Supporting Report
Appendix D
Assessment on Existing
Flood Mitigation Facilities

PREPARATORY SURVEY
FOR
FLOOD RISK MANAGEMENT PROJECT
FOR
CAGAYAN DE ORO RIVER (FRIMP-CDOR)
IN
THE REPUBLIC OF THE PHILIPPINES

FINAL REPORT

VOLUME III SUPPORTING REPORT (I)

Appendix D
ASSESSMENT ON EXISITING FLOOD MITIGATION FACILITIES

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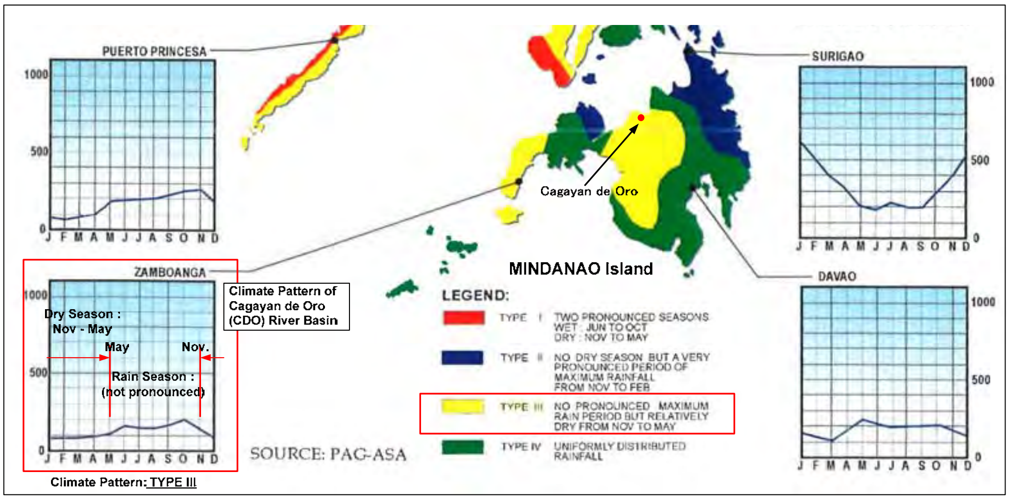
CHAPTER 1 ASSESSMENT ON FLOOD DAMAGE AND EXISTING FLOOD MITIGATION FACILITIES

1.1 Record of Floods

Annual rainfall pattern of the Mindanao Island is shown in Figure 1.1.1. According to the figure, Cagayan de Oro City is categorized as climate pattern of TYPE III in the Philippines, in which a period from November to May is recognized as dry season relatively, and there is no maximum rain period pronounced Philippine Atmospheric Geophysical and Astronomical Service Administration (PAGASA).



Source : PAGASA, DPWH_FCSEC

Figure 1.1.1 Rainfall Pattern of Mindanao Island

Historical big floods hit at Region –X (Cagayan de Oro (CDO) City and other areas) in the last thirty (30) years are identified from data/information collected from i) Office of Civil Defense (OCD) of National Disaster Coordinating Council (NDCC), ii) Mines and Geosciences Bureau (MGB) of DENR, iii) National Disaster Risk Reduction and Management Council (NDRRMC) / Risk Reduction and Management Committees (DRRMC) of Local Government Units (LGU) as summarized in Table 1.1.1. Flood and Damage Records from 1982 to 2012 are tabulate in Table 1.1.2.

Table 1.1.1 Historic Flood Records of Region – X (1982 to 2012)

Year	Type of Disaster	Affected and / or Displaced (nos)				Cost	Remarks
		Family	Persons	Dead	Injured	(P.Mill)	(Data Source)
1982	Heavy Rain	38,020	212,564	30	-	15	OCD
1991	Heavy Rain	33,149	18,849			10	OCD
1993	Heavy Rain “Buhawi”	51,925	222,067		3	81	OCD
1998	Heavy Rain	2,762	12,467	5	3	653	OCD
2009 (Jan)	Flash Flood and Landslide	42,956	213,806	22	4	793	NDRRMC, DRRMC of LGU
2009 (Nov)	Flood & Landside	10,186	44,562	17	12	145	NDRRMC, DRRMC of LGU
2011 (Dec)	Tropical Storm “Sendong”	70,314	228,576	1,206	-	-	NDRRMC, DRRMC of LGU
2012 (Dec)	Typhoon “Pablo”	116,017	523,194	15	-	-	NDRRMC, DRRMC of LGU

Source : JICA Survey Team Note: see details in Table 1.1.2

Table 1.1.2 Flood Record (1982～2012)

DEPARTMENT OF NATIONAL DEFENSE / OFFICE OF CIVIL DEFENSE

Region 10 (1982-2012) Republic of the Philippines,

Type of DISASTER	TIME/DATE OCCURED	LOCATION	DAMAGED HOUSES, PROPERTIES AND INFRASTRUCTURES	AFFECTED AND/OR DISPLACED					ESTIMATED DAMAGE COST (Peso Million)	REMARKS
				FAMILIES	PERSONS	DEAD	INJURED	MISSING		
Tropical Stom "Sendong"	**16tn, Dec. 2011**	**Region VI, VII, IX, X, XI, CARAGA and ARMM**	51,144 houses were damaged totally and partially. Cost of Damages: Infra.=P.1,366mill., Agriculture=P.309mill., Private Properties=P. 393.0mill	131,618	698,882	1,268	6,071	181	2,090	Data Source: NDRRMC: Final Report on the Effects and Emergency Management re Toropical Storm "SENDONG" (Washi) (10 Feb, 2012)
		Region - X (Cagayan de Oro City (CDO), Iligan City and Bukidnon)	39,888 (78%) houses were damaged totally and partially in Region-X. 19,952 (CDO) (39%) 18,819 (Iligan) (37%) 456 (Bukidonon) (0.9%) 661 (Others) (1.3%)	70,314 (53%)	228,576 (33%)	1,206 (95%) CDO= 674 (53%) Iligan= 490 Bukidnon= 42	6,036	162	2,058 (98%) Infrastructure= 1,361(65%) Agriculture= 305 (15%) Private Prop.= 393 (19%)	
Hyphoon "Pablo"	**4tn, Dec. 2012**	**Region IV-B, VI, VII, VIII, IX, X, XI, XII, CARAGA and ARMM**	216,817 houses were damaged totally and partially. Cost of Damages: Infra.=P.7,565mill., Agriculture=P.26,527mill., Private Properties=P. 2,858mill	711,682	6,243,998	1,067	2,666	834	36,949	Data Source: NDRRMC: SitRep No. 38 re Effect of Thphoon "PABLO" (Bopha) (25 Dec, 2012)
		Region - X	12,902 (6%) houses were damaged totally and partially in Region-X. 143 (CDO) 1,367 (Iligan) 6,007 (Bukidonon) 5,385 (Others)	116,017 (16%)	523,194 (8.4%)	15 (1.4%) M.Occidental= 2 M.Oriental= 6 Bukidnon= 6 CDO= 1	-	-	2,150 (5.8%) Infrastructure= 314 Agriculture= 1,833 Private Prop.= 2,993	
FLASHFLOOD / LANDSLIDE & STORM SURGE	**11th, Jan. 2009**	**Cagayan de Oro**, Iligan, Gingoog, Oroquieta, Ozamiz, Misamis Oriental and Lanao del Norte	1,812 Houses totally damaged; 6,104 houses partially damaged;	42,956	213,806	22	4	2	793	RDCC's compliance to PGMA's instructions re the management of the effects of the floods: Reforestation, Rehabilitation and Relocation. 2009/1/11 2:00:00
HEAVY RAIN AND COLD FRONT	**1998**	Camaman-an, Pinikitan **Cagayan de Oro** City		2,762	12,467	5	3		653	Office of Civil Defense and Mines and Geosciences Bureau
HEAVY RAIN	**1982**	**Cagayan de Oro City**		38,020	212,564	30			15	Office of Civil Defense
FLOOD & LANDSLIDE	**24th, Nov. 2009**	**Cagayan de Oro** City, El Salvador City, Iligan City, Camiguin Province, Misamis Oriental Province	462 houses totally damaged; 595 houses partially damaged; 1 Hospital and Rural Health Unit at El Salvador City; a total of Php.36,888,715.00 agricultural damaged and Php.108,231,210.00 public structure	10,186	44,562	17	12		145	Heavy rains brought about by the massing of convect clouds over Camiguin and Misamis Oriental due to TD URDUJA. 7:00 P.M. 24 NOV 2009
HEAVY RAIN	1993	**Cagayan de Oro City**		51,925	222,067		3	13	81	Office of Civil Defense HEAVY PRECIPITATION of "BUHAWI"
HEAVY RAIN	1991	**Cagayan de Oro** City		33,149	18,849				10	Office of Civil Defense
HEAVY RAIN	2000	**Cagayan de oro City**		1,788	8,408	6			4	Office of Civil Defense and Mines and Geosciences Bureau
HEAVY RAIN	1995	**Cagayan de Oro City**		672	3,913	2			2	Office of Civil Defense
FLASHFLOOD DUE TO HEAVY RAINS	29th, Jun. 2008	Brgy. Tablon, **Cagayan de Oro** City	Four (4) houses partially damage / Fifty One (51) totally damage	105	525	0	0	0	-	CSWDO on continuous distribution of relief items like rice and other foodstuffs to include family kits and kitchen utensils at the barangay hall of the affected areas. OCD -10 conducted on - site inspection and assessment at the affected areas. Archdiocese of Cagayan de Oro extended relief assistance to the affected families. 1630H, 29 June 2008
HEAVY RAIN	1996	Cagayan de Oro City		85	510		3	4	20	Office of Civil Defense
HEAVY RAINS	1997	Tibasak and Macasandig Cagayan de Oro City		94	506	3				Office of Civil Defense and Mines and Geosciences Bureau AND BUHAWI
FLOOD	11th, Oct. 2011	**Cagayan de Oro** City, El Salvador City and Province of Misamis Oriental	Totally: 5	120	504					· Caused by TS Ramon · 7 fishermen from Magsaysay, Mis.Or. drifted to Surigao where they were rescued. 0500H 11 October 2011
FLASHFLOOD DUE TO HEAVY RAINS	29th, Jun. 2008	Brgy. Cugman, **Cagayan de Oro** City	Sixty Five (65) houses totally damaged. / Eight (8) partially damage	73	350	0	1	0	0	CSWDO and elements from the MGB -DENR conducted damage assessment in the affected areas of Barangays Gusa, Tablon and Cugman, BDCC Cugman provided Tents for the temporarily shelter in the affected areas. 1630H, 29 June 2008
FLASH FLOOD	26th, Apr. 2008	Zone 1, Estakahan, Brgy, Agusan, **Cagayan de Oro** City	4 Houses totally damage / 1 Partially damage	5	25	0	0	0	For Verification	The Five (5) affectred families temporarily sheltered at Barangay Agusan Gym and have already returned to their respected homes of relatives. April 26,2008 6:30:00 PM
STORM SURGE	21th, Jun. 2008	Brgys. 3,6, Hermano, Mandangoa (Botoc), Cala-cala Cogon, Waterfall All of Balingasag, Misamis Oriental	Eighteen (18) houses partially damage	4	20	0	0	0	Partially damage to Roads and Seawalls estimated Php 2.5 M / Estimated damage to Crops Php 50,000.00	LGU of Balingasag, Misamis Oriental extended assistance to the victims, 15 sacks of Rice and 4 boxes of canned Sardines.All displaced families from Balingasag, Misamis Oriental were temporarily housed at th Evacuation Centers have returned to their respective places / residences. STORM SURGE DUE TO TYPHOON FRANK.1000H, 21 June 2008
FLASH FLOOD	22th, Apr. 2011	Umalag River, Barangay Tablon, **Cagayan de Oro** City	-	0	0	-	3	-	-	• A number of people flocked in the area for a religious activity. • The water rose as a result of continuous heavy rains in the Bukidnon area. • The devotees continued their rites after the water subsided. 9:20 P.M. 22 APRIL 2011
FLASH FLOOD	13th, Oct. 2008	C.M. Recto, Lapasan Highway, Limketkai Drive, Barangays Gusa, Zone 2 A, AB, 2 C, Camaman-an, and Ramonal all of **Cagayan de Oro** City	No Damage to Infrastructures	0	0	0	0	0	No reported damage	One (1) 6X6 Truck from 4ID, PA Two (2) Mini- Dumptrucks from Brgy. Gusa, Two (2) Dump Trucks from Barangay Assistance Center of Cagayan de Oro City. Responded for immediate rescue of stranded students / Teachers of Mindanao Polytechnic College. 6:30 P.M. 13 OCT 08
HEAVY THUNDER STORM	24th, Jun. 2007	Sitio Mabuhay, Lumbia, **Cagayan de Oro City**	Two (20) persons struck by lightning due to Heavy Thunderstorm	0	0	2	0	0	-	Dir. Carmelito A Lupo visited the area and met with Brgy. Capt. Allan Angara and the parents of the victims. Financial assistance of Php 10,000.00 each recommended for the victims. June 24, 2007 4:00 p.m.
FLOOD	9th, Oct. 2010	**Cagayan de Oro**	5 Totally damaged houses	-	-	1	-	-	-	

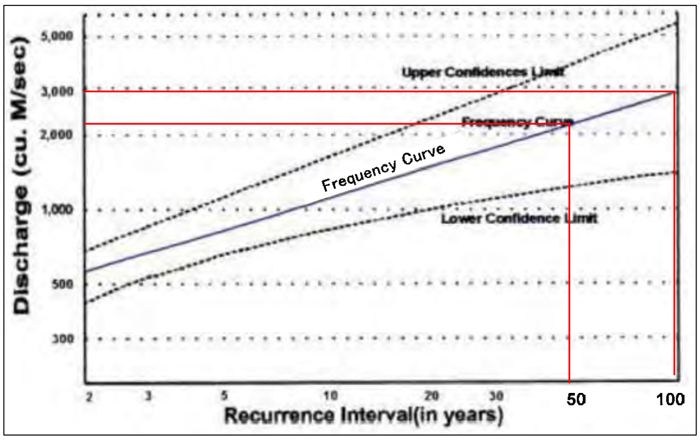
According to information of MGB, it is recorded that fix (6) historical floods occurred in the Cagayan de Oro (CDO) River Basin in 1916, 1957, 1982, 1998, 2009 and 2011 (Tropical Storm Sendong) in the last 96 years. Occurrence of major flood in the CDO River Basin in the past is summarized below (Table 1.1.3).

Table 1.1.3 Historic Flood Records (1982 to 2012)

Year of Major Flood Occurrence	Period (Year)	Flood Occurrence (times)	Frequency of Occurrence of Historical Flood
1916, 1957, and 1982	67	3	3 times within 67 years.
1998, 2009, and 2011	14	3	3 times within 14 years.
2009 and 2011	3	2	2 times within 3 years.
2009, 2011 and 2012	4	3	3 times within 4 years.
1916, 1957, 1982, 1998, 2009 and 2011	96	6	6 times within 96 years.

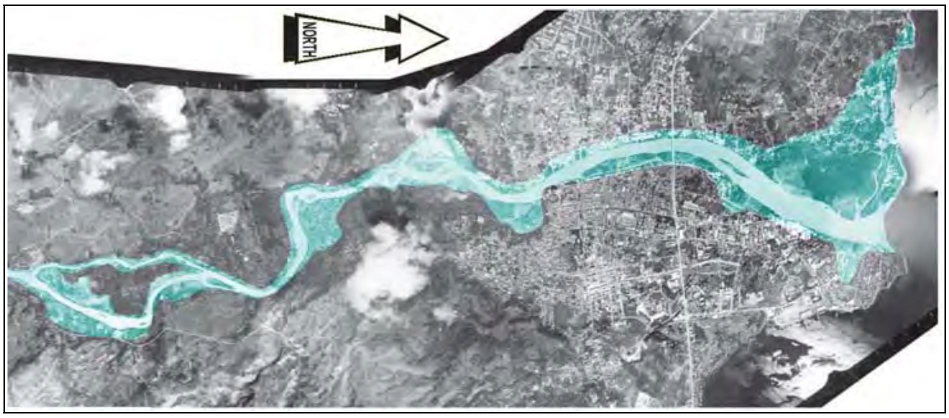
Source : JICA Survey Team

The MGB estimated the 50-year flood peak discharge to be around 2,100 m^3/sec at CDO City (See Figure 1.1.2). The MGB had prepared flood inundation hazard map for 100-year flood based on 1950's satellite-photo on 1999 as shown in Figure 1.1.3.



Source: MGB of DENR (Dr. LBII, 1992)

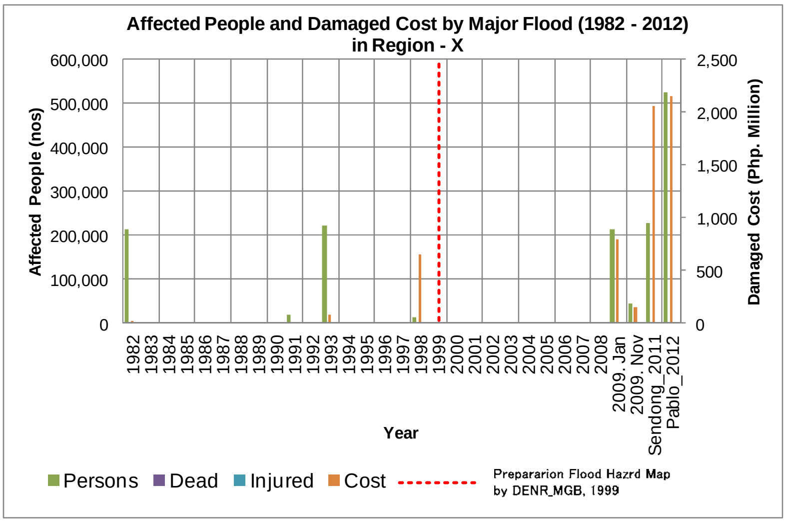
Figure 1.1.2 Flood Frequency Curve of the CDO River



Source: MGB of DENR (Dr. LS.Manzano) , 1999

Figure 1.1.3 Flood Hazard Map for Cagayan de Oro River, 1999 (100-year flood)

The flood hazard map was prepared by DENR_MGB on 1999 (see Figure 1.1.3) after flood in 1998. Figure 1.1.4 shows affected people and damaged cost caused by historic foods in CDO River Basin. Flood inundation areas of the last three (3) major floods (2009 flood, Sendong 2011 and Pablo 2012) are shown in Figure 1.1.2, in which flood prone area also shown based on the 3 floods inundation areas.



Source : JICA Survey Team

Figure 1.1.4 Affected People and Damaged Cost by Historic Floods in CDO River Basin (Region-X)

1.2 Existing Flood Mitigation

1.2.1 Damages by Sendong Flood (December 16th -17th, 2011)

Scale of the Sendong Flood is initially estimated to be around 50-year flood return period analyzed by the Survey Team, which was identified as recorded maximum historic flood experienced in Cagayan de Oro (CDO) City, with the following flood events:

- Flood discharge over topped the Ysalina Bridge located just upstream of the City Hall of CDO (4.2 km upstream from the river mouth);
- Flood inundation depth was more than 5 m from ground level along the river bank;
- Flood water level reached the roof of houses (flood inundation depth about 6 to 7m at upstream of the Kagay-an Bridge)

Picture (1/2) at Left Bank: Sta.5+570

Picture (2/2) Left Bank: Sta.5+570

Source: JICA Survey Team

Figure 1.2.1 Picture of Flood-Mark on House (Left Bank: Sta.5+570)

Flood damages most seriously occurred at Bgy. Balulang (Left Bank), Bgy. Macasandig (Cala-Cala Area) (Right Bank), Bgy. Carmen (Left Bank), Isla de Oro and Isla Delta Areas (Right Bank). The floodwaters flowed directly towards the populated area within floodplains of the Cagayan de Oro River which killed a large number of people and destruction of property.

The following flood durations were estimated based on rainfall data at gauging stations in the river basin and satellite metrological data during the Sendong flood, in addition interview survey was carried out to the people in CDO after the flood.

- Rainfall duration: 12pm (Dec. 16th) – 6 pm (Dec. 17th)
- Flood drop duration: 6am – 12 pm (December 17th)
- Flood Duration: 1day (December 16th – 17th)

Historical flood with biggest discharge and highest flood water level occurred at Cagayan de Oro River Basin in December 2011 (Tropical Storm 'tropical Storm Sending), the peak discharge reached to the Cagayan de Oro City at the same time of high tide. The Survey Team is under examination how sedimentation at the river mouth developed in the past can affect or block the flood discharge to introduce back water toward upstream. According to sand mining company at the Cagayan de Oro River, it is reported that sedimentation at the river mouth was rapidly increased after the Sendong Flood.

The existing river bank revetments were damaged by the Sendong Flood as follows:

Table 1.2.1 Damaged Existing River Bank Revetment

No.	Type of Structure	Location	Station
1	Seawall (at river mouth)	- Downstream of the Kauswagan - Puntod Bridge (right bank)	Sta.0+240 to Sta.0+360
2	Concrete Face Rock-fill Dike with Steel Sheet Pile	- Upstream of left abutment of Ysalina Bridge	Sta.4+460 to Sta.4+590
3	Steel Sheet Piles Revetment (inclined)	Upstream of the Ysalina Bridge / CDO Archbishop (right bank)	Sta.4+480 to Sta.4+610
4	Concrete floodwall (Golden Mile Plan)	Right bank at downstream of the Ysalina Bridge (right bank)	Sta.4+040 to Sta.4+440

Source: JICA Survey Team

1.2.2 Flood Mitigation Measures before the Sendong Flood

River Mouth Area:

Concrete Faced Rock-fill Dike is located partly at right bank of the river mouth area downstream of the Kauswagan - Puntod Bridge between Sta. 0+000.00 and Sta. 1+438.62, which had been damaged and collapsed by scouring at riverbed.

Floodplain having of vegetation of natural mangrove is located along 2 km upstream of the left bank of the river mouth, which is functioning as a natural flood retarding basin without any river structures.

Regional Office of DPWH had been conducting river channel dredging in the river mouth area by use of dredger machine before the Sendong Flood.

Between River Mouth and 6 km Upstream

In the Cagayan de Oro River any continuous dike have not been constructed, the following revetment and bank protection works are partially provided in the major parts of the river bank to prevent flood water from entering into city areas. Each structure was designed and constructed by the different design criteria, design flood scale and budgetary source (Government or Private).

Table 1.2.2 Existing River Bank Revetment

No.	Type of Structure	Location	Station
1	Concrete Face Rock-fill Dike	- Right Bank of River Mouth	Sta.0+ 060.00 to Sta.0+780 (Damaged)
2	Riprap stone filling	- Left Bank of River Mouth (Spoil Bank)	Sta.0+ 240 to Sta.0+360
3	RC Sheet Pile Seawall/Mooring Facility	Right Bank (Catimco)	Sta. 0+940 to Sta. 1+340
4	Concrete Face Revetment	Left Bank, protection of private houses (various places)	Sta.2+ 050.00 to Sta.2+100.00 Sta.2+ 260.00 to Sta.2+400.00 Sta.2+ 440.00 to Sta.2+470.00 Sta.2+ 700.00 to Sta.2+830.00 Sta.2+ 845.00 to Sta.2+860.00
5	Concrete Face Revetment	Left Bank, protection for Liceo de Cagayan University	Sta.3+ 320.00 to Sta.3+420.00
6	Concrete Floodwall (Golden Mile Plan)	Downstream / Upstream of right abutment of Ysalina Bridge	Sta.4+040 to Sta.4+440.00
7	Concrete Face Rock-fill Dike with Steel Sheet Pile foundation	- Downstream left bank (COA) and abutment of Ysalina Bridge - Upstream left bank of Ysalina Bridge	Sta.4+200 to Sta.4+340 Sta.4+460.00 to Sta. 4+580 (Damaged)
8	Concrete Face Rock-fill Dike with RC Sheet Pile foundation	- Right Bank at St. Augustine's Cathedral and Archbishop's Residence	Sta.4+480 to Sta.4+610
9	Concrete Face Rock-fill Dike with Steel Sheet Pile foundation	- Right Bank upstream of St. Augustine's Cathedral - Upstream and downstream at right abutment of Kagay-an Bridge	Sta.4+640 to Sta.4+730 (Damaged) Sta.4+830 to Sta.5+040
10	Concrete Face Rock-fill Dike with Steel Sheet Pile foundation	Left Bank, upstream of Kagay-an Bridge	Sta.5+140 to Sta.5+480

Source: JICA Survey Team

The people have constantly suffered from flood inundation in the City areas during rainy season due to insufficient city drainage facilities.

Upstream from the Kagay-an Bridge (Sta. 4+890)

The Kagay-an Bridge is located at about 5 km upstream from the river mouth. Excavated river channel is formed in this stretch between 1km upstream of the Kagay-an Bridge and the Pelaez Bridge, which runs meandering with sand bars with river slope 1/1,000 to 1/300. Major river structures such as dike and concrete floodwall were not provided in this stretch, however small scale of bank protection works are found to be damaged.

1.2.3 Flood Mitigation Measures after the Sendong Flood

Department of Public Works and Highway (DPWH)

The following urgent rehabilitation works have been conducted by DPWH since the Sendong Flood (as of February 2013).

Table 1.2.3 Urgent Rehabilitation of River Dike and Bridge Works

No.	Structure	Location	Station
1	Construction of Seawall	Right bank at the river mouth	750m Sta.0+000.00 to Sta.0+750.00
2	Construction of Concrete Face Rock-fill Dike	Left bank between Ysalina Bridge and Kagay-an Bridge	130m Sta.4+460 to Sta.4+590
3	Cabula Bridge	Cabula Bridge	18.7km from River Mouth

Source: JICA Survey Team

Additional designs of rehabilitation works are prepared under budgets for rehabilitation works on national disaster (Task Force Sendong) which is financed from the Office of Civil Defense (OCD). The following designs are under review by the Bureau of Design (BOD) of DPWH (as of July 2013).

Table 1.2.4 Additional Urgent Rehabilitation of River Dike Works (Planned)

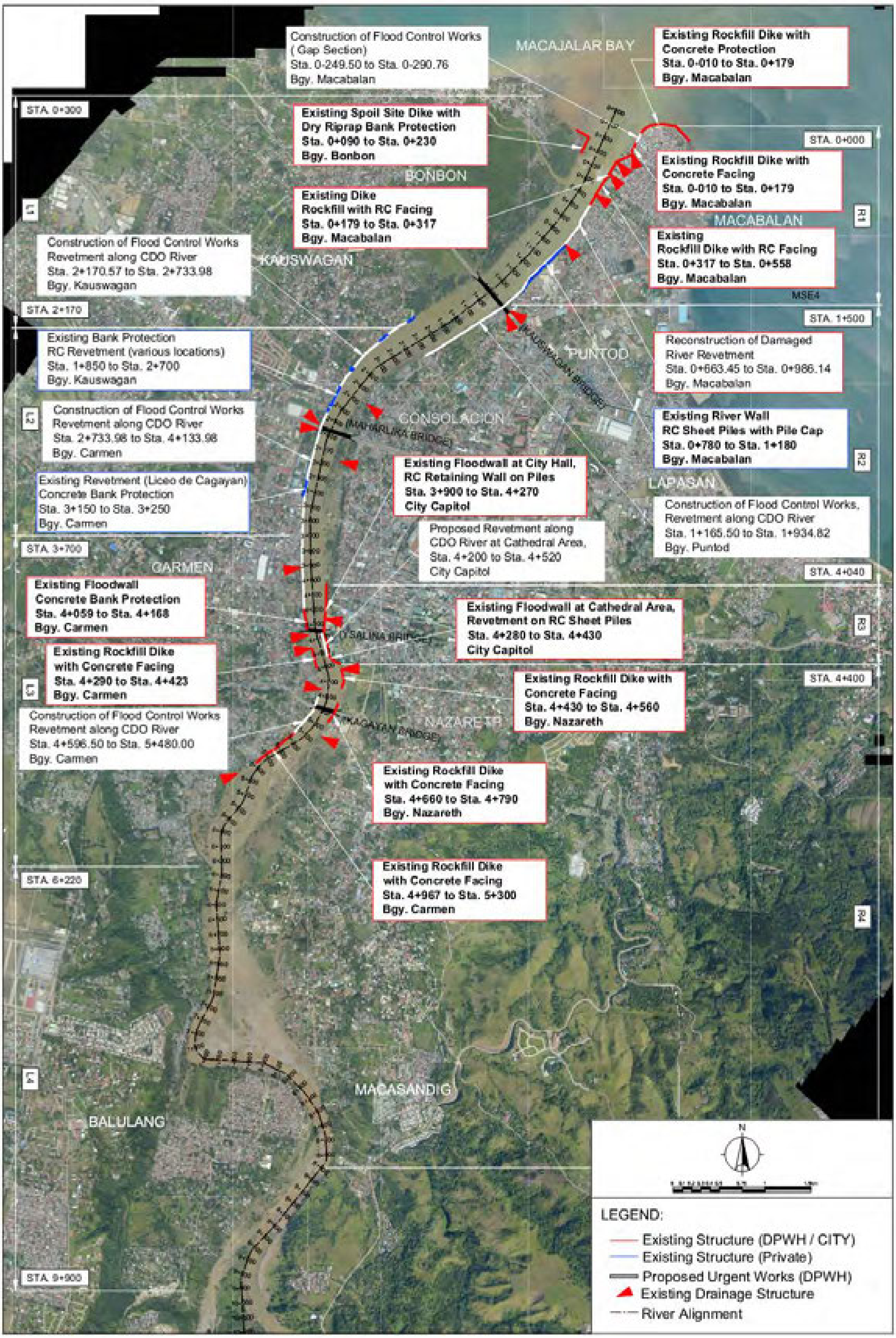
No.	Structure	Location	Station
1	Dredging of River Channel	Between River Mouth and Kauswagan - Puntod Bridge	1,357.8m Sta.0+000 to Sta.1+510
2	Construction of Seawall	Right bank at the river mouth	1,010m Sta.0+500.00 to Sta.1+240.00
3	Construction of Concrete Face Rock-fill Dike	Left bank Between Maharika Bridge and Ysalina Bridge	500m Sta.3+700.00 to Sta.4+200.00
4	Construction of Concrete Face Rock-fill Dike	Left bank between Ysalina Bridge and Kagay An Bridge	380 m Sta.4+360.00 to Sta.4+460.00 Sta.4+610.00 to Sta.4+890.00

Source: JICA Survey Team

For budgetary purposes of detailed design and construction stages, DPWH completed basic design of the Cabula Bridge, whose superstructure / girder was washed away during the Sendong Flood. But detailed design of the bridge has completed (as of July 2013).

DPWH is making efforts to accelerate progress of the construction / rehabilitation works mentioned above and to complete before the rain season in the CDO river basin.

The Table 1.2.2 to 2.2.4 is shown in Figure 1.2.2.



Source: JICA Survey Team

Figure 1.2.2 Location of Existing River Bank Revetment and Urgent Rehabilitation of River Dike

Cagayan de Oro City (COD)

The Cagayan de Oro City identified and set "Planned No-Build Zone" in the city area (within 11.5 km from the river mouth along the Cagayan de Oro River) based on flood inundation areas caused by the Sendong Flood, which has been prepared together with the Department of Interior and Local Government (DILG) in accordance with instruction of the President during his site inspection at COD after the Sendong Flood.

However, "City Land Use Plan/Map" including the "No-Build Zone" based on the inundation areas has not been officially announced and is still under modification and in coordination with Department of Environment and Natural Resources (DENR). It is already scheduled that the City Land Use Plan/Map should be completed by March 2013 for approval from the City Council.

Floodwall and river bank protection works (Golden Mile Plan) provided at right bank of CDO River (City Hall area) were damaged by the Sendong Flood (Refer to Table 1.2.2, item 6). The work has commenced before the Sendong Flood, however, resumption of activities has been suspended for an indefinite period of time.

City drainage improvement works were conducted at the two (2) priority areas to reduce flood inundation conditions in the city during rainy season.

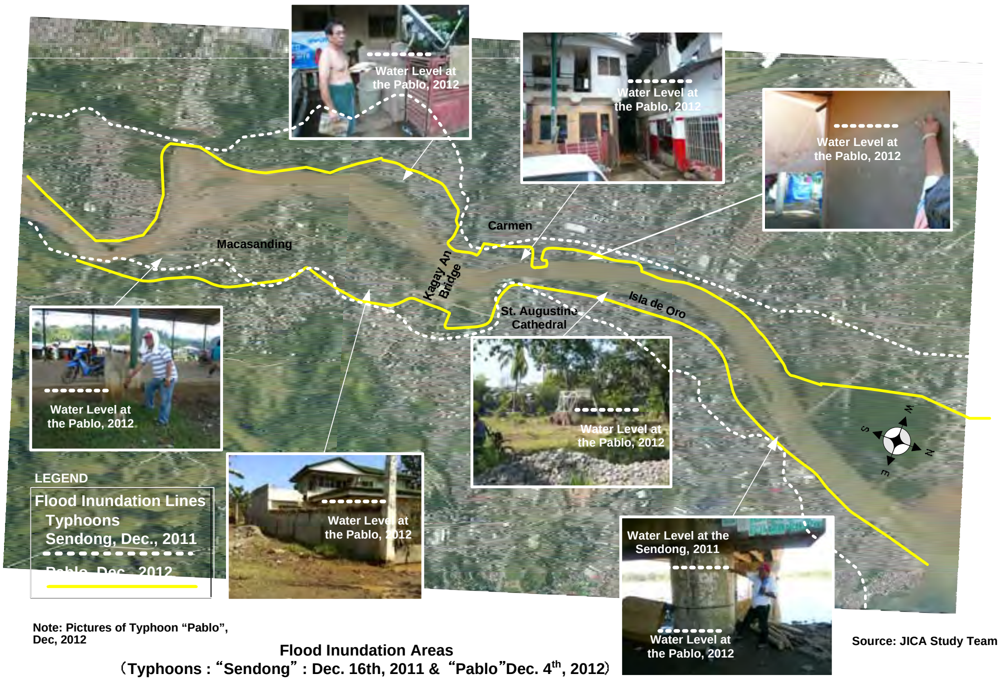
1.3 Evaluation on Existing Flood Mitigation Measures

1.3.1 Flood Inundation of Typhoon Pablo and Existing Flood Mitigation Measures

Typhoon Pablo hit Cagayan de Oro City on December 4th, 2012 after passing over Mindanao Island causing flood damages since the TS Sendong in 2011.

The Survey Team conducted ocular inspection and measuring of flood current as well as flood water level at Ysalina Bridge by taking video during flood due to TY. Pablo. After flooding flood mark survey and damage assessment were carried out in the field. Furthermore, based on the discharge observation by video record, discharge at Ysalina Bridge was estimated so that the rating curve at Cabula Bridge is corrected by applying the estimated discharge.

The following figure shows flood inundation lines caused by typhoons Pablo and Sendong for the purpose of comparing of extent between the two flood inundation areas.



Source: JICA Survey Team

Figure 1.3.1 Flood Inundation Map（TS "Sendong" and TY "Pablo"）

Flood damages caused by the typhoon Pablo are summarized below:

(1) River Mouth Area (Downstream of Kauswagan – Puntod Bridge)

Right Bank

- The JICA Survey Team confirmed during the site investigation that flood inundation did not extend covering a wide area of the right bank located at downstream of the Kauswagan - Puntod Bridge like typhoon Sendong. No flood inundation damages to houses occurred in this area due to typhoon Pablo.

Left Bank

- It is reported that Mangrove Protected Area located at left bank of river mouth was inundated, no damages to houses occurred due to the inundation.

(2) River Mouth (Kauswagan – Puntod Bridge) – 5km Upstream (Kagay-an Bridge)

Right Bank

- Flood water reached the edge of Public Road along the Isla de Oro and Isla Delta between the Mahalika Bridge and the Ysalina Bridge, in which the road and houses that did not suffered from damages caused by inundation. Maximum water depth of more than 2 m was identified at the Isla de Oro from interview of people and by flood marks at the site.
- In Isla Delta area located downstream of the Maharlika Bridge maximum inundation depth of 1-2 m was noted, which caused flood inundation covering the public road and houses along and within the area.
- The followings are confirmed; i) flood inundation at ground floor of annex building of the City Hall Office (flood water depth of 0.5 to 1.0 m from ground level), and ii) flood inflow / overflow entering into the right flood plain (low land swamp area) during the flood.

Left Bank

- The following phenomena were confirmed at the left bank between the Ysalina Bridge and the Kagay-an Bridge: i) flood water entering into the city area at the "Bank without Protective Structure", and ii) flood water overflowed the existing dike on the left bank. Flood water level of more than 2 m was identified reaching second floor of houses.
- Downstream of Ysalina Bridge toward Liceo de Cagayan University, flood water depth reached 2 m height from the ground level as gathered during the site inspection, in which ground floor of houses were inundated completely.

(3) Upstream of the Kagay-an Bridge (Sta. 4+890)

Right Bank

- The Shopping Mall under construction was inundated with the flood water of 0.5 – 1 m depth from the ground level.

- Right bank between the Kagay-an bridge and Macasandig, Cala-Cala area was found to be a flood prone area based on the followings; i) flood inundation line reached the same level as Sendong flood, and ii) low land area created by old river in the past. Designs of structural measures such as dike and revetment works to be located at concave section of river at Sta.9+000 should be made carefully with sufficient strength against direct force of flood flow.

Left Bank

- Flood inundation damages to houses with its maximum depth 1-2 m were confirmed based on interview of residents and flood mark investigation at 2 km upstream from the Kagay-an Bridge.
- It is reported that Balulang area was not affected by flood inundation of Pablo, which was also identified from flood inundation map prepared by the City Planning and Development Office, Cagayan de Oro City (CPDO).

As mentioned above, the following areas are indentified as flood prone areas based on investigation / results of flood inundation damages caused by the typhoon Pablo.

(i) Upstream area of the Ysalina / Kagay-an Bridges (River Narrow Part)

- Right Bank between the Kagay-an Bridge and Macasanding, Cala-Cala area
- Carmen area at left bank of upstream of the Ysalina Bridge

(ii) Downstream of the Ysalina Bridge

- Right bank of flood plain between Isla de Oro and Isla Delta
- Left bank of flood plain between Carmen and the Liceo de Kagayan University

(i) In the low lying portions of land that extends in this area, the followings are confirmed; river channel is still unstable, and trace of old-river is found at the right bank (See Figure 1.3.2). It is noted that the area is in fragile condition against flood inundation due to the following view points; Back water affect caused by the river narrow section between the Ysalina Bridge and the Kagay-an Bridge, and there is no river protection works such as dike.

Source: JICA Survey Team

Figure 1.3.2 Location of Existing River and Old River at Macasandig (Dec. 7th, 2012)

(ii) In the low lying areas, the flood plain has been developed by sediment deposited materials. It is also identified that the area is in fragile conditions against flood inundation in the following view points; Back water affect caused by the tidal water, and there is no river protection works such as dike.

1.3.2 Urgent Rehabilitation Works

(1) River Mouth

i) Rehabilitation Works of Sea Wall at Right Bank of River Mouth

- Rehabilitation works on damaged concrete faced dry masonry dike are undertaken by DPWH Region-X to protect density populated residential areas and some factories located at right bank of river mouth.

River Bank Improvement Works at Right Bank at River Mouth of the Cagayan de Oro River (As of Dec. 2012)

Source: JICA Survey Team

Figure 1.3.3 Location of Urgent Rehabilitation Works and Existing Sheet Piles at Right Bank of the River Mouth

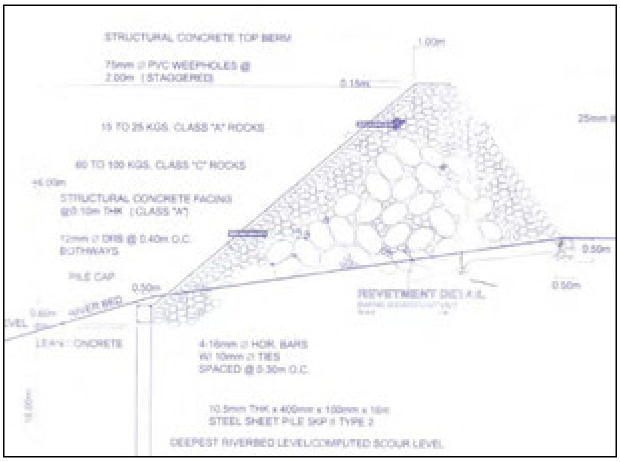
The following design modifications of urgent rehabilitation works at right bank of the river mouth were examined during technical meeting with DPWH Region-X.

- Modification of height of dike (to be reduced); and
- Utilization of the existing concrete sheet pile of low water channel located at Factories Area.

(2) River Narrow Area (Ysalina Bridge to Kagay-an Bridge)

ii) Urgent Rehabilitation Works at the Left Bank

- Installation of steel sheet pile under construction based on the original design of DPWH Region- X is shown below. However, during the technical meeting with the Region- X, the Survey Team suggested the design might create adverse condition of river narrowing section or reducing river width.
- The alternative design of this section is discussed in detail in Chapter 8.



Source: DPWH_Region-X (2013)

Figure 1.3.4

Source: JICA Survey Team

Figure 1.3.5 Location of Installed Steel Sheet Pile and Design of Dike (prepared by DPWH)

iii) Urgent Rehabilitation Works at the Right Bank

- No flood inundation damages has occurred at right bank (low swamp area) located upstream of the St. Augustine Cathedral between the Ysalina Bridge and the Kagay-an Bridge because no houses / people are living in the area. In addition, the area has a function of retarding basin, therefore it is considered that construction of dike along the river bank is not required to protect or to close the area urgently.
- Building facilities of hotel/mall and shopping store are under construction at right river bank located at upstream of the Kagay-an Bridge.

• To install additional sheet pile at right river bank toward upstream from the existing revetment to maintain low water channel; and

• To provide earth dike as high water channel structures at right flood plain located upstream of the buildings with smooth lines (approach angle of more 11 degree).

Source: JICA Survey Team

Figure 1.3.6 Location of Existing Structures around the River Narrow Area (Downstream of the Ysalina Bridge – Upstream of Kagay An Bridge)

1.3.3 Inventory of River Structures and Rehabilitation Works

The followings are summarized in plans of survey area of Table 1.3.1.

- Existing Structures;
- Damaged by Sendong Flood; and
- Proposed Structures in F/S 2009.

Existing river structures, urgent rehabilitation works and proposed river structures in F/S 2009 located along the Cagayan de Oro River are shown in Table 1.3.2 and Figure 1.2.2.

Table 1.3.1 Proposed Flood Control Structures (1/4)

LEFT BANK: Proposed: DPWH - R10 District 1	LEFT BANK: Proposed: DPWH M/P and F/S	LEFT BANK: Existing	STATION	RIGHT BANK: Existing	RIGHT BANK: Proposed: DPWH M/P and F/S	RIGHT BANK: Proposed: DPWH - R10 District 2
			0 - 60	Rockfill Seawall with RC Facing and sheet piles	Improvement / New Retaining Wall	
			0 - 40			
			0 - 20			
			0 + 0.00			
			0 + 20.00			
			0 + 40.00			
			0 + 60.00			
			0 + 80.00			
			0 + 100.00			Construction of Rockfill Dike with sheet piles (On-going)
			0 + 120.00			
			0 + 140.00	Rockfill Seawall with RC Facing		
			0 + 160.00			
			0 + 180.00			
			0 + 200.00			
			0 + 220.00	DO-1		Reconstruction of Rockfill Dike with sheet piles (Completed)
		Slope Protection (Dry Riprap)	0 + 240.00	Rockfill Seawall with RC Facing and sheet piles		
			0 + 260.00			
			0 + 280.00			
			0 + 320.00	DO-2		
			0 + 340.00	Rockfill Seawall with RC Facing (damaged)		Reconstruction of Rockfill Dike with sheet piles (On-going)
			0 + 360.00			
			0 + 380.00			
			0 + 400.00	DO-3		
			0 + 450.00	Rockfill Seawall (damaged)		
			0 + 460.00			
			0 + 500.00			Reconstruction of Rockfill Seawall with sheet piles
			0 + 550.00			
		Creek	0 + 570.00	DO-4		
			0 + 620.00	Rockfill Seawall (damaged)	New Dike Construction	
			0 + 670.00			
			0 + 750.00			
			0 + 780.00			
			0 + 860.00			
			0 + 940.00	DO-5		
			0 + 940.00	RC Sheet Pile River Wall (CATIMCO)		
			1 + 0.00			
			1 + 50.00			
			1 + 100.00			
			1 + 150.00			
			1 + 180.00			
			1 + 200.00			
			1 + 250.00			
			1 + 300.00			
			1 + 340.00			
			1 + 400.00			Improvement/Construction of Dike
			1 + 450.00			
			1 + 500.00	DO-6		
PUNTOD-KAUSWAGAN BRIDGE			1 + 510.00			
			1 + 520.00	DO-7		
			1 + 580.00			
			1 + 650.00			
			1 + 700.00			
			1 + 750.00			
			1 + 800.00			
			1 + 850.00			
			1 + 900.00			
			1 + 950.00			
			2 + 0.00			
		Concrete Bank Protection	2 + 50.00			
Improvement/Construction of Dike			2 + 100.00			
	New Dike Construction		2 + 150.00			
			2 + 200.00			
		Concrete Bank Protection	2 + 270.00	DO-8		
			2 + 300.00			
			2 + 350.00			
			2 + 350.00			
			2 + 400.00			
		Concrete Bank Protection	2 + 440.00			
			2 + 470.00			
			2 + 550.00			
			2 + 600.00			

Table 1.3.1 Proposed Flood Control Structures (2/4)

LEFT BANK Proposed DPWH - R10 District 1	LEFT BANK Proposed DPWH M/P and F/S	LEFT BANK Existing	STATION	RIGHT BANK Existing	RIGHT BANK Proposed DPWH M/P and F/S	RIGHT BANK Proposed DPWH - R10 District 2
Improvement/Construction of Dike	New Retaining Wall Construction		2 + 650.00		New Dike Construction	
		Concrete Bank Protection	2 + 700.00			
			2 + 750.00			
			2 + 800.00			
			2 + 830.00			
			2 + 840.00			
		Concrete Bank Protection	2 + 845.00			
			2 + 860.00			
			2 + 900.00			
			2 + 960.00	DO-9		
MAHARLIKA BRIDGE			2 + 970.00			
	New Retaining		2 + 980.00	DO-10		
Improvement/Construction of Dike			3 + 0.00			
			3 + 50.00			
			3 + 120.00	Creek		
			3 + 150.00	Isla de Oro		
			3 + 200.00			
			3 + 250.00			
			3 + 300.00			
		Concrete Bank Protection	3 + 320.00			
			3 + 360.00	DO-11		
			3 + 400.00			
			3 + 420.00			
			3 + 450.00			
			3 + 500.00			
			3 + 540.00			
			3 + 550.00			
			3 + 600.00			
			3 + 650.00			
	New Retaining Wall Construction		3 + 700.00			
			3 + 720.00			
			3 + 750.00			
			3 + 800.00		New Retaining Wall Construction	
On-going Borja Br.			3 + 850.00			
Improvement/Construction of Dike		DO-12	3 + 910.00			
			3 + 950.00			On-going Borja Br.
			4 + 0.00			
		DO-5	4 + 30.00	Creek		
			4 + 50.00	Flood Wall (Golden Mile)		
			4 + 60.00			
			4 + 80.00		Additional Parapet Wall on Existing Dike/RWall	
			4 + 100.00			
			4 + 150.00			
			4 + 170.00			
			4 + 190.00			
	Dike Improvement	Dike with concrete Piles (COA)	4 + 200.00			
			4 + 270.00			
			4 + 290.00	DO-13		
			4 + 320.00	Flood Wall (Golden Mile)		
YSALINA BRIDGE			4 + 340.00			
Construction of low water banks with sheet piles (On-going)	New Dike Construction	DO-14	4 + 360.00		Dike Improvement	
			4 + 400.00			
			4 + 430.00			
			4 + 440.00			
		DO-15	4 + 450.00			
	Dike Improvement	Concrete Faced Rock-Fill Dike	4 + 460.00			
			4 + 480.00	Concrete Revetment with sheet Piles (Cathedral)		
			4 + 530.00			
			4 + 540.00			
			4 + 570.00			
			4 + 590.00			
	New Dike Construction		4 + 610.00			
			4 + 640.00	DO-16		
			4 + 660.00	Rock fill Dike		
			4 + 680.00	DO-17		
		DO-18	4 + 700.00	Rock fill Dike with Steel Sheet		
			4 + 730.00			
			4 + 750.00			
			4 + 780.00			
			4 + 790.00		New Dike Construction	
			4 + 800.00			

Table 1.3.1 Proposed Flood Control Structures (3/4)

LEFT BANK			STATION	RIGHT BANK		
Proposed		Existing		Existing	Proposed	
DPWH - R10 District 1	DPWH M/P and F/S				DPWH M/P and F/S	DPWH - R10 District 2
Construction of low water banks with sheet piles	New Dike Construction		4 + 830.00	Rock fill Dike with Steel Sheet Pile (Paseo del Rio Mall)	New Dike Construction	
			4 + 850.00			
			4 + 870.00			
KAGAY-AN BRIDGE			4 + 890.00			
Construction of low water banks with sheet piles (On-going)			4 + 900.00			
			4 + 950.00			
			4 + 967.76			
			5 + 0.00			
			5 + 40.00	DO-19		
			5 + 100.00			
		Concrete Faced Rock-Fill Dike	5 + 150.00			
			5 + 210.00			
			5 + 260.00			
			5 + 310.00			
			5 + 360.00			
			5 + 397.88			
			5 + 410.00			
			5 + 490.00			
			5 + 530.00			
		DO-20	5 + 580.00			
			5 + 630.00	Earth Canal		
			5 + 680.00			
			5 + 730.00			
			5 + 780.00			
			5 + 830.00			
			5 + 880.00	Earth Canal		
			5 + 930.00			
			5 + 980.00			
			6 + 0.00			
			6 + 50.00			
			6 + 100.00			
			6 + 150.00			
			6 + 200.00			
			6 + 250.00			
			6 + 300.00	Earth Canal		
Bank Protection			6 + 350.00			
			6 + 400.00			
			6 + 450.00			
			6 + 500.00			
			6 + 550.00			
			6 + 600.00			
			6 + 650.00			
			6 + 700.00			
			6 + 750.00			
			6 + 800.00			
			6 + 850.00			
			6 + 900.00			
			6 + 950.00			
			7 + 0.00			
			7 + 50.00			
			7 + 100.00			
			7 + 150.00			
			7 + 200.00			
			7 + 250.00			
			7 + 300.00			
		Earth Canal	7 + 350.00			
			7 + 400.00			
			7 + 450.00			
			7 + 500.00			
			7 + 513.64			
			7 + 550.00			
			7 + 600.00			
			7 + 650.00			
			7 + 700.00			
	New Dike Construction		7 + 760.00			
			7 + 800.00			
			7 + 850.00			
			7 + 900.00			
			7 + 950.00			
			8 + 0.00			
			8 + 50.00			

Table 1.3.1 Proposed Flood Control Structures (4/4)

LEFT BANK			STATION	RIGHT BANK		
Proposed		Existing		Existing	Proposed	
DPWH - R10 District 1	DPWH M/P and F/S				DPWH M/P and F/S	DPWH - R10 District 2
	New Dike Construction		8 + 100.00		New Dike Construction	
			8 + 150.00			
			8 + 200.00			
			8 + 250.00			
			8 + 300.00			
			8 + 350.00			
			8 + 400.00			
			8 + 450.00			
			8 + 500.00			
			8 + 550.00			
			8 + 600.00			
			8 + 650.00			
			8 + 700.00			
			8 + 750.00			
			8 + 800.00			
			8 + 850.00			
			8 + 900.00			
			8 + 950.00			
			9 + 0.00			
			9 + 50.00			
			9 + 100.00			
			9 + 150.00			
			9 + 200.00			
			9 + 250.00			
			9 + 300.00			
			9 + 350.00			
			9 + 400.00			
			9 + 450.00			
			9 + 500.00			
			9 + 550.00			
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			9 + 800.00			
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			9 + 950.00			
			10 + 0.00			
			10 + 50.00			
			10 + 100.00			
			10 + 150.00			
			10 + 200.00			
			10 + 250.00			
			10 + 300.00			
			10 + 350.00			
			10 + 400.00			
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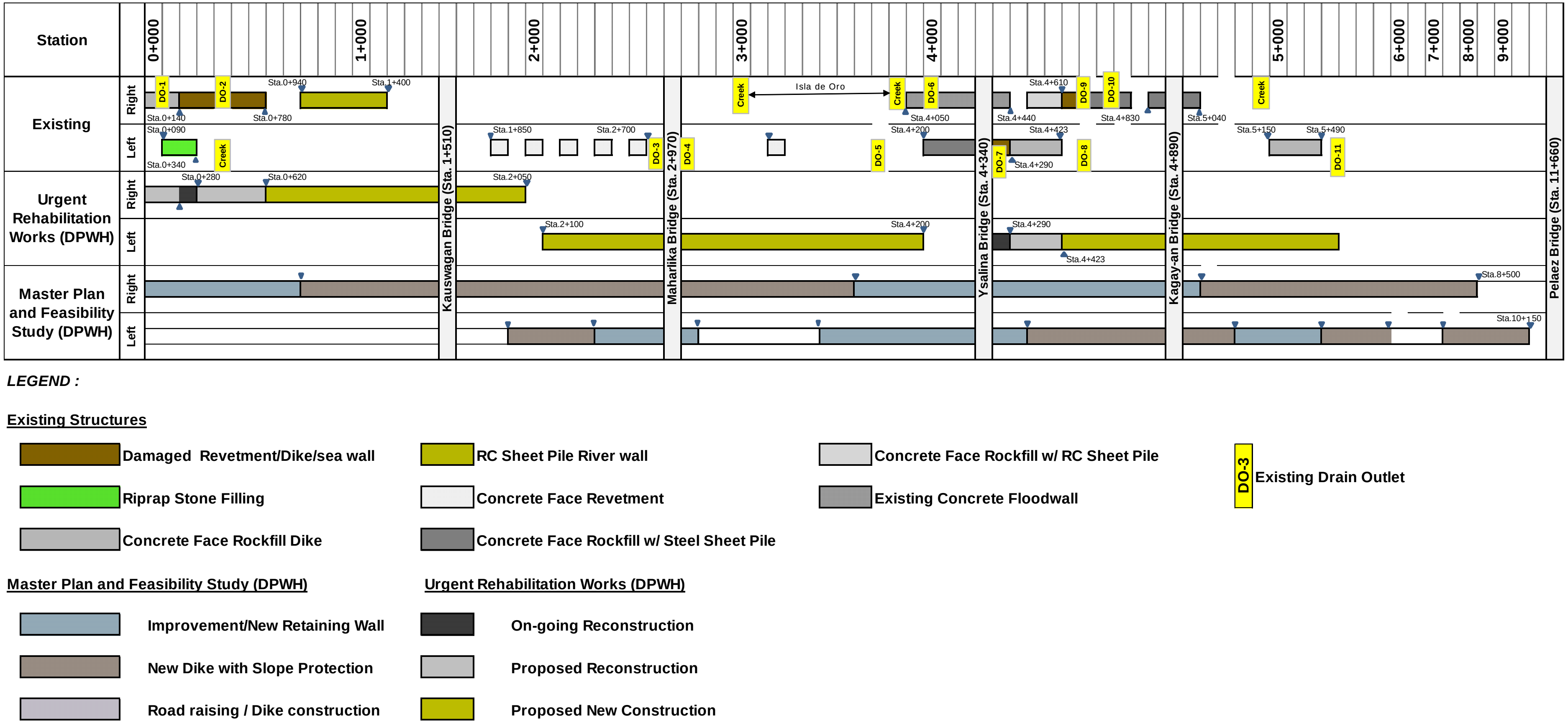
			10 + 800.00			
			10 + 850.00			
			10 + 900.00			
			10 + 950.00			
			11 + 0.00			
			11 + 50.00			
			11 + 100.00			
			11 + 150.00			
			11 + 200.00			
			11 + 250.00			
			11 + 300.00			
			11 + 350.00			
			11 + 400.00			
			11 + 450.00			
			11 + 500.00			
			11 + 660.00	PELAEZ BRIDGE		

Table 1.3.2 Existing, On-Going Construction and Proposed Flood Control Structures



Source: JICA Survey Team

Supporting Report
Appendix E
Study on Sedimentation Movement
Characteristic and
Sabo Facilities

PREPARATORY SURVEY
FOR
FLOOD RISK MANAGEMENT PROJECT
FOR
CAGAYAN DE ORO RIVER (FRIMP-CDOR)
IN
THE REPUBLIC OF THE PHILIPPINES

FINAL REPORT

VOLUME III SUPPORTING REPORT (I)

Appendix E
STUDY ON SEDIMENTATION MOVEMENT CHARACTERISTIC AND SABO FACILITIES

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CHAPTER 1 HISTORICAL DEVELOPMENT OF LANDFORM IN CAGAYAN DE ORO RIVER WATERSHED

1.1 Outline of Topography (Volcanic Topography and Terrace Plane)

1.1.1 Volcanic Topography

The topography of Cagayan de Oro River watershed has a characteristic of volcanic topography as shown in Figure 1.1.1.

Source: JICA Survey Team

Figure 1.1.1 Quaternary Volcano

The headwater of Cagayan de Oro watershed is located in the mountains consisting of Mt. Katanglad (EL.2,949m), Mt. Kitanglad (EL.2,900m) and Mt. Katatungan (EL.2,990m).

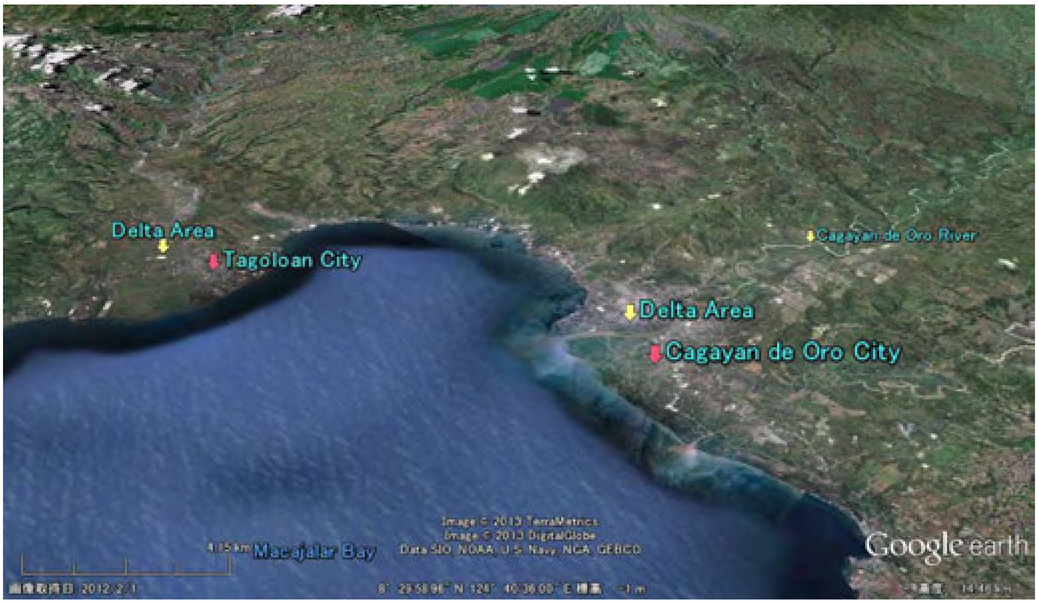
These volcanoes categorized in quaternary volcano are not active at present. These highlands are characterized by rugged relief and steep ridges, and the dendritic drainage pattern.

The age which erosion is active was presumed to be after volcanic activity had subsided.

The sediments which were carried down from mountains have deposited on the broad and gentle slope as well as along the coast line as shown in Figures 1.1.1 to 1.1.2.

One of the topographic characteristics of Cagayan de Oro watershed is the gentle slope which consists of the volcanic deposits and the terraces except the mountain area as shown in Photo 1.1.1.

The terraces especially along shores are assumed to be affected by the sea level changes.



Source: JICA Survey Team

Figure 1.1.2 The Delta formed along the Coast

Source: JICA Survey Team

Photo 1.1.1 The Gentle Slope (from left bank near the Lumbia airport; 10.Sep.2012)

The plateau is highly dissected by erosion with the formation of the deeply incised V- to U-shaped valley as shown in Photo 1.1.2. But both side slopes of the valley that are covered by the vegetation were observed to be in stable conditions.

Stationary meandering is one of the river characteristics, which is presumed to be a steady river condition (See Figure 1.1.3).

Source: JICA Survey Team **Cagayan de Oro River**

Photo 1.1.2 The Dissected Plateau (6.Sep/10.Nov.2012) (1/2)

Pigcutin River (Left Tributary)

Bubunawan River

Source: JICA Survey Team

Photo 1.1.2 The Dissected Plateau (8.Sep.2012) (2/2)

Source: JICA Survey Team

Figure 1.1.3 The Meandering River

1.1.2 Terrace

The terrace deposits which consist of sand, gravel, cobble and boulder are observed along the left bank terrace (around the Lumbia airport) distributed between Pelaez Bridge and Bubunawan confluence (See Figure 1.1.4).

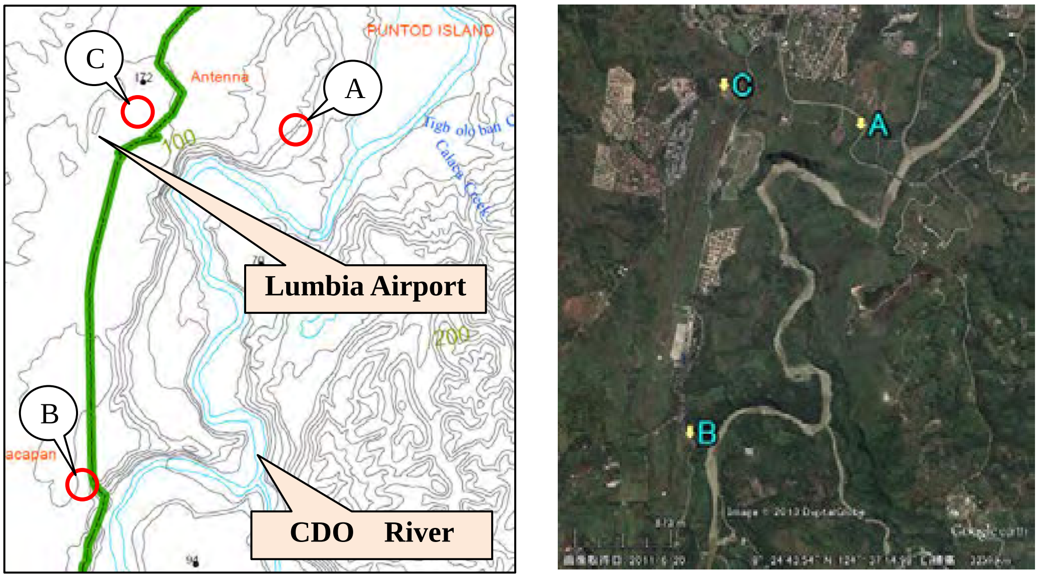
(1) Outcrop A

The elevation of this site is about 100m above sea level. The terrace deposits are divided in layers as shown in Photo 1.1.3.

Boulder layer is observed in the upper layer. Sand and gravel layer is observed on the lower layer which consists of sand, gravel and cobbles.

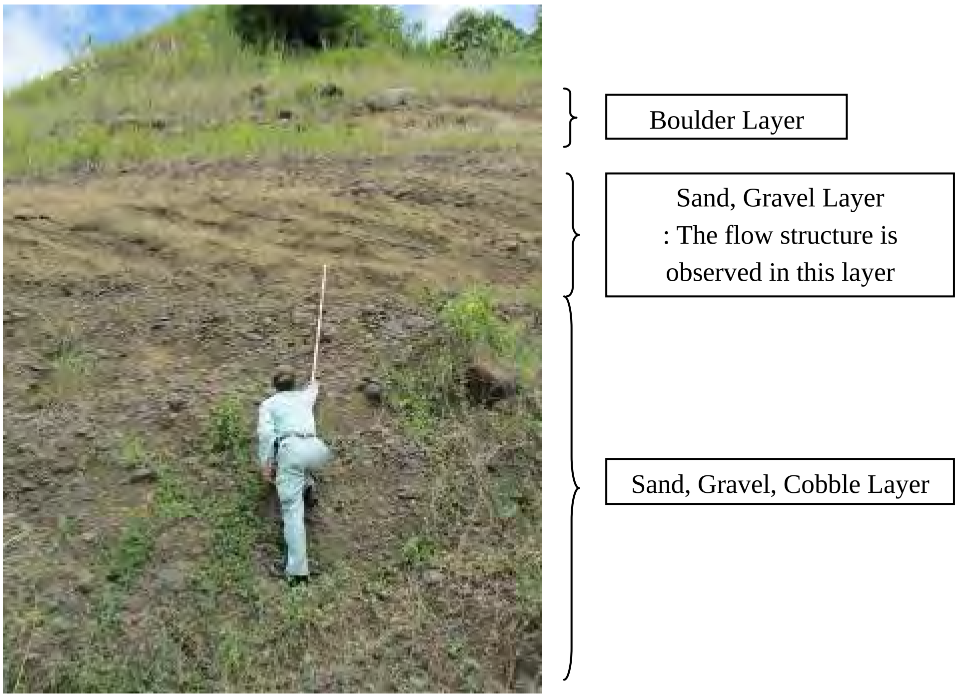
The deposit structure is inclined as observed in the sand and gravel layer. This inclination of the flow structure is considered to have been affected by the river environment.

The obvious flow structure is not observed in the lower layer which consists of sand, gravel and cobbles.



Source: JICA Survey Team 0 1km

Figure 1.1.4 Location of Terrace Outcrop Investigation



Source: JICA Survey Team

Photo 1.1.3 Terrace Outcrop (A)

(2) Outcrop B

The elevation of this site is about 160m above sea level. The terrace deposit of this outcrop consists of sand, gravel, cobble and boulder (See Photo 1.1.4).

The characteristics of the terrace deposit are that the obvious flow structure is not observed in the deposit structure. Judging from this structure, these deposits were presumed to be one transported by a severe flood only.

The flood energy of that time is presumed to be much greater than the present flood energy.

Source: JICA Survey Team

Photo 1.1.4 Terrace Outcrop (B)

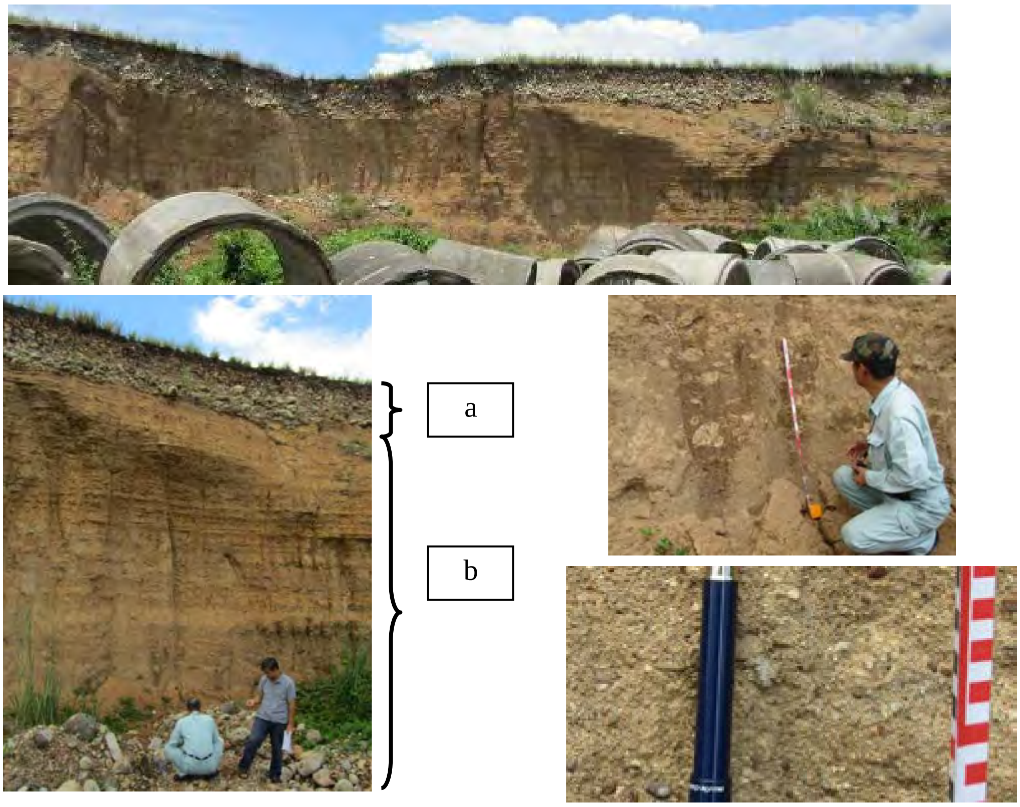
(3) Outcrop C

The elevation of this site is about 170m above sea level. The terrace deposit is divided into two (2) layers as shown in Photo 1.1.5.

The upper layer (a) consists of sand, gravel, cobble and boulder. And the lower layer (b) consists of clay, silt, sand and gravel.

The characteristic of this layer is that the lower layer is a horizontal which is not observed in other area. Furthermore, the disturbed structures were not observed in this layer. Therefore the horizontal layer is presumed to have been formed in the very calm condition like a shallow sea.

On the other hand, the condition of the time in which the upper layer was deposited is presumed to be pluvial age (Hypsithermal : explained later) in which a large amount of sediment had flowed out.



Source: the Survey Team

Photo 1.1.5 Terrace Outcrop (C)

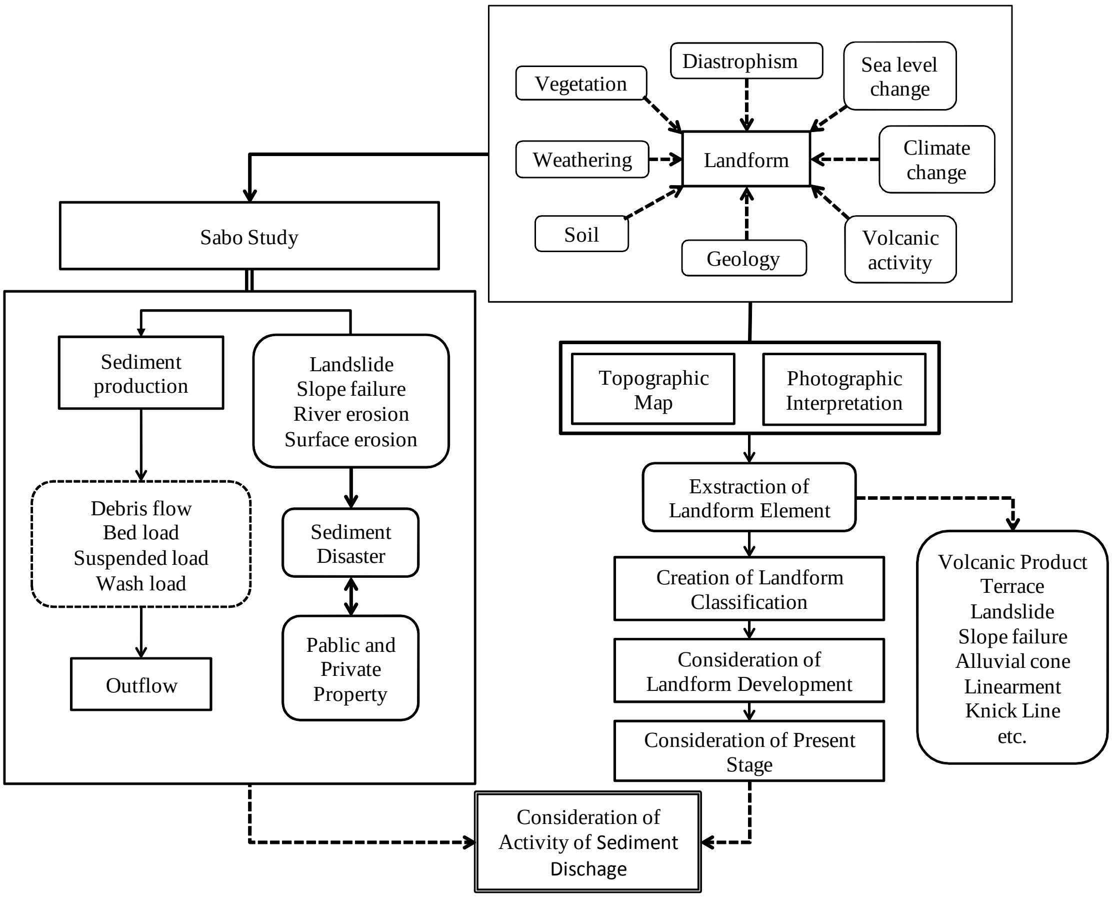
1.2 Historical Development of Landform in Cagayan de Oro River Watershed

1.2.1 Significance of Historical Development of Landform

The current landform has been formed through interaction with diastrophism, sea level change, climate change, volcanic activity, geology, soil, weathering, vegetation, sediment movement like landslide, slope failure, debris flow, and human agency.

Therefore, it is important to understand the process of formation of the landform and the current stage to determine whether the sediment production is active or not. For example, it is difficult to determine that the slope has a high risk of slope failure just because the slope gradient is steep.

Figure 1.2.1 shows the relationship of Sabo study and the history of Landform development.



Source: JICA Survey Team

Figure 1.2.1 The Relationship of Sabo Study and The History of Landform Development

In order to study the history of landform development, the landform elements such as volcanic production, terrace, and landslide, and slope failure are determined using the topographic map and the photographic interpretation. And this result should be complemented by the site investigation. The activity of sediment discharge must be comprehensively considered comparing the result of site investigation with the result of landform development history.

1.2.2 Creation of Landform Classification

As mentioned above, the landform elements were determined by using only the 1/50,000 topographic map. Table 1.2.1 shows the legend of topographic classification.

Cagayan de Oro River Watershed is divided into the following three (3) areas:

i) River area

- Lower Terrace : Height from the river 20-40m ; distributed along the river
- Middle Terrace : Height from the river 60-100m ; intermittent distribution
- Higher Terrace : Height from the river 100-140 m ; distributed vastly

ii) Hilly area

- Gentle slope which consists of volcanic deposit is distributed in northern area
- Gentle slope which consists of the old geology is distributed in northern area and left bank of Cagayan de Oro River.

iii) Highland area

- Lava and welded tuff which consist of old geology are distributed.

Table 1.2.1 Legend of topographic classification

GROUP	PATTERN	CONTENT	COMENTS
River area		Flood plain	River and low land facing the river.
		Lower terrace	Old river area. Relative height from the river ;20-40m.
		Middle terrace	Old river area. Relative height from the river ;60-100m.
		Higher terrace	Old river area. Relative height from the river ;100-140m.
Hilly area		Poorly dissected plateau	Steeper than terrace,and continue to volcanic succesion.
		Dissected plateau	Surface with many small valleys,and easy to erosion.
		Piedmont fan of volcano	Steeper than plateau,and with dissected deep valey. Solitary hill.
Highland area		Volcanic succession	KATANGRAD volcano group KARATUNGAN volcano group
		Alluvial cone	Fan-shaped old deposit formed by a stream at the foot of mountain
Topographic model		Summit level line	Softend topographic conters,and near to the original topographies. Buried vallies of width >400m
		Topographic division area	Group of geomorphological features

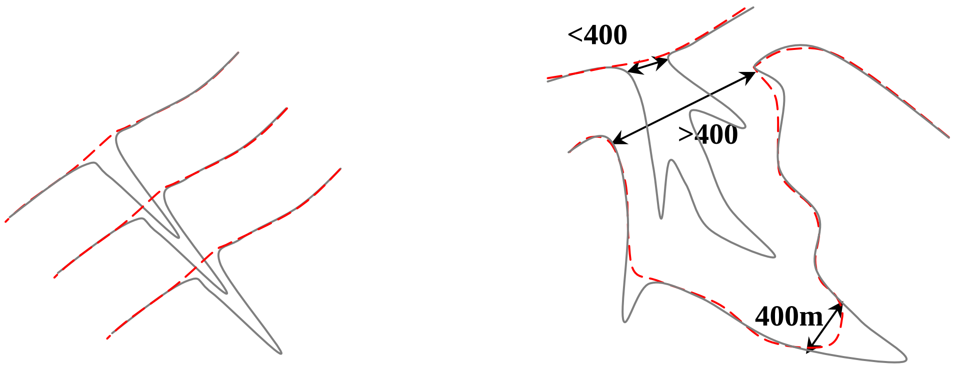
Source: JICA Survey Team

Each plateau has the different natural resistance against the erosion by conditions such as geology, weathering, permeability, etc., that form the plateau, but, their natural resistance is unknown at present.

For example, the zone of lava which consists of the hard rock is poorly eroded, but the zone of the volcanic deposit which consists of soft materials like volcanic soil is easily eroded.

Difference of erosion on the plateau can be confirmed by the summit level.

The topography of the summit level expresses the former topography which has not been eroded. The width of the summit level is 400m (Figure 1.2.2).



When valley width is small, summit level line is buried to the topographic counter valley.

When valley width is bigger than 400m, line can't be buried to the topographic counter valley.

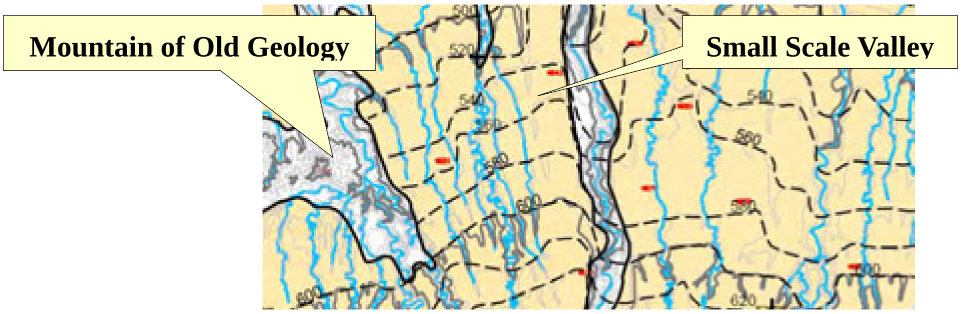
Source: JICA Survey Team

Figure 1.2.2 Summit level line (red broken lines) drawing method

The summit level of the plateau is as shown in Figures 1.2.3 to 1.2.4.

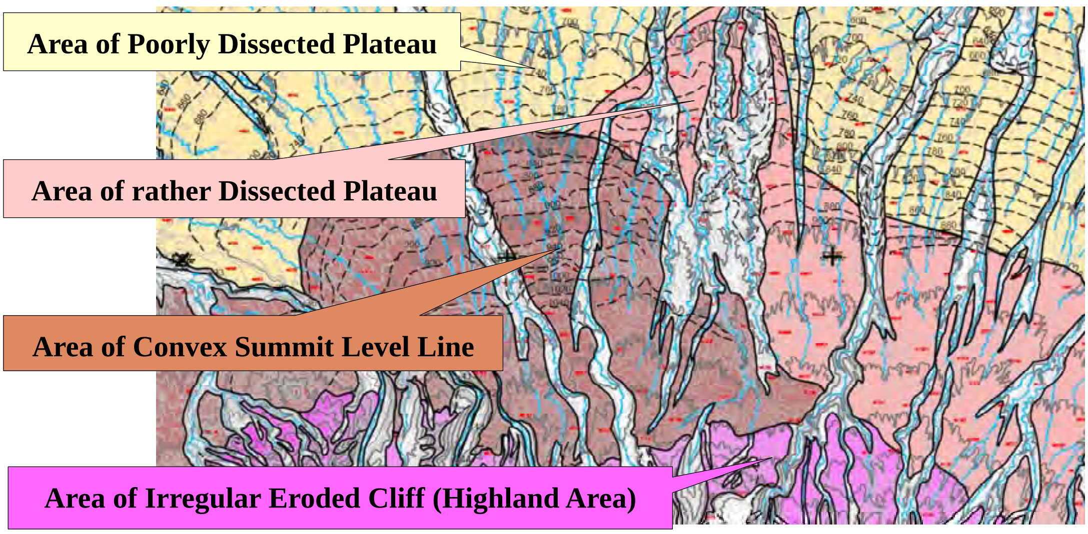
Also, the zone which cannot be recognized as geomorphic surface such as the northern part of Bubunawan River is determined only at the summit level.

Figure 1.2.5 shows Landform Classification Map.



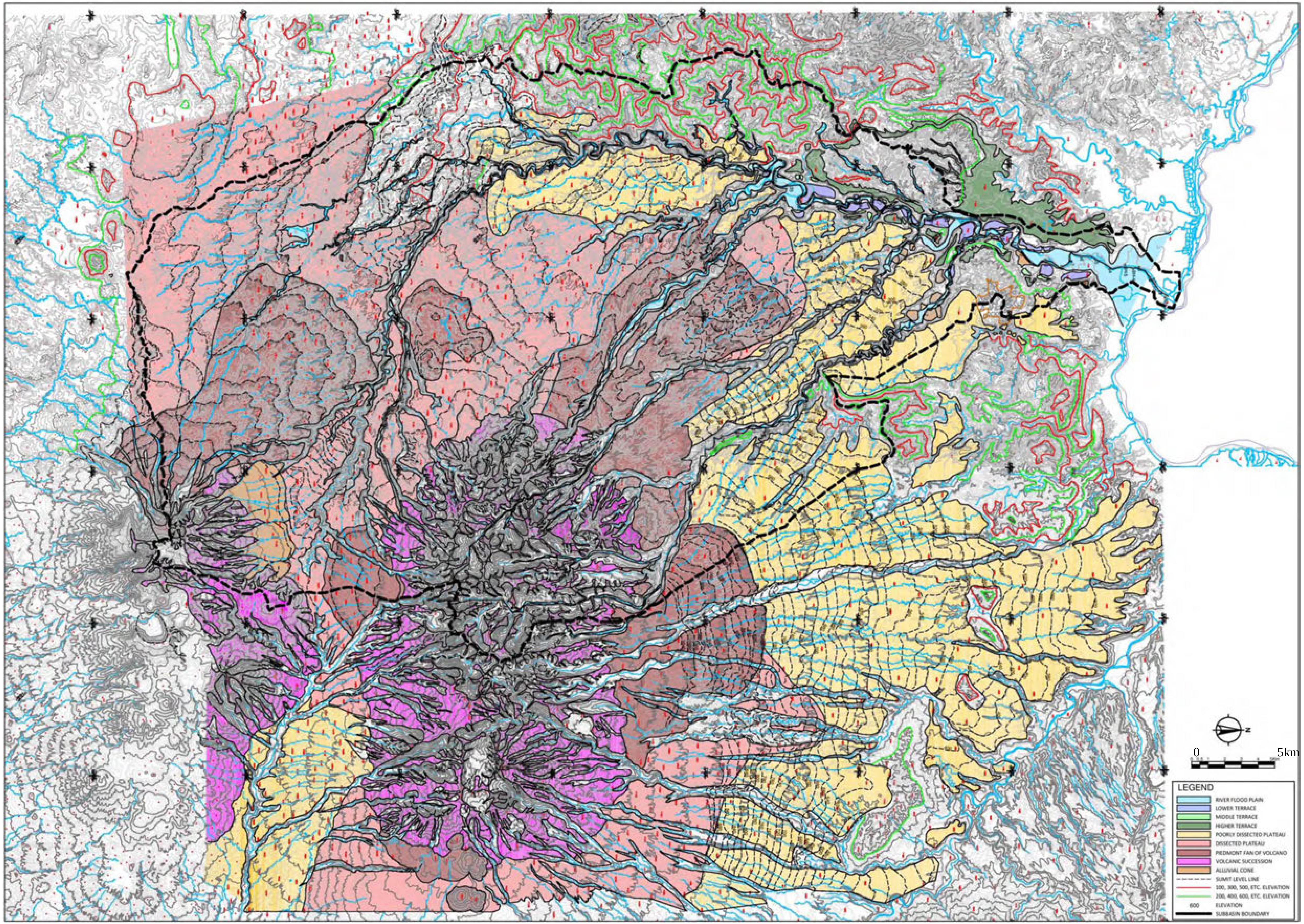
Source: JICA Survey Team 0 3km

Figure 1.2.3 Example of the poorly dissected plateau (East of Libona)



Source: JICA Survey Team

Figure 1.2.4 Pattern of Different Dissect (Northern Slope of Katanglad)



Source: JICA Survey Team

Figure 1.2.5 Topographical Classification Map

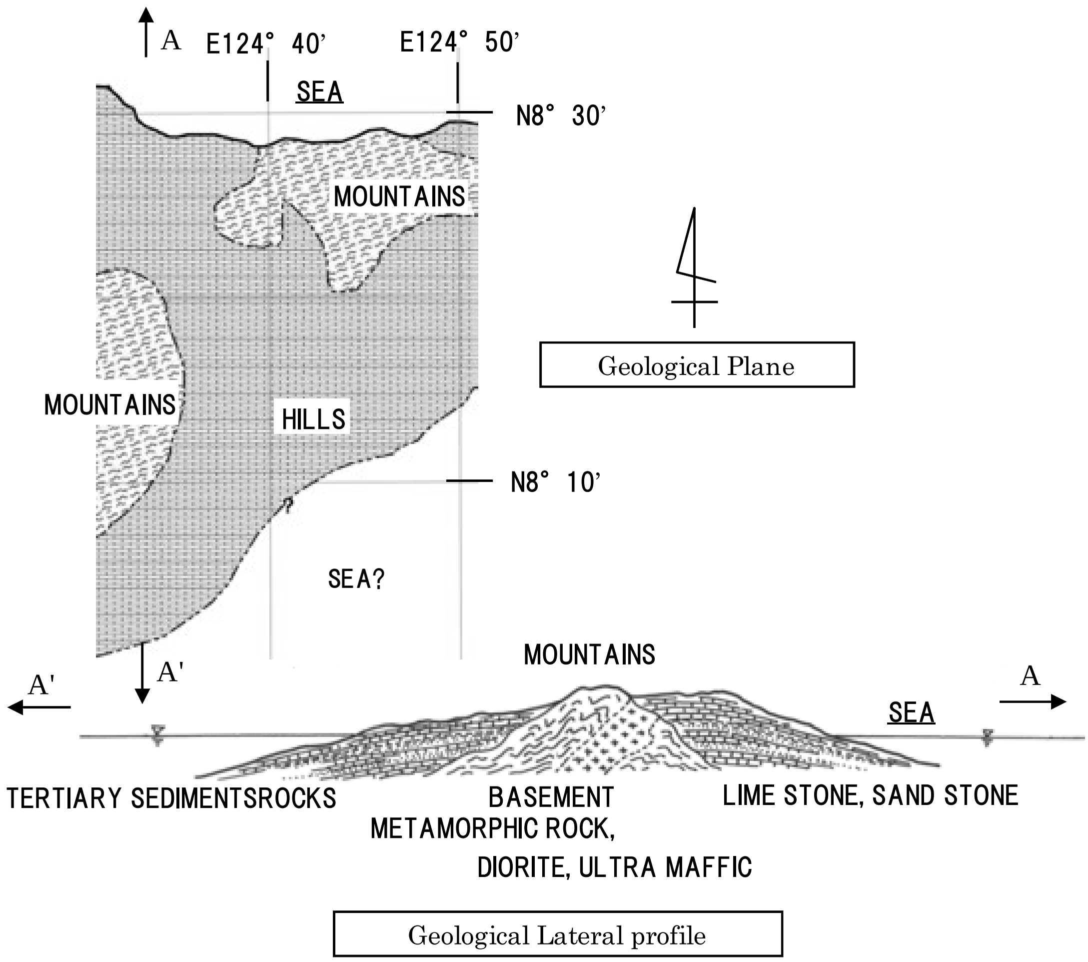
1.2.3 Historical Development of Landform

From the result of site survey and the landform classification, the historical development of Landform in Cagayan de Oro River Watershed is presumed as follows: (Figures 1.2.6 to 1.2.9).

(1) Stage I : Tertiary Pliocene around 3 Ma (approx. 3,000,000 years ago)

The geological layer which consists of mainly limestone of the Pliocene was distributed around the mountains consisting of metamorphic rocks of the Cretaceous age.

(The geological map is referred to Master Plan and Feasibility Study of Flood Control and Drainage Projects of Selected River Basins Nationwide, Package 3, Master Plan; P2-3 (DPWH, June 2011)).

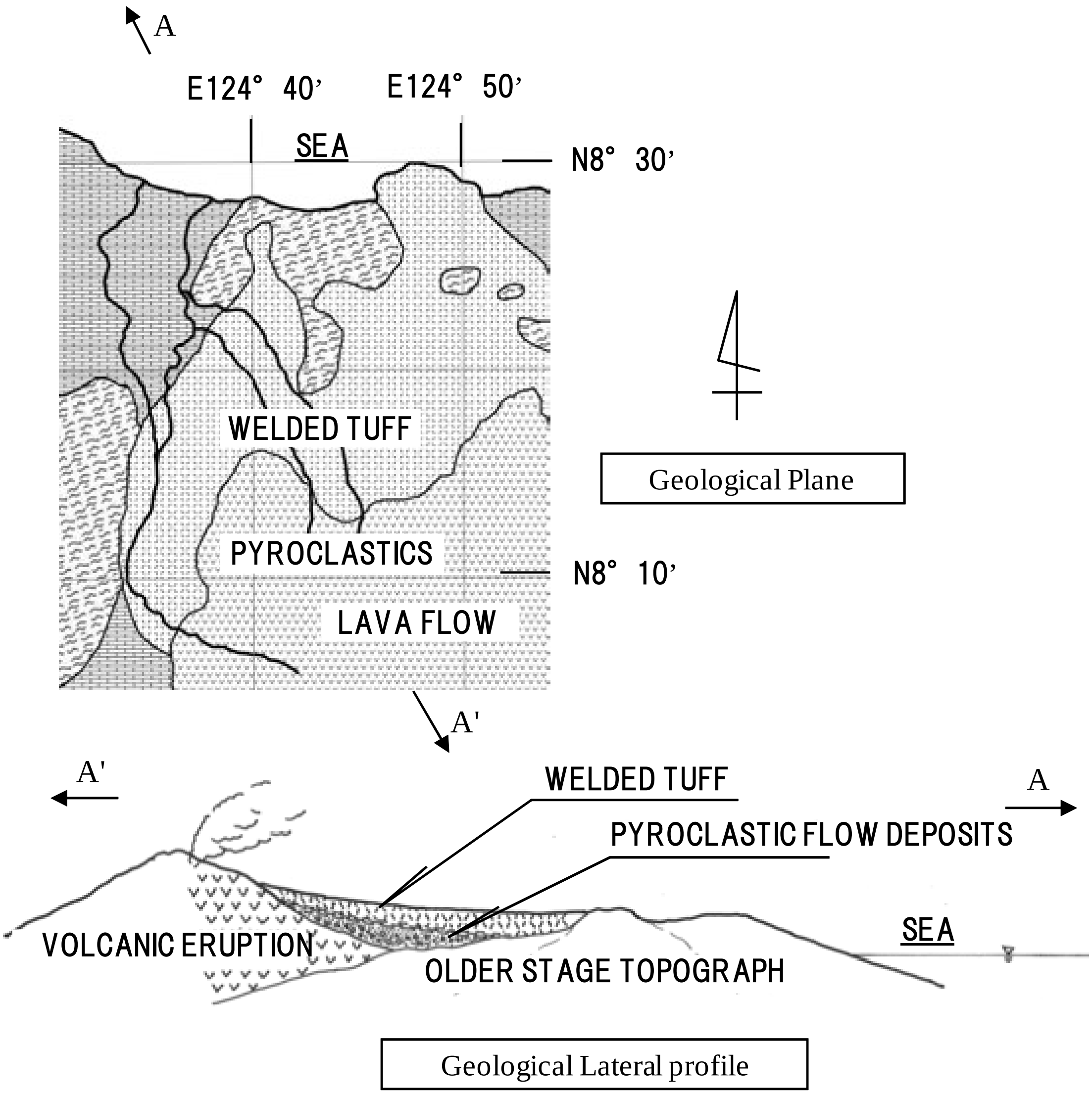


Source: JICA Survey Team

Figure 1.2.6 Stage I: Tertiary Pliocene around 3Ma

(2) Stage II : Quaternary Pleistocene around 1-2Ma (approx. 1~2, million years ago)

i) The volcano was formed in the southern area.
ii) A large amount of pyroclastic material, welded tuff and basaltic lava flowed out around the foot of the mountain.
iii) The foot of the mountain was gradually covered with the flow deposit, gravel and ash, and after that, the plateau was formed around the mountain.



Source: JICA Survey Team

Figure 1.2.7 Stage II: Quaternary Pleistocene

(3) Stage III : Quaternary Pleistocene - Holocene around 1-0.006Ma

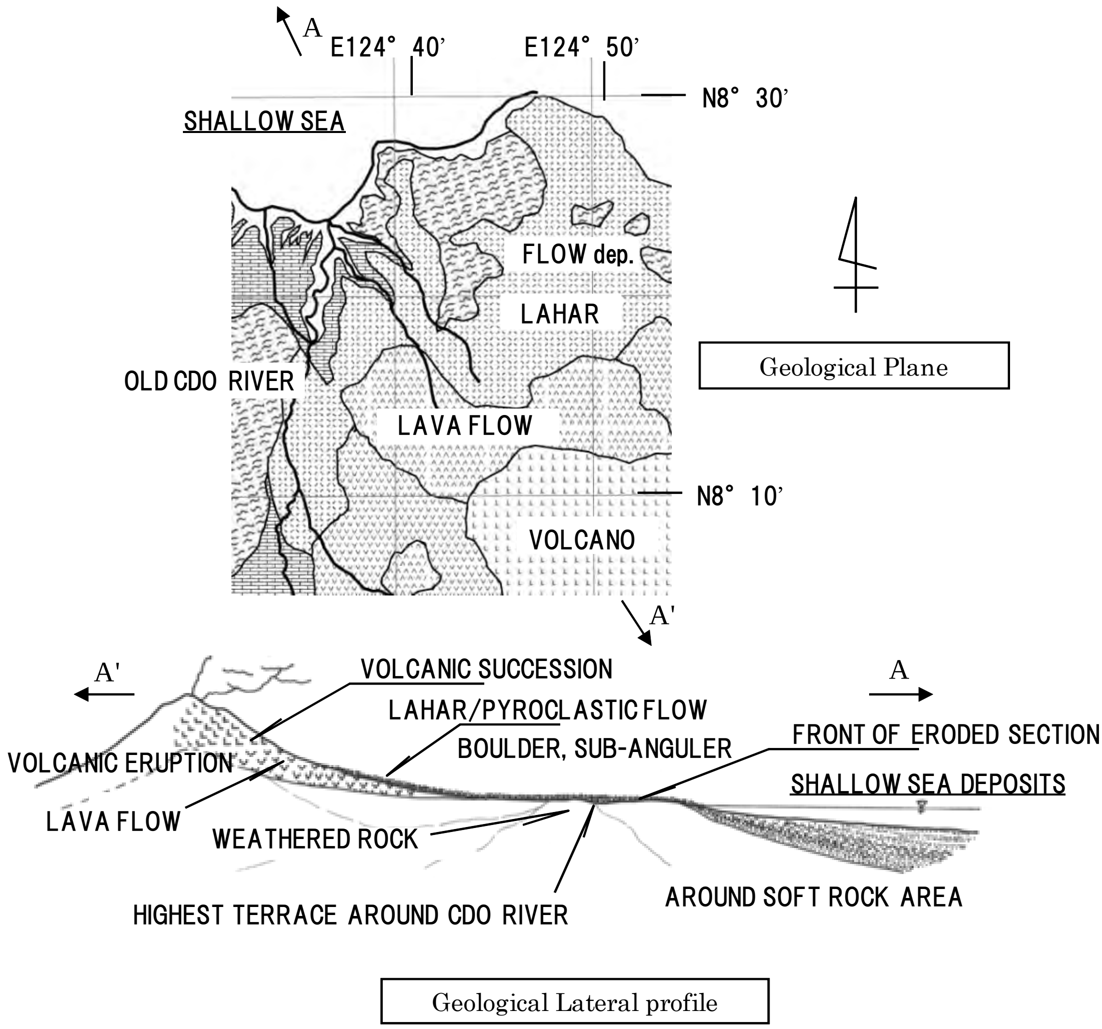
i) The Katanglad mountain range was formed by the continuous volcanic activity.

ii) Pyroclastic flow, volcanic mud flow and volcanic ash were deposited when the volcanic activity was still active.

iii) When the volcanic activity subsided, a large amount of sediment flows out toward the lowland or shallow sea (Photo 1.1.5).

iv) These sediment, which that formed higher terrace along the river, was transported through the old Cagayan de Oro River (Photo 1.1.3～1.1.5).

v) The higher terrace, where Lumbia airport is located, was formed in the surrounding shallow sea.



Source: JICA Survey Team

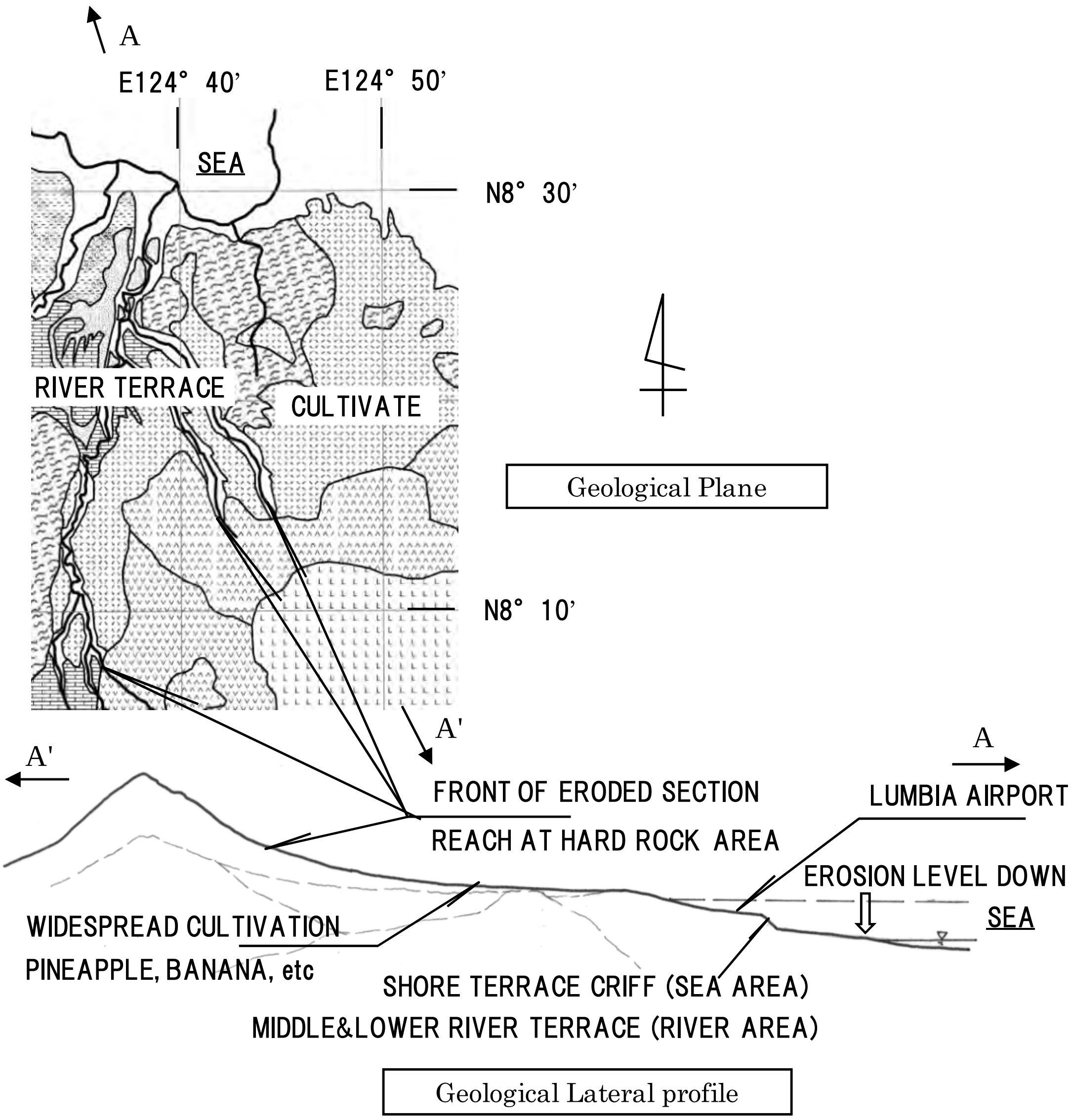
Figure 1.2.8 Stage III: Quaternary Pleistocene

(4) Stage IV : Quaternary Holocene around 0.006Ma – at Present

i) The worldwide lowering of sea level caused the new erosion. Thereby, the terrace was formed along the river.

ii) The valley that have low resistance to erosion was eroded more actively, a large amount of sediment flowed out.

iii) At present, the erosion level arrived at zone which the hard rock (Lava・welded tuff) was distributed thereby, amounts of erosion tends to reduce.



Source: JICA Survey Team

Figure 1.2.9 Stage IV: Quaternary Holocene

(5) Activity of the Sediment Production in the Present Stage

This watershed consists of the landform that was formed in the Late Holocene of Quaternary. After the last ice age, in Holocene era begun from about 12,000 years ago, the temperature rose a little by little, the sea level rose 120m or more.

After that, the Holocene climatic optimum called Hypsithermal which is a warm period existed during 5,000 to 7,000 years ago.

This interval was called “Jomon Transgression” in Japan. The sea level was more than a few meters higher than the present sea level. This phenomenon is presumed to be related to solar activity. The temperature rises little by little from about 2,000 years ago.

In this Hypsithermal period, a lot of sediments are considered to have flowed out toward the downstream by erosive action involving sediments which had been produced in the ice age. In the case of the same rainfall conditions, it is considered that the activities of erosion increase due to the drop of the sea level. As a result, a large amount of sediments were deposited around the coast. After that, as the sea level dropped gradually, the terraces were formed along the sea and the river.

The present erosion stage is considered to be the condition in which the erosion front had progressed already to the upstream. In other words the activity of sediment production is presumed to be the lowest condition in the Holocene period.

CHAPTER 2 THE REALITY OF SEDIMENT PRODUCTION BEFORE AND AFTER SENDONG

2.1 The Real Condition of Slope Failure before Sendong

Slope failure is considered to be the main source of sediment discharge.

Generally, the slope failure is divided two types. One is the surface failure whose thickness is 0.5-2.0m, the other is the deep-seated landslide whose thickness is more than 2.0m (Photo 2.1.1). Both types are affected by the geological structure and the weathering conditions of geology.

Deep-Seated Landslide
(Totsukawa Disaster in Japan 2012)

Surface Failure（CDO River 2012）

Source: JICA Survey Team

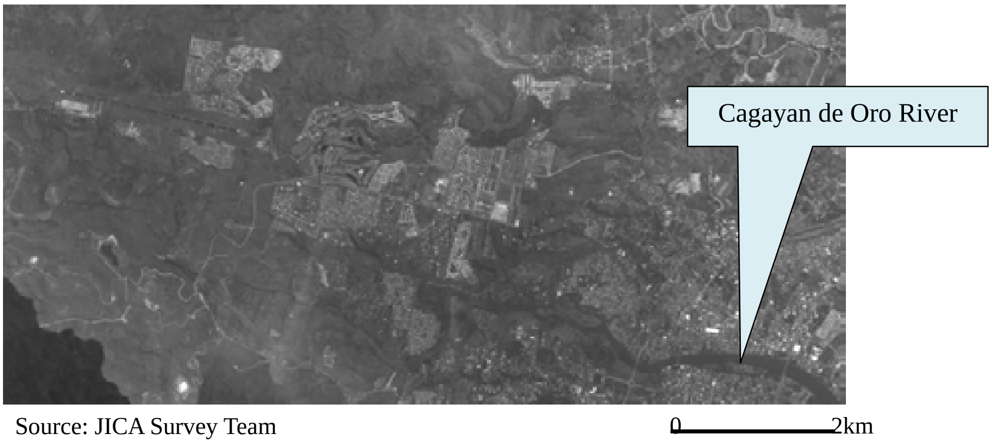
Photo 2.1.1 Case of the Slope Failure (Surface Failure and Deep-Seated Landslide)

Photo 2.1.2 is a satellite photo, which taken by Alos(satellite) before Sendong, and shows a part of Cagayan de Oro River watershed. The specifications of Alos are as shown in Table 2.1.1. Entire satellite photos of Cagayan de Oro River watershed which were taken in 2006 to 2011 are as shown in Photo 2.1.3.

Table 2.1.1 Specificatioqqns of Alos

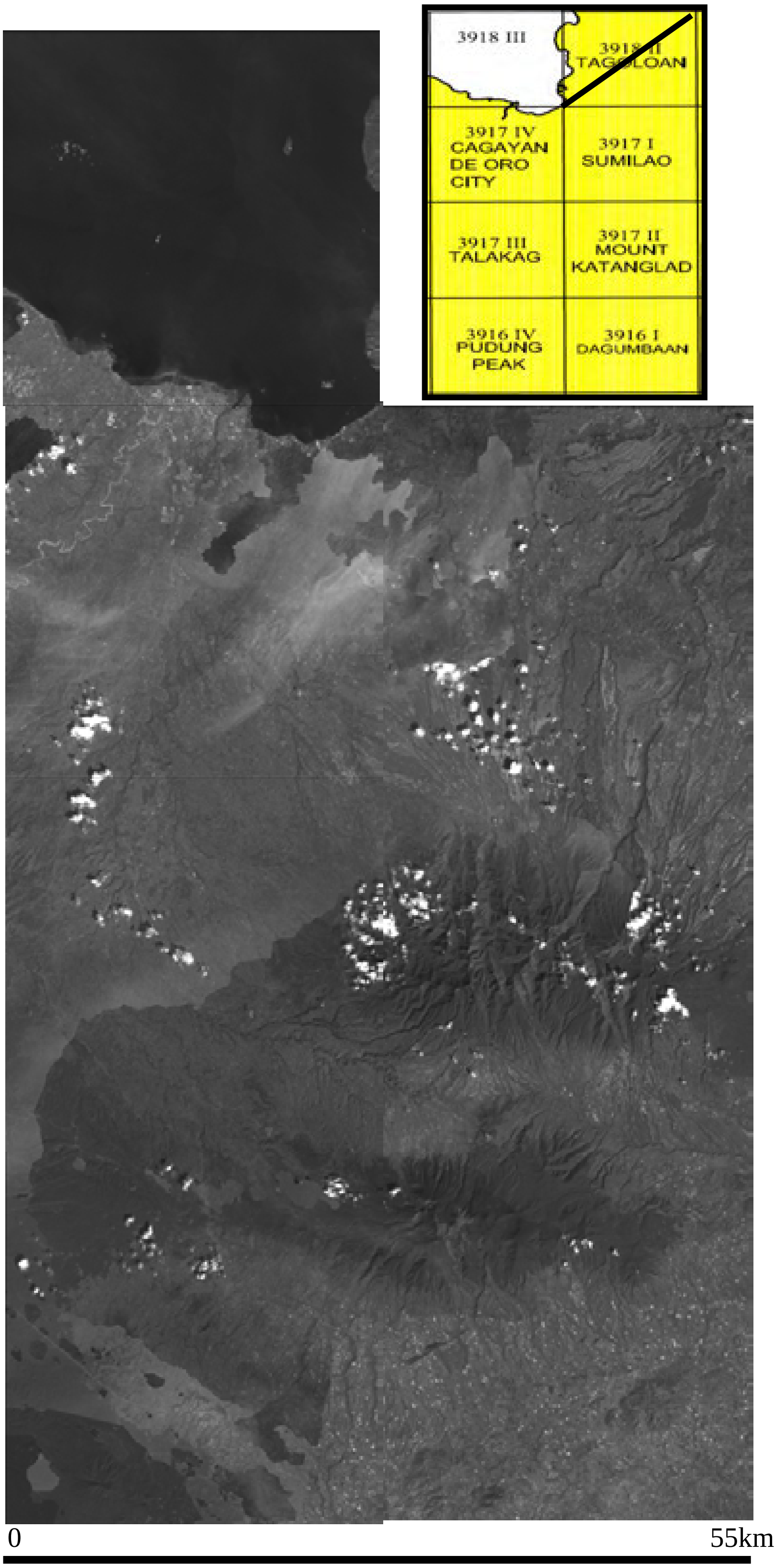
Country	Year of Launch	Height of Orbit	Returning Cycle	Field Angle	Photographic Width	Resolution
Japan	2006	692km	46 days	2.9 degree	35km	2.5m

Photographic interpretation is conducted using these satellite photos. However, these photos cannot be viewed stereoscopically because photos are not overlapped.



Source: JICA Survey Team

Photo 2.1.2 Satellite Photo taken by Alos (select view)



(2006-2011)

Source: JICA Survey Team

Photo 2.1.3 Satellite Photos of Cagayan de Oro River Entire Watershed

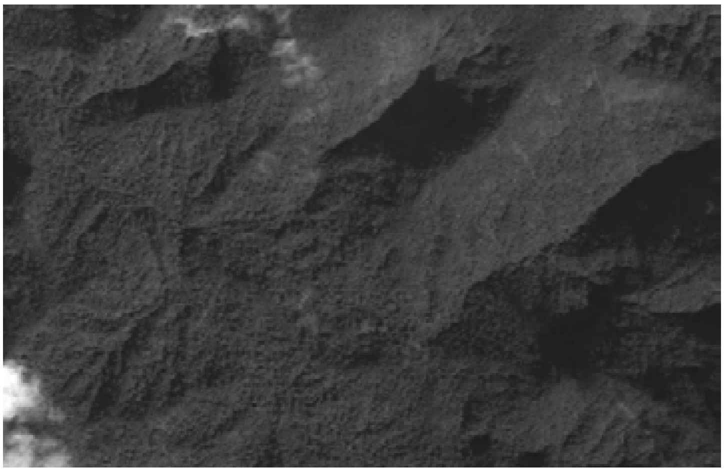
Photos 2.1.4 and 2.1.5 show the satellite photos of the upstream of Bubunawan River and the headwater of Tumalaong River, respectively. According to these photos, the mountain is covered by vegetation, therefore the obvious slope failures and debris flow deposits which are recognized as the white bare land are not observed (except the clouds).

Photo 2.1.6 shows the condition of the downstream of Tumalaong River. According to the photo, the meandering river and the steep cliff along the river in the large plateau are observed. The slope failures are not observed.

The other photos show also the similar results.

Source: JICA Survey Team 0 1km

Photo 2.1.4 Condition of the upstream of Bubunawan River



Source: JICA Survey Team 0 1km

Photo 2.1.5 Condition of the headwater of Tumalaong River

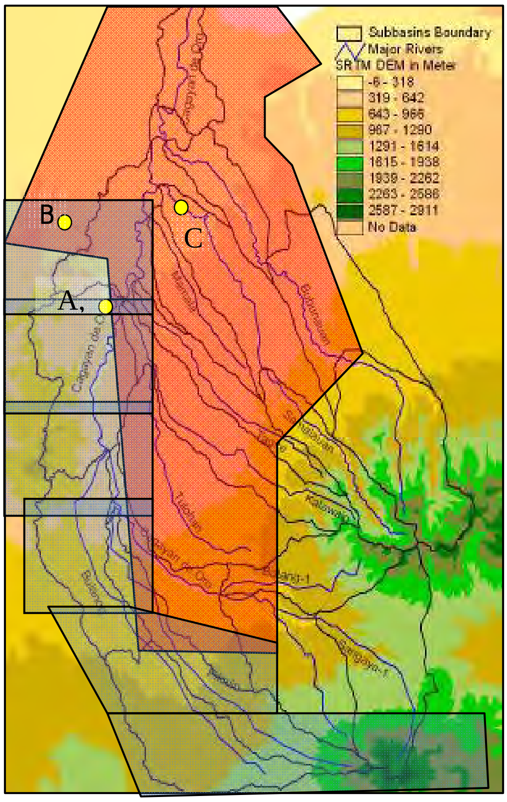
Source: JICA Survey Team 0 1km

Photo 2.1.6 Condition of the downstream of Tumalaong River

2.2 Actual Condition of Sediment Movement after Sendong

2.2.1 Photos using for Photographic Interpretation

As of February 2013, photographing range is as the following Figure 2.2.1 (mark: described below). Photographic Interpretation uses aerial photos (orthophoto) and satellite photos (World view 2). The specifications of World view 2 are as shown in Table 2.2.1. These photos cannot be viewed stereoscopically because photos are not overlapped.



A	Photo 2.2.1
B	Photo 2.2.2
C	Photo 2.2.3

Source: JICA Survey Team   0 16km

Figure 2.2.1 Photographing Range (Red :Aerial, Blue :Satellite ;As of Feb. 2013)

Table 2.2.1 Specifications of World view2

Country	Year of Lanuch	Hight of Orbit	Returning Cycle	Long Strip	Capacity
U.S.A	2009	770km	100min	16.4km - 360km	1 million km^2/day

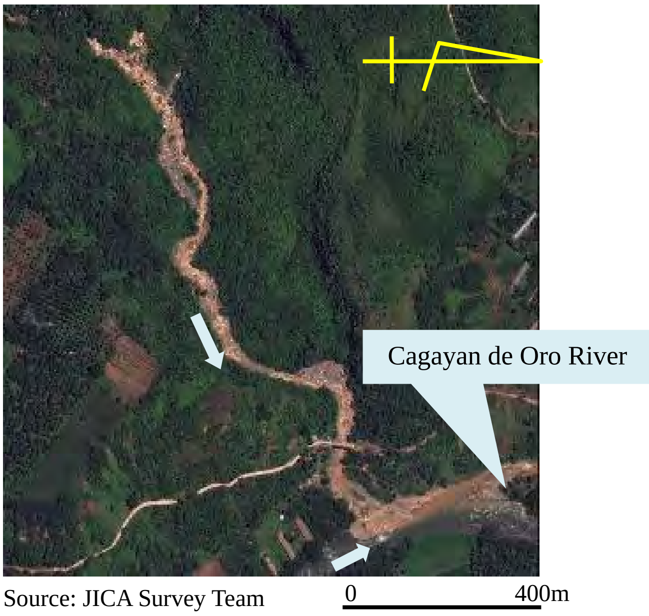
2.2.2 Sediment Movement Phenomena confirmed by Photos

Phenomena confirming by photos are debris flow, slope failure, flood inundation by bed load transport and landslide.

(1) Debris flow

The trace of this debris flow is confirmed at the left tributary (Bitanog River) which is located at the upstream approximately 1km from Uguiaban Bridge. This debris flow site is the only site that is confirmed by photographic interpretation.

A debris flow which occurred in the middle of valley was flowed out with eroding the riverbed, and stopped at the confluence. The condition which was flowed out to the confluence spot is observed on the photo. The real condition of debris flow is explained in chapter 9.3 (See Photo 2.2.1).



Source: JICA Survey Team

Photo 2.2.1 Debris Flow occurred in Bitanog River (A)

(2) Slope Failure

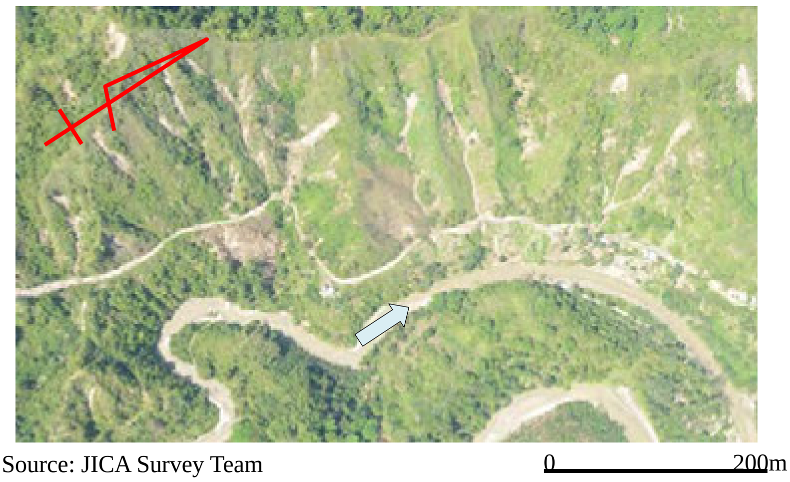
There are a few slope failures in Cagayan de Oro Watershed. But the obvious slope failures affecting sediment production are not observed.

Photo 2.2.2 shows the conditions of the slope failures taken in a part of Iponan River watershed, and is shown as the comparison of Cagayan de Oro watershed.

According to this photo, the sediments due to the slope failures have flowed into the tributary of Iponan River. If there are many slope failures like this, the influence to the downstream is presumed to be great. But slope failures like Iponan watershed are not observed in Cagayan de Oro watershed (Iponan River is shown in Figure 3.1.1).

The geology of Iponan River watershed consists of limestone of the Tertiary, unlike the geology of Cagayan de Oro River watershed that consists of the volcanic deposit. In comparison to the topography of Cagayan de Oro River watershed, that of Iponan River watershed consists of the undulating topography due to erosion.

The weathered Limestone is not resistance to erosion, therefore the slope failures are presumed to tend to be occurred under such environments.



Source: JICA Survey Team

Photo 2.2.2 Slope failures distributing along the tributary of Iponan River (B)

(3) Riverbed inundation

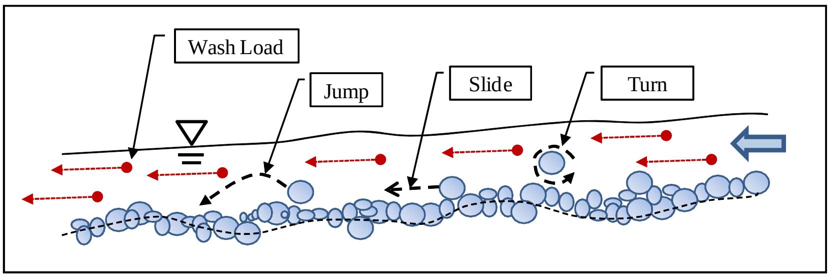
Riverbed inundations which are interpreted on the photo are observed at several places along Cagayan de Oro River and Tumalaong River.

Photo 2.2.3 shows the typical place of immediately the upstream of the Tumalaong causeway. The riverbank and towhead which are eroded widely by the meandering are observed.

These sediment movements are due to the bed load transport, and are considered to be the sediment movement form which transports bed materials to downstream gradually (See Figure 2.2.2). In this interpretation, the marked movement which affects facilities or downstream are not confirmed.

Source: JICA Survey Team 0 400m

Photo 2.2.3 Riverbed inundation observed along Tumalaong River (C)



Source: JICA Survey Team

Figure 2.2.2 Sediment Movement Form by Bed Load Transport

(4) Landslide

In general, landslides which occur along the river have a possibility which forms landslide dam that has a risk of sediment disaster by dam collapsing. In this interpretation, the marked landslides which affect sediment production are not confirmed.

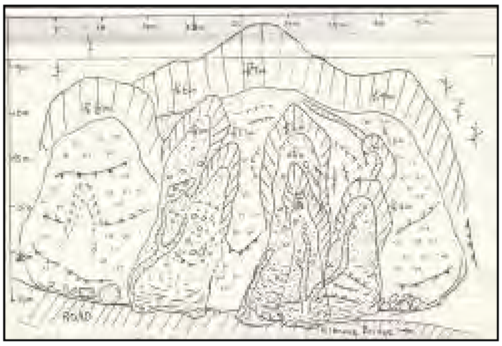
Photo 2.2.4 shows the landslide which was found by chance along the road near Bitanog River (See Figure 3.1.1). The landslide (50m width, 30m height), which is located at the margin of higher terrace, has not affected the sediment production to the downstream. The condition of site is as shown in Photo 2.2.5.

Source: JICA Survey Team

Photo 2.2.4 Landslide along the Road (D:dashed line)

Source: JICA Survey Team

Photo 2.2.5 Condition of Landslide



Source: JICA Survey Team

Figure 2.2.3 Sketch

2.3 About Sediment Production and Sediment Discharge before and after Sendong

2.3.1 Sediment Production before and after Sendong

In the satellite photos before Sendong, the obvious sediment movement phenomena are not confirmed.

Meanwhile in the satellite and aerial photos after Sendong, small slope failures and local debris flow are confirmed. But the marked sediment movements which affect the downstream are not confirmed at the present (The area which is not taken photos will be confirmed after implementation of taking photos of additional aerial photos).

At present, the massive sediment movements are presumed to have not occurred in the upstream because the marked sediment movements are not confirmed in the middle reach of the river.

2.3.2 The qualitative watershed characteristics on the sediment production

The sediment movement phenomena of each watershed are summarized as the following from the result above mentioned.

(1) Downstream area of the main river

The series of terrace cliffs which height is about 100m formed by the river downward erosion are distributed in the downstream area of Cagayan de Oro River. This terrace which the bedrock is limestone is covered by the gravel layer.

According to photographic interpretation, small slope failures are scattered around the cultivated land, but these slope failures are judged to be not affected the downstream because they are separated from the main river.

(2) From the middle reach of area to the upstream area the main river

The river of upstream area is narrow in width, the volcanic plateau is distributed on the right bank, and the hilly area is distributed on the left bank. The tributaries of the left bank have relatively large catchment areas. The volcanic deposits are distributed widely on the bedrock which consists of sedimentary rocks.

In the satellite photos, the inundation trace by the bed load transport and the debris flow trace are confirmed, but each size is small. The traces of sediment movement which affect the downstream of the main river are not confirmed.

(3) The right tributaries of the main river

This area is the plateau which Bubunawan River and Tumalaong River run. The right tributaries reach the main river running radially through the plateau. The fragile pyroclastic materials are distributed widely on the hard bedrock which consists of lava and welded tuff. The valleys are rectangular geometry in the downstream of tributaries, the old landslide landforms are confirmed along the steep cliff.

A few slope failures which flow into the rivers directly are confirmed. But the sizes are all small. The inundation traces by the bed load transport are confirmed, but the sediment movement which affects the downstream of the main river is not confirmed.

(4) Iponan watershed

This watershed is not object watershed of this study, but many slope failures are confirmed on the aerial photos, therefore the conditions of Iponan watershed are shown for comparison with the study area. Granodiorite is distributed in the upstream of the river, and the sedimentary rocks of the Tertiary period are distributed in from the middle reach to the downstream of the river. The landform is relatively steep. The slope failures are confirmed relatively large numbers in the undercut slope. Sediment discharge is considered to be active compared to Cagayan de Oro watershed.

2.3.3 Summary and the policy of site survey

The results above mentioned are summarized as shown in Table 2.3.1.

Table 2.3.1 Results confirmed by Aerial Photos etc.

Phenomena	Contents
Debris flow	Confirmed at the left tributary (Bitanog river) which is located at the upstream from Uguiaban Bridge .The possibility which have flowed out to the downstream is low.
Slope failure	Small slope failures are scattered around the cultivated land (Bubunawan-DelMonte). There are almost no sediments which have flowed into the river.
Riverbed inundation	Riverbed inundations which are due to the bed load transport are confirmed in Bubunawan River and Tumalaong River locally. Effect on the downstream is small.
Landslide	Confirmed along the terrace cliff of the main river and the tributaries on the topographic map. Active landslides are not confirmed by photographic interpretation.

Source: JICA Survey Team

CHAPTER 3 THE CONDITION OF FLOOD DEPOSIT AFTER SENDONG

3.1 Objective Rivers and Point of Investigation

3.1.1 Objective Rivers

The investigation is conducted at the typical sites accessible on the Cagayan de Oro River and tributaries including Bubunawan River and Tumaraong River which were severely damaged due to Sendong.

The objective sites are as shown in Figure 3.1.1. River longitudinal profile is as shown Figure 3.1.2.

By the way, on 4 December 2012 during investigation, the Mindanao Island was affected by typhoon Pablo. The conditions in some sites after Pablo are showed for comparison to the condition before Pablo.

3.1.2 The Object of Investigation

According to the history of landform development, the present erosion stage is considered to be the last erosion stage which the activity of the sediment discharge is the lowest condition in the Holocene. Therefore, the object of investigation is to understand the condition of sediment discharge, which is called the flow form.

The condition of the outflow and the deposit of the debris flow due to landslide or slope failure is one of the important observation items. And fluctuations of riverbed sediment are also the important observation item.

The disaster conditions in the public and private properties are the important judgment indication in the Sabo planning.

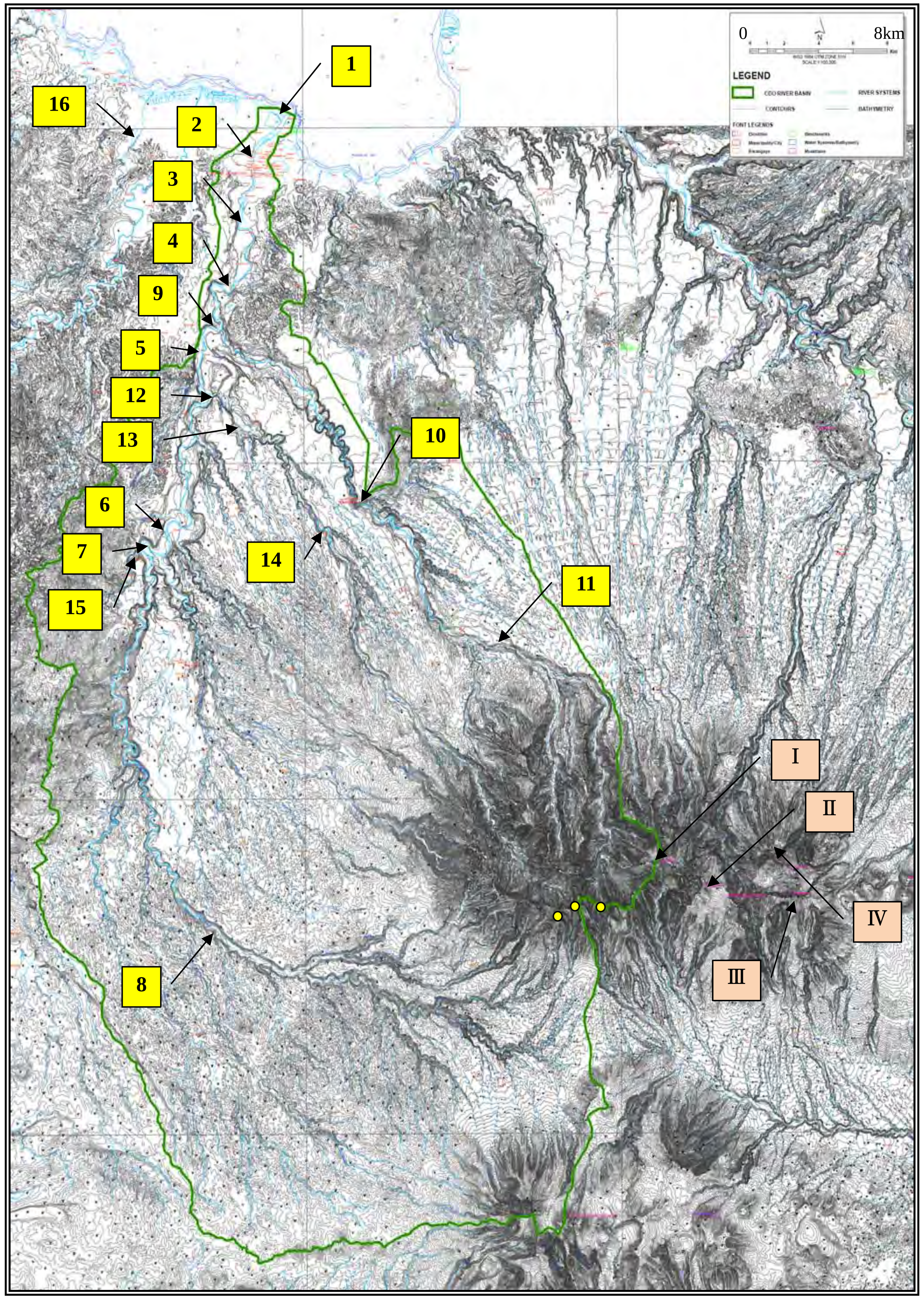
The investigation is conducted at the typical sites accessible on the Cagayan de Oro River and tributaries including Bubunawan River and Tumalaong River which were severely damaged due to Sendong, and Bitanog River which debris flow had occurred.

Generally, the sediment movement forms have the movement forms like debris flow, sediment flow, bed load, suspended load, wash load (See Table 3.1.1).

Table 3.1.1 Sediment Movement Forms

Movement Forms	Characteristics
Debris Flow	The riverbed gradient is higher than 15 degrees (1/4) The slope failure sediment or the riverbed sediment flow out continuously
Sediment Flow	The riverbed gradient is around 2degree to 9 degree The materials in sediment flow contain few boulder
Bed Load	Moved by the “Jump”,” Slide” and “Turn” on the riverbed
Suspended Load	Fine materials flow in the water with the floating condition
Wash Load	Very fine materials flow over a long distance without deposition

Source: JICA Survey Team

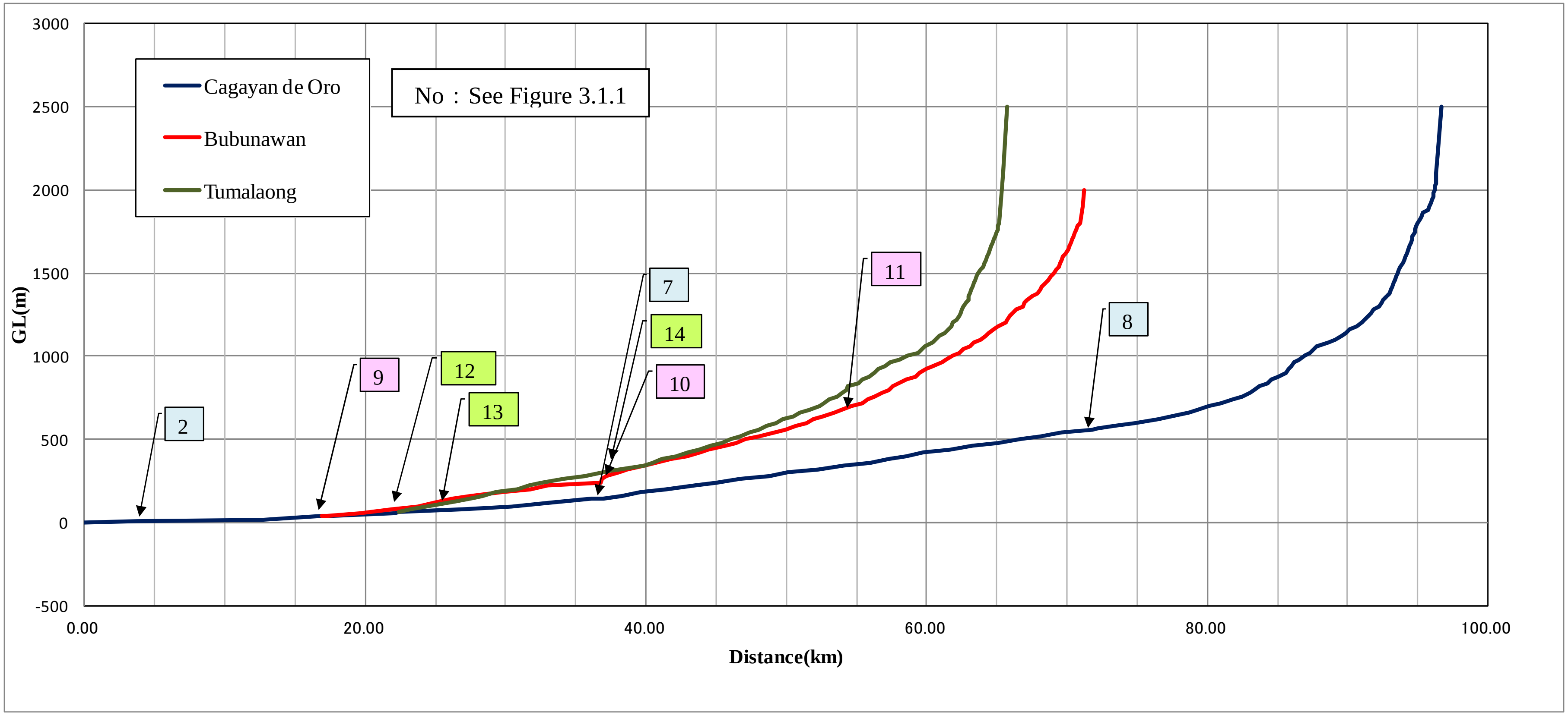


No	River	Name
1	Cagayan de Oro	The estuary of CDO
2		Isla de Oro
3		Cala Cala
4		Pelaez Bridge
5		Cabula Bridge
6		Langoan Bridges
7		Uguiaban Bridge
8		Cosina Dam
9	The confluence of Bubunawan	
10	Bubunawan	CEPALCO dam
11		Kalasyan Causeway
12	The confluence of Tumalaong	
13	Tumalaong	Tumalaong Causeway
14		Mand Steel Bridge
15	Bitanog	Kibanog Bridge
16	Iponan	–

No	Mountain
I	Mt. Nanluyaw
II	Mt. Ma-agnaw
III	Mt. Katanglad
IV	Mt. Kitanglad

Source: JICA Survey Team

Figure 3.1.1 Location Map of Investigation Sites



Source: JICA Survey Team

Figure 3.1.2 River Longitudinal Profile

3.2 The Object of Investigation Rivers

3.2.1 Cagayan de Oro River

(1) Actual Condition of Flood Deposition

i) Estuary

The width of river estuary at Macabalan is about 250m (See Figure 3.1.1). A large amount of sediments flowed out from the upstream. The water depth of the inundation at Sendong was confirmed to have been about 60cm (See Photo 3.2.1 A). No flood deposit with gravels was observed at this zone.

Almost all sediments which consists of fine materials that flowed from upstream is presumed to be deposited on the riverbed, or to have flowed as wash load toward the sea (See Photos 3.1 B, C).

Source: JICA Survey Team

Photo 3.2.1 Around Estuary

ii) Isla de Oro

Isla de Oro is an area of delta formed from sediment deposits with ground elevation of about 3m lower than the surface elevation of the public road (See Photo 3.2.2 A and Figure 3.1.1). Many houses in this area were washed away during TS Sendong. Due to curve shape of the river channel at immediately upstream of the Isla de Oro, the flood is presumed to have had a straight flow. The height of flood was about 2.5m above the ground level at the basketball court (See Photo 3.2.2 B), no flood deposit was observed at this zone (See Photo 3.2.2 C).

As no flood deposit with gravels was observed at this zone, fine materials in the flood are presumed to be flowed out toward sea as wash load (See Photo 3.2.2 C).

Source: JICA Survey Team

Photo 3.2.2 Isla de Oro

iii) Cala Cala

This area is considered as the lower terrace (See Figure 3.1.1). As the river immediately upstream is in meandering shape, the flood of this area was presumed to have had a straight flow like Isla de Oro.

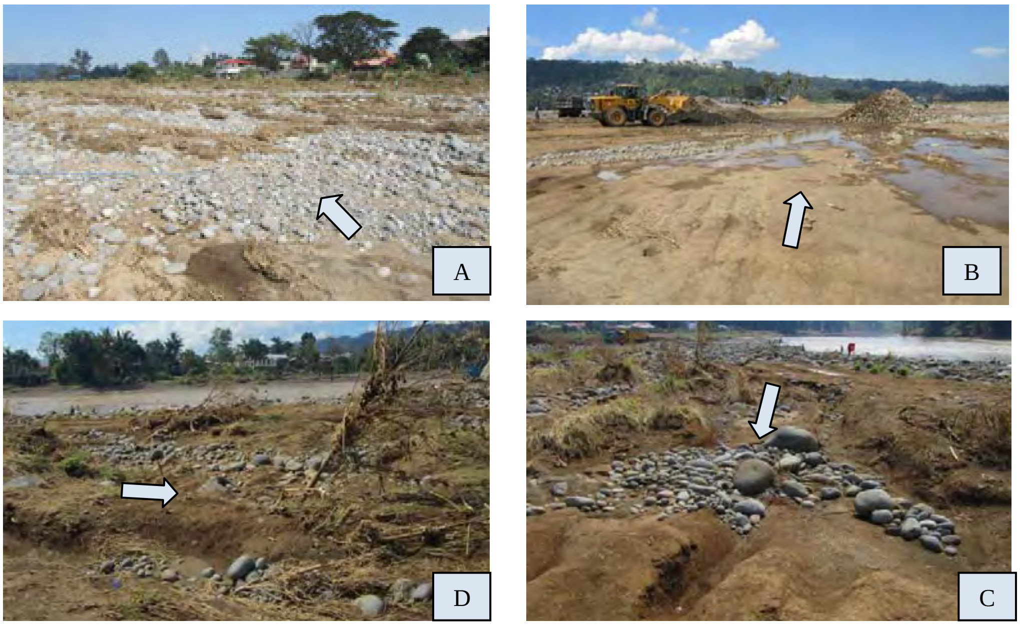
Photo 3.2.3 A is the aerial photo taken immediately after Sendong. At the present, the remarkable trace of flood deposits were not observed on this terrace, fine materials in the flood was presumed to have flowed out toward the sea as wash load, but fine materials and the boulders which consist of old terrace deposits were observed (See Photos 3.3 B, C).

Source: JICA Survey Team

Photo 3.2.3 Cala Cala

Photo 3.2.4 shows the condition of terrace surface after Pablo. A lot of boulders were observed on the terrace, but these boulders are old terrace deposits (See Photo 3.2.4

A). As the terrace surfaces are eroded as shown Photos 3.4 B to D, the flood energy was considered to have had an enormous large energy.



Source: JICA Survey Team

Photo 3.2.4 Terrace Surface after Pablo

iv) Pelaez Bridge

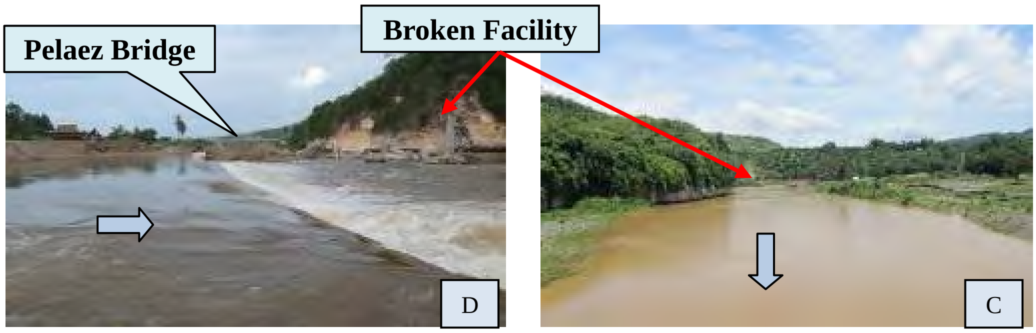
Pelaez Bridge is located at the top of the alluvial area (See Photo 3.2.5 A).

The large delta is located immediately downstream of Pelaez Bridge (See Photo 3.2.5B and Figure 3.1.1). This bridge and facilities in the delta are not damaged by Sendong, but the facility (water pipe bridge) of upstream of this bridge was damaged by Sendong floodwaters (See Photo 3.2.5 C).

As flood deposits were not observed around the bridge, fine materials carried by floodwaters are presumed to have flowed out toward downstream as wash load.

Source: JICA Survey Team

Photo 3.2.5 Pelaez Bridge (1/2)



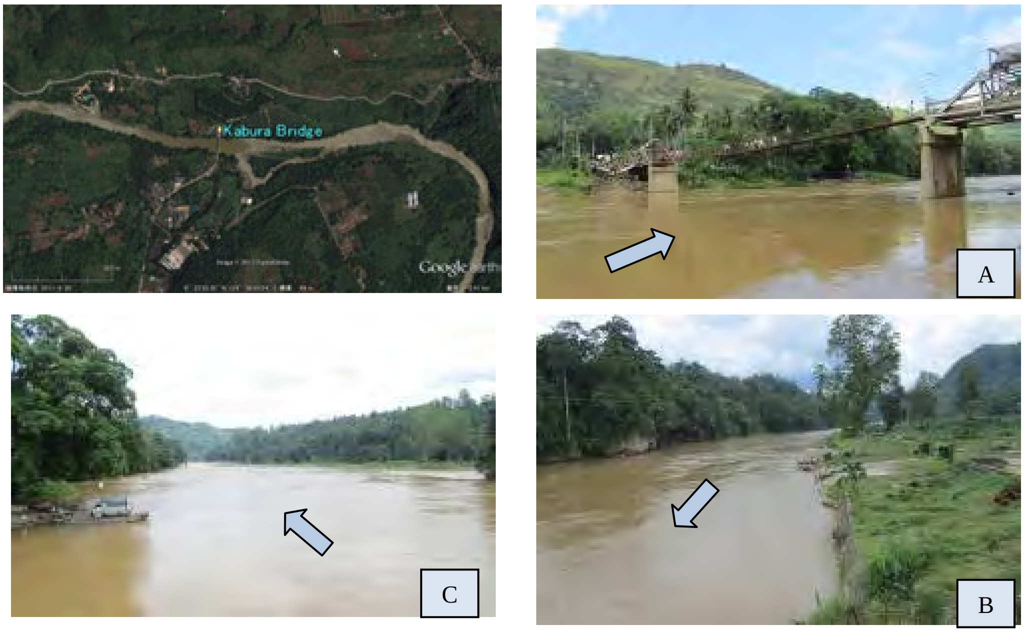
Source: JICA Survey Team

Photo 3.2.5 Pelaez Bridge (2/2)

v) Cabula Bridge

Cabula Bridge was damaged by storm Sendong floodwaters.

At the present, flood deposits were not observed around the bridge, fine materials carried by floodwaters is presumed to have flowed out toward downstream as wash load (See Photos 3.6 B, C and Figure 3.1.1).



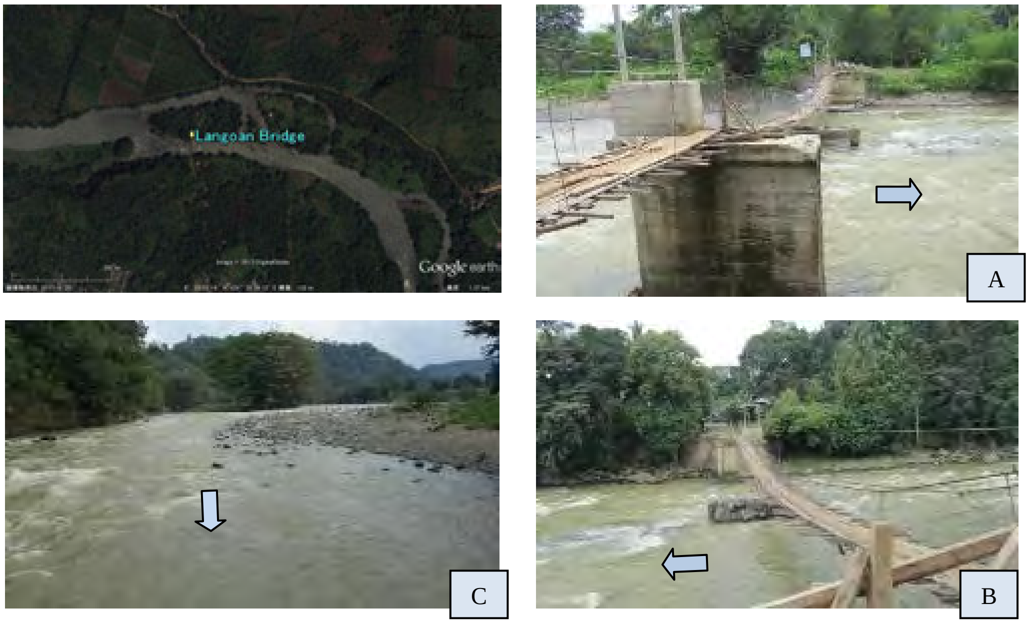
Source: JICA Survey Team

Photo 3.2.6 Cabula Bridge

vi) Langoan Bridge

This bridge area is in a delta and Langoan Bridge is one of the bridges which span between the delta and river bank. This bridge spanning between the delta and the right bank was damaged by Sendong (See Photos 3.7 A, B and Figure 3.1.1).

The flood deposits were not observed around the bridge (See Photo 3.2.7 C).



Source: JICA Survey Team

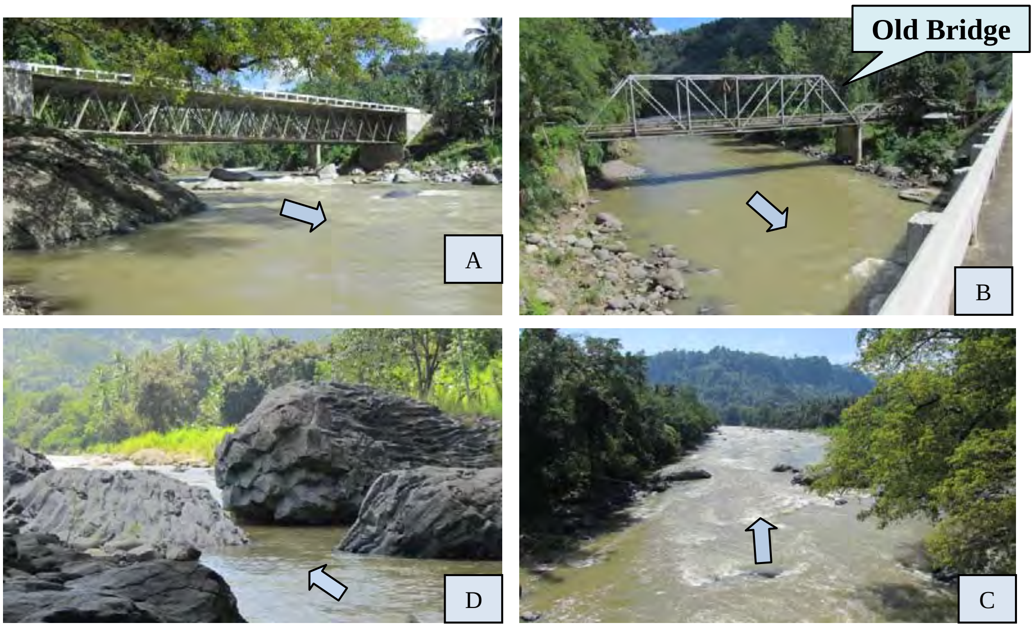
Photo 3.2.7 Langoan Bridge

vii) Uguiaban Bridge

The new Uguiaban Bridge is spanned over Cagayan de Oro River, which is the boundary of Talakag, Bukidon and Cagayan de Oro City leading to the town of Talakag (See Figure 3.1.1). The lower terrace is located at the left bank. Therefore the road of the left bank is a built-up bridge embankment (See Photo 3.2.8 A).

In this spot, the width of the river is narrower compared to the downstream of the bridge, therefore the river stream has little rapids (See Photos 3.8 B, C).

Flood deposits were not observed around the bridge, but the volcanic boulders which seemed to have been fallen from slope failure occurred in the immediate slope were observed in the riverbed on the right bank (See Photo 3.2.7 D).



Source: JICA Survey Team

Photo 3.2.8 Uguiaban Bridge

This new Uguiaban Bridge was destroyed by floodwaters of typhoon Pablo on 4 December 2013. Debris (logs, driftwoods, brushes, etc.) borne by floodwaters accumulated on the bridge steel truss members below which forces the bridge to be unhinged from its anchorage and washed out down river (See Photo 3.2.9).

The main cause of the washout of the bridge is presumed to be the position of the truss.

Source: JICA Survey Team

Photo 3.2.9 Uguiaban Bridge after Pablo

viii) Cosina Dam

The Cosina dam is located at upstream of Cagayan de Oro River (See Figure 3.1.1). This dam was constructed as irrigation dam, but at present this facility is not operational pending completion of irrigation lateral canal (See Photo 3.2.10 A).

The dam is about 2 meters height, and the condition of full capacity is observed. The obvious flood deposit is not observed around the dam including dam reservoir (See Photos3.10 B, C).

The driftwoods which are considered to have been flowed out at Sendong are observed at the intake (See Photo 3.2.10 D).

Source: JICA Survey Team

Photo 3.2.10 Cosina Dam (1/2)

Source: JICA Survey Team

Photo 3.2.10 Cosina Dam (2/2)

Photo 3.2.11 shows the condition after Pablo. According to these photos, new driftwoods are observed at the intake, and the new flood traces are observed around the dam. But the dam reservoir is not filled up with sediment, and the marks of the sediment movements are not observed around the dam.

Source: JICA Survey Team

Photo 3.2.11 Condition after Pablo

(2) Assessment of the sediment discharge

The conditions of sediment discharge of Cagayan de Oro River are summarized as follows.

i) In upstream, the riverbed sediments which consisted of sand, cobble and boulder are observed, but the debris flow deposit is not observed. For this reason, the sediment movement form is presumed to be mainly bed load. A few amount of sediment movement was considered to be moved as shown after typhoon Pablo.

ii) The area from the middle reach to downstream, the sediment movement form is considered to be changed from “bed load” to “suspended load”, “wash load”. In the Cala Cala area, the severe erosion action on the terrace surface was observed after typhoon Pablo as shown. As the flood energy is greater, the fine material is presumed to tend to flow out toward the sea as “wash load”.

3.2.2 Bubunawan River

(1) Actual Condition of Flood Deposition

i) CEPALCO Dam

CEPALCO Dam which is hydroelectric dam is located at the middle reach of Bubunawan River (See Figure 3.1.1).

This dam is being repaired at present (See Photo 3.2.12 A). Photo 3.2.12 B and C show the condition immediately after Sendong (photos taken from Helicopter).

According to the photos, there are thin brownish deposits observed on the left bank terrace where the maintenance office had been built. But the reservoir was not filled up with the flood deposit.

According to the dam management of the company, these deposit that flowed into the dam reservoir by Sendong had been removed already.

Photos 3.12 D and E show the present riverbed condition. As shown in photos, the flood deposit is scarcely observed.

Photo 3.2.12 E shows the immediate upstream of the dam, in spite of the fine weather, the muddy water which flows into Bubunawan River from right tributary was observed.

From this observation, the sediment which consists of the fine materials is presumed to have flowed out constantly from the plateau.

Source: JICA Survey Team

Photo 3.2.12 CEPALCO Dam (1/2)

Source: JICA Survey Team

Photo 3.2.12 CEPALCO Dam (2/2)

Meanwhile, according to the dam management of the company, deposits of fine materials like clay, silt and fine sand is observed every year in the CEPALCO dam reservoir (See Photo 3.2.13 ; by MINDANAO ENERGY).

These fine materials were presumed to have flowed out from the plateau where the cultivated fields (Bananas, Pineapples, etc.) are located, and the fine materials which were trapped within the dam are removed from the terrace etc. of the upstream every year.

Photo 3.2.14 shows the upstream condition of the CEPALCO dam after Pablo. The traces of movement of the riverbed materials are observed. But the remarkable deposits in the CEPALCO dam were not observed.

(Provided by MINDANAO ENERGY)

Photo 3.2.13 The Fine Materials flowed into the Reservoir every year (before Sendong)

Source: JICA Survey Team

Photo 3.2.14 Condition of around the CEPALCO Dam after Pablo (10 Dec. 2012)

ii) Kalasyan Causeway

Kalasyan Causeway is located at the upstream of Bubunawan River (See Figure 3.1.1).

This area is characterized by the gentle slope which consists of deposition formed by the sediment discharge in the Late Pleistocene (See Photo 3.2.15 Left Google earth, Chapter 1.2 (1) III).

In fact, the deposition composed of gravels and cobbles were observed on the riverbed.

Kalasyan Causeway was constructed on the riverbed which was approximately 30m wide, but the left abutment consisting of earth fill materials were washed out during by the floodwaters Storm Sendong (See Photos 3.15 Right Google earth, B).

As shown this photo, the damaged bridge which was washed out is not severely damaged by the sediment flow but by the flood.

According to the nearby residents, there was a deep water section of the river immediately upstream of the causeway, but that deep water section is now shallow after Sendong (See Photos 3.15 C, F).

Therefore, the riverbed materials which consist of gravel and cobbles are presumed to have been transported by "bed load" during the flood (See Photos 3.15 A to D).

In fact, according to observation after Pablo, the river water flows over the road surface of the causeway due to obstruction of the drainage pipes as shown in Photo 3.2.16, therefore the riverbed fluctuation is considered to be caused every severe flooding.

Source: JICA Survey Team

Photo 3.2.15 Kalasyan Causeway

Source: JICA Survey Team

Photo 3.2.16 Condition of around Causeway After Pablo

(2) Assessment of the sediment discharge

The conditions of sediment discharge of Bubunawan River are summarized as follows.

i) In upstream, the riverbed sediments which consisted of sand, cobble and boulder are observed, but the debris flow deposit is not observed. For this reason, the sediment movement form is presumed to be mainly bed load. The sediment movement after Pablo is relatively obvious.

ii) The sediment movement of the fine materials is one of the characteristics of the outflow in this river. The fine materials which are judged to be constantly flowed out every year from the cultivated fields on the plateau are considered to have a influence on the aggradation of riverbed of downstream. Especially, as the flood energy is greater, the fine material is presumed to tend to be flowed out toward the estuary and the sea as "wash load".

3.2.3 Tumalaong River

(1) Actual Condition of Flood Deposition

i) Tumalaong Causeway

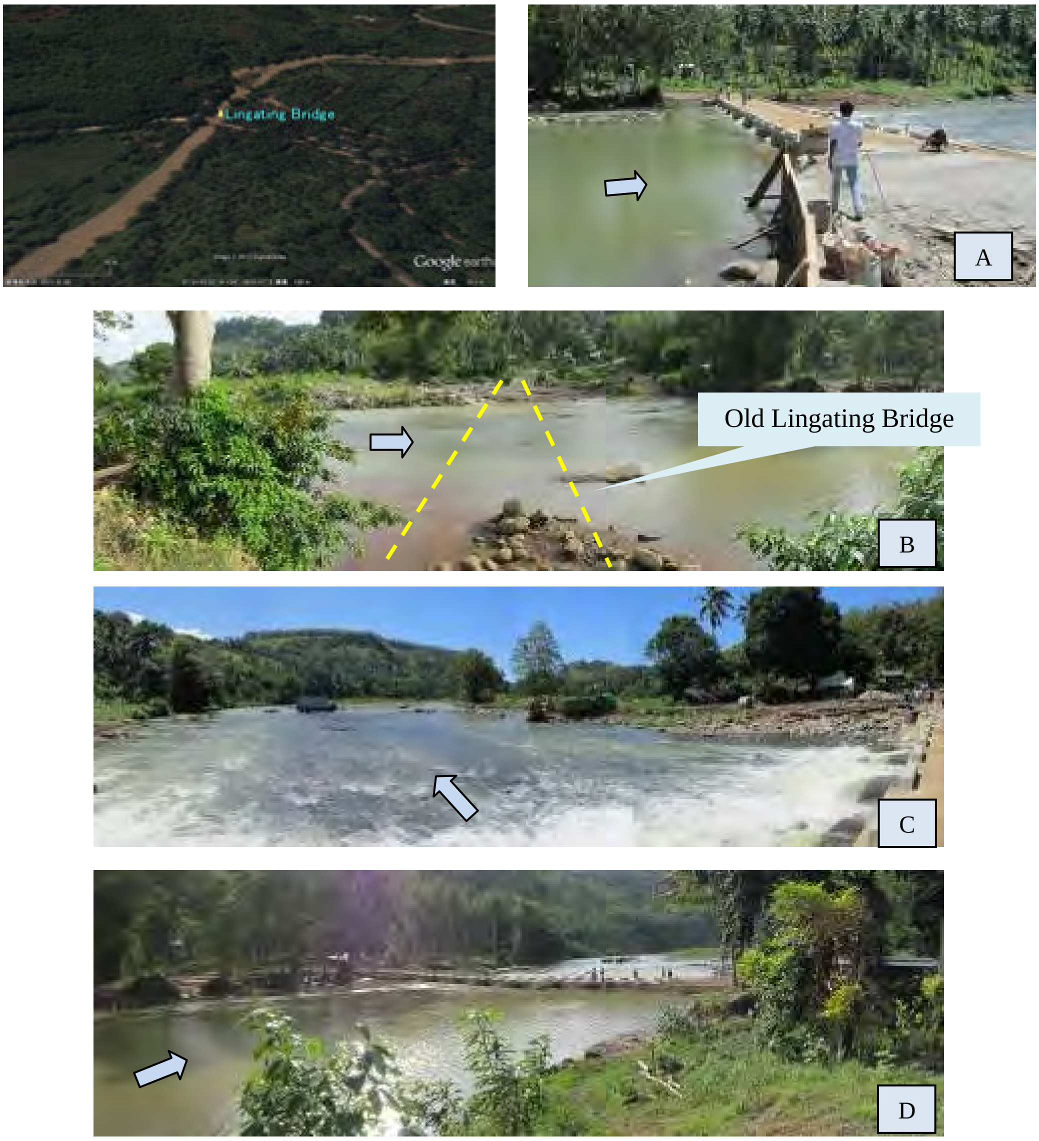
As Bubunawan River case, Tumalaong River was also severely damaged by Sendong. Tumalaong Causeway is located at the downstream of Tumalaong River (See Figure 3.1.1).

As shown in Photo 3.2.17 B, Lingating Bridge was damaged by Sendong.

Tumalaong causeway was constructed after Sendong (See Photo 3.2.17 A).

The riverbed deposits which consist of mainly gravels and cobbles are distributed widely. The river bank erosions are locally observed, so the scouring force is considered to have been comparatively strong (See Photos 3.17 B, D).

In fact, according to the observation after Pablo, the outflow and the restoration of the left bank abutment are observed, the condition exemplifies what is mentioned above (See Photo 3.2.18).



Source: JICA Survey Team

Photo 3.2.17 Tumalaong Causeway

Source: JICA Survey Team

Photo 3.2.18 Condition of after Pablo (1/2)

Source: JICA Survey Team

Photo 3.2.18 Condition of after Pablo (2/2)

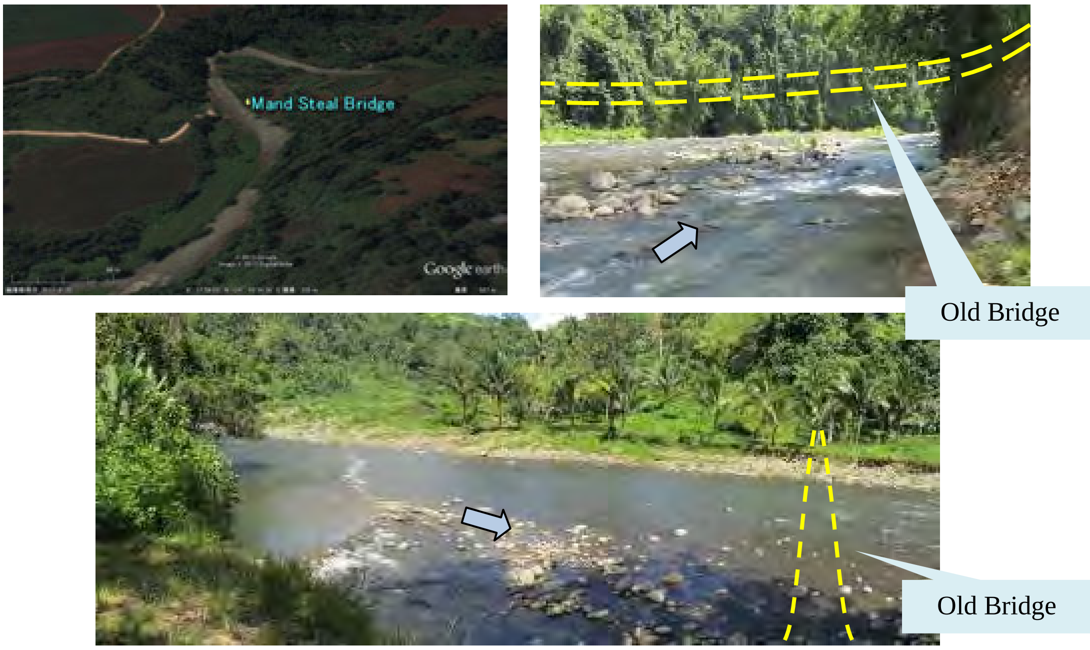
ii) Mand Steel Bridge

Mand Steel Bridge was located at the middle reach of Tumalaong River (See Figure 3.1.1).

As shown in Photo 3.2.19, Mand Steel Bridge a suspension bridge was damaged by storm Sendong. Temporary bridge is not yet constructed at present after storm Sendong.

The observed characteristics of flood deposits on the riverbed, consists of gravels and cobbles.

These deposits on the riverbed are presumed to be transported by “bed load” similar to the condition of Tumalaong causeway (See Photo 3.2.19).



Source: JICA Survey Team

Photo 3.2.19 Old Mand Steel Bridge

(2) Assessment of sediment discharge

The conditions of sediment discharge in Tumalaong River are summarized as follows.

i) In the middle reach of the river, the riverbed sediments which consisted of sand, cobble and boulder were observed, but the debris flow deposit is not observed. For this reason, the sediment movement form is presumed to be mainly bed load.

ii) The sediment movement after Pablo is relatively obvious.

3.2.4 Bitanog River

(1) Actual Condition of Debris Flow

Photos 3.20 (A, B) show the satellite photos after Sendon.

The trace of this debris flow is observed at the left tributary (Bitanog river) which is located at the upstream approximately 1km from Uguiaban Bridge.

Bitanog River flows through the Limestone of the Tertiary period, and the river flows along the higher terrace which is located the right bank of the river.

According to the site investigation, the debris flow is considered to have flowed out eroding the riverbed materials and the riverside slope, and to have stopped at the confluence of Cagayan de Oro River. The material of the debris flow consists of the Limestone and Volcanic boulders (welded tuff), and the gravels (Granodiorite, etc.) of Cretaceous which is in the lower level of the Limestone.

The boulders which are bigger than 2m diameter are observed on the riverbed, therefore the debris flow is presumed to have a large energy force (Photos 3.20 D, E).

The debris flow was deposited at the confluence, but almost all sediments has flowed out by the floodwaters of typhoon Pablo. At the present, the sediments are extracted out from the riverbed by the quarrying merchants.

The embankments of the abutments of the Bridge (Kitanog Bridge) were washed out by the debris flow shown in the photos 3.20 (C, F, G).

According to nearby residents, the debris flow of this river is the first phenomenon observed.

Source: JICA Survey Team

Photo 3.2.20 Condition of the Debris Flow (Bitanog River) (1/2)

Source: JICA Survey Team

Photo 3.2.20 Condition of the Debris Flow (Bitanog River) (2/2)

(2) Assessment of sediment discharge

Debris flow was stopped at the confluence of Cagayan de Oro River, but the main stream was not dammed up at that time. The sediments were presumed to have been safety flowed out gradually to downstream.

CHAPTER 4 ABOUT SABO FACILITIES

4.1 Basic Policy

4.1.1 Fundamental Requirements

There are two (2) types in the sediment disaster. One is the disaster's types is that the facilities are directly damaged by landslide, slope failure, debris flow and volcanic mud flow etc. The other disaster's type is that the facilities are indirectly damaged by natural damming due to landslide or slope failure.

The sediment management is the management that prevents the sediment disaster from occurring. The management consists of "structural measures" which are managed by Sabo facilities and "soft measures", such as early warning and evacuation system inconsideration of both measures.

In this study, the emergency countermeasure against the damages of storm Sendon magnitude is required, the necessary structural measure which is a quick-impact countermeasure is also considered.

The fundamental requirements of structural measures are as follows.

i) The preservation of public and private properties such as schools, hospitals, roads, bridges, houses and cultivated lands.
ii) The disaster form is the sediment disaster due to landslide, slope failure and debris flow.
iii) The sediment production in the upstream is active, and the sediment disaster is concerned in the future.
iv) In the cases the repair is easy and the economic loss is small is not included. And the limited damages are also not included.

4.1.2 Setting of the Object Area and Selection of Sabo Facility

The target areas are the areas which are relatively accessible for the operation and maintenance. As a rule, the areas which are inaccessible for the operation of the target area are not included.

Check dam as a prompt action will be possibly selected as the Sabo facilities in terms of urgency and technical issues (See Photo 4.1.1).

Check Dam in Camigin Island

Slit Check Dam in Japan

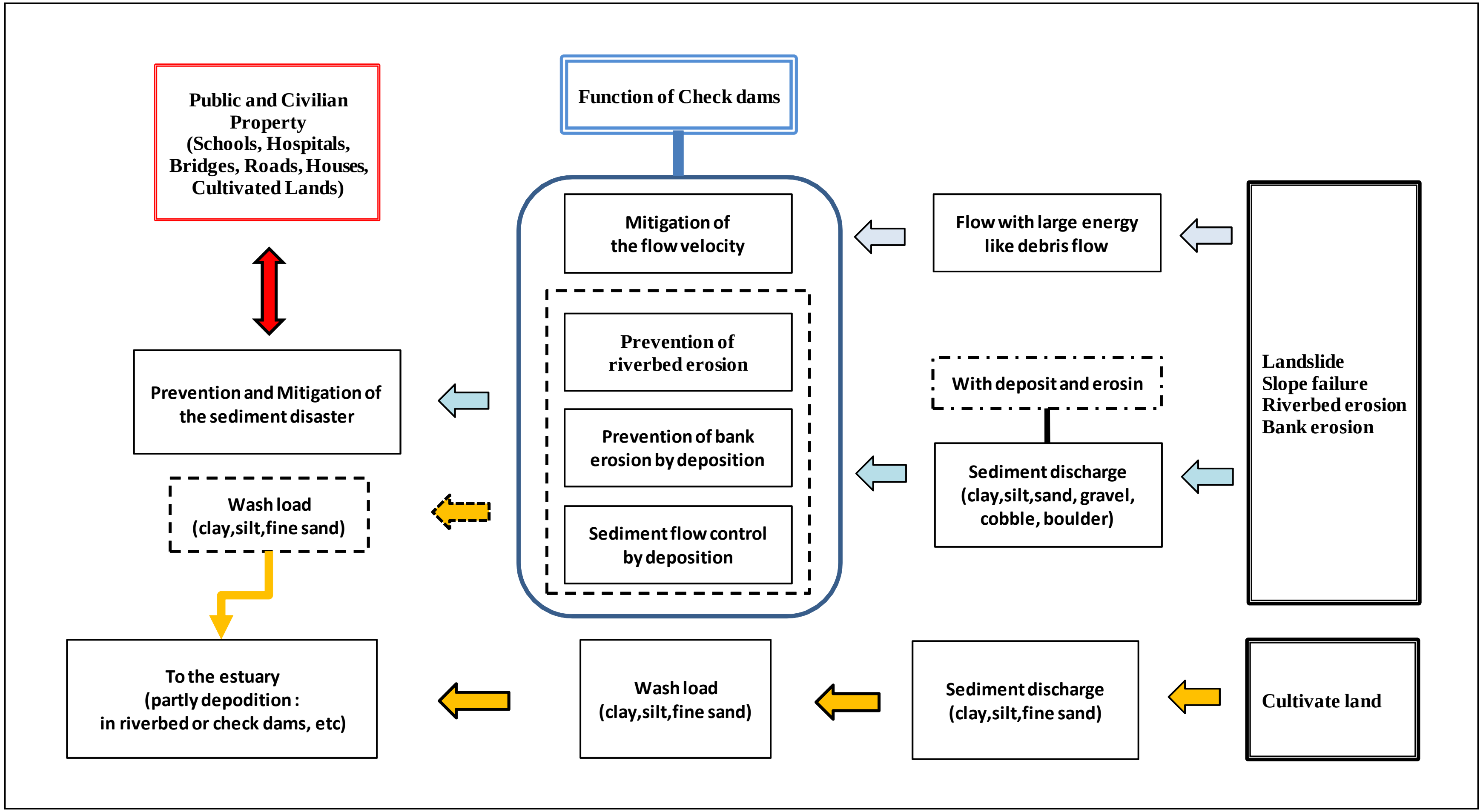
Source: JICA Survey Team

Photo 4.1.1 Cases of Check Dam

4.2 Functions and Range of Application of Check Dam

4.2.1 Functions of Check Dam

The functions of Check dams are to trap the transported sediment like debris flow or volcanic mudflow, and to flow them safety. Specifically, check dam has the function of i) prevention of riverbed erosion, ii) prevention of bank erosion by deposition, iii) mitigation of the flow velocity, iv) sediment flow control by deposition (See Figure 4.2.1).

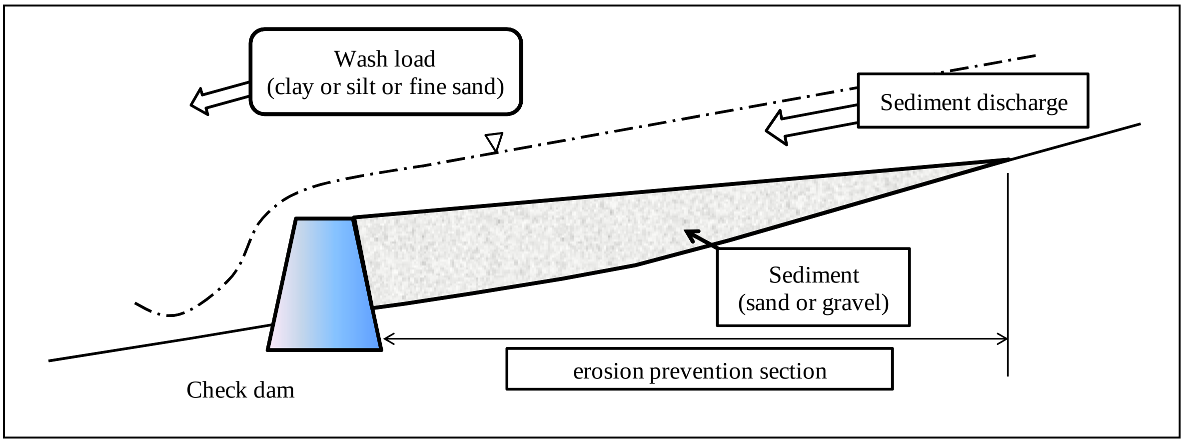


Source: JICA Survey Team

Figure 4.2.1 Functions of Check Dam in Sediment Discharge

The grain size of material trapped in check dam is bigger than clay (or silt or fine sand), and fine materials (clay, silt or fine sand) that flows to downstream section as wash load (See Figure 4.2.2).

In addition, the slit dam requires the maintenance management for the removal of deposits.



Source: JICA Survey Team

Figure 4.2.2 Functions of Check Dam

4.2.2 The Range of Application of the Sabo Facilities

The debris flow is generally subjected to the riverbed gradient (See Figure 4.2.3).

i) The zone where the riverbed gradient is higher than 15 degree (1/4) is prone to have the debris flow occurrence. In other words, the sediment containing much water that occurred in this zone is prone to become the debris flow.

ii) The energy of debris flow is almost maintained on the riverbed which gradient is around 10 degree (1/6).

iii) The energy of debris flow is nearly decayed on the riverbed which gradient is around 3 degree (1/20). The materials contained in flood flow like gravel, cobble and boulders are mostly deposited. The flow in this section is presumed to be “bed load”.

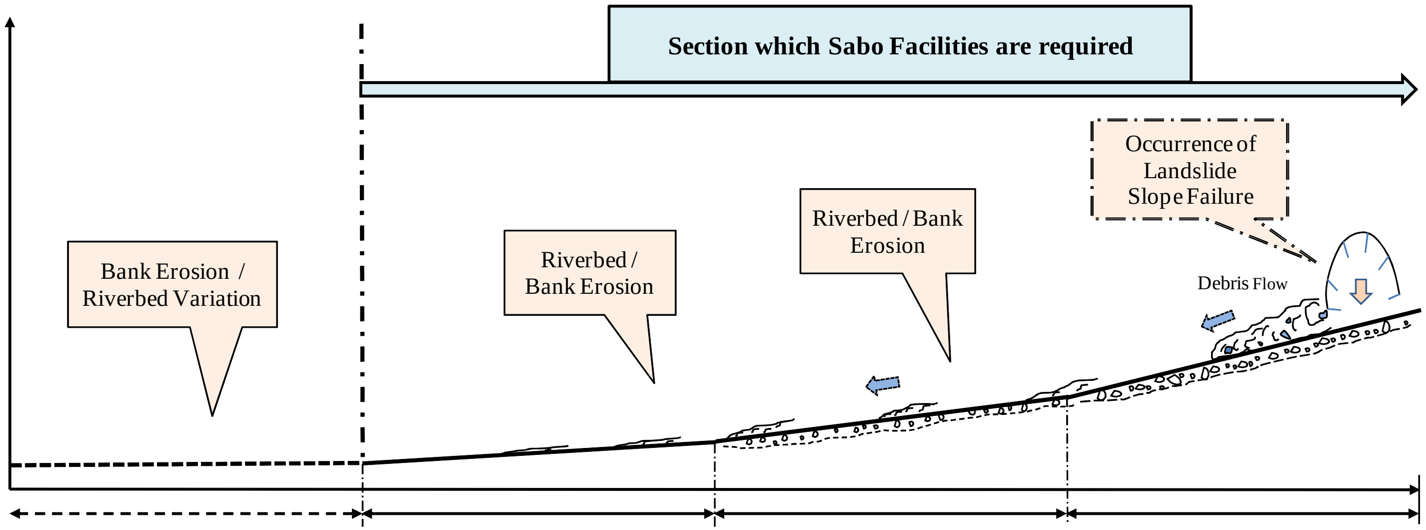
iv) The sediment movement due to “bed load” should be distinguished from those due to debris flow.

Accordingly, the check dams are to be applicable in the range of debris flow from occurrence to deposition.

On the other hand, “wash load” is mostly flows down and not subject to riverbed gradient. As mentioned above, check dams can hardly trap the fine materials.

In case of transportation sediment of the flood containing mostly fine material like “wash load” only, check dams are considered not to be applicable to the control of the transported sediment.

As mentioned above, the marked damages due to driftwoods were not observed in the watershed as a whole. Therefore the countermeasure of driftwoods is outside the Sabo plan.



Riverbed Gradient	θ<1/300-1/200	θ<2-3deg (1/30-1/20)	θ<8-10deg (1/7-1/6)	15deg(1/4)<=θ
Flow Form	Bed Load / Wash Load	Bed Load / Wash Load / (Debris Flow)	Debris Flow	Debris Flow
Debris Flow	(Flood Section)	Deposition Section	Deposition - Flow Section	Occuerrence Section
Material	Fine material, Sand, (Gravel) (Sorting Process)	Fine material, Sand, Gravel, Cobble, Boulder (Sorting Process)	Fine material, Sand, Gravel, Cobble, Boulder (Sorting Process)	Fine material, Sand, Gravel, Cobble, Boulder
Construction Method	Bank, Bank protection	Low Check Dam, Groundsill, Bank, Bank protection	Check Dam, Slit Dam	Check Dam, Slit Dam, Hillside Work

Source: JICA Survey Team

Figure 4.2.3　Zone Division of Debris Flow and Range of Application of the Sabo Facilities (General Illustration)

4.3 Riverbed Gradient and the Characteristic of the Sediment Discharge

As mentioned above, the sediment movement form is related closely to the riverbed gradient. Here, the relationship between the condition of the sediment discharge and riverbed gradient on the investigated river is considered.

4.3.1 Cagayan de Oro River

(1) River longitudinal profile

The riverbed gradient of Cagayan de Oro River is as shown in Figure 4.3.1.

The riverbed gradient from the estuary to the confluence of Bubunawan is 1/457, that to the confluence of Bubunawan and Tumalaong Rivers is 1/199. The Riverbed gradient between the section at 36km and 77km points is 1/94, where Uguiaban Bridge and the Cosina dam are located, respectively.

As shown in the riverbed profile, riverbed slope becomes steep little by little from 77km point, which ranges from 1/41 to 1/6. The zone of debris flow is located in such upstream inland.

(2) Condition of the sediment discharge

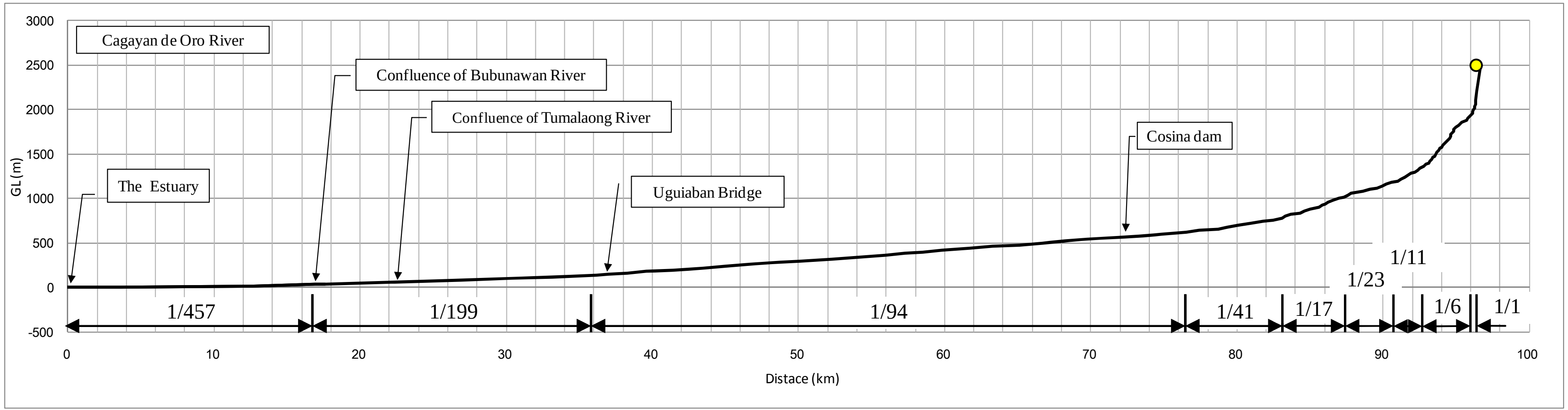
The traces of the debris flow deposits which are the factor of the sediment disaster, namely debris flow deposit, are not observed around the Cosina dam (See Photo 4.3.1 and Figure 4.3.1).

As shown in Figure 4.3.1, the riverbed gradient around the Cosina dam is 1/94, so most debris flow deposits are considered to be already deposited in the upstream area.

The sediment movement form is presumed to be “bed load”.

Source: JICA Survey Team

Photo 4.3.1 No Debris Flow Deposits around Cosina Dam



0km

Estuary (Sand Deposits are observed)

3.7km

Isla De Oro (Flood Deposit is not almost observed)

37.0km

Uguiaban Bridge (Flood Deposit is not almost observed)

72.2km

Cosina dam (Flood Deposit is not almost observed)

Source: JICA Survey Team

Figure 4.3.1 River Longitudinal Profile of Cagayan de Oro River

4.3.2 Bubunawan River

(1) River longitudinal profile

The riverbed gradient of Bubunawan River is as shown in Figure 4.3.2.

The riverbed gradient from the estuary to the CEPALCO Dam is relatively gentle, which ranges from 1/63 to 1/190. In contrast, the riverbed gradient from the CEPALCO Dam towards upstream is relatively steep, which ranges from 1/52 to 1/6. The zone of debris flow is located in such upstream inland.

There is distribution of very hard rock, which is metamorphic rock (Schist) and plutonic rock, at the CEPALCO Dam site. Therefore, in the upstream from the CEPALCO Dam, progression of riverbed erosion is presumed to be relatively slow. This hard rock's has functions as the natural dam.

(2) Condition of the sediment discharge

The trace of the debris flow is not observed in the downstream from Kalasyan causeway (See Photo 4.3.2 and Figure 4.3.2).

As shown in Figure 4.3.2, the riverbed gradient around Kalasyan causeway is 1/33, so most debris flow deposits are considered to be already deposited in the upstream area.

One of the characteristics of the Bubunawan River is the outflow of a large amount of the fine materials from the plateau as shown in the CEPALCO dam.

The fine materials, which are not directly the factor of sediment disaster themselves, are considered to have a influence on the aggradation of riverbed of downstream (See Photo 4.3.3).

Source: JICA Survey Team

Photo 4.3.2 No Debris Flow Deposits around Kalasuyan Causeway

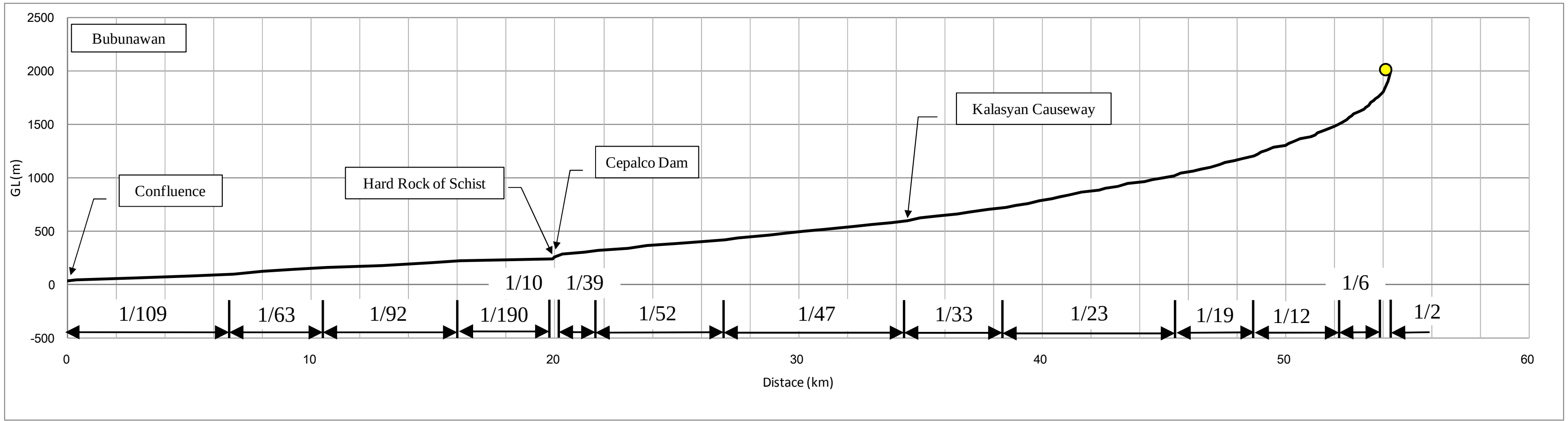
Cultivated Land covered with the Fine Materials

The Mud Flow in the Cultivated Land

The Fine Materials deposited in the CEPALCO

Source: JICA Survey Team

Photo 4.3.3 Outflow of the Fine Materials



0km

Confluence of Bubunawan River

20.0km

CEPALCO Dam (No Debris flow Deposits)

34.5km

Kalasugan causeway (No Debris Flow Deposits)

20.0km

CEPALCO dam (Hard Rock of Schist)

Source: JICA Survey Team

Figure 4.3.2 River Longitudinal Profile of Bubunawan River

4.3.3 Tumalaong River

(1) River longitudinal profile

The riverbed gradient of Tumalaong River is as shown in Figure 4.3.3.

The riverbed gradient from the confluence to 17.5km is 1/63, which is relatively steeper than that of the confluence section of Bubunawan River.

The riverbed gradient from 17.5km to 30km is 1/35, and from 30km to the upstream becomes steep little by little, which ranges from 1/20 to 1/5, where the zone of debris flow is located in upstream inland.

One of the characteristics of Tumalaong River is that the structure of confluence forms tunnel shape which is 10m high and 20m wide (See Photo 4.3.4).

The geology is Limestone in the Pliocene age. The factor which forms the tunnel structure is unknown.

Source: JICA Survey Team

Photo 4.3.4 Tunnel Structure at the Confluence

(2) Condition of the sediment discharge

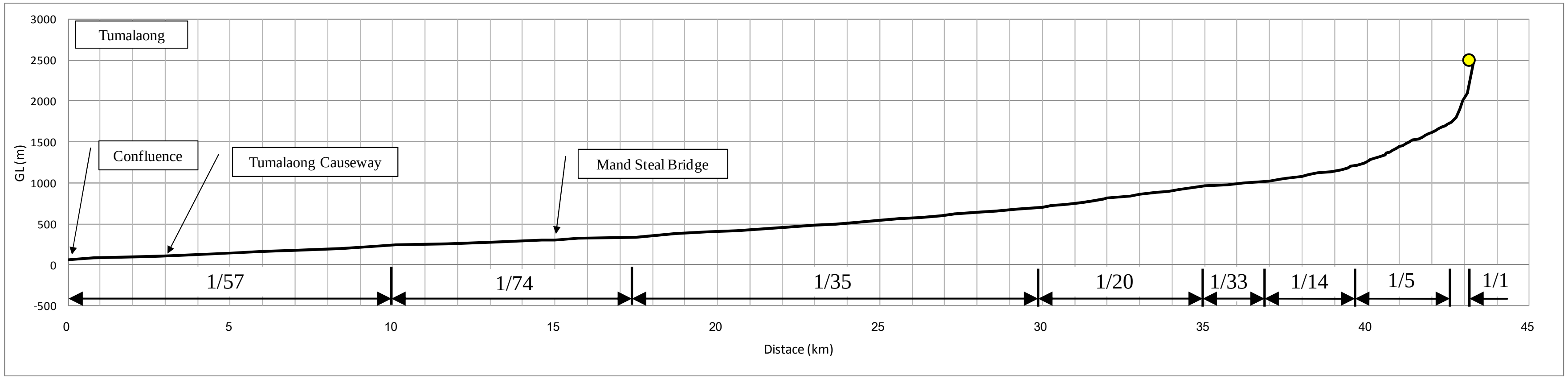
The trace of the debris flow is not observed around the Mand Steel Bridge (See Photo 4.3.5 and Figure 4.3.3).

As shown in Figure 4.3.3, the riverbed gradient around Mand Steel Bridge is 1/74, so most debris flow deposits are considered to be already deposited in the upstream area.

According to the condition of flood deposit in the riverbed, the deposit consists of mainly gravel and cobble. The movement form is presumed to be “bed load”.

Source: JICA Survey Team

Photo 4.3.5 No Debris flow Deposit around Broken Mand Steel Bridge



0km

Confluence of Tumalaong River (Limestone)

3.0km

Tumalaong Causeway (No Debris Flow Deposit)

15.0km

Mand Steel Bridge (No Debris Flow Deposit)

3.0km

Tumalaong Causeway (Riverbed Covered with Gravel)

Source: JICA Survey Team

Figure 4.3.3 River Longitudinal Profile of Tumalaong River

4.3.4 Bitanog River

(1) River longitudinal profile

The riverbed gradient of Bitanog River is as shown in Figure 4.3.4.

The riverbed gradient from the confluence to the starting point of debris flow is the range from 1/50 to 1/17, and the gradient from this point to the upstream inland is in the range from 1/34 to1/45. These gradients are gentler than the deposited gradient (1/20 to 1/30) of debris flow.

(2) Condition of Sediment Discharge

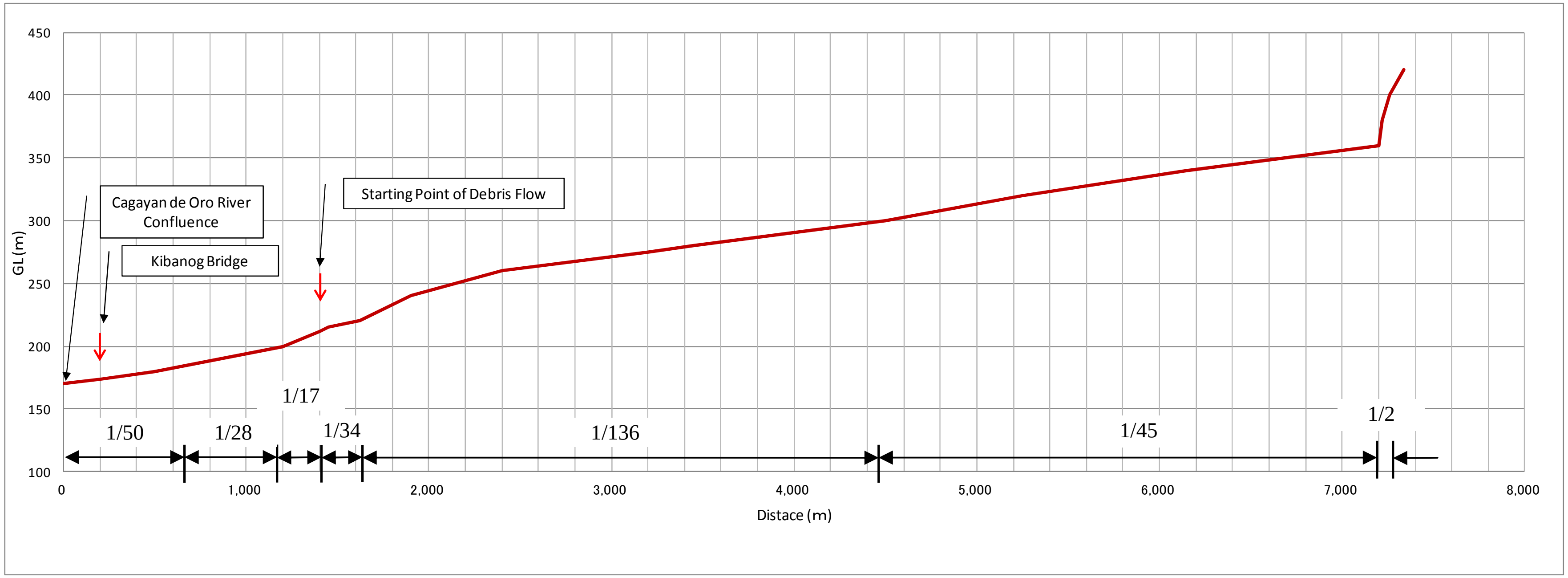
The debris flow has occurred at the gradient which is 1/17.

The debris flow is the outflow of the existing riverbed deposits, and occurred on the gentle gradient. Therefore, the debris flow is considered to have had considerable flood energy.

The debris flow flooded down continuously with bank erosion and slope failure.

The rainfall near this area is observed at Talakag. According to the rainfall data, the daily rainfall, which is 48.8mm, is the rainfall which is not considered to have been caused the debris flow.

Perhaps the local heavy rain is presumed to have been occurred. The debris flow is considered to be occurred in the future depending on the heavy rain.



Condition of Confluence

Condition of Debris Flow

Condition of Debris Flow

Source: JICA Survey Team

Figure 4.3.4 River Longitudinal Profile of Bitanog River

4.4 Sediment Production and Discharge and Disaster Condition

As mentioned above, the characteristics of the sediment production and discharge of the Cagayan de Oro River watershed are summarized as follows:

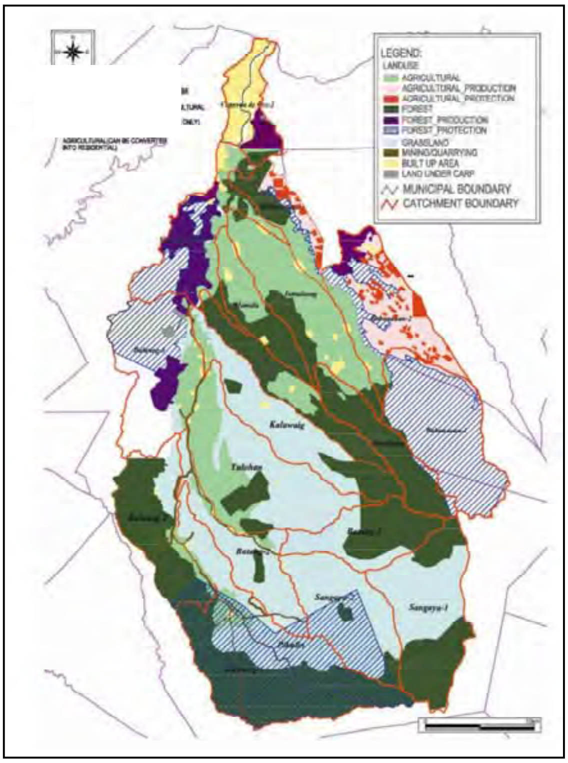
i) According to the results of photographic interpretation, slope failures are almost not observed in this area before and after Sendong. In other words, slope failures due to rainfall on the scale of Sendong rains were presumed to be few in amount.

ii) According to the historical development of landform, the current stage in the volcanic deposit area about the erosion is presumed to be of stable one (See Chapter 9.1). Therefore, these phenomena of few amounts of sediment productions and discharge are in harmony with the current stage about the erosion in the historical development of landform. The sediment which was locally produced by the riverbed fluctuation and the bank erosion is presumed to be flowed smoothly to the downstream as bed load.

iii) The slope failures and debris flow are observed in the tertiary deposit area of the left bank of Cagayan de Oro River which is distributed in the boundary of Iponan River. For this reason, the slope failure characteristics of this area are presumed to be different from those of the volcanic deposit area. But the obvious slope failures are not observed in this area.

iv) Probably the cultivated lands on the plateau are assumed to be the source area of the fine materials (See Figure 4.4.1 and Photo 4.4.1). This issue is considered to be the important sediment management issue.

The above result is summarized as shown in Table 4.4.1.



Source: JICA Survey Team (Left figure)
Master Plan and Feasibility Study of Flood Control and Drainage Projects of Selected River Basins Nationwide, Package 3, Master Plan; P2-23 (DPWH, June 2011) (Right figure)

Photo 4.4.1 Pineapple Field on the Plateau **Figure 4.4.1 Present Land-Use Map**

Table 4.4.1 Condition of Slope Failure and Sediment Discharge

River	Condition of slope failure	Condition of sediment discharge	Condition of disaster	Effect to the downstream
Cagayan de Oro	A little	Sediments transported by bed load Gentle slope more than the zone of debris flow No trace of debris flow	Nothing	Low
Bubunawan	A little	Sediments transported by bed load Gentle slope more than the zone of debris flow No trace of debris flow	Nothing	Low
		Constantly outflow of fine materials	Nothing (Almost carried out every year from the Cepalco dam)	Largish (Aggradation of river bed around the estuary: require study)
Tumalaong	A little	Sediments transported by bed load Gentle slope more than the zone of debris flow No trace of debris flow	Nothing	Low
Bitanog	A little	Debris flow occurred	Embankment of the abutments are flowed out (locally)	Low

Regarding the evaluation criteria for the slope failure and sediment discharge, if the discriminant citeria were set quantitatively, those are able to be described as the following table.

Table 4.4.2 Evaluation Criteria for Slope Failure

Slope failure area ratio(km^2)	Discriminant criteria
Less than 1%	A little
1 to a few %	Middle
A few – 10%	Many

It is said that percentage of areas with slope failure out of the whole watershed area is less than 1% in general as past experiences of the relating survey in Japan. On the other hand, in the mountain area like the Fossa Magna Zone in Japan, which has weak geology and active uplift, the percentage of areas with slope failure is known to be around 10%. In interpretation of an aerial photograph of Cagayan de Oro watershed, the denuded lands by slope failure were not awared, but were able to be seen slightly in local scale Therefore, as for Cagayan de Oro watershed, the discriminant citeria are discriminated as “A little” .

The slope failure deposits is presumed to form a natural dam(namely landslide dam).

In this survey, the definite slope failure and the trace of debris flow were observed in Bitanog river watershed. The piers of Bitanog bridge were visited by this debris flow. However, after debris flow flowed into the main river, debris flow was absorbed by the main river. Therefore, influence on the downstream was judged to be a little.

4.5 Necessity of Check Dam

As mentioned the fundamental requirements (4.1 1.1.1), the necessity of check dam depends on the following two points.

i) An object of preservation exists exactly.
ii) The risk of the sediment disaster is high.

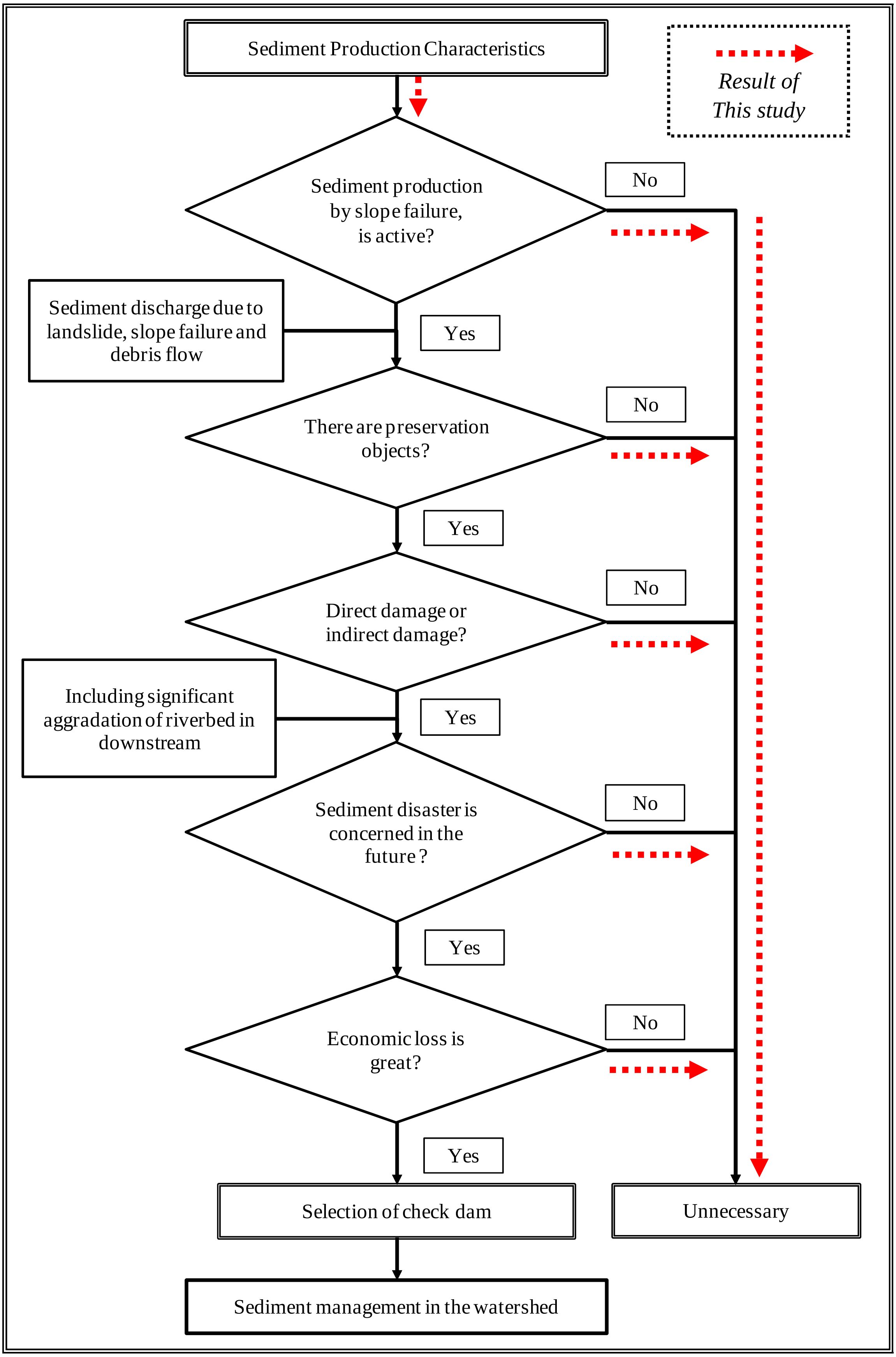
According to the above result, the fundamental requirements of each river are in common as follows.

a) Slope failures are few in amount, and the sediment productivity is not active.
b) There are no objects that obviously need preservation in the upstream and middle reach of the river.
c) The flood disaster was seen, but the sediment disasters were not observed.
d) Including the significant aggradations of riverbed, the risk of sediment disaster is considered to be low in the future.

The selection flow of the necessity of check dams is as shown in Figure 4.5.1.

From the above, the fundamental requirements are not satisfactory against Cagayan de Oro River, Bubunawan River, Tumalaong River and Bitanog River. Consequently the check dams are judged to be no need.

But, the restoration of the abutment of Kibanog Bridge (See Photo 3.20 F,G) is considered to be required the countermeasures that prevent the recurrence of similar disasters.



Source: JICA Survey Team

Figure 4.5.1 Selection Flow of the Necessity of Check Dams

4.6 Issues of Outflow of Fine Material on the Sediment Management

At present, the cultivated lands on the plateau are distributed vastly in the northern part of the Mt. Kitanglad, especially the cultivated lands were planted by pineapple, banana and cone fields etc.

Photos 4.8 to 4.12 are taken in the pineapple fields of Del Monte (4 Nov.2012).

As shown in these photos, the characteristics of outflow of the fine materials are as follows:

i) The surface soil of cultivated lands consists of the brownish soil which contains the fine materials.

ii) The fine materials are presumed to be formed by the weathering of volcanic sediment. Therefore the fine materials consist mainly of clay, silt and sand.

iii) The unlined channels dug on the cultivated land for the prevention of root rot causes conditions that the fine materials tend to easily flow out.

iv) As shown in Photo 4.6.4, the sandbags were arranged in the part of channel for the sake of erosion prevention. But, the fine materials have accumulated through the many channels.

v) The fine materials flows constantly even in fine weather period. The river water in the downstream looks murky due to accumulation of the fine materials.

As mentioned above, the condition of the fine materials in fine weather period is in harmony with the condition of the right tributary in the upstream of the CEPALCO dam. The sediment discharge which contains the fine materials is presumed to increase in volume during rainy period.

The fine materials (wash load) will be mostly deposited around the estuary, which can cause not only riverbed aggradation but also impact to the sea's ecosystem.

Photo 4.6.1 The Vast Cultivated Land (Pineapple Fields of Del Monte Philippines)
Channels and Maintenance Roads are spread in a Matrix-like

Photo 4.6.2 Unlined Side Ditch along the Road Outflow
of the fine materials are observed in the Ditch

Photo 4.6.4 Channel entrenched in the Field
(width : about 40cm)
Upper: The Sandbags are put in the Channel
for the sake of Erosion Prevention
Lower (right): Trace of Outflow
Lower (left): Water contains Fine Materials

Photo 4.6.3 Retaining Wall and Drainage Culvert Deposit
of Fine Materials is observed

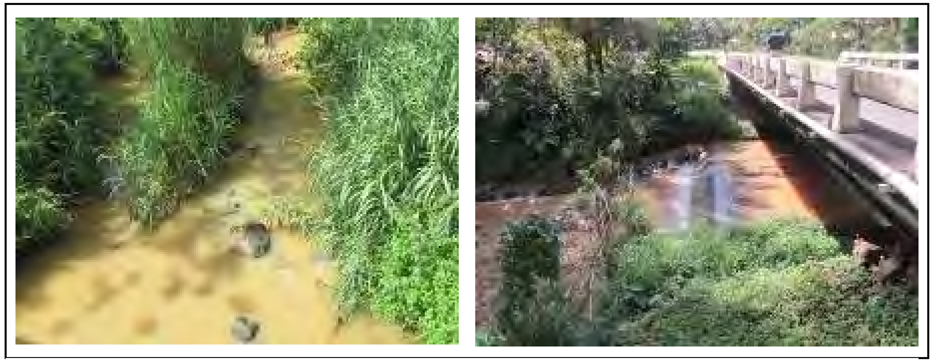


Photo 4.6.5 Cloudy River water
River water in the downstream is much cloudy
due to accumulation of the fine materials.

Source: JICA Survey Team

Supporting Report
Appendix F
Study for River Boundary

PREPARATORY SURVEY
FOR
FLOOD RISK MANAGEMENT PROJECT
FOR
CAGAYAN DE ORO RIVER (FRIMP-CDOR)
IN
THE REPUBLIC OF THE PHILIPPINES

FINAL REPORT

VOLUME III SUPPORTING REPORT (I)

Appendix F
STUDY FOR RIVER BOUDARY

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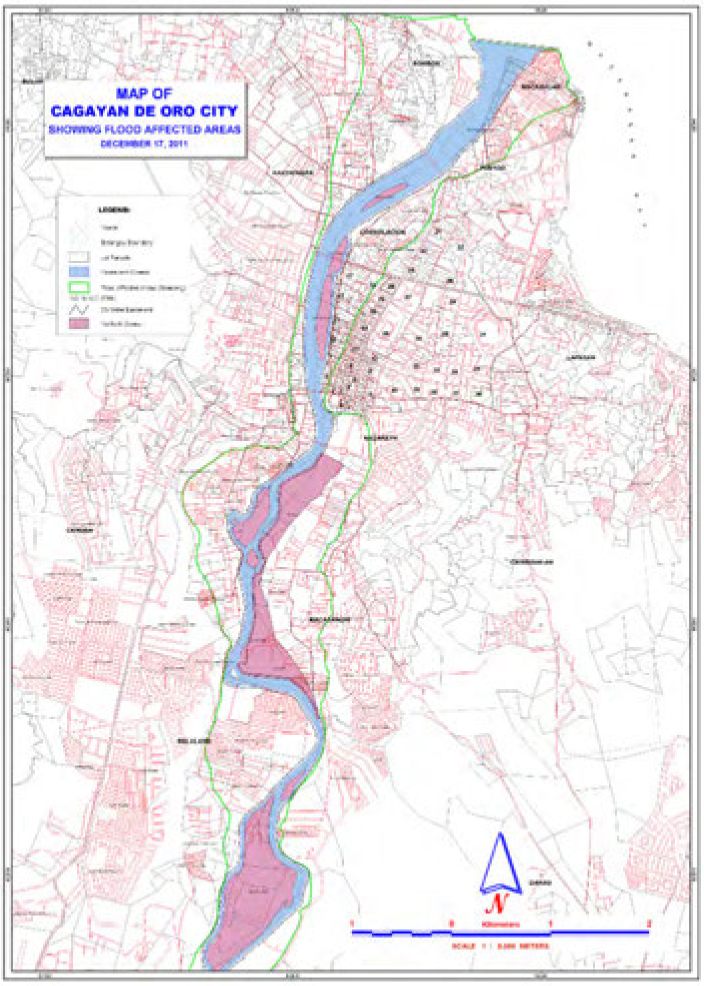
CHAPTER 1 ESTABLISHMENT OF RIVER BOUNDARY (TASK 1-22)

1.1 Present Condition

The previous Master Plan proposed the construction of the dike along the river bank of the Cagayan de Oro River. Residential areas in flood plains were designed to be protected with dike. However, the extraordinary flood brought by Tropical Storm Sendong struck the said flood plain, resulting in a lot of loss of lives and their houses therein. It reminded us that it is too risky to establish residential areas on the flood plains near the river.

At present, the governments are undertaking resettlement activities for the victims in the area and preparing laws, guidelines and comprehensive land use plans to establish the river boundary along the Cagayan de Oro River. The policy is to protect from living and reconstruction of houses in highly flood prone areas to prevent recurrence of such a calamity as TS Sendong. The City Government and DENR is preparing a map showing Non-Build Zone which was identified at seven (7) areas in or adjacent the river in the 11.6 km long section from the river mouth to the Pelaez Bridge. These non-build zones are strictly managed to prohibit resettlement.



Source : City Planning and Development Division, Cagayan de Oro CIty

Figure 1.1.1 No Build Zone in Cagayan de Oro River

1.2 Basic Approach

1.2.1 Objective of Establishment of River Boundary

Objective of establishment of the river boundary along the Cagayan de Oro River is:

to establish river alignment for clear demarcation of flood control area and easement.

Upon definition of the river boundary, it will contribute to prevent recurrence of calamity such as TS Sendong by:

i) securing required land to flow down flood water safely,
ii) protection from living and reconstruction of houses in highly flood prone areas,
iii) control land use and development in river area not to obstruct flow of flood water, and
iv) securing necessary construction area for river structures (dike embankment, flood plain, revetment, sluice gate, etc).

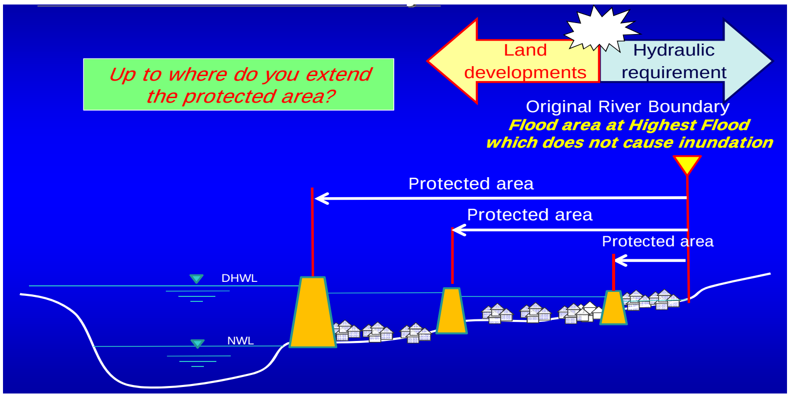
This policy will mitigate flood risks, loss of human lives and damages on properties, buildings and infrastructures over the flood prone area, and contribute for regional developments and economic growth of the LGUs, and peace and safe of residents living adjacent to the river.

1.2.2 Issues for Definition of River Boundary in Cagayan de Oro River

(1) Conflict between land development and requirements for flood control area

In general, there are wider and flat areas along river bank formulated with delta and river terrace in lower reach of river channel. In this area, land development potential is relatively high because of availability of wide and flat areas, convenience for the access to water area.

On the other hand, this area is flood prone area where flood water used to be inundated and seriously damaged during heavy rainfall. As shown in the figure below, the land development is implemented to go to a direction to make river area narrower while the flood control works is conducted to make river area wider. For example, if a dike can be constructed nearby low water channel, protected area by the dike is increased, but flood risk would increase due to raising of flood water level. There is a conflict between the land development and flood control work, therefore it is one of key issue to establish the river boundary taking the balance for both aspects.



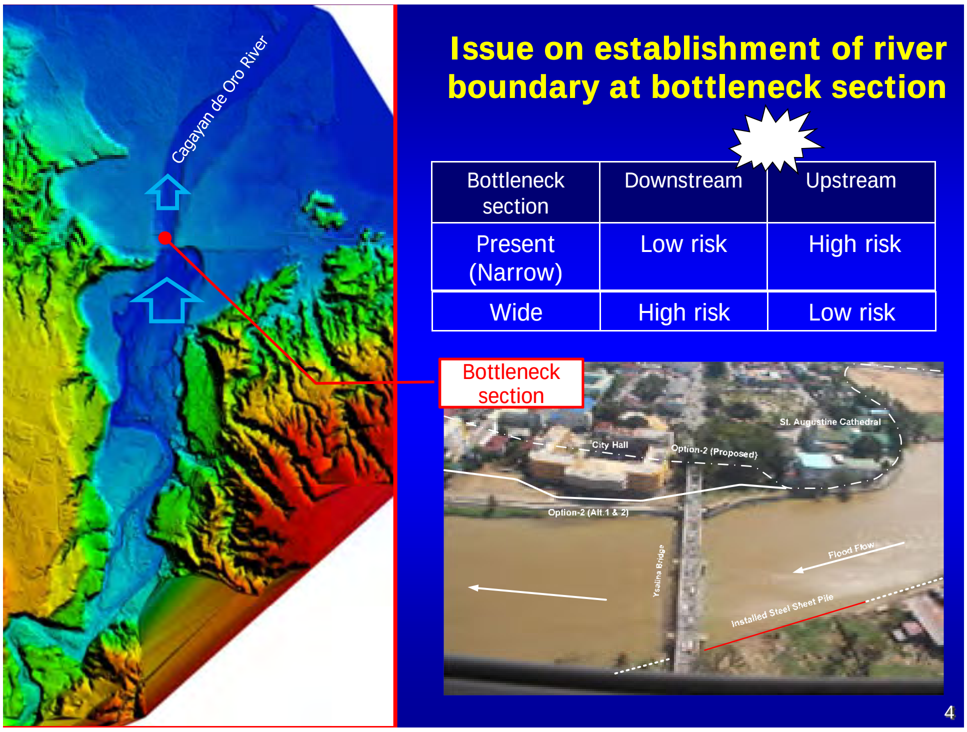
Source: The Survey Team

Figure 1.2.1 Conflict between Land Development and Flood Mitigation Works on Establishment of River Boundary

(2) Issue on Establishment of River Boundary at Bottleneck Section

At 4.1 km upstream from the river mouth of the Cagayan de Oro River, there is a bottleneck section where the river width is the narrowest in the stretch. The bottleneck section is deemed working as a small dam by which flood water is stored in the upstream, and the flood discharge to the downstream is regulated.

In case of establishment of the river boundary at the bottleneck section, as presented in the figure below, if the bottleneck is kept as it is or to be narrower the flood risk in the upstream will be higher due to backwater effect while that in the downstream will be lower. On the other hand, if the bottleneck section is widen the flood risk in the upstream will be lower while the potential risk in the downstream would be increased due to removal of bottleneck effect of the natural dam. It is noted that the setting of river boundary at bottleneck section is closely related to the hydraulic conditions in upstream and downstream of the section.



Source: The Survey Team

Figure 1.2.2 Issue on establishment of River Boundary at Bottleneck Section

1.2.3 Basic Approach to Establishment of River Boundary

In this Survey, river boundary is being studied taking into account present topographic conditions, existing cadastral map, highly flood prone area identified by flood risk assessment, and proposed design for flood risk management. The establishment of river boundary is including very sensitive issues as mentioned above it is being defined in consultation with agencies concerned such as the Government of Cagayan de Oro City, DPWH and DENR-RBCO.

Acts and regulations related to the river boundary, land use plan, and case study of other river boundary in the Philippines were collected and reviewed through discussion with legal section of concerned agencies regarding legal validity of the proposed river boundary as mentioned in Chapter 3.8 in Draft Final Report.

1.3 Definition of River Boundary

The river area and river boundary was not clearly identified in the previous Master Plan. In this Survey, it is defined on the basis of the Water Code of the Philippines (PD1067). Illustration for the river boundary together with the example of the regulation under GOJ is presented in Table 1.3.1.

According to the Water Code, the definition of the River Area is;

"the banks or rivers reckoned from the line reached by the highest flood which does not cause inundation or the highest equinoctial tide whichever is higher."

As mentioned above, in the Water Code of the Philippines, "the line reached by the highest flood which does not cause inundation" is determined as the boundary between river area and easement. It is, however, unclearly mentioned what is "the highest flood", for example, if it means design flood or recorded maximum flood, and what is the concrete definition of "inundation" i.e. ranges of inundation depth, inundation area, or flow velocity over the area. In the River Law of Japan, the river area is defined including bank embankment. River conservation area is established along outer side of the river area. The river conservation area has similar function of easement in the Philippine to prevent from any activities that obstruct management and stability of river structures nearby the area. The width of the river conservation area in Japan is defined depending on the site conditions different from the Water Code in the Philippines that clearly identifies the width of the easement.

Table 1.3.1 Definition of River Area in the Philippines and Japan

<table>
<tr>
<td>
(1) Presidential Decree 1067 (Water Code of the Philippines)
Article 5. Rivers and their natural beds belong to the state.
Article 51. The banks or rivers and streams and the shores of the sea and lakes throughout their entire length and within a zone of three (3) meters in urban areas, twenty (20) meters in agricultural areas and forty (40) meters in forest areas, along their margins, are subject to the easement of public use in the interest of recreation, navigation, floatage, fishing and salvage. No person shall be allowed to stay in this zone longer than what is necessary for recreation, navigation, floatage, fishing or salvage or to build structures of any kind.
Amended Implementing Rules and Regulations Section 31 Determination of Easements -For purposes of Article 51 of the Code, all easements of public use prescribed for the banks or rivers and the shores of seas and lakes shall be reckoned from the line reached by the highest flood which does not cause inundation or the highest equinoctial tide whichever is higher.
Any construction or structure that encroaches into such easement shall be ordered removed or cause to be removed by the Board in coordination with DPWH, LGU or appropriate government agency
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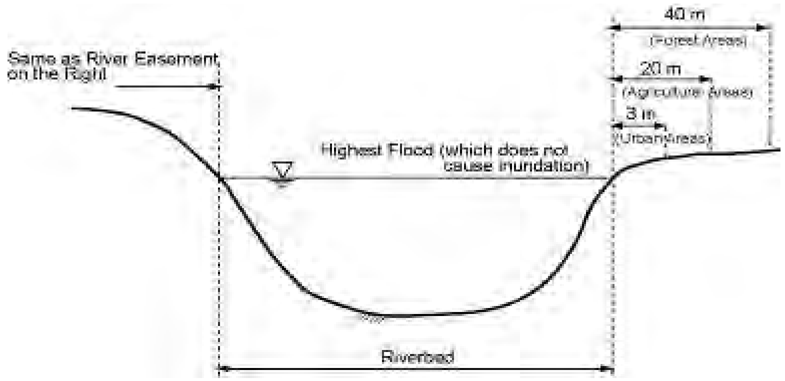

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<tr>
<td>
(2) Boundary of River Area in Japan
River Law in Japan
- River Area = Inside dike with low water channel + Dikes
- River Conservation Area = outside dike (for maintenance of river bank and river structures ≦50m)
</td>
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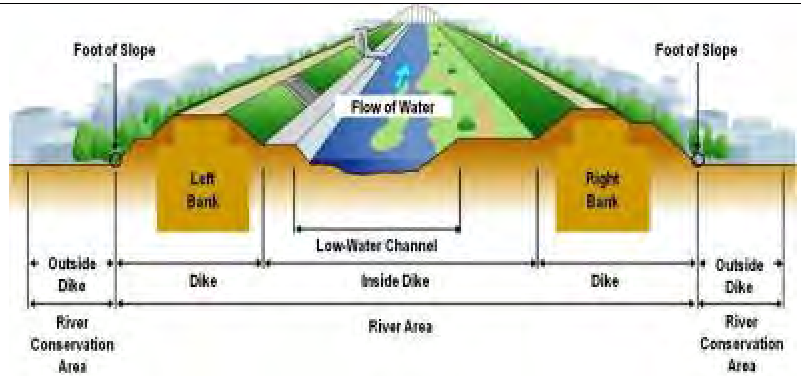

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1.4 Preliminary Study for River Boundary

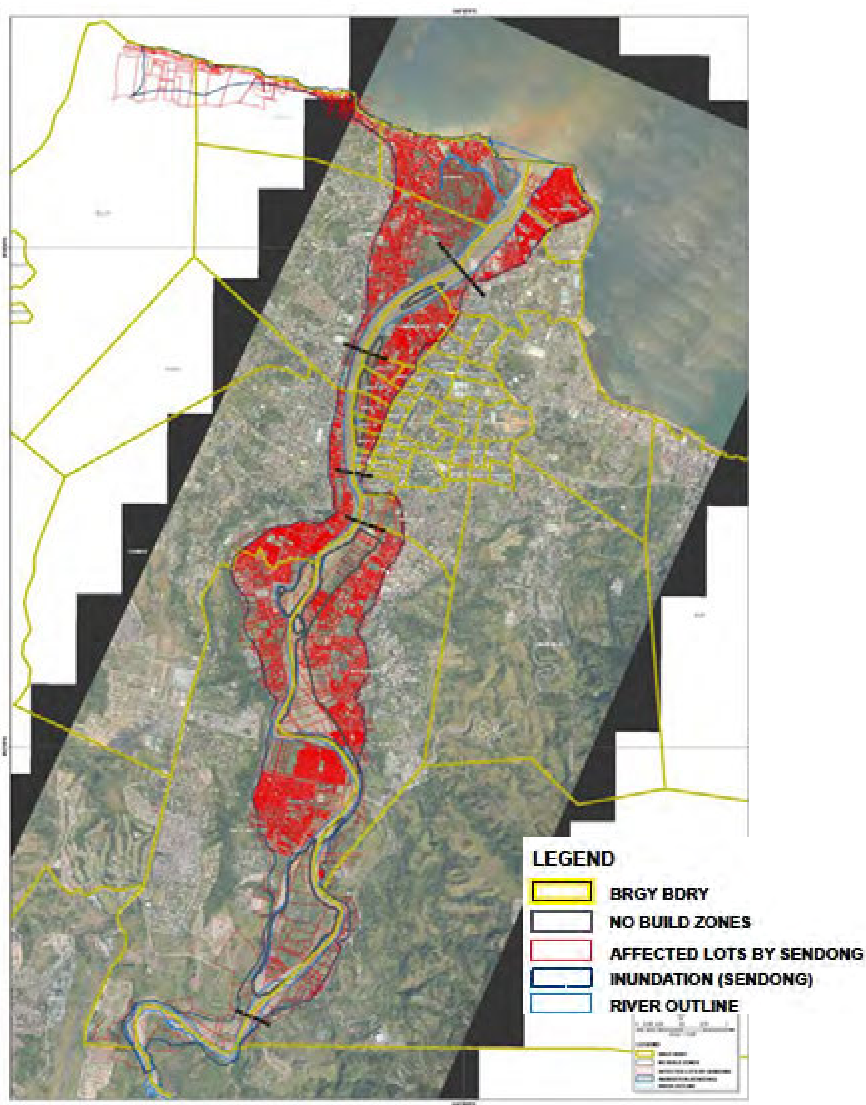
1.4.1 Previous Master Plan Study

In the previous Master Plan, the dike alignment was set along the existing river bank to minimize the number of resettlement of residents affected under the conditions before Sendong. Isla de Oro and Calacala were identified as protected area from flood.

However, the extraordinary flood brought by TS Sendong struck the said flood plain, resulting in a lot of loss of lives and their houses therein. If this dike alignment is adopted, it will reduce flow capacity and increase flood risk significantly. The previous plan should be reviewed and updated based on the lesson learnt from the calamity of Sendong.

1.4.2 Existing Cadastral Boundary

The area between the existing cadastral boundaries on the river banks of the Cagayan de Oro River is owned by the Government as "River Area". This area is the original river area and basically fits to the river course of 1950' shown in the old NAMRIA map.



Source: City Planning and Development Office, NAMRIA,

Figure 1.4.1 Cadastral Map of Lower Cagayan de Oro River

1.4.3 Present Government Policy for Land Use along the River

The highly flood prone areas such as flood plains, sand bars along the bank, and small islands in the channel should be defined as river area. The non-build zone declared by the President is basically located over the area where seriously damaged with deep inundation during the Sendong (Figure 1.4.2). The area is currently prohibited for living and construction of houses.

1.4.4 River Morphology

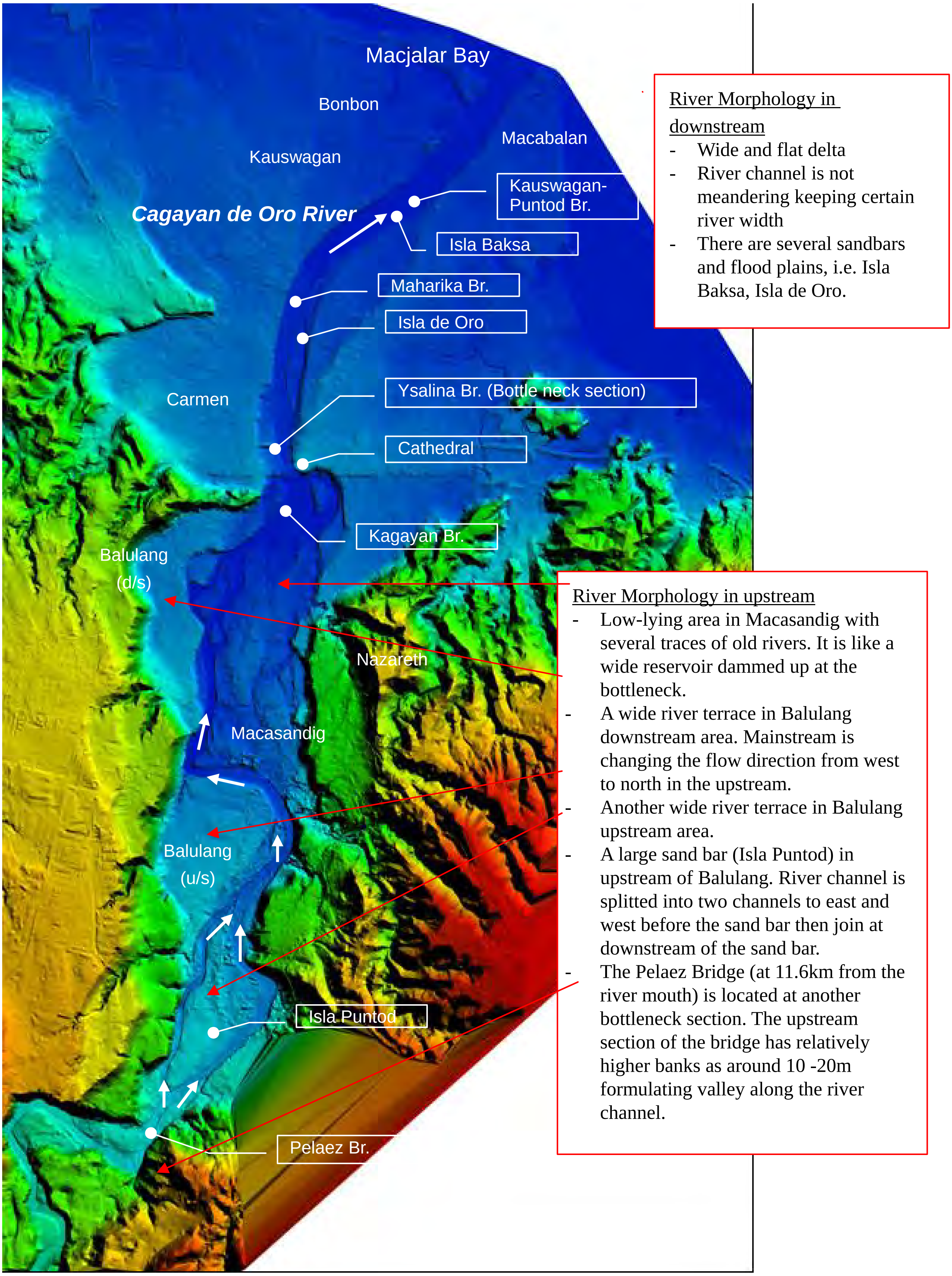
Figure 1.2.1 in previous sub section shows the digital elevation model (DEM) of the downstream of the Cagayan de Oro River generated from the result of airborne survey in 1998. The river morphology in this area is segmented into two areas by the bottleneck section between an elevated land where the Cathedral is located and a ridge like peninsula on the opposite bank of it.

<u>downstream of bottleneck section</u>

- Wide and flat delta is spread in the downstream of the bottleneck section
- River channel is not meandering and keeps a certain river width
- In the downstream of the Ysalina Bridg at 4.1 km from the river mouth, river flow curve toward east formulating a wide flood plain on the right bank (Isla de Oro)
- In the upstream of the Kauswagan Puntod Bridge at 1.8 km from the river mouth, there is a huge sandbar in the middle of channel (Isla Baksa)

<u>upstream of bottleneck section</u>

- River morphology in the upstream of the bottleneck section is like a wide reservoir dammed up at the bottleneck
- In Macasandig area along the right bank from 4.1 km to 6.1 km, natural ground level is low and low-lying area is spread out with several traces of old rivers.
- In Balulang downstream area along the left bank from 4.1 km to 5.3 km, there is a wide river terrace. The mainstream of river hits at the upstream of an elevated portion of this area (hard point), then changing the flow direction from west to north
- In Balulang upstream area along the left bank from 5.8 km to 8.0 km, there is another wide river terrace. In this area mainstream is flowing eastern side.
- In the upstream of the Balulang area, the river channel is splitted into two channels to east and west, and between these channels there is a large sand bar (Isla Puntod). At present, the inlet portion of the western channel is clogged by embankment to protect from entering the flood water into a residential area. After confluence of two channels, mainstream hits an elevated point in Macasandig then changes the flow direction from north to west.
- The Pelaez Bridge (at 11.6km from the river mouth) is located at another bottleneck section. The upstream section of the bridge has relatively higher banks as around 10 -20m formulating valley along the river channel.



Source: The Survey Team (elevation data is derived from 1998 aerial photos taken by F.F. Cruze)

Figure 1.4.2 Topography of Lower Cagayan de Oro River (DEM)

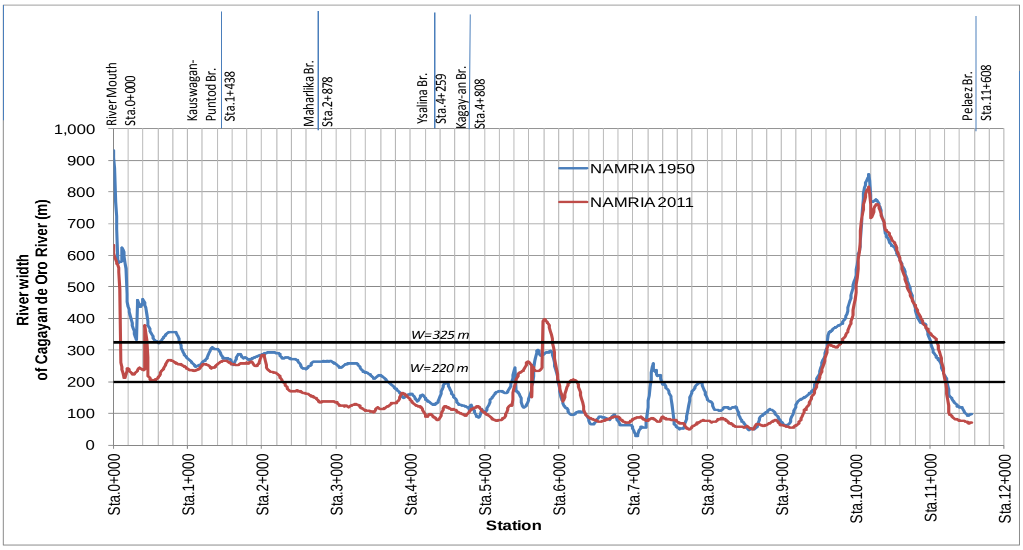
1.4.5 Historical Change of River Alignment

Historical change of river alignment is assessed based on i) topographic map of NAMRIA prepared in 1950's, ii) topographic map (1/50,000) prepared under "Topographic Mapping Project for Peace and Development in Mindanao (JICA 2011)", and iii) aerial photo taken in this Survey. The historical change of river width is presented in Figure 1.4.4 and historical change of river alignment is shown in Figures 1.4.4 and 1.4.5.

The characteristics of historical change of the Cgayan de Oro River are summarized as below:

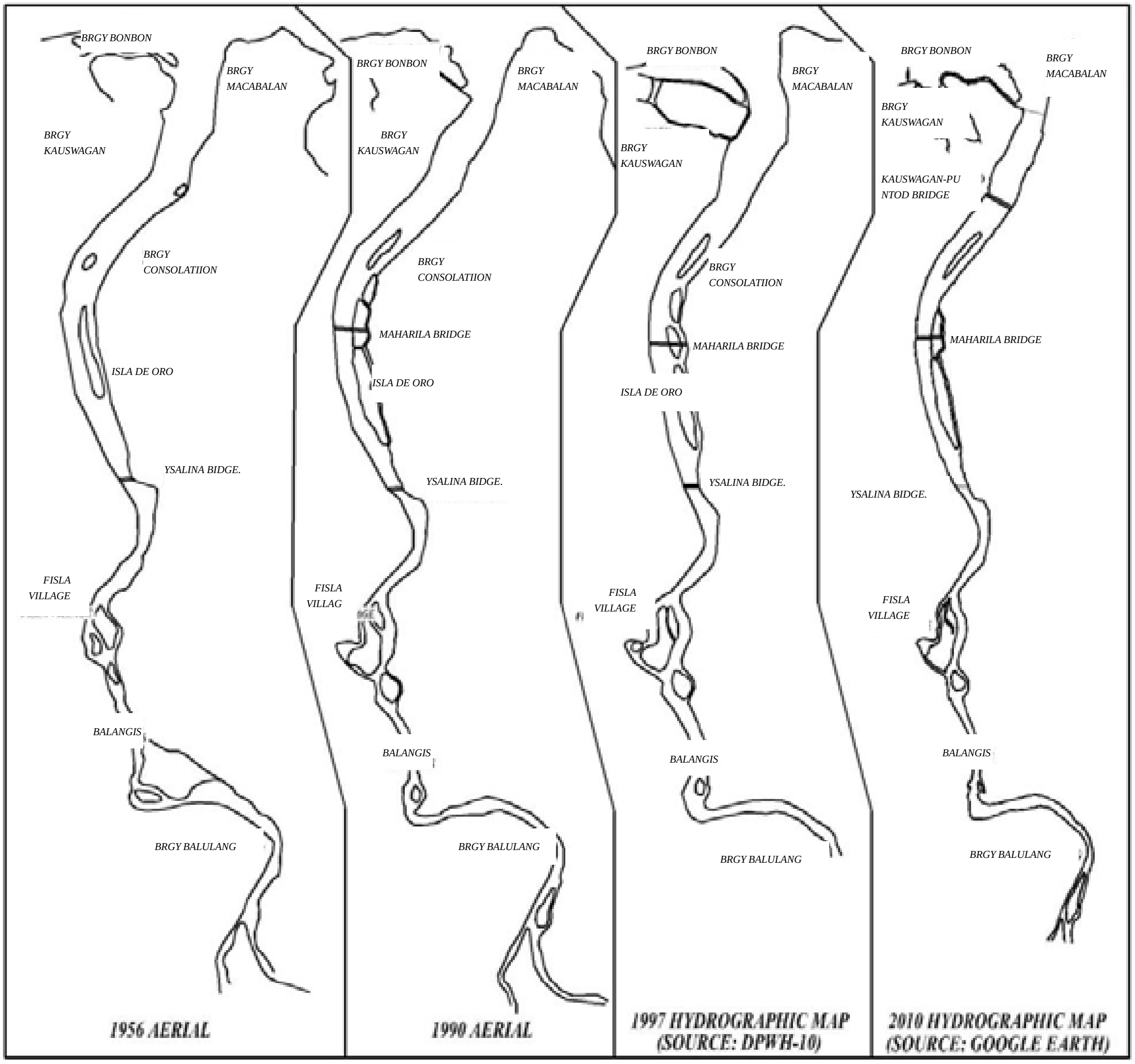
- Relatively stable river alignment for past 60 years
- Development of a sandbar in the upstream of the Kauswagan-Puntod Bridge from 1950 to 2011, but it was eroded at the upstream portion between 2011 and 2012 due to Sendong and Pablo
- Development of a sandbar in the downstream of the Maharika Bridge (Isla delta)
- Historical change of Isla de Oro from a sandbar in the channel to flood plain
- Fixed of river channel at bottleneck at Ysalina Bridge
- Existence of old river in Macasandig
- Development of riverbank erosions at the downstream of Macasandig due to split of river channel
- Movement of front line of banks at river mouth to the downstream

The figure below shows comparison of river width between 1950 and 2011. Previously river channel in the downstream of Kauswagan Bridge (Sta.0+000 – Sta.1+000) and in the Isla de Oro section (Sta.2+000-Sta.4+000) was wider than the present by around 50-100 m. It deems to be affected by developments of sand bars referring to the aerial photo in Figure 1.4.5. The river section between Ysalina Bridge and Kagayan Bridge is also getting narrower.



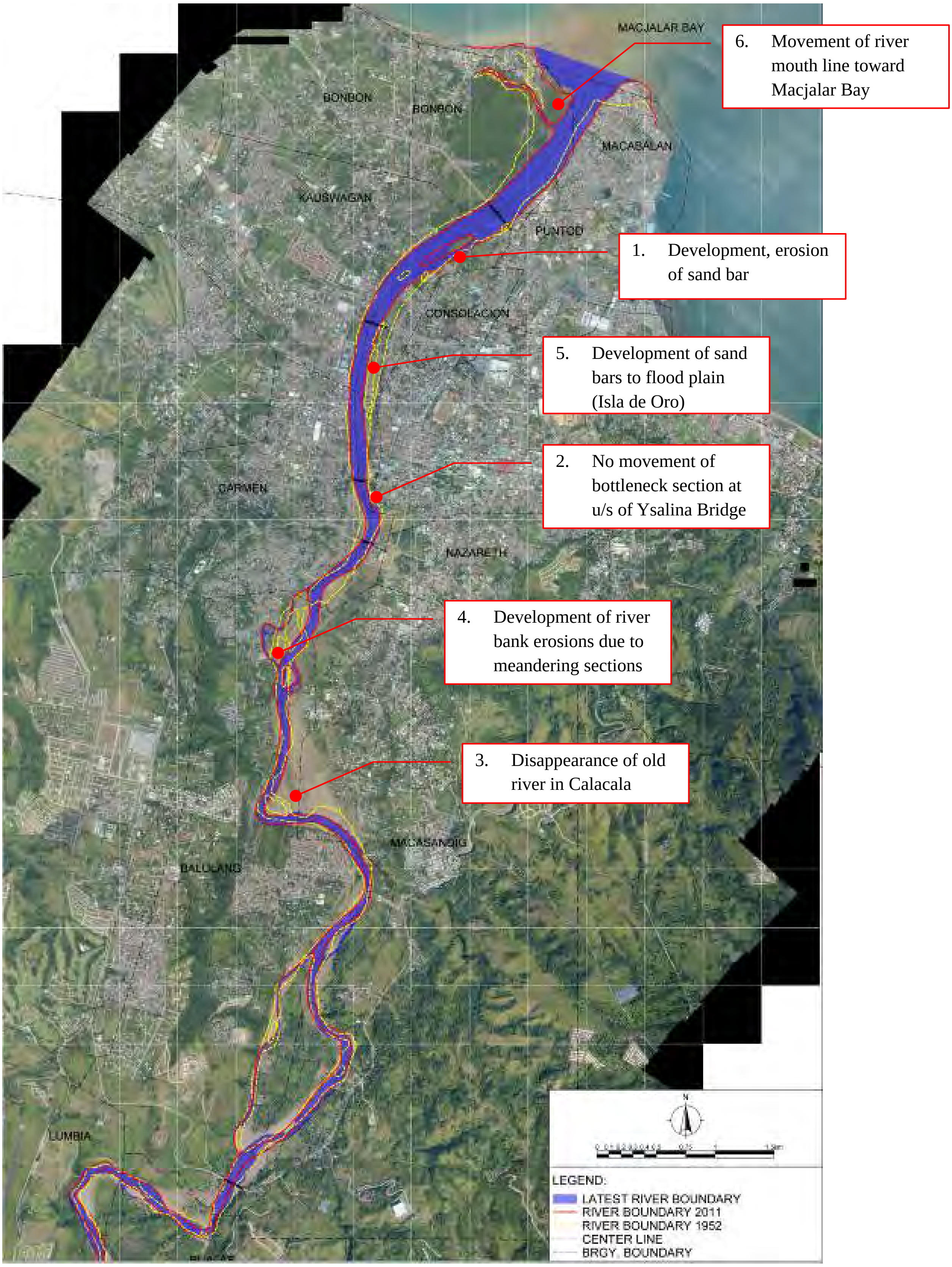
Note: River width of each year is measured based on Figure 1.4.4.
Source: The Survey Team

Figure 1.4.3 Historical Changes of River Width of the Cagayan de Oro River



Source: M/P 2011

Figure 1.4.4 Historical Changes of River Course of the Cagayan de Oro River



Source: The Survey Team

Figure 1.4.5 Historical Changes of River Course of the Cagayan de Oro River from 1952 to 2012

1.4.6 Historical Change of River Bottleneck Section

As described above, there is a bottleneck section at 4.1 km upstream from the river mouth of the Cagayan de Oro River. The existing Ysalina Bridge was constructed crossing the bottleneck section in 1950's. The photos below show old photos taken at the time of construction of the Ysalina Bridge. It was said that there was a pedestrian bridge previously but frequently washed away during floods.

Photo 1.4.1 Old Pictures of Ysalina Bridge and Cathedral

(source: DPWH Region X and Xavier University)

At present, the river channel in this section is getting narrower as below:

i) River width at this section between natural banks is around 300 m based on the topographic map

ii) The length of Ysalina Bridge between abutments is about 200 m. This is because the approach road of left abutment on left bank is embankment.

iii) Alignment of revetment in front of the Committee of Audit (COA) building is located at around 30 m encroaching river side from the left abutment as well as the opposite bank where the City Hall building was extended to the river side recently and the slope protection works with promenade was partially constructed under “the Golden Mile Project” by the City government in late 2000’s. The revetment in front of the extended portion of the City Hall is located at the same position of the first pier of the Ysalina Bridge around 40 m encroaching river side from the right abutment. The river width at low water channel is around 120m.

iv) At present, rehabilitation of damaged revetments by the TS Sendong is undertaking in the immediately upstream of left bank of the Ysalin Bridge. Steel sheet piles of about 100m long were already drive for foundation of the dike. If new dike will be constructed at this section the river width will be made narrower up to 90 m artificially.

The potential flood risk in the upstream is increased due to narrowing the river channel.

Note: i) Bridge length between abutments
ii) River width of low water channel at present (between Piers No.1 and No.3)
iii) The narrowest river section upstream of Ysalina Bridge

Photo 1.4.2 Present Condition of Bottleneck Section at Ysalina Bridge

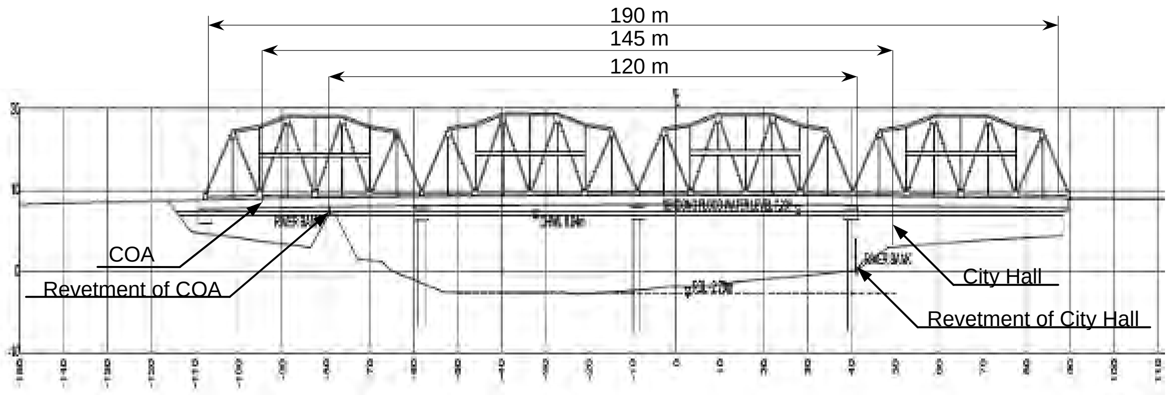


Figure 1.4.6 Cross Section of Bottleneck Section at Ysalina Bridge

The photo below shows an aerial photo in the upstream and downstream of the Kagayan Bridge located at about 500 m upstream of the Ysalina Bridge. There was an old river at upstream of the Cathedral, but it was backfilled. Instead of it, a waterway for local drainage is installed.

In the right upstream of the Kagayan Bridge, a new hotel with shopping mall is under construction at present. As explained previously, this area is located at natural flood plain and repeatedly inundated during Sendon and Pablo. It is noted that future land use in this area and the surrounding areas as well as strengthen of the structural durability of the building and evacuation in case of flood should be considered with close consultation with the owner of the property and LGUs.

The approach road of left abutment of the Kagayan Bridge is embankment type as same as the Ysalina Bridge. This embanked approach road has a function like a spur dike to block the original course of the main water way.

Photo 1.4.3 Present River Condition upstream of Bottleneck Section

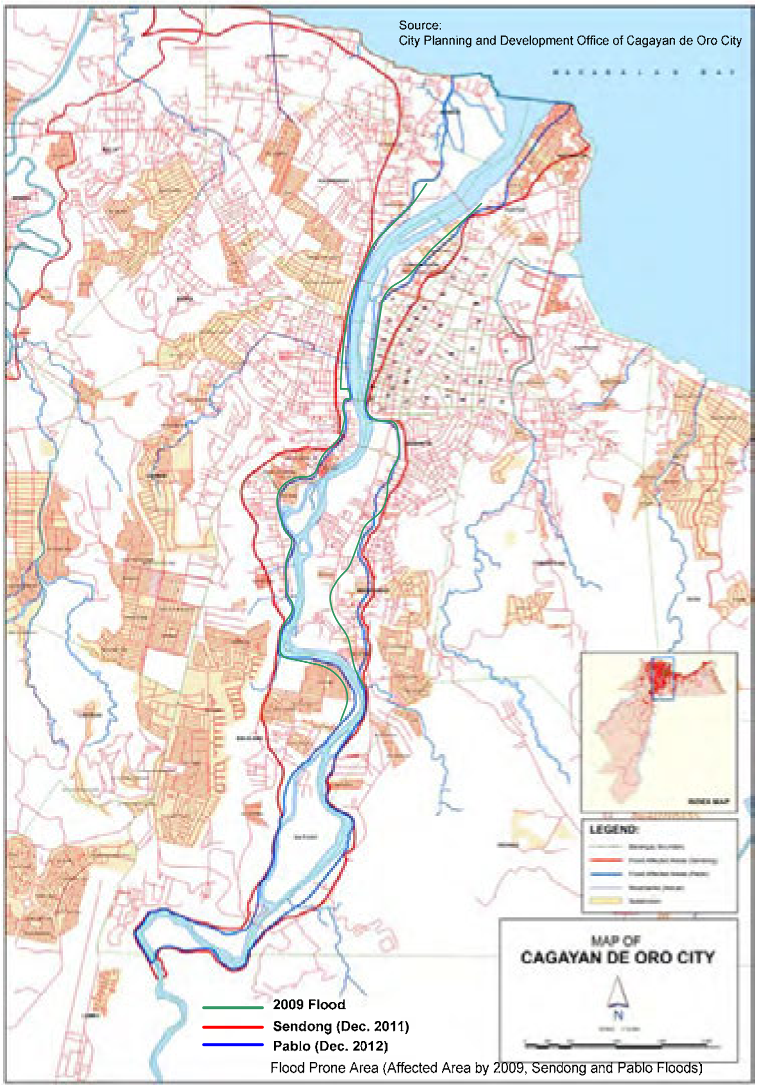
1.5 Assessment of High Flood Risk Area

1.5.1 Inundation Area of Previous Floods

Recently, monsoon flood in January 2009, TS Sendong in December 2011 and TY Pablo in December 2012 are repeatedly hit the lower Cagayan de Oro River resulting tremendous damage in the inundation area. The inundation map of these floods is presented below.

The floods in 2009 and Pablo in 2012 are evaluated at almost same magnitude as 20-year return period showing similar inundation area. The flood of Sendong in 2011 is evaluated at 50-60 –year flood and inundation area was spread out wider up to the whole area over the river terraces in Balulan in the upstream and to the downtown area located at the back of Isla de Oro in the downstream.

The areas with hattching in the figure are flood prone area affected by the above three floods. The extent of flood prone area is wider than the identified areas of Non-Build Zone as mentioned in 1.4, and many people still live in this area.



Source: City Planning and Development Office

Figure 1.5.1 Inundation Map in Cagayan de Oro River in 2009, 2011 and 2012

1.5.2 Assessment for Flood Risk Level

As mentioned above, the flood prone area is widely spread out along the Cagayan de Oro River. Upon setting the river boundary, it should be considered the difference of flood risk level by location such as frequency of flooding, for example, whether the location is inundated every year, or 5-year, or 10-25 year. In addition, the flood risk level is also depending on inundation depth, inundation period and flow velocity.

Taking into account the above, a standard criteria is necessary to assess the flood risk level in the wider inundation area.

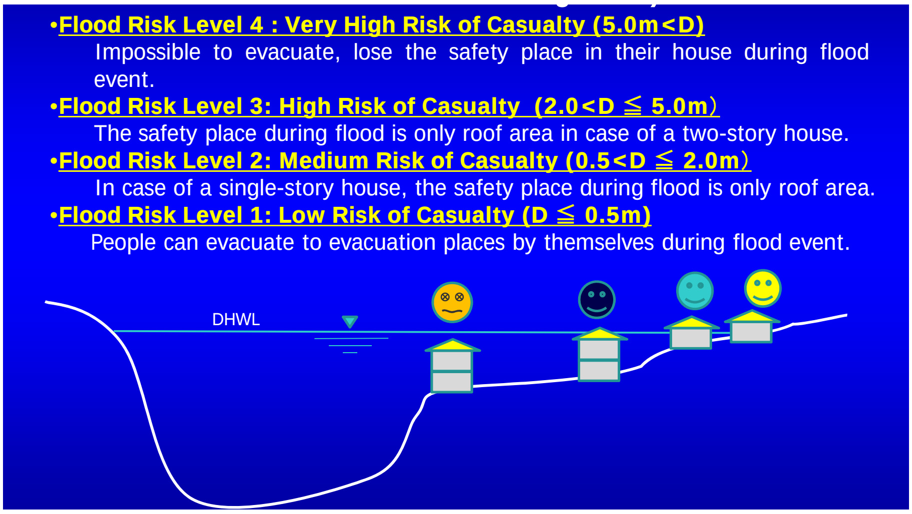
The flood in the Cagayan de Oro River has characteristic of flash flood which cause rapid raising of water level in the waterway and faster flow velocity in the inundation area. This kind of flash flood tends to extend the damage on structures and loss of human lives. In consideration of the said characteristic of floods, an evaluation criteria focusing onto evacuation of residents at the time of flooding is applied. In this study, an approach adapted in the World Bank Study[1] is referred to assess the flood risk level as presented in the figure below:

i) Flood Risk Level 4:
Serious flooding area with inundation depth more than 5.0 m. In this case people are very difficult to evacuate to any safety places even in second story houses.

ii) Flood Risk Level 3:
Flooding area with inundation depth from 2 to5 m in which people can evacuate onto the roof of second story house.

iii) Flood Risk Level 2:
Flooding area with inundation depth from 0.5 to2 m in which people can evacuate onto the roof of single- story house.

iv) Flood Risk Level 1:
Flooding area with inundation depth less than 0.5 m in which people can evacuate to evacuation places by themselves during flood event.



Note: Criteria for assessment of flood risk level is referring to the World Bank Study "Flood Management Master Plan for Metro Manila and Surrounding Areas" (2012)

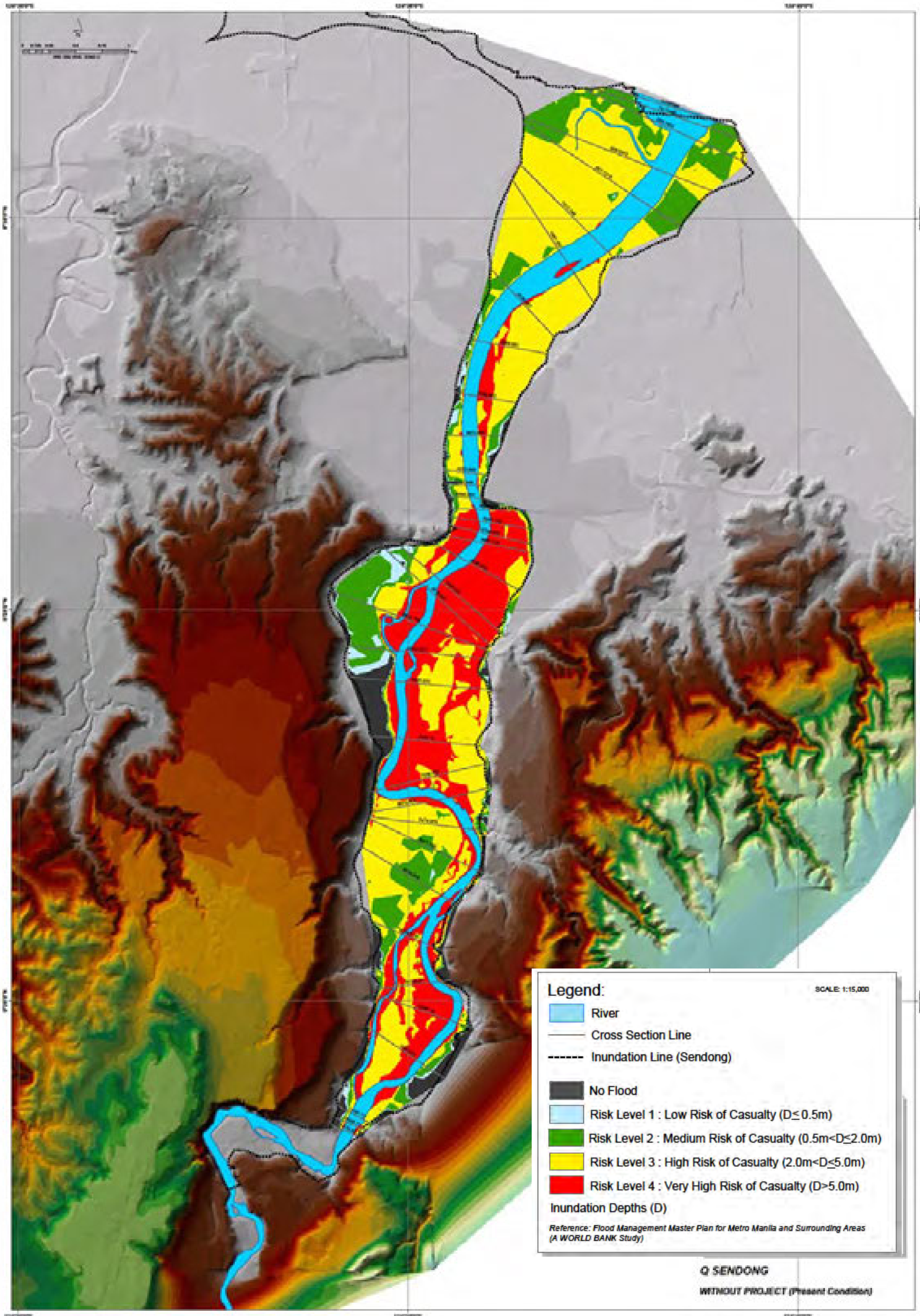
Source: The Survey Team

Figure 1.5.2 Criteria for Assessment of Flood Risk Level

[1] The World Bank Study "Flood Management Master Plan for Metro Manila and Surrounding Areas" (2012)

The Flood Risk Level along the Cagayan de Oro River was analyzed by inundation studies as mentioned in Chapter 7. The figure below shows the Flood Risk Map in Cagayan de Oro River adopting the case of Sendong Flood, which is now evaluated at 50-60 years return period. Color coding in the map is showing the each flood risk level.

As seen in the figure, flood area widely spread out beyond the both banks. Extreme floods of Sendong and Pablo, and 2009 floods attacked this area every times as flush flood resulting in serious damages and loss of human lives. The area of Flood Risk Level 4 covers the Isla de Oro and upstream of the bottleneck section and Calacala areas where seriously damaged on loss of human lives during Sendong. Based on this kind of flood risk map, the alternatives of river boundary will be studied.



Source: The Survey Team

Figure 1.5.3 Flood Risk Map (without Project: Present Condition) in Case of Sendong Class Flood (50-60 years Flood)

1.6 Study for River Boundary

The river boundary along the CDO River should be studied in consideration of existence of wider flood prone area than the Non Build Zone, and based on the results of studies for river morphology, inundation analysis and flood risk level assessment.

Figure 1.6.1 is a base map showing the Flood Risk Level 4 area together with the inundation areas of Sendong and Pablo over the aerial photo taken in this Survey recently. In 2009 similar scale of flood had happened resulting in similar inundation like Pablo. As shown in the map, many residents and sub-division, commercial area are still located in the inundation area along the Cagayan de Oro River even in Level 4 area.

The concept of the river boundary is presented as below and the conceptual illustration of cross section is shown in Figure 1.6.2.

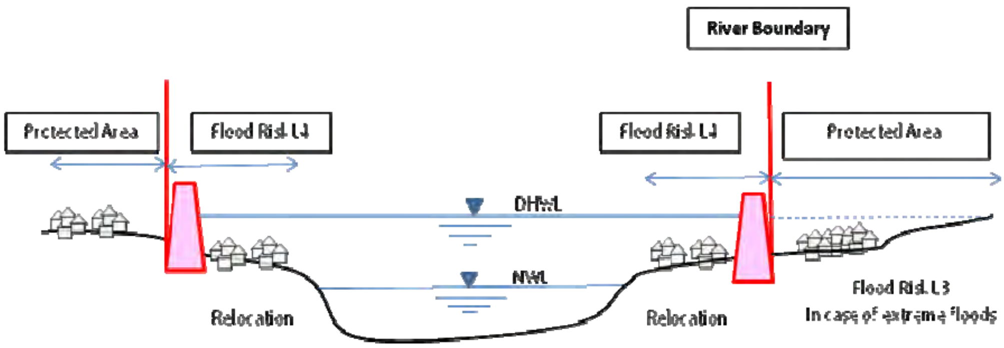
<u>*Concept of River Boundary*</u>

The alignment of river boundary is set along the outer line of Flood Risk Level 4. Under this concept, people living in Flood Risk Level 4 will be relocated, and people living in the Flood Risk Levels 1 to 3 will be protected.

The area of Level 4 is seriously damaged by recent floods repeatedly. This area is not the safety place where people can live. That is why it should be defined as River Area.

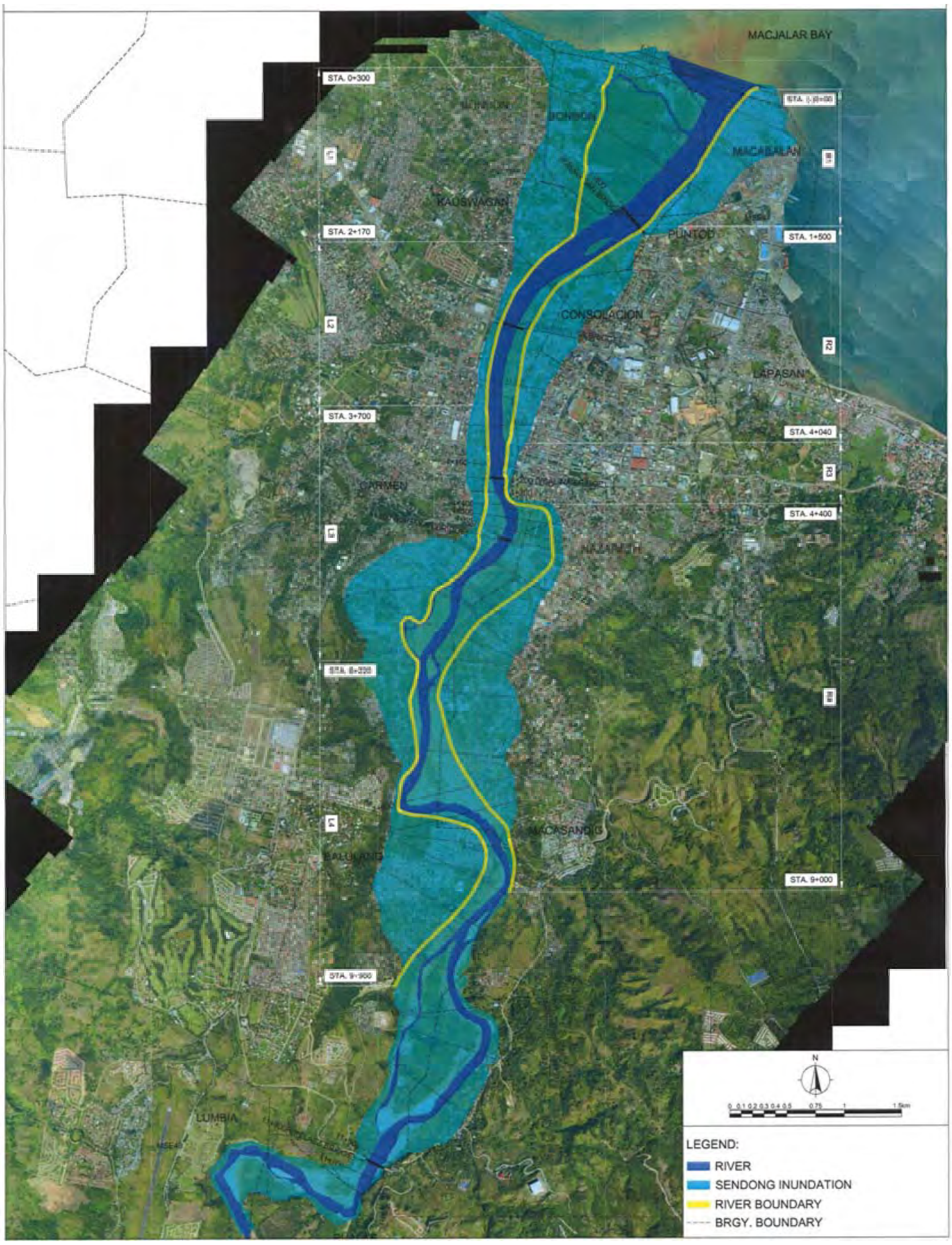
In this case, river width can be set wider than the present condition, which will mitigate flood risk in the area. The number of affected houses is around 1,200.

The flood safety level will be set at 50 years with complementary measures of dams in upstream basin and some non-structural measures to strengthen the evacuation. In this concept, non-structural measures such as flood forecasting, and early warning systems and evacuation system will have an important role to protect human lives in Flood Risk Levels 1 to 3 from serious flooding in case of breaching of the dike by extreme floods like TS Sendong. Possibility of construction of the dam will be studied in the Master Plan Study.



Source: The Survey Team

Figure 1.6.1 Concept of Cross Section of River Boundary



Source: The Survey Team

Figure 1.6.2 Base Map for Study of River Boundary in Cagayan de Oro River

CHAPTER 2 SEGMENTATION OF RIVER AREA

2.1 Segmentation of River Area

Prior to establish the river boundary, the objective river section from the river mouth to the Pelaez Bridge was segmented into eight (8) sections as below taking into account the similarity of characteristics of topography, land use and hydraulics of river and river bank. The location map of segmentation of the river is presented in Figure 2.1.1. The detail of river boundary established in each section is described below:

Left Bank

L1: Road Raising Section

River section from the river mouth to upstream of the Kauswagan Bridge where low-lying wet land spread within the mangrove area.

L2: Kausuwagan Section

River section from the upstream of the Kauswagan Bridge to the upstream of the Maharilka Bridge. In this section, no overtopping occurred from the existing bank during TS Sendong because of higher elevation of the existing bank level.

L3: City Hall Section (left bank)

River bottle neck section nearby City Hall between the downstream of the Ysalina Bridge and the upstream of the Kagayan Bridge. There is a flood prone area where many residential houses still remain.

L4: Balulang Section

River section with elevated natural river bank from the upstream of the Kagayan Bridge to the Pelaez Bridge.

Right Bank

R1: Rehabilitation of Damaged Dike Section

River section from the river mouth to upstream of the Kauswagan Bridge. The damaged dikes (seawalls) are being rehabilitated by DPWH Region X at present.

R2: Isla de Oro Section

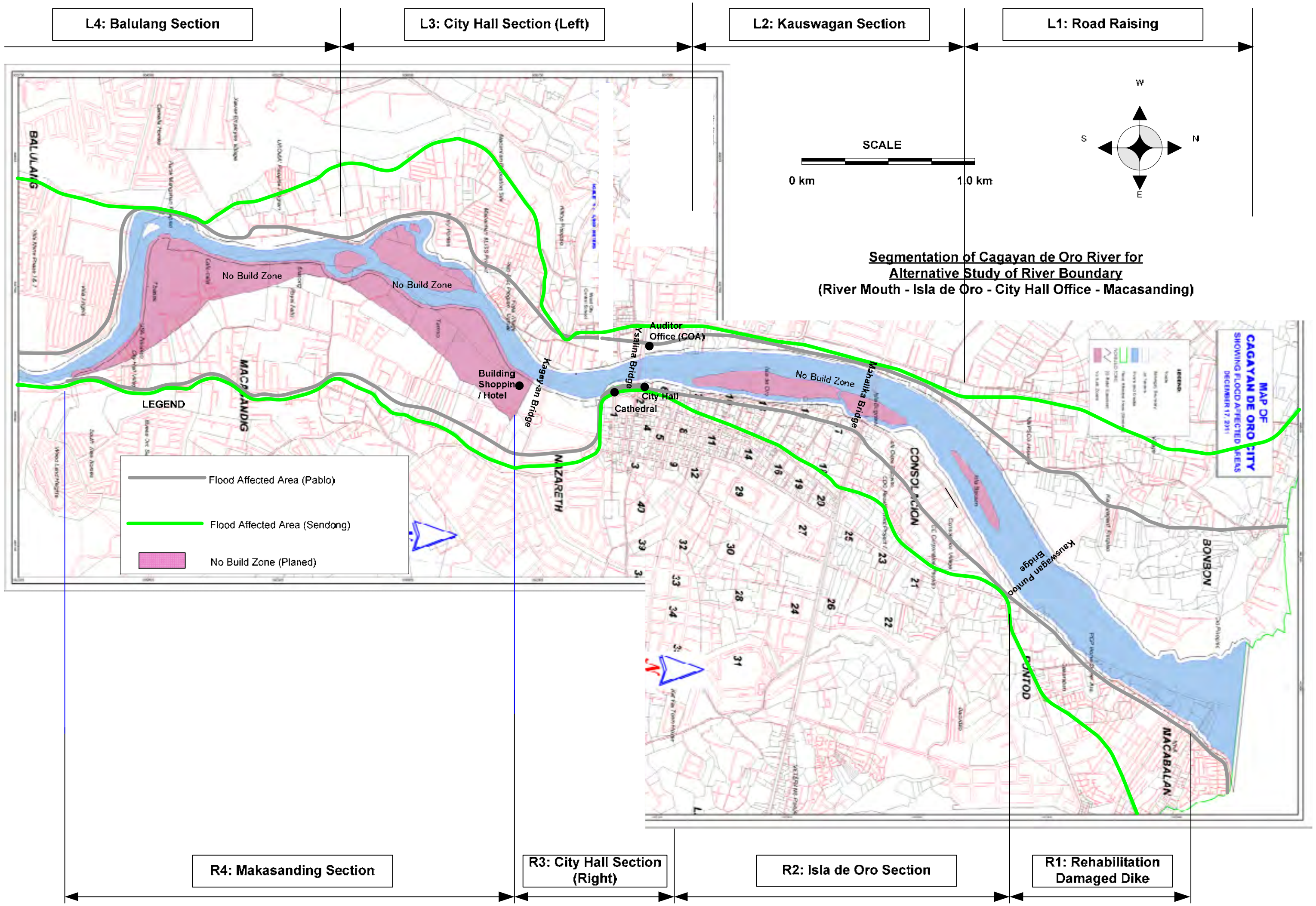
River section with flood prone areas from the upstream of the Kauswagan Bridge to downstream of the Ysalina Bridge. There are flood plains made from sand bars i.e. Isla Baksa, Isla Delta and Isla de Oro.

R3: City Hall Section (right bank)

River bottle neck section nearby City Hall up-and-downstream of the Ysalina Bridge.

R4: Makasanding Section

River section with flood prone areas from the downstream of the Kagayan Bridge to Calacala in Barangay Makasanding. There is a wider flood plain where old river flows.



Source: The Survey Team

Figure 2.1.1 Segmentation of Downstream of Cagayan de Oro River for Study of River Boundary

(1) R1 (Rehabilitation of Damaged Dike Section)

In the river mouth, the inundation area of TS Sendong is widely spread over the low-lying area. Since this area is located at tidal affected area having relatively wider river width, it is not reasonable to extend the river boundary up to the extent of the whole inundation area. One of key issues in this area is to secure height of dike to protect from high tide and flood water rather than the widening of the channel.

The river boundary along the right bank follows the alignment of existing dike, which had been partially damaged during TS Sendong and currently being undertaken by the rehabilitation works.

(2) L1 (Road Raising Section)

Along the left bank of river mouth, mangroves cover the low-laying wet land, and inundation area of TS Sendong is widely spread over the mangrove area and going into the residential area. As same as the R1 section, it is not reasonable to extend the river boundary up to the extent of the whole inundation area.

The proposed measure along the left bank in this area is road raising in low-laying area instead of construction of the new dike since the area belongs to the environmental protected area covered by mangroves. The river boundary in this area basically follows the alignment of proposed road raising.

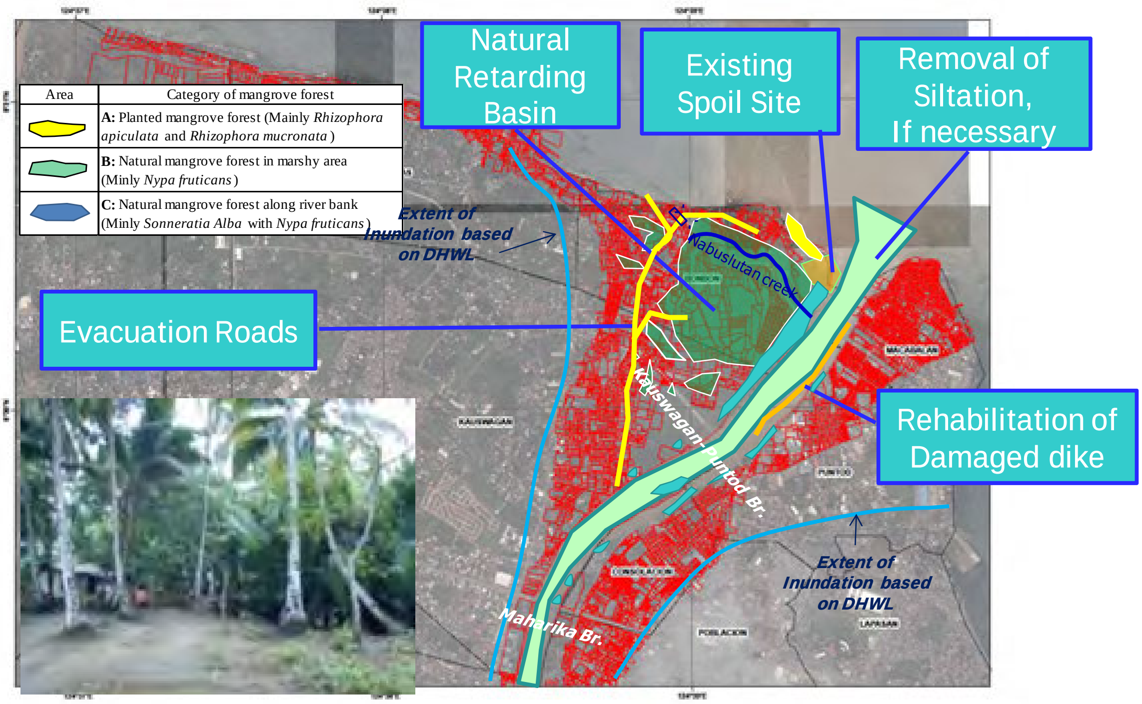


Figure 2.1.2 River Boundary in R1 and L1 Sections

(3) R2 (Isla de Oro Section)

This section is located at inner curve of the mainstream of the CDO Rivers. There exist wide flood plains and sand bars along the channel. They are called Isla Baksa, Isla Delta and Isla de Oro from the downstream. Along the outer side of the Isla Delta and Isla de Oro, a small creek flows parallel with the mainstream. The creek is used as local drainage discharge channel of the surrounding area, and the ground level at right bank of the creek is a slightly elevated forming a natural river bank of the CDO River.

This flood plain was one of seriously damaged areas during TS Sendong. At present it is planned to be declared as “No-Build Zone”.

Since the inundation areas of Sendong is widely spread over the residential area, as the same as R1 and L1 sections it is not reasonable to extend the river boundary up to the extent of the whole inundation area.

<u>River Boundary in R2 Section</u>

The river boundary is established to align at outer side of the Flood Risk Level 4 to relocate residents living in the highest flood risk area. The proposed dike alignment is set along the right bank of the existing creek, thus Non Built Zone is included in the river area.

Isla de Oro will be continuously prohibited from living and construction of structures as Non-Build Zone. The open space in the flood plain is around 100 m wide and can be used for public area, such as river parks, sport fields, a public stadium etc. ,

(4) L2 Section (Kauswagan Section)

The site condition of L2 section is different from the bank of R2 (Isla de Oro section). In some sections, flood plain is very narrow or none at all and the ground level of the bank is relatively higher than the surrounding area. The river boundary in L2 section is proposed to connect between the alignment of L1 section and this natural elevated river banks.

(5) R3 Section (City Hall Section (right bank))

The river at the City Hall section is the bottle neck section in the whole stretch of the Cagayan de Oro River. As mentioned previously, this section is being narrower due to extension of the City Hall building and construction of promenade with revetment.

In this section, the flood water of Sendong and Pablo overflew from the bank. At the time of Sendon, especially, the flood water reached above second floor of the building. So far the rehabilitation of the revetment was stopped waiting for decision of the river boundary. The bottleneck section in front of the City Hall will be designed to mitigate flood risk through widening of the section considering the original cross section of the Ysalina Bridge, position of City Hall building and existing revetments as well as hydraulic impacts to the upstream and downstream of the section.

On the other hand, the Cathedral was constructed since long before, around 400 years ago. It is located at an elevated portion in the surrounding area where must be a good place being free from flooding. It was reported that no inundation occurred even during Sendong. Since the cathedral is located originally on the elevated area not encroaching river area and considering the status as a social and religious symbol, the alignment of river boundary along the Cathedral is set to follow the existing revetment with proposal for rehabilitation of them.

River Boundary in R3 section

The river boundary is set up to the wall of existing City Hall building including the high flood risk area to widen the bottleneck section as much as possible.

(6) L3 Section (City Hall Section (left bank))

As the same as R3 section, the river at the L3 section is the bottle neck section in the whole stretch. As shown in the Flood Risk Map, there is Flood Risk Level 4 area along the left bank in this section.

If the river can be widen as much as possible, then the river boundary will be put on the elevated area along the existing natural dike with the elevation 6.0- 8.0 m, it will have big advantages because the height of the proposed dike will be much lower or any new dikes will not be necessary, and type of slope and toe protection of the bank will be very simple. However, there are many formal residential houses and public buildings in this area. It will require a number of resettlements and land acquisitions.

River Boundary in L3 section

The river boundary is established to align at outer side of the Flood Risk Level 4 to relocate residents living in the highest flood risk area. The river boundary is basically set along the existing Barangay road. The existing road will be widened and upgraded for the usage as road dike.

In this concept, the bottleneck section is controlled at Ysalina Bridge section with the river width of 145 m. In this case, it will need partial resettlement with the number of affected house of about 320 and ROW acquisition of around 4.8 ha.

(7) R4 Section (Cathedral - Calacala)

In this section along the right bank from the upstream of the Cathedral to Calcala in Barangay Macasandig, there are wide low-laying areas where some residential areas were scattered. As shown in the Flood Risk Map, the area of Flood Risk Level 4 is widely spread over the low-lying areas adjacent to the existing river in this section. The Non Build Zone is planned for almost same area as the Floor Risk Level 4.

River Boundary in R4 section

The river boundary is established to align at outer side of the Flood Risk Level 4 to relocate residents living in the highest flood risk area. The river boundary in some areas will be set along the existing Barangay road. In this case, the existing road will be widened and upgraded for the usage as road dike to protect the residential/commercial areas from flooding in this area.

(8) L4 Section(Balulang Section)

Barangay Balulang located on the left bank of the upstream area, is one of the seriously damaged area as well as the area in Isa de Oro and Calacala during TS Sendong.