CHAPTER 9

SUMMARY AND CONCLUSION

9.0.0 SUMMARY

The present research work is an attempt to examine the ecological impact of breaching of embankments made on the sides of rivers flowing in some areas of South 24 Parganas District on the local environment and people in general in one hand and on the communities bracketed in poor and marginal section of the social class on the other. Breaching of embankments is related mainly with the physical forces active in that particular area and some human interventions made to the embankments. The habitable parts of the study area as well as the agricultural fields are protected by these embankments, thus its breaching, caused naturally or anthropologically, invites detrimental effects to both the productive lands and settlements of all communities, but the impact are more effective on the people who live near or on the embankments. The communities in the area are segregated into variable economic and social classes, of which the marginal communities classified into SCs and STs suffer more afflictions from such breaching. These differential sufferings may not be minimized or compensated for by any uniform policy or management. Differential sufferings demand more micro level and group specific management strategies to be monitored by both the local and regional administrations along with the participation of the people from all groups. The embankments made on the natural systems normal for the unique estuarine ecosystem is actually an intervention to the nature of the ecosystem that bears its own rules, always tending to a balance in the gain and loss of matter and energy. The matter being the sediment load and energy being the tides transformed into erosional forces. Thus this unique ecosystem always tends to be stabilized to balance the matter and energy through erosion and deposition. The breaching of environment is an act of erosion, breaching being the result. The human communities need to introduce a management system to be adjusted with the balance to save their own space of production and settlement, equal space to be provided to the natural system, the rivers.
The main objectives of the present research work is to enter into the exercises regarding identification of the natural and anthropogenic factors and processes responsible for decay and breaching of the embankments once engineered to protect the life and resources in various parts of the district located on the active delta region significantly influenced with mangrove forests, to probe into the impacts of decay and breaching of those embankments on physical and human ecological aspects of the selected area and to formulate an eco-friendly management plan on the basis of observation and available data. The objectives of the present study rationally incorporate the hypothesis and the research questions.

The theoretical considerations which are important to fulfill the objectives of the present work include the concept of land as a resource base, fragmentation of habitat and ecology due to disruption of environmental balance. The conceptual issues also involve the concept of agriculture and water bodies including rivers and creeks as resource bases and resource processes.

Thus the aims and objectives of the present study stated earlier succinctly as objectives, include the purposes of studying the ecological impacts of embankment breaching aspires to understand the characteristics, the forces and factors of such breaching and their effects upon nature, economy and society of the concerned area; to comprehend the distinctiveness of the tidal rivers and estuarine ecosystem; their physical attribute and utilization in macro and meso level; to probe into the nature of changes of such ecosystem in accordance with the dynamic and influence of changes in the rivers; to explore the possibilities of minimization of the negative effects of such changes; to search out the potentialities of monitoring the human interventions affecting the regimes of the deltaic rivers; to appraise the impacts of the present embankment building on the physical and social environment of the area under review and to frame plan based overall assessment of the problems resultant of the embankment breaching and its eco-friendly correctional measures. The whole discussion (Chapter 1 to 8) concerning the location of the area, the nature and magnitude of ecological, economic and sociological impact of the breaching of embankments on the resident people may be summarized as below:

1. The South 24 Parganas District has been considered as the area under study. The District is at the southern most fringes of the State of West Bengal and also within the Sundarbans delta, the largest pro-grading delta on the globe. It presents a complex model
of ecological co-existence of diverse aspects in close inter-action with one another. It is predominantly a deltaic region formed mainly by the continuous deposition of silt carried down by the Ganga-Brahmaputra system. The administrative components of the District include 5 Sub-Divisions: (i) Alipore Sadar, (ii) Baruipur, (iii) Canning, (iv) Diamond Harbour and (v) Kakdwip. The District is composed of 33 Police Stations, 29 Community Development Blocks and 7 Municipalities. The study area extends from 21°29'00” North to 22°26'15” North Latitude and 88°03'45” East to 89°04'50” East Longitude. The major part of the District being covered by the Sundarbans region in the south and large Municipalities on the north and west, major emphasis have been given on six specific Blocks where the embankments are mainly concentrated and their breaching is most evident which comply with the objective of the present research. This can also be considered as one of the rationales of selection of these six Blocks like Kultali (Baruipur Sub-Division); Namkhana, Pathar Pratima and Sagar (Kakdwip Sub-Division) and Gosaba and Basanti (Canning Sub-Division).

2. The study area is of recent origin, developed by quaternary sediments deposited by a number of rivers flowing from the Himalayas. Their deposition has initiated the formation of largest prograding delta of the Sundarbans. The formation of Ganga-Brahmaputra delta initiated at the end of Miocene period. The extension of the delta to the present location took place during Pleistocene period. The geological formation covering the Sundarbans belongs to the so called 'Bengal Alluvium'. Since the early Miocene, the eastward prograding delta slowly changed southward with a position of shoreline change from North East–South West to nearly East-West in the Quaternary. Depositional trends started changing from Pleistocene period. The discontinuation of the eastward thickening of sedimentary formations is probably due to the reduction in the rate of subsidence of the Bengal Basin floor along the North-South axis which has lead to rapid filling up of the basin. Bengal deep sea fan has been rapidly formed by sediments deposited by Ganga-Brahmaputra system during the post-Pleistocene period. The recent tilting of Bengal Basin and Sundarbans deltaic plain is toward the east and the fresh water discharge accordingly has shifted eastward. Thus eastward higher sediment discharge is causing subsidence of the Sundarbans delta, the rate being often close to 6 mm/year as measured at some places of Bangladesh.
3. The area is basically a low lying flat alluvial deltaic plain and has been traversed by a large number of tidal rivers, estuaries, creeks and saltwater courses. The delta is a group of a large number of small and big islands. Each island with its discontinuous land mass is surrounded and traversed by the water system of various widths which regularly flood the land mass. The physiography is dominated by deltaic formations that include innumerable drainage lines associated with surface and subaqueous levees, splays and tidal flats. There are also marginal marshes above mean tide level, tidal sandbars and islands with their networks of tidal channels, subaqueous bars and proto-delta clays and silt sediments. The Sundarbans floor varies from 0.9 to 2.11 metres (3.0 to 6.9 ft) above the mean sea level. Three geomorphologic zones are generally identified from the shoreline to the centre of the island: (1) mud-flat, (2) slopes and (3) low ridges. The eastern part of this region is more elevated (about 7m) than the western counterpart.

4. The most important feature of the ‘riverscape’ of the district is the changing courses of most of the rivers. The distributaries flow from the main river in a crisis-cross manner and again re-enter the main stream or merge with some other distributaries. As a result, the same river owes different names at different places making it difficult to keep track of the individual streams. The principal rivers of the District are the Hooghly, Saptamukhi, Thakuran, Bidyadhari, Matla, Gosaba, Haribhanga and Raimangal. The River Hooghly enters the District immediately after the Kolkata Port area and flows south west till it falls into the Bay of Bengal. The Spring tides of the Hooghly are occasionally so strong that they give rise to a phenomenon called a bore (baan). This name is given to the head water (sometime 5-6 metres high) which is formed when an unusually high tide is checked by the narrowing of the river channel. The Saptamukhi system is spread over both the Districts of North 24 Parganas and South 24 Parganas. It is wide and shallow and as a result, has a number of shoals. The Thakuran is also a wide river and meander loops are found on the eastern side of the river. These loops are interconnected amongst themselves by an intricate mesh of tidal channels. The Bidyadhari is the combined flow of the Nona gung and the Harua gung in North 24 Parganas. It serves as the main drainage outlet of the Kolkata Metropolitan area. The Matla is a wide estuary in comparison with Hoogly. The Piyali is a connective stream from the Bidyadhari to the Matla.

5. There are numerous creeks or tidal channels between the large estuaries and rivers called khals that form a network of channels, some ending ultimately in narrow and short
channels serving to draw off the water from each block of land. Each Block is formed like a saucer with high ground along the bank of the *khals* surrounding it, and with one or more depressions in the middle. The rain water in such depression is drained off by the little *khals* into the larger *khals* and ultimately to the sea through the rivers during ebb tide, conversely when the water swells in the rivers during flooding tide. It floods the floor through the same channels. Many of the *khals* connect two large rivers, and consequently the tide flows into them through both ends. Such *khals* are called “Do-Aniya” *khals*. They are very useful as route of water transport between the larger *khals*, but have one serious defect that they are liable to silt up at the point where the two tides meet, for the water is always still there. Even the major rivers in the Sundarban region flowing East of the Hooghly river have relatively small catchment areas and consequently the discharges from the hinterland are small in comparison with the volumes of water which flow in and out each tide. Therefore, the currents in the maze of rivers and creeks of the Sundarban region are almost entirely the results of the fluctuation of the sea level in the Bay of Bengal.

6. The study area experiences two high and two low tides in a period of 23 hours and 52 minutes. The high tide is seen where the influence of the bottom relief and configuration of the coast are prominent, in the immediate vicinity of shallow water bays and estuarine confluence. The average height of tidal wave in the deltaic coast of the Ganges is about 4.92 m. The tidal currents developed in the mouths of the rivers like the Hooghly and Meghna are stronger. Tidal amplitude in the Sundarbans is very high reaching almost up to 7 m. due to this high tidal fluctuation and high tidal amplitude, most of the mangrove forest in the Sundarbans is very frequently inundated with the tidal water. However, during low tide most of the vegetated mangrove forest floor is exposed to air. The resulting dynamic condition favours the most suitable ecological niche for the growth and spread of diverse groups of mangrove species in the Sundarban areas and related fauna. Tidal forces, mainly the high tide are destructive to the embankments.

7. The area lies under the humid monsoon climatic regime. Temperature and humidity condition in the Sundarbans region in the southern part of the District with its swamps and marshes and the wide network of tidal channels, rivers, creeks and islands differs a little from those in the northern island tracts. While the meteorological records at Alipore may be taken as representative of conditions in the northern inland tracts, the records at
Sagar Island can be taken as typical of the Sundarban region. The temperatures are generally lower and humidity higher in the Sunderbans than in the rest of the District. Temperatures begin to rise steadily after February. May is the hottest month when mean daily maximum temperature is 35.3°C (95.5°F) at Alipore and 32.7°C (90.9°F) at Sagar Island. The high moisture content of the air makes the heat in summer oppressive. The maximum temperature may go above 38°C (100.4°F) on some days in the Sunderbans region and above 42°C or 43°C in northern inland region. January is the coldest month with the mean daily minimum temperature at 12.7°C (54.9°F) in the northern parts of the District, and 14.9°C (58.8°F) in the Sundarbans. Relative humidity is generally high throughout the year, during summer the afternoon humidity is comparatively less.

The study area experiences devastating effect of storm at least twice a year. On May 25, 2009 a tropical cyclone hit the Sundarbans in India and Bangladesh with a wind speed of 110 km/hr. Over 8,000 people went missing and about a million were rendered homeless in the two countries. About 300 people were killed in the Sagar Island alone. The Aila, as it is called, was categorized as a severe cyclonic storm. Such extreme weather events are now becoming more frequent and powerful, and experts are drawing linkages between them and the changing climate. Sea level rise and temperature increase are impacting the Sundarbans, in most cases at far greater intensities and scales than the global averages, and in some cases, faster than that recorded in other some parts of India.

8. Mainly two types of tidal surges are found in the study area such as tidal waves and tidal bores. The tidal waves sweep over the area twice a day. The tidal current changes its direction every six hours. The maximum rise and fall of tides occurs in March and April. The tidal wave makes its way across the Sundarbans from west to east and consequently the tide change earlier in the west than it does in the east. In the large rivers the velocity of the current usually varies from 3kmph near the sea surface to 6 km/h an hour higher up in the forests. The speed increases further inland on account of the rivers. The average rise and fall is high in the western rivers than in the east. The average rise and fall near the sea surface is about 2.2 m, further up it is 3 m. Where the tide has little or no stream to contend against, an average rise and fall of 5-6 m is common.

In the Sundarbans, one of the most striking phenomena in the interfluves is the ‘Tidal Bores’. The tides are occasionally so strong that it gives rise to the phenomenon known as a bore (locally known as ‘Ban Daka’ (‘calling the flood’). The name is given to the head
wave formed due to the unusually high tide checked by the narrowing of the river channel. The higher range of tidal bores during the monsoon periods and sometimes during the pre monsoon and post-monsoon accompanied by the cyclonic storm originated by the intense low-pressure over nearby Bay of Bengal accelerates the damages caused either by storms or by bank tidal floods. The combined activities of the cyclones and tidal bores are important hydro-climatic phenomenon in these interfluves of the Sundarbans delta.

9. The vegetation is largely of mangrove type and encompasses a variety of plants including trees, shrubs, grasses, epiphytes, and lianas. Being mostly evergreen, they possess more or less similar physiological and structural adaptations. Most trees have pneumatophores for aerial respiration. The prominent species is Sundari (*Heritiera fomes*) and Gewa (*Excoecaria agallocha*). Prain recorded 334 species under 245 genera. Of the 50 true mangrove plant species recorded, the Sundarbans alone contain 35. Almost all mangrove plant species are evergreen, dwarf, shrubby or tall trees, and grow gregariously without leaving any space on the floor. The mangroves of Sundarbans are housed in a deltaic mass on the Bay of Bengal formed jointly by the river Meghna in the East (now in Bangladesh) and the Ganga in the West (West Bengal, India). This forested part is actually a collection of a large number of small and big islands. The forests of Sundarbans play a critical role as a carbon sink; trees and soils in forests can trap and store carbon dioxide (CO$_2$) from the atmosphere, a process known as carbon sequestration.

10. The Sundarban Biosphere Reserve was constituted by Government of India (GOI) in 1989 and it received the recognition of UNESCO under its Man and Biosphere (MAB) Programme in November, 2001. Sundarban National Park, forming the core area of Sundarban Tiger Reserve, received recognition as World Heritage Site by UNESCO in 1987. It has been nominated by GOI for recognition as Ramsar Site (a wetland of international importance). Sundarban Tiger Reserve was constituted by GOI under Project Tiger scheme, in 1973. Sundarban is the only mangrove forest in the world which is the home of Tiger. Sundarban Tiger Reserve has the highest tiger population in the world. The Sundarbans Biosphere Reserve has three main objectives: Development of sustainable economic, social activities of the population living in the Biosphere Reserve; restoration of the unique mangrove ecosystem of Sundarbans and conservation of its...
biodiversity; facilitating research, monitoring, education and training to perpetuate the achievements made.

11. The settlement pattern of the area resembles circular, determined by circuit embankments. The present settlements are elongated along the inner side of the basins surrounded by embankments. With due course of growth of population and further immigration the settlements, the locations of settlements have been changed, urban centers have been developed at various nodal points and river ports. The rural settlements are mostly located along the embankments which also play the role of transport lines. The rural settlements of South 24 Parganas District are mainly agricultural but fishing villages and forest villages are also evident. Although the villages do not possess well-defined shapes and a distinct internal plan, there is a considerable arrangement both in the internal structure and external outline of the villages, which is very clearly related to the nature of their site and cultural features. Every settlement is unique, and has a personality of its own. The area under study contiguous to the Sundarbans region possesses different settlement patterns in which the time of its origin is somewhat reflected but changed gradually through its activities related with time. The settlement pattern that are found to develop in the study area are semi-nucleated, dispersed, semi compact and hamleted, linear, semi circular, cruciform checkerboard type, hollow square type, star shaped and curvilinear settlement.

12. The study area has witnessed continued immigration of population from almost all sides of the District since the Sultani period, more intensified during the colonial regime when people were given incentives to settle there. Emigration of people from the area reveals two reasons active behind leaving the area. Embankment breaching in a number of areas along with repeated occurrences of flood and cyclone disaster have reduced the provisions of livelihood of the residents, for which they had to emigrate in search of income in other places within or outside the district. Another reason is equally realistic in the area that a remarkable number of youth of below 30 years of age are now eager to earn decent in the states that attract unskilled and skilled youth in diverse organized and unorganized sectors, mainly garment and ornament manufacturing centers. Even the less educated female population is now searching after jobs in urban and metropolitan households to earn sufficient and live decent.
The most remarkable feature of the growth of population in the District is that when almost all the districts of West Bengal experienced a fall in population in Census 1921 due to famine and drought in 1915-16, the District did not experienced any deceleration in the trend of growth. The second important feature is that the trend of growth in population shows an abrupt or exponential growth in 1971 and a quick fall in 1981 which attests the significance of Bangladesh war of independence in that period when a large number of people had to cross the international border and were sheltered in various Blocks of the District, and after the war was over, a significant share of the immigrated population may have returned back to the point of leaving. Another most important and tender cause is the widespread flood disaster of 1978, which washed away extensive parts of settlements with wiping out most parts of the embankments. A large number of lives were lost and many of the rests left the area causing depopulation.

13. Maximum concentration of **ST population** of the area is found in the Khas Ramkarerchar mouza of the Sagar Block. The ST population shares only 2.79% of the total population. Maximum concentration of ST population is found in the Tentultala mouza (31.52) of the Gosaba Block. The mouzas that include above 10% of ST population are Chimta, Taranagar, Baramollakhali, Radhanagar Dakshin, Harishpur etc. Maximum concentration of **SC population** is found in the Beguakhali (81.26%) mouza of the Sagar Block and the mouzas which comprises of more than 50% SC population are Sikarpur, Companir Char, Daspara, Gobindopur, Mahisamari and the mouzas like Ramkrishnapur, Kamalpur, Rudranagar, Bishnupur, Purusottampur have less than 10% concentration of SC population. Block with more than 50% SC population are found in the 5 mouzas namely Patibania, Narayanpur, Bijaybati, Amrabati, Ganesnagar. 98.40 % SC population is concentrated in the Ramdebpur mouza of the Pathar Pratima Block.

14. The study area is quite backward in terms of educational, transport and communication and infrastructural development. The schools remain closed during rainy season and flooding period. Even the ground floor of the schools sometime remains under water for weeks or even one month during rainy season. Most of the mouza of the study area are not electrified. Thus schools, colleges suffer from acute electricity shortage. It becomes literally impossible to carry on laboratory based subjects in schools and colleges. Subjects like commerce, science are mostly avoided by pupils as the cost to
carry on education is quite high. Skilled teachers try to seek job in the cities as their
places of work are not connected owing to poor transport and communication system.

15. The economy of the Sundarbans is based on agriculture, fishing and collection of
non-timber forest produce (NTFP), all natural resource-based activities. Agriculture
offers livelihood to about 60.32 per cent of the population, consisting of both cultivators
as well as daily wage labourers. About 17 per cent are engaged in fishing, which includes
those who own their boats and nets and those who work as daily labourers in the fishing
trawlers. The other organized and unorganized sectors – which include people with
regular employment, such as petty jobs with the government, labourers and the self-
employed make up 22.3 per cent of the workforce. Agricultural activities are known as
the primary sector of economy. Fishing is the main economic activity of the area under
study. Pathar Pratima Block has the maximum area under fishing cultivation (5600 hect.).
For economic support and employment generation, both the Union and the State
government have expended a number of schemes with objectives to provide jobs for the
people who are generally unemployed either any their own enterprise or occupation, but
more importantly to create work opportunities at least temporarily in purpose of income
generation. The public schemes implemented in the area include: Mahatma Gandhi
National Rural Employment Guarantee Act (MGNREGA), Rural Road Construction,
Mangrove Regeneration and Plantation etc.

16. The initial erection of embankment and clearing of mangroves helped construction of
human habitation in the region. The settled people engaged in cultivation of lands were
promoted by the zamindars that made those lands their private property. The floors of
these small basins were used by the local farmers as paddy fields. The peripheries of these
basins were surrounded by the levees of rivers. The farmers gradually increased the
height of those levees to build the embankments. The knowledge of embanking came
from the farmers at first. But the activity was extended from the period of reclamation of
the immature delta and series of small basins were surrounded with these techniques and
gradually the length, breadth, height and numbers of embankment increased. The
confluence points of the small creeks or the outlets called payan, were protected against
the entry of flood water during high tide and opened during the low tide for easy release
of water from the fields. The question of embankment is related to the recovery of
swamps for agricultural purposes, protection of the rural settlements and to some extent, with the clearing of forests.

17. The alignment, structure and strength of the impediments on the sides of the rivers of the area have now been changed to a great extent with the application of modern engineering technology and management. Two types of embankments are now constructed in the concerned area: a) the **boundary impediments** and b) the **cross impediments**. The first one has been constructed along the banks of the river to protect cultivated and residual land from tidal inundation, whereas, the second one has been made occasionally by the local folks as test relief measures. The cross section of an embankment generally undergoes wide variation from place to place in the study area because of the indigenous methods of embankment construction followed earlier. But once a failure or excessive erosion of an embankment occurs, it becomes absolutely impossible to retrieve the exact slope geometry at the point of failure. Therefore attempts were made to measure the approximate dimension of the eroded parts of the embankment at various points with the help of a steel tape. This proves difficult as the existing embankment undergoes various degrees of erosion at different places. A brief inspection along nearly the entire stretch of embankment helped to identify several spots where the embankment geometry could be considered as critical. Slope on the upstream and downstream had been made either excessive height or too steep at these spots.

18. The embankments in the Sundarbans are built without using any heavy earth moving equipment, except embankments made in post-*Aila* period. The earth cut at a point is carried to the locations where the embankment is built anew or repaired is executed by labourers with baskets on their heads. The embanking material is taken from the top layers of the part between the river and the embankment or using top soils of the adjacent rice fields. At some locations, excellent clay or silty clays have been used to build embankments, but in many cases the soils used range from fine sandy loams to silty clay loams that are less resistant against wave attack and are washed out by aggressive current. Presently, the materials used for repair and reconstruction of embankments include: Earth work is done with excavation by mechanical means, providing filter on slopes with well graded brick chips (*khoa*) 37.5 mm down, dry brick block pitching for river side slope with bricks of 20 cm thick in cement mortar and brick blocks for construction of cross wall for separation of bays or river in river side slope.
19. The responsibility of management of the embankments are shared by a number of government: Irrigation and Waterways Department, Disaster Management Department, Sundarban Affairs and Sundarban Development Board, Public Health Engineering Department and the Panchayat Samities. These agencies have distinct duties and responsibilities fixed by the respective Departments that may not direct link to embankments, but in most cases the areas of responsibilities are overlapped. However, the main functions served by the agencies in combination are: management of floods through non structural as well as structural measures including construction and maintenance of embankments, tackling the problems of river and sea erosion through construction of new anti-erosion and river training works as well as maintenance of existing ones and also maintenance and improvement of embankments and dykes constructed for reclamation and protection of land, arrangement of drainage during monsoon period mostly in low lying areas through an intricate system of drainage channels and rivers, having outfall structures, mainly sluices and often pump houses, construction of innovative structures using state-of-the art technology, particularly in the Sundarbans area. These are classic examples of rainwater harvesting and construction of new embankments as well as improvement and strengthening of existing embankments.

20. The structures, mainly of the earthen embankments, can sustain only limited safety levels and are subject to decay, they may fail owing to various triggering mechanisms, particularly with a high probability of failure under extreme conditions. These failures pose significant flood risks to people and property in the inundation area and cause an interruption of services provided by these structures. However, an earth embankment is likely to fail gradually (breaching) because of erosion of its materials by water flow or wave action involving mixed-regime flows, strong sediment transport, and rapid morphological changes. Therefore, determination of the earth embankment breach characteristics (e.g., width, shape, peak outflow, failure time) is quite intricate and difficult, requiring the prediction of complex interactions among soil, water, and structure. Breaching and overtopping has been of quite common phenomenon today. In many cases the old dykes are aligned bordering the scouring bank of meandering rivers. This necessitated another set of embankments called the retiring embankments. On an average two major tropical cyclonic storms occur in each year in Sundarbans. During such cyclonic storms, high waves are generated in the sea face which attack on the
embankments at great velocities and thus overtop embankment without free board, erode river side slopes and crest and cause breach.

21. The nature of embankment failures is quite complex. Heterogeneity of materials within the dike body or the subsoil results in a failure only if a definite limit of outside influence is exceeded. The soils of the dikes are heterogeneous and undergo differential solutions. The permeability of the dike body determines the velocity of percolation of water through the dike and therefore its stability too. This can be seen as solution breaching most frequent on the sides and top of the dykes. The solution wash is furnished by corrosive forces of water currents during forward and retreating tides, therefore related with the velocity of the currents of the tides. The river side wall therefore becomes narrow in breadth, and the thinned out part of the dike is breached easily. Overtopping embankment breaching is resulted with strong and wide upsurge of tide water mostly during the time of cyclonic storms. Sudden and quick rise of the water level in the river flows with force over the top of the embankment and is accompanied with quick solution and removal of the top soil. The height of the quickly recedes and the overtopped gap expands rapidly on both ends. Slump breaching is most frequent on walls faced directly by strong tides. Initially the open wall facing the river or the bay is attacked by the high and strong waves of tide water accompanied with strong gush of storms. The attack erodes the wall almost vertically and as a result, the base of the impediment wall becomes weak that cannot bear the load and falls down straight to the water side. Channel migration and widening often change the main flow path and may endanger a riverine levee system. Significant erosion may occur near channel banks subject to high-energy river flow at the downstream.

22. There are several types of embankment failure evident in the area under study. Slope stability failure is aggravated by the seepage of water. Owing to the defective techniques of embankment building followed in the study area and the lack of technical quality control, failure of this kind appears in many parts. Failure due to scouring is normally more severe in case of tidal rivers where the water level undergoes quick fluctuations. Failure due to tension develops due to a complex stress –strain distribution and is generally concentrated in very small zones. The water percolating through the small tension cracks cause small lumps of soil to disintegrate resulting in local failures, which then propagate to encompass the entire body of the embankment. Failure due to storm
Surge is considered as a natural disaster that defies most security measures taken for the safety of the embankment. Storms and cyclone during the monsoon frequently cause dislocation resulting large breaches across embankments. In recent years the incidents of such storm surges found to be increasing.

23. Two major causes of embankment damage in the Sundarban area are technological causes and hydro-meteorological causes. The unplanned settlement developed even in concave sides of the bends of the meandering rivers of the Sundarbans. The un-cohesive silt available on the upper layer of riverside cannot resist the tidal surges as used in most of embankment of the Sundarbans. The hydro-meteorological causes include improper drainage through sluice gates in these areas, the high average annual rainfall in the area (almost 1625 mms or 65 inches), the flatness of the area with a silty clay soil generates little ground water absorption and accumulation of rainwater in the crop fields where people make crude cuts on the embankments for draining away the water.

24. Siltation and drying up of rivers and canals and other perennial water bodies eventually encouraged shrimp farmers for encroachment and conversion of these natural water bodies into shrimp farms. Coastal embankments caused closure of many of the discharge sluices causing water stagnation in the small closed rivers and canals within the polder areas. Influential shrimp farmers, particularly absentee landlords gradually took control of these water bodies both legally and illegally for shrimp farming. Government started leasing out the canals and rivers, and other water bodies e.g. beels, baors, (commonly called Jal Mohal) to the interested shrimp farmers. Eventually shrimp farmers closed these water bodies permanently, which aggravated the siltation problems in the main rivers furthermore. Large scale conversion of paddy fields into brackish aquaculture is another threat to the stability of the existing embankments. This practice is steadily increasing in this region. To ensure the inflow of saline water the fish farm owners dig deep channels in the embankments. This practice increases the chance of embankment failure during high tides and storm surges due to cyclones.

25. Anthropogenic activities also facilitated the expansion of settlements including housing, settlement and road network in the study areas. Between 2001 and 2015, areas under housing and settlements have increased by 40-57% in the study area. Between 2001 and 2015, the increases in paved and semi paved road networks were almost 105%, in different islands with MGNREGA and PMGSJ. In recent years, there were
considerable growth in both road and marine transportation. The major consequences of marine transportation are the discharge of oils and other wastes which have been continuously polluting the coastal ecosystems. In other case it disturbs the normal flow of water in the river and changes the orientation of currents that ultimately affect the stability of the embankment. Besides the hydro-climatic and human factors, biotic agents also play a significant role to intensify embankment breaching in the study area. Arthropods like crabs, rodents like rats dug in the unconsolidated earthen embankment and decreases its cohesiveness. The small holes or pore spaces are initiated by these agents and those are enlarged to caves in the toe of the embankment through infiltration of water, which finally help collapse the embankment. These holes or caves locally called ‘Ghog’ is responsible for embankment breaching to a certain extent and is a concern to the engineers, especially during the monsoon in the Sundarbans region. Moreover, the cattle grazing over the embankments loosen the bank materials and also uproot the grasses that make the embankment more un-cohesive and vulnerable to erosion.

26. Thus physical impacts cannot be said to have physical ends; undoubtedly they have differential social effects, and for which the question of social impact gets the equal importance like physical impact, in addition it requires the provision of environmental and social justice. Embankment breaching has direct effect on present land use of the study area. Human being is always dependent upon the land, thus any change in land use directly affects them. The Sundarbans region is one of the most disaster prone areas in India. Natural calamities like storm surge, devastating cyclone and other climatic conditions which are acting as a force of breaching of the embankments has detrimental effect on human lives, crops, cattle raising, poultry, fishery, houses, roads, forests and many other types of property and economic infrastructure. Breaching has some direct impact on the river banks, vegetation cover, wetlands and fisheries, changes in settlement, agricultural activities or more preciously, in land use of the area.

27. Shifting of river bank line is a natural process, sometimes it erodes one bank and sometimes it builds the other bank. It causes change of the river courses. The resultant impact of that breaching is decrease in the area of the reviewed islands. An area of 1.20 km$^2$ lands are removed in the Satjelia Island from 1984 to 2017 due to the influence of embankment breaching whereas the lost area is 2.13 km$^2$ in the case of Ghoramara Island. Maximum area is lost in the Mousuni Island (3.64 km$^2$) owing to breaching and 1.79 km$^2$
area is lost in the Jharkhali Island in the period from 1984 to 2017. Embankment breaching also has a direct impact on the vegetations which cannot tolerate saline water. In case of breaching in the embankments the saline water infiltrates into the innermost part of the area under review, make hindrances to sustain the vegetative cover which are fresh water feeder. After the extreme events, the dependence on forests rises for the communities adjoining them leading to rapid deterioration of natural environment, which can have significant repercussions in the long run.

28. A number of wetlands have been formed in the study area beside the river banks and shorelines. Amongst them, some are salt water fed and some are fresh water fed. It is evident from the field observation that most of the wetlands have been situated beside the embankments. These wetlands are being degraded by the embankment breaching. Whenever there is breaching in embankment the salty water infiltrates into the fresh water wetlands hampering the ecological balance of the wetlands. Sometimes these wetlands are silted up by the clayey water of the rivers and oceans which have been infiltrating by the breached areas in the embankments.

29. A group of people dependent solely on fishing is grouped into ‘ecosystem people’ suffers more due to loss of wetlands than the people provided with other source of income. The fisheries of the area are generally categorized into two: large and small ponds filled with sweet water from rain, and the wetlands of saline water partly or seasonally connected with saline water of the rivers or open sea. The sweet water fisheries are located within basins enclosed with embankments. Incidents of breaching cause inundation of these fisheries, the fish species cultured there cannot tolerate the saline water in one hand and the forceful current of the water entered through breaching takes away all the harvests. Moreover, the character of the sweet water fisheries experiences change for few years. Repeated breaching of embankment in the area may cause extinction of some sweet water species that has been reported by people engaged with such fisheries. The saline water fisheries are generally the commercial fisheries used for culture of various fish species are sometimes located at the margins of the islands, but one or multiple canal keep connection with the river to maintain a particular depth of the fisheries. Breaching of embankment and resultant current of saline water do not only take away the fishes cultured with huge investment, but causes siltation that reduces the depth of those fisheries and changes those fisheries into mere mudflats.
30. The harshest impact of embankment breaching is the loss of settlement that makes the inhabitants more vulnerable to breach disaster. Breaching of embankments drives the inhabitants to leave behind them except bearing the losses. They never change location of their settlement before the breaching takes place as they have little earnings that never allow them to replace their houses before it totally collapses. The people settled upon the embankments are more vulnerable to the breaching.

31. Agricultural field and fishing activities are badly affected with saline water intrusion. Even betel vine are also affected. The land has lost its productivity due to presence of high salinity in soil. Breaching of earthen embankments in every rainy season causes agriculture and pisciculture face severe problems. Agricultural land is the vital resource for the people living near embankment and bank line. Almost 49 per cent of the total inhabitants are dependent on agriculture.

32. Breaching of embankments directly or indirectly affect the human lives, when conjugation and opposition tidal surges appear or heavy storm surges occur, then the resulting phenomena is in-land flooding, which has negative impact on human lives. The area under study appears as a bowl as they are surrounded by the embankments to its each side. The situation appears to be pathetic when the embankment collapses. The marine water or the brackish water enters into the land masses and becomes stagnant. It is evident that due to the stagnation of water in the Islands the eco-system of the area totally collapses which causes loss in flora and fauna of that area. The condition becomes more pathetic when the dead bodies of that flora and fauna get mixed up with the water. This stagnated brackish water is harmful to the human lives as they considered as the lap of embryo of some water borne diseases, like diarrhea, cholera, malaria etc. Human mortality and morbidity is one the most devastating impacts of hazard. Many lives are lost at the ambush of the tropical cyclones in the costal part of West Bengal and many more are lost in the subsequent phases which can be termed as direct and indirect consequences. The amount of direct death and injury by high velocity cyclonic winds is mostly attributable to the temporary nature of human shelter. Most of the households are not climate resilient. Loose roof materials fly off and hit as projectiles due to wind gusts. Uprooted trees and other objects find it easy to damage shelters made by temporary materials.
33. Frequent alteration of the land ecosystem and aquatic ecosystem owing to breaching of embankments in the Sundarban area, a number of flora and fauna species become vulnerable in terms of habitat crisis and ecosystem stability. Removal of such kinds of species and thinning out of the biodiversity, complex food web become too fragile food web and converted into individual food chain. The loss of bonding in food web total ecosystem is affected and become instable ecosystem in terms of sustainability. The problems of environmental refugees are one of the most burning issues at this time throughout the world. Environmental refugees are those people who could no longer gain a secure livelihood in their homelands because of drought, soil erosion, desertification, deforestation and other environmental problems, together with the associated problems of population pressures and poverty. It is evident that when there is breaching of embankments the resultant phenomena is the displacement of some people as their homes have been destructed. The people have to leave their place of origin and have to take shelter in camps made by different govt. and no-govt. agencies after the breaching.

34. The Sundarbans offer an exceptional scope of an integrated development of the challenging nature, a fact, which has engaged serious concern of planners and leaders from various disciplines since independence. One cannot deny that people inhabiting in the Sundarbans have now become the most important section of the ecosystem of the region. Heavy influx of population due to Partition of Bengal and other reason along with steadily rising rate of population growth have altered the situation of the ecology. This even dynamic factor has formed a significant impact on the Sundarban. Construction of embankment along the tidal rivers in the region along with provision of sluices therein to provide the requisite of drainage has been thought the most essential consideration have made to look after the islanders of the Sundarbans from tidal flood and surges. Stabilization of the ecological balance and protection of the natural and cultural ecosystems needs necessary review in relation to the existing development policies with holistic approach.

35. Irrigation and Waterways Department have made 3500 km of marginal embankments in the Sundarbans inherited by Independent India. Responsibility of maintaining and upgrading these embankments was assigned to the Drainage Wing of the Irrigation Department (Government of West Bengal). The Irrigation Department has elaborate deployment of manpower in the Sundarbans under the control of Joynagar Division; it has
to spend as much as 60 percent of its budget on its employees and other overheads said Tushar Kanjilal, former member of the SDB. Under each Sub-division, there are several Section Offices manned by an engineer, a work assistant and other workers. Ever since, the landmark constitutional amendments of 1993, the Section Offices no longer have the budget to carry out maintenance of embankments; budgetary allocations are now made to the *Panchayat Samitis*. As a consequence of the landmark amendments, a situation has arisen where budgetary allocation is made to one institution whereas the skill is with some other Government organization. Administrative reforms transferring control over civil servants from line departments to local governments have to be initiated. Though West Bengal has transferred functionaries to Local Self-Government institutions for twelve of the 29 items listed in Schedule XI of the Indian Constitution, the Drainage section of the Irrigation Department is none of them and the District has to wait until then to bridge the gap between intent and practice in terms of better management of embankments as well as conservation of the ecosystem.

36. The SDB seems to have missed its goal; it presently carries out smaller development projects such as construction of brick-paved roads, culverts, jetties and bridges and sinking of tube-wells – thus duplicating the work of the Public Works Department (PWD) and the Public Health and Engineering Department. Similarly, it duplicates the work of other agencies such as the forests, fisheries and agriculture departments and is involved in everything from social forestry, tree planting and fisheries to agricultural extension programmes – mainly seed distribution to small and marginal farmers. Areas of critical planning and research, aspects that the SDB was mandated to perform, remain neglected. There is no doubt that the SDB has been working for the overall development of the region that shows through its budget expenditure. Most of the local people were unfamiliar with SDB, though it has been established long before.

37. Local bodies like the *Panchayats* sometimes work for urgent repairing of the embankments with the fund received from National Rural Employment Guarantee Scheme (NREGS). In many instances it is exceptionally slow in implementing its plans and even influenced by political interests by which repair works at required location may not be given priority. There is a post of *dafadar* to make vigilance of the condition of embankments of a certain stretch in the area. In previous time, local people knew the name of that person and people every day witnessed his presence. The post of such
inspector is still live and budget for salary is allocated regularly but his presence in the actual field has now been questionable. The hierarchy of the body sometimes becomes unable to perceive the results of the delay in management of embankments. Sometimes the meetings of the different bodies are delayed which causes to underutilization of the funds. However the *Panchayats* are really the vigilantes of the functions of different organizations responsible for developmental works, of which embankment management is an integral part. This local body is formed by the people and for the people; therefore it can serve in community level and to its last extent, in individual level. It recommends the needs of the people to the other government and non government organizations serving for the development of the area.

The planning for sustainable development of physical and human resources includes: a) measures for protection of embankments, b) measures for sustenance of economy and c) re-stabilization of ecological balance. The embankments must be constructed with proper building materials which are adjusted to the local hydrologic regime. They must be strong, solid, all weather proof and most importantly long lasting.

a)  
i. The embankment must be built on a stable surface. If the embankment that is constructed is strong made of solid materials but the base is weak then there is every probability of failure of the foundation. Thus a stable base is essential for long lasting embankments. The solid base can be assured only when the impediment is constructed at a safe distance from the edge of the river especially if the river banks are not stable and show carvings and slides.

ii. Clay, silty clay and matured loamy soils have greater cohesiveness than mud. So for embankment construction this type of soil texture will strengthen the structure of embankments.

iii. The Irrigation Department makes brick pitching to protect the outer slope of the embankments. Brick pitching is expensive enough; low cost earth filling can be followed because it is available resource for repairing the embankments long enough. Earthen embankments needs minimum allotment even for reconstruction the embankments rather than repair works. Brick pitching stripes become unstable and dislocated with the wave currents.

iv. There is large discrepancy between the design made on the papers during planning and its implementation on real ground. The authority should follow a proper guideline for
embankment construction and repair works. The authority itself is sure about its quality and durability.

v. The gradient of the landside slope of the embankments towards the basin needs to be less than 2:1 as is advised by construction engineers, the steep walls needs to be avoided because it makes the top overloaded. The soils of the embankments promote natural growth of grasses that helps the soil at hold and the presence of the grass and its roots reduces the salinity of the soil on the slopes of the embankment. Gradually the grass cover of the slope becomes grazing grounds for domestic animals and the hoofs of the animals act as efficient compactors that improve the strength of the embankment as a whole.

vi. Island people living near the shorelines are more vulnerable to the natural hazards and effects of embankment breaching, there must be a proper plan of evacuation of these people from their land and the areas near shore needs to be utilized for embankment construction. Proper land use planning and implementation is necessary to be formulated by the developmental organizations of Govt. The evacuated people need to be rehabilitated in some suitable areas with necessary compensation.

vii. Rural poor living near the embankments excavate pond or canal to conserve water for irrigation and other purposes. Reconstruction of embankment becomes necessary whenever embankment breaching takes place and those excavated areas remain closer to the embankments. The ditches and large holes made by local people needs to be filled up by earth filling so that the crest level remains higher than the high water level.

viii. The Forest Department has started executing a programme of replanting mangroves along the rivers in the estuary. Mangrove vegetation is a very effective and very economic way of obstruction against wave dash during high storm surges. The initiatives of plantation of vegetation taken by Govt. needs to be taken to the populace. The Forest Department and the Irrigation Department needs coordination with each other to select the areas where this reforestation is required most. Villagers must be provided with the seeds so that they can also become a part of this program for their part.

ix. Protection of embankment requires control of river bank erosion by scientific manner, for which use of local materials are necessary. River bank erosion can be managed by planting mangrove saplings and setting sand bags along the shore.
b)  i. Management of natural resources is necessary for survival of all the species in the study area, the human community being the focal point. Effective land utilization needs to be done even in the situation when land is under water. Agricultural lands must be protected by embankments, for which the protection of the embankment itself is more necessary. It will help the agricultural land from salt water intrusion during flooding. There is also an opportunity of pisciculture along with paddy compound by this land embankment that reduces in seasonal migration.

ii. Eco-development strategies must be adapted for planning purposes and providing protection to develop incentives for conservation, supporting sustainable alternatives to harmful use of resources.

iii. Agriculture in the study area is fully dependent on monsoon rains. Saline water intrusion in the agricultural fields and ponds affects farming and fishing activities. Thus rain water harvesting should be done so that irrigation water can be supplied for farming. The stored water can also be used for fish culture. Excavation of canal, digging of pond is required for rain water harvesting. This will reduce migration of people into cities.

iv. The sluices are built with a sliding gate and a flap gate, proper construction and operation of sliding gates can prevent inflow of saline water in the interior part of the shallow basin. The flap gate prevents inflow of water when the sliding gate is not closed on time or is left open. The sliding gate should be in a closed position except at months when excess water needs to be drained out.

v. Better transport and communication system must be provided so that the people can be evacuated easily whenever they will encounter any natural hazard or flood situation. Improvement of waterways for navigation as cheap transport route is necessary as most of the islands are connected by various navigable rivers and open bay water. Increasing number of jetties, up gradation of jetties would facilitate the protection of river banks with preventing erosion in a number of locations.

vi. Number of flood shelters and cyclone shelters in the surveyed islands must be increased. It is found that shelters are not adequate. People move to schools during flood situation. The schools remain closed during the monsoon season for atleast 3 to 4 months. Poor quality food is provided in the shelters and the quantity is also very low.

vii. During flood there is loss of domestic animals. Flood water not only affects agriculture and fishing activities but also the fodder availability of the domestic animals.
becomes questionable. Domestic animals are sometimes washed away during heavy flood. Their life is also threatened by natural hazards thus along with human shelters, shelters for domestic animals must be constructed in a comparatively high level of land.

viii. Plantation of salt resistant crops and plants must be given priority. The examples of salt resistant crops are few species of rice like patnai, balam, valki and nonasal and the examples of few salt resistant plants are

ix. Small scale industries such as bori (cake of pulses paste) making, clay doll making, boutique printing, making of nature based handicrafts preparation must be encouraged in the study area. Govt. must provide loan at a subsidized rate to the rural folk for reducing the pressure on economy.

x. A number of communication programme can be arranged by Govt. and non Govt. agencies through meetings, workshops, seminars, and other activities to increase public awareness and community knowledge regarding sustainable livelihood options with an objective of sustenance of economy. Training needs to be imparted to the poor villagers to get prepared during a natural disaster. It might be a mere torch, a stick or a rope, which can be helpful during such natural disasters.

xi. An integrated approach to planning and management of the Sundarbans mangroves and its cultural landscapes within the large scale of integrated coastal area management programme must be implemented. Creation of employment opportunity, resource based small business generation, eco-tourism development, local socio-economic improvement, women entrepreneurship must be done. Educational facilities and local development for the coastal community needs to be done.

c) i. Maintenance of the upstream water supply in the Sundarbans region is a must for protection of mangrove wetland ecosystems.

ii. Participatory management approach with special emphasis on Sundarbans mangroves should be undertaken.

iii. A multidisciplinary approach needs to be adapted including core management plan of numerous uses of the mangrove wetland resources, especially for forestry, fishery and shrimp farming, wildlife conservation and protection of biodiversity.
iv. The marine hydro-engineering embankment building approach for restoration of coastal wetlands needs to be undertaken as an effort to prevent the tidal salinity intrusion and mitigation of natural hazards in the Sundarbans areas.

v. Developmental project activities like Social Vulnerability Assessment (SVA) and the Environmental Impact Assessment (EIA) or Strategic Environmental Assessment (SEA) should be undertaken as a systematic approach of addressing the environmental issues and their consequences.

vi. It is difficult to segregate ecologically sensitive areas such as Sundarbans mangrove wetlands from the adjoining areas’ planning and management. Environmental management and protective measures needs to be included within the framework of national planning.

vii. The wetland studies must be based on man-environment research tradition, methodologies of proper conservation and management of mangrove wetlands have to be taken into consideration for the local culture and social condition of individual cases, as well as people’s appreciation, attitude and perception of the wetland environment.

viii. Integrated management approach of mangrove wetland ecosystem in the Sundarbans is necessary for the protection of the whole coastal environment. Government, non-governmental organisations, local stakeholders, civil societies, national and international agencies must coordinate with each other for such an important task. Responsibilities should be shared among the public and private sector.

9.2.0 CONCLUSION

Summarizing all the discussion, it may be concluded that breaching of the embankments of the area under review have affected the ecology and economy of the people in general and the marginal communities more dependent upon the land and water free of salinity in particular, but the impact are differential in extent and magnitude. The people living close to the tidal rivers and embankments and reliant more upon the production systems based upon the stable estuarine ecosystem for sustenance are more affected by direct and indirect negative impact of embankment breaching and they need environmental and social justice. The question of differential sufferings needs agreeable, rather, community specific solutions which they may achieve through the plans which embrace their actual
needs. Being predominantly an agricultural area with equal importance on pisciculture, people from both professions living in and outside the areas affected, need suitable plan and management to achieve a balanced development of the area. Active participation in the development program by the local people from every stratum of the society is required.