NRW MANAGEMENT STRATEGY

Final draft

Technical Assistance to Cagayan De Oro City Water District on Non-Revenue Water Reduction Strategy and Implementation

Subcontract Agreement No. 893-S15-013



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Acronyms and Abbreviations

ALC	Active Leakage Control (proactive regular leak detection)
AWB	Annual Water Balance
CDO	Cagayan de Oro
COWD	Cagayan de Oro City Water District
DBP	Development Bank of the Philippines
DMA	District Meter Area
GIS	Geographic Information System
HR	Human Resources
iBox	Fiberglas instrumentation box with solid installation and heavy duty protection
ILI	Infrastructure Leakage Index (a physical loss performance indicator)
IWA	International Water Association
LoS	Level of Service (hours of supply and available pressure)
MAPL	Minimum Achievable annual volume of Physical Losses
PMP	Pressure Monitoring Point
PRV	Pressure Reducing Valve
SMS	(Level of) Service Monitoring System
TESDA	Technical Education and Skills Development Authority
USAID	United States Agency for International Development
VFD	Variable Frequency Drive
VSD	Variable Speed Drive

Content

1 Executive summary

For years, COWD is aware of its high NRW and has the intention to do something against it. Several small efforts have been made like getting technical assistance through Water Operator Partnerships or, most recently, a JICA funded study.

However, there was always a lack of expertise, no comprehensive strategy and, last but not least, no funding. Therefore, NRW levels are high and would remain high, even increase, without a well-planned and comprehensive strategy.

Through investigations, data gathering, execution of flow and pressure measurements, customer meter testing, bulk meter check measurements and many further activities, carried out jointly by Mia and COWD, have led to a good understanding of COWD's NRW situation and made the establishment of a robust water balance possible.

The volume of NRW is around 100,000 m3/day which is equivalent to 58% of the daily system input volume which means that 58% of the water produced or purchased from Rio Verde is lost without generating any revenues.

The annual cost/value of NRW has been calculated to be PHP 494 million which is equivalent to 81% of COWD's operating cost. The two main financial components[1] of NRW are:

- Lost revenue caused by commercial losses:
    - PHP 209 million
- High production cost and lost opportunity for additional sales caused by high physical losses
    - PHP 267 million

Physical losses account for 82% of the volume of NRW. Physical loss performance indicators have been calculated and show that COWD's physical losses are 10 times as high as you would assume from a well-managed water utility in a low or middle income country.

The single most important factor for the high level of physical losses is the inferior quality of the service connections combined with poor quality materials and repairs.

Commercial losses are predominately caused by the significant under-registration of the small (DN 15mm) customer meters which are responsible for more than 90% of COWD's billed volume. The average meter under-registration is 18% which causes massive financial losses. After the implementation of a well targeted customer meter replacement program COWD's revenues would increase by around PHP 150 million annually.

Quantifying the impact of the different NRW reduction interventions a NRW forecast for 2017-2026 has been prepared. After successful implementation of the program, NRW in 2016 could be as low as 25,000 m3/d – a reduction by 75%.

Investments of PHP 2.5 billion will be required to achieve this target, but the financial benefits to COWD from increased revenues and reduced production cost exceed this number by far, they were calculated to be in the order of PHP 3.5 billion, leafing a financial net benefit of around PHP 1 billion.

COWD is not in a position to implement such a program on its own, different implementation options are briefly discussed so that the COWD BOD has a basis for a decision how to proceed.

[1] The remainder of the amount (PHP 18 million) is caused by unbilled unmetered consumption which is non-recoverable.

2 Water Balance and Water Loss Performance Indicators

2.1 Input Values and Underlying Assumptions

It was not possible to establish robust water balances separately for the east and west part of COWD's supply system as the main valve, which separates the two systems, was not tight and has only been replaced recently.

Therefore, the water balance and the water loss PIs are referring to the entire COWD system.

2.1.1 System input volume

The accuracy of the system input volume is most important for the accuracy of the water balance. COWD and Miya have made considerable effort to check all water production meters and their accuracy. Detailed information can be found in the relevant report (0). The results are summarized in Table 1 which shows that COWD's reported supply data are significantly below the actual situation.

Table 1: Supply meter error and adjusted system input volume

Supply meters	Supply meter error	System input volume[2] (m3/year)	Adjusted annual system input volume (m3/year)
Balulang Booster (Carmen Line)	-2.8%	3,649,410	3,754,969
Balulang Booster (Bulua Line)	-7.9%	5,589,587	6,071,987
Bugo Booster	13.4%	5,512,350	4,860,093
Macasandig Old Booster Bank #1	-29%	5,685,558	8,005,439
Macasandig Old Booster Bank #2	4.3%	8,685,766	8,329,760
Production Well #5	28.3%	1,148,286	895,281
Rio Verde (RVWC)	-19.8%	14,653,080	18,261,482
	Total	**44,924,037**	**50,179,011**

As a next step, confidence levels were established for each of the water production meters. And while some of the meters are unreliable or not working at all, the overall confidence limit is 1.7% only, which gives confidence that the total system input volume of 63.21 million m3 per year is a fairly accurate number.

Data in Table 2 has been used for the water balance.

[2] COWD Supply Data 2015

Table 2: Uncertainty Limits of COWD Supply Meters (at 95% Confidence Interval)

Supply meters	Adjusted system input volume (m^3/year)	Uncertainty limit at 95% confidence interval	General remarks
Balulang Booster (Carmen Line)	3,754,969	±3.0%	Adjusted
Balulang Booster (Bulua Line)	6,071,987	±4.3%	Adjusted
Bugo Booster	4,860,093	±4.9%	Adjusted
Macasandig Old Booster Bank #1	8,005,439	±4.4%	Adjusted
Macasandig Old Booster Bank #2	8,329,760	±3.6%	Adjusted
Production Well #5	895,281	±3.6%	Adjusted
Rio Verde (RVWC)	18,261,482	±3.8%	Adjusted
Macasandig New Booster	199,539	±2.4%	No adjustment (Facility is not in use)
Production Well #18	179,335	±28.5%	No adjustment (Defective Converter)
Production Well #15	0	±39.9%	No adjustment (Not in use/No converter)
Production Well #10A	1,040,545	±40.1%	No adjustment (Defective Converter)
Production Well #24	725,940	±40.7%	No adjustment (No Converter)
Production Well #11	3,327,942	±3.1%	No adjustment
Production Well #23	3,354,915	±2.8%	No adjustment
Production Well #28	1,879,136	±2.7%	No adjustment
Production Well #29	2,185,240	±2.7%	No adjustment
Malasag Spring	59,564	±40%	Unmetered
Production Well #10	73,843	±2.5%	Decommissioned
Total	**63,205,011**	**±1.7%**	

2.1.2 Billed consumption

The total volume of billed consumption (=billed volume) was calculated based on a detailed analysis of COWD's billing data and agreed with/approved by COWD.

- Billed metered consumption: 25,625,707 m^3/year
- Billed unmetered (estimated) consumption: 870,868 m^3/year

2.1.3 Unbilled consumption

Unbilled metered consumption

At COWD there are no metered customers that are unbilled.

Unbilled unmetered consumption

Unbilled unmetered consumption is normally a very small component in the water balance. An internationally acceptable provision of 0.8% of the total system input was assumed to calculate the annual volume (505,640 m^3/year, +/- 50%) used for firefighting, mains flushing, and other unmetered but authorized water use. 0.8% is a generous allowance.

2.1.4 Commercial losses

Unauthorized consumption

The level of unauthorized, or illegal, consumption is of course not exactly known and therefore assumptions have been made.

During the ongoing customer census, no indications for a large illegal connection problem were found. The assumptions in

Table 3: Unauthorized consumption estimates

Category	Number	Accuracy estimate	Daily volume per connection (l/d)	Total volume (m3/year)
Residential illegal connection	2,000	+/- 50%	400	292,000
Non-residential illegal connection	200	+/- 50%	2,000	146,000
Customer meter tampering	4,000	+/- 50%	200	292,000
Total		**+/- 30%**		**730,000**

Customer meter inaccuracies and data handing errors

A thorough review of COWD's customer meters has been undertaken including bench testing of a large sample of customer meters. Detailed information can be found in 0.

The main finding is that COWD's customer meters are significantly under-registering:

- DN 15mm customer meters: -18.0%
- All other meters on average - 7.6%

Using these numbers, system-wide under-registration has been calculated to be 5.3 million m3 per year.

Table 4: Customer meter under-registration

Meter size	Billed volume (m3/year)	Metering error	Volume not measured (m3/year)	Confidence interval
DN 15 mm	23,510,321	- 18.0%	5,160,802	+/- 5%
> DN 15 mm	2,115,386	- 7.6%	174,108	+/- 20%
Total			**5,334,910**	**+/- 4.9%**

2.1.5 Distribution network

Length of mains

The total length of the COWD water distribution network (except service connections) is 550,5 km according to COWD's records.

Number of service connections

The number of service connections at COWD is not known and will only be known once the GIS has been completed. Therefore, the number of connections had to be estimated.

Table 5: Number of service connections

	Number of accounts	Ratio	Number of connections	Confidence interval	Comment
Active accounts	87,823	60%	52,694	+/- 10%	The ratio of 60% is based on the results of the customer census
Illegal connections			2,200	+/- 50%	As per the estimate made in Table 3
Existing connections from inactive accounts			6,000	+/- 50%	The large number of inactive accounts has not yet be analyzed and investigated by COWD. But 6,000 +/- 50% is a realistic assumption
Total			**60,894**	**+/- 10%**	

2.1.6 Average pressure

A pressure monitoring program has been carried out. In a total of 82 locations throughout the distribution system, pressures have been logged for 7 days.

The weighted average pressure (during supply hours) has been calculated to be 22.9 psi (16.1-meter head).

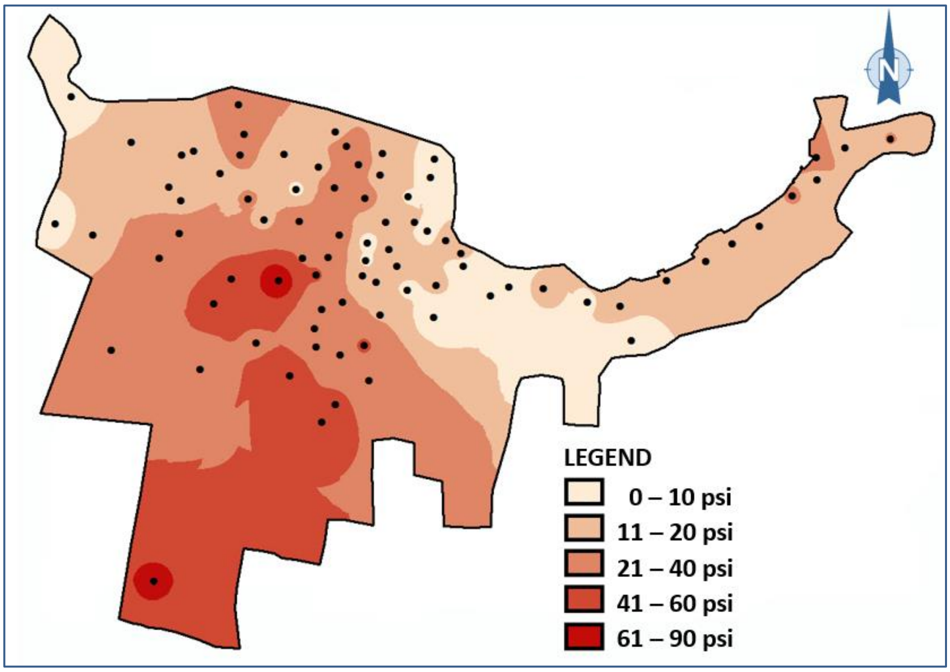

Figure 1: Average operating pressure map of COWD

2.1.7 Average supply time

The pressure measurements have also been used to calculate the average supply time is 22.5 h/d.

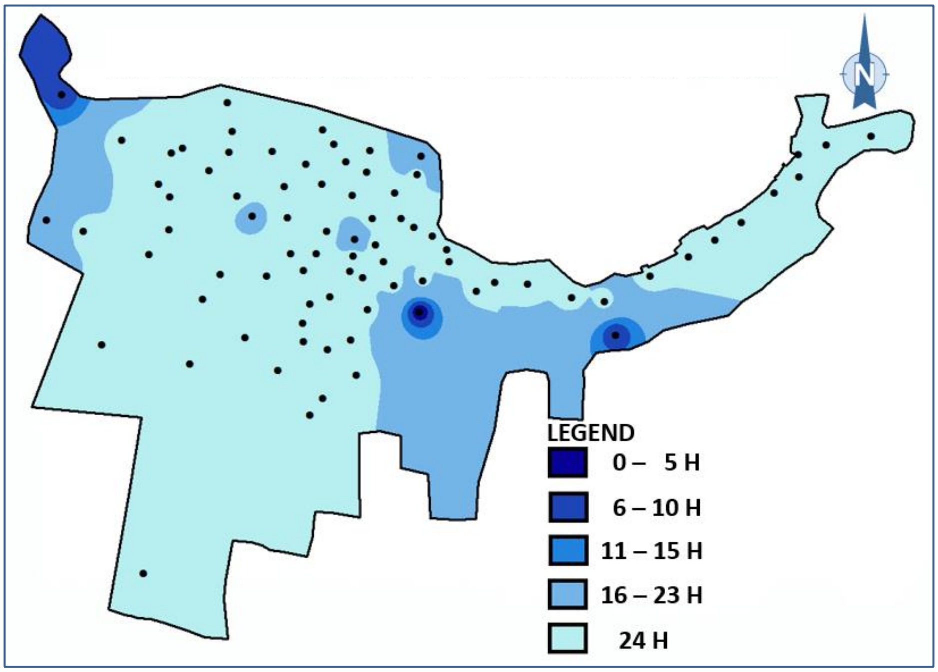

Figure 2; Average supply time map of COWD

2.1.8 Financial data

The average tariff was calculated to be PHP 34.5 per m^3.

COWD basically has two different cost structures when it comes to water production:

- Its own sources, with variable (marginal) cost of PHP 5.84/m3; and
- Bulk supply from Rio Verde which is higher (PHP 10.4) but is not variable since a minimum volume is guaranteed.

It has therefore been decided to conservatively value the volume of physical losses with PHP 5.84 per m3.

However, it was estimated that some 8,700 m3/d could be immediately sold to new (resettlement areas, natural growth) or existing customers and these were valued with the average tariff.

The total annual operating cost in 2015 (without depreciation) were PHP 607,557,121.

2.2 Results

2.2.1 Water balance

<table>
<tr><td rowspan="7">System Input Volume

173,164 m3/d
(+/- 1.7%)</td><td rowspan="4">Authorized Consumption

73,979 m3/d
(+/- 1%)</td><td rowspan="2">Billed Authorized Consumption

72,593 m3/d</td><td>Billed Metered Consumption
70,207 m3/d</td><td rowspan="2">Revenue Water

72,593 m3/d</td></tr>
<tr><td>Billed Unmetered Consumption
2,386 m3/d</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption

1,385 m3/d
(+/- 50 %)</td><td>Unbilled Metered Consumption
0 m3/d</td><td rowspan="5">**Non-Revenue Water**

100,571 m3/d
(+/- 3%)</td></tr>
<tr><td>Unbilled Unmetered Consumption
1,385 m3/d (+/- 50 %)</td></tr>
<tr><td rowspan="3">**Water Losses**

99,186 m3/d
(+/- 3 %)</td><td rowspan="2">**Commercial Losses**

16,616 m3/d
(+/- 6 %)</td><td>**Unauthorized Consumption**
2,000 m3/d (+/- 30%)</td></tr>
<tr><td>**Customer Meter Inaccuracies and Data Handling Errors**
14,616 m3/d (+/- 5%)</td></tr>
<tr><td colspan="2">**Physical Losses**
82,570 m3/d (+/- 4 %)</td></tr>
</table>

Figure 3: COWD 2015 water balance

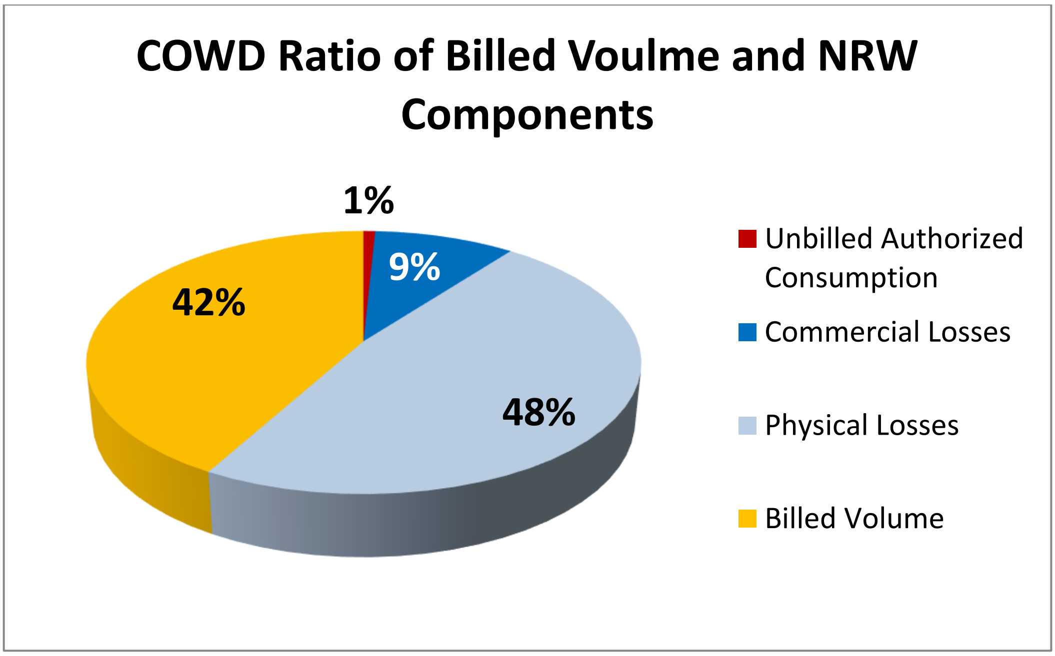

Figure 4 : COWD 2015 Water Balance Pie Chart

2.2.2 Water Loss Performance Indicators

The comparison in Table 6 shows that

- Physical losses are nearly 10 (!) times as high as in well managed water utilities in low and middle income countries; and
- Commercial losses are around 3 times as high.

Table 6: COWD water loss performance indicators and international comparison[3]

	Indicator	COWD	Range	Acceptable[4]	Good[5]	World Class[6]
NRW	Liters/Service Connection/Day (w.s.p.)	**1,762** (+/- 10%)	1,578 – 1,945	410	240	<50
	Value of NRW as % of operating cost	**81%** (+/- 3%)	79% – 84%			
	Volume of NRW as % of system input volume	**58%** (+/- 3%)	56% – 60%			
Physical Losses	Liters/Service Connection/Day (w.s.p.)	**1,446** (+/-11%)	1,290 – 1,603	250	150	<40
	Infrastructure Leakage Index (ILI)	**93** (+/-10%)	84 – 104	12	6	<1.5
Commercial Losses	Percentage of authorized consumption	**22%** (+/-7%)	21% – 24%	16%	9%	<2.5%
	Liters/Service Connection/Day	**273** (+/- 12%)	241 – 304	160	90	<25

[3] under similar pressure conditions
[4] only for low and middle income country situations
[5] would already be on the high side in Europe and very high in Australia
[6] Australia average

2.2.3 Financial result analysis

The annual cost/value of NRW has been calculated to be PHP 494 million which is equivalent to 81% of COWD's operating cost. The two main financial components of NRW are:

- Lost revenue caused by commercial losses:
  - PHP 209 million
- High production cost and lost opportunity for additional sales caused by high physical losses
  - PHP 267 million

The remainder of the amount (PHP 18 million) is caused by unbilled unmetered consumption which is non-recoverable).

3 Analysis of the NRW reduction potential

3.1 Reduction of commercial Losses

3.1.1 Improvement of customer meter accuracy

The volume of commercial losses amounts to 6 million cubic meters per year, around 9% of the total system input volume. The biggest part of it is caused by customer meter under-registration (5.3 M m3 per year) and only around 700.000 m3 is due to unauthorized consumption.

Lost revenue because of old, under-registering customer meters amounts to PHP 184 million per year. This is equivalent to 30% of COWD's annual operating cost.

Table 7: Details on losses through customer meter under-registration

Meter diameter	Billed volume (m3/a)	Meter under-registration	Lost billed volume (m3/a)	Lost revenues[7] (PHP million per year)
DN 15 mm	23,510,321	18.0%	5,160,802	178
> DN 15 mm	2,115,386	7.6%	174,108	6
Total	**25,625,707**		**5,334,910**	**184**

As can be seen in Table 7, the main problem are the small diameter (DN 15mm) customer meters. Based on extensive meter testing, the most economic meter age has been calculated to be 6 years. Therefore, COWD's customer meters should always be replaced when they reach this age. The problem is that at present more than 50% of all DN 15 mm meters are 6 years and more.

With a well targeted meter replacement program it will be possible to reduce the under-registration from 18% to 6% within five years. Significant investments will be required but the financial benefits are very attractive! With initial investments of PHP 67 million the positive cash flow will be PHP 194 after 5 years (see Table 8).

Table 8: Outline of a 5-year meter replacement program

	2017	2018	2019	2020	2021	Total
Number of meters to be replaced	20,000	20,000	15,000	10,000	10,000	75,000
Average meter under-registration	-17%	-13%	-10%	-7%	-6%	
Meter replacement cost (PHP M)	70	70	53	35	35	263
Additional revenues (PHP M)	12	61	103	130	150	457
Cash flow (PHP M)	-58	-67	-16	79	194	

Well targeted improvement of large customer meters will also generate maybe two million additional revenues but this is of course insignificant compared to the potential massive benefits from small meter replacement.

[7] Based on the average tariff of PHP 34.5 per m3

3.1.2 Reduction of unauthorized consumption

The first phase of the customer census gave no indication that COWD has a massive illegal connection problem. While illegal connections will be detected during the customer survey, no significant NRW reduction can be expected from these activities).

3.2 Reduction of physical Losses

About 100,000 m3/day, 48% of COWD's total system input is physically lost from the leaky distribution system.

Using the concept of "Physical Loss Component Analysis", the different leakage components were calculated and the volume of "Hidden Losses" (from unknown, undetected leaks) was calculated.

Two factors are important for this method:

- The leak run time – which is the sum of **A**wareness, **L**ocation and **R**epair time (**A**+**L**+**R**), and
- Leak flow rate

A+L+R time is the time from the occurrence of a leak until the repair is completed. COWD has good records of the leak repair time, but unfortunately these data only include the leaks which were repaired and not the leaks which for one reason or the other have not been repaired for a long time. Therefore, using COWD data (scenario 1, Table 9) the actual time is presumably higher. To overcome this problem a sensitivity analysis with two scenarios with much longer leak run times has been made (Table 10 and Table 11).

Table 9: Physical loss component analysis - scenario 1 (COWD data)

Number of leaks on:		Average A+L+R time (days)	Estimated flow rate (l/h)	Average supply time (h/d)	Average leakage volume (m3)	Total leak volume (m3/a)
Main pipes	60	0.62	1,700	22.5	24	1,426
Service Connections	4,000	2.87	500	22.5	32	129,150
Stub out or anything near SC	2,000	3.13	150	22.5	11	21,128
Hidden losses						**29,986,182**
Total annual volume of physical losses						**30,137,885**

Table 10: Physical loss component analysis - scenario 2 (longer A+L+R time)

Number of leaks on:		Average A+L+R time (days)	Estimated flow rate (l/h)	Average supply time (h/d)	Average leakage volume (m3)	Total leak volume (m3/a)
Main pipes	60	2	1,700	22.5	77	4,590
Service Connections	4,000	14	500	22.5	158	630,000
Stub out or anything near SC	2,000	14	150	22.5	47	94,500
Hidden losses						**29,408,795**
Total annual volume of physical losses						**30,137,885**

Table 11: Physical loss component analysis - scenario 3 (very long A+L+R time)

Number of leaks on:		Average A+L+R time (days)	Estimated flow rate (l/h)	Average supply time (h/d)	Average leakage volume (m3)	Total leak volume (m3/a)
Main pipes	60	2	1,700	22.5	77	4,590
Service Connections	4,000	30	500	22.5	338	1,350,000
Stub out or anything near SC	2,000	30	150	22.5	101	202,500
Hidden losses						**28,580,795**
Total annual volume of physical losses						**30,137,885**

For example, average leak run time of service connection bursts according to COWD data is 2.87 days. In scenario 2 average run time of 14 days has been used and in scenario 3 even unrealistic 30 days.

The difference in results is small: Volume of hidden losses according to COWD data would be 30 million cubic meters per year and in scenario 3 the figure is 28.6 million cubic meters. For further analysis, an average of 29.4 million has been used.

Water utility specific flow rates could be obtained through a leak flow rate measurement, estimation and recording program. But a good first assumption is to use the published average data (Table 12).

Table 12: Flow rates for reported and unreported breaks[8]

Location of break	Flow rate for reported breaks [liters/hour/psi pressure]	Flow rate for unreported breaks [liters/hour/psi pressure]
Main pipe	166	83
Service Connection	6	6

The volume of Hidden Losses gives now an indication of the number of leaks to be detected and repaired. The number can vary widely depending on the mix of mains bursts and service connection leaks.

This has been analysed by assuming different numbers of mains bursts (from 1 leak per kilometre of main, which would be 550 down to only 100 leaks) and the corresponding number of service connection leaks has been calculated. Results in Table 13 show that if mains bursts are between 100 and 550 then the number of service connection bursts is between 23,000 and 10,000.

Table 13: Hidden loss analysis

Leaks on mains		Leaks on service connections	
number	volume (m3/year)	number	volume (m3/year)
550	17,245,429	10,725	12,154,571
500	15,677,663	12,108	13,722,338
400	12,542,130	14,875	16,857,870
300	9,406,598	17,641	19,993,403
200	6,271,065	20,408	23,128,935
100	3,135,533	23,175	26,264,468

[8] Source: IWA Water Loss Specialist Group

Based on the hidden loss analysis and the planned interventions, the impact on the ILI[9] has been assessed and the ILI reduction forecasted. Using the ILI, the volume of physical losses has been calculated.[10]

Table 14: Physical loss reduction forecast

		2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Ongoing leak repair		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Sectorization		✓	✓								
DMA establishment		✓	✓	✓	✓						
Active leakage control		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Pressure management			✓	✓	✓	✓	✓	✓	✓	✓	✓
Service conn. replacement			4,000	4,000	4,000	4,000	4,000	3,000	2,000	1,000	1,000
Mains replacement	km		3	3	11	11	11	17	17	17	17
ILI		91	74	58	47	37	29	22	18	15	13
Volume of physical losses	**m3/d**	**82,716**	**69,341**	**57,615**	**49,510**	**41,690**	**32,913**	**26,035**	**21,314**	**18,827**	**16,306**

The results of the physical loss reduction forecast (Table 14) show that there is the potential to reduce physical losses by more than 65,000 m3/d.

3.3 NRW reduction forecast

Combining the forecasts for commercial and physical loss reduction, a 10-year NRW reduction forecast has been prepared. A summary of the results is shown in Table 15 on the following page and the complete forecast with all details can be found in Table 16.

After a successful 10 year NRW management program the situation in 2026 will look as follows:

- NRW reduced by 75%
- Even without any additional water source the growing demand can be met
- Assuming the connection of the relocation areas plus an annual 3% increase in the number of customers, billed consumption will increase by 52%
- Commercial losses will be reduced by 60%
- Physical losses reduced by 80%
- System input volume 22% below the present level

[9] ILI, Infrastructure Leakage Index, is an IWA recommended physical loss performance indicator. It is the ratio between the present volume of physical losses and the minimum achievable. In an ideal system with good leakage management the ILI would be 1. An ILI of 20 means that physical losses are 20 times the minimum. The present ILI of COWD is around 93.

[10] Annual network growth was assumed to be +3% service connections and +1% main pipes

Table 15: NRW forecast summary

		baseline	2026	change
Number of connections		60,894	85,029	+40%
Length of mains	km	551	633	+15%
Supply time	h/d	22.5	24	+7%
Average pressure	psi	23	23	+/- 0%
Billed authorized consumption	**m3/d**	**72,593**	**110,094**	**+52%**
Non-revenue water components:				
Unbilled authorized consumption	m3/d	1,385	1,862	+34%
Commercial losses	m3/d	16,616	6,673	-60%
Unauthorized consumptions	*m3/d*	*2,000*	*2,000*	*+/- 0%*
Meter under-registration	*m3/d*	*14,616*	*4,673*	*-68%*
Physical losses	m3/d	82,570	16,306	-80%
NRW	**m3/d**	**100,571**	**24,841**	**-75%**
System input volume	**m3/d**	**173,164**	**134,934**	**-22%**
NRW in liters/conn. /d (w.s.p.)		**1,762**	**292**	**-83%**
NRW in % of system input volume		**58%**	**18%**	

The NRW reduction forecast is based on the following assumptions:

- Professional and timely implementation of the NRW management strategy[11]
- Initial investment of PHP 235 million (remainder of COWD's NRW reduction loan)
- Immediate re-investment of all financial gains from NRW reduction as long as necessary (presumably 3 – 4 years)
- After this initial phase sufficient investment as per the financial model (see section 6, page 28) – additional revenues can be used at the COWD's discretion
- Guaranteed long-term support from COWD's Board of Directors.

[11] Options with advantages and disadvantages are discussed in section 7, starting page 23

Table 16: 10-year NRW forecast

		baseline	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Number of connections		60,894	62,721	64,602	67,605	70,665	73,786	75,903	78,085	80,331	82,646	85,029
Length of mains	km	551	556	562	575	589	603	609	615	621	627	633
Supply time	h/d	22.5	22.5	22.5	23.0	23.5	24	24	24	24	24	24
Average pressure	psi	23	23	23	23	23	23	23	23	23	23	23
Billed authorized consumption	**m3/d**	**72,593**	**75,755**	**81,867**	**87,915**	**92,881**	**97,360**	**100,617**	**102,775**	**105,035**	**107,459**	**110,094**
Non-revenue water components:												
Unbilled authorized consumption	m3/d	1,385	1,427	1,470	1,514	1,559	1,606	1,654	1,704	1,755	1,808	1,862
Commercial losses	m3/d	16,616	15,747	11,996	8,806	6,771	5,298	4,698	5,278	5,837	6,317	6,673
Unauthorized consumptions	*m3/d*	*2,000*	*2,000*	*2,000*	*2,000*	*2,000*	*2,000*	*2,000*	*2,000*	*2,000*	*2,000*	*2,000*
Meter under-registration	*m3/d*	*14,616*	*13,747*	*9,996*	*6,806*	*4,771*	*3,298*	*2,698*	*3,278*	*3,837*	*4,317*	*4,673*
Physical losses	m3/d	82,570	82,716	69,341	57,615	49,510	41,690	32,913	26,035	21,314	18,827	16,306
NRW	**m3/d**	**100,571**	**99,890**	**82,807**	**67,935**	**57,840**	**48,594**	**39,266**	**33,017**	**28,905**	**26,951**	**24,841**
System input volume		**173,164**	**175,645**	**164,674**	**155,850**	**150,721**	**145,954**	**139,882**	**135,792**	**133,940**	**134,410**	**134,934**
NRW in liters/conn. /d (w.s.p.)		**1,762**	**1,699**	**1,367**	**1,049**	**836**	**659**	**517**	**423**	**360**	**326**	**292**
NRW in % of system input volume		**58%**	**57%**	**50%**	**44%**	**38%**	**33%**	**28%**	**24%**	**22%**	**20%**	**18%**

4 NRW cause analysis

4.1 General

The extremely high level of NRW, both physical and commercial losses, is the result of decades of

- lack of awareness for the requirements of NRW management and maintenance in general, combined with
- lack of funding
- lack of materials
- poor quality materials
- lack of machinery, equipment and tools
- poor quality repair works by workers which have never had professional vocational training (only leaning by doing)
- poor construction quality in general
- problems, delays and complications caused by the governmental procurement law and regulations.

It has to be highlighted that this uncomfortable situation has not been caused by present COWD management and staff, the roots for the problems date long back. Unfortunately, problems had not been addressed when they were still manageable and therefore the magnitude of the problems is now very serious.

The COWD water supply system has grown rapidly and all focus and investments were always on the expansion and therefore the deteriorating condition of the system has been overlooked for too long.

4.2 Commercial losses

4.2.1 Unauthorized consumption

The initial results from the customer survey gave no indication that there is a large illegal connection problem in Cagayan de Oro. However, it remains to be seen whether other areas of the city are different and more illegal connections will be found.

But at present it does not seem that significant reductions in NRW can be made by the detection and legalization of illegal connections.

4.2.2 Customer meter under-registration[12]

The main reasons for the high meter under-registration or inaccuracies of the water meters are as follows:

- No regular meter replacement which lead to an over-aged meter park
- Often poor quality meter installation (tilted)
- Larger meters often improperly sized
- Absence of comprehensive and robust water meter technical specifications

[12] Details on customer meter under-registration can be found in 0

- No performance meter testing has been done prior to and after the procurement of the water meters (no quality control of supplied meters)
- Poor stocking of meters – therefore no meters available when a defective meter has to be replaced and certainly no meters available for a general, ongoing meter replacement program; tests have shown that it would be most economical toe replace DN 15 mm meters after 6 years. And with a total of some 80,000 customers 15,000 meters would need to be replaced annually even without the present backlog.
- No periodical meter testing; since meter are not removed and tested COWD was not aware of the significant meter under-registration problems.
- No regular customer meter audit program
- No dedicated water meter management team

4.2.2.1 DN15 meters

The summary tables below are based on meter test results of around 600, randomly selected customer meters that have been removed from the customer's connection and brought to the meter workshop for bench testing according to ISO standards.

The weighted error was calculated by weighing the meter errors at different flow in accordance to the demand profile. The final weighted error has been derived from the error test results at two different orientations (horizontal and non-horizontal orientations). The same demand pattern has been applied for the calculation of weighted error on both orientations.

The tables below show the weighted error of the DN15 meters at normal and non-horizontal orientations.

Table 17: Calculated Weighted Error at Horizontal Orientation

Parameters	Average error at 67% x Q_{max}	Average error at Q_n	Average error at Q_t	Average error at Q_{min}
Average error (horizontal installation)	-3.08%	-2.51%	-3.63%	-16.31%
Demand pattern	0%	12.6%	12.2%	-75.2%
			Weighted Error	**-13%**

Table 18: Calculated Weighted Error at Non-Horizontal Orientation

Parameters	Average error at 67% x Q_{max}	Average error at Q_n	Average error at Q_t	Average error at Q_{min}
Average error (non-horizontal installation)	-0.5%	1.0%	-6.9%	-82.1%
Demand pattern	0%	12.6%	12.2%	-75.2%
			Weighted error	**-62%**

The census data showed that approximately 10% of the water meters in Poblacion area were installed in non-horizontal position. The meters installed in non-horizontal position need to be considered as they greatly affect the meter error. The succeeding table shows final weighted error of DN15 meters.

Table 19: Final Weighted Meter Error of DN15 Meters

Meter installation	Weighted error	Estimated[13] occurrence	Final weighted error
Horizontal	-13%	90%	**-18%**
Non-horizontal	-62%	10%	

About 93% of the total billed consumption of COWD comes from customers with DN15 meters and the rectification of the DN 15 mm customer meter (in)accuracy problem has to get top priority.

4.2.2.2 Customer meters larger than DN 15mm

The top 10 meters of the largest customers were investigated in great detail and a general assessment was undertaken for the other meters larger than DN 15 mm.

The average under-registration was calculated to be 7.6%. Many of the meters are oversized (for example 9 of the 10 largest customers have an oversized meter) which results in significant under-registration.

4.3 Physical losses

The high level of physical losses is exactly what has to be expected if:

- Poor quality of materials
- Poor quality of workmanship
- No active leakage control
- Decades of neglected distribution network maintenance
- Significant lack of funds

4.3.1 Leaks on main pipes

Leaks on main pipes do not seem to be a major problem in the COWD distribution network. Only 60 leaks per year are detected and repaired, this means a mains burst frequency of only 11 bursts per 100 km per year which is below the IWA benchmark of 13 for systems in good condition.

Although it needs to be assumed that a considerable number of mains bursts is still out there[14] to be detected the general condition of COWD's main pipes can be considered satisfactory.

Problems related to leaks on main pipes are:

- Lack of repair materials, therefore

[13] Poblacion area as reference

[14] Presumably in areas where the pipeline is close to a drainage pipe and the leak can run unnoticed for a long time

- Use of self-manufactured, highly corrosive and totally inappropriate repair clamps
- Poor quality backfilling (using the excavate material, often saturated, including rocks, lumps of asphalt etc. are thrown back in the trench over the pipe, creating further potential point loads and breaks.
- No suitable granular backfill material brought to the site
- No or insufficient compaction of the backfill
- Due to the absence of road saws, asphalt is removed directly by the excavator, damaging a much larger area of the existing asphalt required, increasing the reinstatement cost

4.3.2 Leaks on service connections

Leaking service connections are without any doubt the main reason for COWD's massive physical loss problem. Contrary to the mains burst frequency, the service connection burst frequency is very high. Even when counting only the "real" service connection burst (and not the leaks on stub outs and other small leaks) then the burst frequency is 66 burst per 1,000 service connections per year – this is 13 times the IWA benchmark for a system in good condition (5 bursts per 1,000 connections).

In addition to all the problems listed in the section above (4.3.1), there are issues specific to service connections:

- Wrong service connection design, service connections are installed much too shallow, especially when crossing roads with heavy traffic
- Poor quality materials and sometimes even wrong materials (pipe saddles for rigid pipes used on PVC pipes)
- No sand bedding
- Leaking service connections are repaired instead of being replaced
- In addition, there are a huge number of accounts that are classified in the billing system as inactive. Some of these inactive accounts may have still existing service connections and if leaks occur on them, it is highly unlikely that they will be reported to COWD because they will not be causing any customer a problem. For this reason, and because of the very high rate of breaks on service lines, it is likely that many of these inactive service lines have unreported breaks running.

There clearly is no chance to ever solving COWD's leakage problem without implementing a radically changed service connection design, installation and replacement policy.

4.3.3 Pressure fluctuations

There are in general massive pressure fluctuations between day and night hours (because of high leakage and therefore insufficient hydraulic capacity of the system during peak hours). But in some parts of the system there are also extreme pressure spikes and transients, sometimes up to 50 psi.

All these regular pressure changes are putting significant additional stress on the weak and deteriorated distribution system.

4.3.4 Extensive spaghetti lines

In some parts of the COWD supply areas hundreds of meters long parallel service connections (spaghetti lines) have been laid in the absence of a main pipe in the road. These service connections are always poorly installed, in the best case shallow below ground but very often above ground, for example in drains beside the road.

These connections do not only add many kilometers of unnecessary pipe length to the system, they are also extremely leakage prone.

5 NRW reduction strategy elements/interventions

In order to keep the length of this strategy document within limits, it was decided to only list all elements, sometimes with a brief comment, but without lengthy explanation or description. Because most of them are self-explanatory and have already been frequently discussed.

Table 20: General elements/interventions

Element/intervention	Comment
Completion of the customer census and the GIS	
Improvement of supply metering	As per the recommendation in 0
Construction of a new warehouse	

Table 21: Commercial loss reduction elements/interventions

Element/intervention	Comment
Investigation of suspicious accounts found during the customer census to detect illegal connections or meter bypasses/tampering	
Investigation of all inactive accounts and cleaning up the customer database	
Establishment of an integrated meter management department/unit	All metering related activities, from preparation of specifications to meter installation and maintenance must be under the responsibility of this unit.
Improvement of the water meter workshop	As per the recommendations in 0
Design of a targeted DN 15 mm customer meter replacement program	
Rectification of stub outs of inferior quality, including the replacement of all customer meters	
Outsourcing of customer meter replacement	COWD's team does not have the capacity to implement a large meter replacement program
Design of a large meter inspection and improvement program.	As per the recommendations in 0
Implementation of the large customer meter improvement program	
Regular inspection, monitoring and maintenance of large customer meters	

Table 22: Physical loss reduction elements/interventions

Element/intervention	Comment
Procurement of trucks, excavators, machinery and equipment	The needs will be determined after the extent of construction and repair work outsourcing has been determined
Vocational leak repair, pipe fitting and service connection replacement by a specialized trainer	Should be done as soon as the new materials will be available.
Sectorization of the distribution system	In accordance with the recommendations of the final hydraulic modelling report
Establishment of DMAs for most parts of the distribution systems	DMAs to be established everywhere as long as technically feasible at acceptable cost
Replacement of Spaghetti lines with main pipes	
Change of service connection design and quality/type of materials	As per the recommendations under this project
Introduction of a strict service connection replacement policy	When a service connection is found leaking, it must be replaced in its entire length from (and including) the pipe saddle to the meter
Visible inspection of service connections in areas with suspected poor quality and/or high physical losses to identify connections due for advanced replacement	
Ensuring good service connection installation quality and backfilling with appropriate material	
Systematic active leakage control in DMAs	
Improvement of pump operations and, where needed, installation of additional variable frequency drives.	
Leak repair on mains using only high quality repair materials (e.g. stainless steel repair clamps) and good quality backfilling	
Control of all sluice valves and replacement of non-functioning or leaking valves	
Inspection of air valves, replacement of leaking or non-functioning air valves, installation of additionally required air valves	
Permanent automatic flow and pressure data collection and analysis, especially DMA monitoring and analysis	
Installation of pressure reducing valves	

6 Financial model of a comprehensive NRW management project

The financial model has been prepared based on the following requirements and assumptions:

- Financeable for COWD without any additional loan in addition to the PHP 235 M left from the existing NRW reduction loan
- 3% annual growth in additional customers and that this will require financing for these additional connections and, in some areas, additional main pipes
- No additional water sources required
- Recovered physical losses will be either sold to additional customers or will lead to a reduction in variable water production cost (electricity and chemicals). The following has been used:
    - Average tariff: PHP 34.5/m3
    - Variable production cost: PHP 5.84/m3
- The NRW reduction and system expansion CAPEX budget has been estimated based on best practice unit rates and the planned interventions
- However, NRW management projects have a significant OPEX component which can only be calculated once a decision on the implementation option (see section 7) has been taken. As of now, a provisional sum has been used.
- Neither price increases nor tariff increases have been taken into consideration

The financial highlights (for the 10-year period) are:

- Total CAPEX and OPEX PHP 2.48 billion
- Financial benefits from NRW reduction[15] PHP 3.52 billion
- Financial benefit for COWD PHP 1.04 billion
- Strong positive cash flow after year 4

Once this strategy has been agreed and a decision on the implementation option has been taken, a more detailed financial model with NPV and IRR calculations can be prepared.

[15] Including additional sales from recovered physical losses

Table 23: Financial model for a comprehensive, 10-year NRW management project

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Rectification of Spaghetti Connections	10.0	20.0	20.0	20.0	10.0					
Sectorization	20.0	30.0								
Full DMA coverage		30.0	40.0	40.0						
Mains repair and other repairs		15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
Service connection replacement		44.0	44.0	44.0	44.0	44.0	33.0	22.0	11.0	11.0
Customer meter replacement		70.0	52.5	35.0	35.0	7.1	1.9	9.3	9.1	20.2
Supply meter improvement	5.0									
Additional equipment and machineries	4.0									
Selective pipe replacement (mains and connections)		8.8	8.8	35.3	35.3	35.3	53.0	53.0	53.0	53.0
NRW reduction cost – CAPEX (and other procurement)	**39.0**	**217.8**	**180.3**	**189.3**	**139.3**	**101.4**	**102.9**	**99.3**	**88.1**	**99.2**
Additional pipelines	11.0	11.1	27.6	27.7	27.8	11.6	11.7	11.8	11.9	12.0
Additional connections with meter	26.5	27.3	43.5	44.4	45.2	30.7	31.6	32.6	33.6	34.6
System expansion cost - CAPEX	**37.5**	**38.4**	**71.2**	**72.1**	**73.1**	**42.3**	**43.3**	**44.4**	**45.5**	**46.6**
Total NRW reduction and system expansion - CAPEX	**76.5**	**256.2**	**251.5**	**261.5**	**212.4**	**143.7**	**146.2**	**143.7**	**133.6**	**145.8**
Funds available/income										
Present NRW O&M budget (available for procurement)	7.5	7.7	8.0	8.2	8.4	8.7	9.0	9.2	9.5	9.8
NRW loan (PHP 235 M left)	235.0									
Total	**242.5**	**7.7**	**8.0**	**8.2**	**8.4**	**8.7**	**9.0**	**9.2**	**9.5**	**9.8**
Financial benefits from NRW reduction	34.5	134.9	229.8	303.3	369.9	423.8	459.7	492.1	521.7	553.7
Total available annual budget	**277**	**142.6**	**237.8**	**311.5**	**378.3**	**432.5**	**468.7**	**501.4**	**531.2**	**563.5**
NRW management OPEX	30.0	100.0	100.0	100.0	100.0	100.0	75.0	50.0	25.0	25.0
Overall cash flow	**208.0**	**24.4**	**10.7**	**60.7**	**226.6**	**515.4**	**862.9**	**1,245.5**	**1,668.1**	**2,085.8**

7 Implementation options

7.1 General

The main intention of this section, as it stands at the moment, is to stimulate discussion at COWD and the consultant is of course ready to assist and comment.

Should COWD decide to implement the suggested comprehensive 10-year NRW management program, which would make it the by far most efficient large water district in the country, the board of directors will have to make important and difficult decisions and get the support of all stakeholders. This section shall provide some initial guidance for the discussions.

Once COWD comes closer to a decision, details of the preferred option can be worked out and recommendations can be given. Ideally this would be included in the final revision of this document at the end of the Be Secure project.

7.2 COWD completely on its own

It would be unrealistic to assume that COWD on its own can design and implement a 2.5 billion NRW reduction project without outside help.

The lack of expertise and experience is not even the main problem, more significant is the lack of capacity to implement such an enormous job and the cumbersome procurement rules which have the potential to lead to frequent and long delays.

7.3 COWD with specialist advisors

An option for COWD would be to contract international specialists as advisors and trainers. While this would help to build the required expertise and get project design right, it would not help to increase COWD's capacity. And of course the procurement difficulties will remain.

7.4 Co-Management contract

A new form of outsourcing of NRW management projects is the Co-Management approach. Miya's 4-year (USD 42 million) contract for Kingston, Jamaica, funded by the Inter-American Development Bank is such type of contract. A joint project committee composed of representatives of the client (National Water Commission) and the contractor (Miya) takes all main decisions. Staff is provided by client and trained, guided and managed by Miya (on behalf of the project committee).

Since funds for the procurement of materials and equipment are included in the total contract price, procurement can be done in a bureaucratic way. The contractor prepares specifications, asks for quotations, negotiates if needed and the project committee takes the final decision.

A possibility would be to tender a co-management contract for the first 5 years with a possibility for extension. It could be discussed whether the system expansion activities (laying of additional pipes and connections) would be included or could simply continue to be done by COWD.

Assuming the latter, the contract amount would be in the order of PHP 1.3 billion[16].

[16] This amount was calculated using the CAPEX and OPEX budget for 2018 - 2022

7.5 Outsourcing or co-management in phases

Should tendering such a large contract be too difficult or should there be restrictions which would COWD not allow to do that (e.g. that funding is not yet available and will only be generate in the course of the project), COWD could start with a short contract, for example 1-2 years, followed by (ideally) automatic extensions or new tenders.

Although this sounds tempting at the first look, several issues have to be considered:

- The available amount of PHP 235 million does not even cover the required NRW reduction CAPEX for 2018, therefore further funds, for example from increased revenues from the beginning of the meter replacement program would need to be made available.
- These additional funds could presumably only be used by COWD directly and thus the public procurement law must be followed
- The short contract duration is disadvantageous. If no immediate follow-on contract is ensured the whole program may come to a stand-still

7.6 Performance based contract in the form of a 10 year PPP

The most drastic solution would be turn-key outsourcing of NRW management to a JV company owned by COWD and a private partner.

This would then be done under a long term contract, anything more than 5 years, to ensure that there will be no cash flow problems in case increase in revenues will be less than presently assumed.

The latest version of the applicable laws would need to be checked should COWD wish to explore this option further.

Appendix 1 - Report on Cagayan de Oro Water District Supply Meters

REPORT ON CAGAYAN DE ORO WATER DISTRICT SUPPLY METERS

Technical Assistance to Cagayan De Oro City Water District on Non-Revenue Water Reduction Strategy and Implementation

Subcontract Agreement No. 893-S15-013

August 2016

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Acronyms and Abbreviations

AC	Alternating Current
COWD	Cagayan de Oro City Water District
GPRS	General Packet Radio Service
mm	millimeter
m/s	meter per second
m^3	cubic meter
m^3/hour	cubic meter per hour
NRW	Non-Revenue Water
PW	Production Well
RVWC	Rio Verde Water Consortium Inc.
SMS	Short Message Service

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1 Executive Summary

In order to evaluate the existing conditions of Cagayan de Oro Water District's supply meters, an extensive field assessment audit was carried out on all the supply meters located in west and east service areas. Each supply meter has been inspected to verify and evaluate their operability and actual field conditions. The following main checkpoints have been considered during the field assessment audit:

- Alarms and parameter settings of the supply meter's converter
- Current operability
- Installation conditions
- Full details of the meter (brand, model, type, size, power source, reporting, location etc.)
- Presence of distorting elements
- Supply schematic diagram
- Site viability for implementing supply meter verification through installation of clamp-on ultrasonic meter

There are several findings that have been found during the field audit which may have direct influence on the performance and operation of the supply meters. All the key findings and essential information gathered from the supply meter audit were documented in the supply meter assessment audit form. The "in a nut shell" key findings are discussed and summarized in the succeeding subsections.

1.1 Calibration and Maintenance

The average age of the supply meters installed in COWD supplied areas is 7 years. There has been no calibration and maintenance made on these meters in the past years. It is being said by COWD technician that there was a meter verification carried out by Tradepoints, a local distributor of Siemens products, couple of years ago for Siemens brand electromagnetic meters. However, Tradepoints only verified and checked the overall operability status of the parameter settings of Siemens electromagnetic meters and not their actual measurement accuracy.

Photo 1: Rio Verde Supply Meter (10-Year Old Meter)

1.2 Sizing

After reviewing the velocity characteristics of each of the supply meter, it can be concluded that vast majority of the supply meters are properly sized. There are few slightly oversized meters like in production well #18 and Macasandig old booster bank #1 with a calculated velocity of 0.32 and 0.74 meter per second. Production well #18 is currently not fully operated as this facility is only utilize for back-up water supply therefore it cannot be judged whether the installed meter is properly sized or not. However, since the supply meters are full-bore electromagnetic type with high turndown measurement ratio, their existing diameter sizes should cover the supply variations in these two particular facilities. The following figure shows the estimated average flow velocities of the COWD supply meters.

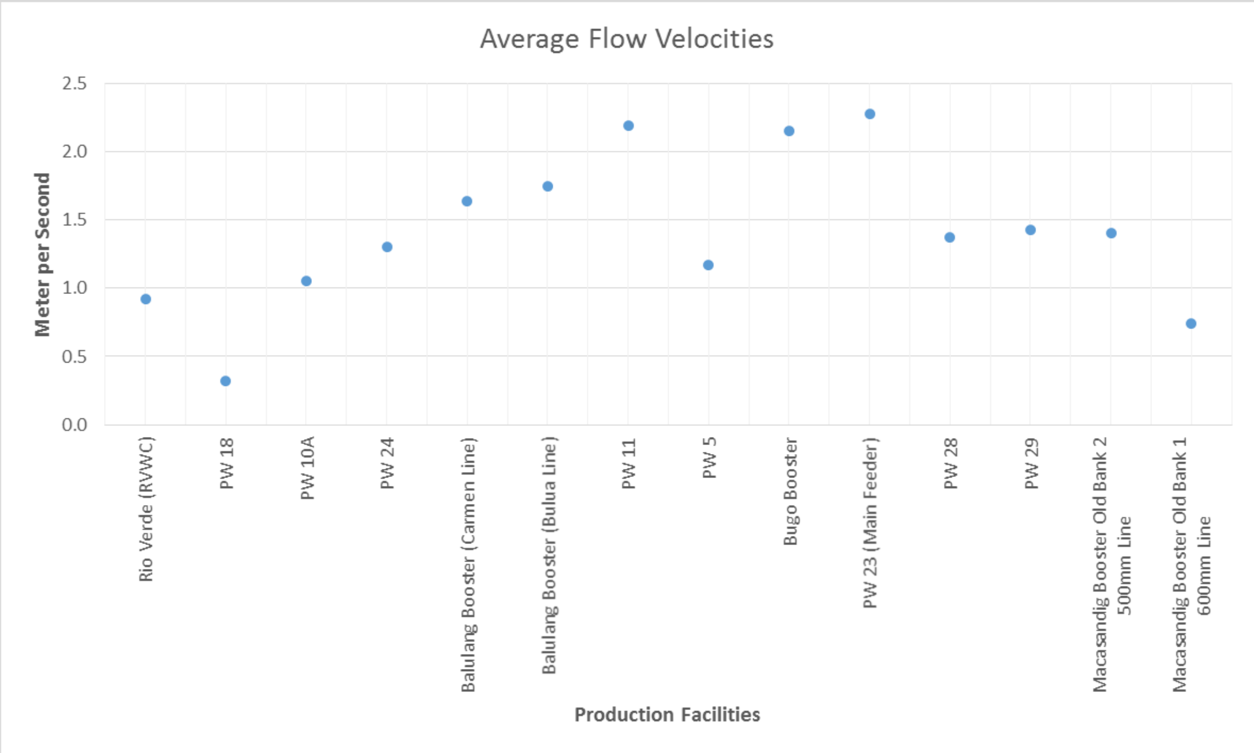

Figure 1: Average Flow Velocities of COWD Supply Meters

1.3 Grounding and Cable Protection

There are no grounding protections systems installed on all the supply meters. Most of the supply meters are powered by AC source that sometimes can cause electrical surges when there is sudden power outage, lightning, current faults and unexpected fluctuations on the power supply voltage. These surges create glitches on the supply measurements and in worst-case, can damage the supply meters' electronic components. Therefore, a grounding system is very important to minimize the effect of electrical surges not only to the supply meters but also to ensure the personnel's safety.

There is no electrical conduit that shields the cable connections between the converter (display) and the meter (sensor). The meter cables are very vital for supplying currents through the meter coils and it also convey signals from the sensors to the converter. These cables are constantly exposed from direct sunlight, seasonal weather changes and chemicals (chlorine) for water treatment which can damage its insulation components and later on could affect the reliability of the supply volume measurements.

Photo 2: No Conduit and Grounding System (PW #10A)

1.4 Reverse Totalizer

It was identified, specifically on Siemens brand meters, that there are two totalizers known as "Totalizer 1" and "Totalizer 2". These totalizers can be seen on the display by navigating the keypads of the meter converter. The Totalizer 1 quantifies the forward water flows while Totalizer 2 quantifies the reverse water flows. It is a common practice in COWD production department that the Totalizer 1 is being read and recorded for their regular supply monitoring. The table below shows the summary readings of the Totalizer 2 (reverse water flows) gathered from each supply meters.

Facility Name	Totalizer 2 (Reverse Water Flows)
Rio Verde (RVWC)	590 m^3
PW #18	Defective display
PW #15	No converter/display
PW #10A	Defective display
PW #24	No converter
Balulang Booster (Carmen Line)	7,890.9 m^3
Balulang Booster (Bulua Line)	4,909.3 m^3
PW #11	8,113,736 USG = 30,713.83 m^3
PW #5	7,308 USG = 27.66 m^3
Bugo Booster	617.88 m^3
PW #23	114,600 m^3
PW #28	13,931 m^3
PW #29	7,046 m^3
Macasandig Old Booster Bank #2 (500mm Line)	61,585 m^3
Macasandig Old Booster Bank #1 (600mm Line)	388.7 m^3
Macasandig New Booster	35,724.2 m^3

Table 1: Reverse Flow Reading in Each Supply Meters

These reverse flows have been accumulating since the supply meters were installed in the water production facilities. Although there are insignificant reverse water flows recorded in the some of the supply meters, it should be taken into consideration that readings must be gathered from the "Net Totalizer" (Net Totalizer=Totalizer 1 - Totalizer 2) and not from Totalizer 1. The supply meters' converter needs re-configuration to enable the net totalizer function.

1.5 Problematic Supply Meters

1.5.1 Production Well #18

The existing supply meter installed in production well #18 has a problem with the display. Some of the digital segments on the character display are fading which makes it very hard to read. There is also problem on its converter as its totalizer continuously accumulates supply volume reading even though the production well is totally shut-off.

Photo 3: Fading Digital Segments (PW #18)

1.5.2 Production Well #15 and #24

The production well #15 and #24 supply meters do not have converters/displays. As per COWD production department, the converters were damaged during Typhoon Sendong. There is a regular flushing exercise carried out in these two production wells. However, there is no means of quantifying the water discharge due to unavailability of the meter converters.

Photo 4: No Converters/Displays (PW #15 and #24)

1.5.3 Production Well #10A

The converter of the supply meter in production well #10A is totally blackout. No records of supply data found in the meter reading ledger. As per COWD technician, the internal battery is drained that is why the converter doesn't have power source to display the totalizer.

Photo 5: Blackout Display

1.6 Correction Factors

For Siemens brand electromagnetic meters, there is a parameter called correction factor which is mainly used to adjust the flow measurements. The correction factor sets as the multiplier of the actual flow measurements. Typically, correction factor is equivalent to 1 when released from the factory.

Basically, an electromagnetic meter is a "plug and play" and calibrated instrument which means that whatever the measurements it reads, it should be at the acceptable limits (considering that there are no operational defects occurred during the manufacturing, shipment and commissioning of the meter).

It was observed that there are few supply meters with correction factors that are not equal to 1 (factory setting). In Balulang booster, particularly the supply meters installed in Carmen Line and Bulua Line the correction factor settings are 0.92 and 1.12, respectively. Reconfigurations on correction factor setting have been made on these supply meters to verify if there would be changes in the supply measurements after the adjustments. The following table shows the results after changing the correction factor into 1.

Facility Name	Old Correction Factor	Flow (m^3/hour)	New Correction Factor	Flow (m^3/hour)	Date Changed
Balulang Booster (Carmen Line)	0.92	424	1	460 (increased)	May 18,2016
Balulang Booster (Bulua Line)	1.12	700	1	628 (decreased)	May 18,2016

Table 2: Correction Factor Setting Adjustment at Balulang Booster Meters

It is proven that the correction factor can directly affect the measurement operations of the Siemens brand supply meters. After changing the correction factors of these two supply meters, there were significant changes observed from the flow measurements. In Carmen Line, the flow rate increased from 424 m^3/hour to 460 m^3/hour while in Bulua Line the flow rate decreased from 700 m^3/hour to 628 m^3/hour. These changes in supply measurement must be considered in the NRW water balance calculation.

1.7 Installation Conditions

Electromagnetic meter is one of the most accurate type of flow meters used around the world. The measurement error of an electromagnetic meter could reach between 0.1% and 0.5% which is very accurate compare to other mechanical water meters. Electromagnetic meter is very sensitive to flow distortions therefore; the installation requirements must be followed to achieve its optimum accuracy. Normally, electromagnetic meter requires straight pipe length equivalent to the 10 times of its nominal diameter (10D) at the upstream side and 5 times of its nominal diameter (5D) at the downstream side. Electromagnetic meter should have certain pipe distance from butterfly/gate valves, check valves, strainers, bends, tees pumps and any appurtenances as these distorting elements could create flow distortion through the meter's measuring tube. In theory, flow distortions through the pipe assembly could significantly increase the measurement error of the electromagnetic meters that could lead to inaccuracy problem.

In the case of COWD, some of their supply meters' assemblies have not met the required straight pipe distances. The succeeding table shows the summary of upstream and downstream pipe run observations gathered during supply meter inspection.

Facility Name	**Upstream Pipe Run (10D)**	**Downstream Pipe Run (5D)**
Rio Verde (RVWC)	With enough straight pipe distance	With enough straight pipe distance
PW #18	Limited straight pipe distance	With enough straight pipe distance
PW #15	With enough straight pipe distance	No straight pipe distance
PW #10A	Limited straight pipe distance	Limited straight pipe distance
PW #24	Limited straight pipe distance	Limited straight pipe distance
Balulang Booster (Carmen Line)	With enough straight pipe distance	Limited straight pipe distance
Balulang Booster (Bulua Line)	With enough straight pipe distance	Limited straight pipe distance
PW #11	Limited straight pipe distance	Limited straight pipe distance
PW #5	Limited straight pipe distance	With enough straight pipe distance
Bugo Booster	Limited straight pipe distance	Limited straight pipe distance

PW #23	Limited straight pipe distance	Limited straight pipe distance
PW #28	Limited straight pipe distance	Limited straight pipe distance
PW #29	Limited straight pipe distance	Limited straight pipe distance
Macasandig Old Booster Bank #2 (500mm Line)	With enough straight pipe distance	With enough straight pipe distance
Macasandig Old Booster Bank #1 (600mm Line)	With enough straight pipe distance	With enough straight pipe distance
Macasandig New Booster	No straight pipe distance	With enough straight pipe distance

Table 3: Remarks on the Supply Meters' Installation Conditions

1.8 Fault Alarm

A fault code "F70 Coil Current", which means that there is an alarm on the supply meter's coil current, was observed in Macasandig old booster bank #1. The alarm has been pending for more than a month.

Photo 6: F70 Coil Current Fault Alarm at Macasandig Old Booster Bank #1

Referring to the Siemens electromagnetic meter literatures, this alarm has to do with the fault in driving the magnetic field on the sensors. The intensity of the magnetic field is very important for electromagnetic meter on measuring the velocity of the flowing water. Therefore, this alarm needs to be resolved immediately as it can possibly contribute to the inaccuracy problem of the supply meter.

2 Results on Supply Meter Assessment Audit

The primary objective of this audit is to verify the actual operational conditions of COWD's supply meters. Each supply meter on all the water production facilities has been inspected and audited thoroughly. All the details including the diameter size, meter make or brand, installation conditions, spot flow rate, age and sizing remarks were gathered in the supply meter audit form. The succeeding table shows the supply meters' general information and influence areas. The observations gathered from the audit are discussed in the following sections.

Facility Name	Meter Brand	Meter type	DN Size (mm)	Supply Area
Rio Verde (RVWC)	Siemens	Electromagnetic	800	West
PW 18	Euromag	Electromagnetic	150	West
PW 15	Euromag	Electromagnetic	150	West
PW 10A	Euromag	Electromagnetic	200	West
PW 24	Siemens	Electromagnetic	150	West
Balulang Booster (Carmen Line)	Siemens	Electromagnetic	300	West
Balulang Booster (Bulua Line)	Siemens	Electromagnetic	400	West
PW 11	Siemens	Electromagnetic	250	East
PW 5	Siemens	Electromagnetic	200	East
Bugo Booster	Siemens	Electromagnetic	300	East
PW 23 (Main Feeder)	Siemens	Electromagnetic	250	East
PW 28	Siemens	Electromagnetic	250	East
PW 29	Siemens	Electromagnetic	250	East
Macasandig Booster Old Bank 2 500mm Line	Siemens	Electromagnetic	500	East
Macasandig Booster Old Bank 1 600mm Line	Siemens	Electromagnetic	600	East
Macasandig Booster New 500mm Line	Siemens	Electromagnetic	500	East

Table 4: COWD Supply Meters' General Information

2.1 Supply Meters in West Area

2.1.1 Rio Verde (RVWC)

Meter Type	Full-bore electromagnetic
Nominal Diameter (mm)	800
Brand	Siemens
Upstream and Downstream Pipe Run (10D and 5D)	With enough straight pipe distance
Spot Flow Rate (m^3/hour)	1,659
Years of Operation	10
Sizing Condition	Properly sized

Table 5: Rio Verde (RVWC) Supply Meter Profile

The supply meter's nominal diameter size is within the acceptable size limit. With an average velocity of 1.1 m/s through the pipeline, the current supply meter should be able to measure the supply volume effectively. Based on the record, the age of this meter is 10 years. Therefore, this supply meter has to be checked and calibrated accordingly. The following photos show the Rio Verde's supply meter and official meter display.

Photo 7: Rio Verde Supply Meter

Photo 8: Official Meter Display

The official meter display is located at the metering house managed by the Rio Verde Management Corporation. The totalizer readings which are being displayed on the converter is generated from the 4-20mA output signal of the Siemens electromagnetic meter.

2.1.2 Production Well #18

Meter Type	Full-bore electromagnetic
Nominal Diameter (mm)	150
Brand	Euromag
Upstream and Downstream Pipe Run (10D and 5D)	Limited straight pipe distance at the upstream
Spot Flow Rate (m^3/hour)	Has problem on the converter
Years of Operation	5.4
Sizing Condition	Slightly oversized

Table 6: Production Well #10 Supply Meter Profile

At the moment, production well #18 is only used for back-up water source. However, from time to time, COWD does water flushing 30 minutes to 1 hour a day. It is being observed during the visit that the converter's register display particularly the totalizer and flow rate indicators were running (accumulating) even though the production well was shutdown. This only means that there is over-reading of the supply input volume of production well #18. Aside from this problem, the converter display is also fading which makes it very hard to read. The succeeding photos show the production well #18 supply meter.

Photo 9: Production Well #18 Meter Converter

Photo 10: Production Well #18 Meter Assembly

2.1.3 Production Well #15

Meter Type	Full-bore electromagnetic
Nominal Diameter (mm)	150
Brand	Euromag
Upstream and Downstream Pipe Run (10D and 5D)	No straight pipe distance at the downstream
Spot Flow Rate (m^3/hour)	No converter
Years of Operation	5.3
Sizing Condition	No supply data

Table 7: Production Well #15 Supply Meter Profile

The supply meter in production well #15 has never been used for the past years as this facility was damaged during the Typhoon Sendong. Regular flushing is periodically done in this facility to prevent water quality issues. These withdrawals have not been quantified because the meter doesn't have the converter. Another issue why this facility couldn't be operated is due to unavailability of the power supply. Photos of production well #15 supply meter and assembly can be seen below.

Photo 11: Production Well #15 Meter Assembly

Photo 12: Production Well #15 Supply Meter

The sizing condition cannot be assessed as there is no record of the historical supply input volume. The supply meter's parameters status cannot be determined because of unavailability of the meter's converter.

2.1.4 Production Well #10A

Meter Type	Full-bore electromagnetic
Nominal Diameter (mm)	200
Brand	Euromag
Upstream and Downstream Pipe Run (10D and 5D)	Limited straight pipe distance on both sides
Spot Flow Rate (m^3/hour)	231.5
Years of Operation	5.3
Sizing Condition	No supply data

Table 8: Production Well #10A Supply Meter Profile

The current meter installed in production well #10A is properly sized based on the calculated average velocity of about 1.05 m/s. The average velocity was determined using the historical supply input volume of this production well. During the visit, there was no logged readings found in the ledger because the meter display is totally blackout. There is no exact date when was the converter failed to display the register.

There are no available straight pipe distances at both sides of the meter. The power/signal cables between the meter sensor and converter are stretched out which can break the internal wires and loose its signal in the long run (see Photo 13).

Photo 13: Production Well #10A Supply Meter

Photo 14: Production Well #10A Meter Assembly

Photo 15: Production Well #10A Converter (Blackout Display)

2.1.5 Production Well #24

Meter Type	Full-bore electromagnetic
Nominal Diameter (mm)	150
Brand	Siemens
Upstream and Downstream Pipe Run (10D and 5D)	Limited straight pipe distance on both sides
Spot Flow Rate (m^3/hour)	No converter
Years of Operation	10
Sizing Condition	Properly sized

Table 9: Production Well #24 Supply Meter Profile

The production well #24 supply meter is defective. It was damaged during Typhoon Sendong. The converter was removed few years ago so there is no readings that has been taken from this supply meter. With the estimated velocity of 1.3 m/s (based on COWD supply input volume estimates), it can be judged that the existing meter installed in this facility is properly sized.

Following the allowable straight pipe distances 10D and 5D for upstream and downstream (U10D5), the current meter's assembly in production well #24 is lacking of straight pipe distances. The succeeding photos show the production well #24 supply meter and its assembly.

Photo 16: Production Well #24 Supply Meter (Detached Converter)

Photo 17: Production Well #24 Meter Assembly

2.1.6 Balulang Booster (Carmen Line)

Meter Type	Full-bore electromagnetic
Nominal Diameter (mm)	300
Brand	Siemens
Upstream and Downstream Pipe Run (10D and 5D)	Limited straight pipe distance at the downstream
Spot Flow Rate (m^3/hour)	430
Years of Operation	6.3
Sizing Condition	Properly sized

Table 10: Balulang Booster (Carmen Line) Supply Meter

The Carmen Line's supply meter assembly is lacking of straight pipe distance at the downstream side. The check valve is so close to the meter which may cause flow distortions through the meter tube. At nominal diameter of 300mm and calculated velocity of 1.64 m/s, the supply meter is properly sized.

During the inspection, it was taken into consideration the parameter settings of the converter as this may have an effect on the measurements of the Carmen Line supply meter. One of the parameter that could make a direct impact on the measurements is the correction factor. After checking the parameters of the converter in Carmen line, it was found out that the correction factor setting has a value of 0.92. As per Siemen's technician, the default setting for correction factor must be 1.0 as the electromagnetic meter is "plug and play" instrument. Therefore whatever the measurements that the meter obtained, it must be the true value and within the acceptable margin of error. In the case of Carmen Line, it is assumed that the meter is set to measure the supply input volume with 8% deductions from its actual measured volume. To verify the actual effect of the correction factor on the supply input volume measurements, COWD carried out adjustments on correction factor. The table below shows the result of changing the correction factor from 0.92 to 1.0.

Facility Name	Old Correction Factor	Flow (m^3/hour)	New Correction Factor	Flow (m^3/hour)	Date Changed
Balulang Booster (Carmen Line)	0.92	424	1	460	May 18,2016

Table 11: Correction Factor Setting Adjustment at Carmen Line Supply Meter

It is clear that there is an increase in flow rate after the correction factor was set to 1.0. The flow rate increased by 8.5% which equates to 36 m^3/hr (or 864 m^3/day). Such corrections have to be considered in the NRW water balance to arrive with good estimates. The photos below show the Carmen Line supply meter and converter.

Photo 18: Balulang Booster (Carmen Line) Supply Meter

Photo 19: Balulang Booster (Carmen Line) Converter

2.1.7 Balulang Booster (Bulua Line)

Meter Type	Full-bore electromagnetic
Nominal Diameter (mm)	400
Brand	Siemens
Upstream and Downstream Pipe Run (10D and 5D)	Limited straight pipe distance at the downstream
Spot Flow Rate (m^3/hour)	710
Years of Operation	6.3
Sizing Condition	Properly sized

Table 12: Balulang Booster (Bulua Line) Supply Meter Profile

The average velocity through the Bulua Line is 1.75 m/s which indicates that the meter installed is properly sized. However, the downstream straight pipe is lacking of allowable spacing because of the check valve is fitted very near to the supply meter.

Similar to Carmen Line, the Bulua Line's correction factor setting has been also checked. The current correction factor setting is 1.12 which is being presumed that the supply input volume in this line is over-registering by 12%. The table below shows the change in flow rate after the adjustment of the correction factor from 1.12 to 1.0.

Facility Name	Old Correction Factor	Flow (m^3/hour)	New Correction Factor	Flow (m^3/hour)	Date Changed
Balulang Booster (Bulua Line)	1.12	700	1	628	May 18,2016

Table 13: Correction Factor Setting Adjustment at Bulua Line Supply Meter

It is observed that the flow rate decreased by 72 m^3/hour (or 1,728 m^3/day). This supply measurement changes should be also considered in the NRW water balance calculations. The following photos show the Bulua Line's supply meter and converter.

Photo 20: Balulang Booster (Bulua Line) Supply Meter

Photo 21: Balulang Booster (Bulua Line) Converter

2.2 Supply Meters in East Area

2.2.1 Production Well #11

Meter Type	Full-bore electromagnetic
Nominal Diameter (mm)	250
Brand	Siemens
Upstream and Downstream Pipe Run (10D and 5D)	Limited straight pipe distance on both sides
Spot Flow Rate (m^3/hour)	399.2
Years of Operation	8
Sizing Condition	Properly sized

Table 14: Production Well #11 Supply Meter Profile

The current meter installed in production well #11 is lacking of straight pipe distance on both sides. But when it comes to meter sizing, the meter is properly sized as the average velocity through this supply line is about 2.19 m/s.

An alarm code "W30 Overflow Max" was observed during the inspection. This type of alarm means that the current flow rate has reached the maximum threshold setting of the meter. It is being said by the COWD technician that it happened because there was an upgrade made on the submersible pump installed in the production well facility. However, the alarm has no direct effect on the reliability of the measurement. The succeeding photos show the supply meter assembly and converter of production well #11.

Photo 22: Production Well #11 Supply Meter Assembly

Photo 23: Production Well #11 Converter

2.2.2 Production Well #5

Meter Type	Full-bore electromagnetic
Nominal Diameter (mm)	200
Brand	Siemens
Upstream and Downstream Pipe Run (10D and 5D)	Limited straight pipe distance at the upstream
Spot Flow Rate (m^3/hour)	141
Years of Operation	8.3
Sizing Condition	Properly sized

Table 15: Production Well #5 Supply Meter Profile

Due to the check valve fitted close to the meter, the upstream pipe section doesn't meet the required straight pipe allowance. The check valve's disk that opens and closes in varying line pressure could create flow distortion that can lead to inaccuracy of the supply meter. Having an average velocity of 1.17 m/s through the supply line, the current meter is properly sized and can be able to cover the supply variations. The succeeding photos show the supply meter assembly and converter of the production well #5.

Photo 24: Production Well #5 Supply Meter Assembly

Photo 25: Production Well #5 Supply Converter

2.2.3 Bugo Booster

Meter Type	Full-bore electromagnetic
Nominal Diameter (mm)	300
Brand	Siemens
Upstream and Downstream Pipe Run (10D and 5D)	Limited straight pipe distance on both sides
Spot Flow Rate (m^3/hour)	617.88
Years of Operation	7.5
Sizing Condition	Properly sized

Table 16: Bugo Booster Supply Meter Profile

The current meter is properly sized. However, the meter doesn't have straight pipe distance on both sides. The presence of butterfly valve and set of pump motors located at the upstream side of Bugo Booster's supply meter could create swirls through the supply pipeline. This swirl is a flow distortion that can affect the reliability of the meter's measuring performance. A pipe reducer is also fitted at the downstream of the meter which also contributes to flow distortions. The meter is located at the elevated concrete platform which makes it very hard to maintain. The following photos show the supply meter and converter of Bugo booster.

Photo 26: Bugo Booster Supply Meter

Photo 27: Bugo Booster Converter

2.2.4 Production Well #23

Meter Type	Full-bore electromagnetic
Nominal Diameter (mm)	250
Brand	Siemens
Upstream and Downstream Pipe Run (10D and 5D)	Limited straight pipe distance on both sides
Spot Flow Rate (m^3/hour)	356.4
Years of Operation	8.3
Sizing Condition	Properly sized

Table 17: Production Well #23 Supply Meter Profile

The current supply meter installed in production well #23 is properly sized. The meter assembly has limited straight pipe spacing on both sides. The photos below show the supply meter and assembly of production well #23.

Photo 28: Production Well #23 Supply Meter Assembly

Photo 29: Production Well #23 Supply Meter

2.2.5 Production Well #28

Meter Type	Full-bore electromagnetic
Nominal Diameter (mm)	250
Brand	Siemens
Upstream and Downstream Pipe Run (10D and 5D)	Limited straight pipe distance on both sides
Spot Flow Rate (m^3/hour)	255
Years of Operation	8.3
Sizing Condition	Properly sized

Table 18: Production Well #28 Supply Meter Profile

The supply meter installed in production well #28 is properly sized. Limited straight pipe distance has been observed on both sides of the meter. Water leakage coming from the pump motor was seen during the site inspection. The succeeding photos show the supply meter and assembly of production well #28.

Photo 30: Production Well #28 Supply Meter Assembly

Photo 31: Production Well #28 Supply Meter

2.2.6 Production Well #29

Meter Type	Full-bore electromagnetic

Nominal Diameter (mm)	250
Brand	Siemens
Upstream and Downstream Pipe Run (10D and 5D)	Limited straight pipe distance on both sides
Spot Flow Rate (m^3/hour)	252.4
Years of Operation	8.2
Sizing Condition	Properly sized

Table 19: Production Well #29 Supply Meter Profile

The meter installed in production well #29 is properly sized. Limited straight pipe distance has been observed on both sides of the meter. The converter's protective cover is missing. The absence of protective covering could make the converter vulnerable to dust and water ingress. It also seen that there is continuous dripping of treated water from the flushing line which perhaps due to untightened valve. The succeeding photos show the supply meter assembly, converter and water dripping at production well #29.

Photo 32: Production Well #29 Supply Meter Assembly

Photo 33: Production Well #29 Converter

Photo 34: Water Dripping at Flushing Line

2.2.7 Macasandig Old Booster Bank #1

Meter Type	Full-bore electromagnetic
Nominal Diameter (mm)	600
Brand	Siemens
Upstream and Downstream Pipe Run (10D and 5D)	With enough straight pipe distance on both sides
Spot Flow Rate (m³/hour)	564.7
Years of Operation	6.9
Sizing Condition	Slightly oversized

Table 20: Macasandig Old Booster Bank #1 Supply Meter Profile

The meter installed in Macasanding old booster bank #1 line is slightly oversized as the estimated velocity is around 0.64 m/s. But since the existing meter is a full-bore electromagnetic type, it should be able to measure the supply input volume accurately because this type of meter is known in having a good turndown ratio. The meter has enough straight pipe distance on both sides. An alarm on the converter was observed during the field audit. The display showed “F70 coil current” alarm indicating that there is a problem on either the sensor coil or the cable connections. The alarm started to manifest in mid of April 2016. It has never been resolved since the time the alarm was started. The monthly logged flow data with 30-minute sampling interval has been plotted and compared to observe whether the alarm has direct influence on the measurement performance of the supply meter in Macasandig old booster bank #1. The following figure shows the monthly logged flow data from the supply meter.

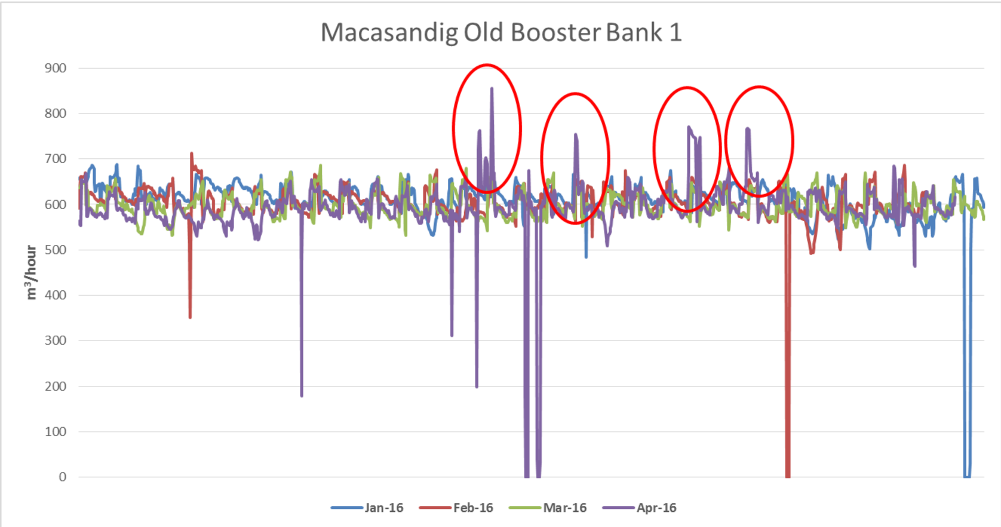

Figure 2: Logged Flow Data for the Past 4 Months (January – April 2016)

The logged flow data for the month of April 2016 shows sudden flow fluctuations which has never been occurred in the past three months. This could be due to the alarm that has manifested in the same month where the fluctuations were observed. However, this needs to be checked and verified by accredited Siemens technician to further understand the source and effect of the alarm.

Photo 35: Actual Installation of Clamp-on Ultrasonic Meter at Macasandig Old Booster Bank #1

Photo 36: Macasandig Old Booster Bank #1 Converter

2.2.8 Macasandig Old Booster Bank #2

Meter Type	Full-bore electromagnetic
Nominal Diameter (mm)	500
Brand	Siemens
Upstream and Downstream Pipe Run (10D and 5D)	With enough straight pipe distance on both sides
Spot Flow Rate (m^3/hour)	1,025
Years of Operation	8.0
Sizing Condition	Properly sized

Table 21: Macasandig Old Booster Bank #2

The supply meter installed in Macasandig old booster bank #2 is properly sized. This supply meter does have enough straight pipe distance on both sides.

Photo 37: Macasandig Old Booster #2 Supply Meter Assembly

Photo 38: Macasandig Old Booster #2 Converter

2.2.9 Macasandig New Booster

Meter Type	Full-bore electromagnetic
Nominal Diameter (mm)	500
Brand	Siemens
Upstream and Downstream Pipe Run (10D and 5D)	No straight pipe distance at the upstream
Spot Flow Rate (m^3/hour)	0
Years of Operation	3
Sizing Condition	No supply data

Table 22: Macasandig New Booster Supply Meter Profile

Macasandig new booster has been shut down few years ago. It is being said that the water sources are not enough to fill up the Macasandig production facility's collecting well that is why it has never been operated anymore.

No data can support whether the supply meter in this facility is in the right size. The supply meter doesn't have straight pipe distance at the upstream. A flange-ended bend is fitted at the upstream side of the meter which leads to absence of required straight pipe distance. The bend could create swirling flow effect through the supply meter. Excessive swirls through the supply meter causes inaccuracy on the measurements.

Photo 39: Macasandig New Booster Supply Meter Assembly

Photo 40: Macasandig New Booster Converter

3 Supply Meter Verification

Several efforts have been undertaken to be able to validate the supply input volume measurements on few selected supply meters. There are several supply meter verification methods which can be used depending on the water production facilities' configuration. Methods that can be carried out for the supply meter verification are drop testing, on-site meter test bench, clamp-on (non-intrusive) transit time ultrasonic metering and insertion electromagnetic meter. In COWD's case, the installation of clamp-on ultrasonic is the best option to use and this method can adapt the current conditions of the supply line network. Moreover, clamp-on ultrasonic meter is more cost-efficient as it does not require hot tapping points, additional work force and there is no need to shut down the production facilities.

The clamp-on transit-time ultrasonic meter uses ultrasound beams to measure the velocity of the water flows. Typically, there are two transducers in single path ultrasonic meters. These transducers emitted and received sound beams and the difference in time that the sound travels from each transducer is relative to the velocity of the water flowing through the pipeline. Theoretically, clamp-on ultrasonic meter can achieve as low as ±0.5% to ±1% measurement error if all the parameters such as pipe thickness, pipe material, circumference are properly inputted in the converter and the allowable pipe run are met accordingly.

The clamp-on ultrasonic meter used in verification of the supply meters is dry-type (non-contact) whereas the transducers are attached on the external surface of the pipe section. The ultrasonic meter has been set to be the "reference instrument" to the existing supply meters or "meter under test". The ultrasonic meter converter and the data loggers installed in the supply meters were programmed to log the flow rate data in every 15 minutes' interval. The logging duration is 24 hours to verify the measurement variance within diurnal supply volume pattern. The supply input volume data that had been recorded from both reference meter and meter under test were compared. The difference in supply input volume measurements would be the basis for determining the degree of measurement variance (or the supply meter error). The accuracy of the ultrasonic meter or the reference meter is highly dependent on the correctness of pipe wall thickness and hydraulic conditions of the supply pipeline.

Seven (7) supply meters were selected to carry out the supply meter verification. These supply meters achieved the straight pipe distance allowance which is one of the main requirements for supply meter verification. The following supply meters underwent verification measures using the ultrasonic meter installation:

1. Balulang Booster (Carmen Line)
2. Balulang Booster (Bulua Line)
3. Bugo Booster
4. Macasandig Old Booster Bank #1
5. Macasandig Old Booster Bank #2
6. Production Well #5
7. Rio Verde (RVWC)

The estimated uncertainty limit of the ultrasonic meter is used as the confidence limit of the flow measurements. The range of confidence limit will mainly depend on the ultrasonic meter's rated margin of error, hydraulic condition through the pipeline, noise present in the site and the accuracy of the pipe thickness inputted in the meter's converter. The field measurements, data downloading and data consolidation tasks have been done by COWD NRW staff. All the data gathered from supply meter verification works are considered accurate and are used in the analysis. The succeeding sections discussed about the findings that obtained from the supply meter verification activities.

3.1 Balulang Booster

As there are no pipe allowances for ultrasonic meter installation in both Carmen and Bulua Line meters' pits, COWD had to excavate some portion of the lot area inside the premises of Balulang Booster facility in order to expose enough pipe sections of both lines. The discharge pipelines of both Carmen and Bulua Line are covered with concrete linings. These linings have been removed to ensure the highest possible quality of ultrasonic meter's measurements.

3.1.1 Carmen Line Meter

The measurements gathered from the Carmen line's supply meter and from clamp-on ultrasonic meter were compared and plotted on the graph below.

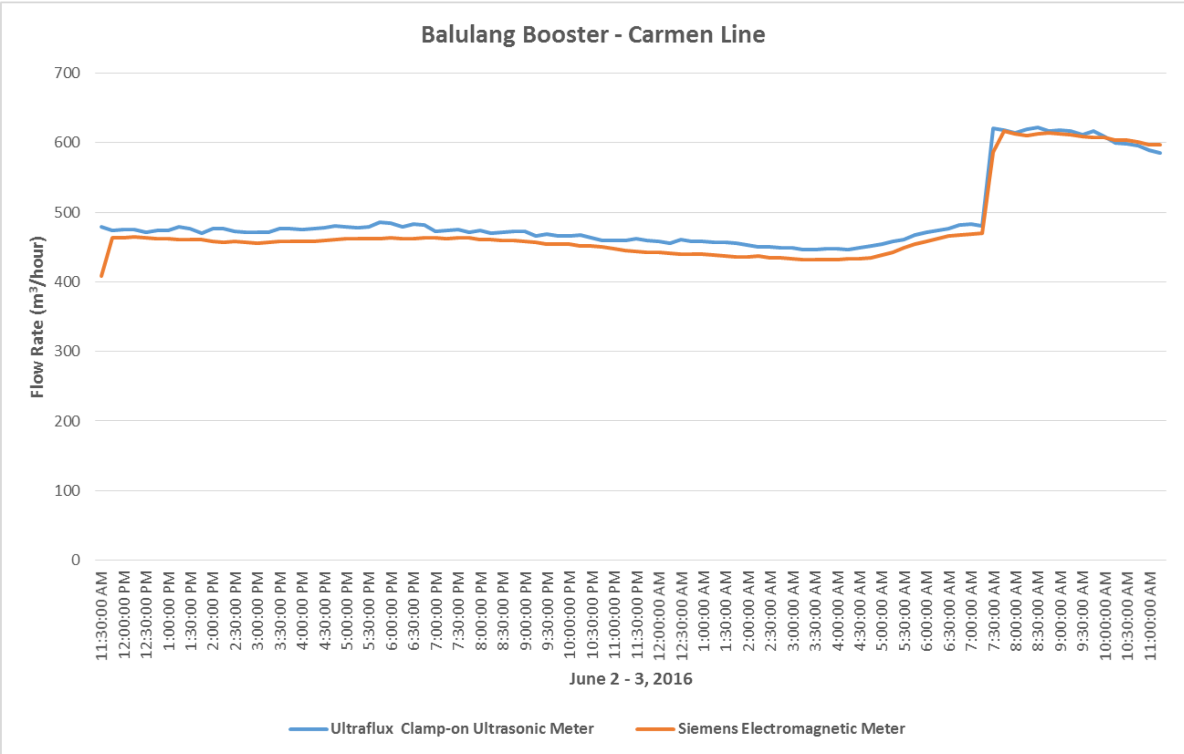

Figure 3: Carmen Line Meter – Flow Measurement Comparison

There is a 2.8% measurement variance between the reference meter and the meter under test. On the graph, the reference meter, which is the ultrasonic meter, measured more water supply compare to the meter under test. This means that the meter under test or the supply meter is under-registering by 2.8% with respect to the reference meter. The following photo shows the actual installation of the reference meter at Carmen line.

Photo 41: Actual Installation of Clamp-on Ultrasonic Meter at Carmen Line

3.1.2 Bulua Line Meter

Several attempts on ultrasonic meter installation have been carried out in Bulua Line supply meter due to ultrasonic meter failures and erratic readings. The first attempt had 5-hour downtime (measurement gaps) on ultrasonic meter due to battery drained. The second attempt gave erratic flow measurements that had doubled the normal supply input volume of Bulua Line. The third attempt has become close to realistic figures except for 2-hour downtime because of battery drained. The following figure illustrates the three flow measurement attempts in Bulua Line.

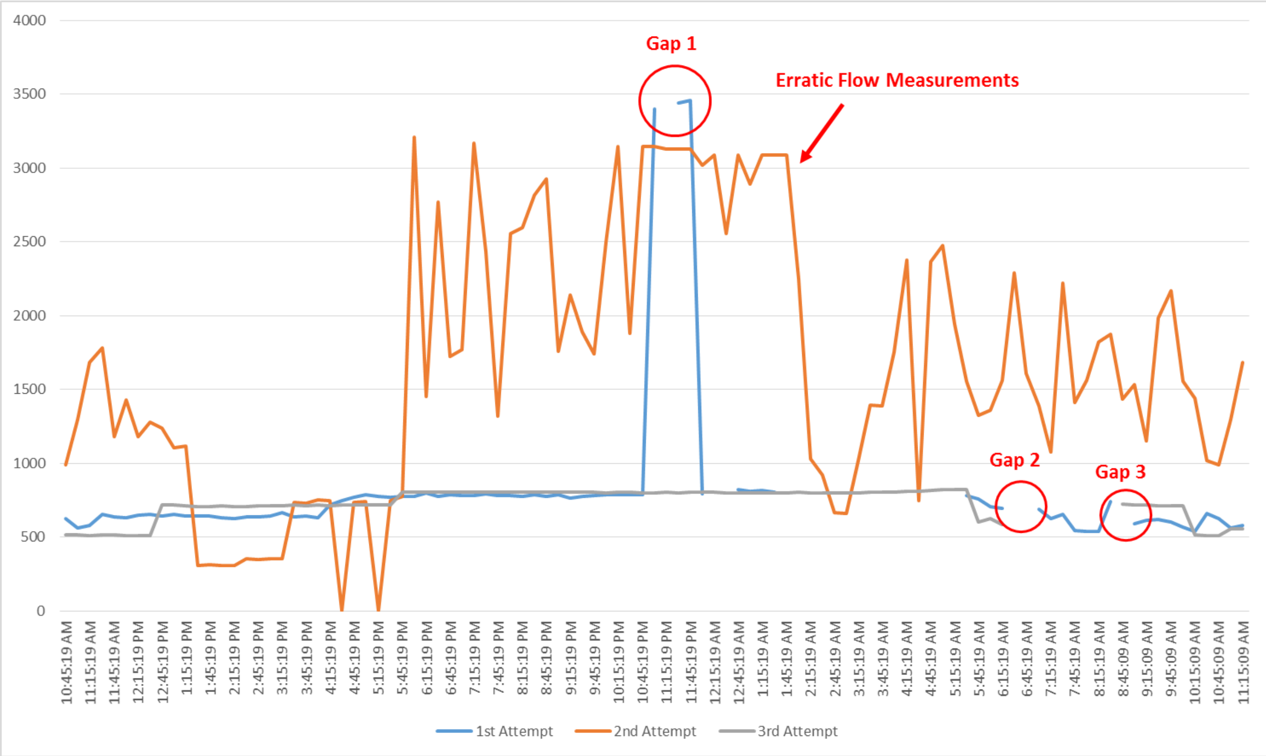

Figure 4: Result of the Three Measurement Attempts in Bulua Line

Of the three attempts, the third flow measurement has lesser gaps (downtime), more improved noise level and has smoother trend. Therefore, the third flow measurement was used for the supply meter verification analysis.

There is a 7.9% measurement variance between the reference meter and the meter under test. On the graph, the reference meter which is the ultrasonic meter measured more water supply compare to the meter under test. This means that the meter under test or the supply meter is under-registering by 7.9% with respect to the reference meter. The comparison graphs of the reference meter and meter under test can be seen in the following figure.

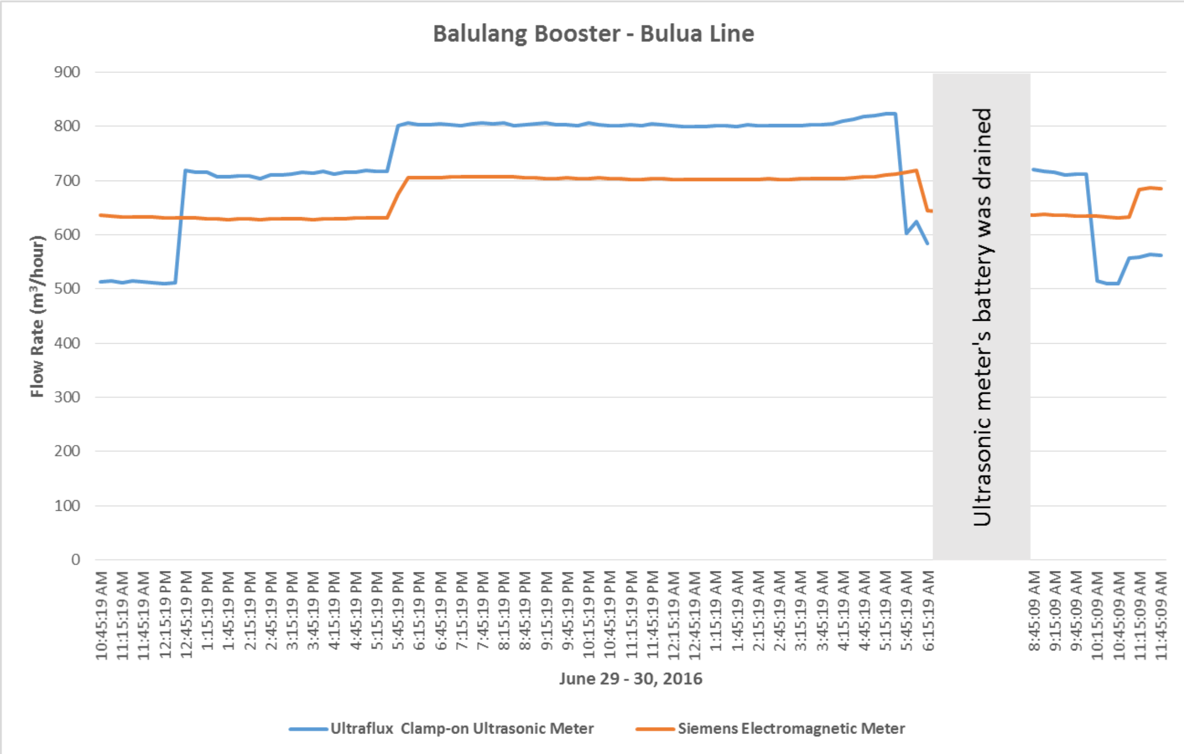

Figure 5: Bulua Line Meter – Flow Measurement Comparison

The following photo shows the actual installation of the reference meter at Carmen line.

Photo 42: Actual Installation of Clamp-on Ultrasonic Meter at Bulua Line

3.2 Bugo Booster Meter

The ultrasonic meter was installed on a bridge crossing pipe which is in line with the outlet pipe of the Bugo Booster. The bridge crossing pipe is not the ideal location where the ultrasonic should be installed as air pockets might be entrapped inside it. However, there is an air valve is installed on the pipe to release the air that is entrapped in the pipeline. This bridge crossing pipe is far from the main outlet of Bugo Booster. But the representative from COWD confirmed that there are no off-takes connected between the Bugo Booster outlet pipe and the bridge crossing pipe as this might possibly contribute significant measurement variance in the supply meter verification.

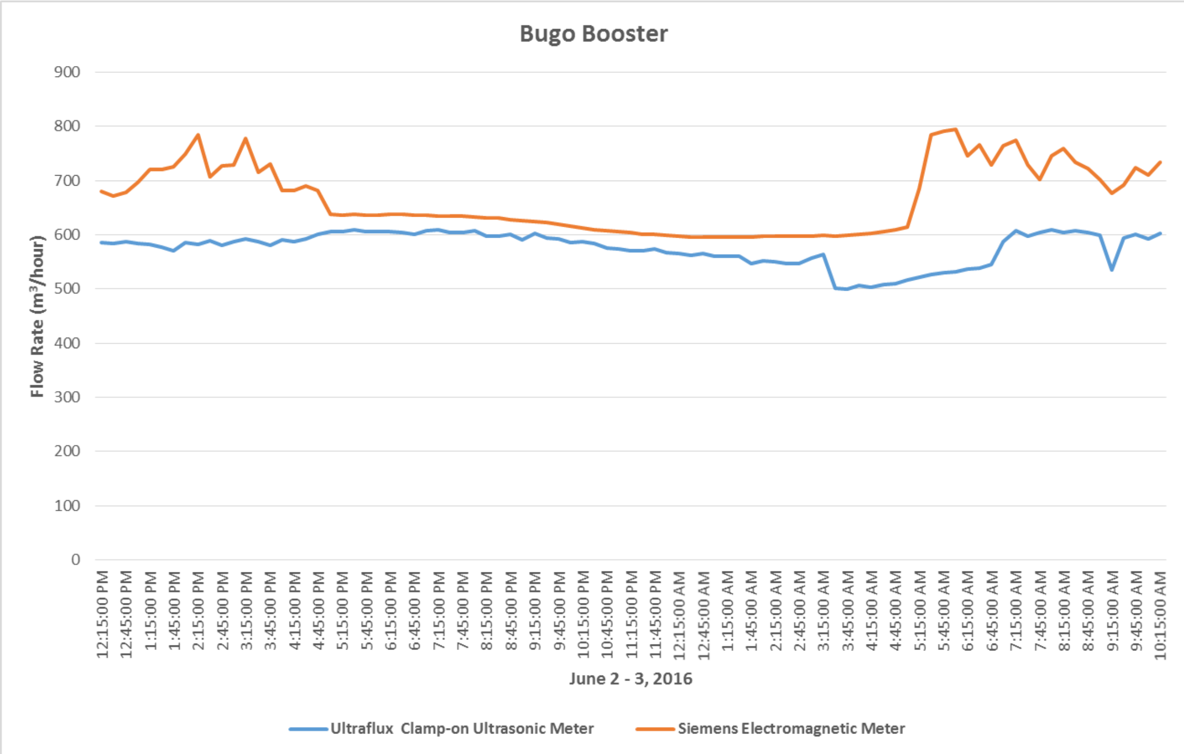

Figure 6: Bugo Booster Meter – Flow Measurement Comparison

After analysing the two measurements on the graph, it is observed that there is measurement variance of 13.4% between the reference meter and the meter under test. The supply meter, which is the meter under test, measured more water supply compare to the reference meter (ultrasonic meter). Therefore, the supply meter is over-registering by 13.4% with respect to the reference meter. The following photo shows the actual installation of the clamp-on ultrasonic on the bridge crossing pipe.

Photo 43: Actual Installation of Clamp-on Ultrasonic Meter at Bugo Booster Line Meter

3.3 Macasandig Old Booster Bank #1 Meter

Based on the results, the supply meter installed in Macasandig old booster bank #1 line is significantly under-registering by 29%. However, the under-registration rate changes between the time windows of 1915H to 2245H and 1130H to 1345H where the under-registration rate varies between 8% to 5%. In principle, the electromagnetic meter's accuracy is almost consistent (linear) at any flow velocities. These extreme variations on the supply meter's accuracy might have to do with the alarm that has been existing on the meter itself. The data graphs downloaded from the supply meter's data logger and ultrasonic meter are shown in the following figure.

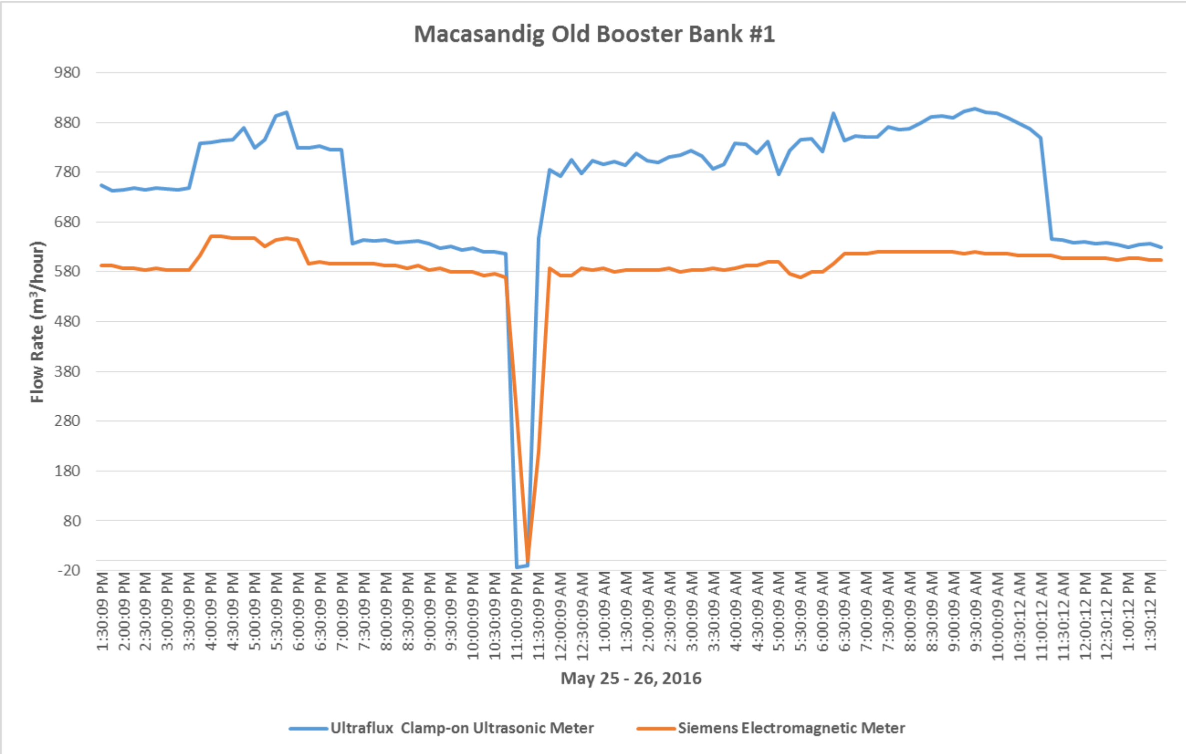

Figure 7: Macasandig Old Booster Bank #1 Meter – Flow Measurement Comparison

Photo 44: Actual Installation of Clamp-on Ultrasonic Meter at Macasandig Old Booster Bank #1 Meter

3.4 Macasandig Old Booster Bank#2 Meter

There is a 4.3% measurement variance that observed after the water supply measurements from the meter under test (supply meter) was compared to the reference meter. The supply meter, which is the meter under test, measured more water supply compare to the reference meter (ultrasonic meter). Therefore, it is over-registering by 4.3%. The variance in meter registration rate observed on this supply meter is not that wide compare to the measurement variance obtained from the supply meter in Macasandig old booster bank #2.

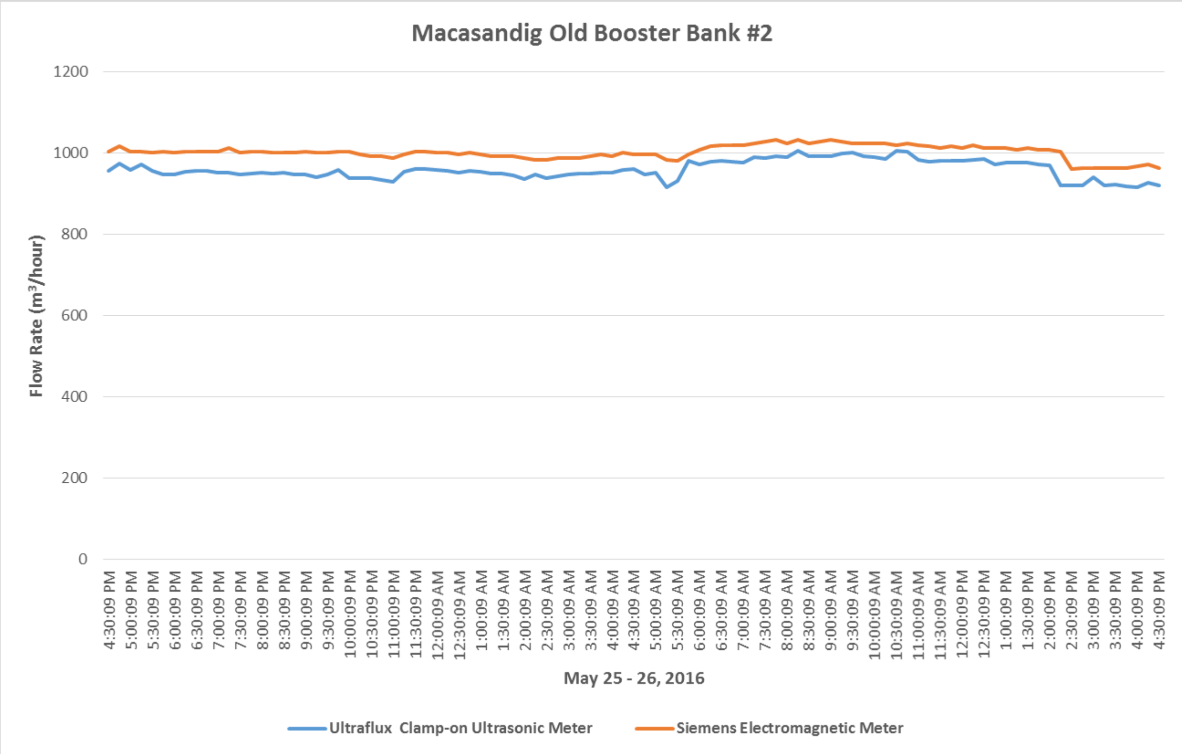

Figure 8: Macasandig Old Booster Bank #2 Meter – Flow Measurement Comparison

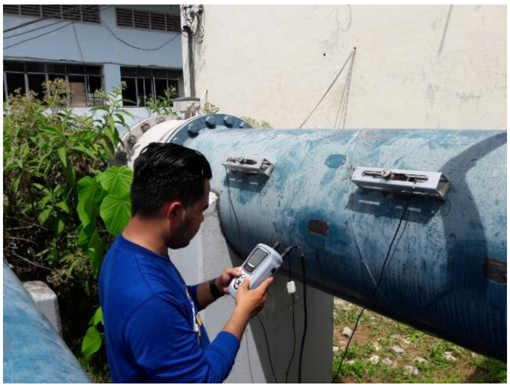

Photo 45: Actual Installation of Clamp-on Ultrasonic Meter at Macasandig Old Booster Bank #2 Meter

3.5 Production Well #5 Meter

There is a significant over-registration rate observed on the supply meter in production well #5. The production well #5 supply meter is over-registering by 28.3% when compared to the measurements collected by the reference meter (ultrasonic meter). Aside from high over-registration rate occurring on this supply meter, there are also back flows observed through the supply pipe outlet. The back flows contributes to the increase in measurement variance between the meter under test and the reference meter. It is quite impossible to have back flows through the supply pipe outlet because there is check valve fitted in the upstream side of the supply meter. This needs further investigation to determine the occurrence of back flows in the system.

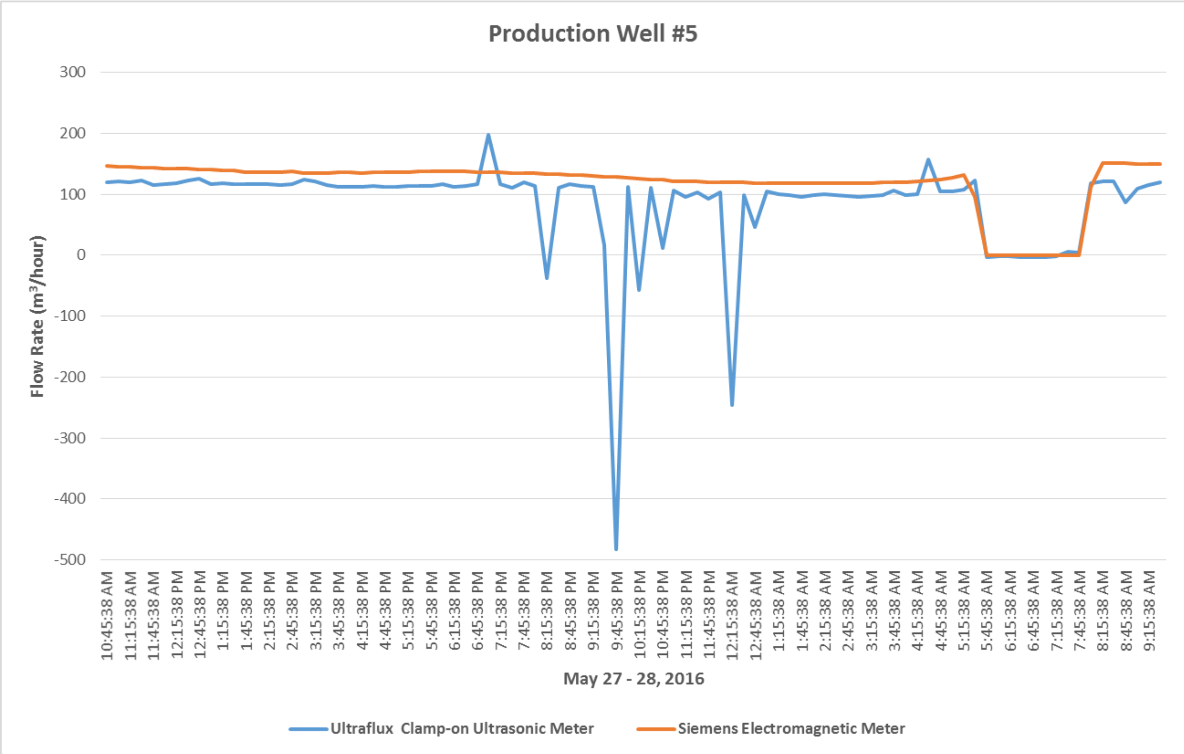

Figure 9: Production Well #5 Meter – Flow Measurement Comparison

Photo 46: Actual Installation of Clamp-on Ultrasonic Meter at Production Well #5 Meter

3.6 Rio Verde Meter (RVWC)

Comparing the logged flow rate from the reference meter and meter under test, there is measurement variance of 19.8% observed between the two flow measurements. The reference meter (ultrasonic meter) measured more water supply compare to the supply meter (meter under test). As a result, the supply meter installed in Rio Verde outlet line is under-registering by 19.8%. The measurement variance is almost consistent throughout the 24-hour measurements. The measurement variance observed will be significant when it is translated into supply input volume as Rio Verde is one of the COWD major water source.

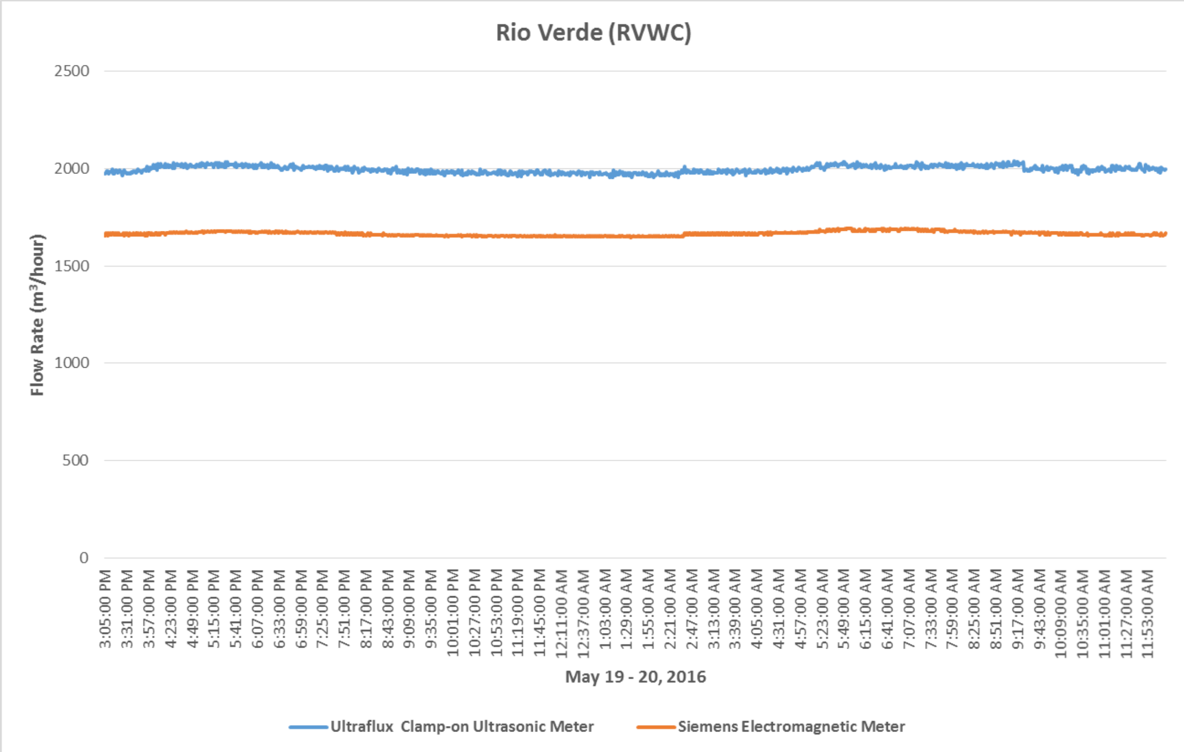

Figure 10: Rio Verde Meter – Flow Measurement Comparison

3.7 Summary of the Supply Meter Verification

The summary of measurement variance obtained from supply meter verification activity can be seen in the table below.

Supply Meters	Supply Meter Error	[1]Annual Supply Input Volume, m^3 (Y2015)	Adjusted Annual Supply Input Volume, m^3
Balulang Booster (Carmen Line)	-2.8%	3,649,410	3,754,969
Balulang Booster (Bulua Line)	-7.9%	5,589,587	6,071,987
Bugo Booster	13.4%	5,512,350	4,860,093
Macasandig Old Booster Bank #1	-29%	5,685,558	8,005,439
Macasandig Old Booster Bank #2	4.3%	8,685,766	8,329,760
Production Well #5	28.3%	1,148,286	895,281
Rio Verde (RVWC)	-19.8%	14,653,080	18,261,482
	Total	**44,924,037**	**50,179,011**

Table 23: Measurement Variance (Error) of the Supply Meters Obtained from Meter Verification

The year 2015 annual supply volume input volume of the seven (7) production sources has been adjusted based on the measurement variance (supply meter error) gathered from the supply meter verification. Vast majority of the supply input volumes have significant adjustments due to high measurement variances.

[1] COWD Supply Data 2015

3.8 Determination of Supply Meters' Uncertainty Limits

All measurements have some degree of uncertainty limits that may come from wide range of factors. For measuring instrument like electromagnetic meters, the common sources of uncertainty have been determined and was considered in the analysis. The common sources that could affect the uncertainty of the electromagnetic meters are the following:

1. Calibration factors – the certified uncertainty limits based on the calibration results.
2. Meter factors – intrinsic error, linearity and repeatability of the meter.
3. Installation factors – variations in pipe characteristics (roughness, ovality, etc.) and presence of distorting elements like valves, bends, pumps, protruding gaskets.
4. Operational factors – changes in operation conditions such as temperature (water and ambient), pressure and flow ranges.
5. Time dependent factors – build-up of deposits and corrosion on the measuring components of the instrument.
6. Data collection and transmission factors – power supply problems, grounding systems, cabling conditions, pulse scaling and measurement conversions.
7. Resolution factors – readout display fluctuating at two different limits.

The above contributing factors have been carefully verified on each supply meter to identify the magnitude of their uncertainties. The determination uncertainty is also based on the uncertainty quoted on the calibration certificate, manufacturer's specification and mostly from engineering judgement referenced to the several experiences on water supply measurement system. The following table shows the best estimate of uncertainty limits at 95% confidence interval of COWD's supply meters.

Supply Meters	Annual Supply Input Volume (m^3)	Uncertainty Limit at 95% Confidence Interval	General Remarks
Balulang Booster (Carmen Line)	3,754,969	±3.0%	Adjusted
Balulang Booster (Bulua Line)	6,071,987	±4.3%	Adjusted
Bugo Booster	4,860,093	±4.9%	Adjusted
Macasandig Old Booster Bank #1	8,005,439	±4.4%	Adjusted
Macasandig Old Booster Bank #2	8,329,760	±3.6%	Adjusted
Production Well #5	895,281	±3.6%	Adjusted
Rio Verde (RVWC)	18,261,482	±3.8%	Adjusted
Macasandig New Booster	199,539	±2.4%	No adjustment (Facility is not in use)
Production Well #18	179,335	±28.5%	No adjustment (Defective Converter)
Production Well #15	0	±39.9%	No adjustment (Not in use/No converter)
Production Well #10A	1,040,545	±40.1%	No adjustment (Defective Converter)
Production Well #24	725,940	±40.7%	No adjustment (No Converter)
Production Well #11	3,327,942	±3.1%	No adjustment
Production Well #23	3,354,915	±2.8%	No adjustment
Production Well #28	1,879,136	±2.7%	No adjustment
Production Well #29	2,185,240	±2.7%	No adjustment
Malasag Spring	59,564	±40%	Unmetered
Production Well #10	73,843	±2.5%	Decommissioned
Total	**63,205,011**	**±1.7%**	

Table 24: Uncertainty Limits of COWD Supply Meters (at 95% Confidence Interval)

Significant uncertainty limits have been estimated on supply meters at Production Well #18, #15, #10A and #24. These supply meters are those with problematic converters and unreliable measurements. Malasag spring does not have meter to measure its supply input volume. Therefore, these supply meters need wider uncertainty limits. The breakdown of the total supply input volume with uncertainty limits of West and East serviced areas can be seen in the following tables.

Supply Meters	Annual Supply Input Volume (m^3)	Uncertainty Limit at 95% Confidence Interval
Bugo Booster	4,860,093	±4.9%
Macasandig Old Booster Bank #1	8,005,439	±4.4%
Macasandig Old Booster Bank #2	8,329,760	±3.6%
Production Well #5	895,281	±3.6%
Macasandig New Booster	199,539	±2.4%
Production Well #11	3,327,942	±3.1%
Production Well #23	3,354,915	±2.8%
Production Well #28	1,879,136	±2.7%
Production Well #29	2,185,240	±2.7%
Malasag Spring	59,564	±40%
Total	**33,096,910**	**±1.6%**

Table 25: Uncertainty Limits of COWD West Supply Meters (at 95% Confidence Interval)

Supply Meters	Annual Supply Input Volume (m^3)	Uncertainty Limit at 95% Confidence Interval
Balulang Booster (Carmen Line)	3,754,969	±3.0%
Balulang Booster (Bulua Line)	6,071,987	±4.3%
Production Well #10	73,843	±2.5%
Production Well #10A	1,040,545	±40.1%
Production Well #18	179,335	±28.5%
Production Well #24	725,940	±40.7%
Rio Verde (RVWC)	18,261,482	±3.8%
Total	**30,108,101**	**±3.0%**

Table 26: Uncertainty Limits of COWD East Supply Meters (at 95% Confidence Interval)

4 General Recommendations

Based on key findings attained from the meter audit works on all the COWD supply meters, the following recommendations are formulated.

Supply Meters	Recommendations
Rio Verde (RVWC)	• Further investigate the source of high measurement variance. • Enable the NET totalizer. • Check the operability status of the transmitter and sensors.

	• It is highly recommended to install grounding system and lightning protection device. • If the high measurement variance still exists, replacement of new supply meter is needed. • A GPRS/SMS data logger should be installed to regularly monitor the supply and pressure oat Rio Verde Line.
PW #18	• Replacement is required. • Full-bore electromagnetic with U0/D0 installation requirements is recommended. • An external or built-in GPRS/SMS data logger is required for flow and pressure monitoring.
PW #15	• Replacement is required. • Full-bore electromagnetic with U0/D0 installation requirements is recommended. • Battery operated meter is needed. • A GPRS/SMS data logger should be installed to regularly monitor the supply and pressure at PW #15.
PW #10A	• Replacement is required. • Full-bore electromagnetic with U0/D0 installation requirements is recommended. • A GPRS/SMS data logger should be installed to regularly monitor the supply and pressure at PW #10A.
PW #24	• Replacement is required. • Full-bore electromagnetic with U0/D0 installation requirements is recommended. • A GPRS/SMS data logger should be installed to regularly monitor the supply and pressure at PW #24.
Balulang Booster (Carmen Line)	• Further investigate the source of measurement variance. • Enable the NET totalizer.

	• Check the operability status of the transmitter and sensors. • It is highly recommended to install grounding system and lightning protection device. • Conduits are required for meter cables' protection • Enable the pressure channel of the Cello data logger • Check valve should be re-fitted 5D away from the supply meter. • If the measurement variance still exists, replacement of new supply meter is needed.
Balulang Booster (Bulua Line)	• Further investigate the source of high measurement variance. • Enable the NET totalizer. • Check the operability status of the transmitter and sensors. • It is highly recommended to install grounding system and lightning protection device. • Conduits are required for meter cables' protection. • Enable the pressure channel of the Cello data logger. • Check valve should be re-fitted 5D away from the supply meter. • If the measurement variance still exists, replacement of new supply meter is needed.
PW #11	• Enable the NET totalizer. • Check the operability status of the transmitter and sensors. • It is highly recommended to install grounding system and lightning protection device. • If the operability status does not meet the acceptable results, replacement of new supply meter is needed.

PW #5	• Further investigate the source of high measurement variance. • Enable the NET totalizer. • Check the operability status of the transmitter and sensors. • It is highly recommended to install grounding system and lightning protection device. • Check valve should be re-fitted at the downstream side 5D away from the supply meter. • If the measurement variance still exists, replacement of new supply meter is needed.
Bugo Booster	• Replacement is required. • Full-bore electromagnetic with U0/D0 installation requirements is recommended.
PW #23	• Enable the NET totalizer. • Check the operability status of the transmitter and sensors. • It is highly recommended to install grounding system and lightning protection device. • Conduits are required for meter cables' protection. • If the operability status does not meet the acceptable results, replacement of new supply meter is needed.
PW #28	• Enable the NET totalizer. • Check the operability status of the transmitter and sensors. • It is highly recommended to install grounding system and lightning protection device. • Conduits are required for meter cables' protection. • If the operability status does not meet the acceptable results, replacement of new supply meter is needed.

PW #29	• Enable the NET totalizer. • Check the operability status of the transmitter and sensors. • It is highly recommended to install grounding system and lightning protection device. • Conduits are required for meter cables' protection. • If the operability status does not meet the acceptable results, replacement of new supply meter is needed.
Macasandig Old Booster Bank #2 (500mm Line)	• Enable the NET totalizer. • Check the operability status of the transmitter and sensors. • It is highly recommended to install grounding system and lightning protection device. • Conduits are required for meter cables' protection. • Enable the pressure channel of the Cello data logger. • If the operability status does not meet the acceptable results, replacement of new supply meter is needed.
Macasandig Old Booster Bank #1 (600mm Line)	• Further investigate the source of high measurement variance. Troubleshoot the "F70" alarm. • Enable the NET totalizer. • Check the operability status of the transmitter and sensors. • Enable the pressure channel of the Cello data logger. • Conduits are required for meter cables' protection. • It is highly recommended to install grounding system and lightning protection device. • If the measurement variance and alarm still exist, replacement of new supply meter is needed.

Macasandig New Booster	• Move/Re-fit the existing supply meter 10D away from the upstream bend. • Enable the NET totalizer. • Check the operability status of the transmitter and sensors. • It is highly recommended to install grounding system and lightning protection device. • Conduits are required for meter cables' protection.
Malasag Spring	• Needs supply meter to obtain accurate supply input volume measurements.

Other recommendations:

- **Operability Status Check** involves verification of possible alarms, transmitter check-up, sensor's insulation and magnetic circuit check. A technician from the accredited meter supplier should carry out the operability status check.
- **Supply Meter Audit** needs to be done annually. Parameter settings should be recorded regularly. A team of two is needed to implement the supply meter audit program.

5 Annex A: Supply Meter Audit Forms

The information and field observations obtained from the supply meter audit were documented in the forms below.

SUPPLY METER AUDIT ASSESSMENT REPORT

Facility Name:	Rio Verde	**Date of Audit:**	5/13/16
Location:	Lumbia	**Time:**	1:00 PM
Water Supply Fed to:	West Area		
Date of last audit:	N/A		

Meter readout (during the time of visit)

Totalizer (m^3):	30951415
Instantaneous flow rate (m^3/hour):	1659
Other parameters:	-
Facility operation schedule (hours/day):	24
Pressure reading in the supply line (psi):	75

METER DETAILS

Meter brand:	Siemens		
Meter model:	Sitrans FM Magflo Mag 5100W		
Meter manufacturer:	Siemens Flow Instruments		
Display (remote or compact):	Remote		
Power supply (external/battery)	AC Powered		
Method of reporting (manual reads/AMR/SCADA):	Manual reads		
Meter type:	Electromagnetic		
Meter size (mm):	800	Grounding (Yes/No):	No
Meter serial number:	7ME651817413T126	With data logger (Yes/No):	No
Meter location:	In pit	Flow:	x
Date of installation:		Pressure:	x
Meter orientation (horizontal, inclined, vertical):	Horizontal		

LINE DETAILS

Pipe size (mm):	800
Pipe material:	Steel

	Upstream	*Downstream*
Pipe run length (mm):	limited space	limited space
Closest appurtenance:	None	None
Pressure reducing component:	None	None

Chemical dosing points upstream (Yes/No):	Yes
Large motor close to flow meter (Yes/No):	No
VFD/VSD installed in the motors? (Yes/No):	Undefined
Pipe always running full? (Yes/No):	Yes
Are control valves fitted? (Yes/No):	No
Is there strainer installed (Yes/No):	No

SITE DETAILS

Inside the building (Yes/No):	No
In pit (Yes/No):	Yes
Pit flooded (Yes/No):	Yes
As-built drawings available (Yes/No):	-
Security (Good/Bad):	Good

OTHER REMARKS/FINDINGS:

Official register (totalizer) is in the meter house. The converter is locked up in a steel cage. No pipe allowances in the meter pit.

Figure 11: Rio Verde (RVWC) Supply Meter Audit Form

SUPPLY METER AUDIT ASSESSMENT REPORT

Facility Name:	PW 18	**Date of Audit:**	5/13/16
Location:	Pueblo de Oro, Calaanan Valley	**Time:**	12:30 PM
Water Supply Fed to:	West Area		
Date of last audit:	N/A		

Meter readout (during the time of visit)

Totalizer (m^3):	2626953.6
Instantaneous flow rate (m^3/hour):	0
Other parameters:	-
Facility operation schedule (hours/day):	30 mins to 1 hour
Pressure reading in the supply line (psi):	0

METER DETAILS

Meter brand:	Euromag		
Meter model:	MUT 2200/EL		
Meter manufacturer:	Euromag International		
Display (remote or compact):	Remote		
Power supply (external/battery)	AC Powered		
Method of reporting (manual reads/AMR/SCADA):	Manual reads and AMR		
Meter type:	Electromagnetic		
Meter size (mm):	150	Grounding (Yes/No):	No
Meter serial number:	2AC0817	With data logger (Yes/No):	Yes
Meter location:	Outdoor	Flow:	✓
Years of operation:	5.4	Pressure:	✓
Meter orientation (horizontal, inclined, vertical):	Horizontal		

LINE DETAILS

Pipe size (mm):	150
Pipe material:	Steel

	Upstream	*Downstream*
Pipe run length (mm):	1200	1670
Closest appurtenance:	Bend	Check valve
Pressure reducing component:	None	None

Chemical dosing points upstream (Yes/No):	No
Large motor close to flow meter (Yes/No):	Yes
VFD/VSD installed in the motors? (Yes/No):	No
Pipe always running full? (Yes/No):	No
Are control valves fitted? (Yes/No):	No
Is there strainer installed (Yes/No):	No

SITE DETAILS

Inside the building (Yes/No):	No
In pit (Yes/No):	No
Pit flooded (Yes/No):	No
As-built drawings available (Yes/No):	-
Security (Good/Bad):	Bad

OTHER REMARKS/FINDINGS:

Stand-by source.
Only used for flushings.
Defective register.
The totalizer and flow rate are running even the well is off.

Figure 12: Production Well #18 Supply Meter Audit Form

USAID FROM THE AMERICAN PEOPLE

SUPPLY METER AUDIT ASSESSMENT REPORT

THE Coca-Cola FOUNDATION

Facility Name:	PW 15
Location:	PNROA Subd., Calaanan, Canitoan
Water Supply Fed to:	West Area (Relocation Area)
Date of last audit:	N/A
Date of Audit:	5/13/16
Time:	11:30 AM

Meter readout (during the time of visit)

Totalizer (m^3):	-
Instantaneous flow rate (m^3/hour):	-
Other parameters:	-
Facility operation schedule (hours/day):	-
Pressure reading in the supply line (psi):	-

METER DETAILS

Meter brand:	Euromag
Meter model:	MUT 2200/EL
Meter manufacturer:	Euromag International
Display (remote or compact):	Remote
Power supply (external/battery)	Battery
Method of reporting (manual reads/AMR/SCADA):	-
Meter type:	Electromagnetic
Meter size (mm):	150
Meter serial number:	ZAC0815
Meter location:	Outdoor
Years of operation:	5.3
Meter orientation (horizontal, inclined, vertical):	Horizontal
Grounding (Yes/No):	No
With data logger (Yes/No):	No
Flow:	☒
Pressure:	☒

LINE DETAILS

Pipe size (mm):	150
Pipe material:	Steel

	Upstream	*Downstream*
Pipe run length (mm):	1910	0
Closest appurtenance:	Bend	Reducer
Pressure reducing component:	None	None

Chemical dosing points upstream (Yes/No):	No
Large motor close to flow meter (Yes/No):	Yes
VFD/VSD installed in the motors? (Yes/No):	No
Pipe always running full? (Yes/No):	No
Are control valves fitted? (Yes/No):	No
Is there strainer installed (Yes/No):	No

SITE DETAILS

Inside the building (Yes/No):	No
In pit (Yes/No):	No
Pit flooded (Yes/No):	No
As-built drawings available (Yes/No):	-
Security (Good/Bad):	Good

OTHER REMARKS/FINDINGS:

Stand-by source.
No power source
Damaged by sendong
Only used for cleaning and flushing

Figure 13: Production Well #15 Supply Meter Audit Form

SUPPLY METER AUDIT ASSESSMENT REPORT

Facility Name:	PW 10A	**Date of Audit:**	5/13/16
Location:	PNROA Subd., Calaanan, Canitoan	**Time:**	11:10 AM
Water Supply Fed to:	West Area (Relocation Area)		
Date of last audit:	N/A		

Meter readout (during the time of visit)

Totalizer (m^3):	940235.3
Instantaneous flow rate (m^3/hour):	231.5
Other parameters:	-
Facility operation schedule (hours/day):	24
Pressure reading in the supply line (psi):	35

METER DETAILS

Meter brand:	Euromag
Meter model:	MUT 2200/EL
Meter manufacturer:	Euromag International
Display (remote or compact):	Remote
Power supply (external/battery)	Battery
Method of reporting (manual reads/AMR/SCADA):	Manual reads
Meter type:	Electromagnetic

Meter size (mm):	200	Grounding (Yes/No):	No
Meter serial number:	GAC3225	With data logger (Yes/No):	No
Meter location:	Outdoor	Flow:	☒
Years of operation:	5.3	Pressure:	☒
Meter orientation (horizontal, inclined, vertical):	Horizontal		

LINE DETAILS

Pipe size (mm):	200
Pipe material:	Steel

	Upstream	*Downstream*
Pipe run length (mm):	1200	790
Closest appurtenance:	Strainer	Check valve
Pressure reducing component:	None	None

Chemical dosing points upstream (Yes/No):	No
Large motor close to flow meter (Yes/No):	Yes
VFD/VSD installed in the motors? (Yes/No):	No
Pipe always running full? (Yes/No):	Yes
Are control valves fitted? (Yes/No):	No
Is there strainer installed (Yes/No):	Yes

SITE DETAILS

Inside the building (Yes/No):	No
In pit (Yes/No):	No
Pit flooded (Yes/No):	No
As-built drawings available (Yes/No):	-
Security (Good/Bad):	Good

OTHER REMARKS/FINDINGS:

Display is fading

Low battery

No flow records

Figure 14: Production Well #10A Supply Meter Audit Form

SUPPLY METER AUDIT ASSESSMENT REPORT

Facility Name:	PW 24	**Date of Audit:**	5/13/16
Location:	Ilaya, Balulang	**Time:**	10:30 AM
Water Supply Fed to:	West Area, Balulang Area		
Date of last audit:	N/A		

Meter readout (during the time of visit)

Totalizer (m^3):	-
Instantaneous flow rate (m^3/hour):	-
Other parameters:	-
Facility operation schedule (hours/day):	24
Pressure reading in the supply line (psi):	50

METER DETAILS

Meter brand:	Siemens		
Meter model:	Sitrans FM Magflo Mag 5100W		
Meter manufacturer:	Siemens Flow Instruments		
Display (remote or compact):	Remote		
Power supply (external/battery)	AC Powered		
Method of reporting (manual reads/AMR/SCADA):	-		
Meter type:	Electromagnetic		
Meter size (mm):	150	Grounding (Yes/No):	No
Meter serial number:	-	With data logger (Yes/No):	No
Meter location:	Outdoor	Flow:	x
Years of operation:	10	Pressure:	x
Meter orientation (horizontal, inclined, vertical):	Horizontal		

LINE DETAILS

Pipe size (mm):	150
Pipe material:	Steel

	Upstream	*Downstream*
Pipe run length (mm):	1000	430
Closest appurtenance:	Strainer	Check valve
Pressure reducing component:	None	None

Chemical dosing points upstream (Yes/No):	No
Large motor close to flow meter (Yes/No):	Yes
VFD/VSD installed in the motors? (Yes/No):	No
Pipe always running full? (Yes/No):	Yes
Are control valves fitted? (Yes/No):	No
Is there strainer installed (Yes/No):	Yes

SITE DETAILS

Inside the building (Yes/No):	No
In pit (Yes/No):	No
Pit flooded (Yes/No):	Yes
As-built drawings available (Yes/No):	-
Security (Good/Bad):	Good

OTHER REMARKS/FINDINGS:

The meter is defective.

No converter/display

Figure 15: Production Well #24 Supply Meter Audit Form

SUPPLY METER AUDIT ASSESSMENT REPORT

Facility Name:	Balulang Booster (Carmen Line)	**Date of Audit:**	5/13/16
Location:	Balulang	**Time:**	9:50 AM
Water Supply Fed to:	West Area		
Date of last audit:	N/A		

Meter readout (during the time of visit)

Totalizer (m^3):	3908618.5
Instantaneous flow rate (m^3/hour):	431.1
Other parameters:	Totalizer 2: 7820.9
Facility operation schedule (hours/day):	24
Pressure reading in the supply line (psi):	50

METER DETAILS

Meter brand:	Siemens		
Meter model:	Sitrans FM Magflo Mag 5000W		
Meter manufacturer:	Siemens Flow Instruments		
Display (remote or compact):	Remote		
Power supply (external/battery)	AC Powered		
Method of reporting (manual reads/AMR/SCADA):	AMR and Manual Reads		
Meter type:	Electromagnetic		
Meter size (mm):	300	Grounding (Yes/No):	No
Meter serial number:	7ME651439814T276	With data logger (Yes/No):	Yes
Meter location:	Outdoor	Flow:	✓
Years of operation:	6.3	Pressure:	x
Meter orientation (horizontal, inclined, vertical):	Horizontal		

LINE DETAILS

Pipe size (mm):	300
Pipe material:	Steel

	Upstream	*Downstream*
Pipe run length (mm):	2010	420
Closest appurtenance:	Tee with blind flange	Check valve
Pressure reducing component:	None	None

Chemical dosing points upstream (Yes/No):	No
Large motor close to flow meter (Yes/No):	Yes
VFD/VSD installed in the motors? (Yes/No):	Yes
Pipe always running full? (Yes/No):	Yes
Are control valves fitted? (Yes/No):	No
Is there strainer installed (Yes/No):	No

SITE DETAILS

Inside the building (Yes/No):	No
In pit (Yes/No):	Yes
Pit flooded (Yes/No):	No
As-built drawings available (Yes/No):	-
Security (Good/Bad):	Good

OTHER REMARKS/FINDINGS:

Correction factor: 0.92
With collector well level moni-
ring.
With VFD
No pipe allowance for UM

Figure 16: Balulang Booster (Carmen Line) Supply Meter Audit Form

SUPPLY METER AUDIT ASSESSMENT REPORT

Facility Name:	Balulang Booster (Bulua Line)	**Date of Audit:**	5/13/16
Location:	Balulang	**Time:**	9:50 AM
Water Supply Fed to:	West Area		
Date of last audit:	N/A		

Meter readout (during the time of visit)

Totalizer (m^3):	9473989.5
Instantaneous flow rate (m^3/hour):	710
Other parameters:	Totalizer 2: 4909.3
Facility operation schedule (hours/day):	24
Pressure reading in the supply line (psi):	100

METER DETAILS

Meter brand:	Siemens		
Meter model:	Sitrans FM Magflo Mag 5000W		
Meter manufacturer:	Siemens Flow Instruments		
Display (remote or compact):	Remote		
Power supply (external/battery)	AC Powered		
Method of reporting (manual reads/AMR/SCADA):	AMR and Manual Reads		
Meter type:	Electromagnetic		
Meter size (mm):	400	Grounding (Yes/No):	No
Meter serial number:	7ME652674802N457	With data logger (Yes/No):	Yes
Meter location:	Outdoor	Flow:	✓
Years of operation:	6.3	Pressure:	x
Meter orientation (horizontal, inclined, vertical):	Horizontal		

LINE DETAILS

Pipe size (mm):	400
Pipe material:	Steel

	Upstream	*Downstream*
Pipe run length (mm):	2520	550
Closest appurtenance:	Tee with blind flange	Check valve
Pressure reducing component:	None	None

Chemical dosing points upstream (Yes/No):	No
Large motor close to flow meter (Yes/No):	Yes
VFD/VSD installed in the motors? (Yes/No):	Yes
Pipe always running full? (Yes/No):	Yes
Are control valves fitted? (Yes/No):	No
Is there strainer installed (Yes/No):	No

SITE DETAILS

Inside the building (Yes/No):	No
In pit (Yes/No):	Yes
Pit flooded (Yes/No):	No
As-built drawings available (Yes/No):	-
Security (Good/Bad):	Good

OTHER REMARKS/FINDINGS:

Correction factor: 1.12
With collector well level moni-
ring.
With VFD. Cement coated pipe.
No pipe allowance for UM

Figure 17: Balulang Booster (Bulua Line) Supply Meter Audit Form

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SUPPLY METER AUDIT ASSESSMENT REPORT

Facility Name:	PW 11	**Date of Audit:**	5/12/2016
Location:	Bantiles, Bugo	**Time:**	4:30 PM
Water Supply Fed to:	East Area		
Date of last audit:	N/A		

Meter readout (during the time of visit)

Totalizer (m^3):	4467200.0
Instantaneous flow rate (m^3/hour):	399.2
Other parameters:	Totalizer 2: 8113736 USG
Facility operation schedule (hours/day):	24
Pressure reading in the supply line (psi):	45

METER DETAILS

Meter brand:	Siemens		
Meter model:	Sitrans FM Magflo Mag 5000W		
Meter manufacturer:	Siemens Flow Instruments		
Display (remote or compact):	Compact		
Power supply (external/battery)	AC Powered		
Method of reporting (manual reads/AMR/SCADA):	AMR and Manual Reads		
Meter type:	Electromagnetic		
Meter size (mm):	250	Grounding (Yes/No):	No
Meter serial number:	7ME651475013T046	With data logger (Yes/No):	Yes
Meter location:	Indoor	Flow:	✓
Years of operation:	8	Pressure:	✓
Meter orientation (horizontal, inclined, vertical):	Horizontal		

LINE DETAILS

Pipe size (mm):	250
Pipe material:	Steel

	Upstream	*Downstream*
Pipe run length (mm):	1770	750
Closest appurtenance:	None	Check valve
Pressure reducing component:	None	None

Chemical dosing points upstream (Yes/No):	Yes
Large motor close to flow meter (Yes/No):	Yes
VFD/VSD installed in the motors? (Yes/No):	No
Pipe always running full? (Yes/No):	Yes
Are control valves fitted? (Yes/No):	No
Is there strainer installed (Yes/No):	No

SITE DETAILS

Inside the building (Yes/No):	Yes
In pit (Yes/No):	No
Pit flooded (Yes/No):	No
As-built drawings available (Yes/No):	-
Security (Good/Bad):	Good

OTHER REMARKS/FINDINGS:

With soft starter

Alarm: W30 Overflow max

Figure 18: Production Well #11 Supply Meter Audit Form

SUPPLY METER AUDIT ASSESSMENT REPORT

Facility Name: PW 5
Date of Audit: 5/12/2016
Location: Bantiles, Bugo
Time: 4:00 PM
Water Supply Fed to: East Area
Date of last audit: N/A

Meter readout (during the time of visit)

Totalizer (m^3): 6573011.0
Instantaneous flow rate (m^3/hour): 141
Other parameters: Totalizer 2: 7308 USG
Facility operation schedule (hours/day): 24
Pressure reading in the supply line (psi): 29

METER DETAILS

Meter brand: Siemens
Meter model: Sitrans FM Magflo Mag 6000W
Meter manufacturer: Siemens Flow Instruments
Display (remote or compact): Compact
Power supply (external/battery) AC Powered
Method of reporting (manual reads/AMR/SCADA): AMR and Manual Reads
Meter type: Electromagnetic
Meter size (mm): 200
Grounding (Yes/No): No
Meter serial number: 7ME652816502N277
With data logger (Yes/No): Yes
Meter location: Indoor
Flow: ✓
Years of operation: 8.3
Pressure: ✓
Meter orientation (horizontal, inclined, vertical): Horizontal

LINE DETAILS

Pipe size (mm): 200
Pipe material: Steel

	Upstream	*Downstream*
Pipe run length (mm):	540	2750
Closest appurtenance:	None	Check valve
Pressure reducing component:	None	None

Chemical dosing points upstream (Yes/No): No
Large motor close to flow meter (Yes/No): Yes
VFD/VSD installed in the motors? (Yes/No): No
Pipe always running full? (Yes/No): Yes
Are control valves fitted? (Yes/No): No
Is there strainer installed (Yes/No): No

SITE DETAILS

Inside the building (Yes/No): Yes
In pit (Yes/No): No
Pit flooded (Yes/No): No
As-built drawings available (Yes/No): -
Security (Good/Bad): Good

OTHER REMARKS/FINDINGS:

With soft starter

Figure 19: Production Well #5 Supply Meter Audit Form

SUPPLY METER AUDIT ASSESSMENT REPORT

Facility Name:	Bugo Booster	**Date of Audit:**	5/12/2016
Location:	Phase III Trenitas Brgy. Bugo	**Time:**	3:20 PM
Water Supply Fed to:	East Area		
Date of last audit:	N/A		

Meter readout (during the time of visit)

Totalizer (m^3):	7087064.0
Instantaneous flow rate (m^3/hour):	617.88
Other parameters:	Totalizer 2: 231
Facility operation schedule (hours/day):	24
Pressure reading in the supply line (psi):	60

METER DETAILS

Meter brand:	Siemens
Meter model:	-
Meter manufacturer:	Siemens Flow Instruments
Display (remote or compact):	Remote
Power supply (external/battery)	AC Powered
Method of reporting (manual reads/AMR/SCADA):	AMR and Manual Reads

Meter type:	Electromagnetic		
Meter size (mm):	300	Grounding (Yes/No):	No
Meter serial number:	-	With data logger (Yes/No):	Yes
Meter location:	Indoor	Flow:	✓
Years of operation:	7.5	Pressure:	✓
Meter orientation (horizontal, inclined, vertical):	Horizontal		

LINE DETAILS

Pipe size (mm):	300
Pipe material:	Steel

	Upstream	*Downstream*
Pipe run length (mm):	1660	550
Closest appurtenance:	Butterfly valve	Enlarger pipe
Pressure reducing component:	None	None

Chemical dosing points upstream (Yes/No):	No
Large motor close to flow meter (Yes/No):	Yes
VFD/VSD installed in the motors? (Yes/No):	Yes
Pipe always running full? (Yes/No):	No
Are control valves fitted? (Yes/No):	No
Is there strainer installed (Yes/No):	No

SITE DETAILS

Inside the building (Yes/No):	Yes
In pit (Yes/No):	No
Pit flooded (Yes/No):	No
As-built drawings available (Yes/No):	-
Security (Good/Bad):	Good

OTHER REMARKS/FINDINGS:

With 2 VFDs
Can't get the meter information as the plate is covered by electri-cal tape. Leakage at STC.
Installed on elevated concrete

Figure 20: Bugo Booster Supply Meter Audit Form

SUPPLY METER AUDIT ASSESSMENT REPORT

Facility Name:	PW 23	Date of Audit:	5/12/2016
Location:	Sitio Tin-Ao Brgy. Agusan	Time:	2:35 PM
Water Supply Fed to:	East Area		
Date of last audit:	N/A		

Meter readout (during the time of visit)

Totalizer (m^3):	23472444.0
Instantaneous flow rate (m^3/hour):	356.4
Other parameters:	Totalizer 2: 114600
Facility operation schedule (hours/day):	24
Pressure reading in the supply line (psi):	51

METER DETAILS

Meter brand:	Siemens		
Meter model:	Sitrans FM Magflo Mag5100W		
Meter manufacturer:	Siemens Flow Instruments		
Display (remote or compact):	Remote		
Power supply (external/battery)	AC Powered		
Method of reporting (manual reads/AMR/SCADA):	AMR and Manual Reads		
Meter type:	Electromagnetic		
Meter size (mm):	250	Grounding (Yes/No):	No
Meter serial number:	7ME651519013T065	With data logger (Yes/No):	Yes
Meter location:	Outdoor	Flow:	✓
Years of operation:	7.5	Pressure:	✓
Meter orientation (horizontal, inclined, vertical):	Horizontal		

LINE DETAILS

Pipe size (mm):	250	
Pipe material:	Steel	
	Upstream	*Downstream*
Pipe run length (mm):	1680	550
Closest appurtenance:	Butterfly valve	Check valve
Pressure reducing component:	None	None

Chemical dosing points upstream (Yes/No):	No
Large motor close to flow meter (Yes/No):	Yes
VFD/VSD installed in the motors? (Yes/No):	No
Pipe always running full? (Yes/No):	Yes
Are control valves fitted? (Yes/No):	Yes
Is there strainer installed (Yes/No):	No

SITE DETAILS

Inside the building (Yes/No):	No
In pit (Yes/No):	No
Pit flooded (Yes/No):	No
As-built drawings available (Yes/No):	-
Security (Good/Bad):	Good

OTHER REMARKS/FINDINGS:

Figure 21: Production Well #23 Supply Meter Audit Form

SUPPLY METER AUDIT ASSESSMENT REPORT

Facility Name:	PW 28	Date of Audit:	5/12/2016
Location:	Phasco Village, Tablon	Time:	12:00 PM
Water Supply Fed to:	East Area		
Date of last audit:	N/A		

Meter readout (during the time of visit)

Totalizer (m^3):	16857980.0
Instantaneous flow rate (m^3/hour):	255
Other parameters:	Totalizer 2: 13931
Facility operation schedule (hours/day):	24
Pressure reading in the supply line (psi):	48

METER DETAILS

Meter brand:	Siemens		
Meter model:	Sitrans FM Magflo Mag5100W		
Meter manufacturer:	Siemens Flow Instruments		
Display (remote or compact):	Remote		
Power supply (external/battery)	AC Powered		
Method of reporting (manual reads/AMR/SCADA):	AMR and Manual Reads		
Meter type:	Electromagnetic		
Meter size (mm):	250	Grounding (Yes/No):	No
Meter serial number:	7ME652672302N457	With data logger (Yes/No):	Yes
Meter location:	Outdoor	Flow:	✓
Years of operation:	8.3	Pressure:	✓
Meter orientation (horizontal, inclined, vertical):	Horizontal		

LINE DETAILS

Pipe size (mm):	250
Pipe material:	Steel

	Upstream	*Downstream*
Pipe run length (mm):	1005	530
Closest appurtenance:	None	Check valve
Pressure reducing component:	None	Butterfly valve

Chemical dosing points upstream (Yes/No):	No
Large motor close to flow meter (Yes/No):	Yes
VFD/VSD installed in the motors? (Yes/No):	No
Pipe always running full? (Yes/No):	Yes
Are control valves fitted? (Yes/No):	Yes
Is there strainer installed (Yes/No):	No

SITE DETAILS

Inside the building (Yes/No):	No
In pit (Yes/No):	No
Pit flooded (Yes/No):	No
As-built drawings available (Yes/No):	-
Security (Good/Bad):	Good

OTHER REMARKS/FINDINGS:

With PRV installed at downstream
Previously feeds the Tablon Resevoir
but it goes direct to the distribution
network.

Figure 22: Production Well #28 Supply Meter Audit Form

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SUPPLY METER AUDIT ASSESSMENT REPORT

Facility Name:	PW 29
Location:	Phasco Village, Tablon
Water Supply Fed to:	East Area
Date of last audit:	N/A
Date of Audit:	5/12/2016
Time:	11:35 AM

Meter readout (during the time of visit)

Totalizer (m^3):	17363430.0
Instantaneous flow rate (m^3/hour):	252.4
Other parameters:	Totalizer 2: 7046
Facility operation schedule (hours/day):	24
Pressure reading in the supply line (psi):	55

METER DETAILS

Meter brand:	Siemens
Meter model:	Sitrans FM Magflo Mag5100W
Meter manufacturer:	Siemens Flow Instruments
Display (remote or compact):	Remote
Power supply (external/battery)	AC Powered
Method of reporting (manual reads/AMR/SCADA):	AMR and Manual Reads
Meter type:	Electromagnetic
Meter size (mm):	250
Meter serial number:	7ME652673202N457
Meter location:	Outdoor
Years of operation:	8.2
Meter orientation (horizontal, inclined, vertical):	Horizontal
Grounding (Yes/No):	No
With data logger (Yes/No):	Yes
Flow:	✓
Pressure:	✓

LINE DETAILS

Pipe size (mm):	250
Pipe material:	Steel

	Upstream	*Downstream*
Pipe run length (mm):	1470	520
Closest appurtenance:	None	Check valve
Pressure reducing component:	None	None

Chemical dosing points upstream (Yes/No):	No
Large motor close to flow meter (Yes/No):	Yes
VFD/VSD installed in the motors? (Yes/No):	No
Pipe always running full? (Yes/No):	Yes
Are control valves fitted? (Yes/No):	Yes
Is there strainer installed (Yes/No):	No

SITE DETAILS

Inside the building (Yes/No):	No
In pit (Yes/No):	No
Pit flooded (Yes/No):	No
As-built drawings available (Yes/No):	-
Security (Good/Bad):	Good

OTHER REMARKS/FINDINGS:

Previously feeds the Tablon Resevoir but it goes direct to the distribution network.

Figure 23: Production Well #29 Supply Meter Audit Form

SUPPLY METER AUDIT ASSESSMENT REPORT

Facility Name:	Macasandig Booster Old Bank 1 600mmØ Line
Location:	Macasandig
Water Supply Fed to:	East Area
Date of last audit:	N/A
Date of Audit:	5/10/2016
Time:	3:50 PM

Meter readout (during the time of visit)

Totalizer (m^3):	5323551.0
Instantaneous flow rate (m^3/hour):	564.7
Other parameters:	Totalizer 2: 365.5
Facility operation schedule (hours/day):	24
Pressure reading in the supply line (psi):	30

METER DETAILS

Meter brand:	Siemens
Meter model:	Sitrans FM Magflo Mag5100W
Meter manufacturer:	Siemens Flow Instruments
Display (remote or compact):	Remote
Power supply (external/battery)	AC Powered
Method of reporting (manual reads/AMR/SCADA):	AMR and Manual Reads
Meter type:	Electromagnetic
Meter size (mm):	600
Meter serial number:	7ME652686802N457
Meter location:	Outdoor
Years of operation:	8
Meter orientation (horizontal, inclined, vertical):	Horizontal
Grounding (Yes/No):	No
With data logger (Yes/No):	Yes
Flow:	✓
Pressure:	☒

LINE DETAILS

Pipe size (mm):	600
Pipe material:	Steel

	Upstream	*Downstream*
Pipe run length (mm):	5690	3410
Closest appurtenance:	None	None
Pressure reducing component:	None	None

Chemical dosing points upstream (Yes/No):	Yes
Large motor close to flow meter (Yes/No):	Yes
VFD/VSD installed in the motors? (Yes/No):	Yes
Pipe always running full? (Yes/No):	Yes
Are control valves fitted? (Yes/No):	No
Is there strainer installed (Yes/No):	No

SITE DETAILS

Inside the building (Yes/No):	No
In pit (Yes/No):	No
Pit flooded (Yes/No):	No
As-built drawings available (Yes/No):	-
Security (Good/Bad):	Good

OTHER REMARKS/FINDINGS:

Pump 3 has VFD
Frequency 37 Hz
44 Hp
Alarm: F70 coil current check
cables

Figure 24: Macasandig Old Booster Bank #1 Supply Meter Audit Form

SUPPLY METER AUDIT ASSESSMENT REPORT

Facility Name: Macasandig Booster Old Bank 2 500mmØ Line
Date of Audit: 5/10/2016
Location: Macasandig
Time: 3:35 PM
Water Supply Fed to: East Area
Date of last audit: N/A

Meter readout (during the time of visit)

Totalizer (m^3): 37749776.0
Instantaneous flow rate (m^3/hour): 1025
Other parameters: Totalizer 2: 61581
Facility operation schedule (hours/day): 24
Pressure reading in the supply line (psi): 33

METER DETAILS

Meter brand: Siemens
Meter model: Sitrans FM Magflo Mag5100W
Meter manufacturer: Siemens Flow Instruments
Display (remote or compact): Remote
Power supply (external/battery) AC Powered
Method of reporting (manual reads/AMR/SCADA): AMR and Manual Reads
Meter type: Electromagnetic
Meter size (mm): 500
Meter serial number: 7ME652675002N457
Meter location: Outdoor
Years of operation: 8
Grounding (Yes/No): No
With data logger (Yes/No): Yes
Flow: ✓
Pressure: ☒
Meter orientation (horizontal, inclined, vertical): Horizontal

LINE DETAILS

Pipe size (mm): 500
Pipe material: Steel

	Upstream	*Downstream*
Pipe run length (mm):	5210	5630
Closest appurtenance:	None	None
Pressure reducing component:	None	None

Chemical dosing points upstream (Yes/No): Yes
Large motor close to flow meter (Yes/No): Yes
VFD/VSD installed in the motors? (Yes/No): Yes
Pipe always running full? (Yes/No): Yes
Are control valves fitted? (Yes/No): No
Is there strainer installed (Yes/No): No

SITE DETAILS

Inside the building (Yes/No): No
In pit (Yes/No): No
Pit flooded (Yes/No): No
As-built drawings available (Yes/No): -
Security (Good/Bad): Good

OTHER REMARKS/FINDINGS:

Pump 6 has VFD
Frequency 50 Hz
95 Hp

Figure 25: Macasandig Old Booster Bank #2 Supply Meter Audit Form

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SUPPLY METER AUDIT ASSESSMENT REPORT

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Facility Name: Macasandig Booster New
Date of Audit: 5/10/2016
Location: Macasandig
Time: 3:20 PM
Water Supply Fed to: East Area
Date of last audit: N/A

Meter readout (during the time of visit)

Totalizer (m^3): 162418.9
Instantaneous flow rate (m^3/hour): 0
Other parameters: Totalizer 2: 35724.2
Facility operation schedule (hours/day): 0
Pressure reading in the supply line (psi): 0

METER DETAILS

Meter brand: Siemens
Meter model: Sitrans FM Magflo Mag5100W
Meter manufacturer: Siemens Flow Instruments
Display (remote or compact): Remote
Power supply (external/battery) AC Powered
Method of reporting (manual reads/AMR/SCADA): Manual Reads
Meter type: Electromagnetic
Meter size (mm): 500
Grounding (Yes/No): No
Meter serial number: 7ME652674902N457
With data logger (Yes/No): No
Meter location: Outdoor
Flow: ☒
Years of operation: 3
Pressure: ☒
Meter orientation (horizontal, inclined, vertical): Horizontal

LINE DETAILS

Pipe size (mm): 500
Pipe material: Steel

	Upstream	*Downstream*
Pipe run length (mm):	1150	8245
Closest appurtenance:	Butterfly valve	Mechanical meter (insertion type)
Pressure reducing component:	None	None

Chemical dosing points upstream (Yes/No): Yes
Large motor close to flow meter (Yes/No): No
VFD/VSD installed in the motors? (Yes/No): Yes
Pipe always running full? (Yes/No): No
Are control valves fitted? (Yes/No): Yes
Is there strainer installed (Yes/No): No

SITE DETAILS

Inside the building (Yes/No): No
In pit (Yes/No): No
Pit flooded (Yes/No): No
As-built drawings available (Yes/No): -
Security (Good/Bad): Good

OTHER REMARKS/FINDINGS:

Not operating

Figure 26: Macasandig New Booster Supply Meter Audit Form

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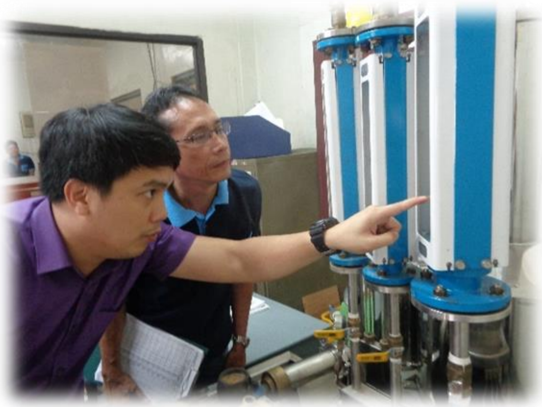
Appendix 2 - Report on Cagayan de Oro Water District Customer Meters

REPORT ON CAGAYAN DE ORO WATER DISTRICT CUSTOMER METERS

Technical Assistance to Cagayan De Oro City Water District on Non-Revenue Water Reduction Strategy and Implementation

Subcontract Agreement No. 893-S15-013



August 2016

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Acronyms and Abbreviations

AWWA M6	Water Meters Selection, Installation, Testing and Maintenance-American Water Works Association (2012)
COWD	Cagayan de Oro City Water District
DN	Nominal Diameter
ft	Feet
JICA	Japan International Cooperation Agency
mm	millimeter
m^3	cubic meter
m^3/day	cubic meter per day
Php	Philippine Peso
R160	Dynamic Range = 160
USD	US Dollar
U0D0	Zero “0” requirement for upstream and downstream lengths

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1.0	08-16-16			
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1 Executive Summary

This report contains the details of key activities that have been undertaken to determine the magnitude of meter under-registration level in Cagayan de Oro Water District. Several efforts have been carried out to obtain a better understanding of the current conditions of COWD's customer meters such as:

1. Establishment of demand pattern
2. Sampling for water meter samples
3. Error testing of more than 600 DN15 water meters
4. Review of top 10 largest customer meters
5. Estimation of meter error on non-domestic meters (DN20 to DN100)
6. Further investigation works on defective meters

The demand pattern was established by logging the flow consumption of more than 40 customers in West and East serviced area. It consists of 30 customers with direct water supply and 11 customers with indirect water supply. The demand patterns from these customers were gathered using portable data loggers with pulse sensors and by installing the R160 positive displacement meters in series with the existing meters. The 7-day flow consumption data from the selected customers were processed into consumption histogram or so called the demand pattern data. The demand pattern data shows that about 75% of the flow consumption fell under the low flow zones and the other 25% is within the medium to high flow zones. The high flow consumption at low flow zones could be due to the effect of low-pressure level and limited water availability in the distribution system.

The best suitable method of sampling technique was used to obtain the statistically represented number of water meter samples. More than 600 units of DN15 water meters with various makes or brand had undergone error testing. Few meters were found defective and has been removed from the sample list. These defective meters were being dismantled to verify what made these meters stop functioning. It was found out that meter aging, water quality issues and tampering are the main problems causing the meters to stop registering water consumption.

The result of error testing has been summarized in this report. Error testing of water meters at different orientations was also carried out to determine its effect. It was observed that significant under-registration could occur at low flow when meters are installed in non-horizontal position. The average meter error and final demand pattern have been analyzed to systematically derive the overall weighted meter error for DN15 meters. Estimations of meter errors have been made for the top 10 largest customer meters and non-domestic meters based on the best technical judgement and several international metering studies carried out by the consultants.

In a nutshell, the estimated annual meter under-registration volume for the entire customer meters is approximately 5,496,336 m^3 (or equivalent to 15,058 m^3/day). This volume is equivalent to 21.22% of COWD's 2015 total annual billed consumption. The main reasons of high meter under-registration or inaccuracies of the water meters are as follows:

- No regular meter replacement (leading to higher number of old meters)
- Wrong meter installations
- Improper sizing of meters
- Absence of comprehensive and robust water meter technical specifications
- No performance meter testing has been done prior to and after the procurement of the water meters

- Poor stocking of meters (COWD needs to wait for the procurement of water meters before they could replace the defective meters which take a long time)
- No periodical meter testing
- No regular customer meter audit program
- No dedicated water meter management team

The general recommendations have been placed in the latter part of the report. It contains strategies to reduce the effect of high inaccuracies on the customer meters.

2 Demand Pattern

One of the major prerequisites for determining the overall weighted meter error is the demand pattern. The demand pattern is used as weighing factor to the meter errors at certain flow rates. The outcome will be the overall weighted meter error which is also defined as the water meter efficiency. The demand pattern establishment is very tedious and data hungry activity as it needs a lot of logged flow data from the water consumers. It also requires reasonable amount of meter error data that can only be gathered by testing a good number of water meter samples (discussed in Section 4). The map below shows the location points where the demand pattern logging was carried out.

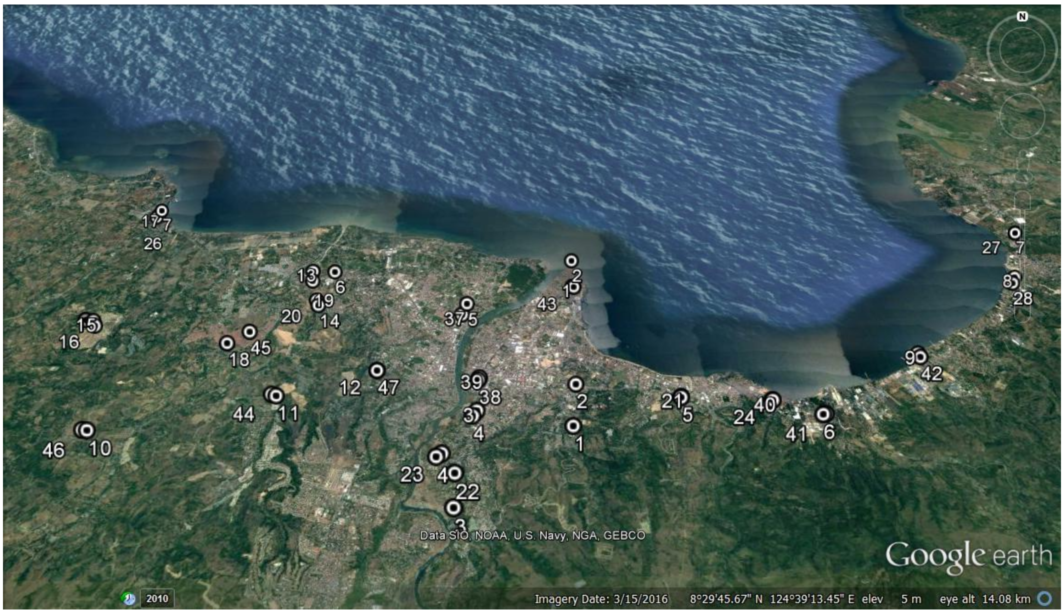


Photo 1: Location Points for Demand Pattern Logging

2.1 Demand Pattern Gathering Methodology

The domestic customers have been categorized into two different supply systems such as direct water supply system wherein the household gets water direct from the distribution network (pressure dependent) and indirect water supply system wherein the household has roof tank or cistern tank before the water supply goes through their taps and fixtures (pressure independent). Categorizing the customers into two supply different supply systems are necessary because the demand pattern characteristics are different on these two supply systems. The demand pattern data that have been gathered will only be used for determining the overall meter efficiency of DN15 water meters. The following photos show the customers with direct and indirect water supply.

Photo 2: Customer with Direct Water Supply

Photo 3: Customer with Indirect Water Supply

COWD team has managed to log 41 domestic customers consisting of 30 direct supply and 11 indirect supply system. The team has connected R160 positive displacement meters which were installed in series with the existing customer meters to record possible low flow caused by roof tanks, leaking internal household pipes and water dripping from faulty taps. Portable data loggers with pulse sensors were also deployed on the R160 meters to log the diurnal flow consumption data. The data loggers were set to log flow consumption in every 1 minute and were installed in field for at least one (1) week to capture the weekdays and weekends flow consumption profile. The succeeding photos show the actual installation of R160 meters and data loggers for demand pattern logging.

Photo 4: Demand Pattern Logging at Zone 5 Sili-Sili, Pagatpat

Photo 5: Demand Pattern Logging at Corona Drive Tibasak, Macasandig

2.2 Result of Demand Pattern Gathering

The downloaded logged flow data had been consolidated in an excel spreadsheet and were being processed into a demand pattern (histogram chart). The succeeding figure shows the demand pattern characteristics of direct supply and indirect supply systems.

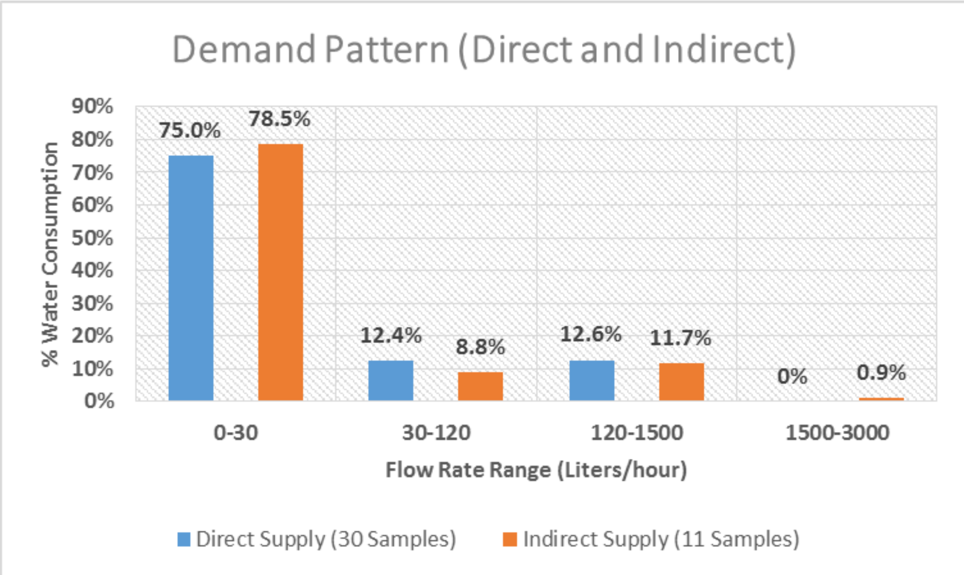


Figure 1: Demand Pattern Characteristics of Direct and Indirect Supply System

It is noticeable that there is no difference at all when comparing the demand characteristics of direct and indirect water supply system. It is also obvious that the water consumption has not been occurring at high flow rate zone. This could be due to the effect of low pressure caused by high physical losses and limited water availability in the distribution system.

In order to obtain the final demand pattern, the two demand patterns (direct and indirect) have been weighted based on the ratio gathered from the customer census data in Poblacion Area where 5% of the total customers reside there do have water tanks (indirect supply) while 95% of them don't have water tanks (direct supply). The following photo shows the basic profile of Poblacion Area.

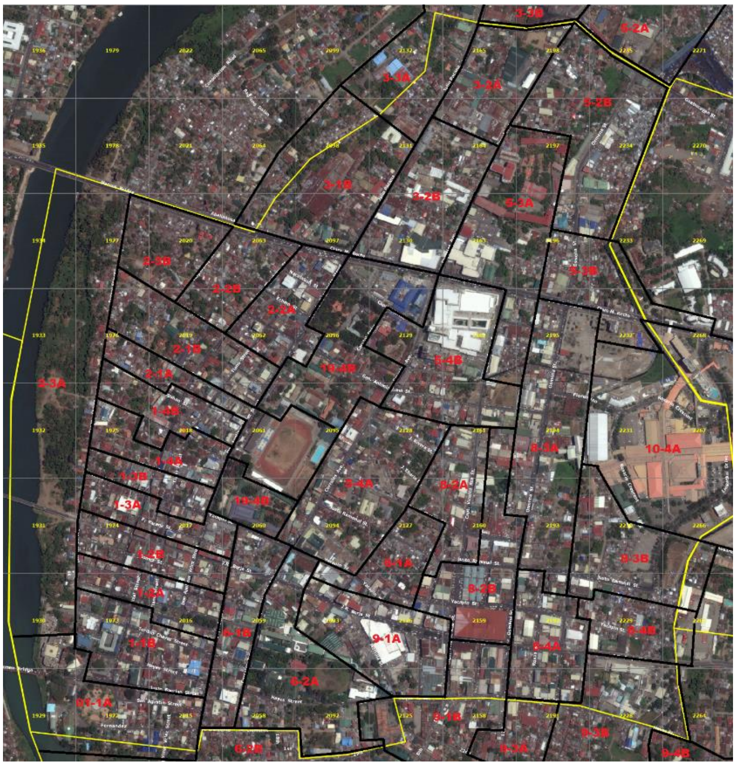


Photo 6: Poblacion Area

Poblacion Area has approximately 6,600 customers. Poblacion Area has been used as basis for the determining the ratio of the customers' water supply characteristics (direct and indirect supply system). Based on the census survey data, 5% of the customers residing in Poblacion Area are having water tanks (roof tank and cistern tank) whilst 95% of the customers are directly fed by the distribution system.

This particular area was also used as basis in determining the number of non-horizontal installed meters. It was found out that about 18% of the water meters within Poblacion area were installed in non-horizontal position.

Other key findings were observed from the census survey data such as:

- Poor water meter readability: 1,652 (25%)
- Water meters without seal: 2,193 (33%)
- Water meter located inside the customer property: 1,685 (26%)

The final weighted demand pattern will be used for obtaining the overall meter under-registration specifically for DN15 water meters. The following graph illustrates the final weighted demand pattern.

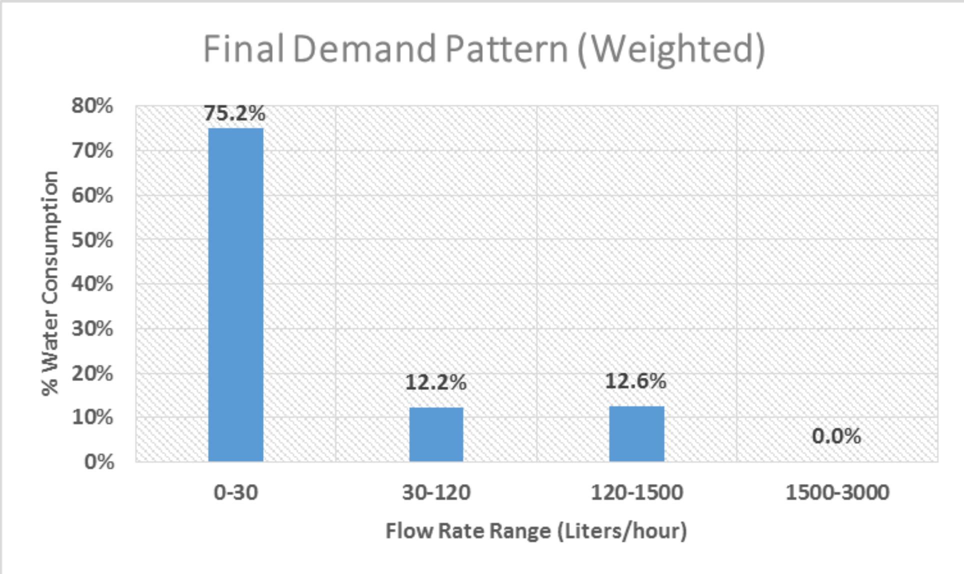


Figure 2: Final Demand Pattern (Weighted)

3 Meter Sampling

3.1 Sampling Methodology

In order to achieve acceptable and statistically representative number of samples, the formula called "Slovin's Formula" was used in the sampling methodology. Slovin's formula is very applicable when there is a limited information about the population's behavior and when the only given statistical parameter is the population size. The following equation shows the Slovin's sampling formula.

$$n = \frac{N}{1 + (N\ x\ e^2)}$$

Equation 1: Slovin's Formula

where:

- *N* is the population size
- *n* is the sample size
- and *e* is the error margin

The sampling has focused on the top ten (10) most commonly used DN15 water meter brands. The calculated sample size, which is based on the population size of 80,015 DN15 water meters and ±5% margin of error, is around 400. However, to improve the level of margin of error and to gain better results, the sample size has been increased to 637 water meters (excluding some rejected meters e.g. faulty dials, defective meters and blurred lens). The added water meter samples have improved the sample size's margin of error to ±3.9%. The succeeding photos are the COWD's top 10 most commonly used water meter brands.

Photo 7: Arad Meter

Photo 8: Asahi Meter

Photo 9: Evjet Meter

Photo 10: Keumsung Meter

Photo 11: Actaris TD88 Meter

Photo 12: Toyokeiki Meter

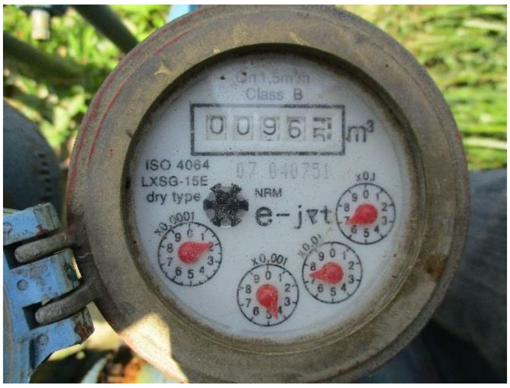


Photo 13: Ejet Meter

Photo 14: Actaris Meter

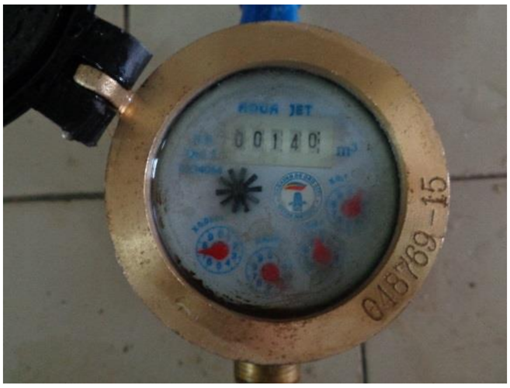


Photo 15: Aqua Jet Meter

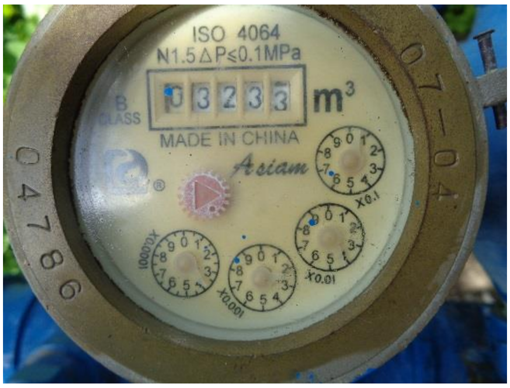


Photo 16: Asiam Meter

The sample water meters were randomly selected from COWD customer database using an Excel-based mathematical function called the random number generator. The table below shows the number of samples and basic details of the top 10 most commonly used water meters.

Top	Meter Brand	Meter Type	Meter Class	Average Age (Years)	Average Registration (m^3)	Number of Samples
1	Arad	Multijet	Class B	11.9	2,865	152
2	Asahi	Multijet	Class B	13.3	3,330	101
3	Evjet	Multijet	Class B	6.8	1,776	71
4	Keumsung	Multijet	Class B DN13	3.6	900	61
5	Actaris TD88	Positive Displacement	Class C	11.0	3,138	33
6	Toyokeiki	Single Jet	R100 DN13	2.6	693	62
7	Ejet	Multijet	Class B	9.0	1,966	27
8	Actaris	Multijet	Class B	8.5	1,805	31
9	Aqua Jet	Multijet	Class B	0.9	240	53
10	Asiam	Multijet	Class B	7.5	2,137	46
					Grand Total	**637**

Table 1: Top 10 Brand of DN15 Water Meter Samples

The total number of samples has been distributed in each meter brand and type. The oldest meter among the sample brand groups is Asahi meter which has 13.3 years in service followed by Arad and Actaris TD88 meters with 11.9 and 11 years in service, respectively. The Toyokeiki brand meters were donated by JICA after the Typhoon Sendong struck the region few years ago. Toyokeiki meter is a Japanese-brand meter and is using basic single jet technology. This brand is the only single jet type meter which COWD is using at the moment. Early this year, some Aqua Jet meters were purchased which will be utilized for expansion service areas and for the replacement of the old and defective meters.

3.2 Rejected Water Meters

On top of the 637 water meter samples, 25 water meters (3.7% of the total water meter samples) were rejected due to the reasons detailed in the following table.

Reasons for Rejection	Number of Rejected Meters	% of the Total Water Meter Samples
Water meters that displays erratic error results	7	1.0%
Water meters that have not been tested due to faulty dials and blurry lens	6	0.9%
Stuck-up or defective water meters	12	1.8%
Total Rejected Meters	**25**	**3.7%**

Table 2: Rejected Water Meter Samples

3.3 Key Observations on Rejected Water Meters

Few rejected water meters were being dismantled to investigate what causing the meters to stop functioning. The photo below displays the actual dismantling of the water meter.

Photo 17: Actual Dismantling of Rejected Water Meter

Water meters that displayed erratic error results have a problem with the synchronization of the dials that can misled the meter readings. Water meters with faulty dials and blurry lens were observed during the physical inspection carried-out on the sample water meters. Faulty dials occurred on the water meters because they had reached their wear and tear. However, in some cases, the meters are exposed to high flow rates for a long period of time that leads to faster rate of wear and tear.

The moisture entrapped inside the meter lens due to worn-out internal gaskets gets the meter lens looked blurry. Another reason is that those water meters with plastic lens get faded as plastic degrades its composition when continuously exposed to direct sunlight.

Vast majority of the rejected meters are stuck-up or dead meters. Sand particles, build-up of sediments and tiny solids are the main reasons why the water meters stopped spinning. Tampering is also one of the problems causing faulty water meters. Photos below show the findings observed from the stuck-up meters.

Photo 18: Sediments build-up in the Measuring Chamber

Photo 19: Sediments build-up on the Impeller

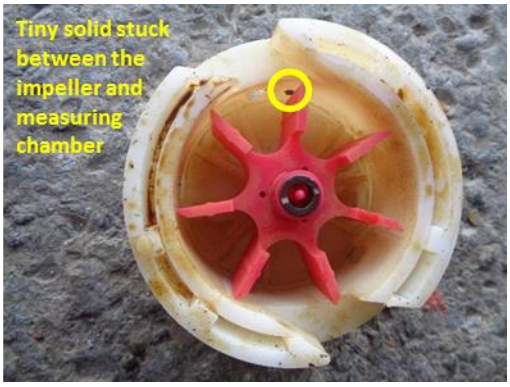


Photo 20: Stuck-up Impeller due to Tiny Solid

Photo 21: Sand Particles on the Magnet Coupler

Photo 22: Meter Tampering (Insertion of Plastic Tie)

Build-up of sedimentation inside the wall of measuring chamber and impeller creates high friction resulting to meter stoppage. Sand particles particularly iron content in it builds on the magnetic coupler attached on the meter's impeller. The iron particles block the magnetic transmission of both magnetic couplers fixed at the impeller and register side. This condition causes the water meter to under-register.

Tampering is prevalent in any water utilities around the world. This illegal modification makes the water meter to under-register or in worst-case, to stop working at all. Photo 22 shows the plastic tie that had been inserted inside the water meter and as a result, the impeller would not spin.

All rejected water meter samples were purged-out from the final list of the test results as these could affect the outcome of the metering analysis. The rejected meters were disposed and had never gotten back in field.

4 Result of Error Testing on DN15 Meters

4.1 Error Testing Methodology

A statistically representative number of water meters with nominal diameter size of 15mm were pulled-out from the field and were sent to the COWD meter testing facility to undergo intensive error testing and physical inspection. A total of 637 DN15 water meter samples were tested using 4-point error testing procedure. The test flow rates used in each water meter are based on the available technical literatures and other technical references. The description of the test flow rates can be seen in the table below.

Test Flow Rate	Flow Rate Description
Q_{min} (minimum)	Lowest flow rate at which the water meter is required to operate within the maximum permissible error (MPE).
Q_t (transitional)	Flow rate which occurs between Q_n and Q_{min} that divides the flow rate range into two zones, the upper and the lower zone.
Q_n (nominal)	Flow rate at which the water meter is required to operate in a satisfactory manner under normal condition of use.
Q_{max} (maximum)	Flow rate at which the water meter is required to operate in a satisfactory for a short period of time maintaining its metrological performance

Table 3: Test Flow Rate Description According to ISO 4064 Part 3

The entire test procedures have been conformed to "ISO 4064:2005 Measurement of Water Flow in Fully Charged Conduits – Meter for Cold Potable Water and Hot Water, Third Edition 2005-10-15". The method used in determining the meter error is called "collection method" in which the quantity of the water passed through the water meter is collected in a calibrated tank and the quantity is being determined volumetrically. By comparing the water volume registered by the water meter against the calibrated reference device (calibrated tank), the error of the water meter can be determined. The following formula is used to calculate the meter error of the water meter samples.

$$\varepsilon = \frac{Vr - Va}{Va} \times 100$$

Equation 2: Meter Error Formula

where:

- ε is the meter error (typically expressed in percentage %)
- V_r is the registered volume (difference between the final and initial meter reading)
- V_a is the actual volume of the calibrated tank

Prior to implementation of error testing, the water meter test bench was inspected in order to verify whether there is possible problem on its operations that may affect the reliability of the test results. Meter test bench is normally exposed to uncertainty caused by various factors. Therefore, the uncertainty factors of the COWD test bench were determined. The five (5) possible sources of uncertainty have been taking into account that may influence the test procedures and results.

1. Calibration factors – Built-in to the measuring instrument (meter test bench) which typically reported in a calibration certificate.
2. Resolution factors – Pertains to the resolution of the measurements scales or readouts (rotameter, load cell, water level indicator etc.)
3. Operator skill factors – Relates to the technical capability of the technician. Wrong meter readings, which is a kind of human error, could worsen the uncertainty of the measurements.
4. Repeatability factors - This is defined as the closeness of the results obtained using the same method on independent test material (water meters) under the same conditions (i.e. same operator, same instrument and same facility)
5. Operational factors – Changes in operating conditions such as temperature, pressure, flow rate and humidity can increase the uncertainty of the measurements.

Aside from meter test bench inspection, a dry-run was also implemented on the meter test bench to ensure that the flow rate settings can be achieved during the actual error testing. However, the test bench did not meet the 3,000 liters per hour maximum flow rate (Q_{max}) when it is at full capacity (12 DN15 water meters were installed). Therefore, the maximum flow rate has been adjusted to 2,000 liters per hour and was applied to all the water meter samples. The adjustment made on the maximum flow rate will not heavily affect the calculation of overall weighted meter error as the demand pattern revealed that there is very insignificant water consumption at the high flow range zone.

4.2 Result of Error Testing

The result of error testing has been consolidated in a excel spreadsheet to easily analyze the data. The average error of each water meter brand at different test flow rates was calculated and is shown in the table below.

Top	Meter Brand	Meter Class	No. of Samples	Average %Error at 67% x Q_{max}[1]	Average %Error at Q_n	Average %Error at Q_t	Average %Error at Q_{min}
1	Arad	Class B	152	-2.90%	-2.04%	-0.95%	-14.09%
2	Asahi	Class B	101	-9.31%	-9.35%	-9.07%	-34.16%
3	Evjet	Class B	71	1.00%	-0.20%	-0.80%	-1.10%
4	Keumsung	Class B DN13	61	-2.47%	-1.11%	-4.54%	-20.70%
5	TD88	Class C	33	-2.08%	-1.89%	-15.79%	-27.33%
6	Toyokeiki	R100 DN13	62	-0.66%	-0.77%	-0.16%	-0.21%
7	Ejet	Class B	27	-3.44%	-2.24%	-9.12%	-33.89%
8	Actaris	Class B	31	-1.70%	1.94%	0.68%	-13.90%
9	Aqua Jet	Class B	53	-0.88%	-1.13%	-0.58%	-14.57%
10	Asiam	Class B	46	-4.32%	-2.04%	-2.89%	-9.28%
			Average Error	**-3.08%**	**-2.51%**	**-3.63%**	**-16.31%**

Table 4: Summary Result of Error Testing on DN15 Meters

[1] 2,000 liters/hour was used for maximum flow rate as the test bench could not meet the 3,000 liters/hour flow rate.

All the water meters that passed the error testing were sent back in field for re-installation or re-use. However, water meters that failed the test were disposed to the meter depository.

4.3 Meter Error at Different Orientations

Meter error of few used water meters has been determined at different orientations. The aim of the test is to simulate the water meters' measuring performance when they are installed in tilted positions. The actual error testing of water meters installed in different orientations can be seen in the photos below.

Photo 23: Meter Error Testing at Horizontal Orientation

Photo 24: Meter Error Testing at 45 Degrees Orientation

Photo 25: Meter Error Testing at 90 Degrees Orientation

The error curve of the water meters at horizontal, 45 degrees and 90 degrees orientations can be seen in the figure below.

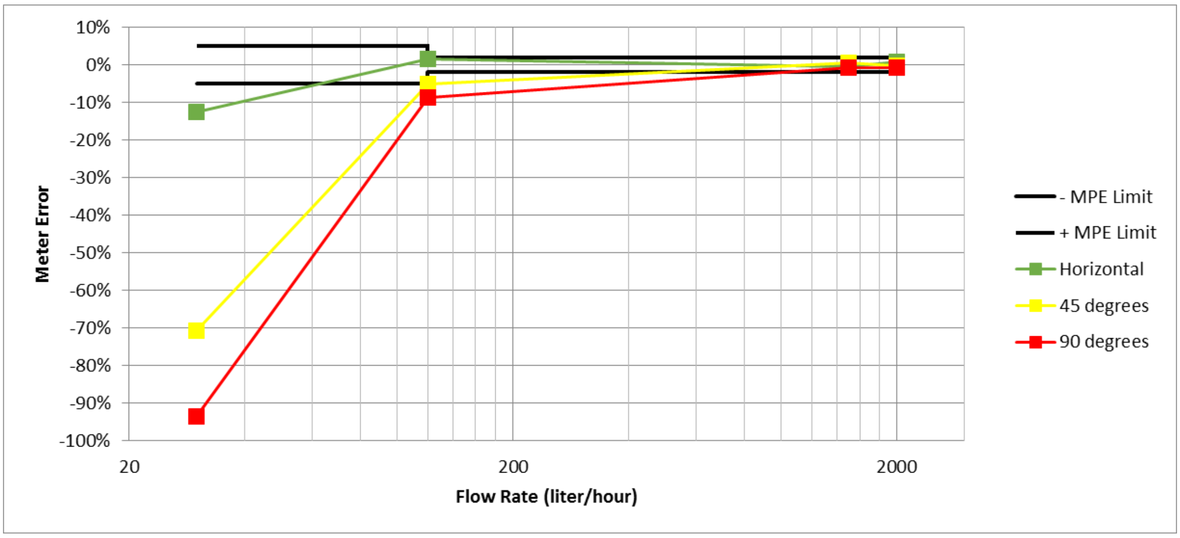


Figure 3: Error Curve of the Water Meter at Different Meter Orientations

The test results showed that the orientation (positioning) of water meters has direct effect on their meter errors. When the meters are installed at 45 and 90 degrees orientation, it significantly under-registers the water consumption especially at low flow zones. This typically happened on the velocity meters such as multijet and single type meters. It was observed during test that even the new water meters were also affected by this phenomenon. Furthermore, the older the meter, the higher the chance it will under-register when installed in non-horizontal orientation. In COWD particularly in Poblacion Area, there is roughly 18% of the total water meters that are installed in non-horizontal position based on the census survey data. Non-horizontal installations would definitely contribute to the inaccuracy of the water meters. Therefore, it has to be considered in the final calculation of the overall meter under-registration.

5 Review of COWD Top 10 Largest Customers

The top 10 largest customers of Cagayan de Oro Water District have been reviewed to be able to attain a better understanding of their water meters' condition and billing trends. The top 10 largest customers only represent the 0.01% of the total number of COWD's customer population. However, these largest customers generate annual revenue of around Php 34 Million which is equivalent to nearly 4% of the total annual revenue of COWD. These customers have average tariff rates ranging between Php 36 to Php 80 per cubic meter. The table below shows the basic profile of the top 10 largest customers.

Top	Top 10 Largest Customers	2015 Annual Billed Consumption (m^3)	2015 Annual Revenue (Php)	Ave. Tariff (Php/m^3)	DN Size (mm)	Meter Age (years)
1	CAGAYAN DE ORO GATEWAY CORP	155,037	10,553,493	68.1	100	3
2	PHIL PORT AUTHORITY PMO CDO	140,286	5,767,883	41.1	250	4
3	LIMKETKAI SONS INC	55,389	4,081,332	73.7	50	12
4	CHIU ROGER LIM (MALL BERRY)	47,840	3,810,367	79.6	50	10
5	CAPITOL COLLEGE GEN. HOSPITAL	41,572	3,086,508	74.2	50	4
6	MOGCHS N DAEL	44,731	1,656,978	37.0	50	4
7	NORTHERN MINDANAO MEDICAL	40,903	1,519,170	37.1	50	13
8	PC INP RECOM 10	34,655	1,294,242	37.3	50	3
9	CHAVES JUANITO LIM	15,593	1,153,121	74.0	40	15

10	PROV JAIL OFF MIS OR	31,632	1,135,619	35.9	25	8

Table 5: COWD Top 10 Largest Customers Profile

A drift in meter error on these particular meters could lead to significant financial loss. Therefore, regular meter audit should be implemented not only on the top 10 largest customer meters but also to those customer meters installed at high-consuming accounts (or on non-domestic customers).

5.1 Cagayan de Oro Gateway Corp. (Centrio Mall)

Cagayan de Oro Gateway Corp. or also known as Centrio Mall is located nearby the COWD main office. With an average monthly consumption of nearly 13,000 m^3 which can generate revenue of around Php 960,000 a month, Centrio Mall has become the top one (1) largest customer of COWD.

The meter of Centrio Mall and its assembly was inspected. It was found out that the meter does not have straight pipe distance on both sides and there was no strainer installed that can protect the meter from tiny debris or solids coming from the distribution network. The meter is properly sized with 3 years in service. The photos below show the Centrio Mall meter and its assembly.

Photo 26: Cagayan de Oro Gateway Corp. (Centrio Mall) Meter

Photo 27: Cagayan de Oro Gateway Corp. (Centrio Mall) Meter Assembly

The monthly consumption trend has been reviewed to check whether there is a decline in consumption caused by metering inaccuracy. The historical consumption of Centrio Mall illustrated that there has been no significant decline in its consumption for the past 1 year. In fact, the chart below shows steady increasing trend in Centrio Mall's consumption.

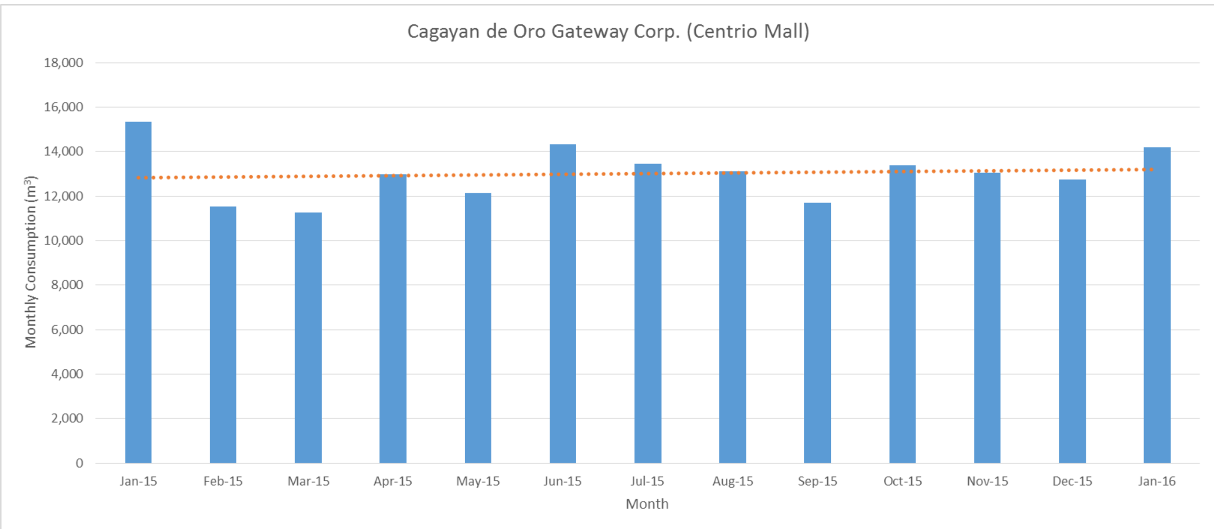


Figure 4: Cagayan de Oro Gateway Corp. (Centrio Mall) Historical Monthly Consumption

5.2 Philippine Port Authority PMO CDO

Philippine Port Authority PMO CDO (PPA) is the COWD's top two (2) largest customer with an average monthly consumption of around 11,700 m^3. It produces Php 480,000 revenue every month. During the field inspection, there was no strainer found in the meter assembly. There is good straight pipe distance on both sides of the meter. The meter is oversized that may lead to considerable under-registration most especially at low flow consumptions. The photos below show the PPA meter and its assembly.

Photo 28: Philippine Port PMO CDO Authority Meter

Photo 29: Philippine Port PMO CDO Authority Meter Assembly

After graphing out the historical monthly consumptions, it is observed that PPA's consumption has been gradually increasing in the past one year. This trend could be a good indication that the meter is still at good condition however, the need of logged flow data and in-situ accuracy testing are highly needed to back-up the assumptions.

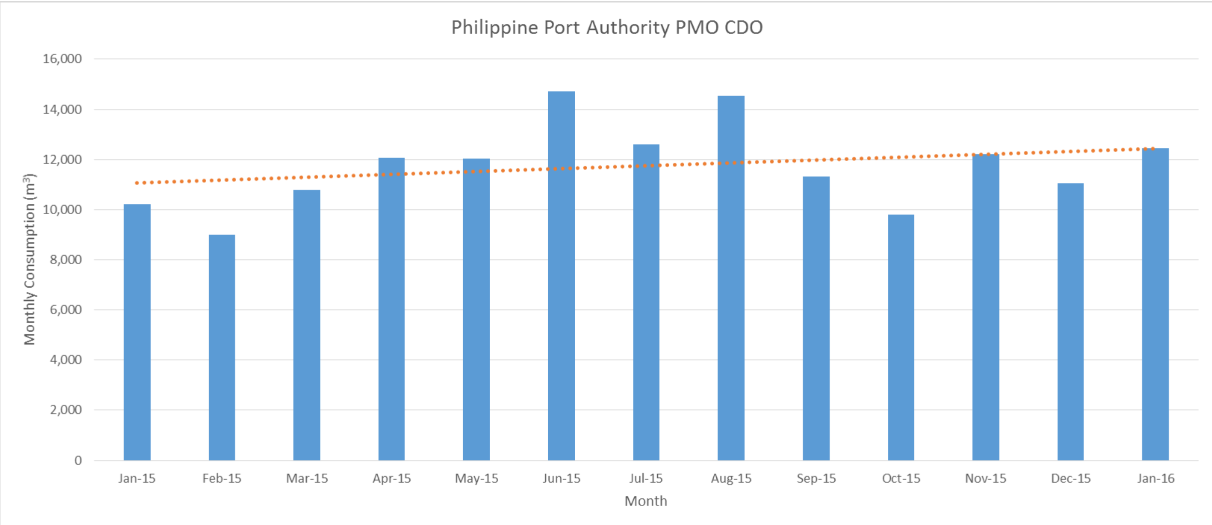


Figure 5: Philippine Port Authority PMO CDO Historical Monthly Consumption

5.3 Limketkai Sons Inc.

Limketkai Sons Inc. is the COWD's top three (3) largest customer. Limketkai Sons Inc. consumes 4,600 m^3 (average) of water every month. COWD generates Php 340,000 revenue from this customer.

The meter is slightly oversized. There was a limited straight pipe distance on both sides meter. No strainer found during the field inspection. It also observed that the meter dial was slightly jerking which could be an indication that there might be a problem on the meter's internal mechanism. The meter installed is already 12 years in service that needs immediate replacement. The succeeding photos shows the Limketkai's meter and its assembly.

Photo 30: Limketkai Sons Inc. Meter

Photo 31: Limketkai Sons Inc. Meter Assembly

Historical monthly consumption shows increasing trend which can be seen in the following figure.

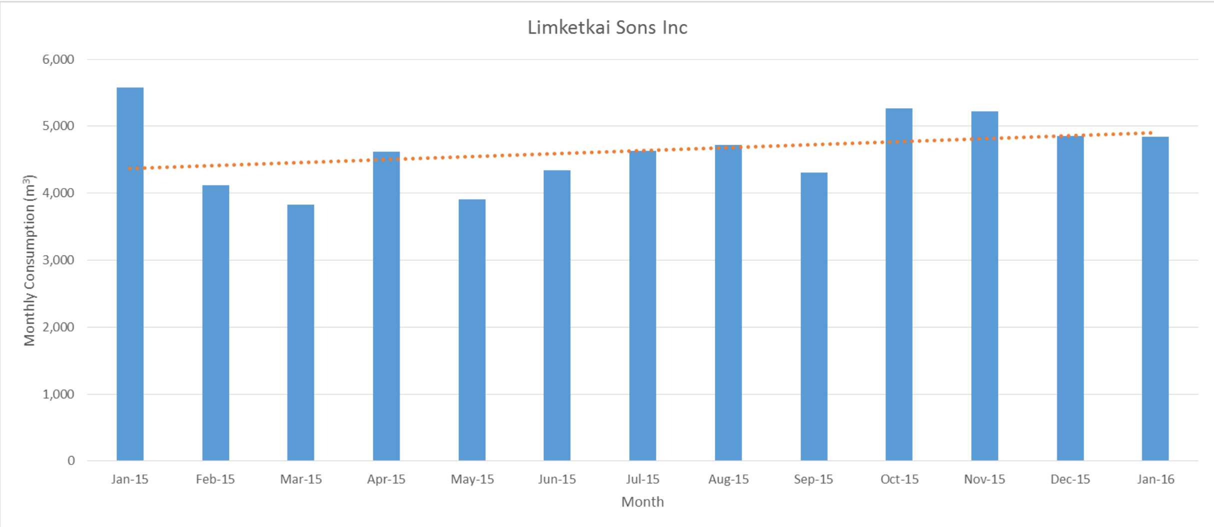


Figure 6: Limketkai Sons Inc. Historical Monthly Consumption

5.4 Chiu Roger Lim (Mall Berry Hotel)

Chiu Roger Lim (account name) or Mall Berry Hotel is the COWD's top four (4) largest customer. It consumes 4,000 m^3 (average) of water every month. COWD can generate monthly revenue of around Php 318,000 from this account.

There was limited straight pipe distance observed on both sides of Mall Berry Hotel's meter. Furthermore, there is no strainer in the meter set assembly. The meter is 10 years in service which needs immediate replacement. It is also slightly oversized.

Photo 32: Chiu Roger Lim (Mall Berry Hotel) Meter

Photo 33: Chiu Roger Lim (Mall Berry Hotel) Meter Assembly

The historical monthly consumption shows steady downward trend that can be seen in the following figure.

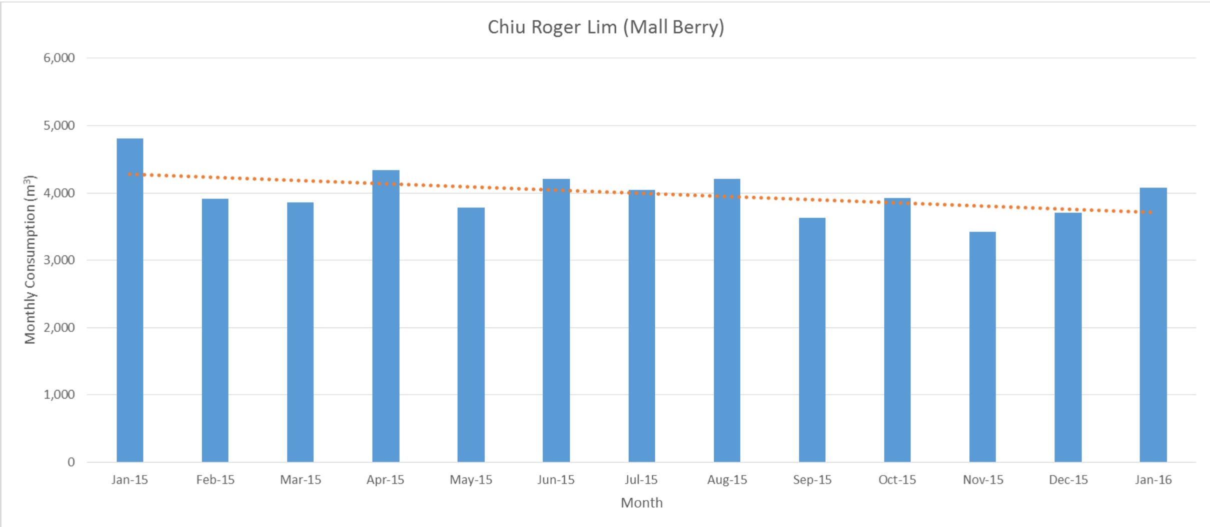


Figure 7: Chiu Roger Lim (Mall Berry) Historical Monthly Consumption

5.5 Capitol College General Hospital

Capitol College General Hospital is the COWD's top four (5) largest customer. This hospital consumes 3,500 m^3 (average) of water every month. COWD can generate monthly revenue of around Php 260,000 from this account.

Limited pipe straight pipe distances have found on both sides. No strainer was installed in the assembly. The meter installed is slightly oversized. Rust build-up has been observed on the meter body. The meter register has been covered by dirt and fogging that makes it very difficult to read. These observations lead to immediate replacement of the meter in Capitol College General Hospital.

Photo 34: Capitol College General Hospital Meter

Photo 35: Capitol College General Hospital Meter Assembly

An upward consumption trend has been observed after graphing out the 1-year historical monthly consumption. The past monthly consumption of Capitol College General Hospital can be seen in the succeeding figure.

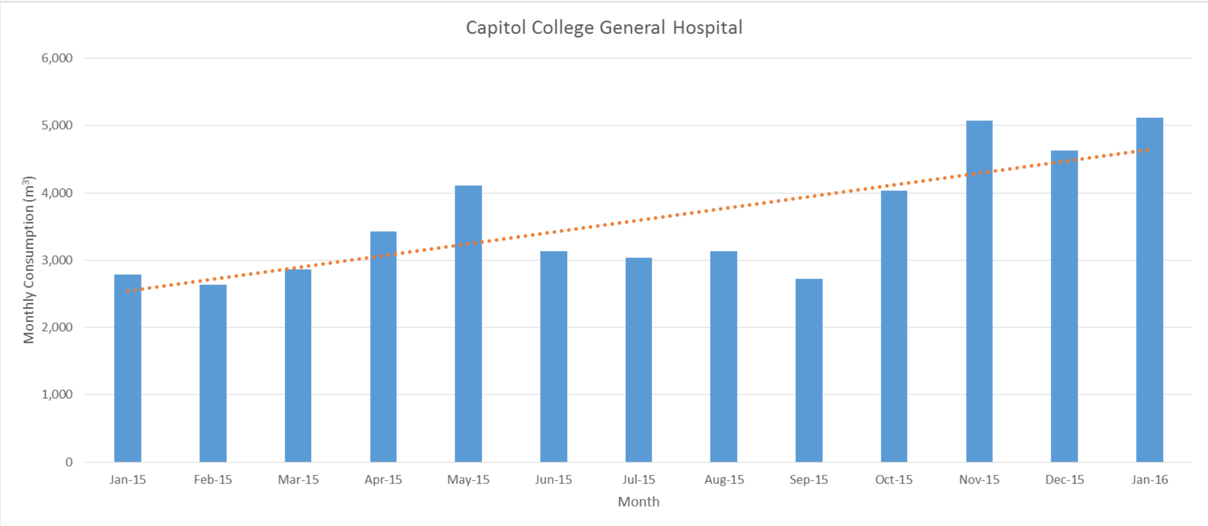


Figure 8: Capitol College General Hospital Historical Monthly Consumption

5.6 MOGCHS N DAEL

MOGCHS N DAEL is a public school and is the COWD's top six (6) largest customer. MOGCHS consumes 3,700 m^3 (average) of water every month. COWD can generate Php 130,000 monthly revenue from this account.

The meter is slightly oversized. There was a limited straight pipe distance on both sides. No strainer was found during the field inspection. It also observed that the meter dial was jerking which could be an indication that there might be a problem with the meter's internal mechanism. The meter installed is already 4 years in service and is located inside the school premise. Immediate meter replacement and relocation are highly recommended. The succeeding photos shows the MOGCHS's meter and its assembly.

Photo 36: MOGCHS N DAEL Meter

Photo 37: MOGCHS N DAEL Meter Assembly

An abrupt decrease in monthly consumption has been observed starting June 2015. This can be an indication that the meter has degraded its accuracy. The figure below shows the graphical representation of MOGCHS 1-year historical monthly consumption.

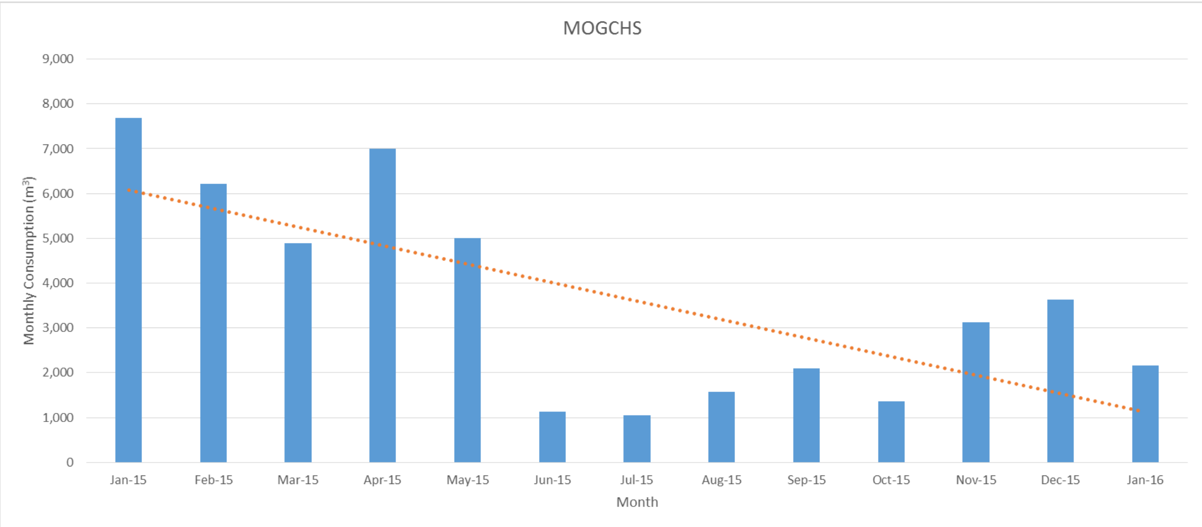


Figure 9: MOGCHS Historical Monthly Consumption

5.7 Northern Mindanao Medical

Northern Mindanao Medical is a public hospital and is the COWD's top seven (7) largest customer. Northern Mindanao Medical consumes 3,400 m^3 (average) of water every month. COWD can generate Php 126,000 monthly revenue from this account.

The meter is slightly oversized. There was a limited straight pipe distance on both sides. No strainer was found in the meter assembly. The meter installed is already 13 years in service that needs immediate replacement. The succeeding photos shows the Northern Mindanao Medical's meter and its assembly.

Photo 38: Northern Mindanao Medical Meter

Photo 39: Northern Mindanao Medical Meter Assembly

There has been significant decreased in consumption which was observed starting June 2015. This consumption decline might have to do with the inaccuracy of the meter considering that it is too old. The figure below shows the historical monthly consumption of Northern Mindanao Medical.

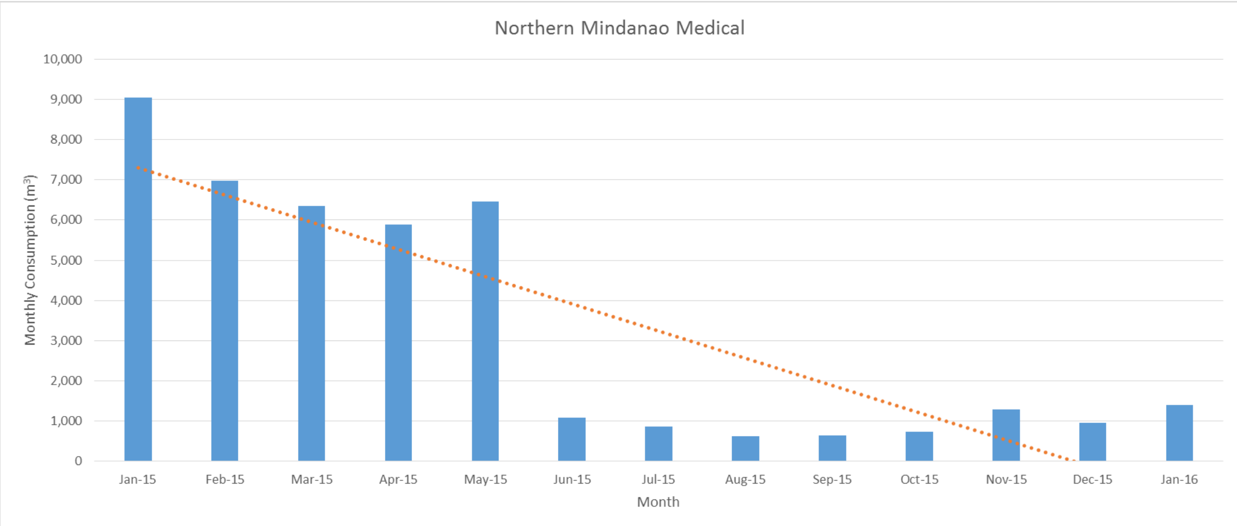


Figure 10: Northern Mindanao Medical Historical Monthly Consumption

5.8 PC INP RECOM 10

PC INP RECOM 10 is a Philippine National Police Camp. PC INP RECOM 10 is the COWD's top eight (8) largest customer. It consumes 3,000 m^3 (average) of water every month. COWD can generate Php 108,000 monthly revenue from this account.

The meter is slightly oversized. There was a limited straight pipe distance on both sides. No strainer was found in the meter assembly. The customer uses pump (at the downstream side of the meter) as the area could not get enough water due to low pressure level. The installed pump could create flow distortion that may affect the measuring performance of the meter. The meter installed is 3 years in service. The succeeding photos shows the Northern Mindanao Medical's meter and its assembly.

Photo 40: PC INP RECOM 10 Meter **Photo 41: PC INP RECOM 10 Meter Assembly**

A decreasing trend in monthly consumption has been observed that might have to with the existing low-pressure level in the area or could be due to meter's degrading accuracy. The figure below shows the 1-year historical monthly consumption of PC INP RECOM 10.

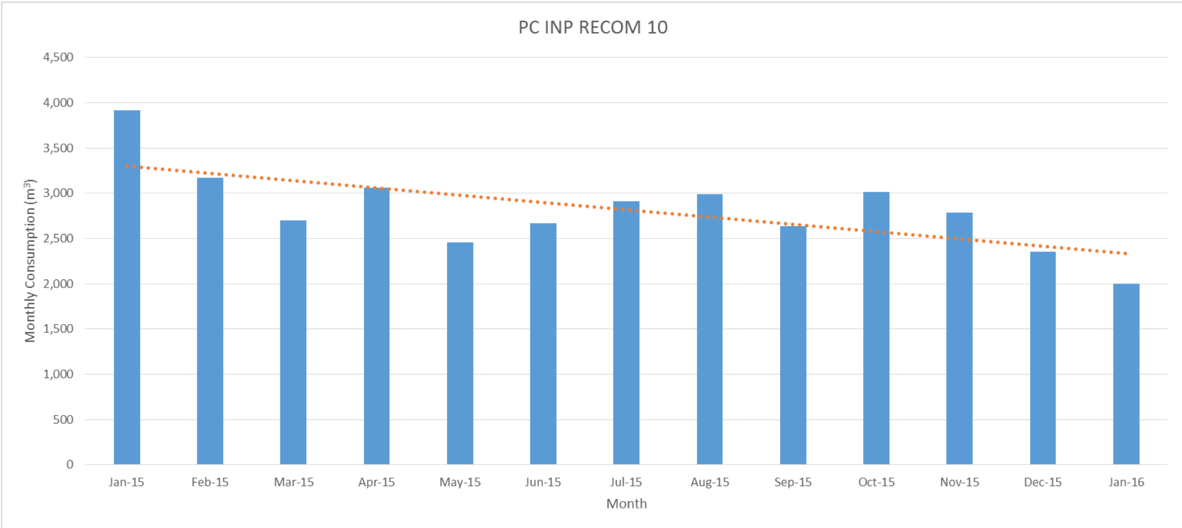


Figure 11: PC INP RECOM 10 Historical Monthly Consumption

5.9 Chaves Juanito Lim (CHALI Resort)

Chaves Juanito Lim (account name) or CHALI Resort is the COWD's top six (9) largest customer. MOGCHS consumes 1,300 m^3 (average) of water every month. COWD can generate Php 96,000 monthly revenue from this account.

The meter is oversized. It was found out during the inspection that this meter is defective. The meter installed is already 15 years in service and is located inside the school premise. Immediate meter replacement and relocation are highly recommended. The succeeding photos shows the CHALI's meter and its assembly.

Photo 42: Chaves Juanito Lim (CHALI Resort) Meter

Photo 43: Chaves Juanito Lim (CHALI Resort) Meter Assembly

A significant decline in the monthly consumption has been observed which started in August 2015. These could be the months when the meter started to lose its accuracy. The succeeding figure shows the 1-year historical monthly consumption of CHALI Resort.

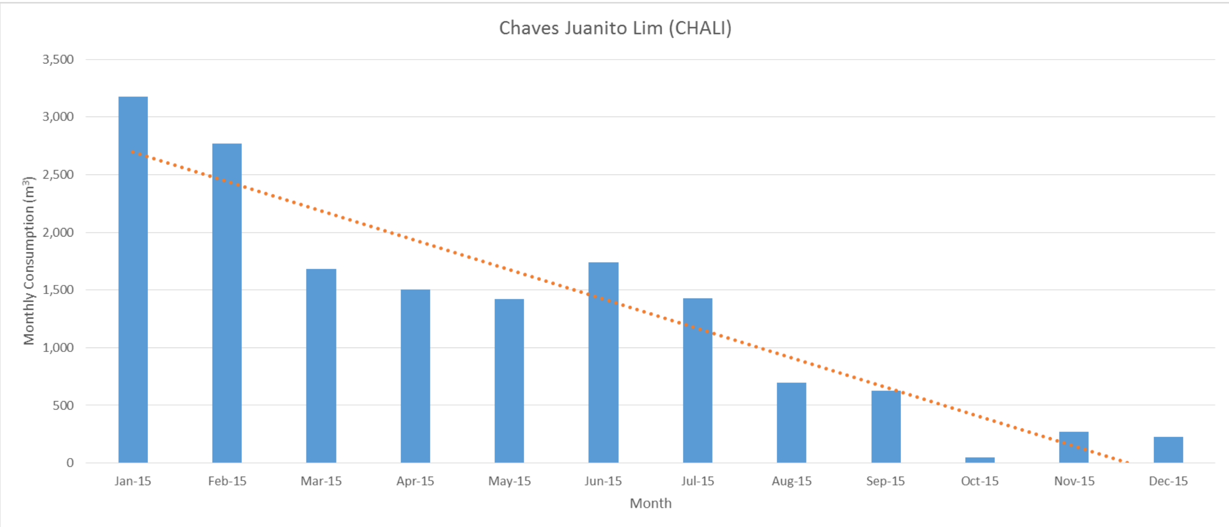


Figure 12: Chaves Juanito Lim Historical Monthly Consumption

5.10 Provincial Jail Off. Mis. Or.

Provincial Jail Off. Mis. Or. is the COWD's top six (10) largest customer. MOGCHS consumes 2,300 m^3 (average) of water every month. COWD can generate Php 95,000 monthly revenue from this account.

The meter is slightly oversized and it is installed in non-horizontal position. A meter installed in non-horizontal position could result in significant under-registration most especially at low flow consumption. The meter installed is already 8 years in service and is located inside the prison premise. Immediate meter replacement and relocation are highly recommended. The succeeding photos shows the Provincial Jail's meter and its assembly.

Photo 44: Provincial Jail Off. Mis. Or. Meter

Photo 45: Provincial Jail Off. Mis. Or. Meter Assembly

There has been significant decreased in consumption which was observed starting January 2016. This consumption decline might have to do with the inaccuracy of the meter considering that it is too old. The figure below shows the historical monthly consumption of Provincial Jail Off. Mis. Or.

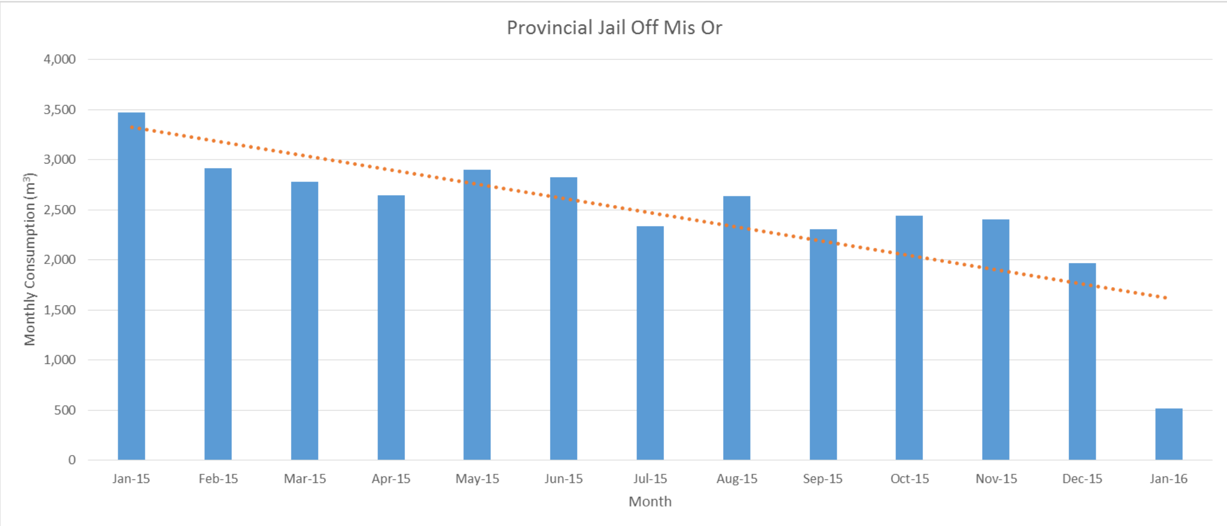


Figure 13: Provincial Jail Off. Mis. Or. Historical Monthly Consumption

5.11 Meter Sizing of Top 10 Largest Customer Meters

The optimal meter size of the top 10 largest customer meters were calculated using the meter sizing technique called historical consumption method. The historical consumption method uses the past 12-month consumption and time of water use of a customer. The table below shows the summary result of the meter sizing of top 10 largest customer meters.

Top	Top 10 Largest Customers	Meter Brand	DN Size (mm)	Meter Sizing Remarks	Recommended Meter Size (mm)
1	CAGAYAN DE ORO GATEWAY CORP	Arad	100	Properly Sized	100
2	PHIL PORT AUTHORITY PMO CDO	Arad	250	Oversized	100
3	LIMKETKAI SONS INC	Arad	50	Oversized	40
4	CHIU ROGER LIM (MALL BERRY)	Arad	50	Oversized	40
5	CAPITOL COLLEGE GEN. HOSPITAL	Liberty	50	Oversized	40
6	MOGCHS N DAEL	Far Meter	50	Oversized	40

7	NORTHERN MINDANAO MEDICAL	Arad	50	Oversized	40
8	PC INP RECOM 10	Arad	50	Oversized	40
9	CHAVES JUANITO LIM	Ever	40	Oversized	25
10	PROV JAIL OFF MIS OR	Arad	25	Oversized	20

Table 6: Recommended Meter Size for Top 10 Largest Customer Meters

5.12 Key Findings on the Top 10 Largest Customer Meters

The summary of the key findings gathered from field inspection and from the analysis undertaken on the historical monthly billed consumption of the COWD top 10 largest customer meters can be seen in the following table.

Top	Top 10 Largest Customers	Service Age (Years)	Strainer	Sizing Remarks	Straight Pipe Distance	Installation Condition	Readability	Meter Location	Billed Consumption Trend
1	CAGAYAN DE ORO GATEWAY CORP	3	No	Properly Sized	None	Horizontal	Good	In Pit (Outside)	Steady increasing
2	PHIL PORT AUTHORITY PMO CDO	4	No	Oversized	Yes	Horizontal	Fair	In pit (Outside)	Increasing
3	LIMKETKAI SONS INC	12	No	Oversized	Limited	Horizontal	Fair	Above ground (Outside)	Steady increasing
4	CHIU ROGER LIM (MALL BERRY)	10	No	Oversized	Limited	Horizontal	Good	Above ground (Outside)	Steady decreasing
5	CAPITOL COLLEGE GEN. HOSPITAL	4	No	Oversized	Limited	Horizontal	Poor	Above ground (Outside)	Increasing
6	MOGCHS N DAEL	4	No	Oversized	Limited	Horizontal	Good	Above ground (Inside)	Abruptly decreasing
7	NORTHERN MINDANAO MEDICAL	13	No	Oversized	Limited	Horizontal	Good	Above ground (Outside)	Abruptly decreasing
8	PC INP RECOM 10	3	No	Oversized	Limited	Horizontal	Fair	Above ground (Inside)	Decreasing
9	CHAVES JUANITO LIM	15	Yes	Oversized	Yes	Horizontal	Good	Above ground (Inside)	Abruptly decreasing
10	PROV JAIL OFF MIS OR	8	Yes	Oversized	Yes	Non-horizontal	Good	Above ground (Inside)	Abruptly decreasing

Table 7: Summary of Key Findings on the Top 10 Largest Customer Meters

6 Annual Meter Under-registration Volume Estimates

6.1 DN15 Meters

The weighted error was calculated by weighing the meter errors at different flow rates with the certain fractions of the water consumption at each flow rate range. The calculated weighted error will denote the magnitude of the meter under-registration for DN15 water meters. The final weighted error has been derived from the error test results at two different orientations (horizontal and non-horizontal orientations). The same demand pattern has been applied for the calculation of weighted error on both orientations.

The tables below show the weighted error of the DN15 meters at normal and non-horizontal orientations.

Parameters	Average %Error at 67% x Q_{max}	Average %Error at Q_n	Average %Error at Q_t	Average %Error at Q_{min}
Average Error (Horizontal Orientation)	-3.08%	-2.51%	-3.63%	-16.31%

Final Demand Pattern	0%	12.6%	12.2%	-75.2%
			Weighted Error	**-13%**

Table 8: Calculated Weighted Error at Horizontal Orientation

Parameters	**Average %Error at 67% x Q_{max}**	**Average %Error at Q_n**	**Average %Error at Q_t**	**Average %Error at Q_{min}**
Average Error (Non-Horizontal Orientation)	-0.5%	1.0%	-6.9%	-82.1%
Final Demand Pattern	0%	12.6%	12.2%	-75.2%
			Weighted Error	**-62%**

Table 9: Calculated Weighted Error at Non-horizontal Orientation

The census data showed that approximately 10% of the water meters in Poblacion area were installed in non-horizontal position. The meters installed at non-horizontal position needs to be considered in the final weighted error as this greatly affects the meter error. The succeeding table shows final weighted error of DN15 meters.

Meter Orientation	**Weighted Error**	**% Occurrence in Field (Poblacion Area as Reference)**	**Final Weighted Error**
Horizontal Orientation	-13%	90%	**-18%**
Non-Horizontal Orientation	-62%	10%	

Table 10: Final Weighted Meter Error of DN15 Meters

About 93% of the total billed consumption of COWD comes from customers with DN15 meters. This represents to about 24,160,824 m^3 annual billed consumption (based on the 2015 billed consumption data). **Given the calculated final weighted error of -18%, the annual meter under-registration volume is therefore equate to around 5,303,596 m^3**.

6.2 Non-Domestic Meters (DN20 to DN100)

It was included in the meter testing plan to implement the error test for non-domestic meters ranging from DN20 to DN100. It is very beneficial to understand the magnitude of inaccuracy on non-domestic customer meters as these accounts have higher water tariff and substantial billed consumption that could generate high revenue stream to the water utility. However since COWD does not have spare water meters to replace the existing meters in field, the error testing for meters ranging from DN20 and above has never been pushed through. In this case, the only alternative option is to estimate the meter error based on the best technical judgement and several international metering studies carried out by the consultants. An estimated annual error degradation rate of 0.8% was used in determining the meter errors of the non-domestic meters. The assumption has made with consideration to the water quality in the network, condition of the meters in field, material quality of the meter, actual meter age and other factors that could affect the wear and tear of the water meters. The following table shows the best estimate of the meter error for DN20 water meters and above.

DN Size (mm)	**Population Size**	**Average Age (years)**	**2015 Annual Billed Consumption (m^3)**	**Estimated Meter Error (- %)**	**Estimated Meter Under-registration Volume (m^3)**
20	109	7.4	111,589	5.9%	6,997

25	152	10.5	322,368	8.4%	29,562
40	69	8.6	306,972	6.9%	22,751
50	38	11.4	225,771	9.1%	22,602
75	2	12.9	21,157	10.3%	2,429
100	7	7.2	146,368	5.8%	9,012
		Total Annual Meter Under-registration Volume (m^3)			**93,353**

Table 11: Estimated Meter Under-registration Volume of Non-Domestic Water Meters (DN20 to DN100)

6.3 Top 10 Largest Customers

The top 10 largest customers were listed based on their generated revenue. These customers only represent the 2% of the total annual billed consumption which generates revenue of approximately Php 34 million annually. A drift in accuracy of these large customer meters could lead to significant losses of utility's revenue. The succeeding table shows the basic profile of the top 10 largest customer meters.

The meter error of the top 10 largest customer meters has been estimated in consideration of their sizing condition, years in service and installation conditions. Some of the meters have been found not working properly in field like in MOGCHS (school) and in Chaves Juanito Lim or also known as CHALI (resort). Judging on their current situation, these meters are assumed to have an error of -100%. It is being assumed that COWD billed these customers by averaging their past three months consumption. However, a 50% under-billing rate was used in the under-registration analysis because it was observed that there have been a decline in the monthly consumption in the past months which affects averaging of the billed consumption. The annual meter under-registration of these largest customer meters were calculated using the estimated meter error listed in the following table.

Top	Top 10 Largest Customers	Service Age (Years)	Estimated Meter Error (- %)	Estimated Annual Meter Under-registration Volume (m^3)
1	CAGAYAN DE ORO GATEWAY CORP	3	1.5%	2,361
2	PHIL PORT AUTHORITY PMO CDO	4	7.0%	10,559
3	LIMKETKAI SONS INC	12	11.0%	6,846
4	CHIU ROGER LIM (MALL BERRY)	10	10.0%	5,316
5	CAPITOL COLLEGE GEN. HOSPITAL	4	7.0%	3,129
6	MOGCHS N DAEL	4	100.0%	44,731
7	NORTHERN MINDANAO MEDICAL	13	11.5%	5,315
8	PC INP RECOM 10	3	6.5%	2,409
9	CHAVES JUANITO LIM	15	100.0%	15,593
10	PROV JAIL OFF MIS OR	8	9.0%	3,128
	Total Annual Meter Under-registration Volume (m^3)			**99,387**

Table 12: Estimated Meter Under-registration Volume of Top 10 Largest Customer Meters

Careful analysis should be given especially on downsizing of water meters. This is for the reason that the nominal diameter of the water meter is proportional to the minimum billing charge that COWD is implementing to their customers.

6.4 Summary of Annual Meter Under-registration Volume

The meter under-registration volume has been summarized in the following table.

Customer Meter Groups	Annual Meter Under-registration Volume (m^3)	% of the Total Annual Billed Consumption (2015)
DN15 Meters	5,303,596	20.5%
Non-Domestic Meters (DN20 to DN100)	93,353	0.36%
Top 10 Largest Customer Meters	99,387	0.38%
Total Annual Meter Under-registration Volume (m^3)	**5,496,336**	**21.22%**

Table 13: Summary of COWD Annual Meter Under-registration Volume

The biggest fraction of the meter under-registration volume comes from DN15 meters which has the largest population size. **The estimated annual meter under-registration volume for the entire customer meters is approximately 5,496,336 m^3 (or equivalent to 15,058 m^3/day). This volume is equivalent to 21.22% of COWD's 2015 total annual billed consumption**. The main reasons of high meter under-registration or inaccuracies of the water meters are as follows:

- No regular meter replacement (which leads to higher number of old meters)
- Wrong meter installations
- Improper sizing of meters
- Absence of comprehensive and robust water meter technical specifications
- No performance meter testing has been done prior to and after the procurement of the water meters
- Poor stocking of meters (COWD needs to wait for the procurement of water meters before they could replace the defective meters which take a long time)
- No periodical meter testing
- No regular customer meter audit program
- No dedicated water meter management team

7 General Recommendations

The recommendations have been formulated based on the key findings observed from the intensive field inspections, meter testing results and metering analysis which were carried in this project. The following are the recommendations that would help improve the customer meter management.

7.1 Regular Meter Replacement Policy

A regular meter replacement is needed to be scheduled periodically at cost efficient manner. Meter replacement is very important to maintain the optimum level of meter under-registration. Replacement has to be carried out in a way that the objective is not only to improve the accuracy of meters but also to optimize their service lifespan. Shorter meter replacement frequency is recommended for large customer meters DN40 and above while longer frequency for small meters. The following table shows the proposed regular meter replacement frequency for COWD customer meters.

DN Size (mm)	Proposed Regular Meter Replacement Frequency (Years)
15	6
20 and 25	4
40 and 50	3
80	2
100	1

Table 14: Proposed Regular Meter Replacement Frequency

7.2 Replacement of the Top 10 Largest Customer Meters

Immediate replacement of the top 10 largest customer meter is highly recommended. The following table shows the recommended meter size and type of meter on each large customer meter.

Top	Top 10 Largest Customers	DN Size (mm)	Meter Sizing Remarks	Recommended Meter Size (mm)	Recommended Meter Type
1	CAGAYAN DE ORO GATEWAY CORP	100	Properly Sized	100	Electromagnetic Meter
2	PHIL PORT AUTHORITY PMO CDO	250	Oversized	100	Electromagnetic Meter
3	LIMKETKAI SONS INC	50	Oversized	40	R100 Multijet Meter
4	CHIU ROGER LIM (MALL BERRY)	50	Oversized	40	R100 Multijet Meter
5	CAPITOL COLLEGE GEN. HOSPITAL	50	Oversized	40	R100 Multijet Meter
6	MOGCHS N DAEL	50	Oversized	40	R100 Multijet Meter
7	NORTHERN MINDANAO MEDICAL	50	Oversized	40	R100 Multijet Meter
8	PC INP RECOM 10	50	Oversized	40	R100 Multijet Meter
9	CHAVES JUANITO LIM	40	Oversized	25	R100 Multijet Meter
10	PROV JAIL OFF MIS OR	25	Oversized	20	R100 Multijet Meter

Table 15: Recommended Meter Size and Type for Top 10 Largest Customer Meters

Careful analysis should be made in downsizing of the large customer meters as it has a direct impact on the water tariff structure (the smaller the meter the lower the tariff rate).

7.3 Water Meter Installation Enhancement

7.3.1 Correction of Meter Orientation

From the accuracy testing of few meters at different orientations, it has been proven that water meters, especially single jet and multijet type meters, could under-register by more than 60% when they are installed in non-horizontal position. In Poblacion Area, the rate of water meters that were installed in non-horizontal position is about 18% of the total customers residing in the area which is very high. Correction in meter installation is required on the water meters (single jet and multijet meters) that are not installed properly.

7.3.2 Installation of Strainers

The absence of strainers especially for woltmann meters ranging from DN50 to DN250 is also causing a problem to the meters. Suspended solids and tiny stones could damage the turbine of the woltmann meters. Therefore, a strainer must be installed to protect the meter from damage.

7.3.3 Adapting Straight Pipe Distances

Straight pipe distances on both sides of the meter is very important to prevent irregularities in the flow conditions. Lack of straight pipe distances from distorting elements could create flow distortions that affect the measuring performance of the large diameter meters such as woltmann, full-bore electromagnetic and ultrasonic meters. Straight pipe distances of 5D (5 times the nominal diameter of the meters) and 3D (3 times the nominal diameter of the meter) are required for upstream and downstream side of the meter, respectively. The use of water meters with U0/D0 straight pipe requirements can also be an alternative for tight meter assemblies.

7.4 Relocation of Water Meters

About more than 26% of the water meters in Poblacion Area is installed inside the customer property premise. These meters should be relocated outside the customer property premises to avoid meter reading estimates whenever the customers are not around. In addition, water meters located inside the customer premises are susceptible to meter tampering.

7.5 Water Meters without Seal

In Poblacion Area, 33% (about 2,193 meters) of the water meters have broken seals. Meter seals are made of copper wire which are used to seal the water meters. Meter seals can help the utility to detect tampering or any fraudulent meter manipulation. Broken meter seal could be an indication of tampering. One way of checking whether the water meter is tampered is to check if there is extreme variations or sudden decline in the customer’s water consumption. Another way is to do field inspection to physically check the water meters and carryout bucket testing. These techniques are very helpful to verify if the water is tampered or not.

7.6 Water Meter Sizing

Correcting the water meter size is very vital especially for commercial and industrial customers with large diameter meters (DN40 and above). These customers are commonly billed under higher water tariff therefore size of the water meters matters. It is a common practice that the utility size the meters based on the size of the service pipe connection. This practice is very wrong as it oversized the meters. Improper sizing of water meters could lead to significant meter under-registration for oversized meters or could damage the meter’s mechanical components that can result in faster wear if the meter is undersized. Photo below shows a resized meter in Yishun, Singapore.

Photo 46: Resized Water Meter in Singapore

Two possible things could happen if a water meter is not properly sized which are being discussed in the following subsections.

7.6.1 Undersized Meters

If the water meter is undersized: the accuracy degradation (and wear and tear rate) is much faster than the normal rate because it exceeds the mechanical resistance of water meter to withstand higher flow rates. And later on, the mechanical components will be damaged unexpectedly which makes the water meter stops registering. In addition to the effect of undersized meters, it could also create high head loss through the service line that may affect the service pressure at the customer side. The photo below shows a damaged meter due to meter under-sizing.

Photo 47: Damaged Turbine of the Large Customer Meter

7.6.2 Oversized Meters

If the water meter is oversized: the demand pattern of the customer will definitely fall within or under the rated starting or minimum flow rates of the water meter and this will result to significant meter under-registration. The figure below shows the demand pattern of a large manufacturing plant in Dar es Salaam City, Tanzania (Africa). The entire demand pattern of this particular customer falls below the minimum flow rate of the existing water meter due to over-sizing. This leads the meter to under-register the billed consumption by approximately 10%.

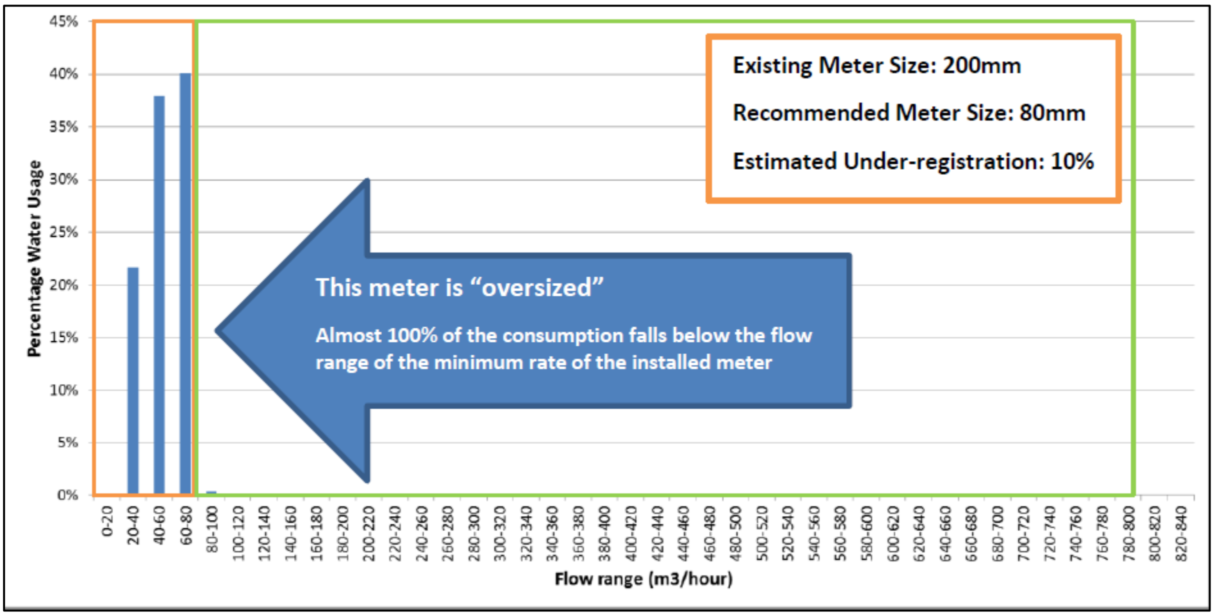


Figure 14: Effect of the Oversized Meter

Even new water meters are not exempted on the effect of improper meter sizing. Therefore to ensure the highest quality of the water meter's metering performance, a thorough water meter sizing have to be carried out. It must also consider in the meter sizing analysis the effect of downsizing of meters as COWD is using LWUA-based tariff structure wherein the size of the meter is proportional to minimum charge fee and tiered water rates. This only means that downsizing of water meter will also step-down the customer's tariff schedule.

7.7 Periodic Meter Testing

Periodic meter testing of water meters must be carried out frequently to oversee their metrological performance and physical conditions over time. It is very important to test the accuracy of the water meters periodically to minimize revenue loss due to meter under-registration. All the water meters especially those with mechanical components tend to under-register due to wear and tear while in service. The degradation of the water meters' accuracy is caused by several factors such as water quality, the quality of materials which the meters are made of, water-use behaviour of the customer and how the utility size the water meters.

The periodic meter testing frequency has been established from the estimated economic lifespan of the water meters and based on the meter testing regulation from AWWA M6 manual. As what have been said in the previous section, a drift in meter error on the customer meters could lead to significant financial loss. The table below shows the proposed periodic meter testing frequency according to water meter size.

Customer Meter DN Size (mm)	Proposed Periodic Meter Testing Frequency (Years)	Number of Samples[2]
15	3	400
20	2	90

[2] Number of samples must be distributed into the different meter makes or brands

25	2	100
40	1	60
50	1	30
80	1	2
100	0.5	5
Top 10 Largest Customer Meters	0.5	All

Table 16: Proposed Periodic Meter Testing Frequency

The number of meter samples have to be tested in an annual basis. The meter samples that passed the test should be returned back to the field and those meters that failed should be disposed in the meter depository. The test results must be kept in a meter test result database.

7.8 Large Customer Meter Audit Program

Regular audit of large customer meters audit has to be done to check and monitor the performance of the meters while in field. Physical inspection should also be carried out in the meter audit. Sealing wire is used as an indication of meter tampering. Therefore, it must be checked whether it is intact or broken. Strainer should be cleaned once in a while because stones and other small debris that trapped in it could restrict the flow that may affect the metrological performance of the meters. The isolation valve installed in the meter assembly is important to stop the water supply when replacing or maintaining the meters. Therefore, it must be exercised frequently to prevent it from damage. The status of these main checkpoints must be documented in a form. The form must also contain the following information:

- Customer Name
- Business Name
- Account Number
- Address
- Water Meter Brand, Size Class/Dynamic Range and Type
- Manufacturing Year
- Installation Date
- Current Totalizer Reading and Spot Flow Rate
- Meter Location
- Length of Upstream and Downstream Straight Pipe Distance from Distorting Devices
- Readability and Installation Condition
- Meter Dial

The portable meter test bench could be utilized for implementing in-situ meter testing that can be part of the large customer meter audit. It has been proven in many water utilities that the in-situ meter testing could help determining the current accuracy of meter in field in no time. In most cases, utilities need to get the approval of schedule for replacement from the customers. Once the customer approved the replacement, the utility staff will replace the meter and send it to the meter testing laboratory for accuracy testing. This practice needs extra effort and will take more than weeks to get the testing done. Therefore, the portable meter test bench can be added in the meter audit program. The succeeding photos shows the actual in-situ meter accuracy testing using the portable meter test bench at the Polymer Plant (top 1 largest customer) in Grand Bahama Island, Bahamas.

Photo 48: Actual In-situ Meter Accuracy Testing

Photo 49: Meter Test Port

After the in-situ accuracy testing had carried-out, it was revealed that the meter is under-registering by 29% that leads to revenue loss of about USD 108,000 annually.

7.9 Water Meter Testing Facility Improvement

The COWD's current water meter testing facility, particularly the meter test bench and the workplace, needs appropriate improvements. The water meter testing facility improvement should include upgrades on the meter test bench, re-layout of the facility's workplace and development of test result database.

7.9.1 Meter Test Bench

Without the meter test bench, a water utility cannot control and monitor the metrological quality and performance of their water meters. Meter test bench is a verification device that mainly determines the accuracy of the water meters. Therefore, to ensure the highest quality of the test results, the test bench reliability should be always maintained accordingly. The following photo shows the semi-automatic test bench used by a private water utility in Indonesia.

Photo 50: Semi-Automatic Meter Test Bench (Two Lines with Total Capacity of 10 DN15 Meters)

In selecting a meter test bench, the range of meter sizes that the utility used must be considered. For COWD, a meter test bench with basic features can be used:

- Range of meter sizes can be tested: DN15 to DN50
- Number of meter can be tested simultaneously: at least 10 units of DN15 meters (minimum)
- Reference instrument: Calibrated Tanks (Gravimetric – optional)
- Clamping unit: Pneumatic or hydraulic
- Flow indicator (Rotameter) flow ranges: 4 liters per hour – 50 m^3 per hour (can be a set of three or more rotameters)
- Auxiliary devices:
    - Air release valve
    - Pump
    - Hydro-pneumatic tank
    - Overhead tank
    - Filters
    - Master meter (electromagnetic meter)
    - Operations: Semi-automatic (with proximity switches on the level scales and automatic shut-off valve)
    - Test method: Flying start and finish method
- The bench must have the special functionality (or features) to perform the following test:
    - Endurance Test (Continuous and Discontinuous Test)
    - Pressure Loss Test

7.9.2 Facility Workplace

The size meter testing facility must be compatible with the size of the water utility. The number of water meters that need to be tested periodically will dictate how big the meter testing facility would be. The meter testing facility layout must be designed properly in such a way that locating the needed equipment, testing the water meters and safekeeping of the tested water meters and records can be performed efficiently. Figure below illustrates recommended layout of meter testing facility for modern type meter shop.

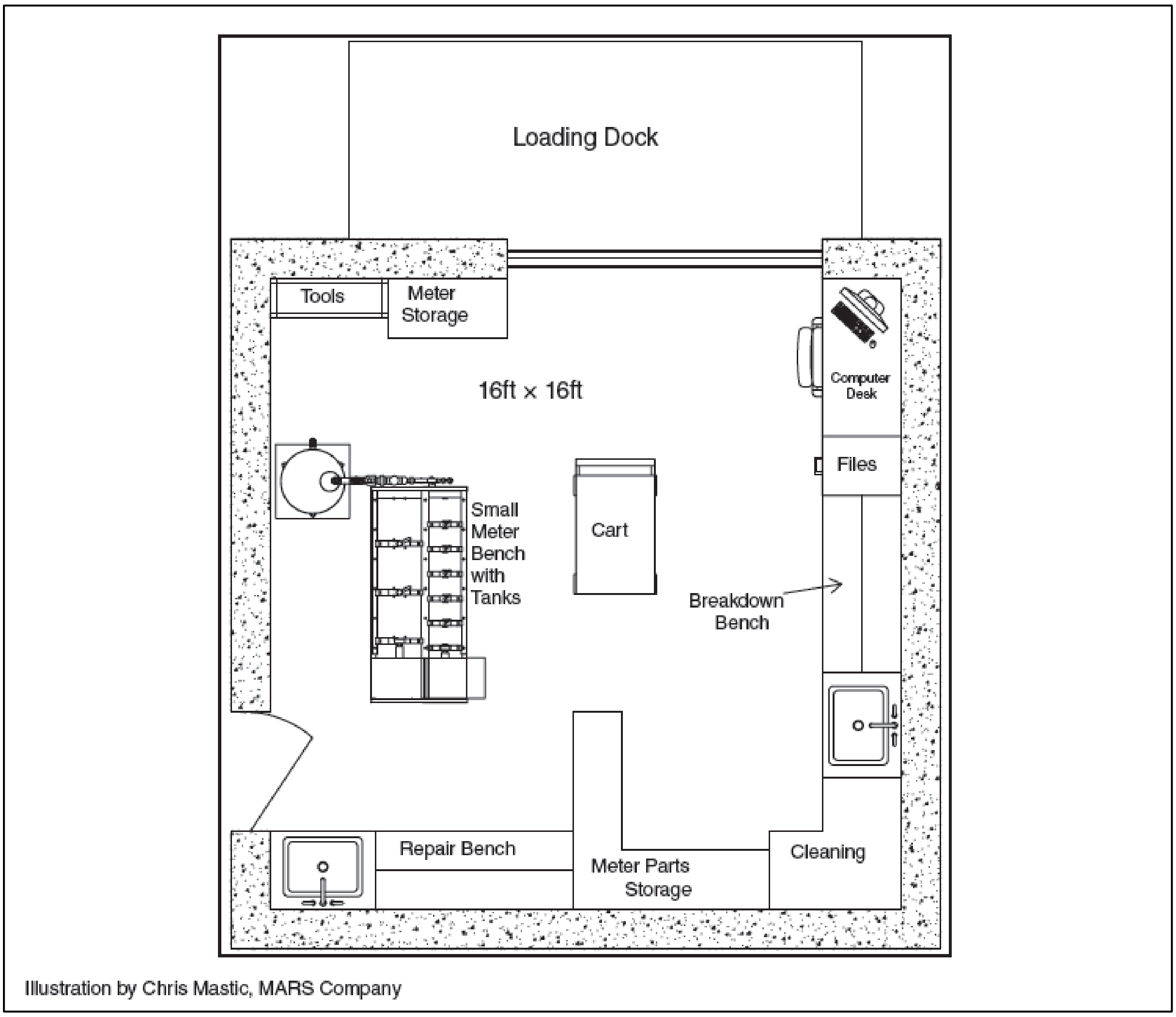


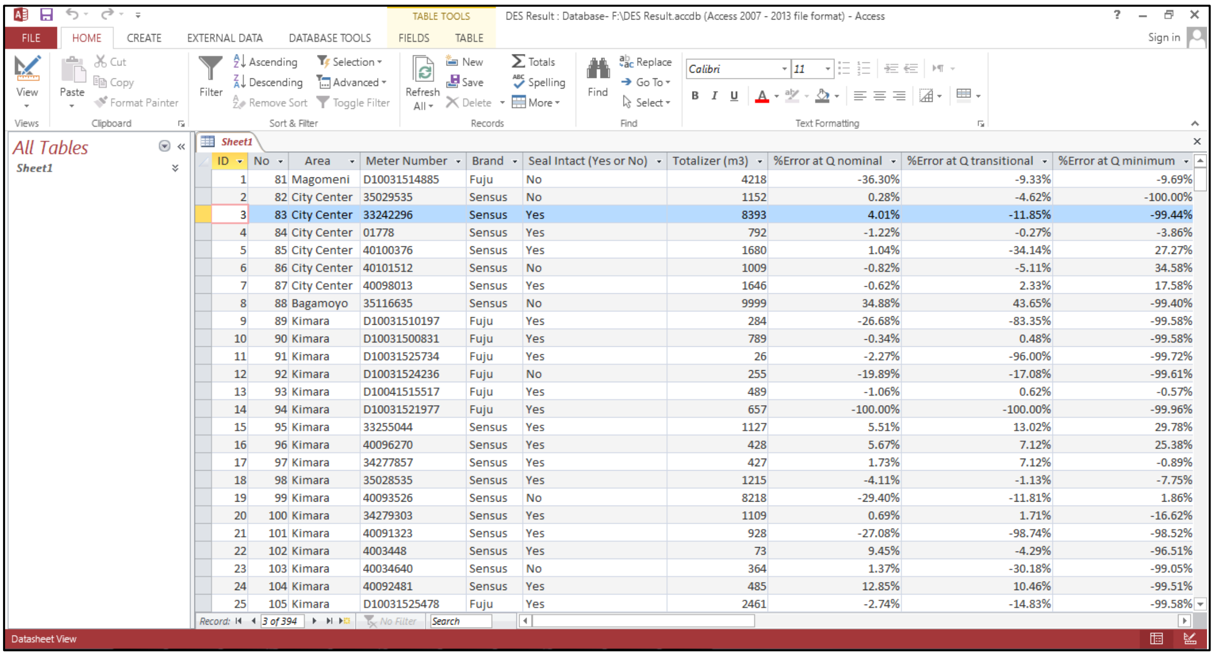
Figure 15: Recommended Meter Testing Facility Workplace for Modern Meter Shop (AWWA M6)

7.9.3 Meter Test Result Database

Meter test results should be recorded in both hardcopy document and in the computerized database system. The test results should be kept in order to have a historical data record of meter performance of different meter makes and sizes. A meter test results could be used in future analytical purposes such as:

- Review of metering performance of a brand with respect to service age and registered volume
- Accuracy analysis of different meter brands or area where the meters were installed
- Obtaining the accuracy degradation rate of a water meter

Photo below shows the screenshot of a MS Access-based meter test result database system.



ID	No	Area	Meter Number	Brand	Seal Intact (Yes or No)	Totalizer (m3)	%Error at Q nominal	%Error at Q transitional	%Error at Q minimum
1	81	Magomeni	D10031514885	Fuju	No	4218	-36.30%	-9.33%	-9.69%
2	82	City Center	35029535	Sensus	No	1152	0.28%	-4.62%	-100.00%
3	83	City Center	33242296	Sensus	Yes	8393	4.01%	-11.85%	-99.44%
4	84	City Center	01778	Sensus	Yes	792	-1.22%	-0.27%	-3.86%
5	85	City Center	40100376	Sensus	Yes	1680	1.04%	-34.14%	27.27%
6	86	City Center	40101512	Sensus	No	1009	-0.82%	-5.11%	34.58%
7	87	City Center	40098013	Sensus	Yes	1646	-0.62%	2.33%	17.58%
8	88	Bagamoyo	35116635	Sensus	No	9999	34.88%	43.65%	-99.40%
9	89	Kimara	D10031510197	Fuju	Yes	284	-26.68%	-83.35%	-99.58%
10	90	Kimara	D10031500831	Fuju	Yes	789	-0.34%	0.48%	-99.58%
11	91	Kimara	D10031525734	Fuju	Yes	26	-2.27%	-96.00%	-99.72%
12	92	Kimara	D10031524236	Fuju	No	255	-19.89%	-17.08%	-99.61%
13	93	Kimara	D10041515517	Fuju	Yes	489	-1.06%	0.62%	-0.57%
14	94	Kimara	D10031521977	Fuju	Yes	657	-100.00%	-100.00%	-99.96%
15	95	Kimara	33255044	Sensus	Yes	1127	5.51%	13.02%	29.78%
16	96	Kimara	40096270	Sensus	Yes	428	5.67%	7.12%	25.38%
17	97	Kimara	34277857	Sensus	Yes	427	1.73%	7.12%	-0.89%
18	98	Kimara	35028535	Sensus	Yes	1215	-4.11%	-1.13%	-7.75%
19	99	Kimara	40093526	Sensus	No	8218	-29.40%	-11.81%	1.86%
20	100	Kimara	34279303	Sensus	Yes	1109	0.69%	1.71%	-16.62%
21	101	Kimara	40091323	Sensus	Yes	928	-27.08%	-98.74%	-98.52%
22	102	Kimara	4003448	Sensus	Yes	73	9.45%	-4.29%	-96.51%
23	103	Kimara	40034640	Sensus	No	364	1.37%	-30.18%	-99.05%
24	104	Kimara	40092481	Sensus	Yes	485	12.85%	10.46%	-99.51%
25	105	Kimara	D10031525478	Fuju	Yes	2461	-2.74%	-14.83%	-99.58%

Figure 16: Example of MS Access-Based Meter Test Result Database

The meter test result database must contain the following information:

- Meter information
  - Meter serial number
  - Meter size
  - Mete brand
  - Meter model
  - Meter type
  - Meter index (totalizer)
  - Meter condition
    - Indication of tampering
    - Meter seal status
    - Fogging
    - Leaking or Stuck-up
  - Location where the meter was installed
  - Manufacturing year
- Test results
  - Maximum flow rate
  - Permanent flow rate
  - Transitional flow rate
  - Minimum flow rate
  - Other test flow rates
- Other information
  - Tested by (name of the technician)
  - Date tested
  - Comments

7.10 Water Meter Stocking

The recommended annual quantity of water meters for regular meter replacement and some additional meters for new service connections and emergency replacements has been forecasted. The total number of water meters was estimated based on the meter replacement frequency, defective meters that require immediate replacement and forecasted new connections. The following table shows the breakdown of the quantity of water meters according to meter size.

DN Size (mm)	For Regular Meter Replacement	For New Service Connection and Emergency Replacement	Total Quantity for Water Meter Stocking
15	13,500	3,500	17,500
20	30	10	40
25	40	15	55
40	25	10	35
50	15	5	20
80	2	1	3
100	10	2	12
Total	13,622	3,543	**17,665**

Table 17: Recommended Quantity of Water Meters for Meter Replacements and New Connections

COWD needs to purchase the above quantity of water meters in order to ensure sufficient supply of meters for meter replacement and installation.

7.11 Water Meter Management Team

The water meter management team must be created to efficiently and efficiently manage any water metering related aspects. The water meter management team should cover the operation and management of the water meters in domestic and non-domestic customers, district metered area flow meters and bulk meters at production facilities. The following should also be part of core responsibilities of the water meter management team.

1. Selection of suitable water meter model and technology
2. Performance testing on new water meters
3. Standardization of water meter installation
4. Field inspection prior to water meter installation
5. Water meter sizing
6. Meter audit
7. Testing of installed water meters
8. Regular replacement of water meters
9. Development of AMI or AMR systems

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