THE REPUBLIC OF THE PHILIPPINES
PHILIPPINE ATMOSPHERIC GEOPHYSIAL AND
ASTRONOMICAL SERVICES ADMINISTRATION

PREPARATORY SURVEY
FOR THE PROJECT
FOR
IMPROVEMENT OF FLOOD FORECASTING AND WARNING SYSTEM FOR CAGAYAN DE ORO RIVER BASIN
IN
THE REPUBLIC OF THE PHILIPPINES

FINAL REPORT

March 2018

JAPAN INTERNATIONAL COOPERATION AGENCY

NIPPON KOEI CO., LTD.

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Preface

Japan International Cooperation Agency (JICA) decided to conduct the Preparatory Survey for the Project for Improvement of Flood Forecasting and Warning System for Cagayan de Oro River Basin and entrust the survey to NIPPON KOEI Co., Ltd.

The survey team held a series of discussions with the officials concerned of the Government of the Republic of the Philippines, and conducted field investigations. As a result of further studies in Japan, the present report was finalized.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned for the Government of the Republic of the Philippines for their close cooperation extended to the survey team

March 2018

Mr. Kunihiro Yamauchi
Director General,
Global Environment Department
Japan International Cooperation Agency

Summary

Summary

1. Outline of the Country

The Republic of the Philippines is an island country located in Southeast Asia. The country has an area of 299,404 km^2, which is almost same as 80% of Japan, and consists of 7,109 islands. According to the "World Risk Report 2014" published by United Nations University, the country is considered to be most exposed to natural disaster risk among emerging countries, and disaster risk reduction is the important issue for the country. In the country, 48% of the number of dead and missing people due to natural disasters in the decade since 2005, and 70% of the affected population are due to floods caused by typhoons and monsoons. Floods are the most severe natural disaster risk, and cause serious mortality and economic loss.

2. Background and Outline of the Project

The Government of the Philippines (GoP) designates major 18 river basins and develops a flood control plan for the rivers with urban areas with large population and the center of economic activity. In the major 18 river basins, Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) is currently working on establishing a River Flood Forecasting and Warning Center (RFFWC), and developing a Flood Forecasting and Warning System (FFWS).

Cagayan de Oro River, which is located in the northern part of Mindanao Island, is one of the 18 major rivers in the Philippines with a length of about 97 km and a catchment area of 1,364 km^2. Although the river has Cagayan de Oro City, which is the central city in the region with about 600,000 population, a flood control plan and project had not been implemented in the basin. Also, the Mindanao Island used to be referred to as a “tropical cyclone free zone” because very few tropical cyclones hit the island in the past. However, in recent years the path of tropical cyclones around the Philippines tends to take a more southern path, therefore, the damage by tropical cyclones in Mindanao are increasing. Recently, in succession with Tropical Depression “Urduja” in 2009, Tropical Storm “Sendong” in 2011, Typhoon “Pablo” in 2012, and Severe Tropical Storm “Vinta” in 2017, the Cagayan de Oro River overflowed and damaged Cagayan de Oro City heavily. In particular, the Tropical Storm “Sendong” hit the northern Mindanao area on December 16, 2011, resulting in tremendous damage of 1,170,000 victims and about 1,250 deaths.

In the Cagayan de Oro River basin, the flood caused by the upstream rain reaches the downstream urban areas in about a few hours, flowing straight through the flood prone areas, and causing damage. It is a very high-risk flood with a short lead time for evacuation. In addition, current low river channel capacity and discontinuous river embankment make the highly populated riverside areas vulnerable for flooding. Therefore, the improvement of FFWS is required to observe rainfall and flood in the basin in real time, conduct accurate flood forecasting and issue flood warning timely.

Under such circumstances, the "Project for Improvement of Flood Forecasting and Warning System for Cagayan de Oro River Basin" was requested by GoP to improve the FFWS for Cagayan de Oro River as well as to enhance the capacity for integrated flood risk management in the basin. Currently, an official development assistance (ODA) loan project "Flood Risk Management Project for Cagayan de Oro River (FRIMP-CDOR)" is on-going by GoP. In addition, this river basin was chosen as a pilot area in the Japan International Cooperation Agency (JICA) Technical Cooperation Project (TCP) “Project for Strengthening Capacity of Integrated Data Management of Flood Forecasting and Warning in the Republic of Philippines". Therefore, close coordination with these projects is necessary.

3. Outline of the Survey Results and Contents of the Project

Dispatch of the survey team was conducted five times in total as shown in Table 1, and discussion with PAGASA and relevant organizations was carried out.

Table 1 Field Survey

Field Survey	Survey Period
First Field Survey	March 13 - April 27, 2017
Second Field Survey	May 10 - June 8, 2017
Second Field Survey (additional 1)	October 9 - October 28, 2017
Second Field Survey (additional 2)	January 18 - January 24, 2018
Third Field Survey	February 18 - February 24, 2018

The goal of this project is sustainable operating of FFWS by PAGASA at Cagayan de Oro RFFWC (CDORFFWC) and reducing flood damages in the basin accordingly. To achieve the project goal, contents of the project was determined though discussions with PAGASA about installation sites and specifications of the equipment based on survey results including natural condition survey (topographic survey and geological survey) and radio propagation test. Table 2 shows the contents of the project.

Table 2 Contents of the Project

Item		Detail	Quantity
1	Installation of Rainfall Gauge Stations		
	(1)	Ground Rainfall Gauge Stations	13 stations
	(2)	X-band Radar Rain Gauge Stations	2 stations
2	Installation of Water Level Gauge Stations		
	(1)	Combination of Rainfall and Water Level Gauge Stations	7 stations
3	Installation of Radio Communication Equipment		
	(1)	Dedicated VHF Radio Communication Link between Hydrological Stations and Repeater Station	1 set
	(2)	Repeater Station (collocated with X-band Radar Rain Gauge Station)	2 set
	(3)	Dedicated Wired Communication Link between CDORFFWC and Cagayan de Oro City Disaster Risk Reduction and Management Department (CDO-CDRRMD)	1 set
4	Installation of Visualization System to Display Measured Data		
	(1)	Operation Terminal and Data Processing Server for X-band Radar Rain Gauge	2 sets (CDORFFWC and PAGASA Hydrometeorology Division)
	(2)	Monitoring Display	2 sets (CDORFFWC and CDO-CDRRMD)
	(3)	Information Delivering Subsystem including Web-site Construction	1 sets (CDORFFWC)
5	Detail Design and Procurement		
	(1)	Procurement (Equipment Procurement, Transportation, Installation Works, Civil Works and Management)	1 set
	(2)	Detail Design including works and Support related bidding, supervision of construction stage and soft component	1 set

4. Period of the Project

The project consists of Detail Design stage and Procurement stage. Detail Design stage is for 4 months, Procurement stage is for 17.5 and Total project period is for 21.5 months.

5. Project Evaluation

The Project consists of the telemetry system for observation of rainfall and water level in the river, X-band radar rainfall equipment, data transmission, processing and display of the rainfall and water level observed, main objective of which project is reduction of causality and loss in Cagayan de Oro River Basin, comply with the following:

- Philippine Development Plan 2017-2022
- Japanese ODA Policies on the Disaster Risk Reduction (DRR)
- Supporting policies on DRR by JICA

Support to implementation of the Project under JICA Grant Aid is judged as Relevance due to conformity with the Japanese Government Policies on the for Japanese ODA Policies on DRR and effective and high priority supporting to Philippines.

Effeteness of the Project are summarized as below and benchmarks and achievements are shown in Table 3.

- Improvement of the missing rate of telemetry data
- Improvement of accuracy of rainfall data with the X-band radar
- Improvement of collecting time of telemetry data
- Improvement of required time for issue of evacuation information

Table 3 Benchmarks and Improvement Results under the Project

Benchmark		Current Situation *	Achievements ** [After three years from completion of the Project]
Hydrological observation density	Mesh size for rainfall observation (size of the catchment area / number of rain gauges, or spatial resolution of radar rain gauge) (km^2)	105 km^2 (=Catchment Area 1,364 km^2/ 13 Existing Rain gauge)	0.022 km^2 It can be monitored with 150 m x150m =0.022 km^2 mesh
	The number of water level gauges	8	15
Missing rate of telemetry data		84.2 % ***	within 5%

Remarks

(*) This data is based on the current performances of Twin Phoenix, National Disaster Management Institute (NDMI) telemetry systems, and Advanced Science and Technology Institute (ASTI)

(**) Achievements are benchmark, which shall be established under the Project.

(***) Operational conditions are shown below:

Twin Phoenix telemetry system	Data Missing Rate
Rainfall gauge stations: 3/6 (operational/ non- operational)	Less than 5%
Water level gauge stations: 0/4 (operational/ non- operational)	100% (no operation)

NDMI telemetry system	
Rainfall gauge stations: 0/5 (operational/ non- operational)	100% (no operation)
Water level gauge stations: 0/4 (operational/ non- operational)	100% (no operation)
Calculations: Non-operational gauge stations is divided by all gauge stations= (3+5+4+4) / 6+5+4+4)=16/19=84.2%	

Qualitative effects are described as follows:

- Lives of residents in the river basin will be saved by the appropriate flood forecasting and warning
- Sharing real time hydrological data observation both PAGASA and Cagayan de Oro City Disaster Risk Reduction and Management Office helps Efficient disaster response system
- Stable data transmission will be enhanced by dedicated communication network
- Flood forecasting particularly urban flooding by PAGASA will be improved by increasing the density of rainfall observations

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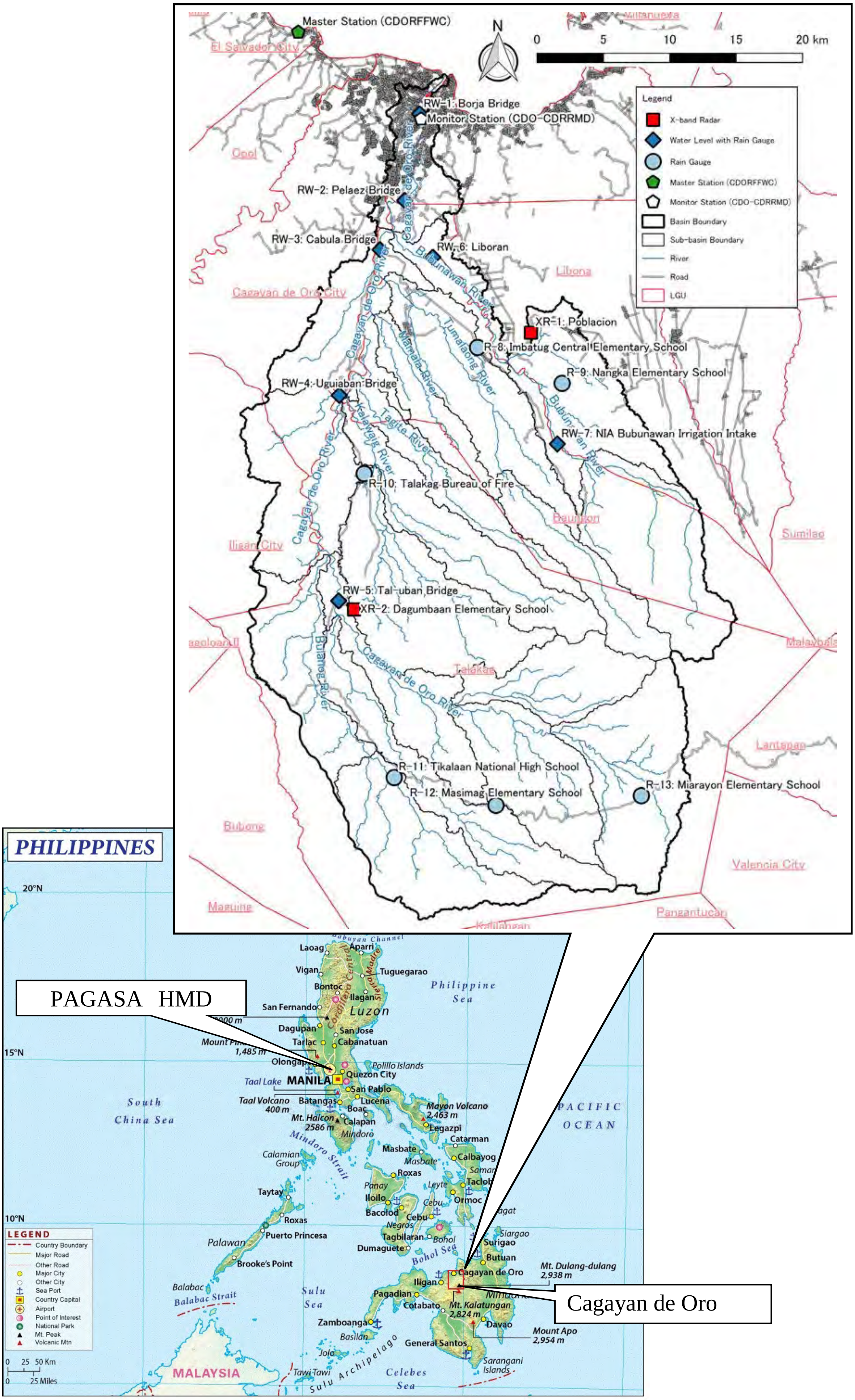

Perspective

X-band Radar Rain Gauge Station

※This picture is shown for reference.
The showing facilities in this picture different from prepared facilities by the Project.

Master Station（CDORFFWC）

※Construction of this building is obligation of Philippines side

Operation Room

※This picture is shown for reference.
The showing facilities in this picture different from prepared facilities by the Project.

Rainfall Gauge Station

※This picture is shown for reference.
The showing facilities in this picture different from prepared facilities by the Project.

Water Level Gauge Station

※This picture is shown for reference.
The showing facilities in this picture different from prepared facilities by the Project.

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※No indication of source means that it is made by JICA study team

Abbreviation

ASTI	Advanced Science and Technology Institute
A/P	Authorization to Pay
B/A	Bank Arrangement
CBR Test	California Bearing Ratio Test
CDO-CDRRMD	Cagayan de Oro City Disaster Risk Reduction and Management Department
CDORFFWC	Cagayan de Oro River Basin Flood Forecasting and Warning Center
CDRRMC	City Disaster Risk Reduction Management Council
CENRO	Community Environment and Natural Resources Office
CNC	Certificate of Non-Coverage
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DPWH	Department of Public Works and Highways
DRR	Disaster Risk Reduction
ECC	Environmental Compliance Certificate
ETSD	Engineering Technical Service Division
FFWS	Flood Forecasting and Warning System
FRIMP-CDOR	Flood Risk Management Project for Cagayan de Oro River
FWWLs	Flood Warning Water Levels
GoP	the Government of the Republic of the Philippines
GMMA	Greater Metro Manila Area
HMD	Hydrometeorology Division
HMTS	Hydro-Meteorological Telemetry Section
ICT	Information and Communication Technology
JICA	Japan International Cooperation Agency
KOICA	Korean International Cooperation Agency
LGU	Local Government Unit
LOS	Line Of Sight
MDRRMC	Municipal Disaster Risk Reduction Management Council
MDRRMD	Municipal Disaster Risk Reduction Management Department
MPRSD	Mindanao PAGASA Regional Services Division
NDMI	National Disaster Management Institute, Korea
NIA	National Irrigation Administration
NPA	New Peoples Army
NSVP-2010	National Structure Code of Philippines, 2010
OCD	Office of Civil Defense
ODA	Official Development Assistance
O&M	Operation & Maintenance
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PCA	Philippine Coconut Authority
PDRRMC	Provincial Disaster Risk Reduction Management Council
PLDT	Philippine Long Distance Telephone
PRFFWC	Pampanga River Flood Forecasting and Warning Center
PRSD	PAGASA Regional Services Division
SMS	Short Message Service
SNS	Social Networking Service
TCP	Technical Cooperation Project
VAT	Value-added Tax
VHF	Very High Frequency
VoIP	Voice Over Internet Protocol
WAN	Wide Area Network

Chapter 1. Background of the Project

Chaper 1. Background of the Project

1-1 Outline of the Grant Aid Project

Cagayan de Oro River, which is located in the northern part of Mindanao Island, is one of the 18 major rivers in the Philippines with a length of about 97 km and a catchment area of 1,364 km^2. Recently, in succession with Tropical Depression "Urduja" in 2009, Tropical Storm "Sendong" in 2011, Typhoon "Pablo" in 2012, and Severe Tropical Storm "Vinta" in 2017, the Cagayan de Oro River overflowed and damaged Cagayan de Oro City heavily. In particular, the Tropical Storm "Sendong" hit the northern Mindanao area on December 16, 2011, resulting in tremendous damage of 1,170,000 victims and about 1,250 deaths.

Also, the Mindanao Island used to be referred to as a "tropical cyclone free zone" because very few tropical cyclones hit the island in the past. However, in recent years the path of tropical cyclones around the Philippines tends to take a more southern path, therefore, the damage by tropical cyclones in Mindanao are increasing. The abovementioned "Sendong", "Pablo", and "Vinta" were formed near the equator, forwarded westward, and landed on the Mindanao Island.

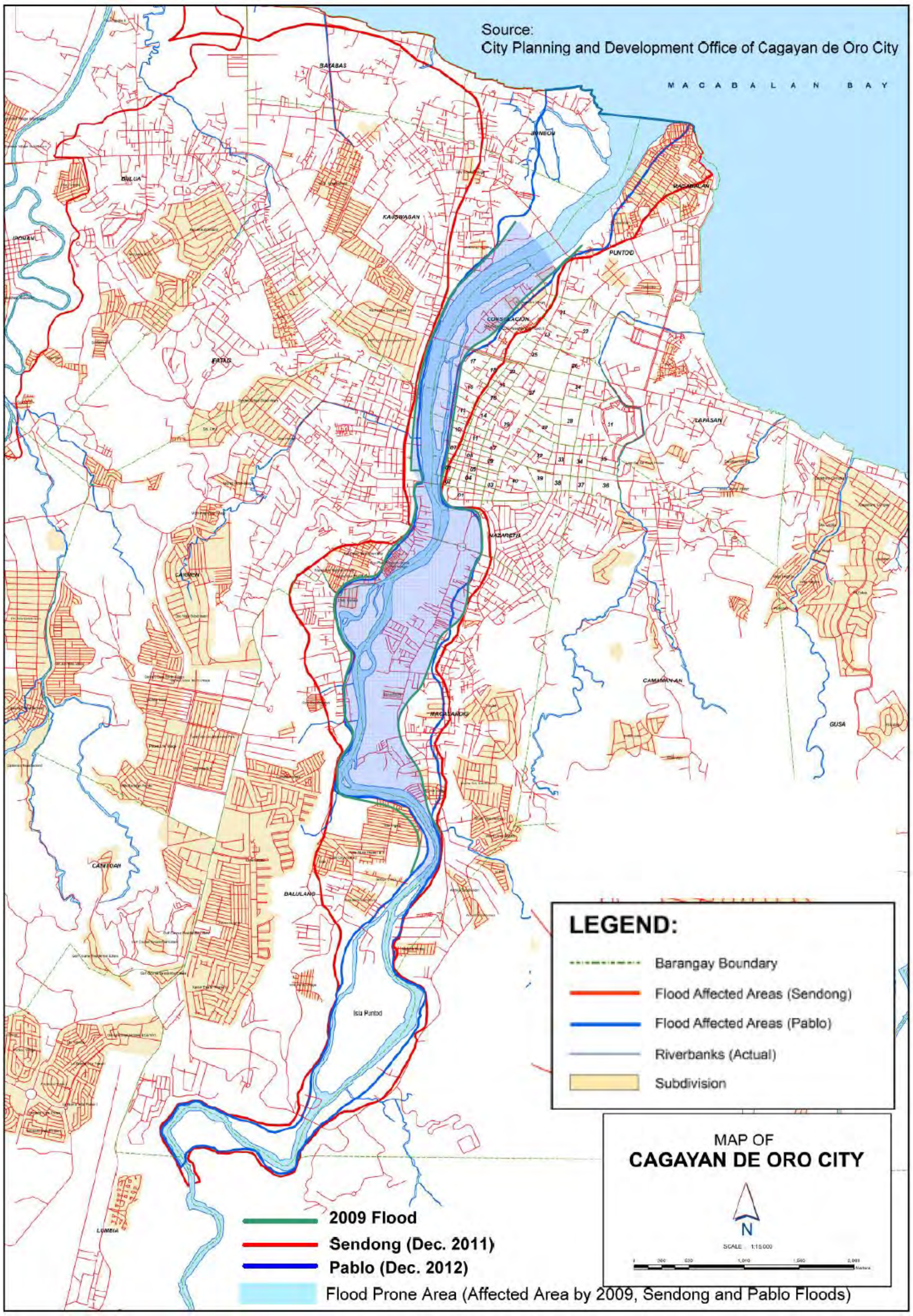
In the Cagayan de Oro River basin, the flood caused by the upstream rain reaches the downstream urban areas in about a few hours, flowing straight through the flood prone areas, and causing damage. It is a very high-risk flood with a short lead time for evacuation. In addition, current low river channel capacity and discontinuous river embankment make the highly populated riverside areas vulnerable for flooding. At the time of Tropical Storm "Sendong", this vulnerability along with the remarkable flood that occurred during midnight caused many human injuries. Past flood inundation map shown in Figure 1-1 indicates that densely populated areas were submerged by Tropical Storm "Sendong".

In December 2017, Severe Tropical Storm "Vinta" also caused flood inundation. Figure 1-2 shows flood situation of Cagayan de Oro River during Severe Tropical Storm "Vinta". The inundated areas might have been relatively smaller than Tropical Storm "Sendong", and no casualties have been reported in Cagayan de Oro City because of the early evacuation carried out before the flood.

In addition to the flood damage caused by tropical cyclones, urban flooding has been also occurred in Cagayan de Oro City as shown in Figure 1-3. In January 2017, the interaction between the tail-end of the cold front and a low-pressure area caused the disastrous urban flooding in the city. According to the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA), the city's poor drainage might be the major reason of the urban flooding. To issue flood warning properly and timely for the urban flooding, dense monitoring of rainfall in spatial and temporal scales are required.

Under such circumstances, the "Project for Improvement of Flood Forecasting and Warning System for Cagayan de Oro River Basin " was requested by the Government of the Republic of the Philippines (GoP) to improve the Flood Forecasting and Warning System (FFWS) for Cagayan de Oro River as well as to enhance the capacity for integrated flood risk management in the basin.

After the flooding by Sendong, an Official Development Assistance (ODA) loan project was formed to reduce the flooding damage through the preparatory survey Japan International Cooperation Agency (JICA) in March 2014, namely: the Flood Risk Management Project for Cagayan de Oro River (FRIMP-CDOR). The loan agreement has been concluded between the Japanese and the Philippine governments in March 2015, and the project is currently ongoing and carried out by the Philippine government. In addition, this river basin was chosen as a pilot area in the JICA Technical Cooperation Project: Project for Strengthening Capacity of Integrated Data Management of Flood Forecasting and Warning in the Republic of the Philippines (Technical Cooperation Project, TCP), which aims to improve the flood forecasting and warning abilities of PAGASA throughout the Philippines.



Source: Final Report of Flood Risk Management Project for Cagayan de Oro River (FRIMP-CDOR) (JICA, March 2014)

Figure 1-1 Past Flood Inundation Map

(Tropical Depression “Urduja” in 2009, Tropical Storm “Sendong” in 2011, Typhoon “Pablo”)

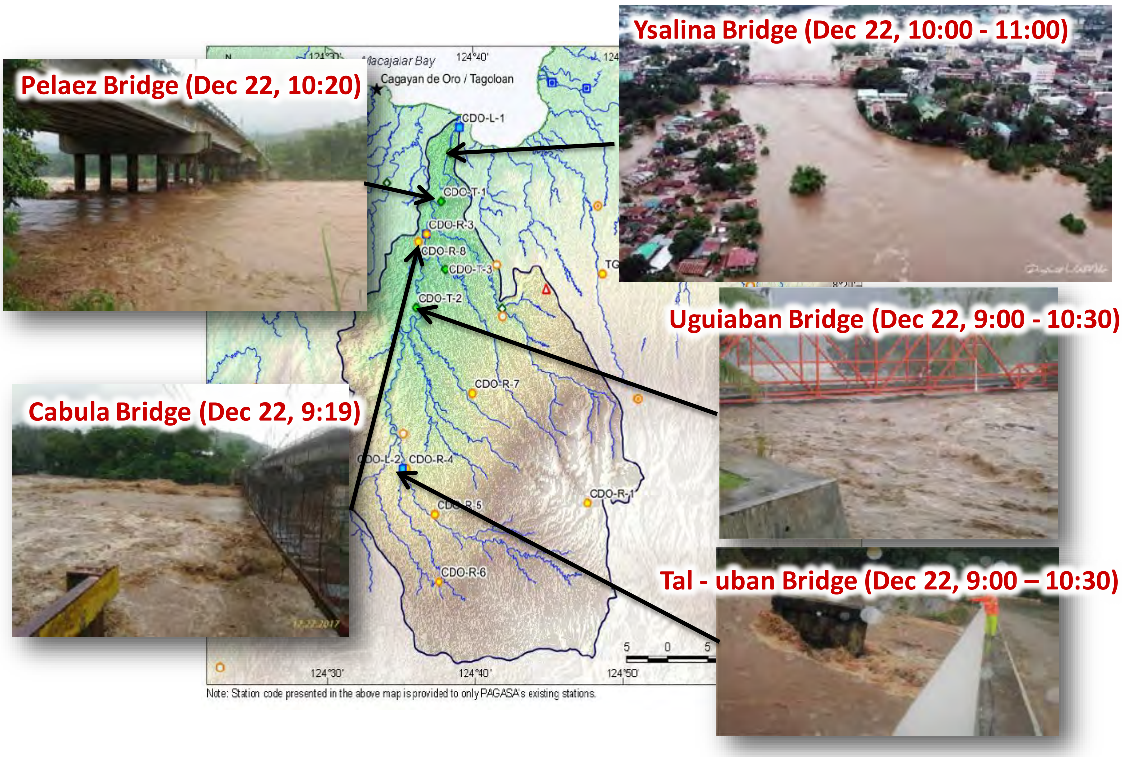
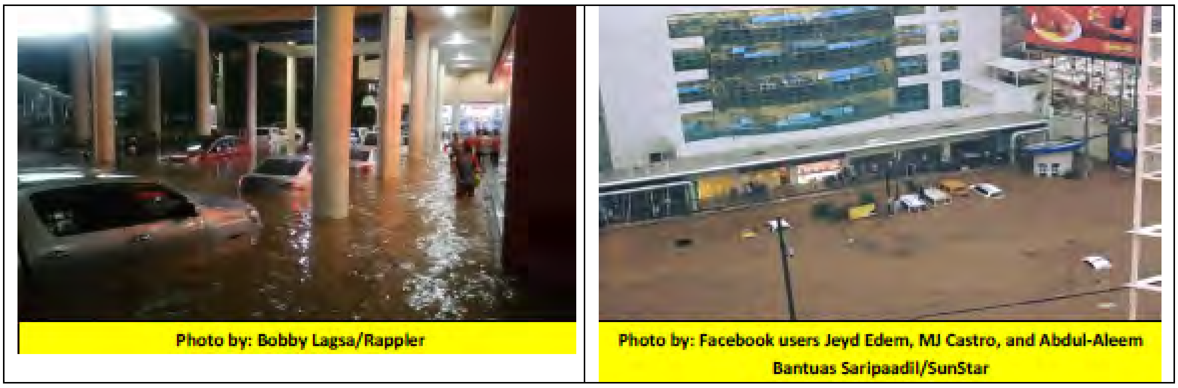


Figure 1-2　Flood Situation of Cagayan de Oro River during Severe Tropical Storm "Vinta"



Source: Heavy Precipitation Event and Urban Flooding in Cagayan de Oro on January 16, 2017 (Mindanao PRSD)

Figure 1-3　Inundation Situation in Cagayan de Oro City during Urban Flooding in January 2017

1-2 Natural Conditions

1-2-1 Rainfall and Topographical Characteristics of the River Basin

Cagayan de Oro (CDO) River originates from the two mountains, i.e.: Mount Kitanglad, whose elevation is 2,927 m, and Mount Kalatungan. The river merges several tributaries and flows through Talakag, Baungon, and Libona local government unit (LGU), Cagayan de Oro City, and finally reaches to Macahalar Bay.

The Cagayan de Oro River basin belongs to a type III tropical climate zone based on the classification criteria by PAGASA. A Type III zone is characterized by an inexplicit difference between the rainy season and dry season. This constitutes a relatively dry season from November to April, and a relatively wet season from May to October. Annual rainfall is about 1,830 mm. The northern part of the Mindanao Island is used to be called as a “tropical cyclone free zone” because of the very few tropical cyclones that hit the area in the past. However, the area is now considered as a “tropical cyclone affected zone” in view of the occurrence of the succeeding flood damages.

The river slope of the Cagayan de Oro River is about 1/1000 in the downstream near the estuary, while the slope in the middle part is about 1/80 to 1/200, and about 1/10 to 1/40 in the upstream areas in the mountainous region (Figure 1-4). The river is one of the steepest rivers among the 18 major rivers (Figure 1-5) and is similar to steep rivers in Japan (Figure 1-6). The flood propagation time is only seven hours from the upstream areas to the flood prone areas in Cagayan de Oro City, assuming flood velocity is 4 m/s considering river slope and flow conditions during field visits because observed data on flood velocity along the river is not longitudinally available. The river flows down the valley which is formed by cutting the plateau in the upstream and middle parts of the mainstream and tributaries. Thus, flood flow reaches the downstream areas in a short amount of time without inundation. On the other hand, since Cagayan de Oro City is located in a relatively flat lowland, flood flow easily inundates and causes damages.

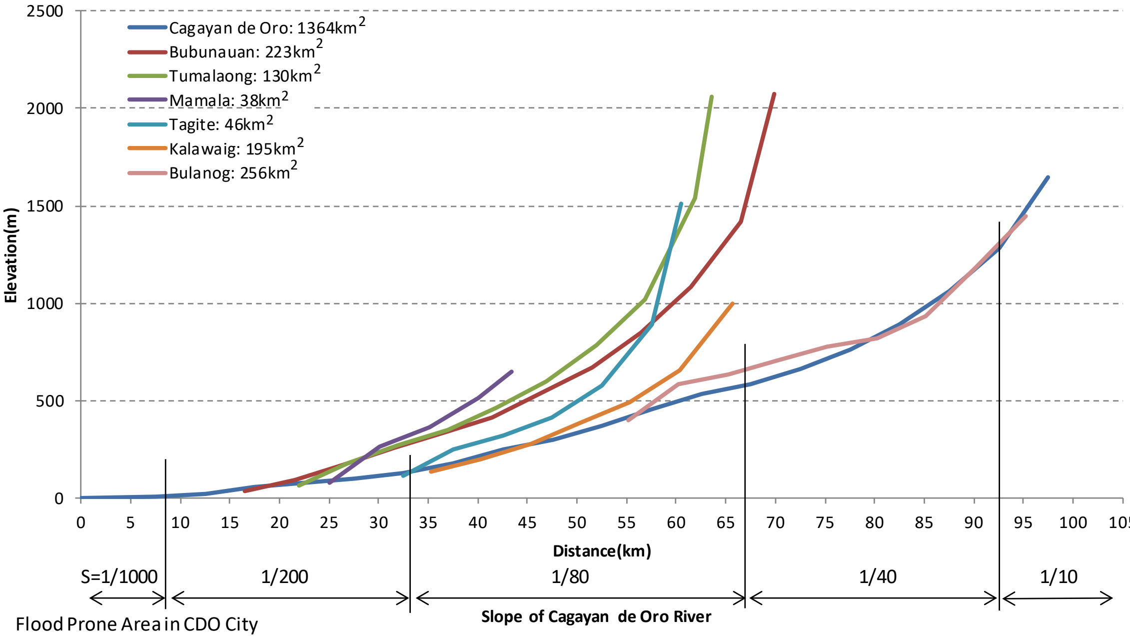
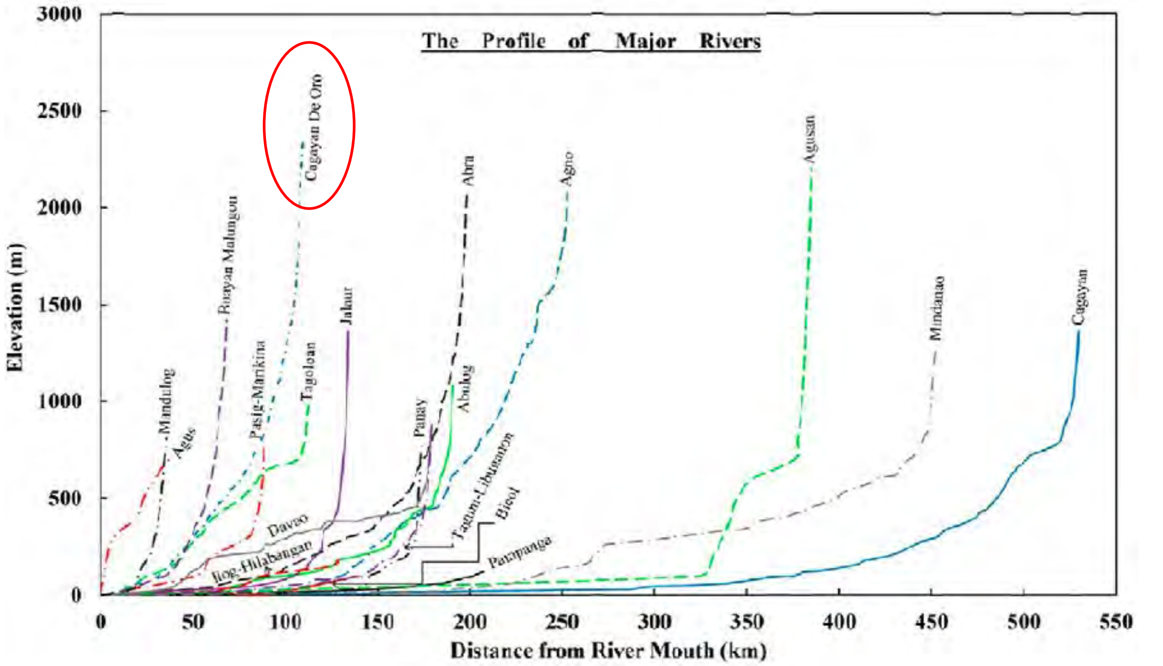


Figure 1-4 River Slope of Cagayan de Oro River



Source: Data Collection Survey on Situation of Nationwide Flood Forecasting and Warning System in the Republic of the Philippines (JICA, 2013)

Figure 1-5 River Slope of 18 Major Rivers in the Philippines

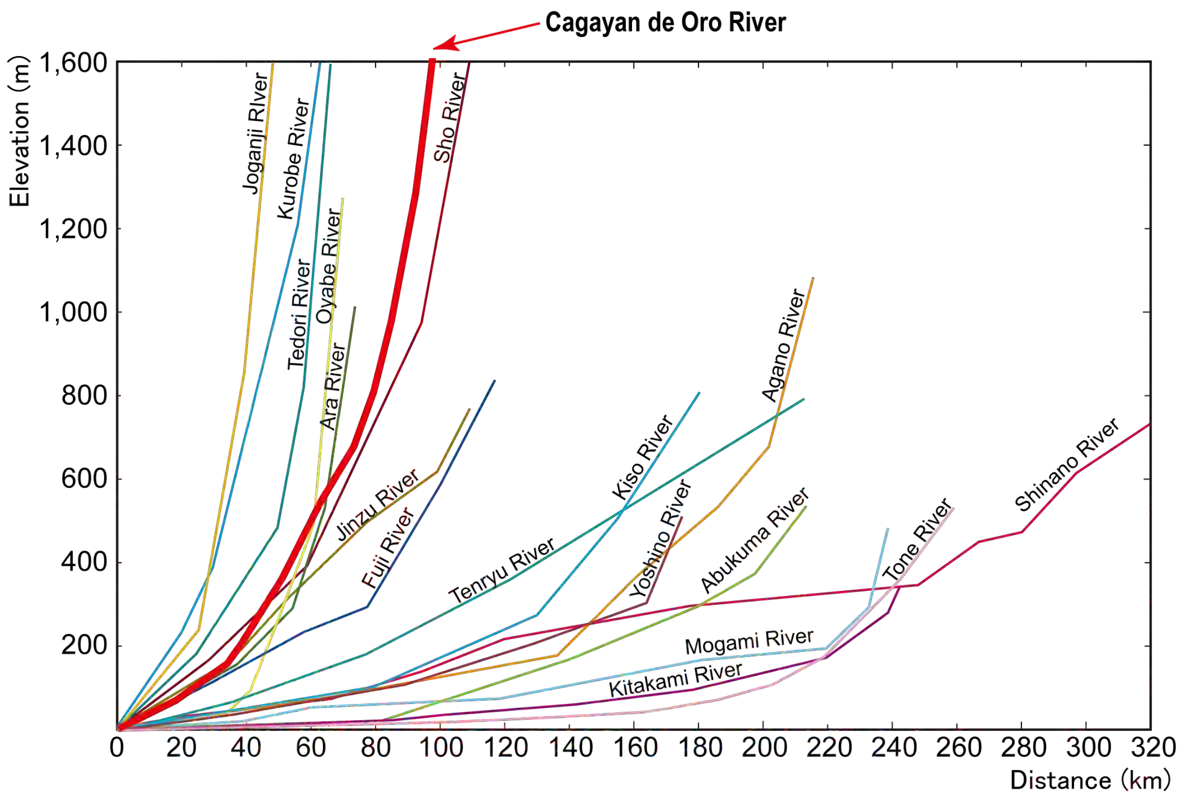


Figure 1-6 Comparison of River Slope between Cagayan de Oro River and Japanese Major Rivers

1-2-2 Natural Condition Survey

1-2-2-1 Objective and Survey Details

Topographic survey and geological survey were conducted by sub-contractors to determine the appropriate design and cost estimates for the flood forecasting and warning system. Table 1-1 shows the outline of the surveys. Table 1-2 and Table 1-3 show survey contents and target sites, and survey quantities, respectively.

Table 1-1　Outline of Natural Condition Survey

Item	Topographic Survey	Geological Survey
Objective	Aims to measure the topographic information required for design and cost estimates for X-band radar towers, repeater stations, and hydrological observation facilities	Aims to acquire the geological information for design and cost estimates for X-band radar towers, repeater stations, and hydrological observation facilities
Survey Contents	Topographic Mapping, Longitudinal Profile Survey, River Cross Section Survey	Borehole Drilling, Standard Penetration Test, Test Pit, Soil Laboratory Test, Load Bearing Capacity Test (California Bearing Ratio Test (CBR Test))
Contract Period	Original: April 19 - June 17（60 days） Amendment: April 19 - June 24（67days） ※Survey works at alternative site at RW-6 were added.	Original: April 19 - June 12（55 days） Amendment: April 19 - June 30（73days）※CBR test at XR-1 was added.
Sub-contractor	Bravo3 Surveying Services	George B. Padilla & Associates
Standard	Latitude and longitude in WGS84, and elevation in mean sea level, which are the same standards applied in previous survey works done by HMD*, and confirmed by the HMD*.	Complying with the standards by American Society for Testing and Materials
Outcome	Survey Report, Topographic Maps, Longitudinal Profile Drawings, and River Cross Section Drawings	Survey Report, Borehole Drilling Logs, Test Pit Logs, Soil Laboratory Test Results

Remarks:
(*) HMD: Hydrometeorology Division

Table 1-2 Survey Contents and Target Sites for Natural Condition Survey

Survey Contents (○:Survey Target)		Outcome	Objective	X-band Radar (2 Sites)	Master Station (1 Site)	Water Level and Rainfall Gauge Station (7 Sites)	Rainfall Gauge Station (6 Sites)
Topographic Survey	Topographic Mapping	Contour Map	To utilize for design and cost estimates of the FFWS facilities	○	○	○	○
	Longitudinal Profile Survey	Longitudinal profile drawing	To utilize for design and cost estimates of the FFWS facilities	○	○	○	○
	River Cross Section Survey	River cross section drawing	To estimate hydraulic condition, such as water level and velocity, and utilize for design and cost estimates of the FFWS facilities	×	×	○	×
Geological Survey	Borehole Drilling, and Standard Penetration Test (SPT)	Borehole drilling log	To acquire soil properties and soil layers, and utilize for design and cost estimates of the FFWS facilities	○	○	○※1	×
	Test Pit (Width1.5m ×Length1.5m ×Depth2.0m)	Test pit log	To acquire soil properties near land surface, and utilize for design and cost estimates of the FFWS facilities	×	×	○	○
	Soil Laboratory Test (Natural moisture content, Atterberg limits, Grain-size distribution, Specific gravity, Shear)	Laboratory test results	To acquire soil properties of samples taken from borehole drilling sites and test pit sites, and utilize for design and cost estimates of the FFWS facilities	○	○	○	○
	California Bearing Ratio Test (CBR Test)	CBR test results	To acquire soil properties of load bearing capacity, and utilize for design and cost estimates of an access road at X-band radar site of XR-1: Poblacion	○※2	×	×	×

※1:Only at RW-2:PelaezBridge and RW-6:Liboran, which are located in the downstream areas

※2:Only at XR-1:Poblacion

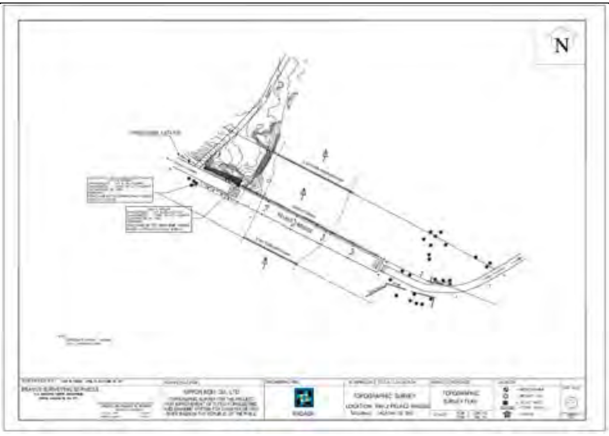
Table 1-3 Survey Quantities of Natural Condition Survey

Type	No.	Name	Topographic Survey			Geological Survey		
			Topographic Map (ha)	Longitudinal Profile (section)	River Cross Section (section)	Borehole Drilling (m)	Test Pit (unit)	CBR Test (unit)
X-band Rainfall Radar	XR-1	Poblacion	16.00	1	-	20	-	4
	XR-2	Dagumbaan	1.00	1	-	20	-	-
Master Station	MS	MPRSD*	0.30	1	-	40	-	-
Water Level and Rain Gauge	RW-1	Borja Bridge	0.54	1	2	-	1	-
	RW-2	Pelaez Bridge	0.50	1	2	30	1	-
	RW-3	Cabula Bridge	0.49	1	2	-	1	-
	RW-4	Uguiaban Bridge	0.26	1	2	-	1	-
	RW-5	Tal-uban Bridge	0.15	1	2	-	1	-
	RW-6	Liboran	0.50	1	3	20	1	-
	RW-7	NIA** Bubunawan Irrigation Intake	0.50	1	3	-	1	-
Rain Gauge	R-8	Imbatug Central Elementary School	0.24	1	-	-	1	-
	R-9	Nangka Elementary School	0.25	1	-	-	1	-
	R-10	Talakag Bureau of Fire	0.25	1	-	-	1	-
	R-11	Tikalaan National High School	0.70	1	-	-	1	-
	R-12	Masimag Elementary School	0.50	1	-	-	1	-
	R-13	Miarayon Elementary School	0.50	1	-	-	1	-
Total			22.66	16	16	130	13	4

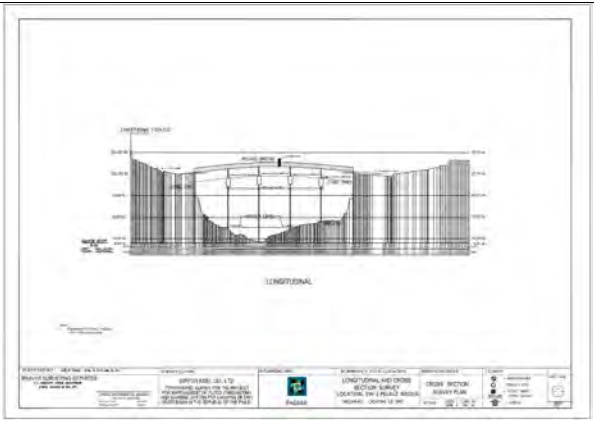
Remarks
(*) MPRSD: Mindanao PAGASA Regional Services Division
(**) NIA: National Irrigation Administration

1-2-2-2 Survey Results

As examples of the results of the natural condition surveys, Figure 1-7 and Figure 1-8 show outcomes of the topographic survey and the geological survey at RW-2: Pelaez Bridge, respectively. The outcomes of these surveys were utilized for design and cost estimates for X-band radar towers, repeater stations, and hydrological observation facilities.



Contour Map



River Cross Section Drawing

Figure 1-7　Example of Topographical Survey Outcomes（RW-2：Pelaez Bridge）

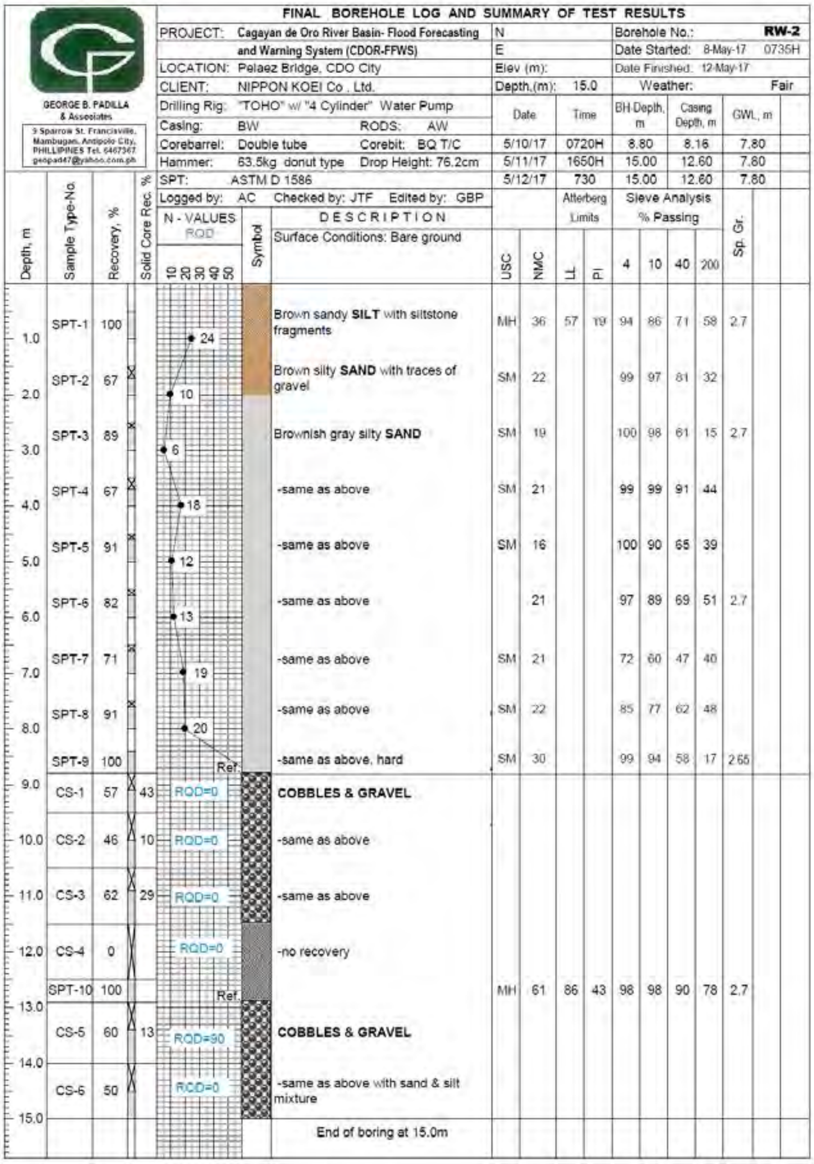


Figure 1-8　Example of Geological Survey Outcomes（RW-2：Pelaez Bridge, Borehole Log）

1-2-2-3 Estimates on Flood Water Level During Tropical Storm "Sendong"

Flood water levels during Tropical Storm "Sendong" in December 2011 were estimated to utilize for design of water level gauge stations of FFWS. Two methods shown below were applied.

(1) Flood water levels from interviews of residents who reside near the area

(2) Flood water levels estimated by non-uniform flow analysis using river cross section data measured by the topographic survey

Table 1-4 shows the results of estimated flood water level during Tropical Storm "Sendong". As reference, Figure 1-9 shows field photos at proposed water level gauging sites with flood water level from interviews of residents who reside near the area. Table 1-5 shows conditions of non-uniform flow analysis.

Table 1-6 shows estimated flood discharges during Tropical Storm "Sendong" that were used for non-uniform flow analysis at proposed water level gauging sites. Among seven water level gauging sites, the flood water levels from interviews are higher than the flood water levels by hydraulic analysis at RW-2, 3, 4, 5, 6, and 7. At RW-1, flood water level from interviews is not shown in the table because of site-condition change by on-going construction of flood walls by FRIMP-CDOR. Thus, the design flood level of 6.27 m determined by FRIMP-CDOR is considered for the design at RW-1.

FRIMP-CDOR estimates that Tropical Storm "Sendong" is about a 50-year return period flood event. Therefore, when FFWS facilities in this project are installed higher than the estimated flood water level during Tropical Storm "Sendong", these facilities may avoid flood damages caused by flood events less than 50-year return period (flood events with low return period and high frequency).

Table 1-4 Results of Estimated Flood Water Level During Tropical Storm "Sendong"

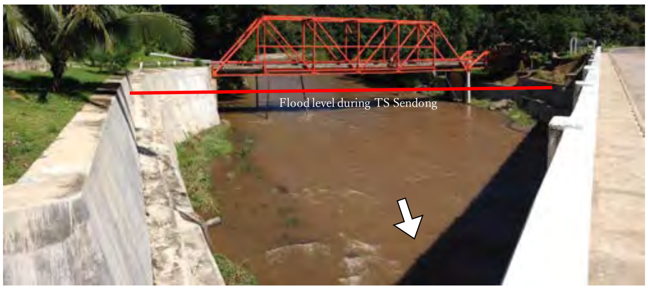
No.	Water Level Gauge Station	River	Flood Water Level during Tropical Storm "Sendong" (m in mean sea level)		
			(1) Interviews from local residents	(2) Hydraulic Analysis	Higher (1) or (2)
RW-1	Borja Bridge	Cagayan de Oro	-	5.75	5.75
RW-2	Pelaez Bridge	Cagayan de Oro	19.62	18.17	19.62
RW-3	Cabula Bridge	Cagayan de Oro	49.52	45.13	49.52
RW-4	Uguiaban Bridge	Cagayan de Oro	150.22	145.97	150.22
RW-5	Tal-uban Bridge	Cagayan de Oro	463.30	460.16	463.30
RW-6	Liboran in Bubunawan River	Bubunawan	80.18	77.98	80.18
RW-7	NIA intake in Bubunawan River	Bubunawan	484.30	484.25	484.30

RW-1: Borja Bridge

RW-2: Pelaez Bridge

RW-3: Cabula Bridge

RW-4: Uguiaban Bridge



RW-5: Tal-uban Bridge

RW-6: Liboran

RW-7: NIA Bubunawan Irrigation Intake

※ : At RW-1, design flood level determined by FRIMP-CDOR is shown.

※: The Flood Water Level from Interviews of Residents who Reside near the Area

Figure 1-9 Field Photos at Proposed Water Level Gauging sites with Flood Water Level

Table 1-5 Condition of Non-uniform Flow Analysis

Item	Condition
Non-uniform Flow	Mix of subcritical flow and super-critical flow
River Cross Section	River cross section data measured by Topographic Survey (three sections each site)
Boundary Condition for Downstream Water Level	Water level estimated by uniform flow analysis
Discharge	Discharge estimated by FRIMP-CDOR （At the sites with no estimated discharge by FRIMP-CDOR, discharges were estimated by discharge ratio and catchment area, as shown in Table 1-6）
Roughness Coefficient	0.035 estimated from river bed conditions
Increase of Water Level by Bridge Piers	Considered
Change of Water Level by Expansion and Compaction of Flow Area	Non-flow areas were set in river cross sections

Table 1-6 Estimated Flood Discharges during TS Sendong Used for Non-uniform Flow Analysis

Site	Water Level Gauge Station	River	Distance to Estuary (km)	Slope	Peak Discharge during Tropical Storm Sendong (m^3/s)	Catchment Area (km^2)
RW-1	Borja Bridge	Cagayan de Oro	3.8	1/1000	5000	-
RW-2	Pelaez Bridge	Cagayan de Oro	12.0	1/200	5000	1317
RW-3	Cabula Bridge	Cagayan de Oro	18.8	1/200	4100	1094
RW-4	Uguiaban Bridge	Cagayan de Oro	36.0	1/80	2300	614
RW-5	Tal-uban Bridge	Cagayan de Oro	60.0	1/80	1285	343
RW-6	Liboran in Bubunawan River	Bubunawan	20.8	1/70	900	203
RW-7	NIA intake in Bubunawan River	Bubunawan	45.7	1/30	486	109

1-3 Environment and Social Considerations

Acquisition of the Environmental Compliance Certificate (ECC) was not required due to the similar projects in the past, such as JICA grant project for FFWS in the Pampanga/Agno River basin, and Japanese Non-project Grant for FFWS in the Bicol River basin. The same process can be adapted to this project. However, in similar projects in the past, PAGASA has obtained a Certificate of Non-coverage (CNC) from the Department of Environment and Natural Resources (DENR) instead of ECC, so it is preferable to acquire a CNC even in this case. PAGASA also agreed to acquire a CNC for this project.

Regarding land acquisition, it shall follow the required process for land acquisition in the Philippines. In addition, if cutting trees is needed after land acquisition, it is necessary to consult with the Community Environment and Natural Resources Office (CENRO) and get approval from them. In the normal case, it is required to plant 20 seedlings per tree cut down. Regarding coconut tree planting, it is necessary to consult with the Philippine Coconut Authority (PCA) also.

1-4 Existing Telemetry System

1-4-1 Twin Phoenix Telemetry System

Outline of the Twin Phoenix Telemetry System is summarized in Table 1-7.

Table 1-7 Outline of the Twin Phoenix Telemetry System

Finance Resource	United Nations Development Programme
System Configuration	Monitoring Station：1 site (MPRSD)
	VHF* Radio Repeater Station：1 site
	Rainfall and Water Level Gauge Station：1 site
	Water Level Gauge Station：3 sites
	Rainfall Gauge Station：5 sites
Data Transmission	VHF* Radio: 162.35 MHz
Contractor	Seven Lake (Philippine company)
Commencement	December 2015

Remarks
(*)VHF: Very High Frequency

It is reported by PAGASA that the said system is operated for almost one year, but the data collection stopped in December 2016. The contractor (Seven Lake) conducted the repairing works, but the following failures at certain stations still remain in May 2017:

(1) Function Issues

- Mambuaya rainfall and water level gauge station: Low battery voltage
- Department of Public Works and Highways (DPWH) Tikalaan rainfall gauge station: The measured data cannot be transmitted during night time
- The data collection of all water level gauge stations in three sites cannot be performed. It is observed that the data collection at some sites are made, but compilation of the data collected cannot be performed due to bugs in the system software

(2) Installation Issues

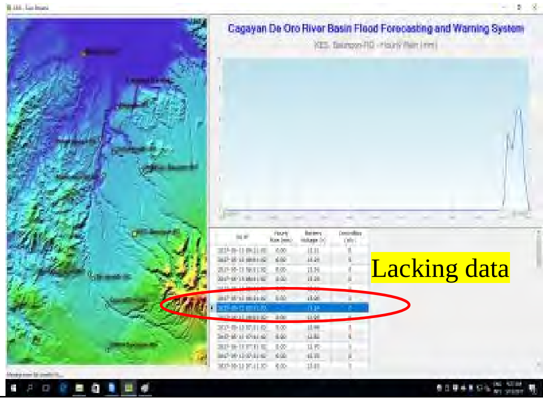
- Since the water level sensor is installed at a high position from the river surface, the measurement data of the water level records as the height of the sensor. (Figure 1-10 No.3)
- Water level sensor cables are not fixed properly, therefore the water level sensor can be washed out when flooding occurs. (Figure 1-10 No.5)
- The rainfall gauge is installed at a high position on the mast, so there is difficulty for the Operation & Maintenance (O&M) works. (Figure 1-10 No.4)
- Anti-rust treatment for the post is not conducted. (Only two years have passed, but there is a lot of rust on the mast.) (Figure 1-10 No.6)

(3) Design Issues

- Outdoor box for the equipment/facilities is not thermal shield treated thus, the temperature inside will be high that causes mal-operation as well as a shorter life-span of the equipment/ facilities

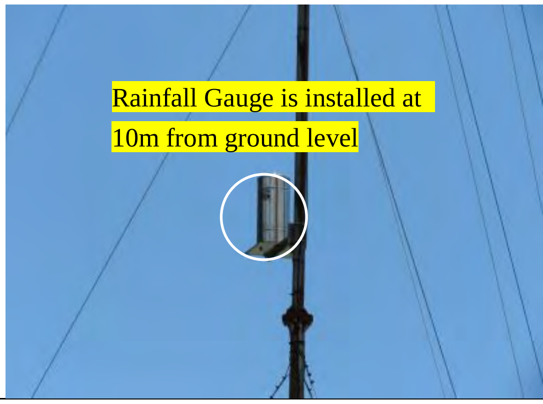
The abovementioned situations are shown in Figure 1-10.

No.1 Twin Phoenix Supervising Equipment



No.2 Twin Phoenix Display

No.3 Water Level Sensor Tal-uban Water Level Gauge Station



No.4 Rainfall Gauge KES Baugon Rain Gauge Station

No.5 Water Level Sensor Pelaez Br Water Level Gauge Station

No.6 Antenna Mast KES Baugon Rain Gauge Station

Figure 1-10 Equipment of Twin Phoenix Telemetry System

1-4-2 NDMI Telemetry System

Outline of the National Disaster Management Institute (NDMI) Telemetry System is summarized in Table 1-8 below.

Table 1-8 Outline of the NDMI Telemetry System

Finance Resource	Korea NDMI
System Configuration	Monitoring Station：1 site (CDO-CDRRMD*)
	Rainfall and Water Level Gauge Station：0 sites + ASTI** station: 2 sites
	Water Level Gauge Station：1 site + ASTI station: 1 sites
	Rainfall Gauge Station：2 sites + ASTI station: 3 sites
	CCTV Station：1 site
	Flood Warning Station/ Post: 5 sites
Data Transmission	SMS
Contractor	Korean Companies (Data PCS, NOAA Solution)
Commencement	December 2015

Remarks
(*) CDO-DRRMD: Cagayan de Oro City Disaster Risk Reduction and Management Department
(**) ASTI: Advanced Science and Technology Institute

Operational conditions at the following stations are observed in May 2017:

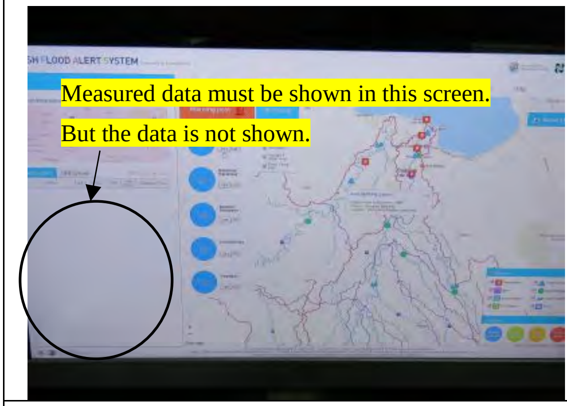
(1) Function Issues

- Measured data of the rainfall and water level gauge stations cannot be displayed at the Cagayan de Oro City Disaster Risk Reduction and Management Department (CDO-CDRRMD). Meanwhile the said measured data can be recorded in the database. (Figure 1-11 No.1)
- Switching on/off for the warning speakers cannot be performed at the CDO-CDRRMD.
- Switching on/off for the warning speakers thru the SMS cannot be undertaken. It cannot be operated just like in the case of flooding in Cagayan de Oro City during January 2017. (Figure 1-11 No.3)
- The defect of the System Software that the collected data are not displayed as mentioned above has not been solved yet, and quick/proper remedy works have not been conducted by the Contractor. (It is contractual problem between PAGASA and the Contractor.)

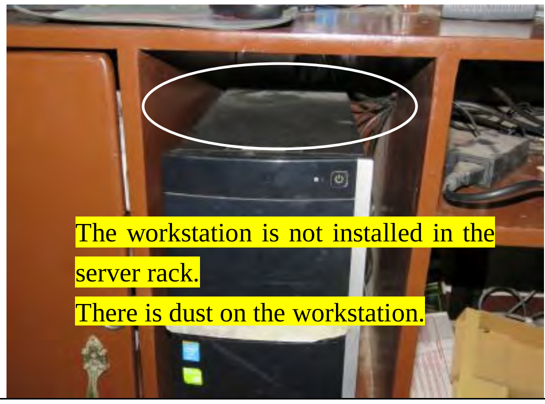
(2) Design Issues

- Data logger and charger equipment are not fixed to the outdoor cabinet properly, which causes it to break when the said equipment falls down. (Figure 1-11 No.4)
- The outdoor box/cabinet for the equipment/facilities is not thermal shield treated, so the temperature inside will be high and will cause mal-operation and a shorter life-span of the equipment/ facilities

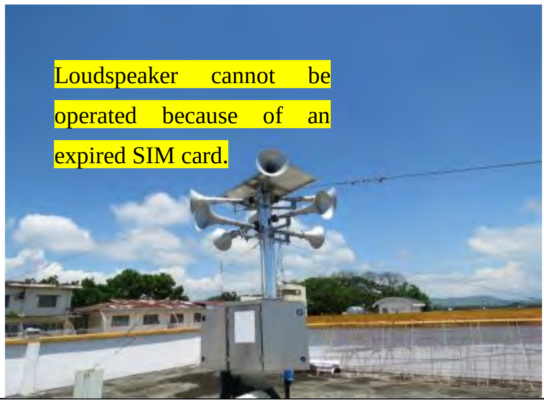
The abovementioned situations are shown in Figure 1-11.



No.1 NDMI Display CDO-CDRRMD



No.2 NDMI Workstation CDO-CDRRMD



No.3 Loudspeaker CDO-CDRRMD

No.4 Data Logger Puntod Station

Figure 1-11 Equipment of NDMI Telemetry System

1-4-3 ASTI Telemetry System

ASTI Telemetry System is the nationwide hydrological data gathering system. It is one of the components of The NOAH Project, The National Operational Assessment of Hazards Project aimed at preventing natural disasters with its construction started in 2012. In this system, hydrological data can be obtained from water level/rainfall gauging sensors through SMS that have been deployed nationwide. The data collected thus are transferred to ASTI server and processed for uploading internet website display. The telemetry controller/logger is an original design by ASTI and equipment fixing-hardware and outdoor metal case are domestically procured while water level sensor and solar panel are imported from abroad.

(1) Installation Issues

- The outdoor box/cabinet is not thermally protected or shielded from sun-light, so temperature will rise inside the cabinet and eventually affect equipment/facilities that may lead to malfunction or a shorter life of equipment. (Figure 1-12 No.1 and No.2)

(2) Design Issues

- In ASTI telemetry system, many gauging stations have been constructed during short period without full assessment from hydrological points of view, and gauging stations are placed mostly on the bridges because it is easier to install. Rainfall gauging stations are excessively congested in a relatively narrow area.
- ASTI does not staff hydrological specialist. So, the hydrological data are not quality-checked before uploading on the website.

(3) Operation and Maintenance

Since then this telemetry system was officially transferred to PAGASA from ASTI last year, operation and O&M works have been discussed inside PAGASA, which will be a burden to current PAGASA maintenance capacity. In addition, because ASTI system has more than 1,000 site gauge stations nationwide, it is not yet decided whether PAGASA can maintain all these gauge stations in future. Considering from hydrological points of view, it is suggested that some gauging stations should be retained for continuous operation, and others dismounted for ease of future maintenance.

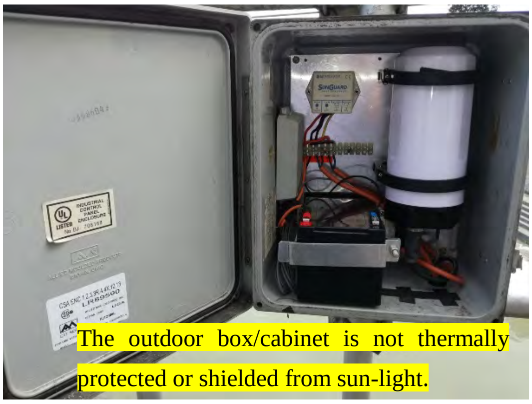
	
No.1 ASTI Cabula Bridge Water Level Gauge Station	No.2 Outdoor box/cabinet (Photo shows the outdoor box in an other basin)

Figure 1-12 Equipment of ASTI Telemetry System

1-4-4 Location of Existing Telemetry System

Locations of the observation stations of the Twin Phoenix and NDMI telemetry systems are shown in Figure 1-13.

Source：Construction of Forecasting and Warning System for Disaster Risk Reduction in the Philippines (III) (NDMI, December 2015)

Figure 1-13 Location of Twin Phoenix, NDMI and ASTI Telemetry Systems

1-4-5 Utilization Scheme of the Existing System

1-4-5-1 Twin Phoenix Telemetry System

The system failures have occurred many times after completion of the Twin Phoenix Telemetry System. The PAGASA Hydro-Meteorological Telemetry Section (HMTS) and MPRSD jointly conducted checking the operational situation in January 2018, but the total remedy works have not been accomplished because of the issues analyzed below.

- Data errors that may come from weak receiving signals
- Quality of the equipment / facilities such as battery and solar controller

Because high reliable and stable operations are required for long period for this FFWS established under the Japan Grant Aid project. Because the issues that have been recurring and persisting in Twin Phoenix System, it is recommendable that integration with Twin Phoenix Telemetry System should be avoided. The JICA Study Team recommends PAGASA that the measured data from the Twin Phoenix Telemetry System can be treated as an ancillary data.

1-4-5-2 NDMI Telemetry System

The responsibility of operation and O&M works for the NDMI Telemetry System is not on PAGASA, but with the CDO-CDRRMD. In addition, an objective of the said system is establishing a flood warning system for the people along the Cagayan de Oro River thus, switching the warning siren on/off differs from the purpose/function of the Twin Phoenix Telemetry System principally. Twin Phoenix Telemetry System aims at collecting rain and water level data and disseminate it to the concerned local government agencies. It is said that data sharing between PAGASA Cagayan de Oro River Flood Forecasting and Warning Center (CDORFFWC) and CDO-CDRRMD is an effective effort to monitor the skill of the flood, but the responsibility and purpose/function of the system are different from each other. The JICA Study Team recommends PAGASA that the NDMI Telemetry System can be operated as an independent system and the measured data from the said system can be treated as ancillary data.

1-4-5-3 ASTI Telemetry System

ASTI, Telemetry System is the nationwide hydrological data gathering system. It is one of the components of the National Operational Assessment of Hazards Project which aims at a nationwide natural disaster prevention started construction in the year 2012. As described in Table 1-8 above, the hydrological data for 1 water level site, 3 rainfall sites and 2 water/rainfall sites, which are established by ASTI, have been combined to the NDMI Telemetry System. On the other hand, combination to the Twin Phoenix Telemetry System has not been achieved. Since the ASTI Telemetry System is transferred to PAGASA from ASTI last year, operation and O&M works have been discussed inside PAGASA, which is big burden to current PAGASA capacity. In addition, since ASTI system has more than 1,000 site gauge stations nationwide, it is not yet decided whether PAGASA can maintain all these gauge stations in future. Considering the current situations that PAGASA does not disclose the concrete plan of utilization and integration of ASTI system, JICA Project should be independent in design from the ASTI system.

The JICA Study Team decided that the integration of the ASTI Telemetry System is not considered under this study works. (Works is not included in the Japan Grant Aid project).

1-4-5-4 Conclusion

Pursuant to the order from the PAGASA Administrator in January 2018, HMTS and MPRSD conducted a joint survey on the operational situation of Twin Phoenix, NDMI, and ASTI telemetry systems, but continuous operation of the said systems has not been concluded yet at the PAGASA side (it will take more time).

The JICA Study Team concluded that the integration of the said three systems to the FFWS under the Japan Grant Aid project is not considered for the following reasons:

- Defect(s) on the design works
- Poor quality of the equipment/facilities
- Defect on planning for the installation places of the water level gauge
- Poor installation works during construction period

Chapter 2. Contents of the Project

Chaper 2. Contents of the Project

2-1 Basic Concept of the Project

The goal of this project is sustainable operating of FFWS by PAGASA at CDORFFWC and reducing flood damages in the basin accordingly.

The objectives of this Feasibility Study for Improving the FFWS in the Cagayan de Oro River basin are to establish a FFWS operated by PAGASA itself as well as to improve the general flood risk management ability in this river.

Table 2-1 Detailed Contents of the Project

Item		Detail	Quantity
1	Installation of Rainfall Gauge Stations		
	(1)	Ground Rainfall Gauge Stations	13 stations
	(2)	X-band Radar Rain Gauge Stations	2 stations
2	Installation of Water Level Gauge Stations		
	(1)	Combination of Rainfall and Water Level Gauge Stations	7 stations
3	Installation of Radio Communication Equipment		
	(1)	Dedicated VHF Radio Communication Link between Hydrological Stations and Repeater Station	1 set
	(2)	Repeater Station (collocated with X-band Radar Rain Gauge Station)	2 set
	(3)	Dedicated Wired Communication Link between CDORFFWC and CDO-CDRRMD	1 set
4	Installation of Visualization System to Display Measured Data		
	(1)	Operation Terminal and Data Processing Server for X-band Radar Rain Gauge	2 sets (CDORFFWC and HMD)
	(2)	Monitoring Display	2 sets (CDORFFWC and CDO-CDRRMD)
	(3)	Information Delivering Subsystem including Web-site Construction	1 set (CDORFFWC)
5	Detail Design and Procurement		
	(1)	Procurement (Equipment Procurement, Transportation, Installation Works, Civil Works and Management)	1 set
	(2)	Detail Design including works and Support related bidding, supervision of construction stage and soft component	1 set

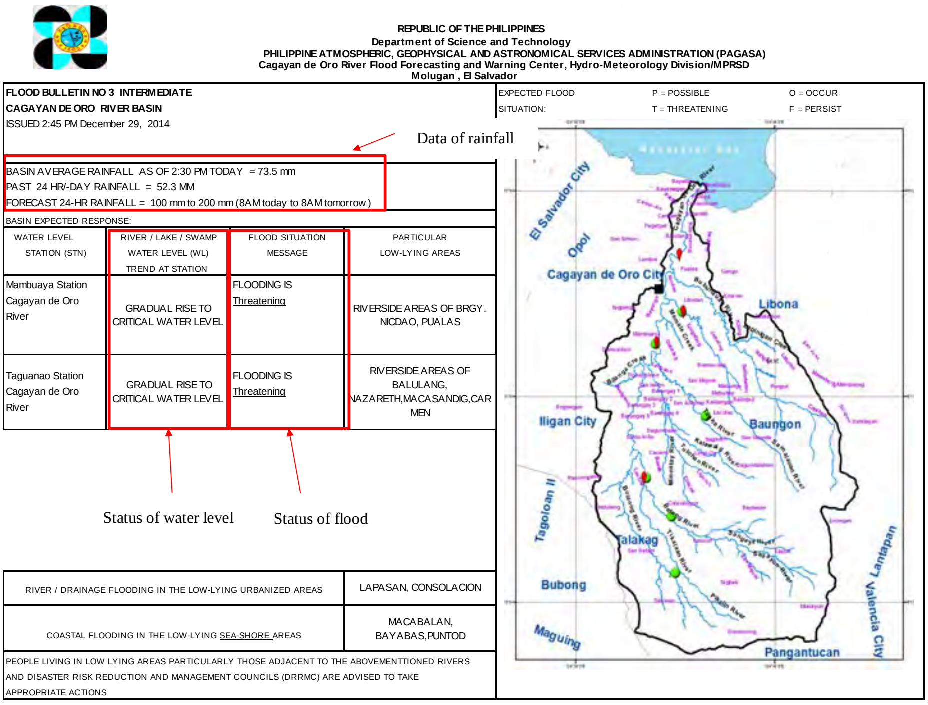
2-2 Outline Design of the Japanese Assistance

2-2-1 Design Policy

2-2-1-1 Basic Policy

(1) Necessity of X-band radar

For issuance of flood warning, in addition to water level data, rainfall data with high density in temporal and spatial scales is also required. Currently, MPRSD forecasts the flood situation based on observed water level and rainfall, then issues a flood advisory and flood bulletin. Flood bulletin published by MPRSD in case of Tropical Storm “Seniang” in 2014 is shown in Figure 2-1, as an example. However, since very few gauges are operating without problems, currently, water level and rainfall data are not sufficient in both quantity and quality for reliable forecasting. Furthermore, it is necessary to monitor upstream rainfall precisely in temporal and spatial scales. Therefore, in addition to water level gauge and rainfall gauge, X-band radar is mandatory in this FFWS.



REPUBLIC OF THE PHILIPPINES
Department of Science and Technology
PHILIPPINE ATMOSPHERIC, GEOPHYSICAL AND ASTRONOMICAL SERVICES ADMINISTRATION (PAGASA)
Cagayan de Oro River Flood Forecasting and Warning Center, Hydro-Meteorology Division/MPRSD
Molugan , El Salvador

FLOOD BULLETIN NO 3 INTERMEDIATE
CAGAYAN DE ORO RIVER BASIN
ISSUED 2:45 PM December 29, 2014

EXPECTED FLOOD SITUATION: P = POSSIBLE, T = THREATENING, O = OCCUR, F = PERSIST

BASIN AVERAGE RAINFALL AS OF 2:30 PM TODAY = 73.5 mm
PAST 24 HR/-DAY RAINFALL = 52.3 MM
FORECAST 24-HR RAINFALL = 100 mm to 200 mm (8AM today to 8AM tomorrow)

BASIN EXPECTED RESPONSE:

WATER LEVEL STATION (STN)	RIVER / LAKE / SWAMP WATER LEVEL (WL) TREND AT STATION	FLOOD SITUATION MESSAGE	PARTICULAR LOW-LYING AREAS
Mambuaya Station Cagayan de Oro River	GRADUAL RISE TO CRITICAL WATER LEVEL	FLOODING IS Threatening	RIVERSIDE AREAS OF BRGY. NICDAO, PUALAS
Taguanao Station Cagayan de Oro River	GRADUAL RISE TO CRITICAL WATER LEVEL	FLOODING IS Threatening	RIVERSIDE AREAS OF BALULANG, NAZARETH,MACASANDIG,CARMEN

RIVER / DRAINAGE FLOODING IN THE LOW-LYING URBANIZED AREAS	LAPASAN, CONSOLACION
COASTAL FLOODING IN THE LOW-LYING SEA-SHORE AREAS	MACABALAN, BAYABAS,PUNTOD

PEOPLE LIVING IN LOW LYING AREAS PARTICULARLY THOSE ADJACENT TO THE ABOVEMENTTIONED RIVERS AND DISASTER RISK REDUCTION AND MANAGEMENT COUNCILS (DRRMC) ARE ADVISED TO TAKE APPROPRIATE ACTIONS

Source: PAGASA PRSD
NOTE: Red comments are added by editor

Figure 2-1 Flood Bulletin Published by MPRSD in Case of Tropical Storm “Seniang” in 2014

According to "PAGASA Modernization Plan", PAGASA is planning to introduce an X-band radar in the main river basin in the Philippines, therefore, the installation of an X-band radar in the Cagayan de Oro River basin also matches the basic policy of their plan. In addition, PAGASA is also planning to update the criteria for the heavy rain warning to reduce damage by urban flooding in the main cities. Recently, Cagayan de Oro City experienced serious urban flooding in January 2017 and not only PAGASA but also CDO-CDRRMD recognizes the necessity of the real-time rainfall observation with high density in temporal and spatial scales. Installation of an X-band radar by this project can comply to this demand also.

Meanwhile, according to the road map proposed in TCP, the flood forecasting method will be improved from Stage 1 to Stage 3, step by step. In this improvement plan, the trend method based on real-time observed water level data at single station is classified as Stage1, the stage correlation method is classified as Stage 2, and flood forecasting using a flood simulation model is classified as Stage 3. To calibrate the flood simulation model, hydrological data accumulated in a sufficient period, including dense rainfall data monitored by an X-band radar, is required. Since the installation of the ground rainfall gauges in the upstream mountainous areas is difficult due to high security risk and poor access, areal rainfall monitoring by an X-band radar is highly recommended.

(2) Site Selection of Hydrological Stations

Sites for installing rainfall gauge and water level gauge, including the sites proposed by TCP, were determined through hydrological analysis, field visits and discussion and confirmation with PAGASA. Since the ground observed rainfall data by new rainfall gauge stations will be used to improve the accuracy of X-band radar rain gauge, the distance from X-band radar rain gauge and the altitude of the new stations should be considered in the site selection.

Meanwhile, FRIMP-CDOR is also ongoing as the structural countermeasure (e.g., construction of new embankment and repairing Cagayan Bridge) up to 10 km upstream from the estuary. Therefore, in order to decide where the water level gauge stations are going to be located within the downstream reach, hydraulic condition changes thru the construction, such as the river topography and planned high water level, should be also considered in the site selection.

(3) Flood Forecasting Method for Issuance of Flood Warning

For the FFWS proposed in this project, the stage correlation method will be applied for flood forecasting. The stage correlation method aims to forecast water level at the downstream water level gauge station based on a stage correlation function that considers flood propagation time and water level observed at the upstream water level gauge station. This method is already applied for flood forecasting of the Pampanga River and operated by the Pampanga River Flood Forecasting and Warning Center (PRFFWC). Since the method requires the pre-established stage correlation function and real-time observed water level at an upstream water level gauge station, flood forecasting by the method will be operated after sufficient data of flood water level at each station accumulated by the FFWS and the correlation function is established.

(4) Selection of Communication Channel

The communication channel should be able to carry hydrological data in real time not only in the normal condition, but also hazardous conditions such as heavy rain or strong winds caused by a typhoon. Therefore, the VHF band radio telemeter system was chosen as the communication method between water level/rainfall gauge stations and the repeater stations, as it can provide reliable communication channels under such harsh condition.

Meanwhile, microwave radio link was chosen as the communication channel between repeater stations collocated with X-band radar rain gauge stations and CDORFFWC, as it can carry big image data measured in X-band radar rain gauge stations on the wide band (up to several Mbps) and reliable radio channel.

Microwave radio link is also the first candidate for the link between CDORFFWC and CDO-CDRRMD, but provider’s commercial link will be used in case the line of sight (LOS) is not secured between those two points.

As for the communication channel between CDORFFWC and PAGASA Headquarters in Quezon, installing a new microwave link is not realistic between Mindanao Island and Luzon Island by PAGASA itself because it entails a huge cost. By this reason, provider’s commercial link or satellite link is recommended.

(5) Design Policy for Database Format

The hydrological data provided by the FFWS should not use vendor proprietary format, but data formats compatible with the database system which is planned to be used by PAGASA (AQUARIUS). In establishing a website for real time monitoring of rainfall and water level, data must be easily understood and useful for end users, since those data are provided to the local government office and disaster office for judging the necessity of evacuation.

(6) Consideration of FFWS which Matches the Needs of the End User Organizations

The proposed FFWS system is requested to assist PAGASA in providing necessary information that matches the needs of the end user organizations. To satisfy this requirement, the data contents and provision method from the FFWS are needed to be reviewed carefully, to secure that provided information are needed by the stakeholder organizations, who are responsible in judging the necessity of evacuation from flood.

(7) Design Policy of Hydrological Stations

The design policy of the FFWS facilities (e.g. water level and rainfall gauge, rainfall gauge, X-band radar rain gauge station) is described as follows:

1) **Water Level Gauge Stations**

- Pressure type water level sensor is adopted by the reasons below.
  - ✓ High reliability is confirmed through working performance of Pampanga and Agno FFWS;
  - ✓ Easy O&M works by PAGASA is available in comparison with the old floating type; and
  - ✓ HMD has been studying the pressure type as standardization of water level sensor.
- During the design phase of the hydrological stations, river bed slope, river bed material, water velocity, erosion and scouring just up/down stream of the station needs to be considered, to prevent those negative effects or the possibility.
- During selection of the location of the monitoring gauge station (house), rainfall hydrological and radio propagation conditions are considered. Ground type of gauge house is basically adopted for the gauge house, however “Raised-Floor-Style house of Gauge Station” was examined and selected finally for the project in viewpoints of disaster prevention such as flooding / heavy rain, risk management of safety and functional maintenance of gauging equipment, and security of building house and equipment inside of the house against robber and acts of destruction.
- Regarding the access road to hydrological stations (water level gauge, rain gauge, radio station for those, and X-band radar rain gauge station), permanent access road is needed (road with one or more traffic lanes or bridges, including the existing road) in principle.
- Regarding the pavement of the access road, the first option is gravel paving, but asphalt or concrete paving is discussed, considering the site condition (e.g., estimated type of vehicle, estimated traffic, importance of the site, disaster prevention, etc.).
- As a basic design policy, to reduce the risk of destruction in case of disaster, a gauge

station (house) is established in the nearby upland, separated from the water level gauge. The purposes of the establishment of gauge house separated from water level gauge are described as below;

i. To reduce risk against collapse or flashed-away of gauge house to be located nearby river bank, water level gauge caused by flood.

ii. To eliminate risk of functional suspension of hydro-meteorological and telemetering system equipment such as water level, rainfall gauging and communication equipment,

iii. To maintain safety access, operation and maintenance of equipment of the gauge house at any time, normal and emergency time.

- When hydrological stations are installed on a steep gradient, the risks of rock fall, slope failure, and landslide are considered.
- At the facility plan and design, the impact of the civil works structure to the surrounding landscape is minimized as much as possible.
- The design concepts described above cannot be applied to RW-2 Pelaez Bridge and RW-6 Liboran water level gauge stations due to acquisition problem. Therefore, the design concepts of the two sites are modified with applying of a unification structure type of water level gauge and gauging house as shown in Table 2-2.

Table 2-2 Reasons of Change of Design Concept and Measures of Basic Designs

No.	Reasons of Change of Design Concept	Measures of Basic Designs (Basic Designs by Change of Design Concept)
RW-2	In original design proposed on June 2017, civil structural facilities were designed as mentioned below (Separation Type of Water Level Gauge and Gauging House); i) “Pier” type of Water Level Gauge structure was designed to be situated at left bank within river channel, downstream of the left bridge abutment. ii) Gauging House was designed to be constructed at the top of the left bank, within flat area owned by private land owner. iii) Water level gauge and Gauging house structures were designed to be connected by concrete PC access bridge, and access road for the gauging house was provided from the existing public road. However, design and location of the gauging house was refused by the land owner for his land use. The owner offered another land for the gauging house at the left bank immediate upstream of the left bridge abutment instead of the downstream site on August 2017, which should be used as leased land with limited rental period. But PAGASA responded to the land owner that the offer of leased land could not be acceptable for permanent land use of gauging house of the FFWS on the left bank (Upstream and Downstream of the left bridge abutment) of the Cagayan de Oro River. As result of discussion of land issues between PAGASA and the land owner, the following alternative sites of water level gauge and gauging house shall be examined instead of original site of left bank. (i) To set at Right bank site, and (ii) To set at Riverbed at left bank side	“(ii) To set at Riverbed at left bank side” is to be applied as the construction site from the following technical and land issue viewpoints; ➢ Direction of river water flow, ➢ Sedimentation in the river bank, and ➢ Land issues (owned by government and private land owner) Gauging house is designed to be constructed at deck, top of Pier type of Water Level Gauge as a unification structure type of water level gauge and gauging house. New design concept of the water level gauging site by using of the unification structure type mentioned below to cope with unacceptable offered from the land owner. (a) Pier type of Water Level Gauge structure is designed to be situated within river channel at immediate downstream of the first line of pier of the bridge from the left abutment, for which Bore Pile (reinforced concrete with diameter of 1,000 mm to 1,500 mm) shall be installed until 10 m to 15 m depth underground of riverbed to stabilize of the structure, (b) A hole (with dia. 100 mm) will be provide inside of center of the bore pile structure to equip with water level censor and its cable inside of the hole. (c) Gauging House will be built at the top of concrete pier with foundation structures (which should be built as one set of a Reinforced Concrete (RC) Bore Pile (10 m to 15 m depth underground of riverbed) and a footing RC concrete (4000 x 4000 x 250 approximately) is designed, which shall be put in river channel just downstream of the line of bridge piers, left abutment side.

No.	Reasons of Change of Design Concept	Measures of Basic Designs (Basic Designs by Change of Design Concept)
		(d) For access to the Gauging House, light (not heavy) type of steel bridge (made of stainless steel) will be provided between the gauging house built at top of the pier and the bridge in the same line of first bridge piers from the left abutment. (e) Adequate distances between the new designed pier and the following existing bridge structures should be maintained in hydraulic viewpoints to prevent damages on the existing structures, natural river bank and new designed structured itself. ✓ Bridge piers (more than10m downstream), ✓ Abutment (more than 40-50m from at left bank) of the Pelaez Bridge, and ✓ Natural river bank (left bank) and
RW-6	In original design proposed on June 2017, civil structural facilities (water level gauge and gauging house) were designed to be built in left bank of the Bubunawan River, Liboran Area as Separation Type of Water Level Gauge and Gauging House, in which PAGASA has already installed water level staff-gauge at the site. The both river bank/land of the Bubunawan river ("Easement" stipulated in the law) is basically owned by the Governments (Department of Environment and Natural Resources, Forestry Agency). However, a farmer who uses the land had strongly given an objection to construction of the gauging house of a facility of Separation Type of Water Level Gauge and Gauging House structures. Accordingly, PAGASA finally determined to cancel construction of gauging house in the left river bank.	For countermeasures against rejection to use the land of the site, the Gauging house is designed to be constructed at deck, top of Pier type of Water Level Gauge as a unification structure type of water level gauge and gauging house. In addition, pier type of unification structure type of Water level gauge and Gauging house structures were designed to be connected by concrete PC access bridge from the existing public road. Pier type of Water Level Gauge structure is designed to be situated within river channel at immediate downstream of the first line of pier of the bridge from the left abutment, for which Bore Pile (reinforced concrete with diameter of 1,000 mm to 1,500 mm) shall be installed until 10 m to 15 m depth underground of riverbed to stabilize of the structure. (a) A hole (with dia. 100 mm) will be provide inside of center of the bore pile structure to equip with water level censor and its cable inside of the hole. (b) Gauging House will be built at the top of concrete pier with foundation structures (which should be built as one set of a Reinforced Concrete (RC) Bore Pile (10 m to 15 m depth underground of riverbed) and a footing RC concrete (4000 x 4000 x 250 approximately) is designed, which shall be put in river channel

2) **Rainfall Gauge Station**

Basically, the design policy of rainfall gauge station is same as that one for water level gauge station. Raised-Floor- Style building was examined and adopted in viewpoints of prevention of natural disaster such as flooding, Heavy Rain, and Inundation, and security for robbery and destroy/damage with considering site conditions / situation.

3) **X-band radar Rain Gauge Station**

The building of X-band radar rain gauge station will consist of an operation room, machine room, accommodation for guard man, supply room, water and wastewater facility, parts storage room, electrical facilities, etc. Especially, the necessity of accommodation for guard man shall be decided in the facility planning and basic design phase, considering the importance of radar rain gauge and radio repeater station in FFWS and the security risk on X-band radar system.

In design of steel tower of the X-band Radar which is required to be heightened with H=20m to 60m above the ground, structural designs of steel tower and designs of foundation piling works underneath were made to have sufficient structural strengths of steel tower against the following loads (i) historical maximum wind speed as Design Wind Speed and (ii) steel tower own weight including weight of X-band Radar equipment, and to maintain pile bearing capacity by the sufficient number and depth of steel or concrete piling works.

2-2-1-2 Design Policy Considering Natural Environment Conditions

(1) Rainfall, Wind, Temperature and Humidity

Because the Cagayan de Oro River basin is located in the rainforest with a tropical climate, rain and water level gauges facilities such as the telemetry equipment, radio equipment and data logger are installed inside the stations in order to protect the equipment from rain and high temperature (outdoor installation might lead to error operation and shorten the equipment lifetime because of high temperature in the box).

In the Philippines, survival wind speeds are classified by the National Structure Code of Philippines, 2010 (NSCP-2010) as follows:

Zone Classification (Basic Wind Speed)	Province
Zone 2 (V=200 kph, 55 m/s)	Misamis Oriental
Zone 3 (V=150 kph, 40 m/s)	Bukidon

In this project, each criterion can be applied to each site in the provinces respectively.

(2) Flood

The flood type in the target area is characterized as follows:

- Flash Flood
  - Because of the short lead time for flood warning and evacuation, expeditious evacuation after flood is difficult.
  - Flood warning and evacuation may be required during the night time.
  - Duration of flood is generally short.
- Flood on alluvial delta (geographic characteristic)
  - Flood with relatively high velocity flowing down in the narrow delta plain
  - Evacuation during flood is difficult due to strong external force by the high inundation velocity

The FFWS established in this project needs to correspond to the above-mentioned flood characteristics. Especially, site selection of the water level gauge stations should be considered carefully in the outline design.

(3) Ground

To avoid the risk of tsunami, all equipment for CDORFFWC will be installed in the second floor of the newly installed CDORFFWC's building.

Based on the result of geological survey conducted by the local survey company, strength calculation is executed.

(4) Lightning

To reduce the risk of the lighting damage that might break FFWS equipment, the following countermeasures will be discussed:

- Outdoor equipment (hydrological station): lighting rod and earth
- Radio antenna: coaxial lighting arrester
- Signal line from rain/water level gauge: arrester
- Power supply for equipment: transformer with arrester

2-2-1-3 Design Policy Considering Social Economic Conditions

Philippines's economy is growing up rapidly, but there is unresolved issue of poverty. This situation may cause a risk of burglary or damage for FFWS. In order to protect FFWS from such risks, fence is installed around gauge house and solar panel is installed at roof of gauge house. And equipment of X-band radar has the risk especially because the equipment is high-priced. Therefore, house for staying guard man or police who guard X-band radar equipment is constructed by the Project.

2-2-1-4 Procurement Plan Considering Business Circumstances in the Philippines

Regarding the construction machine, materials used for civil works and tower construction such as concrete, cement, and steel materials will be procured from a local market in the Philippines. On the other hand, electric construction materials and general-purpose cables are also available in the Philippines, but high frequency coaxial cables are not available, and the quality of such cables is not enough. Therefore, special cables shall be procured in Japan.

2-2-1-5 Selection Policy for Local Contractor (Local Construction Company)

As civil works for building of hydrological stations and tower construction of X-band radar rain gauge station is included in this project, the local contractors qualifying the capability to handle these works in safe and steady are requested.

Referring to the actual work record of the local contractors in the Philippines, the project needs to select a local civil works company who has achieved good result in similar projects in the past and has enough capabilities to implement civil works, facilities and installation work. In the selection of the local contractors, an achieved result of the sub-contractors needs to be evaluated as well.

2-2-1-6 Support Policy for the Operation and Maintenance (O&M) Capability

Facilities introduced in this project is categorized into two groups, i.e., telemetry facilities for water level/rainfall gauge stations and that for X-band radar rain gauge station. Regarding the facilities for X-band radar rain gauge, although some on-board (vehicle) type stations and C-Band or S-Band type radars are already introduced in the Philippines, but the fixed type station has not been introduced in the target area yet. Considering the current situation described above, the works to transfer the required knowledge for O&M shall be undertaken in this Project.

Not only the knowledge transfer for the daily O&M work, but also for independent troubleshooting shall be included in the contents of the software component. The final goal of the software component is the realization of full autonomous O&M by the local staff.

2-2-1-7 Selection Policy for Facilities Procured under the Project

As all facilities introduced in this Project are used for the FFWS, high stability and reliability are needed even at the time of disaster. Therefore, to secure high availability and reliability, the main facilities shall be procured in Japan in principle.

2-2-1-8 Policy for Implementation Works

In the proposed FFWS in this Project, 13 rainfall and water level gauge stations, two X-band radar rain gauge stations, and three towers for micro band radio system are planned to be installed. Because water level gauge stations are installed in the riverbank or on the river way, the civil works in the rainy season might be delayed. To avoid the impact by the rainy season, the civil works shall be performed in parallel by multiple parties in the dry season.

2-2-2 Basic Plan (Construction Plan / Equipment Plan)

2-2-2-1 Design Policy of Stations

The FFWS introduced in this project is consisted of the following observing stations and supervising station, as describe in the following table.

Table 2-3 Observing Stations and Supervising Station

Type		Number of Stations	Name of Station
Observing Station	Water level / rainfall gauge station	7	Borja Bridge (RW-1) Pelaez Bridge (RW-2) Cabula Bridge (RW-3) Uguiaban Bridge (RW-4) Tal-uban Bridge (RW-5) Liboran (RW-6) NIA Bubunawan Irrigation Intake (RW-7)
	Rainfall gauge station	6	Imbatug Central Elementary School (R-8) Nangka Elementary School (R-9) Talakag Bureau of Fire (R-10) Tikalaan National High School (R-11) Masimag Elementary School (R-12) Miarayon Elementary School (R-13)
	X-band radar rain gauge station	2	Poblacion (XR-1) Dagumbaan (XR-2)
Supervising Station	Master station (MS)	1	CDORFFWC
	Monitoring Station	2	CDO-CDRRMD PAGASA, HMD

Using a VHF band (150 MHz) telemetry radio link and microwave (7.5 GHz) digital microwave radio link, the hydrological data were transmitted from the obse stations to CDORFFWC (Master Station), and transferred data is decoded, processed, and displayed in CDORFFWC. The decoded and processed hydrological data are forwarded from CDORFFWC to CDO-CDRRMD and PAGASA HMD through wired line and displayed there.

2-2-2-2 Design of Water Level Gauge Station Network

(1) Conditions Required for Site Selection

The main objective of the FFWS is the contribution to an appropriate forecasting, which assists prompt evacuation when needed. The location of water level gauge station shall be decided based on the following conditions considering flood characteristics of the basin. In addition, at the moment, discharge is continuously monitored at only one station in the basin (Cabula Bridge Station owned and managed by DPWH) and flood characteristics of the basin have not been quantitatively analyzed yet. Therefore, accumulation of the hydrological data should also be considered in the site selection for further enhancement of the FFW services by PAGASA and utilizing river management planning in the future.

- The site located in the upstream near the flood-prone areas in Cagayan de Oro City with high population density and assets.
- The site where the required lead time for real-time flood forecasting, warning and evacuation can be secured until the flood flow reaches the flood-prone areas in the downstream (the further upstream site is better).
- The site located near the confluence of mainstream and an important tributary from the viewpoint of the FFWS.
- The site in the flood-prone areas and the tidal compartment.
- Adding to the above conditions, the site where discharge measurement can be conducted.

Bubunawan River is considered as the most important tributary in the FFWS because of the following reasons:

- Its catchment area (223 km^2) is the largest in the six main tributaries.
- Since it has Mt. Kitanglad in the upstream, flood discharge might be larger than other tributaries due to orographic rainfall in the catchment.
- Typhoons that cause floods in the basin usually come from the east. As Bubunawan River is located in the most eastern part of the basin, flood water from Bubunawan River might arrive to the flood-prone areas in Cagayan de Oro City faster than the other tributaries.
- According to the flood investigation report prepared by PAGASA, Bubunawan River might have had a huge flood discharge during Tropical Storm “Sendong” in 2011.

(2) Site Selection

In accordance with the above conditions, the location of water level gauge stations was determined by the following procedures:

① Set selection criteria to comply the site selection policy

② Select candidate sites on a map considering the selection criteria

③ Confirm site conditions by field visits and narrow down the candidate sites

④ Finally, determine the sites based on radio propagation test results

First, this project carefully chose eight selection criteria for water level gauge stations, i.e.: access, hydrology, security, hydraulics, river improvement plan, construction, observation site by TCP, and radio propagation.

Table 2-4 shows the selection criteria and point of consideration.

Table 2-4 Selection Criteria for Water Level Observation Stations

No.	Selection Criteria	Point of Consideration
①	Access	Access by vehicle for maintenance
②	Hydrology	・Importance of site by flood runoff characteristics ・Lead time for flood forecasting and warning
③	Security	Security issues
④	Hydraulics	・ Stable flow condition ・ Monitoring of water level during flood ・ Properly and safely discharge measurement during flood
⑤	River Improvement Plan	Schedule of large scale river improvement
⑥	Ease of Construction	Construction of gauge station
⑦	Observation Site by TCP	Consistency with the observation site by TCP
⑧	Radio Propagation	Transmission data by telemeter

Next, considering the selection criteria, 12 candidate sites were selected from the map. Then, the candidate sites were narrowed down by confirmation of site conditions by field visits. Finally, among the narrowed down candidate sites, sites for water level gauge stations were determined based on the radio propagation test results.

Table 2-5 shows the list of candidate sites and selection results of water level gauge stations. To contribute to the selection by the selection criterion ② Hydrology, hydrological characteristics at the candidate sites are summarized as shown in Table 2-6. Here, the river where the candidate site is located (mainstream or tributary), the distance from the estuary, lead time, and catchment area are summarized. Among the candidate sites, Pelaez Bridge was determined as the most important water level gauge site in this FFWS since the site is located in the upstream of flood prone areas in Cagayan de Oro City, and flood flows from most area of the river catchment concentrate and reaches the flood prone areas. Therefore, the lead time summarized in Table 2-6 indicates the flood propagation time between each site to Pelaez Bridge. Since no flood velocity has been measured, this project estimates the lead time assuming that flood velocity is 4 m/s based on the river profile and flow regime observed during field visits. In addition, the relationship between the river profile and lead time is summarized as shown in Figure 2-2 and also considered for site selection. Here, elevation was obtained from a Digital Elevation Model (DEM) because no river survey result is available for all river sections.

Table 2-5 Candidate Sites and Selection Results of Water Level Gauge Stations

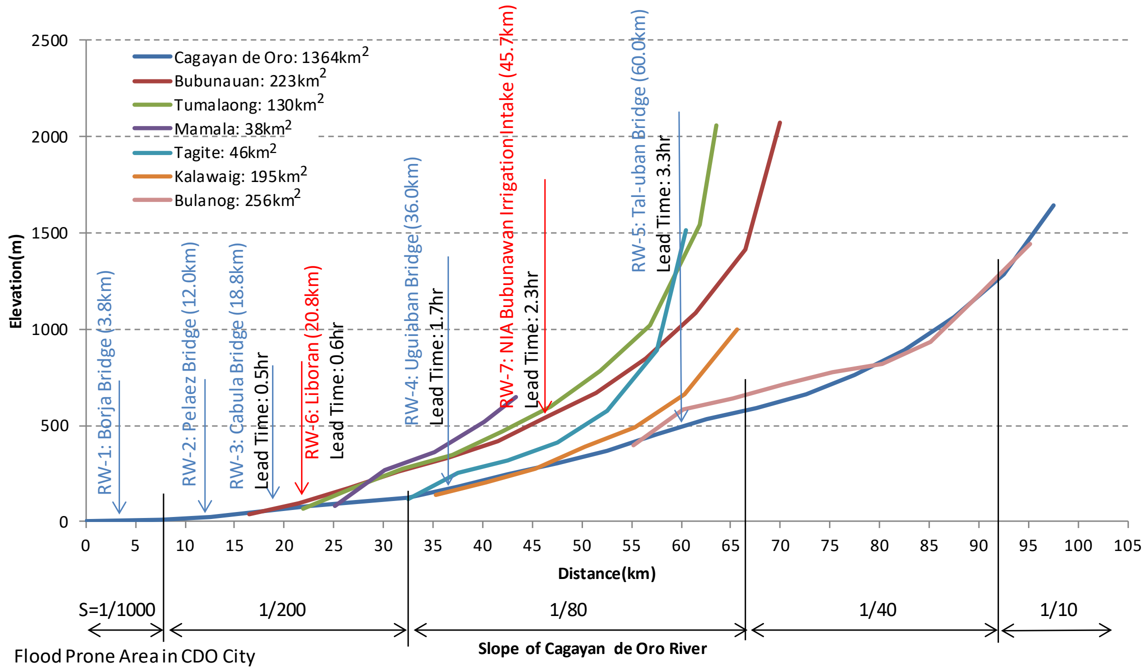
No.	Candidate Site for Water Level Gauge Station	River	Criteria for Selection 1 Access	2 Hydrology	3 Security	4 Hydraulics	5 River Improvement Plan	6 Ease of Construction	7 Observation Site by TCP	8 Radio Propagation	Site Selected	Remarks
1	Borja Bridge	Cagayan de Oro	G	G	G	G	G	G	-	F	RW-1	Tidal compartment
2	Golden Mile Bridge	Cagayan de Oro	G	G	G	G	P	-	-	-	-	Tidal compartment
3	Pelaez Bridge	Cagayan de Oro	G	G	G	G	G	G	G	F	RW-2	Twin Phoenix's site
4	Cabula Bridge	Cagayan de Oro	G	G	G	G	-	G	G	G	RW-3	
5	Mambuaya	Cagayan de Oro	G	G	G	G	-	P	-	P	-	Twin Phoenix's site
6	Uguiaban Bridge	Cagayan de Oro	G	G	G	G	-	G	G	F	RW-4	
7	Tal-uban Bridge	Cagayan de Oro	G	G	G	G	-	G	-	G	RW-5	Twin Phoenix's site
8	NIA Batang Irrigation Intake	Cagayan de Oro	G	G	P	-	-	-	-	-	-	
9	Liboran	Bubunawan	G	G	G	G	-	G	G	G	RW-6	
10	NIA Bubunawan Irrigation Intake	Bubunawan	G	G	G	G	-	G	-	G	RW-7	
11	Tumalaong	Tumalaong	G	F	-	-	-	-	-	-	-	Twin Phoenix's site
12	Alternative site in Tumalaong River	Tumalaong	G	F	-	-	-	-	-	-	-	
										Total	7	

Note: G: Good, F: Fair, P: Poor, —: Not Considered, Highlighted in Yellow: Site Selected

Table 2-6 Hydraulic Characteristics of Candidate List of Water Level Gauge Stations

No.	Site Selected	Candidate Site for Water Level Gauge Station	River	Distance to Estuary (km)	Distance to RW-2: Pelaez Bridge (km)	Lead time to RW-2: Pelaez Bridge (hr) *	Catchment Area (km^2)	Remarks
1	RW-1	Borja Bridge	Cagayan de Oro	3.8	-	-	-	Tidal compartment
2	-	Kagayan Bridge	Cagayan de Oro	4.8	-	-	-	Tidal compartment
3	RW-2	Pelaez Bridge	Cagayan de Oro	12.0	-	-	1,317	TCP & Twin Phoenix's site
4	RW-3	Cabula Bridge	Cagayan de Oro	18.8	6.8	0.5	1,094	TCP's site
5	-	Mambuaya	Cagayan de Oro	30.5	18.5	1.3	874	Twin Phoenix's site
6	RW-4	Uguiaban Bridge	Cagayan de Oro	36.0	24.0	1.7	614	TCP's site
7	RW-5	Tal-uban Bridge	Cagayan de Oro	60.0	48.0	3.3	343	Twin Phoenix's site
8	-	NIA Batang Irrigation Intake	Cagayan de Oro	68.0	56.0	3.9		
9	RW-6	Liboran in Bubunawan River	Bubunawan	20.8	8.8	0.6	203	TCP's site
10	RW-7	NIA intake in Bubunawan River	Bubunawan	45.7	33.7	2.3	109	
11	-	Tumalaong	Tumalaong	24.9	12.9	0.9	109	Twin Phoenix's site
12	-	Alternative site in Tumalaong River	Tumalaong	35.6	23.6	1.6	81	

* Assuming flood velocity is 4 m/s based on the river profile and flow regime observed during field visits



Note 1: Lead time is calculated assuming flood velocity is 4m/s
Note 2: Altitude is from Digital Elevation Model (DEM)

Figure 2-2 River Profile of Cagayan de Oro River and Lead Time to RW-2 from Other Stations

As a result of the selection, Figure 2-3 shows the location map of water level gauge stations selected for this FFWS. Finally, seven sites are selected in total: five in the mainstream of Cagayan de Oro River, and two in Bubunawan River. In particular at RW-5 Tal-uban Bridge, which is located in the most upstream area of the catchment, the lead time to Pelaez Bridge is about three hours and might secure enough time for flood forecasting, warning insurance and evacuation. The reasons for the five sites that were not selected among the 12 candidate sites are as follows:

- No.2 Kagayan Bridge：Since replacement of the bridge is scheduled under the ODA loan project for flood risk management project, the site is rejected by the selection criterion ⑤River Improvement Plan.

- No.5 Mambuaya：The only site where water level gauge can be installed is located at the water hit point after meandering, and installation work of the water level gauge might be large scale and difficult for construction. In addition, the radio propagation test was not good. Therefore, the site is rejected by the selection criterion ⑥Ease of Construction and ⑧Radio Propagation.

- No.8 National Irrigation Administration (NIA) Batang Irrigation Intake : Because it is located upstream of the main river, it can secure more lead time. However, barangay officials did not recommend the site because there is a risk of safety and security such that they might encounter the New Peoples Army (NPA) at the site. Therefore, the site is rejected by the selection criterion ③Security.

- No.11 Tumalaong, and No.12 Alternative Site in Tumalaong River：These are located in Tumalaong River, one of the tributaries, and easy to access. However, the flood runoff volume might be less than Bubunawan River because of smaller catchment area and no high mountains in the upstream. Therefore, the site is rejected by the selection criterion ②Hydrology.

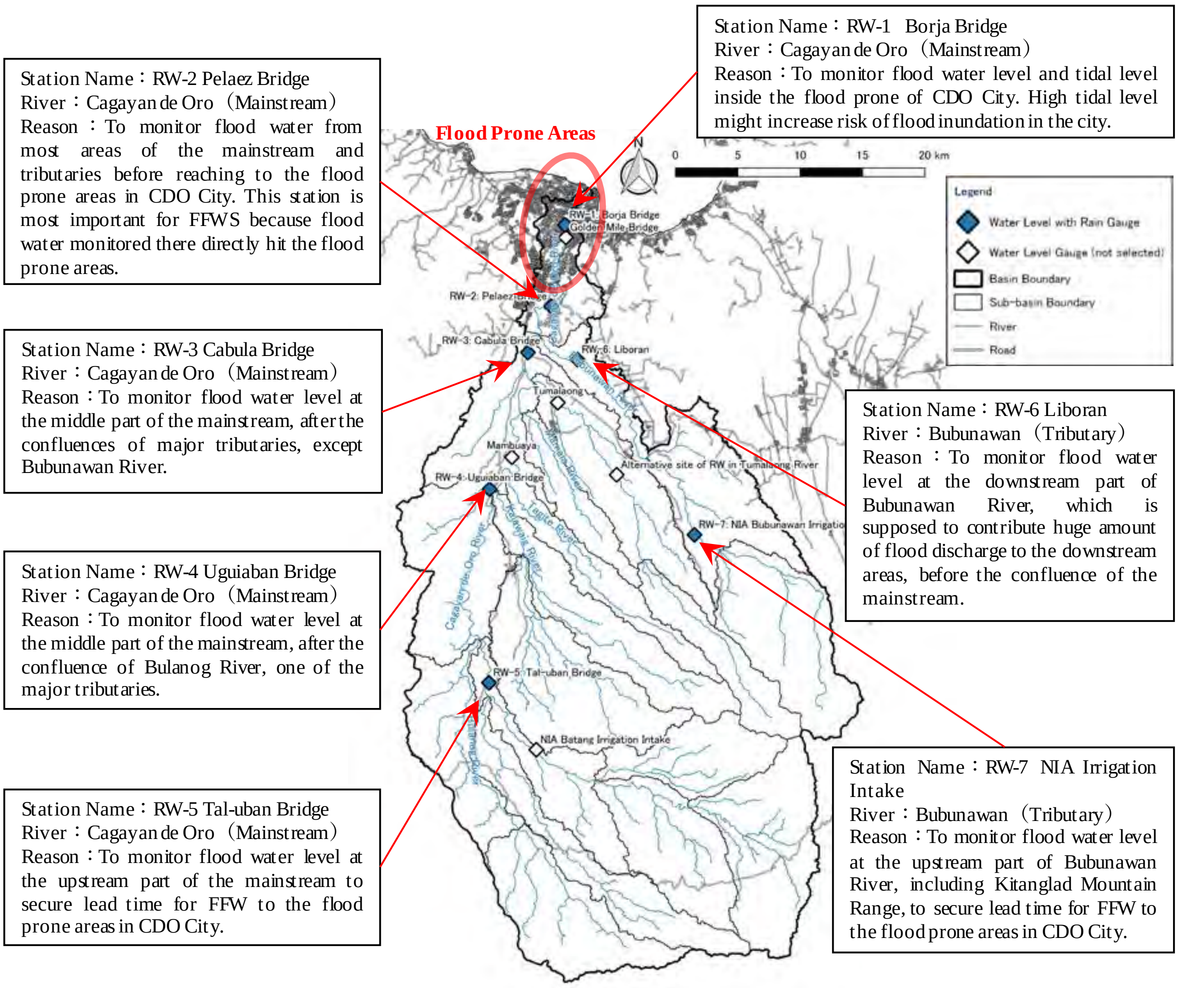


Figure 2-3 Location Map of the Water Level Gauge Stations Selected for this FFWS

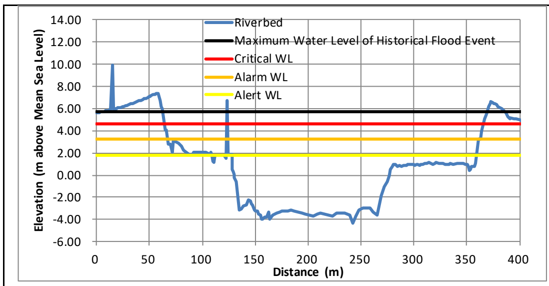
(3) Setting of Flood Warning Water Level

Currently, HMD sets three Flood Warning Water Levels (FWWLs): Alert; Alarm; and Critical Level; which are determined based on the river channel capacity of 40%, 60%, and 100%, at a gauge station, respectively, by complying with the peration Manual of FFWS for River Basin (November 2005) published by PAGASA. In the manual, the critical level shall be set as 100% of a river capacity. However, according to HMD, they recently determined the critical level at 80% of the river channel capacity, not 100%, by considering actual site conditions. In the TCP, water level during Tropical Storm Sendong is assumed at 100% of the river capacity, and FWWLs have been set at four stations, which are Pelaez Bridge, Cabula Bridge, and Uguiaban Bridge in the mainstream, and Liboran in the Bubunawan River, which is one of tributaries. Table 2-7 shows the list of FWWLs and Figure 2-4 shows FWWLs with river cross sections. It should be noted that FWWLs determined by this study need to be reviewed after flood event and updated if necessary.

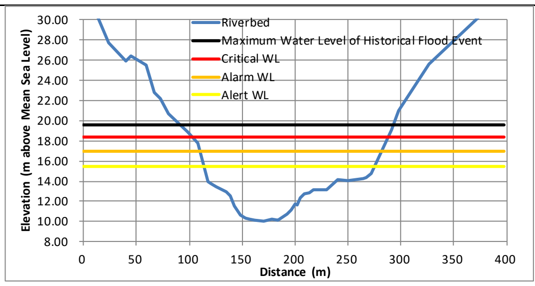
Table 2-7 Flood Warning Water Level at Water Level Gauge Stations

Unit: m above Mean Sea Level

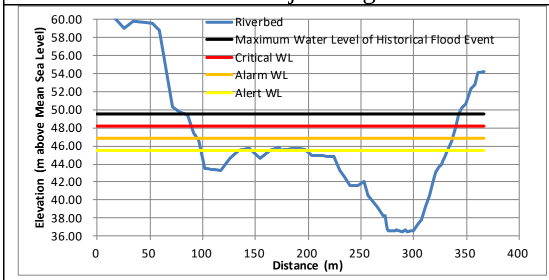
No.	Water Level Gauging Station	River	Water Level during Tropical Storm "Sendong" (100%)	Critical Level (80%)	Alarm Level (60%)	Alert Level (40%)	Remarks
RW-1	Borja Bridge	Cagayan de Oro	5.75	4.61	3.25	1.80	Tidal compartment
RW-2	Pelaez Bridge	Cagayan de Oro	19.62	18.35	16.96	15.48	Twin Phenix, TCP
RW-3	Cabula Bridge	Cagayan de Oro	49.52	48.22	46.89	45.47	TCP
RW-4	Uguiaban Bridge	Cagayan de Oro	150.22	149.44	148.30	146.41	TCP
RW-5	Tal-uban Bridge	Cagayan de Oro	463.30	462.00	460.56	458.98	Twin Phenix
RW-6	Liboran in Bubunawan River	Bubunawan	80.18	79.42	78.57	77.60	TCP
RW-7	NIA intake in Bubunawan River	Bubunawan	484.30	483.70	483.07	482.40	



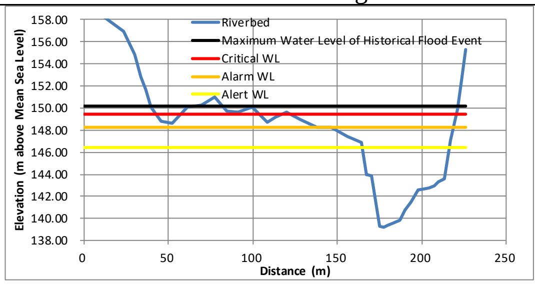
RW-1:Borja Bridge



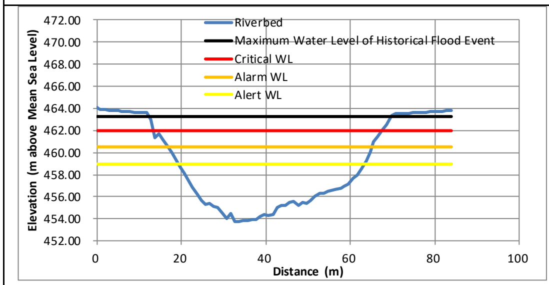
RW-2:Pelaez Bridge



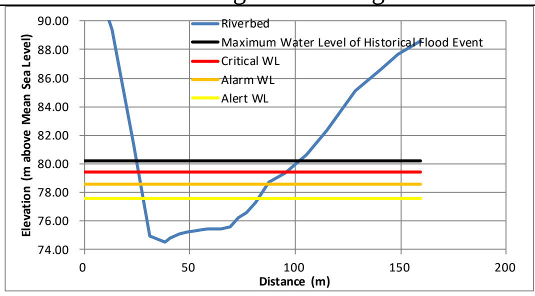
RW-3:Cabula Bridge



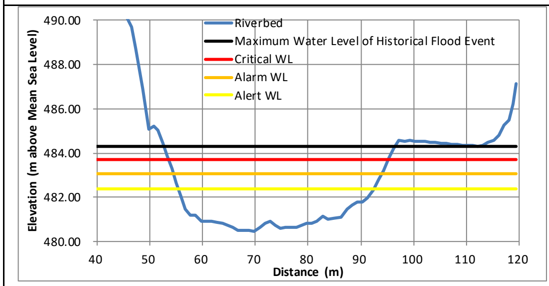
RW-4:Uguiaban Bridge



RW-5:Tal-uban Bridge



RW-6:Liboran



RW-7:NIA Bubunawan Irrigation Intake

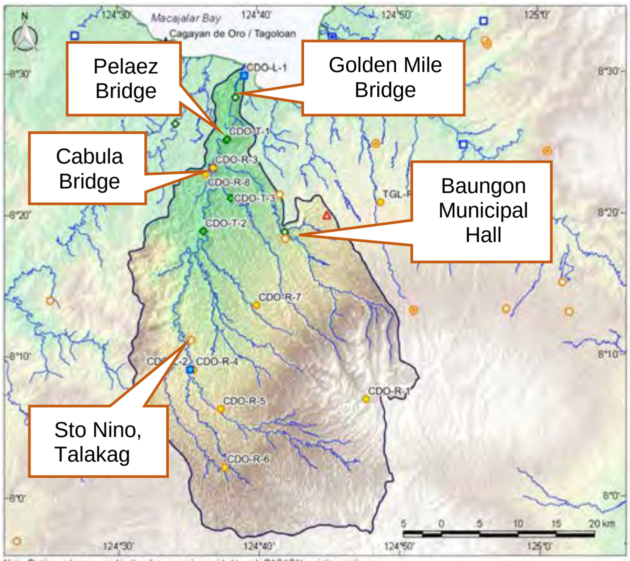
Figure 2-4 Setting of Flood Warning Water Level at Water Level Gauge Stations

2-2-2-3 Design of Rainfall Gauge Station Network

(1) Conditions Required for Site Selection

The Cagayan de Oro River basin belongs to tropical climate zone, and Type III based on classification criteria by PAGASA. Type III is characterized by inexplicit difference between the rainy season and dry season, a relatively dry season from November to April, and a relatively wet season from May to October. However, the recent heavy rain events were experienced in the dry season, for example, Tropical Storm “Sendong” in December 2011, Typhoon “Pablo” in December 2012, and Tropical Depression “Urduja” in December 2009. The basin has high flood risk even in the dry season.

The basin might have relatively large amounts of rainfall due to the orographic effect in the mountainous areas (Mt. Kitanglad and Mt. Kalatungan) although quantitative analysis of rainfall cannot be achieved because of no rainfall gauge currently in the upstream areas. On the other hand, high intensive rainfall in a small area with short duration occurred in Cagayan de Oro City located in the most downstream areas. Figure 2-5 shows daily and hourly rainfall observed during the heavy rainfall event in January 2017. At Golden Mile Bridge located in the downstream city, high intensity rainfall at 97.4 mm/hour was observed between 15 and 16 o'clock on January 16, whereas only 17mm/hour at Pelaez Bridge located in the 5.6 km upstream of the Golden Mile Bridge. Peak rainfall at these stations had an hour difference. It might indicate that a narrow rain area had moved in a short time. Cagayan de Oro River has relatively small catchment area (1,364 km^2 only). However, as stated above, the rainfall characteristics are not uniform.



TOTAL RAINFALL AMOUNT PER AUTOMATIC RAIN GAGE (FROM 2AM OF 16JAN'17 TO 2AM OF 17JAN'17)

Golden Mile Bridge (Cagayan de Oro) *1	196.4 mm
Pelaez Bridge (Cagayan de Oro) *2	135 mm
Cabula Bridge (Cagayan de Oro) *2	135 mm
Sto Nino (Talakag, Bukidnon)*1	66.6 mm
Baungon (Baungon, Bukidnon)*1	46.4 mm

**1. From DOST-ASTI, *2. From PAGASA (NDMI)*

Location Map of Rainfall Gauge Station and Daily Rainfall

Hourly Rainfall during the CDO Flooding Incident

Date	Time	GOLDEN MILE BRIDGE (mm)	PELAEZ BRIDGE(mm)	CABULA BRIDGE (mm)	STO NINO (mm)	BAUNGON (mm)
16-Jan-17	2:00	0	0	0	-	0
	3:00	0	0	0	-	
	4:00	0.8	0.5	0	-	0.2
	5:00	0	0	0	-	0
	6:00	0	0	0	-	0.2
	7:00	0.6	0.5	0	-	0.2
	8:00	0.4	0	0	-	0
	9:00	0	0	0	-	0
	10:00	0	0	0	-	0
	11:00	0	0	0	-	0
	12:00	0	0	0.5	-	0
	13:00	0	1	0	0	0
	14:00	0	4.5	0	0	5
	15:00	19.6	6	1	13.2	10.4
	16:00	**97.4**	17	9	11.6	3.4
	17:00	33.8	34	29.5	1	4
	18:00	13.6	18.5	28	4.2	4.2
	19:00	10.4	12	8	4.2	2.6
	20:00	1.8	3.5	5	6.4	1.8
	21:00	1.2	2.5	2	8	3
	22:00	1.8	8	20.5	7.6	1.2
	23:00	11.2	20.5	23	5.8	9
17-Jan-17	0:00	3.2	6	7.5	3.6	1.2
	1:00	0.6	0.5	1	1	0
	2:00	0	0	0	0	0
24 Hr Acc RR		196.4	135	135	66.6	46.4

Light Moderate Heavy
Intense Torrential

Hourly Rainfall

Figure 2-5 Daily and Hourly Rainfall Observed During Heavy Rainfall Event in January 2017

Considering the rainfall characteristics above, the following conditions should be satisfied in the site selection of the rainfall gauge stations to contribute to the appropriate forecasting that assists prompt evacuation as the first objective of the FFWS.

- Rainfall gauge stations should be installed evenly and densely in selected spaces as much as possible, considering topography and sub-basin division.
- Rain gauge stations should be located on the top of the telemeter house at the water level gauge station to utilize the telemetry facilities.

(2) Site Selection

In accordance with the above conditions, the location of rainfall gauge stations was determined by following procedures:

① Set selection criteria to comply with the site selection policy

② Select candidate sites on a map considering the selection criteria

③ Confirm site conditions by field visits and narrow down the candidate sites

④ Finally, determine the sites based on radio propagation test results

First, this project chosen carefully seven selection criteria for rainfall gauge stations: access, hydrology, security, land acquisition, overlap with water level site selected in this FFWS, overlap with existing site, and radio propagation. Table 2-8 shows the selection criteria and point of consideration.

Table 2-8 Selection Criteria for Rainfall Gauge Stations

No.	Selection Criteria	Point of Consideration
①	Access	Access by vehicle for maintenance
②	Hydrology	Arrangement of rainfall gauges uniformly within a river basin considering elevation and sub basin division
③	Security	Security issues
④	Land Acquisition	Acquirement of secure land for installation of rainfall gauge station
⑤	Overlap with Water Level Gauge Station Selected in this FFWS	Installation of rainfall gauge at the water level gauge station selected in this FFWS to utilize telemeter equipment
⑥	Overlap with Existing Rainfall Gauge Station	Installation of rainfall gauge at a certain distance away from existing rainfall gauge
⑦	Radio Propagation	Transmission data by telemeter

Next, considering the selection criteria, 20 candidate sites were selected from the map. Then, the candidate sites were narrowed down by confirmation of site conditions by field visits. Finally, among the narrowed down candidate sites, sites for rainfall gauge stations were determined based on radio propagation test results. Table 2-9 shows the list of candidate sites and selection results of rainfall gauge stations. In the table, the river catchment where the site is located (mainstream or tributary), and elevation are also summarized. Since the installation of rainfall gauge in the middle areas of the catchment is difficult due to problem of security and access, the areas were excluded from the selection for candidate sites. In addition, considering ease of land acquisition, schools were included in the selection.

Table 2-9 Candidate Sites and Selection Results of Rainfall Gauge Stations

No.	Candidate Site for Rain Gauge	River Catchment	Elevation of Ground (m)	Criteria for Selection*							Site Selected	Remarks
				1	2	3	4	5	6	7		
				Access	Hydrology	Security	Space	WL Site	Overlap	Radio		
1	Borja Bridge	MS of CDO	7	G	G	G	G	G	-	F	RW-1	
2	Pelaez Bridge	MS of CDO	21	G	G	G	G	G	F	F	RW-2	NDMI
3	Cabula Bridge	MS of CDO	48	G	G	G	G	G	F	G	RW-3	NDMI
4	Uguiaban Bridge	MS of CDO	150	G	G	G	G	G	-	F	RW-4	
5	Talakag Central School	MS of CDO	400	G	G	G	P	-	-	−	-	
6	Takalag Bureau of Fire	MS of CDO	405	G	G	G	G	-	-	G	R-10	
7	Tal-uban Bridge	MS of CDO	467	G	G	G	G	G	-	G	RW-5	
8	Cosina Elementary School	Kalawaig	696	G	G	G	G	-	P	−	-	Twin Phenix
9	Indulang Elementary School	MS of CDO	718	G	G	P	-	-	-	−	-	
10	San Rafael Elementary School	Bulanog	848	G	G	P	-	-	-	−	-	
11	Tikalaan National High School	Bulanog	828	F	G	F	G	-	-	F	R-11	
12	Masimag Elementary School	MS of CDO	1275	F	G	F	G	-	-	G	R-12	
13	Miarayon Elementary School	MS of CDO	1410	F	G	F	G	-	-	G	R-13	
14	Liboran	Bubunawan	88	G	G	G	G	G	-	G	RW-6	
15	Imbatug Central Elementary School	Tumalaong	400	G	G	G	G	-	-	G	R-8	
16	Baungon Municipal Hall	Tumalaong	425	G	G	G	G	-	P	−	-	Twin Phenix
17	Nangka Elementary School	Bubunawan	600	G	G	G	G	-	-	G	R-9	
18	Libona Municipal Hall	Bubunawan	601	G	F	G	G	-	F	−	-	AWS (ASTI)
19	NIA Bubunawan Irrigation Intake	Bubunawan	499	G	G	G	G	G	-	G	RW-7	
20	Military Camp in Mt. Kitanglad Range	Bubunawan	-	F	G	P	-	-	-	−	-	
										Total	13	

NOTE; G：Good, F：Fair, P Poor, —: Not Considered, Highlighted in Yellow: Site Selected

As a result of the selection, Figure 2-6 shows the location map of rainfall gauge stations selected for this FFWS. Finally, 13 sites were selected in total: seven overlapped with water level gauge station, and five installed for rainfall gauge only. Although the rainfall gauge station cannot be placed in the middle areas of the catchment due to problem of security and access, the stations are placed within the basin uniformly as much as possible considering topography and sub-basin division. The reasons for not selecting the seven sites among the 20 candidate sites are as follows:

- No.5 Talakag Central School：The site is easy to access. However, the land for installing rainfall gauge station is not available. Therefore, the site is rejected by the selection criterion ④Land Acquisition. Instead of the site, No.6 Talakag Bureau of Fire, which is located near the site, is selected.

- No.8 Cosina Elementary School, No.16 Baungon Municipal Hall, and No.18 Libona Municipal Hall：These sites are easy to access, but rainfall gauges have been installed by the existing FFWS and PAGASA. Therefore, the site is rejected by the selection criterion ⑥Overlap with Existing Rainfall Gauge Station.

- No.9 Indulang Elementary School, No.10 San Rafael Elementary School : Although these sites are easy to access, it was found through interview with school staff that security is not good, for example, school equipment was stolen. Therefore, the site is rejected by the selection criterion ③Security.

- No.20 Military Camp in Mt.Kitanglad Range : The site was recommended by CDO-CDRRMD, and good from the viewpoint of hydrology because it is located in the mountainous area in the upstream of Bubunawan River. However, it is a military facility and might be a target of anti-government organization. Therefore, the site is rejected by the selection criterion ③Security. Since the exact position is unknown, it is not shown in Figure 2-6.

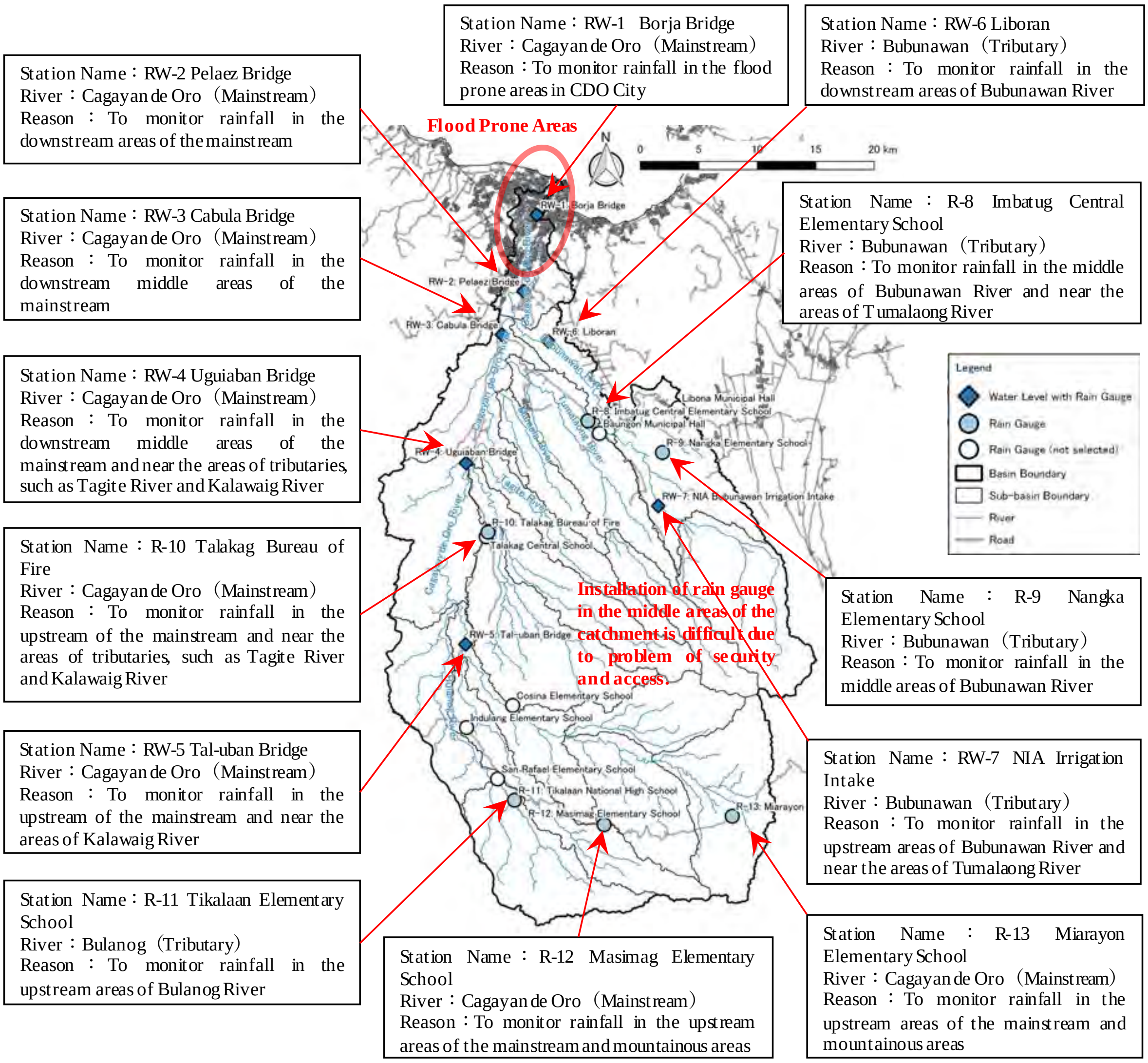


Figure 2-6 Location Map of Rainfall Gauge Stations in this FFWS

2-2-2-4 Design of X-band Radar Rain Gauge Station

(1) Desk-Top Study

X-band radar site must be selected considering the conditions presented in Table 2-10. The candidate sites have been picked out taking into consideration radar coverage, line-of-site in terms of microwave relay and VHF propagation. 8 sites are shown in Figure 2-7 as indicated with yellow pins.

Table 2-10 Candidate Sites of X-band Radar

No.	Candidate Sites	N	E	GL (m)
1.	Macapaya	8°26’48.78”	124°40’16.72”	224
2.	Department of Transportation and Communication (DOTC)	8°27’32.68”	124°38’51.92”	122
3.	Vice Governor’s Land	8°19’21.40”	124°32’20.96”	615
4.	Poblacion	8°19’56.58”	124°43’55.46”	637
5.	Iba elementary school.	8°17’55.40”	124°32’20.96”	667
6.	Dagumbaan elementary school	8°08’42.15”	124°35’44.46”	542
7.	Cosina elementary school	8°06’15.01”	124°36’35.40”	705
8.	San Rafael elementary school	8°02’51.21”	124°38’51.92”	847

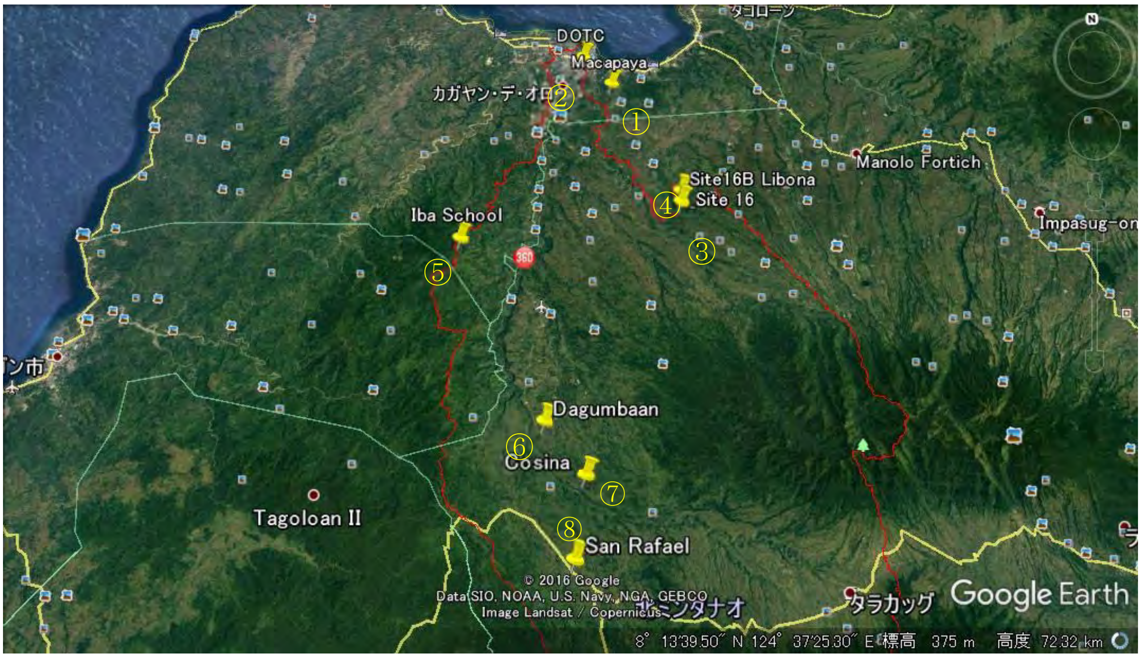


Figure 2-7 Candidate Sites of X-band Radar

(2) Site Survey

The following check items are described in Table 2-11. The survey results for each candidate site are summarized in Table 2-12. Any site which is evaluated as “NOT GOOD” for one or multiple criteria was excluded from the candidate site. “GOOD” represents no issue was found in the criteria. The items described as neither “NOT GOOD” nor “GOOD” represent that such items may be settled at the design stage.

Table 2-11 Survey Items for the Candidate Sites

No.	Survey Items	Description
1.	Security	Interview with the regional DRRMO* regarding local security condition near the site. Especially, collect current updates on activities of rebel groups such as NPA, MAUTE.
2.	X-band Radar Coverage	Confirm visually surrounding terrain topography in reference with radar simulation.
3.	Radar Obstructions near the Site	Confirm obstructions near the site and measure the heights of obstructions.
4.	Connectivity of Microwave Relay	It is required to have microwave relay connectivity for radar data transport. Whether or not the site has a LOS for microwave connections is a crucial matter to discuss.
5.	VHF Radio Propagation	It will contribute in the reduction of construction cost if it is possible to collocate VHF repeater with X-band radar. It is necessary to consider the results of VHF propagation test.
6.	Availability of Commercial Power Supply	Confirm the location of distribution transformer to extend the commercial power supply to the site. Also interview with local electric distribution company.
7.	Access Conditions to the Site	Site access conditions such as vehicle access, access by foot, etc.)
8.	Land Acquisition	Investigate that the land is owned by the government or private. Collect information on the land owner, right-of-way.
9.	Probability of Lightning	In view of altitude of site or openness of site, assume risk of lightning.
10.	Interference to X-band Radar	Investigate if there is other X-band radar within 10 km radius operated by other agencies.

Remark
(*) DRRMO: Disaster Risk Reduction Management Office

Table 2-12 Candidate List of X-band radar Rain Gauge Stations

No	Site Name	Criteria for X-band Radar Site Selection											Selected Site
		1	2	3	4	5	6	7	8	9	10	11	
		Security	Radar Coverage	Obstruction of Radar	Microwave Relay Connectivity	VHF Radio Propagation	Commercial Power	Access Road	Land Space	Lighting Strike	Possibility of Interference	Land Owner	
1	Macapaya Relocation Center	GOOD No security problem	**NOT GOOD** Coverage for river upper stream may be difficult	GOOD Trees nearby are 20 m to 25 m tall.	There are tree obstructions close to CDORFFWC.	It may not be able to obtain sufficient propagation for VHF radio.	GOOD Easily available	GOOD Easily accessible by vehicle	NOT GOOD Not sufficient land space available for installation	Probability may be high.	GOOD Not probable since it is more than 10 km away from the airport.	GOOD Government lot	
2	Iba Elementary School	GOOD No security problem	**NOT GOOD** Radar coverage blocked by mountains for river upper stream.	GOOD Trees nearby are 20 m to 25 m tall.	No LOS directly to CDORFFWC	It may not be able to obtain sufficient propagation for VHF radio.	GOOD Available	GOOD Accessible by vehicle	GOOD Sufficient land space available for installation	Probability may be high.	GOOD Not probable since it is more than 10 km away from the airport.	GOOD Government lot	
3	Vice Governor's Premises (Site 16A)	GOOD No security problem	GOOD Possible to cover the upper stream of the river	GOOD Mostly bush trees	There are tree obstructions close to CDORFFWC	GOOD It is good for VHF radio propagation.	GOOD Available but it needs power line extended from tapping distribution transformer nearby.**	Access may be difficult since it is within the private complex.	**NOT GOOD** Land leveling and cutting trees required for enough land space.	Probability may be high.	GOOD Not probable since it is more than 10 km away from the airport.	Private property	
4	Poblacion	GOOD No security problem	GOOD Possible to cover the upper stream of the river	GOOD No tall trees nearby. It is a farmland	There are tree obstructions close to CDORFFWC	GOOD It is good for VHF radio propagation.	GOOD Available but it needs power line extended from tapping distribution transformer nearby.**	Access road construction will be needed.	GOOD Sufficient land space available for installation	Probability may be high.	GOOD Not probable since it is more than 10 km away from the airport.	Private property	Selected XR-1

No	Site Name	Criteria for X-band Radar Site Selection											Selected Site
		1	2	3	4	5	6	7	8	9	10	11	
		Security	Radar Coverage	Obstruction of Radar	Microwave Relay Connectivity	VHF Radio Propagation	Commercial Power	Access Road	Land Space	Lighting Strike	Possibility of Interference	Land Owner	
5	Dagumbaan Elementary School	GOOD No security problem	GOOD Possible to cover upper stream of river	GOOD Trees are 20 m to 25 m tall.	GOOD It has LOS facing to Site16B	GOOD It is a good for VHF radio propagation.	GOOD Available	GOOD Easily accessible by vehicle.	GOOD Sufficient land space available for installation	Probabilit y may be high.	GOOD Not probable since it is more than 10 km away from the airport.	GOOD Governme nt lot	Selected XR-2
6	Cocina Elementary School	GOOD No security problem	GOOD Possible to cover upper stream of river	NOT GOOD Trees surrounding the location are 30 m to 35 m tall. Not suitable for radar site.	It has tree obstructions facing to Site16B	GOOD It is good for VHF radio propagation.	GOOD Available	GOOD Easily accessible by vehicle.	Insufficient land space available for installation	Probabilit y may be high.	GOOD Not probable since it is more than 10 km away from the airport.	GOOD Governme nt lot	
7	San Rafael Elementary School*	NOT GOOD There are posts of radical group nearby.	GOOD Possible to cover upper stream of river	Not confirmed	GOOD It has LOS facing to Site16B	GOOD It is a good for VHF radio propagation.	GOOD Not Confirmed	GOOD Easily accessible by vehicle.	Not confirmed	Probabilit y may be high.	GOOD Not probable since it is more than 10 km away from the airport.	GOOD Governme nt lot	
8	DOTC Premises	GOOD No security problem	Not possible to cover upper stream of river	NOT GOOD There are cell-phone communicati on towers nearby not suitable for radar site.	It has obstructions facing to CDORFFWC.	It may not be a suitable location for VHF radio propagation.	GOOD Available	GOOD Easily accessible by vehicle.	Sufficient land space available for installation.	Probabilit y may be high.	GOOD Not probable since it is more than 10 km away from the airport.	GOOD Governme nt lot	

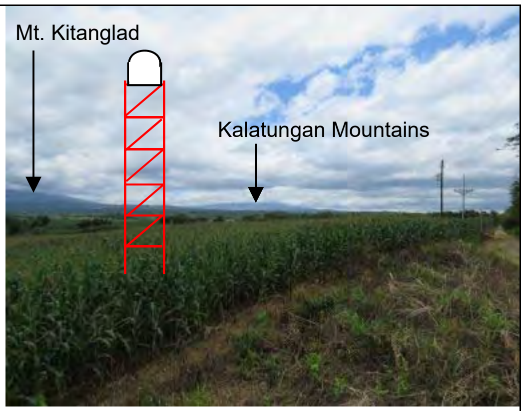
Remarks (*) San Rafael Elementary School was not surveyed, because of security risk
(**) Contact with Bukidnon Second Electric Cooperative Inc.(BUSECO)

From the above examination, the following two sites were selected as X-band radar rain gauge stations.

Table 2-13 Final List of X-band Radar Rain Gauge Stations

Site Name	Reason of Deployment	Issue
XR-1: Poblacion	• To monitor rainfall in the northern slope of Mt. Kitanglad (main purpose) • To monitor rainfall in the downstream of the main stream	• Negotiation with land owner for land use • Application to power distribution company to secure commercial power supply
XR-2: Dagumbaan	• To monitor rainfall in the southern slope of Mt. Kitanglad • To monitor rainfall in the downstream of the main stream of the northern slope of Mt. Kalatungan • To monitor upstream of the main stream	• Elementary School is nearby. Application to Department of Health, to abide by safety of radiation from radar, as this site is adjacent to the elementary school

XR-1: Poblacion



XR-2: Dagumbaan

Figure 2-8 Landscape Photo of X-band Radar Rain Gauge Stations

(3) Requirements of X-band Radar Height

The heights of X-band radar are determined considering desk-top simulation for coverage and the actual obstructions surrounding the sites in the neighborhood. The required heights are given in Table 2-14.

Table 2-14 X-band Radar Antenna Height

X-band Radar Sites	Required Height	Remarks
XR-1: Poblacion	20 m	The radar site is located on top of a hill and there are no trees taller than 15 m. No artificial obstruction is found nearby.
XR-2: Dagumbaan	30 m	The radar site adjoins to the elementary school that is of flat construction and it is in the farm field. There are trees of 20 m to 25 m high near the site. No artificial construction is found nearby.

(4) Selection of Dual Polarization Radar

The comparisons between Mono Polarization and Dual Polarization Radar are given in Table 2-15. The latter is superior in performance than the former in terms of observation accuracy of precipitation and detection range capability. Dual Polarization Radar will be deployed to observe rainfall in the Cagayan de Oro River basin.

Table 2-15 Comparisons between Mono Polarization and Dual Polarization Radar

Items	Mono Polarization Radar	Dual Polarization Radar
Polarization	Reflective power of single polarity	Reflective power of both horizontal and vertical polarities for detection of differential phase.
Observation Parameters	• Radar Reflectivity Z • Average Doppler Velocity V* • Velocity Spectrum W*	• Radar Reflectivity Z • Average Doppler Velocity V* • Velocity Spectrum W* • Differential Reflectivity ZDR • Differential PhaseφDP • Specific Differential Phase KDP • Polarity Correlation ρhv • Linear Depolarization Ratio LDR
Features	Larger rain drops give back more radar reflection than smaller rain drops regardless of the actual rain intensity. Mono polarization radar is not capable of detecting actual shapes of the rain drops which will be one of the causes of deterioration of detection accuracy. Because of this characteristic, single polarization radar needs to be calibrated with ground sensors.	The dual polarization radar is capable of detecting shapes of rain drops. Therefore, it can detect rain intensity accurately. Because of this feature it does not require a ground sensor calibration theoretically. Dual polarization makes possible of obtaining such observation parameters as differential phase unique to dual polarization radar.

Remarks
(*)Doppler Radar Functionality

(5) X-band Radar Coverage

Radar rain gauges using S band or higher have the same technical issues due to high frequency.

- Blind areas exist shadowed by mountains and buildings.
- When radar antenna beaming is set at a high angle to avoid nearby obstructions, the radar experiences difficulty in detecting precipitation near the ground and at far distances

because antenna beaming becomes too high.

- The antenna beam width becomes wider at far distance which also deteriorates detection accuracy.

- It is difficult to catch the reflective power from the target at far distance even with dual polarization radar employed, in the case where rain attenuation is extremely large.

Especially X-band radar using higher frequency of 9GHz to 10GHz will be affected more by the influences of the above described although it has an advantage of higher resolution of radar image. Among others, rain attenuation will be important factor to be considered for determining practical detection range even deployed with double-polarization radar that makes possible differential phase detection. The Ministry of Land, Infrastructure and Transportation specifies theoretical detection capability of X-band double-polarization radar as detection of 1mm/hr precipitation at 80km distance but due to the deteriorations above, detection range in practical use will be approximately 50km radius.

Two sets of X-band radars located at a distance help compensate the observation capability of each other for enhancement of accuracy solving the problems above. The technology of two radar outputs combination is realized and effectively used for rain observation in the radar systems of Weather Agency, Ministry of Land, Infrastructure and Transportation in Japan. In addition, there is no issue on integration of different radar data outputs if the radars are provided by the same manufacture/vendor. X-band radar coverage simulation is presented in Figure 2 8 for the selected two sites. Vertical angle of radar radiation beam is set at 2.0 degrees upward from the horizontal level considering actual radar observation operation. It is known from the simulation that the radar at XR-1 Poblacion alone cannot detect rain around the south side of Mt. Kitanglad where another radar at XR-2 Dagumbaan can effectively observe it.

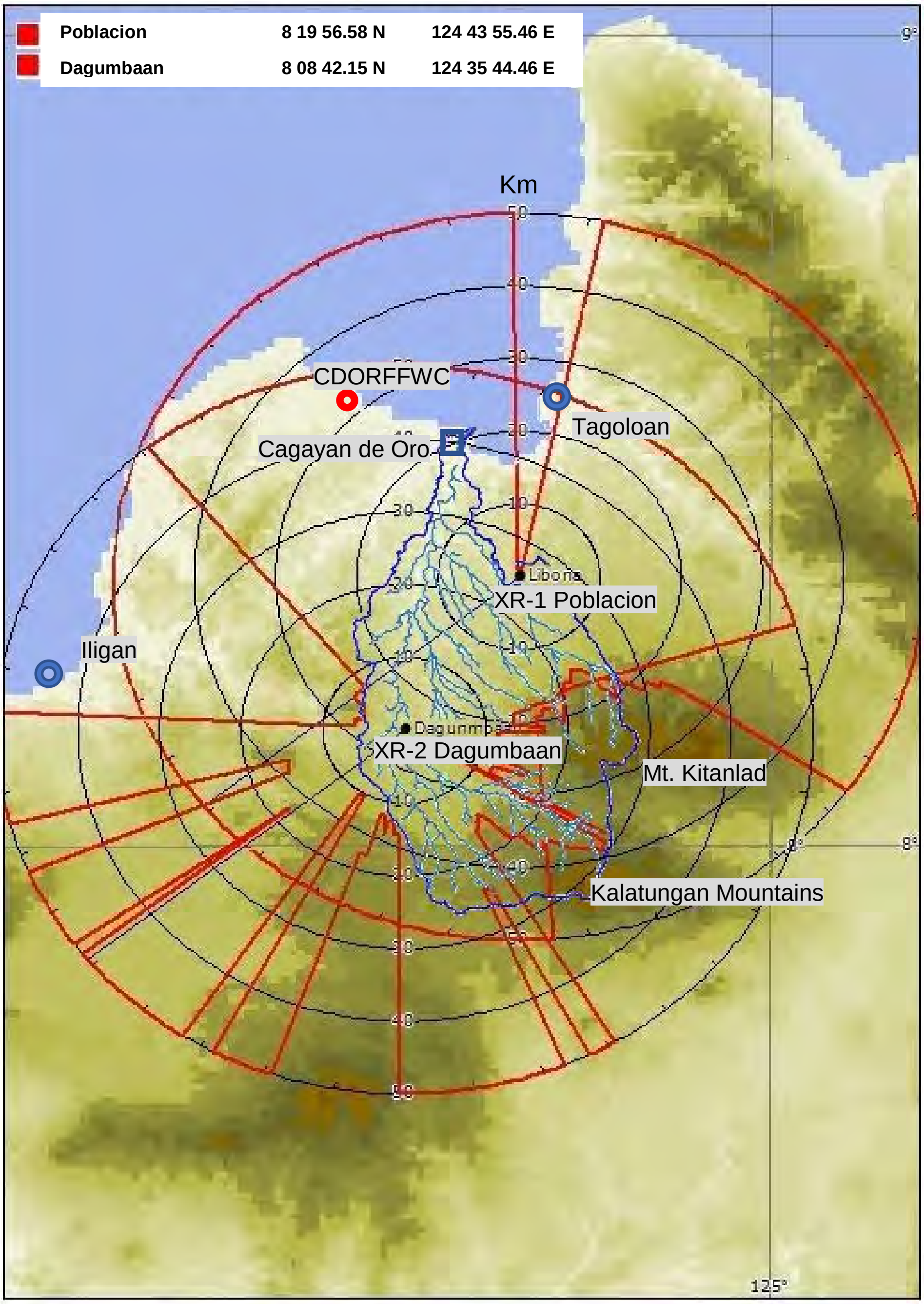


Figure 2-9 X-band Radar Coverage

(6) X-band Radar Raw Data and Discussion on Data Transport

1) X-band Radar Raw Data

The requirement of data speed is tentatively calculated below for transport raw data of X-band radar as referred to typical specifications used in Japan.

Radar Detection Range:	80km	*Theoretical detection range applied only for calculation purpose.
Radar Resolution:	150m	
Mesh Divisions in Range:	534	
Horizontal Sections	360	
Observation Parameters	8	
Radar Antenna Rotation	3rpm	
Transport Availability	50%	

As the conditions above, the requirement of data speed will be:

$$\text{Data Speed (bps)} = \frac{2\ bytes \times 534\ meshes \times 360\ sections \times 8\ parameters \times 8\ bits}{20\ sec \times 50\%}$$

$$= 2.46\ \text{Mbps}$$

2) Data Transport of X-band Raw Data

It will be necessary to have about 4 Mbps to 5 Mbps to transport raw data obtained by the 2 sites of dual polarization radar. In addition to the radar data, hydrological data gathered by conventional ground sensors, Voice Over Internet Protocol (VoIP), and surveillance camera will be transported on the same data channel that will be estimated in total to about 6 Mbps. Considering the advantages and disadvantages of various candidate methods of communications, microwave radio relay will be the most suitable as compared in Table 2-16. Satellite is too expensive in terms of recurring payment; and Internet Protocol Virtual Private Networks (IP VPNs) is not available in the neighborhood of the radar sites. Therefore, microwave radio relay will be the one applicable for X-band radar data transport.

Table 2-16 Communication Methods and Features

Data Transport	Advantages	Disadvantages	Adoption
Microwave Radio Relay	Microwave Radio relay has been used for hydrological data transport long before the existing Agno and Pampanga telemetry systems. It is reliable and resilient to natural disaster.	Initial cost of construction will be expensive.	Good
IP-VPN	IP-VPN is a closed dedicated transport circuit provided by telecommunications company (TELCO) for application of Wide Area Network (WAN).	IP-VPN is still under development in remote areas and its service is still limited. Monthly recurring cost of communication is required.	Not Possible
Satellite	Satellite communication has a high reliability and resilience to natural disaster.	The use of satellite will be very expensive in terms of recurring payment, especially raw data transport of X-band radar that requires a wide band capacity.	Not Possible

(7) Commercial Power Supply near the X-band Radar Site

A logger was installed for commercial power monitoring at the Dagumbaan Elementary School beside the X-band radar site (XR-2) and had been recording power supply fluctuations for 569 hours totally from 21 April to 15 May 2017. Because the X-band radar site (XR-1) is not installed commercial power at present, the power monitoring was not measured.

The logger measured commercial power divided by five because the logger has upper limit of capacity. Periods of each monitoring are following:

1st: 14:12, 21 April 2017 - 18:03, 28 April 2017
2nd: 18:03, 28 April 2017 – 22:29, 5 May 2017
3rd: 22:30, 5 May 2017 – 7:44, 6 May 2017
4th: 7:45, 6 May 2017 – 12:16, 13 May 2017
5th: 12:17, 13 May 2017 – 6:52, 15 May 2017

As the result of the monitoring, it was found that power interruptions occur frequently and total time of power-down for approximately 57 hours. From the result, it is required to provide a fuel tank for the emergency engine generator with a capacity that can sustain power supply continuously for at least two or three days.

Table 2-17 Monitoring of commercial power

Range of Voltage[V]	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100-110	110-120	120-130
Amount of sampling	204,527	2	3	2	0	812	100	1	2	3,756	1,542	5	3
Amount of sampling / Total sampling	10.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.1%	0.0%	0.0%

Range of Voltage[V]	130-140	140-150	150-160	160-170	170-180	180-190	190-200	200-210	210-220	220-230	230-240	240-250	250-260
Amount of sampling	5,171	302	8	6	5	3	51	31,873	558,797	618,550	611,174	10,541	0
Amount of sampling / Total sampling	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.6%	27.3%	30.2%	29.9%	0.5%	0.0%

Total sampling	**2,047,236**
Total monitoring period[Hr]	**569**
Total monitoring period[Day]	**23.7**

Power down(less than 10V)sampling	**204,527**
Total power down(less than 10V)period[Hr]	**57**
Total power down(less than 10V)period[day]	**2.4**

(8) X-band Radar Major Specifications

The major specifications are given in Table 2-18 for the X-band radar.

Table 2-18 X-band Radar Major Specifications

No.	Items	Descriptions	Remarks
1	Frequency	9 GHz Band	
2	Antenna	Parabolic Antenna, Diameter 2.2 m less	Wind Speed 60m/s
3	Radome	Polyurethane, Glass-fiber	
4	Transmitter Output	Peak Power 125 W more	
5	Sensitivity	-110 dBm less	
6	Data Processing	Workstation, Custom Software	

2-2-2-5 Design of Micro Radio Relay

(1) Microwave Radio Relay Configuration

Microwave radio relays will be installed at XR-1(Poblacion) and XR-2 (Dagumbaan Elementary School) and the radar raw data and ground hydrological data will be transported from the sites to CDORFFWC in real time. Also, these data can be monitored at CDO-CDRRMD via IP-VPN with 2 Mbps data speed provided by the Philippine Long Distance Telephone (PLDT) Company. The reason why IP-VPN is used is that there is a hilly location between CDORFFWC and CDO-CDRRMD that obstructs the line-of-sight for microwave radio relay connectivity. The microwave radio relay is configured in Figure 2-10.

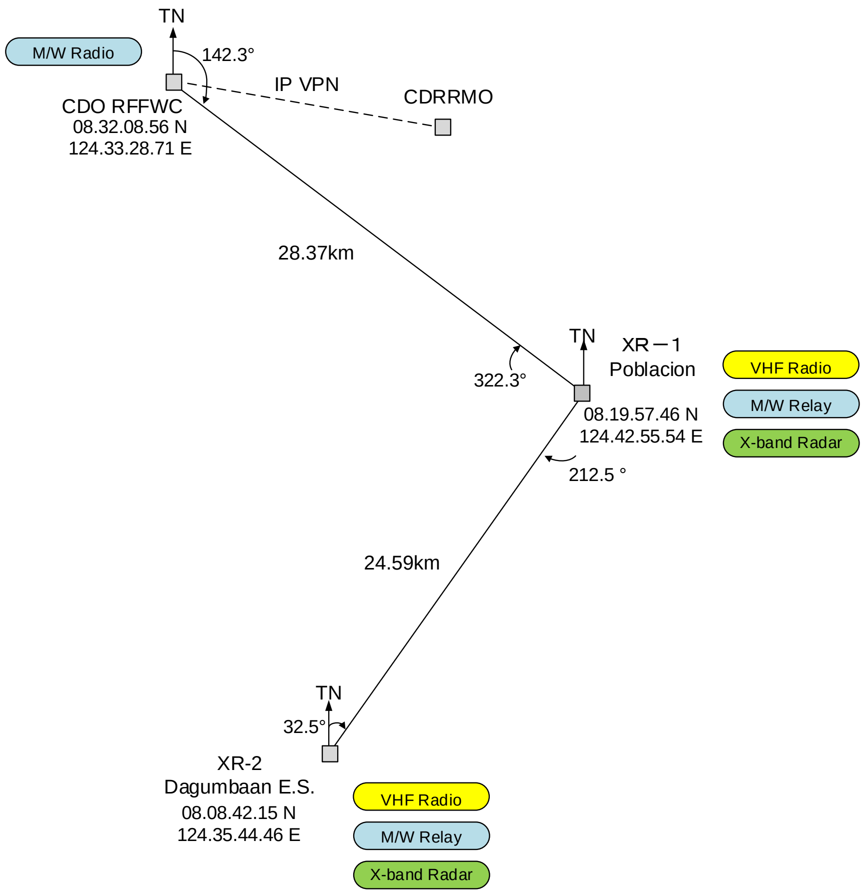


Figure 2-10 Microwave Radio Relay Configuration

1) **Line-of Site between MS CDORFFWC and XR-1 Poblacion**

There is a tree 1.2 km from CDORFFWC that obstructs the line-of-site to XR-1 Poblacion. The mirror test conducted between these 2 sites and it was unsuccessful then mirror test was again conducted between XR-1 and point A at 2km from CDORFFWC as indicated below and line-of site was confirmed at this location. Hence, the tower of 60m height will be constructed at CDORFFWC in order to obtain line-of-site for microwave relay.

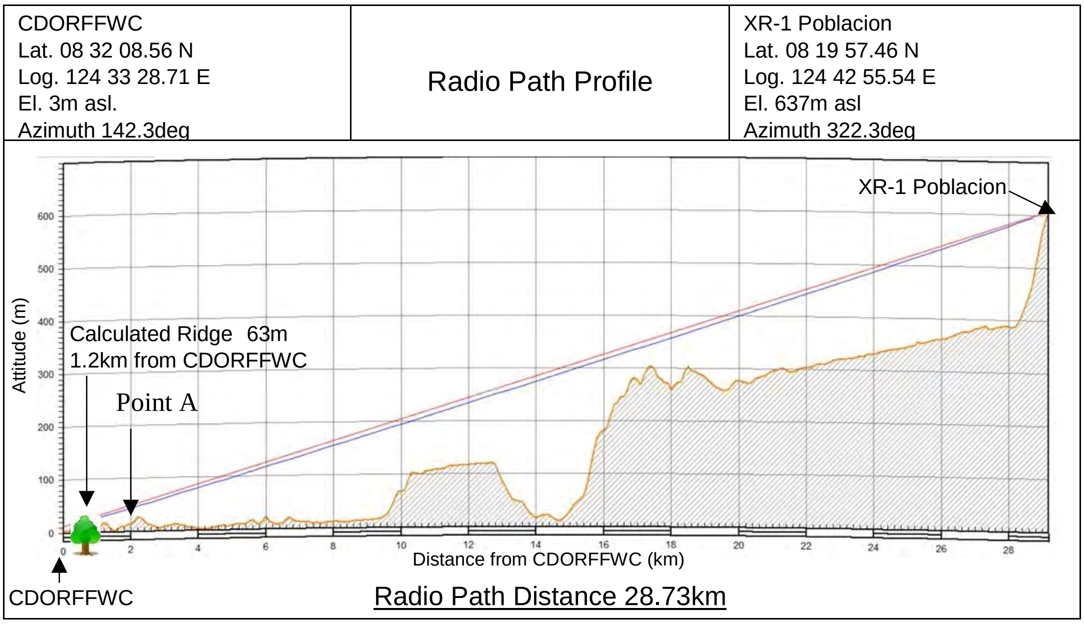


Figure 2-11 Terrain Profile between CDORFFWC and XR-1 Poblacion

2) **Line-of Site Between XR-1 Poblacion and XR-2 Dagumbaan E. S.**

There are no obstructions in the line-of-site between XR-1 and XR-2, as confirmed by the mirror test at the sites.

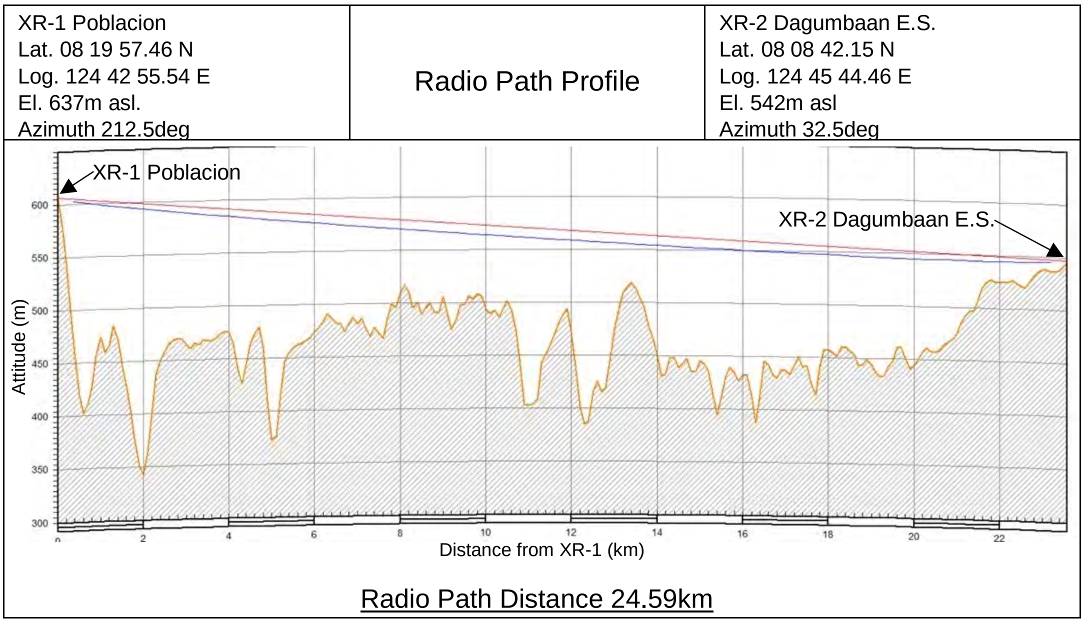


Figure 2-12 Terrain Profile Between XR-1 Poblacion and XR-2 Dagumbaan E. S.

3) **Line-of-Site Between Master station CDORFFWC and CDO-CDRRMD**

There is a hill 7.5 km from CDORFFWC to CDO-CDRRMD that obstructs the line-of-site. Therefore, instead of a microwave radio relay, a IP-VPN will be leased from PLDT.

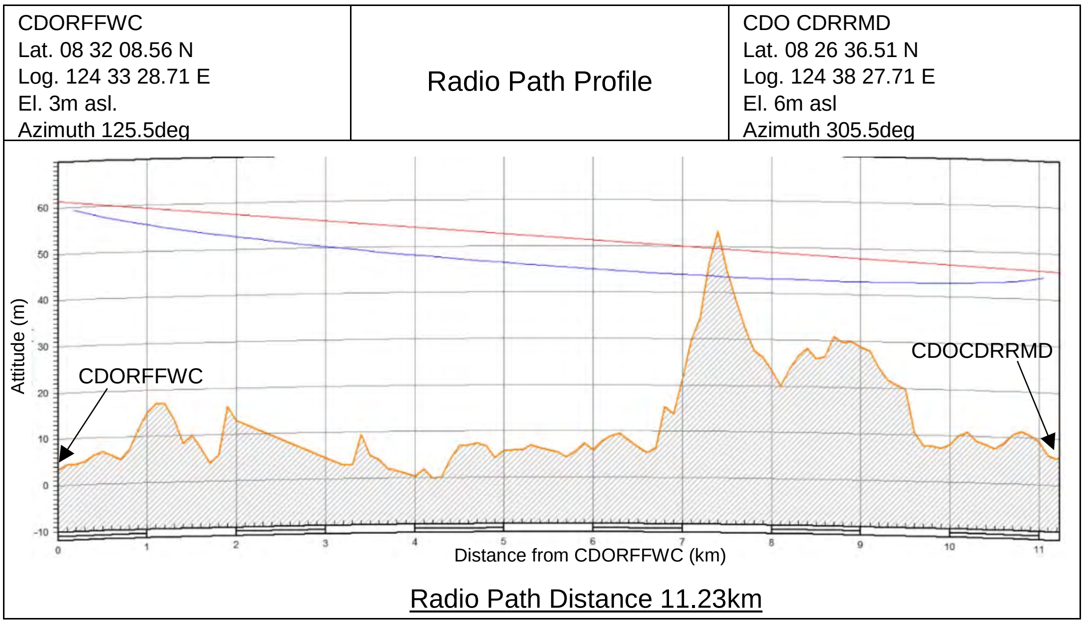


Figure 2-13 Terrain Profile between CDORFFWC and CDO-CDRRMD

(2) Microwave Radio Relay Major Specifications

The major specifications are given in Table 2-19 for the microwave radio relay. The Microwave link reliability is based on ITU-R 530-7/8 published by International Telecommunication Union.

Table 2-19 Microwave Radio Relay Major Specifications

No.	Items	Descriptions		Remarks
1	Radio Link	CDORFFWC – XR-1 Poblacion	XR-1 Poblacion – XR-2 Dagumbaan	
2	Link Distance	29.01 km	23.95 km	
3	Frequency	7.5 GHz	7.5 GHz	PAGASA Existing Frequency
4	Radio Type	ODU-IDU	ODU-IDU	IP Interface
5	Redundancy	Duty/Standby	Duty/Standby	Hot-standby
6	Antenna	1.8 m Parabola Antenna (CDORFFWC) 1.8 m Parabola Antenna (XR-1 Poblacion)	1.8 m Parabola Antenna (XR-1 Poblacion) 1.8 m Parabola Antenna (XR-2 Dagumbaan)	Gain 40.5 dBi more
7	Antenna Height	58 m (CDORFFWC) 12 m (XR-1 Poblacion)	10 m (XR-1 Poblacion) 25 m (XR-2 Dagumbaan)	

There are two types of redundancies, one is Loop Circuit Configuration and the other one is Radio Duplicate System. When both used, it can be the most reliable system. However, Loop Circuit Configuration is not possible due to site restrictions from security reasons, so Radio Duplicate System will be adopted for the microwave radio relay system. As for the radio duplicate system, there are 2 types of change-over, one is hot-standby and the other is cold-standby. The former is faster to switch over when a radio unit is broken.

2-2-2-6 Design of VHF Radio Link for Hydrological Gauge Stations

(1) VHF Radio Propagation Test and Link Design

Based on the site selection of water level and water/rainfall gauge stations from hydrological considerations, the VHF radio propagation test was conducted for all the candidate sites in the field. After studying the results, the VHF radio telemetry links were designed for XR-1, Poblacion and XR-2, Dagumbaan deployed as VHF repeater bases. As shown in Table 2-20, the receiving intensities of the gauge stations are mostly more than 30 dBuV, good for stable radio links. The other few stations are set a little lower than 30 dBuV but it can be compensated by the use of a high gain antenna (8-ele yagi)*1 as well as from the increase of antenna height to 18 m from the ground. Since radio propagation RW-2 (Pelaez Bridge) from XR-1 (Poblacion) is poor, Store and Forward repeater through RW-1(Borja Bridge) is employed instead of a direct link from RW-2 to XR-1. Refer to Figure 2-14.

*1: The antenna composed of linearly aligned conductive rods is called "Yagi Antenna". For example, 5 elements Yagi Antenna consists of 5 conductive rods that are linearly placed. The antenna with more elements performs better to have stable radio communications in distance. This type of high performance antenna is called a high gain antenna.

Table 2-20 Results of VHF Radio Propagation Test

No.	VHF Radio Links			Receive (dBuV)	Noise (dBuV)	Audio Signal (dBm)	Audio Noise (dBm)	S/N (dB)	Remarks
1	RW1	→	RW2	27.8	-5	-9.8	-60	50.2	
	RW2	→	RW1	26.8	-2	-9.6	-60	50.4	
2	XR-1	→	RW1	28.7	-5	-9.4	-49	39.6	
	RW1	→	XR-1	30.0	-5	-9.8	-53.5	43.7	
3	XR-1	→	RW3	46.2	-5	-9.8	-60	50.2	
	RW3	→	XR-1	45.8	-5	-9.8	-60	50.2	
4	XR-1	→	RW4	26.8	-5	-9.8	-50.7	40.9	
	RW4	→	XR-1	24.9	-5	-8.1	-47	38.9	
5	XR-1	→	RW7	68.0	-5	-9.7	-60	50.3	
	RW7	→	XR-1	67.9	-5	-8.2	-60	51.8	Interference (-1~-2dBuV) Time 11:00~12:00
6	XR-1	→	RW6	40.7	-5	-8.2	-60	51.8	
	RW6	→	XR-1	40.4	-5	-8.2	-60	51.8	
7	XR-1	→	R9	74.8	-5	-9.9	-60	50.1	
	R9	→	XR-1	74.6	-5	-8.1	-60	51.9	
8	XR-1	→	R8	70.4	-5	-9.7	-60	50.3	
	R8	→	XR-1	70.4	-5	-8.2	-60	51.8	
9	XR-1	→	R10	62.3	-5	-9.8	-60	50.2	
	R10	→	XR-1	59.9	-5	-8.3	-60	51.7	
10	XR-2	→	RW5	46.6	-5	-9.7	-60	50.3	
	RW5	→	XR-2	46.1	-5	-8.1	-60	51.9	
11	XR-2	→	RW5	51.2	-5	-9.7	-60	50.3	
	RW5	→	XR-2	49.1	-5	-8.1	-60	51.9	
12	XR-2	→	R11	28.5	-5	-9.8	-52.1	42.3	
	R11	→	XR-2	27.8	-5	-8.0	-48.1	40.1	
13	XR-2	→	R12	50.9	-5	-9.9	-60	50.1	
	R12	→	XR-2	50.5	-5	-8.1	-60	51.9	
14	XR-2	→	R13	46.2	-5	-9.8	-60	50.2	
	R13	→	XR-2	45.3	-5	-8.0	-60	52.0	

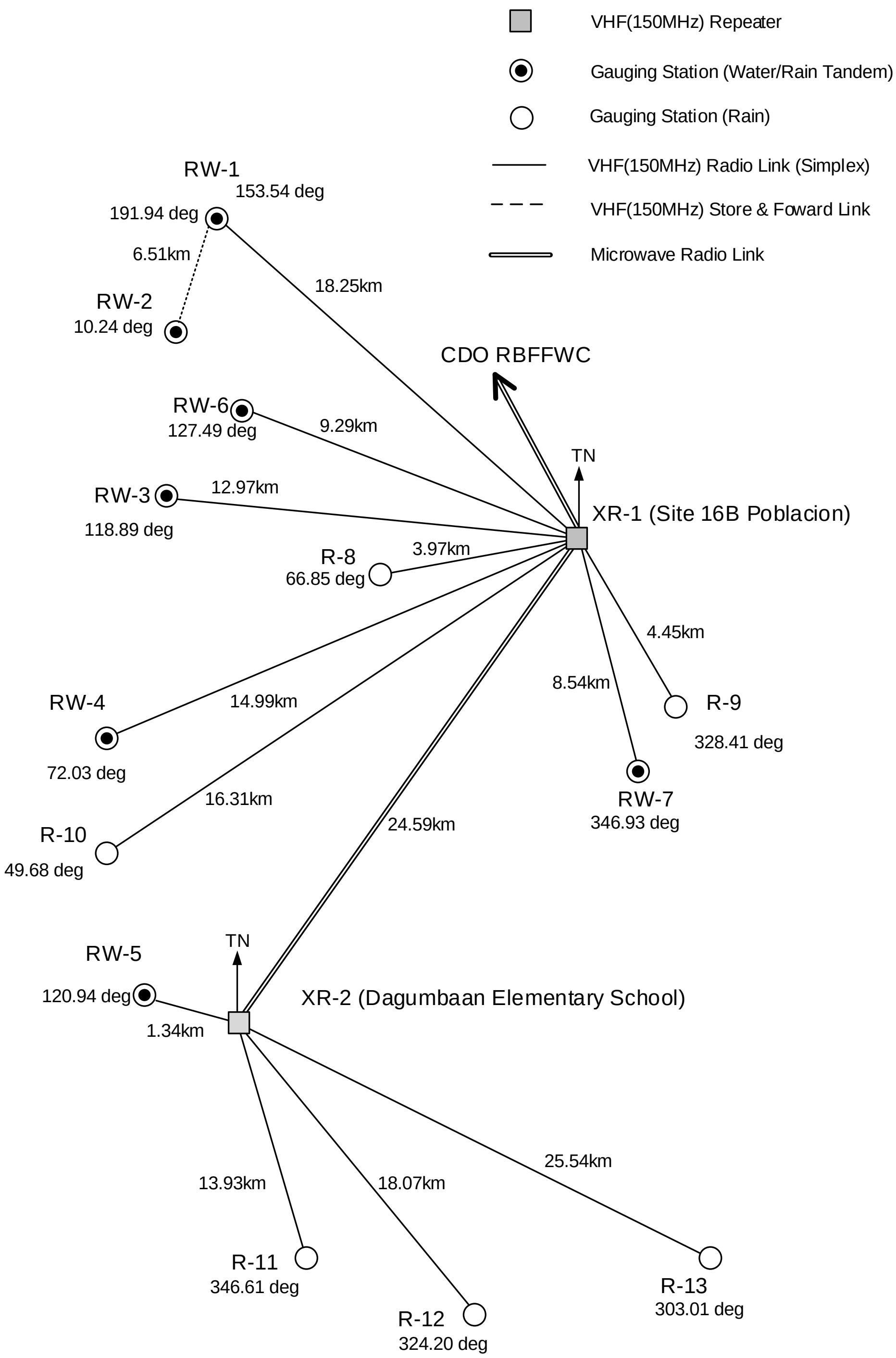


Figure 2-14 Telemetry VHF Radio Link

(2) Telemetry VHF Radio Link Major Specifications

The major specifications are given in Table 2-21 for telemetry VHF radio link.

Table 2-21 Telemetry VHF Radio Link Major Specifications

No.	Items	Descriptions	Remarks
1	Frequency	150 MHz Band	
2	Radio System	Simplex Analog System	Audio frequency shift keying
3	Radio Output	10W/1W	Depending radio link.
4	System Control	Polling and Response	High Level Data Link Control
5	Antenna	5-ele/8-ele Yagi	Depending radio link.
6	Power Supply	Solar Power	Provided with 12V battery.

2-2-2-7 Communication Tower/Antenna Mast and Other Facilities

Based on the results of the field tests, the heights of the communication tower and antenna masts are designed as shown in Table 2-22 for XR-1, XR-2 and MS. The design parameters for the gauge stations are presented in Table 2-23.

Table 2-22 Communication Towers and Facilities for XR-1, XR-2 and MS

No.	Type	Name	Tower Height(m)	Tower Type	Antenna Height (m)			Remarks
					Radio	Micro	VHF	
					2mφPBA*	1.8mφPBA*	Colinear Antenna	
1	MS	CDORFFWC	60	Truss	-	58	-	Air Craft OB Light** Lighting rod
2	XR-1	Poblacion	20	Truss	20	12、10	15	Lighting rod
3	XR-2	Dagumbaan	30	Truss	30	22	25	Lighting rod

Remarks
*PBA: Parabola Antenna
**OB Light: Obstruction Light

Table 2-23 Antenna Mast and Other Facilities for Gauge Stations

No.	Type	Name	Mast Height (m)	Antenna Height (m)	Mast Type	Mast Loads			RF Out (W)
						Yagi	Q'ty	Arr Rod	
1	RW1	Borja Bridge	20	18	Self-Stand	5-ele	2	1	10
2	RW2	Pelaez Bridge	20	18	Self-Stand	8-ele	1	1	10
3	RW3	Cablula Bridge	6	5	Wall-Support	5-ele	1	1	10
4	RW4	Uguiaban	20	18	Self-Ground	8-ele	1	1	10
5	RW5	Tal-Uban Bridge	6	5	Wall-Ground	5-ele	1	1	10
6	RW6	Liboran	10	9	Self-Stand	5-ele	1	1	10
7	RW7	Bubunawan	6	5	Wall-Support	5-ele	1	1	1
8	R8	Imbatug	10	9	Self-Stand	5-ele	1	1	1
9	R9	Nangka	10	9	Self-Stand	5-ele	1	1	1
10	R10	Bureau of Fire	10	9	Self-Stand	5-ele	1	1	1
11	R11	Tikalaan	20	18	Self-Stand	8-ele	1	1	10
12	R12	Masimag	10	9	Self-Stand	5-ele	1	1	10
13	R13	Miarayon	10	9	Self-Stand	5-ele	1	1	10

2-2-2-8 Lightning Protection

The Philippines is a country located in the south-east of Asia where a lot of lightning takes place due to the presence of cumulonimbus cloud during the rainy season. The X-band radar sites are more especially prone to lightning because these are located in the open area on top of the hills. The telemetry gauge stations have also risks of attracting lightning because of the antennas that are 10 m to 20 m high and protruding out from the ground for improvement of reception. Therefore, lighting protections will be practiced as presented in Table 2-24.

Table 2-24 Lightning Protection Methods

Common Grounding	The tower grounding is bonded with the station grounding. This will enable to keep ground potential at the same level when hit by lightning and protect the telemetry equipment from lightning surge.
Single-Point Ground	The grounding terminal box is installed inside the station and all the grounding cables from equipment are terminated at this grounding box. This is called a single-point grounding system enables to maintain grounding potential equal as well as to protect telemetry equipment from intrusion of lightning surge.
Lightning Arrester Rod	The lightning arrester rod is mounted on top of the tower/mast. Lightning is intercepted by this arrester rod so that the X-band radar antenna/microwave antenna and VHF antenna will be safely protected from a direct hit of lightning.
Isolation Transformer	Isolation transformers can prevent lightning surge from intruding through the power lines. This will be provided for the stations X-band radar sites XR-1, XR-2 and CDORFFWC where commercial power is tapped from electric utility poles.
Arrester Devise	Arrester devise shuts lightning surge intruding from antenna to radio equipment. Also, it is used for water-level sensor cable extending outside and is subject to lightning surge induced by lightning hit. Arresters will be provided at both ends of the sensor cable.

2-2-2-9 CDORFFWC Monitoring and Control

(1) Major Functions of Monitoring and Control for X-band Radar

Web-based monitoring and control is possible from CDORFFWC to X-band radars at site. Radar observation, system monitoring, and control is realized by scheduling functions and the operations will be logged in the storage and can be displayed anytime.

Multi-window display, zoom in and out of data are possible and the map data can be edited on the display. The following corrective functions can be realized:

- Radar Range Correction
- Atmospheric Attenuation Correction
- Rain attenuation Correction
- Sea Clutter Detection and Correction
- Bright Band Correction
- Vertical Profile Correction
- Ocular Correction

The system output raw data obtained by the X-band radar and the data format is universal and compatible to products of other vendors for the integration of data.

(2) Major Functions of Monitoring and Control for Microwave Radio Relay

The network monitoring and control system should be able to realize the monitoring and controlling of the status of the microwave radio relays. The following functions will be provided:

- Alarm Acquisition and Real Time Log-in
- Display of Alarms and Events
- Event Logging and Reporting Functions

(3) Major Functions of Monitor and Control for Telemetry System

1) **Telemetry System Control**

- The Monitor and Control can obtain sensor readings at preset intervals (10min, 30min and 60min intervals) from the data logger at gauge station.
- The Gauge Station responds to a poll from the Monitor and Control.
- System software automatically changes data-collection interval to 10min when precipitation occurs.
- On command the Gauge Station selected by the Monitor and Control immediately reads current sensor values and sends readings back to the Monitor and Control.
- When the Monitor and Control is subjected to an external continuous interference, the system software control sequence cannot be suspended due to this interference.

2) **Telemetry System Monitor**

- Automatically the Gauge Station transmits to the Monitor and Control alarms such as door close/open, low battery voltage.

2-2-2-10 Data Communications Between CDORFFWC and PAGASA HMD

(1) Objectives of Data Transport to PAGASA HMD

The X-band dual polarization radar can obtain such data as differential reflectivity ZDR, Phase Difference φDP, Differential Propagation Phase KDP, etc., that cannot be detected by conventional mono-polarization radars. Those radar data will be transported to CDORFFWC and processed with the dedicated data server capable of calculating rainfall accurately and precisely. The raw data simultaneously will be delivered to PAGASA HMD and will be processed in the same way as CDORFFWC so that both act in coordination to attain effective flood forecast and warning. For this raw data transport, a dedicated, highly reliable and a high-speed data connectivity will be necessary between CDORFFWC and PAGASA HMD.

(2) Data Communication Bandwidth and Selection of Applicable Methods

It will be necessary to have about 4 Mbps to 5 Mbps to transport various types of raw data obtained by the dual polarization radar. In addition to the radar data, hydrological data gathered by conventional ground sensors, VoIP and Video Conference should be transported in the same data channel that will be estimated in total about 6 Mbps data speed. Considering the advantages and disadvantages of various candidate methods of communications, IP-VPN will be the most reliable and economical as compared in Table 2-25. PAGASA has already introduced IP-VPN with 1 Mbps data speed for the use of VoIP and Video Conference between MPRSD and PAGASA Headquarter. Under such background, there are two options, one is to upgrade the existing 1 Mbps IP-VPN, and the other is to lease another 6 Mbps IP-VPN. The latter will be recommended because of PAGASA's internal accounting process for the expenses, easy maintenance, and redundancy of the IP-VPN circuits.

Table 2-25 Applicable Communication Methods and Comparisons

Data Transport	Advantages	Disadvantages	Evaluation
Microwave Radio Relay	M/R Relay has been used for hydrological data transport long before the existing Agno and Pampanga telemetry systems. It is reliable and resilient to natural disaster.	Initial cost of construction will be very high. Unlike the existing Agno and Pampanga, the link distance is far long from CDORFFWC to PAGASA headquarter. It is not realistic from the viewpoints of construction cost.	Poor
IP-VPN	IP-VPN is a closed dedicated transport circuit provided by TELCO for application of WAN. PAGASA has already introduced 1 Mbps IP-VPN between MPRSD and the Headquarter. IP-VPN will be one of the most appropriate choice that can be realized.	Monthly recurring cost of communication is required, and communication expenses must be budgeted annually.	Good
Internet VPN	This is an internet connection service provided by Internet Service Provider. Secure Sockets Layer (SSL)/ Transport Layer Security (TLS) encryption technique will be used for security. Internet VPN is economical and PAGASA has already adopted it for communications between MPRSD and the headquarter.	Basically, Internet VPN is a type of best-effort service and service quality will not be guaranteed by TELCO at the time of traffic congestion.	Fair
DICT* Backbone	PAGASA Modernization Plan mentions that wide bandwidth communication backbone will be newly constructed nationwide for connectivity among the government agencies. The nationwide backbone once established, will surely contribute to the enhancement of high-speed data communications. There may be possibility of using this high-speed data circuits between PRSDs and Headquarter.	Currently DICT still has not disclosed the concrete and detailed plans for the construction of nationwide backbone. It entails risk when considering adoption of this backbone in the actual project.	Fair
Satellite	Satellite communication has a high reliability and resilience to natural disaster.	The use of satellite will be very expensive, especially in using raw data transport of X-band radar that requires a wide band capacity.	Fair

Remarks
*DICT: Department of Information and Communication

2-2-2-11 Design of Civil Works

(1) Design of Civil Construction Work

Following the above design policy, the standard design for each hydrological facility is described as follows:

1) **Water Level Gauge Stations**

To minimize the cost and to avoid the reduction of the cross-sectional area of river by facility, the standard design of the water level gauge facility is selected by the following types of structures, revetment type, bridge pier type and piling type. At the upper end of the water level structure, a work deck with hand-hole shall be installed, to change the installation angle of the sensor and store the extra length.

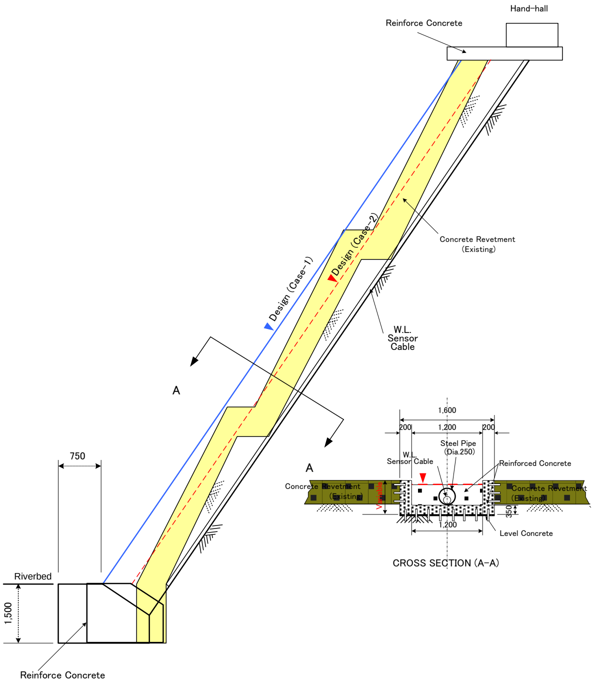


Figure 2-15 Cross Section of Revetment Type Water Level Gauge Station (sample)

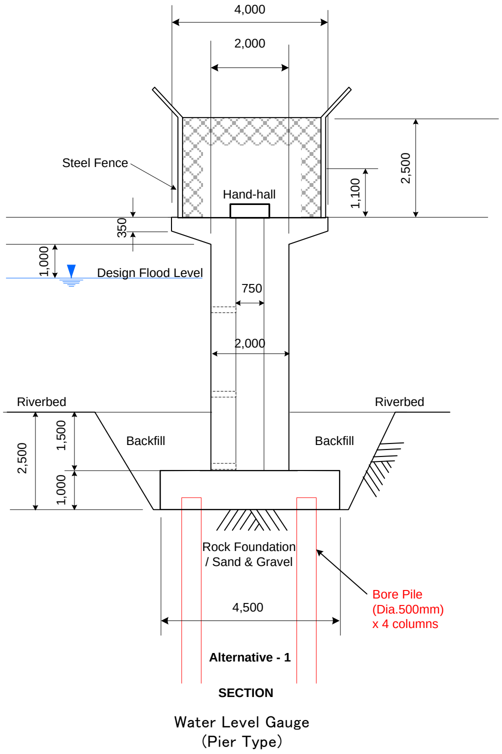


Figure 2-18 Cross Section of Bridge Pier Type Water Level Gauge Station (sample)

Figure 2-16 RW-5: Tal-uban Bridge

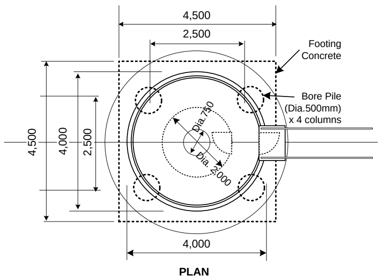


Figure 2-19 Horizontal of Bridge Pier Type Water Level Gauge Station (sample)

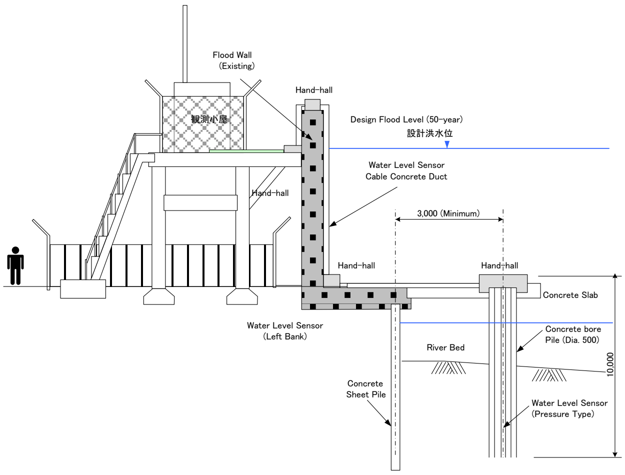


Figure 2-17 Cross Section of River Channel Type Water Level Gauge Station (sample)

2) Gauge House for Water Level Gauge Station (Separated Type)

Basically, water level gauge and gauge house are separated, and are connected to each other via communication cables through an underground concrete duct. Considering the site condition and design requirement, ground type or raised-floor type is chosen for gauge house for water level gauge station.

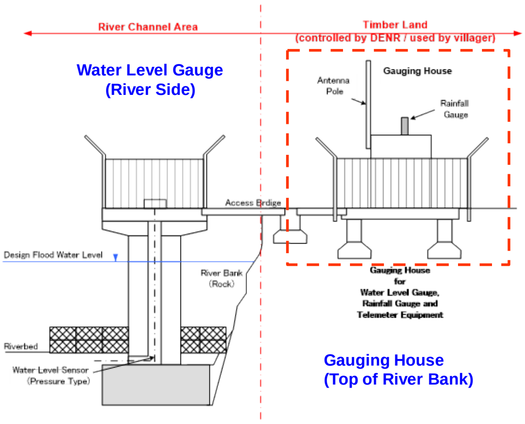


Figure 2-20 Ground Type Gauge House for Water Level Gauge Station

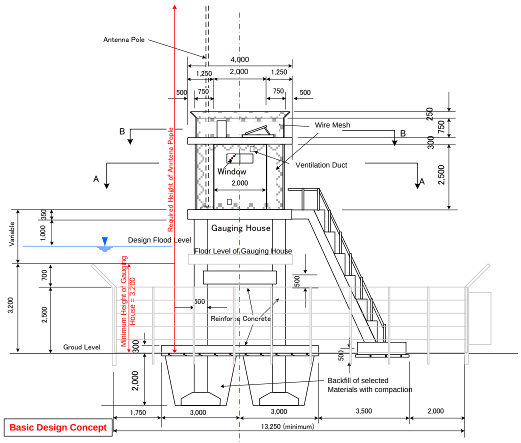


Figure 2-21 Raised-floor Type Gauge House for Water Level Gauge Station(1/2)

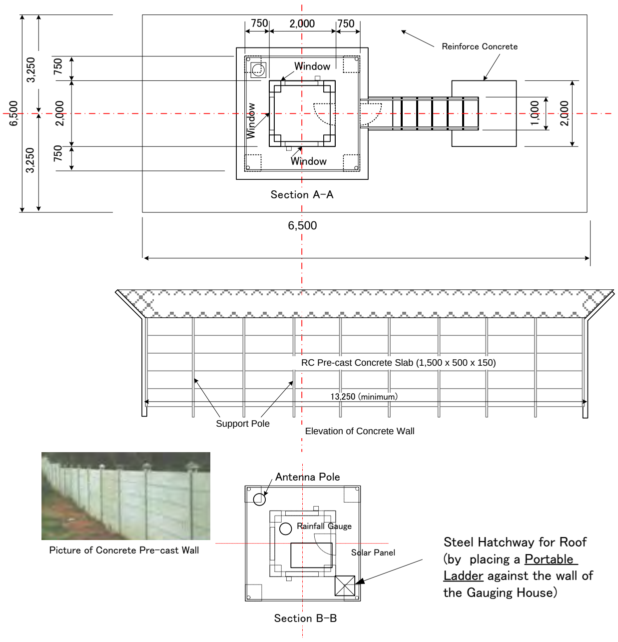


Figure 2-22 Cross Section of Raised-floor Type Gauge House for Water Level Gauge Station(2/2)

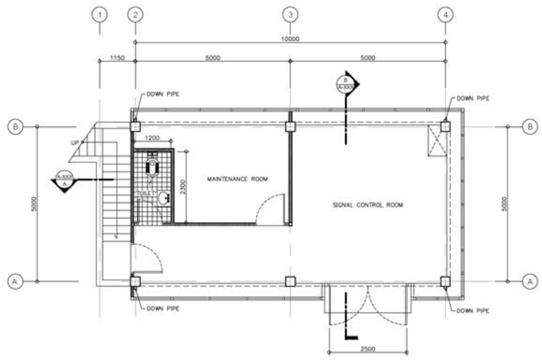


Figure 2-23 Horizontal of house for X-band radar gauge station

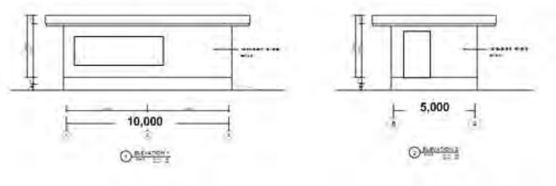


Figure 2-24 Cross Section of house for X-band radar gauge station

3) **Access Facility (Road, Bridge)**

At the design of the access facilities (road, bridge, etc.), the impact on the existing road and traffic shall be minimized as much as possible. Considering the risk of the damage by flood or landslide, the access road shall be available in 24x7. When road access is not available, an alternative access solution (e.g., access bridge) is discussed.

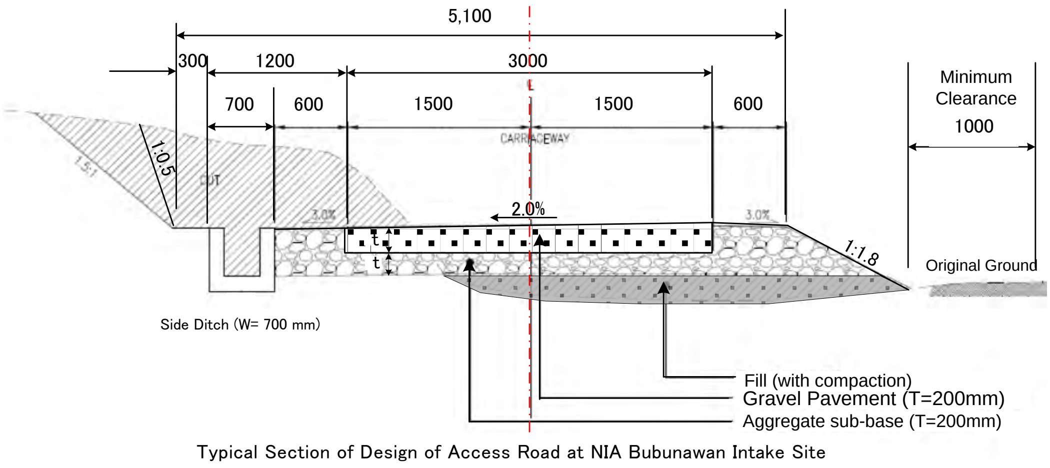


Figure 2-25 Cross Section of Access Road（One Way, W=3,000mm） (sample)

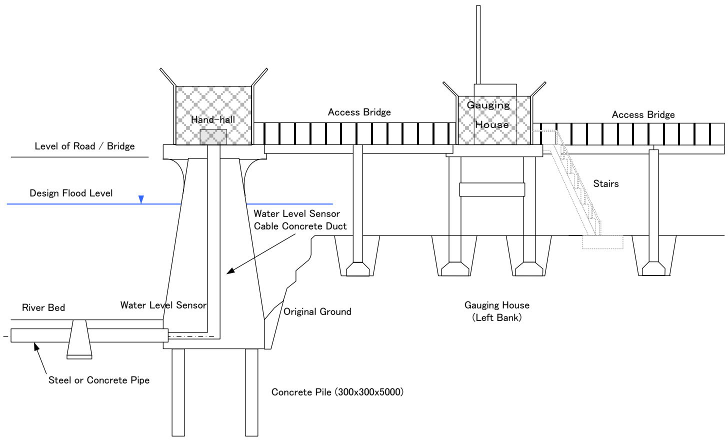


Figure 2-26 Cross Section of Access Bridge (sample)

2-2-2-12 Design of Equipment

In the proposed FFWS system, rainfall and water level data measurements at hydrological gauge stations are transmitted to a repeater site co-located with the X-band radar rain gauge station via 150 MHz band radio link. At the X-band radar rain gauge station, the received data is multiplexed and forwarded to CDORFFWC via 7.5 MHz band microwave link. At CDORFFWC, the received data is decoded and processed, and then those data are forwarded to the related monitoring stations PAGASA HMD and CDO-CDRRMD via DICT network or TELCO IP-VPN.

(1) Hydrological Stations

In the hydrometric stations, rainfall is measured with a tipping bucket type rain gauge, and water level is measured with a water pressure type water level sensor. The measured data are sent from the telemetry stations and forwarded to CDORFFWC via the VHF radio links. To prevent the risk of lacking data, logging data memory device is equipped at each site, so that data transferring reliability is increased in case of radio link trouble.

Solar power supply system for the hydrological stations are provided, because power consumption of those stations is relatively small. For security reason, open/close door is equipped to detect an entrance to the gauge house, which can be monitored at CDORFFWC. It is designed in case that the door is opened by a third party with the purpose of theft, CDORFFWC can inform such situation to the LGU who will be responsible in securing the FFWS facility in the near future (completion of project).

Thirteen telemetry hydrological stations are installed in total, and each station consists of the equipment described in the following table.

Table 2-26 System Configuration of Telemetry Hydrological Stations

Equipment	Function	Quantity	Remark
VHF Telemetry System	Store measured rainfall and water level data, and send those data responding to poling request from Monitoring Station	1 set	
Antenna	Antenna for 150 MHz VHF band	1 set	2 sets in RW-1 (1 set for store and forward)
Arrester	Protect indoor equipment from indirect lighting stroke	1 set	
RF signal divider	Divide signal from/to multiple VHF antenna	1 set	Only for RW-1
Filter	Filter to remove interference wave from other existing FFWS system	2 sets	Only for RW-2, 5
Coax cable	Coax cable to connect antenna and telemetry unit	1 set	
Water level sensor	Water level sensor by measuring water pressure	1 set	Only for water level and rainfall gauge stations (RW-1, 2, 3, 4, 5, 6 and 7)
Data logger for water level sensor	Format converter which change output signal from water level sensor to BCD format	1 set	Only for water level and rainfall gauge stations (RW-1, 2, 3, 4, 5, 6 and 7)
Water level gauge	Tipping bucket type rain gauge	1 set	
Charge controller	To avoid overcharge or over discharge of battery, this controller is installed between solar panel and battery	1 set	
Solar panel	Solar photoelectric generator	1 set	
Battery	Battery to be charged by solar panel, and supply electric power to devices in the station	1 set	
Water level marker	Marker to check water level with eyes, installed beside water (vertical or sloped type)	1 set	Only for water level and rainfall gauge stations (RW-1, 2, 3, 4, 5, 6 and 7)
Door sensor	Door sensor to detect open/close door for security	1 set	

(2) X-band Radar Rain Gauge Station

X-band radar rain gauge station has the function to monitor the rainfall in the 150 m x 150 m mesh size and to send monitored radar data to CDORFFWC via 7.5 GHz band micro radio link. It also has the function to repeat hydrological data from each telemetry hydrological station to CDORFFWC via the same micro radio link above. In this station, monitoring the workstation for data processing and controlling X-band radar equipment is installed. As the power consumption in this station is relatively high because of X-band radar facilities, not the solar panel but commercial power supply is needed. To provide electrical power continuously even in case of long-time power failure, an engine generator is installed in the station. For security reasons, security cameras are installed, since this station has an obtrusiveness in the appearance of the tower, and expensive facilities are installed here.

Two X-band radar rain gauge stations are needed, and each station is consisted of the following equipment.

Table 2-27 System Configuration of X-band Radar Rain Gauge Stations

Unit	Function	Quantity	Remark
Radom	Protection cover for X-band radar rain gauge antenna and controller, for outdoor use	1 set	
Antenna	Antenna of X-band radar rain gauge, which send/receive RADAR radio wave in X-band	1 set	
Antenna controller	Antenna controller which control rotation and angle of RADAR antenna	1 set	
Transmitter	Radio transmitter for X-band radar	1 set	
Receiver	Radio receiver for X-band radar	1 set	
WS for RADAR	WS to control and monitor RADAR facilities	1 set	
Telemetry repeater equipment	Repeater equipment to repeat data from telemetry hydrological stations to Monitoring Station	1 set	
VHF antenna	Antenna for 150 Mhz VHF radio	1 set	
Arrester	Protect indoor equipment from indirect lighting stroke	1 set	
Filter	Filter to remove interference wave from other existing FFWS system	1 set	
7.5GHz band micro wave link equipment	Transceiver for 7.5 Ghz band radio link	1 set	2 sets for XR-1
Parabola antenna	Parabola antenna for 7.5 Ghz band radio link	1 set	2 sets for XR-1
Network SW	Network switch to connect each network node	1 set	
Network camera	Security camera	1 set	
IP phone	IP telephone for line between hydrological stations and Master station	1 set	
Door sensor	Door open / close sensor for security	1 set	
Uninterruptible Power Supply (UPS)	Emergency power supply generator at power stop (e.g., Power failure, outage)	5 sets	
Rectifier	To stabilize voltage of the commercial power supply or UPS	1 set	
Lightning transformer	Protect equipment from indirect lighting stroke through commercial power line	1 set	
Engine generator	When commercial line failure, electric power generated by diesel engine is supplied to monitoring station	1 set	
Power distribution panel	Power distributor of commercial power supply or engine generator (middle size or small size)	1 set	

(3) Master Station and related organization facilities

All hydrological data measured at each hydrological station are sent to Master station (CDORFFWC) via 7.5 GHz micro wave radio link, and decoded and processed by the server, and displayed on the large screen LED display. Each server has a connection to other workstations through a network switching router. Commercial power supply is used for the power supply in Master station, and an engine generator is installed to provide electrical power continuously even during a long-time power failure. master station has dedicated links to HMD and CDO-CDRRMD, respectively. A router is installed for network connection in CDORFFWC, an external display monitor is installed in CDO-CDRRMD, and X-band radar raw data processing server is installed in HMD.

The system in Master station and Monitoring stations (CDORFFWC and CDO-CDRRMD) consists of the equipment in Table 2-28.

Table 2-28 System Configuration of Master Station and Monitoring Stations

Equipment	Function	Quantity	Remark
7.5 GHz band multiplex radio unit	Microwave multiplex radio unit using 7.5 GHz band	1 set	
Parabola antenna	Parabola antenna for 7.5 GHz band radio link	1 set	
Network monitoring WS	WS to monitor 7.5 GHz band multiplex radio unit	1 set	
Network SW	Network switch to connect each network node	1 set	
Security server	Protect each network node from security risk through the internet	1 set	
UPS	Emergency power supply generator at power stop (e.g., power failure, outage)	14 set	
Telemetry Supervisory and Control Equipment	Collect and control data received from telemetry stations	1 set	
NTP server	Using received GPS signal, keep synchronization of each node in the system	1 set	
FFWS server	Collect data from each hydrological station, monitor each telemetry equipment, data processing, display the status	1 set	
Supervisory and control equipment for microwave	Supervisory and Control Equipment for microwave equipment	1 set	
Network printer	Shared printer of each node	1 set	
Facsimile (fax)/Telephone	Telephone with fax machine for external communication	1 set	
VoIP Phone	Voice communication between stations and Monitoring Station	1 set	
Data processing server	Data processing server to decode and post-process data from X-band radar rain gauge station	1 set	
Image data processing server	Image data processing server to generate image data from rainfall data from X-band radar rain gauge	1 set	
X-band radar terminal	Node to monitor X-band radar data and to control equipment status	1 set	
Multiscreen display	Monitoring equipment with multiple display, to display data from X-band radar	1 set	
Multiscreen display controller	Node to control multiscreen display	1 set	
Rectifier	Rectifier to rectify the power supply from commercial power or engine generator	1 set	
Isolation transformer	Protect equipment from indirect lighting stroke through commercial power line	4 sets	
UPS	Emergency power supply generator at power stop (e.g., power failure, outage)	1 set	
Power distribution panel	Power distributor of commercial power supply or engine generator (middle size or small size)	1 set	

Table 2-29 System Configuration of Monitoring Station at HMD

Equipment	Function	Quantity	Remark
Data processing server	Data processing server to decode and post-process data from X-band radar rain gauge station	1 set	
X-band radar terminal	Node to monitor X-band radar data and to control equipment status	1 set	
Facsimile (fax)/Telephone	Telephone with fax machine for external communication	1 set	
VoIP Phone	Voice communication between stations and Monitoring Station	1 set	
UPS	Emergency power supply generator at power stop (e.g., power failure, outage)	1 set	

Table 2-30 System Configuration of Monitoring Station at CDO-CDRRMD

Equipment	Function	Quantity	Remark
LCD display	Monitoring equipment, to display data from X-band radar	1 set	
Display terminal	Node to control LCD display	1 set	
Network Router	Network switch to connect each network node	1 set	
Facsimile (fax)/Telephone	Telephone with fax machine for external communication	1 set	
VoIP Phone	Voice communication between stations and Monitoring Station	1 set	
UPS	Emergency power supply generator at power stop (e.g., power failure, outage)	1 set	

New building for the master station (CDORFFWC) shall be constructed by the Philippines side fund. PAGASA has already contracted with the local construction company and new building will be completed by September 2019. Design conditions for the new equipment layout are as follows:

Space in the room: approximate 6 meters x 10 meters

Celling height: 2.2 meters

Power source: AC 220 V, single phase (Uninterruptible Power Supply (UPS) will be provided under the Project)

Since the JICA Study Team has not discussed the equipment layout mentioned above with PAGASA, the JICA Study Team shall coordinated this issue with PAGASA at the Detailed Design Stage (the JICA Study Team has proposed that new equipment will be installed at all space of office room at second floor).

Tower for micro-wave radio and new building for the diesel engine generator sets shall be constructed under the "Project".

2-2-3 Outline Design Drawing

Overall system configuration is illustrated in 6 Reference (Basic Drawings).

2-2-4 Implementation Plan

2-2-4-1 Implementation Policy

(1) Installation Works of the Facilities

After the completion of civil works to build gauge houses, the installation works for facilities shall be started. These installation works consist of delivery of the facilities/equipment into the site, anchor equipment, adjusting/testing and commissioning. During the installation works, VHF and micro wave antenna are also installed at the designated sites. At the same time of the equipment adjusting/testing, a radio link test shall be conducted to check the signal receiving level and the radio link reliability.

Installation works will also include installation work of the X-band radar and micro wave radio antenna, cabling, installation of water level gauge on the river (bank), delivery of the equipment into sites and cabling for each other. These installation works will also contain health check and tuning after the installation of the facilities/equipment. The proposed FFWS stations are categorized into two groups, the first group is the hydrological stations where water level and/or rainfall gauge is installed, and the second group is CDORFFWC where hydrological data are stored, processed, and displayed. The adjusting/testing in CDORFFWC can be started only after the completion of the installation of the hydrological stations, the installation is planned in the final phase of the civil work. To avoid civil work in the rainy season and to shorten civil work duration, civil work by multiple parties in parallel is recommended.

(2) Civil Structure Construction Works

Expected type or methods of civil construction works are summarized in table below at each major structure, which should be based on Civil Facilities Plan and Basic Designs as mentioned in sub-section above. It is judged that these type / methods of construction works can be done by contractor in the Philippines, and construction equipment and materials also can be procured in the site.

Table 2-31 Methods of Civil Construction Work and Construction Plan

Major Structures	Expected Type or Methods of Civil Construction Works	Notes for Preparation of Construction Plans
1. Revetment Type of Water Level Gauge (installed at Exiting Revetment)	● Partial demolition of existing concrete revetment. ● Embedding of steel pile of cable sensor of water level equipment ● Concrete placing at slope of revetment and slab concrete of deck ● Excavation (Riverbed・Slope) and Temporary Coffering	● Construction plans of Partial demolition of existing concrete revetment. ● Construction plans of foundation excavation of revetment and Temporary Coffering
2. Pier Type of Water Level Gauge	● Bore Concrete Piling Works (Cast-in-Place) ● Concrete placing at water side and upper part for of pier structures ● Excavation (Riverbed・Slope) and Temporary Coffering	● Construction Plan of Cast in Place of Bore Concrete Piling Works (by using of underwater concreting) with coffering works ● Construction Plan of concrete placing of pier structure (upper portion) ● Construction plans of foundation excavation of revetment and Temporary Coffering
3. Gauge House	● Excavation and Back-filling and Embankment works ● Security Fence (Pre-cast Concrete) ● Security Steel Wire Fence ● Foundation works for Building Structures ● Building Works (Reinforcing Concrete) ● Foundation works for Antenna structures	● Adoption of Pre-Cast Concrete Production in Security Fence for shortening of construction time schedule. ● Construction Plan of Electrical works such as Wiring and Grounding etc. ● Construction Plan of Foundation works for Antenna structures (Antenna Height > 10m)
4. X-band Rader Site Works	● Excavation and Back-filling and Embankment works ● Foundation works for Building Structures ● Building Works (Reinforcing Concrete) ● Drainage Works ● Security Fence (Pre-cast Concrete)	● Construction Plan of Foundation of Antenna structures in parallel of with other construction works ● Construction Plan of Drainage Works ● Construction Plan of Water Supply and sewerage system works ● Construction Plan of Electrical works
5. Access Works (Road・Bridge)	● Excavation and Back-filling and Embankment of road works ● Drainage Works ● Steel Access Bridge and PC Girder Bridge (Span > 10m) ● Pavement Works (Gravel, Reinforced Concrete)	● Construction Plan of Drainage Works ● Construction Plan of Road Works with keeping of spaces of temporary and permanent works ● Construction Plan with consideration of space of construction materials.

(3) Tower Construction Works

Micro wave radio antennas are installed on the tower at the X-band radar rain gauge stations and CDORFFWC. The civil works related to those tower construction works cover the foundation works and tower construction work, which are divided into sub-component works such as temporary assembly, painting and metal plating, assembly of the materials, bolting, and electrical facilities installation works.

2-2-4-2 Implementation Conditions

Since this project contains many kind of activities, like civil works, tower construction works, equipment installation works, so all works need to be aligned and scheduled well so that all construction works can be completed in schedule.

2-2-4-3 Scope of Works

Demarcation of project between the Philippine and Japanese sides is summarized in Table 2-32.

Table 2-32 Demarcation of Project between the Philippine and Japanese Sides

Japanese Side	Philippine Side
Procurement of facilities and materials Installation of facilities and system optimization (all stations) Civil works (foundation work, facilitation work, building access road) Tower construction Initial operation guidance	Construction of CDORFFWC building Negotiation and permits with related organizations - Land acquisition (including access road) - Frequency allocation - Custom clearance - Road traffic control during construction - Other required permits Witness of delivery of the equipment, installation works, testing and commissioning Dispatching of counterparts Secure of budget and Value-added Tax (VAT)

2-2-4-4 Consultant Supervision

(1) Detailed Design for the Consultants

The consultancy service contract shall be concluded between PAGASA as the implementing party in the Philippines and the selected Japanese Consultant. The consultancy service contract shall cover the following.

(2) Detailed Design

In this phase, the consultant shall take responsibility for reviewing the details of the Project with PAGASA. Based on this final design review result, the consultant confirms and finalizes the specifications of facilities to be purchased.

In the final review output, referring to the result of the field survey, the consultant takes responsibility for the finalization of the design output and the location of hydrological stations, through a discussion with PAGASA. And the consultant also takes responsibilities for the progress management of the scope of works by the Philippine side and monitoring of implementation schedule.

When the consultant finalizes the specifications of the facilities/equipment and services to be purchased, after the final review of the project plan, the consultant will update the specifications of facilities/equipment and civil works, and update the required costs and project schedule.

1) **Bidding Assist Activity 1**

In this project, the bidding documents are prepared in the Japanese side, and the bidding documents are explained for the final approval of PAGASA.

2) **Bidding Assist Activity 2**

The invitation to the bidders, selling of the bidding documents, and explanation are to be executed in Japan. The witness of bidding and opening of the bidding are executed in the Philippines.

For the activities in this phase, the following personnel are required for the preparation of the detailed design and document by the consultants.

Table 2-33 Personnel and Tasks Required for the Detailed Design

Job Title	Job Contents
Project Manager	Overall project management related planning and executing project Approval of bidding document, conduct of question and answer on the bidding documents, evaluation of bidding
Design engineer (Civil work)	Design of embankment and building of hydrological stations Review of civil related specifications, preparation of the bidding documents
Design engineer (Equipment)	Design of radio communication system and FFWS Review of specifications, preparation of bidding documents for telecommunication system Review of radio communication related specifications, preparation of bidding documents

(3) Supervision Management

The supervision management in this project contains the following activities;

1) **Before Works at Site**

Conduct the kick-off meeting with the stakeholders, preparing progress report during construction period, issue of an interim progress, an inspection of completion, and execution of the required procedures should be done.

2) **Checking and Confirming Drawings**

Before exporting and packaging for shipping, the consultant takes responsibility to check the number of items procured. The inspection engineer will conduct this activity.

3) **Witness of the Items before Shipping**

Before exporting packing for shipping, the Consultant takes responsibility to check the number of items procured. Inspection engineer will conduct this activity.

4) **Inspection before Shipping**

Before shipping the equipment, under the witness of a third-party agency assigned by the consultant will verify the equipment list with shipping list. Joint inspection together with project contractor.

5) **Supervision of Construction**

The supervision operations include the issuance of the certificate of completion of construction, procedures for handing over the completed construction, preparation of the final operational report, etc.

For the supervision operations, this project will employ local staff who will assist in the procurement and supervision to allow the construction to be carried out simultaneously at multiple locations.

The procurement management supervisors are assigned permanently, supervisor for equipment and civil are assigned separately, to share the roles.

The procurement management work is handled by the following members. Since civil works run in parallel in multiple stations, the local staffs are hired as sub-supervisors.

Table 2-34 Supervision Management Organization

Job Title		Job Role
Japanese engineers	Project Manager	・Hosting of negotiation meetings with PAGASA, supervising of equipment inspection and hand over meeting
	Resident Engineer (Facilities/Equipment)	・During the period of equipment installation, staying in the Philippines, supervise procurement and installation work for all facilities ・Control the quality, the progress, payment process, safety management, negotiation with PAGASA, and report to the Project Manager
	Resident Engineer (civil work)	・During whole period of civil works, staying in the Philippines, supervise civil works work locally ・Check the quality, the progress, payment process, safety management, negotiation with PAGASA in the Philippines, and report to the Project Manager
	Supervising Engineer (Civil)	・Supervise the quality related to civil works
	Supervising Engineer (Telecommunication)	・Supervise the quality of installation works
	Supervising Engineer (Telecommunication facility)	・Supervise the quality of telecommunication facilities (Tower)
	Inspection Engineer (facility)/equipment	・Review and approve documents related to material, and quantity confirmation matching with the material list
	Inspection Engineer (Civil works)	・Review and approve documents related to civil work, and quantity confirmation matching with the material list
	Inspection Engineer	・Host inspection test before factory shipping, inspection before shipping
Local Staff	Local Sub-supervisor (Equipment)	・Support the resident engineer for the facilities/equipment ・Assist the progress management of material procurement, progress management of installation, quality control, and safety management
	Local sub-supervisor (Civil)	・Support the resident engineer for civil works ・Assist the progress management of civil work, quality control, safety management

2-2-4-5 Quality Control Plan

The quality management for materials purchased and civil works in this Project shall be performed through the following activities:

(1) Confirmation and Checking of Approval Documents

The contractor must submit the material list and planning documents for all facilities/equipment, materials, and civil works. The consultant must review whether the specifications of facilities/equipment and materials, and that civil work quality satisfy the required specifications or not.

(2) Inspection before Shipping

Before exporting and packaging for shipping, the consultant will check and confirm the quantities of the purchased facilities/equipment and materials.

(3) Inspection Matching Test before Shipping

After all facilities/equipment and materials are ready for shipping, a third-party agency will inspect the quantities of the purchased facilities/equipment and materials using the contract equipment list, shipping list, and confirm that all packaging cargos can endure marine and inland transportations.

(4) Site Test (Commissioning Test)

To check the completion of the installation works and civil works, inspection and site tests are to be executed. Site tests consist of a unit test to check the performance of each equipment, and the total system test to check system function and performance. The consultant is responsible to undertake the said tests at site, and the consultant and PAGASA will attend the said test. After the system performance test, the consultant shall submit the final test report which serves as an evidence of completion of all the activities.

(5) Product Warranty

The contractor has the responsibility of upholding a warranty for one year after hand over, and contractor must conduct remedy works without delay, in case of fault.

2-2-4-6 Procurement Plan

(1) Procurement Policy

The facilities/equipment provided by this project consist of the following:

Facility/Equipment	Main Function
Telemetry equipment including VHF radio	To monitor the water level and rainfall
X-band radar rain gauge equipment	To measure the amount of rainfall using Dual Polarization
Microwave radio equipment	To send and receive hydrological data from the repeater stations to CDORFFWC
Monitoring facilities/equipment	To conduct the processing and display the measured data and sending said data to CDO-CDRRMD and HMD

As the facilities/equipment used for FFWS, high reliability in hazard situation is requested. Since the existing FFWS system is already launched in the target area, but the operational status is not very good. A more stable system is requested to the new FFWS system.

Considering the abovementioned high stability and reliability which are requested to be applied to this FFWS system, the purpose of this Project under the Japanese Grant Aid, and the difficulty to procure the facilities/equipment, which satisfies those quality standards requested within the Philippines, the main facilities/equipment are to be procured in Japan.

But considering the prices and the easy maintenance work, the following equipment are to be purchased in the Philippines:

- UPS
- L2/L2 Switch
- Network Printer
- VoIP Phone
- Fax Machine

Although some servers, workstations, and PC terminals are also available in the Philippines, there is difficulty in verification of software/applications for FFWS for the contractor, so it is concluded that they are to be purchased in Japan.

(2) Transportation Plan

Cagayan de Oro City located in the northern part of Mindanao Island, the distance from Davao International Port is about 250 km. Although Cagayan de Oro City also has Cagayan de Oro International Port, it is concluded that Davao International Port is used for the final destination of sea transportation to secure safety as well as considering the experience in international transportation. It was confirmed that transportation from Yokohama to Davao is possible. For the transport cost estimation, international oversea transportation through Davao Port and inland transportation from Davao and Cagayan de Oro are confirmed.

2-2-4-7 Operation Guidance Plan

(1) Instruction for Initial O&M

The instruction for the initial operation and maintenance will be conducted for the staff of PAGASA and some staff from the concerned organizations/agencies. This guidance is estimated about 1.5 months.

(2) Contents of Initial Operation Guidance

The initial guidance executed by the contractor contains a desk study and operational practices using the actual equipment, and is aimed to handover O&M skills as follows:

Table 2-35 Contents of Initial Operation Guidance

Guidance Contents
1. Guidance of the basic electronics and telecommunication knowledge
2. Operation and maintenance skills
3. Maintenance procedures
4. Fault analysis
5. Trouble shooting
6. Recording method related to O&M works

2-2-4-8 Soft Component (Technical Assistance) Plan

(1) Background of the Soft Component Plan

When Tropical Storm “Sendong” hit the Northern Mindanao area on December 16, 2011, the storm caused tremendous damages to 1,170 victims and caused about 1,250 deaths. After the flooding by “Sendong”, an ODA loan project was formed to reduce the flooding damage through JICA's Preparatory Survey in March 2014, FRIMP-CDOR. The loan agreement has been concluded between the Japanese and the Philippine governments in March 2015 and the project is currently ongoing by the Philippine government.

The Cagayan de Oro River basin is selected for the pilot area in the JICA Technical Cooperation Project entitled the “Project for Strengthening Capacity of Integrated Data Management of Flood Forecasting and Warning in the Republic of Philippines", which aims to improve flood forecasting and warning ability of PAGASA throughout the Philippines.

(2) Objectives of the Soft Component

Based on the background as mentioned above, the objectives of Soft Component Plan are determined as follows:

- Continuous and proper operation of the FFWS, which is constructed under the Grant Aid project, could be established by CDORFFWC and the concerned disaster risk reduction (DRR) organizations such as CDO-CDRRMD, Office of Civil Defense (OCD), and DPWH.
- Improvement and activation of dissemination information capability by disaster risk reduction organizations.

(3) Achievements of the Soft Component

The following achievements of the Soft Component are expected:

① Improvement of the capabilities of O&M works for PAGASA and related DRR organizations.

② Improvement of flood forecasting ability using the stage correlation method.

③ Acquirement of analysis technique for the data of X-band radar rain gauge.

④ Acquirement of evacuation information skill of PAGASA and the concerned disaster risk reduction organizations.

Upon the conduct of the said achievements above, proper O&M of the hydrological stations and data monitoring stations (CDORFFWC and CDO-CDRRMD) can be undertaken. In addition, quick action and response can be performed by PAGASA and concerned disaster risk reduction organizations due to real time data sharing at CDORFFWC and CDO-CDRRMD, which may contribute to the reduction of flood risk in the Cagayan de Oro River basin.

(4) Activities of the Soft Component

The activities of soft component are summarized as shown in Table 2-36.

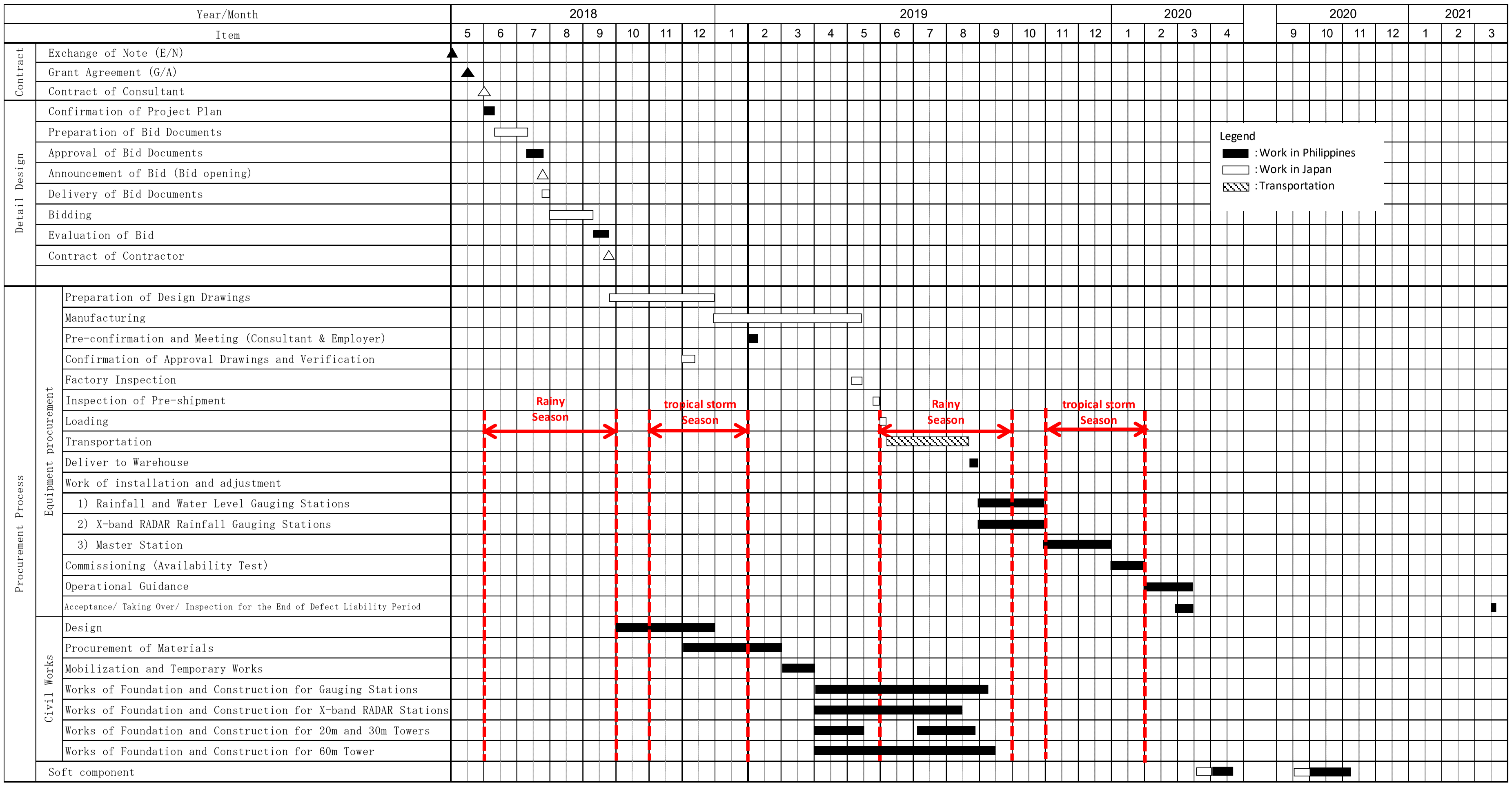
2-2-4-9 Implementation Schedule

The implementation schedule is described in Table 2-37.

Table 2-36 Activities of Soft Components

Achievement	Target Job Title	Current Skill Level and Required Skill Level	Output	Implementation Plan	Target resource and schedule
① Improvement of operation and maintenance skills of FFWS for the Manager of PAGASA and disaster risk reduction organization	Administrative engineers who have O&M skills are set for FFWS	Inexperience in O&M of automated telemetry system and operation system. O&M skill of those system for continuous and autonomous operation	● Training materials (O&M manual and hazard information system manual) ● Achievement level check sheet	The following trainings are provided using FFWS that is installed by this project: ● Operation and maintenance of FFWS (2 days) ● Information management (3 days) ● Alarm establishing criteria (3 days)	Administrative engineer related FFWS Preparation in Japan: 8 days Training in Philippines: 8 days
② Improvement of flood forecasting ability using the stage correlation method	Hydrological engineers who need basic knowledge of the stage correlation method	Although the basic knowledge of the stage correlation method is supposed to be acquired in the technology transfer project, application ability is required for actual flood forecasting	● Training materials (basic FFWS process manual using the stage correlation method) ● Achievement level check sheet	The following trainings are provided using real data of FFWS that is installed by this project: ● Hydrological data about flood runoff (3 days) ● Stage correlation method (5 days) ● Flood forecasting (5 days) ● Closing and evaluation (2 days)	Hydrological engineer Preparation in Japan: 8 days Training in Philippines: 15 days
③ Acquirement of analysis technique for the data of X-band radar rain gauge	Engineers who need the skills of data processing and operation of X-band radar rain gauge	As FFWS combined with X-band radar is being experienced first in the Philippines, O&M skills of X-band radar is mandatory for continuous and autonomous operation	● Training materials (X-band radar data analysis and process manual) ● Achievement level check sheet	The following trainings are provided using FFWS that is installed by this project: ● Calculation of average rainfall over river basin (5 days) ● Measured hydrological data (method of basic processing, utilization of saved data, etc.) (5 days) ● Closing and evaluation (2 days)	X-band radar system engineer Preparation in Japan: 8 days Training in Philippines: 12 days
④ Improvement evacuation information skill of publishing hazard information for the Manager of PAGASA and disaster risk reduction organization	Hazard information engineers who are responsible for hazard evacuation information	Although the basic knowledge of the evacuation information is established in the current FFWS, application ability is required for continuous and autonomous operation	● Training materials (operation and maintenance and hazard evacuation information system process manual) ● Achievement level check sheet	The following trainings are provided using FFWS that is installed by this project: ● Evacuation information and cooperation (2 days) ● Drill for the system (2 days) ● Closing and evaluation (2 days)	Administrative engineer related Hazard information Preparation in Japan: Including item ① Training in Philippines: 6 days

Table 2-37 Implementation Schedule



2-3 Obligation of Recipient Country (Philippines)

The following shall be arranged by the Philippines side for the implementation of the Japanese Grant Aid Project.

(1) Construction of CDORFFWC Building

Construction of new building for CDORFFWC shall be completed by the Philippines side on time schedule. As stated in the sub-chapter 2-2-2-12, PAGASA has already contracted with the local construction company and the completion is scheduled by September 2018.

If the new building is delayed, new equipment will be installed as temporally at vacant space in the first floor in the existing building (current MPRSD). In accordance with the information from PAGASA, the existing meteorological facilities at current MPRSD building will be transferred to Laguindingan International Airport within a few years, thus, there are much space for the new equipment at the MPRSD building.

(2) Land and Access Acquisition

Land acquisitions needed for water level and/or rain gauge station and X-band radar rain gauge stations are shown in Table 2-38, acquisition of which shall be completed prior to the Japanese government cabinet approval.

Table 2-38 Land Owner or Organization to Acquire Permission at Proposed Site

Name of the Proposed Sites: Subject of the Facility of FFWS	Land Owner or Organization to Acquire Permission	Situation on Permission
X-band Radar Rain Gauge No. 1 (XR-1), Libona City, Bukidnon：Small Building and Tower	・ Indigenous People (IP) ・ National Commission on Indigenous People	・ Agreement on the land usage is made with the stakeholders on January 29, 2018 ・ Memorandum of Agreement (MOA) will be signed by the end of March 2018
Rain Gauge Stations and X-band Radar Rain Gauge No. 2 (XR-2)：Gauge House/ Small Building and Tower ・ X-band Radar-2 (XR-2), Dagumbaan I Elementary School, Talakag City, Bukidnon ・ Rainfall Station (R-8) at Imbatung Elementary School Baungon City, Bukidnon ・ Rainfall Station (R-9) at Nangka Elementary School Libona City, Bukidnon ・ Rainfall Station (R-11) at Tikalaan High School, Talakag City, Bukidnon ・ Rainfall Station (R-12) at Masimag Elementary School, Talakag City, Bukidnon ・ Rainfall Station (R-13) at Miarayon Elementary School, Talakag City, Bukidnon	・ Department of Education (DepED) – Bukidnon	・ MOA with DepED is signed on January 31, 2018 ・ MOA with each principal of school is signed on February 2nd, 2018 respectively
Water Level/Rain Gauge Stations：Water Level Facility and Gauge House ・ RW-1, Borja Bridge, Brgy. 7, Cagayan de Oro City ・ RW-3, Cabula Bridge BrgyLumbia, Cagayan de Oro City ・ RW-4, Uguiaban Bridge, Brgy. Dansolohan, Cagayan de Oro City ・ RW-5, Tal-uban, Bridge, Brgy. Basak, Talakag City, Bukidnon	・ DPWH Regional Office 10	・ Official permit letter from DPWH Regional Office 10 is acquired on January 22, 2018
Water Level/Rainfall Gauge station (RW-2), Pelaez Bridge, Brgy. Taguanao, Cagayan de Oro City：Water Level Facility and Gauge House	・ Private land owner for part of the access during construction period ・ Cagayan de Oro City maintains the bridge	・ MOA with the private land owner is signed on November 20, 2017 ・ Official permit letter from Cagayan de Oro city is acquired on December 27, 2017
Water Level/Rainfall Gauge Station (RW-3), Cabula Bridge, Brgy. Lumbia, Cagayan de Oro City：Water Level Facility and Gauge House	・ DPWH Regional Office 10 ・ Private land owner for part of the gauge house	・ Official permit letter from DPWH Regional Office 10 is acquired on January 22, 2018 ・ Deed of Donation with the private land owner is signed on January 17, 2018
Water Level/Rainfall Gauge Station (RW-6), Liboran, Baungon City：Water Level Facility and Gauge House	・ Two claimants of the access area	・ Agreements on the land usage are made with the stakeholders on September 4, 2017
Water Level/Rainfall Gauge Station (RW-7), NIA Bubunawan Intake, Brgy. Salimbalan, Baungon City：Water Level Facility and Gauge House	・ NIA ・ Two claimants of the access area	・ Official permit letter from NIA Head Quarter is acquired on January 4, 2018 ・ Agreements on the land usage are made with the stakeholders on August 30, 2017
Rainfall Gauge Station (RW-10), Bureau of Fire Protection, Brgy. Poblacion, Talakag City：Gauge House	・ Talakag City	・ Official consent letter from Talakag City is acquired on January 12, 2018

(3) Deployment of the Counterparts

PAGASA is requested to deploy counterparts for the civil works, installation work, system commissioning, and soft component activities.

(4) Estimation Guarantee Budget for VAT and Payment

To secure VAT related to materials, sources, and service costs purchased in the Philippines, PAGASA is requested to secure the budget in advance for smooth payment to the contractor and consultant.

(5) Certificate of Non-Coverage

Since there might be no risk of environment impact or resettlement in this project, “Certificate of Non-Coverage” from the Department of Environment and Natural Resources (DENR) shall be issued (PAGASA has already requested DENR on December 2017).

(6) Preparation of Required Application

1) **Application of Frequency**

In this project, 150 MHz VHF band is used for telemetry hydrological data, 7.5 GHz micro wave band is used for multiplex radio link of data transmission, and 9 GHz (X-band) is used for X-band radar. The applications to be used in those radio bands were applied to the National Telecommunications Commission by PAGASA on November 2017. It is to be noted that these applications are preliminary permission, so official applications shall be required referring the model of the equipment provided after the Contract for the project implementation.

- For X-band Radar: 9.730 / 9.770GHz
- For VHF telemetry: 138.20MHz
- For micro radio
  - ✓ CDORFFWC: 7,498/7,659 MHz
  - ✓ XR-1: 7,659/7,498 MHz and 7,631/7,470 MHz
  - ✓ XR-2: 7,470/7,631MHz

2) **Custom Clearance**

To import all necessary facilities/equipment and materials, PAGASA is requested to pay the custom clearance fee and proceed to the required process.

3) **Traffic Restriction Control during Construction Works**

Traffic restriction control shall be applied, if necessary.

4) **Permission of Cutting Trees**

At the installation of hydrological stations (water level/rainfall gauge stations and X-band radar rain gauge stations), if the surrounding trees need to be cut down to avoid the possibility of encountering obstacle to the antenna, solar panel, or rainfall gauge, a required application shall be submitted to CENRO in advance, to get an approval.

5) **Tower Construction Grant (Hight Clearance Permission)**

To install the towers for 7.5 GHz band micro wave radio link in X-band rain gauge stations and CDORFFWC, PAGASA has already requested the said permissions from the Civil Aviation Authority of the Philippines on December 2017.

- CDORFFWC: 60meter
- XR-1: 20meter
- XR-2: 30meter

6) **Installation Permission of X-band Radar**

To abide by applicable regulation(s) that the electromagnetic wave radiated from X-band radar rain gauge station does not affect adversely a human body, PAGASA has already requested the said permissions from the Department of Health and the Food and Drug Administration on December 2017.

7) **Application of Commercial Power Supply**

To secure commercial power supply for the X-band radar rain gauge stations, application documents are needed to be submitted to local power distribution companies (Bukidnon II Electric Cooperative, Inc. and Misamis Oriental II Electric Services Cooperative, Inc.) by PAGASA.

8) **Application of IP-VPN line**

To send hydrological data to HMD and CDO-CDRRMD, IP network link is needed and prepared by PAGASA. In this project, IP-VPN service provided by telecommunication company (e.g., PLDT) is recommended to be used.

9) **Other Required Permissions and Applications**

- Construction permits on the gauging stations and towers from LGUs
- Opening of Bank Arrangement (B/A) and Authorization to Pay (A/P)
- Application of tax exemption for temporary facility and test tools imported by the contractor
- Various tax exemption process related to foreigners (including Japanese) who work for this project

2-4 Project Operation Plan

2-4-1 Organization Structure for O&M

2-4-1-1 PAGASA

(1) PAGASA Maintenance Section/Division

There are three division/sections that are responsible for maintenance of PAGASA telemetry systems and computer network facilities. Each section/division has a responsibility for different facilities; however, recently, one must work in collaboration with each other because of recent development of information and communication technology (ICT) in PAGASA. Among the maintenance divisions/sections, HMTS is responsible for maintenance of FFWS equipment. The Engineering Technical Service Division (ETSD) and ICT Group are both responsible for the maintenance of computer networks in PAGASA.

Table 2-39 PAGASA Maintenance Sections and Responsibilities

Section Name	Responsibilities	Remarks
ETSD	Design and maintenance concerning architecture, electrical, and computer networks	Engineering work
HMTS	Operation and maintenance of hydrological telemetry systems	Trouble-shooting for PRSD
ICT Group	Operation and maintenance of computer networks	The group consists of members dispatched from ETSD and Weather Division.

(2) Number of Technical Staff in O&M Sections

Below table shows the number of technical staff members assigned in each section of O&M.

Table 2-40 Number of Technical Staff（Telecommunication and Computer Network）

	Categories		
	Engineer	Technician	Job Order
ETSD (Computer Network)	3	4	2*
HMTS	3	4	3
ICT Group	1	9 (5+(4)**)	5 (3+(2)**)

Remarks:
(*) Job order means temporary technical staff employed by PAGASA
(**) Technical staff dispatched from ETSD

(3) Responsibilities of O&M Between HMTS and PRSDs

HMTS and PRSDs have three types of maintenance works: daily check, periodical inspection, and emergency inspection or troubleshooting as shown in Table 2-41. HMTS is responsible for maintenance and operation of the Korean International Cooperation Agency (KOICA) and telemetry system of the Greater Metro Manila Area (GMMA) READY Project installed in and near Metro Manila or the National Capital Region as well as for emergency maintenance for some PRSDs. Basically, periodical maintenance, which is supposed to be executed every four months, and daily maintenance are done by PRSDs themselves except for PRFFWC. It must be noted that CDORFFWC has no local personnel assigned for maintenance of telemetry systems and needs manpower urgently. HMTS staff members are engaged in a three shift-duty to cope with 24 hours of service. During the day, in the meantime, work starts at 8:00 a.m. and continues until 5:00 p.m.

Table 2-41 Operation and Maintenance Responsibilities of HMTS and PRSD

	PRFFWC*		Agno river FFWC, Cagayan river FFWC, Bicol river FFWC, CDORFFWC		National Capital Region (KOICA**, GMMA-READY***)	
	HMTS	PRSD	HMTS	PRSD	HMTS	PRSD
Daily Check		✓		✓	✓	
Periodical Check	✓			✓	✓	
Emergency Check	✓		✓		✓	

Remarks:
(*) PRFFWC: HMTS is in-charge of periodical maintenance for PRFFWC.
(**) KOICA Telemetry and Warning System: KOICA telemetry and warning system covers the Tullahan River, Pasig-Marikina River, and San-Juan River, provided not only with rainfall and water level monitoring but with early warning dissemination function.
(***) GMMA-READY Telemetry System: GMMA-READY telemetry system is composed of four rain and water level sub-monitoring systems to cover Bulacan, Rizal, Laguna, and Cavite provinces surrounding Metro Manila.

The number of HMTS staff is ten including job order as shown in Table 2-40. Since the number of staff is only allocated to undertake O&M works for the existing Pampanga, Agno, Bicol, and Cagayan River FFWS, the current number of staff could not conduct O&M works for the FFWS in the Cagayan de Oro River basin and other river basins.

It is needed to establish a new staff organization for the O&M works for FFWS in the Cagayan de Oro River basin and other river basins soon, which does not depend on the current HTMS staff. Judging from the numbers and skills of staffs, it is obvious that the current HTMS staffs are quite short in terms of O&M works in the new FFWS system by the reasons as stated in Sub-clause 4-1-1-1 (Twin Phoenix FFWS at CDORFFWC).

A required number of staff for the O&M works, depending on the established levels of the telemetry system, are summarized in Table 2-42. As the current established level at the Cagayan de Oro River basin is categorized as Stage 1, after completion of the new FFWS under the project, it will be shifted to Stage 2. It means that three or four staff for the O&M works for the telemetry system are need. Because the Stage 2 is applied for rainfall and water level are measured automatically, additional staffs of two personnel are required for maintenance of network and power supply equipment compared Stage 1.

In addition to the above, since the X-band radar rain gauge is provided under the “Project”, a new dedicated (fulltime) staff for the O&M works of the said equipment is needed because another technology and skills are required for proper operation and O&M works. It concludes that at least four O&M staffs are essential at CDORFFWC as shown in Table 2-42.

Table 2-42 Required Number of Staff for the O&M Works at the Established Levels

The Established Levels	Stage 1	Stage 2	Stage 3
	Required Number of Staff		
O&M works for the telemetry system	1 person	3 personnel	4 personnel
O&M works for the X-band radar rain gauge	-	1 person	1 person
Total	1 person	4 personnel	5 personnel

Remarks

Explanations of the established levels of the telemetry system

Stage	Established Level
Stage 1	· Rainfall and water level are measured manually (semi-automatic) · Measured data are stored at a PC or an equipment ledger (paper) · No sharing of the measured date by real-time
Stage 2	· Rainfall and water level are measured automatically. · Sharing of the measured date by real-time can be achieved. · No utilization of the data for flood forecasting model.
Stage 3	· In addition to the rainfall/water level telemetry data, using a spectrum data thru remote sensing technology, visual inspection with CCTV and utilization of such data for the flood forecasting model can be undertaken. · Likewise, analysis using the database system can be conducted.

PAGASA explained thru Detailed Outline Design (DOD) discussion that the deployment plan of staff at MPRSD as shown in Table 2-43 is disclosed by PAGASA.

The plan shows five personnel of staff number at 2020 when the FFWS is completed and Table 2-42 shows four personnel totally at Stage 2. Therefore, required number of staff for the O&M works is satisfied by the plan of PAGASA. But there is difference of professional occupation between Table 2-42 and Table 2-43, the staff will be able to maintain through operation guidance and soft component.

Table 2-43 Deployment Plan of Staff for the O&M Works by PAGASA

Specialist	Current as 2017 Year	Second Quarter in 2018	2019	2020
Hydrologist	2 personnel	2 personnel	2 personnel	3 personnel
Telecommunications	0	1 person	2 personnel	2 personnel
Total	2 personnel	3 personnel	4 personnel	5 personnel

Source PAGASA

2-4-1-2 CDO-CDRRMD

(1) Role of CDO-CDRRMD

The CDO-CDRRMD is the headquarters for the disaster prevention organization, issues the evacuation warnings at the time of hazard such as floods, and protects residents' safety.

Note that the former name is the City Disaster Risk Reduction and Management Office (CDRRMO), which was renamed to CDRRMD (Department) due to organizational change at the end of 2016.

(2) Classification of alarms and their criteria

According to the evacuation drill materials of CDO-CDRRMD, yellow (flooding precaution), orange (flooding warning), and red (flood risk), based on the river water levels and rainfall information of a specific part monitored by NDMI system and weather information received from PAGASA, are classified to issue three kinds of alarms. The criteria are shown in Table 2-44. CDO-CDRRMD can able to collect water level and rainfall from NDMI system. Also forecasts of rainfall precipitation, public storm warning signal, and weather condition are made available from PAGASA.

Table 2-44 Alert Criteria Table in CDO-CDRRMD

Item	Point	Yellow	Orange	Red
Water Level	San Simon	N/A	3.5m	4.5m
	Pontod	N/A	4m	5m
	Kagay-an brdg	N/A	4m	5m
	Taguanao	15.23m	17.92m	20.47m
	Bubunawan	N/A	48m *	49m **
	Cabula	N/A	48m	49m
	Mambuaya	108.58m	109.63m	110.73m
	Tumalaong	110.69m	111.14m	111.58m
	Basik	457.61m	459.45m	460.93m
Rainfall Level	Observed rainfall	Continuous 2.5-7.5mm/h rain in Cagayan de Oro	Continuous 2.5-7.5mm/h rain in Talakag, Baungon, and Libona	>30mm/h rain for 1 hour
	Expected rainfall	Expected 7.5-15mm/h for the next 2 hours	N/A	Expected 2.5-7.5mm/h for next 2 hours in Talakag, Baungon, and Libona
Condition		Public Storm Warning Signal No.1 in CDO or Presence of Low Pressure Area with more than one week rain	N/A	N/A

Source: Evacuation drill materials of CDO-CDRRMD

Remarks
(*): (Actual level -5) x 30% + Cabula level > 48m
(**): (Actual level -5) x 30% + Cabula level > 49m

(3) Communication Flow Path from CDO-CDRRMD

When CDO-CDRRMD issues an alarm, the information is to be transmitted to city residents and neighboring municipalities (municipals), the communication flow path is as shown in Figure 2-27.

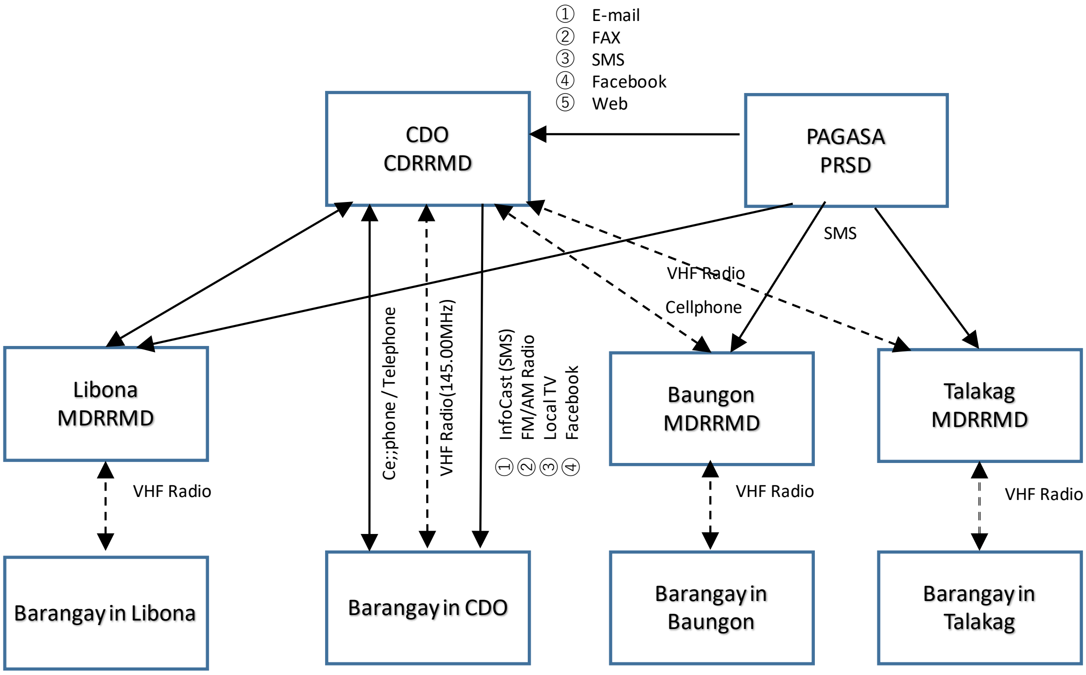


Figure 2-27 Communication flow path from CDO-CDRRMD

Remarks
(*)MDRRMD: Municipal Disaster Risk Reduction and Management Department

1) **Communication method**

Cagayan de Oro City and the neighboring municipalities (municipals) use the VHF band radio as a means of communicating within the area. Different frequencies are allocated to each municipality, but if you need to communicate with different municipalities, it will be informed on the frequency of the other side. For SMS transmission, they are using broadcasting system called InfoCast provided by Smart Telecommunications (communication operator/carrier). Up to 30,000 messages per month can be transmitted free of charge on this system. SMS destinations include barangay captains, school teachers, civil service organization, fire department, and volunteers called Spotters. Furthermore, CDO-CDRRMD uses Facebook to distribute information. The transmission of information to the residents within the barangay is done through megaphone publicity called RECORRIDA.

2) **Communication flow path**

CDO-CDRRMD distributes not only emergency alarms such as flood warnings but also road traffic information, etc., but it is also transmitted according to the flowchart above. PAGASA PRSD always communicate to Libona MDRRMD via to CDO-CDRRMD because it is decided by related organization.

(4) Issues on Warning Dissemination and Suggestions

- Since the facsimile machine is broken at CDO-CDRRMD, e-mail is currently being used instead. It is important to confirm with the recipient that the warning message was received without fail. There may be cases that the recipient is unaware that incoming e-mails have been unattended for a while. It is necessary to have protocols between the government offices so that such messages are received without fail. The following are suggested:

  ✓ Message sender must notify the recipient that a message has been sent to him/her by using alternative communication tools such as cellphone.

- ✓ The recipient must return a confirm receipt of emails to the sender.
- ✓ SMS is one way-communication and should be regarded as a supportive tool.
- ✓ The sender as well as the recipient must record logging of their message exchanges.
- ✓ The procedures must be documented so that every staff member can follow the same way.
- ✓ SMS message transferred and re-texted from e-mail message must be double checked by others before transmitting to avoid mistakes in the message.

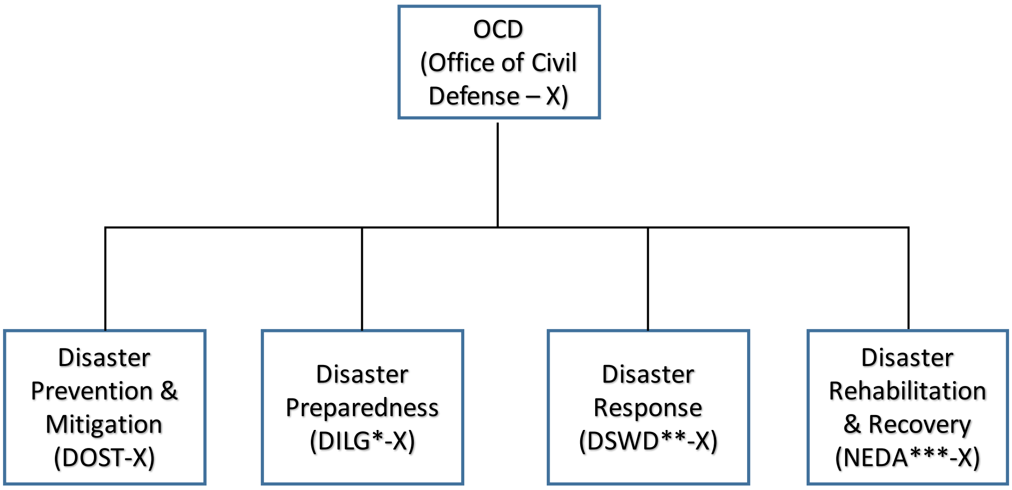
- The most crucial part in dissemination of warning messages is that such messages should reach the local residents without fail. Therefore, it is suggested that more than two methods of communication tools should be employed, i.e., landline telephone and SMS or cellphone and e-mail, etc. This will help improve communication delay due to traffic congestion.
- Names of important contact persons should be posted on the office wall visible to every staff member to notice and be reminded anytime. The information posted must be updated periodically.
- Currently, Social Networking Service (SNS) such as Facebook is often used for broadcasting information. However, it should be reminded that this tool like conventional TV and radio is one-way communication, not possible to confirm that information has been reached to the intended recipients. There may be one suggestion that contents of information to dispatch through SNS should be selected beforehand and stick to the same format.
- Warning messages should be as plain and simple as possible with minimum use of technical terms and expressions. Such messages to the residents should be in local dialect as much as possible.

2-4-1-3 Office of Civil Defense (OCD) Region X

The north of Mindanao is administratively part of the province of Misamis Oriental and Cagayan de Oro is the capital of the province. OCD Region X, the regional office under the national government, is an enforcing organization that controls the evacuation information and disaster recovery. The office is staffed with one person during normal working days and multiple personnel will be assigned and stand-by for emergency on a 24-hour duty.

(1) Role of Council under OCD

The Regional Disaster Risk Reduction and Management Council – Region X is organized in Figure 2-28.



Remarks (*)DILG: Department of Interior and Local Government
(**)DSWD: Department of Social Welfare and Development
(***)NEDA: National Economic and Development Agency

Figure 2-28 Role of Regional Disaster Risk Reduction and Management Council

(2) Information Flow during Disaster

Weather information received from PAGASA is transferred to the Provincial Disaster Risk Reduction Management Council (PDRRMC), City Disaster Risk Reduction Management Council (CDRRMC), and MDRRMC under Region X as shown in Figure 2-29. Landlines such as fax machine and SMS were not disrupted during the disastrous Tropical Storm "Sendong". Five sets of radios and two satellite phones were deployed.

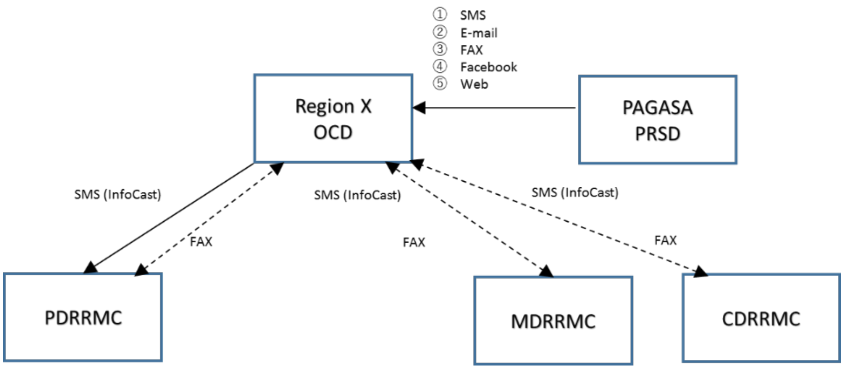


Figure 2-29 Information Flow from Region X OCD

(3) Issues on Warning Dissemination and Suggestions

Basically, the same procedures and protocols as CDO-CDRRMD should be followed by OCD. Facsimile machine is a principal tool of message dissemination to the concerned local government agencies such as PDRRMC and MDRRMC. CDORFFWC also sends flood warning messages to Cagayan de Oro by facsimile. It is important to use other alternative communication tools simultaneously such as cellphone for confirmation of the receipt of the message. Generally, facsimile has advantages compared with other communication tools in terms of paper record and visual confirmation of message contents. However, there are cases that no recipient is ready to receive it during off-duty office hours. There must be inter-agency protocol that some staff should be on duty 24 hours during emergency period. The recipients of facsimile message see to it that confirmation of receipt be returned to the sender.

2-4-2 Required Skill Level and Resource Plan for O&M

(1) Skill Level

To continuously operate and maintain the FFWS to be installed in this project, the following maintenance activities are required:

- Daily check
- Periodic check
- Emergency check or Repair Works

For long-term effective checking and inspection, the management of test result, repair plan, and procurement of maintenance/spare parts and tools are indispensable.

To achieve the above objectives of maintenance, the maintenance staff to be deployed should participate beforehand in the lecture of the initial operation guidance given by the contractor and are subsequently supposed to conduct the maintenance works based on the acquired skill and knowledge. The maintenance of X-band radar rain gauge is more complicated than conventional telemetry equipment. The maintenance staff engaged in radar operation, test and adjustment should have a higher level of technical skill and knowledge.

(2) Resource Plan for O&M

As described in 2-4-1-1(3), PRSD is responsible for daily and periodic checks, while HMTS is for emergency check. However, currently no human resource is assigned for system maintenance. Considering these situations, required human resources for O&M is estimated as shown in Table 2-45.

Table 2-45 Required O&M Organization

Job role	Required resource	Remark
Daily Check Periodic Check	4 personnel（PRSD）	3 persons for telemetry equipment 1 person for X-band radar rain gauge
Emergency Check	2 personnel（HMTS）	As this job do not belong exclusively for CDO, this cost is not including to project cost.

2-5 Project Cost Estimation

2-5-1 Initial Cost Estimation

Based on the demarcation between the Japanese government and the Philippine government, the estimated cost for the project is divided as shown in 2-5-1-1 and 2-5-1-2, respectively.

2-5-1-1 Cost Allocation to the Japanese Government

This section is not disclosed due to confidentiality.

2-5-1-2 Cost Allocation to the Philippines Government

Table 2-46 Cost Allocation to the Philippines Government

Work Item	Cost (Unit: PHP)	Cost (Unit: JPY)
VAT Reimburse Budget	20,303,284.00	48,524,849
Construction Cost of CDORFFWC Building	7,938,630.13	18,973,326
Land Acquisition Cost	80,000.00	191,200
Fees for B/A and A/P	1,366,181.00	3,265,172
Total	29,688,095.13	70,954,547

2-5-1-3 Assumption for Cost Estimation

- Costing Date: June, 2017
- Foreign Exchange Rate used for Costing
- PHP 1 ＝ JPY 2.39
- USD 1 ＝ JPY 112.84
  Note: Average rate from 1 Mar to 31 May 2017
- Construction Period: Described in 2-2-4-9
- Other Condition: This project is implemented in accordance with the Guideline for Grant Aid Cooperation Scheme

2-5-2 Operation and Maintenance Cost

The JICA Study Team estimates that the O&M cost in 2021 (after completion of the Project) is categorized to the items in Table 2-47.

Table 2-47 O&M Cost

Item	Annual Administrative and Maintenance Expense		Remark
	In Philippine Peso	In Japanese Yen	
Human resource cost	2,184,000	5,219,760	Seven staffs: Telecommunication specialist (4), Hydrologist specialist (3)
Electricity expense	1,960,000	4,684,400	For X-band radar sites and CDORFFWC
Fuel expense	428,000	1,022,920	Fuel cost for the diesel engine generator
Transportation expense	105,000	250,950	Gasoline
Communication expense	892,000	2,131,880	Internet connection cost
Land tenancy cost	50,000	119,500	For X-band radar site
Spare parts cost*	531,000	1,268,000	
Supplies expenses**	302,000	721,230	Spare for Generator, inks for printer and lightning arrester
Total	6,452,000	15,418,640	

Remarks (*)Spare parts costs will be required not on a yearly base but on a five year-base. Based on the past experience in the Pampanga / Agno FFWS, amount of the repairing cost for the Telemetry equipment, Telemetry repeater equipment, Water level sensor and UPS at five year-base is estimated as 6.34 million Japanese Yen, and this cost is converted to one year base.

(**)Supplies expenses will be needed a five year-base for Spare for Generator, ten year-base for lightning arrester and one year-base for inks. The cost shown in this table is calculated with yearly cost from the five year-base, ten year-base and one year-base.

The O&M cost above is calculated using the following conditions:

- As shown in the Table 2-40 (Deployment Plan of Staff for the O&M Works by PAGASA), PAGASA understands that two Telecommunications Engineers are need in total, but JICA Study Team understand that four Telecommunications Engineers and three Hydrologists are required for the O&M Works, so Human resource cost is estimated as seven personnel in total and belong to CDORFFWC.

The O&M cost as shown in Table 2-47 is only 6.3% against the overall yearly budget (Php102,152,00 = 244,143,000 Japanese Yen) for MPRSD in Table 2-49 and HMD in Table 2-48, which is not a big burden.

Table 2-48 HMD Actual Expenses / Budget for Maintenance and Other Operating Expenses

Particulars	2014 (Actual Expenses)	2015 (Actual Expenses)	2016 (Actual Expenses)	2017 (Budget)
Personnel Services	15,518	14,158	14,068	14,992
Travel Expenses	1,658	2,371	2,584	2,677
Training and Seminar	170	553	516	586
Supplies and Materials	2,750	3,763	3,827	9,358
Gasoline	276	453	49	684
Water / Electric	6,688	5,699	6,944	6,936
Communication Expenses	1,578	1,218	1,973	1,752
General Services (Janitorial / Security)	4,318	4,133	4,135	4,636
Repair / Maint. Of Gov't Facilities	4,186	1,802	5,637	4,501
Repair / Maint. Of Gov't Vehicles	176	507	813	2,858
Taxes, Insurance / Other Fees	247	419	452	623
Transportation and Delivery	12	149	26	362
Rents	333	295	122	512
Other Services	1,268	1,689	5,681	767
Total	**39,178**	**37,209**	**46,827**	**51,244**

Source: PAGASA

Table 2-49 MPRSD Actual Expenses / Budget for Maintenance and Other Operating Expenses

Particulars	2014 (Actual Expenses)	2015 (Actual Expenses)	2016 (Actual Expenses)	2017 (Budget)
Travel Expenses	1,210	1,577	1,676	1,241
Training and Seminar	584	665	486	624
Supplies and Materials	9,467	16,556	20,252	23,172
Gasoline	850	378	737	1,299
Water / Electric	1,498	2,817	2,904	2,601
Communication Expenses	2,521	4,319	2,421	5,834
Other Professional	865	1,931	3,892	1,997
General Services (Janitorial / Security)	0	586	605	259
Repair / Maint. Of Gov't Facilities	1,556	2,368	3,297	10,801
Repair / Maint. Of Gov't Vehicles	84	239	236	807
Taxes, Insurance / Other Fees	104	2,005	1,319	1,921
Transportation and Delivery	0	299	23	74
Rents	5	16	6	137
Other Services	136	427	625	141
Total	**18,880**	**34,183**	**38,479**	**50,908**

Source: PAGASA

PAGASA has assumed the required O&M cost in 2021 as shown Table 2-50 and outline are summarized below.

- Total 6 engineers reducing one telecommunications engineer from the JICA Study Team plan for the O&M works are deployed at CDORFFWC (one telecommunications engineer for the O&M works of X-band radar rain gauge is include in the particular O&M contract)

The particular O&M contract for the X-band radar rain gauge with supply of the said equipment

The budget for PAGASA has increased year by year due to the PAGASA modernization scheme and more budget will be allocated accordingly.

Table 2-50 O&M Cost-including O&M contract for the X-band radar rain gauge

Item	Annual Administrative and Maintenance Expense		Remark
	In Philippine Peso	In Japanese Yen	
Human resource cost	1,872,000	4,474,080	Six staffs: Telecommunication specialist (3), Hydrologist specialist (3)
Electricity expense	1,960,000	4,684,400	For X-band radar sites and CDORFFWC
Fuel expense	428,000	1,022,920	Fuel cost for diesel engine generator
Transportation expense	105,000	250,950	Gasoline
Communication expense	892,000	2,131,880	Internet connection cost
Land tenancy cost	50,000	119,500	For X-band radar site
Spare parts cost*	531,000	1,268,000	
Supplies expenses**	302,000	721,230	Spare for Generator, inks for printer and lightning arrester
Particular O&M contract for the X-band radar rain gauge (2)	11,427,000	27,310,530	It is estimated from the current the O&M maintenance contract with the supplier of the S-band radar facility
Total	15,695,000	37,509,410	

Remarks (*)Spare parts costs will be required not on a yearly base but on a five year-base. Based on the past experience in the Pampanga / Agno FFWS, amount of the repairing cost for the Telemetry equipment, Telemetry repeater equipment, Water level sensor and UPS at five year-base is estimated as 6.34 million Japanese Yen, and this cost is converted to one year base.

(**)Supplies expenses will be needed a five year-base for Spare for Generator, ten year-base for lightning arrester and one year-base for inks. The cost shown in this table is calculated with yearly cost from the five year-base, ten year-base and one year-base.

It is calculated that the grand total amount is 15.4% against the combined yearly budget for MPRSD (refer to the Table 2-49) and HMD (refer to Table 2-48), which is a big burden to PAGASA. Therefore, JICA Study Team has recommended the plan of Table 2-47 because the expense can be saved compared cost of Table 2-50.

Chapter 3. Project Evaluation

Chaper 3. Project Evaluation

3-1 Preconditions

As stated in 2-3, the following shall be conducted by the Philippine side (recipient country) in a timely manner:

- Budget allocation for VAT
- Construction of new building for CDORFFWC
- Fees related to the usage of the lands and access
- Commissioning fess for authorization pay

If new building for CDORFFWC construction is delayed one year or more, new equipment shall be installed as temporally at the existing MPRSD building, in this case, additional cost will be required.

If construction permit from the LGUs cannot be obtained on time schedule, overall construction will be delayed accordingly, target acquiring permission shall be specified in the Bidding Documents to avoid such delay.

3-2 Necessary Inputs by Recipient Country

The main objective under the Project is the improvement of capability related to the FFWS activity. Proper and continuous operation of FFWS is essential factor. Necessary inputs by the Philippine side are conduct of the O&M works as summarized below.

- Periodic regular maintenance to prevent system shutdown
- Quick repairing works and proper remedy works in accordance with the O&M manual
- Budget allocation for the O&M works
- Management and monitoring of such activities

3-3 Important Assumptions

Important assumptions for the implementation of the Project are defined as preconditions below.

- No change of policies for the natural disaster risk reduction activities in the Philippines;
- Corporations between PAGASA and DRR organizations such as CDO-CDRRMD, OCD, DPWH, etc., shall be maintained; and
- Establishment of the O&M works on the FFWS providing the required budget and numbers of staff, the continuous utilization of the FFWS, and shall be updated as necessary.

3-4 Project Evaluation

3-4-1 Relevance

The Project consists of the telemetry system for observation of rainfall and water level in the river, X-band radar rainfall equipment, data transmission, processing and display of the rainfall and water level observed. The main objective of this project is the reduction of casualty and loss in the Cagayan de Oro River basin, and comply with the following:

- Philippine Development Plan 2017-2022
- Japanese ODA Policies on the Disaster Risk Reduction (DRR)
- Supporting policies on DRR by JICA

Support the implementation of the project under JICA Grant Aid is judged as relevant due to conformity with the Japanese government policies for Japanese ODA policies on DRR and effective and high priority supporting the Philippines.

3-4-2 Effectiveness

Effectiveness of the project is summarized below and benchmarks and achievements are shown in Table 3-1.

- Improvement of the missing rate of telemetry data
- Improvement of accuracy of rainfall data with the X-band radar
- Improvement of collecting time of telemetry data
- Improvement of required time for issue of evacuation information

Table 3-1 Benchmarks and Improvement Results under the Project

Benchmark		Current Situation *	Achievements ** [After three years from completion of the Project]
Hydrological observation density	Mesh size for rainfall observation (size of the catchment area / number of rain gauges, or spatial resolution of radar rain gauge) (km^2)	105 km^2 (=Catchment Area 1,364 km^2/ 13 Existing Rain gauge)	0.022 km^2 It can be monitored with 150 m x150m =0.022 km^2 mesh
	The number of water level gauges	8	15
Missing rate of telemetry data		84.2 % ***	within 5%

Remarks

(*) This data is based on the current performances of Twin Phoenix, NDMI and ASTI telemetry systems.

(**) Achievements are benchmark, which shall be established under the Project.

(***) Operational conditions are shown below:

Twin Phoenix telemetry system	Data Missing Rate
Rainfall gauge stations: 3/6 (operational/ non- operational)	Less than 5%
Water level gauge stations: 0/4 (operational/ non- operational)	100% (no operation)
NDMI telemetry system	
Rainfall gauge stations: 0/5 (operational/ non- operational)	100% (no operation)
Water level gauge stations: 0/4 (operational/ non- operational)	100% (no operation)
Calculations: Non-operational gauge stations is divided by all gauge stations= (3+5+4+4) / 6+5+4+4)=16/19=84.2%	

Qualitative effects are described as follows:

- Lives of residents in the river basin will be saved by the appropriate flood forecasting and warning
- Sharing real time hydrological data observation both PAGASA and Cagayan de Oro City Disaster Risk Reduction and Management Office helps Efficient disaster response system
- Stable data transmission will be enhanced by dedicated communication network
- Flood forecasting particularly urban flooding by PAGASA will be improved by increasing the density of rainfall observations