ADAPTATION TO DISASTER: HOUSING IN FLOOD PRONE AREAS WITH SPECIAL REFERENCE TO THE COLOMBO DISTRICT

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ABSTRACT

Water is a precious commodity and considered a source of life. This life giving water appears as a common thread woven through the religion, literature and art of every culture. Architectural compositions too, are greatly enhanced by the use of water. Moreover, many of the worlds earliest civilization's originated in areas where water was readily available, such as in the Nile Delta and the Indus valley. Even in Sri Lanka, early human settlements were founded near sources of water such as the Malwatu Oya. Despite water's role as a common denominator for life, it also brings death and disaster with it when it floods, showing that too much water is as bad as too little. Flooding causes extensive damage to people and property and can be considered as the most widespread natural disaster which occurs in Sri Lanka.

Flooding is common in many areas of the country and the district of Colombo also has this particular problem. However, one may be tempted to ask "Are there really floods in Colombo?" The answer is a definite "yes". One may not hear of great catastrophes related to floods within the Colombo district, but it nevertheless causes much damage to property and imposes hardships on the people when parts of the city and surrounding areas get flooded after intense rainfalls of even short duration. Therefore, it is imperative that mitigatory measures be taken in order to minimise the damaging effects of floods. In this regard, Architectural solutions for housing and building and proper planning procedures incorporating regulatory controls will ensure that people will have the opportunity of coping with and adapting to floods without incurring loss or damage.

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INTRODUCTION

Amongst the natural disasters that occur worldwide, flooding could be considered as the most common, causing much damage and suffering to millions of people. Sri Lanka too, is faced with this particular hazard and people living in both rural and urban areas are inconvenienced from time to time as a result of it.

Floods in urban areas are caused primarily by inappropriate human activities, which have contributed greatly to the increase in frequency as well as impact of flooding. The phenomenon of urban flooding continues to grow in proportion due to various reasons such as unplanned development and areas in the Colombo district in particular have been susceptible to it. Considering the trend of urbanisation in Sri Lanka it can be safely assumed that the environs of Colombo will see more development and urbanisation in the future and if due attention is not paid to the issue of floods in such development activities, the nature and magnitude of floods will indeed become more critical in times to come.

It must also be noted here that architects have also contributed somewhat to this sorry state of matters by not giving proper guidance to clients who consult them for building and development projects, especially in areas under threat of floods. It must be remembered that the contribution and involvement of architects in the design and construction of buildings within the district of Colombo is considerably more so than in any other area of the country and unfortunately it appears that architects themselves have aggravated the urban flood situation This can be clearly seen in a situation where a client is desirous of building on a piece of land which he has acquired in a low lying area susceptible to flooding. The common practice that is observed in such an instance would be to put up a parapet wall around the site and to fill the land with soil brought from elsewhere, after which construction is carried out with the aid and supervision of an architect, who is responsible for its design. This is an unhealthy approach which will undoubtedly wreak havoc in the natural drainage patterns of the area, ultimately paving the way for inundation and floods.

However, since the process of development cannot be halted, it is obvious that people living in the environs of Colombo will be exposed more and more to flood situations in the future, if proper measures are not taken in this regard. Since the occurrence of flooding cannot be totally eliminated the only option available is to learn to adapt to floods and try to live with it, while at the same time not worsening the situation. Moreover, it must be very clearly stressed at this juncture that architects can indeed contribute to the betterment of the flood situation by bringing forward design solutions that are justifiably suitable in this regard. Therefore, this study will examine the impacts of flooding on urban human settlements and will look at housing in particular, in order to find viable solutions for co-existing with floods.

PROBLEM AREA

For the past five centuries, the city of Colombo gradually developed as the main commercial and administration city of Sri Lanka. However, flooding in the city of Colombo and as well as other parts of the district is an issue that needs to be addressed in order to prevent both social problems and economic losses. There is a network of large canals and tributaries constructed with drains to discharge storm water, but it is proving ineffective due to insufficient maintenance, encroachment and obstructions. As a consequence one would find roads and many parts of the city flooded during heavy rainstorms of even short duration.

Inhabitants living in areas subjected to flooding are frequently required to seek refuge elsewhere when their houses go under water and to depend on rations handed out until they can return to their normal lifestyle when the waters subside. It goes on without saying that some people lose their daily wages as a consequence of these disruptions. Therefore, the problem that can be very clearly identified here, is the lack of proper adaptive methods to floods in housing and building that would enable people to go on with their lives with the minimum of disruption during floods. Furthermore, the architectural problem that is apparent here is the lack of appropriate flood resistant housing that are functional, aesthetically pleasing and suited to the Sri Lankan context.

RATIONALE

Usually the attitude towards a natural disaster such as floods, predominantly concerns with the provision of relief after it has occurred or in the reconstruction of buildings that have been affected. Sometimes people tend to ignore the possibility of a disaster until it actually happens, and are rather reluctant to go to the trouble of preparing for it beforehand. Therefore, it is felt that there is a very pressing need for a document that would present adequate information to people to help them learn to live with and adapt to floods.

It must also be noted that urban planning activities have not given consideration to hazard aspects adequately. Even when information related to disasters is available, it is not integrated in regional and city planning, nor in zonation map preparation. Moreover, the local authorities do not have regulations controlling development in hazard prone areas. The same regulations are adopted in hazard prone areas as in other areas without any special restriction. So, it is hoped that this study, emphasizing the need for enforcing regulatory measures in order to minimise flood damages to human settlements will prove beneficial in this regard.

The issue of flooding has been considerably dealt with by many, such as engineers, R & D scientists and relief workers, but not so much by architects. Since there is not much literature written with an architectural point of view on this particular subject it can be considered that there is justifiable cause so as to study the present subject. A considerable amount of responsibility is vested in an architect to accommodate built environments conducive to the well being of those who occupy them. It is therefore, essential that architects be well equipped with the necessary knowledge of how to design in areas under threat of floods. Therefore, there is a very pressing need of a study focussing on relevant issues outlined above.

RESEARCH OBJECTIVES

The overall objective of this research is to understand how households in urban areas get affected by floods and to identify ways and means of adapting to the disasters caused by them. Disasters caused by floods can be addressed primarily in two ways. The first method employs structural measures such as the establishment of drains and canal networks to control standing floods that are a frequent occurrence within the Colombo district. The second method employs nonstructural measures like development of a mechanism for living with floods. This method could also be viewed as a more viable means of addressing the problem of floods, since more and more people are forced to occupy flood prone areas due to the scarcity of land.

The ultimate goal of this study is to bring forward ideas that conform to nonstructural methods, incorporating architectural solutions to deal with floods. Under this broad perspective, various specific problems are dealt with in order to formulate a comprehensive solution which in turn, would address the issues outlined above.

- The specific problem that needs to be looked at first is the lack of consideration when construction and development takes place in areas subjected to flooding. Therefore, the objective is to identify various land use control and regulatory measures that would prevent haphazard blocking out of land and uncontrolled development in hazard prone areas.

- The next problem that needs to be addressed is the lack of appropriate flood resistant housing. Therefore, the second objective is to investigate methods of designing flood resistant housing for urban areas.

- The final problem that needs to be looked into is how to facilitate the construction of flood resistant housing. Thus the objective here is to identify appropriate technology and materials in this regard.

Hence the overall intention of this dissertation is to present a practical solution and a course of action to be taken when dealing with housing design and construction in areas that are susceptible to floods.

METHOD OF STUDY

The research design to be incorporated in this dissertation would comprise of many different methods depending on the specific objectives that are hoped to be achieved. A reconnaissance survey in affected areas will be carried out in order to gain an insight into the situation of floods in the Colombo district. It will also be beneficial to study how people react to flood situations and try to understand how housing is affected in a flood.

It would also be necessary to selectively read and gather information related to the study area and conduct a literature survey in order to achieve the first objective, which is the identification of land use control and regulatory measures. The next specific objective of investigating methods of designing flood resistant housing could be achieved by both literature surveys and case illustrations. Search in the electronic media through Web Sites for current research work done in that area of study would also be beneficial. Finally, the specific objective of identifying appropriate technologies to be utilized in the design of flood resistant housing could be mainly obtained by literature surveys and through the electronic media giving all the latest information regarding the subject.

The study can be considered as having three main parts, *Introductory*, consisting of Chapter one, *Investigative*, consisting of Chapter two and *Illustrative,* consisting of Chapter three and four. In the introductory section various conceptual issues dealing with disasters and floods are discussed. In the investigative section the situation of floods in the Colombo district is examined. Finally, in the illustrative section various methods are presented by which adaptation to floods is achieved in housing and building.

SCOPE AND LIMITATIONS

The purpose of this investigation is to document the situation of floods in the Colombo district, its effects on households and buildings and finally to present some guidelines for human settlement planning and the for the designing of flood resistant housing.

However, in this endeavour it is not possible to record the flood situation of the entire Colombo district. Therefore, the study is limited to three areas within the district; firstly, the threat of floods in built-up areas within the City of Colombo which gets inundated even after a short period of intense rainfall but usually remaining dry for most of the time when there is no rain. The second situation to be considered is the flooding of the so-called flood detention areas which are low lying marshy lands such as those in the Sri Jayawardenapura Kotte areas. The third situation is the flooding of human settlements located in the flood plains of the Kelani river.

Also, it must be mentioned here that the guidelines presented here do not deal with any construction techniques that are very sophisticated so as to be beyond the scope of this study.

CHAPTER ONE

1 DISASTER, MAN AND HIS ENVIRONMENT

Misfortune always come in by a door that has been left open for them.

Czech proverb

Every year disasters of one kind or another occur in many parts of the world inflicting much damage to man and his environment. Images of horror, destruction and death due to disasters have become quite common in the media such as television and newspapers in recent times. One could safely assume that there is no country in the world, which has not had its share of disaster of some kind.

Disasters, whether natural or man made have its heaviest impact on developing countries where there is a high level of poverty, rapid and haphazard urbanisation, and unstable economic and political conditions. In Asia, natural and manmade disasters have caused untold suffering amongst millions if people and caused millions of US dollars in property damage. The cost of rehabilitation and reconstruction consumes available resources that could have been used for new development. Unemployment, foreign indebtedness and disruption to the balance of trade are long term effects after the occurrence of a disaster.

1.1 DISASTER : CONCEPTUAL ISSUES

The term 'disaster' has many divergent definitions, for it is perceived differently by social scientists, politicians, environmentalists, relief workers, journalists and R & D workers. The Oxford dictionary defines disaster as an 'event that causes great harm or damage'. Much effort has been expended to conceptualise the term disaster and following are a number of definitions, which are worth noting.

Institutions that are actively involved in disaster mitigation and disaster preparedness offer the following definitions:[1]

- Asian Disaster Preparedness Centre (ADPC) definition.

An event, either man-made or natural, sudden or progressive, the impact of which is such that the affected community must respond through exceptional measures.

- Definition in World Disaster Report (1998)

Disasters are exceptional events, which suddenly kill or injure a large number of people or cause major economic losses.

- United Nations Disaster Relief Office (UNDRO) (UN-DHA) definition

An event, concentrated in time and space, in which a society or a community undergoes severe danger and incurs such losses to its members and physical appurtenances that the social structure is disrupted and the fulfilment of all or some of essential factors of the society is prevented.

Moreover, it could be said that disaster in an event, located in time and space, which produces the conditions, whereby the continuity of the structures and the process of social units become problematic. Disaster agents may differ as to their cause, frequency, controllability, speed of onset, length of forewarning, duration, scope of impact and destructive potential.For purposes of clarification disasters could be classified as natural and manmade.

The following categories incorporate natural disasters.

- Atmospheric
  - Lightning
  - Tropical cyclones
  - Hailstorms
  - Extreme summer weather
  - Severe winter storms
  - Snow avalanches
  - Tornadoes
- Biological
  - Disease, infestations
  - Molds
- Geological/Seismic
  - Earthquakes
  - Expansive soils
  - Land slides

Land subsidence
Volcanic activity

- Other
  Wild fires

Manmade disasters encompass the following categories:

- Environmental
  Chemical leakage
  Industrial contamination
  Pollution

- Operational
  Construction accident
  Hazardous material spills
  Mechanical failures
  Structural failures
  Production accidents

- Transportation
  Air plane crashes
  Marine accidents
  Traffic accidents

- Others
  Wars
  Dam failure

Even though, disasters are classified as natural and manmade, this distinction is sometimes lost due to the fact that some natural disasters may be initiated or made worse by man's inappropriate actions, misuse of resources and lack of foresight. This situation can be clearly seen in the occurrence of floods, primarily considered a natural phenomenon, but made worse or even caused by human actions. Since this dissertation focuses on flooding and its effects on human settlements, this will be discussed in greater detail at a later stage of the study.

1.2 IMPACTS OF DISASTER – PHYSICAL, PSYCHOLOGICAL AND SOCIAL ISSUES

Disasters cause a lot of physical damage and its effects are felt on both people and the environment. Environmental effects include damages to buildings, infrastructure and natural resources. People coming into direct contact with a disaster event sustain physical injuries, disabilities or even death. As a result many are psychologically impaired and traumatically stressed due to such events. Physical damage to property or buildings could be reconstructed or rehabilitated in time, but the same cannot be said about the psychological damage incurred. Social problems are the ultimate problems, which arise out of physical and psychological impacts of a disaster. The aftermath of a disaster will find many people displaced, widowed, orphaned or disabled and they become a burden to society if they have no one to take care of them.. Interruption of normal ways of life lead to socio-economic, cultural and sometimes political disruption.

Psychological impacts could occur due to many reasons, such as the loss of a family member or a loved one. Damage to one's dwelling place too could cause great mental distress. Apart from this the loss of community based belongings will result in the loss of culture and identity of the people affected by a disaster.

Table 1. Proportional incidence of disasters (1947-1981) and loss of life by continent.

Continent	Disaster incidence (%)	Lives Lost (%)
Asia	38	85.7
North America	33	1.0
Europe	11	2.2
South America	6	4.2
Caribbean and Central America	7	4.5
Africa	3	2.0
Australia	2	0.4
Total	100.0	100.0

Source:, Awotona, A.,ed. (1997). p.7

According to the above table it appears that geographically, Asia is the most disaster-prone area on the globe. This is due to the fact that much of the continent is densely populated and lies in active seismic zones or near low-lying tropical coastal areas, subjected to cyclones. Above all, the high degree of underdevelopment ensures that most of Asia has a large number of potentially vulnerable human settlements.

In summation one could say that disasters both natural and man-made have devastating effects in the breakdown of cultural, social, political and economical set-up of a community. It appears that in order to minimise the harmful impacts of various disasters especially those caused by natural phenomena it is imperative that people take mitigatory measures and be adequately prepared. It was this intention that led The United Nations to declare the 1990-2000 as the International Decade for Natural Disaster Reduction (IDNDR).

1.3 DISASTER AND THE BUILT ENVIRONMENT

Disasters whether natural or man-made, 'cataclysmic' (fast impact such as earthquakes, floods, cyclones) or 'continuing' (long-term as in the case of wars, droughts and famines), brings destruction to the built environment, thus effecting in loss of place and community of a people. The built environment, which mirrors the way of life and identities of a society, are very vulnerable to the concomitant circumstances of disaster. In elucidation it can be said that the built environment is primarily affected in two ways. Firstly, the direct impact of a disaster harms and destroys buildings and the components of the fabric of the built environment of man. Secondly, the temporary and permanent migration of people from their homes, neighbourhoods and from places to which they belong, to other places too create an impact on the built environment. The latter could be caused by the non-usage of buildings and the resulting deterioration.

Disasters which could be considered as natural phenomena as in the case of floods or earthquakes, make it easier for man to accept it for there is no one particular person to blame. However, the destruction following war is not so easily acceptable for it is a deliberate act aimed at causing harm. In war, the hostile practices that involve the destruction of property is carried out in order to bring about a fall in the unity and power of the enemy. The specific targeting of monuments belonging to the enemy and destroying them, an architectural *damnatio memoriae was* common in acts of warfare.[2] There are 2 common ways of dealing with the targets of *damnatio memoriae.* One of then is to construct something new over the condemned property to symbolise the rise to power of those who conquered. This is best exemplified in the instance where the Flavian dynasty built over the Golden house (*Domus Aurea*) , a sprawling villa belonging to the emperor Nero upon his murder. The other option is to convert the condemned monument to some other use from its original purpose. This is best seen in the conversion of the Hagia Sophia into a mosque.

Even though, disasters bring about destruction and chaos in its wake , it also provides new opportunities for change and growth. This is well illustrated in the 'transformation of London from a mediaeval half-timbered warren into a renaissance city of paved streets and brick buildings'[3] as a result of a fire which originated in a baker's house on 2 September, 1666. Another example was the rebuilding of Lisbon after the earthquake of 1755 wiped out many areas of the city.

1.4 FLOODING AND HUMAN SETTLEMENTS

Flooding could be considered as the most widespread natural disaster, which causes extensive damage to people and property. The concentration of population and the increase of low-income settlements in flood prone low-lying land have made human settlements very much vulnerable to floods. Scarcity of land leads people to occupy areas that lie within floodplains thus paving the way for disaster.

Floods are part of the natural hydrologic process and the causal phenomena for flooding is intense rainfall or inundation associated with seasonal weather patterns. Human manipulation of watersheds, drainage basins and floodplains also contribute to it.

Factors, which contribute to the vulnerability of human settlements in flood prone areas, include the following.

- Location of settlements on floodplains
- Lack of awareness of flooding hazard
- Reduction of absorptive capacity of land (erosion, concrete)
- Non-resistant buildings and foundations
- High risk infrastructural elements
- Unprotected food stocks and standing crops, livestock
- Fishing boats and maritime industries

In Sri Lanka, flooding is the most widespread natural disaster which occurs. According to available data, Sri Lanka has experienced about 10 major floods since 1948. The very recent flood in April 1999 has directly affected around 15,000 families living in 8 districts and damaged over 10,000 homes.[4]

1.4.1 TYPES OF FLOODS

Floods basically constitute of 4 types.

1. Riverine floods

Riverine floods are the resultant of heavy rains occurring in any area of a river's watershed causing it to overflow its streambed. A river's watershed is the natural drainage basin that conveys water runoff. Rainwater that is not absorbed by soil or vegetation seeks surface drainage lines, following local topography and creating rivers and other streams. Flooding occurs when the flow of runoff is greater than the carrying capacity of watershed streams which causes them to overflow their natural streambed.

Riverine flooding usually involves a slow build up of water and a gradual innundation of surrounding land. It is usually possible to predetermine the area of flooding with the help of topographical data and flood history. In Sri Lanka, much damage is incurred due to flooding of major rivers and their tributaries. This situation is made worse by development activities in riverine floodplains resulting in the alteration of natural topography which in turn modifies drainage patterns. Development also effects in the loss of natural vegetation that formerly absorbed water and in the decrease of the permeability of the soil by covering it up with buildings or with non-porous surfaces such as roads, pavements and parking areas. Apart from these the severity of flooding is increased by natural or manmade obstructions in the floodway such as floating debris and bridge piers and also, tidal surge at the river mouth.

2. Flash floods

These result from a combination of steep slopes, a short drainage basin, and a high proportion of surfaces impervious to water which are unable to absorb runoff. Flash flooding involves a quick and intense overflow with high water velocities following rapid accumulation of runoff waters from rainstorms in hilly areas. The other characteristic of a flash flood is the rapid rise of flood water level followed by a relatively quick recession, thus effecting in a comparatively short time period between the start and peak discharge of floodwaters. These type of floods are particularly hazardous because they could occur without much warning. They also have high velocity water which has the power to sweep away most objects in its pathway.

3. Local floods (Standing floods)

These type of floods are quite common in urban areas where there is a high proportion of surfaces impervious to water and unable to absorb runoff quickly coupled with inadequate drainage facilities. Even though, local floods may not be as dangerous as flash floods they cause great inconvenience to urban dwellers, for houses and roads go underwater even after a short period of intense rain. It could be observed that during these floods a relatively large quantity of water remains over areas that are usually dry. Even though, local floods, as the name implies affects comparatively small areas, they caused widespread innundation in Colombo in 1992 and 1999.

4. Coastal floods

Coastal flooding usually occurs due to severe ocean based storm systems such as hurricanes and tropical storms. Flooding occurs when storm tides are higher than normal high tides and are accompanied by water moving at relatively high velocity and velocity wave action. The severity of the storm has a direct bearing on the velocity and range of coastal floods and damaging effects are caused by a combination of the higher water levels of the storm tide and the rain, winds, waves, erosion and battering by debris.

Among the 4 types of floods, riverine floods and local floods are the most common in Sri Lanka. The very high rainfall intensities during the monsoon season induces local floods especially in urban areas such as Colombo and Negombo. In contrast both urban areas and rural areas are vulnerable to riverine floods. Human settlements located on the floodplains of Kelani, Kalu, Mahaveli, Nilvala, Gin and Walawe rivers get affected by riverine floods.

When considering the above types of floods, it appears that if prediction was possible the extent of damage caused by them could be minimised. Flood forecasting depends on seasonal patterns, capacity of drainage basin, flood plain mapping, and surveys by air and land. For seasonal floods early warning is possible well in advance but only minutes before in case of storm surge, flash floods or tsunami.

1.4.2 FLOOD IMPACTS ON SOCIETY

The impacts of floods on society are sometimes difficult to trace or measure due to its complex and varied nature. Floods affect both formal and informal economies and tracing the effects on the latter is sometimes problematic due to its particular nature. Damage by floods can be classified as tangible and intangible, direct and indirect, primary, secondary and tertiary ones. Tangible damages are those which can be measured in monetary terms such as the destruction of a dwelling unit. The term 'intangible' is used for those effects of flooding to which it is not possible to assign monetary values such as the destruction of an archaeological site or the inconveniences suffered by residents as a consequence of a flood.

Direct flood losses are incurred when floodwaters come in to actual contact with damageable property, but indirect losses are those caused as a consequence of these direct flood losses. In elucidation, it can be said that if a factory gets damaged, it is a direct loss, but when the income from factory products is lost, this is a consequential indirect loss.

Primary impacts are those that happen immediately or the first round of impacts of flooding. These impacts most probably lead to further 'knock on' effects which are termed secondary effects. In elaboration it can be said that the primary effect of the contamination of drinking wells due to floods may lead to a shortage of potable water which is a secondary impact.

Therefore, in summation one could say that the effects of a flood is far-reaching and go well beyond the immediate effects of a flood event. Apart from this, development activities are inhibited in areas where people live under threat of floods due to prevailing feelings of uncertainty and insecurity.

1.4.3 IMPACT OF FLOODING ON HOUSEHOLDS

In Sri Lanka floods affect thousands of houses each year. Therefore it is important to understand the devastating effects of floods on both the houses and the people occupying them.

The following list shows a range of flood impacts on households.

Flood impacts on households.

Direct losses

- Damage to house structure and out buildings
- Clean up costs
- Damage to replaceable house contents
- Loss of memorabilia and irreplaceable items and pets
- Damage to health, or death or injury

Indirect losses

- Worry about future flooding and consequent lost opportunities
- Permanent removal from area
- Disruption to household because of flood damage
- Evacuation from house
- Disruption due to flood warning or alarms
- Loss of utility services
- Loss of community
- Cost of additional heating

Indirect loss resulting from flooding of other areas

- Increased travel costs
- Loss of income
- Loss of utility services
- Loss of leisure and recreational opportunities
- Loss of services
- Increased costs of shopping and recreational opportunities

Source: Parker, Dennis J., Green, Colin H., *et al. (1987). p. 98*

The house a person lives in is very sacred to him. It is a reflection of him and society. The house may be a hut or a mansion, yet it is where a person would call 'home'. Thus, any physical damage to the house would not only create practical problems that could be rectified in time by reconstruction, but it would destroy things with sentimental value that could never be replaced. Loss of irreplaceable items such as memorabilia constitute a major loss to residents. Collection of memorabilia is a part of the way people construct their past lives and loss of such items may be particularly important to the elderly and prove to be quite devastating in impact. An item like a photograph may have no market value but may have considerable sentimental value unique to those who own it. Documents such as birth certificates, driver's licences, credit cards, chequebooks, passports and insurance policies may also be lost. Such losses may cause inconveniences to the residents as well as preventing them from drawing on their assets as well as delaying them to gain access to any governmental benefits.

A flood event may pose severe stress conditions on the residents. However, before they are able to resume their normal lifestyles, they are required to recover what they can of their possessions, discover their losses, to clean up their house and make good the damage. Replacement or repair may be needed for the house and this will depends upon the availability of funds, be this savings, loans or recovery of the losses from the insurance and other sources. Those in rented accommodation are dependent upon the speed with which the owner undertakes repairs. Moreover, even when repairs have been undertaken some tenants are not allowed to undertake their own redecoration and so again will depend upon the owner's enthusiasm for undertaking this.

The disruption caused by floods is generally rated by householders as one of the most serious impacts on the household's life and this is strongly related to the severity of both structural damage and contents loss, rather than to any other impacts of flooding. Electricity wiring and installations within the house are amongst the most vulnerable items to be damaged by flooding. Moreover, until these are repaired, most activities within the home will be inhibited.

Apart from these physical damages to the structure and contents of the house, the people themselves are subjected to various conditions as a result of flooding. Death could some times occur in a very severe flood where people are carried away by the surging floodwaters and drowned. But in the aftermath of a flood, various diseases like cholera or diarrhoea become rampant due to contaminated water and food and unsanitary conditions. Apart from these, various post traumatic stress conditions could also be experienced by people exposed to the devastating effects of a flood.

Another problem that is posed by flooding is the worry about the risk of flooding in the future. Floodplain residents frequently report a high degree of worry when they believe that a flood may occur. Threat anxiety might also be expected to be related to ownership and tenancy patterns. Therefore, it can be inferred that house owners have more to lose than tenants and as a consequence may suffer more distress. Whilst flood experience and length of residence are likely to be determinants of threat anxiety, it should also be noted that public indifference towards the flooding risk is widespread and concern for flooding most often forgotten after a flood event.

NOTES

[1] Karunaratne, G. (1991). 'Overview of natural disaster mitigation: IS-01,' ***First National Course in Natural Disaster Management***, p.2

[2] Kostoff, S. (1999). ***The city assembled,*** p. 254

[3] Kostoff, S. (1999). ***The city assembled,*** p. 245

[4] Perera, L. A. S. R., (1999). 'Guidelines for construction in disaster prone area,' ***First National Course in Natural Disaster Management***, p.1

CHAPTER TWO

2 IMPACTS OF FLOODS IN THE COLOMBO DISTRICT

I do not know much about gods; but I think that the river
Is a strong brown God - sullen, untamed and intractable,
Patient to some degree, at first recognised as a frontier;
Useful, untrustworthy, as a conveyor of commerce;
Then only a problem confronting the builder of bridges.
The problem once solved, the brown god is almost forgotten
By the dwellers in cities - ever, however, implacable.

T. S. Elliot (1909-1950), who grew up near the Mississippi, never forgot the rivers symbolic power.'*The Dry Salvages,'* in Complete poems and plays p. 130

Sri Lanka is a pear shaped island located south of the Indian subcontinent in the Indian Ocean. The extreme values of the geographical coordinates of Sri Lanka are:

North	9° 51' N	(Point Palmyrah)
South	5° 55' N	(Dondra)
East	81° 53' E	(Sangamankanda)
West	79° 31' E	(Kachchativu)
	79° 42' E	(Thalaivillu on Main Island)

The main island of Sri Lanka has a maximum length of 435 km in the North South direction and a maximum width of 240 km in the East-West direction. The land area is 65,525 km^2: together with the Internal Waters of 1570 km^2, the area within the national boundary is 67,095km^2.

For administrative purposes, the country is divided into 9 provinces and 24 districts (Fig. 1). Out of these the Colombo district in the Western Province is selected for studying the phenomena of urban flooding. Prior to studying the situation of floods, it is felt that it would be useful to present some information regarding the Colombo district, in order to understand better the prevailing conditions in the proposed study area.

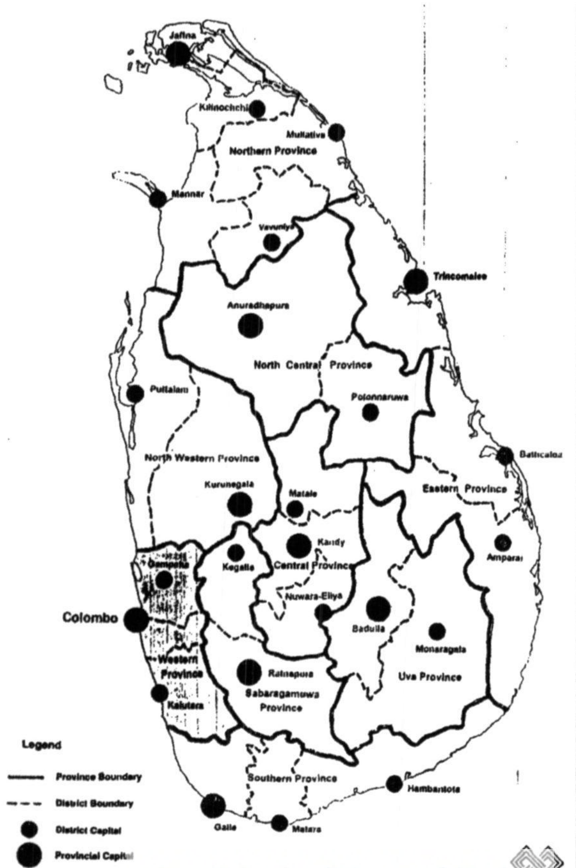


Fig. 1. Map of Sri Lanka-provinces and districts

2.1 DEMOGRAPHIC PARAMETERS AND ENVIRONMENTAL ASPECTS

Colombo district is located in the Western Province of Sri Lanka and has an extent of 69,790 ha. The provincial capital is the city of Colombo which has a history of well over 500 years. When considering the topography, the Colombo district (Annexe 1) can be considered generally as flat land with ground levels differing from less than 1 m to 6 m above mean sea levels (M.S.L.).There are a few elevated and hilly areas which rise to levels from 15 m to 22 m above M.S.L. The raised beach along the coast line (about 3.5 m to 5 m above M.S.L.) is one of the highly built up areas running along the Galle road which is about 200 m from the sea and almost parallel to the coast. There are a number of water bodies such as Beira lake, Kotte lake, Weras ganga, Bolgoda lake, Diyawanna lake and swamps such as Kimbulawala, Nawala, Heen ela and Yakbedda within this area.

CLIMATE AND RAINFALL :

The climate of Sri Lanka is classified as tropical monsoon weather. It has a wet and dry climate but the dry season is rather brief. Rainfall is heavy, that is the only form of precipitation in Sri Lanka (Fig. 2). The annual precipitation is divided into four distinct seasons, caused by the two monsoons: Northeast and Southwest.

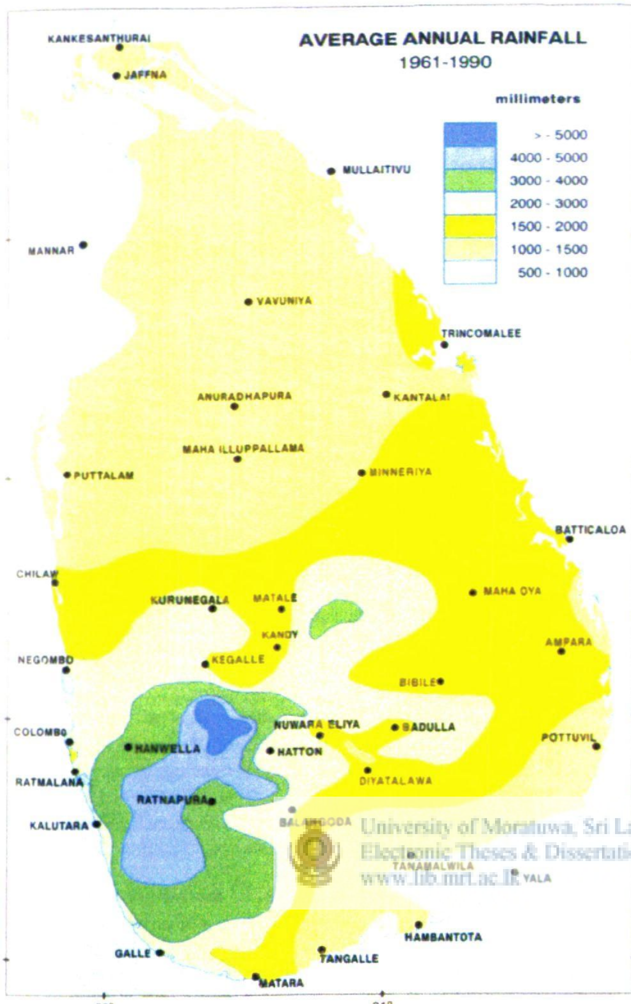
- First Inter-monsoonal;	March through May
- Southwest monsoon;	May through September
- Second Inter-monsoonal	October through November
- Northeast Monsoon;	December through Feb.

In the first Inter-monsoonal season between the Northeast and the Southwest monsoons, convective processes of air caused by the difference in the temperatures between sea and land causes rainfall which is in the form of occasional thunderstorms. These are of relatively short durations, around 1 to 3 hours. Evening thunderstorms continue during May with some showers over the Southwest coastal belt of the Island.

As the equatorial trough sets in over Sri Lanka, and proceeds northward crossing the island in May, the Southwest monsoon season starts. It continues until September. During this period, the humid Southwest monsoon, with abundant moisture supplied by the Indian Ocean, causes widespread rains covering the Southwestern region of the island. Heavy rainfall occurs in May and continues in June in the Southwestern part of the island. These monsoonal rainfall decreases in intensity during July and August, but increase somewhat in September, the last month of this season.

The rainfall in the Colombo district thus depends mainly on the Southwest monsoon and the rains received during the first inter-monsoonal season.

Fig. 2. Average annual rainfall



Source: Somasekaram, T., Godellawatta, H. (1997). p.17.

METEOROLOGY OF THE STUDY AREA:

Colombo is located in the Wet Zone. At the Colombo meteorological observatory operated by department of meteorology (DM), the average annual rainfall is as high as 353 mm for May, the first of the Southwest monsoon season. In the second Inter- monsoon season, the monthly rainfalls are high; 354 to mm (the highest in the year) for October and 324 mm for November.

The mean maximum temperatures are above 30^0 C for December, through May, and are between 29^0 C and 30^0 C for the rest of the year. The mean minimum temperatures are around 25^0 C, during the Southwest monsoon season of May through September. And they are as low as 22^0 C during the Northeast monsoon season of December through February. The number of average rainy days per month and mean annual monthly rainfall are shown below (Table. 2 and in Table 3).

Table 2. Average rainy days in Colombo

Days/Month	Period	Remarks
19	Southwest monsoon	May through September
20	Second Inter- monsoon	October through November
15	First Inter- monsoon	March through April
9	Northeast monsoon	December through February

Source: Nippon Koei Co. Ltd.(March 1994) ***Implementation Programme Annexe - 1***, p. 7

Table 3. Mean annual and monthly rainfall at Colombo

Month	Average										
	1951-80	1982	1983	1984	1985	1986	187	1988	1989	1990	1991
Annual Total	2527.3	2005.5	1,750.1	2493.1	2,232.4	1,456.6	2451.2	2,008..9	2265.7	2341.4	2096.7
January	70.1	4.1	-	211.5	83.5	144.9	98.4	3	35.8	182.7	78.8
February	87.6	0.2	43	179.6	160.8	78.4	0	63.6	6	36.9	55.2
March	121.4	311.8	60.3	162.5	116.1	81.4	73.2	206.4	146.3	184	146.4
April	286.5	108.8	83	254	76.3	216.8	179.3	185	322.9	366.9	142.1
May	288.1	323.7	336.5	491	253.1	230.9	198.4	14602	399.1	324.3	317.4
June	186.2	195	118.6	176.8	316.9	63.8	116.3	325.7	217.2	184.1	309.9
July	154.2	160.9	163.1	127.8	19.6	10.5	12	101.5	138.2	206.3	121
August	99.1	123.6	94	4.9	111.2	76.2	404.8	122.4	49.1	17.9	88.8
September	216.4	104.9	291.5	339.3	343.4	128.4	508.9	374.3	174.5	29.6	112.4
October	396	186.6	94.8	161.3	275.7	163	506.5	117.9	450.4	374.1	353.1
November	329.2	43.9	241.7	360.2	244.9	58.9	217.4	266.9	284.7	255.8	292.7
December	192.5	51	223.6	24.2	230.9	203.4	136	96	31.5	178.8	79.1

Source: Nippon Koei Co. Ltd.(March 1994) ***Implementation Programme Annexe - 1***, p. 7

DEMOGRAPHIC DATA OF THE STUDY AREA:

The Western Province has the largest population of the country (Table 4) and Colombo district could be considered as the most urbanized and densely populated area of the country.

Table 4. National Context 1994

Province	Total Population ('000)	Urban Population ('000)
Western	4542	3065
Central	2233	506
Southern	2299	811
Northern	1339	337
Eastern	1259	127
North Western	2079	530
North Central	1070	277
Uva	1085	141
Sabaragamuwa	1718	204
Sri Lanka	**17624**	**5998**

Source: Urban Development Authority.(May 1998). p.29

Considering the urban trends of Sri Lanka it is most probable that Colombo and its environs will see more growth in population due to urbanisation. Development plans such as the Colombo Metropolitan Regional Structure Plan advocated by the Urban Development Authority of Sri Lanka, if implemented will certainly promote this population growth. Relevant demographic data of the Colombo Metropolitan Region comprising of the Colombo, Kaluthara, and Gampaha districts is shown below (Table 5 and Table 6). It must be taken into notice, the increase of residential land use in the future, a fact very much pertinent in the light of our present study.

Table 5. Growth of Population in Colombo Metropolitan Region (1971-1994).

District	**Total Population (Thousands)**			**Urban Population (Thousands)**		
	1971	1981	1994	1971	1981	1994
Colombo	1498	1699	2007	1138	1264	1842
Gampaha	1173	1390	1695	337	388	869
Kaluthara	729	829	937	159	178	351
CMR	3400	3918	4639	1634	1830	3062

Source: Urban Development Authority.(May 1998). p.29

Table 6. Projected Total and Urban Population - 2000 - Colombo Metropolitan Region

District	Total Land Area			Total Population					Extent in Urban Areas		Urban Population			
	Extent			Enumerated		Projected					Enumerated		Projected	
	Gross	Residential										Computed		
		1981	1996	1981	1994	1996	2006 Low	2006 High	1981	1996	1981	1994	1996	2000
Colombo	69790	23320	28155	1699241	2007703	2009300	2159200	2366500	18130	29100	1264284	1861187	1872146	1929210
		(33.4%)	(40.3%)						(26.0%)	(41.7%)	(74.4%)	(92.7%)	(92.6%)	(92.6%)
Gampaha	139870	71890	77175	1390862	1695728	1718300	1840000	2058900	13551	37790	388342	869104	882547	907921
		(51.4%)	(55.2%)						(9.7%)	(27.0%)	(27.9%)	(51.2%)	(51.2%)	(51.4%)
Kaluthara	159760	36600	41605	829704	937183	946300	994700	1100700	4516	11572	178071	351132	409793	415235
		(22.9%)	(26.0%)						(2.8%)	(7.2%)	(21.4%)	(37.5%)	(43.3%)	(43.3%)
Total	399420	131810	146936	3919807	4640614	4673900	4993900	5526100	36197	78463	1830697	30811423	3162159	3250007
		(35.7%)	(40.0%)						(9.8%)	(21.2%)	(46.7%)	(66.4%)	(67.4%)	(67.5%)

Source: Urban Development Authority.(May 1998). p.29

Urban housing - The Middle and Upper Income Groups

During the latter part of the 20th century a growing shortage of houses in the urban areas for middle and upper income groups was evident. This situation was the outcome of several factors. Housing legislation introduced during the period of the 1971-1977 SLFP Government discouraged the construction of private houses, particularly in the rented sector, and relatively few houses were built. This situation came into existence when in 1973, the Government gave itself the power to acquire excess houses from private individuals who owned more than two houses for themselves, and one for each of their children. As a result more than 10,000 house were compulsorily purchased. Buildable land within urban areas especially in the Colombo district is very much in short supply. As a result land values within the Colombo area have escalated. Demand for housing within Colombo has also increased due to a large influx of ex-patriots and re-immigrating Sri Lankans resulting in rapid rent inflation and to housing shortages which has a domino effect down through the market.

The successive UNP Government (1977-1994) tried to give a lead in creating new housing for these groups with a number of pilot housing schemes in and around Colombo. This however, was an expensive endeavour which made the UNP Government realise that it is more feasible to encourage private house building both by individuals and by developers mainly by releasing serviced land. It appears that this trend is also being pursued by the present PA Government(1994-).

Urban Housing - The Low Income Groups

Sri Lanka's most acute housing shortages are undoubtedly experienced by the urban poor. People migrating to Colombo from rural areas in search of jobs have settled on marginal lands close to their places of work. These settlements are mostly congested and in very poor condition. Demand for housing by the casually employed workers, the dockers, the factory hands and the market porters are met in three different ways which are as follows;

a. Tenement Gardens - These were built by commercial companies for their workers in areas such as Kotahena and Grandpass and rented out. These were usually built in rows under a single roof, and each house would contain a front verandah, two rooms, a rear courtyard and a separate kitchen beyond. The blocks were arranged often around small garden areas and hence the name. They were originally of sound construction but due to dilapidation and multi-occupation they are now referred to as 'slum gardens'.

b. Slums - Slums are to be found in decaying urban areas of Colombo such as Mutwal and Hulftsdorf where in earlier times were occupied by the the Colombo elite before they moved to areas such as the Cinnamon Gardens due to forces created by the expansion of Port activities. Therefore, the abandoned mansions and the older properties of the earlier elite now occupied by the urban poor have become slums due to poor maintenance and deterioration.

c. Shanties - These are illegal squatter settlements occurring on derelict land within the towns and on low lying flood prone lands around their perimeters. Most of these lands are under government or municipal ownership, for example canal (Fig. 3)or railway line reservations. These houses are constructed using improvised and recycled materials and provide unhealthy living conditions.

It is an acknowledged fact that more than half of the population of the Colombo Municipality today live in what are called slums and shanties. Slums to be found in decaying urban areas of Colombo such as Mutwal and Hulftsdorf and the tenement gardens are now seriously overcrowded and in dilapidated condition. According to the 1981 census, there were 509,000 houses out of which 70,000 were slums. 30,000 of these were located in the Colombo Municipality area.

Fig. 3. Shanties built on canal reservations. These pose obstructions to the proper drainage of floodwaters.

2.2 PRESENT SITUATION OF FLOODS IN THE COLOMBO THE DISTRICT

Many parts of the Colombo City are subjected to frequent flooding at present. The reasons for this are urbanisation leading to reduced water infiltration into the soil coupled with quick runoff, and the inadequate and poorly managed drainage canal system. The canals which are badly silted, often clogged by water weeds and polythene bags cannot quickly discharge flood water into the sea. Unplanned land filling activities and subsequent encroachment on the low lying marsh lands have also reduced the city's natural flood storage capacity, thus increasing flood problems.

Within the Colombo Municipal Area, there are 6 major inundation areas identified by the Sri Lanka Land Reclamation and Development Corporation (SLLRDC) which are given below.

Table 7. Major Parameters of Biggest Inundation Areas in Colombo Municipal Council.

Name of Block	Total area (km^2)	Flooding Area (km^2)	inundation depth (cm)	Frequency times/y	Population in Flooding area	Shops and factories
1. St Sebastian	2.86	0.239	30	4	14570	8
2. Serpentine	1.85	0.206	25	4	5170	9
3.Torrington W	1.66	0.193	25	4	1600	0
4. Unity Place	1.24	0.181	35	8	2020	0
5. Dematagoda	1.3	0.175	25	4	4300	12
6. Mattakkuliya	2.07	0.175	15	5	3270	4
Total	10.98	1.169			30930	

Source: Nippon Koei (March 1994). ***Implementation Programme-Annexe-3***, p.8

Apart from this, areas like Nugegoda, Nawala, and Rajagiriya also experience local floods during rainy months. Most middle and upper income homes get inundated due to impermeability of built up areas and obstructions to drainage paths in the form of parapet walls around the premises of these houses.

Floods as recently as in April 1999 had severe impacts upon the city of Colombo and suburbs, as can be gathered by the following excerpts taken from a Compilation of Complaints received at the Emergency Coordinating Unit set up on the directions of H.E. the President Chandrika Kumaratunga.

Location	Impact
Narahenpita Rd. Nawala	*Premises has been inundated due to a blockage in the Narahenpita Canal*
Pelengastuduwa Housing Scheme, Rodney St	*All houses in the scheme have been under water for the first time. All ground floor occupants are displaced. Toilets of the ground floor are overflowing*
Pagoda Rd. Nugegoda	*House ground floor under water. Car in its garage is under water. Please tow it to a nearby garage at the main road.*
Sri Chandraramaya, Wedikanda, Wattala	*About 300 families in the temple vicinity are displaced by storm water. Temple is full of refugees. Flood level on the road was 3 feet high. No food for them. Provide at least bread.*
Waragoda Rd. Kelaniya	*About 25 houses under water. Cause is the filling of the low lying area nearby the SLLRDC without a proper drainage plan. There is also a blockage of a RDA culvert.*
Obesekarapura, Rajagiriya	*Around Esala Sport grounds about 100 house are under water. Problem is food.*
Kuruppu Patumaga, Borella	*Premises has been inundated due to a blockage in the Narahenpita Canal*
Sri Gnanendra Rd. Ratmalana	*About 300 families in the temple vicinity are displaced by storm water. Temple is full of refugees. Flood level on the road was 3 feet high.*
Nawagamuwa	*203 refugees at Bomiriya school, Nawagamuwa church, Ranala school. No food.*
Beddagana Rd. North Kotte	*Beddagana Rd. under water. Road drains not properly maintained. 100 families affected. Remedial measures to be taken to avert a repetition.*
Nugagahawatta, Kirulapona	*Nugagahawatta, Kirulapona a landslide. 4 houses collapsed. NHDA housing scheme.*
Torrington Mw. Colombo 8	*180 houses under water. Need food.*

As a result of these problems, the need to improve the situation was felt. The necessity of rehabilitating the canals and drainage system was already identified in the early 1980s, for instance in ECL - Samitar (1981).[1] However, the first step taken towards the improvement of the situation was the preparation of a report on a storm water and drainage project by W. S. Atkins (1985) under World Bank IDA funding. Later, under the framework of the Sri Lanka Water Supply and Sanitation Rehabilitation project of the National Water Supply and Drainage Board (NWSDB) a study of the canal and drainage system in Colombo was carried out (W S Atkins, et. al., 1988). One of the outcomes of this study was the identification of five marshy lands to be established as the so-called flood retention areas. These marshy lands are Bloemendhal / Main Drain, Mahawatte / Kolonnawa North, Kolonnawa East, Kotte and Heen marshes (covering a total area of 380 ha) and the low lying lands named as the Green Belt (several hundreds of ha) surrounding the Parliament Lake.[2]

These marshy lands which are flat and shallow act as temporary storage 'basins' where flood waters are detained before they are released to the drainage canals which interconnect them. Due to this, these areas are now known as Flood Detention Areas. The identification of these areas was especially important as they paved the way for the implementation of the Greater Colombo Canal and Rehabilitation Project (Nippon Koei et. al., 1991); renamed in 1992 as the Greater Colombo Flood Control and Environmental Project (Nippon Koei et. al., 1992).This project is carried out by the Sri Lanka Land Reclamation and Development Corporation (SLLRDC). Under this project 34 km of the already existing canal system will be rehabilitated and new ones will be constructed (about 10 km).This project will be implemented in the Greater Colombo Area within the Colombo district. This area covers 85.7 sq km and forms the catchment area for the Colombo canal system. This area is bounded on the west by the sea, on the north by the left bank flood bund of the Kelani river, on the east by a line running from Ambatale in north to Kottawa in the south and the southern boundary is a line running from Mt. Lavinia to Kottawa (Annexe 2). It is expected that these canals in combination with the Flood Detention Areas will help alleviate urban flooding.

It is important to mention here that the Central Environmental Authority (CEA) of Sri Lanka in its Wetland Site Report and Conservation Management Plan identifies three marshes i.e. the Kolonnawa marsh (an amalgamation of the Mahawatte / Kolonnawa North and Kolonnawa East marshes since they are adjacent to each other, they are considered to form one continuous marshland), Kotte marsh and Heen marsh which are under their authority as the 'Colombo Flood Detention Areas'.[3] Since the authority of the Bloemendhal / Main Drain vests with the SLLRDC and the Green Belt areas fall under the responsibility of the UDA, these two marshes are excluded from being identified as being part of the 'Colombo Flood Detention Areas'.

However, in this dissertation all five marshes and the Green Belt areas identified by the Canal Study (W. S. Atkins et. al., 1988) will referred to as the Colombo Flood Detention Areas (CFDA), since they all function as temporary storages for flood waters which has no bearing on the fact that they fall under different jurisdictions. The CFDAs fall within a catchment area that is demarcated on map 53566 / W / 1001of the Canal Study (W. S. Atkins et. al., 1988). This map specifically mentions which sub-catchments are included (e.g. Main Drain in the NW, Madiwela Main in the NE, Madiwela South in the SE, and Nugegoda in the SW), and which are excluded from this catchment (e.g. Mattakkuliya/Peliyagoda , Kotikawatta, Malabe, Kotahena, Bambalapitiya and Beira Lake). From which can be concluded that the areas along the Kelani river and the ocean front do not impact on the Colombo Flood Detention Areas catchment area.

Therefore, upon closer look at the information outlined above, three separate areas can be identified within the Colombo district, according to their distinctive characteristics which determine the nature of drainage and floods (Fig. 4). They are;

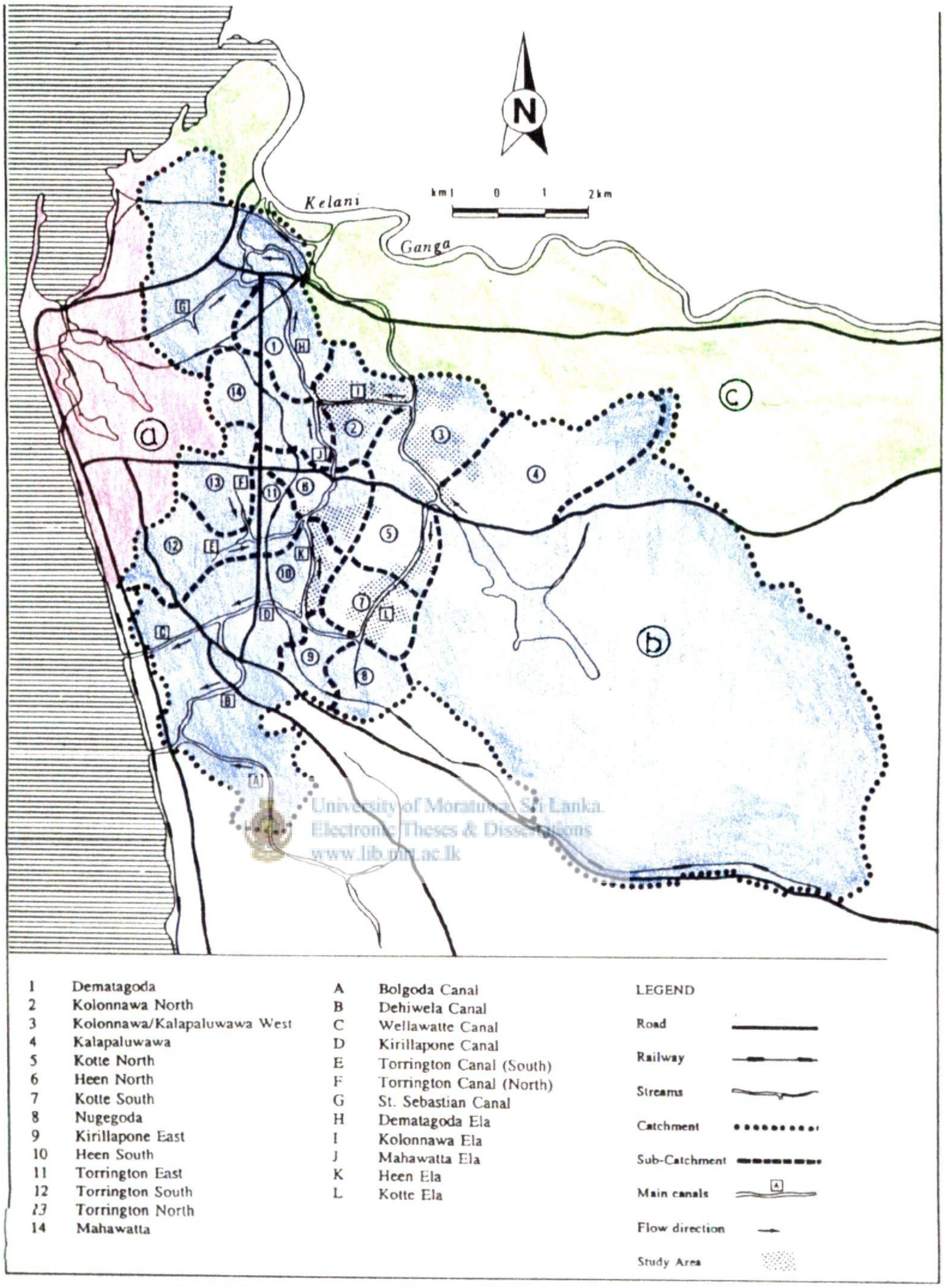
(a.) Colombo City - ocean front area

(b.) Colombo Flood Detention Areas and its catchment

(c.) Flood plains of the Kelani river

Therefore, in order to study the phenomena of urban flooding within the Colombo district, the above three areas are selected and will be examined separately for their unique characteristics which determine the mechanism of rainwater drainage and flooding in these areas.

Fig.4. The three separate areas to be studied.



Source:
Central Environmental Authority. (January 1995). p13

2.2.1 COLOMBO CITY - OCEAN FRONT AREA

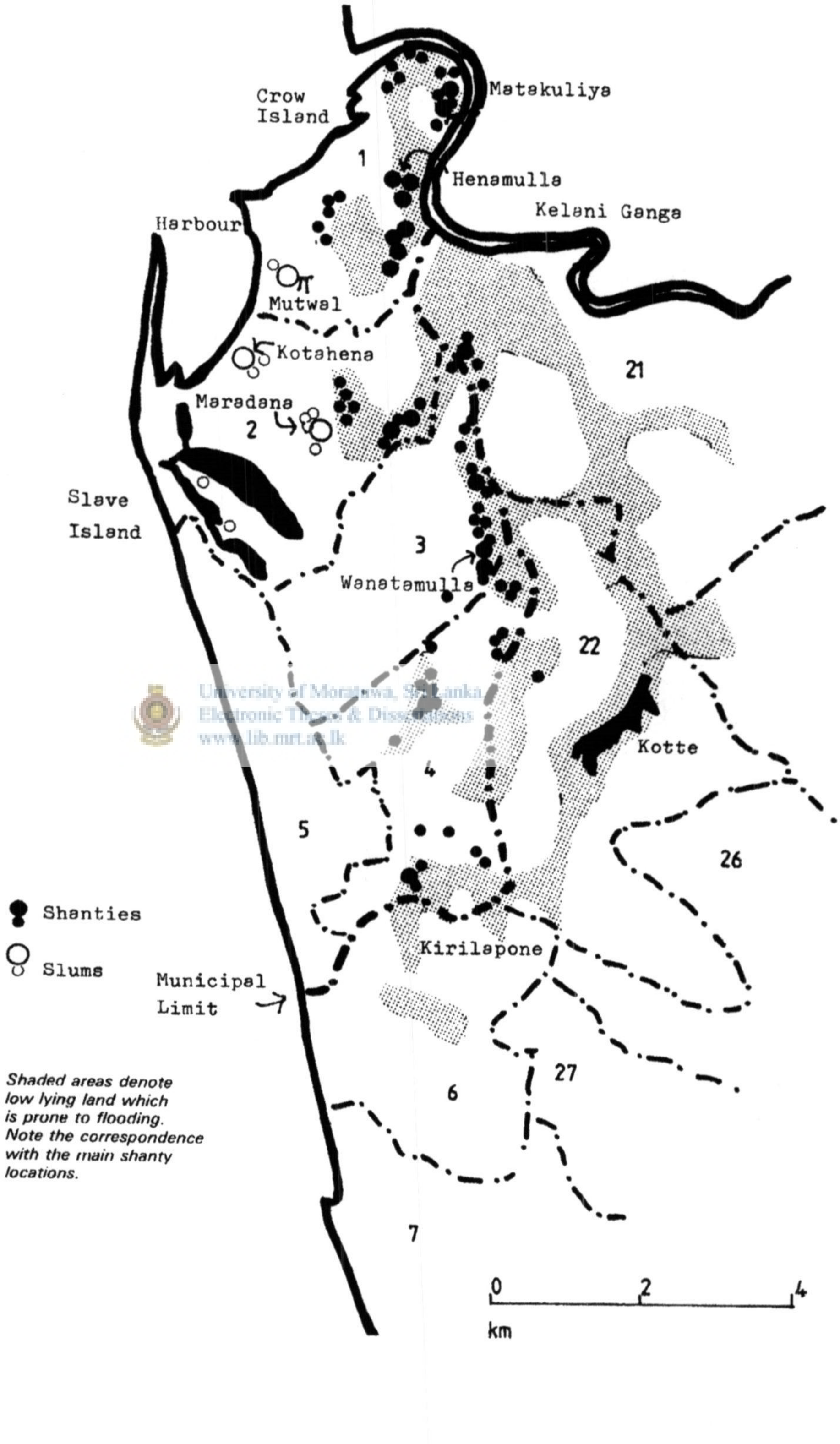
The ocean front area of the Colombo city as identified by the Canal Study (W. S. Atkins et. al., 1988) is excluded from the Colombo Flood Detention Areas catchment. Therefore, it can be inferred that the drainage in this area is not dependent upon the CFDA nor on its canal system. Before studying the system of drainage, a brief look at the historical background of the area and its topographical features will prove useful in the light of the present study. This is the most urbanised and highly built up area within the Colombo district and includes areas such as Fort, Pettah, Galle Face, Cinnamon Gardens and Union Place, all located in and around the Beira lake , the study area's most notable landmark. The buildings comprise mostly of commercial and business establishments and the residences of the well to do are located in areas like the Cinnamon Gardens. Low income houses such as slums and shanties are not abundant within this area for they are mostly concentrated towards the periphery of the Colombo Flood Detention Areas as can be seen from (Fig. 5).

The port located south of the Kelani river is an important feature of the western coastal boundary of the Colombo district. Colombo is said to have originated as a port, linking Sri Lanka with the rest of the world. There is evidence that it was used by the early Arabic, Chinese and Persian traders. It was this small harbour, which later developed to be ranked among the 7 greatest ports of the world that caused rapid expansion of the city. Prior to the improvements, the bay was said to resemble a 'hook' and the strip of land along its southern border, present day Fort and Pettah areas, saw the earliest phases of Colombo's development as a port settlement. During the Colonial period the city became the most important point of entry into the country and as well as the administrative centre of the Colonial territories and ultimately the whole of Sri Lanka.

The Kelani river which lies just north of the harbor, is another natural feature which made its impact on the development of the city. The Kelani river, regularly overflows into the marshes and swamps on its left banks, which had the result of confining the expansion of the settlement to a narrow strip along the coast. The Kelani river could be considered as a natural barrier, having a curved course and flood plains. But it appears that the river has not figured prominently in the growth of Colombo as a trade city. This is unusual in the light of development trends common to other trade cities which took advantage of the meeting of river and sea transport. This can be clearly seen in places such as Basra in Iraq and Rangoon in Burma.

It is interesting to note how the city was shaped in its early phases of growth due to the influences of the sea front on its west and the harbor in the north and the low lying marshes and swamps towards northeasterly directions (Fig. 6). However, the expanding city later reclaimed much of these marshes, which makes true the remark that 'the Colombo city is as artificial as its harbor'.

Fig.5. Slums and Shanties of Colombo.



Source: Robson, D. R., Gormley, A., Sonawane, D. (n.d.). p.32

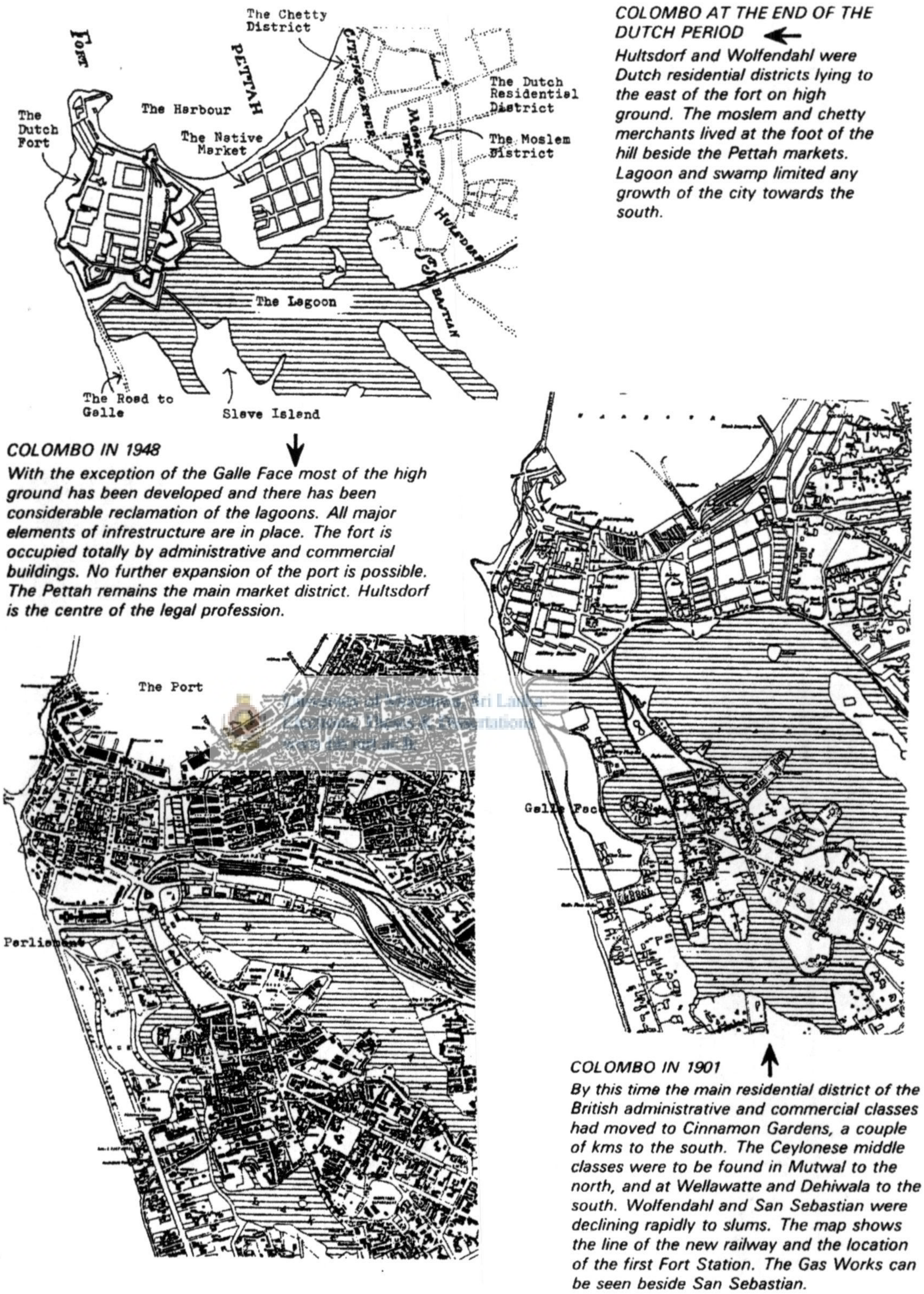


Fig. 6. The growth of Colombo

Source: Robson, D. R., Gormley, A., Sonawane, D. (n.d.). p.24

During the Dutch occupation the area now known as the Fort and Pettah was a narrow stretch of land bordered by a rather deep swampy area forming a kind of natural barrier from the land side. The area around this known formerly by a term meaning ' buffaloes plain',was improved by the Dutch by means of sluices and flood gates connecting it to the large water body there. A Dutch engineer of the name De Bear is given credit for this feat, thus giving rise to the name Beira lake as its known today. This body of water was considerably much larger than the entire built up area of the city during the 18th century. (Fig. 7). In earlier times the Beira lake was a place of activity and recreation, as is apparent from the following: *'Bathing in fresh water is a daily practice among the native inhabitants of Colombo who frequent the lake and canals in large companies of men, women and children, and immerse themselves indiscriminately'.*[4]

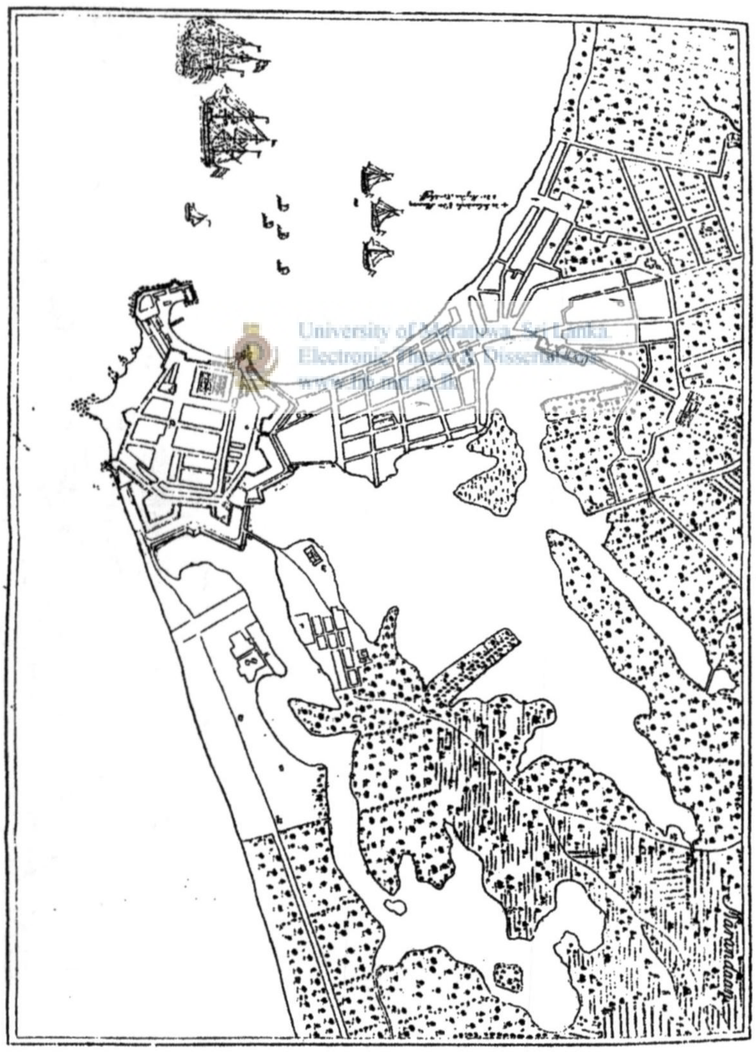


Fig. 7. Historic Sector and Beira Lake
Source: Cordiner, J.(1983). ***A description of Ceylon.***

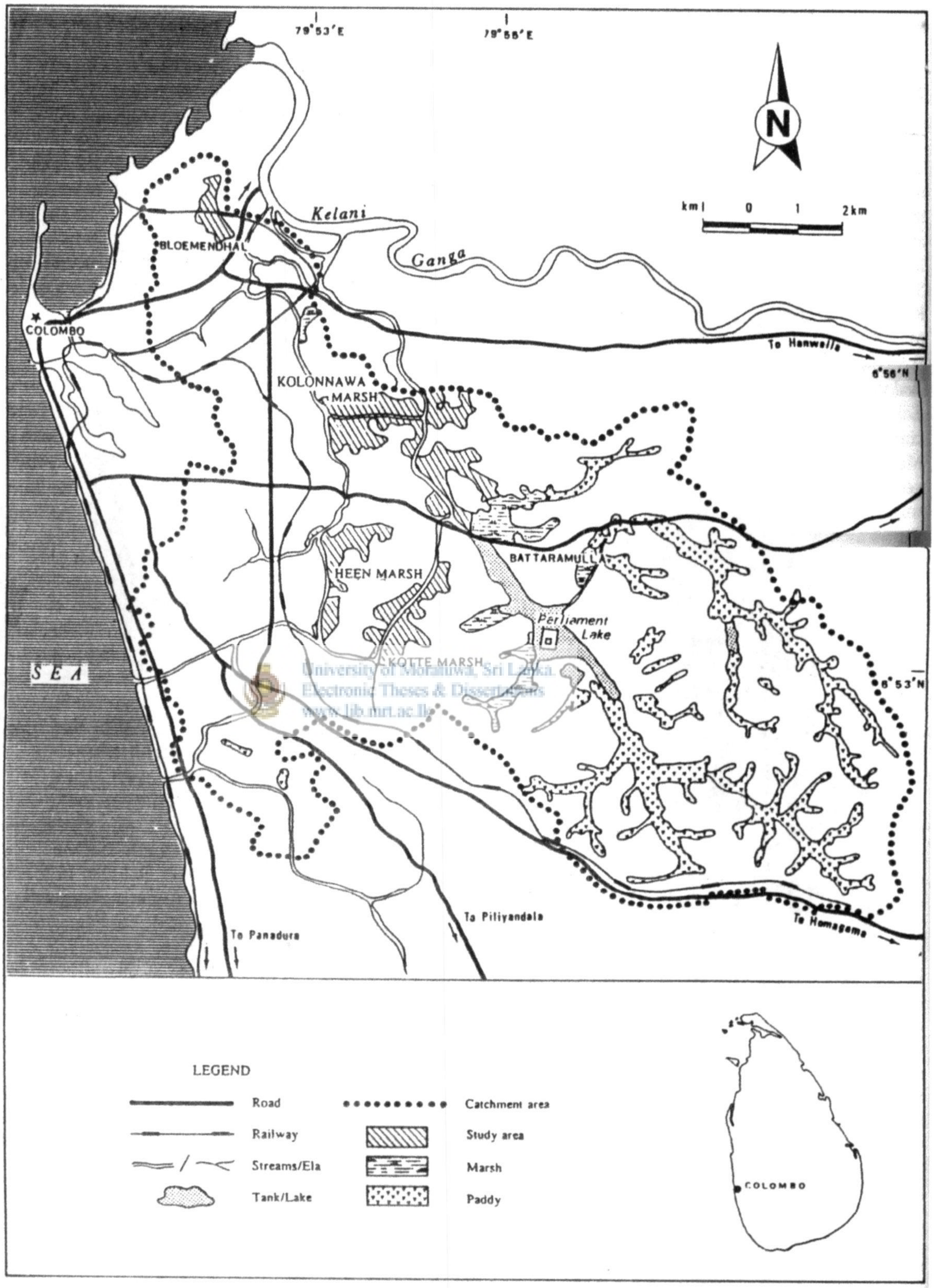
The lake had two main outlets, one near the old Parliament building, and the other by present Lake House building. However, due to stagnation and dumping of sewage , the Beira lake has become somewhat of a problem in present times, in spite of attempts to clean it up. The Beira lake was however, isolated from direct access to the sea during the early part of the 19th century, and the water level was maintained at a level varying from (+) 2.4 m to (+) 3.0 m M.S.L. as a high inland lake. As a result, the city was deprived of a natural outlet to sea. In 1918 as a result of persistent pressure the level was partially lowered to(+) 1.8 m M.S.L. and its bed dredged to (-) 0.2 m M.S.L. Beira lake is artificially kept at this level of (+) 1.8 m M.S.L. by means of pumps installed at Beira Lock and are operated by the Sri Lanka Ports Authority. According to the SLLRDC this is mainly done to prevent buildings along the lake which are constructed on wooden piles from collapsing.

With the growth of Colombo, it was required to devise a means of proper rainwater drainage for the area.The necessity of a system of drainage for the city of Colombo was recognised as far back as the late 19th century. Therefore soon after the establishment of the Municipal Council of Colombo in 1866, a Select Committee on Drainage and Water was elected. As a result, the Drainage Works discharging water to the ocean were started in 1902 and completed in two stages. The first section was completed in 1910 and the second in 1922.[5] However, in present times these have proved to be insufficient due to reasons such as poor maintenance and inadequate capacities to carry all the water discharged from built up areas. Apart from this, drainage in the ocean front areas of the city of Colombo occurs in other ways as well. Firstly, this area is the catchment of the Beira lake and excess rainwater from the lake is carried into the St. Sebastian canal which discharges to the Kelani river. However, when it rains upcountry the level of the Kelani river rises and the North Lock Gates at St. Sebastian Canal North have to be closed to prevent water from entering the Colombo canal system and thus ceasing to be an outlet. When this happens water is pumped (from a small pump house at Maradana) from St. Sebastian Canal South to Beira lake to spill at Galle Face to the sea. This provides some relief to the surrounding areas in relation to drainage Secondly, surface water entering this area from rain and surface runoff discharges through gravitation into the ocean.

According to the observations made it can be concluded that the Colombo city-ocean front area is completely urbanised and future development is thus restricted. Rain induced local floods in this area invariably inundates roads, business establishments and houses. These effect economic activities and also the health of the people. Therefore, considering the situation it appears that to improve the overall canal and drainage system is the only viable solution to the floods in this area.

2.2.2 COLOMBO FLOOD DETENTION AREAS AND ITS CATCHMENT

Fig. 8. Location of the Colombo Flood Detention Areas



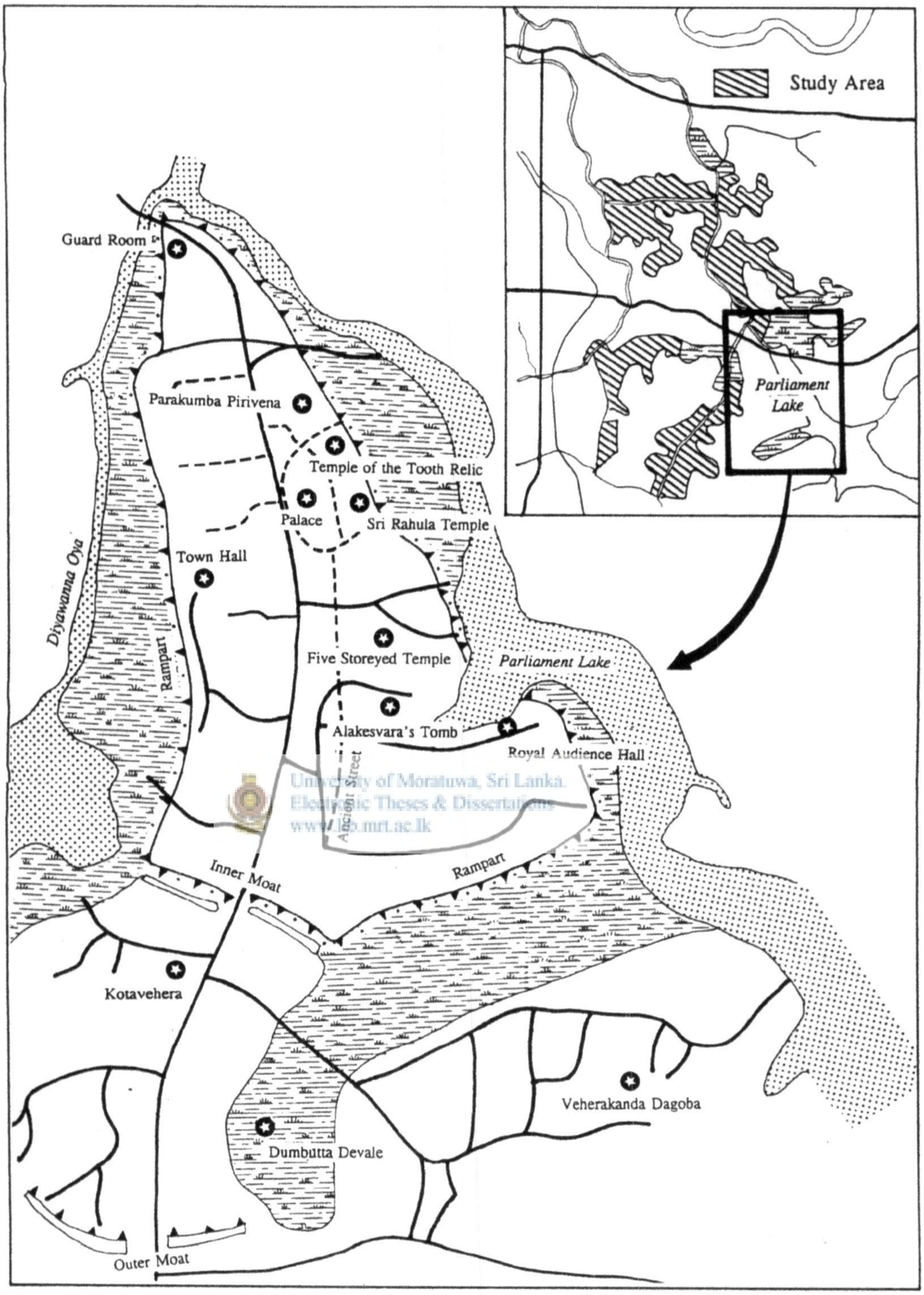
Source: Central Environmental Authority. (January 1995). p. 4

This area constitutes a rather large proportion of the Colombo district and consists of the marshes (described before), the interconnecting canals and their catchment areas. Defining the exact physical boundaries of its geographical location is rather difficult as this area is of irregular shape as can be seen above (Fig. 8).

The most noteworthy area within the CFDA is Sri Jayawardenapura Kotte which has a well documented history as can be seen from the chronicles of Sri Lanka. The ancient city of Kotte was the country's capital from 1410-1542 and again from 1551-1547 AD. At present, various historical sites have been identified (Fig.9) and documented. One of the striking remnants of this bygone era is the defensive wall or rampart about 2 m high and built out of laterite, which is still identifiable on the eastern fringe of the Kotte Marsh and reportedly under restoration at present. It is said that there was a waterway (present day marshes) surrounding the ramparts on three sides, while two deep moats on the southern end connected the waterways across high ground. This had the effect of isolating the so-formed fortress as an island. The use of traps, spikes and elk-horns on the outerground further protected the fortified city. Other features of interest in the ancient kingdom included:

- King's palace on the eastern side;
- A three storied temple for the Sacred Tooth Relic of the Lord Buddha;
- a five storied monastery where 60 monks lived;
- Kota Vehehera, a temple;
- the treasury of the king.

Fig. 9. Historical remains of the ancient city of Kotte



Source: Central Environmental Authority. (January 1995). p. 25

When considering the present situation of this area, the decision to shift the administrative capital of Sri Lanka from Colombo to Sri Jayawardenapura Kotte can be considered as having very direct consequences on the current marshlands. Much of these marshes came in to prominence with the decision to build a new parliament building in this area in 1977 and as well as the development of plans for the new capital. During the past century many of the wetland areas within the CFDA was reduced considerably due to reclamation activities. This is apparent when one considers the present areas covered by the marshes and compares them with earlier records of the same. According to a study carried out, the marsh areas to be found in 1961 can be listed as follows, but much of these areas has been reclaimed since;[6]

Mutwal marsh - originally about 71 ha. Now mostly reclaimed, due to railway line development and land fill for housing and commercial purposes.

Urugodawatte marsh - Originally about 40 ha. Completely reclaimed for the power station and Maligawatta housing scheme.

Dematagoda marsh - Reclaimed for vegetable cultivation.

Gothatuwa marsh - Originally about 280 ha, presently reduced, but included as part of the Kolonnawa marsh, identified for flood water detention.

Kotte marsh - About 240 ha. Less than half of it to be retained as a detention area.

Heen marsh - About 200 ha. Less than half of it to be retained as a detention area.

The mechanism of rainwater drainage in this area can be simply explained in the following manner; when it rains in this area the excess rainwater that is not absorbed by the ground is temporally stored in the detention areas until they are released to the drainage canals. These canals also collect the rainwater brought to them via smaller canals, drains and channels en route to the place where they will ultimately discharge the water that is being conveyed. now. Much of these canals were constructed during the Dutch occupation (1658-1796) to facilitate transportation of goods. The Lock Gates at St Sebastian canal (Fig. 10) and D.R. Wijewardena Mawatha provided entry facilities into Beira lake where warehouses were located on the boundaries There are approximately 34 km of main canals within this area and a number of smaller canals and drains. The main outlets for storm water are the Wellawatta and Dehiwela sea out falls and the St. Sebastian Canal North (connected via St. Sebastian East and the Dematagoda canal to the CFDA).Apart from this, there is a 1.8 m diameter tunnel at Mutwal which discharges storm water to the sea. However, due to obstructions and inadequate maintenance this tunnel does not function properly . Apart from this, a new canal was constructed recently which enables the storm water from the Madiwela East catchment to be diverted to the Kelani river.

At present the trend of reclaiming land for development purposes can be seen in these marshy areas (Fig. 11) and it is not apparent whether adequate measures are being undertaken in order to determine the amount of detention areas that have to be left untouched so as to facilitate proper drainage within the area. If in time these areas are to be fully reclaimed (in a similar fashion that lead to the growth of the Colombo city-ocean front area) the flood situation within the Colombo district would become very problematic indeed. The direct impacts of marsh reclamation activities on the hydrology in the Colombo urban area are increased run off and decreased infiltration and ground water replenishment. Therefore, if development activities are to be carried out in this area, it is important that they adhere to proper methods of human settlement planning and building practices, some of which are discussed in the present study.

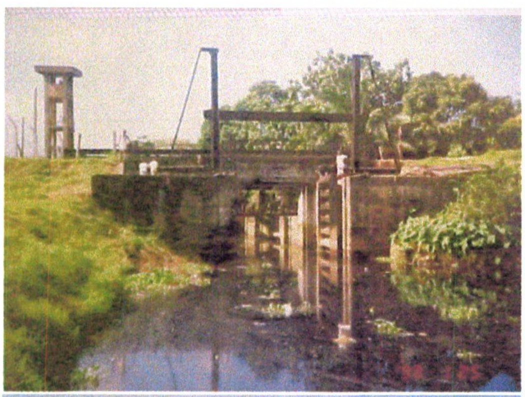


Fig. 10. The lock-gates at the St. Sebastian canal

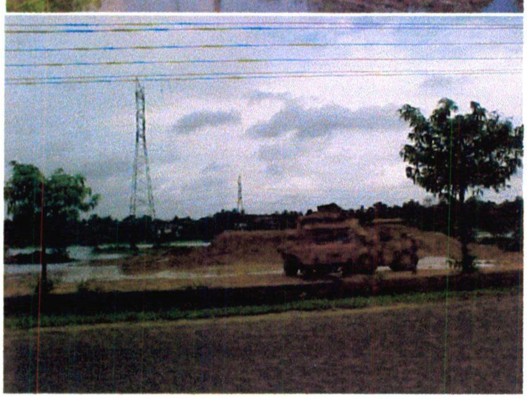


Fig. 11. Reclamation of land for development

2.2.3 FLOOD PLAINS OF THE KELANI RIVER.

As shown above, the flood plains of the Kelani river is also excluded from the catchment of the Colombo Flood Detention Areas. These areas consist of alluvial flood plains which are low lying lands with their ground levels below 1m M.S.L. As explained earlier Colombo is literally built on the banks of the Kelani river near the sea out fall, as such, the city of Colombo and the outskirts are liable to inundation when Kelani is in flood; floods are caused in the river by heavy rainfall, particularly in the upper catchment of the river. Protection against such floods are provided by Colombo flood protection embankments built by C. C. Harvard in 1922- 1924; these consist of 2.25 mile long railway embankment and the1/2 mile stretch Kolonnawa bund along with other ancillary works, which are maintained by the irrigation department. They also maintain the 4.75 mile long Kelani North Flood Protection Bund, built by the Dutch in the 18th century along the northern banks of the river, and which has been strengthened and improved subsequently (Fig. 12).

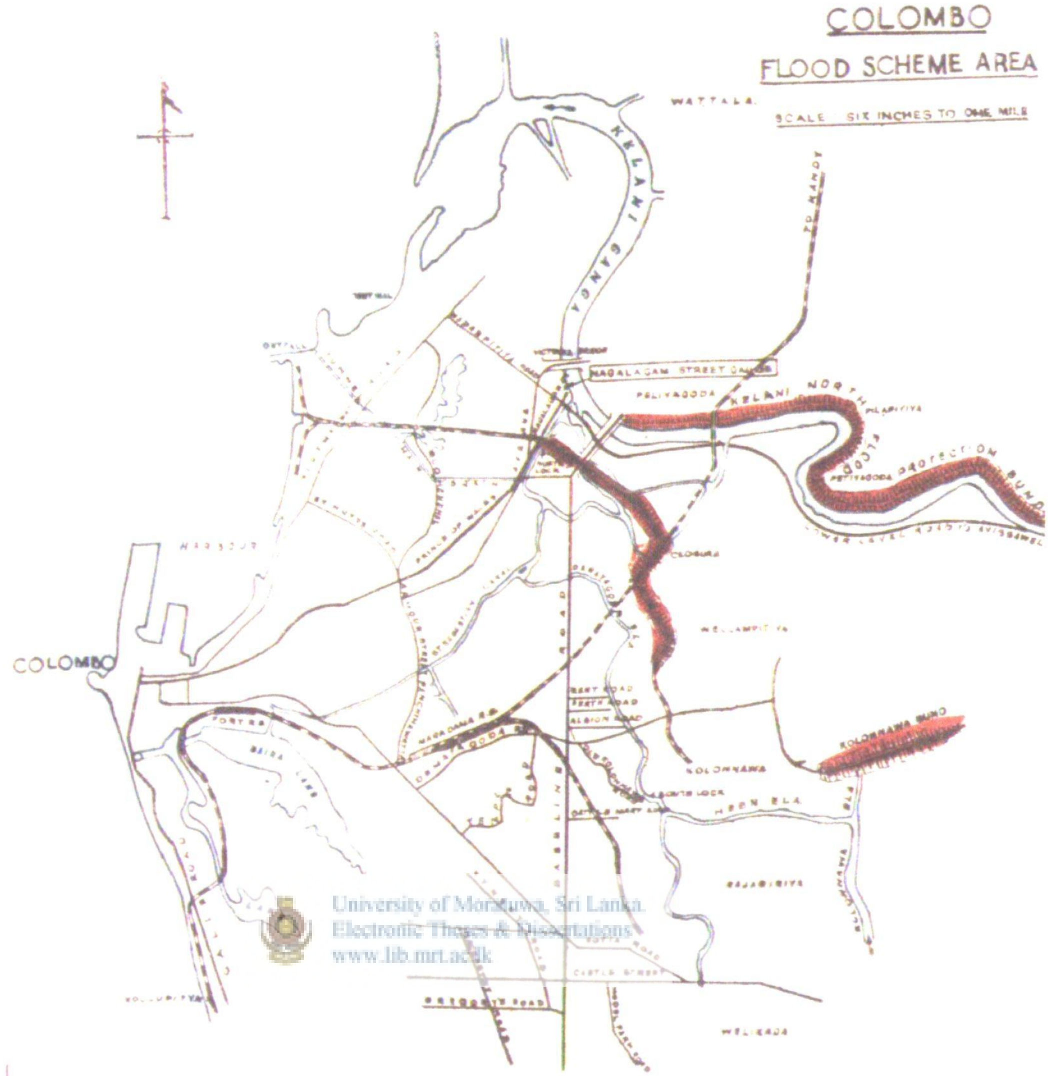


Fig. 12. Location of bunds of the Kelani river.
Source: Irrigation Dept. (1968). p. 39

All flood heights of the Kelani river are measured with respect to mean sea level datum, as read on the fundamental gauge established on the southern bank of the river at the end of Nagalagam street, Grand Pass, Colombo, by the Irrigation Department and usually referred to as *Nagalagam street gauge*.

For convenience in making observations and for the collection of data, several other subsidiary gauges have been erected, along the river and in the vicinity, viz: Victoria bridge, Mahawatte, Harbour Line, Peliyagoda, Railway Bridge, Pethiyagoda, Pilapitiya, Wattala, Talawatte etc. Gauging stations are also established higher up in the river at Kaduwela, 11 miles from Colombo, to facilitate supply of prior information of flood flows in the river. There is a radio system in the Kelani river basin to obtain the data required to issue a flood warning to Colombo city. There is also a standing order prepared to coordinate relevant agencies to mitigate floods in Colombo. This standing order is a part of the Colombo Floods Scheme Organization, originally prepared in 1922, but later amended by the Water Resources Board in October 1966 which is still being used. Therefore, it is apparent that these orders having been prepared more than three decades ago, may not be as efficient as could be hoped, taking into consideration the various changes that have taken place in the physical context of the Colombo city.

Definition of floods in the Kelani river: the following standards are adopted to indicate stages of the flood levels in the river.[7]

- minor flood level - the river is said to have reached "minor flood level", when the level of the water in the Kelani river reaches the 5 feet mark at Nagalagam Street gauge. This condition affects Ambatale Pahala area and a small section of Ferguson Road in Colombo.

- Major flood level - A major flood level is reached when the water level in the river rises to the 8 feet mark, at the same gauge. At this level, areas by Madampitiya Road, Ferguson Road and portion of Mattakkuliya are affected. Kelani North bund (on the right bank) becomes endangered and may be over-topped at certain sections when flood height reaches 9 ft. 6 in..

- Dangerous flood - a flood height of 10 feet is a dangerous flood. The railway main line has to be closed. The Kelani North Flood protection bund (right bank) is not designed against such floods and would be therefore tend to be extremely vulnerable.

- Critical flood - Over 12 feet, flood conditions reach critical stage, severely testing the Colombo South Flood Protection Works. Should the flood height reach the 15 feet mark, the railway embankment, Kolonnawa Bund, etc., are liable to be over-topped. In the event of such collapse, the following would be submerged:

  Colombo North - Bloemendhal Road, Prince of Wales Avenue, Nagalagam Street, parts of Grandpass, Urugodawatte Road, North end of Baseline Road, Kent, Perth and Albion Road, section of Dematagoda Road, Armour Street, Skinner's Road South, Panchikawatte.

  Colombo South - Temple Road, Temple lane and Old Kolonnawa Road, Area South of Cattle Mart, South end of Baseline Road, section of McCarthy Road, Kynsey Road and Gregory Road, East end of Castle Street, Section of Cotta Road, Model Farm Road, Koswatte Road and parts of Thimbirigasyaya.

Normally storm water generated in this area is directed to the river via small channels and drains. However, this area gets flooded each time when there are severe rain storms, especially because it is most likely that there will be heavy rains in its upper catchments areas as well, causing the river to swell and overflow its banks. Even though the bund located at Kolonnawa over the Kittampahuwa canal protects the Rajagiriya area from flooding, those settlements within the bund and in the flood plain itself are more subjected to the ill effects of flooding for the obvious reason that bund prevents water from flowing away from the flood plains and into the city.

Even though, the flood plains of the river are seriously threatened by floods, there are settlements located in this area. Houses located in the Kelani river flood plains are severely impacted during floods (Fig. 13 & Fig. 14).

Fig.13. Flooded houses on the banks of the Kelani river.

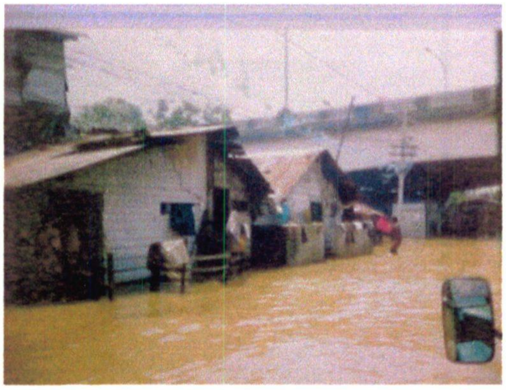


Fig. 14. Flooded houses under the Kelani bridge.

Following are some observations made from a reconnaissance survey on houses and small dwellings in this area which clearly illustrates how wrong choices and harmful actions of people have in turn aggravated the flood situation.

Fig. 15. Houses on the Flood Protection Bunds

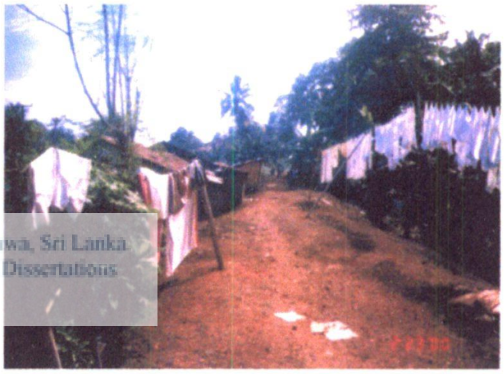


Fig. 16. Houses on the Food Protection Bunds

The above (Fig. 15 and Fig. 16) show how low income settlements have developed along the flood protection bunds thus, not only are these houses situated in a very precarious location but they also impede maintenance activities of the Irrigation Department whose responsibility is to make sure that these bunds are in good order.

This Particular section of the Bund has been selected for enlargement. But this house which is illegally placed will have to be partially demolished (Fig. 17).

Fig. 17. House to be partially demolished.

In some areas it is possible to observe steps cut into the bund to allow people to climb to the top in order to gain entrance to their houses, which obviously is an illegal action.

These two photographs below depict the same house in two instances (Fig. 18 and Fig. 19); the first shows the house during the dry season and the second is taken during a flood. It is obvious from these that this particular household must continually be subjected to the ill effects of floods, but apparently there is no proper mitigatory action taken to make the dwelling flood resistant.

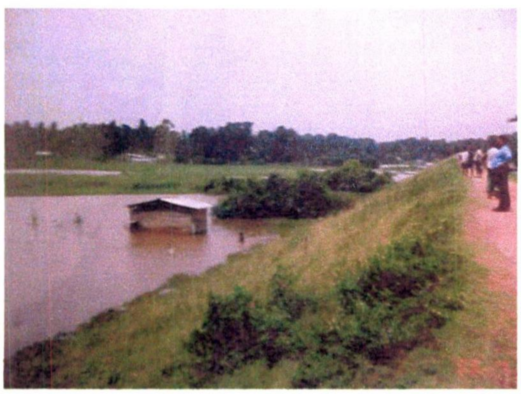


Fig.18. House-during floods.

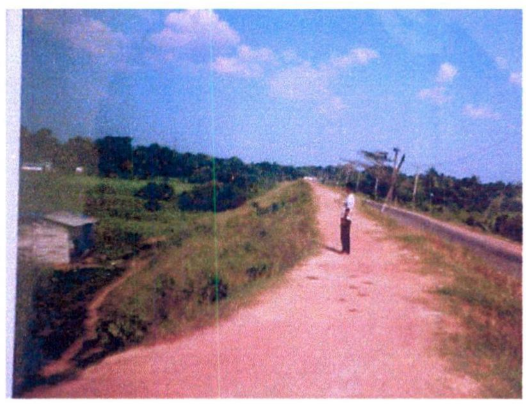


Fig 19. House-when there are no floods.

These photograph (Fig.20 and Fig 21) below show roads which are inundated during floods and making the passage of vehicles and people rather problematic during this time. Interviews conducted among residents of the area revealed that many people refrain from reporting to work and children cut school during rainy weather, when roads become impassable.

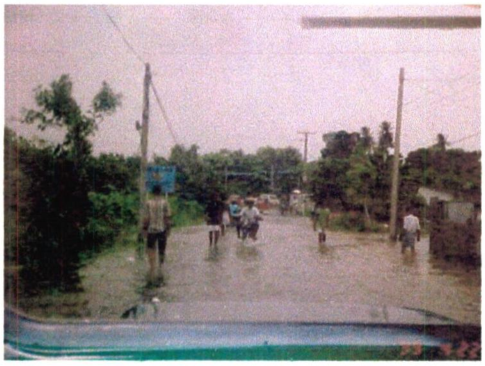


Fig. 20. Flooded roads

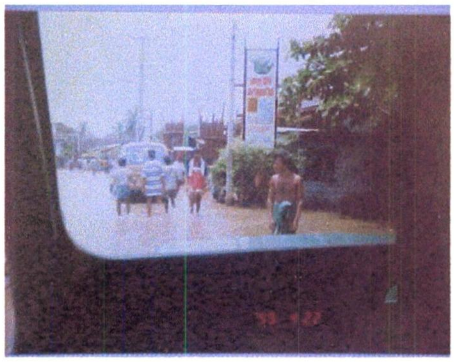


Fig. 21. Flooded roads

Houses located in close proximity to the river are sometimes in danger of being washed away as it is shown in the (Fig. 22). Here, one is made aware of the soil erosion which has taken place on the banks of the river, sometimes aggravated by quarrying of sand.

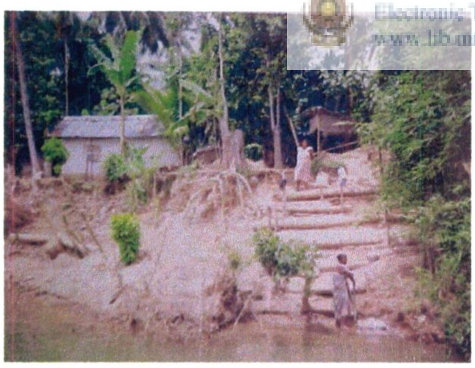


Fig. 22. House in danger of being washed away

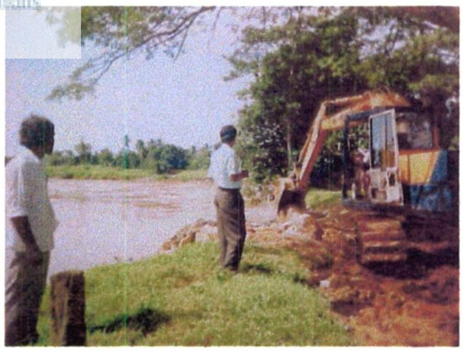


Fig. 23. Construction of groins.

To prevent high currents of water from washing away the banks of the river, structures such as 'groins' are constructed by the Irrigation Department (Fig. .23). Strong currents are diverted to the middle area of the river with the help of 'groins' to prevent them from hitting the river banks directly.

When considering the low income housing settlements in the vicinity of the Kelani river and its floodplains several things come to light. The first is the singular fact that even though these houses are threatened by floods, the inhabitants have not built safer structures to withstand floods or to minimize damages. The only action they seem to have adopted in response to a flood, is to seek refuge at a higher elevation, possibly in a temple or a school. Any possession they consider to be of value, they either take with them when they vacate their houses or they keep it in a higher place such as a very rudimentary loft (*messa)* within the house. These people consider that hazards and discomforts imposed upon them by floods as their lot and seem reluctant to change their way of thinking as regards to the construction of their dwellings.

These houses are in no great way distinctive in style or in construction to other low income dwellings found in areas not subjected to floods. Amos Rapoport hypotheses "*that house form is not simply the result of physical forces or any single causal factor, but is the consequence of a whole range of socio-cultural factors seen in their broadest terms. Form is in turn modified by climatic conditions (the physical environment which makes some things impossible and encourage others) and by methods of construction, materials available, and the technology (the tools for achieving the desired environment).*"[8] Rapoport calls the socio-cultural forces primary and the others secondary or modifying. However, by studying the houses in the affected area it can be inferred that they oppose Rapoport's theory in that they show no modification due to climatic factors.

Despite the availability of a wide range of building materials and new technologies low income human settlements in both rural and urban areas continue to be vulnerable to natural disasters. The reason for this is that either these safer building materials and technologies are not affordable to the vulnerable community or that they are misused due to lack of knowledge, thus increasing the damage risk in disasters. Building codes and other structural mitigation appear to have very little impact upon the reduction of vulnerability of low income settlements, especially because they seldom benefit from such measures. Therefore, it may be pertinent to question ourselves as to why, with the availability of many technical tools and the knowledge, very little is achieved in increasing the safety of such buildings to withstand natural disasters.

In answer to this, it can be said that there is lack of a ' safety culture' and a low perception of disaster risk by the public. However, the urban poor cannot be expected to invest in protecting their dwellings against rare and destructive disaster events, while their priorities may lie elsewhere such as in economic survival or better health and education. Sometimes, the urban poor may be reluctant to invest money for better structures, not because they are ignorant or irresponsible, but because they live in apprehension that the government may evict them from the lands they occupy. So, as a result they choose to invest in those assets that they can take with them such as television sets or stereo setups. In addition to these facts, the increased demand for housing due to population increase in urban areas, often reduces safety standards to a minimum. This is quite evident when studying the dwellings in the flood plains of the Kelani river. The earliest inhabitants in this area chose to build their houses in elevated areas and in such a manner as not to obstruct the flood waters. However, those people building their houses now pay little attention to such matters, because they have no choice but to put up a house wherever there is space, without paying due consideration as to how it will respond in a flood situation.

NOTES

[1] Central Environmental Authority/Euroconsult.(January 1995). ***Wetland Site Report & Conservation Management Plan, Colombo Flood Detention areas***, p.1

[2] Central Environmental Authority/Euroconsult.(January 1995). ***Wetland Site Report & Conservation Management Plan, Colombo Flood Detention areas***, p.1

[3] Central Environmental Authority/Euroconsult.(January 1995). ***Wetland Site Report & Conservation Management Plan, Colombo Flood Detention areas***, p.1

[4] Cordiner, J.(1983). ***A description of Ceylon***, p.25

[5] Hulugalle H. A. J. (1965). ***Colombo Municipal Council Centenary Volume***, p. 200

[6] Central Environmental Authority/Euroconsult.(January 1995). ***Wetland Site Report & Conservation Management Plan, Colombo Flood Detention areas***, p. 24

[7] Water Resources Board. (1968). ***Scheme of Organisation and Standing Orders***, p. 2

[8] Rapoport, A.(1969). ***House form and Culture***, p.47

CHAPTER THREE

3 ADAPTATION TO FLOODS: GUIDELINES FOR HUMAN SETTLEMENT PLANNING.

Due to the scarcity of available land, people are forced to occupy flood prone areas. A community that is vulnerable may be able to adapt to floods if they are willing to tolerate flooding to some extent. In such a situation floods are not eliminated by structural means such as embankments to control riverine floods, seawalls to control coastal floods, dams to control flash floods and canal networks to control standing floods. But instead non-structural methods are employed which enable people to adapt to flood situations. These measures are basically flood plain management techniques which address the need to reduce the losses incurred when flooding does occur rather than trying solely to prevent floods.

3.1 FLOOD PLAIN ZONING

Various social and economic reasons make it necessary for people to occupy floodplains. However, a certain amount of control must be exercised when development takes place in such areas and construction must be done only in places posing the least risk. This concept is incorporated in flood plain zoning. Therefore, by considering the degree of risk and likely damage, zones can be demarcated in flood hazard areas. Through land use control and regulatory measures development can be controlled in these zones, thereby determining the type and density of occupation of each.

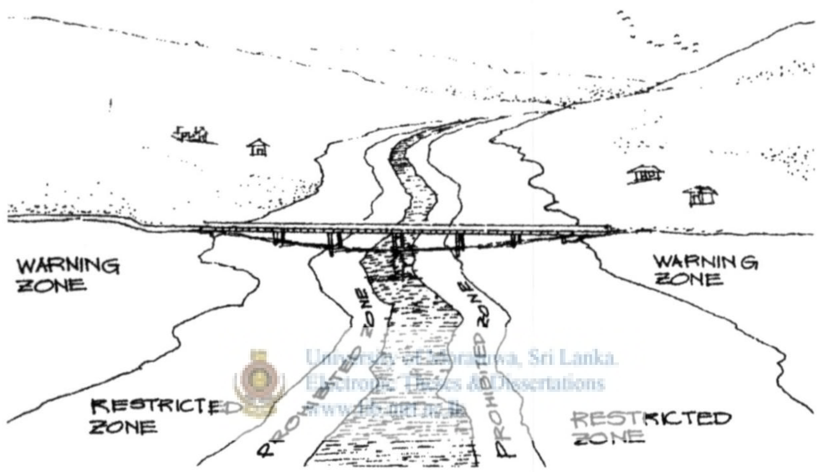
Floodplain zones (Fig. 24) usually identified are as follows;[1]

Prohibited Zone: The essential part of the floodway is identified as the prohibited zone in the floodplain. Any kind of development activity within this zone that would put life and property at risk should be prevented totally. However, the prohibited zone can be used for other activities that do not need occupancy of land.

Restricted Zone: The restricted zone comprises of the area within the floodplain where flooding is not so frequent and severe. As the velocity of floodwaters in this area is low, limited building and agricultural activities could be allowed with restrictions imposed on density and land use. Any buildings in the area must have flood resistant characteristics and have a minimum ground floor level.

Warning Zone: The warning zone can be identified as the area beyond the recorded maximum flood level where inundation is considered rare and hence less vulnerable. However, those who wish to settle within this zone are made to understand that there is a risk involved and they are warned and advised that any loss suffered will have to be borne by them. Therefore, in deciding the choice and type of development, one has to consider the possibility of flooding even though there are no mandatory flood resistant design criteria or regulatory measures enforced within this zone.

Fig. 24. Floodplain Zones



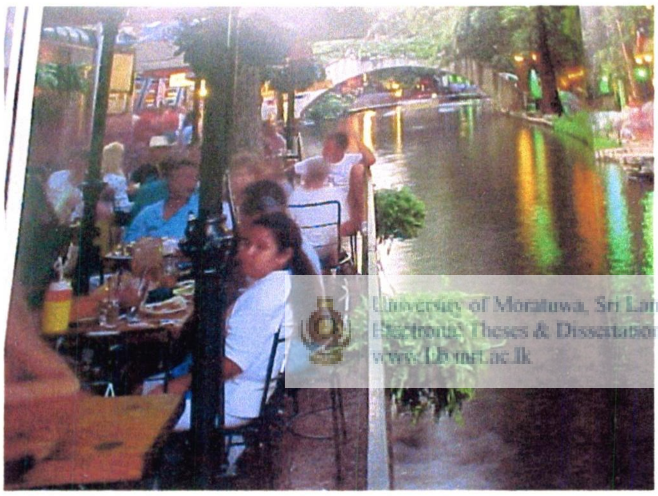
Source: Perera, L. A. S. R., (1999). 'Guidelines for construction in disaster prone area,'

3.2 LAND USE CONTROL AND REGULATORY MEASURES

The type of land use in flood hazard areas are significant aspects to be considered in mitigating effects of flood disasters. In rural areas the conversion of wetlands for agricultural uses and the construction of road networks across flood plains have changed drainage patterns. This is also true in urban areas where increased building activities as well as the conversion of wetlands for non-agricultural uses have resulted in similar situations. Moreover, flooding has very severe impacts on the land itself, where it washes off the fertile topsoil and leaving behind a rugged surface that is unsuitable for any land use. Flooding also causes disturbances to the existing land uses as it brings and deposits large quantities of silt, sand and debris along with its flood waters.

Therefore, in developing flood prone areas one must allocate proper land uses for the different floodplain zones. For instance a passive technique such as a 'river walk' can be used along the banks of a river prone to flooding. This technique has been used to effect in San Antonio, Texas where it is very near the source of its namesake river. Earlier in the 20th century the San Antonio river was a menace during floods. However, after a flood in 1921 a local businessman initiated some changes in the path of the river and converted the loop in the river into a river walk (Fig. 25). The river walks banks are bordered with shops, cafes, cantinas and an outdoor theatre where the audience and stage straddle the river.

Fig. 25. San Antonio, Texas - River walk



Source: Moore, C. W. (1994).

Hence, it is required that in proposing changes of land use in relation to development activities, careful consideration must be given to floodplain management techniques and follow land use control and regulatory measures. Therefore, it is required to formulate Land Use Plans in conjunction with Flood Zone Management Plans. Following is a listing of some specific guidelines for settlement planning in flood prone areas.[2]

1 Settlements should be strictly avoided in the prohibited zone.

2 Regular observation and monitoring should be done in the prohibited zone to prevent illegal settlements.

3 Settlements should not be promoted and encouraged in the restricted zone. Voluntary settlers should be sufficiently warned and advised.

4 Storage facilities should be ensured in unoccupied floodplain areas such as marshes and estuaries for storing peak discharges of floods.

5 Reclamation of land in flood prone areas should be strictly controlled and monitored.

6 Construction of riverbanks or raising the levels of existing riverbanks should be done to prevent inundation of dense settlements in urban areas after assessing their vulnerability.

7 Proper drainage systems and escape routes should be designed in urban areas and in housing settlements prone to floods.

8 At least the emergency routes should be kept free of floodwaters by means of proper drainage systems, embankments etc.

9 People should be educated about the importance of keeping the drainage systems unblocked and the responsibility of keeping them in good condition should be shared by the community and the local authority.

10 Growing of steady trees along river banks and coast lines should be promoted in order to reduce the velocity of flood waters.

11 Similarly housing settlements should be surrounded by green belts with steady tree in order to reduce the velocity of floodwaters.

12 The concept of floodplain zoning should be developed and implemented by every local authority area vulnerable to floods.

13 It is desirable to enforce some planning by-laws to see that welfare and safety of individuals as well as community is protected.

14 Every local authority area prone to floods should have its own Flood Zone Management Plan to control occupation and development of land within this zone.

15 The land use planning by-laws of such Flood Zone Management Plans should be strictly enforced.

3.3 SITE SELECTION AND ANALYSIS

It is always better if site selection avoids flood prone areas. If this is not possible, it is important to check the level of expected floods in relation to the proposed site and to consult local flood history data before making a final site selection. Development should not take place in identified mudslide or erosion prone areas. Development should only take place if site and soil investigations and proposed construction standards assure complete safety for future residents.

Site selection criteria should include drainage, height of the water table, soil and rock formations, topography, water supply and sewage disposal capability as well as economic and planning criteria such as cost, access and compatible land use.

Elevated residential projects which are normally proposed for flood prone areas necessitate careful site analysis which include studying of flooding, soil and wind characteristic

3.3.1 FLOODING CHARACTERISTICS

Floodwaters impose *hydrostatic* forces and *hydrodynamic* forces.[3]

Hydrostatic forces: These result from the static mass of water at any point of flood water in contact with a structure (Fig. 26). They are equal in all directions and always act perpendicular to the surface on which they are applied. Hydrostatic loads can act vertically on structural members such as floors and decks, and can act laterally on upright members such as walls, piers and foundations.

Hydrodynamic forces: These result from the flow of flood water around a structure, including a drag effect along the sides of the structure and eddies or negative pressures on the structures down-stream side (Fig. 27). These are more common in flash floods, coastal, floods and when water is wind driven.

Fig. 26. Hydrostatic forces

Source: FEMA, (March 1984) p. 10

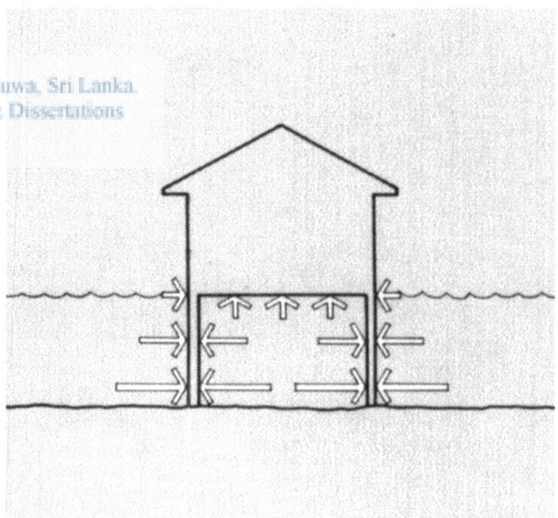
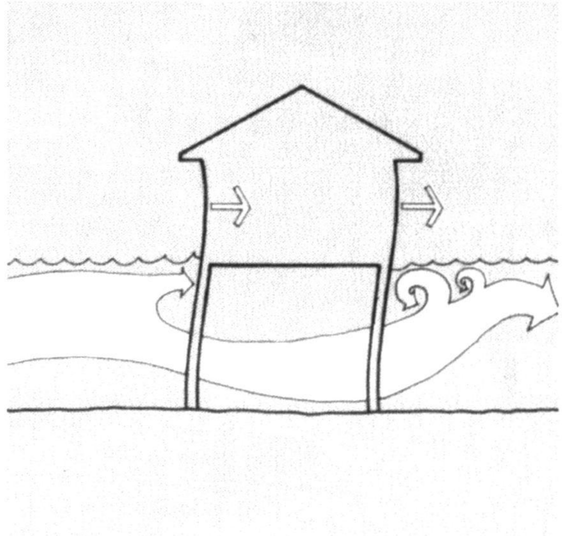


Fig. 27. Hydrostatic forces

Source: FEMA, (March 1984) p. 10



3.3.2 SOIL CHARACTERISTICS

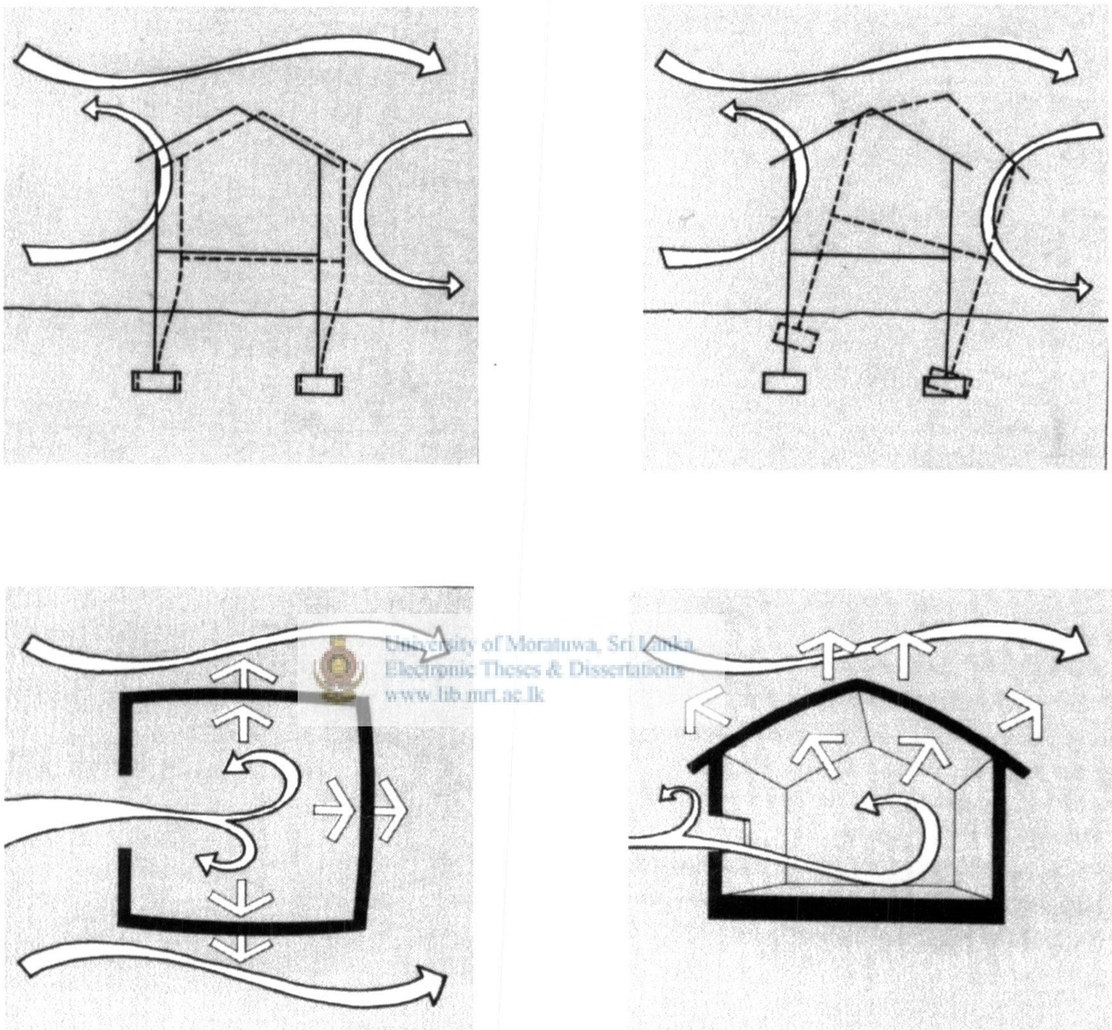
The characteristics of the soil is very important when constructing in a flood area. Its bearing capacity for instance will determine appropriate design options. If fill is to be used, highly erodable soil should not be used unless the fill is adequately protected. When erosion removes the soils supporting the foundations, the foundations are at risk of failing.

Therefore, it may be desirable to consult a qualified soils engineer familiar with the soils at the site before design is initiated. Detailed topographic maps must also be developed as part of the site-specific investigation and would also prove useful in developing grading and landscape plans.

3.3.3 WIND CHARACTERISTICS

Buildings which are elevated off the ground are more vulnerable to wind effects. The following diagrams (Fig. 28) show the effect of wind forces on elevated structures.

Fig. 28. Wind Forces



Source: FEMA, (March 1984). p. 12

NOTES

[1] Perera, L. A. S. R. (1999). 'Guidelines for construction in disaster prone area,' ***First National Course in Natural Disaster Management***, Pp. 4-5

[2] Perera, L. A. S. R. (1999). 'Guidelines for construction in disaster prone area,' ***First National Course in Natural Disaster Management***, Pp.6-7

[3] FEMA. (March 1984). p.10

CHAPTER FOUR

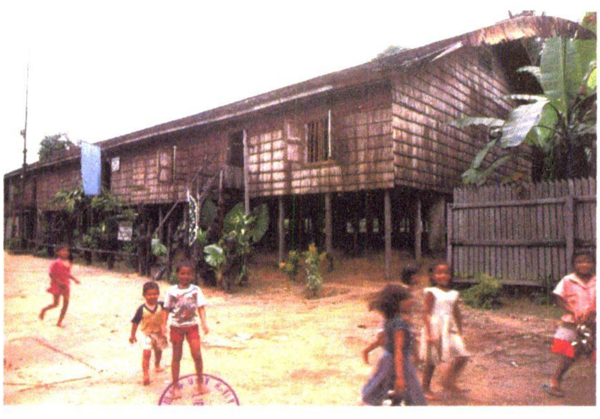
4 ADAPTATION TO FLOODS : GUIDELINES FOR DESIGN AND CONSTRUCTION OF FLOOD RESISTANT HOUSING

Architecture is the first manifestation of man creating his own universe, creating it in the image of nature, the law which govern our own nature, our universe. The laws of gravity, of statics and of dynamics, impose themselves by a reductio ad absurdam : everything must hold together or it will collapse.[1]

Le Corbusier in Towards A New Architecture

Designs for flood resistant housing usually calls for elevated structures amongst other requirements. However, in Sri Lankan traditional architecture we do not have a precedence for elevated secular buildings, unlike in some South Asian countries such as Indonesia or Malaysia. In these countries the elevated house is commonplace as it has many advantages for life in a monsoon climate, raising the house to a height at which the cooling upper breezes can penetrate while providing excellent underfloor ventilation in hot weather. It also keeps the occupants safe and dry away from rain muds and floods. Below is an illustration which very clearly depict the type of elevated secular buildings to be found in the Indonesian countryside (Fig. 29).

Fig. 29. Children playing out side a Malay house on stilts



Source: Dawson, B., Gillow, J.(1994).

In Sri Lanka, two types of elevated structures have been used but they were not for housing purposes. One is the '*ambalama*' or the wayside resting place (Fig 30) which was traditionally constructed under the patronage of the ancient kings or the noblemen of the time to provide a place of rest for wayfarers. It was also a gathering place for the village folk in the evenings, where they got together to exchange news and generally to socialize. Even though, it is possible to find this type of building at present in various parts of the country, they no longer function as an important social institution as before.

The other type of elevated building used traditionally has been of religious significance. A special type of image house (*Pathmagara*) evolved in the 17th and 18th centuries during the Kandyan period. They were shrine rooms built on pillars known as '*tampita vihara*', its name deriving from its form of construction (Fig 31). The '*tampita vihara*' structure accessed by a flight of steps was instrumental in inspiring awe and reverence in the heart of devotees by its elevation which lifted it above other buildings signifying its importance.

Even though Sri Lankan villagers built their traditional vernacular houses firmly on the ground they nonetheless used a type of elevated structure to store their paddy harvest. These grain storages (*vee bissa*) were located outside the dwelling and was constructed on top of boulders (Fig 32) to keep it out of harms way in rainy weather and to prevent rising damp and infestations from insects and vermin.

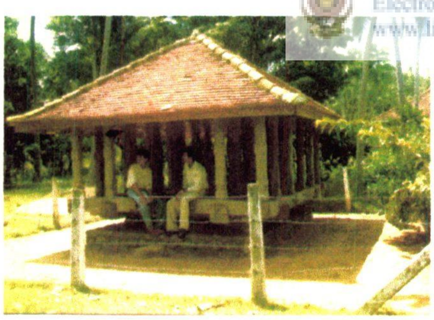


Fig. 30. Panavitiya *Ambalama*

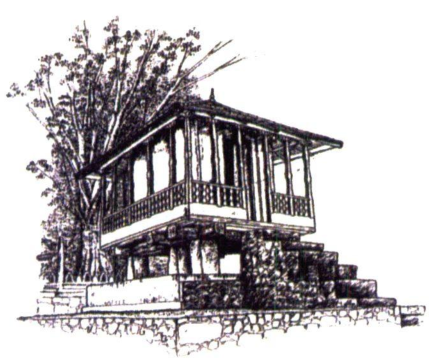


Fig 14 Tampita Vihara of Niwakka.

Fig. 31. *Tampita Vihara* - an elevated structure

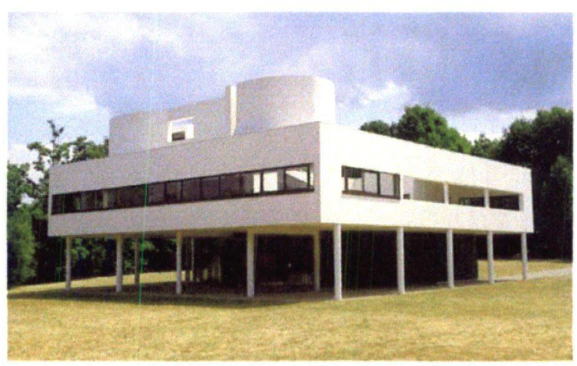
Source: Alwis, P. (1997)

Fig.32. Grain storage- *vee bissa*

Rapoport says that a " *house is a cultural phenomenon, its form and organisation are greatly influenced by the cultural milieu to which it belongs.*"[2] He expounds that factors such as climate is only secondary or modifying in the determination of house form. Therefore, even if elevated residential structures may look and feel alien to us, it is time that we understand its need, in order to minimise flood damages that are all too common at present.

The 20th century gave rise to many new innovations in the fields of science and technology. Architecture too was influenced by these great discoveries and many new features were introduced to buildings as a result. Many of 20th century's most celebrated buildings have been elevated residential structures. The inspiration from Le Corbusier's raised houses in the 1920s paved the way for modern architecture and was made possible by structural innovations. The Villa Savoie at Poissy (1929), for example is elevated above ground with the use of pilots, thus freeing the ground level for parking and allowing for a spatial continuity with the surrounding landscape (Fig. 33). Corbusier expresses his delight at all the possibilities afforded by elevated design in his book Towards A New Architecture : " *the house on columns! The house used to be sunk in the ground: dark and often humid rooms. Reinforced concrete offers us the columns. The house is in the air, above the ground; the garden passes under the house.*"[3]

Fig. 33. Villa Savoie at Poissy
Source: www.bc.edu

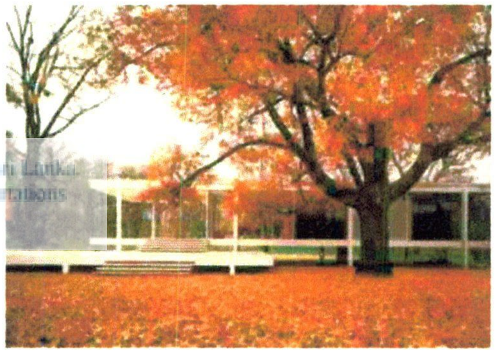


However, Corbusier did not have to concern himself with the problem to of flooding when he designed Villa Savoie, since it stood on a mound in the middle of a pasture unaffected by floods. Other well-known practitioners of modern architecture however, used the principles of the elevated residential design, in order to create both aesthetically satisfying and functionally suitable buildings in areas susceptible to the hazards of floods.

Farnsworth House (1950) designed by Mies Van der Rohe can be cited as one such example. It is considered as one of the greatest icons of modern architecture and its design has been primarily influenced by the nature of its flood prone site. The house was built in close proximity to the Fox River in rural Illinois, USA, which overflowed its banks each spring. Therefore, the house had to be designed in such a way as to accommodate this body of water. Mies solved the problem by raising the plane of the ground floor above the flood level, thus incidentally creating his first clear span building. The resulting building appears to be floating above the ground (Fig. 34).

Fig, 34. Farnsworth House

Source: www.cc.columbia.edu



Designing houses for flood prone sites need careful consideration for it is essential that the final product combine both a good design and good flood protection qualities. Good design encompasses the effective use of the site, and the fulfilment of the needs and requirements of those who will ultimately occupy the building. It must also pay attention to the needs of the surrounding neighbourhood and community.

The best houses designed allows for a clear transition from ground to dwelling, integrating the foundation with the rest of the structure. It is also better if the elevated building does not stand out conspicuously against the background but rather it blended harmoniously with its surroundings. This can be achieved by the creative use of landscaping with trees, shrubs, boulders or fences to enhance the appearance of elevated structures by softening the effect of potentially harsh or barren exposures. Landscaping if used effectively also lessens soil erosion and protects the dwellings from the impacts of debris and high velocity flood waters. In order to achieve continuity with the surrounding areas, terracing and level changes can be used with great effect. These strategies provide a sense of variety by indicating various functions that occur simultaneously on a single site.

The site considerations outlined above are only a part of a total design scheme. The following design examples are indicative of these and many other important factors in flood resistant design.

Example 1: Floating House for low income families [4]

Klong Toey, Bangkok,

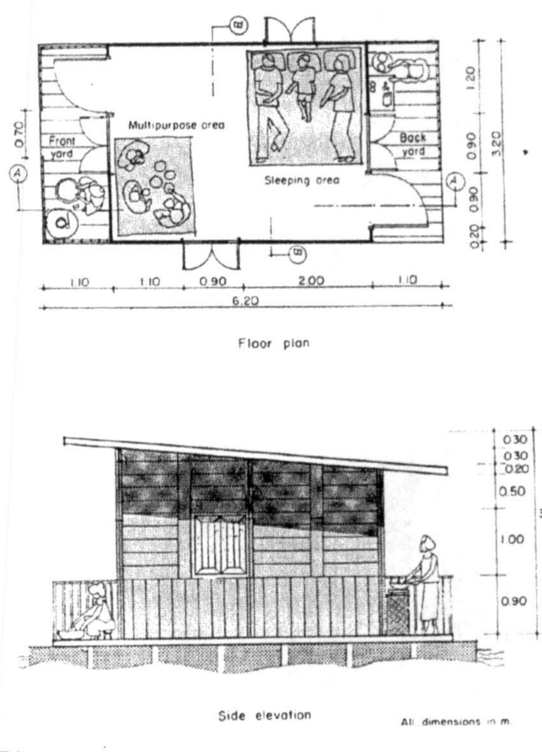
Thailand

Architect : Sigit, I.E.L.

The proposed design is a ferrocement floating house ideally suited for marshy lands subjected to frequent flooding. The National Housing Authority of Thailand was instrumental in building a demonstration house of the above type at Klong Toey which is one of the largest slum and squatter settlements in Bangkok. The environmental conditions in the settlement are very poor with services or public utilities almost nonexistent. It is located in a swampy area subjected to frequent flooding with condensed houses built with used materials.

Therefore, the need for a better type of house which suited both the environment and as well as the needs and affordability of the people was fulfilled with this particular design. The proposed design is for a prefabricated ferrocement system using half cylindrical ferrocement pontoons for the floating foundation, ferrocement planks for the walls and floors, and corrugated ferrocement sheets for roof covering (Fig. 35). The advantage of this design is that it could be built incrementally (step-by-step), depending on the availability of funds of the owner (Fig. 36). The construction of the house does not need heavy machinery and can be built manually, using self help and/or hired labour.

Fig. 35. Ferrocement floating House - Floor Plan & Side Elevation
Source: Sigit-Arifin, I. E. L., et. al. (April 1990). p. 136



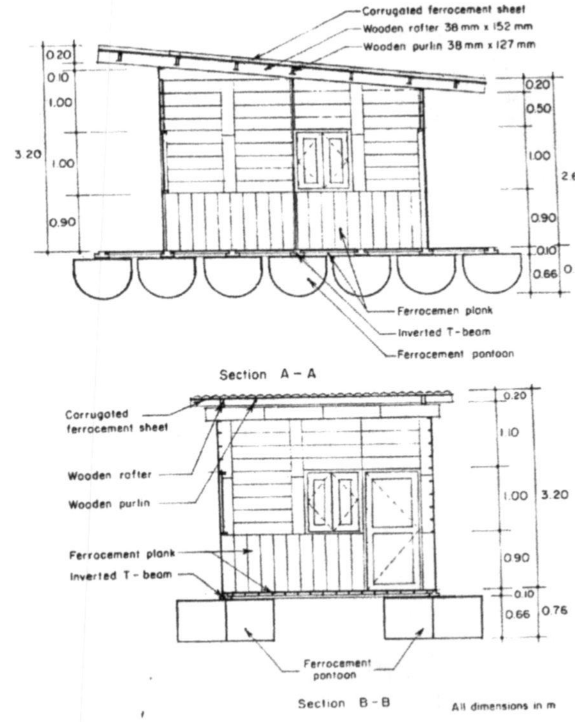


Fig. 36. Ferrocement floating House - Sections
Source: Sigit-Arifin, I. E. L., et. al. (April 1990). p. 138

The construction technique of the ferrocement house is such that, it can be easily dismantled and re-built in another site in case the family moves on. This can be considered a very useful feature for slum people occupy land on a temporary basis; they can be evicted at any time by the Government. It has also been found to be less expensive in comparison with other housing solutions.

The National Housing Authority and a private developer have offered to produce the ferrocement planks and pontoons in order to make the design affordable for poor people. It is hoped that the people will acquire the building components in either of two ways; namely according to their affordability when they are building step-by-step or through credits or loans from their 'building component credit'. In conclusion one can say that the proposed ferrocement prefabricated housing system has considerable potential for low income families.

Example 2 : Water Bungalow

Epitamulla road, Pitakotte

Sri Lanka

Architect : Anura Rathnavibhushana.

The 'water bungalow' is a proposal by Archt. Anura Rathnavibhushana, who wishes to build a house for himself and his family at Pita Kotte which is in a low lying marshy area. In this regard he is proposing a house on stilts (Fig. 37) which will be similar in appearance to those houses used in the Philippines and other Far Eastern countries. The particular site considered is part of a larger marshy area susceptible to floods during heavy rains. Therefore, the design opts to elevate the house in an attempt not to disrupt the natural conditions of the locality. The designer also proposes to excavate ponds within the site, so that during the rainy months the extra water can be collected in them, thus reducing the level of the flood waters to some extent He also wishes to cultivate mangrove plants such as *kirala, kadol* and the many species of water lily in attempt create a habitat for various water fowl and other animal species common to this type of environment. Therefore, on the whole it appears that this proposal aims to find an environmentally friendly solution to building a house in a flood prone site.

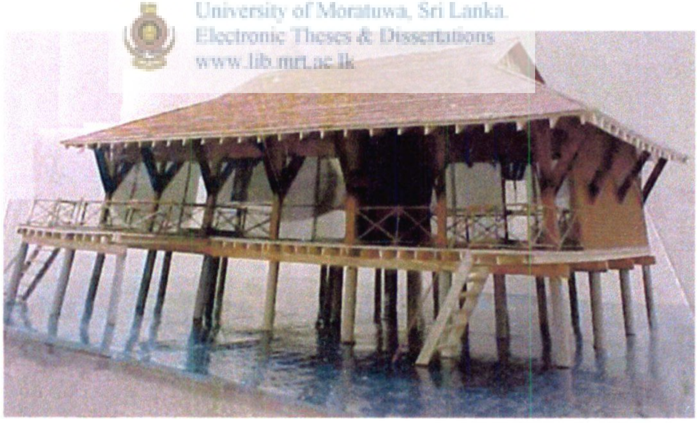


Fig. 37. 'Water Bungalow"

Courtesy: Archt. A. Rathnavibhushana

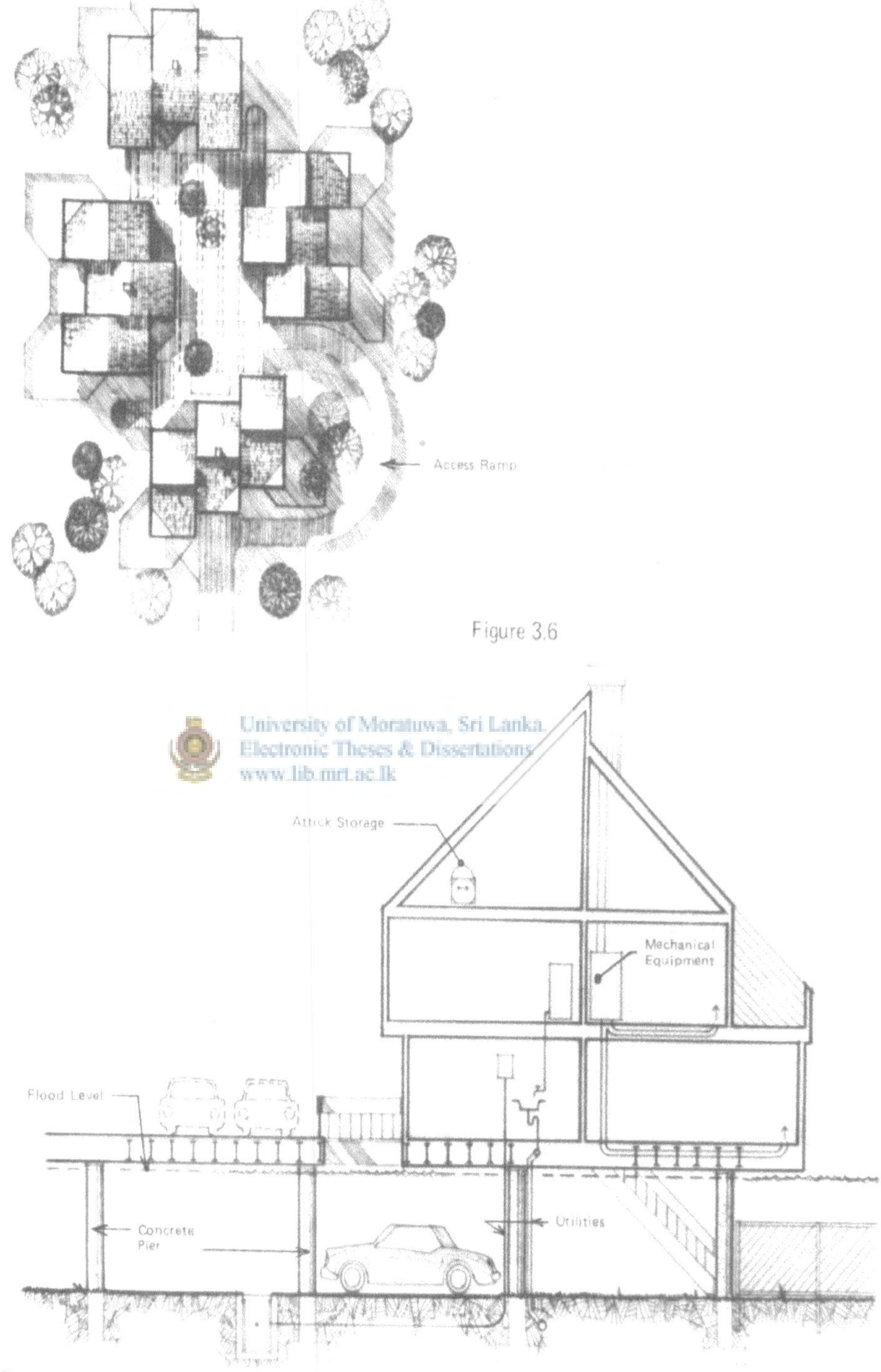
Example 3 : Luxury Town Houses[5]
Bridgeport, Connecticut,
USA.
Architect : unknown

Here the architects have designed these luxury town houses around a raised social deck (Fig. 38 and Fig. 39) to accommodate an elevation requirement of 10 feet above grade. Parking facilities are provided underneath the deck. Steel girders resting on concrete piers support both the social deck and the town houses. For the protection of utility services and to allow for added insulation the deck is constructed with a double floor system. Timber ramps and stairs are used to access the deck from which it is possible to gain entrance to the town houses. The ramp is especially useful since it gives easy access for children, the handicapped and the elderly. This ramp can also be used for driving automobiles and rescue vehicles up to the deck level during times of floods.

Fig. 38. Luxury Town Houses - Bridgeport, Connecticut

Source: FEMA 54 (March 1994). p. 22

Fig. 39. Luxury Town Houses - Bridgeport, Connecticut
Site layout & Section



Source: FEMA 54 (March 1994). p. 23

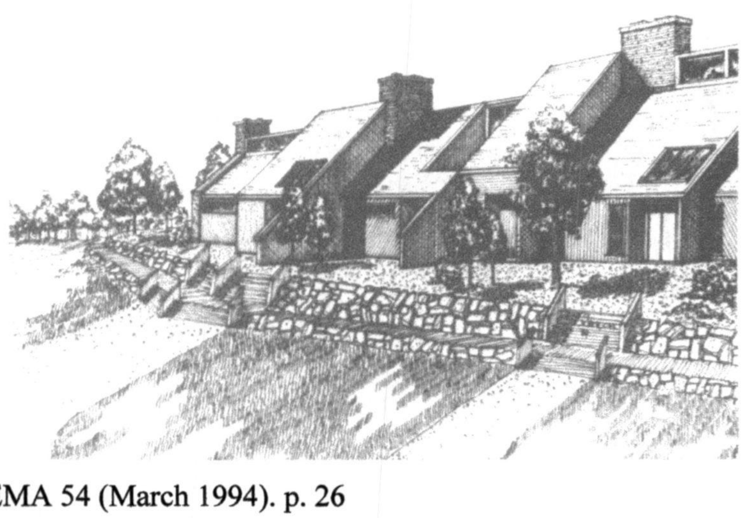
Example 4 : Residential Development[6]
Charlestown , Rhode Island,
USA.
Architect : unknown

The locality of Charlestown under study is a beach front area consisting of vacation house development. This area has high development pressure and a number of constraints relative to historic, scenic and community values influence the design. It is necessary to elevate structures with careful consideration to the natural environment of the area in order not to produce ungainly and visually distracting elements.

Prior to the commencement of work an inventory of critical natural factors was made in order to determine how and where development should take place in the Charlestown floodplain. Consequently a specific land area deemed acceptable was selected within the floodplain. Afterwards necessary analyses were carried out to determine appropriate methods of elevation for the development.

Earth fill with heavy stone revetment was finally chosen as the method for elevating residential structures as it was considered that this method fulfilled necessary functional and aesthetic requirements (Fig. 40 and Fig. 41). Since, the land available for safe building in the floodplain is limited, the houses were clustered together. This had the added advantage of keeping down the cost of the earth fill.

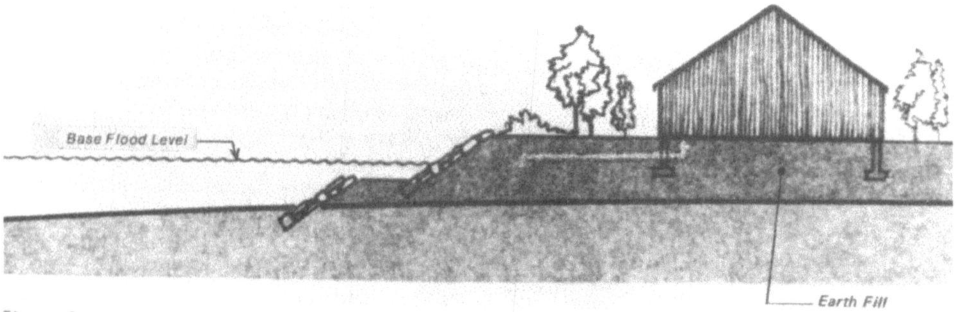
Fig. 40. Residential development - Charlestown, Rhode Island
Perspective



Source: FEMA 54 (March 1994). p. 26

In order to maintain a visual continuity with the existing buildings of the site, a small scale single-family scheme was chosen. All the houses as well as a small amount of private space and all utilities are located on the common filled area. Low intensity land uses such as parking, road and driveways, playground etc. are located on the lower surrounding areas. Ramps and steps are used to access the finished floor from the parking area.

Fig. 41. Residential development - Charlestown, Rhode Island
Section



Source: FEMA 54 (March). p. 25

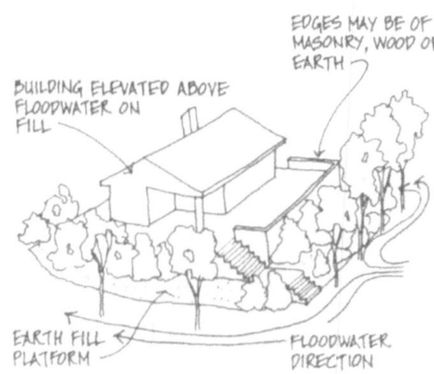
4.2 SITE DESIGN

In designing for a flood prone site it goes on without saying that the integration of development and site in a complementary manner to each other is of paramount importance. A careful analysis is required so that the house can be located on the most favourable place within the site in relation to topography and orientation. This will also be instrumental in deciding the locations of fenestration (for views etc.), access and parking.

Once the decision is taken as to where to construct the house, one needs to carefully consider the relationship and compatibility of development with the surrounding neighbourhood and community in order achieve a sense of continuity with the surrounding locality. Having a good perception about the physical characteristics of the surrounding locality will ensure that the new building will not be out of context or become a part of an unattractive 'hodge-podge' of unrelated development.

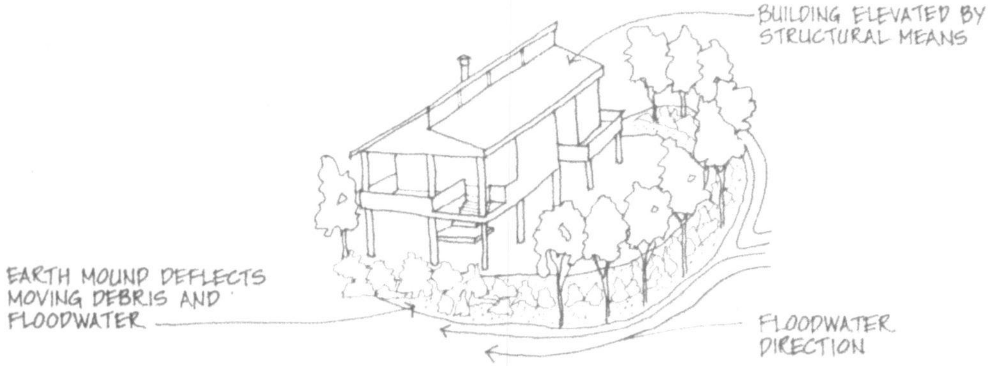
Landscaping is another important aspect in site design (Fig. 42 and Fig. 43). The creative and innovative use of trees, shrubs, bushes, fences and walls will serve two purposes. Firstly it will help integrate the elevated portion of the building with its surroundings. Secondly, it will help control erosion and protect the dwelling from impact of high velocity water and debris. Terracing and creating level changes will also prove beneficial, for it will give a sense of variety and it will help identify different uses of the various parts of the site as well as integrate the building with the site.

Fig. 42. Landscaping, an important aspect in site design



Source: FEMA 54 (March). p. 36

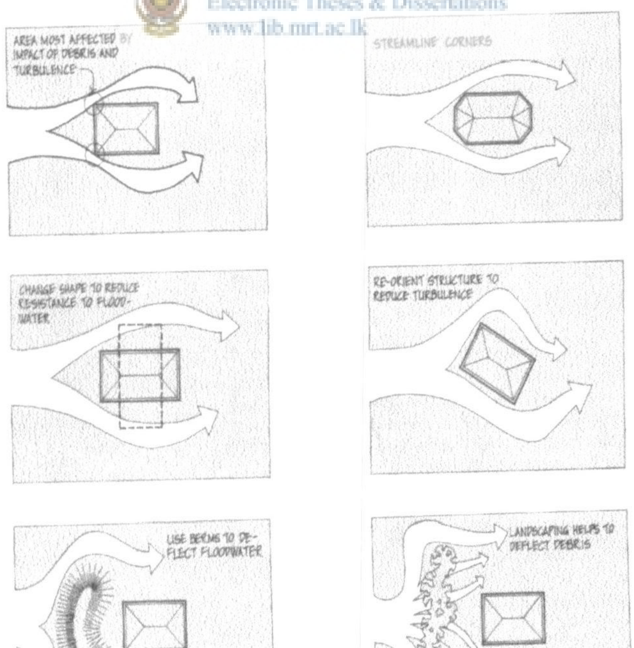
Fig. 43. Landscaping, an important aspect in site design



Source: FEMA 54 (March). p. 36

Site design for elevated structures should follow standard planning criteria applicable to any site work. However, special attention should be paid to factors such as slopes, natural grades, drainage, vegetation, orientation, zoning, and location of surrounding buildings. Another important fact to consider is the expected direction of flow of flood waters.

Fig. 44. Site design to reduce flood hazards



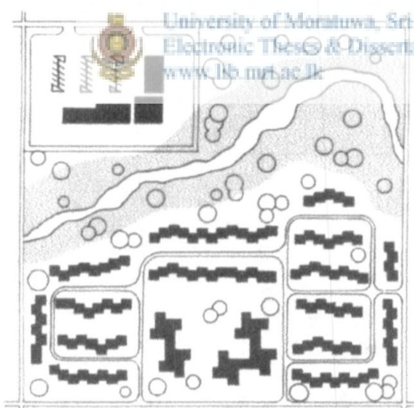
Source: FEMA 54 (March). p. 36

4.2.1 SITE FLOODING CHARACTERISTICS

Buildings in flood prone sites should be positioned in places that will experience the least velocities and lowest flood levels. In coastal areas it is feasible to locate the building as far back from the beach as possible and if there is provision to locate them behind dunes. The orientation of the building should be such that it will present the smallest cross-section to the flow of flood water. This will help reduce the surface area on which flood and storm forces can act.

When a number of buildings are to be placed within the same site, the principle of site design is the same as for an individual building. One method is to disperse the buildings throughout the site, applying the above described criteria to each building. The other option is to group buildings together in clusters on the safest parts of the site, leaving the more vulnerable areas open. This approach has the benefits of reducing flood damage as well as allowing greater opportunities for protecting the natural features of the site (Fig. 45).

Fig. 45. Building clusters dispersed throughout the site



Source: FEMA 54 (March). p. 13

A careful study of adjacent buildings, bulkheads, or other structures should be carried out prior to site layout, so that their potential to screen and divert flood waters and water borne debris and for their potential to become floating debris themselves can be properly perceived. Bulkheads also have the ability to divert flood waters around their ends, adversely affecting adjacent sites.

4.2.2 ACCESS AND EGRESS

It is important to consider the ways and means of access and egress from a building in site design for it determines the safety of the occupants at times of evacuation in a flood situation. The proper siting of roads will ensure that police and fire protection and other critical services can be provided with minimum trouble. These can be achieved by locating parking and driveways as well as the building in the area of a site least likely to be flooded.

In new developments it is better if roads can be located to approach buildings away from the floodplain, so that there will be less chance for access roads to be inundated by flood water or blocked by debris. Roads should be constructed so as not to disrupt drainage patterns and have adequate bridge openings and culverts to allow the unimpeded flow of water and this will help reduce potential erosion, siltation and runoff problems. If roads are to be raised, the slope of embankments should be minimised, and open faces stabilised with ground cover or terracing.

4.2.3 VEGETATION

Vegetation in a flood prone site helps in decreasing the rate of storm water runoff by holding water, thus allowing it to filter in to the ground or evaporate gradually. Apart from this vegetation also helps prevent erosion and sedimentation from flooding. Whenever it is practical natural vegetation should be retained and new plantings should be introduced in areas that will be most affected by runoff.

Some times it may not be possible to maintain vegetation under low lying elevated buildings. In such an instance crushed stone can be used to control erosion in this area as well as in other locations where it is difficult to maintain plants. Larger trees and bushes are suitable for deflecting floating debris away from elevated foundations. Therefore, trees, plantings etc. provide a dual function of utility and aesthetics.

4.2.4 FLOOD WATER DRAINAGE AND STORAGE

To avoid floods it is essential that there is good drainage within the site. In both riverine areas and other built up urban areas, good site drainage should allow flood waters to recede from a site without eroding it or leaving standing water that would cause stagnation leading to damage to structural elements or health hazards. In a site that is not located on a floodplain (such as in the coastal area of the Colombo city) the only form of water to enter into a site is through rainfall, whereas in a riverine site both precipitation and surface runoff from upstream portions of the watershed can enter into the site. The degree of flooding and the amount of flood damage depends largely on what happens to this water. Development activities may sometimes result in increasing the amount of storm water runoff, thus paving the way for floods. Ideally, runoff rates after development should not exceed the rates before development.

Site design should be carried out in such a way as to protect the individual site as well as to minimise flooding in other areas. The amount of non-porous surfaces and the amount of on-site surface water storage are two important factors that determine the ability of a site to absorb water.

There are various methods by which water can be diverted away from erodable areas. Using open channels is one such method where water can be taken away from short steep slopes, and to collect and transport runoff water to larger drainage courses. Channels with low gradients will have water flowing at a slower rate enabling it to have a grass cover, whereby it will act as a percolation trench by allowing gradual infiltration while the water is being transported. If it is not possible to have a grass cover, concrete or an asphalt cover could be used for channel linings. However, such materials could increase the rate of water flow within the channel, thus necessitating the need to have constant velocity checks to monitor runoff.

Fill material, from either on site or brought from elsewhere can be used to improve drainage and control runoff. However, careful consideration should be given to site conditions including, soil conditions, slope stability, flood water velocities and duration of flooding in order to avoid erosion during flooding. Using fill material or carrying out cut and fill activities will result in the restructuring of the topography of the site. Therefore, exposed cut and fill slopes or borrow and stockpile areas must be adequately protected. Diverting runoff from the face of slope is essential as well as using ground cover or retaining walls to stabilise the slopes.

4.3 BUILDING DESIGN

Housing for flood prone areas need careful consideration for there are several methods by which it is possible to design flood resistant structures, but most of them deal with elevating the building in some form, may it be on stilts or on earth mounds. However, flood resistant housing solutions more often than not prefer elevating the building on some form of columns or stilts for this method does not hamper nor obstruct the flow of flood water in any great way.

In designing elevated structures special consideration must be paid to the means of access to the building including any needed stairs as well as the path leading up to the bottom of these stairs. The other important aspect to consider is the form or configuration of the building for this will have a direct bearing on the way flood waters will flow around it especially if the house is built using another method of elevation such as locating it on a mound of earth. Finally, aspects such as texture, colour and the treatment of balconies, terraces, windows, railings, shutters, screens and entries should be looked at as well as the arrangement of interior spaces.

In the effort of designing a flood resistant house one must never forget the fact that the ultimate goal of this exercise is to produce a habitable living space for a family who will one day be calling it 'home'. Therefore, the initiatives that the designer takes in order to make the dwelling flood resistant should not inhibit nor prove problematic to those who will be living in it on a day to day basis.

4.3.1 AESTHETIC CONSIDERATIONS

Aesthetic aspects are very important in any design for this is what basically attracts a person to any particular building. Apart from this, aesthetic values also reflect the nature of the social and cultural milieu of a community. Therefore, in selecting an elevated design solution for a flood prone site will require special attention to be paid to how the building will look eventually.

Residential development requires a considerable financial investment, and if it is aesthetically appealing it contributes to the economic value of the area, both for the owner and the entire community. It is important that the development activity undertaken in a flood prone area be attractive and appealing, for good quality tends to foster better quality whereas poor conditions lead to even poorer conditions. Therefore, appealing design is an important element of making the most of our limited development resources.

4.3.2 CONFIGURATION

The configuration of the building designed for a flood prone site is an important factor, especially if the building is set on the ground. Circular plan shapes are said to be the best shape for buildings for it reduces the impact of water on the structure. However, this shape may not be functionally feasible, thus necessitating the adoption of other plan shapes such as the square or rectangle. However, 'L,H,U' shapes should be avoided but the 'V' shape can be used with the point facing the direction of the incoming flood waters (Fig. 46). Whenever, rectangular shapes are used the shorter side must be arranged to face the direction of flow of water (Fig. 47).[7]

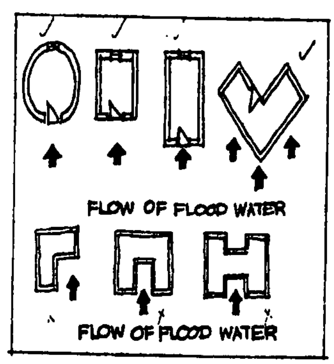


Fig. 46. Configurations
Source: Perera, L. S. R. (1999). p. 11

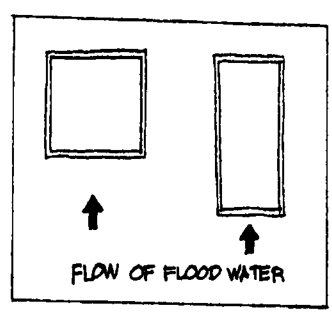


Fig. 47. Orientation of rectangular buildings
Source: Perera, L. S. R. (1999). p. 11

4.4 MATERIALS AND CONSTRUCTION TECHNIQUES

The following discussion will focus on the common methods of designing flood resistant buildings (such as elevated residential structures) and the materials and construction techniques that are required in the process. Since elevated residential structures are not too common in Sri Lanka, there is a lack of building codes especially dealing with this type of structures which makes it necessary as well as timely for the development of appropriate design standards and codes to be used in this country. Until such time it is prudent for the designer to follow a conservative approach in designing flood resistant housing.

4.4.1 FOUNDATIONS

In a flood resistant building, the foundations need much consideration for it is the most crucial element of the structure that determines the success of the building, for it must withstand various forces imposed by flooding. As mentioned earlier most flood resistant solutions deal with elevating the building. The common methods employed in elevating residential structures are earth fill, elevated foundations, shear walls, posts, piles and piers.

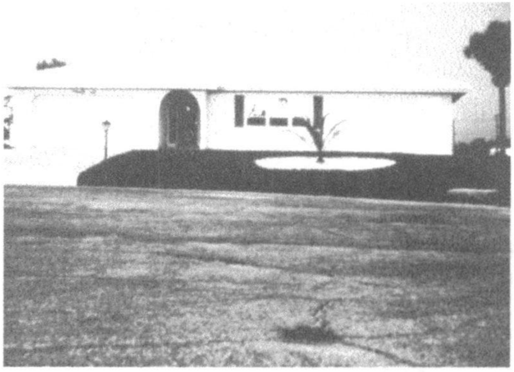
The selection of an elevation method depends largely on the physical conditions of the site, the nature of floods and associated hydrologic factors and the cost. In some situations it may be more feasible to employ a combination of several methods. For example, a building can be raised on fill at one end and piers or posts at the other. This method could provide ground floor access at the end of the building away from the floodplain while ensuring that there will be minimum obstructions to flood waters at the end nearer to the flood source). Also, when it is not possible to raise the entire house either on an earth mound or posts, it may be required to raise the floor level of at least one room to be used during an emergency as a flood shelter .

FILL

This method can be used in areas with low-velocity flooding and in areas where fill would not constrict the flow of waters thus increasing flood heights or velocities. Earth fill can be used to elevate a building two or three feet above grade or even higher in some locations. Earth fill is an elevation technique that has wide appeal due to its conventional appearance and which can be used most effectively and economically with proper materials and construction practices. The other advantages of this method includes the ease with which one can gain access to the building (no stairs are required), the possibility of connecting the filled area to higher ground for emergency evacuation in a flood and the safety of building elements from deterioration caused by exposure to flood waters.

Before fill is put into place it is necessary to remove any unstable topsoil and vegetation. Afterwards the fill must be properly compacted using a pneumatic or vibrating compacting equipment. It is also essential that adequate provision is made for surface drainage and erosion protection.

Fig. 48. Elevation by earth fill
Source: FEMA 54 (March 1994), p66



ELEVATED FOUNDATIONS

Elevated foundations may be deemed suitable in some situations due to various conditions such as site topography, poor soil conditions, aesthetics or cost. In such an instance extended masonry or reinforced concrete foundations can be used to elevate the structure up to three or four feet above grade. Such a foundation can be bermed using earth fill for a more conventional look and to provide easy access.

Elevated foundations must be designed to withstand both hydrostatic forces of standing water and the hydrodynamic forces of velocity waters. This may require added reinforcement in the walls of the structure. It is also required that adequate openings must be provided in the foundation for the unimpeded flow of flood waters especially if it is not bermed with earth fill. This will further ensure that both hydrodynamic and hydrostatic forces acting on the foundation will be minimised.

SHEAR WALLS

Shear walls are more suited for massive structures like apartments or hotels, but can also be used for smaller residential structures (Fig. 49). Shear walls act as deep beams in resisting forces in the plane of the wall. Since shear walls have low resistance to lateral forces, they should be only used in areas subject to low to moderate velocity flooding. Shear walls should always be placed parallel to the expected flow of flood waters.

Fig. 49. Elevation by shear walls
Source: FEMA 54 (March 1994), p66

POSTS

Post foundations use long slender wood, concrete or steel posts fixed in pre-dug holes. The cross section of the posts can be round, square or rectangular though the latter shapes are preferred for they are easier to frame into than round ones.

Fig. 50. Elevation by posts
Source: FEMA 54 (March 1994). p. 66

PILES

Pile foundations also use long, slender wood, concrete or steel posts but they are either driven or jetted into the ground. Piles are structurally stronger than posts and are therefore more suited to areas with high velocity flooding and extreme winds.

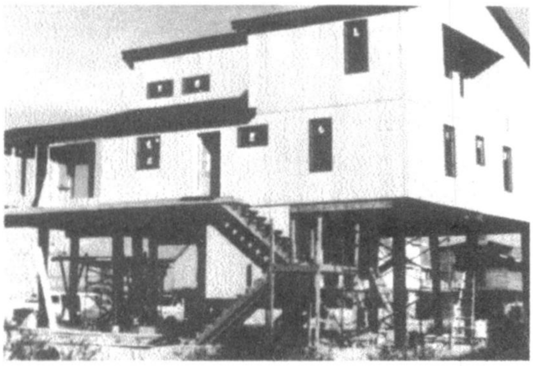


Fig. 51. Elevation by piles
Source: FEMA 54 (March 1994). p. 72

PIERS

Piers are best suited for areas away from a river or coastline where flood waters move with low velocities. Therefore, these are the best type to be used in urban areas subjected to local or standing floods. Pier foundations use brick, concrete masonry blocks or poured in place concrete to elevate structures.

Fig. 52. Elevation by piers
Source: FEMA 54 (March 1994). p. 74

4.4.2 SERVICES AND MECHANICAL EQUIPMENT

In flood resistant design special attention should be paid to services such as water, electricity and sewerage disposal and related equipment, for potential harm can be incurred to them due to the ill effects of floods. In an elevated structure the connection between the underground utility line into the floor above further exposes the line to possible damage and/or contamination by flooding and storm action. Underground services are also at risk due to damage when erosion of the protective soil cover leaves them exposed during flooding.

Damage to utility lines can lead to contamination of drinking water, discharge of effluent from sewer lines and fire and/or shock from damaged electrical systems.
Electrical and telephone lines which are mostly supplied from overhead service lines should be connected through the utility company's meter system beyond the expected reach of flood waters. If this is not possible the connection should be made within a waterproof enclosure. All distribution panels or other major electrical equipment should also be located above expected flood levels

Septic tanks should be floodproofed adequately to ensure that flooding does not cause the tank to rise out of the ground if the tank is partially empty, as well as to ensure against discharge of effluent.

4.4.3 BUILDING MATERIALS

One of the ways in which to protect building materials is to elevate the building higher than the minimum floodplain management requirements. Even so, there is no guarantee that the flood waters may not reach the building and consequently ruining the building materials. Following are some considerations about various materials and the precautions that are needed to be taken in order that they may be safe.

Wood : Elements made out of wood need to be properly treated with chemical preservatives to make the wood resistant to fungi attacks, insects, and rot, especially if they are exposed to climatic conditions. Connections should be made in such a way as not to allow water to collect on or in them. Also they can be protected with flashings or by treating saw cuts and drill holes with preservatives, and by painting connections.

Steel : Steel elements in riverine areas need to be protected by galvanization or by painting with rust-retardant paints. However, the need for painting can be eliminated through the use of surface oxidising steels (high strength low alloy). In environments near the sea, exposed structural steel should be avoided for they undergo very rapid corrosion. Small connecting devices such as bolts, nails angles, bars, and straps should be hot-dipped galvanized after fabrication and given a protective coating of paint after installation. Regular inspection, maintenance and replacement of corroded parts is required when steel is used in coastal environments.

Concrete and masonry : Both reinforced concrete and masonry can be mixed with chemical additives and by special treatments and coatings to improve its durability. Surface treatments such as silicone and epoxy paints can be used to reduce water absorption and penetration of water.

4.4.4 GLASS PROTECTION

Glass used in buildings must be well protected for they are particularly vulnerable to damage in even moderate storms and routine high winds. Window panes and other glass openings if broken may allow rain and flood waters and high winds to enter the building. If water enters, it may damage the finishes and harm furnishings of the interior and eventually damage structural elements. Glass window panes can be protected by exterior shutters. For small openings the traditional louvred shutter can be used for protection. However, for fairly large areas of glass additional protection can be achieved by using ½ inch plywood attached to the back of the shutter, which will take the direct forces from the storm (Fig. 53).

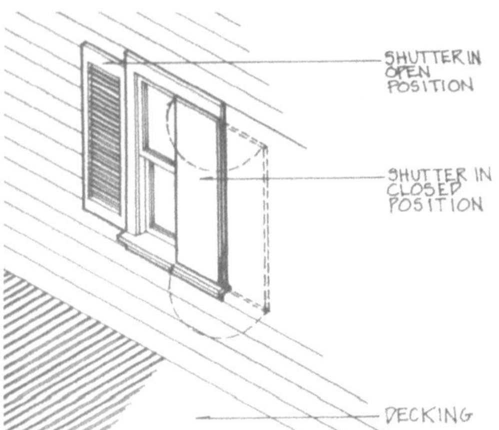


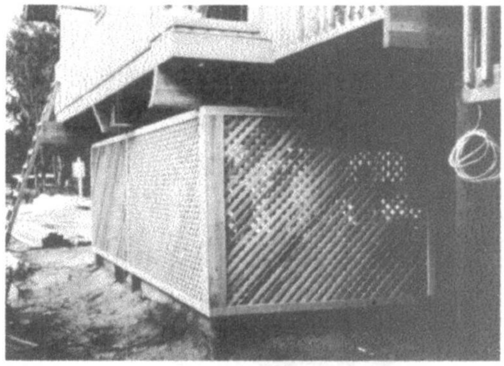
Fig. 53. Shutters for window protection

Source: FEMA 54 (March 1994). p. 92

4.4.5 BREAKAWAY WALLS

In areas prone to severe foods with high velocity waters, it is essential that the building is elevated in such a way as to avoid any obstruction to the flow of flood waters. However, if this is not possible or if there is need to utilise the spaces under the elevated structure, it can be constructed with breakaway walls (latticework etc.) designed to collapse under stress without harming the structural support of the building (Fig. 54). In designing breakaway walls attention must be paid to loads from the flood waters and the nature of waterborne debris.

Fig. 54. Breakaway walls
Source: FEMA 54, (March 1994). p. 97



4.4.6 RETROFITTING EXISTING STRUCTURES

Houses already constructed in flood hazard areas with little regard to flood resistant aspects may sometimes need some form of retrofitting in order to make it more adaptable to flood situations. In countries such as the USA where they have the technology to raise-in-place existing residential structures, seek to follow this process rather than demolish the building. However, in these instances the principal consideration is the cost, rather than the technology for they have the technology to raise almost any structure, even multistory buildings.

However, in Sri Lanka this method cannot be adopted since the necessary technology is not available. But various other options are at hand which will also improve flood resistant qualities of a house. For example, if a house gets flooded completely it may be feasible to make an additional room above the reach of flood waters to act as a flood shelter and to protect building materials by coating them with proper chemicals and preservatives having water resistant qualities.

NOTES

[1] Le Corbusier. (1970). ***Towards a new Architecture***, trans. Etchells, F. p. 74.

[2] Rapoport, A. (1969). ***House form and Culture***, p. 46.

[3] Le Corbusier. (1970). ***Towards a new Architecture***, trans. Etchells, F. p.

[4] Arifin-Sigit, I. E. L., et. al. (April 1990). Pp. 133-142

[5] FEMA 54 (March 1994). Pp. 22-23

[6] FEMA 54 (March 1994). Pp. 24-26

[7] Perera, L. A. S. R. (1990). p. 11

CONCLUSION

CONCLUSION

According to this study several important aspects come to light regarding the phenomena of urban floods and its resulting repercussions on households . In elucidation it can be said that this study which examines the issue of flooding in the Colombo city and its environs, clearly indicates the causes which gave rise to this situation and the measures that are required to be taken in order to mitigate it.

In conclusion it is apparent that several causal factors have contributed towards creating flood situations;

- Unsatisfactory methods of garbage disposal
- Unplanned land filling activities
- Obstructions to drainage paths
- Insufficient maintenance of drainage paths such as canals and drains
- Insufficient capacity of canals and drains

Many people are inconvenienced and put to much trouble as a result of floods in this area. This situation hampers with their normal lifestyles and many suffer economic losses as a consequence. Therefore, this study clearly indicates the requirement of adaptive methods to floods and the need for flood resistant housing.

Hence, it is the duty and responsibility of residents of the Colombo city and visitors alike to ensure that their actions do not aggravate this situation. Residents must take appropriate measures to facilitate the proper disposal of garbage so as not to block drainage paths and thus obstruct flow of stormwater. The people must be made to realise that they have a moral obligation to care for the environment and be made to understand that subsequently they themselves will be benefited by it.

However, the responsibility of ensuring reduction of the negative impacts of floods and the mitigation of flood disaster, rests heavily upon the professionals and the decision makers. Therefore, it is important that 'sustainable development' policies and programmes be adopted which can be seen as an attempt to ensure development patterns that will allow for a mutual process of adaptation between environment and human communities. The basis for such sustainable development programmes is the broad assumption that the environment will not be a hazard for the community and that the community will not pose a hazard to the natural environment. Moreover, any development plan has to incorporate measures to reduce risk and vulnerability.

In respect of the issues outlined, architects have an important role to play in enabling people to adapt to floods and to allow them to live with minimum discomfort under such conditions. This can be achieved by the design of suitable flood resistant housing and proper site design. Elevated structures deemed suitable for areas susceptible to floods, even though somewhat alien in the context of Sri Lankan residential buildings may have to be proposed in this regard.

In summation one can say that mitigation of flood disasters is an inter-disciplinary affair, no sector being independent of another. It is an activity that needs the collaboration of individuals comprising of relief workers, field workers, professionals of specific disciplines - architects, planners, social scientists, geographers, engineers, and economists among others. Finally, it must be noted that even though natural disasters such as floods are an obstacle to development it also provides an opportunity for change, a challenge and a spearhead.

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ANNEXES