SUPPORTING REPORT (1)

ANNEX 8 : STORM WATER DRAINAGE

THE STUDY ON STORM WATER DRAINAGE PLAN
FOR THE COLOMBO METROPOLITAN REGION
IN
THE DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA

FINAL REPORT

VOLUME III : SUPPORTING REPORT (1)

ANNEX 8 : STORM WATER DRAINAGE

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CHAPTER 1 PRESENT DRAINAGE SYSTEMS

1.1 Overview of Present Drainage Systems in the Study Area

The study area is broadly bounded by Negombo Lagoon and Damdugam Oya to the north, the proposed route of the Outer Circular Highway to the east, and the Bolgoda Lake watershed to the south.

There are several drainage basins that are entirely or partly included in the study area. The delimitation of drainage basins in the study area for the purpose of the present study is shown in Figure 1.1.1 and tabulated below:

Relevant River Basins and Study Area

Basin	Basin Area (km^2)	Within Study Area (km^2)
Ja Ela	860	173
Kalu Oya	60	60
Kelani Ganga	2,292	89
Greater Colombo	85	85
Bolgoda	394	394
Other Areas along Coast	-	29
Total	-	830

Note: Extent of basin area is estimated from 1:50,000 scale topographic map.

1.2 Major Drainage Systems

1.2.1 Attanagalu Oya and Ja Ela (Figure 1.2.1)

The Ja Ela basin with a drainage area of 860 km^2 is located between the Maha Oya basin to the north and the Kelani Ganga basin to the south. The basin has a complicated waterway system with interconnections and branches in the downstream reaches.

The Attanagalu Oya originates from the hills with the highest elevation of 300 m above MSL at the eastern boundary of the basin, located some 40 km away from the sea. From Gampaha to Ekala, the Attanagalu Oya runs through flat land along the A33 Road in parallel with the Uruwal Oya, which drains the southern part of the basin. These two streams interconnect at some locations in this area.

Around Ekala, the two main streams branch in different directions. One stream goes to the north as the Dandugam Oya. The other is a man-made canal called the Ja Ela flowing to the west.

The Dandugam Oya turns to the south near the International Airport after joining the two tributaries, the Mapalam Oya and Kimbulapitiya Oya draining the northern part of the basin. The river crosses the Negombo Road and runs through the northern part of the Muthurajawela Marsh, then eventually pours into the Negombo Lagoon.

The Ja Ela flows down a deep-cut section before crossing the Negombo Road and goes through the Muthurajawela Marsh, then pours into the Negombo Lagoon.

These two streams are also interconnected through the Old Negombo Canal, which branches from the Dandugam Oya in the north and runs along the seaward side of the Negombo Road down to the Kelani Ganga to the south.

1.2.2 Kalu Oya (Figure 1.2.2)

The Kalu Oya basin is a relatively small catchment located between the Ja Ela basin to the north and the Kelani Ganga basin to the south. Topography of the basin is flat, as a whole, with a maximum elevation of 40 m above MSL at the northeastern boundary. The stream originates in the northeastern part of the basin some 15 km away from the sea. Draining the semi-urbanized areas in the basin, the main stream flows crossing the Kandy Road and Negombo Road afterwards, then joins the Old Negombo Canal.

Because of the low lying topography in the basin, marsh lands are formed along the main stream and tributaries. The marshlands spread widely in Pinammeda, Horape and Mabole areas located along the reaches between the Kandy Road and Negombo Road. The ground elevation in these marshlands is less than 1 m above MSL.

The Kalu Oya is the only major drainage for the basin, crossing the Negombo Road of which the surface elevation is more than 5 m higher than the marshlands. The drainage of the Kalu Oya is affected by the water level of the Kelani Ganga connecting through the Old Negombo Canal. This difficulty of drainage is a main cause of the inundation in the basin.

1.2.3 Hamilton Canal and Old Negombo Canal (Figure 1.2.3)

The Muthurajawela Mash, a wetland of vast extent, lies along the western coast between the Negombo Lagoon and Kelani Ganga. The Marsh, with an area of 3,068 ha, is separated from the sea by a sand barrier along the coast. There are two major canals connecting the Negombo Lagoon with the Kelani Ganga, which were constructed in colonial time for navigation purposes.

The Hamilton Canal runs along the coast north to south with a length of 15 km. This canal is well maintained with a road running alongside and is still utilized as a navigation waterway for fishery boats.

The Old Negombo Canal originally connected the Dandugam Oya with Kelani Ganga but is separated into two sections by a bund constructed along the southern bank of Ja Ela. This canal was also constructed for the purpose of navigation or irrigation for paddy cultivation envisaged in the past but is no longer utilized for such purposes at present.

1.2.4 Kelani Ganga (Figure 1.2.4)

The Kelani Ganga drains a basin area of 2,292 km^2 originating in the central highlands of the country with a highest elevation of 1,500 m. The river flows down the western slopes of the central highlands, collecting water from its tributaries. The main stream of the river reaches the boundary of the study area around Biyagama and runs through the flatland, then eventually pours into the Indian Ocean near Crow Island in the north of Colombo. The length of the river is 145 km from its origin to estuary. Within the study area, the length of the main stream section from Biyagama to Crow Island is around 20 km with a gradient of 1/6,000.

1.2.5 Greater Colombo Canal System (Figure 1.2.5)

According to the GCFC&EIP, the Greater Colombo area is defined as the area covering the local authority areas of Colombo MC, Sri Jayawardenapura Kotte MC, Kolonnawa MC, Dehiwela - Mount Lavinia MC, and Moratuwa MC. The total area of the Greater Colombo area is 165 km^2.

In view of drainage systems, the Greater Colombo area is composed of a major drainage basin and other small catchments. The major drainage basin covers an area of 85 km^2 bounded by Nugegoda - High Level Road to the south, Talangama - Hokandara watershed to the east, Kelani flood bunds to the north, and elevated urbanized areas of Colombo along the coast to the west. The streams collect runoff in the upstream catchment and flow into Parliament Lake. After Parliament Lake, the urbanized areas are drained by the canal system improved by the GCFC&EIP Phase I. Runoff in the basin is discharged through the North Lock Gate to the Kelani Ganga and the Mutwal Tunnel to the sea in the north as well as the Wellawatta and Dehiwala sea outfalls in the south.

There are lowlands with a ground elevation lower than 1 m above MSL. The majority of lowlands spread around Parliament Lake, Heen Ela, Kolonnawa Ela, and Kotte Ela and function as storm water retention areas in the major drainage basin. The total area of these lowlands was estimated at 686 ha in the study stage of the GCFC&EIP Phase I but would be decreasing due to land filling for development.

The rest of the Greater Colombo area mainly consists of small drainage basins along the coast or belongs to the Bolgoda basin.

1.2.6 Bolgoda Lake (Figure 1.2.6)

The Bolgoda basin, located between the Kelani Ganga basin to the north and the Kalu Ganga basin to the south, has a drainage area of 394 km^2. In the upper catchment area, the streams originate from the hills with a highest elevation of 20 m above MSL at the eastern boundary of the basin. The lower catchment area lies in the lowlands widely spreading along the coast with water surfaces and surrounding marshlands. There is a unique water system in the basin comprising the two major lakes with incoming and outgoing waterways.

The Weras Ganga is one of the major water waterways continuing from Bolgoda Lake North. The Weras Ganga collects runoff in the northern part of the basin. The drainage area of the Weras Ganga is the most developed area of the basin covering the urban areas of Nugegoda, Dehiwala - Mount Lavinia, Moratuwa, Maharagama and Kesbewa. Marsh lands spread along the Weras Ganga and incoming streams, which are partly subject to land fillings for development.

North Bolgoda Lake, with a water surface area of 760 ha at normal water level of 0.07 m above MSL, is located connecting with the southern end of the Weras Ganga. The lake collects runoff from the Weras Ganga catchment in the north and the Maha Oya catchment in the east through the Bolgoda Ganga. Incoming runoff to the lake is finally drained through the Panadura Ganga, which is the largest outfall to the sea.

The Bolgoda Ganga is a waterway interconnecting the North and South Bolgoda Lakes. The length of the waterway is around 12 km between the two lakes. The waterway remains almost natural and the areas along the waterway have not been developed because of the difficulty of access through the wetlands.

South Bolgoda Lake has a water surface area of 340 ha at normal water level of 0.10 m above MSL and still remains natural as a whole. Collecting incoming runoff mainly from the Bolgoda Ganga, the lake would drain runoff southwards through the two canals called Kepu Ela and Aluth Ela connecting to the Kalu Ganga but flow directions of both canals would depend on the water level of the Kalu Ganga. There is another canal named Talpitiya Ela connecting the lake with the sea but its sea outfall is closed by sandbar almost throughout the year.

The Maha Oya and Panape Ela are the major streams draining the upper catchment, almost corresponding to the eastern half of the basin.

The Bolgoda basin can be broadly classified into three regions in the light of the current development and land use. The northern region, in and around the Weras Ganga catchment, is covered by the highly urbanized areas of Nugegoda, Dehiwela-Mount Lavinia, Moratuwa and Kesbewa. The southern region, covering the southern half of the basin, remains rural as a whole, such as Panadura, Kalutara, Bandaragama and Horana areas. The northeastern region around Homagama occupying the upper catchment of the Maha Oya is semi-urbanized with a mixture of urban centers and rural areas

CHAPTER 2 STORM WATER DRAINAGE PROJECTS IN THE STUDY AREA

2.1 Storm Water Drainage Projects in the Past

2.1.1 Kelani Ganga Flood Protection Scheme

The historical water level records at Nagalagam Street located near the Victoria bridge across the Kelani Ganga indicate that the maximum water level was 13.5 ft (4.11 m above MSL) in the year 1837, followed by 11.9 ft (3.63 m) in 1872, 12.6 ft (3.84 m) in 1922, and 12.85 ft (3.92 m) in 1947. These floods are classified as 'critical' according to the criteria used by the Irrigation Department.

Classification of Kelani Ganga Flood

Classification	Water Level at Nagalagam Street	MSL Level (m above MSL)
Minor Flood	Greater than 5 feet	1.32
Major Flood	Greater than 8 feet	2.23
Dangerous Flood	Greater than 10 feet	2.84
Critical Flood	Greater than 12 feet	3.45

Source: Kelani Ganga Flood Protection Study, 1992

The major facilities relevant to the Kelani Ganga Flood Protection Scheme are shown in Figure 2.1.1. To protect the downstream basin areas from the critical floods, a series of flood bunds (dikes) were constructed since 1924 and strengthened thereafter. The flood bunds along the southern bank of the Kelani Ganga were constructed to prevent the city of Colombo from flooding. On the other hand, the bund levels along the northern bank are kept lower than the southern bank. The protection level of the northern bank is for a 50-year return period flood. In the case of a flood event exceeding the protection level, flooding would overtop the northern bank but the southern bank is still offers protection. The city of Colombo located on the southern bank of the Kelani Ganga is therefore protected against 500-year flood events.

The Kelani Ganga flood protection designates 'unprotected areas' that would be inundated as flood detention areas. In the vicinity of the city of Colombo, the areas such as Kittanpahuwa, Wenawatta, Megoda Kolonnwa, and Mahabuthagamuwa are regarded as unprotected areas. However, these areas are being urbanized due to pressure of development without any protection measures against the Kelani Ganga flooding. These areas would suffer from flooding even classified as 'minor' with a frequency of once in 2 years.

Besides the Kelani Ganga flooding, the unprotected areas are located in lowlands where the difficulty of storm water drainage has always existed. Development in these areas has been proceeding without provision of proper storm water drainage as a whole, especially in unauthorized housing areas formed in and around marshlands. Such areas are inundated frequently due to stagnant storm water.

Along the Kenani Ganga, incoming canals and streams are affected by water level of the main stream during flood. Flood gates are therefore placed at outlets to the main stream. The North Lock Gate located near the Victoria Bridge crossing the Kelani Ganga was constructed by the Irrigation Department and is one of the outlets from the drainage area of the GCFC&EIP Phase I. A new floodgate was constructed at the outlet of the Madiwela East Diversion Canal under the Phase I project.

In the northern side, a floodgate is located on the Old Negombo Canal at the Hekitta Road. Some gates are also found along the Kelani northern bunds. It seems that such gates are not operable due to deterioration and the lowlands along the bunds therefore suffer from difficulty of drainage.

2.1.2 New Capital City Drainage Project Feasibility Study

This study was carried out in 1981 and is called the 'Samitar Study'. The objective of this study was to provide improved storm water drainage for Colombo and its environs, particularly in the area of the new capital city of Sri Jayawardenapura Kotte, where the present Parliament Complex is located. The proposals of the study comprise inflow and outflow regulation for the area of the new capital city as shown in Figure 2.1.2. The planning scale for the proposed improvement was a 200-year return period flood.

The inflow regulation is to reduce storm water runoff from the Madiwela catchments located upstream of the area of the new capital city by means of the following two diversion schemes:

1) Madiwela East Diversion

A diversion dam is proposed at Akurugoda to divert storm water runoff from 8.6 km^2 of the Madiwela East catchment towards the Ambatale valley and into the Kelani Ganga. A diversion canal conveys storm water runoff from the pond called Talangama Tank to the Ambabale catchment.

2) Madiwela South Diversion

Another diversion dam across the Kavaiyan Ela is proposed in the south of the Duwa Lake (Parliament Lake) to divert storm water runoff from 15.1 km^2 of the Madiwela South catchment into the Weras Ganga catchment. A diversion canal has to be constructed to convey storm water runoff to the Weras Ganga.

The outflow regulation implies modification and improvement of the existing canal network in the Northward and Westward drainage systems located downstream of the area of the new capital city, consisting of the following measures:

1) Gotatuwa Pumping Station

A pumping station is proposed at the Gotatuwa bund for the disposal of storm water runoff from the Northward drainage system into the Kelani Ganga and to draw off the Madiwela catchments through the Westward drainage system.

2) Improvement of Northward Drainage System

The proposed improvement of the Northern drainage system consists of the channel improvement of the Kolonnwa Ela, Mahawatta Ela, Dematagoda Ela, Orugowatha Canal, St. Sebastian Canal and Main Drain together with construction of a new tunnel at Mutwal.

3) Improvement of Westward Drainage System

The proposed improvement of the Western drainage system consists of the channel improvement of the Heen Ela, Kotte Ela, Torrington Canal, Kirillapone Canal, Wellawatta Canal, Dehiwala Canal and Bolgoda Canal.

4) Storm Water Retention Area

The necessity of providing storm water retention areas by conservation of existing marsh areas was proposed by the study. The proposed retention areas and ponds are the Main Drain, Gotatuwa, Yakbedda, Madinnagoda, Heen Ela and Kotte Lake. The total extent of the retention areas and ponds is 290 ha in the Northward and Westward drainage systems.

The Samitar Study covered the corresponding basin area of the Greater Colombo basin and established the basic concept for the improvement of storm water drainage in the basin. Of the proposals of the Samitar Study, the improvement of existing canal systems were materialized by the succeeding studies and implemented afterwards as described hereunder.

2.1.3 Greater Colombo Flood Control and Environment Improvement Project Phase I (GCFC&EIP Phase I)

The major canal system in and around the city of Colombo was improved by Phase I of the Greater Colombo Flood Control and Environment Improvement Project (GCFC&EIP).

The project area of the GCFC&EIP was defined as a drainage basin with an area of 85 km^2, which covers a major part of the Colombo Municipal Council area and some parts of the Sri Jayawardenapura Kotte Municipal Council and the Dehiwala - Mount Lavinia Municipal Council areas.

The Project Preparation Report - Storm Water Drainage was prepared in 1985 under the Sri Lanka Water Supply and Sanitation Rehabilitation Project handled by the National Water Supply and Drainage Board (NWSDB). This study was a kind of pre-feasibility study proposing a feasibility study for the rehabilitation of the canal systems.

This feasibility study was carried out in 1988 as "The Study of the Canal and Drainage System in Colombo" under NWSDB. The review and update of the study and detailed design were afterwards conducted in 1992 as "The Greater Colombo Canal and Drainage System Rehabilitation Project" under the Sri Lanka Land Reclamation and Development Corporation (SLLRDC). The project was implemented from 1992 to 1998 and called the Greater Colombo Flood Control and Environment Improvement Project Phase I (GCFC&EIP Phase I). The major drainage canals improved during the Phase I project are 44 km in the total length including 24 stretches as shown in Figure 2.1.3 and Table 2.1.1.

The Northern System drains the northern part of the drainage area encompassing an area of 22.2 km^2. The eastern part of the Northern System is mostly built-up areas extending from the Colombo Municipal Council area to the east. An area east of the Dematagoda Canal is mostly agricultural land with homesteads and sparsely used cropland. The major canals in the system are Kolonnawa Ela, Kolonnawa Ela North, Mahawatta Ela, Dematagoda Ela, St. Sebastian Canal, St. Sebastian North and East Canals, and the Main Drain. The system drains to the north from either the North Lock Gate or Mutwal Tunnel Outlets.

However, the North Lock Gate is subject to closure during the wet season when the water level of the Kelani River becomes high and the Mutwal Tunnel to the sea is almost closed due to its deterioration. Therefore, the storm water in the Northern System is likely to flow down to the south during the wet season.

The Southern System starts at Kotte Ela North at the branch of the Kolonnawa Ela coming from Parliament Lake, and flows southwards through the Kotte Ela South, Kirillapone Canal and branches into the Wellawatta and Dehiwela Canals, then eventually drains to the sea. The western part of the system is a densely populated residential area continuing southwards from the Colombo Municipal Council area. A backswamp called Kotte Lake spreads along the Kotte Ela North and impounds storm water occasionally. The Southern System drains an area of 14.7 km^2.

The Western System drains the Torrington area of 8.6 km^2 to the Heen Ela connecting to the Kirillapone Canal in the Southern System. This drainage area is predominantly urbanized and includes well-established residential areas in the southern part of Colombo.

The Eastern System contains mostly of the Sri Jayawardenapura Kotte Municipal Council area where the new capital city is located. The drainage area of Parliament Lake is 40.2 km^2 and is predominantly surrounded by rural areas except the developed areas around Parliament Lake. Part of the storm water in this drainage area is diverted to the neighboring drainage area by the Madiwela East Diversion Canal to reduce storm water flow to the downstream of the System. The Madiewela East Diversion Canal starts from the Talangama Tank and goes down northwards through the neighboring drainage area, then drains into the Kelani Ganga.

At the time of the study, it was proposed that the existing lowlands in the drainage area of the major canal system should be preserved as storm water retention areas to relieve the downstream canal system of flood wave peaks. According to the study reports, there were some 686 ha of lands lower than 1 m above MSL functioning as retention basins. Of the areas, the study recommended that 174 ha around Parliament Lake should be kept for retention purposes. The other 512 ha to the west of Parliament Lake was already subject to land filling. The study concluded that 380 ha out of 512 ha should be kept as storm water retention area together with the implementation of the Madiwela East Diversion Canal in addition to the improvement of the major canal system. This conclusion was finally adopted in the implementation of the GCFC& EIP Phase I.

2.1.4 Urban Drainage in the Greater Colombo Area

Besides the rehabilitation of the canal systems, local drainage problems needed to be alleviated in urbanized areas in Colombo Municipal Council (CMC). Therefore, the Project Preparation Report - Storm Water Drainage prepared in 1985 also proposed the eight local drainage schemes for the priority areas in CMC. Out of eight, the first four were implemented but the remaining four were suspended due to the shortage of funds.

Meanwhile, on 4th June 1992, Colombo was hit by the worst flood recorded with an exceptional rainstorm of 495 mm in 24 hours. This flood paralyzed Colombo during a period of about one week, depriving people of their properties. It was revealed afresh that not only the canal system but also the urban drainage systems were essential. In response to people’s strong desire, SLLRDC prepared the project promotion report of "Colombo Metropolitan Storm Water Drainage Project" and proposed to tackle the improvement of storm water drainage systems in Colombo and the suburbs in parallel with the implementation of Phase I of GCFC&EIP.

In 1993, SLLRDC conducted a feasibility study for the Greater Colombo area (Colombo and its environs, consisting of five MCs/UCs), aimed at establishing an overall storm-water drainage improvement plan, including the flood damage survey in the area. The findings of the flood damage survey are given in the table below.

Outline of Flood Damage in the Greater Colombo Area

Location	Total Area (km^2)	Total Population	Flooding Area (km^2)	Flood Damage (Rs. Mill/yr.)	Population in Flooded Areas	No. of Houses
CMC	37.33	752,400	1.70	173.55	45,770	6,500
DMMC and MMC	44.30	419,800	4.59	139.76	54,120	8,190
Kolonnawa UC and Kotte UC	22.40	191,900	1.95	8.37	4,070	900
Total	104.03	1,364,100	8.27	321.68	103,860	15,590

Source: Implementation Program for Phase II of GCFC&EIP, 1994

It was revealed that 103,860 people and 15,590 houses are directly affected with an annual damage of Rs. 321.68 million in the whole Greater Colombo area. The flood damage in Dehiwala - Mount Lavinia Municipal Council (DMMC) and Moratuwa Municipal Council (MMC) areas is the next highest to that of CMC area and the number of houses affected by floods in this area is greater than that of the CMC area.

Based on that feasibility study in 1993, the GCFC&EIP Phase II was taken up for implementation. This project is to prevent localized flooding in five urgent areas identified within the Colombo MC. In addition, the Phase II work included the Review of F/S carried out by SLLRDC in 1993. The Review of F/S covered 19 storm water drainage schemes in the CMC area, five schemes in DMMC and MMC areas and some other small scale pump drainage schemes in the areas of Kolonnawa UC and Kotte MC as shown in Figure 2.1.4.

Five schemes in DMMC and MMC areas, namely Kawdana, Attidiya, Mahakuburuowita, Lunawa North and Lunawa South, were reviewed as priority projects, of which two schemes, Kawdana and Attidiya, were taken up for detailed design under the Phase II of GCFC&EIP and the construction work is now in progress under the Phase III of GCFC&EIP. The main reason for promoting these two schemes was that these involve the least land acquisition and fewer shanty relocations, when compared with the other three schemes. The Mahakuburuowita scheme was found not feasible for implementation due to high cost.

In the Review of the F/S conducted in 1996, the proposed Lunawa Project (Lunawa North and South) was evaluated as the top priority scheme to come up for implementation in the next stage. The project is foreseen to alleviate flood problems over an area of 1.67 km^2, which corresponds to 36.4 % of the total flood-prone area in the whole of DMMC and MMC.

2.1.5 Greater Colombo Flood Control and Environment Improvement Project Phase II (GCFC&EIP Phase II)

To alleviate the major local floods (inundation) habitually observed in the Colombo Municipal Council (CMC), GCFC&EIP Phase II was implemented from 1998 to 2001 by SLLRDC. The project includes the following five drainage schemes located in the highly built-up area inside the CMC and the total coverage area is around 560 ha.

1) Torrington West Scheme
2) Dematagoda Scheme
3) St. Sebastian-2 Scheme
4) Serpentine Canal Scheme
5) Unity Place Scheme

These schemes were recognized as the most urgent schemes to resolve the fundamental problems on the storm water drainage system in each drainage area, which were confirmed through the investigations of the drainage system and inundation surveys during the Review of F/S. The project includes construction of trunk drains including underground pipes/culverts under the roads and rehabilitation of existing open channels. The total length of drainage channels improved in this project is around 7 km. All these trunk drains were connected to the main canals improved under the GCFC&EIP Phase I or directly to the sea. The principal features of each scheme are summarized in Figure 2.1.5 and Table 2.1.2.

2.2 On-going Storm Water Drainage Projects

2.2.1 Greater Colombo Flood Control and Environment Improvement Project Phase III (GCFC&EIP Phase III)

A large part of the Dehiwala - Mount Lavinia Municipal Council (DMMC) area is already urbanized but a satisfactory storm water drainage system has not been provided. Unlike the CMC area, there is no systematic drainage network in these areas. In general, storm water drainage in these areas consists of natural streams as trunk drains partly canalized with masonry or concrete works and smaller open drains collecting and leading storm water to the trunk drains. It appears that such drains have been constructed part-by-part without a proper engineering design processes.

In order to improve the drainage condition in the urban area to the south of CMC area, the following 5 storm water drainage improvement schemes were proposed by SLLRDC. These schemes were designed on the basis of a rainstorm event with a 2-year return period to alleviate the frequent inundation.

1) Mahakunbruowita Scheme
2) Kawdana Scheme
3) Attidiya Scheme
4) Lunawa Lake North Scheme
5) Lunawa Lake South Scheme

Out of the 5 schemes, the Kawdana and Attidiya schemes are being implemented as the GCFC&EIP Phase III project by SLLRDC. The total coverage area of the two schemes is 522 ha. A storm water drainage system including trunk drain channels, secondary drains and roadside ditches is to be constructed for the entire area. The total length of all the drain channels to be constructed is around 40 km. The principal features of Phase III Schemes are summarized in Figure 2.2.1 and Table 2.2.1.

2.2.2 Lunawa Lake Environment Improvement and Community Development Project

The project area covers the Lunawa Lake basin with a drainage area of 615 ha including the two major drainage areas, namely, Lunawa Lake North (353 ha) and Lunawa Lake South (262 ha) extending over DMMC and MMC areas. The drainage system in the basin consists of the trunk drains connecting to Lunawa Lake and their distinct tributaries (secondary drains) and tertiary drains mainly constructed along roads. The total length of such drains was estimated to be around 135 km.

This project is composed of two major components. One is storm water drainage improvement with resettlement site construction and procurement of O&M equipment. In this component, two drainage schemes, that is, the Lunawa Lake North scheme and the Lunawa Lake South scheme are to be implemented. These schemes were identified and studied together with the two drainage schemes that are now being implemented under the GCFC&EIP Phase III. The construction work consists mainly of improvement of existing trunk drains and secondary drains. Other than the trunk and secondary drains, part of the tertiary drains (roadside drains) are also to be improved. The total length of drains to be improved under this project is around 87 km.

Drainage Canals to Be Improved Under Lunawa Project

(Unit: m)

Drains	Lunawa Lake North	Lunawa Lake South	Total
Trunk Drains	3,930	2,770	6,700
Secondary Drains	2,840	1,340	4,180
Tertiary Drains	43,028	33,369	64,344
Total	49,798	37,479	87,277

Source: SAPROF Study for Lunawa Lake Environment Improvement and Community Development Project, 2001

The community development component envisages a community's contribution to sustain an effective drainage-based flood alleviation program, which aims to empower the community as a self-help and voluntary organization in both terms of replicating environmental-conservation practices and upgrading their living standard on a sustainable basis. The community development component aims at facilitating the following:

1) Formation of Settlement Development Committees (SDCs), which will be assisted by the strengthened technical and management support of the local authorities;
2) Create community awareness of flood control, solid/wastewater management and better hygiene;
3) Ensure the community's contribution to tackle the identified problems and the provision of support activities to promote the said processes; and
4) Inculcate community responsibility to sustain the benefits accrued from the project and institutionalize a mechanism of self-help activities by the community.

Two groups of communities are subject to upgrading under the project, i.e. about 450 families to be relocated in connection with the implementation of drainage improvement works and accommodated in four resettlement sites, and 441 families in 11 under-served communities affected by inundation. The principal features of the project are summarized in Figure 2.2.2 and Table 2.2.2.

CHAPTER 3 EXISTING PROBLEMS ON STORM WATER DRAINAGE

3.1 Existing Problems on Storm Water Drainage

The study area is mostly situated in the coastal lowland, which is naturally prone to flooding problems. However, it is generally pointed out that the storm water drainage problems in the study area have been worsening due to the following causes:

1) Insufficient storm water drainage systems are provided during urbanization.
2) Bottleneck portions of drainage canals remain or are created at crossing structures.
3) Sea outfalls of drainage canals are likely to be closed by sand bars.
4) Flow capacity of the drainage canal is decreased due to deposition of waste and garbage, sedimentation, and aquatic plants.
5) Water retarding capacity is decreasing due to land reclamation in the lakes, canals, wetlands, paddy fields, etc. because of high demands for land development.
6) Storm water runoff is increasing due to land development in the upstream basin.

Causes of storm water drainage problems would be different by drainage basin, depending on the characteristics of the drainage system. To provide proper measures against storm water drainage problems, it is essential to first identify the problems and clarify their causes by drainage basin. Assessment of existing problems on storm water drainage in the study area was therefore carried out through field observations, collection of information from local authorities concerned, and a flood damage survey.

3.2 Flood Damage Survey

3.2.1 Ja Ela Basin

(1) Summary of Flood Damage Survey

Figure 3.2.1 indicates the locations of inundation areas identified through the flood damage survey. The results of a questionnaire survey regarding inundation are summarized below:

Number of Inundation Areas by Local Authority

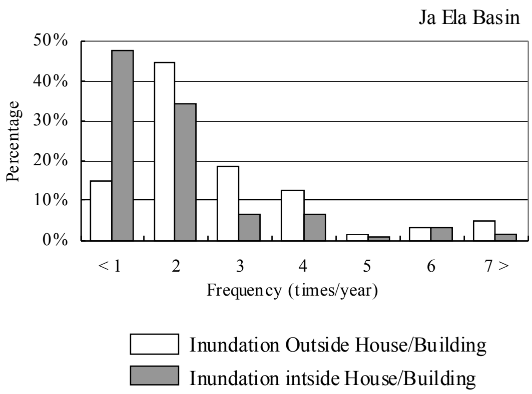
Local Authorities	No. of Inundation Areas	No. of Questionnaires
Wattala PS	32	64
Katana PS	3	7
Katunayake Seeduwa UC	8	18
Ja Ela UC	8	22
Ja Ela PS	5	10
Gampaha PS	4	8
Total	60	129

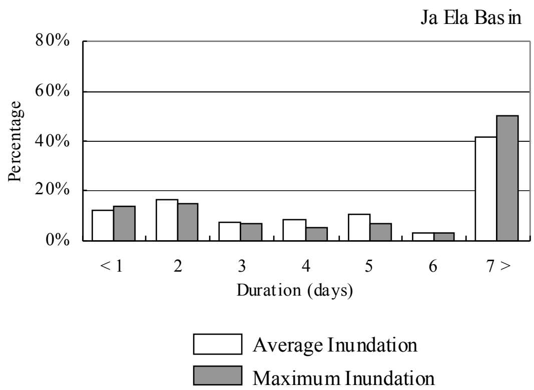
Frequency of Inundation

Frequency (times/year)	1 or Less	2	3	4	5	6	7 or More
Inundation Outside House/Building	15%	45%	19%	13%	2%	3%	5%
Inundation Inside House/Building	48%	34%	6%	6%	1%	3%	2%

Duration of Inundation

Duration (days)	1 or Less	2	3	4	5	6	7 or More
Average	13%	17%	7%	9%	10%	3%	42%
Maximum	13%	15%	6%	6%	6%	3%	50%





Frequency and Duration of Inundation

Cause of Inundation

Cause	Percentage
Overflow from principal canals	18%
Drains insufficient	21%
Poor maintenance of drains	20%
Drains clogged by garbage dumping	13%
Landfill along canals and lakes	15%
Loss of woods, grasslands, paddy fields and wetland due to development	7%
Other	7%

Source: Flood Damage Survey in 2001, JICA Study Team

(2) Assessment of Existing Problems on Storm Water Drainage

1) Overflow from the Main Stream

The main streams of the basin collect and drain runoff from a rather wide drainage area of 860 km^2. When widespread heavy rainstorms occur in the basin, a large volume of flood runoff concentrates into the main streams such as the Attanagalu Oya and Urwal Oya in the middle reaches and the Dandugam Oya and Ja Ela in the downstream reaches. The main streams overflow when flood runoff exceeds their flow capacity. Such flooding happens in lowlands along the main streams.

Along the main streams in the basin, the inundation areas identified in Gampaha PS, Katana PS, and some locations near the Negombo Road are subject to the overflow from the main stream. A vast extent of lowlands in Gampaha PS, Katana PS and Ja Ela PS along the main stream would get inundated in the case of large scale flooding but there are few inundation areas identified in such areas. Inundation by flooding of the mainstreams mostly spreads over paddy fields and surrounding residential areas would not be seriously affected.

2) Influences of Water Level on Muthurajawela Marsh

The drainage system in the basin is characterized by Muthurajawela Marsh in the downstream end of the basin. The Marsh covers a vast extent in the downstream basin and functions as a natural flood plain. Storm water runoff collected through the main stream retards in the Marsh before draining into the Negombo Ragoon. During the period of flood retardation, the water level of the Marsh rises and causes inundation of surrounding areas. Surrounding lowlands around the Marsh are inundated directly. Inundation would also expand over the surrounding drainage areas due to storm water drainage backing up due to the water level rising in the Marsh.

The inundation areas identified in the Muthurajawela Marsh surrounding areas are subject to the influences of water level on Muthurajawela Marsh. Resident's dwellings are constructed in lowlands, which were marshlands originally, without proper manner of landfill and drainage facilities. These inundation areas are characterized by a longer duration of inundation lasting one week or more. In contrast, in other urbanized areas the duration of most inundation events is less than 2 days.

3) Lack of Storm Water Drainage Systems

Urbanized areas in the basin are located mainly along the Negombo Road. In these areas, it is observed that drainage canals sufficient for discharging storm water runoff into the mainstreams or Muthurajawela Marsh are not provided as a whole. Insufficiency of such drainage canals would attribute to local inundation by storm water runoff in the urbanized sub-drainage areas.

The inundation areas identified in urbanized areas along the Negombo Road are mainly subject to the lack of storm water drainage systems. On the eastern side of the Negombo Road, the only substantial drainage crossings are the Dandugam Oya and Ja Ela. Drainage canals connecting to these main streams should therefore be required for establishing proper storm water drainage systems.

Inundation of local roads is also reported at many locations. It is observed that, in many cases, road crossing culverts are constructed with almost the same size as the existing stream. Under-sized crossing culverts are presumed to cause the inundation.

3.2.2 Kalu Oya Basin and Kelani Ganga North Bank

(1) Summary of Flood Damage Survey

Figure 3.2.2 indicates locations of the inundation areas identified through the flood damage survey. The results of a questionnaire survey regarding inundation are summarized below:

Number of Inundation Areas by Local Authority

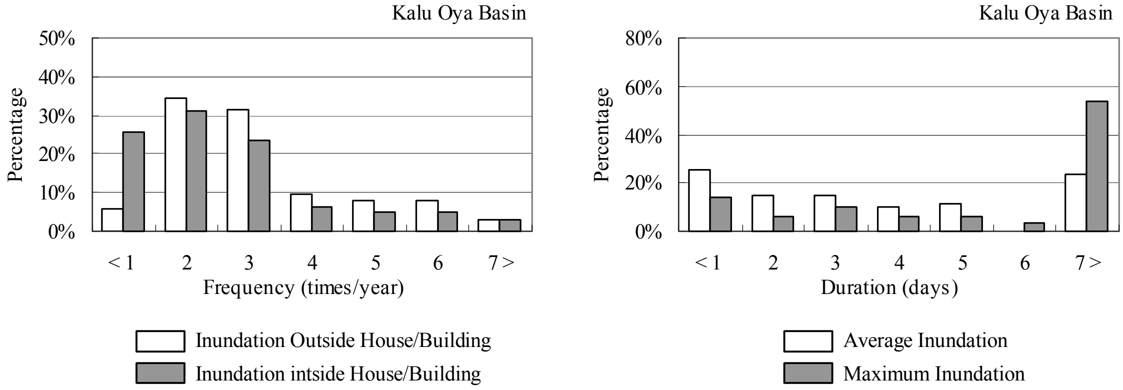
Local Authorities	No. of Inundation Areas	No. of Questionnaires
Wattala-Mabole UC	9	26
Mahara PS	2	4
Peliyagoda UC	6	13
Kelaniya PS	22	49
Biyagama PS	6	12
Total	45	104

Frequency of Inundation

Frequency (times/year)	1 or Less	2	3	4	5	6	7 or More
Inundation Outside House/Building	6%	34%	31%	10%	8%	8%	3%
Inundation Inside House/Building	26%	31%	24%	6%	5%	5%	3%

Duration of Inundation

Duration (days)	1 or Less	2	3	4	5	6	7 or More
Average	25%	15%	15%	10%	12%	0%	24%
Maximum	14%	6%	10%	6%	6%	3%	54%



Frequency and Duration of Inundation

Cause of Inundation

Cause	Percentage
Overflow from principal canals	17%
Drains insufficient	20%
Poor maintenance of drains	21%
Drains clogged by garbage dumping	15%
Landfill along canals and lakes	11%
Loss of woods, grasslands, paddy fields and wetland due to development	5%
Other	11%

Source: Flood Damage Survey in 2001, JICA Study Team

(2) Assessment of Existing Storm Water Drainage Problems

1) Difficulty of Natural Drainage to Kelani Ganga

The Kelani Ganga north bank area is protected by a bund against 50-year flood events of the Kelani Ganga. According to the Kelani Ganga Flood Protection Study, the water level of the Kelani Ganga at Nagalagam Street was estimated at 3.52 m above MSL in the case of a 50-year flood event. The Kelani bunds were therefore constructed with a higher crest elevation than the flood level. On the other hand, ground elevations of the widespread lowlands in the Kalu Oya basin and Kelani north bank are 1.0 m above MSL or less, which is much lower than the bunds. Such elevations are also lower than a 'minor flood' of 1.32 m above MSL at Nagalagam Street.

All the drainage systems in the Kalu Oya basin and Kelani north bank are eventually connected to the Kelani Ganga at the downstream end and are affected by the water level of the Kelani Ganga. The lowlands suffer from inundation due to the drainage problems caused by the water level of the Kelani Ganga in every rainy season. Once heavy a rainstorm occurs together with a high water level in the Kelani Ganga, storm water runoff is not drained and overflows from the Kalu Oya main stream and other drainage canals connecting to the Kelani Ganga. In such a case, inundation spreads widely and continues for one week or more, especially in the lowlands.

The difficulty of natural drainage to Kelani Ganga is the fundamental constraint on storm water drainage in the Kalu Oya basin and Kelani north bank. The majority of inundation areas identified in Wattala-Mabole UC, Peliyagoda UC, and the southern part of Kelaniya PS and Biyagama are subject to the difficulty of natural drainage to Kelani Ganga .

2) Lack of Storm Water Drainage Systems

In the Kalu Oya basin and Kelani north bank, the areas along the Negombo Road and Kandy Road have been urbanized. In these areas, it is observed that drainage canals sufficient for discharging storm water runoff into the Kalu Oya mainstream or Kelani Ganga are not provided as a whole. Insufficiency of such drainage canals would attribute to local inundation by storm water runoff in the urbanized sub-drainage areas.

Besides the drainage canals, gates are constructed at the downstream ends of drainage systems to protect against reverse flow during flood of the Kelani Ganga. It seems that such gates are not in proper operation due to deterioration. The lowlands along the bunds therefore suffer from a difficulty of storm water drainage.

Localized inundation areas in Mahara PS and the northern part of Kelaniya PS and Biyagama PS are located in relatively higher areas and would be subject to the lack of storm water drainage systems.

3) Landfill in Lowlands

Along with the urbanization in the Kalu Oya basin and Kelani north bank, lowlands such as marsh areas and paddy fields have been reclaimed for development. Although widespread lowlands still remain at present, these will be subject to reclamation in the future because of development needs. It has been pointed out that such reclamation will adversely affect storm water drainage systems due to a decrease in the storm water retention effects of the lowlands.

At present, it seems that the influences of reclamation are not distinctly revealed. The problems, which are due to the lack of technical considerations for storm water drainage, would be limited to local inundation created in the vicinity of reclaimed lands or in the reclaimed lands themselves. The adverse effects are anticipated to increase in the future if urbanization continues expanding over the entire drainage area without proper measures for storm water drainage.

The landfill in lowlands is a threat potentially causing widespread inundation by storm water runoff due to the drainage difficulties of the Kelani Ganga. A large amount of land reclamation in existing marsh areas and paddy fields would cause a significant concentration of storm water runoff to the channels and remaining lowlands. Inundation would be caused by overflow from the channels as well as altered concentration of storm water runoff to the remaining lowlands, which might include not only marsh and paddy lands but also other land use categories. To avoid the adverse effects of the concentration of storm water runoff, a systematic approach should be considered necessary for implementation of land reclamation together with provision of a storm water drainage system.

3.2.3 Greater Colombo Basin and Kelani Ganga South Bank

(1) Summary of Flood Damage Survey

Figure 3.2.3 indicates locations of the inundation areas identified through the flood damage survey. The results of a questionnaire survey regarding inundation are summarized below:

Number of Inundation Areas by Local Authority

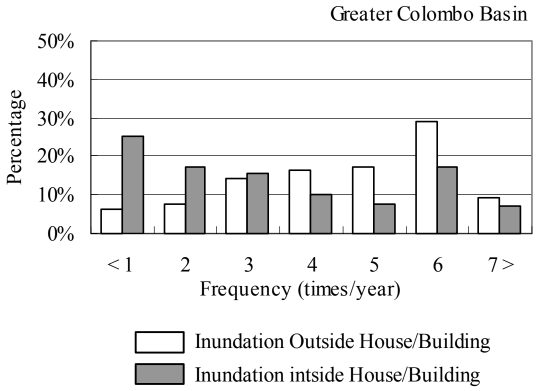
Local Authorities	No. of Inundation Areas	No. of Questionnaires
Colombo MC	105	332
Kolonnawa UC	5	17
Kotikawatta-Mulleriyawa PS	9	20
Sri Jayawardenapura Kotte MC	9	23
Maharagama PS	12	29
Kaduwela PS	8	20
Total	148	441

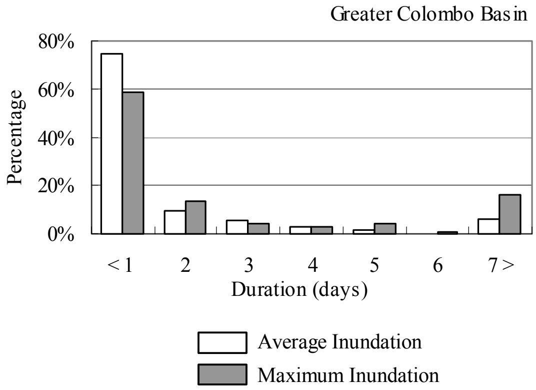
Frequency of Inundation (times/year)

Frequency (times/year)	1 or Less	2	3	4	5	6	7 or More
Inundation Outside House/Building	6%	8%	14%	16%	17%	29%	9%
Inundation Inside House/Building	25%	17%	16%	10%	7%	17%	7%

Duration of Inundation

Duration (days)	1 or Less	2	3	4	5	6	7 or More
Average	75%	10%	6%	3%	1%	0%	6%
Maximum	59%	13%	4%	3%	4%	1%	16%





Frequency and Duration of Inundation

Cause of Inundation

Cause	Percentage
Overflow from principal canals	9%
Drains insufficient	29%
Poor maintenance of drains	28%
Drains clogged by garbage dumping	22%
Landfill along canals and lakes	5%
Loss of woods, grasslands, paddy fields and wetland due to development	1%
Other	7%

Source: Flood Damage Survey in 2001, JICA Study Team

(2) Assessment of Existing Storm Water Drainage Problems

1) Deterioration and Under-capacity of Existing Storm Water Drainage System

The storm water drainage system in the CMC area was originally designed and commissioned in the early 20th century and was gradually enlarged to cover the entire CMC area by the 1970s. However, the system has been deteriorated due to the insufficiency or difficulty of maintenance, especially for the storm sewers constructed underground, which would be ignored for a long period after construction. In addition, the capacity of the drainage facility could not cope with peak storm water runoff that has been increasing with land use enhancement accelerated in urbanized areas after establishment of the existing system. It is also pointed out that roadside drains such as side ditches and gullies are blocked with silt and garbage and then storm water runoff on the road surface cannot be drained properly. As a result, the CMC area frequently suffers from local inundation in many places.

In the Greater Colombo basin, the Greater Colombo Flood Control and Environment Improvement Projects (GCFC&EIP) have been implemented since 1992. Under the GCFC&EIP Phase I, the main canals, of about 44 km in total length in and around the CMC area, were improved. These improved canals constitute the primary system of storm water drainage, which collects and drains storm water runoff from the entire basin. The flood safety levels were provided on the basis of maximum water level in the canal system, i.e. 1.85 m above MSL in Parliament Lake and 1.75 m above MSL for the urban part west of Parliament Lake. After the completion of the GCFC&EIP, the flood safety levels along the main canals were evaluated as follows:

Flood Safety Level in GCFC& EIP Phase I

Area	Return Period (years)
St. Sebastian Canals and Main Drain in Northern System	5
Dematagoda Canal and Torrington Canals	10
Other Canals and Parliament Lake	25

Source: Design Report, SLLRDC, 1992

Subsequently, in the GCFC&EIP Phase II, storm water drainage channels were constructed about 7 km in total length in five sub-drainage areas for draining storm water runoff into the main canals, which had been improved under Phase II. The canals improved under Phase II are regarded as trunk drains in the sub-drainage systems of the Greater Colombo basin. Phase II was implemented as an urgent project to solve the frequent local inundation in the sub-drainage areas that were faced with the most critical situation.

Phase II represents a direct approach to alleviate the present problems due to the deterioration and under-capacity of existing storm water drainage system. The same approaches need to be undertaken for the remaining sub-drainage areas. In combination with the trunk drains, improvements, restoration, and proper maintenance for further small drains are also required to alleviate frequent local inundation.

2) Urbanization in Unprotected Areas

The lowlands along the Kelani Ganga in Kolonnawa UC and Kotikawatta PS suffer from inundation due to difficulty in the natural drainage and absence of a proper storm water drainage system. These areas have been urbanizing along the Ambatale Road and Avisawella Road but a proper storm water drainage system was not provided. Many under-served dwellings are observed on the fringe of mash lands and most of those would be unauthorized. Such dwellings are prone to frequent inundation by stagnant storm water in the marshlands.

The Kolonnawa and Kotikawatta areas are located beyond the existing flood bunds. According to the Irrigation Department responsible for the Kelani Ganga Flood Protection Scheme, no protection for these areas against flooding of the Kelani Ganga is considered at present. Development should have been restricted in these areas under the present flood protection scheme, which designates these areas as flood plains in the case of the Kelani Ganga flooding. However, these areas have been urbanizing substantially and some measures would be necessary to alleviate the present problems.

Possible solutions for the present problems on storm water drainage in the Kolonnawa and Kotikawatta can only be studied dependant upon the basic principles of the flood protection scheme and land use in the future. Review of the present flood protection scheme should be necessary to find out which areas will remain unprotected or be protected. Principles of land use in these areas should also be established based on the conclusions in reviewing the flood protection scheme.

3.2.4 Bolgoda Basin

(1) Summary of the Flood Damage Survey

Figure 3.2.4 indicates the locations of the inundation areas identified through the flood damage survey. The results a of questionnaire survey regarding inundation are summarized below:

Number of Inundation Areas by Local Authority

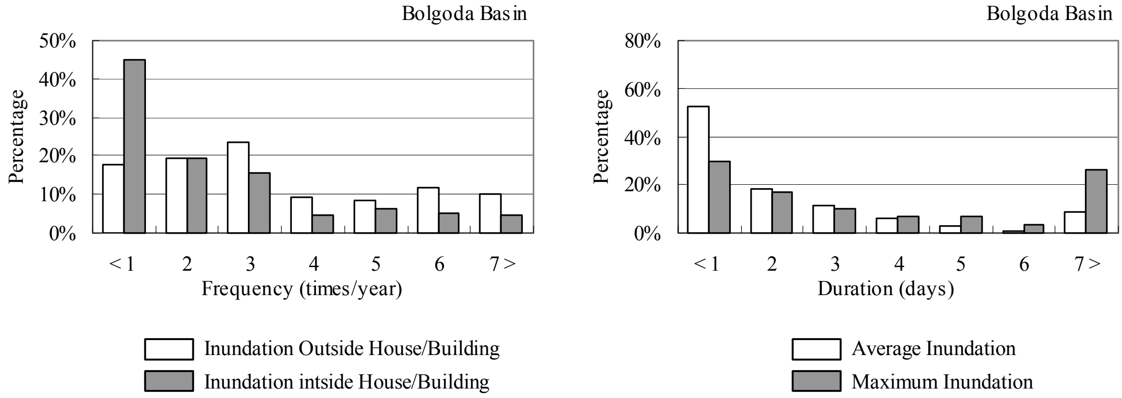
Local Authorities	No. of Inundation Areas	No. of Questionnaires
Dehiwala Mt. Lavinia MC	30	91
Moratuwa MC	11	31
Kesbewa PS	11	30
Homagama PS	9	18
Kalutara PS	15	30
Panadura UC	6	14
Panadura PS	27	54
Bandaragama PS	19	38
Dodangoda PS	13	28
Total	141	334

Frequency of Inundation (times/year)

Frequency (times/year)	1 or Less	2	3	4	5	6	7 or More
Inundation Outside House/Building	18%	19%	23%	9%	8%	12%	10%
Inundation Inside House/Building	45%	19%	15%	4%	6%	5%	5%

Duration of Inundation

Duration (days)	1 or Less	2	3	4	5	6	7 or More
Average	52%	18%	12%	6%	2%	1%	9%
Maximum	30%	17%	10%	7%	7%	3%	26%



Frequency and Duration of Inundation

Cause of Inundation

Cause	Percentage
Overflow from principal canals	19%
Drains insufficient	27%
Poor maintenance of drains	25%
Drains clogged by garbage dumping	15%
Landfill along canals and lakes	9%
Loss of woods, grasslands, paddy fields and wetland due to development	3%
Other	2%

Source: Flood Damage Survey in 2001, JICA Study Team

(2) Assessment of Existing Storm Water Drainage Problems

1) Lack of a Storm Water Drainage System

The Dehiwela-Mount Lavinia MC, Moratuwa MC, Panadura UC, and Kesbewa PS are growing with the urbanizing expansion from CMC to the south but a satisfactory storm water drainage system has not been provided to cope with the urbanization. The lack of systematic storm water drainage contributes to frequent local inundation at many locations in these areas. It is also pointed out that roadside drains such as side ditches and gullies are blocked with silt and garbage and then storm water runoff on the road surface cannot be drained properly.

The other areas in the basin are almost rural with low-density residential areas and agricultural lands. Storm water drainage depends on natural streams except for limited locations of town/village centers. Most of the local inundation found in these rural areas would be caused by overflow from natural streams in the case of heavy rainstorms.

Along the downstream water system, there are a number of control structures constructed by the Irrigation Department responsible for flood protection of major river systems. Most of these were constructed for the purposes of irrigation and preventing salt-water intrusion from reaching paddy fields. Some flood protection structures also exist on the Aluth Ela and Kepu Ela connecting to the Kalu Ganga. These are the gates to prevent flooding of the Kalu Ganga from the canals. These structures are old as a whole and were constructed in the colonial time. Many of such structures would not be in operation for the original purposes.

It was reported that some 10,300 ha of paddy fields can be identified on the basis of the maps published in 1980's but more than 50% of those are not cultivated due to several reasons at present such as unsuitable soils for cultivation, water-logging and conversion to other uses. Irrigation canals in such abandoned cultivation areas have been altered substantially to storm water drainage canals along with urbanization. However, many of such canals are not improved or maintained satisfactorily for the purpose of storm water drainage since the responsibility of canal maintenance is not smoothly transferred from the Irrigation Department to SLLRDC or local authorities concerned. As a result, the canals have insufficient flow capacity to handle storm water runoff from the urbanized drainage area due to lack of proper improvement. This issue is one of the major storm water drainage problems in the urbanizing areas.

2) Influences of the Water Level of Downstream Water Systems

The majority of the inundation areas identified in the southern part of the basin, i.e. Panadura PS, Bandaragama PS, and Kalutara PS, would be affected by water the level rising in the downstream water systems in the basin. An important characteristic of the drainage system in the Bolgoda basin is the downstream water system comprising the two major lakes with incoming and outgoing waterways. The water system and surrounding wetlands cover a vast extent in the downstream basin areas and functions as a natural flood plain. Storm water runoff collected through the incoming streams retards in the water system before being drained to the Panadura outfall and Kalu Ganga. During the period of flooding in the basin, the water level of the system rises and causes inundation in the surrounding lowlands. Inundation would also expand due to storm water drainage backing up due to the affect of the water level rising in the system.

3.2.5 Estimated Flood Damage

Based on the results of the inundation analysis and an assessment of direct and indirect damages, the amount of annual damage under the present conditions is estimated at Rs. 1,757 million/year for the entire study area.

Estimated Flood Damage in the Study Area

Sub-basin	Estimated Extent of Inundation Area by Return Period (ha)					Annual Damage (Million Rs.)
	2-year	5-year	10-year	25-year	50-year	
Ja Ela	1,113	1,609	1,938	2,755	3,390	509
Kalu Oya	283	384	449	496	558	329
Greater Colombo	153	288	408	581	774	549
Bolgoda	2,419	2,929	3,278	3,645	3,913	370
Study Area	3,968	5,210	6,073	7,477	8,635	1,757

Note: Estimated through the hydrological study discussed in Annex 3.

3.3 Flow Capacity of Objective Drainage Channels

3.3.1 Ja Ela Basin

The flow capacities of the main streams in the Ja Ela basin were evaluated from the channel cross sections surveyed and estimated probable runoff. Figure 3.3.1 shows the longitudinal profiles of the Dandugam Oya and Ja Ela and water surface profiles of the probable flood runoff.

The flow capacity of the Ja Ela is smaller than the probable 2-year flood runoff in most downstream reaches and the flood plain near Ekala. Other than these sections, the flow capacity is larger than the probable 5-year flood runoff except for a few locations.

The flow capacity of the Dandugam Oya is smaller than the probable 2-year flood runoff in the downstream reaches from the flood plain near Kotudoda while the upstream reaches from the flood plain mostly indicate a flow capacity larger than the probable 5-year flood runoff.

Flow Capacity of the Main Stream of the Ja Ela Basin

Ja Ela (Unit: m^3/sec)

Section	Minimum	Maximum	Average
0-10 km	12	85	38
10-22 km	14	133	55
22-26 km	12	43	24
26-28 km	14	53	26

Dandugam Oya (Unit: m^3/sec)

Section	Minimum	Maximum	Average
0-12 km	53	227	120
12-23 km	22	245	76
23-34 km	30	337	70
34-40 km	14	223	69

Note: Estimated through the hydrological study discussed in Annex 3.

3.3.2 Kalu Oya Basin

The flow capacity of the Kalu Oya was evaluated from the channel cross sections surveyed and estimated probable runoff. Figure 3.3.2 shows the longitudinal profile of the Kalu Oya and water surface profiles of the probable flood runoff.

The flow capacity of the Kalu Oya is smaller than the probable 2-year flood as a whole except the most downstream reaches and upstream of the Kandy Road.

Flow Capacity of Kalu Oya

(Unit: m^3/sec)

Section	Minimum	Maximum	Average
0-6 km	6	28	13
6-13 km	3	22	10
13-15 km	2	27	10

Note: Estimated through the hydrological study discussed in Annex 3.

3.3.3 Greater Colombo Basin

The flow capacities of the main streams in the Greater Colombo basin were evaluated from the channel cross sections surveyed and estimated probable runoff. Figure 3.3.3 shows the longitudinal profiles of the major canals and water surface profiles of the probable flood runoff. The GCFC&EIP Phase I indicates that the allowable water level of the canal system is 1.85 m above MSL at Parliament Lake and 1.75 m above MSL for the urban part west of Parliament Lake.

Under the GCFC&EIP Phase I, the canal bed level was dredged down to 1.0 m below MSL for the entire improved section. The canal bank was improved by raising it to an elevation of 1.8 m to 2.0 m above MSL for the urbanized sections. The canal bank level remains at lower elevations for the other sections located along the low-lying areas, which function as the storm water retention areas. The present flow capacity of the canal system is evaluated as follows:

Flow Capacity of Canal System in Greater Colombo Basin

(Unit: m^3/sec)

Canal	Minimum (m^3/sec)	Maximum (m^3/sec)	Average (m^3/sec)
Main Drain	9	27	16
St. Sebastian Canal	3	17	8
Dematagoda Ela	5	18	11
Heen Ela	12	44	22
Torrington Canal	7	47	29
Kolonnawa Ela	5	60	30
Kotte Ela	19	48	32
Kirillapone Canal	17	56	31
Wellawatta Canal	12	47	34
Dehiwela Canal	8	35	14

Note: Estimated through the hydrological study discussed in Annex 3.

3.3.4 Bolgoda Basin

The flow capacities of the main streams in the Bolgoda basin were evaluated from the channel cross sections surveyed and estimated probable runoff. Figure 3.3.4 shows the longitudinal profiles of the major canals and water surface profiles of the probable flood runoff. The flow capacities of the main streams were evaluated as follows:

Flow Capacity of Mainstream in Bolgoda Basin

(Unit: m^3/sec)

River/Canal	Minimum	Maximum	Average
Bolgoda Canal	30	55	44
Weras Ganga	14	228	98
Panadura Ganga	127	577	267
Bolgoda Ganga	8	38	17
Maha Oya	7	95	36
Panape Ela	6	114	30
Aluth Ela	8	44	22
Kepu Ela	4	135	29

Note: Estimated through the hydrological study discussed in Annex 3.

CHAPTER 4 PLANNING SCALE AND COMPREHENSIVE MASTER PLAN

4.1 Basic Concepts of Planning Scale for the Storm Water Drainage Plan

4.1.1 Basin-wide Approach

The planning scale of the storm water drainage plan is subject to the national policy of flood control, which designates a long-term target of flood safety level. Such a target needs to be decided for all the river basins at first in order to effectively control the flood in the basin. To achieve the designated target level of flood safety, a basin-wide master plan is formulated to establish necessary measures for flood control throughout a basin. In general, the basin-wide master plan focuses on flood control of the main river system in the basin as a framework, which gives basic principles for the subsequent detailed plans in the basin.

The study area covers some 830 km^2 in the Colombo Metropolitan Region (CMR). Even though the study does not cover flooding of the Kelani Ganga, which is one of the major rivers in the country, a similar approach to the above should be deemed necessary in order to establish basic principles for storm water drainage in such a wide extent of the study area. The primary objective of the study is to formulate a basin-wide storm water drainage plan for the main waterways in the relevant basins.

4.1.2 Targeted Planning Scale

(1) Main Streams and Tributaries

Planning scale is generally indicated using a rainstorm event return period and also gives a safety level against such a flood caused by said rainstorm in an objective river basin. The planning scale is decided on the basis of ‘degree of importance’ of the river in view of flood control, which is evaluated mainly from the following:

1) Scale of the river
2) Socio-economic importance of the area to be protected against flood
3) Direct and indirect damages anticipated by flooding
4) Historical records of flood disasters

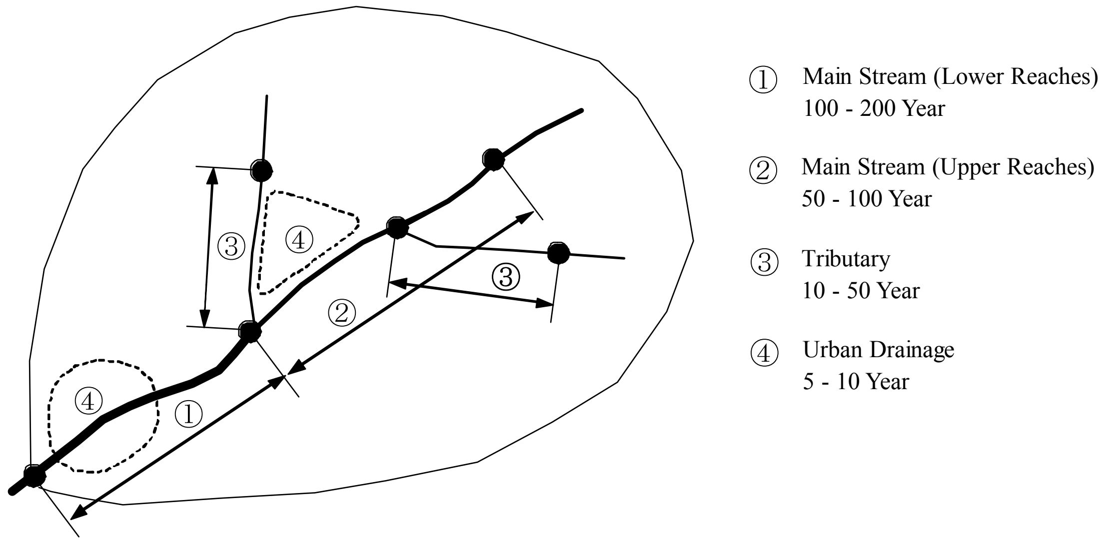
From the above, the planning scale would be different for different rivers. It is therefore necessary to consider a balance of planning scale among different river basins in a country. A Japanese guideline suggests the degree of importance of a river and a corresponding planning scale as follows:

Importance of River and Planning Scale for Flood Control Master Plan

Degree of Importance	Description	Planning Scale (Return Period)
A	Important stretches in large scale rivers	200 years or More
B		100 – 200 years
C	Stretches of large scale rivers other than A or B above Middle scale rivers Rivers in urban areas	50 – 100 years
D	Small scale rivers	10 – 50 years
E	Tributaries	10 years or Less

Source: Guidelines for River and Sabo Works, Ministry of Land, Infrastructure and Transport, Japan

In a river basin, a balance of planning scale should be maintained between upper and lower reaches as well as between main streams and tributaries in view of consistency in planning scales for the entire basin. When a planning scale is applied for a main stream in lower reaches, an equivalent or lower planning scale is given for that main stream in its upper reaches. Planning scales for tributaries are lower than that for main streams.



Basic Concept of Planning Scale (Example)

For the study area, the Kelani Ganga Flood Protection Scheme indicates an example of planning scale applied for a large river system in Sri Lanka. The basin area of the Kelani Ganga is 2,292 km^2 and the flood protection levels by existing bunds in the downstream reaches were evaluated for a 500-year return period on the left bank and for a 50-year return period on the right bank. These flood protection levels would suggest the planning scales for the neighboring basins related to the study area. The degree of importance of the Kelani Ganga may be evaluated as A or B. The others are evaluated as follows based on a relative comparison with the Kelani

Ganga:

Degree of Importance of Basins Relevant to the Study Area

Basin	Scale of Basin Area (km^2)	Characteristics of Area to be Protected	Suggested Degree of Importance
Kelani Ganga	2,292	Urbanizing areas (right bank) Highly urbanized and socio-economic center of the country (left bank)	A or B
Ja Ela	860	Limited urbanizing areas in the downstream reaches and mostly rural areas in the middle and upstream reaches	C
Kalu Oya	60	Urbanizing areas in the entire basin	C or D
Greater Colombo	86	Highly urbanized areas and socio-economic center of the country	C or D
Bolgoda	467	Limited urbanizing areas in the north and mostly rural areas in the other parts of the basin	C

From the suggested degree of importance above, the planning scale of a 50-year return period, which is the same as recommended by the Colombo Metropolitan Regional Structure Plan (CRMSP), would be reasonable for the basin-wide storm water drainage plan for the basins relevant to the study area.

The flood safety level accomplished by the completion of GCFC&EIP Phase I gives a suggestion to decide a planning scale for the study. The present safety level of the main canals in the Greater Colombo basin was evaluated in the range of a 5-year to 25-year return period. Substantial improvement was accomplished by GCFC&EIP Phase I but further improvement should also be considered in order to cope with economic growth in the basin and the increase of social requirements for flood protection in the future. Provision of a higher planning scale is therefore necessary for the storm water drainage plan.

A large-scale flood event experienced in the past was also taken into consideration for application of planning scale. It is a usual practice to determine a planning scale based on the actual experienced rainstorm event that caused basin-wide damages. The recent major events occurred in 1992 and 1999 in the study area. Of those, the 1992 event was exceptionally large and is regarded to be beyond any measures for protection while the return period of the second largest event in 1999 was evaluated around 40-year. To prevent the same scale flooding, the planning scale of a 40-year return period or more should be applied.

As a conclusion of the points discussed above, a planning scale of a 50-year return period is reasonable as the long-term target for the basin-wide master plan in the study area.

(2) Urban Drainage

Urban drainage improvement envisages establishing a storm water drainage network in a small basin, which comprises trunk drains, roadside drains, storm sewers, etc. and is sometimes planned in combination with a sewerage system. To establish the urban drainage plan, such details of the storm water drainage network should be investigated throughout the basin. In this study, the primary objective of the study is to formulate a basin-wide storm water drainage plan for the main waterways in the study area of 830 km^2. Hence, the study does not cover the details of urban drainage improvement requiring in-depth investigations for a large number of sub-basins in the study area.

It is a common understanding that frequent inundation at many locations requires immediate solutions. Hence, measures for alleviation of the frequent local inundation would be likely to be studied and implemented on ad-hoc basis. Such a manner of implementation would cause an inconsistent arrangement of drainage facilities as well as imbalanced service levels of drainage basins in between. A systematic approach is necessary to proceed with consistent planning and implementation in improvement of the urban drainage system by individual sub-basin.

For the systematic approach, a guideline is required for an appropriate planning scale of urban drainage improvement. In the study area, the urban drainage improvement in the sub-basins was implemented under the GCFC&EIP Phase II by the above-mentioned manner. The planning scale of a 2-year return period was applied for the GCFC&EIP Phase II and the latter projects such as the Phase III and Lunawa Lake follows the same. The drainage areas of the schemes in these projects range from 0.25 to 3.11 km^2. The planning scale of a 2-year return period seems to be rather low for trunk drains in a drainage area with the similar scale.

The planning scale is a key factor that dominates the scale of project costs, especially in highly urbanized areas. With a high planning scale, construction costs for drainage facilities increase. Land acquisition and compensation costs are also important elements of urban drainage schemes. The large extent of facilities necessary to achieve a high planning scale is sometimes constrained physically by intensive land use and results in excessive costs. The planning scale of the GCFC&EIP Phase II was decided mainly from these viewpoints.

On the other hand, one of the important issues on urban drainage in the Colombo Metropolitan Region (CMR) is to establish guidelines for the future. For this purpose, a higher planning scale would be desirable at least for trunk drains. In the light of the basic concept for application of planning scale discussed in sub-section 4.1.2, a planning scale of a 5 to 10-year return period would be applicable as the long-term objective for urban drainage improvement.

4.1.3 Options for Planning Scale

The study proposes the planning scale of a 50-year return period for the basin-wide master plan for storm water drainage in the study area on the basis of the engineering considerations as described above. However, the planning scale is one of the fundamental subjects to determine a policy of flood management for the future and the final decision will be made by the government in compliance with various administrative issues in the country.

For the decision-making by the government, the study presents several options of planning scale for comparative examination. The following options of planning scale are to be taken into consideration:

1) 50-year Return Period
2) 25-year Return Period
3) 10-year Return Period

The planning scale of a 50-year return period is a basic option proposed by the study. The lower return period is the option for reducing the total investment of structural measures. The possibility of a rainstorm event exceeding the planning scale becomes higher as the lower return period is applied. Floods exceeding the planning scale are beyond control under the storm water drainage measures provided and bring widespread damage by inundation. To alleviate the damages, non-structural measures are required on the premise that widespread inundation occurs in the case of a rainstorm event exceeding the planning scale.

The study indicates storm water drainage measures including structural and non-structural measures for the respective options and an evaluation of their viability.

4.2 Planning Scale of GCFC&EIP

4.2.1 Consistency of Planning Scale

It should be noted that implementation of a basin-wide storm water drainage plan takes 10 to 20 years or more for implementation. During such a long period, the implementation plan is subject to change due to various reasons.

Before implementation of a project, a feasibility study is undertaken to materialize project features, confirm project viability and prepare a detailed implementation program. During the feasibility study, several modifications on technical issues from the master plan would arise in the course of in-depth investigations and studies. Modifications would also arise during latter stages such as detailed design and construction. Change of social requirements and constraints on financial arrangements also affect the implementation plan.

In light of the situations above, the master plan should be reviewed and updated at around 10 years after the time of plan formulation. However, the target of planning scale is not changed easily or without significant reasons since the planning scale is decided as basic policy of flood control by the government.

4.2.2 Relation to Existing Projects

The concepts of the present GCFC&EIP undergoing since 1992 were formulated by several studies undertaken in the 1980s. Since an idea of a 'basin-wide plan' would not be defined clearly in the previous studies, the GCFC&EIP attempted to formulate a basin-wide plan by integrating the original plans of the previous studies.

The planning concept of the GCFC&EIP is recognized as follows:

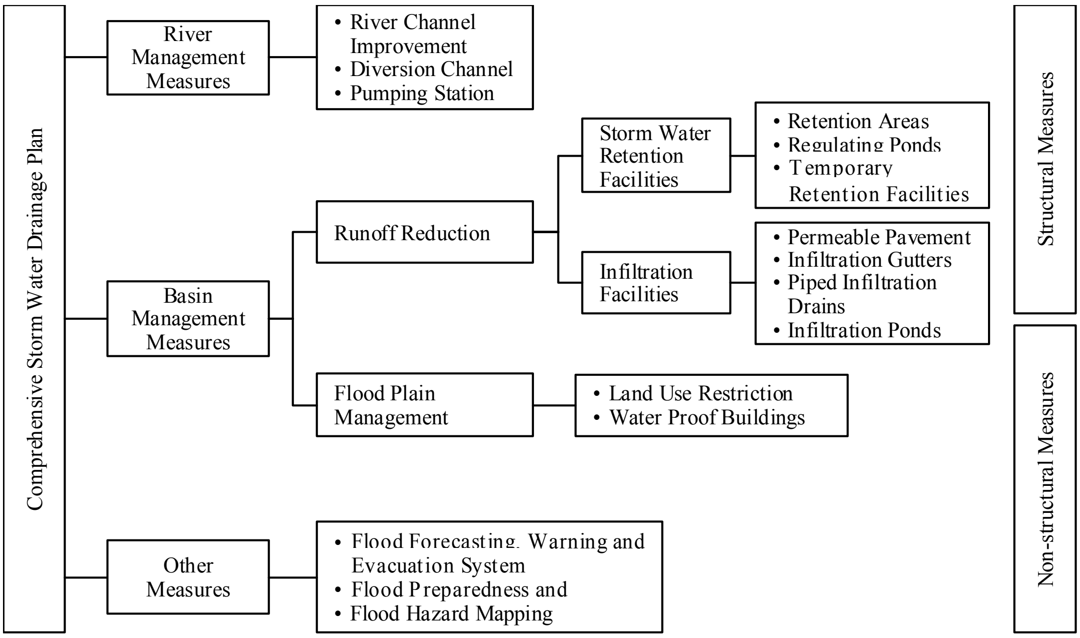
1) The main drainage canal system in the Greater Colombo basin should be improved first to secure a certain high safety level in the entire basin (GCFC&EIP Phase I).
2) The urban drainage schemes in the Greater Colombo area should be improved in the latter stages in order to alleviate frequent local inundation at many locations. Improvement of trunk drains and, to some extent, of smaller drains in the respective sub-drainage areas is to be undertaken (GCFC&EIP Phase II, Phase III, and Lunawa Project).

This concept agrees with the basic planning concept of the study in terms of the implementation process for the flood control plan, i.e. the basin-wide storm water drainage plan is formulated and implemented at first, followed by the urban drainage schemes for individual sub-drainage areas.

The planning concept of the GCFC&EIP was formulated in the early 1990s and the original plans by the previous studies were established in the 1980s. As described above, it is necessary to update the planning concept in order to cope with future requirements. The position of the study is therefore to succeed and update the concept of the GCFC&EIP as well as to extend the coverage area of storm water drainage plans to the neighboring basins in the Colombo Metropolitan Region.

4.3 Basic Concept of the Comprehensive Storm Water Drainage Plan

The study envisages formulating a comprehensive storm water drainage plan integrating structural and non-structural measures. A conceptual diagram of the comprehensive storm water drainage plan is illustrated below:



Concept of Comprehensive Storm Water Drainage Plan

In compliance with the present conditions discussed in the previous chapters, the conceivable structural and non-structural measures for the study are identified as follows:

4.3.1 Structural Measures

(1) Improvement of the main drainage system

Improvement of the main drainage system is a fundamental measure for the basin-wide storm water drainage plan, including improvement of the main streams and drainage channels and construction of diversion facilities. Plans for improvement of the main drainage system are based on analyses on the storm water runoff regime and potential flood damage in an objective basin.

(2) Storm water retention areas

Storm water drainage in urbanized areas employing solely river and drainage channel improvement is not only extremely costly but also causes immense effects on natural and social environments. Therefore, it is realistic to incorporate storm water retention areas with the storm water drainage plan.

In the study area, it is expected that existing marsh and lowlands are to be utilized as storm water retention areas. The GCFC&EIP planned that approximately 380 ha of marsh and lowland should be reserved as storm water areas. However, piecemeal reclamation is occurring both legally and illegally because of the lack of clear enforcing administrative capabilities. There are opinions to reduce storm water retention areas by partially switching from storm water retention to construction of sea outfalls or pumping stations.

The study attempts to secure water retention areas for the future, by clearly defining a required extent (nature reserves and development areas that are designated to be flood plains in case of flooding, etc.) that is in concert with other basin development plans after carefully considering the various demands apparent in this background.

(3) Construction of facilities for storm water runoff reduction

The study proposes basic principles for subsequent studies on urban drainage improvement in the light of present and future urbanization by basin. It is pointed out that the urban drainage schemes have been studied and implemented mainly based on the channel improvements likely to be constrained by urbanized condition.

To resolve such constraints, temporary storm water retention facilities need to be introduced to urban systems in highly urbanized areas. The utilization of existing open lands such as playgrounds, parks, school compounds, etc. for temporary storm water retention areas is a conceivable measure for preventing local inundation caused by rapid concentration of storm water runoff to the drainage channels. New land development in the basin should also be subject to this measure to reduce storm water runoff from development areas by provision of storm water retention facilities.

4.3.2 Non-Structural Measures

(1) Legislative restrictions on reclamation of marsh and lowlands

There are large expanses of marsh and lowlands in the study area, which have large storm water retention effects. However, due to the reclamation of marsh and lowlands for development housing and industrial estates following the recent rapid expansion of the urbanizing areas, the storm water retention effects of the marshes and lowlands have declined.

It is both technically and financially difficult to replace the storm water retention effects of marshes and lowlands with other structural riparian works. Therefore, it is imperative for storm water drainage that the existing marshes and lowlands should be properly conserved as storm water retention areas. Legal means of restraining the reclamation will be analyzed.

(2) Development control and land use regulation

Land use regulation is an important issue to harmonize the storm water drainage and the need for land development in the CMR. A study will be conducted to prepare a future land use plan including urbanization controlling areas, conservation areas, green areas for storm water retention, etc. for the purpose of regulating disordered land development adversely affecting storm water drainage.

(3) Disaster preparedness

The study will also focus on disaster preparedness in case that a rainstorm would exceed the design scale of the structural measures. It is also necessary to consider the preparedness before provision of structural measures since it will take a long period to implement structural measures throughout the study area. The following will be the main items of non-structural measures to be studied and proposed through assessment of the present disaster preparedness system in Sri Lanka:

1) Clarification of possible inundation areas from an inundation hazard map
2) Introduction of 'pilot type' housing in possible inundation areas
3) Institutional arrangements for establishment of a flood preparedness system

4.3.3 Institutional Development Plan

A comprehensive institutional set-up of interrelated organizations will be required for effective performance of integrated flood control including both structural and non-structural measures. A basic concept of such an institutional set-up is recommended through review of present roles and responsibilities of different organizations concerned with project implementation and O&M works relating to flood protection and storm water drainage.

4.3.4 Operation and Maintenance Plan

An operation and maintenance plan for storm water drainage systems in the study area will be prepared based on the study on the present operation and maintenance systems of SLLRDC and local authorities. The plan mainly consists of the following:

1) Strategy for operation and maintenance
2) Organizational set-up with staff arrangement

3) Financial management
4) Equipment plan
5) Staff training plan

4.3.5 Human Resources Development Plan

The storm water drainage projects are being implemented mainly around the city of Colombo but will be evolved to the suburbs. Capacity building for project implementation and operation and maintenance of storm water drainage facilities is a key issue for SLLRDC as well as local authorities. The present main problem on this issue is the insufficiency of human resources managing storm water drainage in local authorities.

As a short-term objective, on-the-job training under the leadership of SLLRDC is regarded as a practical method for improving the capability of local authorities. The study proposes strengthening the leadership of SLLRDC to implement effective training programs for local authorities.

The study also focuses on a comprehensive program to train engineers and technicians in the sector of storm water drainage. Such a program is recommended as a long-term objective.

CHAPTER 5 STORM WATER DRAINAGE PLAN IN THE JA ELA BASIN

5.1 Basic Principle for Planning

In the Ja Ela downstream basin, there are two main streams i.e. Dandugam Oya and Ja Ela. Problems of flooding of the main streams to the downstream urban areas along these rivers are relatively small, suggested by the following characteristics of the basin:

1) Paddy lands extending from Ekala to Gampaha in the middle basin are naturally functioning as flood retention areas, which effect to reduce flood peak runoff to the downstream reaches.
2) The Muthurajawela Marsh is the major flood plain in the downstream end and retards flood runoff in vast wetlands where significant raising of water level is not expected.
3) The urbanized areas are located between the above-mentioned paddy lands and Muthurajawela Marsh. The combined effects of the upstream paddy lands and downstream wetlands contribute to alleviating a high concentration of flood runoff of the rivers.

The future land use projection indicates that the urbanization in the basin will proceed mainly along the Negombo Road and at a few inland locations such as Gampaha and Minuwangoda. In the light of the projection, a significant increase of storm water runoff of the mainstreams is not expected within the time-scale to the target year 2010.

On the other hand, the Colombo-Katunayake Expressway (CKE) is being constructed in parallel with the Negombo Road. The route of CKE runs along the Muthurajawela Marsh and crosses the two main streams of the basin. The necessary openings for storm water drainage across the CKE have already been studied and should therefore be taken into consideration for the storm water drainage plan.

The storm water drainage plan for the Ja Ela basin is therefore proposed to protect the future urbanized areas along the Negombo Road by means of the following principles:

1) The capacities of the two main streams in the downstream areas should be preserved to secure a required flow capacity for attaining the designated planning scale into the future.
2) The paddy lands in the middle basin presently functioning as a storm water retention area should be conserved to the extent required for the future.

3) The Muthurajawela Marsh should be conserved as a flood plain to maintain the natural flood retarding capacity for the storm water runoff of the main streams.

5.2 Basic Flood Runoff

The basic flood runoffs in the Ja Ela basin for probable 10, 25, and 50-year rainstorm events under the future land use conditions are estimated for several base points along the river channel as shown in Figures 5.2.1 to 5.2.3. In comparison with the estimated flood runoff with the basin retention effect as shown in Figures 5.2.4 to 5.2.6, the peak runoffs of basic floods increase by 41% for a 10-year return period, 69% for a 25-year storm, and 87% for a 50-year storm in the Dandugam Oya at Negombo Road.

Comparison of Flood Discharge with and without the Basin Retention Effect in Ja Ela Basin

Location	Return Period (years)	Basic Flood Runoff (m^3/sec)	Flood Runoff with Basin Retention Effect (m^3/sec)
Dandugam Oya at Negombo Road	10	205	145
	25	295	175
	50	365	195
Ja Ela at Negombo Road	10	65	50
	25	90	60
	50	110	70

Figure 5.2.7 shows the comparison of flood hydrographs in the Dandugam Oya at Negombo Road and the Ja Ela at Negombo Road. The estimated hydrographs show the difference in the total volume of runoff with and without the runoff retention effect of the basin. These volumes are regarded as the maximum capacity of retention in the upstream basin for the respective return periods under the future land use conditions.

5.3 Study on Structural Measures

5.3.1 Conceivable Structural Measures

The conceivable structure measures for storm water drainage in the Ja Ela basin are illustrated in Figure 5.3.1.

(1) Channel Improvement of Dandugam Oya

The channel improvements for the Dandugam Oya downstream reachesare proposed to protect the projected urbanization areas along the Negombo Road for securing the necessary channel width for the main stream running through the potential urbanization areas in a long-term objective for flood protection. The stretch of channel improvement is selected in compliance with natural flood retardation into the marsh at the downstream end, the projected future urbanization along the river channel, and the possible storm water retention area on the upstream side. The proposed length of channel improvement is 9.9 km from the edge of the Muthurajawela Marsh to the junction with the Mapalam Oya as shown in Figure 5.3.2.

(2) Channel Improvement of Ja Ela

The channel improvements for the Ja Ela downstream reaches are also proposed to protect the projected urbanizing areas along the Negombo Road. The stretch of channel improvement is selected in the light of the same considerations as the Dandugam Oya. The proposed length of channel improvement is 7.0 km from the edge of the Muthurajawela Marsh to the downstream end of the possible storm water retention area around Ekala as shown in Figure 5.3.3.

(3) Diversion Channel from Kotugoda to Seeduwa

Besides the proposed structural measures above, a short-cut channel from Kotugoda to Seeduwa with a length of 3.1 km is an alternative for the channel improvement to the Dandugam Oya as shown in Figure 5.3.4. This alternative is expected to contribute to reducing runoff from the stretch of the Dandugam Oya between Kotugoda to Seeduwa.

(4) Storm Water Retention Areas

As a result of the hydrological study, it is identified that the paddy lands extending along the main streams function as a natural flood plain in case of flood. These paddy lands need to be conserved as a storm water retention area to reduce peak runoff to the downstream, together with the channel improvement of the main streams. In combination with the channel improvements, the following areas located at the upstream ends of the proposed channel to be improved are the conceivable storm water retention areas. Locations of the proposed retention areas are shown in Figure 5.3.5.

Conceivable Retention Areas

Main stream	Location	Elevation in Retention Area (above MSL)	Extent of Retention Area (ha)
Mapalam Oya	Walanagoda - Unnaruwa	Below 4m	1,357
Dandugam Oya	Madawala - Heenatiyana - Urukalana		
Ja Ela	Kotugoda - Ekala -Visakawatta		
Uruwal Oya	Tibbotugoda - Ratmalwita	Below 7m	101
Attanagalu Oya	Medagama - Asgiriya South	Below 10m	275
		Total	1,733

The retention areas are defined by ground surface elevation around the proposed locations. The retention areas in the lower basin are defined as the lands lower than 4.0 m above MSL along the Ja Ela in Kotugoda - Ekala - Visakawatta, the Dandugam Oya in Madawala - Heenatiyana - Urukalana, and the Mapalam Oya in Walanagoda - Unnaruwa. By the same definition, the retention areas in the upper basin are also delimitated as the lands lower than 7.0 m above MSL along the Uruwal Oya in Tibbotugoda - Ratmalwita, and lower than 10.0 m above MSL along the Attanagalu Oya in Medagama - Asgiriya South.

(5) Channel Improvement and Storm Water Retention Areas in the Upper Basin

In view of the basin-wide plan, the objective stretch of each main stream should extend from the downstream end to upstream of Gampaha. However, the future land use projection indicates that the urbanization in the basin will be limited to the areas along the Negombo Road along with a few inland locations such as Gampaha and Minuwangoda within the time-scale to the target year 2010. Moreover, the channel improvements for the entire stretche will take a huge amount of funding and a long period for implementation. It is therefore assumed that the stretches upstream from the proposed retention areas in the lower basin would be improved after the channel improvement of the downstream sections. Hence, the channel improvement of the upper reaches is not included in this storm water drainage plan.

On the other hand, the channel improvement of the downstream stretches is based on the basin-wide flood regime that may be affected by the channel improvement of the upper reaches. In principle, river channel improvement should be planned and implemented from downstream to upstream. Channel improvement of the upper reaches should not affect that of lower reaches improved in advance.

In the Ja Ela basin, the large inundation areas are also identified around Gampaha. If the inundation areas are resolved by channel improvement only, runoff concentrates rapidly and exceeds the design capacity of the improved river channel downstream. Such a channel improvement of the upper reaches is not acceptable in the light of the above-mentioned principle. In this study, the channel improvement plan of the lower reaches is formulated on the assumption that future channel improvements to the upper reaches would be performed properly without adverse affects to the lower reaches. The channel improvement to the upper reaches should also be planned in combination with storm water retention areas to prevent excessive runoff to the lower reaches.

(6) Urban Drainage Improvement

Present problems of urban drainage in the Ja Ela basin are due to the insufficiency of the drainage system, which contributes to local inundation by storm water runoff in the urbanized sub-basins. For the time being, construction of trunk drains discharging storm water runoff into the main streams or Muthurajawela Marsh is a main issue of urban drainage in the Ja Ela basin. The urbanized areas in the Ja Ela basin are mainly located along the Negombo Road and are relatively less dense at present. It is therefore desirable that a systematic planning of urban drainage by sub-basin should be prepared before urbanization. Such planning of urban drainage needs to be undertaken subsequent to this study.

5.3.2 Comparative Study of Alternative Drainage Plans

(1) Alternative Combinations

The storm water drainage plan for the Ja Ela basin is prepared comprising a combination of the conceivable measures described above, a comparative study is carried out for the following alternative combinations:

Alternative Combinations

Case	Channel Improvement of Ja Ela	Channel Improvement of Dandugam Oya	Kotugoda - Seeduwa Diversion Channel
J1	Length = 7.0 km Width = 45m	Length = 9.9 km Width = 65m (3.5-7.5 km) Width = 55m (7.5-13.4 km)	-
J2	Length = 7.0 km Width = 50m	Length = 9.9 km Width = 70m (3.5-7.5 km) Width = 60m (7.5-13.4 km)	-
J3	Length = 7.0 km Width = 55m	Length = 9.9 km Width = 75m (3.5-7.5 km) Width = 65m (7.5-13.4 km)	-
J4	Length = 7.0 km Width = 45m	Length = 9.9 km Width = 65m (3.5-7.5 km) Width = 55m (7.5-13.4 km)	Length =3.1km Width=20m
J5	Length = 7.0 km Width = 60m	Length = 9.9 km Width = 80m (3.5-7.5 km) Width = 70m (7.5-13.4 km)	-
J6	Length= 7.0 km Width = 80m	Length = 9.9 km Width = 100m (3.5-7.5 km) Width = 90m (7.5-13.4 km)	-

(2) Design Features of Channel Improvement Alternatives

The alternative combinations are designed on the condition that an allowable water level should be secured by the proposed channel improvement. The estimated water level from a 50-year rainstorm event under the present land use condition is adopted as the allowable water level.

Allowable Water Level

Location	Allowable Water Level (above MSL)
Ja Ela at Negombo Road	1.65
Dandugam Oya at Negombo Road	1.58
Retention Area Walanagoda – Unnaruwa Madawala - Heenatiyana - Urukalana Kotugoda - Ekala –Visakawatta	3.50 (Average)

For the channel improvement, it is necessary to consider the proposed openings for the construction of the Colombo-Katunayake Expressway (CKE) at crossing points of the Dandugam Oya and Ja Ela. The final proposals for these openings are given by SLLRDC as follows:

1) Dandugam Oya Crossing: 4 spans @ 20m (= 80m)
2) Ja Ela Crossing: 4 spans @ 15m (= 60m)

The width of channel improvement is subject to the above openings.

Case J1 consists of the channel improvement of the two main streams in the basin. The stretches for the channel improvement are selected in the downstream reaches to the Muthurajawela Marsh. The cross section of the proposed channel improvement is designed as a simple section comprising the lower part for normal water level and the upper part with dike embankments on both channel banks to cope with the design flood. The cases J2, J3, J5 and J6 consider the requirement of a larger channel capacity for further decrease of flood levels in the channel.

The longitudinal profile of the channel improvement is designed in light of the present longitudinal profile of the main stream. The average riverbed gradient of the proposed stretch for channel improvement of the Ja Ela is designed at 1/7600 between 2.0 km to 9.0 km and the riverbed elevation varies from 2.7 m to 1.8 m below MSL. The average depth of the proposed channel improvement is 4.5 m to cope with the design flood level of a 50-year return period.

The average riverbed gradient of the proposed stretch for channel improvement of the Dandugam Oya between 3.5 km to 13.5 km is designed with the riverbed elevation of 4.9 m below MSL. The average depth of the proposed channel improvement is 7.4 m.

The Kotugoda - Seeduwa diversion (J4) envisages constructing a 7.5 km long channel between it and the Dandugam Oya at 20.5 km . The cross section of the proposed diversion channel is designed as trapezoidal with a 20 m width. The gradient of the proposed channel is designed at 1/1400 and the channel bed elevation varies from 4.9 m to 2.2 m below MSL.

(3) Effect of Retention Areas in the Lower Basin

The alternative combinations above are based on the conservation of storm water retention areas as described in sub-section 5.3.1. The effects of the retention areas in the lower basin are analyzed for the four options of the delimitation level such as 4 m above MSL for the base option, and 3 m, 2 m, and 1 m above MSL for the other options of retention area reduction. For these options, it is assumed that the proposed retention areas in the upper basin remain as described in the sub-section 5.3.1 above.

Extent of Retention Area by Delimitation Level

(Unit: ha)

<table>
<tr><th rowspan="2">River/Location</th><th colspan="4">Delimitation Level (above MSL)</th></tr>
<tr><th>4 m</th><th>3 m</th><th>2 m</th><th>1 m</th></tr>
<tr><td>Mapalam Oya
/Walanagoda - Unnaruwa</td><td rowspan="3">1,357</td><td rowspan="3">948</td><td rowspan="3">572</td><td rowspan="3">237</td></tr>
<tr><td>Dandugam Oya
/ Madawala -Heenatiyana - Urukalana</td></tr>
<tr><td>Ja Ela
/ Kotugoda - Elakala -Visakawatta</td></tr>
<tr><td>Uruwal Oya
/Tibbotugoda - Ratmalwita</td><td colspan="4">101
(Delimitation Level 7m)</td></tr>
<tr><td>Attanagalu Oya
/Medagama - Asgiriya South</td><td colspan="4">275
(Delimitation Level 10m)</td></tr>
<tr><td>Total</td><td>1,733</td><td>1,329</td><td>953</td><td>618</td></tr>
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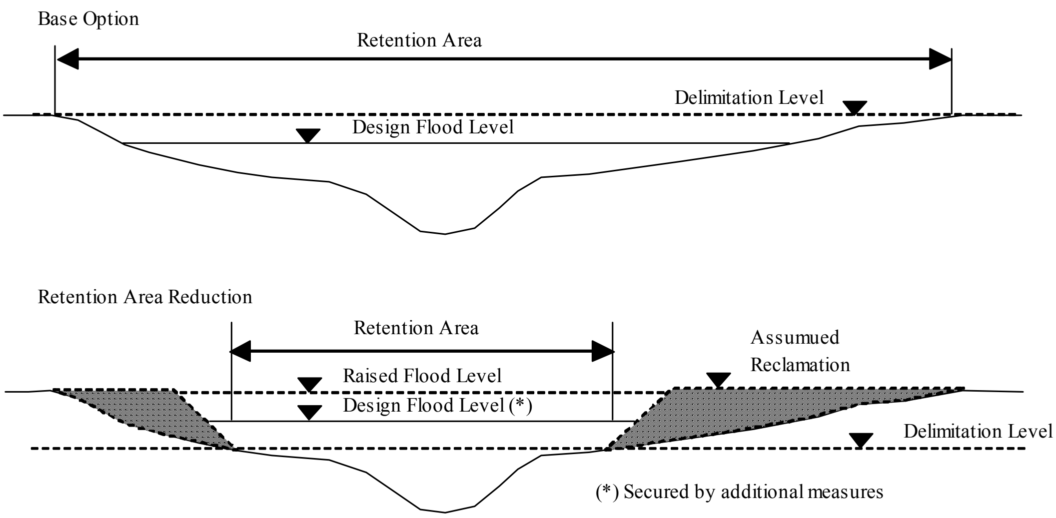


Assumptions for Reduction of Retention Area

It is assumed that land reclamation would be conducted above the delimitation level with a sufficient height to cope with the inundation level increasing with the reduction of the retention area. The results of the analysis for the effects of retention area are retrieved as shown in Table 5.3.1, Figure 5.3.6 and summarized below:

Extent of Retention Area and Water Level (50-year Return Period)

Retention Area 1,357+376 ha
Delimitation Level 4.0 m above MSL

Case	Water Level (above MSL)		
	Ja Ela	Dandugam Oya	Retention Area
J0	1.65	1.58	3.51
J1	1.47	1.47	3.40
J2	1.35	1.46	3.35
J3	1.30	1.45	3.31
J4	1.49	1.55	3.19
J5	1.26	1.44	3.28
J6	1.17	1.40	3.21

Retention Area 948+376 ha
Delimitation Level 3.0 m above MSL

Case	Water Level (above MSL)		
	Ja Ela	Dandugam Oya	Retention Area
J0-a	1.69	1.65	3.61
J1-a	1.51	1.53	3.49
J2-a	1.39	1.52	3.44
J3-a	1.34	1.50	3.40
J4-a	1.52	1.60	3.25
J5-a	1.29	1.49	3.36
J6-a	1.19	1.46	3.29

Retention Area 572+376 ha
Delimitation Level 2.0 m above MSL

Case	Water Level (above MSL)		
	Ja Ela	Dandugam Oya	Retention Area
J0-b	1.76	1.73	3.70
J1-b	1.57	1.61	3.57
J2-b	1.44	1.59	3.52
J3-b	1.38	1.58	3.47
J4-b	1.58	1.66	3.31
J5-b	1.33	1.58	3.46
J6-b	1.23	1.52	3.35

Retention Area 237+376 ha
Delimitation Level 1.0 m above MSL

Case	Water Level (above MSL)		
	Ja Ela	Dandugam Oya	Retention Area
J0-c	1.82	1.84	3.79
J1-c	1.62	1.70	3.65
J2-c	1.49	1.68	3.59
J3-c	1.43	1.66	3.53
J4-c	1.62	1.73	3.36
J5-c	1.38	1.64	3.49
J6-c	1.28	1.60	3.40

When the water level rises with the reduction of the retention area, the capacity of the drainage facilities downstream should be enlarged to lower the water to the allowable level. The total extent of the lower retention areas required for securing the allowable water levels is derived from the graphs shown in Figure 5.3.6. Case J2 satisfies the allowable water levels in the lower retention areas, Ja Ela at Negombo Road, and Dandugam Oya at Negombo Road when the total extent of the lower retention areas is reduced from 1,357 ha to 650 ha. The corresponding delimitation level is 2.2 m above MSL in the lower retention area. Case J5, with the larger channel, keeps the allowable water levels on the condition that the lower retention area is reduced to 500 ha corresponding to the delimitation level of 1.8 m above MSL.

Required Extent of Lower Retention Area (50-year Return Period)

Case	Required Retention Area by Allowable Water Level (ha)			Minimum Required Retention Area (ha)
	Ja Ela 1.65 m	Dandugam Oya 1.58 m	Lower Retention Area 3.50 m	
J1	100	700	920	920
J2	---	640	650	650
J3	---	560	400	560
J4	100	1,150	200	1,150
J5	---	500	---	500
J6	---	330	---	330

Note: --- means the water level for the required retention area of 0 ha is still lower than the allowable water level.

(4) Economic Evaluation

The alternatives are evaluated by the economic evaluation. Benefit-cost ratio (B/C) and economic internal rate of return (EIRR) for each alternative are computed from economic cost and annual benefit from flood damage mitigation. In addition to the benefit of flood damage mitigation, land enhancement benefit is taken into account for lands free from inundation by alternative measures.

The land area equivalent to the reduction of the retention area is also regarded as free from inundation and would be available for possible development. This opportunity for development is counted as an incremental benefit combined with the flood damage reduction benefit by structural measures while the cost for land development is also incorporated in with the economic evaluation.

Economic Evaluation for Alternative Combinations (50-year Return Period)

Case	Retention Area (ha)	Project Cost (million Rs.)	Annual Benefit (million Rs.)	B/C	EIRR (%)
J1	920+376	2,663	264	1.10	10.9
J2	650+376	2,965	349	1.30	12.6
J3	560+376	3,507	394	1.24	12.1
J4	1,150+376	3,029	191	0.84	8.7
J5	500+376	3,679	440	1.34	12.9
J6	330+376	4,400	645	1.63	15.2

(5) Effect of Retention Areas in the Upper Basin

The above-mentioned analysis is based on the condition that the retention areas in the upper basin along the Uruwal Oya and Attanagalu Oya would remain and any increase of storm water runoff from upstream of the lower retention areas would not occur in the future. On the other hand, the analysis described here is to consider the exceptional case that both retention areas in the upper basin would be reclaimed totally. For this case, it is assumed that the channel improvement of the upper reaches would also be done together with the reclamation.

The results of this case indicate that the water levels in the retention area and in the Dandugam Oya at Negombo Road are higher than the respective allowable water levels at case J5-U comprising the same openings for the CKE.

Reduction of Retention Area in the Upper Basin (50-year Return Period)

Case	Water Level (above MSL)		
	Ja Ela	Dandugam Oya	Retention Area (**)
J1+U (*)	1.73	1.86	3.85
J2+U (*)	1.71	1.84	3.76
J3+U (*)	1.49	1.82	3.70
J4+U (*)	1.76	1.98	3.56
J5+U (*)	1.42	1.81	3.66
J6+U (*)	1.30	1.77	3.55

Note: (*) '+U' indicates channel improvement of the upper reaches.
(**) for the retention areas in the lower basin.

5.3.3 Study on Optional Planning Scales (25-year and 10-year Return Periods)

The alternative combinations are similar to those described in sub-section 5.3.1 above, but the cross section of the channel is reduced and is sufficient for the probable 25-year and 10-year flood runoff. In these cases, it is assumed that the channel improvement is only composed of the construction of dikes (flood bunds) on both sides of the channel to secure the required channel width. The estimated water level from a rainstorm event for each return period under the present land use condition is adopted as the allowable water level.

Allowable Water Level

Location	Allowable Water Level (above MSL)	
	25-year	10-year
Ja Ela at Negombo Road	1.47	1.24
Dandugam Oya at Negombo Road	1.43	1.22
Retention Area Walanagoda – Unnaruwa Kotugoda - Elakala –Visakawatta Walanagoda - Heenatiyana - Urukalana	3.24 m (Average)	2.83 m (Average)

The effect of the retention area is also carried out on the alternatives for the planning scales of 25-year and 10-year return periods. The effect of raising the water level in the retention areas and the required additional measures for reducing the water level are as shown in Tables 5.3.2, 5.3.3, and Figures 5.3.7 and 5.3.8. The alternative combinations with required retention areas are evaluated by benefit-cost ratio (B/C) and economic internal rate of return (EIRR).

Extent of Retention Area and Water Level (25-year Return Period)

Retention Area 1,357+376 ha
Delimitation Level 4.0 m above MSL

Case	Water Level (above MSL)		
	Ja Ela	Dandugam Oya	Retention Area
J0	1.47	1.43	3.24
J1	1.36	1.40	3.19
J2	1.34	1.40	3.18
J3	1.33	1.39	3.17
J4	1.37	1.48	2.98
J5	1.31	1.39	3.17
J6	1.25	1.37	3.14

Retention Area 948+376 ha
Delimitation Level 3.0 m above MSL

Case	Water Level (above MSL)		
	Ja Ela	Dandugam Oya	Retention Area
J0-a	1.50	1.47	3.31
J1-a	1.38	1.44	3.26
J2-a	1.36	1.44	3.26
J3-a	1.35	1.43	3.24
J4-a	1.39	1.51	3.03
J5-a	1.33	1.43	3.23
J6-a	1.38	1.49	3.30

Retention Area 572+376 ha
Delimitation Level 2.0 m above MSL

Case	Water Level (above MSL)		
	Ja Ela	Dandugam Oya	Retention Area
J0-b	1.56	1.54	3.39
J1-b	1.43	1.51	3.33
J2-b	1.41	1.50	3.32
J3-b	1.39	1.49	3.31
J4-b	1.44	1.56	3.08
J5-b	1.38	1.49	3.30
J6-b	1.31	1.46	3.27

Retention Area 237+376 ha
Delimitation Level 1.0 m above MSL

Case	Water Level (above MSL)		
	Ja Ela	Dandugam Oya	Retention Area
J0-c	1.63	1.64	3.48
J1-c	1.48	1.59	3.41
J2-c	1.46	1.58	3.39
J3-c	1.44	1.58	3.38
J4-c	1.48	1.62	3.13
J5-c	1.38	1.49	3.30
J6-c	1.36	1.54	3.33

Extent of Retention Area and Water Level (10-year Return Period)

Retention Area 1,357+376 ha
Delimitation Level 4.0 m above MSL

Case	Water Level (above MSL)		
	Ja Ela	Dandugam Oya	Retention Area
J0	1.25	1.22	2.83
J1	1.17	1.20	2.80
J2	1.15	1.20	2.79
J3	1.14	1.19	2.79
J4	1.18	1.25	2.61
J5	1.13	1.19	2.78
J6	1.08	1.17	2.76

Retention Area 948+376 ha
Delimitation Level 3.0 m above MSL

Case	Water Level (above MSL)		
	Ja Ela	Dandugam Oya	Retention Area
J0-a	1.26	1.24	2.87
J1-a	1.17	1.21	2.83
J2-a	1.16	1.21	2.83
J3-a	1.15	1.21	2.82
J4-a	1.18	1.26	2.63
J5-a	1.14	1.20	2.81
J6-a	1.09	1.19	2.79

Retention Area 572+376 ha
Delimitation Level 2.0 m above MSL

Case	Water Level (above MSL)		
	Ja Ela	Dandugam Oya	Retention Area
J0-b	1.29	1.28	2.94
J1-b	1.20	1.26	2.90
J2-b	1.19	1.25	2.89
J3-b	1.18	1.25	2.88
J4-b	1.21	1.30	2.67
J5-b	1.17	1.24	2.88
J6-b	1.11	1.22	2.85

Retention Area 237+376 ha
Delimitation Level 1.0 m above MSL

Case	Water Level (above MSL)		
	Ja Ela	Dandugam Oya	Retention Area
J0-c	1.34	1.37	3.02
J1-c	1.24	1.34	2.97
J2-c	1.23	1.33	2.96
J3-c	1.21	1.32	2.96
J4-c	1.24	1.35	2.72
J5-c	1.20	1.32	2.95
J6-c	1.15	1.30	2.92

Economic Evaluation for Alternative Combinations (25- and 10-year Return Period)

a) Planning scale: 25-year return period

Case	Retention Area (ha)	Project Cost (million Rs.)	Annual Benefit (million Rs.)	B/C	EIRR (%)
J1	1,170+376	2,222	132	0.66	6.5
J2	1,080+376	2,288	188	0.90	9.1
J3	950+376	2,381	266	1.22	11.9
J4	1,357+376	2,462	156	0.88	9.0
J5	930+376	2,471	282	1.25	12.2
J6	780+376	2,830	383	1.47	13.5

b) Planning scale: 10-year return period

Case	Retention Area (ha)	Project Cost (million Rs.)	Annual Benefit (million Rs.)	B/C	EIRR (%)
J1	1,020+376	2,076	207	1.04	10.4
J2	950+376	2,147	250	1.22	12.0
J3	850+376	2,249	310	1.49	14.2
J4	1,357+376	2,345	137	0.88	9.1
J5	810+376	2,331	335	1.55	14.8
J6	680+376	2,699	420	1.69	15.2

5.4 Proposed Storm Water Drainage Plan

The study proposes the planning scale of a 50-year return period for the storm water drainage plan in the Ja Ela basin. The Ja Ela and Dandugam Oya are the main streams in the basin. A certain high planning scale is required for such main streams as mentioned in the sub-section 4.1. In case that the project cost for the planning scale of a 50-year return period becomes a financial burden to the government, a stage-wise implementation is proposed. The planning scale of a 10-year or 25-year return period is to be attained in the first stage and is to be increased in the latter stages.

The results of economic evaluation show that the cases J2, J3, J5, and J6 indicate good economic viability when the land enhancement benefit would be expected. Of those, case J6 with the larger openings than the already proposed openings of the CKE is regarded as a reference. In view of the long-term objective for flood protection, it would be desirable to secure the allowable maximum channel width for each main stream running through the potential urbanization areas. The following case J5 is therefore proposed as the storm water drainage plan for the Ja Ela basin.

1) Channel Improvement of Ja Ela (total length 7.0 km)
   - Width 60 m from 2.0 to 9.0 km
2) Channel Improvement of Dandugam Oya (total length 9.9 km)
   - Width 80 m from 3.5 to 7.5 km

- Width 70 m from 7.5 to 13.4 km

3) Strom Water Retention Area (total 876 ha)
   - Lower Retention Areas: 500 ha
   - Upper Retention Areas: 376 ha

The general layout for the proposed storm water drainage plan is illustrated in Figure 5.4.1.

CHAPTER 6 STORM WATER DRAINAGE PLAN IN THE KALU OYA BASIN

6.1 Basic Principle for Planning

The Kalu Oya basin faces the difficulty of natural drainage from the lowlands on the right bank of the Kelani Ganga. The higher embankment of the Negombo Road and Railway separates these low-lying lands, which might be a cause of the formation of the marshlands on the upstream side.

The Kalu Oya main stream is the only major drainage for the basin crossed by the Railway and Negombo Road. The drainage of the Kalu Oya is affected by the backwater of the Kelani Ganga. It is reported that the inundation in the lowlands sometimes continues for one week or more once a heavy rainstorm occurs.

The Kalu Oya basin is subject to urbanization expanding from Colombo and is expected to be urbanized rapidly. Further urbanization is projected, not only in the downstream areas along the Negombo Road, but also in the upstream areas along the Kandy Road and the planned route of the Outer Circular Highway. According to future land use projections, urbanization will be expanding throughout the basin.

The route of the Colombo-Katunayake Expressway (CKE) being constructed runs from south to north in the Kalu Oya basin. The necessary openings for storm water drainage across the CKE have already been studied and should therefore be taken into consideration for the storm water drainage plan.

In view of storm water drainage, the Kalu Oya basin requires solutions for the fundamental drainage problems and protection against future increase of storm water runoff due to the urbanization in the basin. For these objectives, a combination of the following measures is conceivable

1) Channel improvement of the Kalu Oya downstream of the existing inland marsh area
2) Diversion of storm water runoff to the Muthurajawela Mash as a storm water retention area
3) Conservation of lowlands as storm water retention areas
4) Reduction of storm water runoff by introduction of storm water retention facilities in urban areas

6.2 Basic Flood Runoff

The basic flood runoffs in the Kalu Oya basin for probable 10, 25 and 50-year rainstorm events under future land use conditions are estimated for several locations along the river channel as shown in Figures 6.2.1 to 6.2.3. In comparison with the estimated flood runoff with the basin retention effect as shown in Figures 6.2.4 to 6.2.6, the peak runoffs of basic floods increase around five times if the storm water runoff is confined completely within the channels without the retention areas. The significant difference in peak runoff with and without retention effect in the basin suggests the difficulty of drainage to the Kelani Ganga causing stagnation of storm water runoff over the low-lying lands in the Kalu Oya basin.

Comparison of Flood Discharge with and without Basin Retention Effect

Location	Return Period (years)	Basic Flood Runoff (m^3/sec)	Flood Runoff with Basin Retention Effect (m^3/sec)
Kalu Oya at Negombo Road	10	110	20
	25	150	30
	50	185	35

Figure 6.2.7 shows the comparison of flood hydrographs in the Kalu Oya at Negombo Road. The estimated hydrographs show the difference in the total volume of runoff with and without the runoff retention effect of the basin. These volumes are regarded as the maximum capacity of retention in the upstream basin for the respective return periods under the future land use conditions.

6.3 Study on Structural Measures

6.3.1 Conceivable Structural Measures

Based on the basic principle of storm water drainage planning, the conceivable structural measures for storm water drainage in the Kalu Oya basin are identified as described hereafter and illustrated in Figure 6.3.1.

(1) Channel Improvement of Kalu Oya

A general plan of the channel improvement of the Kalu Oya is shown in Figure 6.3.2. The Kalu Oya main stream should be improved to preserve a required width to accommodate urbanization. Even though the difficulty of drainage due to the very flat channel-bed gradient continuing from the Kelani Ganga will remain, the channel improvement and storm water retention area are essential requirement as basic measures for improvement of storm water drainage in the basin.

The cross section of the proposed channel improvement is designed as a simple section comprising the lower part for normal water level and upper part with dike embankments on both channel banks to cope with the design flood.

Crossings of the proposed channel improvement downstream of the Kalu Oya are subject to the designed opening width of the Colombo Katunayake Expressway (CKE). The final proposals for these openings as given by SLLRDC indicate an opening width of 25 m for the Kalu Oya.

(2) Old Negombo Canal Improvement

A general plan of this alternative is shown in Figure 6.3.3. Because of the natural difficulty of drainage and future increase of storm water runoff, an additional retention area should be provided. The Muthurajawela Marsh with a vast extent of flood plain is a conceivable retention area. The storm water runoff from the basin should be diverted to the Muthurajawela Marsh through the Old Negombo Canal to reduce runoff concentrating to the Kalu Oya.

(3) Diversion Channel to Muthurajawela Marsh

A general plan of this alternative is shown in Figure 6.3.4. This alternative is another option for diverting storm water runoff to the Muthurajawela Marsh by constructing a new diversion channel connecting Kalu Oya with the Old Negombo Canal near the Muthurajawela Marsh.

(4) Wattala Pumping Station

To mitigate the difficult drainage condition from the Kalu Oya to Kelani Ganga, a Wattala pumping station is a conceivable alternative to drain storm water to the Kelani Ganga at the most downstream end of the Kalu Oya (Figure 6.3.5).

(5) Storm Water Retention Areas

As described in sub-section 6.1 above, the reduction of basin retention effect is a potential threat that could cause widespread inundation by the storm water runoff from the Kalu Oya basin. A large extent of land reclamation in the existing marsh areas and paddy fields would cause a significant concentration of storm water runoff to the channel and remaining lowlands. Inundation would be caused by overflow from the channel as well as altered concentration of storm water runoff to the remaining lowlands, which might include not only marsh and paddy lands but also other land use categories. Even though demands of low land development are high in the basin, a required extent of storm water retention area should be preserved in the future in compliance with the constraints of storm water drainage downstream. A delimitation of storm water retention area is proposed, based on the future land use projections and inundation analyses.

The retention areas are defined by ground surface elevation around the proposed locations. The retention areas in the lower reaches are defined as the areas lower than 2.0 m above MSL along the Kalu Oya and its tributaries. The extent of storm water retention area is estimated at 434 ha in total. On the other hand, the conceivable retention areas are also identified upstream of the Kandy Road. These areas are defined by the higher level of 4.0 m above MSL and cover the total extent of 89 ha. The proposed retention areas are shown in Figure 6.3.6

(6) Urban Drainage

Because of the present drainage difficulty and future increase of storm water runoff in the Kalu Oya basin, the urban drainage improvement requires various measures to be effective by systematic integration. The following measures will be key elements of the urban drainage improvement plan to be studied and formulated subsequent to this study:

1) Improvement of Trunk Drains in Sub-basins

Storm water drainage of the present urbanized areas in the Kalu Oya basin generally consists of natural streams as trunk drains partly canalized with masonry or concrete works and smaller open drains collecting and leading storm water to the trunk drains. In parallel with the urbanization, these drains have been constructed part by part without proper engineering design processes. Resulting from such situations, local inundation problems have been expanding over the present urbanized area.

It is anticipated that the same problematic situations will expand over urbanizing areas in the future if no adequate measures will be undertaken. Urban drainage improvement in such areas as well as in new development areas is therefore proposed for the purpose of improvement of trunk drains.

Due to the topographical constraints, the difficulty of securing natural drainage retention area would remain along the downstream reaches of the Kalu Oya basin. In such a case, a pumping station with a sufficient capacity for drainage in a sub-basin will be required at the downstream end of a trunk drain.

2) Introduction of Storm Water Retention Facilities

Even though the storm water retention area is proposed by using part of the existing low-lying lands, the extent of the retention area will be constrained by the future urbanization projected. The remaining extent of lowlands would not be sufficient for the significant concentration of storm water runoff in the future. To alleviate the concentration of runoff, storm water retention in the upstream area is required.

For this purpose, a number of storm water retention facilities such as retarding ponds, storage facilities, etc. need to be constructed by sub-basin. Individual capacities of such facilities are much smaller than the retention area but accumulated effects are expected to contribute to the alleviation of the concentration of runoff to the retention area. Those facilities are also useful for reduction of peak runoff to trunk drains in the sub-basins. Examples of the storm water retention facilities are shown in Figure 6.3.7.

6.3.2 Comparative Study of Alternative Drainage Plans

(1) Alternative Components

The conceivable alternative components described above are evaluated by a preliminary cost-benefit analysis. Scale alternatives are also taken into consideration for the component projects. The following alternative components are examined:

Alternative Components

Case	Measures
K1	Channel Improvement of Kalu Oya (B= 40m, L= 5,000m)
K2	Channel Improvement of Kalu Oya (B= 45m, L= 5,000m)
K3	Channel Improvement of Kalu Oya (B= 50m, L= 5,000m)
K4	Wattala Pumping Station (Q= 10 m^3/sec)
K5	Wattala Pumping Station (Q= 20 m^3/sec)
K6	Wattala Pumping Station (Q= 30 m^3/sec)
K7	Diversion Channel to Muthurajawela Marsh (B= 30m, L=1,200+2,400m)
K8	Improvement of Old Negombo Canal to Muthurajawela Marsh (B= 30m, L= 4,500m)
K9	Improvement of Old Negombo Canal to Muthurajawela Marsh (B= 35m, L= 4,500m)
K10	Improvement of Old Negombo Canal to Muthurajawela Marsh (B= 40m, L= 4,500m)

Note: B: width of channel, L: length of channel, Q: discharge capacity

The alternative components are evaluated by economic evaluation. Economic cost, annual benefit by flood damage mitigation, benefit-cost ratio (B/C) and economic internal rate of return (EIRR) projected by the economic evaluation are shown in Table 6.3.1 and summarized below:

Evaluation of Alternatives (50-year Return Period)

Case	Water Level (above MSL)		Project Cost (Million Rs)	Annual Benefit (Million Rs)	B/C	EIRR (%)
	Negombo Road	Retention Area				
K1	1.69	1.81	1,476	108	0.99	9.9
K2	1.65	1.76	1,658	134	1.07	10.6
K3	1.63	1.73	1,856	153	1.08	10.7
K4	1.82	1.97	2,276	6	0.03	-
K5	1.80	1.95	3,792	23	0.07	-
K6	1.67	1.85	4,484	83	0.20	-
K7	1.56	1.68	1,345	185	1.80	16.1
K8	1.57	1.80	816	105	1.93	17.0
K9	1.53	1.77	890	123	2.01	17.6
K10	1.50	1.75	1,025	135	1.83	16.4

(2) Alternative Combinations

As seen in the results of the cost-benefit analysis, alternative components to divert storm water to the Muthurajawela Marsh (cases K7, K8, K9 and K10) indicate good economic viability. Cases K1, K2 and K3 of channel improvement of Kalu Oya give a lower EIRR. Cases K4, K5 and K6 for the Wattala pumping station appear not to be economically viable.

Both options to divert storm water to the Muthurajawela Marsh are therefore incorporated into the alternative components for the storm water drainage plan. On the other hand, the channel improvement of Kalu Oya is an essential measure for storm water drainage in the Kalu Oya basin from the technical point of view. Since this stretch is the only substantial waterway in the Kalu Oya basin to drain storm water runoff to the Kelani Ganga, the channel improvement is a fundamental requirement for storm water drainage in the basin.

Alternative combinations of the component projects are examined based on the condition that an allowable water level should be secured in the Kalu Oya inland marsh area. The estimated water level of 1.67 m above MSL from a 50-year rainstorm event under the present land use condition is adopted as the allowable water level.

Evaluation of Alternative Combinations

Case	Measures
K11	K1+K8+Retention Area
K12	K2+K9+Retention Area
K13	K3+K10+ Retention Area
K14	K1+K7+K8+ Retention Area
K15	K1+K6+K8+Retention Area
K16	K1+K7+ Retention Area
K17	K1+K9+ Retention Area
K18	K1+K10+ Retention Area
K19	K3+K7+K10+ Retention Area
K20	K3+K6+K7+10+ Retention Area

(3) Effect of Retention Area

The alternative combinations above are based on the conservation of storm water retention areas as described in sub-section 6.3.1. The effects of the retention areas in the lower reaches are analyzed for the four options of the delimitation level. The results of the analysis are as shown in Table 6.3.1, Figure 6.3.8 and summarized below:

Extent of Retention Area by Delimitation Level

(Unit: ha)

Lower Retention Areas	Delimitation Level (above MSL)			
	2 m	1.5 m	1.0 m	0.5 m
	434	357	250	131
Upper Retention Areas	89			
Total	523	446	339	220

Retention Area and Water Level (50-year Return Period)

Case	Retention Area 434+89 ha	Retention Area 357+89 ha	Retention Area 250+89 ha	Retention Area 131+89 ha
	Average Water Level in Retention Area (above MSL)			
K0	2.15	2.05	2.16	2.42
K11	1.72	1.77	1.85	2.07
K12	1.67	1.72	1.79	1.99
K13	1.64	1.68	1.74	1.92
K14	1.59	1.63	1.70	1.88
K15	1.58	1.65	1.80	2.06
K16	1.62	1.66	1.75	1.94
K17	1.70	1.75	1.83	2.04
K18	1.69	1.73	1.81	2.02
K19	1.52	1.56	1.61	1.74
K20	1.34	1.41	1.50	1.72

Note: K0 indicates the present drainage system.

When the water level rises with the reduction of the retention area, the capacity of the drainage facilities downstream should be enlarged to lower the water to the allowable level. The total extent of the lower retention areas required for securing the allowable water levels is derived from the graphs shown in Figure 6.3.8. Case K13 satisfies the allowable water level in the basin with a retention area of 360 ha corresponding to the delimitation level of 1.5 m above MSL in the lower retention areas. Case K20 with the larger channel keeps the allowable water levels with the condition that the retention area is reduced to 160 ha corresponding to the delimitation level of 0.6 m above MSL.

(4) Economic Evaluation

The alternative combinations are evaluated by the economic evaluation. Benefit-cost ratio (B/C) and economic internal rate of return (EIRR) for each alternative are computed from economic cost and annual benefit from flood damage mitigation as well as land development cost and land enhancement benefit.

Comparison of Alternative Combinations (50-year Return Period)

Case	Retention Area (ha)	Project Cost (million Rs.)	Annual Benefit (million Rs.)	B/C	EIRR (%)
K11	434+89	1,927	162	1.02	10.2
K12	434+89	2,182	192	1.08	10.6
K13	360+89	2,463	422	1.98	17.8
K14	290+89	2,806	655	2.93	24.1
K15	340+89	5,896	519	0.90	9.0
K16	340+89	2,390	493	2.34	20.3
K17	434+89	2,001	173	1.11	10.9
K18	434+89	2,136	182	1.08	10.7
K19	200+89	3,331	888	3.20	25.7
K20	160+89	7,422	1,113	1.75	15.2

Note: Average water level in the retention area is 1.67 m above MSL for all cases.

6.3.3 Study on Optional Planning Scales (25-year and 10-year Return Periods)

The alternative combination is the same as described in sub-section 6.3.1 above, except that the cross section of the channel is reduced but still sufficient for the probable 25-year and 10-year flood runoff. In these cases, it is assumed that the channel improvement is only composed of the construction of dikes (flood bunds) on both sides of the channel to secure the required channel width. The estimated water level from a rainstorm event for each return period under the present land use condition is adopted as the allowable water level. The allowable water level in the retention area is 1.60 m for a 25-year return period and 1.51 m above MSL for a 10-year return period.

The effect of the retention area is also carried out on the alternatives for the planning scale of 25-year and 10-year return periods. The required additional measures for reducing water level in the retention area are summarized in Tables 6.3.2 and 6.3.3, Figures 6.3.9 and 6.3.10. The alternative combinations are evaluated by B/C and EIRR to identify the most economical combination.

Retention Area and Water Level (25-year Return Period)

Case	Retention Area 434+89 ha	Retention Area 357+89 ha	Retention Area 250+89 ha	Retention Area 131+89 ha
	Average Water Level in Retention Area (above MSL)			
K0	1.85	1.92	2.03	2.25
K11	1.63	1.67	1.74	1.92
K12	1.59	1.63	1.69	1.85
K13	1.55	1.59	1.65	1.80
K14	1.52	1.55	1.60	1.76
K15	1.40	1.46	1.59	1.88
K16	1.54	1.58	1.64	1.81
K17	1.61	1.65	1.72	1.90
K18	1.58	1.63	1.70	1.87
K19	1.44	1.48	1.53	1.65

Retention Area and Water Level (10-year Return Period)

Case	Retention Area 434+89 ha	Retention Area 357+89 ha	Retention Area 250+89 ha	Retention Area 131+89 ha
	Average Water Level in Retention Area (above MSL)			
K0	1.68	1.73	1.83	2.02
K11	1.50	1.54	1.60	1.72
K12	1.44	1.48	1.55	1.66
K13	1.38	1.43	1.50	1.62
K14	1.39	1.43	1.48	1.59
K15	1.15	1.20	1.29	1.56
K16	1.46	1.50	1.53	1.64
K17	1.44	1.49	1.56	1.69
K18	1.39	1.44	1.53	1.67

Comparison of Alternative Combinations for Reduction of Retention Area

a) Planning Scale: 25-year Return Period

Case	Retention Area (ha)	Project Cost (million Rs.)	Annual Benefit (million Rs.)	B/C	EIRR (%)
K11	434+89	1,772	148	1.08	10.7
K12	390+89	1,879	298	1.90	16.8
K13	330+89	1,975	489	2.84	23.0
K14	265+89	2,594	690	2.98	24.1
K15	250+89	5,762	797	1.53	14.6
K16	310+89	2,249	551	2.78	22.8
K17	434+89	1,802	161	1.15	11.2
K18	390+89	1,801	302	2.00	17.5
K19	175+89	2,807	987	3.90	29.3

Note: Average water level in retention area is 1.60 m above MSL for all cases.

b) Planning Scale: 10-year Return Period

Case	Retention Area (ha)	Project Cost (million Rs)	Annual Benefit (million Rs.)	B/C	EIRR (%)
K11	434+89	1,751	149	1.25	11.8
K12	320+89	1,810	405	3.41	25.7
K13	250+89	1,899	618	4.66	32.1
K14	215+89	2,533	713	3.84	28.5
K15	150+89	5,671	969	2.66	21.9
K16	290+89	2,219	481	3.04	24.0
K17	325+89	1,704	389	3.50	26.2
K18	275+89	1,699	525	4.59	31.6

Note: Average water level in retention area is 1.51 m above MSL for all cases.

6.4 Proposed Storm Water Drainage Plan

The results of the comparative study for the alternative combinations of options of planning scale and reduction of retention area are summarized below:

Summary of Comparison of Alternative Combinations

Case	Planning Scale (Return Period)	Retention Area (ha)	B/C	EIRR (%)
K11	50-year	-	-	-
	25-year	434+89	1.08	10.7
	10-year	434+89	1.25	11.8
K12	50-year	434+89	1.08	10.6
	25-year	390+89	1.90	16.8
	10-year	320+89	3.41	25.7
K13	50-year	360+89	1.98	17.8
	25-year	330+89	2.84	23.0
	10-year	250+89	4.66	32.1
K14	50-year	290+89	2.93	24.1
	25-year	265+89	2.98	24.1
	10-year	215+89	3.84	28.5
K15	50-year	340+89	0.90	9.0
	25-year	250+89	1.53	14.6
	10-year	150+89	2.66	21.9
K16	50-year	340+89	2.34	20.3
	25-year	310+89	2.78	22.8
	10-year	290+89	3.04	24.0
K17	50-year	434+89	1.11	10.9
	25-year	434+89	1.15	11.2
	10-year	325+89	3.50	26.2
K18	50-year	434+89	1.08	10.7
	25-year	390+89	2.00	17.5
	10-year	275+89	4.59	31.6
K19	50-year	200+89	3.20	25.7
	25-year	175+89	3.90	29.3
	10-year	-	-	-
K20	50-year	160+89	1.75	15.2
	25-year	-	-	-
	10-year	-	-	-

Note: - not subject to comparison.

Although B/C and EIRR become higher because of the land enhancement benefit as the planning scale is lowered, the study proposes the planning scale of a 50-year return period for the storm water drainage plan in the Kalu Oya basin. As mentioned in sub-section 4.1, a certain high planning scale is required for the Kalu Oya basin being urbanized and expected as a future development area next to the Greater Colombo basin. In case that the project cost for the planning scale of a 50-year return period becomes a financial burden to the government, a stage-wise implementation is proposed. A planning scale of a 10 or 25-year event is to be attained in the first stage and is to be increased in the latter stages.

The alternative combinations of K14, K16, K18 and K19 include the diversion channel component (K7) and indicate a higher B/C and EIRR than the others without K7. However, the diversion channel requires additional crossings for both Negombo Road and CKE, which would cause rather difficult technical and social problems.

Based on the above considerations, case K13 with the highest B/C and EIRR among the alternative combinations without the diversion channel component is proposed as the storm water drainage plan for the Kalu Oya basin:

1) Channel Improvement of Kalu Oya
    - Total Length 5.0 km
    - Width 50 m from 0.0 km to 3.8 km (Trapezoidal Cross Section)
    - Width 25 m from 3.8 km to 5.0 km (Rectangular Cross Section)
2) Channel Improvement of Old Negombo Canal
    - Total Length 4.5 km
    - Width 40 m (Trapezoidal Cross Section)
3) Storm Water Retention Area (449 ha)
    - Lower Retention Areas: 360 ha
    - Upper Retention Areas: 89 ha

The general layout for the proposed storm water drainage plan is illustrated in Figure 6.4.1.

CHAPTER 7 STORM WATER DRAINAGE PLAN IN THE GREATER COLOMBO BASIN

7.1 Basic Principle for Planning

In the Greater Colombo basin, the present safety level of the main canal system was evaluated in the range of a 5-year to 25-year return period. Substantial improvement was accomplished by the GCFC&EIP Phase I but further improvement should also be considered in order to cope with economic growth in the basin and an increase in social requirements for flood protection in the future.

It is projected that the Greater Colombo basin will be urbanized extensively with land development expanding to the suburbs. As a result, it is anticipated that the inundation in the case of heavy rainstorms will be worsening due to the significant increase in storm water runoff to be caused by the extensive urbanization even though the existing storm water retention areas will be conserved properly.

To alleviate the increase of storm water runoff, it is essential to conserve the presently functioning storm water retention areas and preserve other lowlands available for the purpose of storm water retention as much as possible. In addition, the existing storm water drainage system should also be augmented to increase the flood safety level.

For the purpose of the above, a combination of the following measures is proposed as a basin-wide storm water drainage plan:

1) Conservation of existing storm water retention areas and utilization of other lowlands for storm water retention purposes
2) Augmentation of the capacity to drain storm water runoff out of the basin
3) Increase in the flow capacity of existing major drainage canals

7.2 Basic Flood Runoff

The basic flood runoffs in the Greater Colombo basin for the probable 10, 25, and 50-year rainstorm events under the future land use conditions are estimated for several base points along the river channel as shown in Figures 7.2.1 to 7.2.3. In comparison with the estimated flood runoffs with the basin retention effect as shown in Figures 7.2.4 to 7.2.6, the peak runoffs of the basic flood increases by 88 % for a10-year return period, 109 % for a 25-year event, and 114 % for a 50-year event in Krillapone Canal at Open University Bridge.

Comparison of Flood Discharge with and without Basin Retention Effect

Location	Return Period (years)	Basic Flood Runoff (m^3/sec)	Flood Runoff with Basin Retention Effect (m^3/sec)
Kirillapone Canal at Open University Bridge	10	75	40
	25	115	55
	50	150	70

Figure 7.2.7 shows the comparison of flood hydrographs in Kirillapone Canal at Open University Bridge. The estimated hydrographs show the difference in the total volume of runoff with and without retention areas. These volumes are regarded as the maximum capacity of retention in the upstream basin for the respective return periods under the future land use conditions.

7.3 Study on Structural Measures

7.3.1 Conceivable Structural Measures

Based on the basic principle of storm water drainage planning, the conceivable structural measures for storm water drainage in the Greater Colombo basin are identified as described hereafter and illustrated in Figure 7.3.1.

(1) Augmentation of Drain-out Capacity from Basin

As indicated by the hydrological analysis, the peak storm water runoff from the Greater Colombo basin in Krillapone Canal at Open University Bridge under the projected future land use conditions would increase by 114 % compared with runoff from the present land use conditions when subjected to a 50-year event . The high water level under such an event exceeds the allowable water level of the existing canals as designated by GCFC&EIP Phase I. To cope with the increase of storm water runoff, measures for augmentation of the drainage system to release storm water runoff from the basin will be required in combination with the conservation of storm water retention areas.

In the light of the current urbanized conditions of the basin, the following measures, including the previous proposals, are taken into consideration:

1) Maradana Pumping Station and Improvement of Galle Face Sea Outfall

The general plan of this alternative component is shown in Figure 7.3.2. This alternative component was originally proposed by SLLRDC and envisages draining storm water runoff from the St. Sebastian South Canal to Beira Lake. Storm water runoff is finally drained into the sea through the Galle Face outfall. According to the proposal by SLLRDC, the principal features of this component are given below:

- Clearing the heavily silted-up channel section between the Macallum road bridge and Maradana Technical College bridge
- Extension of improvement of the St. Sebastian Canal from the end of the improved section under GCFC&EIP Phase I to the Maradana Technical College bridge
- Repair or replacement of the existing gate (now non-operative) located at the downstream side of the Maradana Technical College bridge
- Pumping storm water runoff at a maximum flow capacity of 5 m3/sec from the St. Sebastian Canal to Beira Lake through the improved sections above
- Construction of two (2) gates on either side of the semi-circular spillway at Galle Face outfall to replace the permanently blocked existing gates in order to stabilize the water level of Beira Lake during pumping.

Of the above, there is an exiting pumping station at the upstream side of the Maradana Technical College Bridge. Capacity of this pumping station is unknown and it seems not to be in operation. The proposed alternative component here assumes to construct a new pumping station.

2) North Lock Pumping Station

The general plan of this alternative component is shown in Figure 7.3.3. The existing North Lock Gate is located at the railway crossing on the St. Sebastian Canal beside Nagalagam Street. When the North Lock Gate is closed during flood in the Kelani Ganga to prevent reverse flow, it is not possible to drain storm water runoff from the St. Sebastian Canal to the Kelani Ganga. To resolve this issue, this alternative component envisages constructing a pumping station on the upstream side of the North Lock Gate together with reconstruction of the old Gate. The capacity of the pumping station is assumed at 10 m^3/sec suggested by the previous study.

3) Gotatuwa Pumping Station

The general plan of this alternative component is shown in Figure 7.3.4. The Kolonnwa Ela is completely closed off at Gotatuwa by a closing bund constructed under the Kelani Ganga Flood Protection Scheme. The area on the riverside of the closing bund is a flood plain of the Kelani Ganga. The Gotatuwa pumping station plan envisages draining storm water runoff from the Kolonnawa Ela to Kittanpahuwa Ela downstream of the closing bund. The capacity of the pumping station is assumed at 40 m^3/sec referring to the previous proposal. Even though the downstream side of the closing bund is unprotected from the Kelani Ganga flood, this alternative component considers the improvement of the Kittanpahuwa Ela from the closing bund to the Kelani Ganga in order to cope with the pump discharge.

4) Madiwela South Diversion Canal

The general plan of this alternative component is shown in Figure 7.3.5. This alternative component was also referred to in the previous proposal but a supplemental study was carried out to formulate the preliminary plan. According to the hydrological study discussed in Annex 3, storm water runoff at the upstream end of Parliament Lake is estimated at 55 m^3/sec for a 50-year return period. When this runoff is diverted out of the basin, runoff downstream of Parliament Lake is significantly reduced.

The Madiwela South diversion canal envisages diverting storm water runoff from the upstream basin to the Bolgoda basin. A closing bund is proposed upstream of Parliament Lake. To lead storm water runoff in the reverse direction, the stream in the upstream basin is canalized and a crossing culvert is constructed at the railway and High Level Road. The maximum water level in the lowland upstream of Parliament Lake is set at 2.4 m above MSL and the design runoff of the crossing culvert is estimated at 40 m^3/sec for the probable 50-year rainstorm event. The downstream side in the Bolgoda basin is also canalized to cope with the diverted runoff.

5) Restoration of the Existing Mutwal Tunnel

The existing Mutwal tunnel connects the upstream end of the Main Drain with the sea outfall in the compound of the Fishery Corporation as show in Figure 7.3.6. However, the existing tunnel is deteriorated and does not function at all. In the Greater Colombo basin, the only substantial permanent sea outfalls are located at Wellawatta and Dehiwala in the south. The restoration of the existing Mutwal tunnel, therefore, contributes to smooth drainage in the northern system as well as augmentation of the drain-out capacity of the basin. The restoration works cover road crossing culverts, inlet channels, a 1.8 m diameter tunnel section, and the outfall. The flow capacity of the tunnel is estimated at 5 m^3/sec.

6) New Mutwal Tunnel

The general plan of this alternative component is shown in Figure 7.3.7. The new Mutwal tunnel was also proposed by the previous study for augmentation of the drain-out capacity of the Greater Colombo basin. As proposed, an inlet channel branches from the Main Drain around 100 m upstream of the crossing of the Port Access Road. A tunnel section with a 4.0 m diameter and a length of 740 m starts near Walls Lane and runs to the north. An outfall to the sea is located on the sea side of the Muthwella Mawatta. The flow capacity of the tunnel is estimated at 15 m^3/sec.

7) Widening of Wellawatta and Kirillapone Canals

The preliminary plan for this alternative component is shown in Figure 7.3.8. This alternative component envisages increasing the flow capacity of the Wellawatta and Kirillapone Canals for augmentation of the drain-out capacity from the basin. The existing channel width varies from 17 to 20 m in the Wellawatta Canal and from 26 to 35 m in the Kirillapone Canal. The proposed channel width is 30 m for the Wellawatta Canal and 35 m for the Kirillapone Canal. The flow capacities of the widened canals are estimated at 60 m^3/sec in the Wellawatta Canal and 70 m^3/sec in the Krillapone Canal.

(2) Storm Water Retention Area

The inland lowlands in the Greater Colombo basin are generally recognized as storm water retention areas. It was recommended that storm water retention areas of 380 ha along Kolonnawa, Heen Ela, and Kotte Ela should be kept with the main canal system improved under the GCFC&EIP Phase I. But it is generally understood that these retention areas are likely to be filled because of development pressure.

To cope with the anticipated increase of storm water runoff in the future, an adequate amount of storm water retention area should be conserved. The study attempts to estimate the required extent of storm water retention area in the Greater Colombo basin for the future.

In this study, all the lowlands in the basin are regarded as possible retention areas at first. The retention areas are defined by ground surface elevation. The extent of retention area along the main canals is estimated at 435 ha by the delimitation level of 2 m above MSL. Although the figures in the table are obtained from the digital elevation model (DEM) of MIKE11 based on the topographic data as far as available, the total of the retention areas of Kolonnawa Ela, Heen Ela, and Kotte Ela is estimated at 344 ha, which is close to the published figure and is acceptable for the starting point of the subsequent discussions in this section. The proposed retention area is shown in Figure 7.3.9.

Storm Water Retention Area

(Unit: ha)

Retention Area	Land Area Lower than 2 m above MSL
Kolonnawa Ela	157
Heen Ela	72
Kotte Ela	115
Parliament Lake Surroundings	30
Other Areas	61
Total	435

(3) Urban Drainage

A key factor for urban drainage in the Greater Colombo basin is to proceed with consistent planning and implementation in improvement of the urban drainage system by individual sub-basin.

In the Greater Colombo basin, the urban drainage improvement in the sub-basins was implemented under the GCFC&EIP Phase II with a planning scale of a 2-year return period because of the physical constraints on implementation in the densely urbanized areas. However, as described in sub-section 4.1, a planning scale of a 5-year return period or more would be desirable at least for the trunk drains. Hence, the present planning scale of the urban drainage schemes in the small catchments under the GCFC&EIP is regarded provisional in a sense, for the purpose of early implementation to alleviate frequent local inundation as soon as possible.

For the urban drainage improvement in the Greater Colombo basin, introduction of the storm water retention facilities as mentioned in sub-section 4.1 will be necessary in combination with trunk drains in the sub-basins. The storm water retention facilities envisage alleviating rapid concentration of storm water runoff to trunk drains of which widening would be constrained by the built-up condition in the highly urbanized areas. Detail planning of the urban drainage systems introducing the storm water retention facilities needs to be undertaken subsequent to this study.

7.3.2 Comparative Study of Alternative Drainage Plans

(1) Alternative Components

The conceivable alternative components described above were evaluated by a preliminary cost-benefit analysis. Scale alternatives are also taken into consideration for the components. The following alternative components were examined:

Alternative Components

Case	Measures
G1	Maradana Pumping Station (Q= 5 m^3/sec) and Improvement of Galle Face Outfall
G2	Maradana Pumping Station (Q= 10 m^3/sec) and Improvement of Galle Face Outfall
G3	North Lock Pumping Station (Q= 10 m^3/sec)
G4	North Lock Pumping Station (Q= 15 m^3/sec)
G5	Gotatuwa Pumping Station (Q= 30 m^3/sec)
G6	Gotatuwa Pumping Station (Q= 40 m^3/sec)
G7	Madiwela South Diversion Channel
G8	Restoration of Existing Mutwal Tunnel (D=1.8m)
G9	New Mutwal Tunnel (D= 3m)
G10	New Mutwal Tunnel (D= 4m)
G11	Widening of Wellawatta and Kirillapone Canals

Note: Q: discharge capacity, D: diameter

Annual benefit is estimated as a monetary value, which is a contribution to reducing potential inundation damage by a 50-year rainstorm event under the future land use conditions. The results of the cost-benefit analysis are summarized in Table 7.3.1.

(2) Alternative Combinations

To cope with a 50-year rainstorm event under the future land use condition, a storm water drainage plan in the Greater Colombo basin requires a combination of some alternative components.

The analysis discussed here adopts the average water level of 1.75 m above MSL in the retention areas along the Kolonnawa Ela, Heen Ela and Kotte Ela as the allowable water level. This water level represents almost the same condition as the allowable water levels of 1.85 m above MSL at Parliament Lake and 1.75 m above MSL for the urban part west of Parliament Lake in the Greater Colombo basin. Resulting from the hydrological analysis, the following alternative combinations were prepared:

Alternative Combinations

Case	Measures
G12	• G7 Madiwela South Diversion Channel • G8 Restoration of Existing Mutwal Tunnel (D=1.8m) • Retention Area
G13	• G7 Madiwela South Diversion Channel • G9 New Mutwal Tunnel (D= 3m) • Retention Area
G14	• G7 Madiwela South Diversion Channel • G10 New Mutwal Tunnel (D= 4m) • Retention Area
G15	• G8 Restoration of Existing Mutwal Tunnel (D=1.8m) • G9 New Mutwal Tunnel (D= 3m) • Retention Area

Case	Measures
G16	• G8 Restoration of Existing Mutwal Tunnel (D=1.8m) • G10 New Mutwal Tunnel (D= 4m) • Retention Area
G17	• G7 Madiwela South Diversion Channel • G11 Widening of Wellawatta and Kirillapone Canals • Retention Area
G18	• G7 Madiwela South Diversion Channel • G8 Restoration of Existing Mutwal Tunnel (D=1.8m) • G9 New Mutwal Tunnel (D= 3m) • Retention Area
G19	• G7 Madiwela South Diversion Channel • G8 Restoration of Existing Mutwal Tunnel (D=1.8m) • G10 New Mutwal Tunnel (D= 4m) • Retention Area
G20	• G7 Madiwela South Diversion Channel • G8 Restoration of Existing Mutwal Tunnel (D=1.8m) • G11 Widening of Wellawatta and Kirillapone Canals • Retention Area
G21	• G7 Madiwela South Diversion Channel • G9 New Mutwal Tunnel (D= 3m) • G11 Widening of Wellawatta and Kirillapone Canals • Retention Area
G22	• G7 Madiwela South Diversion Channel • G10 New Mutwal Tunnel (D= 4m) • G11 Widening of Wellawatta and Kirillapone Canals • Retention Area

(4) Effect of Retention Area

The alternative combinations above are based on the conservation of storm water retention areas as described in sub-section 7.3.1. The effect of the retention areas is analyzed for the following four options of delimitation level.

Extent of Retention Area by Delimitation Level

(Unit: ha)

Retention Area	Delimitation Level (above MSL)			
	2 m	1.5 m	1.0 m	0.5 m
Kolonnawa Ela	157	142	119	42
Heen Ela	72	56	31	5
Kotte Ela	115	101	77	13
Parliament Lake Surroundings	30	27	13	6
Other Areas	61	54	44	3
Total	435	380	284	71

With the reduction of the storm water retention area, the capacity of drainage facilities should be enlarged to cope with the increased runoff. The results of the analysis are as shown in Table 7.3.1 and Figure 7.3.10.

Case G19 satisfies the allowable water level with a retention area of 380 ha corresponding to the delimitation level of 1.5 m above MSL. Case G20 with the larger facilities keeps the allowable water level with the condition that the retention area is reduced to 290 ha corresponding to the delimitation level of 1.0 m above MSL.

Retention Area and Water Level (50-year Return Period)

Case	Retention Area 435 ha	Retention Area 380 ha	Retention Area 284 ha	Retention Area 171 ha
	Average Water Level in Retention Area (above MSL)			
G0	2.07	2.09	2.20	2.69
G17	1.76	1.77	1.83	2.27
G18	1.76	1.77	1.83	2.28
G19	1.74	1.74	1.81	2.23
G20	1.74	1.75	1.81	2.24
G21	1.71	1.72	1.78	2.20
G22	1.69	1.69	1.76	2.15
G23	1.68	1.68	1.74	2.14
G24	1.58	1.58	1.62	1.92

Note: G23 = G7+G8+G10+G11
G24 = G4+G7+G8+G10+G11

(5) Evaluation of Alternative Combinations

The alternative combinations are evaluated by a cost-benefit analysis to identify the most economical combination. The results of the cost-benefit analysis for the alternative combinations are summarized below:

Comparison of Alternative Combinations (50-year Return Period)

Case	Retention Area (ha)	Project Cost (million Rs.)	Annual Benefit (million Rs.)	B/C	EIRR (%)
G17	435	5,393	678	1.40	13.5
G18	435	4,473	681	1.70	15.7
G19	380	4,389	886	2.23	19.5
G20	360	5,307	933	1.93	17.5
G21	320	5,940	1,114	2.06	18.4
G22	290	6,009	1,251	2.28	20.0
G23	280	6,133	1,303	2.33	20.3
G24	170	8,804	1,850	2.32	20.3

Note: G23 = G7+G8+G10+G11
G24 = G4+G7+G8+G10+G11
Average water level in retention area is 1.75 m above MSL for all cases.

7.3.3 Study on Optional Planning Scales (25-year and 10-year Return Periods)

(1) Comparative Study of Alternative Drainage Plans

The cost-benefit analysis was carried out for the alternative components in the same manner as described in the sub-section 7.3.1.

For the planning scale of a 25-year return period, most of the alternative components individually achieve the allowable water level of 1.85 m MSL at Parliament Lake and 1.75 m MSL for the urban part west of Parliament Lake.

The results of the hydrological study indicate that the existing major canal system in the Greater Colombo basin is sufficient for runoff from a probable 10-year rainstorm event under the future land use condition. Hence, the present major canal system in the basin will provide the safety level for a10-year return period in the future, assuming that the storm water retention area is delimitated at less than 2 m above MSL. But some additional measures would be necessary if the retention areas are reduced

The results of the cost-benefit analysis for the alternative components are shown in Tables 7.3.2 and 7.3.3.

(2) Effect of Retention Area

Similarly to the descriptions in sub-section 7.3.2 above, the effect of retention area is analyzed. The results of the analysis are summarized in Tables 7.3.2 and 7.3.3, Figures 7.3.11 and 7.3.12, and summarized below:

Retention Area and Water Level (25-year Return Period)

Case	Retention Area 435 ha	Retention Area 380 ha	Retention Area 284 ha	Retention Area 171 ha
	Average Water Level in Retention Area (above MSL)			
G0	1.86	1.87	1.93	2.27
G7	1.59	1.59	1.64	2.02
G8	1.71	1.72	1.78	2.20
G9	1.57	1.57	1.62	1.99
G10	1.54	1.54	1.58	1.94
G12	1.52	1.52	1.56	1.90
G13	1.73	1.73	1.80	2.22
G14	1.71	1.71	1.77	2.18

Retention Area and Water Level (10-year Return Period)

Case	Retention Area 435 ha	Retention Area 380 ha	Retention Area 284 ha	Retention Area 171 ha
	Average Water Level in Retention Area (above MSL)			
G0	1.48	1.48	1.52	1.85
G8	1.46	1.46	1.49	1.82
G9	1.42	1.43	1.46	1.77
G10	1.41	1.41	1.44	1.73

Comparison of Alternative Combinations

a) Planning Scale: 25-year Return Period

Case	Retention Area (ha)	Project Cost (million Rs.)	Annual Benefit (million Rs.)	B/C	EIRR (%)
G7	190	3,327	1,144	3.74	27.8
G10	340	855	452	5.72	38.3
G12	170	3,451	1,247	3.94	29.8
G13	150	4,112	1,373	3.65	28.2
G14	135	4,181	1,461	3.83	29.1
G15	320	908	478	4.83	37.4
G16	310	978	549	6.09	39.8
G19	125	4,305	1,515	3.86	29.3

Note: Average water level in retention area is 1.75 m above MSL for all cases.

b) Planning Scale: 10-year Return Period

Case	Retention Area (ha)	Project Cost (million Rs.)	Annual Benefit (million Rs.)	B/C	EIRR (%)
G8	330	302	103	3.81	28.9
G9	270	785	295	4.22	30.8
G10	240	855	393	5.12	35.1

Note: Average water level in retention area is 1.48 m above MSL for all cases.

7.4 Proposed Storm Water Drainage Plan

The study proposes a planning scale of a 50-year return period for the storm water drainage plan in the Greater Colombo basin. In the light of the socio-economic importance of the basin in the country, a high planning scale needs to be provided for the future. If the project cost for the planning scale of a 50-year return period becomes a financial burden to the government, a stage-wise implementation is proposed, i.e. a planning scale of a 25-year event to be attained in the first stage and the 50-year event in a latter stage. The planning scale for a10-year return period with a significant decrease of storm water retention area would not be affordable in view of the social requirements for storm water drainage and conservation of appropriate natural environment in the basin even though the benefit of land development is quite large.

For the planning scale of a 50-year return period, the cases G19, G22, G23 and G24 indicate high B/C and EIRR. Case G19, which also comprises the components of G10 and G8, can be completed for the least cost among the three combinations and shows the highest economic viability for the 25-year and 10-year return periods. It is therefore proposed as the storm water drainage plan for the Greater Colombo basin.

1) Restoration of Mutwal Tunnel
    - Total Length 554 m
    - Diameter 1.8 m
2) Construction of New Mutwal Tunnel
    - Total Length 740 m
    - Diameter 4.0 m
3) Madiwela South Diversion Channel
    - Total Length 8,800 m
    - Width 32 m (Trapezoidal Cross Section)
4) Storm Water Retention Areas (380 ha)

The general layout for the proposed storm water drainage plan is illustrated in Figure 7.4.1.

CHAPTER 8 STORM WATER DRAINAGE PLAN IN THE BOLGODA BASIN

8.1 Basic Principle for Planning

8.1.1 Storm Water Drainage Plan for Bolgoda Basin

The Bolgoda basin is characterized by the drainage system in the downstream lowlands consisting of the two major lakes and waterways interconnecting each other. These constitute an integrated system functioning as a natural flood plain. According to the future land use projection, extensive urbanization in the basin is not expected within the time-scale to the target year 2010 except the Weras Ganga basin covering the areas of Dehiwela - Mount Lavinia, Moratuwa, Maharagama and Kesbewa in the northern part of the Bolgoda basin.

For the basin-wide flood management in a long-term view, conservation of existing natural drainage systems in the downstream end is an essential need in the basin. Any large-scale structural measures such as channel improvements and runoff diversion facilities will not be affordable within the time scale to the target year 2010 from both technical and environmental viewpoints. On the other hand, the Weras Ganga basin requires channel improvements to the main stream and major tributaries to cope with runoff to be increased by the projected urbanization. Therefore, the present study mainly focuses on the storm water drainage plan for the Weras Ganga basin.

From the considerations above, the storm water drainage plan in Bolgoda basin is proposed on the basis of the following principles:

1) Conservation of existing water surface areas and surrounding lowlands for storm water retention as well as environmental protection in the entire Bologda basin
2) Channel improvement of the Weras Ganga for draining storm water runoff concentrating from its urbanized catchment
3) Channel improvements to the tributaries of the Weras Ganga for alleviating storm water drainage problems in the respective drainage areas

8.1.2 Study on the Storm Water Drainage Plan in Weras Ganga Basin

The Phase I - Master Plan study was carried out, based on the available topographic maps with the scale of 1:50,000 and 1:10,000, for the storm water drainage plans of the respective main streams together with conservation of the retention areas as the primary objectives.

It was identified that the majority of existing problems in the Weras Ganga basin were directly caused by the unsatisfactory conditions of the Weras Ganga main stream as well as the principal drainage channels (major tributaries) or urban drainage channels to drain storm water runoff into the Weras Ganga. It is therefore necessary to conduct a series of in-depth studies on the characteristics of the particular problems on storm water drainage in the entire Weras Ganga basin. Such studies require accurate baseline data including topography, urbanization and drainage system, which are obtainable from the latest maps with a scale of 1:2000 or more detail.

A series of in-depth studies were enabled with the latest 1:2,000 scale topographic maps produced by the Survey Department in 2001, which cover the entire Weras Ganga basin. As a result of the in-depth studies carried out in the early stage of the Phase II - Feasibility Study, the storm water drainage plan for the Weras Ganga basin was formulated. Details of the study on the storm water drainage plan are discussed in Volume IV - Supporting Report (2). The storm water drainage plan for the Weras Ganga basin is outlined in the subsequent sections and is incorporated with the storm water drainage plan for the Bolgoda basin.

8.2 Basic Flood Runoff

The basic flood runoffs in the Bolgoda basin for probable 10, 25, and 50-year rainstorm events under the future land use conditions were estimated for several locations along the river channel as shown in Figures 8.2.1 to 8.2.3. In comparison with the estimated flood runoff with the basin retention effect as shown in Figures 8.2.4 to 8.2.6, the peak runoffs of a basic flood increases by 35% for a 10-year return period, 45% for a 25-year storm, and 55 % for a 50-year storm in the Panadura Ganga at the sea outfall if the retention and areas are eliminated.

Comparison of Flood Discharge with and without Basin Retention Effect

Location	Return Period (years)	Basic Flood Runoff (m^3/sec)	Flood Runoff with Basin Retention Effect (m^3/sec)
Panadura Ganga at Sea Outfall	10	175	130
	25	210	145
	50	240	155

Figure 8.2.7 shows the comparison of flood hydrographs in Panadura Ganga at the sea outfall. The estimated hydrographs show the difference in the total volume of runoff with and without retention areas. These volumes are regarded as the

maximum capacity of retention in the upstream basin for the respective return periods under future land use conditions.

8.3 Study on Storm Water Drainage Plan

8.3.1 Conceivable Structural Measures

The conceivable structural measures for storm water drainage in the Bolgoda basin are illustrated in Figure 8.3.1.

(1) Channel Improvement of Weras Ganga and Tributaries

The structural measures for the Weras Ganga basin envisage alleviating the causes of inundation. Existing problems and relevant drainage channels that require channel improvement are described below:

Existing Problems and Relevant Rivers and Drainage Channels

Problems	Rivers and Drainage Channels	Conceivable Improvement
Flooding in Weras Ganga	• Weras Gagna	• Dredging of channel bed • Construction of dike
Obstruction of storm water drainage by reduction of flow capacity in the downstream end of the major tributary connecting to the Weras Ganga	• Bolgoda Canal • Rattanapitiya Ela • Maha Ela	• Removal of water plants growing in the channel • Dredging of channel bed • Widening of channel
Overflow from major tributary due to inadequate flow capacity of channel or under-sized crossing structure for storm water runoff	• Nugegoda Ela • Delkanda Ela • Depawa Ela • Maha Ela	• Widening of channel
Drainage difficulty due to absence or lack of improvement of channel for storm water drainage	• Nugegoda Ela • Delkanda Ela • Depawa Ela • Maha Ela Tributary • Werahara Tributary	• Widening of channel • Construction of channel
Drainage difficulty in low-lying areas with ground elevation of 1.0 m above MSL or less	• Minor Tributaries in Kandawala, Telewala, Katubedda and Urban Drainage Channels in Weras Ganga Right Bank	• Widening of channel • Provision of urban drainage system

Locations of rivers and channels listed above are shown in Figure 8.3.2.

(2) Storm Water Retention Area

In combination with the channel improvements above, it is also important to provide storm water retention areas by preserving the present water surface areas and surrounding lowlands for runoff retention purposes. The Weras Ganga basin is already urbanized and the lowlands in the basin tend to be reclaimed. The land use projection indicates that the basin area will be highly urbanized in the future and the remaining lowlands will be quite limited especially in the northern part of the basin.

The storm water drainage plan for the Weras Ganga basin is formulated on the condition that the marsh areas remaining in the future land use projection will be utilized as storm water retention areas. The proposed retention areas in the Weras Ganga basin are shown in Figure 8.3.3 and listed below:

Storm Water Retention Areas

Location	Extent (ha)
Upper Nugegoda Ela	7
Lower Nugegoda Ela	20
Delkanda Ela	9
Bellanwilla-Attidiya Marsh	108
Weras Ganga Swamp and Surrounding Marsh	65
Maha Ela Marsh and Lowland	132
Katubedda Tributary	23
Thumbowila Tributary	8
Total	372

On the other hand, the other part of the Bolgoda basin will not be subject to extensive development. Conservation of the existing water system downstream is a subject of a longer term than the time-scale of the master plan and should be discussed in view of basin-wide flood control as well as environmental management in the Bolgoda basin.

In this study, the storm water drainage plan is proposed on the condition that the lowlands lower than 1.5 m above MSL will be conserved. Such lowlands in the Bolgoda basin are shown in Figure 8.3.4.

(3) Urban Drainage

It is desirable to proceed with consistent planning and implementation in improvement of the urban drainage system by individual sub-basin following the GCFC&EIP Phase III and Lunawa Project.

For the urban drainage improvement in the present urbanized areas, a similar approach to that in the Greater Colombo basin is recommended to cope with the built-up conditions. Introduction of storm water retention facilities combined with trunk drains will be required for urbanized sub-basins. The remaining areas require construction of trunk drains discharging storm water runoff into the main streams or lakes under a systematic planning of urban drainage improvement by sub-basin. Such planning of urban drainage needs to be undertaken subsequent to this study.

In the storm water drainage plan for the Weras Ganga basin, urban drainage improvement of the highly urbanized area on the right bank of the Weras Ganga is proposed for alleviating drainage difficulties due to the topographic constraints. Improvement of the existing urban drainage system comprises construction of drains including urban drainage channels and retention ponds at the downstream ends of existing minor tributaries of the Weras Ganga.

(4) Additional Sea Outfalls

If a significant decrease of storm water retention area of the basin arises, provision of additional sea outfalls would be the only solution to lower flood water levels in the lakes and rivers and for decreasing flood damage in the basin. Possible locations for additional outfalls can be identified as follows:

1) Connection of Panadura Ganga with Lunawa Lake by diversion channel and culvert crossing Galle Road
2) Channel and sea outfall improvement of Talpitiya Canal connecting with South Bolgoda Lake

However, the storm water drainage plan here does not include the measures above. As described in section 8.1 above, extensive urbanization is not expected on a basin-wide basis within the time-scale to the target year. Hence, the conservation of storm water retention area is the most affordable measure for basin-wide storm water management under the socio-economic frame of the target year 2010. Structural measures for storm water drainage should therefore be proposed premising the conservation of storm water retention areas.

The additional sea outfalls are regarded as longer-term options under a planning frame comprising basin-wide urbanization or a great reduction of storm water retention area in the basin.

8.3.2 Comparative Study on Alternative Drainage Plans

(1) Component Schemes

The conceivable structural measures for the Weras Ganga and tributaries are grouped into the component schemes broadly demarcated by sub-basin as follows:

Component Schemes of Storm Water Drainage Plan

Component Scheme	Measures
1) Weras Ganga	• Weras Ganga Dredging: length 5,500 m • Flood Protection Wall on Right Bank: length: 2,300 m • Weras Ganga Swamp Retention Area: 65 ha • Maha Ela Marsh and Lowland Retention Area: 132 ha
2) Nugegoda-Rattanapitiya Scheme	• Channel Improvement of Nugegoda-Ela: length 1,580 m • Channel Improvement of Delkanda Ela: length 1,760 m

Component Scheme	Measures
	• Channel Improvement of Rattanapitiya Ela: length 2,130 m • Retention Areas: total extent 36 ha
3) Bolgoda Canal Scheme	• Channel Improvement of Bolgoda Canal: length 2,400 m • Bellanwila-Attidiya Marsh Retention Area: 108 ha
4) Boralesgamuwa North Scheme	• Channel Improvement of Depawa Ela: length 3,090 m
5) Boralesgamuwa South Scheme	• Channel Improvement of Werahara Tributary: length 980 m
6) Maha Ela Scheme	• Channel Improvement of Maha Ela: length 2,700 m • Channel Improvement of Maha Ela Tributary: length 1,760 m
7) Ratmalana-Moratuwa Scheme	• Urban Drainage Improvement: 11,120 m • Kandawala Retention Pond: 3 ha • Telewala Retention Pond: 10 ha • Channel Improvement of Katubedda Tributary: length 1,250 m • Retention Area: 23 ha

(2) Dredging Width of Weras Ganga

The Weras Ganga Scheme envisages alleviating direct flood damage in the densely urbanized lowland on the right bank as well as improving the principal drainage channels such as Bolgoda Canal and Rattanapitiya Ela connecting to the Weras Ganga by increasing its flow capacity.

For the dredging of the Weras Ganga, alternative dredging widths of 20, 40, and 60 m were examined. Hydraulic analyses were carried out for the respective dredging widths under the storm water drainage plan comprising all the component schemes and retention area described above. The results of water level projections are summarized below:

Water Level of Weras Ganga by Dredging Width

Dredging Width	Water Level (above MSL)		
	Elawella Road	Borupana Bridge	Confluence with Maha Ela
20 m	1.42	1.01	0.95
40 m	1.41	0.99	0.93
60 m	1.41	0.96	0.88

The alternatives of the storm water drainage plan with different dredging widths are evaluated in the economic evaluation. Benefit-cost ratio (B/C) and economic internal rate of return (EIRR) for each alternative are computed from economic cost and annual benefit from flood damage mitigation as well as land development cost and land enhancement benefit.

Comparison of Alternative Dredging Widths

Dredging Width	Project Cost (Million Rs)	Annual Benefit (Million Rs)	B/C	EIRR (%)
20 m	5,128	624	1.50	13.9
40 m	5,317	706	1.60	14.7
60 m	5,657	715	1.52	14.1

(3) Required Extent of Retention Area in Weras Ganga Basin

Of the proposed retention area of 372 ha, a required extent of retention area is analyzed by hydraulic simulation under the following assumptions:

1) The upstream retention areas of 36 ha in the Nugegoda-Rattanapitiya sub-basin should be kept, essentially, for the storm water drainage plan in the sub-basin.
2) The following locations of retention areas would be subject to loss, suggested by present situations of land filling and its influence to the marshes in the vicinity of future urbanized areas:
   - Marsh areas with small extent surrounded by highly urbanized area, such as Katubedda Tributary and Thumbowila Tributary, total extent of 31 ha
   - Bellanwila-Attidiya Marsh, north, east and southeast, 40 ha
   - Maha Ela Marh and Lowland upstream of Colombo-Piliyandala Road, 26 ha

Influence by loss of retention area is evaluated with a relationship between an extent of retention area and average of water level in the Weras Ganga. When the average water level 'without' the project is regarded as an allowable water level, the required extent resulting from the hydraulic simulation analysis is shown by each retention area as follows:

Retention Areas for Storm Water Drainage Plan in Weras Ganga Basin

Retention Area	Proposed Retention Area (ha)	Required Extent of Retention Area (ha)
Upper Nugegoda Ela	7	7
Lower Nugegoda Ela	20	20
Delkanda Ela	9	9
Bellanwila-Attidiya Marsh	108	88
Weras Ganga Swamp and Surrounding Marsh	65	65
Maha Ela Marsh and Lowland	132	106
Katubedda Triburary	23	0
Thumbowila Tributary	8	0
Total	372	295

A total extent of 372 ha of storm water retention area is initially proposed according to the future land use projections. The result of the analysis for the required extent of storm water retention area shows that a total of 295 ha should be ensured for minimizing the influence of the loss of the initially proposed retention area. If the balance of 77 ha is assumed to be free from inundation, the economic evaluation of the storm water drainage plan for the Weras Ganga basin results in the following.

Economic Evaluation for Proposed Storm Water Drainage Plan by Retention Area

Retention Area	B-C (million Rs.)	B/C	EIRR (%)
372 ha	1,853	1.60	14.7
295 ha	3,768	2.22	19.2

(2) Effect of Reduction of Lowlands

The assessment of effect by reduction of lowland in the entire Bolgoda basin is conducted to identify basin-wide impacts.

The lowland is defined by ground surface elevation around the downstream water system. The lowland is defined as the area lower than 1.5 m above MSL. By this definition, the extent of lowland becomes 4,739 ha.

Reduction of the lowland will cause an increase of runoff and water level in drainage channels and remaining areas. In the assessment, the four cases of delimitation level were provided such as 1.5 m, 1.0 m, 0.5 m and 0.0 m above MSL.

Extent of Lowland by Delimitation Level

(Unit: ha)

Delimitation Level (above MSL)			
1.5 m	1.0 m	0.5 m	0.0 m
4,739	3,710	2,227	950

It was assumed that land reclamation would be conducted above the delimitation level with a sufficient height to cope with the inundation level increasing due to the reduction of the lowlands. The results of water level rising at the Weras Ganga, North Bolgoda Lake, and South Bolgoda Lake are shown in Figure 8.3.5 and summarized below:

Effect of Reduction of Lowlands (50-year Return Period)

Delimitation Level (m)	Lowland (ha)	Water Level (above MSL)		
		Weras Ganga	North Bolgoda Lake	South Bolgoda Lake
1.5	4,739	1.43	0.69	0.78
1.0	3,710	1.51	0.70	0.79
0.5	2,227	1.73	0.74	0.83
0.0	950	1.89	0.78	0.92

As mentioned above, the ground surface elevation of reclaimed land is assumed to be sufficient to protect against flood water level in the remaining lowlands. On the other hand, the water level rising in the remaining lowlands affects the water level of the incoming channels. Difficulty of drainage would arise in the incoming channels affected by backwater and then flooding occurs in the upper reaches.

8.3.3 Study on Optional Planning Scales (25-year and 10-year Return Periods)

The type of alternative combinations is the same as described in the sub-section 8.3.1 above. The comparative study for different dredging width of the Weras Ganga for each planning scale is summarized below:

Comparison of Alternative Dredging Width

25-year Return Period

Dredging Width	Project Cost (million Rs)	Annual Benefit (million Rs.)	B/C	EIRR (%)
20 m	4,911	931	2.21	19.0
40 m	5,100	1,012	2.29	19.6
60 m	5,439	1,021	2.16	18.8

10-year Return Period

Dredging Width	Project Cost (million Rs)	Annual Benefit (million Rs.)	B/C	EIRR (%)
20 m	4,909	878	2.09	18.2
40 m	5,099	955	2.17	18.8
60 m	5,438	963	2.04	18.0

The effect of the retention area is also carried out on the conceivable plans for the planning scale of 25-year and 10-year return periods. The effect of raising the water level in the retention areas is examined in the same manner as described in sub-section 8.3.2. The required extent of retention area for each planning scale is obtained from the results of simulation analyses tabulated below:

Water Level of Weras Ganga for Optional Planning Scales

Return Period	Water Level (above MSL)		
	Elawella Road	Borupana Bridge	Confluence of Maha Ela
25-year	1.33	0.92	0.85
10-year	1.20	0.82	0.77

Note: dredging width = 40m

Economic Evaluation for Optional Planning Scale

Return Period	Retention Area (ha)	Project Cost (million Rs.)	Annual Benefit (million Rs.)	B/C	EIRR (%)
25-year	295	5,100	1,012	2.29	19.6
10-year	295	5,099	955	2.17	18.8

8.4 Proposed Storm Water Drainage Plan

The study proposes a planning scale of a 50-year return period for the storm water drainage plan in the Weras Ganga sub-basin. The Weras Ganga is one of the main streams constituting the water system in the Bolgoda Basin. Such a main stream should be improved with a high planning scale as mentioned in section 4.1. On the other hand, the proposed plan includes the improvement of the tributaries with a planning scale of a 10-year return period.

The reduction of the lowlands would have only a small effect on raising the water level in the lakes because there will be no great change in the land use in the Bolgoda basin to the year 2010 and the storm water runoff from the entire basin will not increase significantly. However, a large reduction of the lowlands is not acceptable without proper offsetting measures for storm water drainage. Conservation of the lowlands needs be undertaken in compliance with future land use for a longer time-scale.

On the other hand, the loss of lowland, including the proposed retention areas in the Weras Ganga basin, would cause water level rising of some 0.5 m in the Weras Ganga. The lowlands in the Weras Ganga basin should be conserved as a part of the storm water drainage plan.

As a conclusion of the considerations above, the following storm water drainage plan is proposed for the Bolgoda basin:

(1) Storm Water Drainage Plan for the Weras Ganga basin:

1) Weras Ganga Scheme

- Weras Ganga Dredging: length = 5,500 m, channel bed width =19 m to 40 m
- Flood Protection Wall on Right Bank: length = 2,300 m
- Weras Ganga Swamp Retention Area: 65 ha
- Maha Ela Marsh and Lowland Retention Area: 106 ha

2) Nugegoda-Rattanapitiya Scheme

- Channel Improvement of Nugegoda-Ela: length = 1,580 m, channel bed width = 5 m to 13 m
- Channel Improvement of Delkanda Ela: length = 1,760 m, channel bed width = 3 m to 13.5 m
- Channel Improvement of Rattanapitiya Ela: length = 2,130 m, channel bed width =19 m
- Retention Areas: total extent 36 ha

3) Bolgoda Canal Scheme

- Channel Improvement of Bolgoda Canal: length = 2,400 m, channel bed width =17 m to 19 m
- Bellanwila-Attidiya Marsh Retention Area: 88 ha

4) Boralesgamuwa North Scheme

- Channel Improvement of Depawa Ela: length = 3,090 m, channel bed width =6 m

5) Boralesgamuwa South Scheme

- Channel Improvement of Werahera Tributary: length = 980 m, channel bed width =15 m

6) Maha Ela Scheme

- Channel Improvement of Maha Ela: length = 2,700 m, channel bed width =32 m
- Channel Improvement of Maha Ela Tributary: length = 1,760 m, channel bed width =15 m

7) Ratmalana-Moratuwa Scheme

- Urban Drainage Improvement: 11,120 m
- Kandawala Retention Pond: 3 ha
- Telewala Retention Pond: 10 ha
- Channel Improvement of Katubedda Tributary: length 1,250 m, channel bed width = 8 m

(2) Conservation of Lowlands in Entire Bolgoda Basin (4,739 ha)

The general layout for the proposed storm water drainage plan is illustrated in Figures 8.4.1.

8.5 Study on Madiwela South Diversion

The Madiwela south diversion is one of the proposed component projects in the storm water drainage plan for the Greater Colombo basin. This scheme aims at reducing storm water runoff from the upstream catchment of the Greater Colombo basin to the downstream canal system. Storm water runoff is diverted to the Bolgoda basin bounded by the High Level Road and is discharged into the Weras Ganga through the Maha Ela. The estimated peak runoff from this diversion is 40

m^3/sec on the condition that the storm water runoff is retarded effectively by a proposed retention area upstream of Parliament Lake.

Salient features of the Madiwela South Diversion Scheme are shown in Figures 8.5.1 to 8.5.2. The length of the diversion channel is 8,600 m. The channel cross section is designed with a bed width of 32 m. Depth of the channel depends on existing ground level along the diversion route. The channel depth is relatively shallow for the stretches in the retention areas located in Parliament Lake upstream and Maha Ela downstream. On the other hand, the stretch around the border of the drainage areas is subject to deep excavation with a maximum depth of 10 m at the High Level Road. The bed gradient of the channel is designed at 1/4,600 for enabling the diversion. The highest water levels for a 50-year return period are estimated at 2.2 m above MSL at Parliament Lake upstream and 1.0 m above MSL at the downstream end of the Maha Ela.

With a combination of the proposed storm water drainage plan for the Weras Ganga basin and Madiwela South Diversion Scheme, water levels in the Weras Ganga are estimated for a 50-year rainstorm event under the future land use conditions as shown in Figure 8.5.3 and summarized below:

Influence of the Madiwela South Diversion Scheme

Location	Water Level above MSL, 50-year Return Period	
	Proposed Plan	Proposed Plan + Madiwela South Diversion Scheme
Bolgoda Canal at Elewalla Road	1.42	1.43
Weras Ganga at Borupana Bridge	1.00	1.09
Weras Ganga at Maha Ela Confluence	0.94	1.04
Weras Ganga at Kospalana Bridge	0.62	0.65

The increment in water level between the cases above is some +10 cm in the stretch from the Borupana Bridge to Maha Ela Confluence. This increment of water level is similar to that from the loss of the retention areas as discussed in the previous section and is not negligible. To prevent the Weras Ganga water level from rising due to the Madiwela South Diversion Scheme, some additional measures are required to further increase the flow capacity in the stretch downstream of the Maha Ela confluence. Such measures would comprise an enlargement of the opening width at the Kospalana Bridge in combination with an increase in the dredging width downstream of the Maha Ela confluence as shown below:

Comparison of Weras Ganga Water Level with Madiwela South Diversion Scheme

Location	Water Level above MSL, 50-year Return Period	
	Kospalana Opening 40 m Dredging Width 40 m	Kospalana Opening 80 m Dredging Width 80 m
Bolgoda Canal at Elewalla Road	1.43	1.42
Weras Ganga at Borupana Bridge	1.09	1.02
Weras Ganga at Maha Ela Confluence	1.04	0.96
Weras Ganga at Kospalana Bridge	0.65	0.61

The additional measures above are not a subject of the priority project. The Madiwela South Diversion Scheme is one of the long-term objectives of the storm water drainage plan in the Greater Colombo basin. Its realization will depend on the implementation of the storm water drainage plan in the Greater Colombo basin together with the required additional measures in the Weras Ganga basin.

Tables

Table 2.1.1 Major Drainage Canals Improvement under GCFC&EIP Phase-I

Name of Canal	Length (m)	Type of Work	Width (m)	Cross Section	Bank Protection
Northern System					
1. Kolonnawa Ela South	658	R	30	Trapezoidal	T
2. Kolonnawa Ela	1,367	R	20	Trapezoidal	T
3. Kolonnawa Ela North	1,571	R	20	Trapezoidal	T
4. Mahawatta Ela	1,775	R	10-12	Rectangular, Trapezoidal	G,T
5. Dematagoda	3,400	R	20	Rectangular	G,T, SHP
6. St. Sebastian South	1,918	R	10	Rectangular	G
7. St. Sebastian North	1,954	R	5-9	Rectangular, Trapezoidal	G, T
8. St. Sebastian East	1,252	R	3-7	Rectangular, Trapezoidal	G, T
9. Main Drain	1,698	R	6-8	Rectangular	C, G, SHP
10. Connection Main Drain & Bloemndhal Marsh	305	R	4	Trapezoidal	T
11. Connection Mahawatta Ela & Heen Ela	295	N	10	Rectangular	G
Southern System					
12. Kotte Ela North	1,603	R	30-40	Rectangular, Trapezoidal	T, G
13. Kotte Ela South	929	R	30	Trapezoidal	T
14. Kirillapone	2,708	R	30	Rectangular, Trapezoidal	SHP, G, T
15. Welawatta	1,886	R	25	Rectangular, Trapezoidal	SHP, G
16. Dehiwala	3,836	R	10	Rectangular	G
17. Bolgoda	1,977	R	3	Trapezoidal	T
18. Connection Kotte Ela North & Heen Ela	1,750	N	20	Rectangular, Trapezoidal	T, G
Western System					
19. Torrington South	775	R	5-7	Rectangular	C, G
20. Torrington North	889	R	7	Rectangular	G, SHP
21. Torrington	840	R	9-12	Rectangular, Trapezoidal	T, G
22. Heen Ela	2,783	R	15-20	Rectangular, Trapezoidal	T, G
Eastern System					
23. Madiwela East Diversion	7,520	N	8-25	Trapezoidal	T, WM
24. Link Canal	306	N	5	Rectangular, Trapezoidal	T
Total Length	43,995				

Note: Type of Work: R (Rehabilitation), N (New Construction)
Bank Protection: T (Turfing), G (Gabion), SHP (Steel Sheet Piling), C (Concrete Lining), WM (Wet Masonry)

Table 2.1.2 Principal Features of GCFC&EIP Phase-II Schemes (1/2)

Item	Description	
1. Unity Place Scheme		
Drainage Area of Scheme	1.09 km^2	
Max. Discharge at Downstream End	8.5 m^3/sec	
Total Length of Drainage	835 m	
Major Drainage Facilities		
(1) Tunnel		
Diameter	2400 mm	
Total Length	835 m	
(2) Access Shaft / Manhole	5 nos.	
(3) Sea Outfall Structure	Reinforced Concrete	
2. Torrington West Scheme		
Drainage Area of Scheme	1.72 km^2	
Max. Discharge at Downstream End	12.7 m^3/sec	
Total Length of Drainage	2,149 m	
Major Drainage Facilities		
(1) Hume Pipe Culvert		
Size and Length	750 mm dia.	237 m
	1050 mm dia.	190 m
	1200 mm dia.	146 + 210 m
(2) Box Culvert		
Size and Length	1.20 m (W) x 1.00 m (H)	52 m
	1.50 m (W) x 1.35 m (H)	444 m
	2.00 m (W) x 1.75 m (H)	756 m
	4.00 m (W) x 2.20 m (H)	114 m
(3) Access Shaft / Manhole	39 nos.	
(4) Outfall to Torrington South Canal	Gabions	
3. St. Sebastian-2 Scheme		
Drainage Area of Scheme	0.38 km^2	
Max. Discharge at Downstream End	3.2 m^3/sec	
Total Length of Drainage	1,464 m	
Major Facilities		
(1) Drain with Cover Slabs		
Size and Length	0.40 m (W) x 1.00 m (H)	296 m
	1.00 m (W) x 1.00 m (H)	280 +195 m
(2) Box Culvert		
Size and Length	0.90 m (W) x 0.75 m (H)	195 m
	1.50 m (W) x 1.35 m (H)	444 m
(3) Access Shaft / Manhole	13 nos.	
(4) Outfall to St. Sebastian South Canal	Gabions	

Table 2.1.2 Principal Features of GCFC&EIP Phase-II Schemes (2/2)

Item	Description	
4. Dematagoda Scheme		
Drainage Area of Scheme	0.25 km^2	
Max. Discharge at Downstream End	3.2 m^3/sec	
Total Length of Drainage	533 m	
Major Facilities		
(1) Box Culvert		
Size and Length	1.50 m (W) x 1.35 m (H)	533 m
(2) Access Shaft / Manhole	7 nos.	
(3) Outfall to Dematagoda Ela	Gabions	
5. Serpentine Scheme		
Drainage Area of Scheme	2.16 km^2	
Max. Discharge at Downstream End	14.2 m^3/sec	
Total Length of Drainage	1,877 m	
Major Facilities		
(1) Open Drain (Serpentine Canal)		
Size and Length	Concrete Flume	
	4.00 m (W) x 1.60 m (H)	359 m
	Improvement of Existing Drain	
	4.50 m (W) x 1.60 m (H)	536 m
	5.50 m (W) x 1.80 m (H)	185 m
	Gabion & Steel Sheet Pile	
	7.00 m (W) x 2.30 m (H)	354 m
(2) Box Culvert		
(Serpentine Canal Diversion Culvert)		
Size and Length	2.00 m (W) x 1.75 m (H)	352 m
(3) Outfall to Dematagoda Ela	Gabion & Steel Sheet Pile	
	3.00 m (W) x 3.00 m (H)	91 m

Table 2.2.1 Principal Features of GCFC&EIP Phase-III Schemes

Item	Description
1. Kawdana Scheme	
Drainage Area of Scheme	
(1) Kawdana A	0.960 km^2
(2) Kawdana B	0.427 km^2
Kawdana C	0.022 km^2
Max. Discharge at Downstream End	
(1) Kawdana A – Drainage K1	8.45 m^3/sec
(2) Kawdana B – Drainage K2	1.66 m^3/sec
(3) Kawdana B – Drainage K4	3.61 m^3/sec
(4) Kawdana C – Drainage K3	0.38 m^3/sec
Major Drainage Facilities	
(1) Open Channel Improvement	Masonry Wall Protection: 421 m
(2) Concrete Flume	1,512 m
(3) Pipe Drains	249 m, 750 – 1,500 mm dia.
(4) Side Drains	5,538 m
(5) Manholes / Access Shafts	8 nos.
(6) Improvement of Road Culverts	4 nos.
(7) Improvement of Bridges	3 nos.
(8) Penetration Macadam	19,973 m^2
(9) Laterite Filling	40,000 m^2
2. Attidiya Scheme	
Drainage Area of Scheme	
(1) Attidiya A	1.244 km^2
(2) Attidiya B	0.061 km^2
(3) Attidiya C	0.161 km^2
(4) Attidiya D	0.502 km^2
(5) Attidiya E	0.057 km^2
(6) Attidiya F	0.067 km^2
(7) Attidiya G	0.616 km^2
Max. Discharge at Downstream End	
(1) Attidiya A – Drainage A1	11.85 m^3/sec
(2) Attidiya B – Drainage A2	0.79 m^3/sec
(3) Attidiya C – Drainage A3	2.21 m^3/sec
(4) Attidiya D – Drainage A4	5.92 m^3/sec
(5) Attidiya E – Drainage A5	0.76 m^3/sec
(6) Attidiya F – Drainage A6	10.83 m^3/sec
(7) Attidiya G – Drainage A7	5.99 m^3/sec
Major Drainage Facilities	
(1) Open Channel Improvement	Steel Sheet Pile Protection: 906 m Wet Masonry: 470 m
(2) Concrete Flume and Trough	2,331 m
(3) Pipe Drains	2,354 m , 750–1,500 mm dia.
(4) Side Drains	18,820 m
(5) Box Culverts	1,578 m 1,500 mm (H) x 1,500 mm (W) –1,750 mm (H) x 3,750 mm (W)
(6) Manholes / Access Shafts	84 nos.
(7) Improvement of Road Culverts	2 nos.
(8) Improvement of Road Bridges	8 nos.
(9) Improvement of Foot Bridges	5 nos.
(10) Asphalting	3,698 m^2
(11) Penetration Macadam	79,909 m^2
(12) Laterite Filling	33,960 m^2

Table 2.2.2 Principal Features of Lunawa Lake Environment Improvement and Community Development Project (1/2)

Component-I: Storm Water Drainage Improvement Component

Item	Quantity & Description
(1) Storm Water Drainage Improvement	
1) Main/Secondary/Tertiary Drains Improvement	
a) Length of Drainage Improvement	
• Main Canals	6.7 km
• Secondary Canals	4.2 km
• Tertiary Drains	76.4 km
Total	87.3 km
b) Major Work Item	
• Earth canal	4.4 km (Main/Secondary)
• Concrete channel	5.4 km (Main/Secondary)
• Box culverts	0.5 km (Secondary[diversion])
• Steel sheet pile	0.6 km (Main/Secondary)
• Flume with cover slab	15.7 km (Tertiary)
• Side drains	48.7 km (Tertiary)
• Contingency	12.0 km (Tertiary)
• Reconstruction of bridges	11 bridges
• Rehabilitation of existing diversion	
• Estimated dredging volume	L.S. (about 70,000m^3)
2) Lunawa Lake Dredging	
• Location	Outlets of Lunawa Ela (N1) and outlets of two main canals flowing into north lake (S1 &S2)
• Estimated dredging volume	About 35,000 m^3
• Disposal area	Filling at southern most corner of the Lake
• Work road	L = About 700m
3) Sea Outfall Improvement	
• Sand bar breaching:	Maintain top of sand bars at about +1m (above MSL) on constant basis and excavate a flood release channel when heavy rains occur
• Provision of excavator	One unit of backhoe, long-arm type with dozer blade
4) Non-structural Measures	Dissemination of remaining flooding risks by hazard map etc.
(1) Construction of Resettlement Sites	
1) No. of Relocates	
• Households along downstream of Lunawa Ela and around Lake (USIP Survey)	384 households
• Extra assumed for other parts of main canals and secondary canals	66 households (approximate estimate)
Total	450 households

Table 2.2.2 Principal Features of Lunawa Lake Environment Improvement and Community Development Project (2/2)

Item	Quantity & Description
2) Resettlement Sites • Resettlement site No.1 (Badu Watte) • Resettlement site No.2 (Dewata Mawatha) • Resettlement site No.3 (Father's Land) • Resettlement site No.4 (Mahajana Watte) Total	 2.0 acres for 90 houses 1.5 acres for 65 houses 1.5 acres for 65 houses 6.0 acres for 270 houses 11.0 acres for 470 houses
(3) Procurement of O/M Equipment	O/M equipments Survey equipments Vehicles
(4) Additional Field Survey and Investigations by SLLRDC	L.S.

Component-II: Community Development Component

Item	Quantity & Description
(1) Resettlement Works	 Survey House foundation Utility works
(2) Upgrading of Under-Served Settlements and Resettlement Sites 1) No. of families subject to Upgrading Program • Resettled communities: • On-site upgrading Total 2) Infrastructure Development • Drainage systems • Solid waste management • Wastewater disposal system • Sewage disposal system • Rehabilitation of internal roads 3) Procurement of equipments 4) Institutional building	 450 families 441 families in selected 11settlements 891 families Construction of micro drains Provisions of waste disposal bins, composting barrels Construction of connections Construction of connections Repair of damaged roads

Note: Quantity & descriptions above will be revised at detail design stage

Source: JBIC ODA Special Assistance for Project Formation (SAPROF) for Lunawa Lake Environment Improvement and Community Development Project, 2001

Table 5.3.1 Comparative Study of Alternative Combinations - Ja Ela Basin (Return Period 50-year) (1/3)

Cases for Alternative Combinations

Planning Scale (Return Period)	Case	Ja Ela Channel Improvement	Dandugam Oya Channel Improvement	Kotugoda Seeduwa Diversion Channel	Retention Area (ha)	Water Level			Project Cost (Million Rs)	Annual Benefit (Million Rs)	B/C	EIRR
						Ja Ela	Dandugam Oya	Retention Area				
50-year	J0				1733	1.65	1.58	3.51				
50-year	J1	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	-	1733	1.47	1.47	3.40	2,785	66	0.31	-
50-year	J2	L = 7.0 km B = 50 m	L = 10.0 km B = 70 m (3.5-7.5 km) B = 60 m (7.5-13.4 km)	-	1733	1.35	1.46	3.35	3,163	82	0.34	3.0%
50-year	J3	L = 7.0 km B = 55 m	L = 10.0 km B = 75 m (3.5-7.5 km) B = 65 m (7.5-13.4 km)	-	1733	1.30	1.45	3.31	3,729	93	0.33	2.8%
50-year	J4	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	L = 3.1 km B = 20 m	1733	1.49	1.55	3.19	3,087	195	0.84	8.7%
50-year	J5	L = 7.0 km B = 60 m	L = 10.0 km B = 80 m (3.5-7.5 km) B = 70 m (7.5-13.4 km)	-	1733	1.26	1.44	3.28	3,919	140	0.47	4.9%
50-year	J6	L = 7.0 km B = 80 m	L = 10.0 km B = 100 m (3.5-7.5 km) B = 90 m (7.5-13.4 km)	-	1733	1.17	1.40	3.21	4,687	183	0.52	5.4%

Table 5.3.1 Comparative Study of Alternative Combinations - Ja Ela Basin (Return Period 50-year) (2/3)

Cases for Effect by Reduction of Retention Area

Planning Scale (Return Period)	Case	Ja Ela Channel Improvement	Dandugam Oya Channel Improvement	Kotugoda Seeduwa Diversion Channel	Retention Area (ha)	Water Level: Ja Ela	Water Level: Dandugam Oya	Water Level: Retention Area
50-year	J0				1733	1.65	1.58	3.51
50-year	J0-a				1324	1.69	1.65	3.61
50-year	J0-b				948	1.76	1.73	3.70
50-year	J0-c				618	1.82	1.84	3.79
50-year	J1	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	-	1733	1.47	1.47	3.40
50-year	J1-a	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	-	1324	1.51	1.53	3.49
50-year	J1-b	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	-	948	1.57	1.61	3.57
50-year	J1-c	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	-	618	1.62	1.70	3.65
50-year	J2	L = 7.0 km B = 50 m	L = 10.0 km B = 70 m (3.5-7.5 km) B = 60 m (7.5-13.4 km)	-	1733	1.35	1.46	3.35
50-year	J2-a	L = 7.0 km B = 50 m	L = 10.0 km B = 70 m (3.5-7.5 km) B = 60 m (7.5-13.4 km)	-	1324	1.39	1.52	3.44
50-year	J2-b	L = 7.0 km B = 50 m	L = 10.0 km B = 70 m (3.5-7.5 km) B = 60 m (7.5-13.4 km)	-	948	1.44	1.59	3.52
50-year	J2-c	L = 7.0 km B = 50 m	L = 10.0 km B = 70 m (3.5-7.5 km) B = 60 m (7.5-13.4 km)	-	618	1.49	1.68	3.59
50-year	J3	L = 7.0 km B = 55 m	L = 10.0 km B = 75 m (3.5-7.5 km) B = 65 m (7.5-13.4 km)	-	1733	1.30	1.45	3.31
50-year	J3-a	L = 7.0 km B = 55 m	L = 10.0 km B = 75 m (3.5-7.5 km) B = 65 m (7.5-13.4 km)	-	1324	1.34	1.50	3.40
50-year	J3-b	L = 7.0 km B = 55 m	L = 10.0 km B = 75 m (3.5-7.5 km) B = 65 m (7.5-13.4 km)	-	948	1.38	1.58	3.47
50-year	J3-c	L = 7.0 km B = 55 m	L = 10.0 km B = 75 m (3.5-7.5 km) B = 65 m (7.5-13.4 km)	-	618	1.43	1.66	3.53
50-year	J4	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	L = 3.1 km B = 20 m	1733	1.49	1.55	3.19
50-year	J4-a	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	L = 3.1 km B = 20 m	1324	1.52	1.60	3.25
50-year	J4-b	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	L = 3.1 km B = 20 m	948	1.58	1.66	3.31
50-year	J4-c	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	L = 3.1 km B = 20 m	618	1.62	1.73	3.36
50-year	J5	L = 7.0 km B = 60 m	L = 10.0 km B = 80 m (3.5-7.5 km) B = 70 m (7.5-13.4 km)	-	1733	1.26	1.44	3.28
50-year	J5-a	L = 7.0 km B = 60 m	L = 10.0 km B = 80 m (3.5-7.5 km) B = 70 m (7.5-13.4 km)	-	1324	1.29	1.49	3.36
50-year	J5-b	L = 7.0 km B = 60 m	L = 10.0 km B = 80 m (3.5-7.5 km) B = 70 m (7.5-13.4 km)	-	948	1.33	1.58	3.46
50-year	J5-c	L = 7.0 km B = 60 m	L = 10.0 km B = 80 m (3.5-7.5 km) B = 70 m (7.5-13.4 km)	-	618	1.38	1.64	3.49
50-year	J6	L = 7.0 km B = 80 m	L = 10.0 km B = 100 m (3.5-7.5 km) B = 90 m (7.5-13.4 km)	-	1733	1.17	1.40	3.21
50-year	J6-a	L = 7.0 km B = 80 m	L = 10.0 km B = 100 m (3.5-7.5 km) B = 90 m (7.5-13.4 km)	-	1324	1.19	1.46	3.29
50-year	J6-b	L = 7.0 km B = 80 m	L = 10.0 km B = 100 m (3.5-7.5 km) B = 90 m (7.5-13.4 km)	-	948	1.23	1.52	3.35
50-year	J6-c	L = 7.0 km B = 80 m	L = 10.0 km B = 100 m (3.5-7.5 km) B = 90 m (7.5-13.4 km)	-	618	1.28	1.60	3.40

Table 5.3.1 Comparative Study of Alternative Combinations - Ja Ela Basin (Return Period 50-year) (3/3)

Cases without Retention Effect in Upper Reaches

Planning Scale (Return Period)	Case	Ja Ela Channel Improvement	Dandugam Oya Channel Improvement	Kotugoda Seeduwa Diversion Channel	Retention Area (ha)	Water Level		
						Ja Ela	Dandugam Oya	Retention Area
50-year	J1-U	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	-	1357	1.73	1.86	3.85
50-year	J2-U	L = 7.0 km B = 50 m	L = 10.0 km B = 70 m (3.5-7.5 km) B = 60 m (7.5-13.4 km)	-	1357	1.71	1.84	3.76
50-year	J3-U	L = 7.0 km B = 55 m	L = 10.0 km B = 75 m (3.5-7.5 km) B = 65 m (7.5-13.4 km)	-	1357	1.49	1.82	3.70
50-year	J4-U	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	L = 3.1 km B = 20 m	1357	1.76	1.98	3.56
50-year	J5-U	L = 7.0 km B = 60 m	L = 10.0 km B = 80 m (3.5-7.5 km) B = 70 m (7.5-13.4 km)	-	1357	1.42	1.81	3.66
50-year	J6-U	L = 7.0 km B = 80 m	L = 10.0 km B = 100 m (3.5-7.5 km) B = 90 m (7.5-13.4 km)	-	1357	1.30	1.77	3.55

Table 5.3.2 Comparative Study of Alternative Combinations - Ja Ela Basin (Return Period 25-year) (1/3)

Cases for Alternative Combinations

Planning Scale (Return Period)	Case	Ja Ela Channel Improvement	Dandugam Oya Channel Improvement	Kotugoda Seeduwa Diversion Channel	Retention Area (ha)	Water Level			Project Cost (Million Rs)	Annual Benefit (Million Rs)	B/C	EIRR
						Ja Ela	Dandugam Oya	Retention Area				
25-year	J0				1733	1.47	1.43	3.24				
25-year	J1	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	-	1733	1.36	1.40	3.19	2,275	27	0.16	-
25-year	J2	L = 7.0 km B = 50 m	L = 10.0 km B = 70 m (3.5-7.5 km) B = 60 m (7.5-13.4 km)	-	1733	1.34	1.40	3.18	2,365	33	0.19	-
25-year	J3	L = 7.0 km B = 55 m	L = 10.0 km B = 75 m (3.5-7.5 km) B = 65 m (7.5-13.4 km)	-	1733	1.33	1.39	3.17	2,494	38	0.21	-
25-year	J4	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	L = 3.1 km B = 20 m	1733	1.37	1.48	2.98	2,462	156	0.88	9.0%
25-year	J5	L = 7.0 km B = 60 m	L = 10.0 km B = 80 m (3.5-7.5 km) B = 70 m (7.5-13.4 km)	-	1733	1.31	1.39	3.17	2,591	43	0.23	-
25-year	J6	L = 7.0 km B = 80 m	L = 10.0 km B = 100 m (3.5-7.5 km) B = 90 m (7.5-13.4 km)	-	1733	1.25	1.37	3.14	2,992	60	0.27	-

Table 5.3.2 Comparative Study of Alternative Combinations - Ja Ela Basin (Return Period 25-year) (2/3)

Cases for Effect by Reduction of Retention Area

Planning Scale (Return Period)	Case	Ja Ela Channel Improvement	Dandugam Oya Channel Improvement	Kotugoda Seeduwa Diversion Channel	Retention Area (ha)	Water Level		
						Ja Ela	Dandugam Oya	Retention Area
25-year	J0				1733	1.47	1.43	3.24
25-year	J0-a				1329	1.50	1.47	3.31
25-year	J0-b				953	1.56	1.54	3.39
25-year	J0-c				618	1.63	1.64	3.48
25-year	J1	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	-	1733	1.36	1.40	3.19
25-year	J1-a	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	-	1329	1.38	1.44	3.26
25-year	J1-b	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	-	953	1.43	1.51	3.33
25-year	J1-c	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	-	618	1.48	1.59	3.41
25-year	J2	L = 7.0 km B = 50 m	L = 10.0 km B = 70 m (3.5-7.5 km) B = 60 m (7.5-13.4 km)	-	1733	1.34	1.40	3.18
25-year	J2-a	L = 7.0 km B = 50 m	L = 10.0 km B = 70 m (3.5-7.5 km) B = 60 m (7.5-13.4 km)	-	1329	1.36	1.44	3.26
25-year	J2-b	L = 7.0 km B = 50 m	L = 10.0 km B = 70 m (3.5-7.5 km) B = 60 m (7.5-13.4 km)	-	953	1.41	1.50	3.32
25-year	J2-c	L = 7.0 km B = 50 m	L = 10.0 km B = 70 m (3.5-7.5 km) B = 60 m (7.5-13.4 km)	-	618	1.46	1.58	3.39
25-year	J3	L = 7.0 km B = 55 m	L = 10.0 km B = 75 m (3.5-7.5 km) B = 65 m (7.5-13.4 km)	-	1733	1.33	1.39	3.17
25-year	J3-a	L = 7.0 km B = 55 m	L = 10.0 km B = 75 m (3.5-7.5 km) B = 65 m (7.5-13.4 km)	-	1329	1.35	1.43	3.24
25-year	J3-b	L = 7.0 km B = 55 m	L = 10.0 km B = 75 m (3.5-7.5 km) B = 65 m (7.5-13.4 km)	-	953	1.39	1.49	3.31
25-year	J3-c	L = 7.0 km B = 55 m	L = 10.0 km B = 75 m (3.5-7.5 km) B = 65 m (7.5-13.4 km)	-	618	1.44	1.58	3.38
25-year	J4	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	L = 3.1 km B = 20 m	1733	1.37	1.48	2.98
25-year	J4-a	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	L = 3.1 km B = 20 m	1329	1.39	1.51	3.03
25-year	J4-b	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	L = 3.1 km B = 20 m	953	1.44	1.56	3.08
25-year	J4-c	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	L = 3.1 km B = 20 m	618	1.48	1.62	3.13
25-year	J5	L = 7.0 km B = 60 m	L = 10.0 km B = 80 m (3.5-7.5 km) B = 70 m (7.5-13.4 km)	-	1733	1.31	1.39	3.17
25-year	J5-a	L = 7.0 km B = 60 m	L = 10.0 km B = 80 m (3.5-7.5 km) B = 70 m (7.5-13.4 km)	-	1329	1.33	1.43	3.23
25-year	J5-b	L = 7.0 km B = 60 m	L = 10.0 km B = 80 m (3.5-7.5 km) B = 70 m (7.5-13.4 km)	-	953	1.38	1.49	3.30
25-year	J5-c	L = 7.0 km B = 60 m	L = 10.0 km B = 80 m (3.5-7.5 km) B = 70 m (7.5-13.4 km)	-	618	1.42	1.57	3.37
25-year	J6	L = 7.0 km B = 80 m	L = 10.0 km B = 100 m (3.5-7.5 km) B = 90 m (7.5-13.4 km)	-	1733	1.25	1.37	3.14
25-year	J6-a	L = 7.0 km B = 80 m	L = 10.0 km B = 100 m (3.5-7.5 km) B = 90 m (7.5-13.4 km)	-	1329	1.27	1.41	3.20
25-year	J6-b	L = 7.0 km B = 80 m	L = 10.0 km B = 100 m (3.5-7.5 km) B = 90 m (7.5-13.4 km)	-	953	1.31	1.46	3.27
25-year	J6-c	L = 7.0 km B = 80 m	L = 10.0 km B = 100 m (3.5-7.5 km) B = 90 m (7.5-13.4 km)	-	618	1.36	1.54	3.33

Table 5.3.2 Comparative Study of Alternative Combinations - Ja Ela Basin (Return Period 25-year) (3/3)

Cases without Retention Effect in Upper Reaches

Planning Scale (Return Period)	Case	Ja Ela Channel Improvement	Dandugam Oya Channel Improvement	Kotugoda Seeduwa Diversion Channel	Retention Area (ha)	Water Level		
						Ja Ela	Dandugam Oya	Retention Area
25-year	J1-U	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	-	1357	1.55	1.68	3.45
25-year	J2-U	L = 7.0 km B = 50 m	L = 10.0 km B = 70 m (3.5-7.5 km) B = 60 m (7.5-13.4 km)	-	1357	1.52	1.68	3.43
25-year	J3-U	L = 7.0 km B = 55 m	L = 10.0 km B = 75 m (3.5-7.5 km) B = 65 m (7.5-13.4 km)	-	1357	1.50	1.67	3.41
25-year	J4-U	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	L = 3.1 km B = 20 m	1357	1.56	1.79	3.18
25-year	J5-U	L = 7.0 km B = 60 m	L = 10.0 km B = 80 m (3.5-7.5 km) B = 70 m (7.5-13.4 km)	-	1357	1.48	1.66	3.40
25-year	J6-U	L = 7.0 km B = 80 m	L = 10.0 km B = 100 m (3.5-7.5 km) B = 90 m (7.5-13.4 km)	-	1357	1.40	1.63	3.35

Table 5.3.3 Comparative Study of Alternative Combinations - Ja Ela Basin (Return Period 10-year) (1/3)

Cases for Alternative Combinations

Planning Scale (Return Period)	Case	Ja Ela Channel Improvement	Dandugam Oya Channel Improvement	Kotugoda Seeduwa Diversion Channel	Retention Area (ha)	Water Level			Project Cost (Million Rs)	Annual Benefit (Million Rs)	B/C	EIRR
						Ja Ela	Dandugam Oya	Retention Area				
10-year	J0				1733	1.25	1.22	2.83				
10-year	J1	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	-	1733	1.17	1.20	2.80	2,170	18	0.11	-
10-year	J2	L = 7.0 km B = 50 m	L = 10.0 km B = 70 m (3.5-7.5 km) B = 60 m (7.5-13.4 km)	-	1733	1.15	1.20	2.79	2,261	22	0.13	-
10-year	J3	L = 7.0 km B = 55 m	L = 10.0 km B = 75 m (3.5-7.5 km) B = 65 m (7.5-13.4 km)	-	1733	1.14	1.19	2.79	2,391	26	0.15	-
10-year	J4	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	L = 3.1 km B = 20 m	1733	1.18	1.25	2.61	2,345	137	0.82	9.1%
10-year	J5	L = 7.0 km B = 60 m	L = 10.0 km B = 80 m (3.5-7.5 km) B = 70 m (7.5-13.4 km)	-	1733	1.13	1.19	2.78	2,483	29	0.16	-
10-year	J6	L = 7.0 km B = 80 m	L = 10.0 km B = 100 m (3.5-7.5 km) B = 90 m (7.5-13.4 km)	-	1733	1.08	1.17	2.76	2,888	41	0.20	-

Table 5.3.3 Comparative Study of Alternative Combinations - Ja Ela Basin (Return Period 10-year) (2/3)

Cases for Effect by Reduction of Retention Area

Planning Scale (Return Period)	Case	Ja Ela Channel Improvement	Dandugam Oya Channel Improvement	Kotugoda Seeduwa Diversion Channel	Retention Area (ha)	Water Level		
						Ja Ela	Dandugam Oya	Retention Area
10-year	J0				1733	1.25	1.22	2.83
10-year	J0-a				1329	1.26	1.24	2.87
10-year	J0-b				953	1.29	1.28	2.94
10-year	J0-c				618	1.34	1.37	3.02
10-year	J1	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	-	1733	1.17	1.20	2.80
10-year	J1-a	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	-	1329	1.17	1.21	2.83
10-year	J1-b	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	-	953	1.20	1.26	2.90
10-year	J1-c	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	-	618	1.24	1.34	2.97
10-year	J2	L = 7.0 km B = 50 m	L = 10.0 km B = 70 m (3.5-7.5 km) B = 60 m (7.5-13.4 km)	-	1733	1.15	1.20	2.79
10-year	J2-a	L = 7.0 km B = 50 m	L = 10.0 km B = 70 m (3.5-7.5 km) B = 60 m (7.5-13.4 km)	-	1329	1.16	1.21	2.83
10-year	J2-b	L = 7.0 km B = 50 m	L = 10.0 km B = 70 m (3.5-7.5 km) B = 60 m (7.5-13.4 km)	-	953	1.19	1.25	2.89
10-year	J2-c	L = 7.0 km B = 50 m	L = 10.0 km B = 70 m (3.5-7.5 km) B = 60 m (7.5-13.4 km)	-	618	1.23	1.33	2.96
10-year	J3	L = 7.0 km B = 55 m	L = 10.0 km B = 75 m (3.5-7.5 km) B = 65 m (7.5-13.4 km)	-	1733	1.14	1.19	2.79
10-year	J3-a	L = 7.0 km B = 55 m	L = 10.0 km B = 75 m (3.5-7.5 km) B = 65 m (7.5-13.4 km)	-	1329	1.15	1.21	2.82
10-year	J3-b	L = 7.0 km B = 55 m	L = 10.0 km B = 75 m (3.5-7.5 km) B = 65 m (7.5-13.4 km)	-	953	1.18	1.25	2.88
10-year	J3-c	L = 7.0 km B = 55 m	L = 10.0 km B = 75 m (3.5-7.5 km) B = 65 m (7.5-13.4 km)	-	618	1.21	1.32	2.96
10-year	J4	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	L = 3.1 km B = 20 m	1733	1.18	1.25	2.61
10-year	J4-a	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	L = 3.1 km B = 20 m	1329	1.18	1.26	2.63
10-year	J4-b	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	L = 3.1 km B = 20 m	953	1.21	1.30	2.67
10-year	J4-c	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	L = 3.1 km B = 20 m	618	1.24	1.35	2.72
10-year	J5	L = 7.0 km B = 60 m	L = 10.0 km B = 80 m (3.5-7.5 km) B = 70 m (7.5-13.4 km)	-	1733	1.13	1.19	2.78
10-year	J5-a	L = 7.0 km B = 60 m	L = 10.0 km B = 80 m (3.5-7.5 km) B = 70 m (7.5-13.4 km)	-	1329	1.14	1.20	2.81
10-year	J5-b	L = 7.0 km B = 60 m	L = 10.0 km B = 80 m (3.5-7.5 km) B = 70 m (7.5-13.4 km)	-	953	1.17	1.24	2.88
10-year	J5-c	L = 7.0 km B = 60 m	L = 10.0 km B = 80 m (3.5-7.5 km) B = 70 m (7.5-13.4 km)	-	618	1.20	1.32	2.95
10-year	J6	L = 7.0 km B = 80 m	L = 10.0 km B = 100 m (3.5-7.5 km) B = 90 m (7.5-13.4 km)	-	1733	1.08	1.17	2.76
10-year	J6-a	L = 7.0 km B = 80 m	L = 10.0 km B = 100 m (3.5-7.5 km) B = 90 m (7.5-13.4 km)	-	1329	1.09	1.19	2.79
10-year	J6-b	L = 7.0 km B = 80 m	L = 10.0 km B = 100 m (3.5-7.5 km) B = 90 m (7.5-13.4 km)	-	953	1.11	1.22	2.85
10-year	J6-c	L = 7.0 km B = 80 m	L = 10.0 km B = 100 m (3.5-7.5 km) B = 90 m (7.5-13.4 km)	-	618	1.15	1.30	2.92

Table 5.3.3 Comparative Study of Alternative Combinations - Ja Ela Basin (Return Period 10-year) (3/3)

Cases without Retention Effect in Upper Reaches

Planning Scale (Return Period)	Case	Ja Ela Channel Improvement	Dandugam Oya Channel Improvement	Kotugoda Seeduwa Diversion Channel	Retention Area (ha)	Water Level		
						Ja Ela	Dandugam Oya	Retention Area
10-year	J1-U	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	-	1357	1.27	1.34	2.85
10-year	J2-U	L = 7.0 km B = 50 m	L = 10.0 km B = 70 m (3.5-7.5 km) B = 60 m (7.5-13.4 km)	-	1357	1.25	1.33	2.84
10-year	J3-U	L = 7.0 km B = 55 m	L = 10.0 km B = 75 m (3.5-7.5 km) B = 65 m (7.5-13.4 km)	-	1357	1.24	1.33	2.83
10-year	J4-U	L = 7.0 km B = 45 m	L = 10.0 km B = 65 m (3.5-7.5 km) B = 55 m (7.5-13.4 km)	L = 3.1 km B = 20 m	1357	1.28	1.41	2.63
10-year	J5-U	L = 7.0 km B = 60 m	L = 10.0 km B = 80 m (3.5-7.5 km) B = 70 m (7.5-13.4 km)	-	1357	1.22	1.32	2.82
10-year	J6-U	L = 7.0 km B = 80 m	L = 10.0 km B = 100 m (3.5-7.5 km) B = 90 m (7.5-13.4 km)	-	1357	1.16	1.30	2.78

Table 6.3.1 Comparative Study of Alternative Combinations - Kalu Oya Basin (Return Period 50-year) (1/2)

Cases for Alternative Combinations

Planning Scale (Return Period)	Case	Alternatives	Retention Area	Water Level		Project Cost	Annual Benefit	B/C	EIRR
				Negombo Road	Retention Area	(Million Rs)	(Million Rs)		
50-year	K0		523	1.83	1.98				
50-year	K1	Channel Improvement of Kalu Oya (B= 40 m, L= 5,000 m)	523	1.69	1.81	1,476	108	0.88	9.0%
50-year	K2	Channel Improvement of Kalu Oya (B= 45 m, L= 5,000 m)	523	1.65	1.76	1,658	134	0.98	9.8%
50-year	K3	Channel Improvement of Kalu Oya (B= 50 m, L= 5,000 m)	523	1.63	1.73	1,856	153	1.00	10.0%
50-year	K4	Wattala Pumping Station (Q= 10 m^3/sec)	523	1.82	1.97	2,276	6	0.03	-
50-year	K5	Wattala Pumping Station (Q= 20 m^3/sec)	523	1.80	1.95	3,792	23	0.07	-
50-year	K6	Wattala Pumping Station (Q= 30 m^3/sec)	523	1.67	1.85	4,484	83	0.22	-
50-year	K7	Diversion Channel to Muthurajawela Marsh (B= 30 m, L=1,200 m)	523	1.56	1.68	1,345	185	1.69	15.3%
50-year	K8	Improvement of Old Negombo Canal to Muthurajawela Marsh (B= 30 m, L= 4,500 m)	523	1.57	1.80	816	105	1.59	14.6%
50-year	K9	Improvement of Old Negombo Canal to Muthurajawela Marsh (B= 35 m, L= 4,500 m)	523	1.53	1.77	890	123	1.72	15.4%
50-year	K10	Improvement of Old Negombo Canal to Muthurajawela Marsh (B= 40 m, L= 4,500 m)	523	1.50	1.75	1,025	135	1.62	14.8%
50-year	K11	K1+K8	523	1.57	1.72	1,927	162	1.02	10.2%
50-year	K12	K2+K9	523	1.54	1.67	2,182	192	1.08	10.7%
50-year	K13	K3+K10	523	1.52	1.64	2,515	215	1.05	10.5%
50-year	K14	K1+K7+K8	523	1.50	1.59	2,906	254	1.09	10.8%
50-year	K15	K1+K6+K8	523	1.38	1.58	6,045	257	0.52	5.1%
50-year	K16	K1+K7	523	1.53	1.62	2,456	231	1.17	11.4%
50-year	K17	K1+K9	523	1.55	1.70	2,001	173	1.05	10.4%
50-year	K18	K1+K10	523	1.54	1.69	2,136	182	1.04	10.4%
50-year	K19	K3+K7+K10	523	1.44	1.52	3,495	307	1.12	11.0%
50-year	K20	K3+K6+K7+10	523	1.20	1.34	7,529	349	0.59	6.2%

Table 6.3.1 Comparative Study of Alternative Combinations - Kalu Oya Basin (Return Period 50-year) (2/2)

Cases for Effect by Reduction of Retention Area

Planning Scale (Return Period)	Case	Alternatives	Retention Area	Water Level	
				Negombo Road	Retention Area
50-year	K0		523	1.98	2.15
50-year	K0-a		446	1.88	2.05
50-year	K0-b		339	1.96	2.16
50-year	K0-c		220	2.21	2.42
50-year	K11		523	1.57	1.72
50-year	K11-a	K1+K8	446	1.60	1.77
50-year	K11-b	K1+K8	339	1.64	1.85
50-year	K11-c	K1+K8	220	1.84	2.07
50-year	K12		523	1.54	1.67
50-year	K12-a	K2+K9	446	1.56	1.72
50-year	K12-b	K2+K9	339	1.59	1.79
50-year	K12-c	K2+K9	220	1.76	1.99
50-year	K13		523	1.52	1.64
50-year	K13-a	K3+K10	446	1.53	1.68
50-year	K13-b	K3+K10	339	1.55	1.74
50-year	K13-c	K3+K10	220	1.70	1.92
50-year	K14		523	1.50	1.59
50-year	K14-a	K1+K7+K8	446	1.51	1.63
50-year	K14-b	K1+K7+K8	339	1.56	1.70
50-year	K14-c	K1+K7+K8	220	1.72	1.88
50-year	K15		523	1.38	1.58
50-year	K15-a	K1+K6+K8	446	1.44	1.65
50-year	K15-b	K1+K6+K8	339	1.59	1.80
50-year	K15-c	K1+K6+K8	220	1.83	2.06
50-year	K16		523	1.53	1.62
50-year	K16-a	K1+K7	446	1.55	1.66
50-year	K16-b	K1+K7	339	1.62	1.75
50-year	K16-c	K1+K7	220	1.79	1.94
50-year	K17	K1+K9	523	1.55	1.70
50-year	K17-a	K1+K9	446	1.57	1.75
50-year	K17-b	K1+K9	339	1.61	1.83
50-year	K17-c	K1+K9	220	1.80	2.04
50-year	K18	K1+K10	523	1.54	1.69
50-year	K18-a	K1+K10	446	1.56	1.73
50-year	K18-b	K1+K10	339	1.59	1.81
50-year	K18-c	K1+K10	220	1.77	2.02

Table 6.3.2 Comparative Study of Alternative Combinations - Kalu Oya Basin (Return Period 25-year) (1/2)

Cases for Alternative Combinations

Planning Scale (Return Period)	Case	Alternatives	Retention Area	Water Level		Project Cost	Annual Benefit	B/C	EIRR
				Negombo Road	Retention Area	(Million Rs)	(Million Rs)		(%)
25-year	K0		523	1.72	1.85				
25-year	K1	Channel Improvement of Kalu Oya (B= 40 m, L= 5,000 m`	523	1.62	1.71	1,396	86	0.78	8.0%
25-year	K2	Channel Improvement of Kalu Oya (B= 45 m, L= 5,000 m`	523	1.59	1.67	1,504	113	0.95	9.6%
25-year	K3	Channel Improvement of Kalu Oya (B= 50 m, L= 5,000 m`	523	1.57	1.65	1,612	131	1.05	10.4%
25-year	K4	Wattala Pumping Station (Q= 10 m^3/sec)	523	1.71	1.83	2,276	7	0.04	-
25-year	K5	Wattala Pumping Station (Q= 20 m^3/sec)	523	1.67	1.80	3,792	32	0.10	-
25-year	K6	Wattala Pumping Station (Q= 30 m^3/sec)	523	1.43	1.63	4,484	139	0.38	3.2%
25-year	K7	Diversion Channel to Muthurajawela Marsh (B= 30 m, L= 1,200 m`	523	1.50	1.58	1,306	184	1.87	16.1%
25-year	K8	Improvement of Old Negombo Canal to Muthurajawela Marsh (B= 30 m, L= 4,500 m	523	1.51	1.69	742	95	1.65	14.8%
25-year	K9	Improvement of Old Negombo Canal to Muthurajawela Marsh (B= 35 m, L= 4,500 m	523	1.48	1.66	772	113	1.92	16.5%
25-year	K10	Improvement of Old Negombo Canal to Muthurajawela Marsh (B= 40 m, L= 4,500 m	523	1.42	1.63	801	139	2.28	18.7%
25-year	K11	K1+K8	523	1.52	1.63	1,772	148	1.08	10.7%
25-year	K12	K2+K9	523	1.50	1.59	1,910	175	1.20	11.6%
25-year	K13	K3+K10	523	1.47	1.55	2,048	199	1.28	12.1%
25-year	K14	K1+K7+K8	523	1.47	1.52	2,712	219	1.05	10.4%
25-year	K15	K1+K6+K8	523	1.21	1.40	5,891	284	0.62	6.4%
25-year	K16	K1+K7	523	1.49	1.54	2,336	205	1.15	11.2%
25-year	K17	K1+K9	523	1.51	1.61	1,802	161	1.17	11.3%
25-year	K18	K1+K10	523	1.47	1.58	1,832	179	1.28	12.1%
25-year	K19	K3+K7+K10	523	1.37	1.44	2,988	266	1.17	11.3%

Table 6.3.2 Comparative Study of Alternative Combinations
- Kalu Oya Basin (Return Period 25-year) (2/2)

Cases for Effect by Reduction of Retention Area

Planning Scale (Return Period)	Case	Alternatives	Retention Area	Water Level	
				Negombo Road	Retention Area
25-year	K0		523	1.72	1.85
25-year	K0-a		446	1.78	1.92
25-year	K0-b		339	1.87	2.03
25-year	K0-c		220	2.05	2.25
25-year	K11		523	1.52	1.63
25-year	K11	K1+K8	523	1.52	1.63
25-year	K11-a	K1+K8	446	1.54	1.67
25-year	K11-b	K1+K8	339	1.57	1.74
25-year	K11-c	K1+K8	220	1.72	1.92
25-year	K12		523	1.50	1.59
25-year	K12-a	K2+K9	446	1.52	1.63
25-year	K12-b	K2+K9	339	1.53	1.69
25-year	K12-c	K2+K9	220	1.65	1.85
25-year	K13		523	1.47	1.55
25-year	K13-a	K3+K10	446	1.49	1.59
25-year	K13-b	K3+K10	339	1.51	1.65
25-year	K13-c	K3+K10	220	1.60	1.80
25-year	K14		523	1.47	1.52
25-year	K14-a	K1+K7+K8	446	1.48	1.55
25-year	K14-b	K1+K7+K8	339	1.49	1.60
25-year	K14-c	K1+K7+K8	220	1.62	1.76
25-year	K15		523	1.21	1.40
25-year	K15-a	K1+K6+K8	446	1.26	1.46
25-year	K15-b	K1+K6+K8	339	1.39	1.59
25-year	K15-c	K1+K6+K8	220	1.68	1.88
25-year	K16	K1+K7	523	1.49	1.54
25-year	K16-a	K1+K7	446	1.51	1.58
25-year	K16-b	K1+K7	339	1.54	1.64
25-year	K16-c	K1+K7	220	1.68	1.81
25-year	K17	K1+K9	523	1.51	1.61
25-year	K17-a	K1+K9	446	1.53	1.65
25-year	K17-b	K1+K9	339	1.55	1.72
25-year	K17-c	K1+K9	220	1.68	1.90

Table 6.3.3 Comparative Study of Alternative Combinations - Kalu Oya Basin (Return Period 10-year) (1/2)

Cases for Alternative Combinations

Planning Scale (Return Period)	Case	Alternatives	Retention Area	Water Level		Project Cost	Annual Benefit	B/C	EIRR
				Negombo Road	Retention Area	(Million Rs)	(Million Rs)		
10-year	K0-10		523	1.59	1.68				
10-year	K1	Channel Improvement of Kalu Oya (B= 40 m, L= 5,050 m	523	1.54	1.59	1,384	71.58	0.75	8.0%
10-year	K2	Channel Improvement of Kalu Oya (B= 45 m, L= 5,050 m	523	1.52	1.57	1,493	88.61	0.89	9.2%
10-year	K3	Channel Improvement of Kalu Oya (B= 50 m, L= 5,050 m	523	1.51	1.56	1,601	100.03	0.91	9.3%
10-year	K4	Wattala Pumping Station (Q= 10 m^3/sec)	523	1.57	1.65	2,276	28.17	0.17	-
10-year	K5	Wattala Pumping Station (Q= 20 m^3/sec)	523	1.33	1.46	3,792	184.06	0.69	7.3%
10-year	K6	Wattala Pumping Station (Q= 30 m^3/sec)	523	1.14	1.34	4,484	298.01	0.96	9.7%
10-year	K7	Diversion Channel to Muthurajawela Marsh (B= 30 m, L= 1,200 m	523	1.42	1.46	1,300	185.74	2.12	17.1%
10-year	K8	Improvement of Old Negombo Canal to Muthurajawela Marsh (B= 30 m, L= 4,500 m	523	1.41	1.53	732	118.25	2.43	18.7%
10-year	K9	Improvement of Old Negombo Canal to Muthurajawela Marsh (B= 35 m, L= 4,500 m	523	1.32	1.46	762	176.02	3.51	23.9%
10-year	K10	Improvement of Old Negombo Canal to Muthurajawela Marsh (B= 40 m, L= 4,500 m	523	1.25	1.41	792	223.21	4.32	27.3%
10-year	K11	K1+K8	523	1.44	1.50	1,751	149.25	1.25	11.8%
10-year	K12	K2+K9	523	1.37	1.44	1,889	196.78	1.52	13.6%
10-year	K13	K3+K10	523	1.31	1.38	2,027	242.54	1.75	15.1%
10-year	K14	K1+K7+K8	523	1.35	1.39	2,685	234.78	1.28	12.0%
10-year	K15	K1+K6+K8	523	0.97	1.15	5,869	483.60	1.22	11.6%
10-year	K16	K1+K7	523	1.44	1.46	2,319	178.61	1.12	10.9%
10-year	K17	K1+K9	523	1.37	1.44	1,781	191.82	1.58	14.0%
10-year	K18	K1+K10	523	1.30	1.39	1,810	234.52	1.90	15.9%

Table 6.3.3 Comparative Study of Alternative Combinations - Kalu Oya Basin (Return Period 10-year) (2/2)

Cases for Effect by Reduction of Retention Area

Planning Scale (Return Period)	Case	Alternatives	Retention Area	Water Level	
				Negombo Road	Retention Area
10-year	K0		523	1.59	1.68
10-year	K0-a		446	1.63	1.73
10-year	K0-b		339	1.72	1.83
10-year	K0-c		220	1.85	2.02
10-year	K11	K1+K8	523	1.44	1.50
10-year	K11-a	K1+K8	446	1.47	1.54
10-year	K11-b	K1+K8	339	1.51	1.60
10-year	K11-c	K1+K8	220	1.51	1.72
10-year	K12	K2+K9	523	1.37	1.44
10-year	K12-a	K2+K9	446	1.41	1.48
10-year	K12-b	K2+K9	339	1.46	1.55
10-year	K12-c	K2+K9	220	1.51	1.66
10-year	K13	K3+K10	523	1.31	1.38
10-year	K13-a	K3+K10	446	1.35	1.43
10-year	K13-b	K3+K10	339	1.41	1.50
10-year	K13-c	K3+K10	220	1.48	1.62
10-year	K14	K1+K7+K8	523	1.35	1.39
10-year	K14-a	K1+K7+K8	446	1.38	1.43
10-year	K14-b	K1+K7+K8	339	1.42	1.48
10-year	K14-c	K1+K7+K8	220	1.49	1.59
10-year	K15	K1+K6+K8	523	0.97	1.15
10-year	K15-a	K1+K6+K8	446	1.01	1.20
10-year	K15-b	K1+K6+K8	339	1.09	1.29
10-year	K15-c	K1+K6+K8	220	1.36	1.56
10-year	K16	K1+K7	523	1.44	1.46
10-year	K16-a	K1+K7	446	1.46	1.50
10-year	K16-b	K1+K7	339	1.48	1.53
10-year	K16-c	K1+K7	220	1.54	1.64
10-year	K17	K1+K9	523	1.37	1.44

Table 7.3.1 Comparative Study of Alternative Combinations - Greater Colombo Basin (Return Period 50-year) (1/2)

Cases for Alternative Combinations

Planning Scale (Return Period)	Case	Alternatives	Retention Area	Water Level				Project Cost	Annual Benefit	B/C	EIRR
				Dematagoda Ela	Kirillapone Canal	Parliament Lake	Retention Area	(Million Rs)	(Million Rs)		
50-year	G0		435	2.14	1.97	2.13	2.07				
50-year	G1	Maradana Pumping Station (Q= 5 m^3/sec) and Improvement of Galle Face Outfall	435	2.09	1.94	2.10	2.04	1,325	79	0.66	6.5%
50-year	G2	Maradana Pumping Station (Q= 10 m^3/sec) and Improvement of Galle Face Outfall	435	2.04	1.91	2.07	2.00	2,304	153	0.74	7.4%
50-year	G3	North Lock Pumping Station (Q= 10 m^3/sec)	435	2.04	1.91	2.07	2.00	2,199	153	0.78	7.8%
50-year	G4	North Lock Pumping Station (Q= 15 m^3/sec)	435	1.98	1.89	2.05	1.97	2,908	219	0.84	8.4%
50-year	G5	Gotatuwa Pumping Station (Q= 30 m^3/sec)	435	1.96	1.82	1.97	1.91	4,592	362	0.88	8.9%
50-year	G6	Gotatuwa Pumping Station (Q= 40 m^3/sec)	435	1.93	1.80	1.95	1.88	5,977	418	0.76	7.6%
50-year	G7	Madiwela South Diversion Channel	435	1.90	1.74	1.88	1.83	3,565	524	1.36	13.1%
50-year	G8	Restoration of Existing Mutwal Tunnel (D= 1.8 m)	435	2.11	1.95	2.11	2.05	361	45	1.39	13.4%
50-year	G9	New Mutwal Tunnel (D= 3 m)	435	2.05	1.92	2.08	2.01	1,022	127	1.37	13.2%
50-year	G10	New Mutwal Tunnel (D= 4 m)	435	2.00	1.89	2.06	1.98	1,092	197	1.98	17.9%
50-year	G11	Widening of Welawatta and Kirillapone Canals	435	2.08	1.87	2.08	2.00	2,066	161	0.86	8.6%
50-year	G12	G7+G8									
50-year	G13	G7+G9									
50-year	G14	G7+G10									
50-year	G15	G8+G9									
50-year	G16	G8+G10									
50-year	G17	G7+G11	435	1.84	1.66	1.82	1.76	5,393	678	1.40	13.5%
50-year	G18	G7+G8+G9	435	1.80	1.68	1.81	1.76	4,473	681	1.70	15.7%
50-year	G19	G7+G8+G10	435	1.77	1.66	1.79	1.74	4,543	729	1.80	16.4%
50-year	G20	G7+G8+G11	435	1.81	1.64	1.80	1.74	5,516	718	1.46	13.9%
50-year	G21	G7+G9+G11	435	1.77	1.61	1.77	1.71	6,177	785	1.43	13.6%
50-year	G22	G7+G10+G11	435	1.74	1.59	1.75	1.69	6,247	835	1.51	14.3%
50-year	G23	G7+G8+G10+G11	435	1.73	1.59	1.74	1.68	6,371			
50-year	G24	G4+G7+G8+G10+G11	435	1.50	1.50	1.65	1.58	9,041			

Table 7.3.1 Comparative Study of Alternative Combinations - Greater Colombo Basin (Return Period 50-year) (2/2)

Cases for Reduction of Retention Area

Planning Scale (Return Period)	Case	Alternatives	Retention Area	Water Level			
				Dematagoda Ela	Kirillapone Canal	Parliament Lake	Retention Area
50-year	G0		435	2.14	1.97	2.13	2.07
50-year	G0-a		300	2.16	2.00	2.15	2.09
50-year	G0-b		280	2.26	2.10	2.26	2.20
50-year	G0-c		150	2.76	2.57	2.75	2.69
50-year	G17	G7+G11	435	1.84	1.66	1.82	1.76
50-year	G17-a	G7+G11	300	1.85	1.66	1.83	1.77
50-year	G17-b	G7+G11	280	1.91	1.73	1.90	1.83
50-year	G17-c	G7+G11	150	2.36	2.15	2.34	2.27
50-year	G18	G7+G8+G9	435	1.80	1.68	1.81	1.76
50-year	G18-a	G7+G8+G9	300	1.81	1.69	1.81	1.77
50-year	G18-b	G7+G8+G9	280	1.88	1.75	1.88	1.83
50-year	G18-c	G7+G8+G9	150	2.33	2.18	2.33	2.28
50-year	G19	G7+G8+G10	435	1.77	1.66	1.79	1.74
50-year	G19-a	G7+G8+G10	300	1.78	1.67	1.79	1.74
50-year	G19-b	G7+G8+G10	280	1.84	1.73	1.85	1.81
50-year	G19-c	G7+G8+G10	150	2.28	-	2.28	2.23
50-year	G20	G7+G8+G11	435	1.81	1.64	1.80	1.74
50-year	G20-a	G7+G8+G11	300	1.82	1.65	1.81	1.75
50-year	G20-b	G7+G8+G11	280	1.88	1.71	1.87	1.81
50-year	G20-c	G7+G8+G11	150	2.32	2.13	2.31	2.24
50-year	G21	G7+G9+G11	435	1.77	1.61	1.77	1.71
50-year	G21-a	G7+G9+G11	300	1.78	1.62	1.78	1.72
50-year	G21-b	G7+G9+G11	280	1.84	1.68	1.84	1.78
50-year	G21-c	G7+G9+G11	150	2.26	2.08	2.26	2.20
50-year	G22	G7+G10+G11	435	1.74	1.59	1.75	1.69
50-year	G22-a	G7+G10+G11	300	1.75	1.60	1.75	1.69
50-year	G22-b	G7+G10+G11	280	1.81	1.66	1.82	1.76
50-year	G22-c	G7+G10+G11	150	2.21	2.04	2.22	2.15
50-year	G23	G7+G8+G10+G11	435	1.73	1.59	1.74	1.68
50-year	G23-a	G7+G8+G10+G11	300	1.73	1.59	1.74	1.68
50-year	G23-b	G7+G8+G10+G11	280	1.79	1.65	1.80	1.74
50-year	G23-c	G7+G8+G10+G11	150	2.19	2.03	2.20	2.14
50-year	G24	G4+G7+G8+G10+G11	435	1.50	1.50	1.65	1.58
50-year	G24-a	G4+G7+G8+G10+G11	300	1.50	1.50	1.65	1.58
50-year	G24-b	G4+G7+G8+G10+G11	280	1.54	1.55	1.69	1.62
50-year	G24-c	G4+G7+G8+G10+G11	150	1.84	1.84	1.98	1.92

Table 7.3.2 Comparative Study of Alternative Combinations - Greater Colombo Basin (Return Period 25-year) (1/2)

Cases for Alternative Combinations

Planning Scale (Return Period)	Case	Alternatives	Retention Area	Water Level				Project Cost (Million Rs)	Annual Benefit (Million Rs)	B/C	EIRR
				Dematagoda Ela	Kirillapone Canal	Parliament Lake	Retention Area				
25-year	G0		435	1.85	1.70	1.85	1.79				
25-year	G1	Maradana Pumping Station (Q= 5 m^3/sec) and Improvement of Galle Face Outfall	435	1.80	1.67	1.82	1.75	1,325	84	0.75	7.7%
25-year	G2	Maradana Pumping Station (Q= 10 m^3/sec) and Improvement of Galle Face Outfall	435	1.75	1.64	1.79	1.72	2,304	163	0.84	8.6%
25-year	G3	North Lock Pumping Station (Q= 10 m^3/sec)	435	1.75	1.64	1.79	1.72	2,199	162	0.88	8.9%
25-year	G4	North Lock Pumping Station (Q= 15 m^3/sec)	435	1.69	1.61	1.77	1.69	2,908	230	0.95	9.5%
25-year	G5	Gotatuwa Pumping Station (Q= 30 m^3/sec)	435	1.65	1.55	1.68	1.62	4,592	381	1.00	10.0%
25-year	G6	Gotatuwa Pumping Station (Q= 40 m^3/sec)	435	1.64	1.53	1.66	1.59	5,977	436	0.86	8.6%
25-year	G7	Madiwela South Diversion Channel	435	1.65	1.51	1.63	1.59	3,565	442	1.46	13.8%
25-year	G8	Restoration of Existing Mutwal Tunnel (D= 1.8 m)	435	1.83	1.68	1.83	1.77	361	45	1.51	14.1%
25-year	G9	New Mutwal Tunnel (D= 3 m)	435	1.77	1.65	1.80	1.74	1,022	123	1.42	13.4%
25-year	G10	New Mutwal Tunnel (D= 4 m)	435	1.73	1.63	1.78	1.71	1,092	180	1.94	17.2%
25-year	G11	Widening of Welawatta and Kirillapone Canals	435	1.81	1.61	1.80	1.73	2,066	145	0.83	8.4%
25-year	G12	G7+G8	435	1.62	1.50	1.61	1.57	3,688	488	1.57	14.5%
25-year	G13	G7+G9	435	1.58	1.47	1.58	1.54	4,349	557	1.52	14.2%
25-year	G14	G7+G10	435	1.55	1.45	1.56	1.52	4,419	602	1.62	14.9%
25-year	G15	G8+G9	435	1.77	1.64	1.78	1.73	1,146	149	1.53	14.3%
25-year	G16	G8+G10	435	1.73	1.63	1.76	1.71	1,276	192	1.86	16.6%
25-year	G17	G7+G8+G10	435	1.53	1.44	1.55	1.51	5,393	627	1.65	15.1%

Table 7.3.2 Comparative Study of Alternative Combinations - Greater Colombo Basin (Return Period 25-year) (2/2)

Cases for Reduction of Retention Area

Planning Scale (Return Period)	Case	Alternatives	Retention Area	Water Level			
				Dematagoda Ela	Kirillapone Canal	Parliament Lake	Retention Area
25-year	G0		435	1.85	1.70	1.85	1.86
25-year	G0-a		300	1.86	1.71	1.80	1.87
25-year	G0-b		280	1.94	1.78	1.93	1.93
25-year	G0-c		150	2.39	2.22	2.39	2.27
25-year	G7		435	1.65	1.51	1.63	1.59
25-year	G7-a		300	1.65	1.51	1.63	1.59
25-year	G7-b		280	1.70	1.56	1.68	1.64
25-year	G7-c		150	2.08	1.93	2.06	2.02
25-year	G10		435	1.73	1.63	1.78	1.71
25-year	G10-a		300	1.76	1.64	1.78	1.72
25-year	G10-b		280	1.82	1.70	1.84	1.78
25-year	G10-c		150	2.24	2.10	2.26	2.20
25-year	G12	G7+G8	435	1.62	1.50	1.61	1.57
25-year	G12-a	G7+G8	300	1.62	1.50	1.61	1.57
25-year	G12-b	G7+G8	280	1.67	1.54	1.66	1.62
25-year	G12-c	G7+G8	150	2.04	1.90	2.04	1.99
25-year	G13	G7+G9	435	1.58	1.47	1.58	1.54
25-year	G13-a	G7+G9	300	1.58	1.47	1.58	1.54
25-year	G13-b	G7+G9	280	1.62	1.51	1.62	1.58
25-year	G13-c	G7+G9	150	1.99	1.86	1.99	1.94
25-year	G14	G7+G10	435	1.55	1.45	1.56	1.52
25-year	G14-a	G7+G10	300	1.55	1.45	1.56	1.52
25-year	G14-b	G7+G10	280	1.59	1.49	1.60	1.56
25-year	G14-c	G7+G10	150	1.94	1.82	1.95	1.90
25-year	G15	G8+G9	435	1.77	1.64	1.78	1.73
25-year	G15-a	G8+G9	300	1.77	1.65	1.78	1.73
25-year	G15-b	G8+G9	280	1.84	1.71	1.85	1.80
25-year	G15-c	G8+G9	150	2.27	2.12	2.28	2.22
25-year	G16	G8+G10	435	1.73	1.63	1.76	1.71
25-year	G16-a	G8+G10	300	1.74	1.63	1.77	1.71
25-year	G16-b	G8+G10	280	1.80	1.69	1.83	1.77
25-year	G16-c	G8+G10	150	2.22	2.09	2.24	2.18
25-year	G17	G7+G8+G10	435	1.53	1.44	1.55	1.51
25-year	G17-a	G7+G8+G10	300	1.54	1.44	1.55	1.51
25-year	G17-b	G7+G8+G10	280	1.58	1.48	1.59	1.55
25-year	G17-c	G7+G8+G10	150	1.92	1.81	1.93	1.88

Table 7.3.3 Comparative Study of Alternative Combinations - Greater Colombo Basin (Return Period 10-year) (1/2)

Cases for Alternative Combinations

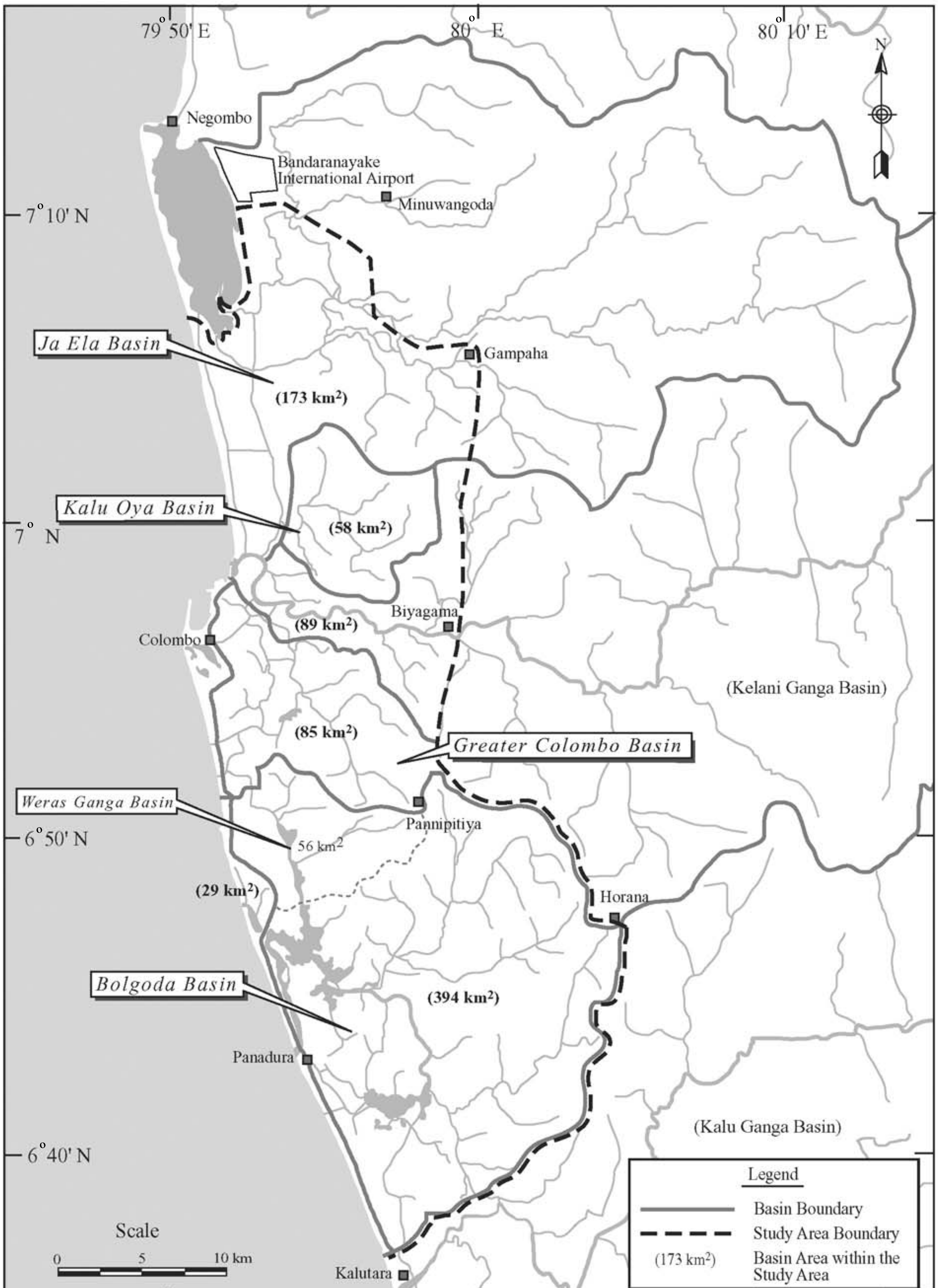
Planning Scale (Return Period)	Case	Alternatives	Retention Area	Water Level				Project Cost	Annual Benefit	B/C	EIRR
				Dematagoda Ela	Kirillapone Canal	Parliament Lake	Retention Area	(Million Rs)	(Million Rs)		
10-year	G0		435	1.53	1.40	1.53	1.48				
10-year	G1	Maradana Pumping Station (Q= 5 m^3/sec) and Improvement of Galle Face Outfall	435	1.48	1.36	1.49	1.44	1,325	88	0.85	8.7%
10-year	G2	Maradana Pumping Station (Q= 10 m^3/sec) and Improvement of Galle Face Outfall	435	1.41	1.33	1.47	1.40	2,304	165	0.92	9.3%
10-year	G3	North Lock Pumping Station (Q= 10 m^3/sec)	435	1.41	1.33	1.47	1.40	2,199	164	0.96	9.7%
10-year	G4	North Lock Pumping Station (Q= 15 m^3/sec)	435	1.35	1.31	1.45	1.37	2,908	223	0.99	9.9%
10-year	G5	Gotatuwa Pumping Station (Q= 30 m^3/sec)	435	1.34	1.25	1.35	1.30	4,592	360	1.02	10.1%
10-year	G6	Gotatuwa Pumping Station (Q= 40 m^3/sec)	435	1.32	1.24	1.34	1.29	5,977	389	0.82	8.4%
10-year	G7	Madiwela South Diversion Channel	435	1.37	1.25	1.36	1.32	3,565	322	1.14	11.1%
10-year	G8	Restoration of Existing Mutwal Tunnel (D= 1.8 m)	435	1.50	1.38	1.51	1.46	361	43	1.54	14.0%
10-year	G9	New Mutwal Tunnel (D= 3 m)	435	1.46	1.35	1.48	1.42	1,022	114	1.41	13.2%
10-year	G10	New Mutwal Tunnel (D= 4 m)	435	1.43	1.34	1.47	1.41	1,092	154	1.78	15.8%
10-year	G11	Widening of Welawatta and Kirillapone Canals	435	1.49	1.32	1.49	1.42	2,066	123	0.76	7.8%

Table 7.3.3 Comparative Study of Alternative Combinations - Greater Colombo Basin (Return Period 10-year) (2/2)

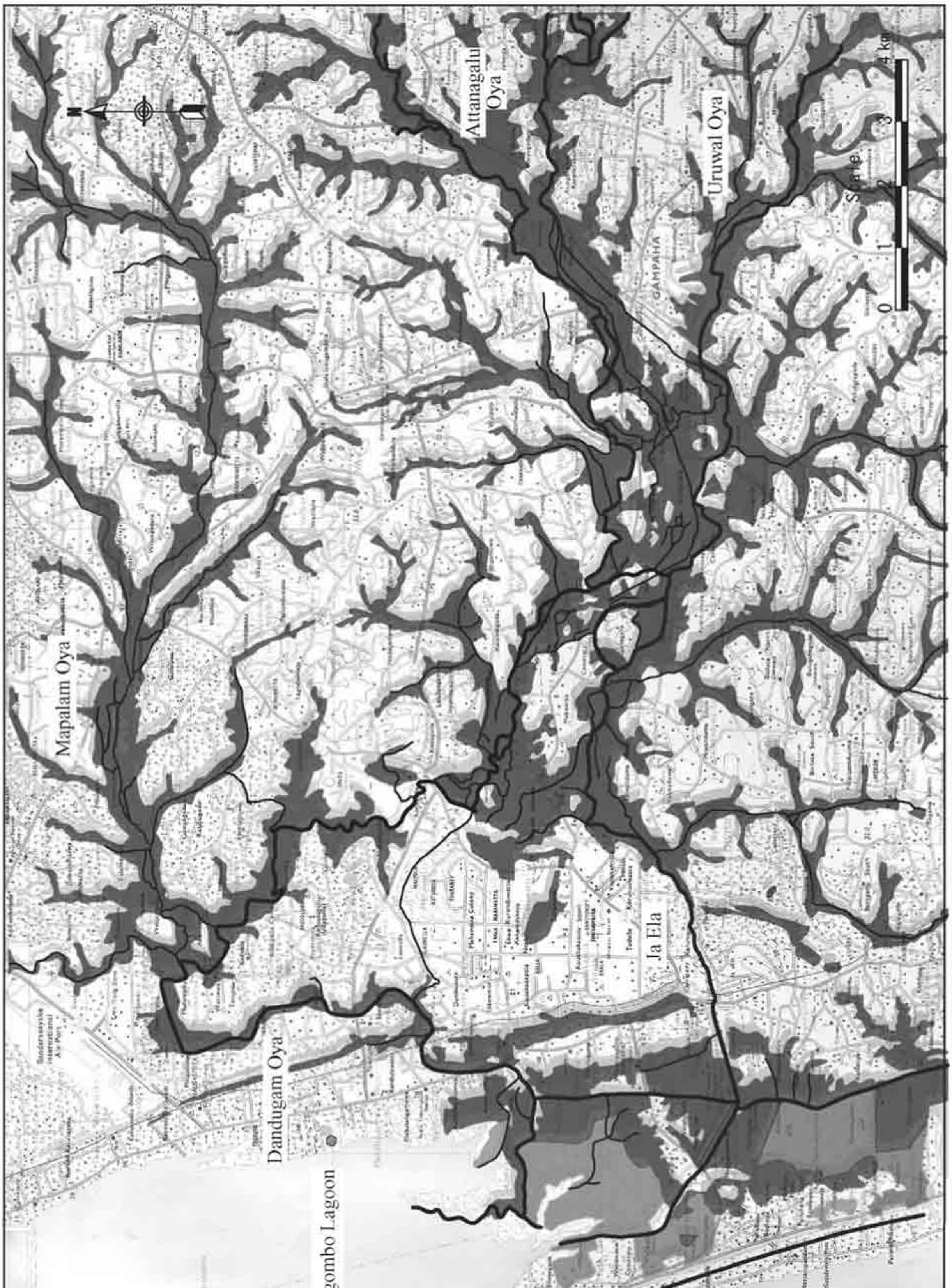
Cases for Reduction of Retention Area

Planning Scale (Return Period)	Case	Alternatives	Retention Area	Water Level			
				Dematagoda Ela	Kirillapone Canal	Parliament Lake	Retention Area
10-year	G0		435	1.53	1.40	1.53	1.48
10-year	G0-a		300	1.53	1.40	1.53	1.48
10-year	G0-b		280	1.57	1.44	1.57	1.52
10-year	G0-c		150	1.91	1.76	1.90	1.85
10-year	G8		435	1.50	1.38	1.51	1.46
10-year	G8-a		300	1.51	1.38	1.51	1.46
10-year	G8-b		280	1.54	1.42	1.55	1.49
10-year	G8-c		150	1.87	1.73	1.87	1.82
10-year	G9		435	1.46	1.35	1.48	1.42
10-year	G9-a		300	1.47	1.35	1.48	1.43
10-year	G9-b		280	1.50	1.39	1.51	1.46
10-year	G9-c		150	1.82	1.69	1.82	1.77
10-year	G10		435	1.43	1.34	1.47	1.41
10-year	G10-a		300	1.44	1.34	1.46	1.41
10-year	G10-b		280	1.47	1.37	1.49	1.44
10-year	G10-c		150	1.77	1.65	1.79	1.73

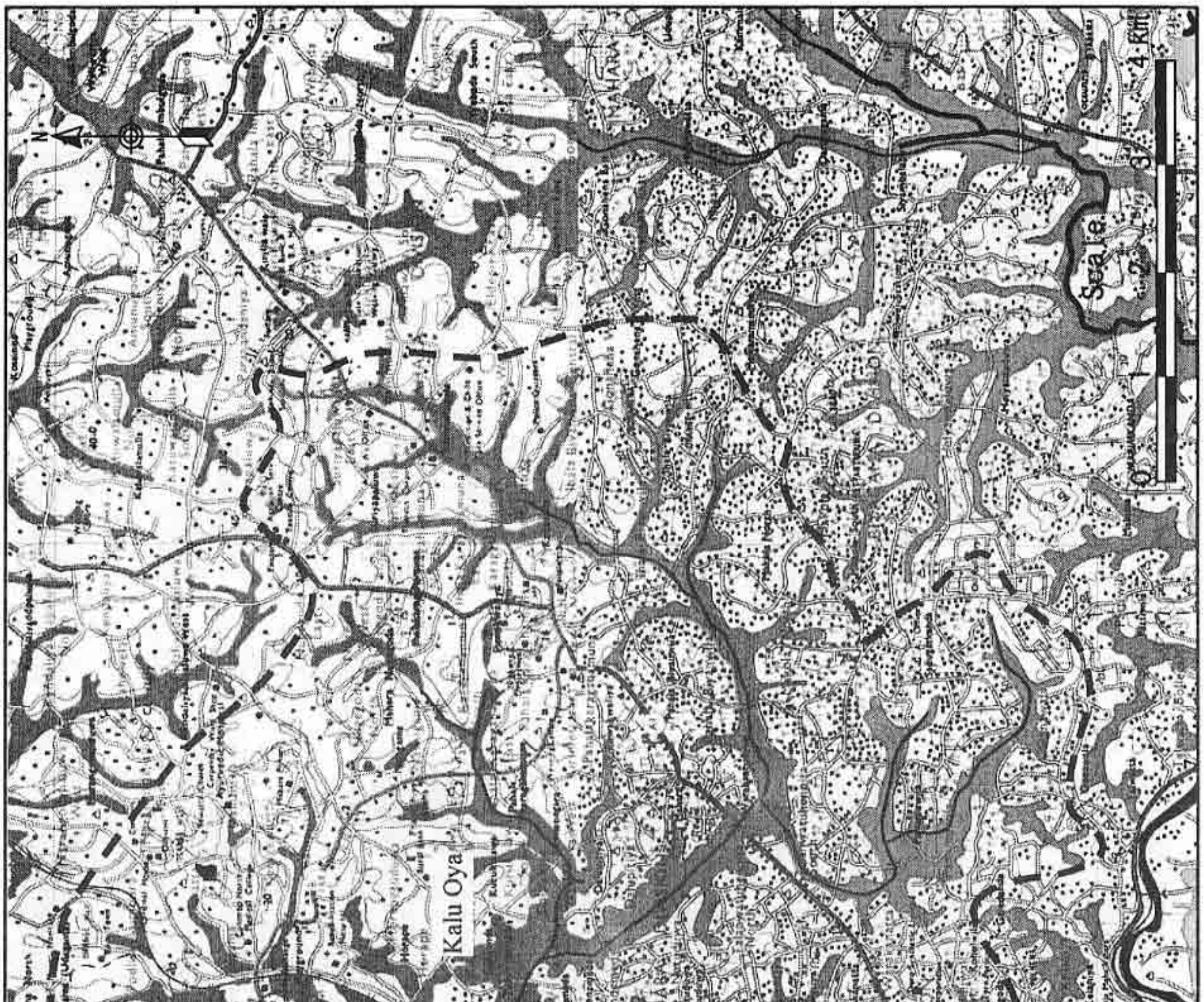
Figures



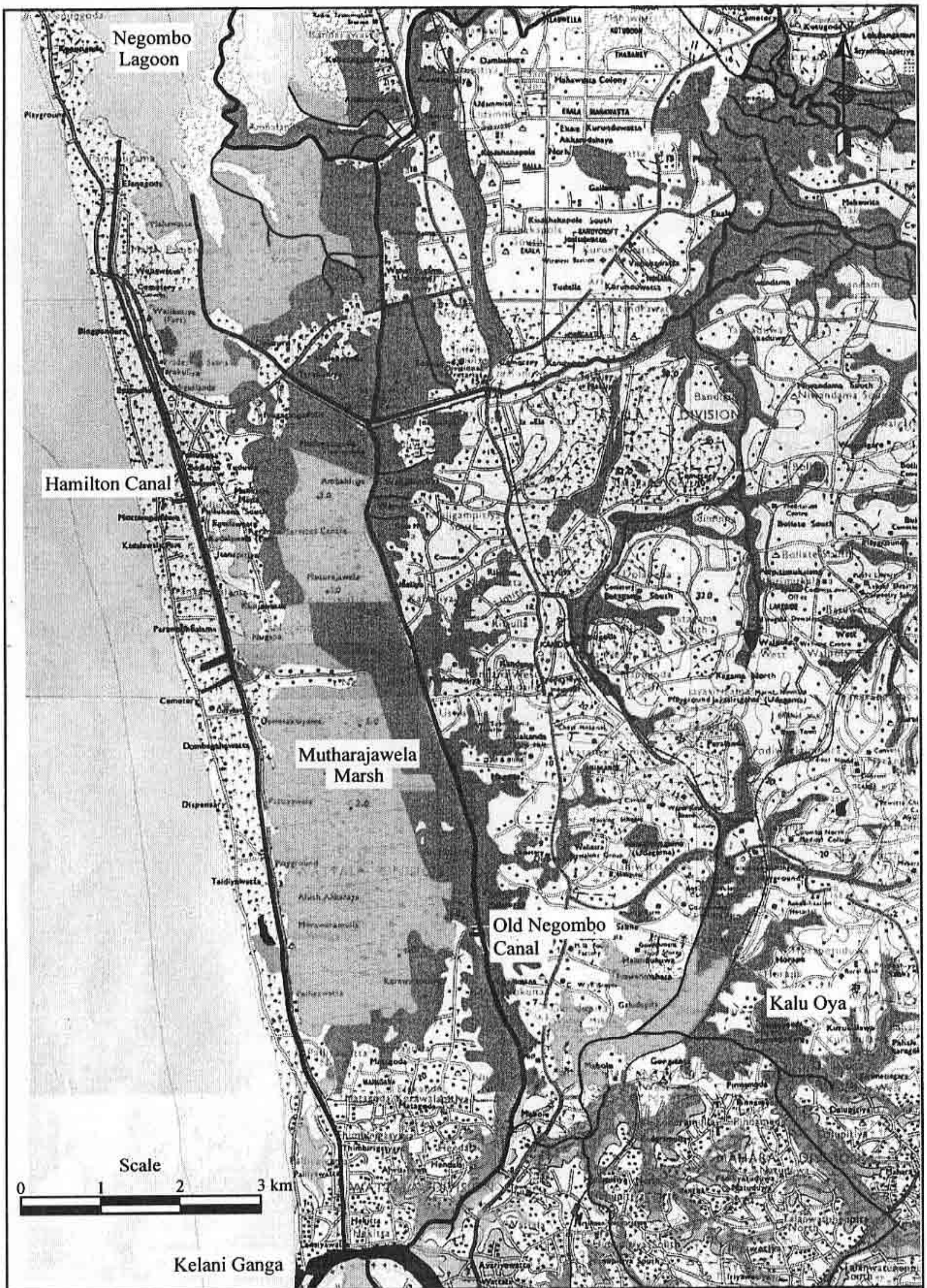
The Study on Storm Water Drainage Plan for the Colombo Metropolitan Region in the Democratic Socialist Republic of Sri Lanka	Figure 1.1.1 Study Area and Relevant Drainage Basins
JAPAN INTERNATIONAL COOPERATION AGENCY	



The Study on Storm Water Drainage Plan for the Colombo Metropolitan Region in the Democratic Socialist Republic of Sri Lanka	Figure 1.2.1 River System in Ja Ela Basin
JAPAN INTERNATIONAL COOPERATION AGENCY	



The Study on Storm Water Drainage Plan for the Colombo Metropolitan Region in the Democratic Socialist Republic of Sri Lanka	Figure 1.2.2 River System in Kalu Oya Basin
JAPAN INTERNATIONAL COOPERATION AGENCY	



The Study on Storm Water Drainage Plan for the Colombo Metropolitan Region in the Democratic Socialist Republic of Sri Lanka	Figure 1.2.3 Hamilton Canal and Old Negombo Canal
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