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CHAPTER 1
BASELINE CONDITIONS

Introduction

The Cagayan de Oro City Water District (COWD) is a Government – Owned and Controlled Corporation created by virtue of the Presidential Decree No. 198 or otherwise known as the "Provincial Water Utilities Act of 1973." The said Decree declared a national policy favoring local operation and control of water systems thereby authorizing the formation of local water districts in the Philippines. Soon after the Decree was signed, the COWD was created as the first Water District in the country on 01 August 1973.

True to its mandate, the District envisions "to be an outstanding Water District in the country" while it carries the mission "to provide excellent water service to the community we serve." A fast growing government corporation of more than 400 workforce, the District operates embracing the core values of accountability, being result-driven, teamwork and faith in One Almighty. These vision, mission and core values serve as COWD's guide and lead in all opportunities to plan and program for the delivery of best service to the public.

One of the thrusts of the COWD is water security, which can only be addressed through a holistic, integrated planning approach, that is, taking both internal and external environmental factors at all times. The major strategies would include NRW Reduction Program, Climate Change Resiliency and Wastewater and Septage Management. Thus, this vulnerability assessment of the COWD plays a very important part in performing its mandate to ensure availability of potable water for the public of today's and the future's generation. Through this vulnerability assessment, COWD shall be able to optimize use of limited resources through more scientific and more intelligent planning. This exercise shall help ensure the resiliency of the facilities, in general, in order to continue providing water services during and soonest after any calamity.

Service Area

Generally, the service area of the COWD covers the entire of the City of Cagayan de Oro that comprises 80 barangays: 40 urban and another 40 classified as rural barangays. Being the largest city in Northern Mindanao, ithas a total land area of about57,000 hectares with a population of more than 600,000 in 2010. As such, the City was ranked as 10th most populous city in the Philippines in 2010 (Wikipedia).The Macajalar Bay in the north, Bukidnon in south, Tagoloan in the east and Opol in the west, bound Cagayan de Oro. The topography of the City is characterized by a narrow plain along the Macajalar Bay and by the highlands separated by steep inclined escarpment in the south expanding from east to west. The lowlands are relatively flat with elevation not exceeding 10 meters above the mean sea level while the highlands consist of plateaus, terraces and gorges. Only 28% of the City's total land area has slope between 0 and 8 percent while the rest of 72% is sloping higher than 8%, posing greater challenge to development.

The terrain and topography of Cagayan de Oro allows all seven rivers and six major creeks to drain to the Macajalar Bay. These rivers are the Cagayan de Oro River,Iponan, Alae, Agusan, Gusa, Cugman and the BigaanRiver. On the other hand, the most notable creeks are the Binono-an creek, Bitan-ag, Induiong, Kolambog, Sapong and Umalag creek. The headwaters of these rivers are from the adjacent province of Bukidnon. For instance, the Cagayan de Oro River, which serves as the natural boundary between Bukidnon and Cagayan de Oro, has its headwaters in the Kalatungan Mountain Range. This traverses 3 more municipalities in the Bukidnon province, namely: Talakag, Baungon and Libona. This suggests that more tributaries along the way are draining into the Cagayan River and down to the Macajalar Bay passing through the major parts of Cagayan de Oro at the lowlands.

Presently, the District has extended services to 64 barangays or 80% of the total 80 barangays within Cagayan de Oro and eight (8) coastal barangays of Opol. Opol is a municipality of the province of Misamis Oriental located adjacent and west of Cagayan de Oro. In terms of land area, served area covers a little more than 40% while in terms of population, served population equates to more than 80%. The barangays that remained unserved up to present are those that are located in the hinterlands up to more than 35 kilometers from the City proper and altitude of more than 400 meters. Table 1 summarizes the service area of COWD as of 2015 while Table 2 lists the name of barangays served with corresponding population as of 2010. Figure 1 shows a map of Cagayan de Oro indicating the relative locations of the barangays.

Table 1
Summary of COWD Service Area
(ExcludingOpol)

PARTICULAR	TOTAL	SERVED	UNSERVED
LAND AREA (has)	56,967	23,597	33,369
% to TOTAL	100%	41%	59%
NO. of BRGYS	80	64	16
% to TOTAL	100%	80%	20%
POPULATION (est)	602,422	560,783	41,305
% to TOTAL	100%	93%	7%

Source: cagayandeoro.gov.ph

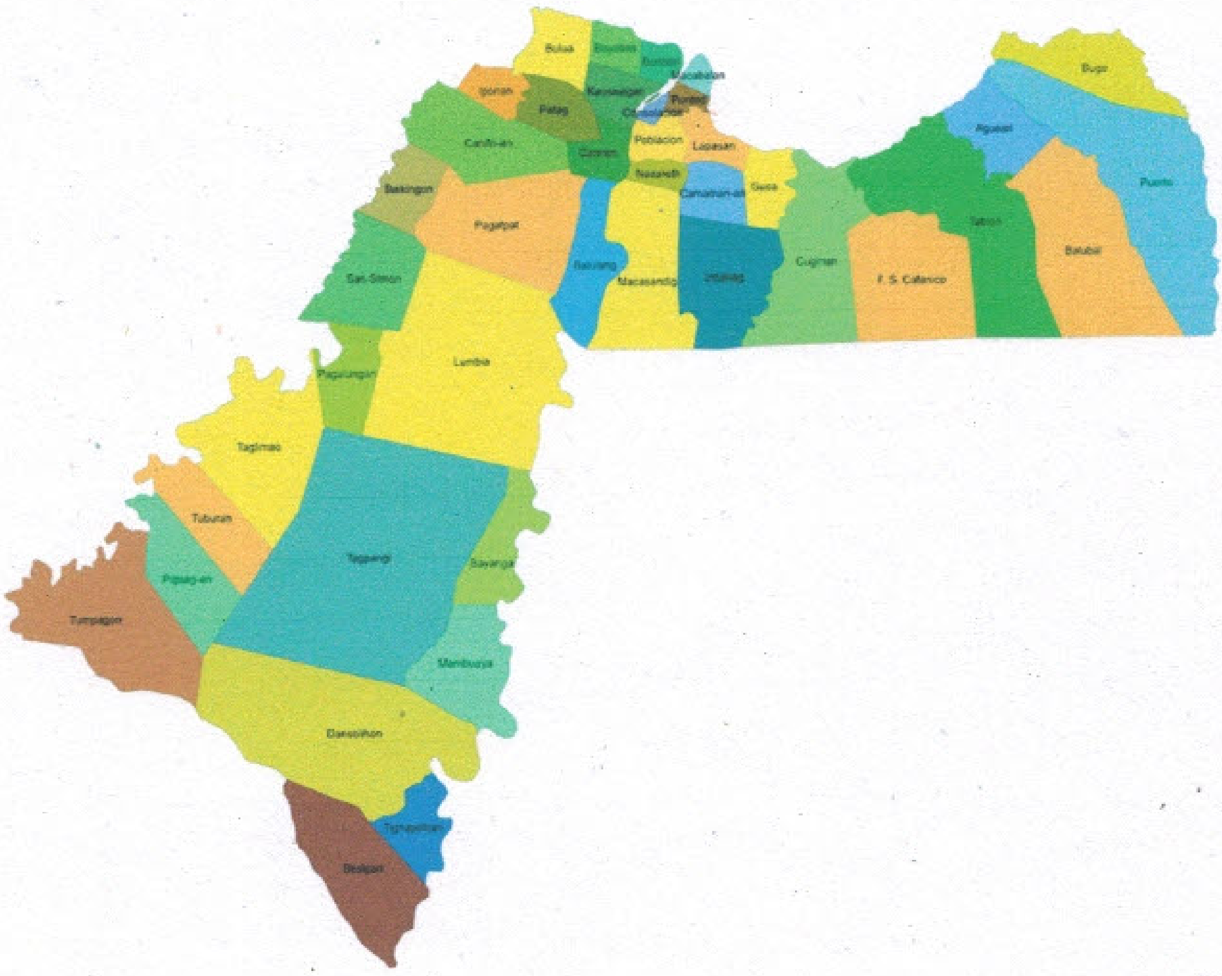


Figure 1
Relative Locations of Barangays

Table 2

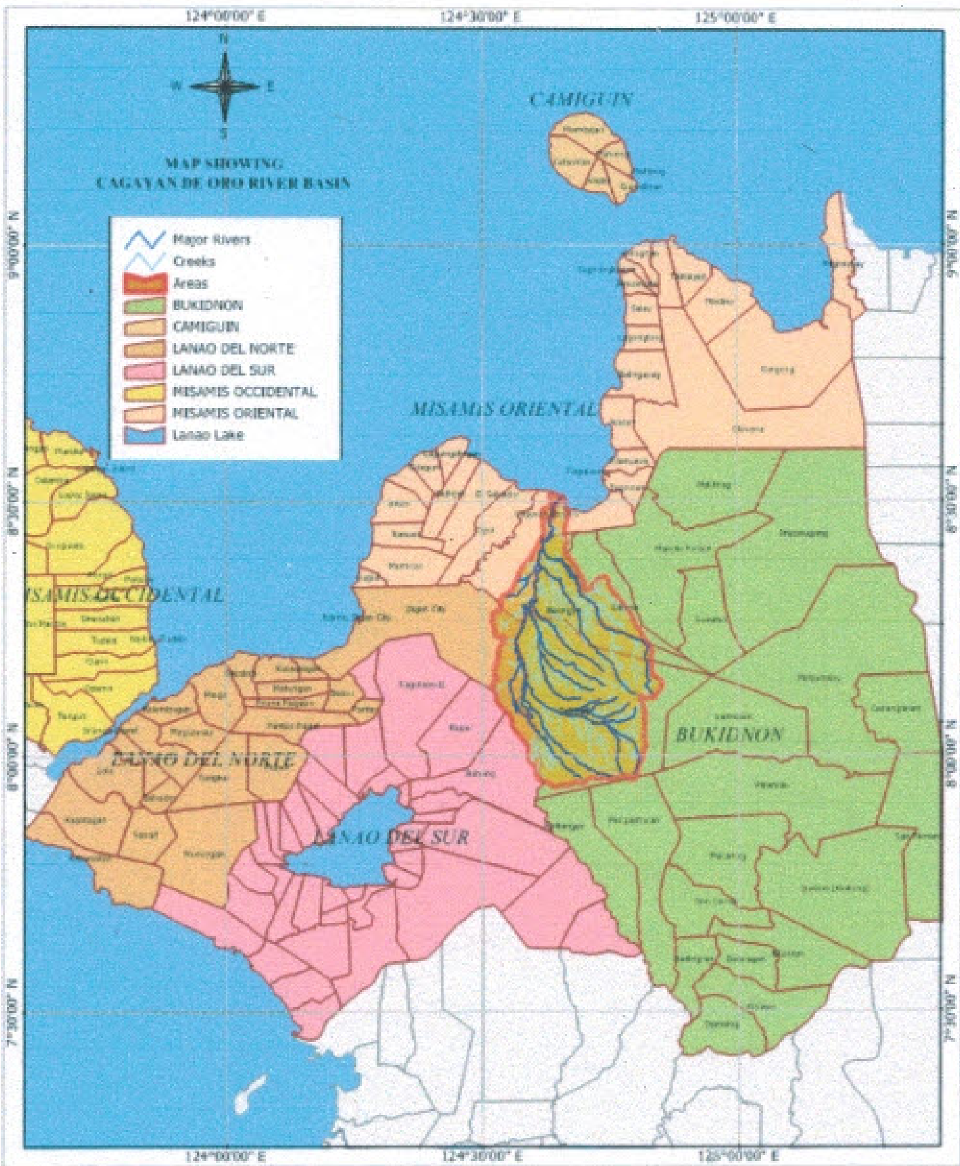
List of Barangays and Population

Table 3 List of Barangays and Population					
NO.	NAME	POPULATION	NO.	NAME	POPULATION
1	Barangay 39	46	48	Agusan	14,812
2	Barangay 37	77	49	Canitoan	15,069
3	Barangay 05	83	50	Patag	17,219
4	Barangay 02	84	51	Puntod	18,399
5	Barangay 33	86	52	Tablon	18,608
6	Barangay 38	94	53	Macabalan	20,303
7	Barangay 04	108	54	Cugman	20,531
8	Barangay 20	121	55	Iponan	20,707
9	Barangay 09	132	56	Macasandig	23,310
10	Barangay 16	143	57	Camaman-an	24,651
11	Barangay 08	157	58	Gusa	26,117
12	Barangay 03	177	59	Bugo	27,122
13	Barangay 06	212	60	Bulua	31,345
14	Barangay 21	254	61	Balulang	32,531
15	Barangay 11	342	62	Kauswagan	34,541
16	Barangay 19	419	63	Lapasan	41,903
17	Barangay 01	453	64	Carmen	67,583
18	Barangay 12	469	***SUB-TOTAL***		***560,783***
19	Barangay 14	479	**UNSERVED BARANGAYS**		
20	Barangay 29	485	65	Pigsag-an	1,256
21	Barangay 28	541	66	San Simon	1,346
22	Barangay 07	542	67	Tuburan	1,395
23	Barangay 10	616	68	Besigan	1,404
24	Barangay 34	621	69	Taglimao	1,418
25	Barangay 36	791	70	F.S. Catanico	1,710
26	Barangay 40	830	71	Pagalungan	1,806
27	Barangay 30	875	72	Tumpagon	2,232
28	Barangay 23	916	73	Baikingon	2,342
29	Barangay 24	929	74	Mambuaya	2,490
30	Barangay 25	1,295	75	Tagpangi	2,684
31	Barangay 27	1,380	76	Bayanga	2,769
32	Barangay 32	1,410	77	Balubal	2,893
33	Barangay 18	1,496	78	Tignapoloan	4,514
34	Barangay 31	1,506	79	Dansolihon	4,811
35	Barangay 22	1,944	80	Indahag	6,235
36	Barangay 13	2,330	***SUB-TOTAL***		***41,305***
37	Barangay 17	2,342	**SERVED BARANGAYS IN OPOL**		
38	Barangay 26	2,383	81	Barra	14,334
39	Barangay 35	2,395	82	Bonbon	2,698
40	Barangay 15	2,966	83	Igpit	10,123
41	Pagatpat	5,178	84	Luyong Bonbon	3,491
42	Bonbon	9,195	85	Malanang	3,593
43	Consolacion	9,919	86	Molugan	9,575
44	Nazareth	10,658	87	Poblacion	3,690
45	Puerto	11,475	88	Taboc	2,918
46	Bayabas	12,999	***SUB-TOTAL***		***50,422***
47	Lumbia	14,079	**OVERALL TOTAL**		**652,510**

SOURCE: https://psa.gov.ph/content/2010-population-cagayan-de-oro-city-larger-140-thousand-compared-its-2000-population-results

The Cagayan de Oro River Basin

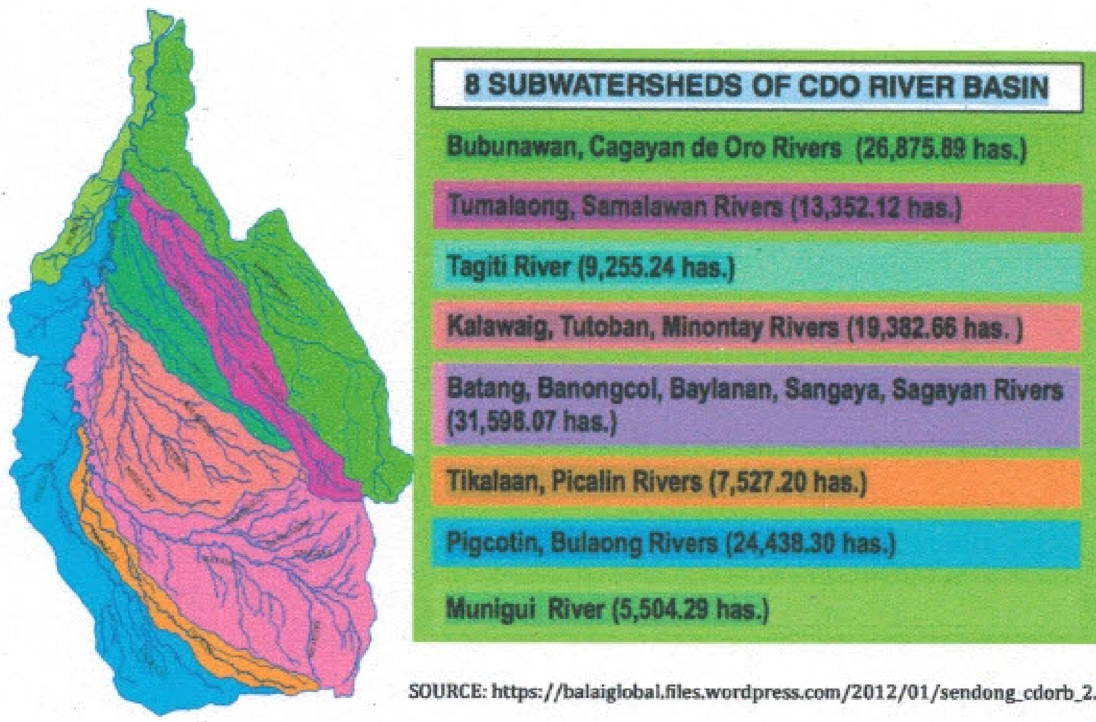
The existing rivers and creeks that connect to the Cagayan de Oro River and discharge into the Macajalar Bay are called the Cagayan de Oro River Basin. The said basin occupies a total land area of about 137,934 hectares. Figure 2 shows the Location Map of the Cagayan de Oro River Basin and Figure 3 depicts the Drainage System of the Basin.



OURCE: https://balaiglobal.files.wordpress.com/2012/01/sendong_cdorb_2.pdf

Figure 2
Location Map of the Cagayan de Oro River Basin

The entire Cagayan de Oro Basin comprises 8 major rivers or subwatershedstraversing 5 municipalities and 2 cities: Talakag, Baungon, Libona, Pangantucan (from Bukidnon);Iligan City (of Lanao del Norte); Bubong (of Lanao del Sur; and Cagayan de Oro City. These 8 subwatersheds are the following: Bubunawan, Cagayan de Oro Rivers; Tumalaong, Samalawan Rivers; Tagiti River; Lalawaig, Tutoban, Minontay Rivers; Batang, Banongcol, Baylanan, Sangaya, Sagayan Rivers; Tikalaan, Picalin Rivers; Pigcotin, Bulaong Rivers; and Munigui River. Figure 4 shows the locations of these subwatersheds.



SOURCE: https://balaiglobal.files.wordpress.com/2012/01/sendong_cdorb_2.pdf

Figure 3
Location of Subwatersheds of the Cagayan de Oro River Basin

Climate-Related Disruptions in the Cagayan de Oro River Basin

Historical records would reveal that large floods in the Basin happened in 1916, 1957, 1982, 1998 and 2009, 2011 and 2012. The floods in 1916 and 1957 were only mentioned in the accounts of historians and news reports. Information as to quantitative intensity of rainfall could not be ascertained. Table 3 summarizes the destructive typhoons that frequented the Basin while Appendix 1 presents the details of these past disruptions.

Table 3
Summary of Climate Disruptions in the Cagayan de Oro Basin

Year	Month	max 1-day rainfall (mm/day)	Additional Information	Affected Families/Person in CDO	Estimated Damage Million PhP
1916	?	n/a	n/a	n/a	n/a
1957	January	n/a	Storm 01W	n/a	n/a
1982	March	84.2	Tropical Akang	38,020/212,564	14.9
1998	August	129.3	Heavy Rain and colf front	2,762/12,467	653
2009	November	237.1	Tropical Depression Urduja	34,959/174,839	n/a
2011	December	180.9	TS Sendong	>60,000	9614
2012	December	78.1	TY Pablo	33,027/9089	18.5

It appears that the precipitation intensity does not necessarily translate always to more damage and more number of affected families and individuals. In addition, it would seem that flooding had become more frequent in the past 6 years, which happened three times within this period, with 2 years in succession, 2011 and 2012. Compared to the events that happened within the last 30 years or so, flooding was less frequent at intervals of more than 10 years. In fact, the flood that occurred in the Basin in 1957 came 41 years after1916, followed after 25 years in 1982, then 16 years after in 1998, then a little closer after 11 years in 2009.

As further shown in Appendix 1, the most disastrous climate event that happened in Cagayan de Oro in the last 3 decades was that one brought by typhoon Washi in 2011. Storm Washi (Sendong) recorded a 1-day rainfall in Cagayan de Oro of 180.9mm, which was even more than the average total precipitation during the wet season over the past 30 years. This implies that a rainfall volume, which under normal condition, covers the precipitation events of about 6 to 7 months,took place in just one day during that disastrous event of Sendong. Moreover, upstream of the Cagayan de Oro River, of which discharge drainsinto the Cagayan de Oro River, recorded a precipitation of 475mm over a 24-hour span. This is more than twice the total precipitation over about 7-month period during the wet season. Weather authorities like NASA and JAXA indicated that total rainfall accumulation around the Cagayan de Oro River exceeded 400mm. This phenomenon amounted to a 1 in 20 - year event over Misamis Oriental. This results to about 5% chance of occurrence in any given year, a probability of such horrible risk that is quite high. On the other hand, the swelling of the rivers around Cagayan de Oro, which crested at 7 to 9 meters, amounted to a 75-year flood event in some areas. This equates to about 1.33% chance of occurrence in any given year.

It is however important to note that in this event, the Cagayan de Oro River had swollen tremendously causing the flood waters to rise up to more than 3 meters in many areas in the City in less than an hour. Unfortunately, when rainfall was heaviest, the Macajalar Bay was also at high tides exacerbating the inundation effects of the typhoon. The sea waters aggravated the flooding situation in areas which were supposedly safer during low tides. Moreover, the affected City at the height of the flashfloods was amidst 90 km/h winds.

In the following year, 2011, also during the month of December, another typhoon was formed, Typhoon Bopha. It was the strongest tropical cyclone to ever hit Mindanao with winds of 280 km/h. However, precipitation totals brought by Bopha in eastern Mindanao was only between 100mm and 240mm over a period of about 8 days. This intensity of rainfall was much lower than that of Washi. In effect, flood levels reaching facilities of COWD were not as damaging as that of Sendong. Unlike in 2011, only five wells were affected with flood levels as deep as half a meter only in 4 wells to about 3 meters in 1 well. The major booster station serving the central and business district of the City was left unaffected.

The flood eventsin 2009 werebrought about by a tail end of a cold front after typhoon Auring in January and Urduja in November took place. It could be observed that documentation of the details of the events accounting of the damage, the extent of rainfall and other salient characteristics of a visiting typhoon had not appeared to have taken the attention of many. There was not much information on this matter except for some accounts in the news prints. Probably, this was because events like these at that time were bizarre to the City, in general. Cagayan de Oro is not within the typhoon belt of the island. In fact, not until 2011 December did the COWD, for instance, learned about how it felt like having typhoon signal no. 2 then moving up to signal no. 3 soon after. All the more were the flood cases prior to 2009. The only documentations that could be readily accessed about those disastrous phenomena are the newspaper clippings, recall and accounts of common people. Moreover, it may be worthy to note that all those climate disruptions that adversely affected the City, in general, were all related to flooding events brought about by storms and typhoons. The past drought in the 90's has not left remarkable disruptions, specifically, to the operations of the District. This could probably be due to a richer groundwater reserve then or simply because of a lack of the appropriate tool to determine and quantify the impacts of hazards like droughts.

The flood area of the City during a 1 – in – 100 flood event (per projections of the NOAH project) would cover at least 9 of the production wells and the central booster pumping station of the COWD. These are PW1, PW4, PW7, PW9, PW16 and the Macasandig Booster Station east of the Cagayan de Oro River. On the west of the river are PW14, PW19, PW24 and PW25. These are the facilities that are nearest to the Cagayan de Oro River and of lowest elevation on the average. The distance from the river ranges from about 91 meters to about 531 meters while ground elevation varies from about 6.75 meters above mean sea level to about 13.25 meters. Fortunately, the rest of the 20 wells are outside the flood zone areas. In fact, 13 wells are not even within the vicinity of the peripherals of the Cagayan de Oro River although nearer smaller creek or river.

Figure 4
Map of COWD Facilities within 1 – IN – 100 FLOOD ZONE

Hazards and Damage in COWD Facilities during Past Disruptions

For the past 3 years, all extreme climate-related events recorded in the region that had directly impacted the COWD were associated with hazards due to flooding. The biggest calamity that hit COWD was that in 2011 due to Tropical Storm Sendong (Washi). That disaster brought down six (6) production wells and all the facilities in the area, one major and central booster station, entire office building and everything in it and all of the laboratory facility. The water supply capacity of the District was down by close to half, leaving more than 40,000 connections or approximately 240,000 people with limited water supply. This situation of extreme water scarcity endured for more than 15 days amounting to about PhP48 Million of revenue losses, that is more than half of the District's gross revenues in a month. The total rehabilitation cost was estimated at more than PhP150 Million.

The rainfall intensity recorded at the height of SendonginLumbia, a barangay upstream of the City, was about 180.9 mm within a span of 24 hours. That was equivalent to 1 – in – a 20 year event, at least, for the province of Misamis Oriental, where Cagayan de Oro belongs. During that year of 2011, December recorded a total rainfall of 333.6mm. This suggests that more than half of the total precipitation within the month fell just in a day, and that was when Sendong came. For over 3 decades, the average total rainfall during the month of December had been about 190mm, of which 95% of that fell over Cagayan de Oro in just one (1) day. Moreover, a weather station in Capehan, a barangay located along the Bubunawan river, which is a tributary of the Cagayan de Oro river, recorded a very huge rainfall of 475mm over a span of 24 hours during Sendong.

That phenomenon brought havoc to COWD with flood waters reaching as high as three (3) to six (6) meters above ground. The production wells that were completely submerged in 3 to 6 meter depth of floodwaters are those that are located by the banks of the Cagayan de Oro River.The average distance of these 6 areas from the banks of the Cagayan de Oro River is about 300 meters. The farthest, which is the PW4, recorded the lowest flood depth. PW19 and PW24, are the second and third nearest the river bank but sustained the deepest flood depth, and PW9 while the nearest, was lower in flood depthby about 1.8 meters. These are further depicted in Table 4.

Table 4
Distance, Ground Elevation & Flood Level in Affected Facilities

Facility	Distance (meters)	ground elevation (meters)	2011 flood depth(meters)	2012 flood depth(meters)
Macasandig BPS	493	9	3	0
PW1	493	6.75	3	0
PW4	531	8	2.7	0.5
PW7	363	13.25	3.7	1.2
PW9	49	3.25	3.7	1.5
PW19	91	6.75	5.5	0.5
PW24	106	12.5	5.5	2.7
average	303.71	8.50	3.87	0.91
st.dev	214.50	3.48	1.17	0.97

During that tragedy, the COWD has been very fortunate to receive aids and assistance of various forms and kinds, including cash of more than PhP53 Million from the Government of the Philippines and about PhP50 Million worth of new production facilities from the People of Japan through the Japan International Cooperation Agency (JICA) – Appendix 2.

When typhoon Pablo (Bopha) visited the region in 2012, though it was the strongest tropical cyclone recorded to have hit Mindanao, the estimated damage in facilities of COWD was much lower, about PhP1.5 Million only. The revenue losses were very minimal at about PhP2 Million in about 4 days compared to more than PhP48 Million for about 16 days in 2011.

Practically, similar wells were flooded during the Pablo, except the PW1 located at the Macasandig Booster Station. Fortunately, the flood depthswere much lower as well. Similar in 2011, the highest flood was recorded in PW24 at about 2.7 meters high and lowest in PW4 and PW19 at about 0.5 meter while flood waters did not reach the floor level of the booster station in Macasandig, where PW1 is also located. It was observed that flood depthstend to decrease the farther the area is from the river. The flood depthobservations were measured based on the flood depthsin these facilities of the Water District.

Adaptation Actions After the Major Disruptions

The event brought about by Sendong has been a very costly realization for the COWD and the people of Cagayan de Oro. Years before 2011, the City had never known how it would feel like having storm signals. When Signal No. 3 was flagged down over the City almost in the eve of 17 December 2011, the City was in complete shock of the tremendous destruction it brought. The tragedy claimed millions of properties and thousands of lives.

Year 2011 was the first time in more than four (4) decades of existence of the COWD that its facilities were floodedthat horrendously. Thus, in realization of more frequent and more ferocious typhoons coming, the COWD, in rehabilitating the system, "building back better"has become the by-word. Donors like the JICA, imposed building back better as a prerequisite to COWD's receiving the grant of new equipment to replace the damaged ones. The controllers of all pumps and motors were raised to platforms as high as the water level during the last flood. These platforms have been built on steel structures that proved strong in the last typhoon. All other structures like the pedestal of transformers and the entire laboratory facility would be elevated. Generator sets in those areas badly hit by Sendong have been placed in mobile carts to facilitate transfer and evacuation of such upon preparation for the coming of any prediction of at least Signal No. 2 typhoon. Another minor but very important adaptation implemented was the sealing of sounding holes of the production wells, albeit, upon further evaluation recently of these facilities, it has been found out that more openings in these wells need to be sealed soonest – Appendix 3. Similarly, Figures 5, 6, 7, 8and 9 demonstrate these adaptation measures mentioned.

Figure 5
Elevated Controller at BPS Macasandig

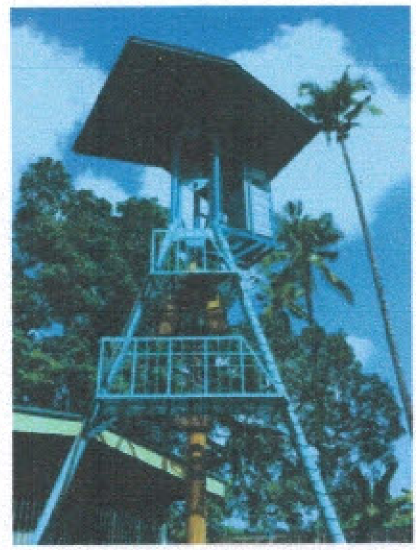


Figure 6
Typical Elevated Contoller in PW

Figure 7
Elevated Transformers at BPS Macasandig

Figure 8
Typical Submersible Pump in PWs

Figure 9
Genset in Mobile Cart

When typhoon Pablo came closely after Sendong, these adaptation infrastructures were not yet fully completed. Nevertheless, the COWD managed to cope with the expected fierceness of the coming storm. A core team was created and held briefing on the necessary preparations to keep facilities as safe as possible and mitigate damage to those that were determined to be unavoidably affected. Laboratory equipment and generator sets were evacuated to farther and elevated locations. In consequence, no major equipment were damaged except for controllers that were not yet elevated at that time. Supply interruption was much shorter.

Another significant adaptation measure that the COWD, together with JICA, adopted was the replacement of the damaged centrifugal and turbine pumps into submersible pumps. This is shown in Figure 9. Submersible pumps are more resilient to flooding as motors are already submerged in water during normal operations. Appendix 3 provides the details of the adaptation initiatives that the COWD implemented to become more resilient against floods in the future.

Historical Precipitation Rates

A review of the precipitation records of the Basin from 1982 would reveal that annual precipitation averages at about 1,700 millimeters of rain at a standard deviation of 314 millimeters. Fitting a line to determine the trend of this climate data demonstrates an increasing rainfall rate year after year. This can be readily seen as shown in Figure 10. The years 1997 and 1998 were the time when El Nino hit the country. However, as shown, the lowest mean annual precipitation rate over the past 2 decades did not occur during the El Nino years.

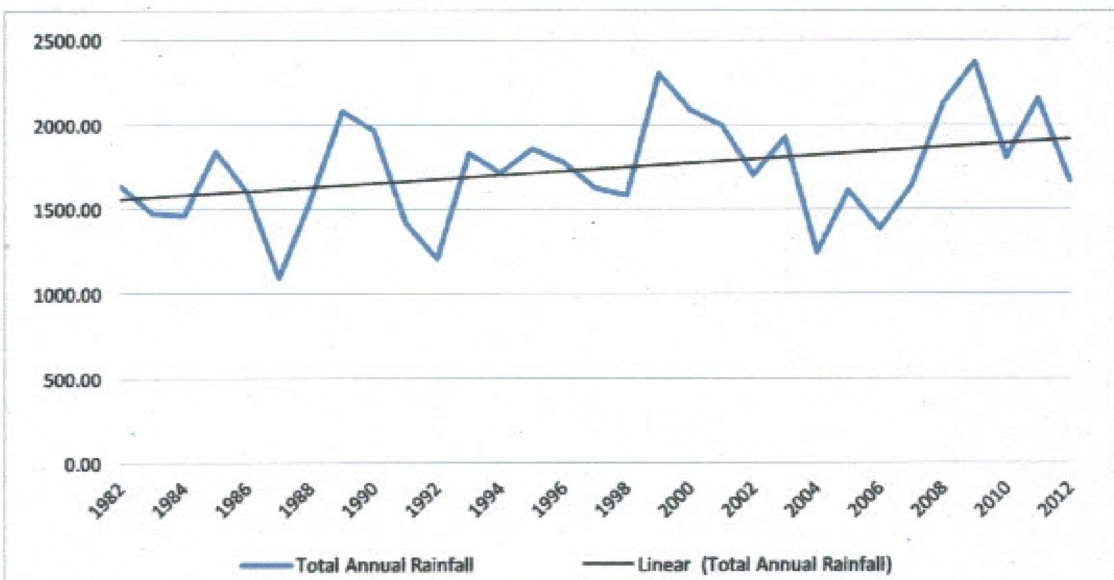


Figure 10
ANNUAL RAINFALL (1982-2012)
Cagayan de Oro City

Examining further the climate behavior of the area in terms of the precipitation data, the average monthly rainfall from 1982 to 2012 looks more defined. Figures 11 and 12 demonstrate this behavior more clearly. Figure 11 provides the graphical presentation of the average monthly rainfall over 30 years while Figure 12 shows the monthly rainfall from 1982 to 2012. It could be observed that the months of January to May are drier and the wet season starts to pick up from June to November and starts to decline again beginning December. The months of December and January to May have monthly average rainfall of 125mm, 92mm, 81mm, 54mm, 53mm, 127mm, respectively, resulting to a season average of 532mm. On the other hand, the months of July to November average at 245mm, 201mm, 221mm, 189mm and 133mm, respectively, giving a total of 1,202 mm rain for the season. It turns out that the total precipitation received during the wet season is almost twice that of the dry season.

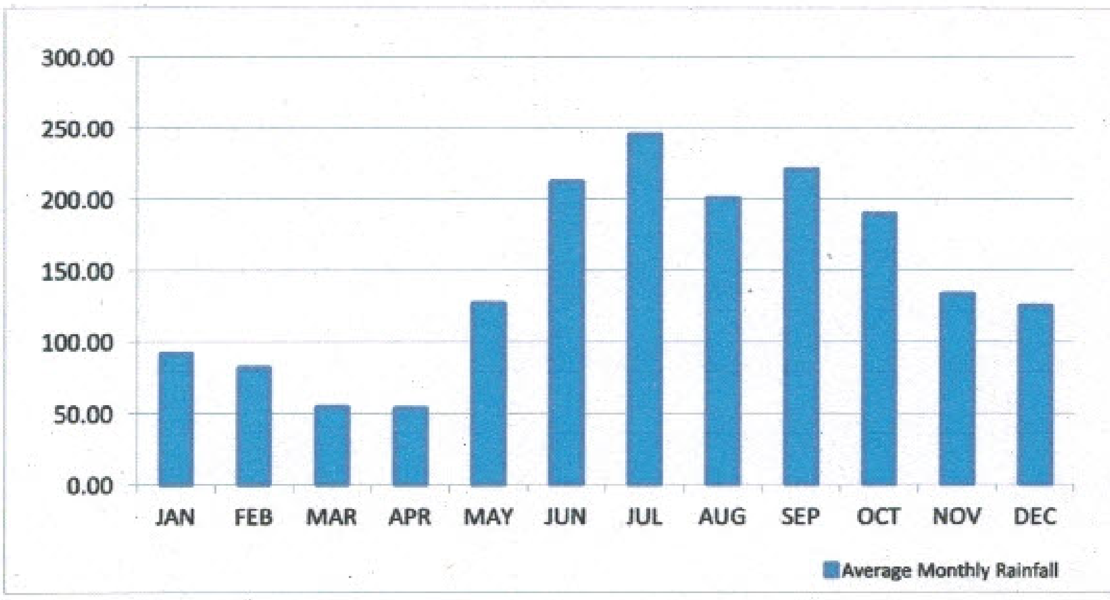


Figure 11

AVERAGE MONTHLY RAINFALL (1982 - 2012)
Cagayan de Oro City

In terms of variability, the precipitations during the months of January within the dry season appeared to be the most dispersed with a standard deviation of 97mm of rain. On the other hand, the months of March appeared to be the most homogeneous in terms of precipitation catch, with a standard deviation of 44mm. This can be seen in Appendix 4. On the other hand, the spread of rainfall quantity is most pronounced during the months of November at a standard deviation of 124mm of rainfall spread for the last 30 years or so. Although, generally, rainfall quantity of all months during the past 3 decades are quite dispersed with standard deviations ranging on the average from 44mm to 124mm of rain of each month.

However, it may also be of importance to observe that it seems that at least once in a decade, there is a year that recorded high precipitation rates even during dry months. Specifically, these are shown in in years 1982, 1999 and 2009. This is illustrated in Figure 13 that follows. Furthermore, referring back to Table 3, it seems that the most recent flooding that happened in Cagayan de Oro occurred during the months when precipitations were not necessarily abundant. For instance, in January 2009, the City was flooded brought about by excessive rain as effects of the tail of a cold front.

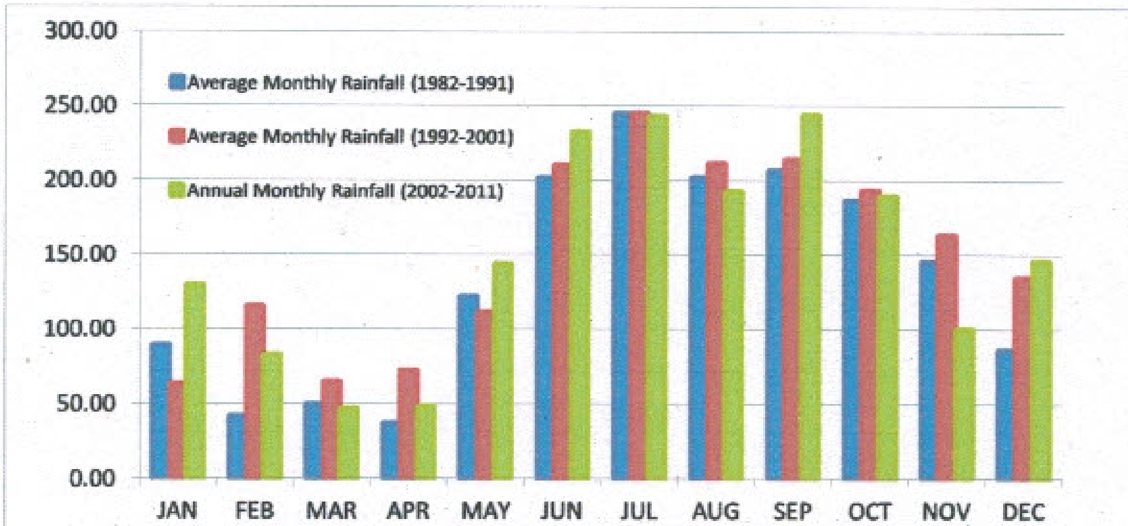


Figure 12
AVERAGE MONTHLY RAINFALL BY 10 YEAR PERIOD
(1982-1991, 1992-2001, 2002-2011)
Cagayan de Oro City

Based on the recent study conducted by the Manila Observatory (October 2015) for BeSecure Project of the USAID, Cagayan de Oro City has type III monsoonal climate under the Corona Classification system. Under this climate classification, July showed the month with highest rainfall but at the same time "showed a continuous decline in precipitation from 1971 to 2000." On the other hand, it has been observed that precipitation rate in November and December tends to increase decade after decade. Supposedly, these months mark the beginning of the typical dry season of the region, but the shown "trends depict a shifting climate in the area over the 30 – year baseline period."

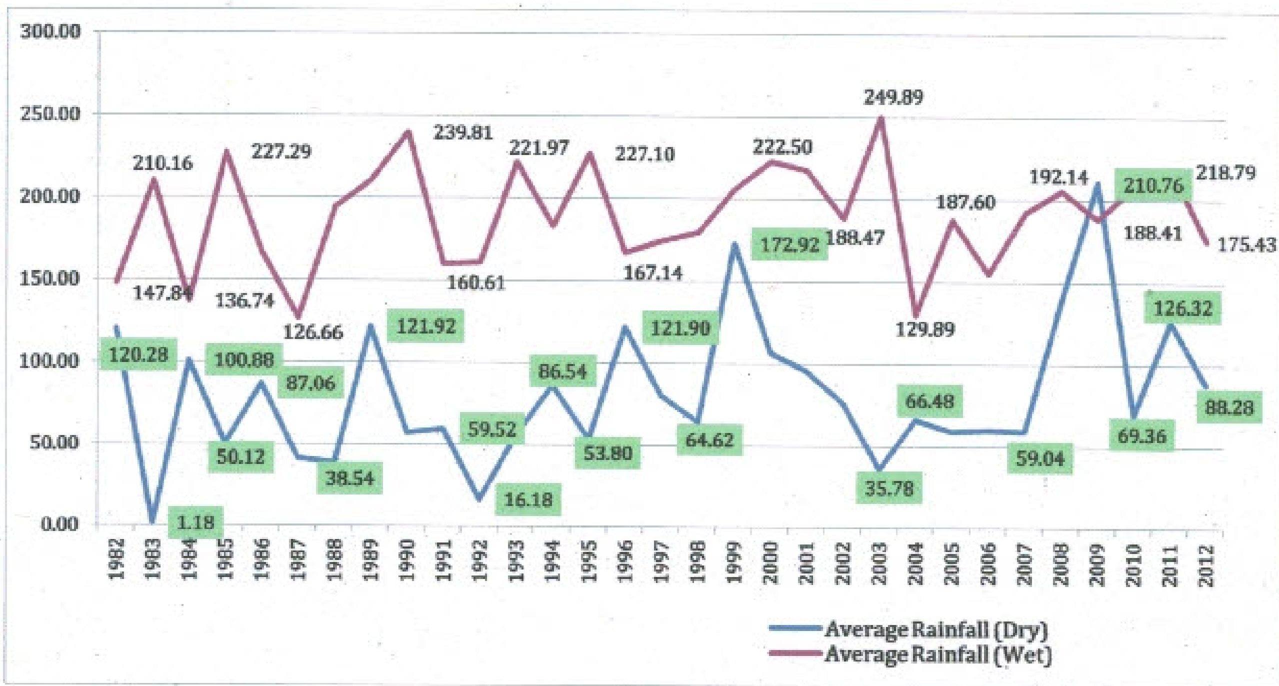
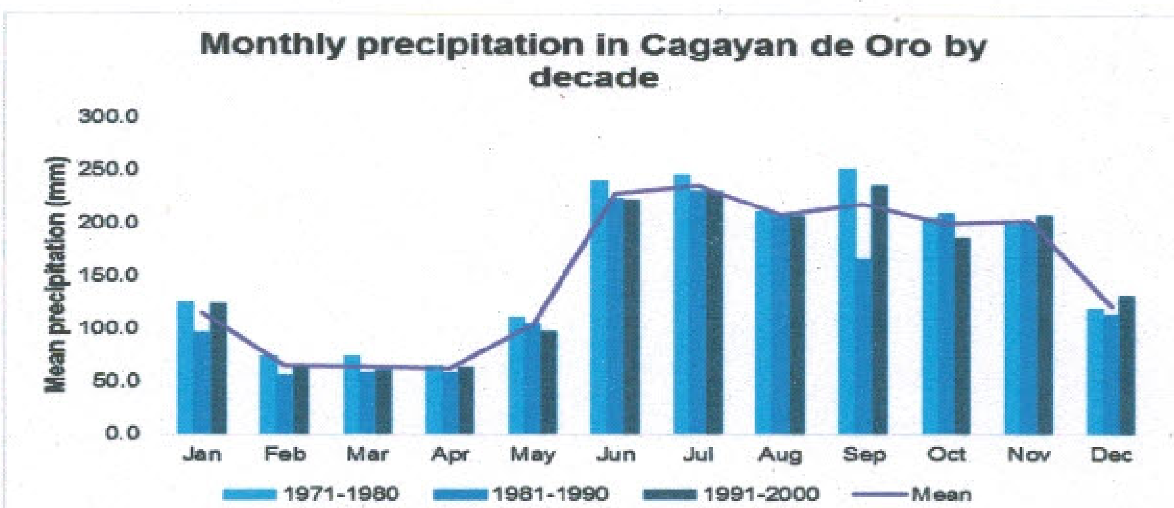


Figure 13
AVERAGE RAINFALL (DRY & WET SEASON)
Cagayan de Oro City



source: Manila Observatory (October 2015)

Figure 14
Decadal monthly total precipitation in Cagayan de Oro City for the baseline period (1971-2000) using bias-corrected model output.

Temperature Characteristics

As shown in Figure 15, the temperature tended to rise gradually for the past 17 years. The details of the temperature variations are presented in Appendix 5. Examining further Figure 11, it could be observed that the temperature went down after the El Nino phenomenon in 1998 and started to rise up again after about a decade.

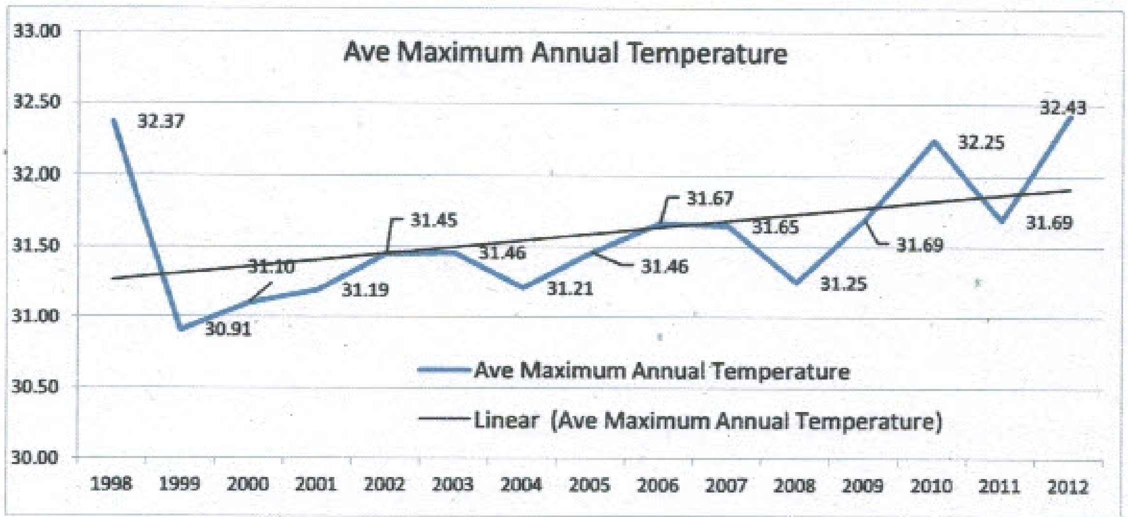


Figure 15
AVERAGE ANNUAL TEMPERATURE (1998-2012)
Cagayan de Oro City

Scrutinizing further the historical monthly temperature pattern as depicted in Figure 16, it could be observed that temperature is lowest in the months of December and January to February and starting to pick up beginning March and continues to rise until May. April and May appear to be the hottest months throughout the past 17 years. By June temperature starts to decline again until December of each year.

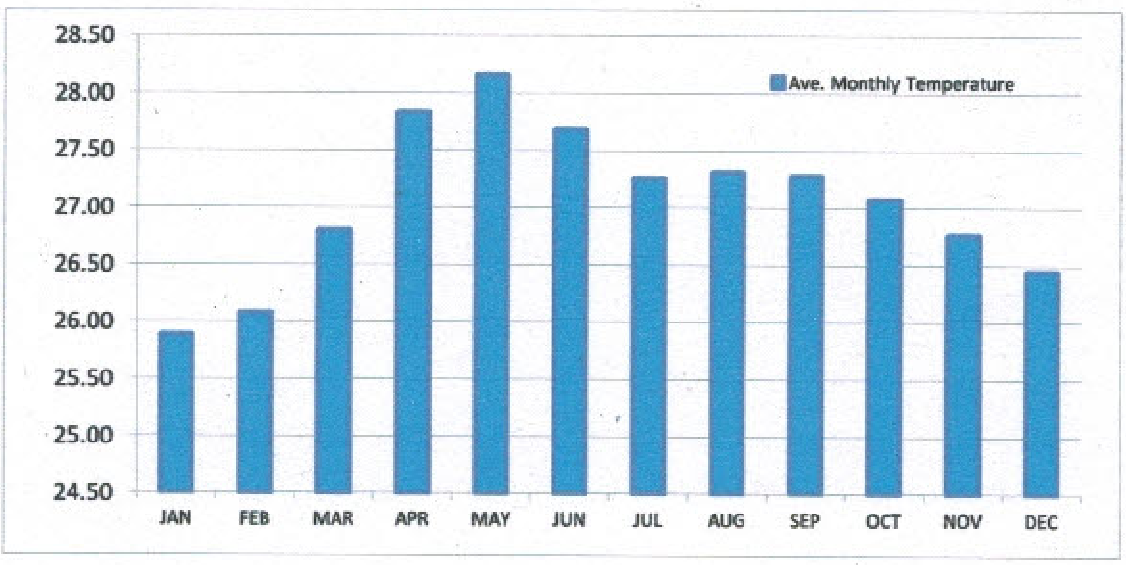
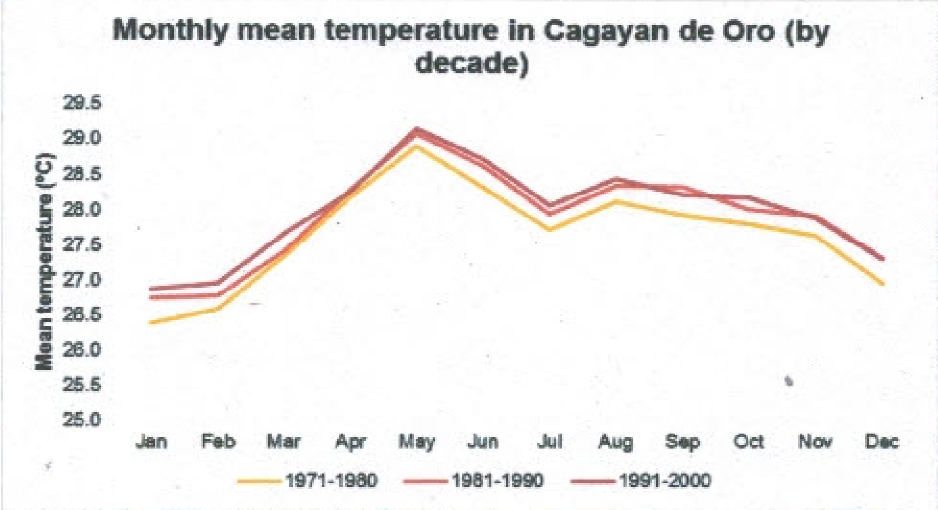


Figure 16

AVERAGE MONTHLY TEMPERATURE (1998 - 2012)
Cagayan de Oro City

Based on the recent study of Manila Observatory (October 2015), mean daily temperature historical trend for Cagayan de Oro indicates a continuous increase over the past 3 decades. This is clearly depicted in Figure 17. The largest leap in mean daily temperature occurred between 1970's and 1980's. Throughout the 3 decades, December to February consistently showed the largest mean daily temperature increases, suggesting warmer nights in the City during these periods.



Source: Manila Observatory (October 2015)

Figure 17
Decadal monthly mean temperature in Cagayan de Oro City for the baseline period (1971- 2000) using bias-corrected model output

Water Sources

From the start, the District has been relying on the groundwater for major source of water. The water produced for supply comes from deep wells extending from 150 up to 250 meters depth. Over the years, the COWD has expanded its well fields into 4 major areas: Bugo-Tablon well field, Macasandig, Balulang and Calaanan. Only in 2007 when COWD started to tap the surface water as source for supply. This source, which takes about a third of the District's total supply capacity, is coming from one of the tributaries of the Cagayan de Oro river, specifically, the Bubunawan river in Bukidnon province.

As presented in Appendix 6,Calaanan well field has the least number of operating wells, thus, for comparison purposes, only Balulang, Macasandig and Bugo-Tablon areas are considered comparable to each other. It could be noted that the oldest wells are situated within the Macasandig well field. The wells in this area have been in operation for close to 40 years already, averaging at 29 years. While this is the well field that recorded the biggest capacity at the beginning of operation at 961.70 liters per second (lps), this is the same well field that has logged the biggest total well field discharge rate reduction of about 0.23 lps per year and an average annual discharge rate reduction per well of 2.68 lps. The Balulang well field appears to have the best performance in terms of well capacity sustainability although this is also the well field that gives the least yield at about 340 lps at the beginning of operation or about an average of 49 lps per well in the area. Over an average of 15 years in operation, the total field yield has improved by about 0.01 lps or at an annual average increase of 0.07 lps per well.

Figures 18 to 22 depict the graphical presentation of the total depths and screen locations of the various wells in their respective well fields. The deepest wells are found in the Macasandig well field, averaging at 220 meters with a minimal standard deviation of 24 meters, the lowest among 4 well areas. The well depths are more homogeneous but water level at each well seems to vary more widely from each other. This can be inferred as indicated by the dispersed locations of the screen averaging at about 129 meters and with a standard deviation of 69 meters, the highest among 4 well fields. On the other hand, Balulang well field appears to have the most varied well depths as well as screen locations, and probably, thus, the water level in the wells. The average well depth is about 180 meters and screen locations of about 104 meters at standard deviation of about 60 meters and 49 meters, respectively.

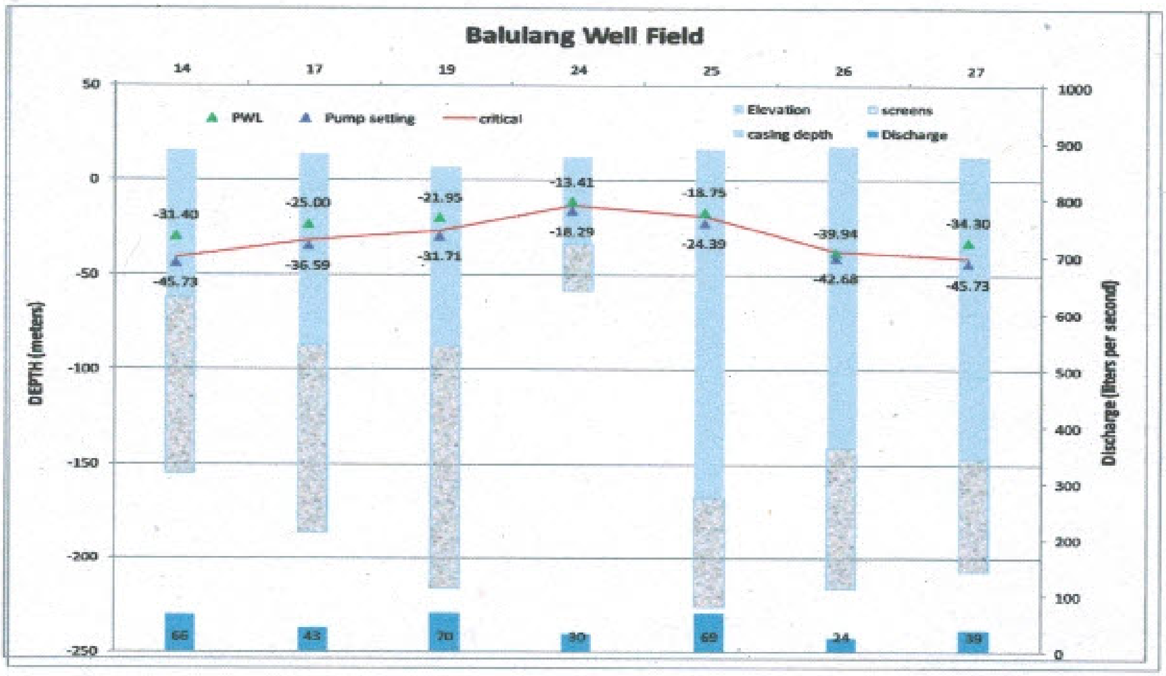


Figure 18
Balulang Well Area – Depth, Screen Location & Discharge

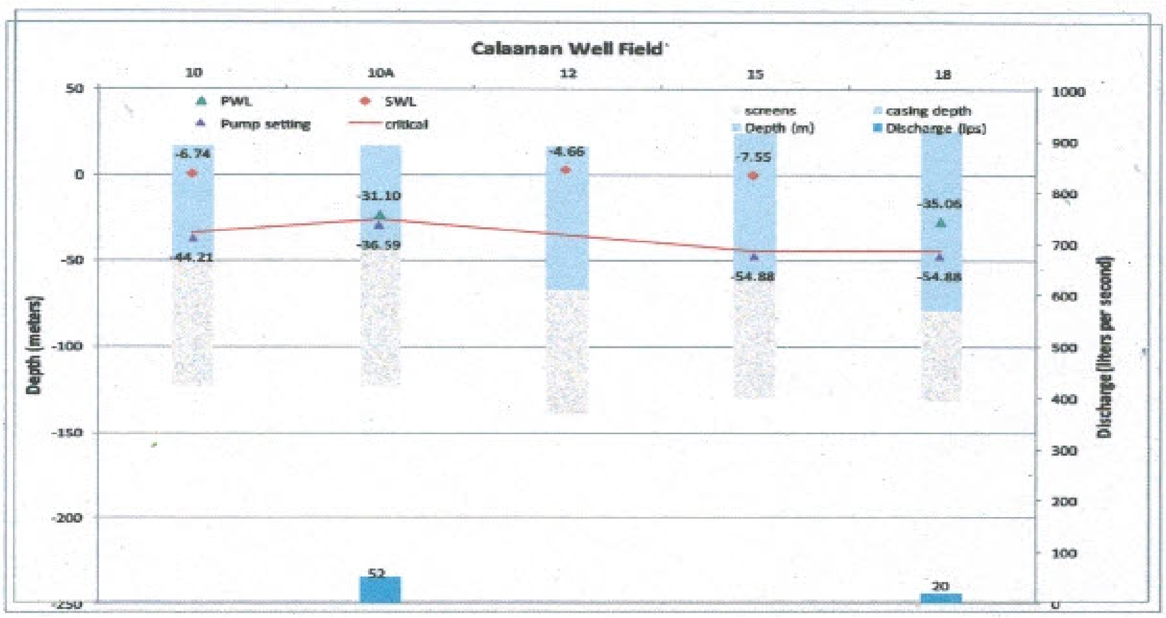


Figure 19
Calaanan Well Area – Depth, Screen Location & Discharge

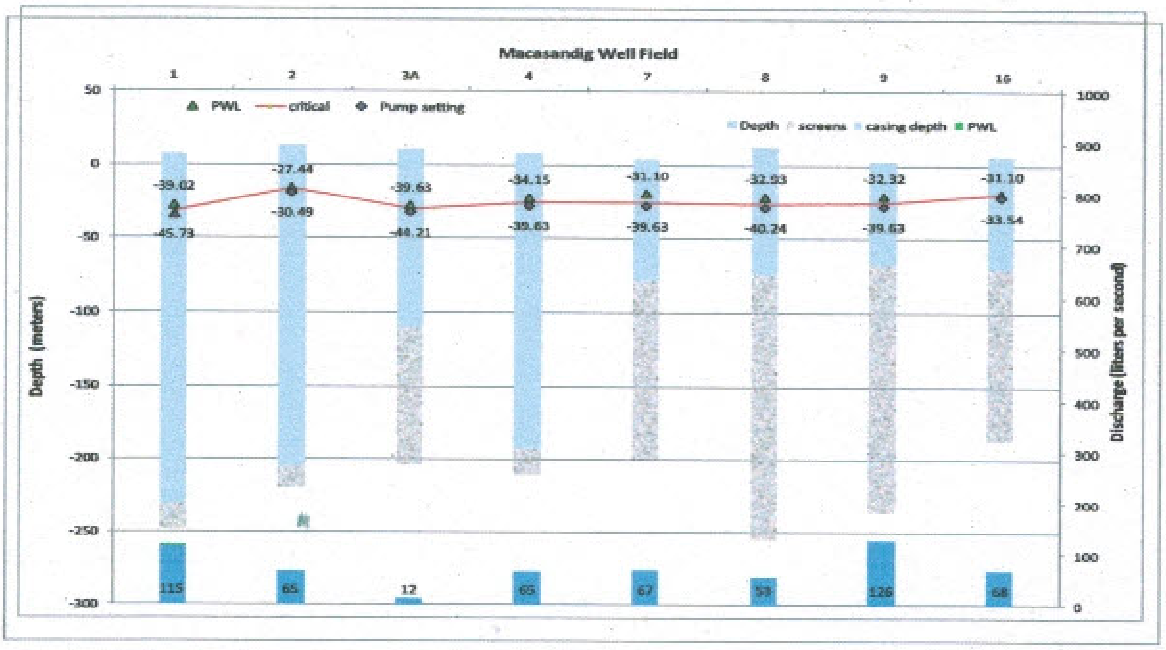


Figure 20
Macasandig Well Area – Depth, Screen Location & Discharge

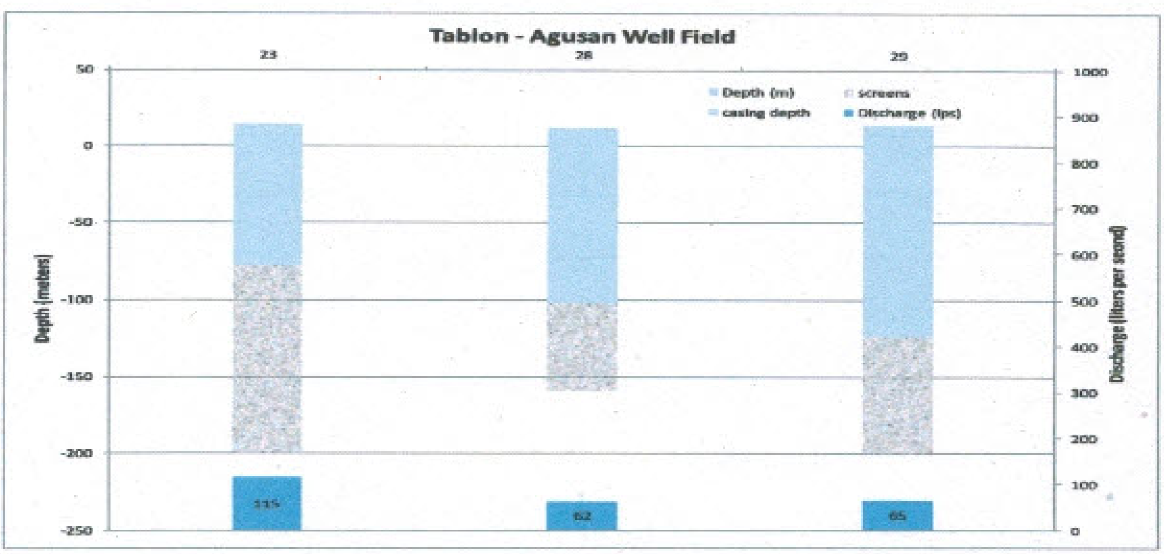


Figure 21
Bugo Well Area – Depth, Screen Location & Discharge

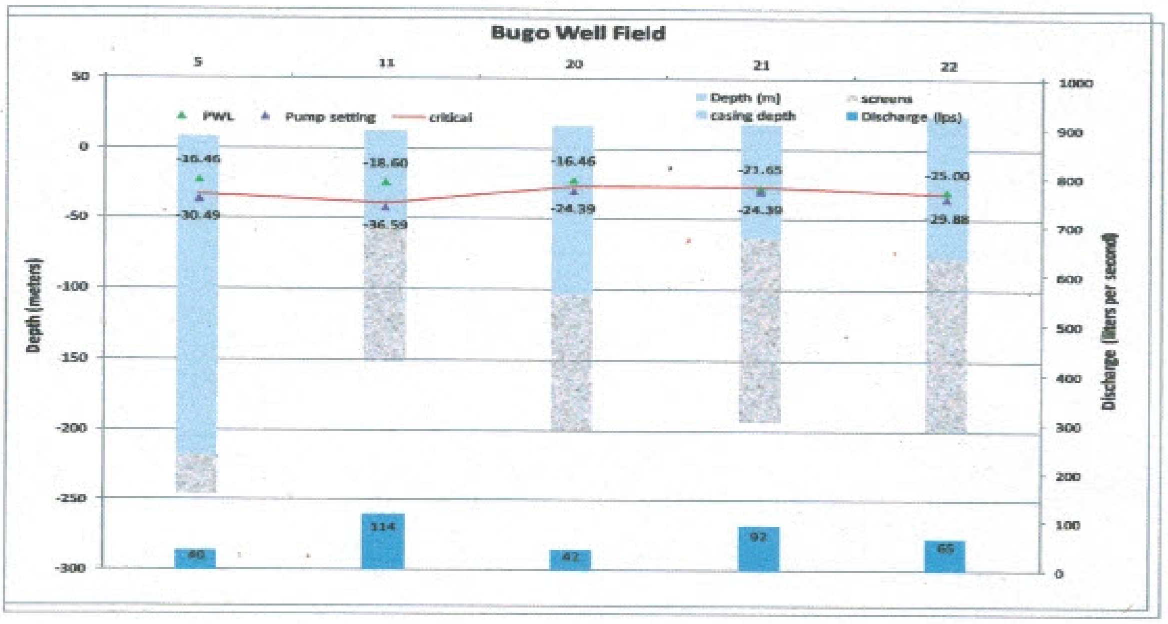


Figure 22
Tablon - Agusan Well Area – Depth, Screen Location & Discharge

Specific Capacity of Wells

The Macasandig Well Field demonstrates relatively homogeneous specific capacity at an average of 3.38 lps per meter of drawdown. In fact, this seems to be the best yielding well field with about 0.06 lps/m reduction in average specific capcity annually for about 25 years.Improvement in specific capacity may be attributed to reduction in discharge rate whereby corresponding drawdown per unit of discharge is also reduced. The PW1, PW16 and PW4are the wells in the area that demonstrated improvement in specific capacity from start of operation to present. It maybe also important to note that most of the the old wells, about 25 years or more operational, are located in this well field.

The specific capacity of the wells in the Bugo Well Field appear to be as almost as homogeneous as the those in Macasandig. However, the specific capacity of the wells in the area is much lesser and all wells have shown reduction in specific capacity over time.

On the other hand, the nearby well field, the Agusan – Tablon area depicts a rather more dispersed specific capacity considering the most recent records. However, this picture is not very much similar to the specific capacity data of same wells when they were first operated. Nevertheless, the area got the highest mean specific capacity so far. This well field, on average, also registers the biggest annual decrease in specific capacity. even if with one well whose specific capacity has instead improved from its beginning operation. This one well increased in discharge after lowering further the pump setting to avoid further throttling of the pump. Appendix 7 shows the historical data on pumping water level of wells.

Table 5
SWL, PWL, Dd, Q and Sp. Capacity Per Well Field

MACASANDIG WELL FIELD													
PW	START						RECENT						
	DATE	SWL	PWL	Dd	Q	SP CAP	DATE	SWL	DATE	PWL	Dd	Q	SP CAP
9	1986	0.00	-12.64	-12.64	144.00	11.39	2011	-9.21	2015	-32.93	-23.72	117.41	4.95
1	1983	-1.70	-22.73	-21.03	91.00	3.72	2015	-17.7	2015	-39.02	-21.32	115.02	5.39
16	1996	-10.86	-24.68	-13.82	85.36	2.40	2011	-11.88	2015	-30.95	-19.07	68.01	3.57
7	1988	-1.50	-13.20	-11.70	92.00	6.26	2013	-10.59	2015	-31.40	-20.81	66.62	3.20
4	1993	-9.76	-38.72	-28.96	88.30	1.82	2011	-13.11	2015	-33.84	-20.73	65.49	3.16
2	1983	-5.53	-15.80	-10.27	103.70	4.86	2009	-17.7	2015	-36.59	-18.89	65.24	3.45
8	1986	-1.80	-15.10	-13.30	126.40	7.48	2012	-11.7	2015	-32.62	-20.92	53.38	2.55
3A	2001	-11.75	-27.53	-15.78	58.99	1.50	2015	-23.18	2015	-39.63	-16.45	11.99	0.73
BALULANG WELL FIELD													
PW	START						RECENT						
	DATE	SWL	PWL	Dd	Q	SP CAP	DATE	SWL	DATE	PWL		Q	SP CAP
19	1997	-6.74	-11.23	-4.49	61.00	3.39	2011	-11.25	2015	-21.95	-10.70	69.97	2.11
25	1999	-8.89	-16.83	-7.94	110.60	4.30	2015	-12.42	2015	-18.75	-6.33	68.71	2.20
14	1994	-9.80	-20.95	-11.15	94.60	3.08	2010	-17.52	2015	-31.40	-13.88	65.62	1.34
17	1996	-9.63	-19.08	-9.45	57.03	1.99	2011	-16.16	2015	-25.00	-8.84	42.90	1.04
27	1999	-12.29	-28.18	-15.89	94.64	2.34	2006	-16.00	2015	-34.30	-18.30	39.43	0.78
24	2000	-3.73	-7.74	-4.01	33.12	2.89	2011	-4.51	2015	-13.41	-8.90	30.28	1.69
26	1999	-15.70	-43.89	-28.19	94.64	1.59	2015	-15.30	2015	-39.94	-24.64	23.97	0.43
BUGO WELL FIELD													
PW	START						RECENT						
	DATE	SWL	PWL	Dd	Q	SP CAP	DATE	SWL	DATE	PWL	Dd	Q	SP CAP
11	1986	0.00	-13.85	-13.85	125.00	9.03	2012	-3.81	2015	-18.60	-14.79	113.82	5.08
21	1998	-6.67	-12.48	-5.81	100.00	5.22	2012	-12.22	2015	-21.65	-9.43	92.18	2.72
22	1999	-11.44	-17.50	-6.06	100.00	3.46	2011	-16.70	2015	-25.00	-8.30	65.24	1.56
20	1997	-6.80	-11.81	-5.01	64.00	3.44	2014	-12.40	2015	-16.46	-4.06	42.21	1.46
5	1982	0.00	-5.58	-5.58	46.66	8.36	2012	-4.75	2015	-16.46	-11.71	39.68	1.87
TABLON - AGUSAN WELL FIELD													
PW	START						RECENT						
	DATE	SWL	PWL	Dd	Q	SP CAP	DATE	SWL	DATE	PWL	Dd	Q	SP CAP
23	1999	-4.06	-6.75	-2.69	100.00	9.25	2006	-9.35	2015	-16.46	-7.11	114.95	16.16
29	2000	0.00	-6.95	-6.95	94.64	13.62	2007	0.00	2015	-16.46	-16.46	64.67	3.93
28	2000	0.00	-10.78	-10.78	94.64	8.78	2007	-4.22	2015	-15.85	-11.63	61.89	5.32
CALAANAN WELL FIELD													
PW	START						RECENT						
	DATE	SWL	PWL	Dd	Q	SP CAP	DATE	SWL	DATE	PWL	Dd	Q	SP CAP
10A				0.00			2015	-9.0	2015	-31.10	-22.10	51.61	1.29
18	1997	-28.43	-49.85	-21.42	50.79	0.65	2015	-31.6	2015	-35.06	-3.46	19.75	0.30
10	1986	-4.30	-18.80	-14.50	67.50	2.92							
12	1991	-6.90	-30.92	-24.02	76.84	2.03							
15	1994	-11.91	-34.85	-22.94	75.00	1.60	2015	-7.6					

The wells in the Balulang Well Field recorded the least specific capacity other than those from Calaanan. In fact, the specific capacity of the wells are much thinly spread from the mean. However, the well field has registered the least reduction in specific capacity, too, from beginning of operation up to most recent data. One probable expalanation could be the observation that the discharges of the wells in these well field are generally kept low. Moreover, these are also the wells that are relatively younger, mostly less than 20 years in operation, more or less, similar with wells in Tablon - Agusan area and Bugo.

<u>Service Connections, Consumption, Water Production and NRW</u>

Appendix8 shows the historical growth of COWD's number of service connections, average consumption per connection, NRWand water production from 1976 to 2015. On the other hand, Figures23a, 23b and 23c below present the variations in NRW and total water production, NRW and average consumption per connection and number of service connections and total water production, respectivelyof the COWD for the past more than 30 years.

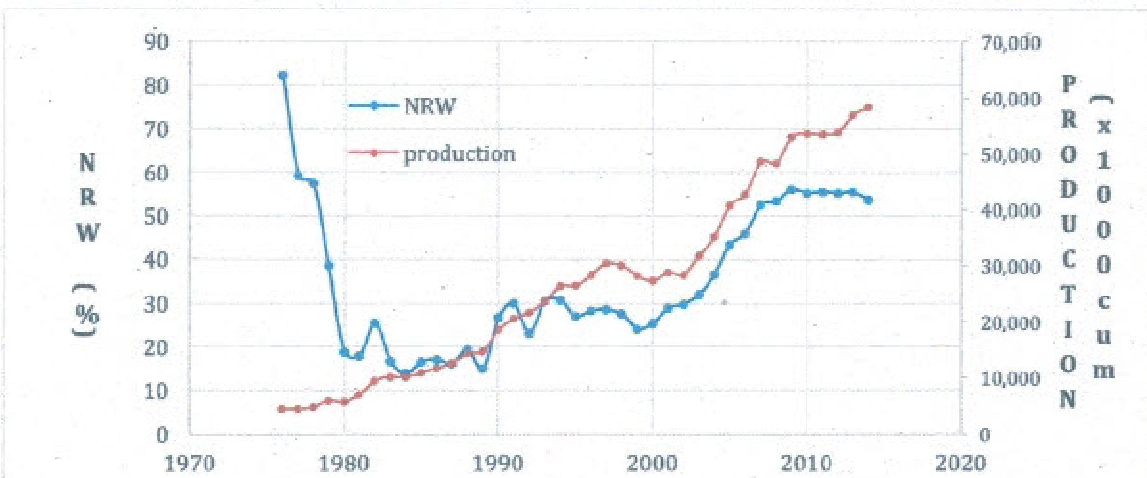


Figure 23a
NRW and Water Production from 1976 to 2014

Figure 23a suggests that the trend of the NRW level seems to closely follow that of the water production. Both start to pick up starting 2000 until present. Nevertheless, the R^2 value of these variables is quite low at 23%. This suggests that about 23% of the variation in the NRW level is attributed to the changes in the water production volume. The larger 77% of the variation in the NRW level can be influenced by other factors, which may probably include age and physical condition of pipes, water meter accuracy, data handling errors and pilferage.However, while linear relation between NRW and water production is rather weak, but such linear relationship is highly significant given a P-value of about 0.002 at 95% confidence level. Thus, it is shown that NRW increases as water production increases. This can be so because with more water production would mean more pressure to the system and therefore, increase in system loss would be inevitable as well, especially if coupled with deteriorating aged pipe system.

The water production solely from the wells (groundwater sources) during the early operation of the COWD was pegged at a little more than 4 million liters in a year, which is a little less than a month's water production capacity at present. This shows that production capacity of the COWD has multiplied by about 13 times over the last four decades. The records show that production increase was biggest in 2007 by close to 6 million cubic meters when the District had its first delivery of surface bulk water supply at 40 MLD. The second biggest leap in production capacity of more than 5.6 million cubic meters was in 2005, immediately after the District completed construction of 5 wells in Bugo and Tablon areas. It is also recalled that between 1998 and 2006, the District had integrated into its system 12 more wells and 2 major booster stations (Bugo and Balulang).

On the contrary, water production reduced the biggest in 1999 at more than 1.8 million cubic meters. The reduction extended for 3 years more, up to 2002. It could be recalled that two years before 1999, the country was plagued with the strongest El Nino.Cagayan de Oro City experienced power outages causing interruptions in operations of many of the production wells of COWD at that time then.Not all of the production wells at that time were then equipped with standby power generating sets.

On the other hand, Figure 23b depicts the growth in consumption per connection per month in cubic metersvis – a – vis NRW. The former tends to follow a decreasing trend over time as the latter follows an increasing trend. The linear association between NRW and consumption per connection is stronger at R = 71%. This results to an R^2 of about 50%, which suggests that 50% of the variation in the consumption per connection is due to variation in the NRW and the other half could be attributed to some other factors. These other factors could be the leakages due to aged deteriorating pipelines and water pilferage.

It can be noted that the NRW in the early years of the District's operation was very high at about 82% and started to go down beginning 1977. However, the NRW picked up again starting 2004 until 2007. It may be understandable to have a very high NRW during the early years of operation of the District since all its pipelines then were part of the old pipeline system of the defunct waterworks of the City. Pipeline system could have needed massive rehabilitation at that early part of its operations. The District was able to lay new pipelines starting in the late 70's until early 90's, in 3 major phases while it continued to utilize the pipelines laid even earlier than 1973. Over the past 4 decades, COWD focused major projects on expansions. That suggests that pipeline network since the early part of 2000 until the present has sustained the tear and wear and a big portion must have deteriorated already over the last 40 years or so.

Furthermore, the linear relationship that exists between consumption per service connection and NRW is somewhat negative, such that the former tends to decrease by about 0.16 cubic meters per month for every percentage increase in NRW. This negative impact of the NRW on the monthly consumption of a connection is statistically significant at 95% level of confidence given a P-value of practically zero.The details of the results are shown in Appendix 8.

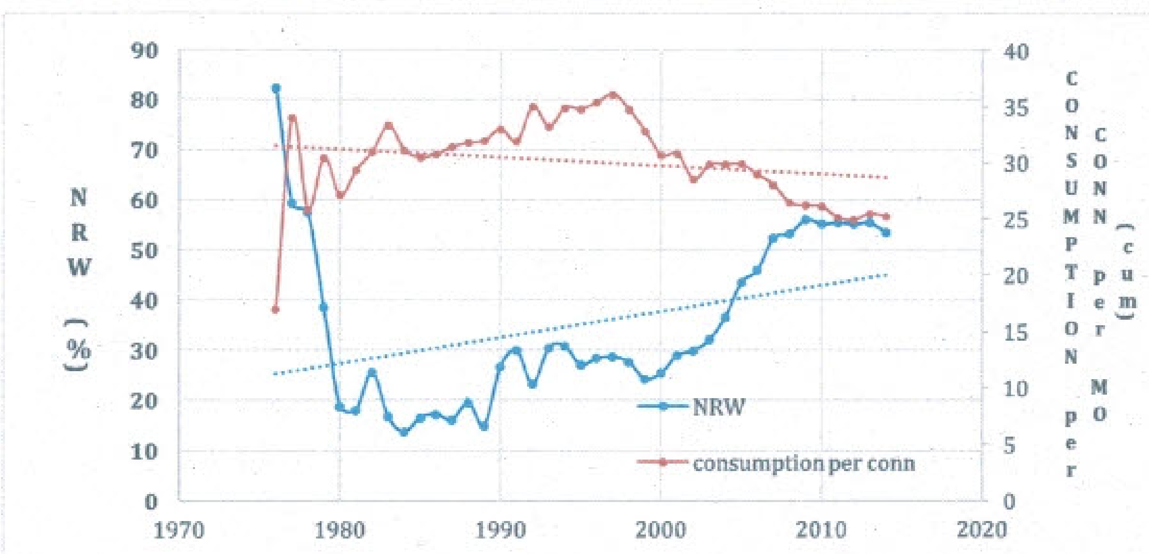


Figure 23b
NRW and Average Consumption per Connection

Given the high NRW, incidents of low pressure to no water have been prevalent in more elevated and/or congested locations in the distribution system of the District. This results to intermittent supply during the 24-hour period of the day, like from only 4 to 18 hours in 24 hours. Instead of the water to reach these connections, it got wasted somewhere else and formed part of the NRW. It could be observed that the consistent drop in consumption per connection year after year started in 2007 and continued until the present.

Looking at the rate at which the COWD has grown in terms of the number of service connections, records would show that it has grown by more than twenty folds. The total number ofclose 86,000 service connections in 2014 against 3,500 when it only started in 1973 is both a strength and a challenge. Figure 23c shows the annual growth in the number of service connections and total water production in a period of about 4 decades (1976 – 2014). The graph demonstrates that both growths tend to be linearly increasing year after year. While production appears to follow the trend of the growth in the number of service connections, the latter seems growing at a faster rate than the other with slope of about 2,087 against 1,459.

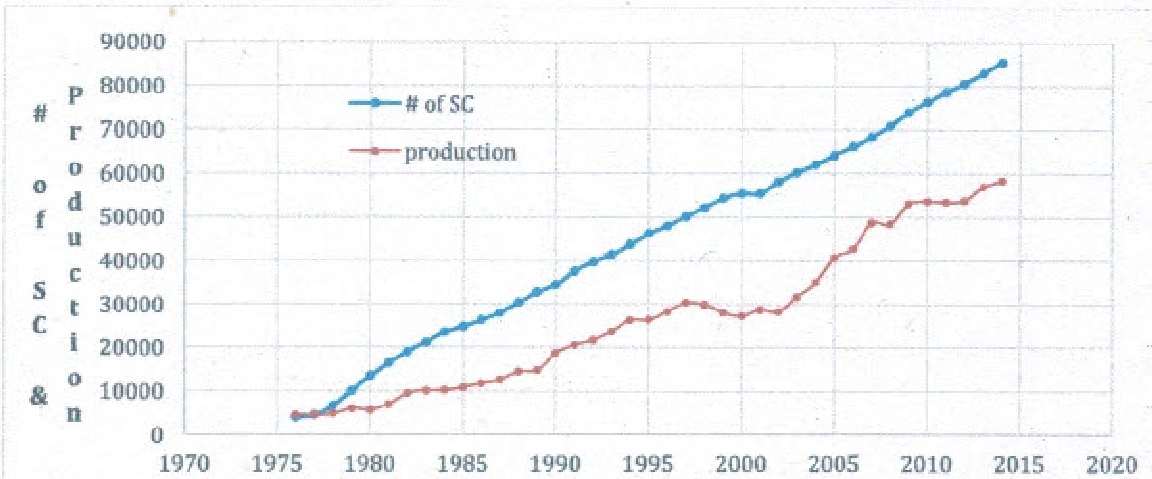


Figure 23c
NRW and Average Consumption per Connection

<u>Other Discussions</u>

In over four (4) decades of existence, the biggest and longest service interruption that COWD experienced so far was that in 2011. The flood event brought by Sendong exposed the vulnerabilities of the District as the water provider of the City. That calamity allowed COWD to realize that at least six (6) of its major producing wells are within flood hazard zones. In addition, the costly realization prompted the District to assess and plan for reinforcement and protection of all major water sources to mitigate risks from climate change effects. Water quality and water availability are the two major aspects of the system that were greatly affected due to the vulnerability of the facilities, especially the water production facilities. This caused longer service disruption and costly restoration and rehabilitation of said facilities. Nonetheless, it was observed that despite increasing trend of temperature in the past 30 years, the production capacities of the wells appeared to continue improving year after year.

Chapter 2
DATA PROJECTIONS and PROJECTED IMPACTS

Population, Water Demand & Water Production Projections

The population of Cagayan de Oro demonstrates growth rates from 2% to 5% based on historical data from 1976. Similarly, population projections depict similar growth rates until the 54th year (2029). The population growth will tend to slow down at 1% onwards, at least, until 2050.This is illustrated in Figure 24a that follows. The same Figure 24a shows the water demand projections from 2015 until 2050. This water demand trend factors in the present NRW level of the District and its projections until 2050 as well. It could be noted that not until 2029 when water demand starts to follow the increasing trend of the population of the City. The decreasing water demand despite increase in population is attributed to the projected reduction in the District's NRW, from a high 53% now to about 25% in 2029. Beginning 2029, with about 25% NRW in the system, water demand starts and continues to rise onwards primarily due to increasing population as well. This tells that the water losses take a substantial portion of the total water demand of the utility.

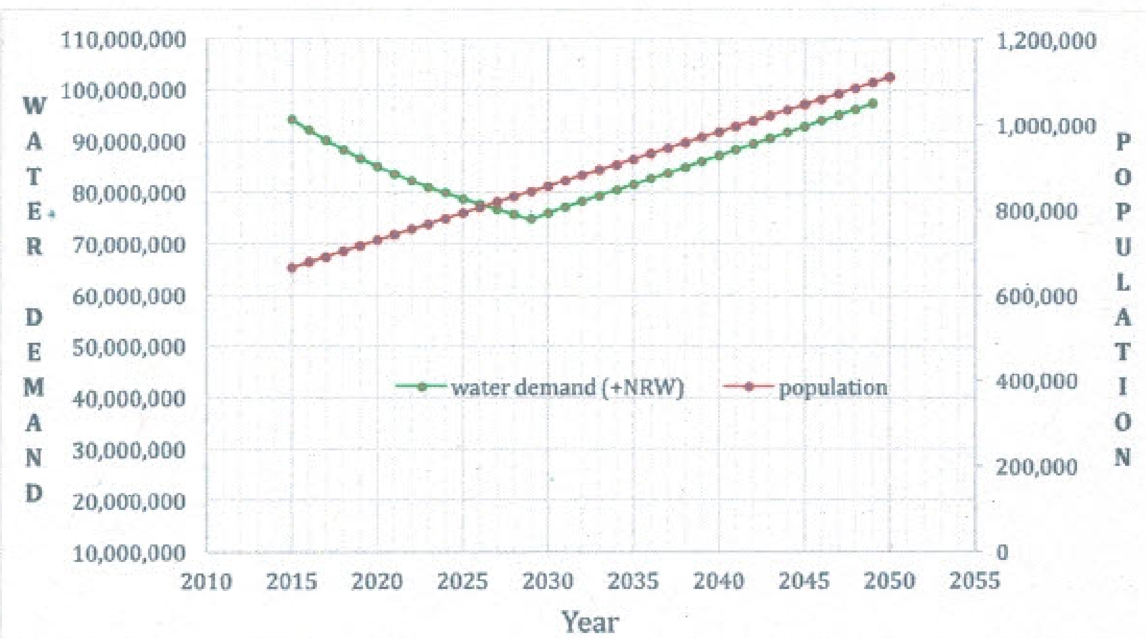


Figure 24a
Water Demand (with NRW) & Population Projections

Figure 24b shows the water demand projections vis – a – vis the water production from 2015 until 2050. Similarly, water demand has factored in the NRW of 53% at present, reducing at 2% annually until 2029, after which it has been conservatively projected to stay at 25% until 2050. On the other hand, water production is being projected based on the District's water supply plan. Based on Figure 24b, water production gradually increases at about 100 liters per second (lps) annually from 2016 until 2021. This annual increase of 100 lps in water production is attributed to operation of additional wells and regeneration of old and existing wells in the next 5 years. By 2022, the District projects an additional source of about 50 Million liters per day (MLD) into the system, bringing the total water production to more than 95 million liters. It can be noted from the graph that, at this time, supply starts to become sufficient to meet the water demand with still about 39% water losses. This situation where water production can be adequate to serve the water demand continues until 2050 at an NRW of about 25%.

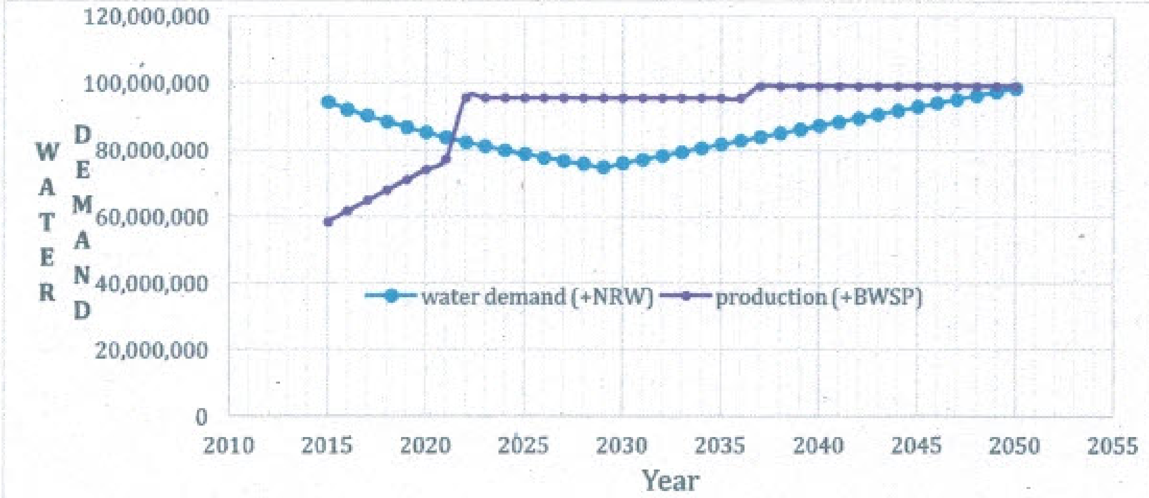


Figure 24b
Water Demand (with NRW) &Water Production Projections

It is apparent in Figure 24b that not until 2022 when COWD would be able to provide adequate water services to the population within the service area. At present, several parts within the service area experience intermittent supply within the 24 – hour period. This is one of the major impacts of very high NRW in the system.The utility has never been able to attain efficient service. This is being addressed at present as the COWD receives the grant of a technical assistance on NRW Reduction from the USAID – BeSecure Project. This technical assistance helps prepare the COWD to be able to fully implement the NRW Reduction

Program until NRW level can reduce to 25%. Other than implementing the NRW Reduction Program, the District plans to augment supply again in 2037 by about 50 MLD and retiring about 8 of the existing wells. These are the wells that could have been displaced by flood control efforts of the City. However, despite these efforts, the projection line would indicate that supply again will be inadequate by 2050. Also, it is important to note that the water production projections include the existing 40 MLD that the District presently purchases from a private provider.

Temperature and Rainfall Projections

Given the historical temperature and precipitation variability in the past 30 years, the figures that follow, Figure 25 and Figure 26, present the changes in temperature and rainfall in 2020 and 2050. The forecast has been generated employing the linear regression method.

The said figures indicate increase in both maximum temperature and rainfall in all months of the year in 2020 and 2050, except for the months of April and May. Comparatively, these are the months of the year with the hottest temperature and least rainfall. In greatest increase in temperature is forecast to happen in the months of June and August come 2050 where temperatures are seen to be as high as 36°C. This is about 4°C higher than present temperature level. The month of December, which usually starts the colder temperature, will tend to rise by about 2°C in 2050. Rainfall forecasts also show escalating rates but not as high as the temperature. Biggest increase in temperature volume is forecast to occur in the month of December but is forecast to decrease in the month of August in 2050.These projections coincide with the projections of the Manila Observatory (October 2015) which says that the projected 2025 mean increase in temperature from the baseline is approximately 1.2°C and around 2.0°C in 2050. Further, said study projects that the mean temperature in the City would be highly variable and this could result in warmer nights and even hotter days.

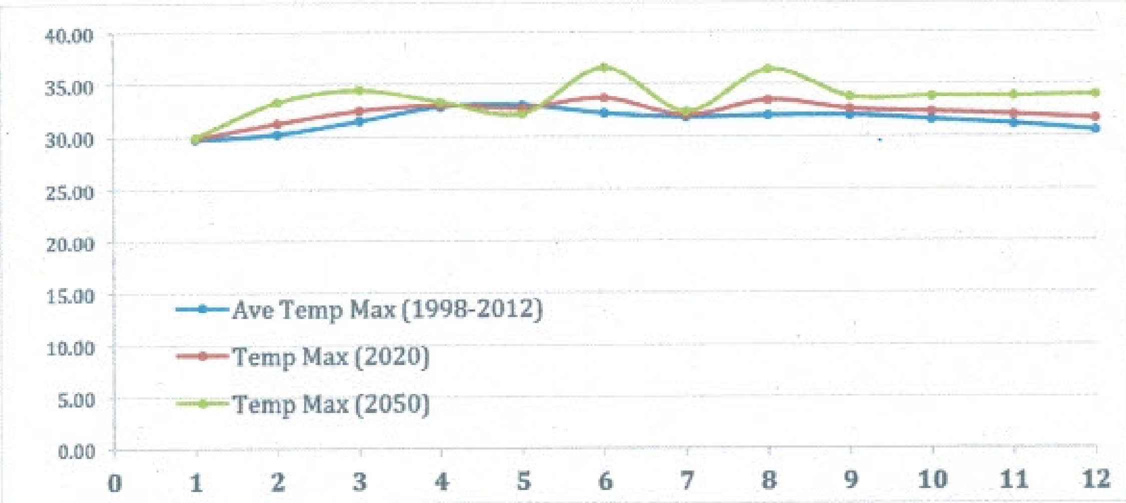


Figure 25
Maximum Temperature Variability
(1998-2012, 2020 & 2050)

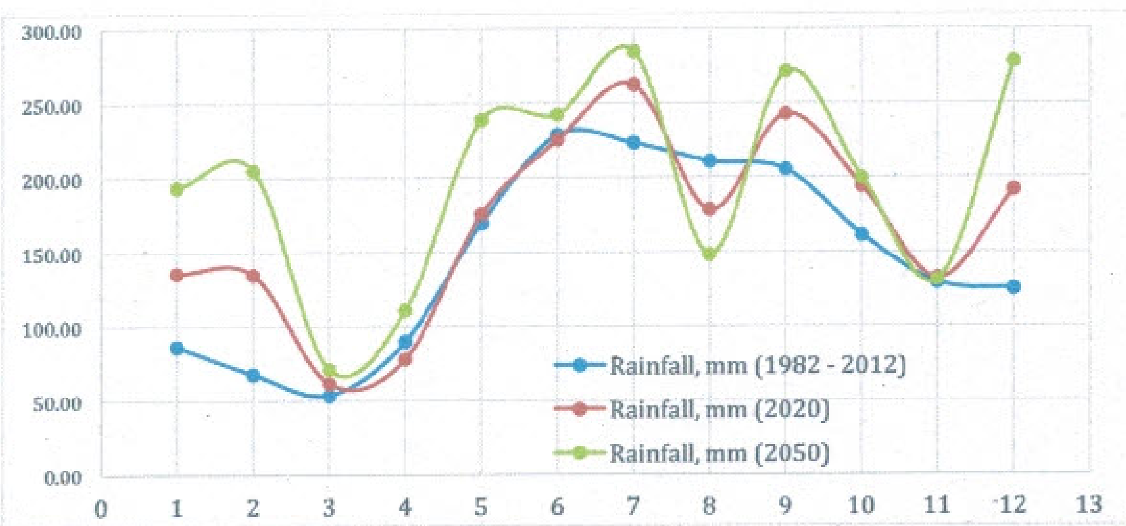


Figure 26
Total MonthlyRainfall Variability
(1998-2012, 2020 & 2050)

The Figure above illustrates the rainfall monthly variability from 1982 to 2050. Projection data suggest that the rainfall amount in 2050 would be lesser in the months of August and November. However, in general, precipitation is projected to escalate decade after decade. More rain will be expected even on drier months like December to May. Moreover, according to the Manila Observatory (October 2015), the rainfall in 2025 and 2050 will be higher than the baseline mean, although precipitation will tend to decrease from 2011 to 2065.Specifically, the month of November is expected to experience drastic decline in precipitation across all decades until 2065. Throughout the projection period, according to the study, Cagayan de Oro is projected to be wetter from 2011 to 2040.

Locations of the COWD Facilities Relative to the Flood Map of the City

The Philippine Government has planned for a river control infrastructure protecting the lowlands from similar fate the City suffered in 2011. Two of the existing COWD production wells will be most likely affected. These are PW9 and PW19. In addition, Appendix 11tabulates the locations and geo-referencesof COWD major production wells and and booster stations, including the Office building and laboratory located with the Macasandig Booster Station. The same table-appendix shows the distance of these facilities from a body of water, which could be a risk to flooding, especially during heavy rainfall from upstream and/or at the lowlands. These facilities are shown in Figure 4 of this report. It could be glimpsed from this table that 5 facilities are located within less than 100 meters from the river bank or creek. Another 14 of these major facilities are situated within 100 to 400 meters from the water body; 7 within the next 600 meters; only 3 are beyond 700 up to less than 1 km and only 1 located a little more than a kilometer away from the Cagayan de Oro River.

It may be important to note though that among the five (5) bodies of water that are of proximity to the COWD wells and other facilities, only the Cagayan de Oro River has recorded swelling that inundated production facilities. The said river is the biggest of the five (5). The wells in Balulang and Macasandig areas are located on the opposite banks of the Cagayan de Oro River. The farthest wells from the Cagayan de Oro River in these both well fields are PW 27 in Balulang and PW 8 in Macasandig. The wells in Balulang are, on the average, nearest to the respective surrounding body of water, at a mean distance of about 163 meters and standard deviation of about 97 meters. In fact, this is the well field that is most homogeneous in terms of distance from the surrounding body of water.

In terms of elevation, the Macasandig well field reflects the wells that, on the average, have lowest eleveation, at 9.3 meters and standard deviation of about 3 meters. PW 9 in Macasandig has the lowest elevation of about 3.25 meters. The Bugo and Calaananwells appear to have the safest elevation level and distance from surrounding dangerous bodies of water. Moreover, the body of water that is of proximity to Bugo is a smaller river while that of Calaanan is a small creek. The Balulang and Macasandig well fields appear to be the ones bearing the highest risks against flooding.

Even before that disastrous event in 2011, climate projections for Cagayan de Oro have included identification of the flood plains of the City, in general. For instance, the 50 - year flood map of the City would indicate that about 5 wells in the Macasandig area, including the major booster station and at least 3 wells in Balulang are expected to be covered in flood waters deeper than 1.5 meters. These are the wells also that will be affected by the flood control program of the Government. However, the 25 – year flood map suggests that all facilities of the District are safe from major floods.

COWD does not have a treatment facility except for the laboratory located in the same place where the major booster station in Macasandig is also located. However, all three booster stations and all directly – fed to the distribution wells are equipped with chlorination facilities to ensure the potability of supply. This is so because the District is utilizing primarily the groundwater as source. The surface water source is purchased in bulk from a private company that logically owns the needed treatment facility for the surface water.

Hazard & Risk Assessment of Facilities

A vulnerability assessment was run to determine the hazards and risks that water system sustains. The hazard assessment and risk prioritization rating utilized a 3-point scale where 3 is for high vulnerability, 2 for medium and 1 for low. The details of the spreadsheet of the assessment is attached as Appendix12 while the summary of such is presented as Table 6 in this report. As shown in said Table 6, there are 14 threats that have been assessed to affect the water sources, water supply at the distribution level and financial health of the District. All the 14 threats with 28 corresponding adaptation options identified have been considered for implementation in 2016. Similarly, these adaptation options are aligned with the strategic goals of the District. The vulnerability assessment and the identification of the corresponding adaptation options will have to undergo evaluation and review on a yearly basis.

It is striking to note that the District's water system is most vulnerable to inadequate water supply due to high NRW. This is not necessarily climate – related but is certainly aggravated by the adverse impacts of climate change. The NRW level at the moment is alarming at about 53%, which when converted to volume of water wasted would amount to about 80 MLD. This volume could already have supplied another 80,000 more new connections. There are 3 adaptation options identified to address this risk: reduction of NRW at specific area in Macabalan, which has recorded a NRW of more than 80%; establishing a GIS; and managing 21 identified District Metering Areas (DMAs). Of these three (3), managing existing DMAs scored highest; second is the establishment of a GIS. Both yield high returns in terms of savings in avoidable cost per unit vulnerability index. The implementation of these adaptation measures contribute to the attainment of the District's goal to reduce NRW level. All of these adaptation measures are given priority for immediate implementation.

Second in the rank is still not climate related but another NRW- caused threat. The NRW of COWD jeopardizes the financial condition of the District resulting to decrease in revenue generation. Four adaptation measures shall be implemented to reduce the risk: replacement of aged small and big water meters; conduct of survey of disconnected accounts implement applicable fix cutting policies; and conduct of post inspection of disconnections, reconnections and new connections. These adaptation options focus to redress the financial impacts of the NRW and are similarly given priority for speedy implementation.

The third ranked risk is shared by 6 threats to both the water source at the production wells and the water supply at reservoirs and storage facilities. Three of these 6 threats are climate – related while the other 3 are caused by human malpractices. Those that are climate related include the intrusion of contaminants due to flooding of at least 9 wells located within the flood zone (climate-related); salt water intrusion in all wells; and 3 wells affected by the river control project of the Government. On the other hand, the non – climate related threats are intrusion of domestic wastes due to increasing population density around, at least, 3 wells; vandalism at wells due to absence of fence; and possible contamination at reservoirs and storage facilities through open vents and manholes. The other six threats are all non-climate related except for one, which is possible damage in reservoirs due to underground movement and/or landslide, which may be triggered by flooding.

There are five (5) measures that are due for implementation to address the climate-related threats to water sources. These measures are all directed to contribute to the District's goal of ensuring water safety and climate change resiliency and to deliver reliable 24 – hour water supply. The easiest and least costly options are the sealing of all well openings, conduct of monthly bacteriological test and salinity test at the sources, in the short term, drilling of new site wells to address reduction in supply due to possible relocation of wells affected by a Government project and exploring options for alternative water sources in the long term.

Similarly, adaptation measures are identified for implementation to attend to threats on sources, which are more man – caused rather than climate – related. For instance, the District shall have to commence exploring options to engage in septage management, at the least, condemn septic tanks and instead install portable toilets at production wells, secure wells and reservoirs with perimeter fence to deter entry of unscrupulous individuals who would possibly vandalize sources, and seal all openings in these storage facilities.

The fourth ranking threats are occurring at the distribution level concerning water quality due to low pressure and inadequate treatment. The other threat of same rank is taking place at storage and water production facilities and concerns about their structural stability due to possible occurrence of calamities like landslides, earthquakes and strong winds. The threats on water quality at the distribution level is rather crucial despite ranking much lower. The adaptation measures that are identified to address these threats contribute to the attainment of the District's goal of reducing NRW and ensuring water safety and climate change resilience at the same time. The initiatives addressing water quality issues include selective mainline replacement, keeping chlorine residual at no less than 0.30 ppm at the farthest end of the distribution network, rehabilitation of service lines and regular conduct of information drive on water quality issues. On the other hand, efforts on hardening structures against calamities like strong wind, earthquakes and landslides shall also be pursued.

The last three threats are still on water quality issues both at the sources and distribution network. These concerns can be resolved by sealing of all openings, provision of additional chlorinating facility and ensure adequate flushing out of water and increasing dosage of chlorine when necessary after pipe repairs. All these initiatives are aligned with COWD's strategic goal of ensuring water safety and climate change resilience.

TABLE 6

Summary of the Risks of the Facilities

No.	Threat	Adaptation Option	Adapt Score	Adapt Rank	Strategic Goals
1	inadequate water supply due to high Non Revenue Water (NRW)	• *Reduce NRW% @ Macabalan DMA* • *Manage the Twenty One (21) DMAs* • *Establish GIS*	*-6.537* *-23.637* *-13.841*	*8* *4* *6*	• *Reduce Non-Revenue Water (NRW)* • *Access Appropriate Technology & Information*
2	inadequate revenue generation due to high Non Revenue Water (NRW)	• *Program on Replacement of 1/2"Ø Water Meter (40,000)* • *Implement Program on Replacement of Water Meter (big meters)* • *Conduct survey and implement applicable fix cutting of service connections (based on CY 2013-2015 Inactive Accounts)* • *Post Inspection of Disconnection, Reconnection & New Connection*	*-52.006* *-18.860* *-0.050* *-10.332*	*2* *5* *20* *7*	• *Reduce Non-Revenue Water (NRW)*
3	Intrusion of contaminants due to flooding for PW nos. 1,,4,7,9,14,16,19,24,25	• *Sealing of all openings* • *Conduct bacteriological test*	*-1.724* *-0.019*	*10* *23*	• *Ensure Water Safety & Climate Change Reseliency*
4	intrusion of domestic wastes due to increasing population density around PWs 8, 25, 27	• *Septage Management (desludging)* • *Installation of Portalet*	*-0.031* *-0.012*	*21* *25*	• *Ensure Water Safety & Climate Change Reseliency*
5	Vandalism of PW #8, #21 & #22 due to absence of fence	• *Secure Production Wells with perimeter fence*	*-0.597*	*12*	• *Ensure Water Safety & Climate Change Reseliency*
6	Salt Water Intrusion	• *Implement the Climate Change Adaptation Program (Focus on monitoring of water level and danger of saltwater intrusion to PWs)*	*-34.552*	*3*	• *Ensure Water Safety & Climate Change Reseliency*
7	3 PWs affected by river control project of Government	• *Relocate three (3) wells* • *Develop alternative water source*	*-53.339*	*1*	• *Deliver Reliable 24-Hour Water Supply*
8	Intrusion of contaminants thru open utility manhole and vents due to vandalism, sabotage or other possible mean of entry	• *Secure all manholes & vents of all storage facilities* • *Assessment of all storage facilities as to security concerns (for installation of perimeter fence and or assignment of security personnel/guards)*	*-0.013* *-0.024*	*21* *22*	• *Ensure Water Safety & Climate Change Reseliency*

No.	Threat	Adaptation Option	Adapt Score	Adapt Rank	Strategic Goals
9	Intrusion of contaminants during low pressure due to deteriorated pipes submerged in canals & drainages	• *Selective mainline rehabilitation/replacement . Maintain pressure in the system* • *Conduct Bacteriological test on all Production Wells* • *Maintain 0.30 PPM Chlorine Residual @ Macasandig Booster Pumping Station* • *Regular information Drive on Intrusion of contaminants* • *Implement Rehabilitation of " After the Meter" existing service connections at Tabako, Puntod/Lapasan with possible Intrusion of contaminants*	-1.129 0.176 -0.356 -0.086	11 27 14 19	• *Reduce Non-Revenue Water (NRW)* • *Ensure Water Safety & Climate Change Resiliency*
10	water quality issue due to tapping of service connection lines at raw water line	• *Transfer all the tapped service connections*	-0.092	18	• *Ensure Water Safety & Climate Change Resiliency*
11	Facility damage upon underground movement due to landslide, flood and/or earthquake	• *Implement rehabilitation plan on all storage facilities as to safety against calamity* • *Hardening of existing structure (control panels, roofing, windows, doors, macasandig BS & PW#1*	-0.571 -0.200	13 16	• *Ensure Water Safety & Climate Change Resiliency*
12	Intrusion of contaminants by vandalism thru openings *in the ff PWs:* 2,3,5,8,10,11,15,17,18,20,21,22,23,26,27,28,29	• *Sealing of all openings*	-4.695	9	• *Ensure Water Safety & Climate Change Resiliency*
13	water quality issue due to inadequate disinfection for PW #18,19, no chlorinating unit	• *Install Chlorinating Unit*	-0.244	15	• *Ensure Water Safety & Climate Change Resiliency*
14	contamination due to intrusion of contaminants during conduct of repair of motors, pumps & other appurtenances.	• *Conduct flushing every after repair* • *SOP on repair & maintenance*	-0.130	17	• *Ensure Water Safety & Climate Change Resiliency*

Chapter 3

Conclusions and Recommendations

One major conclusion of this vulnerability assessment is that the District's biggest threat at the moment is the inadequacy in water supply at the distribution level because of the very high NRW, which is not at all climate related. However, the NRW is very much adversely affected by the effects of climate change in many ways. With increases in temperature projections, decrease in precipitations and becoming stronger and more frequent typhoons subject the water supply to even more threats in addition to dwindling flow due to losses. Therefore, it is imperative that the District should take aggressive initiatives to address the NRW problem above all else. The adaptation options which are immediate are to construct and monitor district metering areas (DMAs). These are also logically, the first steps to addressing the NRW after or, at least, alongside with the establishment of a Geographic Information System (GIS). All these three adaptation options shall cost the District around Php90M against total cost of damage and rehabilitation costs of more than Php610M.

Another major and important conclusion of this assessment is based on the fact that the City has been experiencing more frequent and stronger typhoons exposing major sources to threats of flooding. There are a number of adaptation options to address these threats. The option with highest adaptation score happens to require a huge investment cost. However, third in the rank is a very simple, quick, easy and the least costly to undertake yet very effective adaptation option, and that is the sealing of all openings of each flood - prone well. Therefore, this can be acted upon immediately before other options.

All those identified 28 adaptation options will have to be incorporated in the District's Business Plan to ensure that the 14 threats similarly identified will be addressed. By so doing, the District will be saved from avoidable prolonged adverse impacts of climate and non-climate hazards. Putting into action these adaptation plans starts at their inclusion in the Business Planning. The actual implementation of the Business Plan will be another story of challenges and successes. Notwithstanding challenges, majority of these adaptation measures are for implementation in 2016 as shown in Table 7 that follows.

Table 7
Status of the Adaptation Measures

No.	Threat	Adaptation Option	
1	inadequate water supply due to high Non Revenue Water (NRW)	• *Reduce NRW% @ Macabalan DMA* • *Manage the Twenty One (21) DMAs* • *Establish GIS*	• *Formed the DMA & now preparing program of works for rehab* • *Procuring meters* • *On going data gathering; procured hardware & software with Grant from USAID BeSecure & Cocacola Foundation*
2	inadequate revenue generation due to high Non Revenue Water (NRW)	• *Program on Replacement of 1/2"Ø Water Meter (40,000)* • *Implement Program on Replacement of Water Meter (big meters)* • *Conduct survey and implement applicable fix cutting of service connections (based on CY 2013-2015 Inactive Accounts)* • *Post Inspection of Disconnection, Reconnection & New Connection*	• *Procurement of meters* • *Finalizing standard layout design with assistance from BeSecure Project* • *Currently implemented* • *Currently implemented*
3	Intrusion of contaminants due to flooding for PW nos. 1,,4,7,9,14,16,19,24,25	• *Sealing of all openings* • *Conduct bacteriological test*	• *Currently implemented*
4	intrusion of domestic wastes due to increasing population density around PWs 8, 25, 27	• *Septage Management (desludging)* • *Installation of Portalet*	• *Preparing proposal for possible JV with grant from BeSecure Project* • *For implementation this year (2016)*
5	Vandalism of PW #8, #21 & #22 due to absence of fence	• *Secure Production Wells with perimeter fence*	• *For inclusion in 2017 budget*
6	Salt Water Intrusion	• *Implement the Climate Change Adaptation Program (Focus on monitoring of water level and danger of saltwater intrusion to PWs)*	• *For implementation this year (2016)*
7	3 PWs affected by river control project of Government	• *Relocate three (3) wells* • *Develop alternative water source*	• *For validation prior to implementation in 2 years time* • *Conduct of FS within the year (2016) by grant of USAID BeSecure*
8	Intrusion of contaminants thru open utility manhole and vents due to vandalism, sabotage or other possible mean of entry	• *Secure all manholes & vents of all storage facilities* • *Assessment of all storage facilities as to security concerns (for installation of perimeter fence and or assignment of security personnel/guards)*	• *For implementation this year (2016)* • *For implementation this year (2016)*

No.	Threat	Adaptation Option	
9	Intrusion of contaminants during low pressure due to deteriorated pipes submerged in canals & drainages	• *Selective mainline rehabilitation/replacement* • *Maintain pressure in the system* • *Conduct Bacteriological test on all Production Wells* • *Maintain 0.30 PPM Chlorine Residual @ Macasandig Booster Pumping Station* • *Regular information Drive on Intrusion of contaminants* • *Implement Rehabilitation of " After the Meter" existing service connections at Taboko, Puntod/Lapasan with possible intrusion of contaminants*	• *Implementation per DMA formation* • *For implementation this year (2016)* • *For implementation this year (2016)* • *For implementation this year (2016)* • *For implementation this year (2016)*
10	water quality issue due to tapping of service connection lines at raw water line	• *Transfer all the tapped service connections*	• *For implementation this year (2016)*
11	Facility damage upon underground movement due to landslide, flood and/or earthquake	• *Implement rehabilitation plan on all storage facilities as to safety against calamity* • *Hardening of existing structure (control panels, roofing, windows, doors, macasandig BS & PW#1*	• *Structural evaluation this year (2016)* • *For implementation in 2017*
12	Intrusion of contaminants by vandalism thru openings in the ff PWs: 2,3,5,8,10,11,15,17,18,20, 21,22,23,26,27,28,29	• *Sealing of all openings*	• *For implementation this year (2016)*
13	water quality issue due to inadequate disinfection for PW #18,19, no chlorinating unit	• *Install Chlorinating Unit*	• *For implementation this year (2016)*
14	contamination due to intrusion of contaminants during conduct of repair of motors, pumps & other appurtenances.	• *Conduct flushing every after repair* • *SOP on repair & maintenance*	• *For implementation this year (2016)*

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