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HYDRO-METEOROLOGICAL INVENTORY OF ORISSA CYCLONES

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NATIONAL INSTITUTE OF HYDROLOGY
JALVIGYAN BHAWAN
ROORKEE - 247 667 (UTTARANCHAL)

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PREFACE

The Bay of Bengal has always been known for its fierce cyclone, and yet every time one of them strikes the coastal region of whether in India or in Bangladesh, thousands of lives and crores of Rupees of property is devastated every time. The full extent of the havoc caused by the October-1999 cyclone in Orissa will be known for the cruel act of the nature. This cyclone was probably even more awesome in its intensity because of wind speed more 240 kmph placed it in the catastrophic category and named as 'Super Cyclone'. Once such storm strikes, there is no escape because the roads and highways are blocked by uprooted trees and the collapse of power line plunges large areas in to darkness.

As always, the poor are the worse sufferers since their flimsy hutment, whether in countryside or in towns, cannot withstand the devastating impact of the howling winds. Even as Orissa limps back to life, the focus- once the immediate needs of relief and rehabilitation have been met – should shift to preparing a comprehensive plan for dealing with such tragedies in future. A team of the Institute consisting of Dr. S. K. Mishra, Scientist E, Shri R. P. Pandey, Scientist C, and Shri T. R. Nayak, Scientist C, visited the cyclone affected areas in Orissa during December 1999 for the investigations and collection of necessary information/data. The available information on the cyclones in Orissa has been compiled and discussed in this report.

This report has been prepared by Dr. S. K. Mishra, Scientist E, and Shri R. P. Pandey, Scientist C, and Dr. K.S. Ramasastri, Scientist F and Director of the Institute.

(K.S. RAMASASTRI)
Director

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Sl. No.	Name and Address
1.	Sh. G.C. Sahu, Engineer-in-Chief, Water Resources Department, Govt. of Orissa, Sicha Sadan, Bhubaneshwar-751 001
2.	Dr. B.P. Das, Advisor to Govt. of Orissa, Rajeev Bhavan, Near Orissa Secretiarate, Bhubaneshwar-751 001
3.	Sh. A.K. Mohanti, Engineer-in-Chief II, Water Resources Department, Govt. of Orissa, Sicha Sadan, Bhubaneshwar-751 001
4.	Sh. R.P. Das, Chief Engineer (OWPO) & Incharge Narage Barrage Project, Cuttack
5.	Sh. B.B. Singh Samat, Chief Engineer (Planning & Research), Water Resources Department, Govt. of Orissa, Sicha Sadan, Bhubaneshwar-751 001
6.	Sh. B.C. Nayak, Chief Engineer (Floods), Water Resources Department, Govt. of Orissa, Sicha Sadan, Bhubaneshwar-751 001
7.	Sh. B.B. Mishra, Engineer-in-Chief (Retd.), Plot no. 2839, Jhenpada Bhubaneshwar
8.	Sh. Prafulla Kumar Mishra, Chief Engineer (Retd.), HIG-1/21, Kapilaprasad BDA Colony, Bhubaneshwar-751 020
9.	Dr. H.N. Verma, Director, Water Technology Centre Shailashree Vihar, Bhubaneshwar
10.	Dr. Prabhakar Nanda, Sr. Scientist, Water Technology Centre for Eastern Region (ICAR), Sailashree Vihar, Bhubaneshwar
11.	Dr. G. Behra, Chief Executive, Orissa Remote Sensing Application Centre (ORSAC) Suryakiran Building, Saheed Nagar, Bhubaneshwar
12.	Sh. A.K. Patnayak, Director, Groundwater Survey & Investigation HP Building, Delta Square, Unit VIII, Bhubaneshwar-751 012
13.	Sh. B. B. Basak, Scientist D, Ministry of Water Resources, Central Ground Water Board, Bhujal Bhawan, Khandagiri, Bhubaneshwar-751 030
14.	Sh. J. Patnayak, Superintending Engineer, Groundwater Survey & Investigation Unit VIII, Paika Nagar, Bhubaneshwar
15.	Sh. Purna Chandra Das, Superintending Engineer, Southern Irrigation Circle, Barhampur, Dist. Ganjam (Orissa)
16.	Sh. B. K. Jena, Sub-Divisional Officer, Balikuda Irrigation Sub-Division, Balikuda Jagatsinghpur, Orissa
17.	P.K. Rautroy, Assistant Engineer, Qr. No. D/8, Jobra Irrigation Colony Jobra, Cuttack
18.	Sh. G.P. Roy, Assistant Director, Computer Centre, Water Resources Department, Govt. of Orissa, Sicha Sadan, Bhubaneshwar-751 001
18.	Sh. Jatin Kumar Swain, Office of the Engineer-in-Chief, Water Resources Department, Govt. of Orissa, Sicha Sadan, Bhubaneshwar-751 001
19.	Sh. A.K. Nayak, Assistant Engineer, Groundwater Survey & Investigation HP Building, Delta Square, Unit VIII, Bhubaneshwar-751 012
20.	Sh. Manmohan Patnayak, Writer & Journalist and Chief Executive Director, KAPATARU (NGO),Guptabrandaban, Gosainnuagaon, Barhampur, Ganjam-760 003
21.	S. Ralee Moharana, Press Photographer, Sharada Photo Studio Bijipur, Barhampur, Ganjam (Orissa)

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ABSTRACT

A cyclone is the combination of heavy wind, rainfall, and/or high surge. The scientific understanding on the subject is not much developed due to lack of data and abnormal atmospheric conditions arising in the affected region and endagering the lives of human being. The favourable demographic nature of low-lying coastal areas facilitates settlements, industries, and agricultural activities. According to an estimate, about 60% of the total 5.5 billion population live in coastal areas and 65% of cities with population more than 2.5 million are located along the world's coast-lines. With the enhanced human interference in the nature's activities, the problems of these coastal areas are aggravating. The devastating action of cyclones in Bangladesh, India, France and other countries in the recent past forces the engineers, scientists, research scholars to focus on the problems of coastal areas for possible remedial measures.

Of late, the State of Orissa faced two severe cyclones in October 1999. The first occurred during October 17-18, 1999 and hit the Orissa coast at Gopalpur. This severe cyclone caused extensive damages to life and property in Ganjam district. The second cyclone of catastrophic category stroke on October 29-31, 1999 (named as super-cyclone '99) and hit the Orissa coast near Paradip and inflicted unprecedented damages in the districts of Kendrapara, Jagatsingpur, Cuttack, Bhubneshwar, Puri, Jajpur, Balasore, and others. The supper cyclone devastated about 3 million ha of cropped area in addition to sizeable loss of cattle (200,000+) and human lives (50000+), based on the personal inquiries with the local inhabitants.

The October-99 super cyclone of Orissa is distinguished to have far exceeded all historical cyclones occurred in India. The wind speed exceeded 260 kmph, extremely intense rainfall varied from 400–960 mm in 2-3 days, and a tidal wave of 5 to 6 m height swept across a 20 km strip of 100 km coastal stretch in Jagatsinghpur and Kendrapara district and created havoc. The maximum rainfall intensity was of the order of 40 mm/hr for 3 to 6 consecutive hours at some places and heavy winds and rain prevailed continuously for about 36 hours. The tide caused huge destruction to life and property,

and submerged, severely scoured, and breached large saline embankments in the area from Astrang to Basudevpur. Deltaic areas from Mahanadi to Subernarekha were submerged up to 3 m depth by stagnation due to impeded drainage. Extremely high flood of 5,00000 Cusec was experienced in Baitarani at Akhuapada on October 30, 1999. The obstructed drainage network and high flood due to continuous intense rainfall in several sub-basins created submergence of agricultural lands up to more than a week in deltaic areas. The largest concentration of urban population of 1.5 million in Cuttack and Bhubneshwar suffered unprecedented damage from intense rainfall of 500-600 mm and cyclonic gale of 200-250 Kmph.

The above extraordinary event forces to re-look at the cyclonic phenomena of the country in general and Orissa in particular. The disturbance of the hydrologic regime of the region compels to fix the design criteria taking into account the abnormal features of the above event. To this end, there is a pressing need to revise the design considerations, viz., revision of empirical formulae used to determine design discharges accounting for the backwater effect of surges, probable maximum precipitation, instrumentation for data collection etc. The impacts of cyclonic surges on the surface water and ground water quality and soil salinity, etc. are of vital research importance, leading to specialised studies on these aspects.

1.0 INTRODUCTION

Coastal seas and plains perform the most taxonomically rich and productive ecosystem on the earth. They occupy only 8% of the total surface but they account for more than 20% of global plan growth. Since the earliest civilisation, man has been highly dependent on both the land and sea components of coastal regions. According to an estimate (Vongvisessomjai, 1994), 60% of the total 5.5 billion people live in coastal areas and 65% of cities with population more than 2.5 million are located along the world's coast-lines. The world's population likely to exceed 11 billion in the next 100 years and it is expected that 75% of it will live in coastal areas (Vongvisessomjai, 1994). This demographic pattern is due to the generally favourable nature of low-lying coastal areas, for these facilitate settlements, industries, and agricultural activities. With the increasing human interference in the nature's activities, the problems of these coastal areas also increasing. The devastating action of the wind, rain, and surge, combined in what leads to the occurrence of a cyclone, in Bangladesh, India, France and others in the recent past forces the engineers, scientists, research scholars to focus on the problems of coastal areas for possible remedial measures.

1.1 Cyclone

A cyclone refers to an abnormal state of atmosphere that results in the formation of an area of low pressure and strong circulating wind fields. Tropical cyclones begin as clusters of tropical thunderstorms, drawing their energy from the heated surface of the ocean. The heat released from the water vapour condenses into rain, warms the air and causes the moisture flow upwards. This reduces pressure near the ground surface and, in turn, promotes a faster flow of air. Rotation of the earth further intensifies the storm, the winds spiral inwards, and hot moist air is pushed upwards in a ring of cumulonimbus clouds. As the air rises and cools, the moisture condenses and consequently, it is released as heavy rain under high winds. This released energy is pumped into rotating cloud mass, making it rise and spin even faster. Once the wind gets accelerated to 119 kilometre per hour (kmph), a cyclone is born. The formation of a tropical cyclone depends on warm moist air and sea surface temperature of at least 80 °F (or 26 °C).

The term cyclone is derived from the Greek word "kyklos" which signifies among others the coil of a snake. The description is apparently justifiable from the shape of depressions available from satellite imageries looking like a coil. Tropical cyclones are known by different names in different parts of the globe. Term hurricane comes from Spanish word huracan, meaning evil spirit. The Indian tribes of the Caribbean called the god of stormy weather Hunrakan. Many other local names are used to describe these wind storms. The Atlantic basin, East Pacific, and South Indian Ocean use the word hurricane. Typhoon is used in the West Pacific Ocean as *Baguio*. Cyclone is used in the North Indian Ocean and near Australia. Willy-willi is a local term describing a hurricane in Australia

To describe it physically a severe cyclone is a vast whirl in the atmosphere extending from 150 to 1000 kms across and 10 to 17 m high with fierce wind spiralling round a central low pressure area. The whirling body moves with a speed of 300 to 500 km a day. The speed of the wind in a mature cyclone can be 150 to 200 km per hour which accounts for its most destructive potential. The great loss of life and property associated in severe cyclones is caused by high winds, heavy rains, and in some cases by storm tides, often described as tidal surge which inundates low-lying areas near the sea coast. At river estuaries, there is a piling of water due to draining of excessive rain water and the storm tides of the sea. The flood havoc is accentuated when the cyclone strikes the coast at the time of high astronomical tides.

1.2 Cyclonic Surge

Another marine phenomenon of cyclonic surge or storm surge can cause inundation of low-lying coastal areas. A cyclonic surge can be construed as the difference between the actual tide influenced by a meteorological disturbance and the tide which would have occurred in the absence of the meteorological disturbance. The high winds and low pressures associated with cyclones usually lead to significant surge levels and thus give rise to extreme anomalies in the water level. A gradual rise in the level may begin more than 24 hrs before the cyclone makes its nearest approach to the site. Alternatively, a gradual fall below the normal tide may occur for many hours during the approach of a cyclone. The practical importance of a given cyclonic surge at a site will thus depend on the stage of the normal water level at the time of cyclone's passing.

For a physical realisation, a storm surge is a raised dome of water about 60 to 80 km across and typically about 2 to 5 m higher than the normal tide level. Cyclones associated with storm surge cause huge loss of lives and property. It is perhaps the major killer in the tropical deltaic regions. Among all the tropical regions, India and Bangladesh are the worst sufferers of storms and surges. Their frequency in the Bay of Bengal is roughly four fold higher than that in the Arabian sea (Gupta et al. 1996). On an average, one cyclone takes place almost every year in the Bay of Bengal.

Cyclones have been hitting the coastal belt of India very frequently with varying degree of fury. The months of May, June, October, and November are the most probable period for cyclones or heaviest storms in India. These cyclones produce extreme winds which may exceed 200 kmph. These winds generally cause extensive damage to property and cause airborne debris to become potentially lethal missiles. It is important to remember that the passage of the cyclone centre or "eye" produces a temporary lull in the wind and it is soon replaced by extreme winds from another direction. A typical cyclone may cover 300-500 km distance in a day (Gupta et al. 1996). The phenomenal seas accompanying cyclones are dangerous both for vessels out at sea and for those moored in harbours; serious erosion of the adjacent foreshore can also occur. Normally, cyclones also produce flood rains, which can cause further damage and death by drowning. The natural drainage ways, roads, and water resources systems etc. suffer serious damages due to these flood rains.

Out at sea a storm surge can be only a metre high. Such waves are, however, caused by the displacement of a whole body of water - not just of surface water, as in the usual swell of the ocean – such that the sea floor rises, and so does the wave, and it breaks enormous force and speed. Storm surges are in fact made up of several waves, which may be separated by minutes or even hours. People are often killed because they come back after the first wave, as exemplified below:

"An eyewitness in Hawaii recalls travelling on the school bus in 1946. One of the students shouted out that there was no water left in the ocean. Everyone thought he was joking. But tidal waves have a series of peaks and troughs. If a trough comes first, the sea will recede violently before rushing back again. Some of the students and teachers went to see why the ocean was acting so strangely, and 24 died as the returning wave crashed over them." (Source: NOAA, 1993)

The main physical phenomenon responsible for storm surges is the forcing of long waves by pressure and wind fields in severe storms and cyclones, in the regions where coastal topography acts strongly to enhance the amplitude of the forced wave.

1.3 Factors Affecting Storm Surge

Some important physical phenomena that may affect predictions of the magnitude of severity of storm surges in the Bay of Bengal are the following:

a) ***Topographic effects on the wind field:*** The prediction of wind fields, which are affected by the complex land topography, is one of the most important task for coastal engineers and oceanographers. In areas surrounded by the mountains, the wind field is affected by both small-scale roughness such as trees and houses and by large–scale land topography itself (Gary et al., 1996). Consequently, these predictions affect surge height simulation. Compared to Japan, the meteorological forcing is predominant over topographical effects, as the topography is relatively uniform in northern Bay of Bengal. It remains to be determined which of the effects is predominant in Orissa coast.

However, visual inspection of the affected site suggests the dominance of meteorological conditions.

b) ***Coastal flooding:*** Floods are the most common disaster in the low-lying coastal areas. The most devastating flood producing rains are generally associated with tropical cyclones and the low-lying coastal areas suffer from most destructive floods. Floods created by tropical cyclones can reach catastrophic proportions when aggravated by wind induced surges along the coast line and can be felt a long distance inland due to back-up of rivers at high flow and subsequent flooding.

c) ***Wave effects and wind stress:*** The changing sea-surface roughness due to wind waves alters the wind stress and thus influences storm surges. Very high waves are normally predicted where the cyclone winds are strongest.

d) ***Wave set-up***: The sea level rise in the near shore area induced by breaking of swells. Extremely strong winds produce very high waves. When they reach the shore they will cause set-up and be a hazard in themselves. High waves in shallow waters behave in non-linear fashion probably increasing the potential for disaster. The available numerical models developed for deep sea cannot be used for regions where the sea is shallow like the coasts of Bengal and Bangladesh. Data on the depth of the sea near the coasts need to be gathered for the evaluation of these models.

e) ***River flooding:*** River floods affect the water levels during storm surges in the estuary of a large river and can cause large unpredictable sea level rise with long duration. (Gary et al., 1996).

f) ***Change in topography due to sediment transport:*** There are two types of mechanism of sediment transport. One is uni-directional transport by strong currents in the shallow water (including newly-flooded area as tidal flats and low-lying land) caused by high tide and waves. The other is transport by combined wave-current flows in deep water. Changes in topography due to sediment transport both due to floods and due to surge are well known phenomena in the deltaic regions. However, an unexpected incident occurred due to wind in 1978-79 in the village of Purnabandhagonda in Keoghar district in Orissa when a 300m hill was toppled at the height of 150 m and it buried the village.

1.4 Classification of Cyclones

In general, all cyclones are dangerous. Some are, however, more furious and cause havoc. In order to differentiate the destructive power of the cyclones based on the order of the magnitude of the combined effect of wind velocity, surge height, rain amount, and other factors, the National Oceanic and Atmospheric Administration (NOAA) has classified the cyclone's-disaster-potential-scale into five categories, widely known as the Saffir-Simpson hurricane scale. The criteria for each category are shown in Table 1.0.

Table 1.0: The saffir-simpson cyclone scale chart (NOAA, 1994)

Classification	Wind Speed (kmph)	Pressure (mb)	Storm Surge (m)	Damage
Tropical Depression	< 61			
Tropical Storm	62 to 118		0.3 to 1.0	
Category – ONE Cyclone	119 to 153	>980	1.1 to 1.7	Minimal
Category – TWO Cyclone	154 to 177	979-965	1.8 to 2.6	Moderate
Category –THREE Cyclone	178 to 209	964-945	2.7 to 3.8	Extensive
Category – FOUR Cyclone	210 to 249	944-920	3.9 to 5.5	Extreme
Category – FIVE Cyclone	> 249	<920	>5.5	Catastrophic

1.5 Cyclone Prediction

From the ancient times the seafarers have learnt to predict the cyclone or heavy storms and winds from experience by interpreting various symptoms appearing in the sea and the atmosphere, which causes havoc in the coastal regions. Different changes occurring in the atmosphere and the ocean and the abnormal behaviour of marine animal are thought to be the sign of arrival of cyclone and heavy storms (Athiyaman and Jayakumar, 1996). The traditional way of cyclone prediction is normally based on the following symptoms or changes observed by seafarers in the atmosphere and the ocean:

- **Big waves and noisy winds along with dark clouds in the sky**: The storm surge associated with high waves and noisy winds with dark clouds are expected due to the formation of cyclone (Andrew, 1993).
- **Fastly moving star and westerly winds:** In the Bay of Bengal, the cyclone movement is generally between west and north. Due to the clockwise rotation of the cyclone, when it moves towards the shore, the feeling of westerly winds by the sailors is taken as a clue for the arrival of cyclone.
- **Sea looking aggressive due to the heat at the time of cyclone:** The rough sea surface and warm air movement is generally associated with the evolution of cyclone, which forms a clue.
- **From the divine world elephant trunk sucking water from the sea (water-spouts):** The water-spouts in the sea resembles a long thin rope like an elephant trunk (David, 1982). Superstitious faith forces the sailors to believe that the elephant from the divine world is taking water from the sea. The appearance of such a phenomenon in the ocean is considered as a sign of heavy rain or storm.
- **Heavy easterly winds or north easterly winds:** Easterly winds are considered for arrival of rain and north easterly winds for arrival of cyclone.
- **Reddish sky:** The reddish sky in the evening is the sign of rain arrival, while the reddish sky in the morning is the sign for arrival of heavy winds.
- **Abnormal behaviour of the marine animals:** Seafarers also predict the cyclone and heavy rain from the following abnormal behaviour of marine animals:
  - The sea snakes role like the ball and float on the sea surface at least a day before the arrival of cyclone or heavy storm.
  - The fishes like *panavayan, vedan, tirukkai* (ray fish) appear on the sea surface with their tail pointing upward before the onset of a cyclone.
  - The shark chases the fish *karivalai (*mullets) during the onset of a cyclone.
  - During the period of cyclone the turtles move in pairs.

Scientific and technological advancements have enabled to predict cyclones and depressions well in advance and permit to take precautionary measures before any major disaster occurs. Scientific observations have shown that the necessary conditions for the development of tropical cyclones generally are (NOAA, 1994):

- Ocean sea surface temperature greater than 80 °F (or 26 °C).
- Small wind speed and changes in direction with height between the lower and upper troposphere (1000 mb to 200 mb height), and a vertical wind shear less than 16 kmph.
- Existence of pre-existing light westerly trades.
- Temperature distribution with height, which will overturn when saturated leading to cumulonimbus activity.
- Location north of 5° latitude.
- Existence or development of a large-scale anticyclone (high pressure) in the upper troposphere. It allows the evacuation of mass from the hitting of cyclone.

1.6 Bay of Bengal Cyclones: Model Studies

The northern Bay of Bengal, especially along the coasts of Bangladesh and India, is subjected to the worst storm-surge problem in the world (Murty et al., 1986). As recently as 1991, 150,000 people were killed during a severe cyclone and surge, mostly by drowning. One way to help alleviate the problem is to improve numerical models so that they become accurate enough to forecast flooding (Gary et al. 1996). Better warnings can then be issued so that people have enough time to evacuate to shelters. A number of models have been developed, but further progress is hindered by the lack of data. Comprehensive data are essential in order to test predictions and to identify and correct errors in the models. A permanent monitoring network, capable of providing reliable data during surges, is still awaited. The accuracy of models for forecasting flooding in specific locations is also limited by the accuracy of cyclone forecasts and by outdated and insufficiently detailed bathymetric and topographic data. Meanwhile, however, the models can be enhanced on the basis of experience gained in other surge-prone regions.

The most notable difference between surges in the Bay of Bengal and in Japan is the difference in the relative scales of topography and wind forcing. In the inner Bay of Bengal, both the continental shelf and the corner of the bay have dimensions of the order of 100 km. Off Bangladesh the shelf is also shallow – mostly less than 20 m. Cyclones generate extreme surges in this area because of the strong wind-induced circulation of a large amount of sea water. Compared with Japan, the meteorological forcing is more significant in determining where the flooding will be most severe, since the topography is more uniform within the affected area. Accurate flooding forecasts would thus require accurate predictions of cyclone development and parallel efforts in meteorological research will be essential for a solution to this problem. On the other hand, the enclosed bays of Japan have dimensions of the order of 20-40 km in average depth, 60 km in length and 10 km in mouth width, so are smaller than the cyclones. Also, the continental shelf is narrower, of the order of 20-30 km, again smaller than the cyclones. Surge development is thus more restricted and smaller surges result. Topography is a more significant factor in determining where the surge height will be greatest. They are not quite so sensitive to cyclone parameters, track, and timing as in Bangladesh.

The inclusion of moving boundaries in surge models in the Bay of Bengal has been found to reduce by up to 1 m, the predicted surge height. It is, therefore, important that models should include moving boundaries. Apart from this, an important potential result from such models is the detailed prediction of flooded areas. At present, such predictions remain unverified and there is uncertainty about wheather the effects of different types of terrain (buildings, vegetation, etc.) can be sufficiently well represented in order to make accurate predictions.

The effect of mountains on the wind has been shown to have a significant effect on storm surges in Japan. In Bangladesh and India, however, where the topography is much flatter, the effect is likely to be small. In south-east Bangladesh and Myanmar (Burma), there are hills close to the coast and the size of their effect should be determined. The effect of land friction on the wind field, especially where the wind is offshore, should also be investigated.

Perhaps the most important subject for future improvement in models of surges in the Bay of Bengal is the inclusion of wave field calculations. The extremely strong winds produce very high waves and their propagation should be modelled properly. When they reach the coast they will cause set-up and also cause a hazard in themselves. High waves in shallow water such as the shelf of Bangladesh will behave in a strongly non-linear fashion and appropriate ways of modelling such waves should be determined.

The rivers that enter the Bay of Bengal through Bangladesh are subject to strong seasonal flooding and, in fact, pose more frequent and widespread source of flooding there. Significant increases in sea level are expected during floods, as in Wenzhou Bay. This effect should be incorporated into surge forecasting models in Bangladesh, for the simultaneous occurrence of river floods and storm surge has the potential to worsen the disaster.

Sediment transport and topography-change happen constantly in Bengladesh. During a storm surge, large sudden changes can be expected. This should be assessed quantitatively, and models for predicting the changes developed.

1.7 History of the Coastal Belt of Orissa

The coastal belt of Orissa has been formed by the silt carried by rivers like Rushikulya, Mahanadi, Brahmani, Baitarni, Budhabalang, and Subernarekha and other small rivers having their origin in the Eastern Ghats and Northern Plateau. Consequent to silt deposition, these rivers have spread over the coastal area in a number of branches and converted the land to delta, making the land to be more prone to the natural fury of floods since time immemorial. Villagers have generally settled on the higher ridges along river banks and their lives and properties are frequently affected by floods, leading to the diversion of significant attention of the administrators of Orissa since several years. Fig. 1 presents the location map of Orissa's cyclone hit areas.

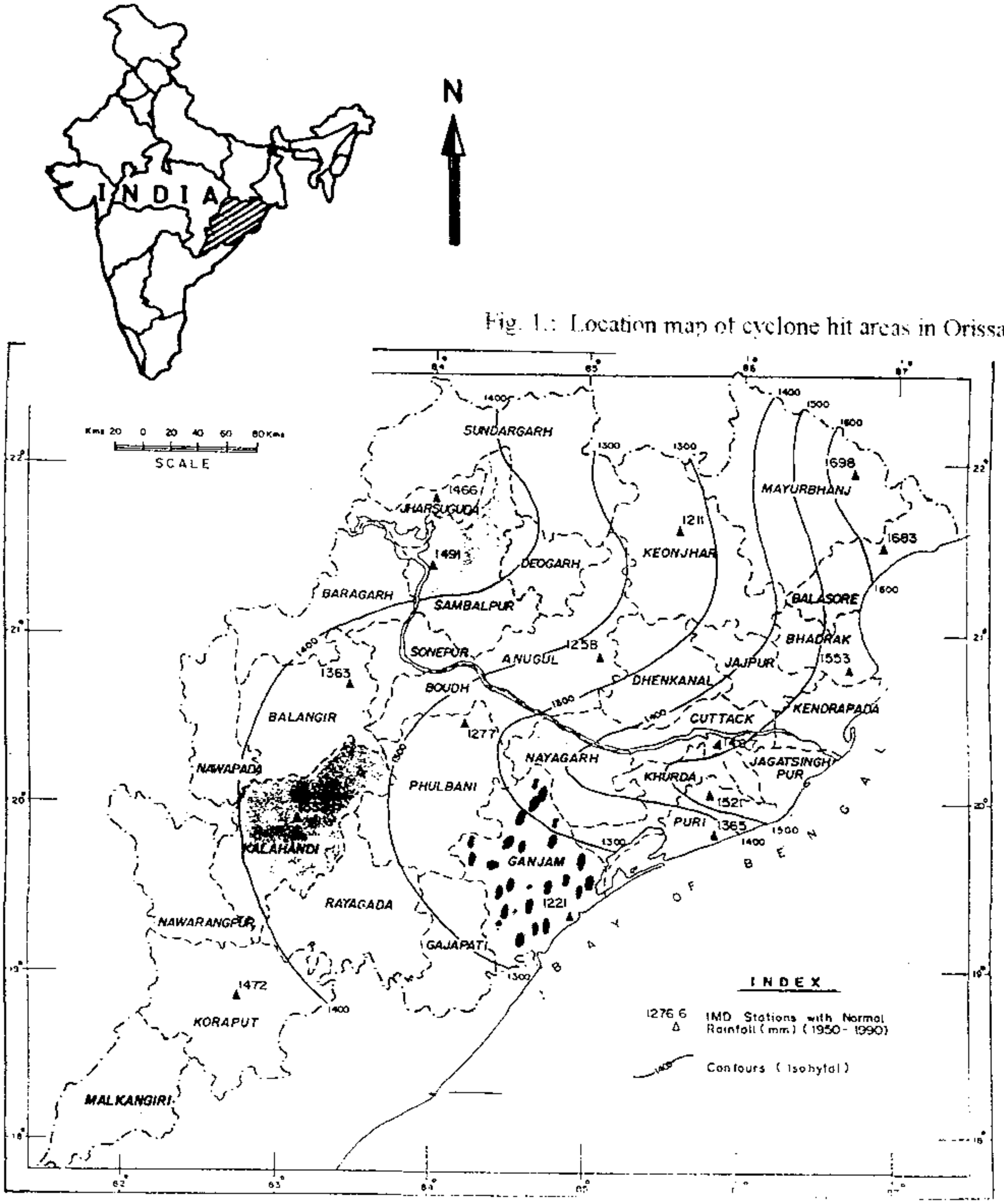


Fig. 1.: Location map of cyclone hit areas in Orissa

It appears from the available history of tidal inundation that cyclones were also a regular feature during the late 19 century though the meagre population in the coastal areas due to difficult living conditions that time was sporadically located along the banks of deltaic rivers. The crops and property damages occurring due to floods used to compensate by good subsequent harvests through the land nourishment by fresh flood-silt. People did not use to have tenacity to settle in the low lands of the coastal belt that is severely affected by cyclones.

The coastal strip of about 10 km width was covered by forests and communication was practically non-existent, except by boats through creeks and rivers. Consequent to an ample scope for fishing, villages of fishermen developed all along the coastal. These fishermen did not have to care for growing paddy, for they used to exchange sea and estuarine fish for cereal from the people living inland. Thus, habitations were mostly concentrated along the river mouths on high sand dunes.

During the ancient Hindu Kingdom of Orissa, maritime trade developed considerably. The laborious, persevering, and enterprising people were able to develop a gigantic culture, the relics of which are found on the face of the Hindu temples at Konark, Bhubaneshwar, and Puri. In the 10^{th} century, Orissa was established as one of the most prosperous and rich kingdom of the east coast of India. In addition to inland trades, the people of Orissa established maritime relations with Sumatra and Java and other kingdoms of far-east. It was the last kingdom in North India to be invaded by the Mughals.

In the reign of Mughals, the prosperity of Orissa deteriorated considerably. The maritime trade was destroyed and the prosperous ports of Tamralipti, Cheletola, Chilika, and Kalingpatna ceased to operate. What remained in the sea coast of Orissa was habitation of impoverished fishermen forced to rely on cattle. Under the British rule, people further impoverished to such an extent that they were converted to agriculturists completely. Having known the rich potential of the coastal Orissa, the Britishers established minor ports at Balasore, Chandabali, Hukitola, Puri, and Gopalpur along the

Orissa coast to develop their trade. Subsequently, the temptation of British imperialism to rule all over India led to their disinterest in Orissa and consequently, on the developments of the ports.

After independence, the population of Province of West Bengal and Orissa grew significantly, mostly because some East Bengal refugees and some people of Midnapoor found this coastal belt well matched with ecological background of their lace and settled by clearing forests on the highly productive land. In Orissa, this situation was more prominent between Devi river and Dhamra mouth. The poor inhabitants and landless labourers of the coastal districts, exploited during the British Rule, also moved to this coastal strip in quest of fertile land. These people used to produce enough paddy and estuarine fish and led a happy life for about 20 years. However, the ill-fated cyclones of 1967 and 1971 inundated their reclaimed lands developed by hard labour. The 1971 cyclone was the then most destructive, for the tidal bore raised the water level by 15 to 18 ft along the coast from False point to Dhamra mouth. The 1971 cyclone led to toll of about 7000 human beings both along the coast and on the banks of some low-lying creeks.

During the first, second, and third plan periods, enough attention was not paid to the planning of the coastal belt of Orissa, for other multifarious problems in hand. These unfortunate people mostly uneducated and non-conversant with such calamity could not discriminate between safe and unsafe areas and settled where the paddy land was available.

1.7.1 Socio-Economic Setting

As mentioned above, the entire coastal belt of Orissa is of alluvium. There are a number of tidal creeks along the coast through which tides flow up to 25 km inland. For completeness, it is necessary to study the socio-economic setting of the people residing in this coastal belt of Orissa. This area covers either fully or in part the following blocks (Table 2) within 25 km stretch of the land along the coast:

Table 2.0: Number of blocks in the coastal districts of Orissa

Sl. No.	Name of the district	Number of Blocks
1	Ganjam	17
2	Puri	14
3	Cuttuck	12
4	Balasore	17
5	Mayurbhanj	3

These areas are thickly populated and nearly 3.9 Million of people live in this area; nearly 70% of the population depend on agriculture, 5% on fishing, and 25% on other professions other than fishing and agriculture. Nearly 90% of the population live in thatched roof houses and fall under low-income group. The communication system of this area is extremely poor. Agriculture is the main source of income, but because of frequent floods, saline inundation, and severe cyclones, the economical structure of this area is extremely poor.

1.7.2 Problems due to Cyclonic Wind

There were cyclonic storms in November, 1942; October 1967; October 1968; and October, 1971, November 1973, may 1979, November 1995 and two events in October 1999. Available statistics shows that the cyclonic wind recurs frequently due to unknown reasons. Cyclones usually form in the months of October and November, when the Kharif paddy is usually in flowering stage. The cyclonic winds blows-off flowers and paddy crop is badly damaged. Due to the high wind velocity, trees are uprooted, kuchcha houses are blown away, and most of the houses collapse, on account of which heavy loss of human and cattle lives occur. The inhabitants are rendered homeless and poverty strikes. Thus, the cyclonic winds practically hit the back-bone of the economical structure of the area.

1.7.3 Problems of Salinity

A number of gherry bunds have been constructed to protect the coastal belt of Orissa from floods and especially from normal saline inundation. Because of the cyclonic storms, the water level in the tidal creeks rises and spills over the gherry bunds, causing innumerable breaches. This saline inundation washes away the villages and, in turn, makes the people homeless and finally results in a heavy toll of human and cattle lives. The sweet water tanks, wells, and ponds get filled up with saline water, leading to starvation. After the saline flood, severe epidemic spreads in the area, the land becomes unproductive, and the standing paddy is damaged. It has been noticed that even the dried straw of paddy drenched by saline bore does not catch fire. Thus, saline floods cause serious problems to human and cattle lives.

1.7.4 Problems of Communication

Due to lack of communication facilities in the coastal belt, it becomes difficult to rescue the affected people of the area. The relief does not reach them in time nor are they able to vacate the area, even after having come to learn about the incoming cyclone through warning. Though not impossible, it is very costly to have proper communication system in this area.

1.8 Super-Cyclone '99 of Orissa

During the second fortnight of October 1999, the coasts of Orissa (India) faced two highly devastating cyclones. The first severe cyclone occurred on October 17, 1999 and hit the Ganjam district. Another catastrophic cyclone named as "super-cyclone '99" (herein afterwards referred as super cyclone) occurred on October 29 and hit near Paradip. The latter broke all previous records of devastation and created havoc in Paradip, Kendrapara, Jagatsingpur, Cuttack, Puri, Bhubaneshwar, Jajpur, Bhadrak and Baleshwar districts of Orissa. Normally a cyclone vents its fury in a time space of about four to eight hours but the super cyclone hung over Paradip and other places for almost a day, bringing with it the winds of gale force (wind speed > 200 kmph) and incessant rain. This caused an ever-experienced devastation in the history of cyclones in India.

1.9 Objectives

The objective of the present study is to document the Orrissa cyclones along with the hydro-meteorology of the region and present the state-of-the-art of cyclonic phenomena in the region, cyclone prediction accomplishments, and experiences derived from the 1971 and October-1999 cyclones of Orissa for future research in the field in the country.

2.0 FEATURES OF THE COASTAL BELT OF ORISSA

2.1 East Coast Belt of India

The East Coast Belt of India is frequently encroached by the waters of the Bay of Bengal. The belt extends northwards for a distance of 1000 km from Kanyakumari to the deltas of Krishna and Godavari in an average width of 100-130 km and north-eastwards for a distance of 1375 km up to the delta of Ganga. The belt almost vanishes at the point where the Eastern Ghats (referred here as Mahendragiri) comes down to the coast. Further north, it again widens as it extends across the Chilika Lake, the Mahanadi delta, Balasore coastal plains to merge with the deltaic plains of the Ganga.

2.2 Coastal Belt of Orissa

The State of Orissa spreads over an area of 1,55, 707 sq. km is bounded between North latitudes 17°49' to 22°34' and East longitudes 81°24' to 87°29'. The State comprises of 3 revenue divisions, 30 districts, 58 sub-divisions, and 314 community development blocks. The State's population largely depends on agriculture. The total population of the State as per 1991 census is 31.660 million, out of which the rural population is 27.425 million, urban population is 4.235 million. Features of the coastal belt of India and Orissa, in particular, follow.

There are eleven principal rivers traversing the State. These rivers can be grouped under eight major river basins within the State whereas the Indravati, Kolab, Machakund sub-basins form part of Godavari river basin. Most of the major rivers flow in easterly and south-easterly directions with gentle gradient. The rivers are generally effluent in nature. The salient features of the major river basins are given in Table 3.0.

Orissa State can, in general, be characterised by picturesque landforms. The coastal belt of Orissa extending to a length of 550 km constitutes the north portion of the east coast belt of India. The southern and central parts of the State in Rayagada, Kalahandi, Phulbani, and Gajapati districts present a rugged hilly tract. Plateau occupies the northern districts of Sundergarh, Keonjhar, and Mayurbhanj and parts of Nawarangpur district in the south-west. Undulating plains characterise the major river valleys. A narrow coastal plain borders the Bay of Bengal. Physiographically, the State can be divided into five distinct units: (I) coastal plains, (ii) northern uplands, (iii) erosional plains of Mahanadi valley, (iv) south-western hilly region, and (v) sub-dued plateaus.

The coastal plains covering the districts of Ganjam, Puri, Cuttuck, and Balsore from south to north form an extensive flat alluvium tract between the hills in the west and the coast in the east. It presents a flat gently sloping due east topography of insignificant elevation difference. The general elevation of the coastal plains is 1 to 10 m above mean sea level.

Table 3.0: Major river basins of Orissa

River	Drainage Area (sq. km)	Annual Flow (Mm^3)
Mahanadi	65,579	51,061
Brahmani	22,248	18,311
Baitarni	12,789	5,452
Subarnarekha	21,23	7,941
Budhabalang	4,847	637
Rushikulya	7,753	1,762
Vamsadhara	8,015	3,460
Nagavali	3,746	2,430
Indravati	7,512	2,800
Kolab	7,639	2,615
Machakund	1478	4044

Northern uplands covering Mayurbhanj, Keonjhar, and Sundergarh districts and Pallahara sub-division of Dhenkanal district are undulating, frequently intersected by hill ranges with general slope from north to south. The elevation in the central part of the upland generally varies from 300 to 600 m and forms watersheds of Baitarni and Brahmani river systems.

The erosional plains of Mahanadi river basin lie between the northern uplands and southern hilly region of the Eastern Ghats. The tract covers major parts of undivided districts of Sambalpur, Bolangiri, Dhenkanal, and northern parts of Phulbani and western part of Puri district. The altitude of this tract lies between 150 and 300 m above mean sea level.

South western hilly region lies to the south and south-west of Mahanadi valley region, stretching through Phulbani, Ganjam districts and part of Koraput district. Major part of this region has an elevation of over 600 m acting as the watershed of the two sets of rivers, one set flowing directly to the Bay of Bengal, namely the Rushikulya, the Nagavali and Vamsadhara, and the others feeding the Godavari and Mahanadi river systems.

The plateau extends throughout the western part of Kalahandi, Nuapara and Koraput, Malkangiri, Rayagada, Nawarangpur district with the average elevation varying from 300 to 600 m above mean sea level.

2.3 Zoning of the Coastal Belt of Orissa

There are some tidal swamps and tidal forests in the coastal plain, for example, Chilika Lake, a brakish water lagoon, is situated inside the coastal belt. For a detailed study from cyclone point of view, the coastal belt of Orissa is divided into the following reaches, approximately of 25 km width each, which are affected by cyclonic storms from time to time.

Zone I:

	(i)	Ichhapuram to the Rushikulya mouth.
	(ii)	Rushikulya mouth to Chilika mouth.
	(iii)	Chilika mouth to Surlake cut.
Zone II:		Surlake cut to Devi mouth.
Zone III:		Devi mouth to Mahanadi mouth.
Zone IV:		Mahanadi mouth to Dhamra mouth.
Zone V:		Dhamra mouth to West Bengal border.

Zone I

Sub-zone (i)

This reach extending from Ichhapuram to Rushikulya mouth has an important tourist resort at Gopalpur, midway of subzone, and is thickly populated. There is Surole swamp in the beginning of the reach in which Bahuda river falls. This swamp is protected from the ingress of the sea by high sand bars. There are also sporadic low lands, for example, Gangi-Tampara, very close to the sea-shore. Small rivulets originating from the hills near Barhampur fall into the sea near Gopalpur. High sand bars and mounds have been formed along the coast in this zone and as a result of this, ingress of salt water is restricted to only low pockets situated in this subzone, thus protecting these areas from tidal surges. Nevertheless, this portion of the coastal belt is sometimes subjected to cylconic damages due to high wind velocity. In October 1972, these areas were lashed by a cyclone of severe intensity.

Subzone (ii)

River Rushikulya enters the sea in the beginning of this subzone and is affected by tides up to 5 kms. This is a major river of Orissa and a number of irrigation schemes have been constructed across the river and its tributaries; these irrigate areas up to the sea coast. This sub-zone is densely populated and is protected by high sand bars and mounds. The Chilika Lake, the islands in which are moderately populated, plays an important role in the economic development of the State. The land adjoining to the Chilika Lake is not subjected to high saline bore. The rise and fall of the tide outside the Chilika Lake, i.e. in the sea, is 2 miles whereas inside at Balugaon, it is only 0.1 mile. No cyclonic bore travels much into the main land through the rivers falling in the lake. Several rivulets including the Daya and Bhargabi which are the branches of the Mahanadi fall in the Chilika lake. The level of Chilika actually rises due to flood waters during monsoons and not due to ingress of sea water during cyclones. The Chilika lake and the adjoining land have been subjected to fury of cyclonic wind from time to time. The Gadakrishna-Prasad Block situated in Parikud island of Chilika was badly devastated during 1968 due to heavy winds. The existing saline embankments have been constructed round the islands to protect the cultivated area from the ingress of the sea water during normal tide. Future plans cover the development of Chilika Lake and its adjoining areas and deepening of its mouth.

Subzone (iii)

This subzone constitutes the coastal belt of Puri and Brahmagiri area that is extremely fertile and thickly populated. It has a continuous sand bar along the coast. The Government of Orissa has devloped Casurina plantation in several reaches along this coast. The Surlake has a mouth in the sea through an artificial drainage cut. This subzone is subjected to heavy floods from the branches of the Mahanadi, being embanked at both the banks to extend canal irrigation.

Zone II

This zone includes the mouths of Kusabhadra, Prachi-Kadua, and Devi. The area is densely populated and the soil is sandy in nature. The mounds are discontinuous at various places and sporadic wood growth exists at some places. The Govt. of Orissa has developed Casurina plantations at several reaches along the coast. Paddy lands up to about 4 miles from the sea coast are provided with irrigation by the delta canals. The terrain is flat and even cyclone of moderate intensity may produce immense devastation to this thickly populated area. This area has been subjected to heavy floods. In order to protect the area embankments have been constructed and these are raised and strengthened.

Zone III

This zone contains the mouths of Borwan, Jatadhari, and Mahanadi through which a number of branch canals of Mahanadi river and a number of drainage channels drain to the sea. This zone was once covered by a dense forest. It, however, is now almost deforested and converted to agricultural land. Discontinuous sand bars and mounds still exist along this coast. A network of creek exists in this area, serving the people in several ways. The area is subjected to saline inundation and is flat in nature.

Two all-weather roads one from Cuttuck and the other newly constructed from Daitari mines connect Paradip Port. This coastal belt was subjected to heavy devastation during the cyclone of 1971 as the eye of the cyclone passed through the vicinity of Paradip Port. These areas are densely populated and the population is rising fast. The Paradip area is developing fast, leading to heavy urbanisation.

Zone IV

In this zone, the mouths of Mahanadi, Hujitoala, Kharanasi, Jambu, Kendrapatia, Hansua, Chitaukolna, Maipure, and Dhamara lie. This zone was devastated most during 1971 cyclone. A number of spill channels from the Mahanadi and the Brahmani find their exit to the sea through the above-mentioned mouths. There is an extensive network of creeks in this coastal belt. A number of saline gherry bunds and double embanked spill channels have been constructed to prevent normal and cyclonic inundation but these are inadequate to provide protection to the area from high tidal bores due to cyclone. Therefore, it is necessary to prepare a Master Plan for this area as the area is most vulnerable to tidal bore. This zone is thickly populated and inhabitation has extended nearly to the sea-shore by reclaiming the forest. About 3 decades ago, this area was sparsely populated and the growth of forests that act as storm barriers was controlled by Zamindars like those of Kanika and Aul. After the abolition of Zamindari, no strict measures were taken to preserve these forests. The Hansua and Kandrapatia spills are situated in this area and as these are extremely flat creeks. The tidal surge during 1971 cyclones penetrated deep into the land and caused unprecedented havoc on both the banks causing destruction to life, property, and agriculture fields. The tidal surge caused immense damage during 1971 cyclone. On local enquiry, it has been ascertained that the surge water crossed the shore and inundated the coastal land. These areas are extremely flat and low and practically, there is no protection from high surges.

The Hukitola Bay is getting silted up and heavy land erosion is taking place along the sea coast near Satbhaya. This area is subjected to saline ingress during the dry season. However, during the flood season, the salinity is washed away by floods and rain. The Chandabali river port situated on the left bank of river Baitarni has lost its importance as the traffic is divided into rail and road. It is, however, not contemplated to use Chandabali through Dhamra as a fishing harbour.

Zone V

This zone covers the river mouths of Dhamra, Gamei, Kansabansa, Kantiachara, Atala, Budhabalang, Saratha, Hanskura, and Subernarekha. Major rivers like Dhamra, Budhabalang, and Subernarekha enter the sea in this zone. The effect of littoral drift, described below, along Balasore coast in this northern most zone has caused land accretion along the entire coast and prominently near the mouth of the Subernarekha. In normal low tides, the sea recedes to about 11 km at Chandipur.

> ***Littoral drift:*** *The whole east coast of India is subjected to an intense coastal or littoral drift from south to north due to the oblique action of waves against the coast. The net quantity of sand which moves along the coast, from south-west to*

north-east, due to this drift is estimated to be about 1.5 Million tonnes per year. The river mouths along the sea coast of Orissa are diverted north-east under the influence of this littoral drift. The Hutikola spill is an example of intense sand drift.

This coastal belt covers a substantial part of Balasore. There are very few sand bars from Saratha mouth to West Bengal border. There are few creeks in this zone and some areas near the coast are very low and subjected to saline inundation even during the normal high tides. The area is densely populated and the paddy fields are highly productive. A saline embankment along the left bank of Dhamra river continues along the coast up to Gamei mouth and a number of saline gherry bunds exist in north Balasore area. The defunct coast canal along this coast also exists; some portion of the canal serves as communication link from one village to other. This canal lost its importance due to road and railway developments. However, it is very useful for washing of the saline land by the fresh water received from a number of cross-drainage.

It generally appears from the above that each arm of the delta makes a mouth directed N-E, protruding from the coast. These mouths maintain this direction and profusion owing to the formation of sand spits by the coastal drift. The sand spit and the mouths have progressed N-E in some cases for a considerable distance, resulting in the formation of a calm area to the north of the mouth which is quickly filled with the river deposits carried by the current. When silt and sand deposit at the mouth becomes considerable, rivers through the sand find a new outlet to the sea. This can be brought about by a cyclone or flooded by a tidal wave overtopping the sand spit from the sea-side. The river then forms a new mouth and this mouth again starts moving north-east due to littoral drift. This is a continuous process repeated through ages along the coast of Orissa.

2.4 Geological Setting

Geological setting along with climate and topography plays an important role in the movement of ground water. The State is underlain by diverse rock types which range in age from Precambrian to Cenozoic era. The Precambrians occupy nearly 80% of the total geographical area of the State. The Tertiary and Quaternary formations are restricted mainly to the narrow coastal tract. The Gondwana group of rocks belonging to Paleozoic and Mesoic era occur in isolated locations in different parts of the State. These formations occur in Talcher area of Angul district and Ib river valley area of the Sambalpur and Sundergarh districts. Hydrogeologically, the State can be broadly divided into three distinct units, as follows.

(i) Area with Precambrian Consolidated Formations: This area covers the following districts: Sundergarh, Keonjhar, Mayurbhanj, Subarnapur, Bolangiri, Phulbani, Boudh Gajapati, Nuapara, Kalahandi and parts of Nayagarh, Khurda, Balasore, Cuttuck, Ganjam, Koraput, Kalahandi, Angul, Dhenkanal, Sambalpur, Bargarh. The consolidated formations include the hard crystalline and partly metamorphosed compact sedimentary formations belonging to Pre-cambrian era. The rock types are mainly granites, granite gneisses, schistose rocks, khondalites, charnokites, quartzites, calscsilicates, shale, hyllite, sandstone, limestone, marble etc. These rocks are devoid of primary porosity. The groundwater occurs in secondary porosity resulting from weathering, fracturing, and jointing. The hard rock aquifers exhibit considerable variation both laterally and vertically, in depth. The weathered mentle is composed of loose regolith with inter-granular porosity, which facilitates free circulation of groundwater through deeper fractures and forms potential repository of groundwater. In general, the average thickness of weathered resiuum varies from 15 to 20 m. The water bearing fracture zones generally occur within 100 m depth, but deeper potential fractures have also been encountered in some of the bore holes.

(ii) Area with Semi-consolidated Gondwana and Tertiary Formation: These formatins are found in the following districts: Parts of Sundergarh, Mayurbhanj, Angul, Dhenkanal, Khurda, Sambalpur, Phulbani, Bolangiri, and others. The consolidated formations include Gondwana sedimentaries ranging in age from Upper Carboneferous to Cretaceous and the Baripada beds of Middle-Pliecene age. The Gondwanas include sandstones, shales, siltstones, and Conglomeratic beds whereas the Baripada beds consist of fossiliferous limestones, stratified semi-consolidated sand beds with intercalated shales. The coarse to medium grained, weathered, fractured, and friable Gondwana sandstones and the semi-consolidated sand beds of Baripada formation from the aquifers. The groundwater occurs in under water table conditions in the near surface aquifers and under confined conditions in the deeper aquifers. The depth of weathering in Gondwanas generally extend to a depth of 15 m.

(iii) Area with Unconsolidated Quaternary Formations: These formations are found in coastal tract of Puri, Khurda, Cuttuck, Jagatsingpur, Jajpur, Kendrapada, Balasore, Bhadrak, Ganjam, and inland river valleys. The unconsolidated sedimenta include liestocene and recent alluvium. The older alluvium is generally overlain by laterites that form conpicuous but significant horizon. The laterites are vesicular essentially ferruginous and form good repository of groundwater. Maximum development of alluvial formations occur along the coastal tract, exceeding 600 m thickness. Alluvium also occurs as discontinuous patches adjoining the river courses, where the thickness is limited to 45 m. The sand and gravel layers act as repository of groundwater, which occurs under unconfined condition in shallow zones and under semi-confined to confined condition in the deeper zone. The coastal tract holds potential for large scale groundwater development as the sand zone forms prolific aquifers. However, the coastal tract is beset with salinity problems both in shallow as well as deeper aquifers at different locales.

2.5 Climate

The normal rainfall values for various places in Orissa are given in Table 4.0. It is apparent from the table that the normal rainfall varies from 1211.1 mm at Keonjhar to 1697.9 mm at Baripada. An isohyetal map of Orissa is given in Fig. 2. The State experiences hot summer with temperature as high as 45 °C. During winter, mornings and nights are cool. The mean monthly summer temperature of the western parts is 37°C and it is 28 °C in southern parts of the State. The mean monthly winter temperature varies from 18 °C to 22 °C in different parts of the State.

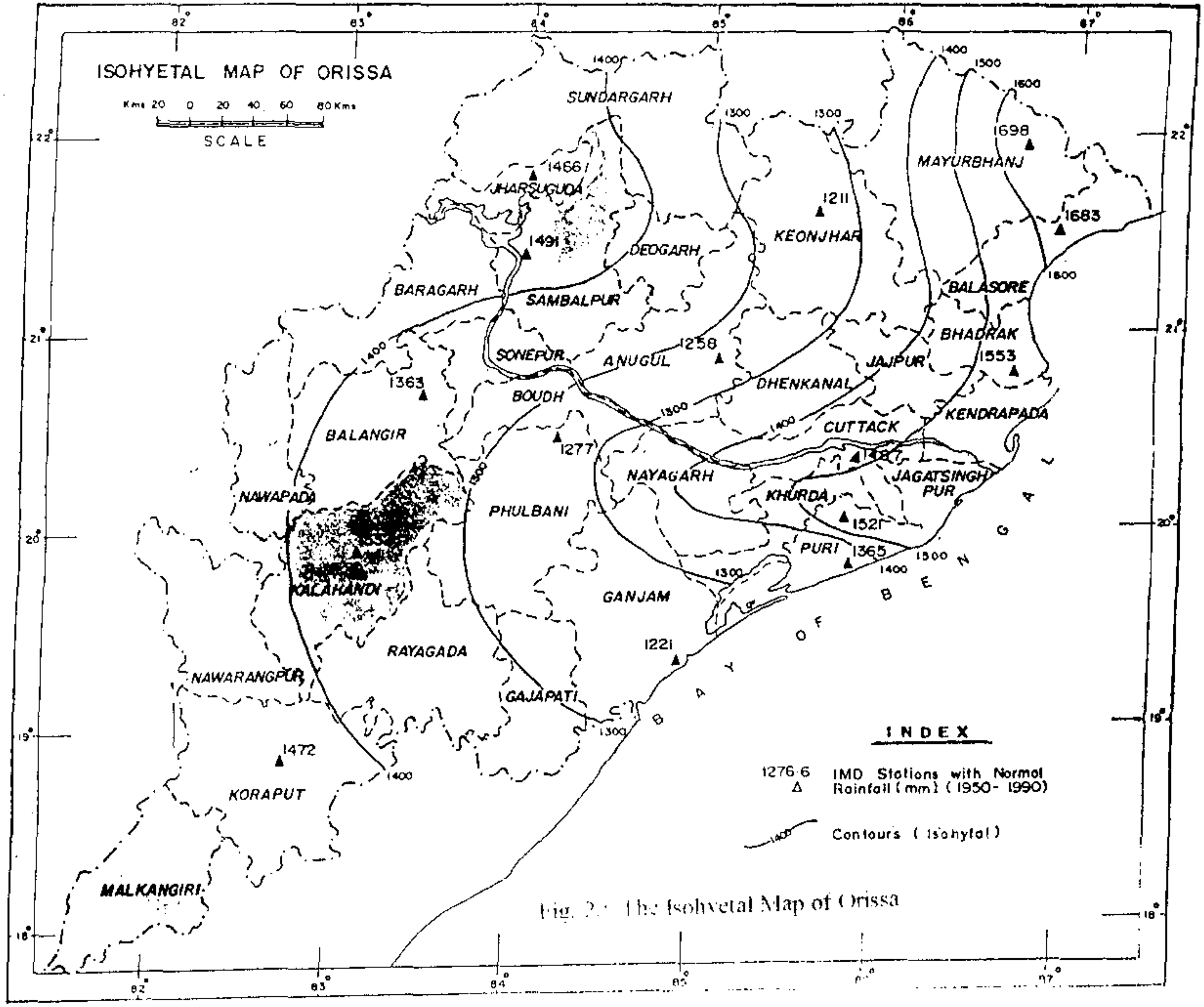


Fig. 2.: The Isohyetal Map of Orissa

Table 4.0. Normal rainfall of various places

(Source: India Meteorological Department)

Sl. No.	Place	Normal Rainfall (mm)	Sl. No.	Place	Normal Rainfall (mm)
1	Koraput	1471.8	9	Jharsuguda	1466.3
2	Phulbani	1276.6	10	Balasore	1682.7
3	Bhawanipatna	1331.8	11	Baripada	1697.9
4	Sambalpur	1491.9	12	Bolangiri	1362.9
5	Puri	1364.9	13	Chandbali	1552.7
6	Bhubaneshwar	1520.3	14	Gopalur	1221.2
7	Angul	1258.2	15	Keonjhar	1211.1
8	Cuttuck	1487.0			

2.6 Ground Water

Ground water monitoring is carried out through a network of observation wells, known as National Hydrograph Network Stations (NHNS). The NHNS set-up is a system of spatially distributed observation points at which periodic monitoring and recording of ground water level, temperature, collection water samples for water quality analysis is done. Orissa State is covered by 1052 observation wells, which also serve as NHNS.

Groundwater monitoring is carried out through a network of observation open wells and piezometers all over the State. These wells serve as permanent Hydrograph Network Stations (NHS). The existing network provides an optimal spatial distribution stations in the region through which necessary information on groundwater regime is available with fair degree of accuracy. Normally, water levels in open wells are measured four times in a year during the periods mentioned below (Table 5.0):

Water samples from the above observation wells are also collected for quality analysis of the ground water.

2.6.1 Distribution of National Hydrograph Stations

A total of 1052 National Hydrograph Stations (NHS) have been established and are being monitored in the State. Out of 1052 NHS, 1008 are open/dug wells and 44 piezometers, which are generally located in the coastal tract. According to district, the distribution is furnished in Table 6.0.

Table 5.0: Periods of groundwater level observations

Period	Representative Levels
April 20-30	Water level of pre-monsoon
August 20-30	Peak water level of monsoon
November 1-10	Water level of post-monsoon
January 1-10	Water level of irrigation (lean) period

Table 6.0: Number of NHS in various districts of Orissa

District	Number of		Total no. of NHS
	Dug wells	Piezometers	(April '98)
Sundergarh	41	--	41
Jharsuguda	7	--	7
Bargarh	54	1	55
Sambalpur	44	--	44
Deogarh	6	--	6
Angul	38	--	38
Dhenkanal	41	--	41
Keonjhar	57	--	57
Mayurbhanj	69	1	70
Balasore	29	4	33
Bhadrak	15	7	22
Jajpur	30	4	34

Kendrapada	15	1	16
Jagatsingpur	16	8	24
Puri	45	12	57
Ganjam	87	--	87
Nayagarh	15	--	15
Khurda	23	1	24
Cuttuck	43	5	48
Boudh	29	--	29
Phulbani	32	--	32
Gajapati	19	--	19
Rayagad	19	--	19
Koraput	48	--	48
Malkhangiri	28	--	28
Nawarangpur	18	--	18
Kalahandi	49	--	49
Nawapara	19	--	19
Bolangiri	43	--	-
Suvernapur	29	--	29
Total	1008	44	1052

2.6.2 Groundwater Quality

The groundwater quality of shallow wells in the State varies widely, depending on the physiography, soil texture, and underlain formation. In the coastal plain where most wells are located in the alluvium, the quality is relatively saline. In the coastal districts, the electrical conductivity and chloride concentration ranges between 14600 to 30 micro Seimens per cm and 4360 and 3.5 mg/l. The maximum and minimum values recorded for nitrate, fluoride, iron besides electrical conductivity and chloride content in the well water of these districts are shown in Table 7.0.

Table 7.0: Maximum and minimum concentrations of chemical parameters in different coastal districts

District	Electrical conductance		Chloride		Nitrate		Fluoride		Iron	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Puri	4539	87	1049	71	192	0.01	12.00	0.16	34.00	0
Ganjam	14600	160	4360	71	418	0.14	2.31	0	3.00	0
Kendrapada	2769	299	629	14	261	0.49	6.94	0.17	7.20	0.07
Jagasingpur	1680	187	239	14	63	0.10	3.70	0.11	2.10	0.06
Gajapati	1360	90	188	35	41	0.23	1.95	0.14	0.66	0.13
Balasore	3390	30	922	35	85	0	2.10	0.03	1.90	0.01
Bhadrak	5860	300	1673	11	51	0	6.20	0.20	4.75	0.04

The concentration of iron more than the permissible limit (> 1.0 mg/l) has been recorded in 46% wells of Puri district, 30% wells of Kendrapada district, and 21% of Jagatsingpur district. Some locations having very high values of iron concentration are shown in Table 8.0.

Table 8.0: Location of wells having very high concentration of iron

Location	District	Iron content (mg/l)
Budhibar	Puri	30.0
Chari Chhak	Puri	22.0
Sardeipur	Puri	34.0
Dhauli	Puri	31.0
Sadanandpur	Puri	14.0
Kanakpur	Jagatsingpur	2.1
Balikuda	Jagatsingpur	2.0
Chatua	Jagatsingpur	7.2
Gangua	Jagatsingpur	1.7
Rajgarh	Jagatsingpur	2.6

The quality of water in the wells located in the districts away from the coast is relatively fresh. The elctrical conductivity and chloride concentration varies from 4089 to 33 micro seimens per cm and 1358 to 1.8 mg/l, respectively and 13% of wells in the districts away from the coast possesses electrical conductivity more than 1000 micro seimens per cm. Some wells contain fluoride more than 1.5 mg/l and the iron content more than the permissible limit has been recorded in 50, 44, 35, 24, 21, 19, and 18% wells of Phulbani, Khurda, Koraput, Cuttuck, Sambalpur, Bargarh, and Mayurbhanj districts, respectively.

3.0 DESCTRIPTION OF ORISSA CYCLONES

3.1 Cyclonic Disturbances

The analysis (presented elsewhere) of the data of the period 1891-1970 does not reveal any trend in the frequency of occurrence of the disturbances. Based on monthly analysis, the severe storms are found to be more frequent in the months of May, October, and November. The tracks of cyclonic storms for the months of October and November for the period 1891 to 1960 are given in the report on "The inspection of Paradeep Port after the Cyclone of 29/30th October, 1971 by C.V. Gole, Director, Central Water & Power Research Station, Poona.

3.2 Depressions

The coastal belt of Orissa falls within the seasonal activity of two branches of monsoon currents: (i) due to normal monsoon trough and (ii) due to passage of depressions. The degree of accentuation of the seasonal trough decides the activity of the monsoon. The monsoon trough does not remain stationary. It moves north or south sometimes to a considerable extent and the distribution of rainfall is appreciably affected as the trough moves. It may be stated that the distribution of rainfall over this region is partly due to fluctuation in position of the monsoon trough and partly due to depressions.

The depressions are formed over the Bay during August-September and move along the path associated with the trough of the monsoon. The combined effect of these two causative factors may be termed as monsoon depression. The normal track of the monsoon depression is in the N-W direction. This gives heavy to very heavy rainfall over places located in their tracks, based on the rainfall records at some stations in the Mahanadi, Brahmani, Batarni, Salandi, Budhabalang basins. Sometimes, these depressions also cause cyclones or cyclonic storms.

3.3 Historical Cyclones

History of very severe cyclones is available, but in an incomplete shape. The following cyclones are found to be of prime importance (derived from a French Mission of Mahanadi River):

(i) In May 1893, a very violent northerly cyclone crossed the coast near Dhamra in the month of June. The extraordinary cyclones occurred in 1900 and 1911 to the south of False point and those of 1892 and 1905 occurred in Dhamra area.

(ii) In July 1894 and 1916, cyclones occurred in the south of False point; in 1912 and 1919, between False point and Dhamra; and in 1892 and 1910, very violent cyclones occurred in the north of Dhamra. In August 1900, a cyclone crossed the coast south of False point and another in 1918 in Dhamra area.

(iii) On 21st September, 1893, there occurred a cyclone at False point and another in the Dhamra area.

(iv) In November, 1891, there was a very violent cyclone at False point and Dhamra. Very few cyclones crossed the coast in December.

3.4 Cyclone of 1971

Along the coastal belt of Orissa, there was no establishment to measure the intensity of the October 1971 cyclone. However, there are a few meteorological observatories at some places where rainfall was recorded and wind velocities were observed only at Chandipur, Paradeep, and Gopalpur. There was no arrangement to measure the height of the tidal surge. Therefore, the heights of the surge along the coastal belt could be ascertained only approximately through enquiries. Some scientific data were recorded at Paradeep and some by a Japanese ship named "Ms Heioyomaru" which was at the Irone Ore berth at Paradeep. The major features of this cyclone are as follows:

a) The maximum geostrophic wind speed was 88 knots on 29th October, 1971.
b) The isobar curvature was 6.0 degrees with radius of curvature 420 /K.
c) The ratio between wind gradient (U) and geostrophic wind velocity (Vg) was 0.55 (=U/Vg).

d) Maximum fetch length in was 178 Nautical miles and minimum was 23 Nautical miles.

e) Maximum wave height at the end of the decay was 17.5 ft at about 17.30 hrs on 29th at Paradeep.

The storm surge analysis was also performed using the simplified equation of motion based on the available meteorological data. The results were compared with the observed for verification and they agreed well. The observations revealed that the water level at Paradeep was about 1.5 m higher than the astronomical tidal level. Heavy floods occurred in the rivers Baitarni, Brahmani, Salandi, and Subernarekha soon after the cyclone. The water levels observed at various places are given in the following Table 9.0.

Table 9.0: Observed water levels at different places after 1971 cyclone

Sl. No.	Place	R.L. (GTS) (ft)
1.	Ghanghalia creek at Paradeep road crossing	9.60
2.	Hansua creek at Rajnagar	12.82
3.	Gopalur I.B.	10.85
4.	Dhamra mouth	12.75
5.	Dhamra on left bank of Dhamra river	12.00
6.	Chandbali (left bank of Baitarni river)	12.15
7.	Bajrapur (at the confluence of Brhmani and Baitarni)	12.20
8.	Bansada on Matei right	12.00
9.	Gamei mouth	13.21

3.4.1 Damages

The cyclonic calamities were larger than those due to floods until 1966. The floods caused inundation in the upper reaches of the delta and saline inundation occurred in the low-lying coastal belts. Fortunately, both did not occur simultaneously and if both these had occurred, the damages would have been colossal.

The 1971 cyclone affected 6 districts out of which Mayurbhanj, Dhenkanal, and Keonjhar were affected only due to wind velocity. It resulted in the loss of human (= 7623) and cattle lives, destroyed human inhabitation due to ferocious wind and saline water entering through the creeks. The maximum extent of salinity affected about 25 km stretch. A detail description of these damages is given in Appendix-I and for further details, refer the Ministers Committee report on "Floods and Flood Relief", Vol. I, 1972.

3.4.2 Expert Committee Recommendations

The details of the recommended measures (by an Expert Committee) based on the 1971 cyclone effects are given in Appendix I. Succinctly, the Committee generally recommended to adopt a Master Plan to mitigate the vagaries of cyclonic storms in the coastal belt of Orissa State, in what follows:

- Provision of artificial dykes along with afforestation of about 1 km strip along the coast for places where sand dunes are not wide and high and plantation will induce the development of these dunes by natural process.
- Plantation for a width of about 1 km along the coast where high and wide sand dunes exist to protect the existing sand dunes and to develop them further.
- Simplification of the system of rivers and creeks in the coastal belt and the area behind by (a) reducing the number of outlets to the sea as far as possible; (b) keeping open the major river mouths and other outlets required for efficient drainage of the area and where sluices are to be provided preferably non-return sluices, for prevention of tidal bore from entering inland; and (c) providing new drainage cuts in the areas of drainage congestion.
- In preparing the Master Plan several interests have to be kept in view as stated in the following:

    a) Combating saline inundation,
    b) Reducing river floods,

c) Promoting inland navigation,

d) Development of pisciculture,

e) Development of Salt Pan, and

f) Development of road network.

The Committee also recommended short- and long-term measures, as follows.

Short-term Measures

The following works need to be taken up as short-term measures:

- Locate and prepare a list of the existing high mounds not inhabited and shift adjoining villages to high mounds after raising, if required.
- Construct new high mounds for settlement of people living in low-lying areas.
- Afforestation of a coastal strip of 1 km width and provide embankments where necessary to prevent the area from direct ingress of high tides.

Long-term Measures

For the following investigations/studies, a time bound program may be drawn:

- Aerial photographs and contour survey of the coastal area.
- Cross-sections of the shore up to low water tide levels and cross-sections of rivers and creeks.
- Current-meter measurements of rivers.
- Measurements of tides with gauges.
- Storm surge recorders at about 10 miles intervals along the entire coast.
- Salinity measurement of water (from November to May).
- Afforestation studies.
- Pisciculture development studies.
- Model studies when closing of major and important creeks are involved.

For preparing a long-term Master Plan, the Committee suggested to carryout the following field investigations:

- Accurate contour maps 1 in 15,000 scale with 0.5 m contour interval to be prepared for the entire coastal area affected by tidal inundation.
- Regular soundings and tidal gauging observations should be taken both fore- and back-shore and inside the creek at several pre-determined locations.
- Longitudinal sections of rivers, branches, tidal creeks and their cross-sections need to be taken and velocities and discharges observed at some pre-determined locations.
- Salinity measurements should be carried out continuously in lower reaches of rivers and creeks.
- Survey the levels of all existing embankments and gherry bunds in the lower reaches.
- Investigation for construction of village mounds and preparation of a plan for protection of the coast.

3.5 October 1999 Cyclones

The tropical cyclones cause large-scale destruction and loss of life and property in the coastal areas. The state of Orissa faced two severe events of cyclones in the month of October, 1999. The first severe cyclone Occurred during October 17-18, 1999 and hit the Orissa coast at Gopalpur. This severe cyclone caused extensive damages to life and property in Ganjam district. The second cyclone of catastrophic category stroke on October 29-31, 1999 (named as super cyclone '99) hitting the Orissa coast near Paradip and inflicted unprecedented damages in the districts of Kendrapara, Jagatsingpur, Cuttack, Bhubneshwar, Puri, Jajpur, Balasore, and others. Fig. 3 presents the path of the Super cyclone-1999. This cyclone belongs to the ever-experienced worst cyclone in the history of cyclones in India, which devastated 3 million ha of cropped area in addition to sizeable loss of cattle (200,000+) and human lives (50000+). These data are, however, based on the personal inquiries of the authors with the lacal inhabitants.

(i) October 17-18 cyclone

Orissa on the East Coast along with West Bengal and Andhra Pradesh has locational disadvantage of being in the path depressions/sever cyclonic storms that occur during the south west monsoon (June 15-October 31). Severe cyclone indeed occurs when south west monsoon recedes. October 17-18, 1999 cyclone brought the intense rainfall of 452 mm at Burhanpur in 36 hours accompanied by the strong cyclonic wind of about 180 kmph which hit the Ganjam district near Gopalpur. The irrigation infrastructure and the flood protection embankments of coastal areas have sustained severe damage which has resulted in serious distress to distribution network/headworks of about 2 lacks ha. in Ganjam and the adjoining districts. Fig . 4 presents the isohyetal map of the October 17-18, 1999 cyclone in Orissa. Fig. 5 presents the effect of the October 17-18, 1999 cyclone in Ganjam district, Orissa.

(ii) October 29-31 cyclone

The supper cyclone originated in the Way of Bengal near Andaman-Nikobar Islands on 25th October, 1999, concentrated into very severe cyclonic storm, and finally had landfall at Paradeep on 29th October morning. The meteorological and hydrological characteristics of this cyclone are discussed below:

Meteorological

The strong gale of the super cyclone-99 exceeded 260 kmph with an extremely intense rainfall varying from 400–960 mm in 2-3 days (October 29 to November 1, 1999) in the coastal districts of Orissa. The maximum rainfall intensity was of the order of 40 mm/hr for 3 to 6 consecutive hours at Markona on 29th and 30th October, 1999. High-speed winds and rain prevailed continuously for about 36 hours. In the morning of October 29, the cyclonic gale caused a tidal wave of 5 to 6 m height rapidly, which, in turn, swept across a 20 km strip of 100 km coastal stretch in Jagatsinghpur and Kendrapara district and created havoc. The tide travelled inland, caused huge destruction to life and property, and submerged, severely scoured, and breached large saline

Fig. 3.: Path of the Super cyclone -1999

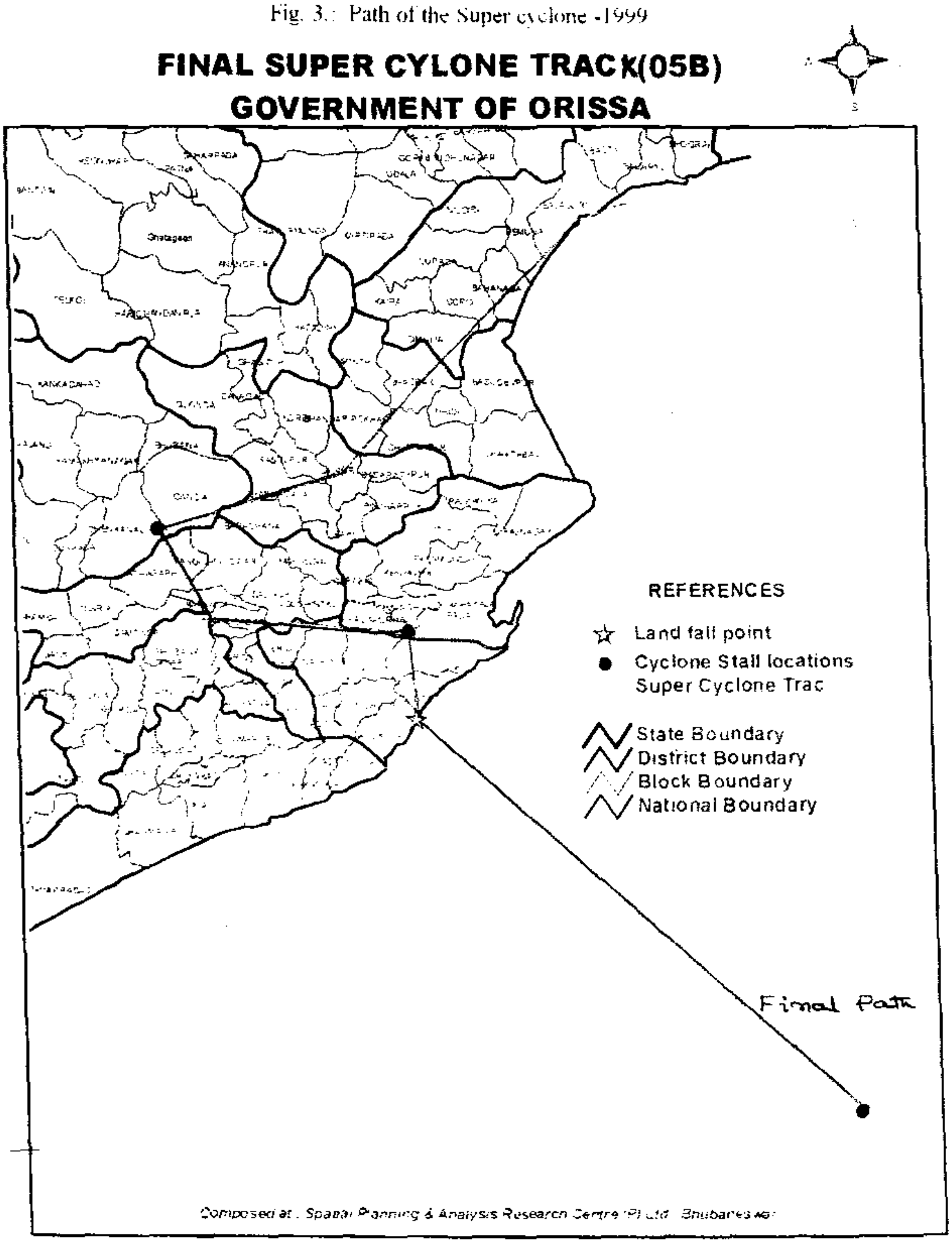
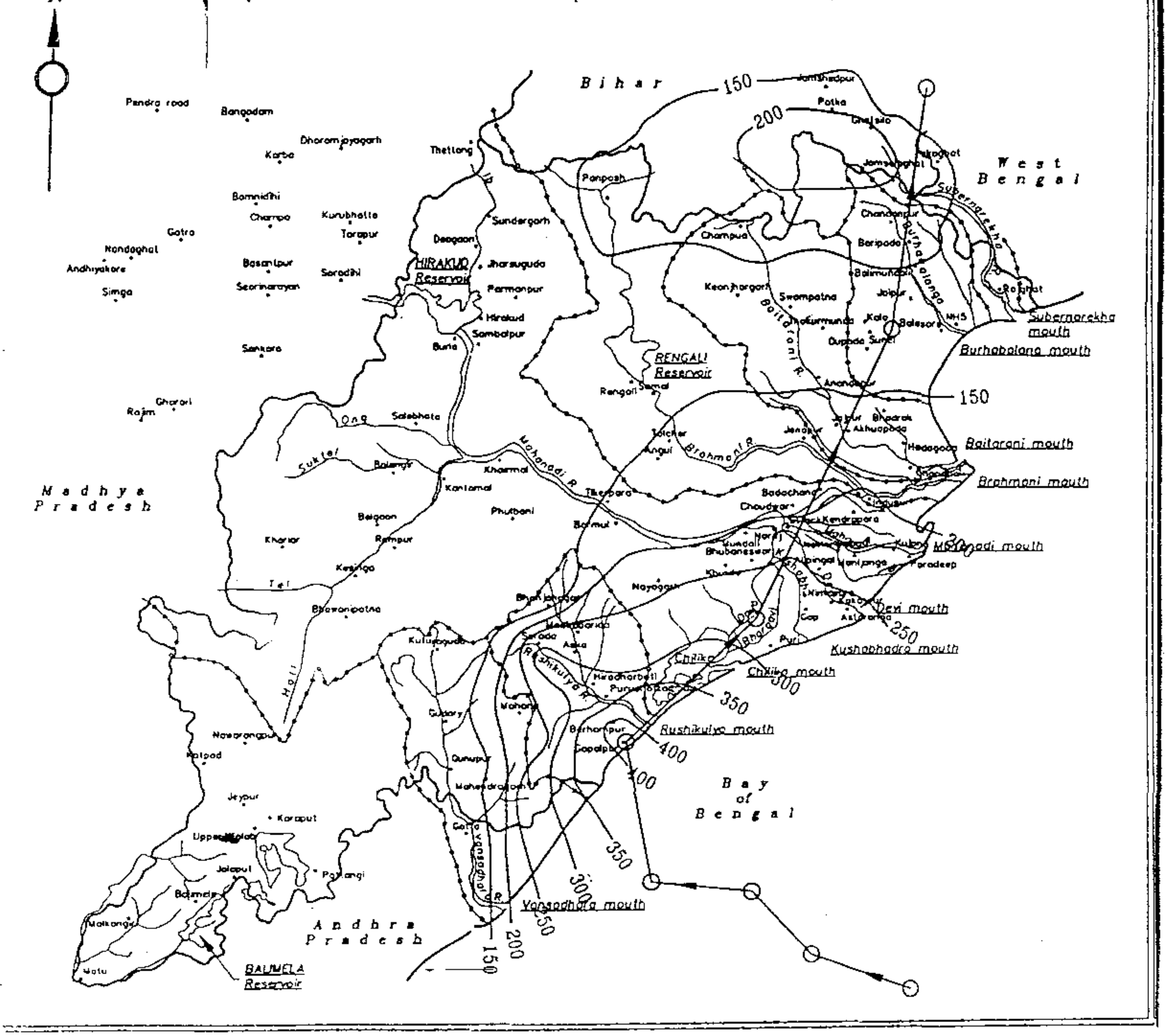


Fig. 4.: The Isohvetal Map of October 17-18, 1999 cyclone in Orissa



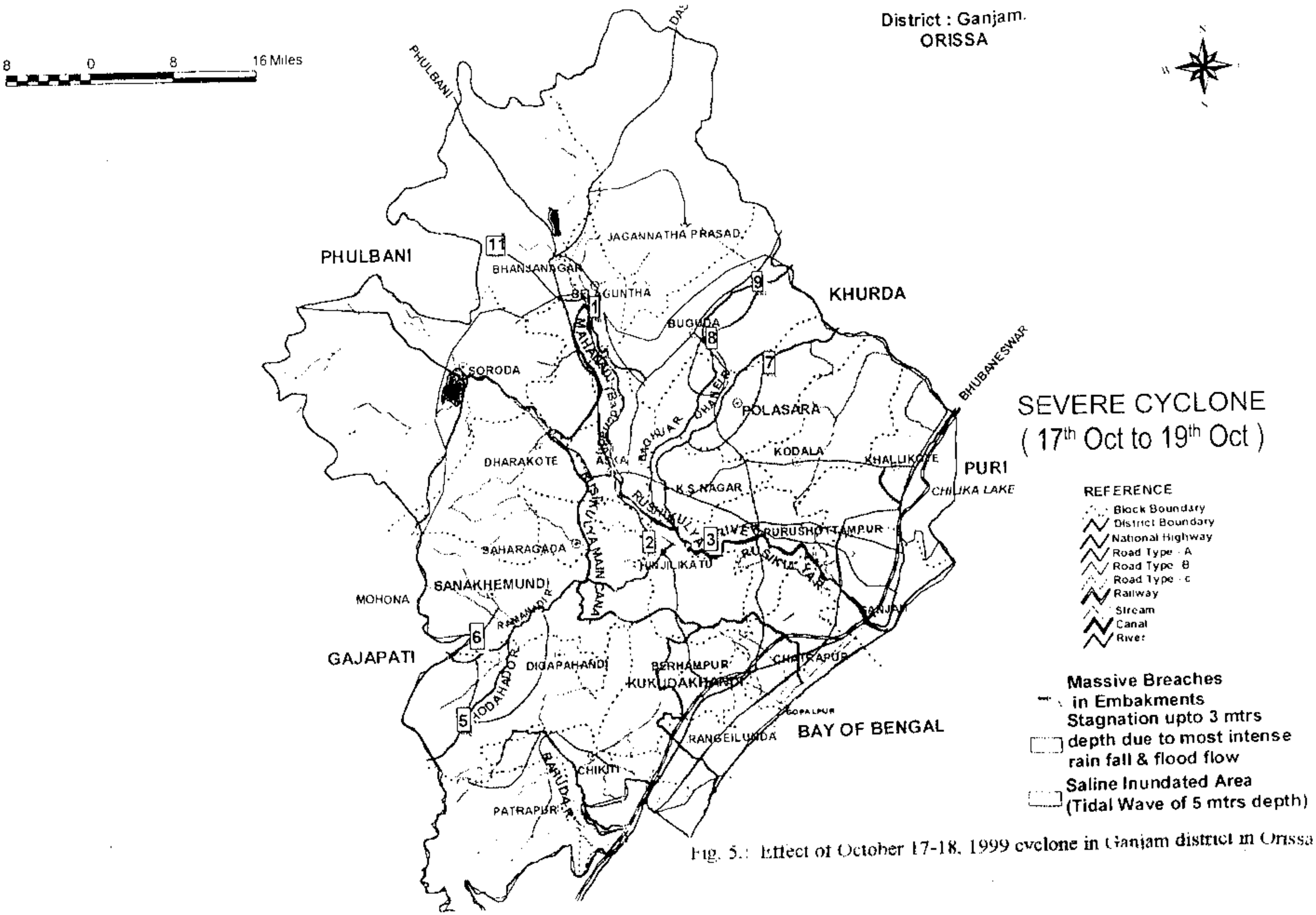
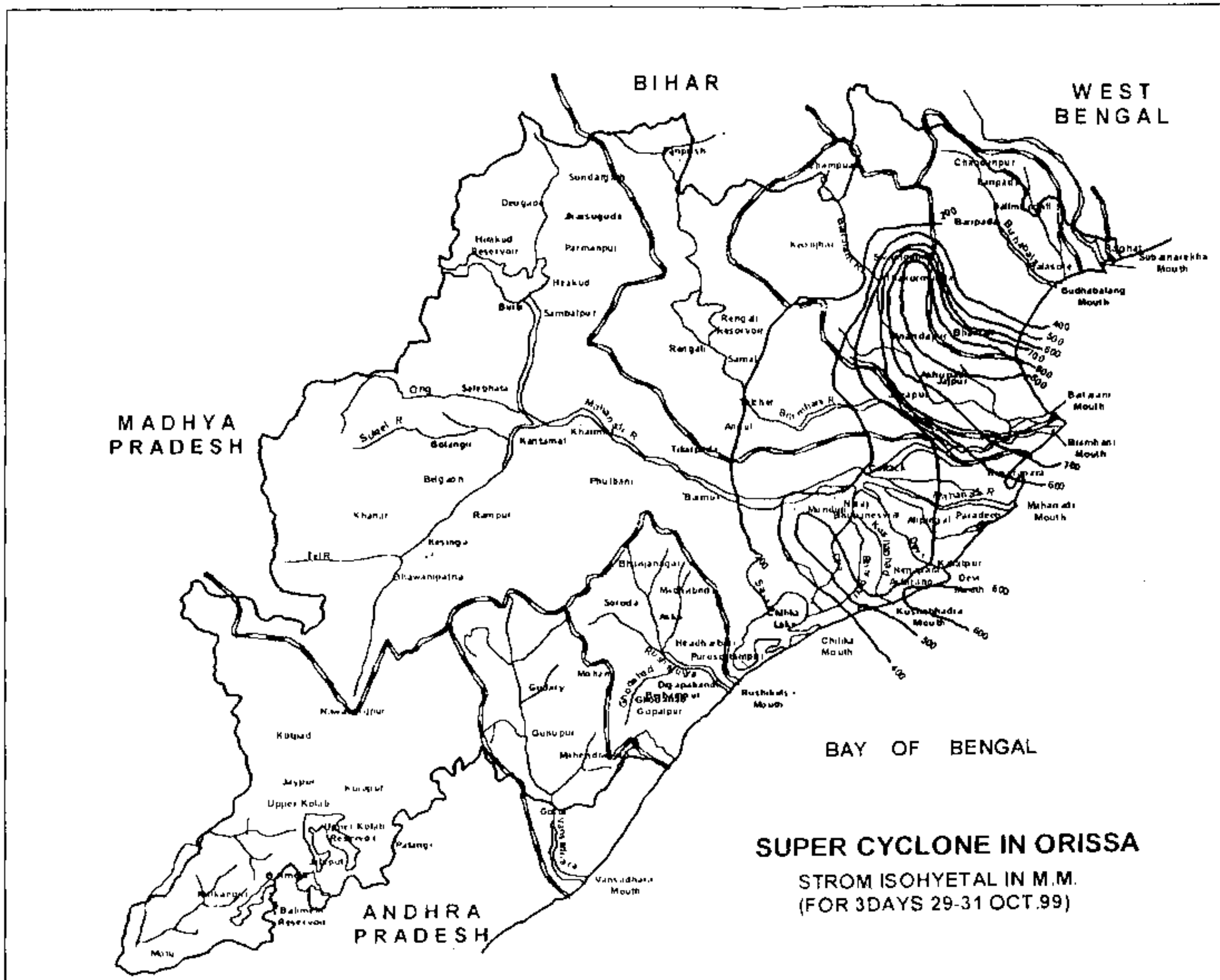


Fig. 5.: Effect of October 17-18, 1999 cyclone in Ganjam district in Orissa

embankments in the area from Astrang to Basudevpur. Deltaic areas from Mahanadi to Subernarekha got submerged up to 3 m depth by stagnation due to impeded drainage. Extremely high flood occurred in several sub-basins and resulted in the highest ever flood of 5,00000 Cusec in Baitarani at Akhuapada on October 30, 1999. The obstructed drainage network and high flood due to continuous intense rainfall in several sub-basins created submergence of agricultural lands up to more than a week in deltaic areas. The largest concentration of urban population of 1.5 million in Cuttack and Bhubneshwar suffered unprecedented damage from intense rainfall of 500-600 mm and cyclonic gale of 200-250 Kmph. Fig. 6 presents the isohyetal map of the October 29-31 cyclonic event. The most severe precipitation occurred over Badrak, Keonjhar and Mayurbhanj district. The Water Resources Department, Govt. of Orissa has reported the measurements of rainfall during Super Cyclone – 99 as follows (Table 10.0)

Hydrological

During the Super Cyclone-99, the parts of the sub-basins received most intense rainfall particularly in Mahanadi, Brahmaniand and Baitarani river systems. The large river basins of Mahanadi and Brahmani received intense rainfall only in their tails and consequently did not generate high flood at the head of their delta. It is however interesting to note that all the deltaic branches of these rivers were flowing above danger level, at locations as for as 20 km inland from their sea mouth. The basins of Baitarani and Burhabalang are relatively smaller and received very intense rainfall over most of their basins and consequently generated extremely high flood. The peak discharge in Baitarani river system is assessed as 4,98,000 at Akhuapada against the total safe carrying capacity of 1,50,000 Cusec in main and branch channels. The deltaic tract of these river systems are extremely flat with the slope in the order of 1:5000 to 1:10000 comprises of Kanas, Astarang area in Puri district; Balikuda and Ersama in Jagatsingpur district; Rajnagar and Mahakalapada in Kendrapara district; Kanika, Dhamnagar and Basudevpur area in Bhadrak district. The floods in Baitarani and its branches caused serious damages to roads, embankments, channels, etc. in Keonjhar, Jajpur, Bhadrak and Kendrapara district. The habitation area in Anantapur and the town of Jajpur was



ISOHYETAL MAP (ORISSA)

R.G.Station		Rain Fall in m.m.
1	BHADRAK	- 867
2	SUNEI DAM SITE	- 784
3	ANANDAPUR	- 724
4	CHANDABALI	- 645
5	AKHUAPADA	- 622
6	ASTARANGA	- 600
7	BHUBANESWAR	- 556
8	KALO DAM SITE	- 522
9	KUJANGA	- 475
10	GOP	- 465
11	JENAPUR	- 447
12	KHURDA	- 416
13	BALASORE	- 360
14	KENDRAPARA	- 342
15	NIMAPAR	- 337
16	PURI	- 319

RESERVOIR
BASIN BOUNDARY
ISOHYETALS
NATIONAL BOUNDARY
RIVER
STATE BOUNDARY
RAINGAUGE STATION
▲ GAUGE DISCHARGE SITE

Fig. ... The Isohyetal Map of October 29-31, 1999 Super-cyclone in Orissa seriously affected by flood spill. All minor projects around the Anantapur have been totally devastated due to flood.

The Salandi dam was constructed in 1965 with the design flood capacity of its spillway as 1,15000 Cusec. During the super Cyclone –99, heavy rainfall in the order of 700 – 900 mm over 90% of its catchment area generated a peak floof of about 2, 95000 Cusec in to the reservoir on 30th October 1999. The release of flood water through spillway became must for the safety of the reservoir. Consequently, the release from reservoir coupled with down stream runoff contribution resulted severe flood in the order of 1,06000 Cusec at Bhadrak urban area.

Table 10.0: Records of rainfall during super Cyclone-99

(Source: Water Resources Department, Govt. of Orissa)

Sl. No.	Name of District	**Rain Gauge Station**	**Total rainfall during Super Cyclone (mm)**
1	Mayurbhanj	1. Sunei Dam (Udala)	784
		2. Kalo Dam site	522
2	Keonjhar	3. Anandapur	724
		4. Hadgarh	690
		5. Bonth	716
3	Bhadrak	6. Oupada	955
		7. Bhadrak	867
		8. Markona	850
		9. Chandbali	645
4	Jajpur	10. Jajpur	507
		11. Akhuapada	562
5	Kendrapada	12. Alva	750
6	Jagatsingpur	13. Manijanga	477
		14. Kunjanga	475
7	Puri	15. Astarang	600
		16. Kakatpur	547
		17. Nimapara	535
8	Khurda	18. Bhubneshwar	556

The arable lands of Mahanadi and Brahmani basins falling under coastal areas of Puri, Nayagarh, Jagatsingpur, Kendrapara, cuttack, Dhenkanal and Jajpur (rainfall 600-700 mm) were affected primarily by water stagnation due to poor drainage capability of these flat lands. Fig. 7-to-16 shows the details of the effects of Super cyclone–1999 in various districts in Orissa. The paddy crops during flowering-stage went under standing water for almost a week. And this caused crop loss in the order of about 90 to 95% in these areas. The tidal wave of 5-6 m height travelled in land and spilled laterally through all the coastal rivers and creeks up to 20 – 30 Km all along the coast from Astaranga in Puri to north of the Basudevpur in Balasore district. The Jagatsingpur and Kendrapara district suffered massive loss of life and property first due to heavy winds and rains and second due to severe flood and high tide in lower reaches.

3.6 General Experiences of Orissa's '99 Cyclones

a) People could not follow the government recommendation that they drink boiled water as it was perceived as a luxury under circumstances.
b) Alternative recommendations need to be contemplated for future. Uncooked food distributed posed problems. Canned food needs to be supplied well in advance of cyclone season.
c) Uprooted trees proved to be a hindrance blocking escape routes. Electric supply and telephone network was very severely damaged. HAM radio network connection proves to be invaluable. Paradip is reported to have been built as a State Port inspite of warnings that the region was cyclone prone. Increase in concentration of opulation in disaster prone areas should be avoided.
d) There are 1041 multipurpose shelters compared to Orissa's 50 (ratio=20 approx.) . The biggest ever avacuation of 14 districts of Andhra Pradesh restricted the deaths to 976 in 1990. The role Non-Government Organisations (NGO) as the link between the Mandal level and village level for preparation and execution of contingency plans proved to be very effective in Andhra Pradesh. India is not exosed to cyclones as much as Japan or USA (6% exposure as compared to 30% by China and Japan).

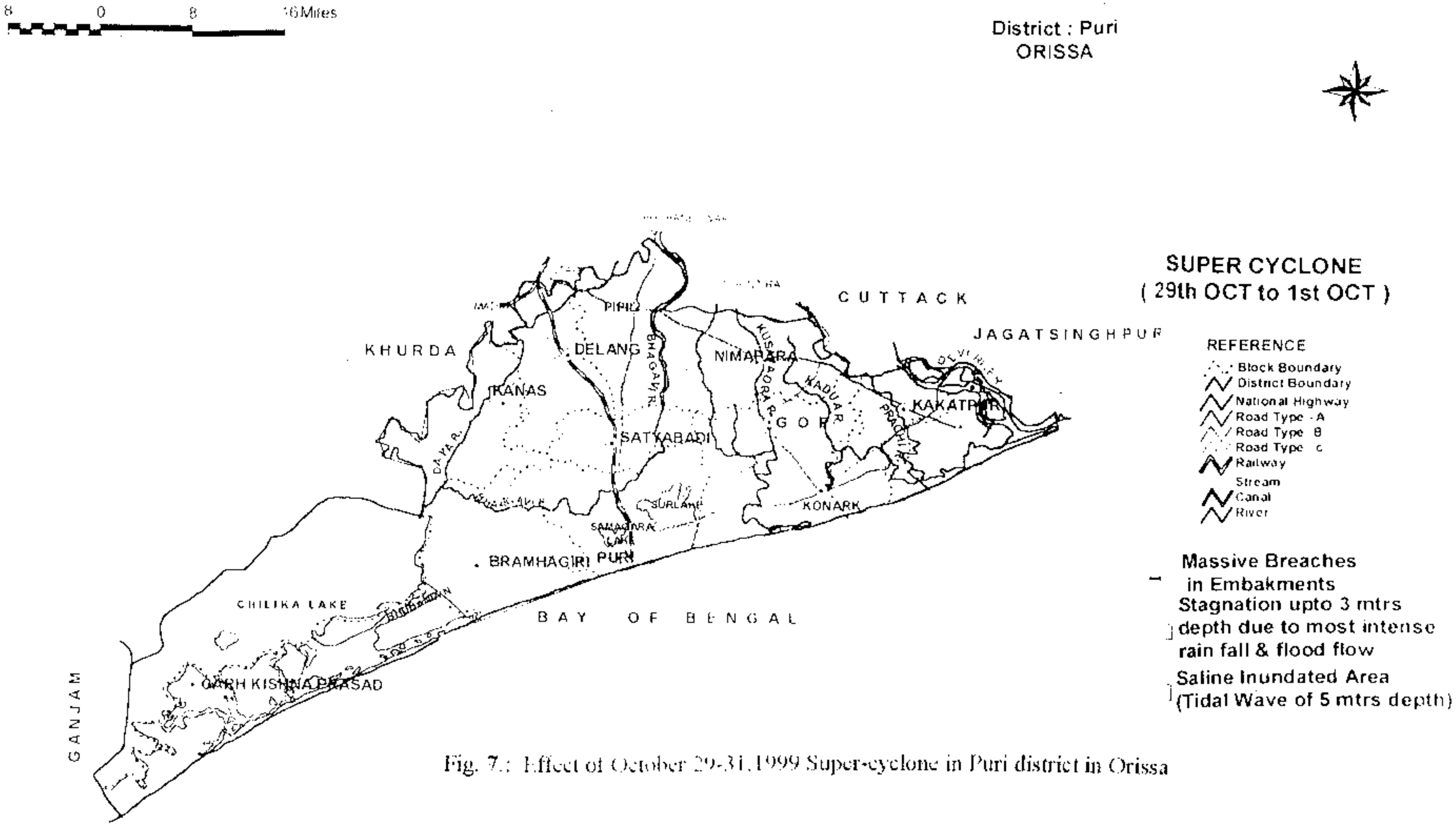


Fig. 7.: Effect of October 29-31,1999 Super-cyclone in Puri district in Orissa

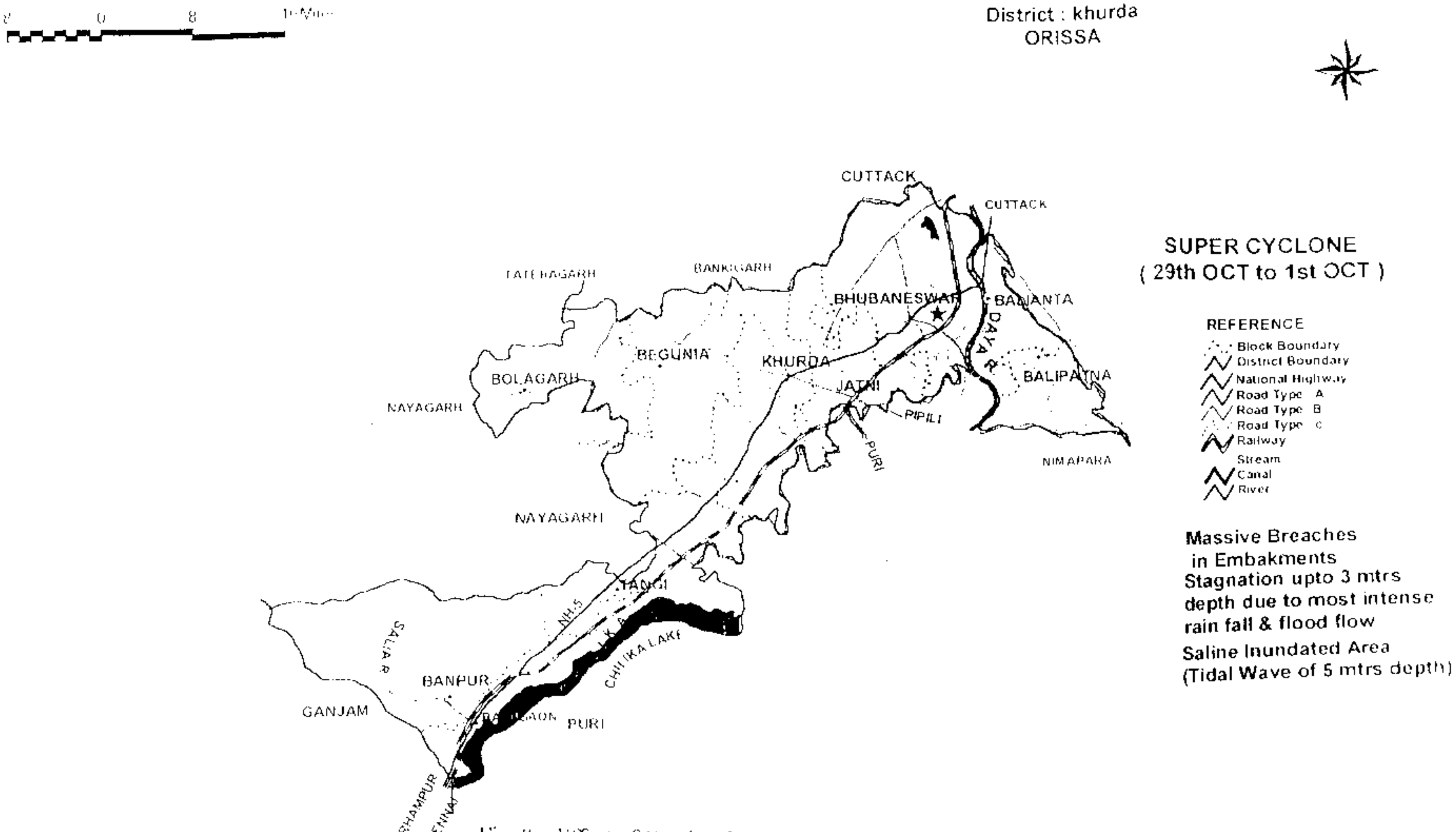


Fig. 8.: Effect of October 29-31,1999 Super-cyclone in Khurda district in Orissa

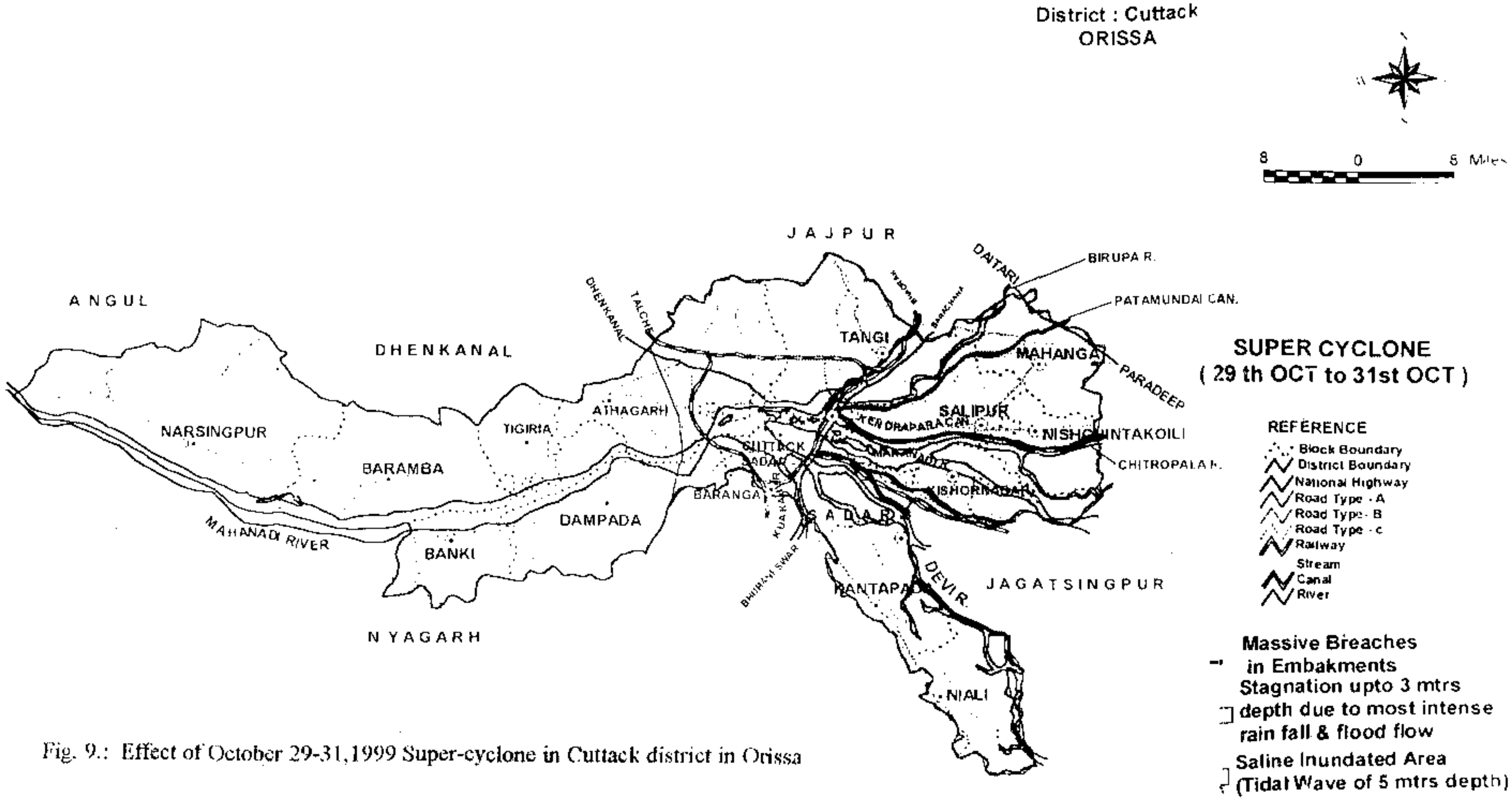


Fig. 9.: Effect of October 29-31,1999 Super-cyclone in Cuttack district in Orissa

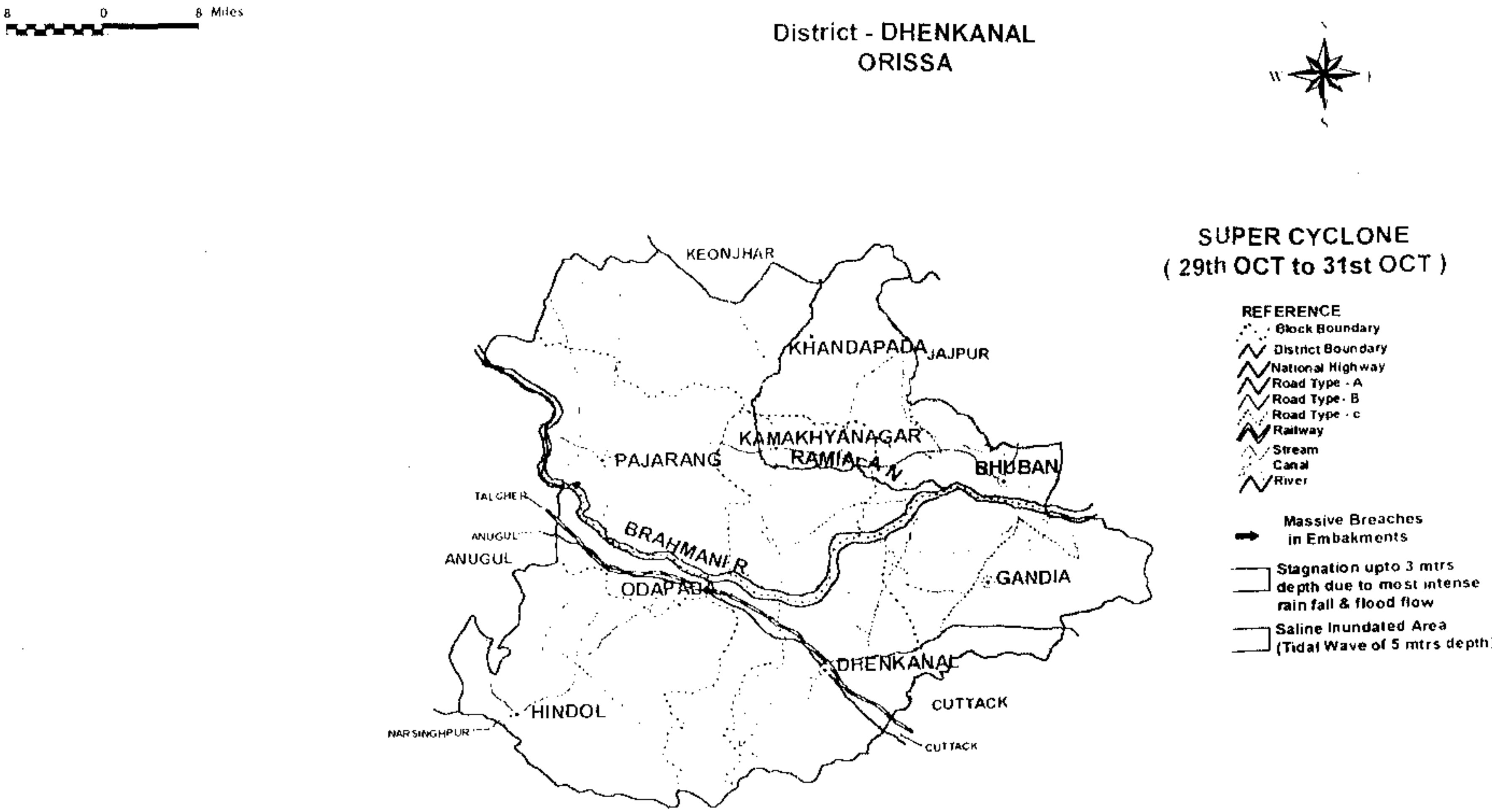


Fig. 10.: Effect of October 29-31,1999 Super-cyclone in Dhenkhal district in Orissa

Fig. 11.: Effect of October 29-31,1999 Super-cyclone in Kendrapada district in Orissa

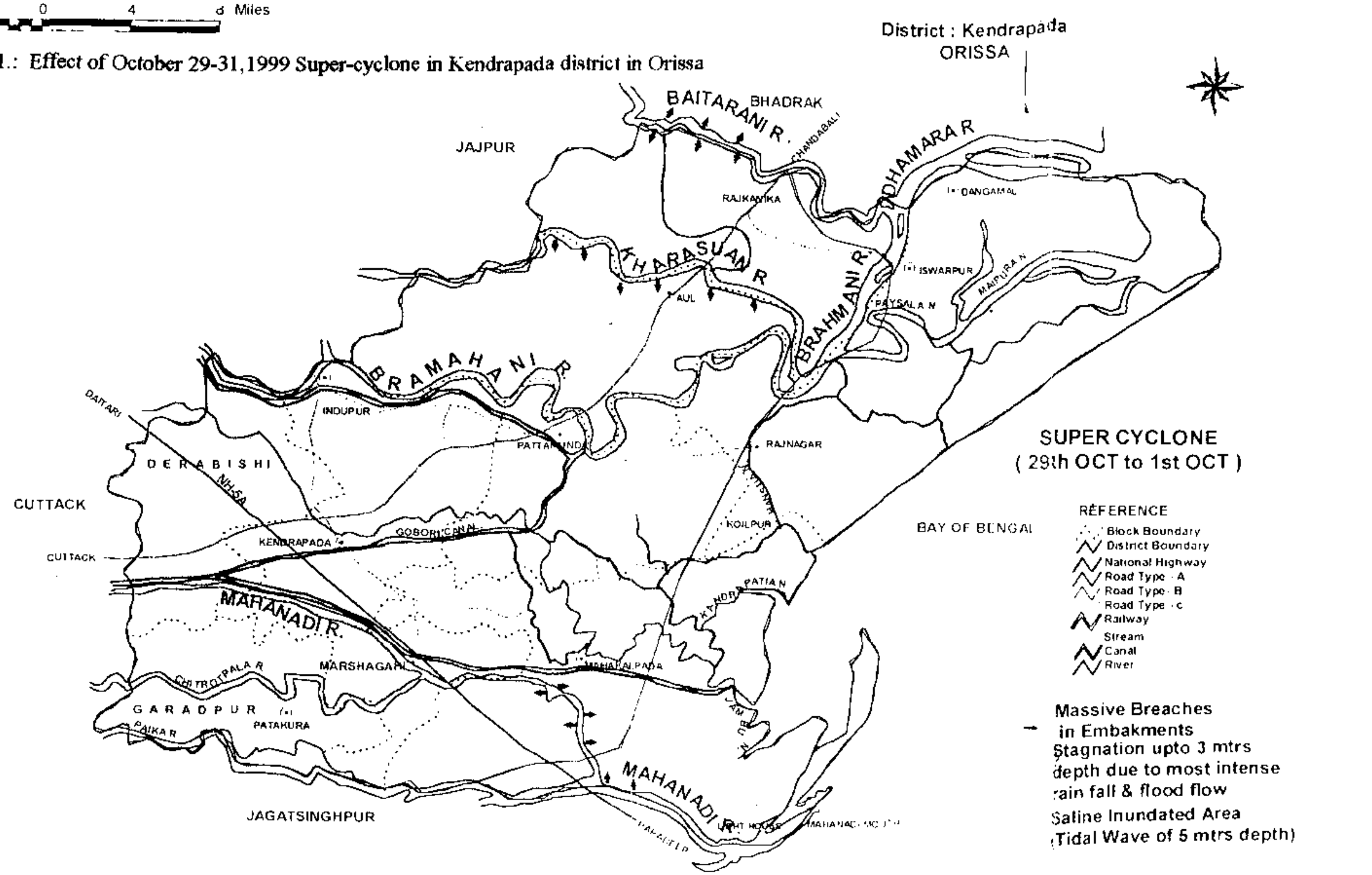
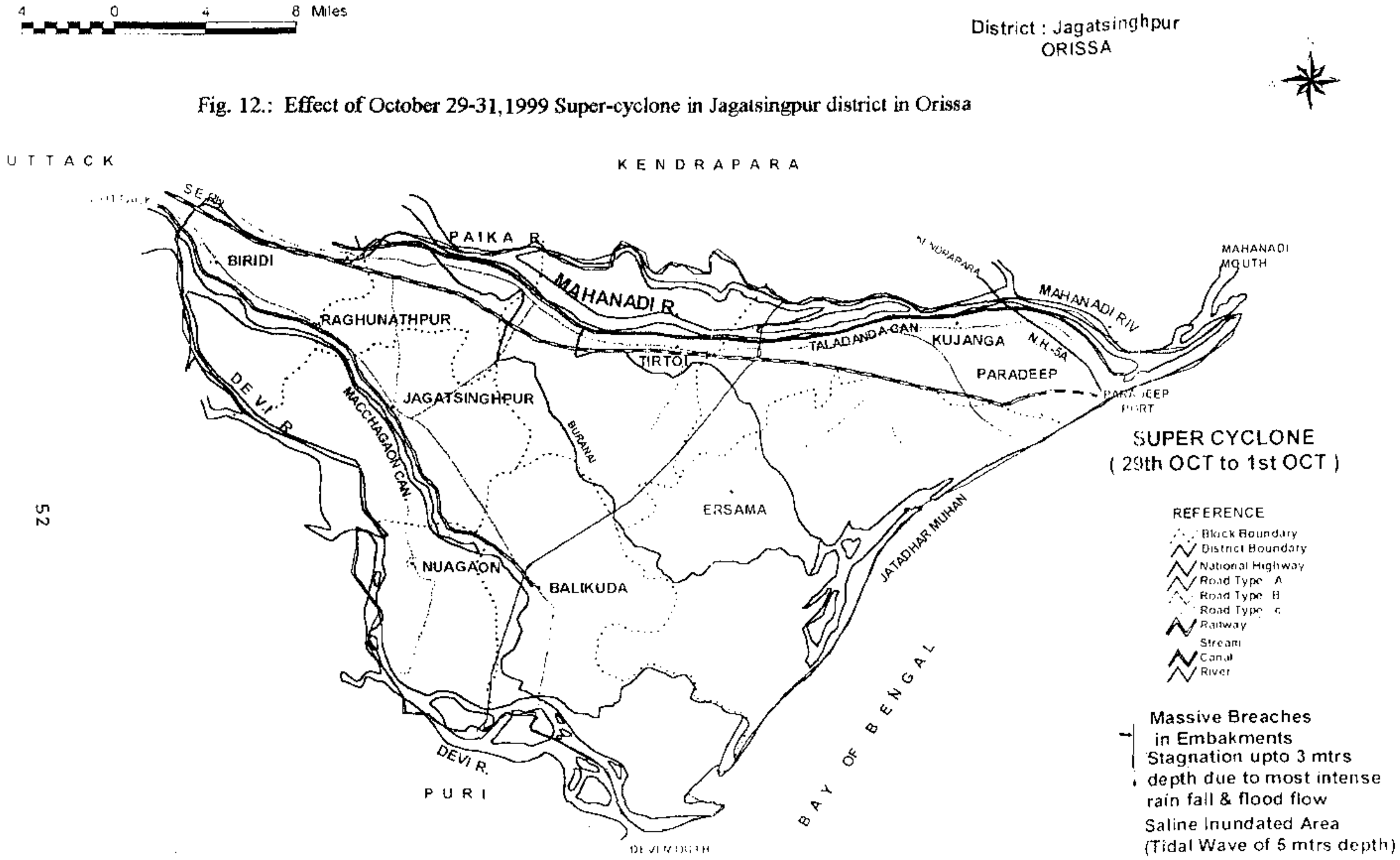


Fig. 12.: Effect of October 29-31,1999 Super-cyclone in Jagatsingpur district in Orissa



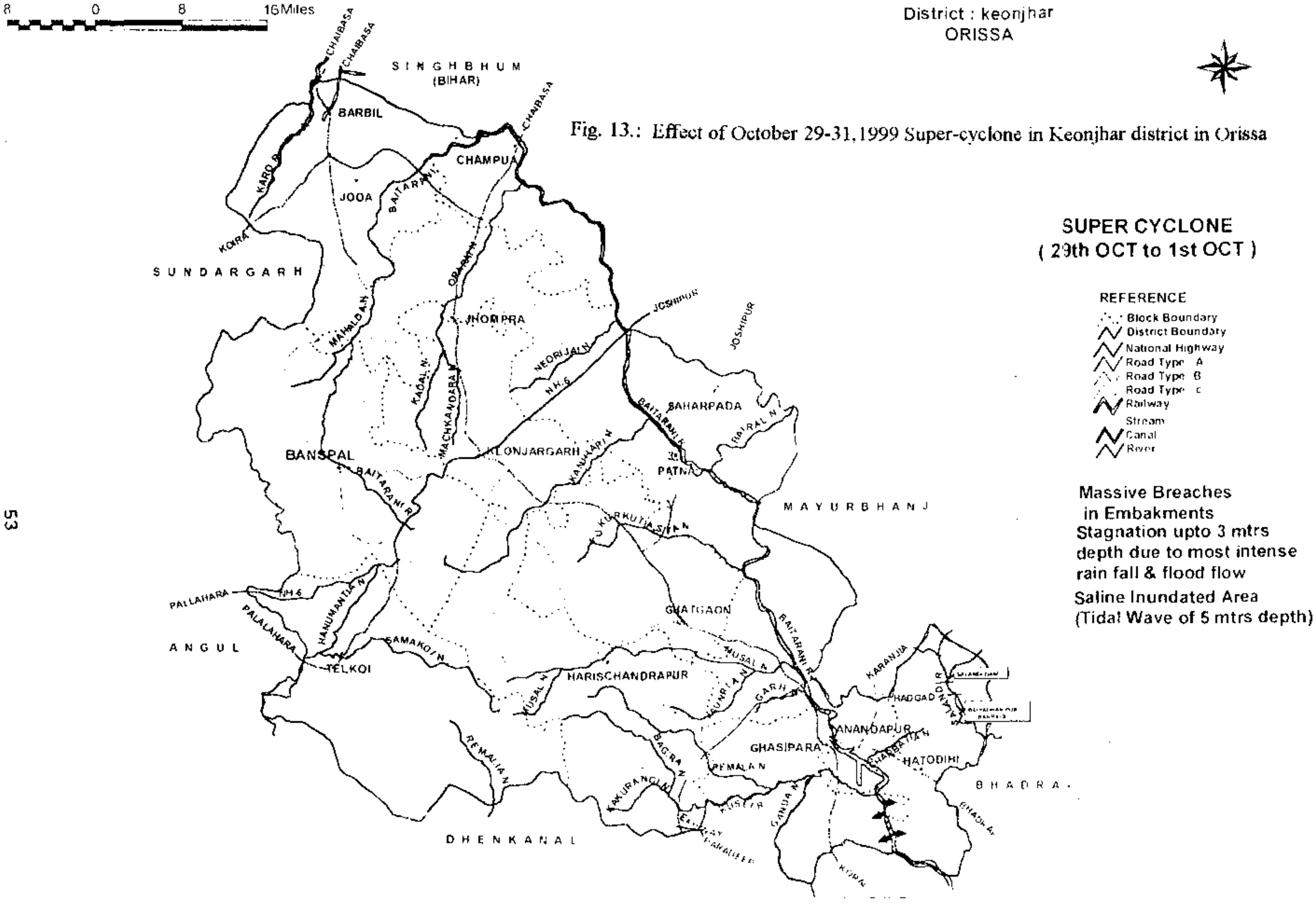


Fig. 13.: Effect of October 29-31, 1999 Super-cyclone in Keonjhar district in Orissa

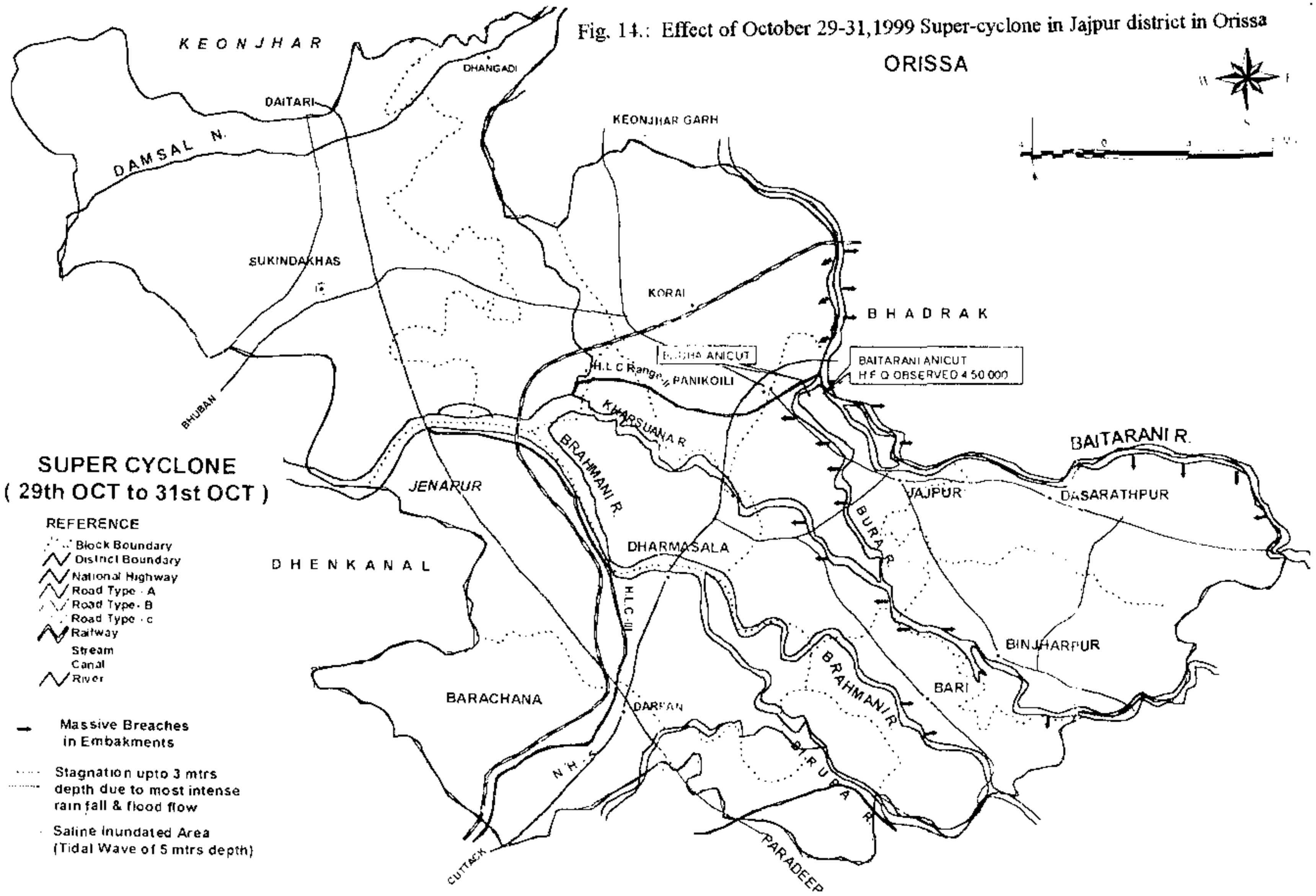


Fig. 14.: Effect of October 29-31,1999 Super-cyclone in Jajpur district in Orissa

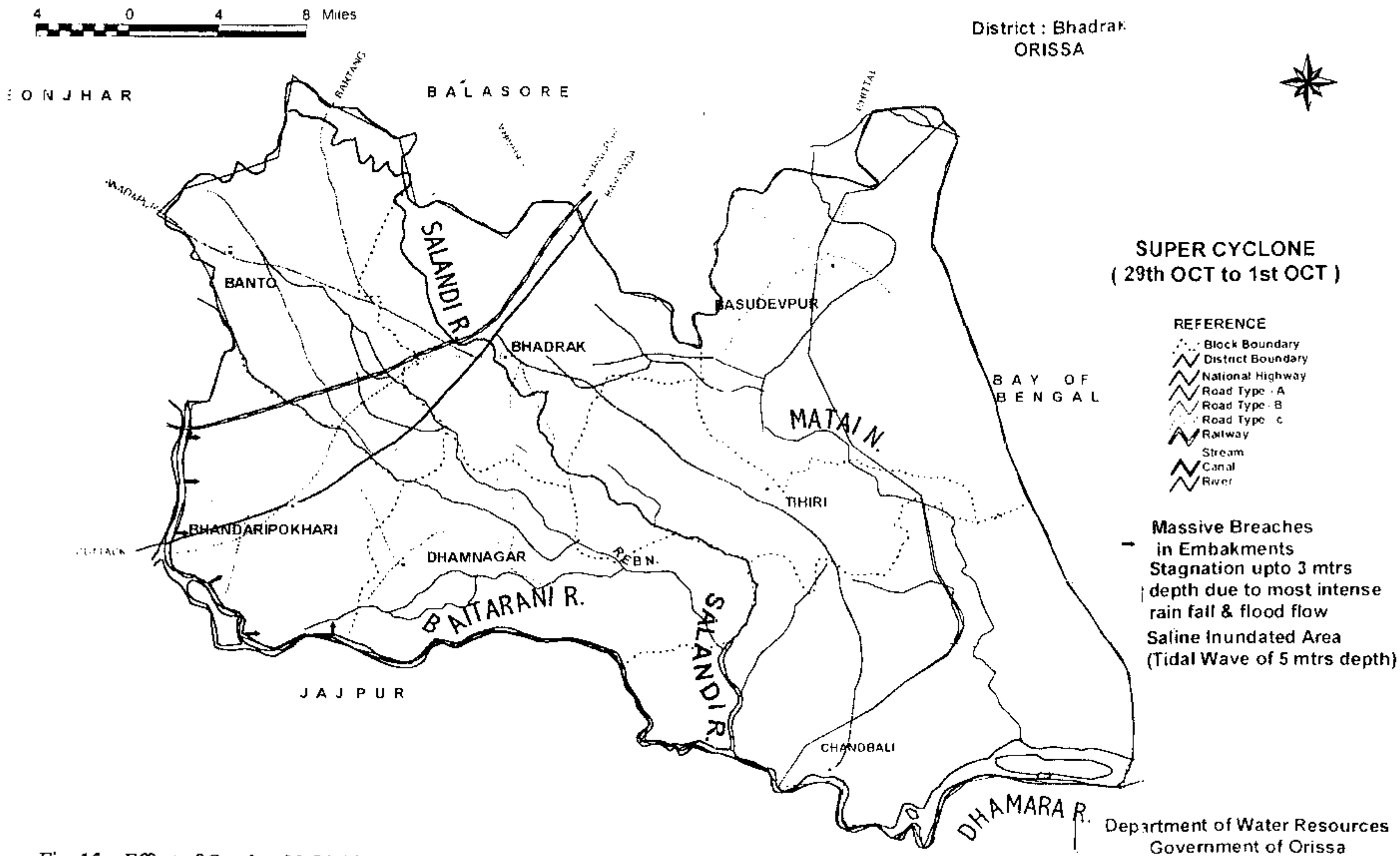


Fig. 15.: Effect of October 29-31,1999 Super-cyclone in Bhadrak district in Orissa

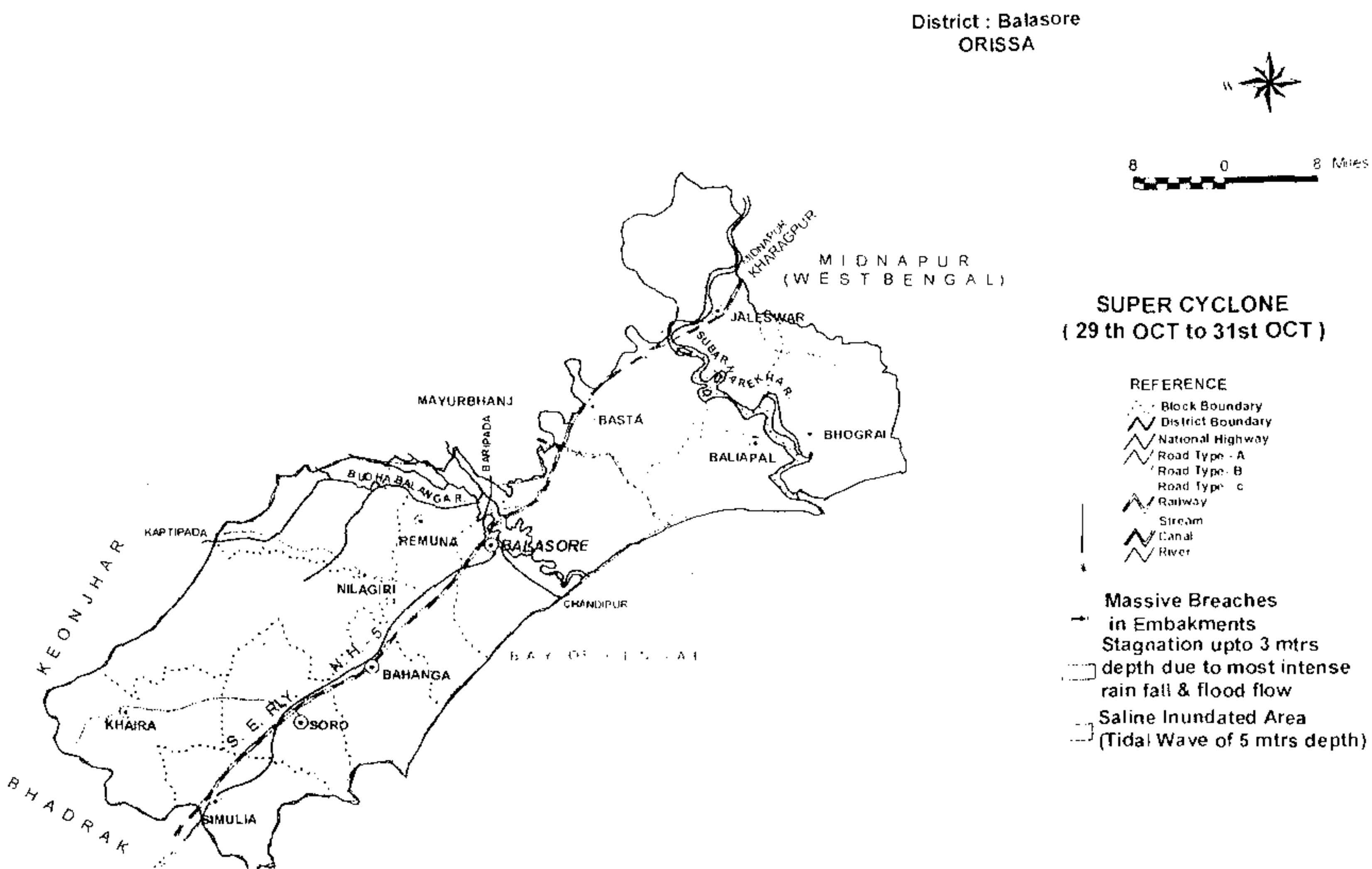


Fig. 16.: Effect of October 29-31,1999 Super-cyclone in Balasore district in Orissa

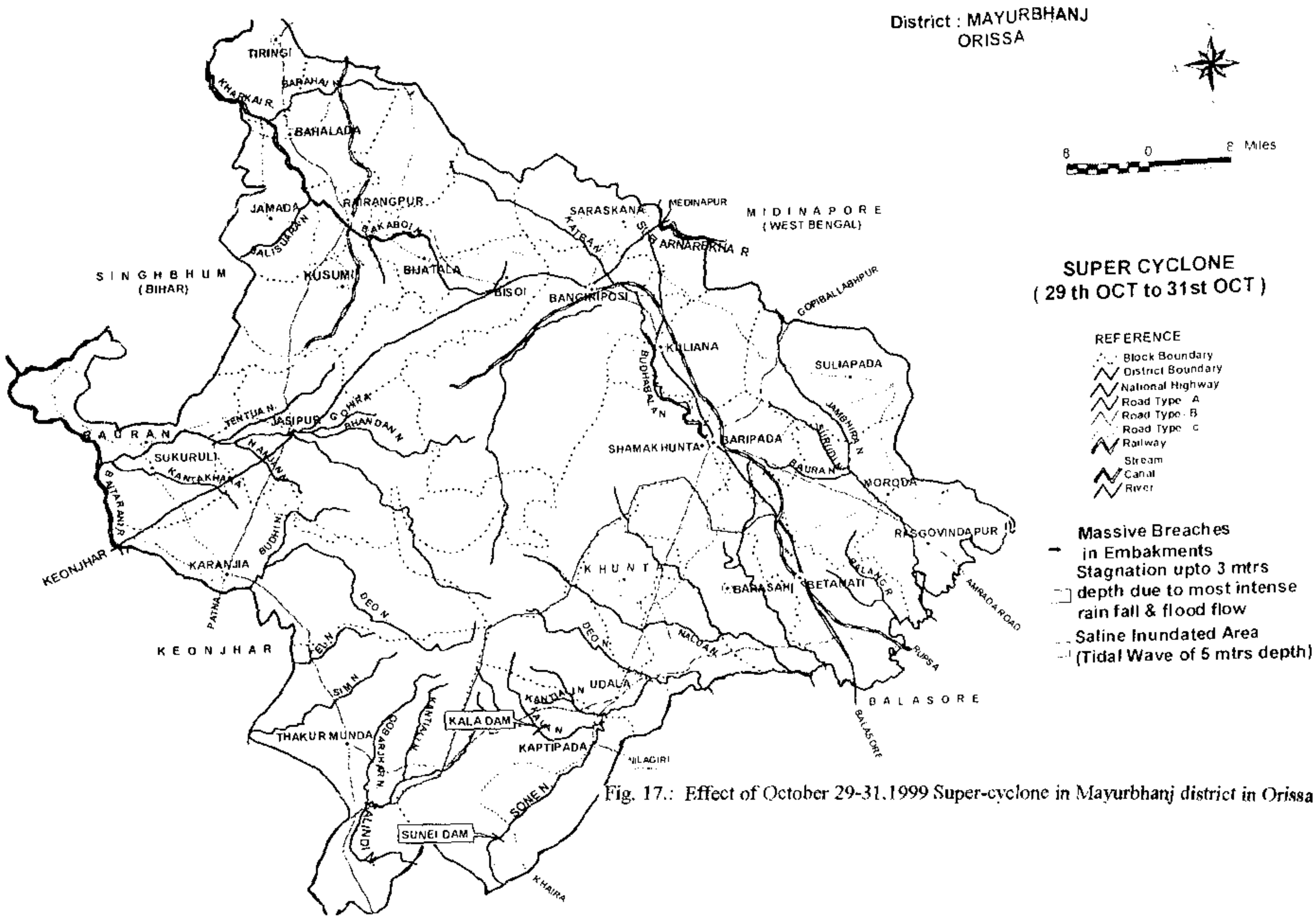


Fig. 17.: Effect of October 29-31.1999 Super-cyclone in Mayurbhanj district in Orissa

Disaster management experience from these countries could be valuable. Boiling of water as advised by the government was perceived as an unaffordable luxury.

e) Nearly 1,50,000 people were evacuated within 10 km of the sea in the districts of Puri, Bhadrak, Jagatsinghpur, Kendrapada, and Balasore districts. What caught everyone was the sheer intensity of the cyclone, called the super-cyclone. 12 days earlier to the cyclone had come and gone in Ganjam district. People were in a carefree mood and devalued the warnings over radio and TV (the existence of transisters in villages can be expected). Depletion of mangrove forests might also be one of the reasons, which sharpened the impact of cyclone.

f) The observed flood at different places have exceeded the design flood discharge. There is need to revise the design flood values in view of the October 1999 cyclones. A comparison of the design flood and the observed flood for Baitarani sub basin is presented in Table 11.0.

Table 11.0: A comparison of the design flood and the observed flood for Baitarani sub basin

Sl. No.	Name of place/Project	Catchment area (Sq. km)	Design flood (Cusec)	Observed flood (31/10/99) (Cusec)
1	Baunsagarh	2.60	1600	2050
2	Chakratirtha	7.4	3509	3575
3	Garh	21.50	5016	5806
4	Taradia	22.49	8077	10363
5	Gharara	32.03	10643	12625
6	Bahia	5.18	2681	2525
7	Chatra	4.61	2460	4055
8	Purunia	8.29	3821	5600
9	Sunaghai	7.38	2970	3148
10	Dengachua	2.60	1600	1675
11	Ghosarapada	2.59	1600	1200
12	Sindhei	39	9600	14650

13	Chamarposi	2.60	1600	1775
14	Patharkundi	2.60	1600	1550
15	Ostapura	4.33	2347	2325
16	Jhadeshwar	3.88	2162	1750
17	Phapuria	25.90	8980	9025
18	Khalana	2.46	1540	1550
19	Rudrabandha	3.51	2005	1975
20	Haripur	1.82	1224	1550
21	Padanpur	1.90	1264	1255
22	Madanpur	4.53	2428	2375
23	Jhindova	4.27	2348	2125
24	Manjuribahal	1.35	980	1050
25	Mahisabahali	3.25	1893	1875
26	Jaunria	24.60	11169	12038
27	Baghira	10.36	4248	4708

3.7 Chemical Analysis for Soil Salinity

The soil samples collected from some of the places in the cyclone-affected area were tested at the Soil Laboratory of National Institute of Hydrology, Roorkee. The soil suspension was of the soil water ratio equal to 10 gm of soil : 100 ml of double-distilled water. The test results are given in Table 12.0.

4.0 CYCLONE WARNING SYSTEM IN OTHER COUNTRIES

(i) Australian Warning System

The general name given to cyclone was and warning messages is an advice or tropical cyclone advice. The TCWC issues these messages and liases with the police, State and Territory Emergency Services and the media.

Tropical cyclones developed with tropical depressions. They are formerly designated tropical cyclones and named when winds of at least gale force have developed. The name given to a system at this time is used throughout its life.

Immediately, it is recognised that a cyclone might endanger life or property of coastal or island communities within 48 hrs, the Bureau's public warning system is activated. A tropical cyclone or developing depression that does not threaten any coastal or island community will be mentioned only in Bureau's weather notes and in advice to shipping and aviation

A cyclone watch is issued if a cyclone or potential cyclone exists and there strong indications that winds above gale force will affect coastal or island communities within 24 to 48 hrs of issue. The message contains a brief estimates of cyclone's location, intensity, severity category and movement and identifies the coastal are that could be affected. Watch messages are renewed every 6 hrs.

Table 12.0: Soil-test results of post '99 cyclones

Sl. No.	Location	PH-value
1	Cuttuck	7.97
2	Kandarpur	8.00
3	Balia (22 km from Cuttuck)	7.31
4	Jagatsingpur (50 km from Cuttuck)	7.27
5	Baliakuda	7.93
6	Guda Panchayat	6.35
7	Ambiki (Ersama)	7.40
8	Ersama	8.40
9	Paradeep	8.35
10	Angu Canal	7.07
11	Huma (Ganjam)	6.76

A cyclone warning is issued as soon as gales (gale force interprets as wind speed > 119 kmph) or stronger winds are expected to affect coastal or island community within 24 hrs. It identifies the communities being thretened and contains the cyclone's name, its location, intensity (including maximum wind gusts and its severity category) and its movement. Forecast of heavy rainfall, flood and abnormally high tides are included when necessary. Community under threat are also advised to take precautions necessary to safeguard their lives and property.

Cyclone warnings are issued every 3 hrs. When a cyclone is under a radar surveillance close to the coast, hourly advice may be issued.

A tropical cyclone advice is prefixed "Flash" when it is the first warning to a community not previously alerted by a cyclone watch. It is also issued when major changes are made to the previous warnings due, for example, to unexpected movements towards the coast are rapid intensification.

A Warning Contains Information on the Severity of Cyclone in terms of Winds and Tides

As well as indicating expected maximum wind gusts near the centre of the cyclone, the warning will usually indicate the strength of the maximum gusts expected over a particular areas in any of the following items:

- Gale with gusts to 125 kmph.
- Destructive winds with gusts above 125 kmph.
- Very destructive winds with gusts above 170 kmph.

The warning may mention above normal tides. The effect in terms of risk of flooding at the coast will be described as follows:

- Abnormally high tides could cause serious flooding.

- Exceptionally high tides could cause serious flooding.
- Dangerously high tides could cause inundation of low lying coastal land.

If evacuation of waterfront areas becomes necessary, additional messages from police or local government authorities will say who should move and will give details of evacuation shelters.

EXAMPLE OF WARNING MESSAGE

TOP PRIORITY- FOR IMMEDIATE BROADCAST

TROPICAL CYCLONE ADVICE NUMBER 22 ISSUED BY THE BUREAU OF METEOROLOGY (BRISBANE) AT 5 AM EST MONDAY 11/02/91.

A TROPICAL CYCLONE WARNING IS CURRENT FOR COASTAL AND ISLAND COMMUNITY BETWEEN YEPPOON AND CAPE MORETON.

AT 5 AM, SEVERE TROPICAL CYLONE ANN, CATEGORY 3 WAS LOCATED ABOUT 90 KMS EAST-NORTHEAST OF GLADSTONE AND MOVING IN SOUTHERLY DIRECTION AT ABOUT 15 KMPH.

VERY DESTRUCTIVE WINDS ARE EXPECTED ALONG THE COAST BETWEEN GLADSTONE AND MARYBOROUGH AND ACROSS FRASER ISLAND THIS MORNING.

GALES ARE EXPECTED SOUTHWARDS ALONG THE COAST FROM MARYBOROUGH TO CAPE MORETON AND OFFSHORE NORTHWARDS FROM GLADSTONE TO YEPPOON.

BEACHFRONT RESIDENTS BETWEEN GLADSTONE AND MARYBOROUGH WARNED THAT DANGEROUS TIDES COULD RISE UP TO 2 M ABOVE NORMAL AND CAUSE INUNDATION TO LOW LYING COASTAL LANDS THIS MORNING.

HEAVY RAIN IS EXPECTED TODAY SOUTH OF BUNDABERG WITH SIGNIFICANT STREAM RISES.

DETAILS OF SEVERE TROPICAL CYCLONE ANN CATEGORY 3, AT 5 AM EST.
CENTRAL PRESSURE: 950 HECTO-PASCAL
LOCATION OF CENTRE: WITHIN 20 KM OF 23.3 DEGREES SOUTH, 152 DEGREE EAST ABOUT 90 KM EAST-NORTHEAST OF GLADSTONE.
RECENT MOVEMENT: SOUTH AT 15 KMPH
DESTRUCTIVE WINDS: OUT TO 120 KM FROM THE CENTRE
MAXIMUM WIND GUSTS: 200 KMPH NEAR THE CENTRE

RESIDENTS BETWEEN YEPPOON AND CAPE MORETON ARE ADVISED TO TAKE PRECAUTIONS AND LISTEN TO FURTHER ADVICES

THE NEXT ADVICE WILL BE ISSUED AT 6 AM EST

5.0 CYCLONE SAFETY PRECAUTIONS

Preventive Measures

If you learn now, what to do when a cyclone threatens, you may well save the lives of every one in your family. You can not stop a cyclone. You can not wait until one hits to learn what to do to survive. Make sure your whole family is prepared. Test their knowledge.

Before the cyclone season

- Check your house is in good condition, particularly the roof.
- Trim tree branches well clear of your house.
- Clear property of loose sheet iron and other potential missiles.
- Know your community disaster plan.
- In case of storm tide warning, know your nearest safe high ground and the best access route.
- Prepare an **EMERGENCY KIT** (hold ready in home)
    1. Portable radio with fresh spare batteries
    2. Torch, fuel lamp, candles and matches.
    3. Water containers, tinned food, tin opener, self–contained cooking gear and essential spare cloths.
    4. First aid kit and essential medicines.
    5. Masking tape and plastic (garbage) bags.

Up on a cyclone warning:

- Listen constantly radio, TV for further warnings and advice.
- Batten down house, secure doors, board or tape windows.
- Paper pasted on windows with glue made from flour or starch is also effective. Store loos articles inside, place documents, photos, valuables, and clothing in plastic bags.
- Look up pets, fill water containers, fuel car and place under cover, then remain indoor.

- Prepare an evacuation kit (carry in small bags). This consists of your emergency kit plus warm utility clothing (jeans, skivvies etc.), personal essentials and valuables in plastic bags.

On Warning of a Local Evacuation (Sea Notes Opposite)

- Look up dwelling, switches of electricity, gas, water, etc. Take your evacuation kit.
- Wear strong clothing to protect against cuts from debris. Wear strong footwear (not thongs) for protection.
- Follow advice given.
- Heed warnings- they are not given lightly!

When a Cyclone Strikes

- Keep calm- heed warnings and advice.
- Stay inside, shelter in the strong part of the house- perhaps bathroom, internal toilet or passage way.
- If house starts to break up, protect yourself with mattresses, rugs or blankets. Anchor yourself to strong fixtures (such as water pipes) or get under a strong table or bed.
- Beware of calm 'eye'. Don't assume the cyclone is over- if a calm period is due to the 'eye', violent winds will soon resume from the opposite direction.

After the Cyclone

- Don't go outside until advised officially that the cyclone has passed.
- Listen to your radio.
- If you have to evacuate, don't go home until advised. Use root recommended and stay calm.
- Don't go sight seeing.
- Above all, don't ignore warnings!

Evacuation Note:

Based on the predicted wind strengths and storm tide heights, it may be necessary to evacuate some areas to avoid causalities. Be ready to move to higher ground or shelter facilities as directed by police and emergency service panel. High winds and flooded roads will be hazardous during movement. Advice will be given through local radio, TV and other media. Police and State/Territory emergency Service will also give verbal warnings. Heed these warnings! Note: Managers of resorts hotels, motels, caravan parks should take steps to ensure visitors are familiar with the dangers and know what to do in the event of a cyclone. Many of these life-saving precautions can be taken immediately.

6.0 RECOMMENDATIONS AND RESEARCH NEED

Hydrology needs to be specialised for coastal regions frequently affected by cyclones consisting of rain, wind, and storm tides. As such, the hydrology can be divided into three major components: atmospheric, surface water, and ground water. The atmospheric hydrology addresses the meteorological aspects of the atmosphere that leads to rainfall, the prime source of surface runoff and ground water. A rainfall storm is perhaps the simplest and most simplified form of a cyclone.

(i) Meteorologic Instruments

In a severe cyclone, for example, super-Cyclone 99, the recording instruments (for example, raingauges, barometer, thermometers, anemometer, sun-shine recorder, wind speed and direction recorder and others) generally break during high winds or the observers fail to attend the instrument for readings, for they are not able to come out of their homes and several other psychological reasons force them not to do so. Therefore, it is necessary that special automatic instruments, connected to radar/satellites, capable of recording the data for at least a few days to the fullest extent be installed in the cyclone-prone areas. It was observed during the visit of the cyclone-affected areas of Orissa that the amount of the rainfall during 36 hrs exceeded the annual rainfall amount and the radar system collapsed during high winds. Therefore, it is mandatory to revise the codes for the design of radar systems for coastal areas.

(ii) Hydrological Instruments

The super cyclone-99 was associated with abnormally high tide of about 5 to 7 m at places. Under abnormal backwater conditions, the stage recorders should be of self recording type and some identified cross-sections of the estuarine rivers need to be instrumented with automatic recorders for rainfall, wind speed, stage-discharge and sediment load measurement.

The following issues are of paramount importance from hydrologic research view point:

(i) Specialised hydro-meteorological study for coastal areas

a) Revision of runoff coefficients and other hydrological parameters for hydraulic design purposes
b) Revision of probable maximum precipitation
c) Hydrologic zoning of coastal areas based on cyclone vulnerability
d) Impacts on surface water, ground water quality
e) Regional storm-surge modelling studies

(ii) Remote sensing application in cyclone studies in general and cyclone prediction in particular

(iii) Special instrumentation for coastal areas

(iv) Optimisation of manual observational errors during cyclonic storms

(v) Revision of design criteria for hydraulic structures

(vi) Evolution of the concept of delta safety program parallel to the existing dam safety program in the country

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EXPERT COMMITTEE RECOMMENDATIONS AFTER 1971 CYCLONE

The recommendations given below are derived from the report "The protection of the coastal area of Orissa against floods: General recommendation" submitted by Ir. Ferguson of Holland in 1971 to the Technical Expert Committee constituted vide Govt. of Orissa resolution no. 32198 dated November 16, 1971. The Committee recommended that the effect of cyclonic storms for the vulnerable areas is a point of consideration everywhere and the measures for reduction of victims to flood and cyclone have to be applied throughout the coastal belt. To this end, the Committee divided the whole belt into five zones, described in the next chapter. The major recommendations are as follows:

(i) To build a defence belt covering a width of about 1 km from the coast and considering the changes that are affecting the coast line with possible accretion in some parts and erosion in others. A coastal embankment with plantations on the land side and afforestation on the sea-side should be constructed all along the shore line to cover 1 km stretch of the coast to help not only break the speed of the wind and check inland saline inundation but also to help build up the shore line by natural process.

(ii) The defence belt of about 1 km zone from Andhra Pradesh border to West Bengal border should be legally protected from any kind of encroachment and grazing and reclamation in this area is to be converted to restore forest.

(iii) The people should not be allowed to grow or develop villages in low-lying areas subjected to tidal inundation, which should be demarcated and notified.

(iv) Where people have already settled in low-lying areas, villagers may shift to the high mounds constructed by the Government adjoining to the villages. Double storied community centres, buildings, and institutions should be constructed using reinforced cement concrete (RCC) roofs and maintained by the State Government in this area. These will also serve as shelters in the event of disastrous cyclones and tidal bores.

(v) The public buildings and existing drinking water tanks flooded by saline water due to tidal surge of 1971 should be strongly embanked, keeping the crest levels 2m higher than the recorded highest water level due to the tidal surge of 1971. The tops of these embankments will also serve as village mounds for shelter in the event of tidal inundation.

(vi) The entire relief operation depends on the communication facilities, a great problem in the coastal area. Roads need to be developed on the flood, tide, and drainage systems and canal embankments. These embankments may be of wider crest for shelter to the people during cyclonic storms. The existing road communication and cart tracks need to be developed for easy communication during cyclonic storm. A separate road map that forms a part of the entire Master Plan for entire area should be drawn up with a provision for future development.

The Committee recommended to take up the following short- and long-term protective measures for each zone in stages.

- Short term protective measures such as construction of pucca and raised mounds, plantations and afforestation, and construction of shelter homes.
- Long term protective measures such as closing of creeks, provision of drainage head works; creek embankments, construction of coastal embankments; modification of sand dunes; construction of dykes connecting to the existing drains; and creeks for the basic cause of their workability such as navigation, fishery, lift irrigation, roads, and any other long term schemes.

The design and planning of the embankments need to be taken up keeping in view the inherent danger of the enormous loss of life and property, if these embankments breach. The Committee with consideration to local conditions recommended some specifications as a general guide for constructing such embankments, based on the maximum cyclone surge level 1971 cyclone in Zones III and IV. For other zones, the criterion for design would be the 1971 cyclone with a path of travel suitably altered for yielding maximum surge in the zone under consideration.

The embankment of coastal area should be of a standard section having top width equal to 15'0" so that these also serve as roads; the country side slope equal to 2:1 and the water side slope equal to 3:1 as a protection against wave wash. Embankments must have a free board of 6 ft above the maximum tidal surge levels, observed during 1971 cyclone for Zone III and IV or calculated for the other zones. The above mentioned embankment slopes are for clay sections. Sandy sections should be covered with clay to a minimum thickness of 2'0". Invariably, the embankments should be turffed with locally available grass. Ordinarily, costly pitching work does not need to be attempted. The embankment should be located along the creek behind the plantation. Adequate precautions will be necessary while aligning the embankments, particularly, by the side of the creeks. During high tides, most of these creeks overflow the banks. Certain amount of valley storage for the saline water for few hours should be given for adequate elbow passage, for flushing the creeks, while fixing the alignment of embankments. Some creeks may be closed after thorough investigation for they are not necessary for drainage and navigation. The Committee recommended to provide non-return sluices on tidal embankments for draining rainwater and prevention of tidal bore from entering inland. Rust resisting materials may be used for constructing non-return sluices under saline conditions.

The measures recommended by the Committee for taking up in each zone for reducing damages, specially due to the tidal bore, are furnished below.

Zone I:

Subzone (i)

The existing sand dunes with undulating surface need to be brought to generally minimum level to prevent spill and gaps using local available materials. Sand dunes may be developed artificially if they do not exist either by afforestation or by construction. Short embankments need to be constructed wherever possible to close the gaps at a reasonable cost. General measures already described should be taken up for this reach according to requirements.

Subzone (ii)

The delta formed by Rushikulya system is a strip of coastal alluvium containing higher percentage of clay loam contents generally affected by salinity. There are high sand dunes along the coast and the general recommendation should be followed to provide necessary protection to this area.

Subzone (iii)

In this reach, very high sand dunes with plantations exist in may places and not much work is necessary to be done as natural barrier is existing to prevent tidal surge inundation; only plantation be provided where necessary.

Zone II

This zone is in Puri district and fairly high sand dunes from Surlake cut to Prachi Kadua mount exist. Casurina has been planted in most of this reach from Surlake cut to the sea coast near Konark temple. After detailed investigation, some embankments along the coast and creeks may be constructed as per general measures.

Zone III

The area under this zone covers in parts the Cuttuck and Puri districts. Along this coast, sand dunes of small width and low heights exist except for some gaps and forest growth is much scattered. The landscape of this zone is low and intercepted by many drains and creeks. This low-lying land of about 16 km width from the coast need protection from cyclonic surge by construction of coastal embankments along the tidal creeks, afforestation, roads, village mounds, shelter sheds. This area falls between Devi and Mahanadi rivers and is protected from floods by embankments. Some creeks existing in this zone may be closed, after a through investigation for navigation and drainage. The people living in this area rely mostly on agriculture and fishing. The tidal creeks and river estuaries provide ways and scope for considerable fishery development. Some of the tidal creeks should be constructed with their top level according to 1971 cyclonic factors. The gaps of the existing embankments should be filled for dependable road communication and there should be easy drainage for rain and surplus irrigation water. The inland water transport should be considered along with the development of road communication of the area. The roads should be constructed on the top of the tidal embankments and these should be linked with the main roads for ensuring easy communication.

In brief, the main points for development of the area can be summarised as below:

- Prevention of tidal inundation.
- Continuous inland water transport from Devi mouth to Mahanadi mouth.
- Providing all weather roads across the area and connecting this to existing main roads.
- Providing fresh water for irrigation to Kharif and Rabi crops.
- Ensuring fishery development.

It was found necessary to prepare a Master Plan of the area in the light of the newly built up Paradeep Port.

Zone IV

This zone had the greatest calamity and suffered from maximum loss of human and cattle lives. Large scale damage to inhabitants, crops and other properties occurred during 1971 cyclone. Some villages were completely washed away by tidal surge.

The coast-line of this zone is subjected to tidal ingress and severe damage. At the mouth of Mahanadi, the False Point spit projects into the sea, forming a shallow water bay into which a large number of tidal creeks originating from Mahanadi fall. The Jambu drainage channel also meets this bay. It is observed that whenever a severe cyclone hits between the Mahanadi mouth and the Dhamra mouth, tide levels in this bay and the adjoining coast rise high. The coast has no natural protection due to non-existence of high and wide sand dunes. Moreover, a number of rivers like Kendrapada, Hansua, Chicharikotha, Baunsgarh, Maipura, and Dhamra fall into the sea in this zone. The area behind the coast for a width of about 25 km is very low. Therefore, tidal surges encroach inland comfortably and inundate a vast area and, in turn, cause extensive damage.

A thorough investigation is necessary for preparing a Master Plan to protect this area. To this end, it will be necessary to collect the details of the existing coast-line and creeks. A scheme for afforestation along the sea-coast for a width of about 1 km providing mounds for shelter and protecting drinking water tanks from saline inundation needs to be chalked out. Afforestation along the banks of the tidal creeks needs to be taken up simultaneously, embankment behind the forest growth along the creeks to be taken up with non-returnable sluices wherever required, and road communication to be provided. In order to reduce the length of embankments and afforestation area and to get more area for agriculture, some creeks not serving as drainage channels, or if diversion channels are available, may be closed. The cut-off creeks may be converted to fresh water tanks for providing lift irrigation to adjoining areas.

Zone V

An embankment along the left bank of the Dhamra continues along the coast up to Gamei mouth. There used to be a very thick mangrove forest in front of this embankment towards the sea, acting as a wind barrier. In this reach, there has been a wide land accretion and new settlers have cleared the entire forest and reclaimed the land and forest, which was protecting the coast, no longer exists. In this reach, it is necessary to raise and strengthen the existing embankments to the required standard and to afforest a belt of about 1 km width between embankment and sea. From Gamei mouth to Budhabalang mouth about 1 km wide area should be afforested and wherever sand dunes do not exist, coastal embankments be constructed behind the afforested belt, leaving the river mouths open. Wherever necessary, embankments need to be constructed along the tidal rivers with non-returnable drainage sluices to protect the adjoining area from saline inundation by tidal bores. Detailed investigation may be made to provide necessary structures in the coast canal such that this can be used for Rabi irrigation and limited navigation. The country-side embankment of the coast canal may be developed to a road and bridges may be provided across the all embankments from Dhamra to Chandipur, as an all weather road. The construction of this road will greatly help mitigate the development of the area. The road can be connected to Bhadrak-Chandabali road through Basudevpur and two or three link roads constructed from this road to the National Highway No. 5 at suitable locations between the Gamei mouth and Chandipur. In the reach from the Budhabalang mouth to the Saratha mouth, similar measures from Gamei mouth to the Budhabalang mouth may be taken up. In this reach, the coast canal is extensively used for transporting water during high tides, from Budhabalang to Bhograi lock and then to West Bengal. The reach of the coast canal from Budhabalang to Jamkunda lock may be improved after detailed investigations. There is a network of tidal creeks in this reach between Basta and sea coast and this area is very low and is subjected to floods and tidal inundation. Keeping the drainage problem in view, most of these embankments need to be constructed along the banks of the creeks, which may be kept open for drainage purposes. It may be examined to keep only one channel for drainage purpose in this low area.

Whenever breaches occur in the existing flood embankments on the right bank of the Subernarekha river, a very large quantity of flood water crosses the Basta-Baliapal road and enters this low-lying area and, in turn, causes extensive damage. Thus, the existing embankments on the right bank of the Subernarekha should be raised and strengthened to prevent breach during highest floods. There is a small Jalka river which brings large volume of flood water to this low-lying area during high floods. The Jalka crosses the State Highway at Basta over a long cause-way. Other similar works were also proposed at different sites in this zone as a part of recommendations and, therefore, not outlined for avoiding repetition.

TABLE II.1: PLACES AFFECTED IN 1999 ORISSA CYCLONE

Sl. No.	Places Affected	Cause
1	Blocks Kakatpur to Rajnagar along the coast: Kakatpur, Astharango, Balikuda, Erasama, Kujangour, Mahakalapada, Paradeep and Rajnagar; also Patmundal, Marenaghai?	Tidal intrusion, Cyclone
2	Rajakanika, Aul, Kendrapara, Binjarpur, Baru, Charadapur [or Prahaladapur (Centroid of triangle connecting Jagatsinghpur, Kendrapara and Paradeep)], Nischinthakoili, Devalisi(Between Kendrapara and Salaipur), Mahanga, Barachana, Dharmasala,	Cyclone and Flood
3	Raghunathpur, Krishnaprasad, Brahmagiri, Puri, Gop,Satyabadi, Pipili, Delango, Palasa, Nimapada, Khurda,Begunia,Jatni, Bhubaneshwarm Cuttack Sadar,Idgadh, Alipatna, Birdi, Barango, Salaipur, Athagarhm Odapada, Hindol, Dhenkanal,Kamakyanagar, Gaundia, Tangi, Chowdwar, Tirthol	Cyclone
4	Jajpur,Basudevpur,Rahulpur,Soro, Chandabali, Oupada, Kaira, Bhardakh, Tihidi,Simulia, Bahanaga, Boniti,Nilgiri, Balasore, Remuna, Dasaratpur , Anandapur, Narabhandari, Pokori, Dhamnagar,Hathadihi	Floods

Path of cyclone:
1) Between Balikuda and Erasama -→ 2) Centroid of triangle connecting Jagatsinghpur, Kendrapara and Paradeep --→ 3)Kapilas near Cuttack ---→ 4)Dhenkanal --→ 5)Jajpur ----→6) Balasore --→ Back to the sea

TABLE II.2: SUMMARY OF MAJOR 1999 CYCLONES

Date	Area affected	Wind Speed	Surge Height	Cate gory	Deaths	Damage to Property	Distance from the eye	Remarks
1	2	3	4	5	6	7	8	9
Oct. 16	Ganjam				120	500 Crore	Zero	
Oct. 25	Malaysia							
Oct. 25 & 26	Andamans	50-60 Kmph						winds on an unusually warm sea sucks in increasing amounts of water vapour
Oct. 27-28	Bay of Bengal							A full blown cyclone raging on the sea instead of veering to Bangladesh as usual heads staright for Orissa.
Oct. 28	In and around Paradip	Stalled for 8 hours						20,000 people moved to safety, A large number could not be shifted due to lack of time. The cyclone stalled for 8 hours 300 KM away from the coast --- increasing in ferocity.
Oct. 29	Between Erasama and Balikuda						Zero	
Oct. 29	Centroid of triangle connecting Jagatsingh-pur, Kendrapara and Paradeep	Stalled for 3 hours						

1	2	3	4	5	6	7	8	9
Oct. 29 (21.30 Hrs)	Kapilas	Stalled for some time						Attracted towards a negative pressure at Cuttack. It then moved towards Anandpur & built a cloud mass of almost 250Km extent collecting water vapours on the way. It retreated back to Jajpur & started raining heavily all the way through Bhadrak to Balasore where it dissipated into the sea.
Oct. 29	Paradip	240-260 kmph	7 m		2 in house collapse	2000 houses flattened		Cyclone of catastophic intensity, termed super cyclone.
Oct. 29	Bhubaneshwar	150-170 kmph				Electric and telephone poles uprooted. Most of the roads littered with uprooted trees and branches		Expected to move towards the Bihar Pleateau sparing Calcutta (HTC and PTI)
Oct. 29	Bhubaneshwar (noon)	220 kmph					zero	Scooters and cycles are seen to fly in the air.(HT Page 11 November 7)
Oct. 29	Srikakulam district Budagattepalem Village, AP							9 Fishermen missing
Oct. 30	Bhubaneshwar	80-100 kmph						
Oct. 30	Orissa					Telecom links totally snapped in affected areas		

1	2	3	4	5	6	7	8	9
Oct. 30								Engineers of National Highway Authority of India (NHAI) rushed to Orissa to assess the damage to the road network PM declares it as a national calamity
Oct. 30	Digha, WB				1 dead fishermen fished out			40 trawlers, 400 Fishermen were still missing
Oct. 31						Officials, said that 15 million people badly affected. Lakhs of thached houses damaged and lakhs marooned.		Emergency satellite telephone link was established. 25 fishing boats had taken shelter in creeks hed. Minister of State for surface transport, Devendra Pradhan Paradip port has not suffered any major damage.
Oct. 31	Orissa		5 - 6 meters		At least 22 killed in Bhubanesh war and Cuttack			According to IAF sources relief and rescue operations were severely hampered due to bad weather. Bhubaneshwar airport expected to become operational in 2 days. Coast guard vessels continued search operations. (Sea water entered almost 15 km inside these areas). Paradeep port, Jagatsinghpur and Kendrapara are the worst affected in state.
Nov.1			All major rivers in the state rising due to heavy rains					Villages along Orissa coast believed to have been washed away. Information about another lakh living in the inside area of Jagatsinghpur, Kendrapara and Bhadrakh districts yet to be ascertained.

1	2	3	4	5	6	7	8	9
Nov. 1	Cuttack		4 to 6 feet under water in several areas					
Nov. 1	Paradeep port				42 bodies recovered	Conveyor belt damaged. A survey launch sunk		Heavy generators were flown in to port
Nov. 1	Soro (Balasore dist.)				20	900 villages devastated. A three kilometer railway line between Soro and Marcona washed away		The villagers of Soro had to spend the last two days on tree tops without food.
Nov. 2	Orissa					NH still cut off.		Hundreds of motorbike riders were despatched to obtain information. Motorised boats of defence services have been requisitioned as it is feared that the entire road network along the coast has been washed away. Roads between Cuttack Rajnagar, Cuttack-Paradeep, Bhadrak Chandbali, Jajpur - Aul-Rajakanika-Chandabali cut off.
Nov. 2	Cuttack district		4 to 6 feet of water		300 people feared dead	Large number of villages affected		Editorial of HT claims that people showed a curious reluctance to move to safer areas inland. Calls for a comprehensive plan to deal with disasters. Flash floods had cut off almost all roads to Jagatsinghpur, Kendrapara, Jajpur and Bhadrak.
Nov. 2	Balasore district				31 bodies found			(15 Khoira and 8 in Simulia blocks)
Nov. 2	Puri District				51 bodies recovered			
Nov. 2	Kendrapara Dist.				15 deaths reported			

1	2	3	4	5	6	7	8	9
Nov. 2	Jagatsinghpur							No reports as sea water submerged vast areas
Nov. 2	Bhadrak to Balasore					NH–5 between Bhadrakh & Balasore submerged and severely damaged		
Nov. 3	Cuttack							Army evacuated 16000 people
Nov. 3	Paradip							An industrial accident, a gas leak, was prevented in Paradip. Contaminated water was reported to have been taking its toll through epidemics in the port city
Nov. 3	Kochela				6 dead due to diorhhea			
Nov. 3	Kendrapara, Near Jamboo (Known as Jamboo dweepa in mythology), Tentuliakenda		7.62 to 9.144 m		86 dead 100+ missing			The water from the Jamboo canal with the swirling waters of Luna river on west even as tidal waves were lashi mmmng it on the east.
Nov. 4	Paradip							Paradip port cleared
Nov. 5	District of Balasore				36 bodies recovered			
	Bhubaneshwar, Cuttack					Power supply still not restored		
Nov. 6	Districts of Jagatsinghpur and Kendrapara				Around 30 starvation deathsreported, which was denied by the administration.	15 lakh people affected in Kendrapara		Self-help and many people helping the authorities was a positive feature. Desperation was also a wide spread phenomena. Out breaks of water borne diseases like cholera and gastro-entritis were reported. General scarcity of commodities were also noticed. Severe damage to crops were also reported. Orissa govt claimed that relief was being received by 90% of cyclone affected people.

Table III.1. Sequential events of the super-cyclone

Date	Place	Details/Remarks	Dead	Damage
16-10-99	Ganjam	Not much damage	120 dead	500 Crore
25-10-99	Malaysia	An area of low pressure		
25 and 26th - 10-99	Andamans	50-60 Kmph winds on an unusually warm sea sucks in increasing amounts of water vapour.		
27-28 -10-99	Bay of bengal	A full blown cyclone raging on the sea instead of veering to Bangladesh as usual heads staright for Orissa.		
29-10-99	Paradip	Cyclone of catastophic intensity.240-260 Kmph. 7-m high storm surges, domes of water above normal tidal level	2 dead in house collapse	2000 houses flattened
	Bhubaneshwar	150-170 Kmph Expected to move towards the Bihar Pleateau sparing Calcutta		
	Srikakulam district	9 Fishermen missing		
30-10-99		PM declares it as a national calamity		Engineers of National Highway Authority of India (NHAI) rushed to Orissa to assess the damage to the road network

	Digha, WB	40 trawlers, 400 Fishermen were still missing	1 dead fishermen fished out	
31-10-99		Officials, said that 15 million people badly affected. Emergency satellite telephone link was established		Minister of State for surface transport, Devendra Pradhan: Paradip port has not suffered any major damage. Lakhs of thached houses damaged and lakhs marooned. 25 fishing boats had taken shelter in creeks.
31 October 1999		According to IAF sources relief and rescue operations were severely hampered due to bad weather. Bhubaneshwar airport expected to become operational in 2 days.	Coast guard vessels continued search operations.	
1st Nov.1999		Villages along Orissa coast believed to have been washed away. Information about another lakh living in the inside area of Jagatsinghpur, Kendrapara and Bhadrakh districts yet to be ascertained.		Most of them believed to be washed away
2nd Nov. 1999		Editorial of HT claims that people showed a curious reluctance to move to safer areas inland. Calls for a comprehensive plan to deal with disasters. Flash floods had cut off almost all roads to Jagatsinghpur, Kendrapara, Jajpur and Bhadrak.	300 people feared dead in Cuttack	Rs.1000 billion lost in Cuttack district alone

3rd November		Army evacuated 16000 people. An industrial accident, a gas leak, was prevented in Paradip. Contaminated water was reported to have been taking its toll through epidemics.	Cyclone toll in Cuttack district is 115	
4th Nov. 1999		Paradip port Cleared		
5th Nov.			36 bodies recovered from the dist. Of Balasore	
November 6th 1999		Around 30 starvation deaths, which was denied by the administration, took place in districts of Jagatsinghpur and Kendrapara. Self-help and many people helping the authorities was a positive feature. Desperation was also a wide spread phenomena.		

November 7th 1999		Ham radio network conection proves to be invaluable. Paradip is reported to have been built as a state port inspite of warnings that the region was cyclone prone. Increase in concentration of population in disaster prone areas should be avoided. There are 1041 multipurpose shelters compared to Orissa's 50 (Ratio ≈ 20). The biggest ever evacuation of 14 districts of Andhra pradesh restricted the deaths to 976 in 1990. The role of NGO as the link between the Mandal level and village level for preparation and execuation of contingency plans proved to be very effective in Andhra Pradesh. India is not exposed to cyclones as much as Japan or USA (6% exposure as compared to 30% by China and Japan). Disaster management experience from these countries could be valuable. Boiling of water as advised by the government was perceived as an unaffordable luxury. Nearly 150000 people were evacuated within 10Km of the sea in the districts of Puri, Bhadrak, Jagatsinghpur, Kendrapara and Balasore districts. What caught everyone off guard was the sheer intensity of the cyclone, called the super-cyclone. 12 days earlier a cyclone had come and gone in Ganjam dist. People were in a carefree mood and devalued the warnings over Radio and TV(At least it can be expected that at least transistors exist in villages). Depletion of Mangrove forests might also be one of the reasons which sharpened the impact of cyclone.		

DIRECTOR:	:	**Dr. K. S. Ramasastri**
STUDY GROUP	:	**Dr. S. K. Mishra, Scientist E1** **Shri R.P.Pandey, Scientist C** **Shri T.R.Nayak, Scientist C** **Dr. K.S.Ramasastri**
STENO	:	**Shri. T. P. Panikar**