4.5.3 Alternative City Development Models and their Comparison

There are various types of model in city development, characterized by number of population, geographic condition, land use, transportation array, natural environment, administrative services, economic development activities, prevailing culture and tradition, etc. In addition preparedness against disaster is one of the important aspects to be considered, especially in Banda Aceh City.

In case of Banda Aceh City, it is deemed that there would be five (5) conceivable models to be adaptable. These models are as described in Table 4.5.1 and schematically shown in Figure 4.5.3.

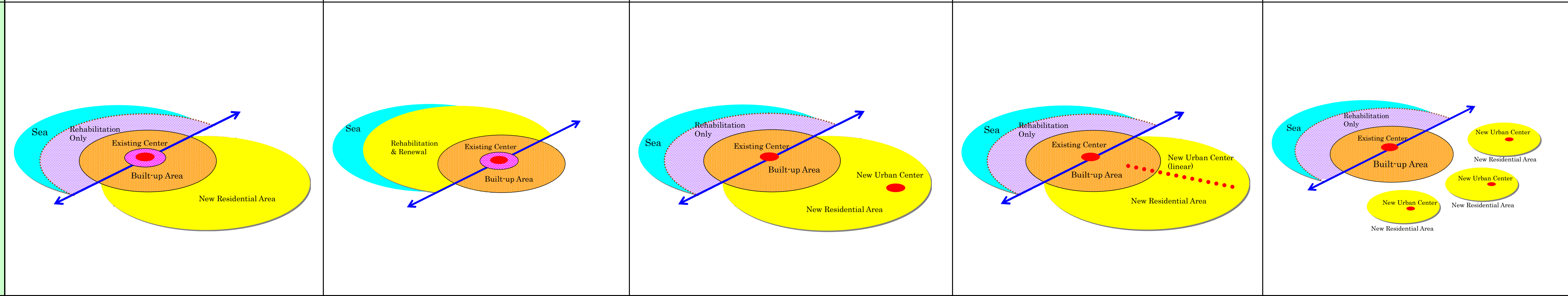
Table 4.5.1 Outlines of Five Conceivable City Models

Models	Characteristics
Model A: Center Growth with Dual Residential Areas	➢ Residential area tends to expand to southern area since coastal area was devastated. ➢ Administration and commercial activities remain mostly at the present location.
Model B: Center Growth with Coastal Area Development	➢ Coastal area will be re-developed to state of pre-disaster condition, while developing the southern area. ➢ Administration and commercial activities remain mostly at the present location.
Model C: Dual Center with Dual Residential Area	➢ New urban center will be located to de-centralize administrative and commercial activities from the present urban center. ➢ Residential area will extend between two (2) centers.
Model D: Linear Growth with Dual Residential Area	➢ Commercial and business center will grow along arterial road in future. ➢ Residential area will be developed in the south.
Model E: Linked Multi Center with Multi Residential Area	➢ Sub-centers will be developed in form of cluster. The existing urban center and sub-centers will be linked by artery road. ➢ Administrative centers will be relocated to disperse risk of disaster. Commercial activities would subsequently grow around new administrative centers.

Source; JICA Study Team

	A	B	C	D	E
MODEL	***CENTER GROWTH WITH DUAL RESIDENTIAL AREA***	***CENTER GROWTH WITH COASTAL AREA DEVELOPMENT***	***DUAL CENTER WITH DUAL RESIDENTIAL AREA***	***LINEAR GROWTH WITH DUAL RESIDENTIAL AREA***	***LINKED MULTI-CENTER WITH MULTI RESIDENTIAL AREA***

DEVELOPMENT PATTERN



SCHEMATIC CONCEPT

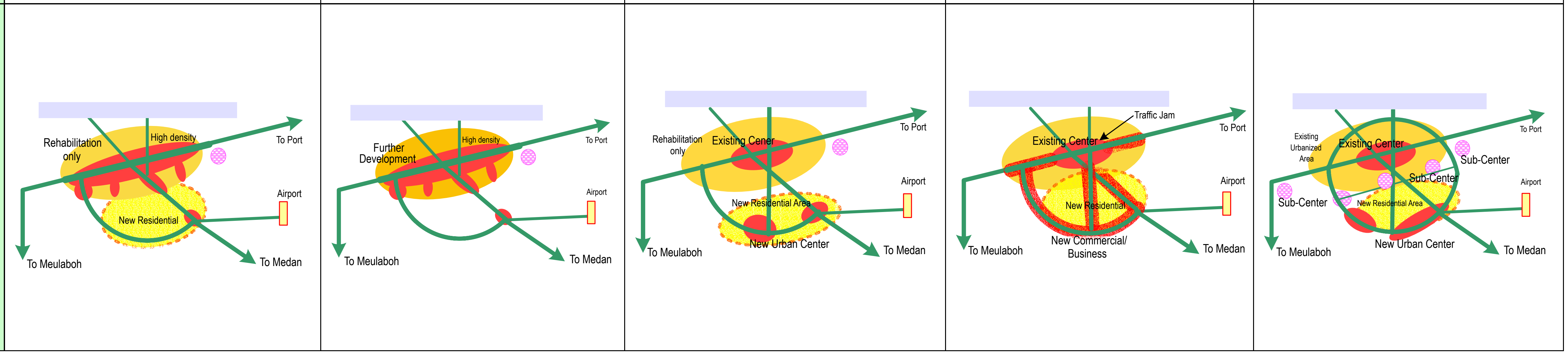


Figure 4.5.3 Alternatives of City Development Model

The above five (5) models are evaluated by means of rating system as presented in Table 4.5.2.

Table 4.5.2 Evaluation of Five Development Models

Evaluation Items	Model A	Model B	Model C	Model D	Model E
Flexibility for future development	3	3	3	3	3
Amenity in urban life	3	3	3	5	5
Prospect for commercial and industrial development	1	1	3	3	5
Efficiency in road traffic	1	1	3	3	5
Urban environment (in order of good to inferior)	1	1	3	5	5
Preparedness against disaster	1	1	3	3	5
Total	10	10	18	22	28

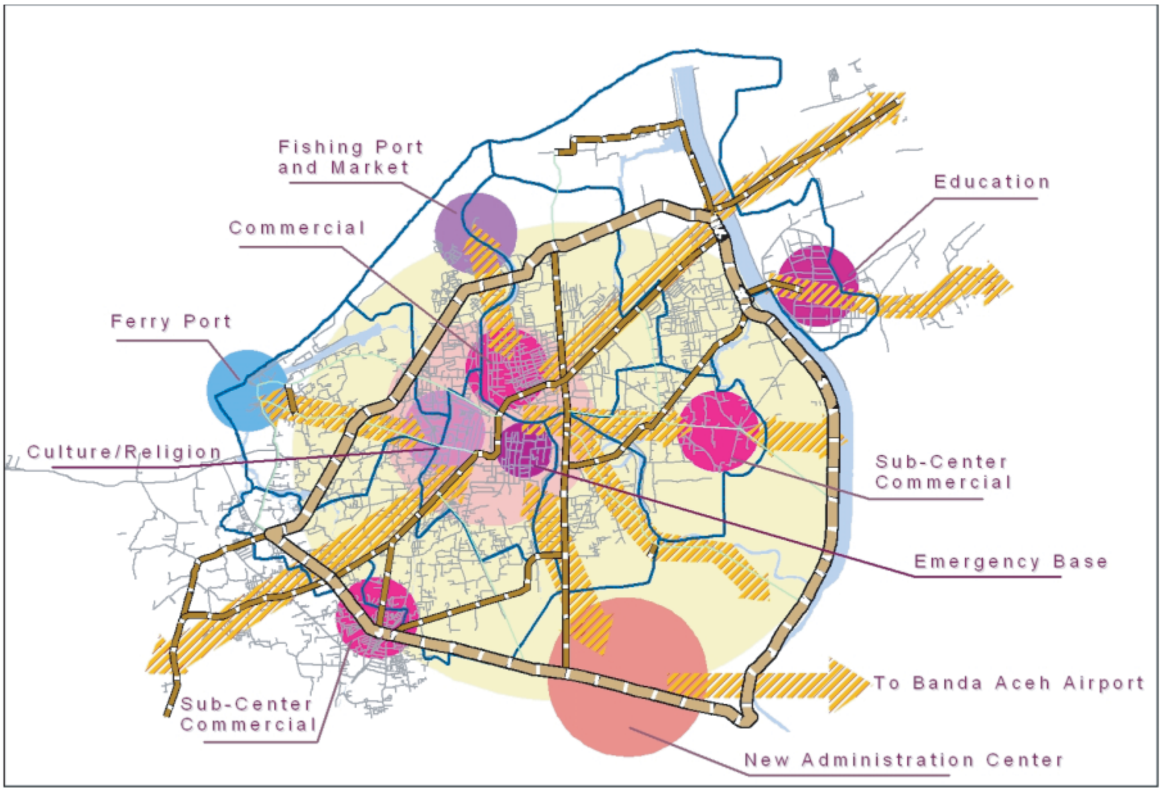
Source: JICA Study Team
Rating: 5 points for high, 3 points for medium, 1 for low.

4.5.4 Selected Model and Proposed Urban Development Concept

According to the above evaluation, Model E is considered to be most feasible and adaptable for re-building of Banda Aceh City.

From geographic point of view, the selected model is recommendable; there are marginal limitation of urban expansion and over-concentration in the existing city center. Even before the disaster, urban environment has been showing a tendency of deterioration mainly due to concentration of commercial activities and traffic in a narrow area and lack of infrastructure.

On a basis of the selected model, city development concept is worked out, in which urban functions are allocated with mutual linkage and network. New administration center is proposed to be located in the south area to cope with expansion and renewal of administration function. This will attract related private business/commercial development. The proposed city development concept is shown in Figure 4.5.4.



Source: JICA Study Team

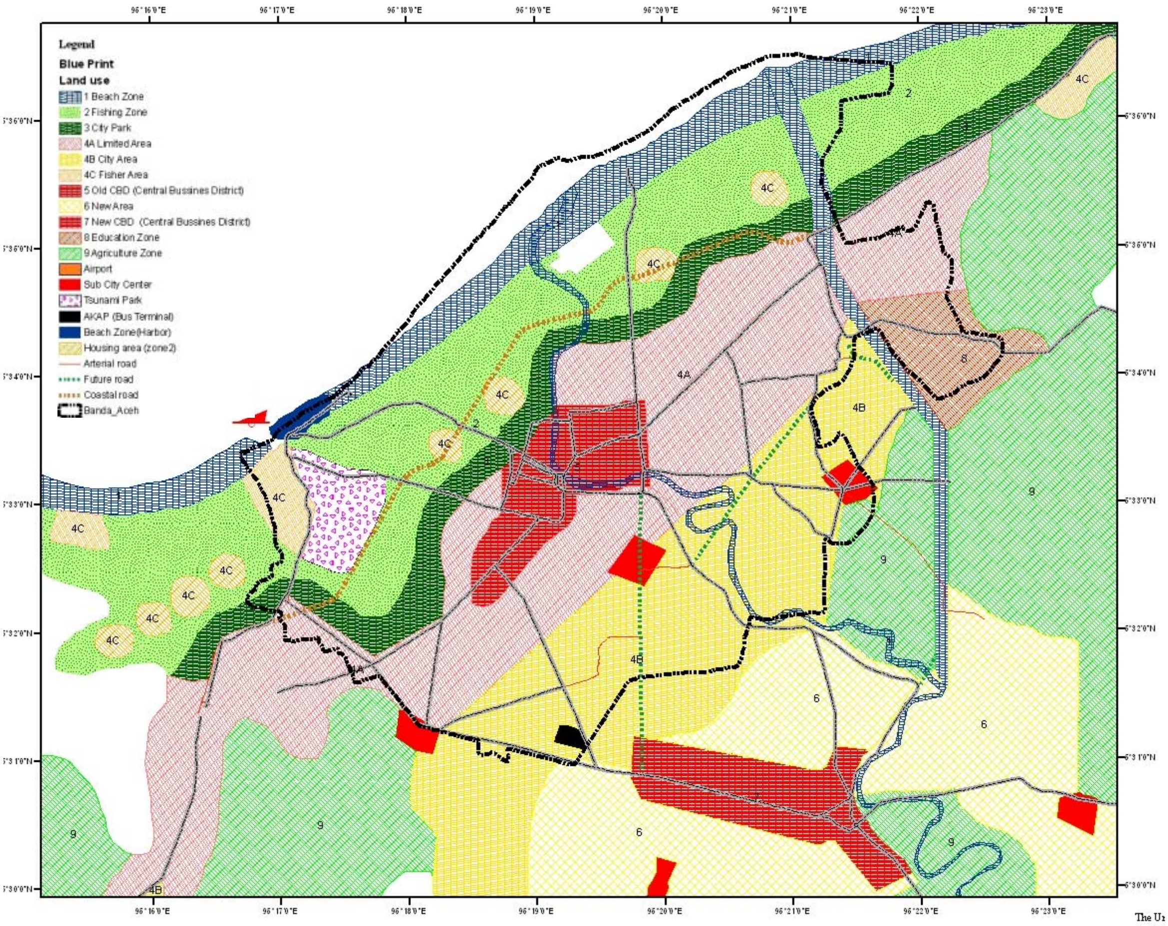
Figure 4.5.4 Proposed City Development Concept

4.6 PROPOSED ZONING AND LAND USE PLAN

4.6.1 Proposed Zoning

The Blueprint also covers the zoning for the entire Aceh Region and Nias, and it is of concept of regional land use and the urban development as presented in Figure 4.6.1.

The Blueprint proposes 9 zonings for Banda Aceh City. It however appears that the Blueprint pays less attention to population increase and disaster preparedness. Under the present study, the said zoning was reviewed in the light of the proposed city development concept, population growth, available land resources and disaster preparedness. As a result, it is proposed to divide the city area into four (4) zones with keen attention to disaster preparedness as given in Table 4.6.1 and Figure 4.6.2.



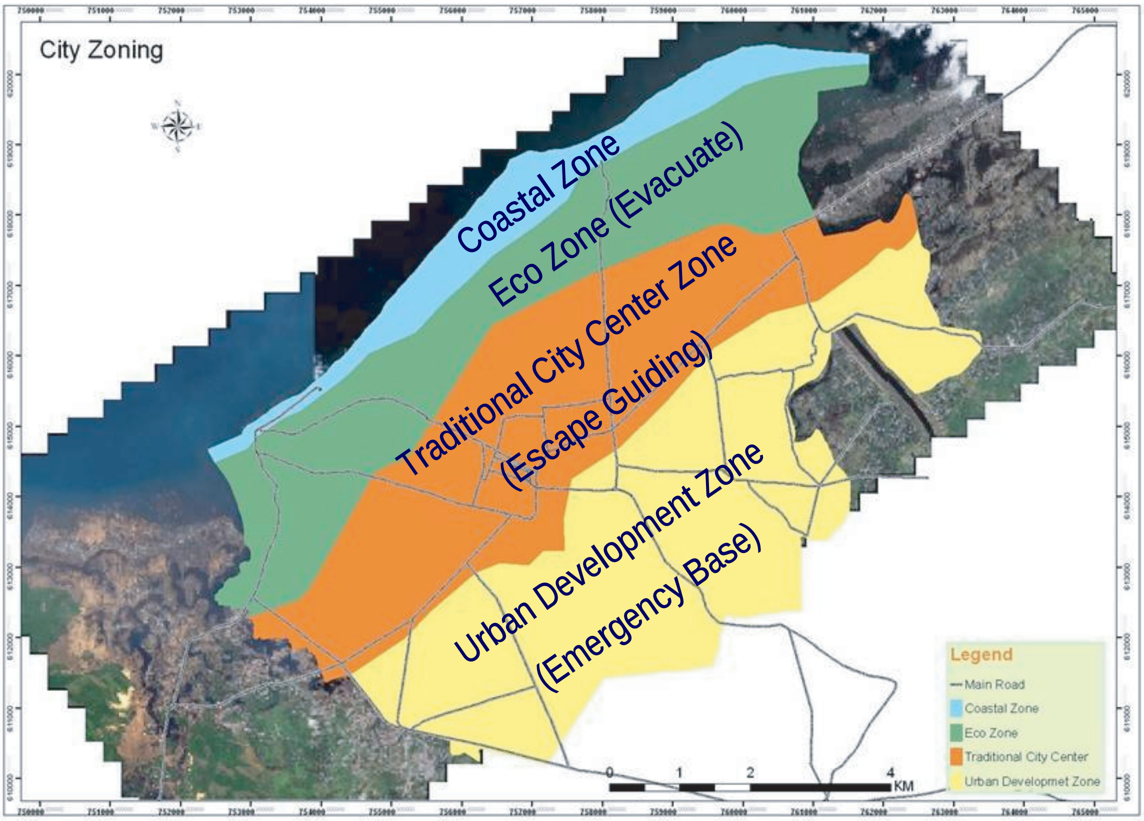
Source : BAPPENAS, Blueprint, 2005

Figure 4.6.1 Zoning in Blueprint

Table 4.6.1 Proposed Zoning

No.	Zoning in Blueprint	Proposed Zoning under the Study
1.	Coastal	Coastal Zone
2.	Fishery (non-residential area)	Eco Zone : Evacuate Area
3.	City Park	
4.	Residential	Traditional City Center Zone: Escape Guiding Area
5.	Old City Center	
6.	New Residential	Urban Development Zone: Emergency Base - Disaster Mitigation Center
7.	New Central Business District (CBD)	
8.	Higher Education	
9.	Agriculture	

Source : JICA Study Team



Source: JICA Study Team

Figure 4.6.2 Zoning with Disaster Preparedness

4.6.2 Proposed Land Use Plan

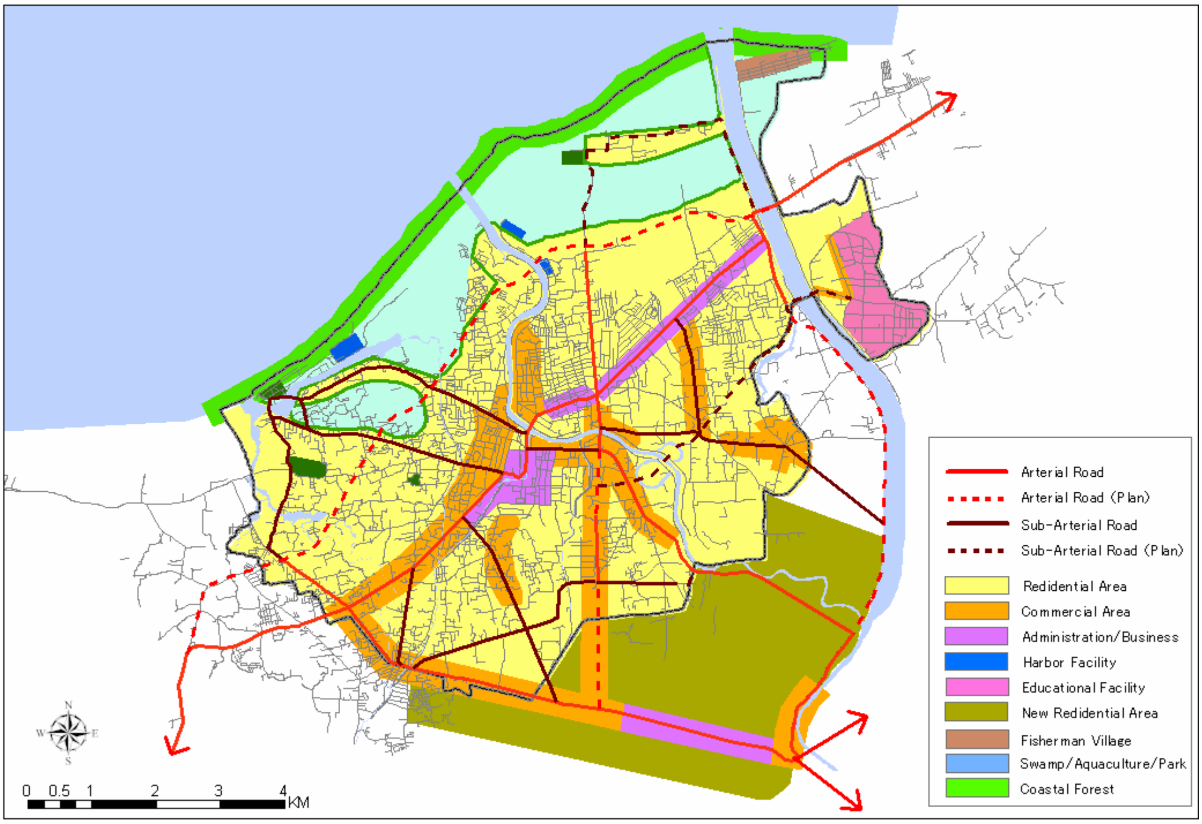
The land use plan is worked out on the basis of the proposed urban development concept and zoning and in due consideration of the present land use pattern and usable land after the disaster. Table 4.6.2 summarizes the proposed land use pattern in conjunction with the proposed zoning.

Table 4.6.2 Proposed Land Use Pattern

Zone	Disaster Zone Classification	Location / Function	Land Use / Disaster Preparedness
1.Coastal	Tsunami Mitigation Measures	Port Palm tree / Mangrove	• Restoration of aqua eco-system • Coastal forest • Ferry terminal • Seawall facilities along shoreline
2. Eco-Zone	Evacuate Area	Disaster memorial facilities Fish cultivation and port Fish market	• Re-construction of residential area for returnees • Escape buildings and towers • Escape roads and relief roads • Ring road (north part) • Revival and conservation of aqua-eco system • Re-building of fish culture industry • Use of nature such as aquaculture and parks (education, recreation and tourism) • Dumping site for garbage and solid waste • Septage treatment plant
3.Traditional City Center Zone	Escape Guiding Area	Grand Mosque Museum Existing commercial center	• Commercial activities area • Cultural facilities area • Escape buildings • Road transport facilities such as bus terminal • Escape and relief roads • Administrative service areas • Emergency relief center • Educational facilities
4.Urban Development Zone	Emergency Base	New CBD New residential area	• New Central Business District • New residential areas • Ring road • New north-south road and east-west road • Universities, religious centers and cultural centers • Agricultural lands • Emergency base

Source: JICA Study Team

The proposed land use plan is also developed on the map as shown in Figure 4.6.3.



Source: JICA Study Team

Figure 4.6.3 Land Use Plan of Banda Aceh City

More detailed land use is worked out for the respective land use category as given in Table 4.6.3.

Table 4.6.3 Details of Land Use for Broad Land Use Category

Broad Land Use Category	Detail of Land Use	Location
Residential	Original settlement (coast area) Existing residential area as of Dec. 2005 except submerged land New residential zone	Ulee Lheu, Alue Naga, Daya Raya (Area that will not be submerged at high tide) Same as left (Density will increase) In southern area (New development of housing lots in mostly present agricultural land.)
Commercial	The commercial zone will consist of Linear zone along streets and Areal zone surrounding centers	<Linear commercial zone along streets> Along Jl. Teuku Umar and Jl. Cut Nyak Dhien (existing east-west main road) Along Jl. Tengu Imom Lueng Bata (main road to southeast) Ulee Kareng and along the streets crossing at Ulee Kareng (east sub-center) Along Jl. Soekarno Hatta (southwest ring road) Along south extension of Jl. Syiah Kuala <Areal commercial zone> Existing vegetable and fish market and surrounding area Pasar Aceh and surrounding area
Culture/ Education, Business and Administration	Culture/ Education (Grand Mosque, Hall and University) Old Business and Administration services New Business and Administration	Grand Mosque and surrounding area Darussalam (Syiah Kuala) and Lueng Bata (universities) Along Jl. Mohammad Daud Beureueh and Jl. Tengku Nyak Arief (east-west main road) Along Jl. Soekarno Hatta (southwest ring road)
Coastal	Natural coast, vegetation, aquaculture Original settlement Port Fish Market Disposal Site and Treatment Plant	Coast Ulee Lheu, Alue Naga, Deah Raya Ulee Lheu, New Lampulo Lampulo North Kuta Raja
Park and Open Space	Recreation and sports for citizens Emergency bases for relief and refugee Memorial, educational facilities	Escape play set (south of existing east-west main road) Park for emergency bases (north of existing east-west main road) Big tree park (Ulee Lheu) Big ship park (east Jaya Baru) Syiah Kuala park (Deah Raya)

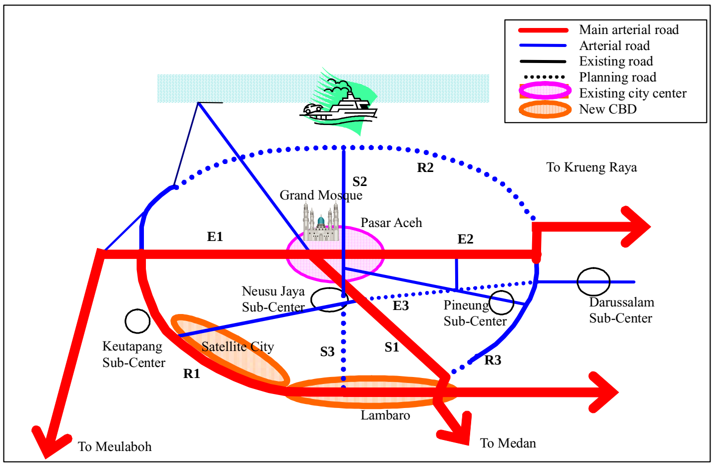
Source : JICA Study Team

4.7 ROAD FRAMEWORK PLAN

In accordance with the new city development concept and knowing the present traffic situation in the city, improved road framework plan is established as seen in Figure 4.7.1.

It is proposed to complete the ring road and to construct coastal road <R2> which will be connected to existing road <R1>. This is to bifurcate traffic passing through the city center.

It is also proposed to align new road <R3> in the south and <S2-S3> with north-south direction between the coast and existing city center to link main arterial road such as coastal road and <E1-E2> road. These roads will be not only effective to link among the sub-centers to be developed but also contribute to emergency case. In the south new road<R3> and the third east-west road <E3> are proposed to be routed as alternative route and/or as additional linkage among sub-centers.



Source : JICA Study Team

Figure 4.7.1 Road Network Structure

4.8 HOUSING DEVELOPMENT PLAN

4.8.1 Damages on Houses and Dislocated People

Housing plan is formulated with the special attention to the dislocated families who wish either return to their homeland or resettle their houses in the new settlement areas.

Owing to disaster, houses were damaged and/or destroyed and according to the survey, existing houses could be broadly divided into three (3) by degree of the damages; namely, heaviest at coastal area, heavy at city and no damage as summarized in Table 4.8.1.

Table 4.8.1 Condition of Housing Damages

Description	Unit	Modern Houses	Semi-modern Houses	Traditional Houses	Total
No Damage	houses	835	10,231	70	11,136
Damaged	houses	543	6,650	—	7,193
Destroyed	houses	2,798	34,275	278	37,351
Total	houses	4,176	51,156	346	55,680
Damage Amount	Rp, million	139,676	1,979,246	4,918	2,123,840

Source: Preliminary Damage & Loss Assessment, December 26, 2004 Natural Disaster, Technical Annex

According to the above table, out of the whole houses of 55,680, 44,544 houses were damaged, of which 37,351 houses or 67 % of the entire houses are reported destroyed. Majority of damaged and destroyed houses are concentrated in the coastal area.

Due to damage/destroy of houses as many as 65,000 people are dislocated, though part of them has started to move in to their original location without regard to quality of accommodation. The latest situation of dislocated people is as reported in Table 4.8.2.

Table 4.8.2 Condition of Dislocated Population

(as of 12 April 2005)

Accommodation				Total
Tent	Temporary House	Rental House	Mosque	
6,921	2,892	55,653	34	65,500

Source: Banda Aceh City

PU, IOM, NGOs and various organizations have constructed temporary and permanent houses and many projects are on-going or planned. UNHCR forecast that most people will be settled in permanent houses in 2 years[1].

4.8.2 Housing Development Plan

The required number of houses for dislocated people is estimated at 13,100 assuming average family size of 5, while there would be required another 10,800 houses in 2009 due to influx of population. The requirement of houses would therefore amount to 23,900 in 2009.

According to the news release, the Indonesian Government proposes the following measures for housing scheme:

1 26 June 2005, Reuter

Table 4.8.3 Housing Scheme Proposed by the Government

<table>
<tr><th rowspan="2"></th><th rowspan="2">Low Income People</th><th colspan="2">Medium - High Income People</th></tr>
<tr><th>Rental</th><th>Owned</th></tr>
<tr><td rowspan="5">Return to original village</td><td rowspan="5">Public low-cost rental flats as ‘escape buildings’ will be constructed in coastal area for people without assets.

Support for formation of fishermen’s union, agricultural union and retail union will be made. Aids for funds, facilities and housing will be given through the union.</td><td colspan="2">Structural Measures</td></tr>
<tr><td colspan="2">Public facilities including escape road, escape building (school, mosque, health center, market, rental flat etc.), infrastructure (water supply, drainage and sanitation) and parks on disaster preparedness will be planned and implemented.
Participatory village plan will be supported to be made by the residents.
The structure of buildings shall be strong enough for earthquake-proof and shall be high-floored for tsunami.</td></tr>
<tr><td>Rental houses will be constructed mainly by aid of NGOs and donors.</td><td>Land consolidation system will be promoted.
Reduced land area for public facilities will be paid that will be part of fund for reconstruction of houses.
Low interest housing loan will be made.
Tax reduction will be considered.</td></tr>
<tr><td colspan="2">Non-structural Measures</td></tr>
<tr><td>Public mediation between the house owner (lender) and the tenant will be facilitated.
Preferential taxation system will be applied.</td><td>Consultation system will be made in the city for
Housing loan of low interest rate will be made.
Preferential taxation system will be applied.</td></tr>
<tr><td rowspan="5">Resettled to inland area</td><td rowspan="5">Public low-cost rental flats will be constructed in inland area for people without assets.

Subsidy to rent or tax reduction will be given.</td><td colspan="2">Structural Measures</td></tr>
<tr><td>Promotion and incentive will be given to landowners in the inland area to prepare decent rental houses.</td><td>The structure of buildings shall be strong enough for earthquake-proof.</td></tr>
<tr><td colspan="2">Development of residential neighborhood will be promoted with public incentive measures.
Public low price housing will be prepared.
Infrastructure (road, water supply, drainage, sanitation, electricity) will be developed.</td></tr>
<tr><td colspan="2">Non-structural Measures</td></tr>
<tr><td>Subsidy to rent or tax reduction will be given.</td><td>Tax reduction will be considered for acquisition of housing.</td></tr>
</table>

Source: JICA Study Team

4.9 DISASTER PREPAREDNESS

4.9.1 Disaster Control and Mitigation Plan

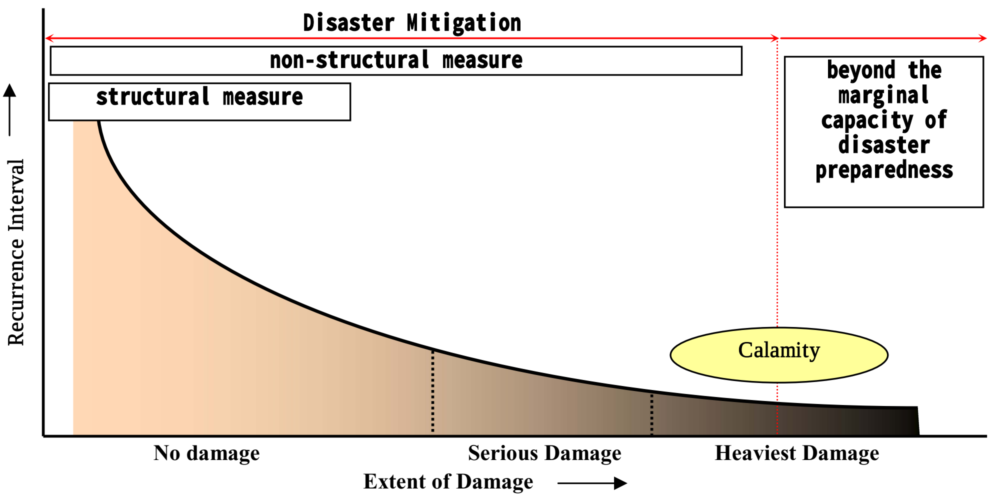
City planning with disaster preparedness is formulated in combination with both structural measure and non-structural measure systems. Major concerns for the disaster preparedness are;

(1) Banda Aceh City expands southward; namely, more safely side against natural disasters such as tsunami, high tide and flooding,

(2) Plan of disaster preparedness is organized into both structural measure and non-structural schemes, and

(3) Phased disbursement of public investment should be considered in rehabilitation and reconstruction of basic infrastructures.

A concept on integrated disaster preparedness is shown schematically in Figure 4.9.1. Vertical axis shows recurrence interval of natural disaster while horizontal axis is extent of damage. It shows disaster management mitigation, which consists of structural measure and non-structure measure, has a limited capacity against disaster.



Source: Footnote 1

Figure 4.9.1 Schematic Diagram of Integrated Disaster Preparedness

In general, disaster preparedness by structural measure is formulated on the basis of design criteria for the magnitude of natural disaster. Take design criteria for flood control structure for instance, the

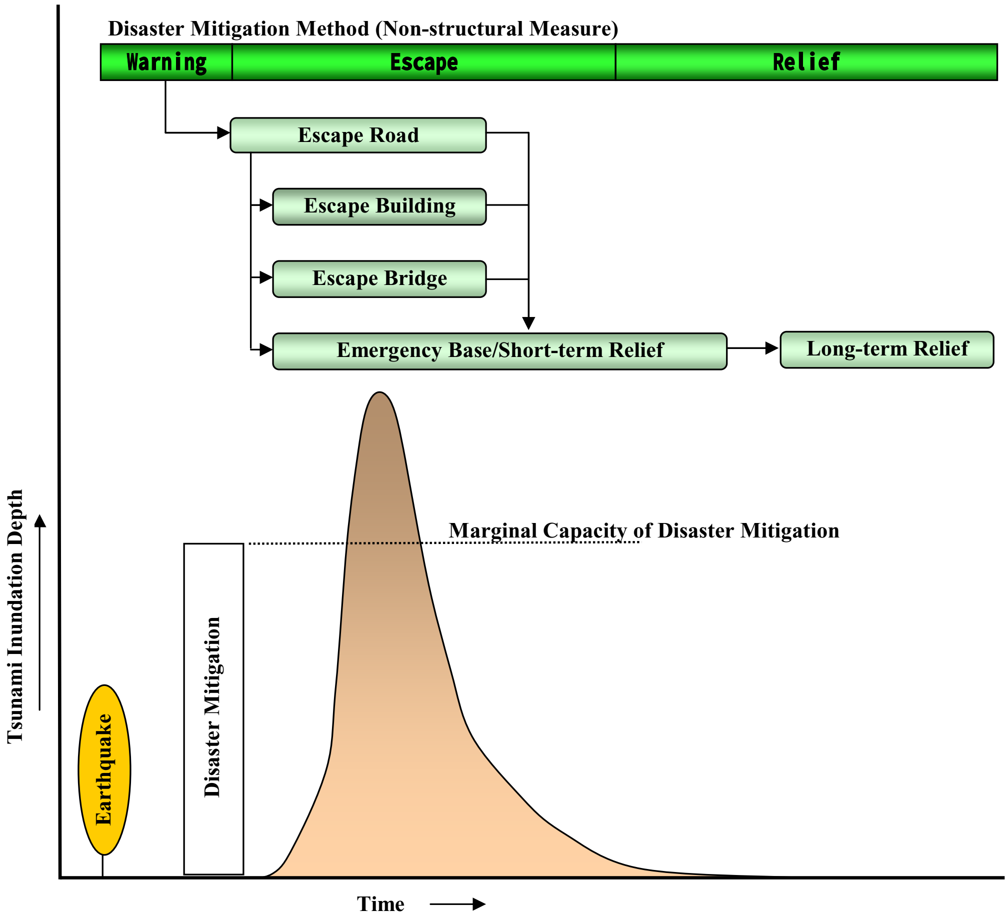
1 Yoshiaki Kawata, Characteristics of Catastrophic Disasters and Philosophy of their Reduction, Journal of Geography, 2001

dike along river channel is designed against flood with a probability of once in 20-year or more. The safety against flood with a probability of design flood is ensured, once the flood control structures are constructed in accordance with the said design criteria.

However, there is a likelihood of natural disaster beyond the design criteria. In case of natural disaster beyond the capability of structural measure, the non-structural measure would be more effective in mitigating damage and reducing duration.

Taking into account the casualties in the Banda Aceh City, tsunami is the most serious disaster among natural disasters such as flooding, earthquake, big fire, and so on. Although structural measures against large-scale tsunami can reduce inundation area and tsunami run-up height, the measures can not control tsunami completely. Thus, the efficient disbursement of public investment taking into account marginal capacity of structural measures is required in rehabilitation and reconstruction of basic infrastructures.

Applying the concept on disaster preparedness (Figure 4.9.1), the integrated disaster management system for the Banda Aceh City is illustrated in Figure 4.9.2, in which horizontal axis indicates time and vertical axis for tsunami run-up height. Also, the upper part of the figure, implementation process of disaster mitigation methods is illustrated.



Source : JICA Study Team

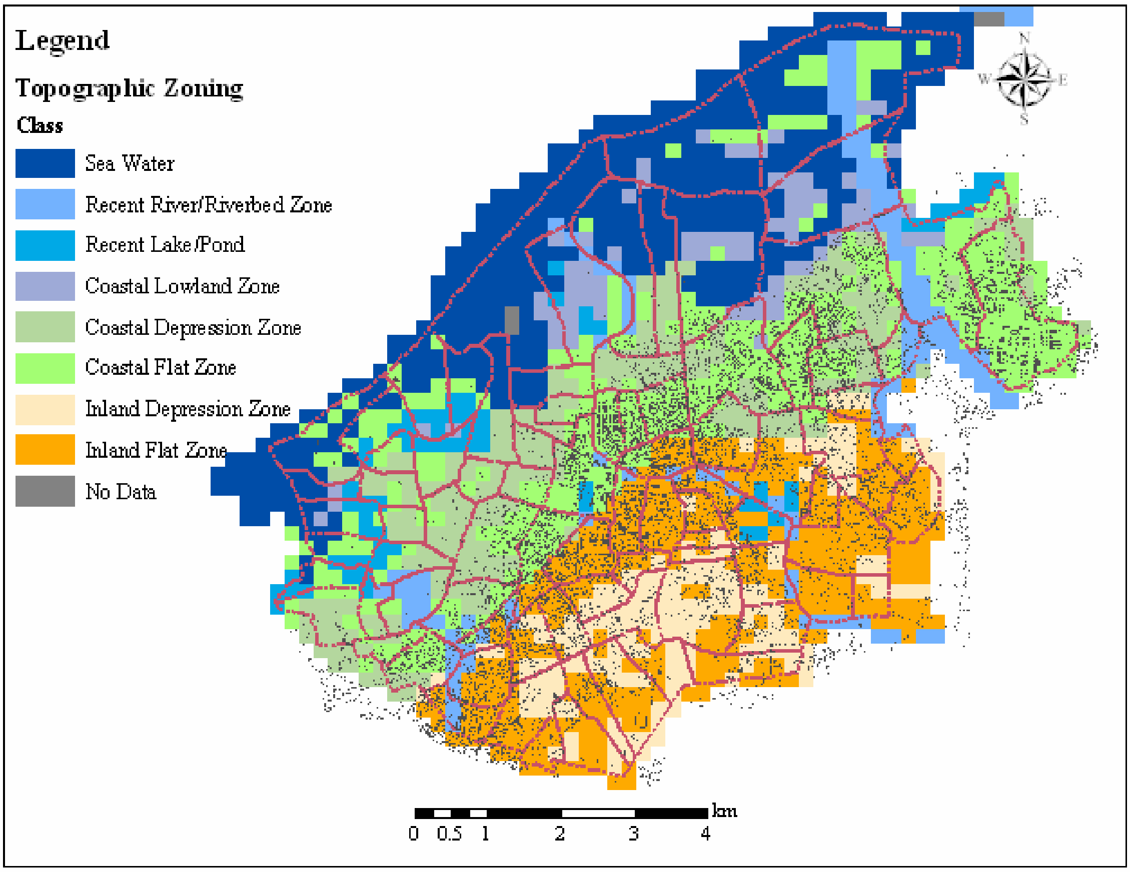
Figure 4.9.2 Schematic Diagram of Integrated Disaster Management System in Banda Aceh

4.9.2 Hazard Potential

To evaluate the Hazard Potential is one of the important issues where a particular natural hazard could potentially be a problem. The maps are constructed by establishing risk factors, such as topographic condition, road space, density of population, etc., then noting where such factors exist in combination. The areas meeting the risk factors are illustrated by coloring them on a base map.

Hazard potential in the Banda Aceh City was then evaluated preliminary based on the limited physical data with satellite photos. The topographic condition was characterized by classifying broadly into coastal (lowland) and inland (upland) zones, which were further sub-divided into 8 zones (Figure 4.9.3).

Topographic zoning map shows that zone of sea water extends with a radius of 1 to 2 km from shoreline, and coastal lowland zone where hampered diurnal change of tide level is located around sea water zone. The land subsidence due to earthquake would occur in and around the zones. Both in the lowland and upland zones, depression zone occupies widely where the malfunctioning of drainage system is expected.



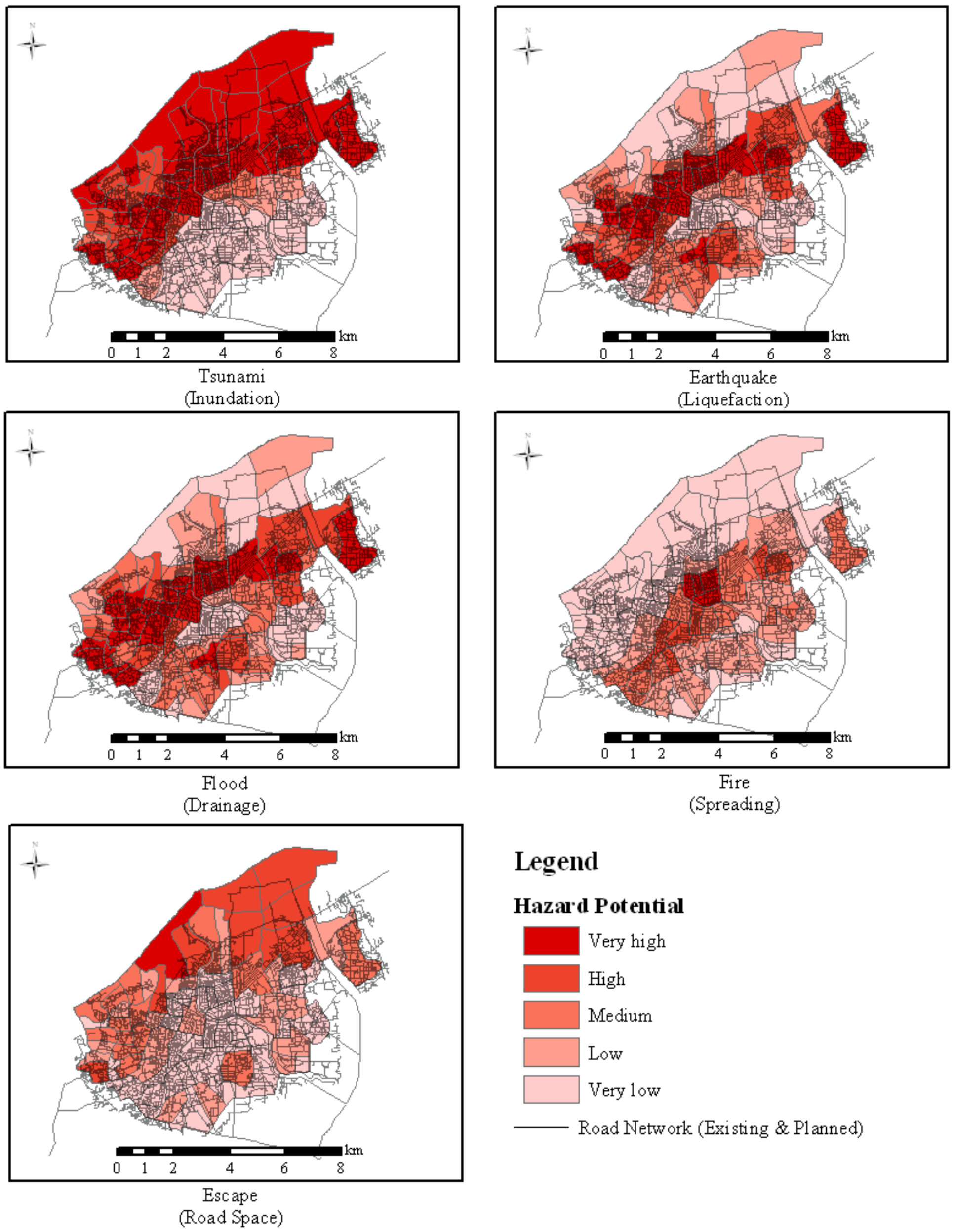
Source : ARRIS (GIS) prepared by JICA Study Team

Figure 4.9.3 Topographic Zoning

Risk factors (Table 4.9.1) are the criteria to decide where a particular hazard is present. The following factors are evaluated by Desa against natural hazards; namely, tsunami inundation, liquefaction, drainage, fire spreading and escape from hazard. The preliminary results are shown in Figure 4.9.4.

Table 4.9.1 Risk Factors for Natural Hazard

Natural Hazard	Topographic Factors	Physical Factors
(1) Tsunami inundation	Coastal lowland zone	Land area of Desa
(2) Earthquake (Liquefaction)	Depression/Lowland zone	Land area of Desa
(3) Flood (drainage)	Depression/Lowland zone	Land area of Desa
(4) Fire spreading	none	Building Area/Land Area
(5) Escaping activity	none	Road Space/Land Area



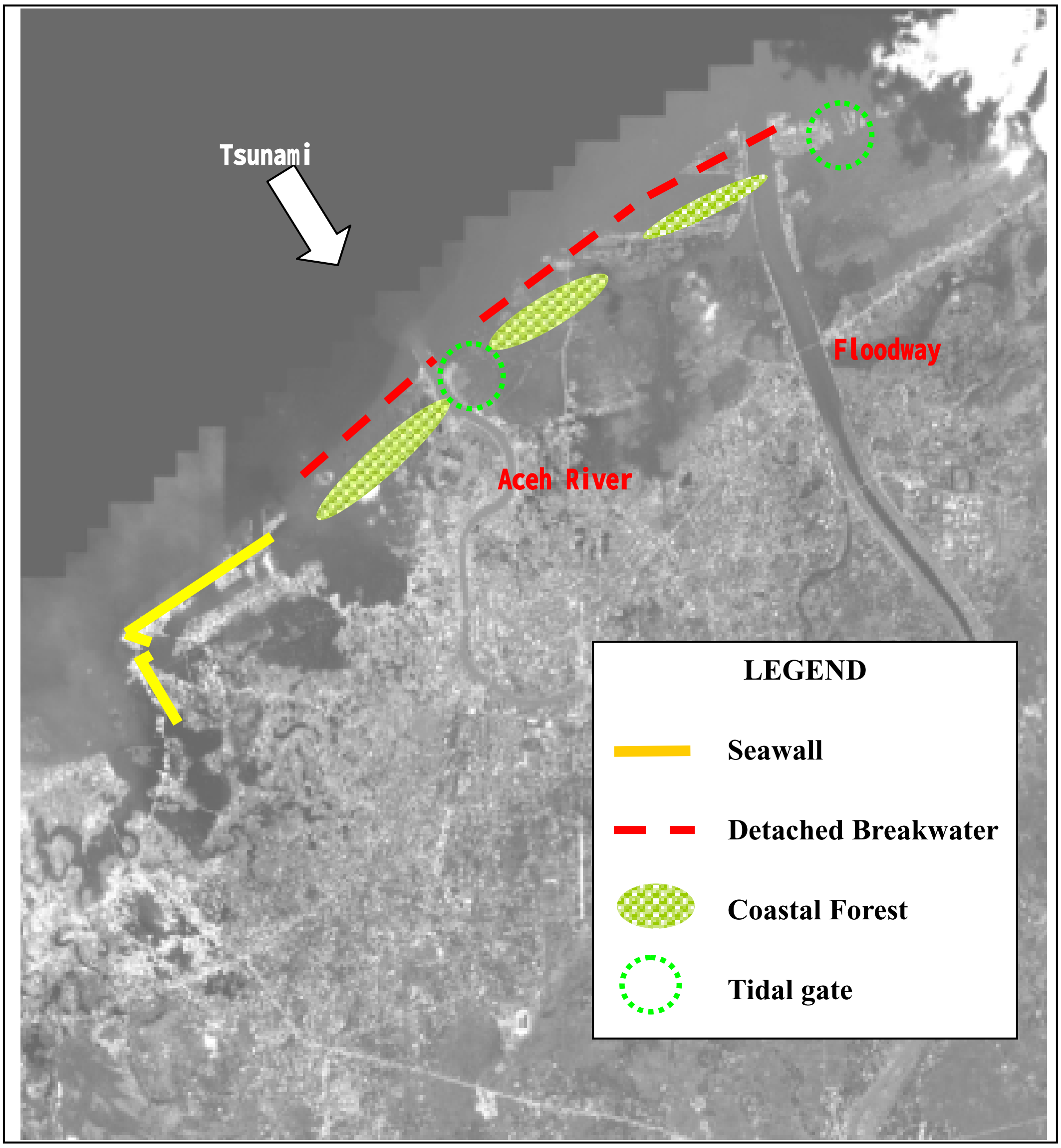
Source : ARRIS (GIS) prepared by JICA Study Team

Figure 4.9.4 Potential Hazard Maps

4.9.3 Disaster Mitigation Structures at Shoreline

Tsunami wave height generated by earthquake on 26 December 2004 reached about 10 m at shoreline based on the trace on palm trees. For protecting completely Banda Aceh City from a huge tsunami, the sea wall of 15-m high along shoreline is required. However, such a high sea wall requires remarkable amount of public investment and it would be an obstacle from the viewpoint of environmental conservation. Thus, the structural measures at shoreline are designed to cope with small-scale and medium-scale tsunami. The structural measures are arranged in combination with (i) detached breakwater, (ii) seawall, (iii) coastal forest, and (iv) tidal gate at river mouth.

Proposed structural measures at shoreline are illustrated as shown in Figure 4.9.5.



Source: JICA Study Team

Figure 4.9.5 Structural Arrangements at Coastline

(1) Detached Breakwater

A series of detached breakwaters are structures situated offshore and generally parallel to the shore. Detached breakwaters protect the adjacent shoreline by attenuating incoming wave energy due to storm surge, mid-scale and small-scale tsunami.

Sand transported along the beach is then carried into the sheltered area behind the breakwater where it is deposited in the lower wave energy portion. If the breakwater attenuates much wave energy, sediment may eventually fill in the lee of the breakwater and form a tombolo (Figure 4.9.6).

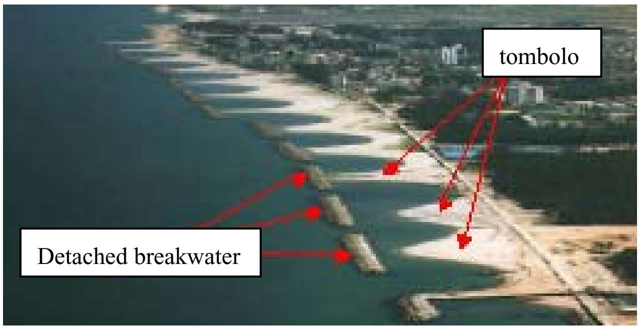
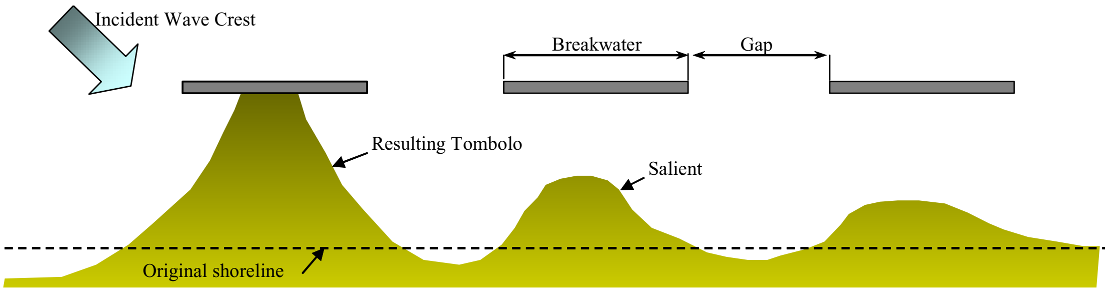


Figure 4.9.6 A series of Detached Breakwater

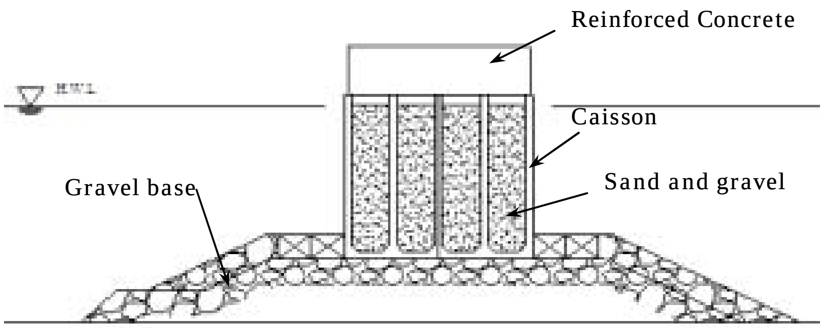
The breakwater-tombolo system may then act as a groin, disrupting the long shore sediment transport processes in the area. A salient is also a seaward growth of the shoreline (Figure 4.9.7)



Source : USACE, Coastal Engineering Technical Note, CETN III-48

Figure 4.9.7 Types of Shoreline Changes associated with Multiple Breakwaters

Detached breakwater with composite wall-type typically consists of caissons[2] sitting on a gravel base. Exposed faces are vertical or slightly inclined (Figure 4.9.8). It may protrude above High Water Level.



Source : JICA Study Team

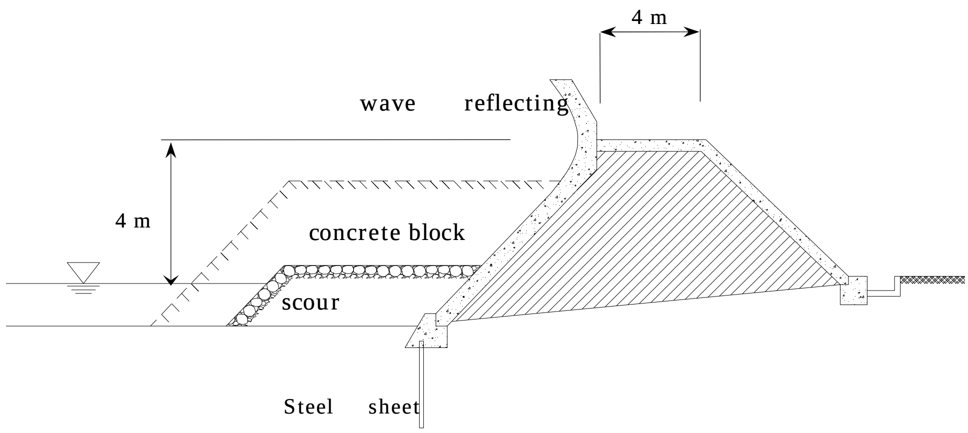
Figure 4.9.8 Typical Cross Section of Detached Breakwater (Composite Wall-type)

2 A concrete or steel shell filled with sand or gravel.

(2) Seawall

a) Structure

A seawall is a structure built along the shoreline parallel to the beach. Its purpose is to impose a landward limit to coastal erosion and to provide protection to development behind the wall. Seawalls are commonly constructed from dumped rock, concrete and gabions. The face of a seawall may be vertical, curved, stepped or sloping. Figure 4.9.9 shows typical cross section of a rigid seawall.



Source : JICA Study Team

Figure 4.9.9 Typical Cross Section of Rigid Seawall

Whilst many rigid seawalls have been built over the world along the shoreline in the past, there is now general tendency away from this form for the following reasons:

- Failure can occur from a single freak wave or group of waves;
- Most rigid structures tend to be highly reflective to incoming waves; and
- Toe scour at the base of the wall can result in failure by undermining.

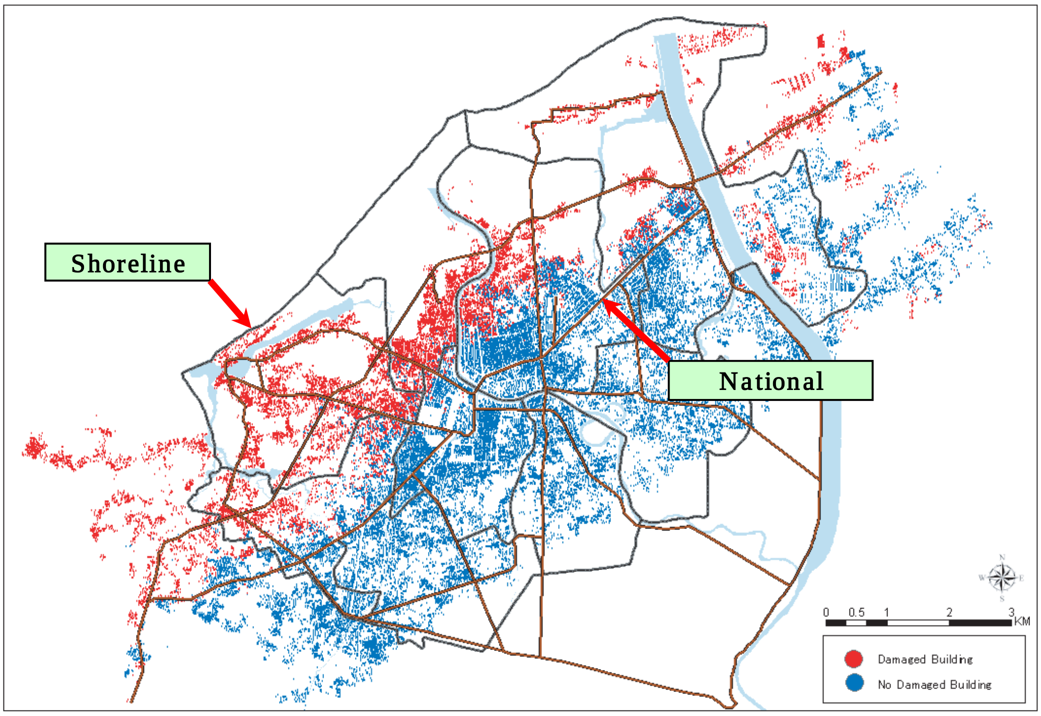
However, the performance of rigid seawalls can be improved by incorporating various features such as a curved wave deflection barrier (wave reflecting wall) along the crest of the wall, which significantly reduces wave overtopping and enables the crest to be lowered. In selecting the foundation level of a seawall, consideration must be given to the possibility of local scour at the toe. This may result in the failure of rigid structures. Flexible structures can tolerate settlement without failure. Incorporation of a scour blanket to protect against toe erosion is commonly provided as a safeguard against failure or damage from this cause.

b) Height of Seawall

Crest level adopted in the design needs special attention. A crest level which is never overtopped will significantly increase the cost of seawall. As the crest level is reduced, the probability of failure caused by overtopping is increased. The crest level for seawall is set at 4 m above mean sea level as mentioned below:

Collapsed Houses and Building

Fully and half collapsed houses due to Tsunami on 26 December 2004 are depicted by analyzing satellite images. Figure 4.9.10 shows the distribution of damaged (fully or partly collapsed) houses in red and non-damaged houses in blue.



Source : ARRIS (GIS) prepared by JICA Study Team

Figure 4.9.10 Damaged and Non-damaged Houses and Building

Assuming that the tsunami inundation depth varied in proportion to the distance from the shoreline with a radius of 3.5 km for the range from 10 m at shoreline to none at national road, the number of houses by inundation depth is enumerated as given in Table 4.9.2.

Table 4.9.2 Tsunami Inundation Depth and Damaged Houses and Building

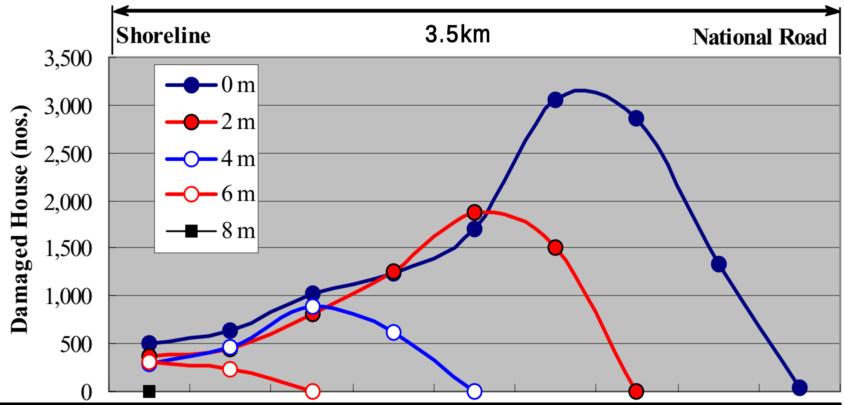
Tsunami Inundation Depth (m)	Houses and Buildings (nos.)			
	Damaged (a)	Non-damaged (b)	Total (c)=(a)+(b)	Damage Ratio % (d)=(a)/(c)
9	510	2	512	99.6
8	632	77	709	89.1
7	1,028	411	1,439	71.4
6	1,240	695	1,935	64.1
5	1,711	1,346	3,057	56.0
4	3,059	1,674	4,733	64.6
3	2,854	1,808	4,662	61.2
2	1,333	2,873	4,206	31.7
1	32	16,094	16,126	0.2
Total	12,399	24,980	37,379	33.2

Source : ARRIS (GIS) prepared by JICA Study Team

Damage ratio varies for the range from 99.6 % at shoreline and 0.2 % at the national road. Almost all of the houses and buildings inundated of less than 1m deep were not damaged.

Tsunami peak cut-off by Seawall

Assuming that the seawall enables to cut the tsunami wave height in proportion to the height of seawall; namely, 4-m high seawall attenuates 4-m tsunami wave height, the damage ratio by tsunami inundation depth as given in Table 4.9.2 is multiplied to the number of houses and buildings. Figure 4.9.11 shows the relationship between damaged houses and buildings and tsunami inundation depth by height of seawall.



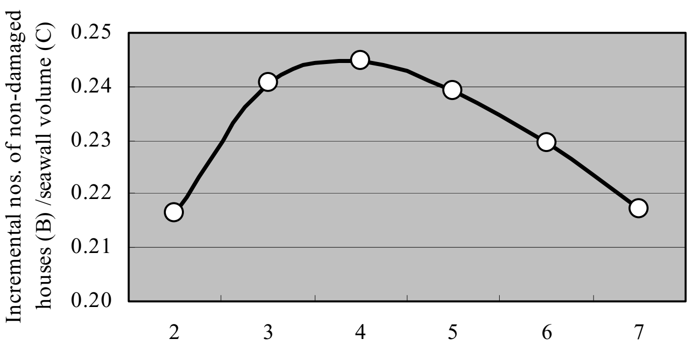
Seawall Height									
8 m	1								
6 m	3	2	1						
4 m	5	4	3	2	1				
2 m	7	6	5	4	3	2	1		
None	9	8	7	6	5	4	3	2	1
	Inundation Depth (m)								

Source : ARRIS (GIS) prepared by JICA Study Team

Figure 4.9.11 Damaged Houses by Height of Seawall

Height of Seawall

Besides, the volume of main body of seawall by height is estimated on the basis of the typical cross section (crest width 4 m, slope of seaside 1:0.1, slope of upland 1:0.5 and full length 9,300 m). The cost-benefit relationship as shown in Figure 4.9.12 was analyzed by assuming that the volume of seawall is estimated as Cost (C) and the incremental number of non-damaged houses due to the reduction of tsunami inundation depth is counted as Benefit (B). Among various height of seawall, a 4-m high seawall would be the most economical for public investment taking into account the pre-tsunami condition in the Banda Aceh City.



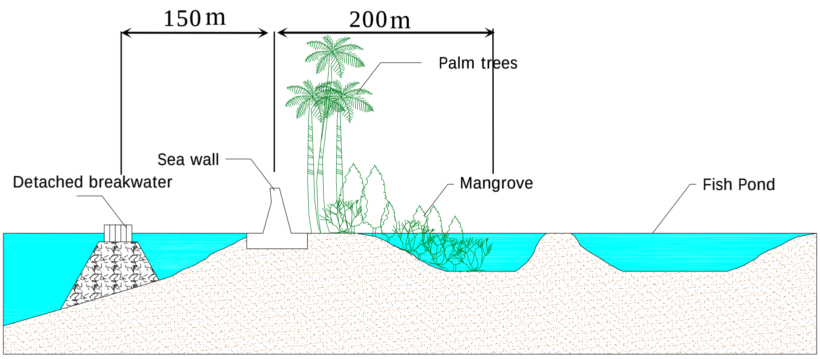
Source : JICA Study Team

Figure 4.9.12 Height of Seawall and B/C

(3) Coastal Forest

Seawalls and breakwaters are regarded as artificial structural measure against tsunami. However, it may be noted that the artificial measures involve rather high construction and maintenance cost and environmental changes along shoreline.

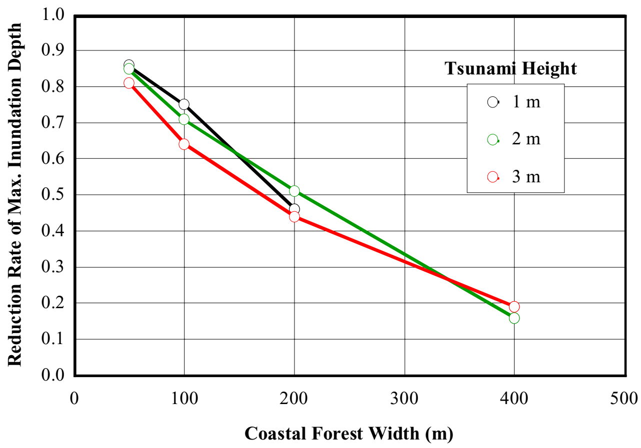
Coastal forest, with mangrove, sago palm, casuarinas tree and coconut tree, is known as natural functions to reduce the tsunami force and it is one of the solutions for disadvantages due to artificial measures. The construction of seawalls and breakwaters combined with coastal forest is likely to ensure the pre-tsunami environmental condition (Figure 4.9.13).



Source : JICA Study Team

Figure 4.9.13 Schematic Diagram of Arrangement of Coastal Forest

Quantitative effect due to coastal forest is evaluated preliminary on the basis of the results of numerical simulation in the past3. Coastal forest is generally collapsed by tsunami of over 4-m height. However, in case of tsunami wave height of 3 m, coastal forest with forest density of 30 trees per 100 m2, the diameter of trunk of 15 cm, and forest width of 200 m can reduce tsunami inundation depth to 50-60 % and flow velocity to 40-60 % (Figure 4.9.14).



Source : Footnote 3

Figure 4.9.14 Coastal Forest Width and Reduction Rate of Inundation Depth

Out of the parameters, such as forest density, diameter of trunk and forest width, to evaluate the quantitative effect, the most outstanding parameter is the forest width to amplify the reduction rate of tsunami inundation. Thus, the forest width of more than 200 m would be

[3] Kenji Harada and Yoshiaki Kawata, "Study on the effect of coastal forest to tsunami reduction", Annuals of disaster prevention, Research Institute of Kyoto Univ., No.47C, 2004

required to maintain for the purpose of reducing tsunami inundation.

The planting of mangrove forest depends largely on the soil character, density, topography and so on. Also, increasing public awareness of coastal environmental issues means community members will often bring valuable experience, knowledge and skills to coastal management activities and issues. Community consultation and public education about coastal management will be therefore an important part of the restoration of mangrove forest.

As a pilot system, trial-and-error method for planting is required in cooperation with NGO who are keen to restore coastal conservation along shoreline. Increasing public awareness of environmental issues means community members will often bring valuable experience, knowledge and skills to coastal management activities and issues. Community consultation and public education about coastal management is therefore an important part of the Government's coastal management policy.

In combination with detached breakwater, the coastal forest is regarded as the alternative measures against small and medium-scale tsunami until the seawall is completed for the whole stretch of shoreline in future.

(4) Tidal Gate


Figure 4.9.15 Tidal Gate

Tsunami travels in a form of bore into river channel. Tsunami inundation map on 26 December 2004 also shows the furthermost point of tsunami inundation at floodway reached 6.5 km upstream section from river mouth, although the tsunami inundation at inland extended with a radius of 3.5 km from shoreline. The collapse of bridge due to tsunami has been often reported due to hydraulic bore traveling to upstream.

Tidal gates for the river mouth of the floodway and the Aceh River are required to cope with small-scale and medium scale tsunami and to mitigate the damages along river channel (Figure 4.9.15 and Figure 4.9.16).

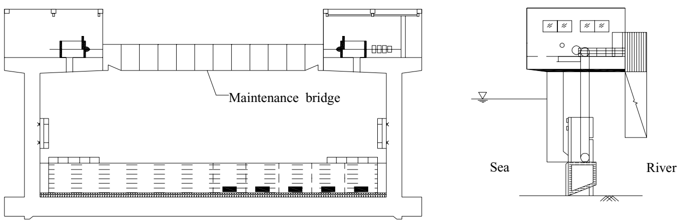


Figure 4.9.16 General Layout of Tidal Gate

The operation room of the tidal gate on the maintenance bridge can be used for "Tsunami Watch Point". In case of tsunami, the tsunami inspector disseminate tsunami warning and gate operator closes the gate to prevent hydraulic bore intrudes into river channel.

Lower priority is given to the construction of tidal gate because of high construction cost. The tidal gate would be required when the land use along river channel is developed.

4.9.4 Emergency Facility Plan

(1) Emergency Road Network

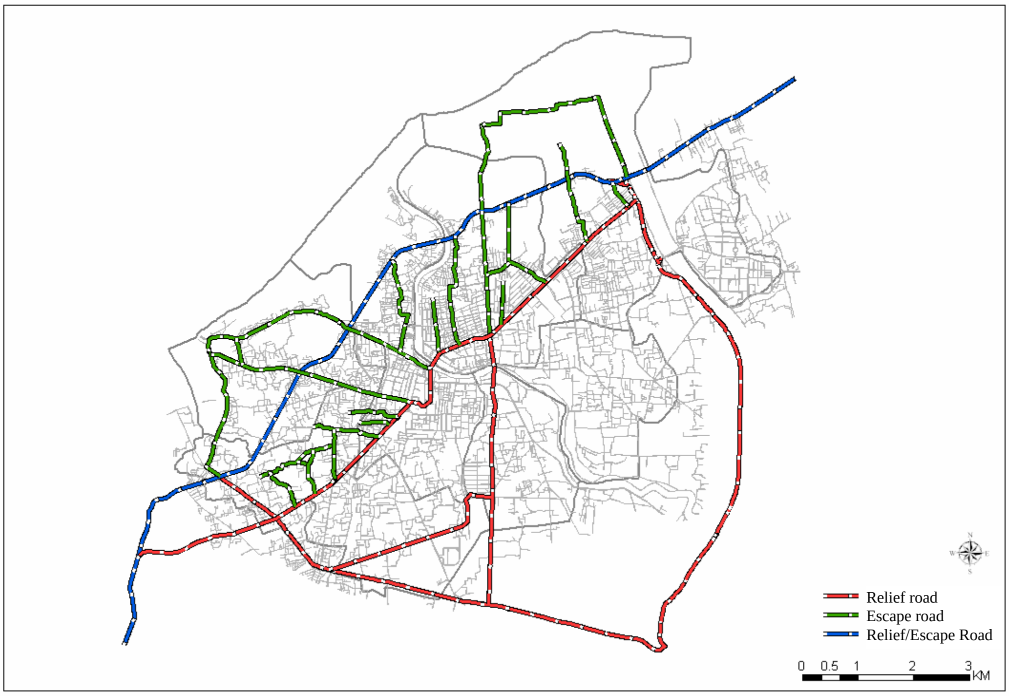
Emergency road network is organized into (i) escape road which citizens are able to escape from disaster in a short time, and (ii) relief road for immediate treatment (first-aid), evacuating citizens, and supplying relief materials. The network ensures to connect with southward area where is much safer against serious disasters.

Emergency road network is provided for smooth activities in an emergency such as people's escape, rescue and relief by relevant government agencies. The relief road plays an important role for providing immediate treatment, evacuating citizens and supplying relief materials, while the escape road leads the citizens to escape from disaster to safer place (Figure 4.9.17).

The emergency road network forms a belt line linking among historical city center, new city development area, new sub-center, emergency bases and airport. The new sub-centers and emergency bases are located at much safer area against disaster.

The escape roads are connecting coastal zone to national road. The road provides safely escape for the citizens. Escape building are provided along the escape road for the people failed to get out in time.

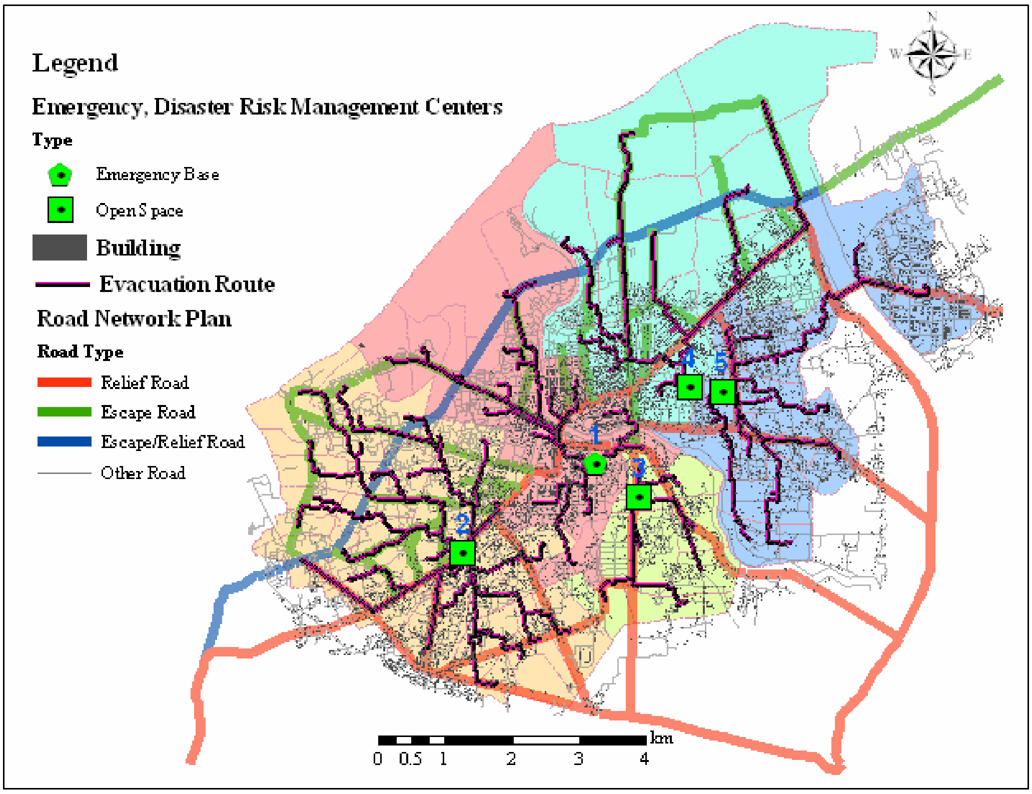
The emergency road network is available not only for escape, rescue and relief activities during disastrous event but also for supplying goods and materials for dislocated families after the disastrous event.



Source : ARRIS (GIS) prepared by JICA Study Team

Figure 4.9.17 Emergency Road Network

The most effective escape route with shortest distance to emergency base and/or emergency management centers (open space) was analyzed by Desa. Figure 4.9.18 shows the results of analysis by GIS simulation.



Source: ARRIS (GIS) prepared by JICA Study Team

Figure 4.9.18 Escape Route by Desa

(2) Relief Road

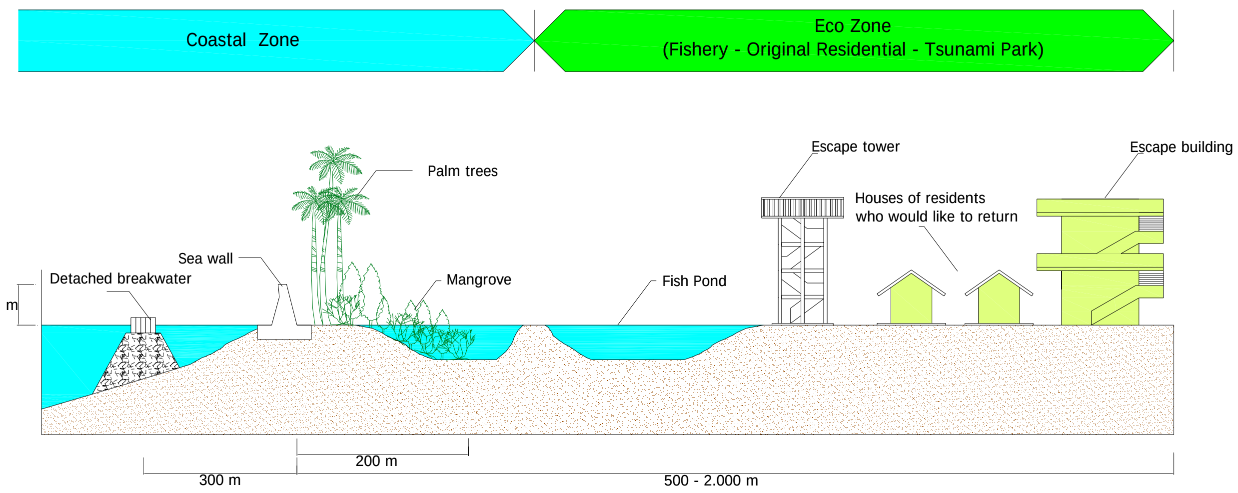
For the purpose of rescue and relief activities, a peripheral road delineated around the residential area of Banda Aceh City connects with southern area, new north-south and east-west arterial roads. The relief road ensures the linkage with the network of escape roads.

Banda Aceh City has been developed as a business district of NAD along the arterial national road connecting the eastern side along the Strait of Malacca and the western side along the Indian Ocean. However, the alignment of the road is not in a straight and the traffic congestion used to occur at the center of the city.

Relief road is delineated to ensure the immediate response to stricken area from both directions with the concept of "fail-safe"; namely, access from the eastern side (Syiah Kuala) and the western side (Jaya Baru). The road also provides the linkage with city center, sub-centre and major public facilities (emergency bases). Especially, the relief road is regarded as a belt line connecting with city center and the sub-center as satellite districts.

Along the relief road, emergency bases having relatively wider area are provided for temporary settlement (a shelter tent) of dislocated families and for various relief activities. City parks, plaza in the mosques and schoolyard might be the site of proposed emergency bases. Whilst the low-lying areas extend southward crossing the proposed alignment of relief road, the area by filing up is available for emergency purposes.

The schematic longitudinal profile of coastal area to relief road is shown in Figure 4.9.19.



Source: JICA Study Team

Figure 4.9.19 Schematic Diagram from Coastal Area to Relief Road (1/2)

(3) Escape Road

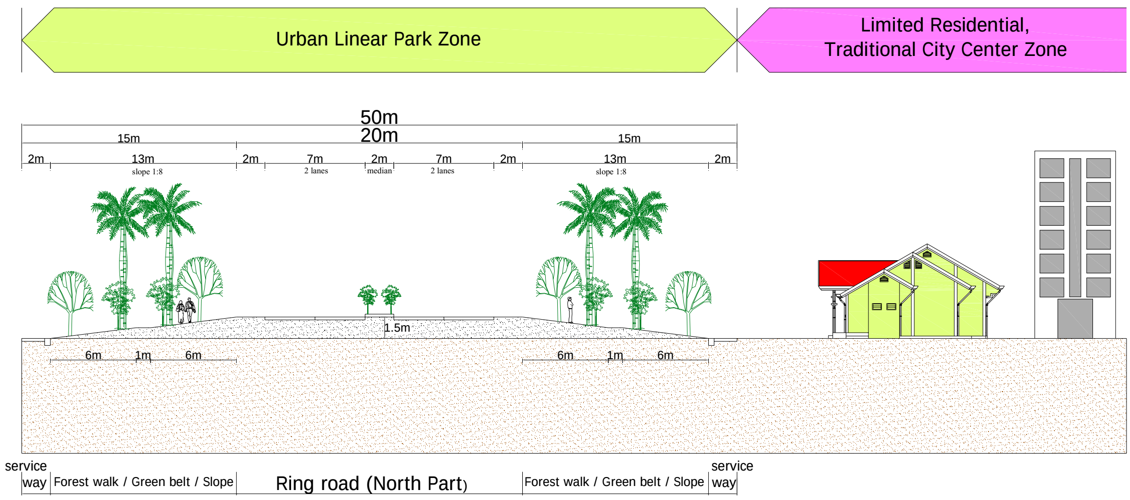
The network of escape roads located between the relief road and the east-west national road ensures that the citizens are able to escape from disasters in a short time.

The tsunami run-up on 26 December 2004 ceased along this arterial national road although the road was impassable for all the type of vehicles due to floating logs and debris. The alignment of the road is regarded as the fringe of historic tsunami hazard.

Most serious concerns for the purpose of disaster mitigation are how to lead the citizens lived hazard area to the southward; namely safer side. Several existing south-north roads are proposed as possible escape roads for the citizens. Signboards and lights are provided in case of tsunami in the night time.

Time required for escape is quite limited when the tsunami generated by earthquake at the nearest fault. Thus, the place having higher elevation, such as tower, building with public stairs and bridges, are provided along the escape road.

Locations and the number of escape tower, building and bridges are examined taking into account the population distribution, escape road network and distance from the houses. The possible distance for escape on foot is estimated at the radius of 900 m (15 minutes at a walking speed of 1.0 m/sec on the average among the aged, handicapped and children).



Source: JICA Study Team

Figure 4.9.19 Schematic Diagram from Coastal Area to Relief Road (2/2)

(4) Public Emergency Facilities for Disaster Preparedness

Public emergency facilities for disaster preparedness are organized into (i) escape buildings, (ii) escape bridges, (iii) emergency bases and (iv) city parks.

Public emergency facilities are provided assuming the following functions and period (Table 4.9.3).

Table 4.9.3 Classification of Emergency Facilities and Required Period

	Emergency Facility	Required Period	Function
1.	Escape building	Temporary (a half to whole day)	• Temporary escape from tsunami inundation to the building, bridge, and tower.
2.	Public facility for emergency use	Short (a couple of days)	• Dislocated families station immediately after tsunami.
3.	Emergency bases, Park with open space	Long (1 to 2 months)	• A base for rescue and relief activities conducted by government agencies and NGOs. • Shelter tents are provided for refugee.
4.	Temporary Housing	Rather Long (more than 2 months)	• Temporary houses are provided in open-space.

a) Escape Building

Source : Guidline for tsunami-escape building, 2005

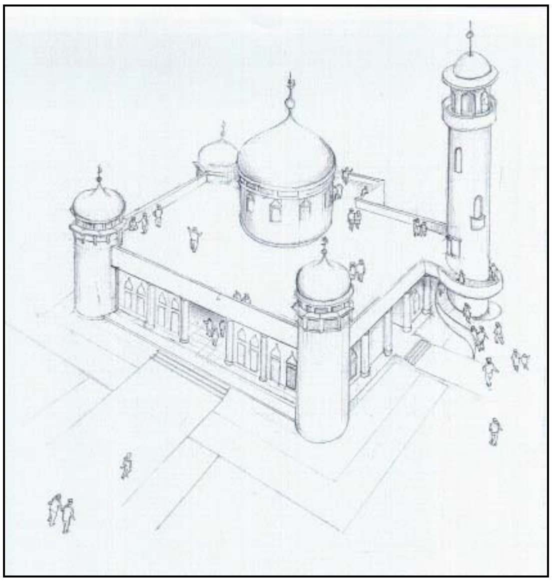
Figure 4.9.20 Escape Tower

In an emergency, some citizens failed to get out in time rush into the flat roof with external stairs of escape buildings located along escape roads. The height of flat roof is higher than the tsunami inundation depth on 26 December 2004; namely, it varies for the range from 10-m high near shoreline to at least 2-m high around national road. The building is tsunami and earthquake proofed. Schools, mosques, markets, rental flats and building of ferry terminal could be good alternatives for the building. Also, the existing private buildings could be utilized as escape building. Escape towers are one of alternatives for fishermen and tourists since there is none of the houses and building with 10-m high in the coastal area (Figure 4.9.20).

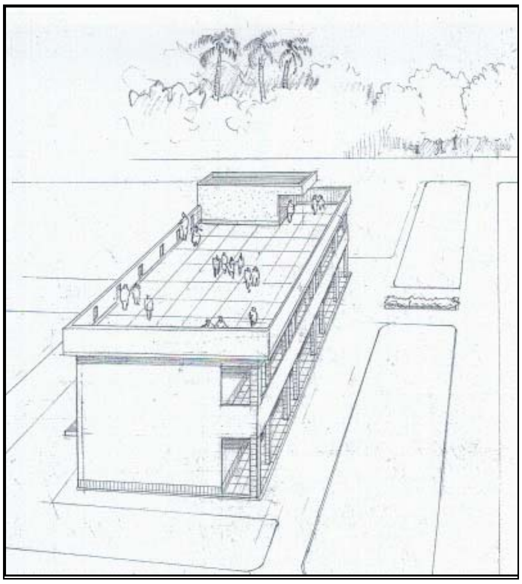
Administrative guidance by the government agencies are necessary to make the existing buildings with flat roof, such as mosques, schools, public buildings and shopping centers, renovated as escape building with external stairs.

General plans for escape building by renovating mosque and school are illustrated in Figure

4.9.21. In the case of school, the 2nd floor can be utilized as storehouses for requisites for use in the event of disaster. The location map of required escape building is shown in Figure 4.9.22.

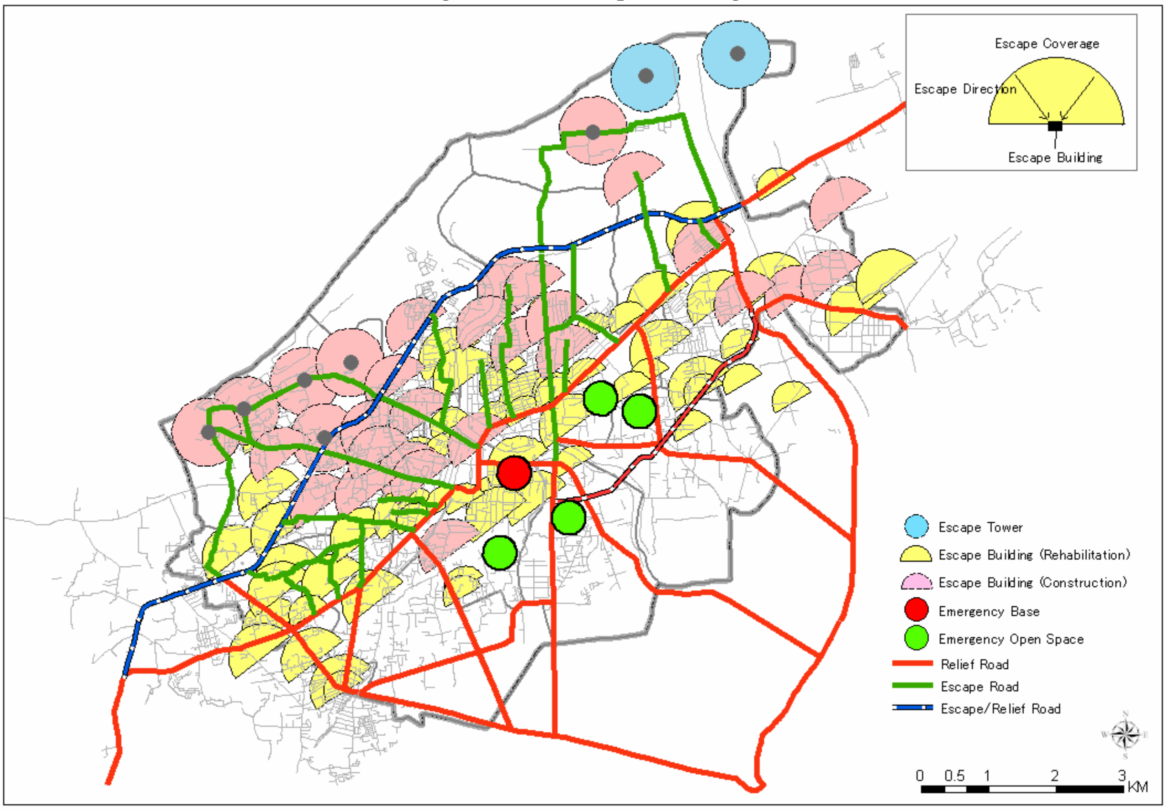


a) Escape Building of Mosque



b) Escape Building of School

Figure 4.9.21 Escape Building

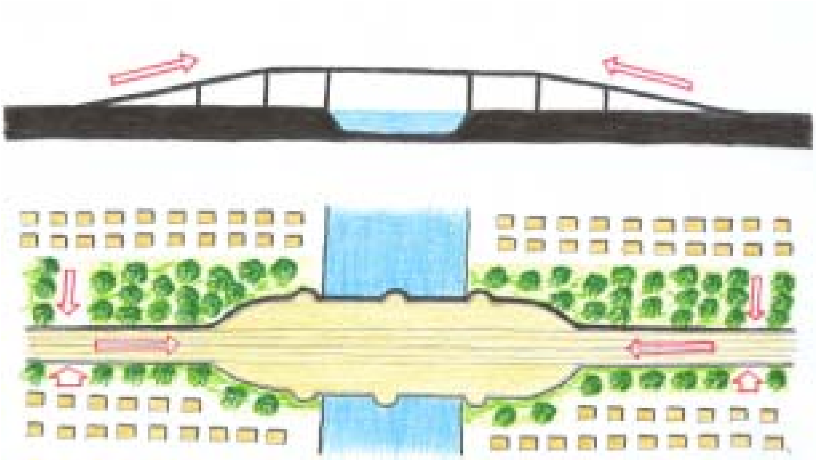


Source : ARRIS (GIS) prepared by JICA Study Team

Figure 4.9.22 Location of Emergency Public Facilities

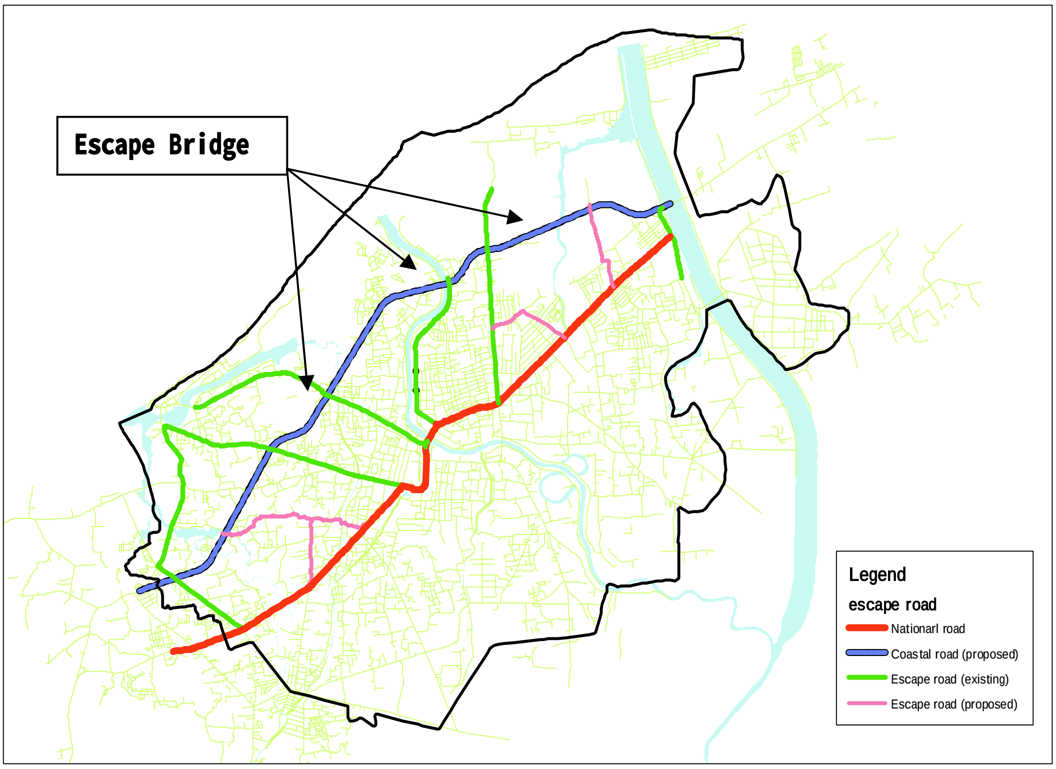
b) Escape Bridge

Bridges along the relief road are raised above 10-m from the water surface of the river so that the people rushes into the crest of the bridge during tsunami inundation. The enlargement of the bridge crest enables the people to stand temporarily. About 50 to 100 persons working at fishpond could escape to the bridge. The general plan is illustrated as shown in Figure 4.9.23. The location map is shown in Figure 4.9.24.



Source : JICA Study Team

Figure 4.9.23 General Plan of Escape Bridge

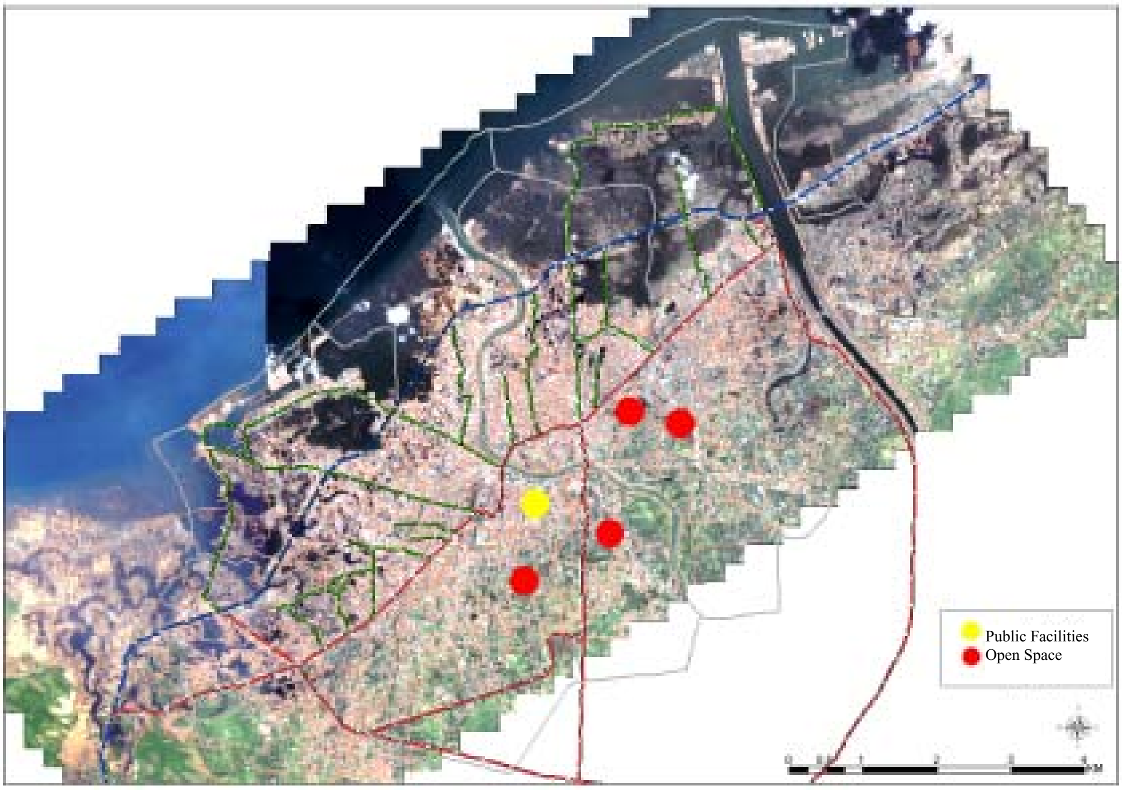


Source : JICA Study Team

Figure 4.9.24 Location of Escape Bridge

c) Integrated Emergency Base and Open Space for Disaster Preparedness

Integrated emergency base and open spaces are utilized for the purpose of not only the destination of escape but also the base for rescue, relief and temporary housing. The location map is shown in Figure 4.9.25.



Source : JICA Study Team

Figure 4.9.25 Location of Emergency Public Facilities and Open Spaces

Integrated emergency base is located under the condition that (i) along main arterial road, (ii) in the vicinity of hazard area, and (iii) nearer to city center and sub-center. The base is operated and maintained under the management of city office and will be a operation and information center for disaster preparedness in an emergency, while the base is utilized for place for a ceremony and/or a event in a normal condition. The building for the base has a flat roof with external stair and its upper floor is equipped with requisites for use in the event of disaster.

Open spaces as emergency base are the land for a shelter tent and/or temporary houses for dislocated families. Mosques situated by the Desa are also regarded as open space.

Low-lying areas extend southward crossing the proposed alignment of relief road, the area by filing up is available as open space for emergency purposes.

d) City Park for Disaster Preparedness

Over 70,000 casualties were recorded when the tsunami rampaged on 26 December 2004. One of the most serious reasons for such a calamity is that the people did not aware of tsunami generated by earthquake.

City parks are provided as part of public education and disaster awareness. The functions of city parks are:

i) Public education : The awareness of tsunami disaster is handed down from generation to generation. A science museum provided with signboard showing earthquake induced tsunami, tsunami disaster in 2004 and system on disaster preparedness is constructed.

ii) Emergency base : Open-spaced city parks would be one of the emergency bases which is equips with requisites for use in the event of disaster.

iii) Recreation : City parks are available for the place of recreation and relaxation of citizens and tourists.

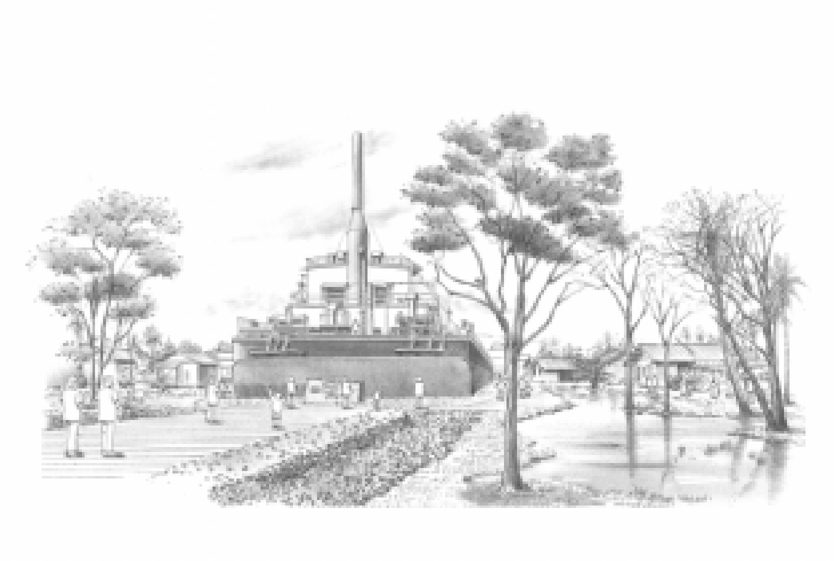
iv) Memorial Park : City Park mourned over casualties in the vicinity of cemetery.

The location map of proposed city parks is shown in Figure 4.9.26. The artistic views are shown in Figure 4.9.27.

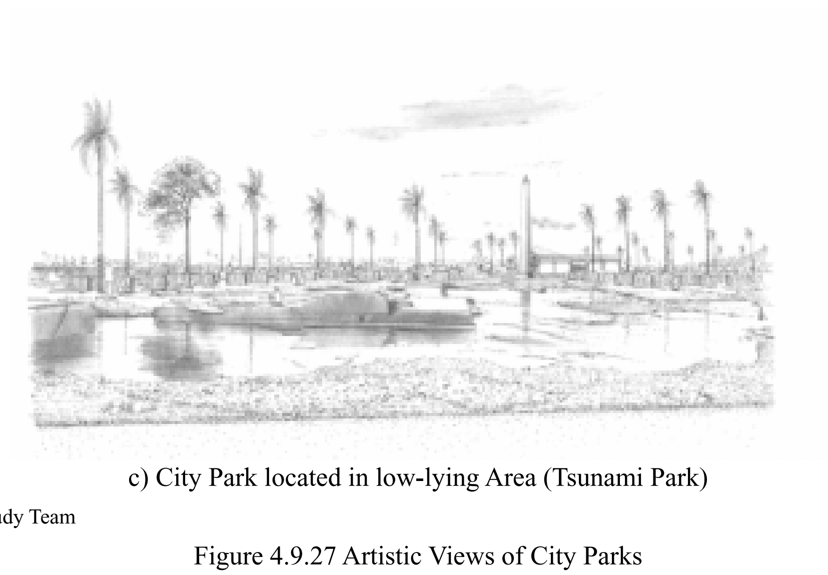
Source: JICA Study Team

Figure 4.9.26 Location Map of City Parks

a) City Park utilized a Big Tree as a Symbol (Big Tree)



b) City Park utilized PLN burge (Big Ship)



c) City Park located in low-lying Area (Tsunami Park)

Source : JICA Study Team

Figure 4.9.27 Artistic Views of City Parks