating benches and other street furniture.

Landscape Objective:

The tree plantation should be iconic as the Upper Walkway has high visibility from either riverbank. The plantation should have a profusion of flowers imparting a joyous character to the riverfront. The tree plantation should be such that the access points to the lower walkway should get defined clearly.

Planting Palette:

The upper walk will have large trees that will grow to a maximum height of 10 to 15 mts, having a spreading canopy of 6 to 12 mts. The tree palette has been selected such that, combination of pairs of tree canopies are similar, and having similar growth rates. The intention is to create a canopy that is all flowering. Consideration is given in the choice of species, such that at least some species are in flower throughout the year.

Upper Walkway Planting Palette:

Fig. 7.30 Cassia javanica Tree
Canopy height 10-12 mts Canopy dia. 6-8mts

Fig. 7.31 Cassia javanica flower

Fig. 7.32 Delonix regia Tree
Canopy height 10-12 mts Canopy dia. 6-8mts

Fig. 7.33 Delonix regia flower

Fig. 7.34 Tababuea rosea Tree Fig. 7.35 Tababuea rosea Flower
Canopy height 10-12 mts Canopy dia. 6-8mts

Fig. 7.36 Samanea saman Tree Fig. 7.37 Samanea saman Flower
Canopy height 15-20 mts Canopy dia. 10-12mts

Fig. 7.38 Pelataphorum pterocarpum Tree Fig. 7.39 Pelataphorum pterocarpum Flower
Canopy height 10-12 mts Canopy dia. 6-8mts

Fig. 7.40 Kigelia pinnata Tree
Canopy height 10-12 mts Canopy dia. 6-8mts

Fig. 7.41 Kigelia pinnata Flower

Planting Plan for Upper Walkway:

The spacing of the clusters of different tree species is determined by the location of the steps/ramps that connect the upper and lower walkways. Spacing for trees in the Upper walkway is 6000mm C/C. There will be 2 trees between successive light poles spaced 12000 C/C.

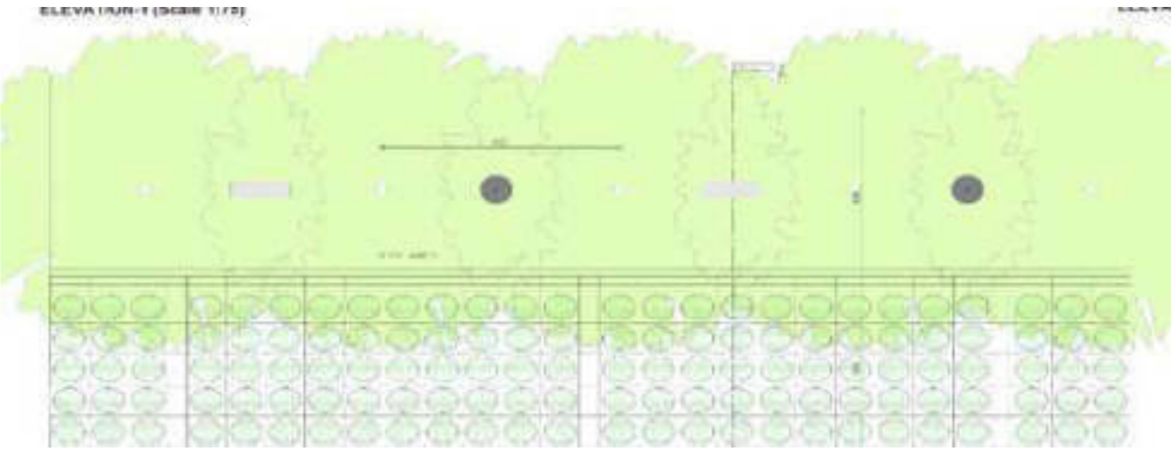


Fig. 7.42 Detail showing planting plan for upper walkway (Typical) (Source-HCP)

Fig. 7.43 Detail showing tree species cluster planting for upper walkway (Typical)

The detailed distribution of the tree species is given the figures below Part 1 to Part 6.
Samane saman is a large canopy tree exclusively used around the river bend where the canopy in the upper canopy will have to overhang the vertical embankment without the vetiver slope.

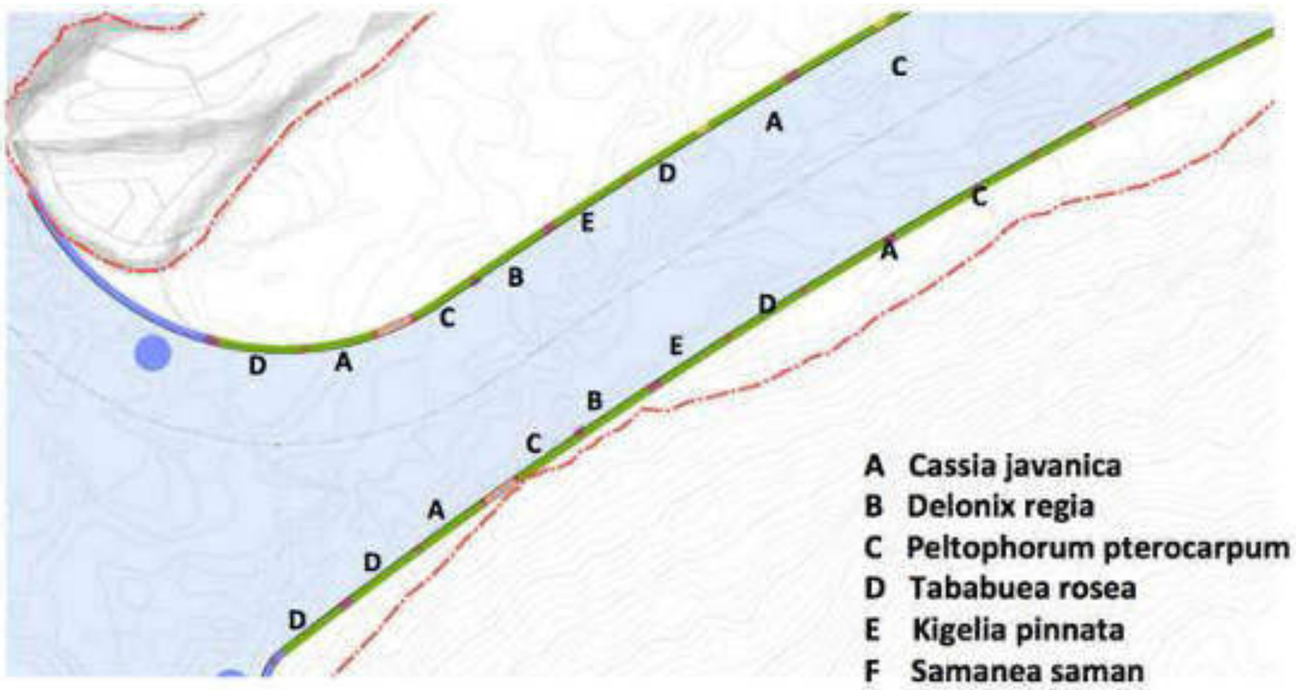


Fig. 7.44 Detail showing tree species cluster planting for upper walkway Part 1

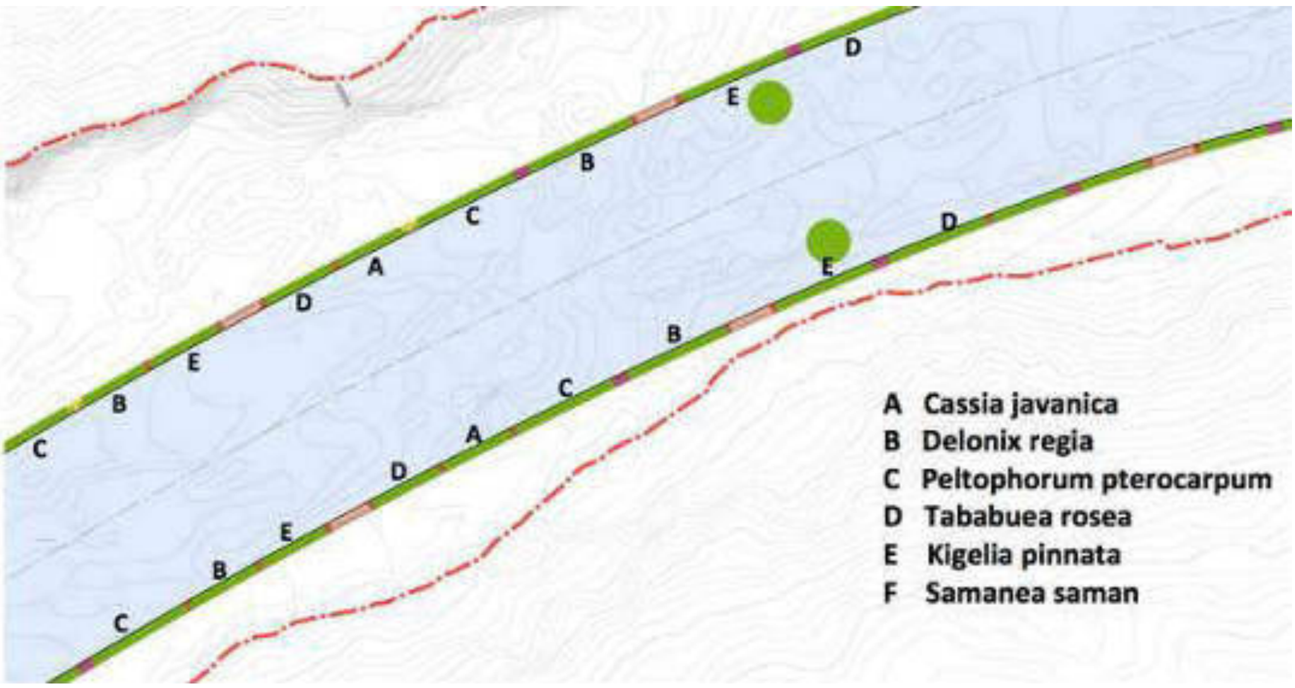


Fig. 7.45 Detail showing tree species cluster planting for upper walkway Part 2

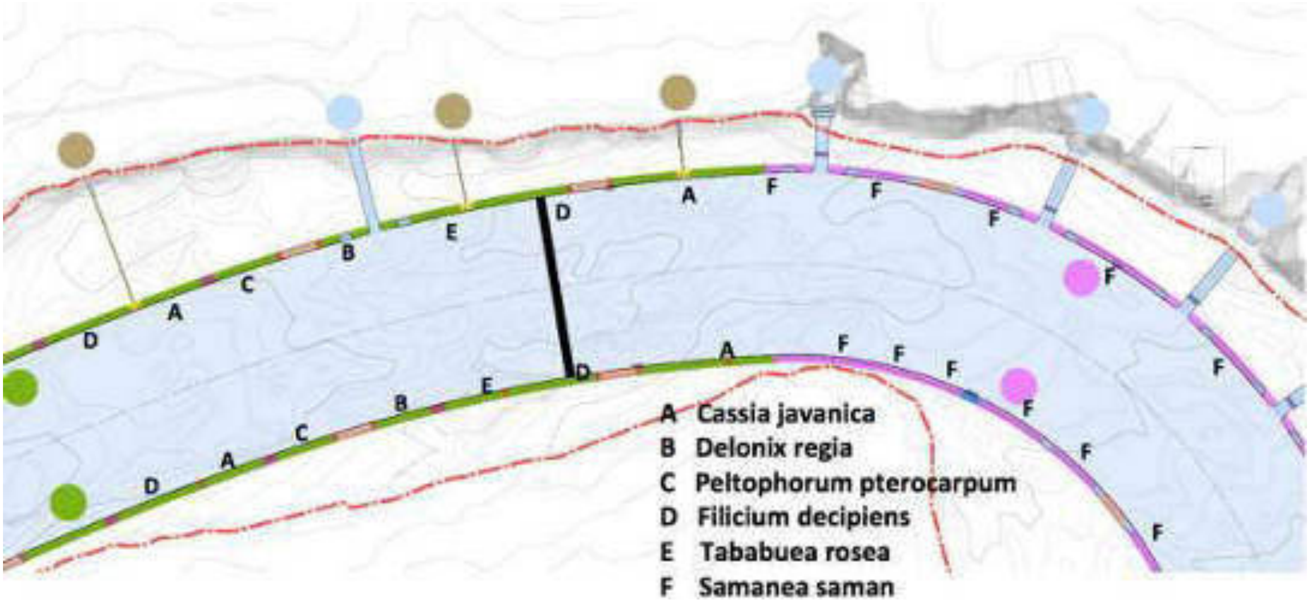


Fig. 7.46 Detail showing tree species cluster planting for upper walkway Part 3

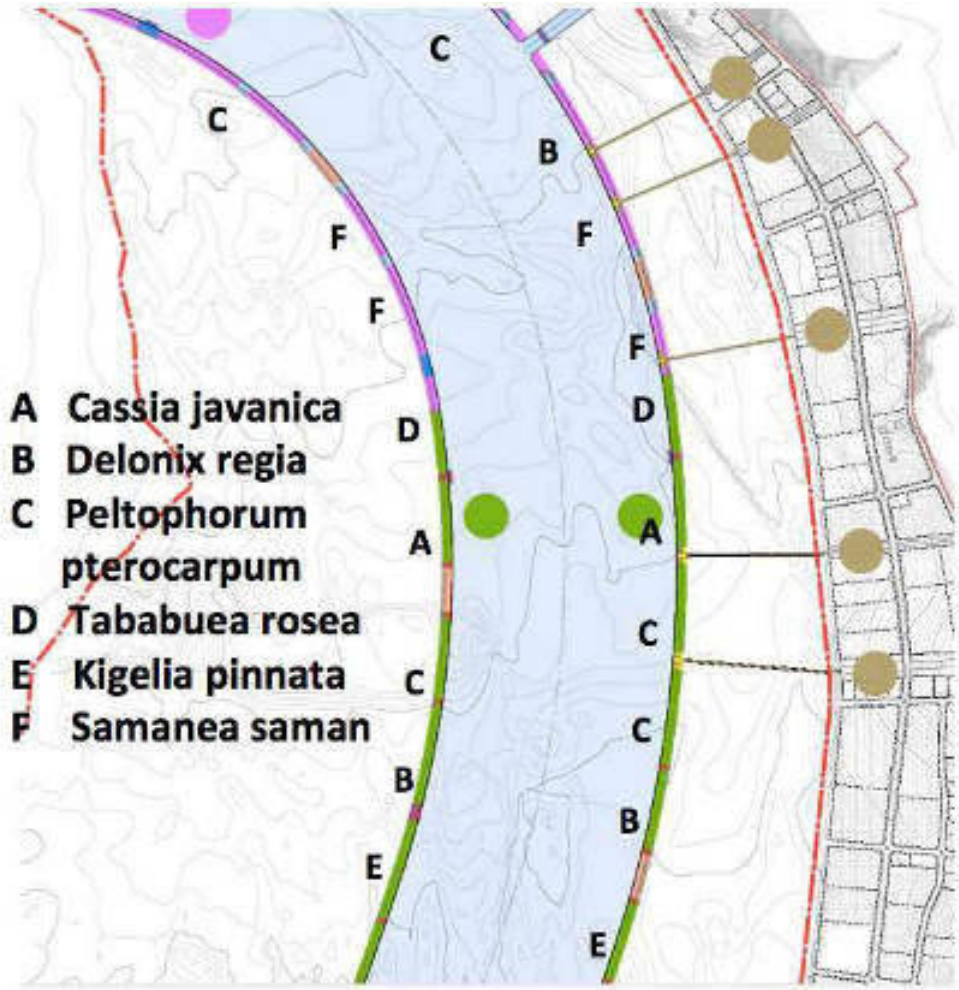


Fig. 7.47 Detail showing tree species cluster planting for upper walkway Part 4

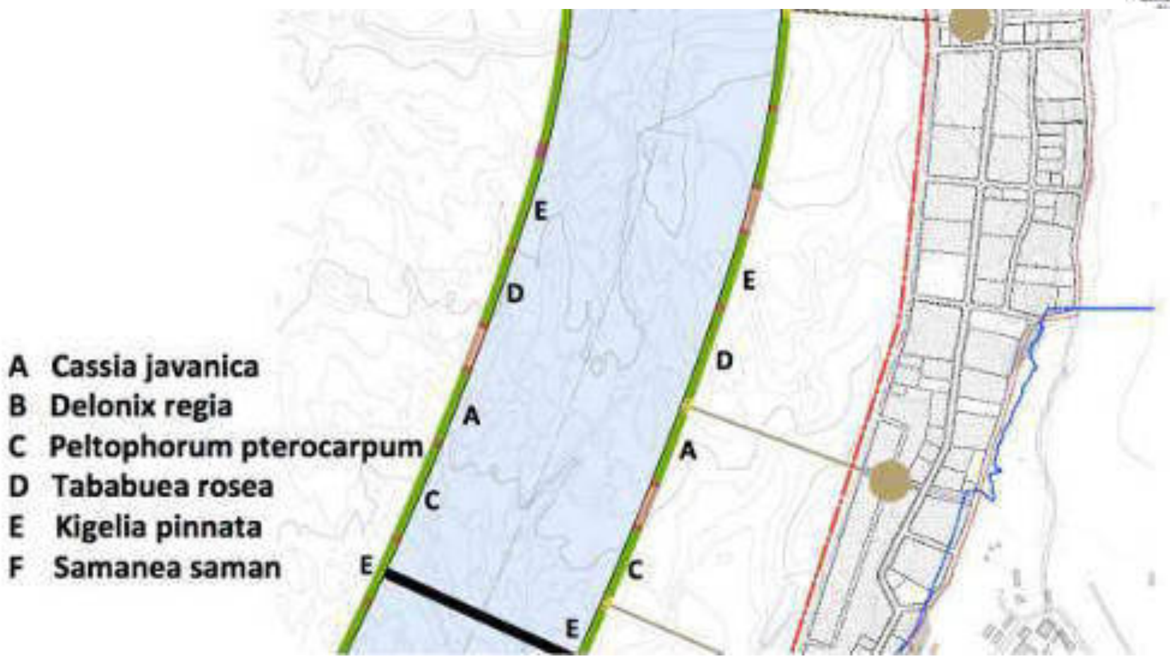


Fig. 7.48 Detail showing tree species cluster planting for upper walkway Part 5

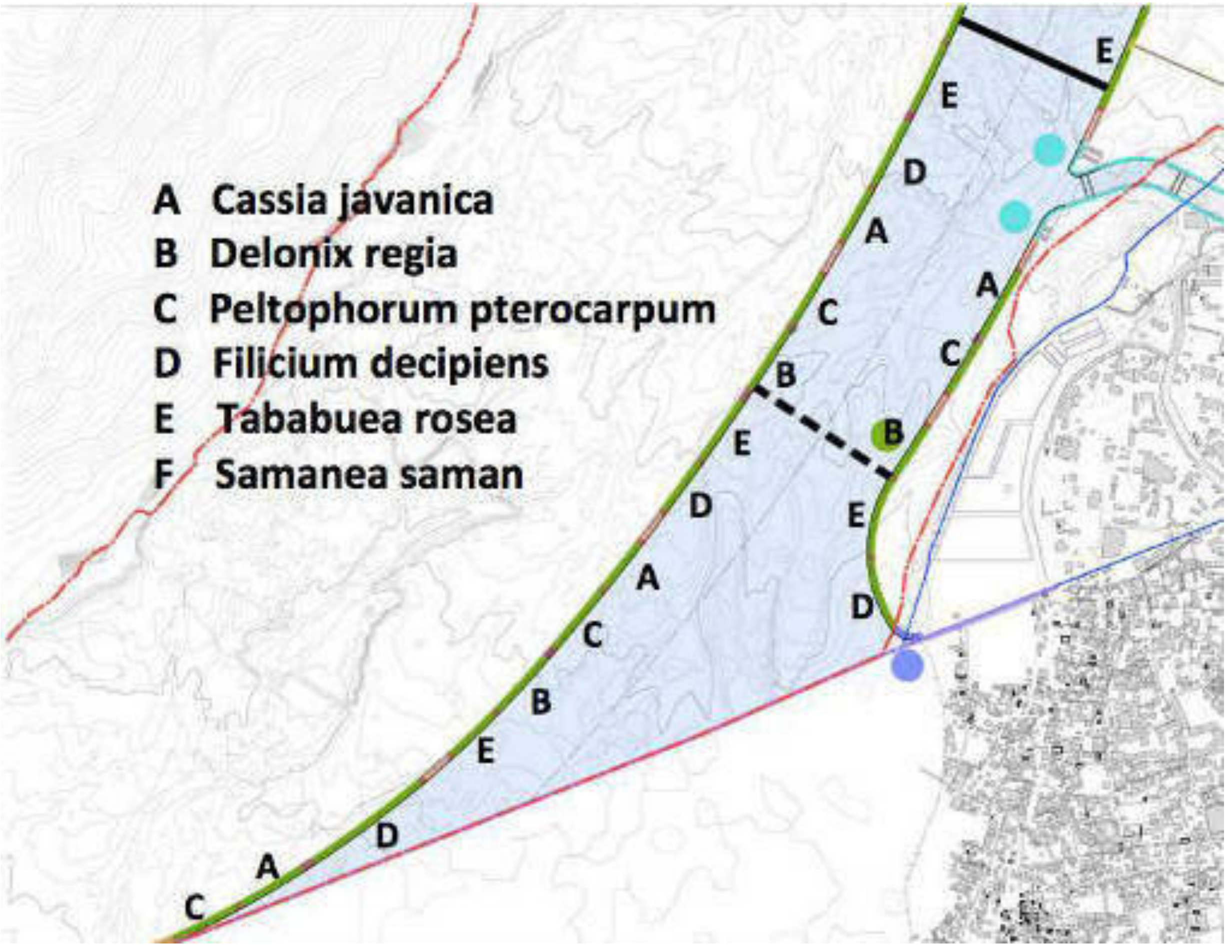


Fig. 7.49 Detail showing tree species cluster planting for upper walkway Part 6

Upper Walkway Street Furniture:
The typical layout for street furniture is given below:

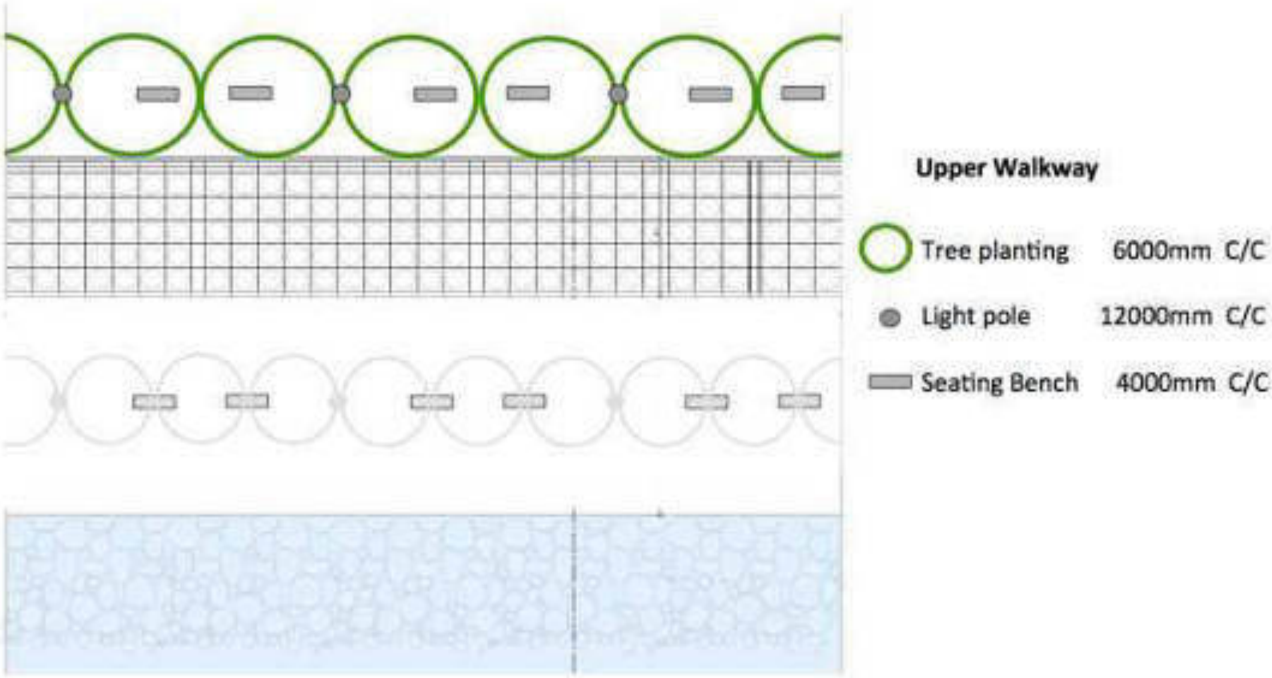


Fig. 7.50 Upper walkway street furniture (typical)

Street furniture in other site specific contexts are given below for the upper and lower walkways:

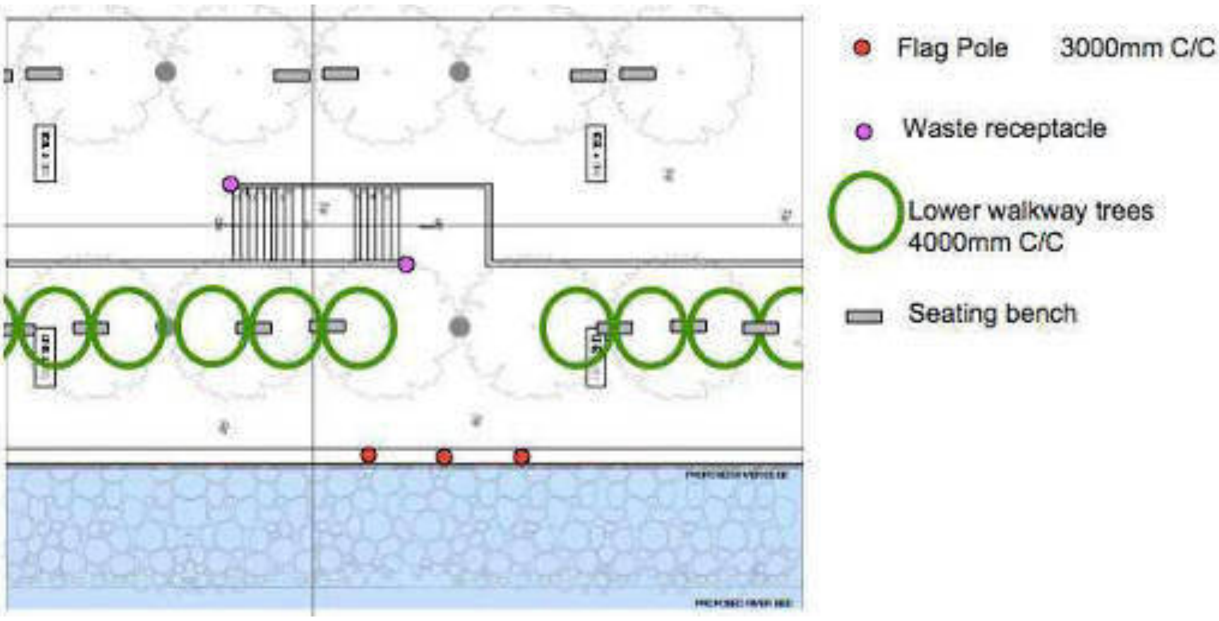


Fig. 7.51 Walkway street furniture parallel access type 1

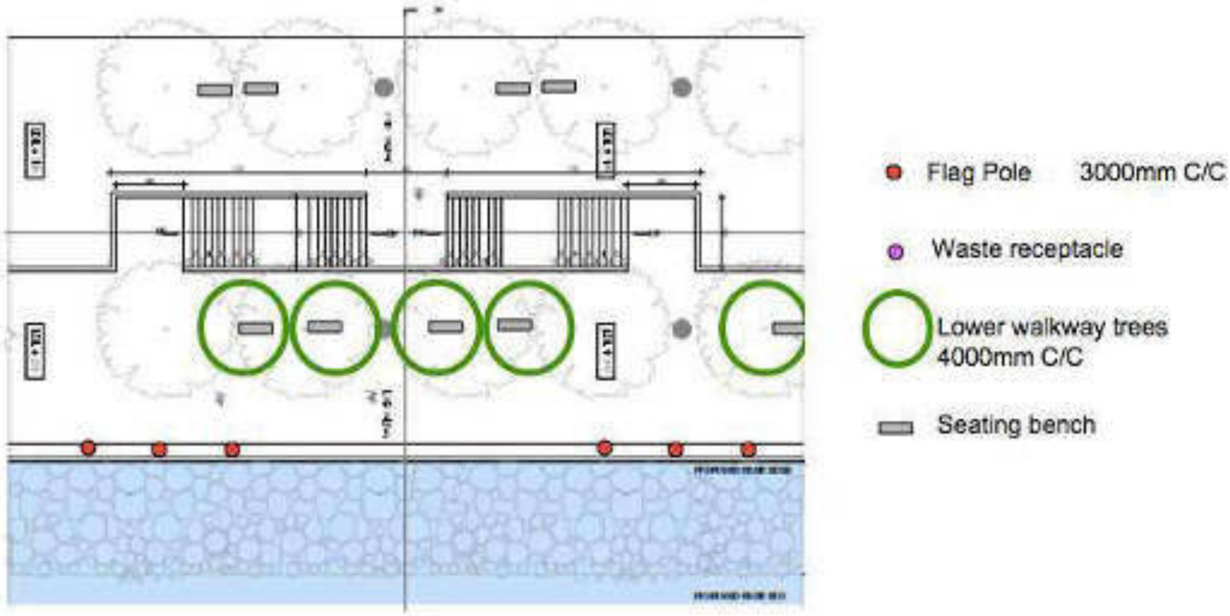


Fig. 7.52 Walkway street furniture parallel access type 2

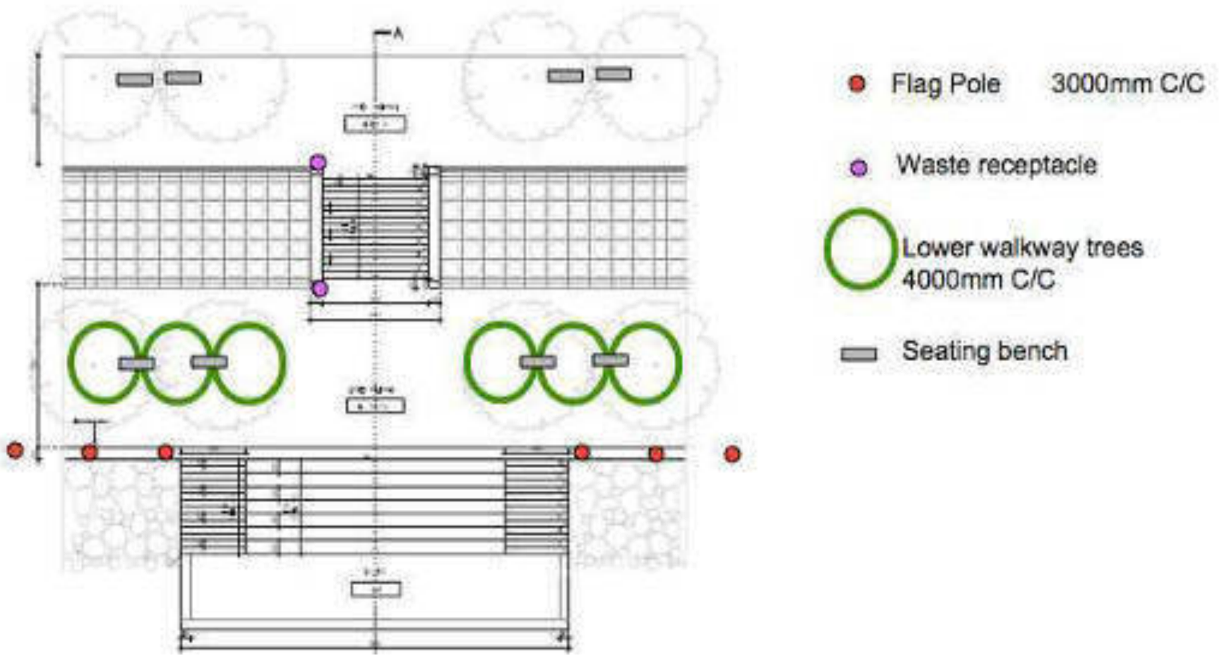


Fig. 7.53 Walkway street furniture parallel access type 3

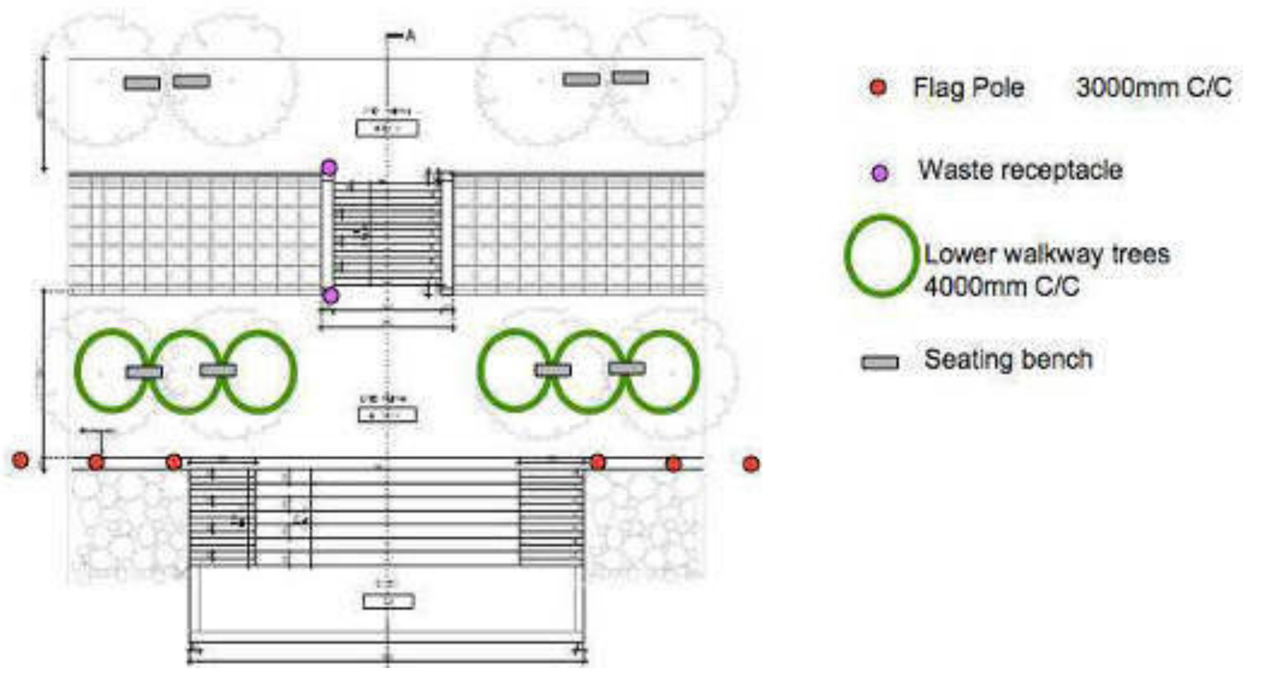


Fig. 7.54 Walkway street furniture perpendicular access.

Detailed Drawings:
Refer Drawing No- LS-PL-04

7.12 Detailed Landscape Design for the Sloped Hillsides along Highway Zone A and B

Landscape Context:
The slopes below the Phuentsholing-Samste highway forms a part of the buffer zone for the northern and eastern boundary of the proposed development. Presently the slopes are fairly random and are facing destabilization at several locations due to the road cutting and local precipitation.

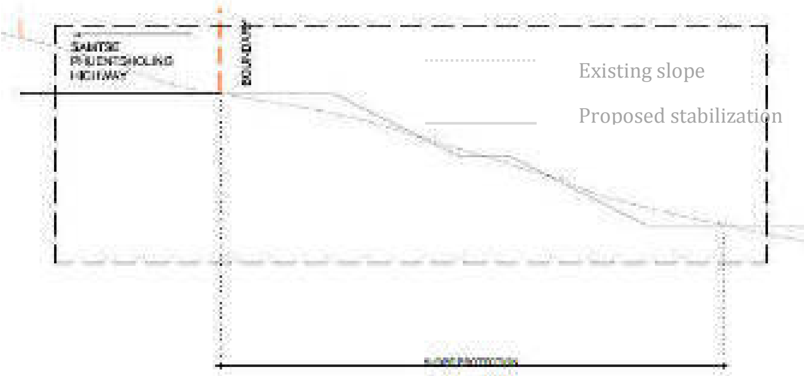


Fig. 7.55 Hill slopes requiring stabilization (plan) Fig. 7.56 Hill slopes requiring stabilization (Typical section)

Landscape Objective:
The random slopes below the Phuentsholing-Samste highway presently are unstable as evidenced by the frequent landslides in this area. The stabilization of these slopes in a sustainable manner is important to protect the proposed development. The plantation should mimic that of natural indigenous vegetation and provide a barrier against invasive alien species.

Planting Palette:

There are two sub-palettes that form the plantation in this area:

a. Plantation in the horizontal portion of the terrace

b. Plantation in the sloped portion of the terrace

The tree palette is also selected on the basis of the tree's ability to attract birds for nesting and natural pollinators like butterflies, bees and bats.

The ground cover in both the palettes will be Vetiver grass.

a. Planting Palette for the Horizontal Part of the Terrace.

It is proposed that fast growing native species with a vigorous root system be planted on the horizontal part of the terrace. This will provide a green buffer around the proposed development and at the same time prevent soil erosion. The trees will also protect the development from invasive alien species due to their thick foliage and also cyto-weedicides produced by them.

Fig. 7.57 Accasia catechu tree
Tree Ht 6-8 mts Canopy spread 4-6 mts

Accasia catechu flower

Fig. 7.58 Aegle marmelos tree
Tree Ht 6-8 mts Canopy spread 5-6 mts

Aegle marmelos flower

Fig. 7.59 Albizia gamblei tree
Tree Ht 6-8 mts Canopy spread 5-6 mts

Albizia gamblei flower

Fig. 7.60 Bischofia javanica tree
Tree Ht 8-10 mts Canopy spread 5-6 mts

Bischofia javanica flower

Fig. 7.61 Streospermun colias tree
Tree Ht 8-10 mts Canopy spread 4-6 mts

Streospermun colias flower

Fig. 7.62 Shorea robusta tree Shorea robusta flower
Tree Ht 8-10 mts Canopy spread 4-6 mts

Planting Plan for the Horizontal Portion of the Terrace:
The six species in the palette will be planted in typical grids in the flat strips of the terraced slope embankment. The planting plan takes into account the heights and canopy spread of the species and their ability to grow together as mixed canopies. The intent is to mimic their distribution in the natural environment.

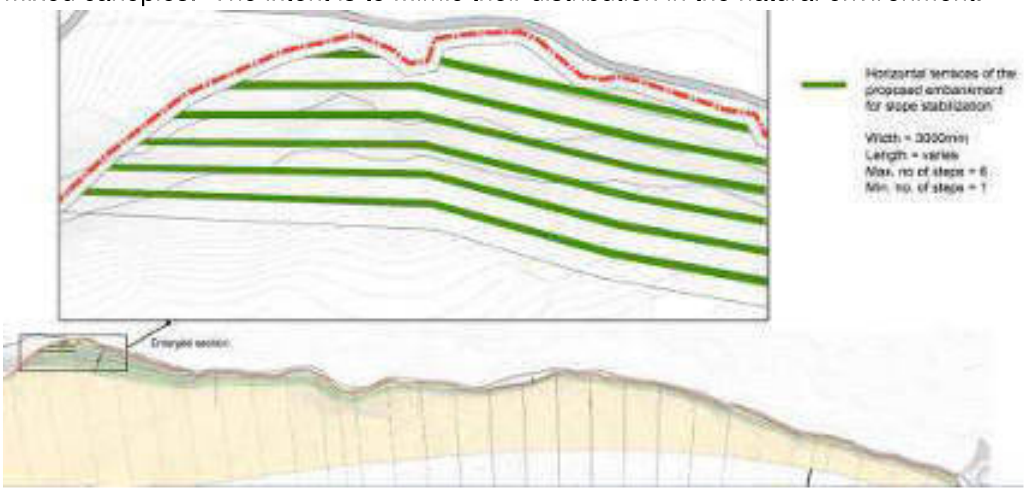
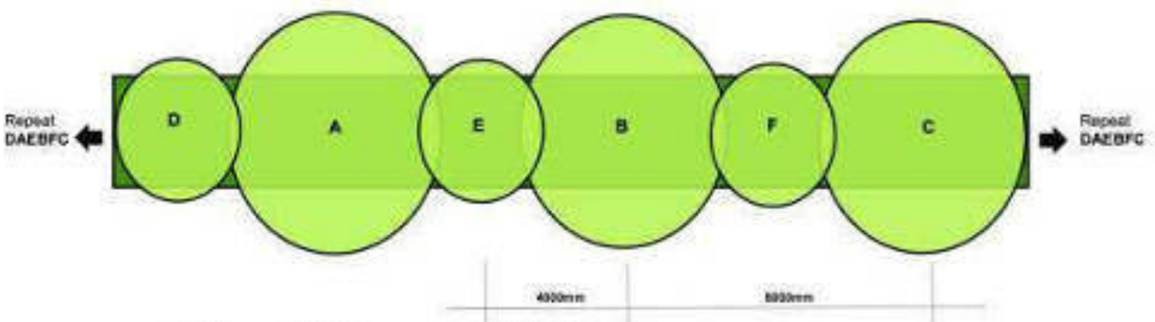


Fig. 7.63 Plan showing the horizontal terraces with enlarged section of the pla



Symbol	Species	Canopy level
A	Bischofia javanica	Higher
A	Shorea robusta	Higher
A	Streospermun colias	Higher
A	Aegle marmelos	Lower
A	Accasia catechu	Lower
A	Albizia gamblei	Lower

Fig. 7.64 Detailed Planting Plan showing repetitive planting grid.

b. Planting Palette for the Sloped Portion of the Terrace.

This palette will also have native species with vigorous root system. The shrubs here are smaller in size but planted more closely. This palette will provide further control against invasive species as well as erosion control. It will add to recreating bio-diversity and provide habitat for birds and animals.

Fig. 7.65 Bixa orellana tree
Tree Ht 4-5 mts Canopy spread 3-4 mts

Bixa orellana flower

Fig. 7.66 B Morus macroura tree
Tree Ht 4-5 mts Canopy spread 3-4 mts

Morus macroura flower

Fig. 7.67 B Premna coriacea tree
Tree Ht 4-5 mts. Canopy spread 3-4 mts

Premna coriacea flower


Fig. 7.68 B Thespesia lampas tree Thespesia lampas flower
Tree Ht 4-5 mts Canopy spread 3-4 mts


ig. 7.69 B Vitex pinnata tree Vitex pinnata flower
Tree Ht 4-5 mts Canopy spread 3-4 mts


Fig. 7.70 B Zanthoxylum armatum tree Zanthoxylum armatum flower
Tree Ht 4-5 mts Canopy spread 3-4 mts


Fig. 7.71 B Alnus nepalensis tree Alnus nepalensis flower
Tree Ht 4-5 mts Canopy spread 3-4 mts


Fig. 7.72 B Toona microcarpa tree Toona microcarpa flower
Tree Ht 4-5 mts Canopy spread 3-4 mts


Fig. 7.73 B Trema orientalis tree Trema orientalis flower
Tree Ht 4-5 mts Canopy spread 3-4 mts

Planting Plan for the Sloped Portion of the Terrace:

The six species in the palette will be planted in typical grids in the sloped parts of the terraced hill slope embankment. The species are generally small in habit with the average crown and height being 3mts.

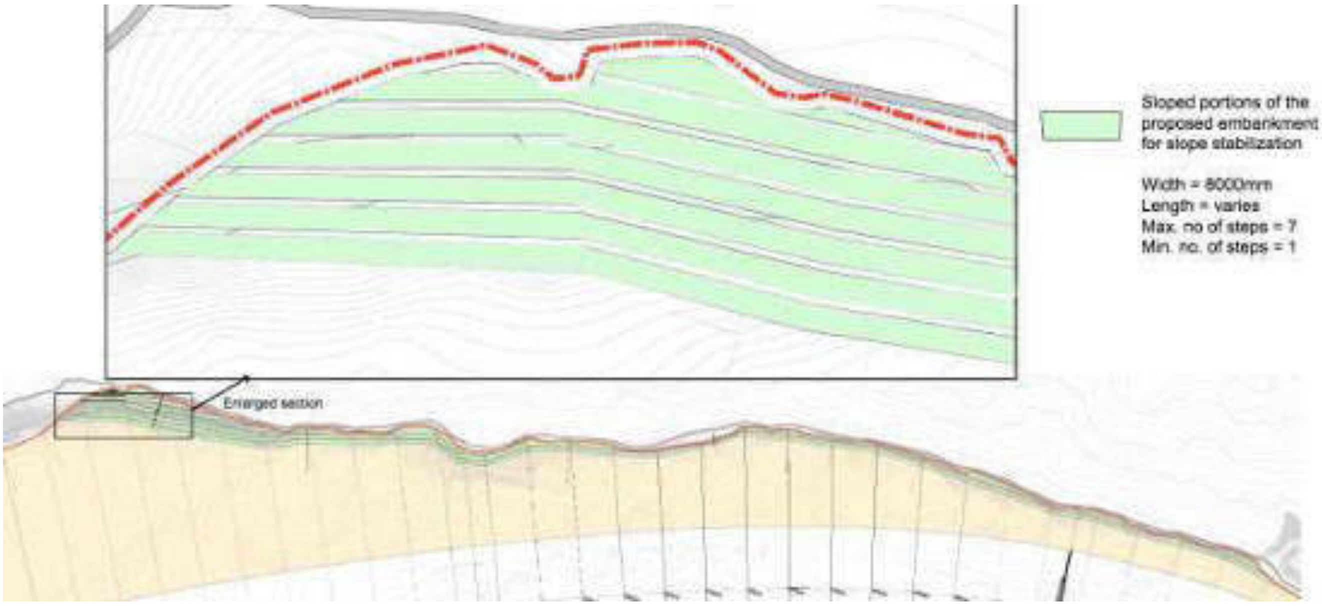


Fig. 7.74 Plan showing the horizontal portions with enlarged section of the plan

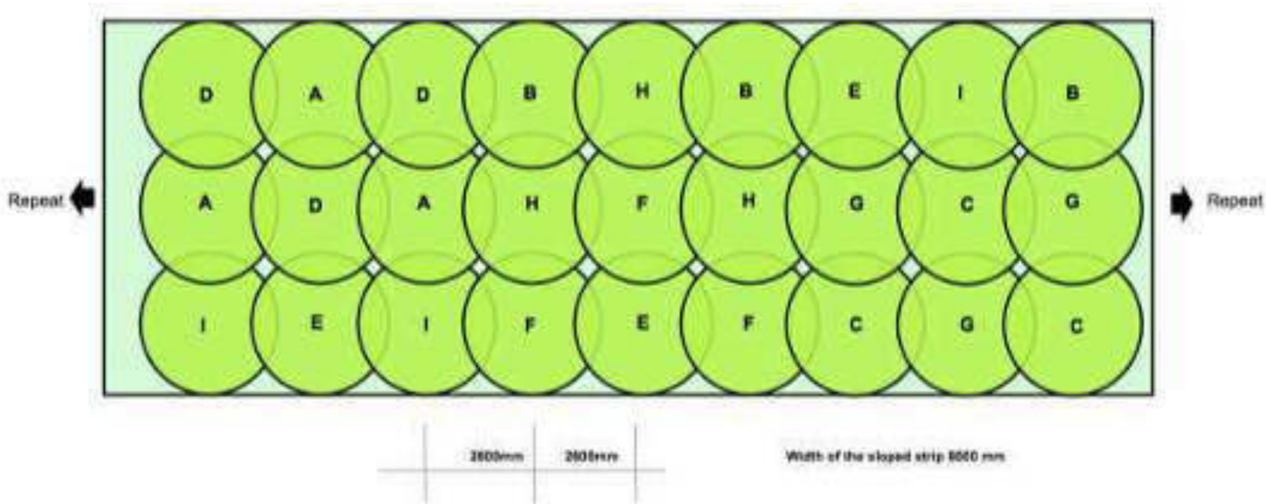


Fig. 7.75 Detailed Planting Plan showing repetitive planting grid.

Symbol	Species	Symbol	Species
A	Bixa orellana	E	Thespesia lampas
B	Morus macroura	F	Vitex pinnata
C	Trema orientalis	G	Zanthoxylum armatum
D	Premna coriacea	H	Alnus nepalensis
		I	Toona microcarpa

7.13 Detailed Landscape Design for the Urban Street Network.

The Town Masterplan has laid out a road grid that has ten different types of roads as shown below:

Fig. 7.76 Masterplan showing the various road types (Source- HCP)

The landscape treatment for each road type will be different in terms of the street design as well as the tree palette. The landscape of the road will contribute significantly to identity of road itself.

The different types of roads being considered for detailing in IDPR 2nd draft are:

i. 40 meter wide Riverfront Street
ii. 30 meter wide Main Street
iii. 24 meter wide Riverfront Street
iv. 18 meter wide Buffer Street
v. 18 meter wide Major Street
vi. 12 meter wide Local/Neighborhood Street
vii. 7.5 meter wide Service Street

i. 40 Meter Wide Riverfront Street

Landscape context:
This is the widest road in the township. It forms the main spine along the Zone C riverfront parks.

Fig. 7.77 Masterplan showing 40 mts Riverfront road

Landscape Objective:
The intent is to create an arching canopy effect with large trees having spreading crowns. A mix of local species interspersed with flowering tree will provide the necessary relief. The species that are selected have the ability to combine canopies of neighboring trees.

Fig. 7.78 Arched canopy avenue

Fig. 7.79 Rain tree (Samanea saman) avenue

Planting palette (Trees)

Fig. 7.80 Adenanthera pavonina tree
Tree Ht 8-10mts Canopy spread 6-8 mts

Adenanthera pavonina fruit

Fig. 7.81 Bombax ceiba tree
Tree Ht 8-10mts Canopy spread 5-6 mts

Bombax ceiba flower

Fig. 7.82 Cassia grandis tree
Tree Ht 8-10mts Canopy spread 6-8 mts

Cassia grandis flower

Fig. 7.83 Cassia javanica tree
Tree Ht 8-10mts Canopy spread 6-8 mts

Cassia javanica flower

Fig. 7.84 Cochlospermum vitifolium tree
Tree Ht 8-10mts Canopy spread 6-8 mts

Cochlospermum vitifolium flower


Fig. 7.85 Colvillia racemosa tree Colvillia racemosa flower
Tree Ht 8-10mts Canopy spread 6-8 mts


Fig. 7.86 Kigelia pinnata tree Kigelia pinnata flower
Tree Ht 8-10mts Canopy spread 6-8


Fig. 7.87 Melia azedarach tree Melia azedarach flower
Tree Ht 8-10mts Canopy spread 6-8 mts

Fig. 7.88 Parkia biglandulosa tree
Tree Ht 8-10mts Canopy spread 6-8 mts

Parkia biglandulosa flower

Fig. 7.89 Samanea saman tree
Tree Ht 8-12mts Canopy spread 6-10 mts

Samanea saman flower

Fig. 7.90 Swietenia mahogany tree
Tree Ht 8-10mts Canopy spread 6-8 mts

Swietenia mahogany fruit/seeds

Fig. 7.91 Terminalia Arjuna tree
Tree Ht 8-10mts Canopy spread 6-8 mts

Terminalia Arjuna fruit/seeds

Planting Palette (Shrubs):
The central median has the higher shrub in the center, flanked by medium shrubs on either side. The shrub palette is choose on the basis of compatibility for color, texture and flowers.

Tall shrubs for median center.
The purpose of these shrubs (kept trimmed to a height of 2 mts) is both aesthetic as well as to cut out the glare of oncoming headlights.

Fig. 7.92 Senna surattensisHt.

Fig. 7.93 Caesalpinea pulcherrima

Fig. 7.94 Hibiscus sp Ht. Trimmed at 2 mts

Fig. 7.95 Murraya exotica Ht. Trimmed at 2 mts

Fig. 7.96 Malpighia coccigera

Fig. 7.97 Pisonia alba

Medium shrubs for either edge of the median.
The purpose of these shrubs that are kept trimmed to a height of 1 mt is purely aesthetic

Fig. 7.98 Alamanda nerifolia Ht. Trimmed 1 mt

Fig. 7.99 Hemelia petans mini Ht. Trimmed 1 mt

Fig. 7.100 Galphimia gluaca Ht. Trimmed 1 mt

Fig. 7.101 Thurneria ulmifolia Ht. Trimmed 1 m

Landscape Planting Plan:

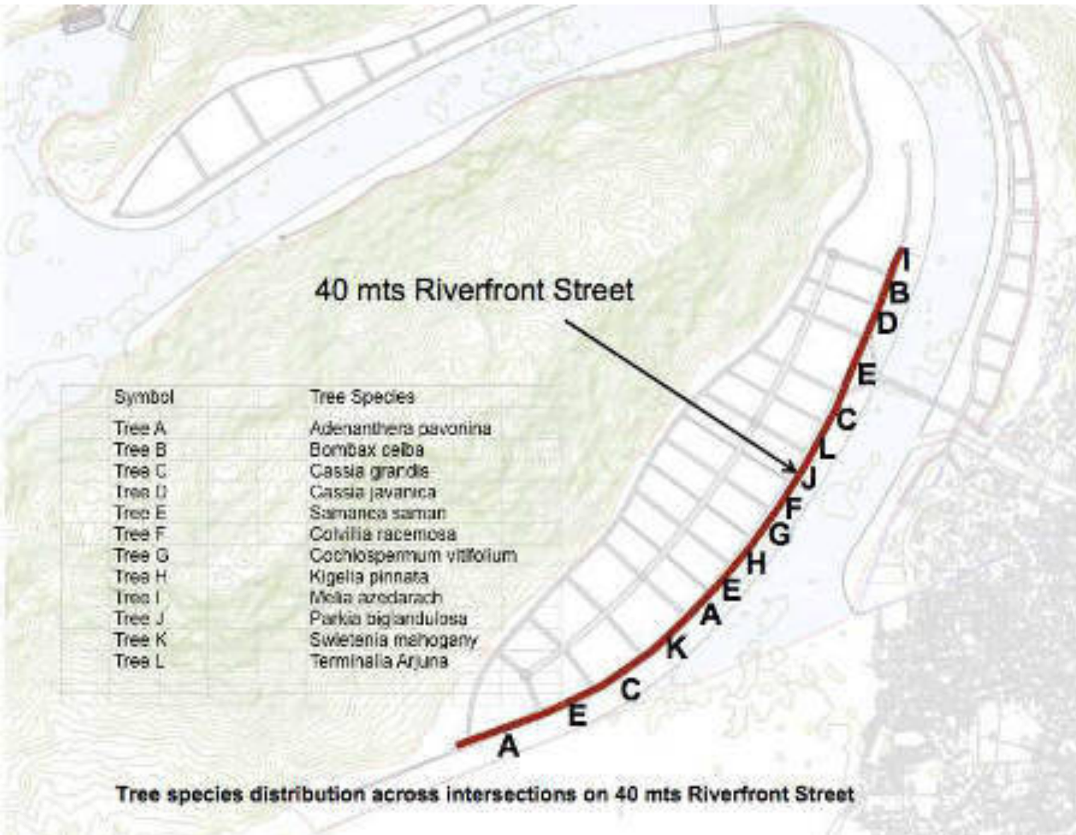


Fig. 7.102 Tree species distribution on 40 mts Riverfront Street

Fig. 7.103 Landscape Plan showing 40 mts Riverfront Street (typical)

Fig. 7.104 Landscape section showing 40 mts Riverfront Street (typical) (Source-HCP

ii. 30 Meter Wide Main Street

Landscape context:
This street is the central axis of the town in Zone C. It will be the commercial hub of the town that traverses all zones in the township.

Fig. 7.105 Masterplan showing 30 mts Main Street

Landscape Objective:
The intent is to create a slightly more business district look to the tree-scape using more upright canopies. The Trees will provide shade in the summer months but allow filtered sunlight to come through in the cold winter months. The intent is to create a mix of flowering and evergreen species.


Fig. 7.106 Avenue intent showing use of more upright tree species.

Planting Palette (Trees):


Fig. 7.107 Adenanthera pavonina tree
Tree Ht 8-10mts Canopy spread 6-8 mts

Adenanthera pavonina fruit

Fig. 7.109 Swietenia mahogany tree

Tree Ht 8-10mts Canopy spread 6-8 mts

Swietenia mahogany fruit/seeds

Fig. 7.110 Alstonia scholaris tree

Tree Ht 6-8mts Canopy spread 4-6 mts

Alstonia scholaris Flower

Fig. 7.111 Bombax ceiba tree

Tree Ht 8-10mts Canopy spread 5-6 mts

Bombax ceiba flower

Fig. 7.112 Tababuia rosea tree Tabebuia rosea flower
Tree Ht 8-10mts Canopy spread 5-6 mts

Fig. 7.113 Mimosops elengi tree Mimosops elengi flower
Tree Ht 8-10mts Canopy spread 5-6 mts

Shrub Palette:
The central median has only tall flowering shrubs for aesthetics and blocking the glare from oncoming headlights.

Fig. 7.114 Tabernaemontana coronaria Ht. Trimmed 2 m

Fig. 7.115 Malpighia coccigera Ht. Trimmed 2

Fig. 7.116 Hemelia petans Ht. Trimmed 2 m

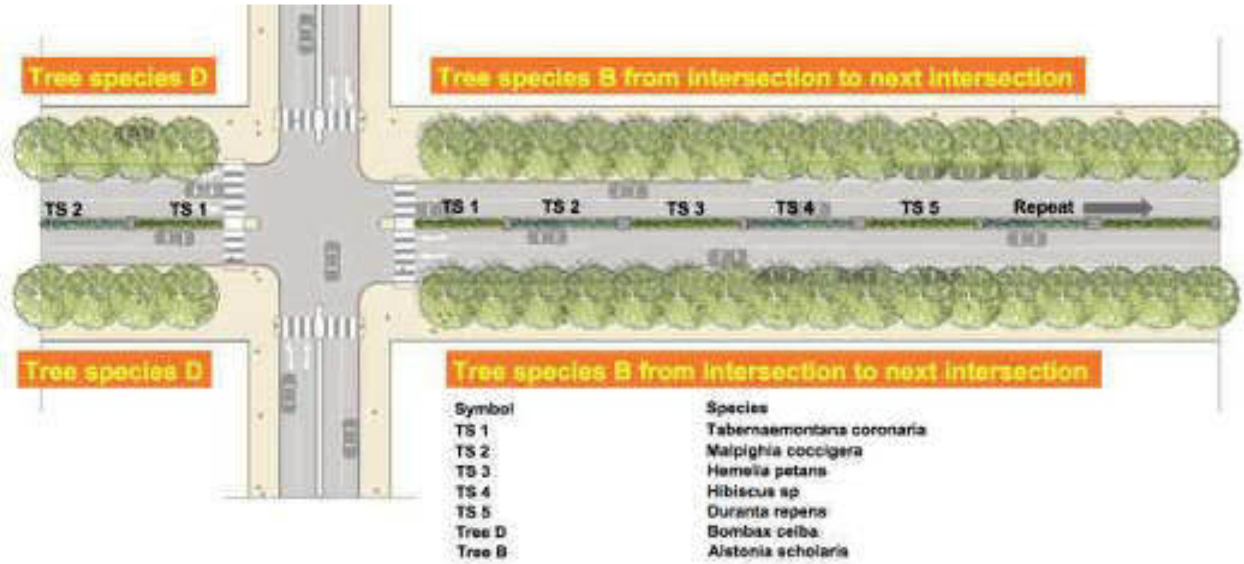
Fig. 7.117 Hibiscus sp. Ht. Trimmed 2 mt

Fig. 7.118 Duranta repens Ht. Trimmed 2 m

Landscape Planting Plan:

Symbol	Tree species
A	Adenanthera pavonina
B	Bombax ceiba
C	Swietenia mahogany
D	Alstonia scholaris
E	Mimosops elengi
F	Alstonia scholaris
G	Tababuia rosea

Fig. 7.119 Tree species distribution on 30 mts Main Street



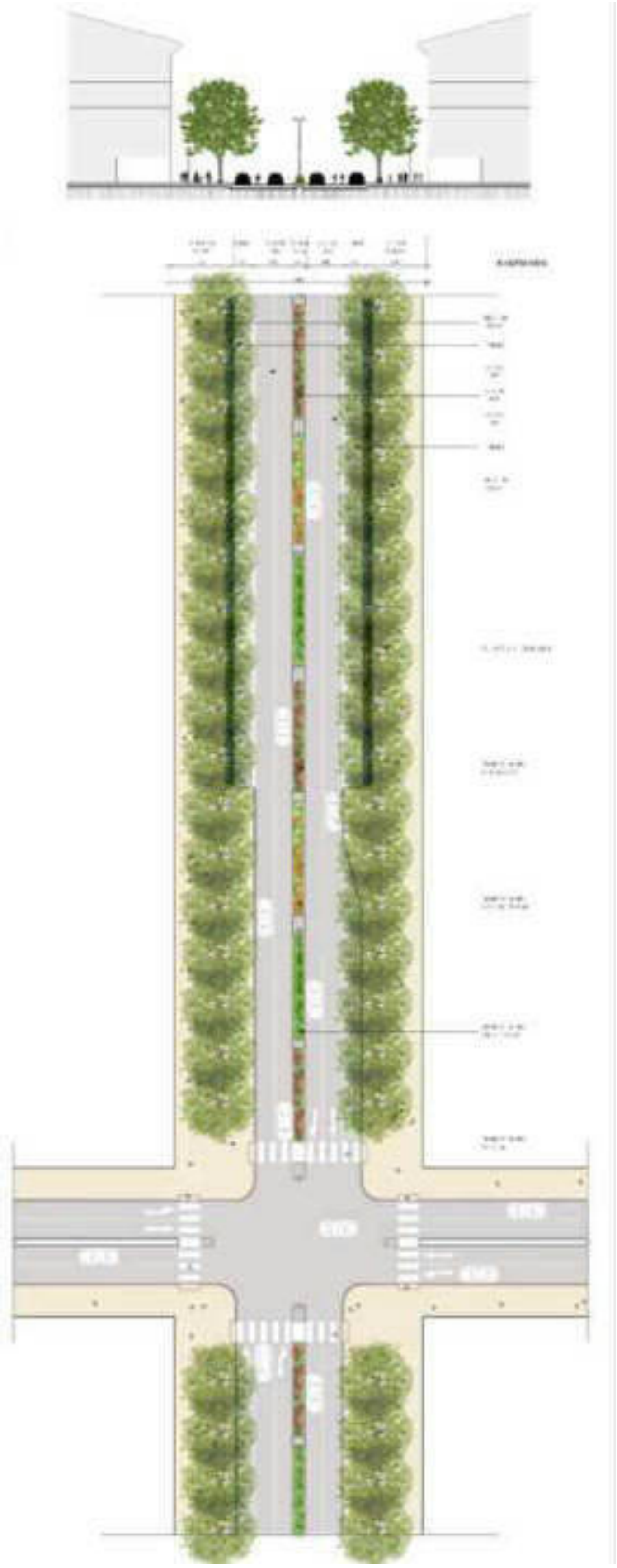


Fig. 7.120 Landscape Plan showing 30 mts Main Street (typical) (Source-HCP)

iii. 24 Meter Wide Riverfront Street

Landscape Context:
This road forms the main spine along the Zone B and Zone A Riverfront parks.

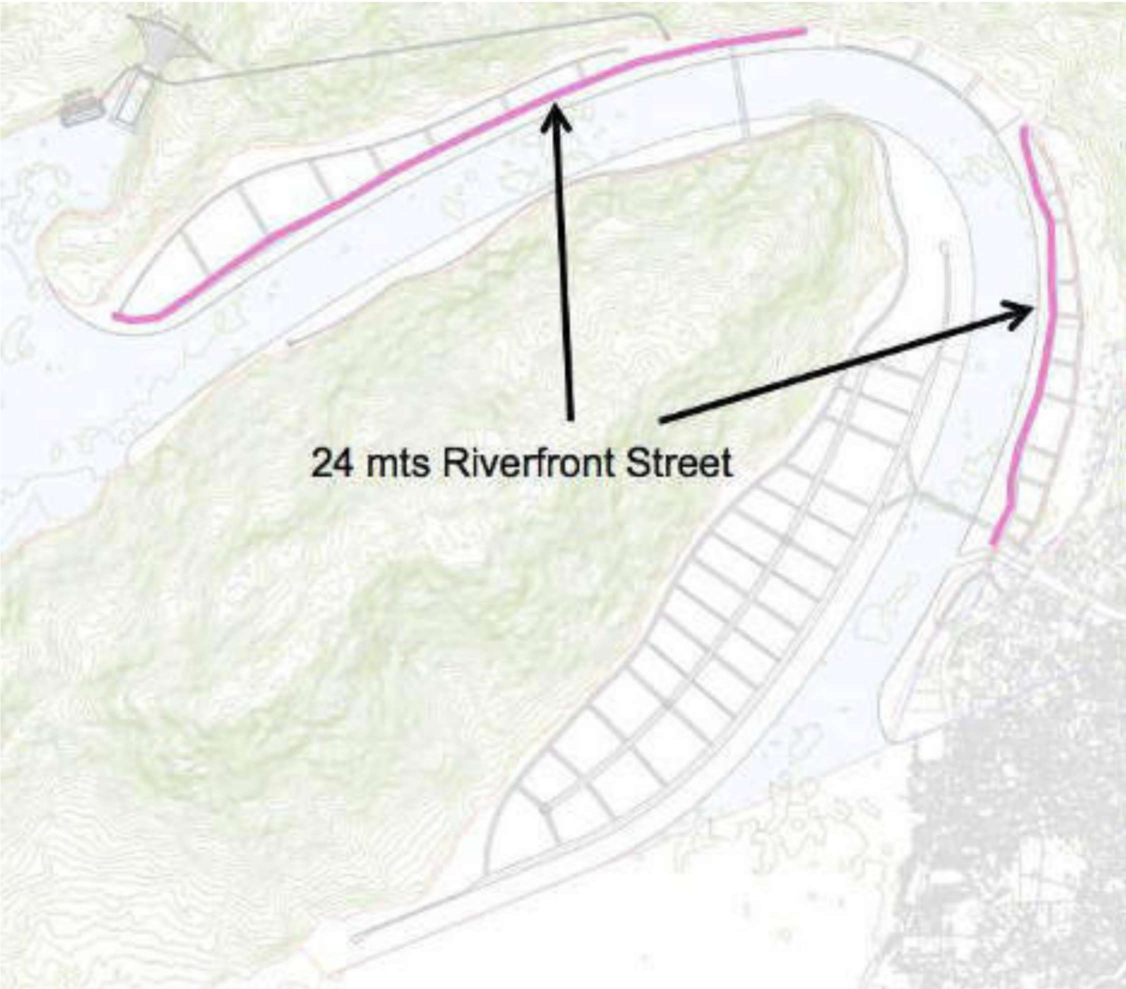


Fig. 7.121 Masterplan showing 24 mts Riverfront Street

Landscape Objective:
The aim is to generally mirror the intent of the 40 mts Riverfront Street of Zone C. The intent is to create an arching canopy effect with large trees having spreading crowns. A mix of local species interspersed with flowering tree will provide the necessary relief. The species that are selected have the ability to combine canopies of neighboring trees.

Planting Palette (Trees):

Fig. 7.122 Adenanthera pavonina tree
Tree Ht 8-10mts Canopy spread 6-8 mts

Adenanthera pavonina fruit

Fig. 7.123 Bombax ceiba tree
Tree Ht 8-10mts Canopy spread 5-6 mts

Bombax ceiba flower

Fig. 7.124 Cassia grandis tree
Tree Ht 8-10mts Canopy spread 6-8 mts

Cassia grandis flower


Fig. 7.125 Cochlospermum vitifolium tree
Tree Ht 8-10mts Canopy spread 6-8 mts

Cochlospermum vitifolium flower


Fig. 7.126 Colvillia racemosa tree
Tree Ht 8-10mts Canopy spread 6-8 mts

Colvillia racemosa flower


Fig. 7.127 Kigelia pinnata tree
Tree Ht 8-10mts Canopy spread 6-8 mts

Kigelia pinnata flower

Fig. 7.128 Melia azedarach tree
Tree Ht 8-10mts Canopy spread 6-8 mts

Melia azedarach flower

Fig. 7.129 Parkia biglandulosa tree
Tree Ht 8-10mts Canopy spread 6-8 mts

Parkia biglandulosa flower

Fig. 7.130 Samanea saman tree
Tree Ht 8-12mts Canopy spread 6-10 mts

Samanea saman flower


Fig. 7.131 Swietenia mahogany tree
Tree Ht 8-10mts Canopy spread 6-8 mts

Swietenia mahogany fruit/seeds


Fig. 7.132 Terminalia Arjuna tree
Tree Ht 8-10mts Canopy spread 6-8 mts

Terminalia Arjuna fruit/seeds

Landscape Planting Plan:

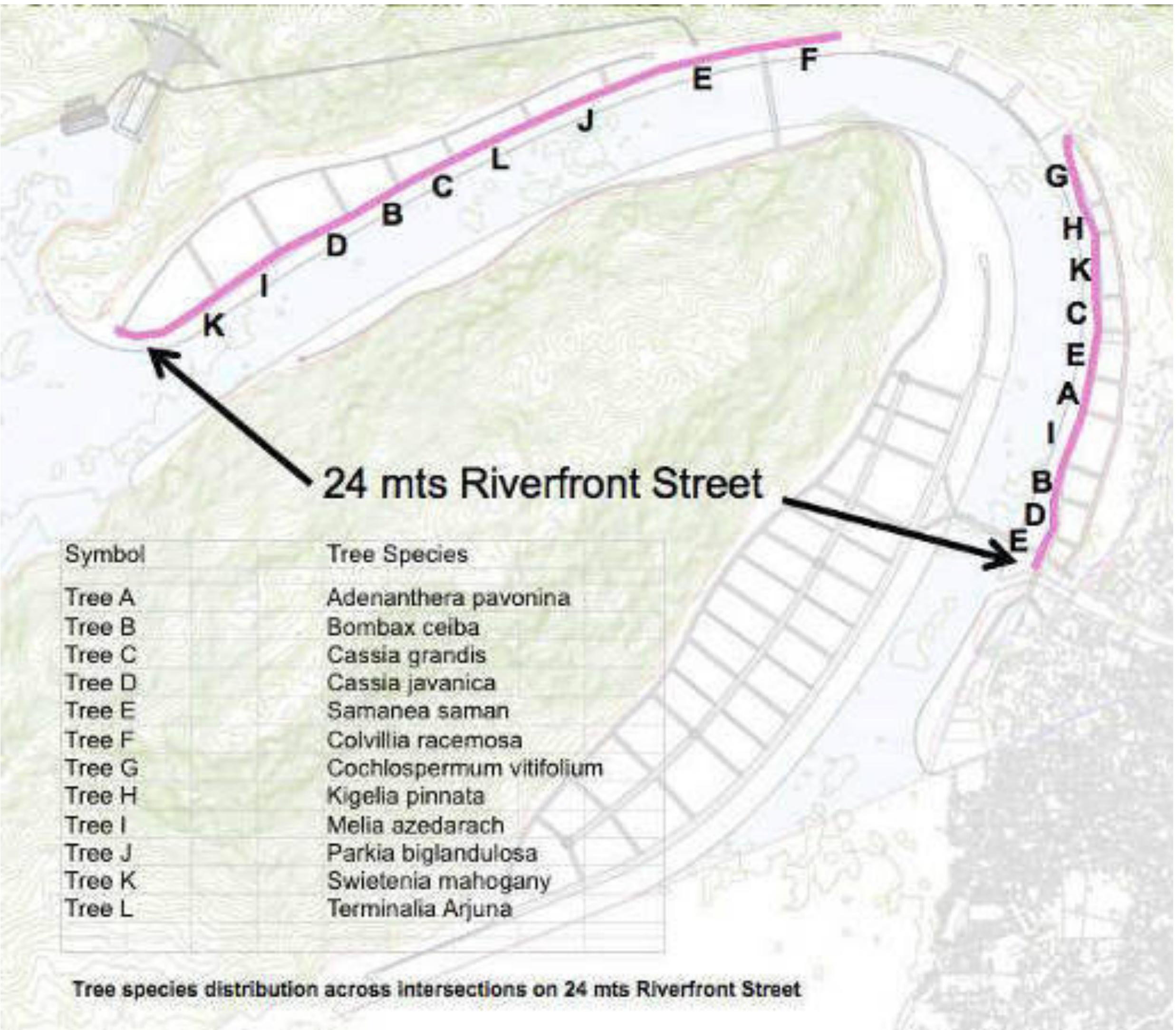
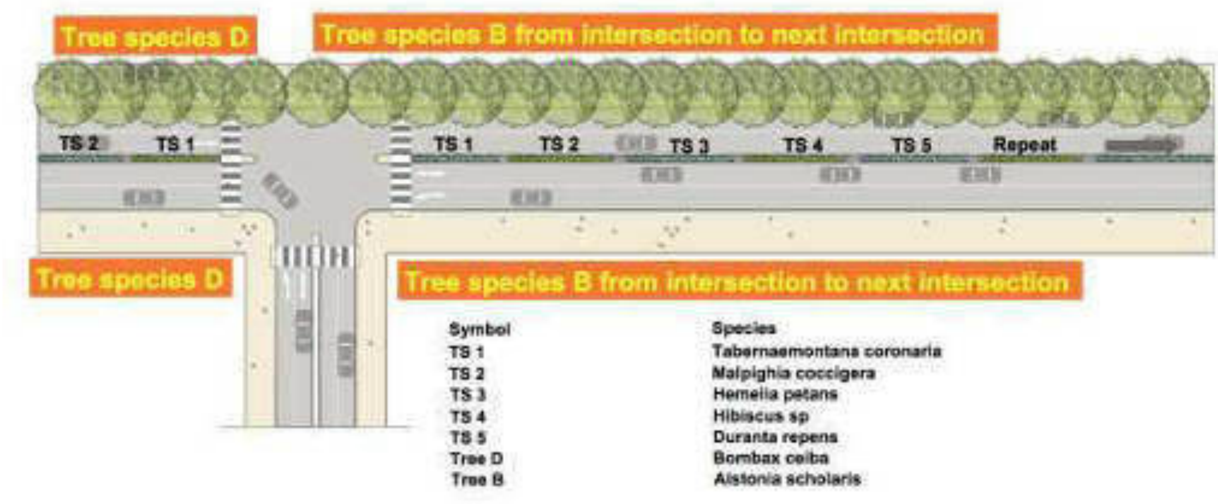


Fig. 7.133 Tree species distribution on 24 mts Riverfront Street



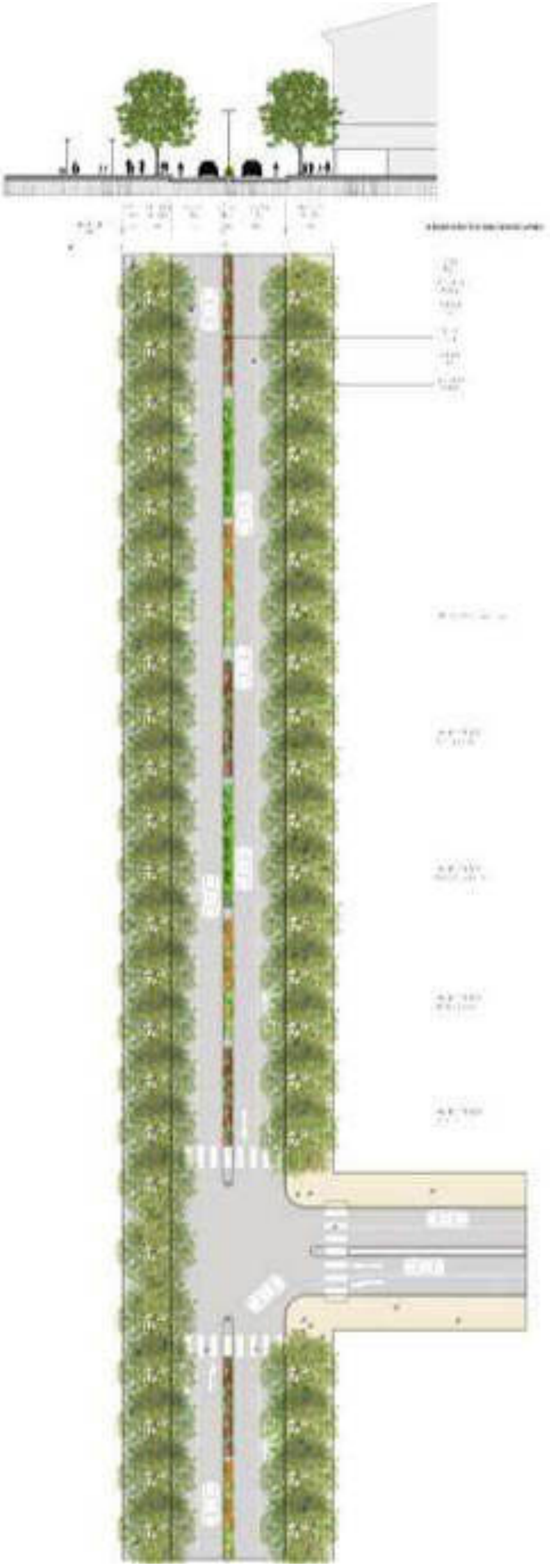


Fig. 7.134 Landscape Plan showing 24 mts Riverfront Street (typical) Source-HCP

iv. 18 Meter Wide Type 1 and Type 2 Main Streets

Landscape Context:
These form the internal road network for the township.

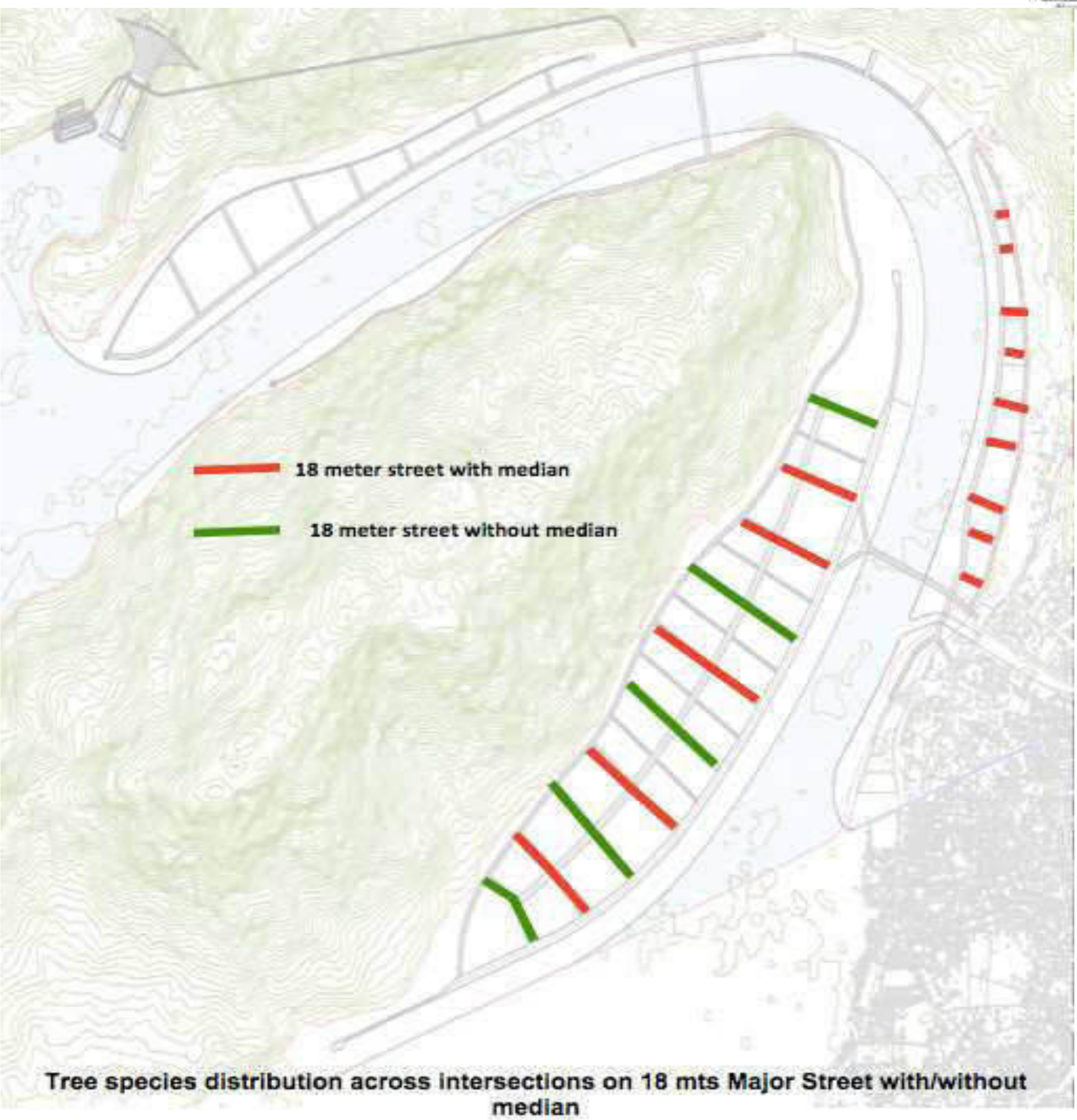


Fig. 7.135 Landscape Plan showing 18 mts Main and Neighborhood Streets

Landscape Objective:
These streetsgive character to the neighborhoods. The intent is to create an canopies with medium spread that have a profusion of flowers. The species that are selected have the ability to combine canopies of neighboring trees. The selection of the trees species allows for flowering to be staggered in such a way that there some flower always at any given time of the year.

Planting Palette:

Fig. 7.136 Delonix regia tree
Tree Ht 6-8mts Canopy spread 6-8 mts

Delonix regia flower

Fig. 7.137 Bauhinia blakeana tree
Tree Ht 6-8mts Canopy spread 6-8 mts

Bauhinia blakeana flower

Fig. 7.138 Brownea ariza tree
Tree Ht 6-8mts Canopy spread 6-8 mts

Brownea ariza flower

Fig. 7.139 Colvillia racemosa tree

Colvillia racemosa flower

Tree Ht 6-8mts Canopy spread 6-8 mts

Fig. 7.140 Lagerstroemia indica tree Lagerstroemia indica flower

Tree Ht 6-8mts Canopy spread 6-8 mts

Fig.7.141 Michelia champaca tree Michelia champaca flower

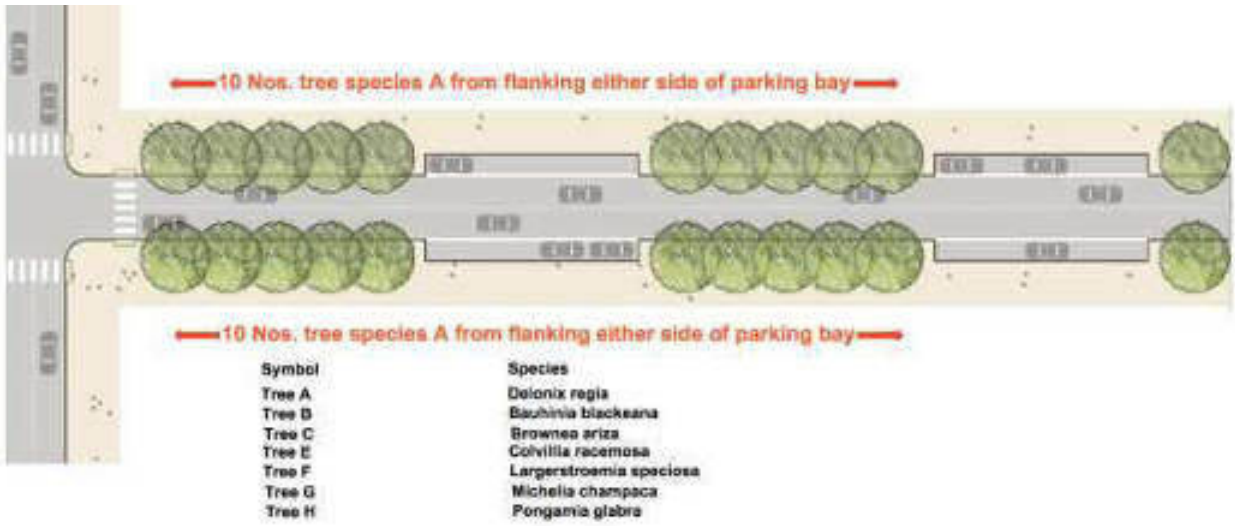
Tree Ht 6-8mts Canopy spread 6-8 mts

Fig. 7.142 Pongamia pinnata tree Pongamia pinnata flower

Tree Ht 6-8mts Canopy spread 6-8 mts

Landscape Planting Plan for 18m road without Median Type 2 Main Street:

These neighborhood streets are lined with tree avenues punctuated with parking bays. The design envisages six species of trees that are placed sequentially very 60 mts or ten trees in a stretch.



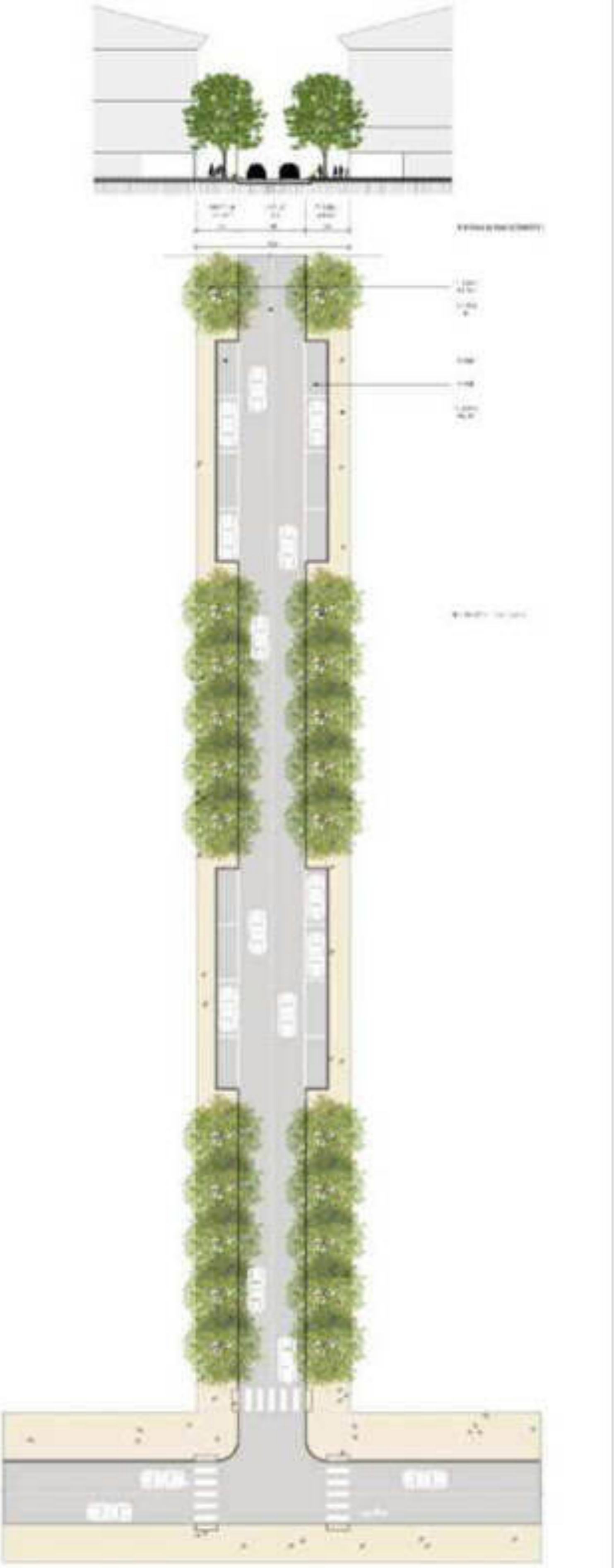
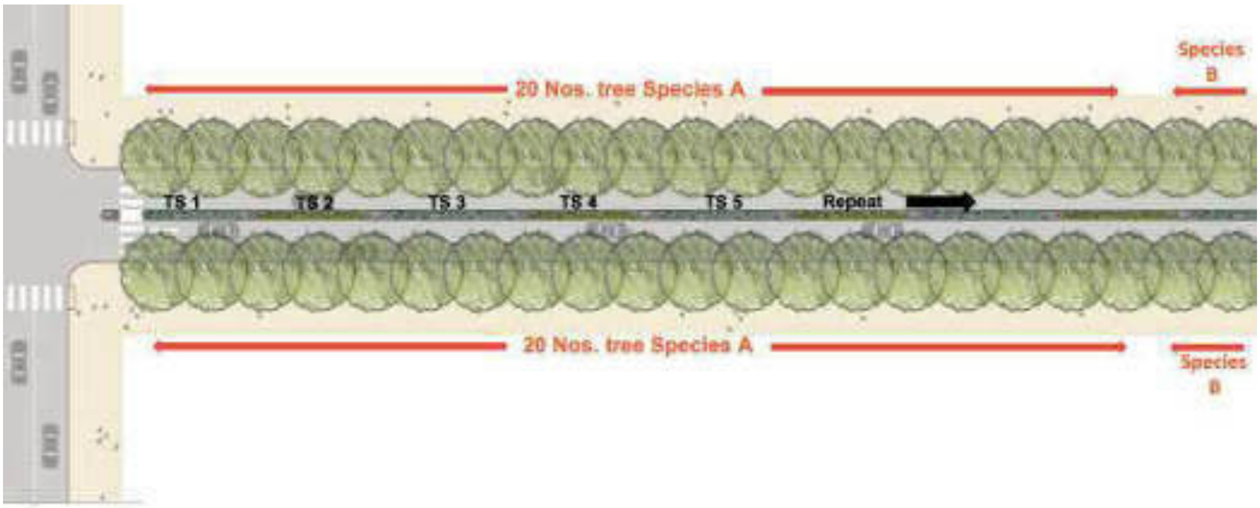


Fig. 7.143 Landscape Plan showing 18 mts Type 2 Main Street (Source-HCP)
As can be seen from the palette, the trees selected are more or less of similar habit. They are all flowering in nature and the selection ensures that at least one species will be flowering at any given time of the year.

Landscape Planting Plan for 18m road with Median Type 1 Main Street:



Symbol	Species
TS 1	**Tabernaemontana coronaria**
TS 2	**Malpighia coccigera**
TS 3	**Hemelia petans**
TS 4	**Hibiscus sp**
TS 5	**Duranta repens**
Tree A	**Delonix regia**
Tree B	**Bauhinia tomentosa**

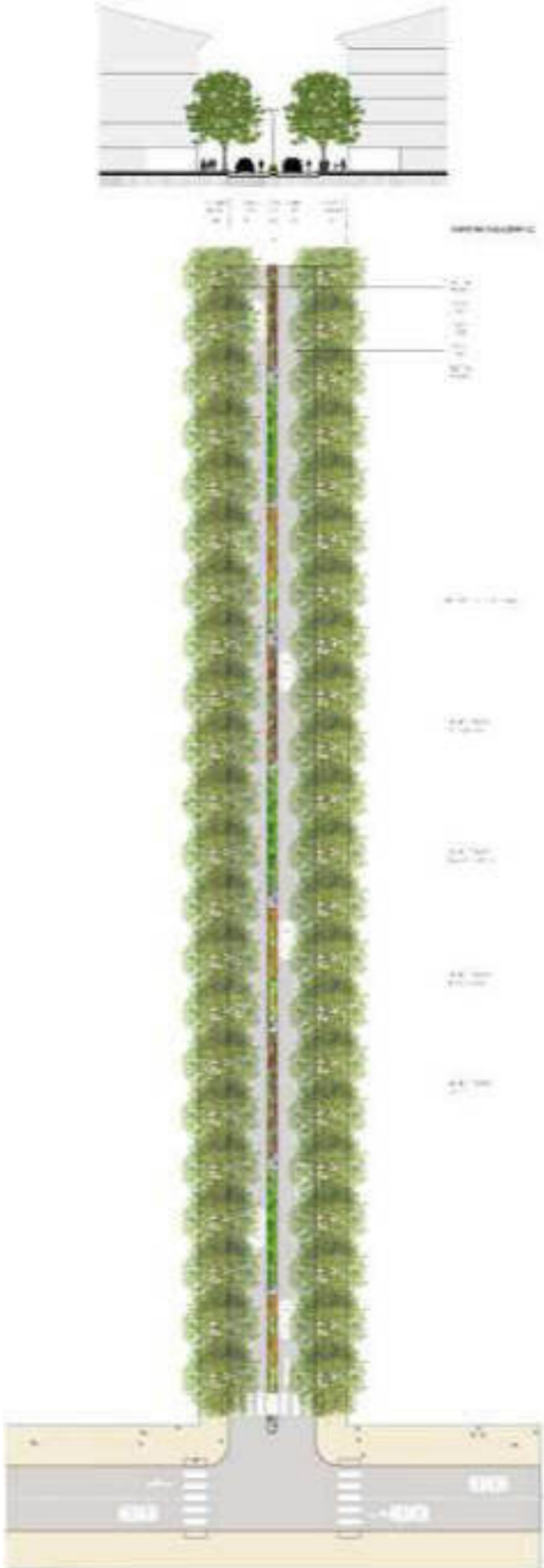


Fig. 7.144 Landscape Plan showing 18 mts Type 1 Main Street (Source-HCP)

Detailed drawings:

Drawing links- SN-PL-02
ST-LP-01
ST-LP-02
ST-LP-03
ST-LP-04
ST-LP-05

Appendix 1 List of Tables

Appendix 2 List of Figures

	Appendix 2 Table 1.1		
Sl. No	Tree Species found in the Phuentsholing valley		
1		59	Tamarindus indicua
2	Dellenia pentagyna	60	Carallia brachiata
3	Magnolia insignis	61	Anogeissus acuminata
7	Crateva religiosa	62	Terminalia alata
8	Crateva uniloculars	63	Terminallia bellerica
9	Bixa orellana	64	Terminalia crinat
10	Casearia graveolens	65	Callistemmon citrinus
14	Callophylum polyanthum	66	Syzygium formosum
15	Garcinia xanthochymus	67	Syzygium jambol
16	Mesua floribunda	68	Careya arborea
17	Saurauia macrotiricha	69	Lagerstromia parviflora
18	Saurauia roxburghii	70	Daubanga grandiflora
19	Shorea robusta	71	Tetrameles nudiflora
20	Thespesia lampas	72	Mastixia arborea
21	Bombax ceiba	73	Tamilnadia ulignosa
22	Eriolaena candollei	74	Wenlandia coriacea
23	Firmiana flugens	75	Mimusops elengi
24	Pterygota alata	76	Ligustrum robustum
25	Sterculia hamiltonii	77	Nyctanthes arbor-tristis
26	Sterculia roxburghii	78	Olea dioica
27	Sterculia villosa	79	Alstonia scholaris
28	Grewia abutifolia	80	Holarrhena pubescens
29	Grewia rothii	81	Plumeria rubra
30	Grewia serrulata	82	Fagrea obovata
31	Aegle marmelos	83	Ehretia laevis
32	Micromelum integerrimum	84	Solanum erianthum
33	Murraya koenigii	85	Rhynchotechum ellipticum
34	Murraya paniculata	86	Streospermun colias
35	Tetradium glabrifolium	87	Phlogacanthus thyrsiflorus
36	Zanthoxylon armatum	88	Premna coriacea
37	Garuga pinnata	89	Premna bracteata
38	Aglaia spectabilis	90	Vitex pinnata
39	Chukrasia tabularis	91	Vitex peduncularis
40	Dysoxylum mollissimum	92	Horsfieldia kingii
41	Toona microcarpa	93	Knema erratica
42	Ilex godajam	94	Cinnamonum glaucescens
43	Bhesha robusta	95	Litsea monopetala
44	Hovenia acerba	96	Neocinnamonum caudatum
45	Lepisanthes rubignosa	97	Phobe attenuata
46	Choerospondias axillaris	98	Bischofia javanica
47	Semecarpus anacardium	99	Bridelia tomentosa
48	Spondias pinnata	100	Croton caudatus
49	Accacia catechu	101	Drypetes subsessilis
50	Avvacia lenticularis	102	Endospermum chinense
51	Albizia gamblei	103	Glochidion nubigenum
52	Albizia lebbeck	104	Lasiococca symphyllifolia
53	Bauhinia malabarica	105	Trema orientalis
54	Bauhinia purpurea	106	Broussonetia papyrifera
55	Bauhinia varigata	107	Ficus racemosa
56	Butea monosperma	108	Morus macroura
57	Dalbergia latifloia	109	Alnus nepalensis
58	Erythrina stricta	110	Caryota urens
		111	Bambusa balcooa

List of invasive alien species sighted in the Buffer Zone			
1	**Cardamine flexuosa**	Herb, commonly found in damp, recently disturbed soil and wasteplaces. These conditions are prevalent in nursery or garden centre plants, and hairy bittercress seeds may be introduced with those plants. Once established, particularly in lawn areas, it is difficult to eradicate. It is an annual or biennial plant. Difficult to eradicate once established.	
2	**Commelina benghalensis**	Commelina benghalensis can be an annual or perennial herb.. Believed to be native only to tropical Asia and Africa, Commelina benghalensis is a widely distributed herbaceous weed that commonly invades agricultural sites and disturbed areas. Though not commonly reported to invade natural areas, this rapidly reproducing plant is considered one of the most troublesome weeds for 25 crops in 29 different countries.	

3	**Chromolaena odorata**	C. odorata is a very widely distributed tropical shrub that is still expanding its range, and is considered one of the world's worst weeds. It continues to spread due to its effective short- and long-distance dispersal. It can form pure stands where established, often in disturbed areas, grasslands, fallow areas and forestry plantations, and is highly competitive. It is viewed as a major environmental weed, but is appreciated by some agriculturalists as it shortens fallow time in shifting cultivation.	
4	**Lantana camara**	Considered by IUCN as one of the world's 100 most invasive species, and among the world's 10 worst weeds, Lantana grows on all types of well-drained soils and in a wide rainfall range (from seasonal dry forests to rainforest) but is also very drought-resistant. It rarely invades undisturbed, closed-canopy forest but rapidly colonizes gaps, edges and disturbed or logged habitats. It can become the dominant understorey species in infested areas blocking natural succession processes, and reducing biodiversity.	

5	**Melilotus alba**	Melilotus alba is an annual to biennial herb that can grow from 3-8 ft. (0.9-2.4 m) tall. It is part of an invasive community of exotics, which require special management to restrict growth and encourage the reestablishment and recovery of the native grassland habitats. It easily invades open areas and may compete for resources with native species or indirectly affect the grassland habitats by altering edaphic conditions.	
6	**Caesalpinia decapetala**	Mysore thorn (Caesalpinia decapetala) originates from tropical and eastern Asia but is now a serious weed in many locations such as Himalayan foothills, where it has the capability to take over large areas of agricultural land, limiting animal movement. This sprawling, thorny and noxious shrub also invades forest margins, smothering native vegetation. This robust thorny evergreen shrub grows from two to four meters high or climbs to 10 meters or higher. It often forms dense thickets. The stems are covered with minute golden-hair and thorns which are straight or hooked, numerous and not in regular rows or confined to nodes.	

7	**Senegalia catechu**	Listed as on of the invasive trees in Bhutan, Senegalia catechu is a deciduous, thorny tree which grows up to 15 m (50 ft) in height. Extremely hardy and adaptable, this tree will very qiuckly soils that range from sandy to clay. Although very useful, this tree is considered invasive because it overtakes native trees in disturbed areas.	
8	**Mikania micrantha**	Mikania micrantha is a neotropical fast growing vine that has become a major weed in SE Asia and the Pacific during the latter part of the 20th century. It is still extending its range but a major effort to find biological control agents is under way. Once established it smothers native vegetation including native trees and is a weed of various crop systems. In Phuntsholing valley, this is a serious threat choking trees even upto 800m altitudes.	
9	**Imperata cylindrica**	I. cylindrica is a serious weed not only in crops but also in natural areas, causing serious economic and environmental damage. The ability of I. cylindrica to effectively compete for water and nutrients, spread and persist through the production of seeds and rhizomes that can survive a wide range of environmental conditions, and its allelopathic effects and pyrogenic nature, allow it to exclude native plant species and other desirable plants and	

		dominate large areas of land.	

Appendix 2 Table 1.3 Estimate of Outflows

Stream	Catchment Area in Ha.	Runoff from the premises on rainfall intensity			Proposed Area of the Retention Pond in Sq. M.
		30mm / hr	50mm/hr	75 mm/hr	
C 1	59.00	5752.96	9588.27	14382.40	3844.00
C 2	34.00	3315.27	5525.44	8288.16	2304.00
C 3	28.00	2730.22	4550.36	6825.55	1936.00
C 4	21.00	2047.66	3412.77	5119.16	1444.00
C 5	12.00	1170.09	1950.16	2925.23	802.78
C 6	15.00	1462.62	2437.70	3656.54	1024.00
C 7	26.00	2535.20	2535.20	6338.01	1764.00
C 8	35.00	3412.77	5687.96	8531.93	2304.00
C 9	24.00	2340.19	3900.31	5850.47	1600.00

Appendix 2 Table 1.4 Top soil analysis Zone C

Sr. No	Parameter	Unit	S1	S2	S3	S4	S5	S6
1	Porosity	%	45	37	41	47	50	51
2	Water Holding Capacity	%	39.23	36.71	37.26	42.61	43.95	45.40
3	Permeability	mm/hr	41.4	62.3	48.6	36.4	28.1	20.2
4	Particle Size Distribution							
a	Sand	%	81.12	97.84	90.56	77.12	66.18	56.84
b	Silt	%	1.72	0.00	0.00	18.72	14.28	22.28
C	Clay	%	17.16	2.16	9.44	9.16	19.44	20.88
5	Texture	--	Loamy sand	Sandy	Sandy	Loamy sand	Sandy loam	Sandy loam
6	Bulk Density	g/cm^3	1.28	1.26	1.28	1.27	1.43	1.05
7	Cation Exchange capacity	meq/100gm	8.08	6.02	7.60	8.90	12.30	5.60
8	Electrical Conductivity	dS/m	0.174	0.116	0.128	0.174	1.620	0.148
9	Exchangeable Sodium	%	<0.1	<0.1	0.37	0.58	<0.1	<0.1
10	pH		7.12	6.95	7.15	7.48	6.01	6.69
11	OC(Organic carbon)	%	0.15	0.41	0.24	0.85	0.82	1.41
12	Total-N	Kg/ha	296	799	479	1650	1581	2876
13	Available-P_2O_5	Kg/ha	10.11	7.90	6.10	9.70	14.10	23.20
14	Available-K_2O	Kg/ha	75	49	76.20	51.20	62.22	81.33
15	Calcium	g/kg	0.13	0.05	0.19	0.22	0.48	0.13
16	Magnesium	g/kg	0.55	0.21	0.22	0.25	0.87	0.12
17	Sodium	g/kg	0.37	0.26	0.43	0.52	0.31	0.31
18	Potassium	g/kg	0.01	0.01	0.01	0.07	0.01	0.02

Appendix 2 Table 1.5 Endangered **trees species sighted on Kaileshwar Hill**

Sl No.	Species	Sl No.	Species
1	Tetrameles nudiflora	7	Knema erratica
2	Olea dioica	8	Litsea monopetala
3	Saurauia roxburghii	9	Tetradium glabrifolium
4	Ehretia laevis	10	Wenlandia coriacea
5	Chukrasia tabularis	11	Casearia graveolens
6	Phlogacanthus thyrsiflorus	12	Rhynchotechum ellipticum

Representative list of endangered trees sighted at Kaileshwar Hill. (Source: 1. Chettri, N, Sharma, E., Shakya, B., Thapa, R., Bajracharya, B., Uddin, K., Oli, K.P., & Choudhury, D. 2010: Biodiversity in the Eastern Himalayas; Status, Trends and Vulnerability to Climate Change: Climate Change Impact and Vulnerability in the Eastern Himalayas- Technical Report 2, ICIMOD. 2. Field observations)

Appendix 2 Table 1.6 Tree species for Buffer Zone planting

Tree species for Buffer Zone planting			
1	Dillenia indica	32	Tamarindus indicua
2	Crateva unilocularis	33	Terminalia alata
3	Bixa orellana	34	Terminallia bellerica
4	Casearia graveolens	35	Terminalia crinat
5	Callophylum polyanthum	36	Syzygium formosum
6	Garcinia xanthochymus	37	Syzygium jambol
7	Saurauia roxburghii	38	Careya arborea
8	Shorea robusta	39	Lagerstromia parviflora
9	Thespesia lampas	40	Daubanga grandiflora
10	Bombax ceiba	41	Tetrameles nudiflora
11	Eriolaena candollei	42	Mastixia arborea
12	Pterygota alata	43	Tamilnadia ulignosa
13	Sterculia roxburghii	44	Wenlandia coriacea
14	Grewia abutifolia	45	Mimusops elengi
15	Aegle marmelos	46	Ligustrum robustum
16	Murraya koenigii	47	Olea dioica
17	Zanthoxylon armatum	48	Holarrhena pubescens
18	Chukrasia tabularis	49	Fagrea obovata
19	Toona microcarpa	50	Ehretia laevis
20	Bhesha robusta	51	Solanum erianthum
21	Hovenia acerba	52	Rhynchotechum ellipticum
22	Accacia catechu	53	Streospermun colias
23	Avvacia lenticularis	54	Phlogacanthus thyrsiflorus
24	Albizia gamblei	55	Premna coriacea
25	Albizia lebbeck	56	Premna bracteata
26	Bauhinia malabarica	57	Vitex pinnata
27	Bauhinia purpurea	58	Vitex peduncularis
28	Bauhinia varigata	59	Horsfieldia kingii
29	Butea monosperma	60	Knema erratica
30	Dalbergia latifloia	61	Cinnamonum glaucescens
31	Erythrina stricta	62	Ficus racemosa

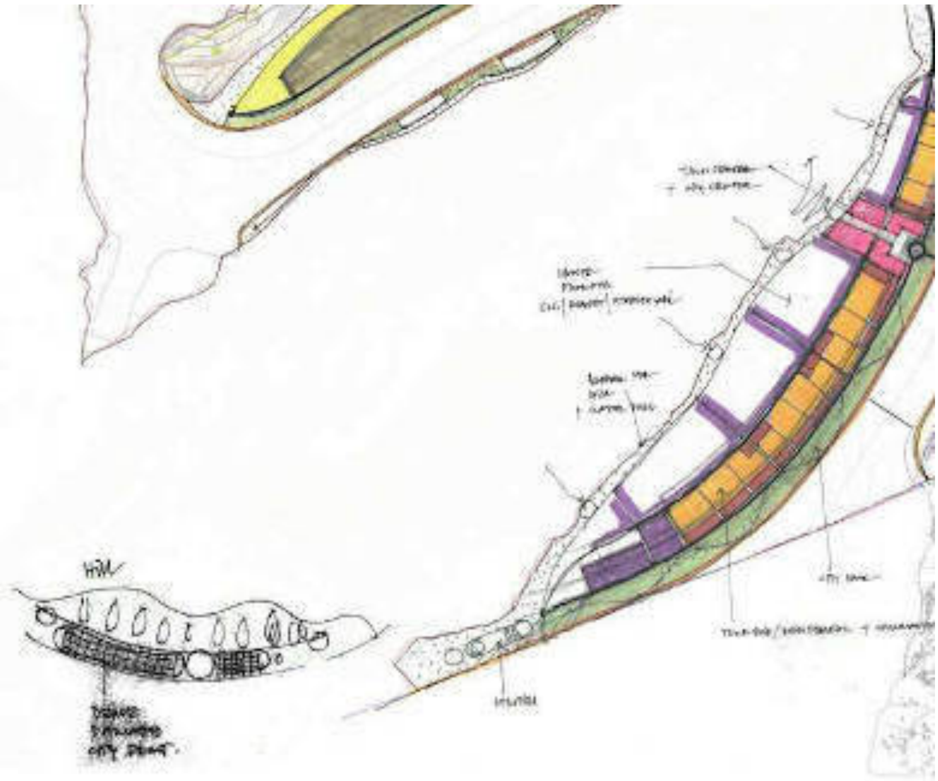
Appendix 2 Table 1.7 Topsoil balancing

Estimation for Topsoil based on Revised Land Use Plan				
Zone	Acres	Number of trees	Topsoil required per unit (M3)	Topsoil requirement (M3)
Total Landscape area excluding Buffer zones	265.88			
Trees				
Recreational Development (acres)	27.15	845		
Embankment (50%) (acres)	59.74	4,950		
Riverfront parks (acres)	48.55	1,510		
Detention ponds (acres)	2.42	134		
Mini golf course (acres)	71.77	2,233		
Bio-diversity parks (25%) (acres)	46.23	925		
Amusement parks (50%) (acres)	10.02	312		
Buffer and forest area (acres)	160.05	2,401		
Roads (Length in Kms)	Kms			
Road type 42 M Row	8.00	7,920		
Road type 36 M Row	12.50	8,250		
Road type 24 M Row	13.50	8,910		
Total Trees		38,389	38,389	4,799
Shrubs in Road median and planting strips in Kms	Kms	Shrubs area M2		
Road type 42 M Row	8.00	60,800		
Road type 36 M Row	12.50	82,500		
Road type 24 M Row	13.50	20,250		
Shrubs (30% of landscape area)	79.76	3,22,722		
Total Shrub area		4,86,272	19,45,088	2,43,136
Total Lawns (15% of landscape area excluding mini golf) M2	39.88	1,61,361	1,61,361	48,408
Total Groundcovers M2	73.12	2,95,829	17,74,972	88,748.58
Total Vetiver plantation	63,800.00	5,74,200.00	5,74,200.00	15,950
Total soil required for plantation				4,01,041.63
Add 12.5 % for wastage				451171.8295
Top soil available from Zone C scraping to depth of 400mm	280.97			454818.5017

Appendix 3 Detention Ponds

Mitigation strategies that are proposed in this development have a very high aesthetic impact potential. They create bio-diversity habitats within the development that brings the user experience closer to nature.

The location of the channels that connect the outflows to the river form natural partitions that contributes to the zoning grids in the masterplan.



Detention ponds create water bodies that harbor wildlife and provide opportunities for recreational activities like bird watching, fishing and nature walks. These water bodies have been used to great effect in several riverfront developments as can be seen from the pictures below.

Detention pond forebay at Park Hyatt, Goa, India

Stromwater pond at Falling Waters resort, Bangalore, India

Source: Design guidelines: Stormwater pollution control ponds and wetlands, Ann Milligan (1918): ISBN 1-876144 20 3

Source: The SuDS Manual (C753), Woods Ballard, B, Wilson, S. ISBN: 978-0-86017-759-3

Source: Design guidelines: Stormwater pollution control ponds and wetlands, Ann Milligan (1918): ISBN 1-876144 20 3

Aesthetic, recreational and cultural objectives are all considered to be important in the design of proposed ponds and channels.
This includes retaining existing ecological and cultural values and mimicking as much as possible the physical characteristics of natural wetlands, including the structural and functional complexity of fringing, emergent and submerged vegetation. Planting native species ensures that the character of constructed wetlands is in keeping with the local surroundings. Provision is also made for recreational activities such as bird watching and picnicking. Wetland microhabitats are included in design criteria. These include the installation of aquatic islands to provide shelter and basking areas for native species (water birds and turtles). The planting of indigenous trees, shrubs and ground cover provides feeding and nesting sites for terrestrial and water birds. Additional habitats are provided where regionally or nationally significant species are known to occur. Separating faunal habitats from pollutant treatment areas adds to the biodiversity support role of such constructed wetlands.
Walking and cycling trail proposed around these constructed wetlands, will allow individuals and families, the opportunity to interact with nature.
There is growing evidence that the green spaces, which urban wetlands represent, are an important way for communities to feel connected with nature. This connection reduces stress, crime rates and incidents of violence and increases psychological wellbeing. Urban wetlands are important assets for the whole community. They provide essential ecosystem services, including biodiversity support and aesthetic, recreational and cultural values. Permanent urban wetlands can act as refugia for many species during dry periods and droughts. In an increasingly urbanised world, constructed wetlands must be managed and valued for the important ecosystems that they are.

Field studies of wet storm water ponds in the NURP program reveal that 90% removal of TSS is attainable with a pond surface area that is about 1% of the watershed area. Pitt (1994a and 1998) studied the pond-surface-area-to-watershed-area ratios and found that open-space watersheds with
highly permeable soils require less pond surface area, down to about 0.6% of the watershed area. He also found that ratios varied, with requirements of 0.8% for residential land use areas and 1.7% for commercial areas, up to 3% for totally paved areas (see Table 5.02-1). An estimate of 1% is often used for watersheds with mixed land use, but this must be analyzed on a site-specific basis.

Baffles and curved flow paths are often used to increase settling efficiency. Schueler (October 1992) uses the natural-looking variation in bottom contours to enhance flow
characteristics in his wetland designs. The actual dynamics of flow and sedimentation in storm water ponds relative to the pond shape are not well described in available literature. Design of storm water treatment ponds remains a developing technology.

Sizing for Treatment (Pitt Method)
The Maryland Department of Natural Resources (Barfield et al., 1986) indicates that the ratio of pond surface area to peak discharge is a practical criteria for design of sedimentation ponds. Our evaluation indicates that this ratio is also easier to compute and apply as a practical design tool than detention time, and it can be more readily field checked for compliance. Pitt found that a ratio of approximately 5.66 cfs of outflow for each acre of pond surface area resulted in a predicted sediment trapping efficiency of approximately 90% in urban storm water with particle size and rainfall distribution found in Madison, Wisconsin, runoff (Pitt, April 29-30, 1998).

Thus, the treatment goal for wet ponds is to remove about 90% of the suspended solids by using a design ratio of 5.66 cfs of pond outflow per acre of pond surface area. When Wisconsin Department of Natural Resources staff analyzed the water quality volume using.

Pitt and Walker models for local conditions, they found that the assumptions, such as particle size distribution, were critical to the calculations (Personal communications). Although their goals, assumptions and analysis methods differed somewhat from those used in this manual, they concluded that a water quality volume based on 1.25- to 1.5-inch events would provide a reasonable average annual removal rate of 80%. The design recommendations of this manual are more conservative than the assumptions used in their modeling; therefore, their conclusions support this manual's 90% goal.
Using the Pitt method, the stage and discharge for the pond spillway are designed so that the maximum flow out should be less than or equal to 5.66 cfs per acre of pond surface area. The maximum discharge should occur when the elevation of the pond has the entire water quality volume. Using the entire water quality volume and specific outflow rate as the design criteria also makes it relatively easy to field check the as-built structure to see whether it complies with the criteria

Bench Areas

Storm water-treatment ponds should be designed with shelves or benches that slope gradually into the open-water area and form a transition between the open-water area of the pond and the surrounding property. A 3- to 10-foot bench should be constructed. Slopes of 10:1 (10 ft horizontal to 1 ft vertical) to 6:1 are recommended. When enough area is available, a 10-ft bench with a 10:1 slope is recommended. Bench areas may comprise 10-20% of the total pond area. Emergent vegetation, such as cattails and grasses, should be encouraged, but often they will grow voluntarily on bench areas.

Wetland Vegetation
Aquatic vegetation provides some aquatic nutrient uptake, prevents erosion and provides an aesthetically more pleasing and perhaps more effective way of removing nutrients than other measures. Walker (1990), in documentation for his P8 model, also indicates that there is evidence that vegetation in a pond or wetland may provide increased settling effectiveness by laminar settling. In these cases, vegetation slows flow and acts like settling plates to remove suspended particles. Vegetated bench areas also provide wildlife habitat and help prevent children from entering open water areas. In addition, vegetated bench areas discourage the use of adjacent grassed areas by geese. Geese prefer open, grassy areas and tend to overpopulate mowed park areas that are immediately next to open water.

Wetland Designs
Wetlands treatment systems should be designed using the surface outflow rate method discussed here as the main water quality treatment design mechanism. We encourage the use of wetlands for treatment, but detailed designs of wetland treatment systems are beyond the scope of this manual. Wetlands may reduce dead storage, but can provide added benefits that make up for the dead-storage loss. Wetland systems must be designed in consultation with professionals who are knowledgeable in the field of wetland design, construction or restoration. Refer to the section on "Special Considerations" below and refer to experts, such as Schueler, Dindorf, Eggers and others in the references for further information. Unless carefully designed, discharges to wetlands may disrupt the wetland systems to such an extent that they destroy the wetland vegetation and habitat values. Therefore, discharges to natural wetland
Systems should generally not be allowed or given treatment credit, or allowed unless there are no other available options. Allowing discharges to natural wetlands without pretreatment and rate controls should be avoided wherever possible.

Wetland Conversion

Several years of monitoring may be required to obtain representative data. An alternative to monitoring involves utilizing available literature and models to provide a range of probable values. If the pond system is modeled, the variability of the model should be recognized. Expected ranges of pond and wetland performance should be analyzed as part of the project-development process.

The variability of flow rate and pollutant loading should also be discussed. The treatment efficiency of natural and constructed treatment systems will vary greatly no matter how well a system is designed. Generally, it is better to build a treatment pond in an upland area than to alter natural wetlands.

References

1 American Society of Civil Engineers (ASCE). “Design and Construction of Urban Stormwater Management Systems,” Engineering Practice No. 77. New York (1992).

2 Booth, D.B., and C.J. Jackson. “Urbanization of Aquatic Systems-Degradation Thresholds, Stormwater Detention, and the Limits of Mitigation,” *Water Resources Bulletin*, Vol. 33, pp. 1077-1090 (1997).

3 Environmental Protection Agency (EPA). “Results of the Nationwide Urban Runoff Program,” EPA Final Report, NTIS No. PB84-185545, Washington, DC (1983).

4 EPA. “Methodology for Analysis of Detention Basins for Control of Urban Runoff Quality,” EPA440/5-87-001 (September 1986).

5 EPA. “Low-Impact Development Design Strategies: An Integrated Design Approach,” (2006). See http://www.epa.gov.

6 Mays, L.W. *Stormwater Collection Systems Design Handbook*, McGraw-Hill Book Company, New York (2001).

7 Jones, J., James C.Y. Guo, and B. Urbonas. “Safety on Detention and Retention Pond Designs,” *Journal of Storm Water* (2006).

8 Guo, James C.Y. *Urban Hydrology and Hydraulic Designs*, Water Resources Publications, Littleton, Colorado (2006).

9 Guo, James C.Y. “Hydrology-Based Approach to Storm Water Detention Design Using New Routing Schemes,” *ASCE Journal of Hydrologic Engineering*, Vol. 9, No. 4 (2004).

10 Guo, James C.Y. and B. Urbonas. “Runoff Capture and Delivery Curves for Storm Water Quality Control Designs,” *ASCE Journal of Water Resources Planning and Management*, Vol. 128, No. 3 (2002).

11 Guo, James C.Y. “Design of Circular Infiltration Basin Under Water Mounding Effects,” *ASCE J. of Water Resources Planning and Management*, Vol. 127, No. 1 (2001).

12 Guo, James C.Y. “Detention Basin Sizing for Small Urban Catchments,” *ASCE J. of Water Resources Planning and Management*, Vol. 125, No. 6 (1999).

13 Guo, James C.Y. and B. Urbonas. “Maximized Detention Volume Determined by Runoff Capture Rate,” *ASCE J. of Water Resources Planning and Management*, Vol. 122, No. 1 (1996).

14 USWDCM. *Urban Stormwater Drainage Criteria Design Manual*, Urban Drainage and Flood Control District, Denver, Colorado (2001)

15 Australian Bureau of Statistics (ABS) (2008). ‘3235.0- Population by Age and Sex, Regions of Australia.’ Available at http://abs.gov.au/ausstats [Accessed 3 August 2009].

16 Battty, L. C., Atkin, L., and Manning, D. A. C. (2005). Assessment of the ecological potential of mine-water treatment wetlands using a baseline survey for macroinvertebrate communities. *Environmental Pollution* 138, 412–419.

17 Birch, G. F., Matthai, C., Fazeli, M. S., and Suh, J. (2004). Efficiency of a constructed wetland in removing contaminants from stormwater. *Wetland* 24, 459–466.

18 Bolund, P., and Hunhammar, S. (1999). Ecosystem services in urban areas. *Ecological Economics* 29, 293–301.

19 Boyer, T., and Polasky, S. (2004). Valuing urban wetlands: A review of non-market valuation studies. *Wetlands* 24, 744–755.

20 Cai, Y., Zhang, H., Pan, W., Chen, Y., and Wang, X. (2013). Land use pattern, socio-economic development, and assessment of their impacts on ecosystem service value: study on natural wetlands distribution area (NWDA) in Fuzhou city, southeastern China. *Environmental Monitoring Assessment* 185, 5111–5123.

21 Catford, J. A., Walsh, C. J., and Beardall, J. (2007). Catchment urbanisation increases benthic microalgal biomass in streams under controlled light conditions, *Aquatic Science* 69, 511–522.

22 Chen, C. Y., Stemberger, R. S., Klaue, B., Blum, J. D., Pickhardt, P. C., *et al*. (2000). Accumulation of heavy metals in food web components across a gradient of lakes. *Limnology and Oceanography* 45, 1525-1536.

23 Cheremisinoff, N. P. (2002). ‘Handbook of Water and Wastewater Treatment Technologies.’ (Butterworth- Heinemann: USA.)

24 Chiesura, A. (2004). The role of urban parks for the sustainable city. *Landscape and Urban Planning* 68, 129–138.

25 Dallimer, M., Irvine, K. N., Skinner, A. M. J., Davies, Z. G., Rouquette, J. R., *et al*. (2012). Biodiversity and the Feel-Good Factor: Understanding Associations between Self-Reported Human Well-Being and Species Richness. *Bioscience* 62, 47–55.

26 Davis, J. A., and Froend, R. (1999). Loss and degradation of wetlands in southwestern Australia: underlying causes, consequences and solutions. *Wetlands Ecology and Management* 7, 13–23.

27 Davis, J., Lake, P., and Thompson, R. (2010). Freshwater biodiversity and climate change. In ‘Greenhouse 09: Living with Climate Change’. (Eds I. Jubb, P. Holper and W. Cai.) pp. 73–83. (CSIRO Publishing: Melbourne.)

28 Davis, J., Sim, L., and Chambers, J. (2010). Multiple stressors and regime shifts in shallow aquatic ecosystems in antipodean landscapes. *Freshwater Biology* 55, 5–18.
29 De Deckker, P., and Williams, W. D. (1986). 'Limnology in Australia.' (CSIRO Publications: Melbourne, Australia.)
30 Department of Sustainability and the Environment (DSE) (2013). 'Victorian Wetlands.' Available at http://www.dse.vic.gov.au/__data/.../VCE_ Powerpoint_accessible_version.doc [Accessed 6 July 2013].
31 Ehrenfeld, J. G. (2000). Evaluating wetlands within an urban context. *Ecological Engineering* 15, 253–265.
32 Ellis, J. B., Shutes, R. B. E., and Revitt, D. M. (2003). 'Guidance Manual for Constucted Wetlands, R & D Technical Report P2 - 159/TR2.' (Environment Agency: UK.)

Appendix 4 Vetiver Grass

The impact of using vetiver planting on the river embankment slope multiple advantages. There is proven scientific data to support the fact that vetiver grass plays a major role in reducing the velocity of high flood waters (Gray DH, and Leiser AT. 1982).

Analysis has been made of the cost of the vetiver planting in relation to conventional stone-based engineering. It is highly interesting to note that the former approximately cost only 1/8 of the latter, while producing the same slope protection capability coupled with incomparable aesthetic or landscape value (Ke et al. (2003).

In situations where vetiver plantation in the precast concrete pavers is interspersed with decorative pebble filled precast concrete pavers, the presence of vetiver grass will greatly reduce the amount decorative pebbles displaced during high flood conditions. This in turn will reduce the infra structure maintenance cost of re-positioning the dislodged decorative pebbles.

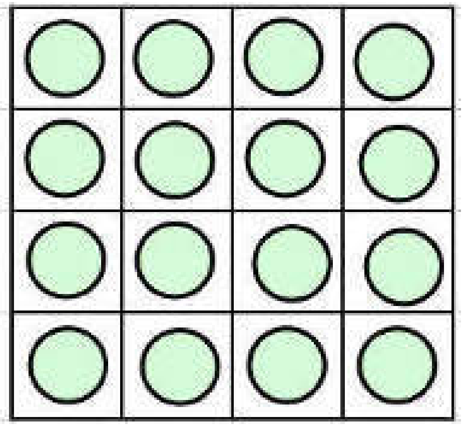
Since the sloped embankment on either side of the river is vast expanses of hard concrete, during summer, heat islands will be created. This will greatly diminish the user experience. Vetiver planting will contribute enormously to reducing local heat islands and enhancing the user experience.

Impact of Vetiver planting on the Masterplan:

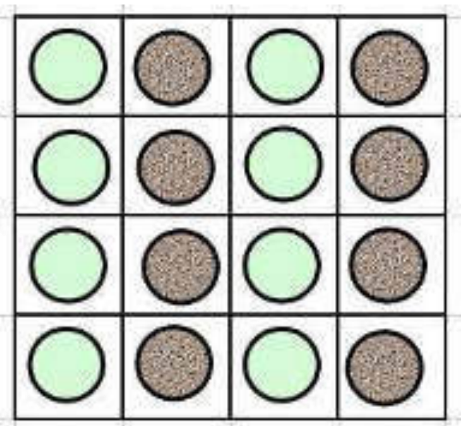
The use of vetiver will soften the vast expanse of hard concrete on either side of the embankment. This will be aesthetically pleasing and greatly enhance the user experience.

Vetiver planting can be done in various combinations with decorative pebbles or pure stand.

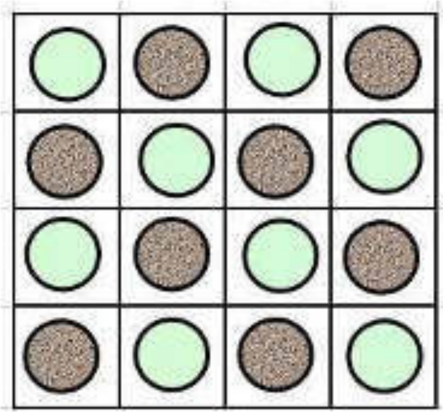
Option 1: Pure stand of vetiver planting.



Option 2: Vetiver planting alternating with decorative pebbles as vertical bands.



Option 3: Vetiver planting alternating with decorative pebbles in diamond arrangement.



The green cover provided by the vertiver plantation will provide perching and nesting opportunities for birds. This area will evolve into a re-created bio-diversity habitat. This environment will encourage residents to indulge in outdoor lifestyle activities such as bird watching etc.

The following table shows some of the grasses and groundcovers that are used in erosion control:

Diameter and tensile strength of root of various ground covers

Ground cover	Avg diam. of roots (mm)	Avg tensile strength (MPa)
Juncelles serotinus	0.38±0.43	24.50±4.2
Paspalum dilatatum	0.92±0.28	19.74±3.00
Trifolium repens	0.91±0.11	24.64±3.36
Vetiver grass	0.66±0.32	85.10±31.2
Eremochloa ophiuroides	0.66±0.05	27.30±1.74
Paspalum notatum	0.73±0.07	19.23±3.59
Zoysia matrella	0.77±0.67	17.55±2.85
Cynodon dactylon	0.99±0.17	13.45±2.18

(Cheng H, Yang X, Liu A, et al. 2003. An experimental study on mechanic performance and mechanism of soil-reinforcement by herb root system. Proceedings of the Third International Conference on Vetiver and Exhibition, Guangzhou, China)

Experience from several World Bank funded projects on slope stabilization have proven the unique capability of Vetiver Grass (*Chrysopogon zizanioides* L Roberty) in providing a sustainable mitigation against seasonal flooding and erosion of river banks.
The Vetiver System (VS), which is based on the application of vetiver grass (*Vetiveria zizanioides* L Nash, now reclassified as *Chrysopogon zizanioides* L Roberty), was first introduced by the World Bank for soil and water conservation in India in the mid 1980s. While this application still plays a vital role in agricultural land management, R&D conducted in the last 20 years has clearly demonstrated that, due to vetiver grass' extraordinary characteristics, VS also has important application as a bioengineering technique for steep slope stabilization, wastewater disposal, phyto-remediation of contaminated land and water, and other environmental protection purposes.
The World Bank in 1987 and referred to Vetiver grass as "A Hedge Against Erosion".

It has emerged that the tensile strength of Vetiver roots is as strong as, or even stronger, that of many hardwoods. In fact, because of its long (2-3.5 m) and massive root networks which are also very fast-growing (functional in only 4-6 months), it is better than many types of trees which normally take 2-3 years to be effective. Amplifying this in Technical Bulletin No. 1998/2 (Hengchaovanich, 1998) and followed up by a number of presentations in several countires, that expounded the efficacy of Vetiver for slope stabilization, the enginering sector has begun to take notice of Vetiver (Grimshaw, 2003). This resulted in its applications having taken off significantly on highways and railways in many countries, in particular Thailand, China, South America, Australia, the Philippines and Madagascar (Hengchaovanich and Freudenberger, 2003), to name just a few, in the last few years.

That vetiver has the 'innate power' to penetrate through soils mixed with stone or pebbles, through asphalt layer and through hard pan (Chomchalow, 1997), have been well documented. Until the publication of the two papers described below, no attempt has yet been made to try to plant vetiver in mostly rocky strata. Huang et al. (2003) narrated in details their experiences in the planting of vetiver on the weathered shale and mudstone slope of the Maitian Hydropower station in Jiuxiang, (near Kunming), Yunnan Province, China. It was a bold attempt to stabilize a slope by the Vetiver Eco-engineering Technique - VET, (which in the original design scheme envisaged the use of concrete or 'hard' engineering) against the odds of hard substrate, relatively cold and drought climatic conditions and high altitude (approx 2000 m above mean sea level). Compared with control slope in the vicinity, which collapsed after a severe rainstorm, vetiver protected slope was able to withstand the onslaught precipitation very well without any damage. Vetiver hedgerows have been found to able to resist scouring of water flow of 0.028 m3/s.

Analysis is made of the cost of the vetiver planting in relation to conventional stone-based engineering. It is highly interesting to note that the former approximately cost only 1/8 of the latter, while producing the same slope protection capability coupled with incomparable aesthetic or landscape value.

In his paper, Ke et al. (2003) explained the rationale for using vetiver for erosion control, slope stabilization and scour prevention at two rivers in China. He endorsed its utilization vis-à-vis the conventional 'hard/stone-based' techniques prevalent elsewhere in his country for equivalent efficacy yet with better ecological impacts and much lower costs. He is to be commended for contributing to the database of vetiver growth characteristics, root lengths from various locations in China. The paper made some important observations: at Hanjiang River dike at Wuhan, Hubei, apart from stabilizing the bank slope, vetiver managed to stay luxuriant although partly-submerged in river water.

It was reported by the second author (Feng, 2002) that when severe flooding occurred on the Yangzi (Changjiang) River last year (of which the Hanjiang River is a tributary), vetiver planted there remained intact. Another good observation pointed out by the paper is that vetiver planted on the Youjiang River Bank in the Baise Water and Power Project in Guangxi province, was already working effectively after merely 1.5-2 months' of growth and was protecting against scouring from flood with velocity of 2.0 m/s.

Although vetiver had been tried with relative success in China and Vietnam as mentioned above, when one is to propose its use for riverbank stabilization or flood erosion control to a prospective client whose knowledge on vetiver is scant, oftentimes the hydraulic characteristics of vetiver hedges are queried, in particular the Manning coefficient n.

Experiments carried out by Metcalfe et al. (2003) throws some light into the behavior of vetiver hedges in deep flow. Hedges planted in rows were found to be in hydraulic resistance Class A (the highest) with resistance decreasing with increased hedge spacing and suitable for steep slopes/highly erosive flows, while those planted in diamond-shaped pattern were in Class B retardance category and suitable for slower flow rate/shallow slopes where sedimentation was high.

Bibliography:

Behling A. 1998. These soybeans survive wet feet. In: The Corn and Soybean Digest, February 1, 1998 issue, Kansas, USA

Cheng H, Yang X, Liu A, et al. 2003. An experimental study on mechanic performance and mechanism of soil-reinforcement by herb root system. Proceedings of the Third International Conference on Vetiver and Exhibition, Guangzhou, China

Chowchalow N. 1997. Veteveria 2: 1, Pacific Rim Vetiver Network, ORDPB, Bangkok

Gray DH. 1994. Influence of vegetation on stability of slopes. In: Vegetation and Slopes. Institution of Civil Engineers, London. 2-25

Gray DH, and Leiser AT. 1982. Biotechnical slope protection and erosion control, Van Nostrand Reinhold, New York, NY

Greenfield JC. 1996. Vegetative vs mechanical soil conservation system as they affect moisture conservation and sustained production. Proceedings of the First International Conference on Vetiver. Office of the Royal Development Projects Board, Bangkok. 1-7

Greenway DR. 1978. Vegetation and slope stability. In: Anderson and Richards (eds.), Slope Stability,John Wiley and Sons, New York, NY

Grimshaw RG. 1994. Vetiver grass—its use for slope and structure stabilizatioon under tropical and semitropical conditions. In: Vegetation and Slopes. Institution of Civil Engineers, London. 26-35

Grimshaw RG. 2003. Vetiver grass-a world technology and its impact on water. Proceedings of the Third International Conference on Vetiver and Exhibition, Guangzhou, China

Hengchaovanich D. 1998. Vetiver Grass for Slope Stabilization and Erosion Control. Tech. Bull. No. 1998/2, PRVN / ORDPB, Bangkok, Thailand

Hengchaovanich D, and Nilaweera N. 1996. An assessment of strength properties of vetiver grass roots in relation to slope stabilization. Proceedings of the First International Conference on Vetiver. Office of the Royal Development Projects Board, Bangkok. 153-158

Hengchaovanich D, and Freudenberger KS. 2003. Vetiver Victorious: The Systematic Use of Vetiver to save Madagascar's FCE Railway. Tech. Bull. No. 2003/2, PRVN / ORDPB, Bangkok, Thailand

Huang B, Xia HP, and Duan G. 2003. Study on Application of veetiver eco-engineering technique for stabilization and revegetation of Karst stoney slopes.
Proceedings of the Third International Conference on Vetiver and Exhibition, Guangzhou, China

Islam MN. 2000. Embankment erosion control: towards cheap and simple practical solutions for Bangladesh. Proceedings of the Second International Conference on Vetiver. Office of the Royal Development Projects Board, Bangkok. 307-321

Islam MN. 2003. Role of vetiver in controlling water-borne erosion with particular reference to Bangladesh coastal region. Proceedings of the Third International Conference on Vetiver and Exhibition, Guangzhou, China

Ke CC, Feng ZY, Wu Xj, et al. 2003. Design principles and engineering samples of applying vetiver ecoengineering technology for land landslide control and slope stabilization of riverbank. Proceedings of the Third International Conference on Vetiver and Exhibition, Guangzhou, China

Kong XH, Lin WW, and Hao H. 2003. A preliminary experiment on slope rehabilitation with vetiver and native plant technique. Proceedings of the Third International Conference on Vetiver and Exhibition, Guangzhou, China

Le Viet Dung, Luu Thai Danh, Truong P, et al. 2003. Vetiver system for wave and erosion control in the Mekong delta, Vietnam. Proceedings of the Third International Conference on Vetiver and Exhibition, Guangzhou, China

Metcalfe O, Smith R, and Truong P. 2003. Hydraulic characteristics of vetiver hedges in deep flows. Proceedings of the Third International Conference on Vetiver and Exhibition, Guangzhou, China National Research Council. 1993.

Vetiver Grass: A Thin Green Line Against Erosion. National Academy
Press, Washington DC, USA

Sanguankaeo S, Chaisintarakul S, and Veerapunth E. 2003. The application of the vetiver system in erosion control and stabilization for highways construction and maintenance in Thailand. Proceedings of the Third International Conference on Vetiver and Exhibition, Guangzhou, China

Appendix 5

Green corridors and the quality of urban life in Singapore

Singapore is a highly urbanized island city-state that was once covered with dense tropical forest. Clearing of natural areas began in the late 19th century, and gathered momentum particularly in the post-1960's period after independence from the British Colonial authorities. With the advent of internal self-government in 1959, the Singapore government was con- fronted with a plethora of problems including rapid population growth, housing shortages, high unemployment and inadequate infrastructure. The economic and social programs that were initiated to address these problems included land use planning and land/building development. This often entailed the clearing of natural areas such as forests, ridges, swamps, coral-fringed coasts, and the damming of rivers for reservoirs. As a result, between 1960 and the mid 1990's, the portion of Singapore covered by forests decreased from 6.5% to 4.4%, and mangroves dropped from 7.9% to 2.4% (Hilton 1995). At the same time, the proportion of developed areas almost doubled from 27.9% in 1960 to 49.3% in 1996 (Wong 1989, Ministry of Information and the Arts 1996).

As Singapore's natural areas were cleared, they were replaced with other forms of nature "constructed" to satisfy a range of human needs: specially designed parks, roadside trees and shrubs, road dividers, open spaces such as car parks, walls and pedestrian bridges covered with creepers. Singapore's landscape was transformed from dense tropical forest to an equally dense built-up environment, entailing a sort of paradox. On the one hand, natural areas continue to be destroyed. However, on the other hand, policies and actions have been introduced to "green" the city. As a result, the form of nature most familiar to Singaporeans is managed "messicol" vegetation planted deliberately to provide some balance in an increasingly urban environment. The average Singaporean has little contact with naturally occurring unmanaged vegetation and wildlife on the island. In the Revised Concept Plan for Singapore, the Urban Redevelopment Authority (URA) included a Green and Blue Plan that identified areas of open space through- out the island designed to meet recreational needs, protect the natural environment, and improve biodiversity (Liu 1991). The Plan incorporated earlier proposals by the Nature Society of Singapore, which identified areas suitable for nature conservation (Briffett 1990). Subsequent to this, government agencies have sought to establish the overall nature of the island-wide network by carrying out master planning strategies and regional studies through Development Guide Plans, or by undertaking micro studies of parks, reserves or specific development sites. Plans for all 55 planning districts were completed in 1998. One study was a comprehensive overview of water body planning and design concepts, the purpose of which was to exercise a degree of planning control and to encourage developers to protect, improve, and enhance existing water body areas in Singapore (Urban Redevelopment Authority 1993).

After the Revised Concept Plan was adopted, the former Parks and Recreation Department of Singapore (now incorporated into the National Parks Board) published a proposal for an island-wide park connector network (Straits Times 1992) designed to meet the perceived growing need for a range of alternative recreational facilities. The implementation of the entire park connector program, which will ultimately extend for a total of approximately 300 km, was envisioned to take up to 30 years (Straits Times 1995). The park connectors were planned primarily along existing water drainage culverts and river systems to act as connectors to national, regional and local neighbor- hood parks and coastal areas throughout Singapore. They were intended as an open space facility for off- road cycling, jogging, exercise and walking across the island, away from the danger, inconvenience, and pollution of the main roads.

Considerable work is still required in the selection, formation, and implementation of connectors in order to bring about the original vision. This includes landscaping, trail construction, facilities such as lighting, seating and exercise centers, and in particular the construction of road crossovers at grade road cycle crossings, tunnels, and bridges (Straits Times 1996). Work on the network has begun, with priority to the outdoor recreation needs of the city-state's completely urban population. The potential to cater to wildlife as well as human recreational needs in the connector network was first put forward in 1993 in the Singapore Green Plan - Action Programmes. The original Green Plan, from which the action program was developed, was prepared by the Ministry of the Environment for the Rio Summit as its contribution to the blueprint for a global sustainable development action program. In this plan, the Ministry described Singapore's green network as "a tapestry of green to make parks and nature sites more accessible to the public and to provide corridors for the movement of bird life" (Ministry of the Environment 1993).

Urban park connector systems in other parts of the world today frequently incorporate recreational and wildlife requirements. A primary feature of these multi-purpose systems is the interaction between people and wildlife, and the many ways in which each influences the other. Corridor planning, design and management approaches have evolved accordingly to incorporate land planning and ecological factors into decision-making. This study examined how the island- wide park connector network proposed by the National Parks Board of Singapore can be designed to meet the needs of human users and, by improving biodiversity, meet the needs of wildlife. As the island- wide park connector scheme is still in the early stages of implementation, it is an appropriate time to evaluate planning, design, and management criteria to better meet the needs of people and wildlife in the connector system.

PROJECT AIMS AND OBJECTIVES

This study explores human relationships with nature in Singapore. The population is totally urbanized and a scarce number of natural areas remain in their original form. An entire generation is growing up in an "urban jungle" rather than a more natural setting. We see this study as particularly relevant to Asia, where urbanization is taking place at an accelerating rate and, in our view, there is an urgent need to understand urban dwellers' relationships with nature.
The focus in this study is Singapore's green corridor. Specifically, how people use the corridors, what kind of wildlife and habitats are in these areas, and what the relationships are between human use and wildlife needs. The primary aim is to understand human- nature interactions, which may inform policy makers and the planners, the design, use and management of Singapore's green corridor system.

The research objectives were:

- -to assess the degree to which selected corridors in Singapore meet social, cultural, and recreational needs as well as wildlife habitat requirements;
- - to develop, test, and analyze monitoring techniques for assessing the effectiveness of corridor systems to meet human social, cultural and recreational needs, and wildlife habitat requirements;
- -to ascertain the reasons for, and benefits of, creating open space corridors in urban settlements;
- -to develop planning, design and management criteria for urban green corridors in Singapore.

Results

One hundred fourteen bird species were recorded from all sites combined (Table 1). Despite differences in characteristics, an introduced species, the Javan Myna was the most abundant species at all sites.
Based on January and March 1997 surveys, the maximum mean number of bird species was recorded in Ulu Pandan Canal (29.50+2.50) and the minimum at East Coast Park (10.50+0.50). In the study of one of the established park connectors at the Ulu Pandan Canal 60 bird species were identified. Some of these bird species (Greater Racket-tailed Drongo and Banded Woodpecker) are usually found in native habitats such as the rainforest. In contrast the bird community in the more recently established connector, the Jurong Canal, was relatively depauperate with only 37 bird species recorded. The Ulu Pandan Canal connector is bor- dered by a diverse natural habitat. Three secondary woodlots (1-2 ha in area) were within 100 m of this connector (Sodhi and Briffett 1996). The bird commu- nity of Ulu Pandan was also similar to an established urban park, the Kent Ridge Park. The Duxton Plain Park bird community was different from all other surveyed areas because it had the highest abundance of human-associated species such as the Feral Pigeon, House Crow and Eurasian Tree Sparrow. This area is located in the Central Business District of Singapore and is the most intensely urbanized. The bird diversity was the highest in the Bishan Park (1.3) and lowest in West Coast Park (0.9). These data should be inter- preted cautiously because of uneven sampling among sites.
Mean total bird species appeared to increase, although not significantly, with percent vegetation cover. Diversity was not significantly correlated ($P > 0.50$) with any of the site characteristics (coverage by built areas, open areas, vegetation and water). PCA and subsequent correlation revealed that as the amount of vegetation cover increased the abundance of both parkland bird species (Purple-backed Starling, Javan Myna and Pink-necked Pigeon) and forest bird species (Greater Racket-tailed Drongo, Olive-winged Bulbul, Short tailed Babbler and Greater Green Leafbird) increased.
Based on activity surveys conducted along five of the linear areas it was found that bird species forage and sing in linear areas, including the Ulu Pandan Canal connector (Briffett et al.1997:70). Therefore connectors can possibly serve as functional habitats for some bird species.

IMPLICATIONS FOR DESIGN AND MANAGEMENT

This study has important implications for the design and management of the park connector system in Singapore and possibly other similar urbanized tropical areas. Management and landscape planners should not only concentrate on planning within the connector, for example, planting of native vegetation, but also should plan to incorporate surrounding landscape features that will eventually enhance the biodiversity value of connectors. This was confirmed in other research conducted on metapopulations elsewhere (Janzen 1983). The study shows that human-made corridors or linear habitats are success- ful in attracting a large number of both migratory and resident bird species. It was noted that the bird species carried out a variety of activities within the corridors suggesting that these corridors serve as functional habitats for bird species.

CONCLUSIONS

This study demonstrated that the planning, design and management of the corridor system has a signifi- cant effect on how people use the corridors, what wildlife are attracted to them, and what maintenance practices are employed. It has also indicated that each of these levels of decision making affects the others. It is necessary to design a comprehensive strategy that covers planning, design, management and maintenance and establishes fundamental principles on which all of these should be based. There is also a need to account for how each of these corridors is related to the others. The implementation details of such a plan can be revised at regular intervals to ensure that planting and maintenance techniques and the intro- duction of new designs and landscapes accord with the overall vision established in the plan. Corridor strategies should ultimately be based not only on the "biotic, abiotic and cultural factors peculiar to each local landscape," but also, "on the basis of inhabitant's values and perceptions" (Ahern 1995). Corridors extend through many different environments, from predominantly natural, such as woodlands, un- spoiled coastal shores and wetlands to predominantly urban, such as city centers and industrial estates. Each length presents different challenges in terms of what can be achieved through planning and design, and what kind of management program to adopt. Equally important, without knowledge of public attitudes and commitment to public participa- tion, many innovative corridor schemes have failed through abuse and lack of support. Many researchers advocate the involvement of local groups and commu- nities in the management of corridors and case studies are presented to confirm this (Adams and Dove 1989, Barker 1986, Goode 1990).

If sustainability is the aim, ecology should be incorporated into the regional planning of urban landscapes. Ecological principles could be considered a framework comprising content, context, dynamics, heterogeneity and hierarchies (Flores et al. 1998), as applied in a case study of the New York Metropolitan area (Yaro and Hiss 1996). Heterogeneity, diversity and connectivity within and among the components of green spaces contribute powerfully to the features and processes for which they are valued (Flores et al.1998). These factors also contribute to the complexity of interactive effects and potential conflicts amongst the multiple uses of corridor systems.

LITERATURE CITED

Adams, L.W and L.E. Dove. 1989. Wildlife reserves and corridors in the urban environment. National Institute of Urban Wildlife, Columbia, Maryland, USA. 91pp.

Ahern, J. 1995 Greenways as a planning strategy. *Landscape and Urban Planning.* 33:131-155.

Barker, G.M.A.1986. European approaches to urban wildlife programmes. Integrating man and nature in the metropolitan environment. National Institute for Urban Wildlife. Columbia, Maryland, USA. Pp.183- 190.

Briffett, C. 1990. Master plan for the conservation of nature in Singapore. The Nature Society, Singapore.

Briffett, C., Kong, L., Yuen, B., Sodhi, N.S. 1997. The planning and ecology of park connector systems in urban areas. Pilot study based on Ulu Pandan Canal Clementi, Singapore. National University of Singapore.

Flores,A.,Pickett,S.T.A.,Zipperer,W.C.,Pouyat,R.V., Pirani, R. 1998. Adopting a modern ecological view of the metropolitan landscape: the case of a greenspace system for the New York City region. *Landscape and Urban Planning* 39: 295-308.

Goode, D.A.1990. Public participation in urban nature conservation in Britain. Wildlife Conservation in Metropolitan Environments. National Institute for Urban Wildlife. Columbia, Maryland, USA. Pp193- 199.

Hilton, M.J., Manning, S.S. 1995. Conversion of coastal habitats in Singapore: indications of unsustainable development. *Environmental Conservation* (22) 4. Winter, Switzerland.

Janzen, D.H. 1983. No park is an island: increase in interference from outside as park size decreases. *Oikos* 41: 402-410. Copenhagen.

Jongman, R.H.G., ter Braak, C.J.F. and van Tongeren, O.F.R. 1987. Data analysis in community and landscape ecology. Pudoc, Wageningen, The Nether- lands.

Kong, L. Yuen, B., Briffett, C. and Sodhi, N. 1997. Nature and nurture, danger and delight: urban women's experiences of the natural world. *Landscape Research* 22: 245-266.

Kong, L. Yuen, B., Sodhi, N and Briffett, C. 1998. The construction and experience of nature: Perspectives of urban youth. *Tijdschrift voor Economie en Sociale Geografie* (TESG).

Liu, T.K. 1991. Concept Plan Singapore in the 21st Century. City Trans Asia. Singapore.

Ministry of the Environment. 1993. Nature Conserva- tion, The Singapore Green Plan-action programmes. Singapore p. 51.

Ministry of Information and the Arts. 1996. Singapore Facts and Pictures Singapore.

Straits Times, Singapore. 1992. First stage of nature corridor project to link parks opens Singapore. Sat., August 15.

Straits Times, Singapore. 1995. Island-wide green network to link parks Singapore. Sat., Nov, 18. p.10.

Straits Times, Singapore. 1996. New bicycle crossing for park connectors. Singapore. April 12.

Urban Redevelopment Authority. 1993. Aesthetic treatment of waterbodies in Singapore April.

Wong, P.P. 1989. The transformation of the physical environment. In Kernial Singh Sandhu and Paul Wheatley, eds., The Management of Success: The Moulding of Modern Singapore, Singapore: Institute of Southeast Asian Studies. Pp. 771-87.

Yaro, R. and Hiss, T. 1996. A region at risk: the third regional plan for the New York-New Jersey-Con- necticut metropolitan area, Washington, DC. Island Press.