KERALA URBAN WATER SUPPLY IMPROVEMENT PROJECT

KOCHI CORPORATION WATER SUPPLY SYSTEM

DETAILED PROJECT REPORT

VOLUME - I

PREPARED FOR KERALA WATER AUTHORITY

KERALA, INDIA

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VERSION 13

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1 EXECUTIVE SUMMARY

An investigation of the water supply system of the Kochi Corporation area has been undertaken. The investigation included the collection of a large amount of cost, performance and asset data, field inspections, interviews with senior and middle level staff, reviews of various documents and reports from past studies and works and various detailed analyses using contemporary analytical techniques.

Key Findings:

The key findings of the investigation were as follows.

- Over time KWA has been developing the Kochi water supply systems and has been installing assets which were designed to the standards that applied at the time and to meet the growing demands of the city. Kochi have enjoyed a very good coverage of metered household connections, and water usage tariffs have been levied and paid. This was well in advance of other cities in India. However, in more recent years the levels of service have been deteriorating and areas affected by intermittent water supplies and low pressures have been growing. Water losses have been steadily increasing and as a consequence the quality of water at customer taps has also been deteriorating which is increasing the risk to public health. A backlog of capital maintenance has been steadily growing and is now at a stage where an intervention is required.
- The review found that as a result of the large water losses in the networks all of the water treatment plants servicing the city are being challenged by the demand for ever higher volumes of water. In addition, the treatment plants are not able to meet the drinking water quality standards introduced in 2012 as they were designed and built before this standard applied. Most water treatment plants are now operating above their respective design capacities and are using techniques and processes which are not able to meet the new Indian drinking water standards. The solution is twofold: (1) Reduce the demand on the treatment plants by reducing the large water losses in the networks; and (2) Refurbish and upgrade the treatment plants to meet the newer Indian drinking water standards.
- The review also found that most pump stations are operating above their respective design capacities which is causing them to operate inefficiently and unreliably. A backlog of pump station capital maintenance is also growing. The pump stations require refurbishment and upgrading, and one pump station requires replacing.
- The review found that pipelines are suffering faults at a rate that is ten times the accepted norm and approximately half need replacing.
- These finding are not unusual and are commonly found as cities grow, assets age and deteriorate, and new standards are introduced. While this is understandable, periodic interventions are required before the water supply systems deteriorate further and start to noticeably fail.
- The review found that high non-revenue water is having an adverse effect on the entire water supply system including the delivery of customer service and the overloading of the water treatment plants and pump stations. The failing of the pipelines is placing an ever-increasing maintenance burden on the KWA in trying to keep up with fixing leaks. The review found that the high non-revenue water is adding over 33% to the KWA's annual operating costs. To appreciate the scale of non-revenue water, the water currently being lost above an acceptable non-revenue water target of 20% would service an additional 111,000 households (590,000 people) in Kochi City.

- Finally, the review also found that the KWA's existing information management systems need to be upgraded to support the interventions recommended in this report and to ensure the benefits so gained will be sustained into the long-term future.

A program of works has been developed to directly address these findings.

The KWA has a history of being a leading water utility in India but this is now slipping as the assets age and standards evolve. This project will bring many benefits to the KWA including: (1) customers who will enjoy an equitable, un-interrupted and healthy supply of water; (2) the KWA which will have an enhanced image of improved customer service, compliance with water quality standards, reduced operating costs, reduced greenhouse gas (equivalent) emissions, an engaged workforce, improved safety and the long-term sustainability of its operations; and (3) Government for the effective and efficient use of water and financial resources.

Two works packages have been developed for Kochi City and estimated costs were assessed based on 2019 prices and submitted to KWA in early 2020. The KWA has obtained administrative sanction from Government of Kerala and is preparing bidding packages to procure the works. The procurement has been delayed to the prevailing pandemic and it is currently scheduled to be completed before end of 2022. The project costs are now revised as per latest schedule of rates prevailing in KWA as well as market rates to assess revised cost updated up to November 2022. These revised costs are shown in the following abstract table. The detailed estimate costs are provided in Volume II of this report. As per the project clearance by Department of Economic Affairs, Government of India, the project is planned to be implemented in two phases.

Kochi Project Capital Costs

WATER SUPPLY IMPROVEMENTS IN KOCHI					
			1 USD =	81.63	INR
Sl. No.	**Package**	**Project Area**	**Description**	**Estimated cost (Rs Cr)**	**Estimated cost USD $ millions**
1	**CW1**	**Kochi**	**Water Treatment plants and Pump stations**		
			Pumping stations	6.3	0.8
			Water treatment plant (i) Civil & Mechanical Works (ii) Pumps & Motors (iii) Valves	65.9	8.1
			SCADA for plant operations	0.5	0.1
			Instrumentation	10.0	1.2
			Total Package CW1	**82.7**	**10.1**
2	**CW2**	**Kochi**	**Networks, Property service connections, Customer meters**		
			Networks	310.3	38.0
			Booster pumping stations	8.7	1.1
			Tanks Rehabilitation	0.9	0.1
			Property service connections & Customer meters	276.4	33.9
			Set up Costs	6.8	0.8
			SCADA system for network flow and pressure monitoring	0.5	0.1
			Total Package CW2	**603.6**	**73.9**
			Total Cost CW1 + CW2	**686.3**	**84.1**

Project Costs Capex + Opex

Data											
One USD$	INR	81.63	**ADB November 2022**								
Physical contingencies	%	0%									
Price inflation	%	0%									
Network length	Km	706									
Maintenance cost for WTW rehab	%	3%									
GST	%	18%									
COC Project Cost Financial Plan	Total	1	2	3	4	5	6	7	8	9	10
Inflation rate		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Inflation index		1	1	1	1	1	1	1	1	1	1
CW1 - Expenditure profile	100%	10%	20.0%	20.0%	25.0%	25.0%					
CW1 - Production Capex	82.67	8.27	16.53	16.53	20.67	20.67					
CW1 - Maintenance Cost	16.49		0.25	0.74	1.24	1.86	2.48	2.48	2.48	2.48	2.48
GST @18%	17.87	1.49	3.02	3.11	3.94	4.06	0.45	0.45	0.45	0.45	0.45
CW1 - Subtotal	**117.03**	**9.76**	**19.8**	**20.38**	**25.85**	**26.59**	**2.93**	**2.93**	**2.93**	**2.93**	**2.93**
CW2 - Expenditure Profile	**100%**	10%	10.0%	20%	20%	20%	10%	10%			
CW2 - Distribution Capex	603.63	60.36	60.36	120.73	120.73	120.73	60.36	60.36			
CW2 - Maintenance Cost	122.5		13.24	12.76	12.14	11.51	14.89	14.72	14.56	14.41	14.27
CW2 - Operator Fee	236.04	34.36	29.93	21.79	21.79	21.79	21.25	21.25	21.29	21.29	21.29
GST @18%		17.05	18.64	27.95	27.84	27.73	17.37	17.34	6.45	6.43	6.40
CW2 - Subtotal	**1135.37**	**111.77**	**122.17**	**183.23**	**182.50**	**181.76**	**113.87**	**113.67**	**42.30**	**42.13**	**41.96**
Total COC Packages Cost	1252.40	121.53	141.97	203.61	208.35	208.35	116.80	116.60	45.23	45.06	44.89
	INR Cr	USD$m									
COC Package cost for Yr1- Yr7	1117.21	137									
COC Package cost for Yr8 - 10	135.19	17									
COC total package cost	**1252.40**	**153**									

In addition to the above capex and opex costs, the project needs standard provisions towards Physical Contingencies at 5%, price contingencies towards annual inflation and project supervision charges for Loan Implementation Support Unit (LISU) and project administration charges for KWA which are to be provisioned as part of total project investment plan in compliance to ADB guidelines.

2 TERMINOLOGY, ACRONYMS AND UNITS

Asset Management	A process to maximise the benefits delivered by an asset over its lifetime
CCMS	Customer Contact Management System
CCTV	Closed Circuit Television
CMS	Contract Management System
COC	Kochi Corporation Area
Connection	Households are limited to one connection each. Non-domestic properties may have one or more connections
Current State	2017 in its current form
ERP	Enterprise Reporting System
Faults per Kilometre	Number of malfunctions (normally leaks and bursts) of a pipeline over a given period
GIS	Geographic Information Management System
Household	One or more people dwelling under the same roof and making up a family unit
ILI	Infrastructure Leakage Index
IMS	Information Management System
IS10500 2012	Indian drinking water quality standard
IWA	International Water Association
KSWAN	Kerala State-Wide Area Network
KUWSIP	Kerala Urban Water Supply Improvement Project
KWA	Kerala Water Authority
LIMS	Laboratory Information System
Lpcd	Litres per person (capita) per day
Meter Assembly	A customer water meter and the pipework and valves which support the meter
MRBS	Meter Reading and Billing System
Non-Revenue Water	Water exiting a water supply network which is not paid for
Pipeline Faults	Any malfunction of a pipeline or in-line fitting
Population	Number of people residing in a corporation area
Project Areas	Kochi City Corporation Area
Property Service Connection	The pipeline and meter that connects a water main in a street to the internally plumbing within a property
Road Opening	Cutting a road surface and excavating a trench
Road Reinstatement	Repairing a road surface following an excavation to return it to its pre-existing condition
SCADA	Supervisory Control and Data Acquisition
Suppressed Water Use	The additional volume of water that would be used if water was supplied according to a minimum standard
Turbulent Flow	The opposite of laminar flow. Velocities at any point in the flow vary erratically in magnitude and direction

Unmetered Water	The different between the volume of water measured entering a pipeline network and the volume of water measured exiting a pipeline network
Water Balance	Water accounting tool used to calculate non-revenue water
Water Production	The harvesting of raw water and its conversion to drinking water ready for human consumption

Units

GL	Gigalitres = 10^9 litres
ML	Megalitres = 10^6 litres
Kl	Kilolitres = 10^3 litres
Cubic metres	m^3 = 10^3 litres
GL/year	= 2,740 kl/day
ML/year	= 2.74 kl/day
ML/day (also MLD)	= 1,000 kl/day
kWh/m^3	The energy used per cubic meter of water (pump and/or treated)

3 STRUCTURE OF REPORT

This detailed project report is work in progress and is presented to KWA for discussion purposes. The report comprises of following parts.

a) Volume I – This volume contains a narrative report providing the objectives, study findings, proposed service improvement strategies and proposals
b) Volume II – This volume contains cost estimates for Kochi
c) Volume III – This volume comprises of related drawings presented in two parts, (a) Part I – Process Instrumentation Drawings for all proposed improvements in water treatment plants and pumping stations and (b) Part II – Existing Networks in Kochi

Version 6 of this report was submitted to the KWA on 9 June 2019. Feedback on the report was provided by the Managing Director and Senior Staff of the KWA and this feedback has been incorporated the Version 7 and the estimated cost was further updated in June 2021. This report presents updated cost estimate up to November 2022.

4 OBJECTIVES AND PERFORMANCE MEASURES

The objectives of the KUWSIP are as follows:

- To improve customer service by providing each household and each non-domestic property with a potable[1], pressured and reliable supply of water for 24 hours every day
- To improve efficiency by refurbishing water treatment plants and pump stations and by reducing non-revenue water to twenty percent
- To maintain the improved customer service and efficiency in perpetuity
- To improve safety and staff engagement

The performance measures are applied at the outlet of the water treatment plants and at customer taps.

[1] To current Indian Drinking Water Standard IS10500 and WHO Drinking Water Guidelines Version 4

The role of a water treatment plant is to turn enough raw water into product water to meet customer needs where the product water is safe to drink (safe), is healthy to drink (healthy), has a low impact on assets (inert) and is resistant to change (stable). A different circumstance applies at customer taps where the aim is to supply enough, but not too much, water that is safe and healthy and in a manner that reduces within-property wastage.

Performance measures and targets have been developed and these are as follows.

- Water Production Performance Measures and Targets: Table 1
- Water Delivery Performance Measures and Targets: Table 2
- Customer Service Performance Measures and Targets: Table 3
- Efficiency Performance Measures and Targets:
- Table 4

Table 1 Water Production Performance Measures and Targets

Parameter	Measure	Target
Water Production – Quantity	Water Treatment Plant production capacity at outlet	Design capacity
Water Production – Quality	Percentage compliance with drinking water standard at outlet	100%
	Alkalinity at outlet	> 50 < X < 100 mg/l
	pH at outlet	7.2 < X < 8.5
	Chlorine concentration at outlet	2.5 < X < 4.0 mg/l
	Turbidity at outlet	NTU < 0.15
	Corrosion inhibitors at outlet	0.5 to 3.0 mg/l
Water Production – Reliability	Water Treatment Plant availability Water Pump Station availability	99.5% 99.5%

Note that the measuring point will depend upon the configuration of each water treatment plant but will normally at a location just before the water enters the transmission pipeline. To achieve these performances the water treatment plants and their associated raw water and product water pump stations and storages must work in concert.

Table 2 Water Supply Delivery Performance Measures and Targets

Parameter	Measure	Target
Water Delivery – Quantity	Minimum residual pressure at communication pipe offtakes	> 12 metres
Water Delivery – Quality	Percentage compliance with drinking water standard at outlet Chlorine residual at customer taps	100% 0.3 < X < 0.5 mg/l

Water Delivery – Reliability	Number of water supply interruptions in a rolling twelve-month period	12

Table 3 Customer Service Performance Measures and Targets

Parameter	Measure	Target
Customer Service Centres	Number of customer service centres resourced and operational	100%
Customer Contacts (Complaints and Enquiries)	Resolution of contact within a set time period: Priority 1: 10 hours Priority 2: 3 days Priority 3: 14 days	 95% 90% 90%
Meter Reads	Percentage of customer meters read each month	95%
Water Bills	Percentage of water bills collected by the due date	90%

Table 4 Efficiency Performance Measures and Targets

Parameter	Measure	Target
Electricity Usage	Efficiency target[2]	'x' kWh/m^3
Non-Revenue Water	After seven years	<20%

5 KERALA WATER AUTHORITY SPATIAL ORGANISATION

With regard to its operations and maintenance the KWA has a spatially based organisational structure. Table 5 shows that the KWA is broken down into number of Subdivisions and Sections. For some data sets the data is collected by subdivision while for other data sets the data is collected by section.

The city level data is presented in the main body of this report while data broken down into subdivisions and sections is contained in Appendix A.

Table 5 KWA Operations and Maintenance Organisation

Kochi Municipal Corporation Area	
Subdivision	**Section**
Kaloor	Section1
	Section 2
Karuvelipady	Section1
	Section 2
Pallimukku	Section1
	Section 2

[2] To be quoted by contractor

Kochi Municipal Corporation Area	
Subdivision	**Section**
	Section 3
Vyttila	Section1
	Section 2

6 WATER USE

6.1 Project Areas

The project area for Kochi city comprises of Kochi City Corporation area and the key statistics of are shown in Table 6.

Table 6 Key Project Area Statistics

Statistic 2017	Kochi Corporation
Area	95 km^2
Population	669,432
Water Connections	146,564
Water Produced/year	73,564,508m^3
Water Delivered/year	36,046,609 m^3

6.2 Population

Several sources of data were used to develop estimates of the existing and future populations. The three main sources of data were the website of the project city[3], the web site of the Office of the Registrar General and Census Commissioner India[4] and the web site of the World Bank[5].

The 2011 census formed the basis from which all population figures were derived. The base year for this study was the calendar year of 2017. This means that unless otherwise stated, all population and related data in the report refers to the period 1 January 2017 to 31 December 2017.

Population forecasts were made from the base year of 2017 to the year of 2051. Three different methods were used to forecast future populations, and these were as follows.

1. **Extrapolation:** Historical population trends were assumed to continue into the future. These trends reflected a steady decline in the growth rate for each city.
2. **National Average:** The forecast population increase for India as a whole applied to each city using the base year of 2017.
3. **National Urbanisation:** The National Average to which is added the national urbanisation rate for each city

Population forecasts were made for each year of the first ten years (2020 to 2031) and thereafter for every ten years up to 2051. These forecasts are shown in

[3] https://cochinmunicipalcorporation.kerala.gov.in/
[4] http://censusindia.gov.in/
[5] https://datacatalog.worldbank.org/dataset/population-estimates-and-projections

Table 7 for Kochi City.

Table 7 Population Forecasts for Kochi Corporation Area

Method	1971	1981	1991	2001	2011	2021	2031	2041	2051
Extrapolated	398,166	467,566	520,962	569,672	601,574	617,522	637,096	654,051	669,007
National Average	398,166	467,566	520,962	569,672	601,574	724,319	790,965	838,717	866,190
National Urbanisation	398,166	467,566	520,962	569,672	601,574	724,319	897,137	1,079,198	1,184,894

6.3 Households and Connections

The number of water supply connections in Kochi were provided by the KWA. The connections were broken down into the following categories.

1. Industrial
2. Domestic
3. Non-Domestic
4. Special

The category of Special relates to temporary water supplies to construction sites. All water supply connections are metered, with the meters read monthly.

The number of connections for each of these categories was extracted for 2017 from the KWA customer and billing system 'eAbacus' and a summary is shown in Table 8. For the purposes of this study the number of domestic connections was assumed to equal the number of households.

Table 8 Kochi Water Supply Connections 2017

Connections 2017	Kochi
Industrial	20,249
Domestic	126,085
Non-Domestic	229
Special	1
Total	146,564

The relationship between the number of people making up a household and future years was developed using data from the Institute of Indian Geographers and the United Nations[6,7]. This relationship is contained in Table 9 and shows that there is expected to be a steady decline in the number of people per household over future years (albeit that Kochi remains higher than the national average due to its continuing urbanisation).

Combining the data from **Error! Reference source not found.**9 and Table 910 gives the forecast number of domestic connections and therefore households for Kochi and the outcome is shown in Table 10.

Table 9 Forecast Number of People per Household

Project Area	2011	2021	2031	2041	2051

[6] http://iigeo.org/wp-content/uploads/2014/07/Vol.36-No.12014-Transaction-IIG-1.pdf

[7] http://www.un.org/en/development/desa/population/publications/pdf/ageing/household_size_and_composition_around_the_world_2017_data_booklet.pdf

COC	5.46	5.13	4.84	4.56	4.29

Table 10 Household Forecasts for Kochi

Project Area	2011	2021	2031	2041	2051
COC	128,933	164,840	216,795	276,917	322,839

Using data extracted from the KWA customer and billing system 'eAbacus', the change in the number of connections over 2017 is shown in Table 11. It can be seen that there these was increase in the number of domestic connections for Kochi while all other categories of connections decreased.

Table 11 Change in Number of Connections During 2017

Category 2017	Type	COC
Disconnections	Domestic	4552
	Other	2290
Connections	Domestic	6781
	Other	694
Difference	Domestic	2229
	Other	-1596
Connections	Domestic	126085
	Balance	20479

The changes in the number of connections within the project areas of Kochi is expected to be largely a consequence of domestic activity. Consequently, for this study the number of connections for the categories of Industrial, Non-Domestic and Special has been assumed to be constant over time.

6.4 Water Balance and Non-Revenue Water

6.4.1 Water Accounting Tool

This study has adopted the IWA's water balance as its water accounting tool which is shown in Figure 1.

The total water uses for Kochi can be considered to comprise the water that leaves the water treatment plants and passes through the customer water meters, and the water that leaves the water treatment plants but does not pass through a meter. The two categories of the water balance used in this study are the metered water and the unmetered water.

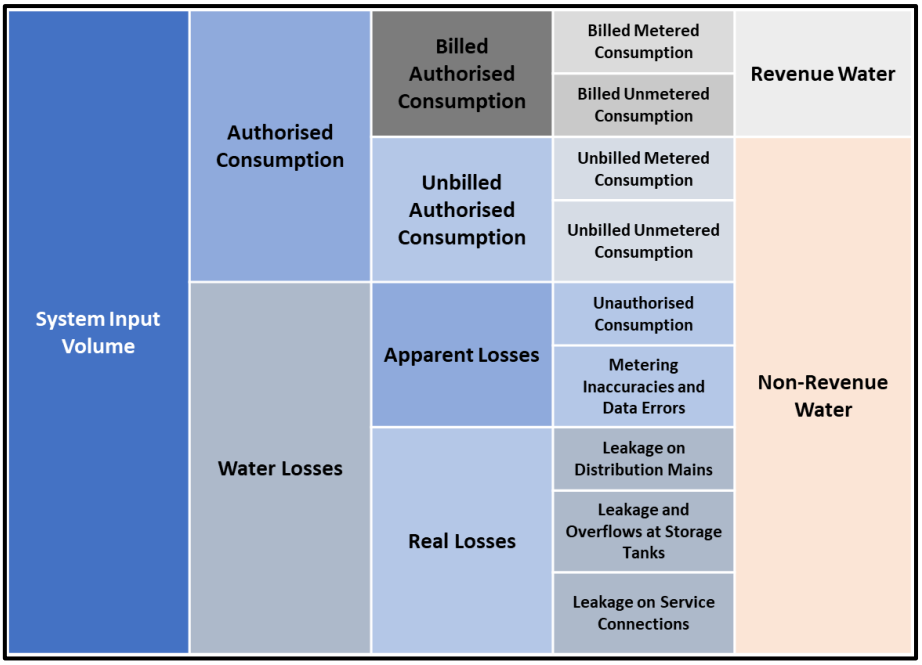


Figure 1 Water Balance Tool

The term 'Non-Revenue Water' (NRW) is defined as the water that is harvested by a water authority but is not billed. In fact, different terms are used to describe water that is lost; the three most common of these being 'Non-Revenue Water', 'Unaccounted for Water' and 'Unmetered Water'. The definition of these terms is given in Figure 2.

This report uses 'Unmetered Water' as it is simple to calculate. Regardless of which term is used the objective remains the same. This objective is to reduce non-revenue water, or unmetered water, to an economic level. An economic level is the level at which it is cheaper to pay the cost of producing and transferring the water that is being lost than it is to pay the cost of further reducing the amount of water being lost. A target non-revenue water (unmetered water) of 20% has been set for the project.

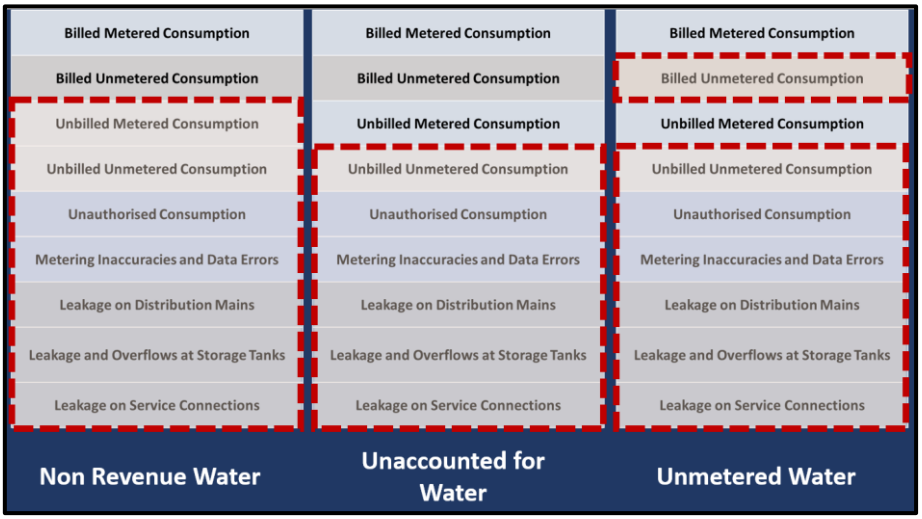


Figure 2 Terms Used to Describe Water Lost Using the IWA Water Balance

6.4.2 Standpipes

It is noted that Kochi has 5,900 standpipes. Each of these standpipes is estimated to use 1.5 kl per day. Therefore, Kochi is supplying 3,230,000 kl of water per year through the same. This water is unmetered and is not billed and is classified as non-revenue water.

6.4.3 Volume of Water Billed for 2017

The volume of water billed for each of the connection categories was extracted for 2017 from the KWA customer and billing system 'eAbacus'. This data is shown in Table 12 for Kochi.

Table 12 Volume of Water Billed for Kochi

Connection Category (2017)	Kochi Corporation	
	kl/year	Average kl/day
Industrial	320,897	879
Domestic	25,789,629	70,657
Non-Domestic	9,935,363	27,220
Special	720	2
Total	36,046,609	98,758

6.4.4 Water Use Ratios for 2017

By combining the data from **Error! Reference source not found.** to Table 12 various ratios can be derived and these are shown in Table 13 for Kochi.

Table 13 Water Use Ratios for Kochi

Statistic (2017)	Kochi
Population	669,432
Domestic Water Use (kl)	25,789,629
Total Water Use (kl)	36,046,609
Domestic Connections	126,085
Total Connections	146,564
People per Connection	5.31
Domestic Water Use per Person (lpcd)	106
Domestic Water Use per Household (lpcd)	560
Total Water Use per Person (lpcd)	148
Total Water Use per Connection (lpcd)	674

6.4.5 Unmetered Water for 2017

Two sampling tests were undertaken as part of this study to determine the volumes of unmetered water for Kochi. The results showed that the volume of unmetered water for Kochi was approximately 51%. These measures are commensurate with many other Indian (and Asian) cities.

As shown in Figure 1 the unmetered water percentage is made up of a number of water accounting components and a further more detailed examination of these components was undertaken, with the results shown in Table 14. Table 14 also shows the target for each of these parameters set for this project. An understanding of these components and the targets is essential for the development

of unmetered water (non-revenue water) improvement strategies. Strategies are now required for each of these water accounting components that when implemented will active the target values.

Table 14 Water Balance Parameters for Kochi

Item (2017)	Kochi	Target
Production	100%	100%
Metered Water	49.0%	80.0%
Unmetered Water	51.0%	20.0%
• Meter Inaccuracies and Data Errors	4.9%	3.2%
• Unauthorised Consumption	2.8%	0.0%
• Real Losses	43.3%	16.8%

6.5 Water Production and Pipeline Transfer Capacity

The water production capacity for Kochi is shown in Table 15. It is noted that the water treatment plants for Kochi serve the Kochi Corporation area and other adjacent areas.

Table 15 Water Production for Kochi

Item (2017)	Kochi	
Unit	GL/year	kl/day
Production Capacity	118.6	325,000
Metered Water	36.0	98,630
Unmetered Water	37.5	102,656
Total Water Required	73.5	201,286

A review of the pipeline transfer capacity was undertaken and showed that the transfer capacity for both cities was satisfactory.

6.6 Supressed Water Use

Kochi currently delivers less than a safe, pressurised water supply to all its customers. Should this be reversed, which is the intention of this project, it is likely that the water use will increase over its historic volumetric rates.

There is little measured data regarding the current reliability of the supply to customers, but engineers in the Sections were interviewed in regard to the supply to their respective areas and asked to estimate the current level of service provided to customers in terms of the hours per day and days per week each was receiving water. It was found that on average, domestic households receive water 80% of the time in Kochi.

The matter being assessed here is that if water was available for 24 hours per day would the water use per connection or per person increase? Customers have adapted their behaviours to the prevailing circumstances and in some cases have installed sumps or roof storages which they fill when the water is available and use when it is not. In these cases, any increase in water use would be expected to be marginal.

On the other hand, some increase can be expected and this should not be ignored when planning for a future 24/7 supply. No data has been found on the effect of increasing the number of hours of

water supply and the volume of water supplied. However, data is available for what is termed the 'bounce back' effect after water restrictions are lifted. This data suggests an increase in water use from 3% to 8%[8]. This data is from developed countries that have relatively high tariffs and whether it can be used in the Indian context is questionable. However, it is the only guide that has been found and for this study it is assumed that the domestic water use will increase on average 3% as a result of moving from an average per connection of 19 hours per day (80%) of water of questionable quality to a 24 hours per day of water of a drinking water quality standard.

6.7 Water Balance

Water balances for Kochi have been prepared using the various data contained in above sections of this report. These water balances have been prepared for what is termed the current state and the future state and are shown in Table 16 for Kochi City. The 'current state' is the year 2017 in its existing form while the 'future state' is the year 2017 as it would have been if all of the improvements proposed later in this report had have been previously implemented.

The water balance table is theoretical, and care must be taken in interpreting the numbers. It is nevertheless useful to show the impact of non-revenue water on a water utility. For example, if non-revenue water had been contained at 20% during 2017 the KWA would have been receiving an additional amount of revenue from higher water sales while at the same time reducing its treatment costs and pumping costs for lower volume of treated water.

Table 16 Water Balance for Kochi

Kochi Water Balance (2017)			**Current State**	**Future State**	**Change**
System Input Volume		kl	73,564,508	51,470,398	-22,094,110
Billed Authorised Consumption	Billed Metered Consumption	kl	36,046,609	41,176,319	5,129,710
	Billed Unmetered Consumption	kl	0	0	0
Unbilled Authorised Consumption	Unbilled Metered Consumption	kl	0	0	0
	Unbilled Unmetered Consumption	kl	0	0	0
Apparent Losses	Unauthorised Consumption	kl	2,090,703	0	-2,090,703
	Metering Inaccuracies and Data Errors	kl	3,604,661	1,647,053	-1,957,608
Real Losses	Leakage on Distribution Mains	kl	31,822,535	8,647,027	-23,175,508
	Leakage on Overflows and Storages	kl			
	Leakage on Service Connections	kl			
Non-Revenue Water		%	51%	20%	-31%

6.8 Infrastructure Leakage Index

The International Water Association's Infrastructure Leakage Index (ILI) provides four strategies for managing real losses, which form a large part of Kochi's non-revenue water (see Table 166). The ILI model is depicted in Figure 3. The components of the ILI model adopted for this project are as follows.

[8] https://www.escosa.sa.gov.au/ArticleDocuments/484/130207-ReviewOfDemandForecastsforSA.pdf.aspx?Embed=Y

6.8.1 Speed and Quality of Repairs

It is proposed to upgrade the Customer Redressal System (CDS) and introduce a Maintenance Management System coupled with enhanced quality of repairs to improve the management of the pipeline networks. Together these will facilitate the speed and quality of repairs.

6.8.2 Active Leakage Control

It is proposed to introduce a preventative maintenance program (also linked to the Maintenance Management System) which will include an active leakage control program.

6.8.3 Pipeline and Asset Management

It is proposed to replace currently poorly performance pipelines and associated property service connections and introduce an asset management procedure for managing pipelines and property service connections into the future (again linked to the Maintenance Management System but also introducing a Geographic Information System).

6.8.4 Pressure Management

Pressure management is an effective tool for reducing real losses. However, at this stage the KWA is not in a position to deploy this tool.

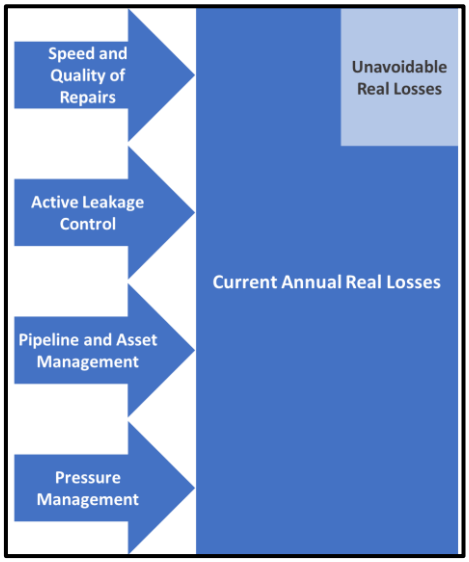


Figure 3 Infrastructure Leakage Index Model

Hence to tackle non-revenue water the following are required.

1. Upgrade to the Customer Redressal System
2. A new Maintenance Management System
3. A new Geographic Information Management System
4. A preventative maintenance program which includes active leakage control
5. A pipeline and property service connection replacement program
6. The adoption of an asset management procedure for managing pipelines and property service connections

6.9 Under Performing Meters

Over time meters degrade and increasingly under-record the volume of water passing through them, and the degree of under-registration increases as the meter ages. This deterioration is exacerbated by water with higher than preferred turbidity, as is experienced in some locations in Kochi.

Figure 4 shows the results from a study of the under-registration of Class B water meters as a result of aging (it is understood the KWA uses Class B meters). The age profile of the Kochi meter fleet is not known however it is understood that meters are not regularly replaced. With an estimated average meter age ten years the under-recording of flow is likely to be least ten percent depending upon the individual household diurnal pattern of water use.

It is proposed to replace all meters in the Kochi corporation areas over the first six years of the project. It is not possible to precisely measure the flow to households and properties and a four percent error is tolerated as a practical and economic limit. Hence a long-term reduction in non-revenue water would equate to the difference between the current estimated average ten percent under-recording and the accepted four percent error tolerated. The four percent error in meter inaccuracies equates to a 3.2% contribution to non-revenue water when the non-revenue water target is 20% and this is the number included in Table 14.

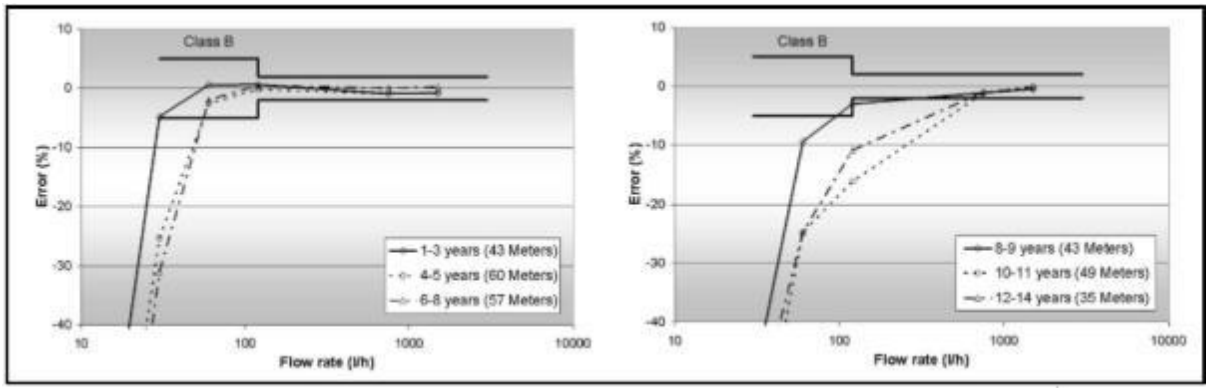


Figure 4 Results from Study on Under-registration of Class B Water Meters

Apart from replacing meters it is proposed to introduce an asset management procedure for managing meters.

6.10 Scheduling of Non-Revenue Water Works

In order to forecast water use, it is necessary to first determine the timeframe over which the non-revenue works will be implemented. The project has a nominal period of ten years. A target for non-revenue water has been set at 20% (see

Table 4). Given the current high non-revenue water and the large volume of work required to reduce the non-revenue water to this level a seven-year implementation period has been set. This seven-year period comprises one year for establishing the project and six years for implementing the non-revenue works. To recap, the non-revenue works are derived from the Infrastructure Leakage Index model and comprise the following.

1. Replace poorly performing pipelines
2. Replace all property service connections
3. Replace all customer meters
4. Undertake preventative maintenance including active leak detection
5. Upgrade customer redressal system (customer contact management)
6. Install a new maintenance management system
7. Install a new geographic information system
8. Adopt asset management procedures for pipelines, property services and customer meters

Training will be required in all of these items. Note that items 5 to 8 would be undertaken during the project establishment year (first project year). Once developed it is imperative that these systems be maintained.

The quantities and dimensions of these items appear later in this report.

6.11 Forecast Water Use

The forecast water uses for Kochi have been calculated using 2017 as the base year and the various data contained in the above Sections of this report. The period 2020 to 2029 (yearly) is covered. Table 17 show the forecasts for water use for Kochi.

Table 17 Forecast Water Use for Kochi Municipal Area (kl/year)

Project Year		Actual	1	2	3	4	5	6	7	8	9	10	11	12
Year Number		2017	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Project Phase		Planning	Establish	Project Implementation						Project Operation			Continuation	
Population	#	669,432	724,319	724,319	739,985	755,989	772,340	789,044	806,110	823,545	841,357	859,554	878,144	897137
Connections		146,564	160,502	161,368	165,258	169,261	173,380	177,618	181,980	186,469	191,088	195,843	200,737	205,774
People per Connection		5.30	5.17	5.14	5.11	5.08	5.05	5.02	4.99	4.96	4.93	4.90	4.87	4.84
Domestic Connections	#	126,085	140,023	140,889	144,779	148,782	152,901	157,139	161,501	165,990	170,609	175,364	180,258	185,295
Non-DomesticConnections	#	20,479	20,479	20,479	20,479	20,479	20,479	20,479	20,479	20,479	20,479	20,479	20,479	20,479
Water Use	#	36,046,609	38,161,111	38,184,365	38,812,141	39,454,009	40,110,285	40,781,290	41,467,357	42,142,382	42,832,007	43,536,548	44,256,326	44,991,672
Domestic Water Use	kl	25,789,629	27,904,131	27,904,131	28,507,648	29,124,219	29,754,124	30,397,653	31,055,101	31,726,768	32,412,963	33,113,998	33,830,195	34,561,883
Supressed Water Use	kl	0	0	23,253	47,513	72,811	99,180	126,657	155,276	158,634	162,065	165,570	169,151	172,809
Total Domestic Water Use	kl	25,789,629	27,904,131	27,927,385	28,555,161	29,197,029	29,853,305	30,524,310	31,210,377	31,885,402	32,575,027	33,279,568	33,999,346	34,734,692
Non-Domestic Water Use	kl	10,256,980	10,256,980	10,256,980	10,256,980	10,256,980	10,256,980	10,256,980	10,256,980	10,256,980	10,256,980	10,256,980	10,256,980	10,256,980
Production (NRW 51%)	#	73,564,508	77,879,819	77,927,275	79,208,451	80,518,386	81,857,724	83,227,123	84,627,259	86,004,862	87,412,260	88,850,098	90,319,033	91,819,739
Unmetered Water	%	51%	51%	51%	51%	51%	51%	51%	51%	51%	51%	51%	51%	51%
Unmetered Water	#	37,517,899	39,718,707	39,742,910	40,396,310	41,064,377	41,747,439	42,445,833	43,159,902	43,862,479	44,580,253	45,313,550	46,062,707	46,828,067
NRW Reduction Strategies														
Unauthorised Consumption	kl	2,090,703	2,213,344	1,770,675	1,328,006	885,338	442,669	0	0	0	0	0	0	0
Meter Inaccuracies	kl	3,604,661	3,816,111	3,384,628	2,953,144	2,521,661	2,090,178	1,658,694	1,658,694	1,685,695	1,713,280	1,741,462	1,770,253	1,799,667
Real Losses	kl	31,822,535	33,689,252	27,154,544	22,320,429	18,307,998	14,931,440	12,056,172	8,708,145	8,849,900	8,994,722	9,142,675	9,293,829	9,448,251
Unmetered Water	kl	37,517,899	39,718,707	32,309,847	26,601,580	21,714,997	17,464,287	13,714,866	10,366,839	10,535,596	10,708,002	10,884,137	11,064,082	11,247,918
Unmetered Water	%	51%	51%	46%	41%	35%	30%	25%	20%	20%	20%	20%	20%	20%
Domestic Water Use	kl	25,789,629	27,904,131	27,927,385	28,555,161	29,197,029	29,853,305	30,524,310	31,210,377	31,885,402	32,575,027	33,279,568	33,999,346	34,734,692
Water Use	kl	36,046,609	38,161,111	38,184,365	38,812,141	39,454,009	40,110,285	40,781,290	41,467,357	42,142,382	42,832,007	43,536,548	44,256,326	44,991,672
Production	kl	73,564,508	77,879,818	70,494,211	65,413,721	61,169,006	57,574,571	54,496,156	51,834,196	52,677,978	53,540,009	54,420,685	55,320,408	56,239,590

Figure 5 shows graphically the water use forecasts for the Kochi Corporation area without and with the intervention described in this report.

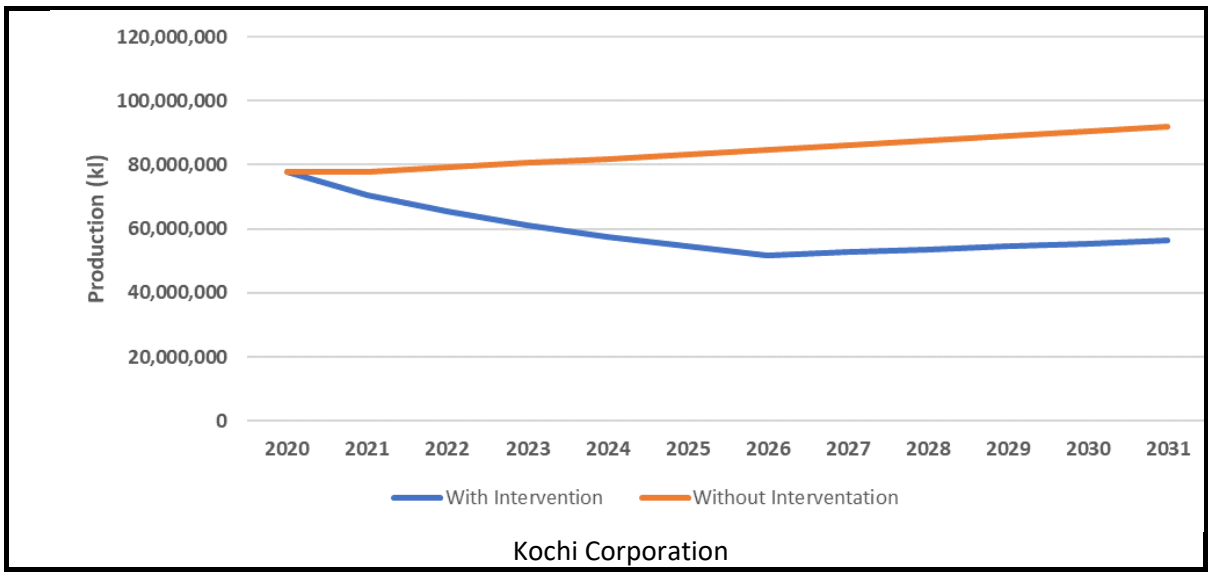


Figure 5 Kochi Water Use Forecasts – With and Without an Intervention

6.12 Sectional Data

The data presented in this report has been presented for each municipality as a whole. However, the data has been broken down by Section and tables of this section data covering populations, connections and water use are contained in Appendix A.

7 PUMP STATIONS

7.1 Kochi Pump Stations

The water supply system of Kochi includes raw water pump stations, product water pump stations and booster pump stations. These pump stations together with their respective pump capacities are contained in **Table 18.**

Table 18 Pump Stations in Kochi

PS No	Pump Station Location	Pump Station Type	Inlet to/Outlet from/Booster to	Type of Pump
KPS01	Aluva	Inlet	Aluva 48 MLD WTP	Vert Turbine
KPS02	Aluva	Inlet	Aluva 72 MLD WTP	Vert Turbine
KPS03	Aluva	Inlet	Aluva 70 & 35 MLD WTP	Vert Turbine
KPS04	Aluva	Outlet	Aluva 48 MLD WTP (dysfunctional)	HSC Vert Turbine
KPS05	Aluva	Outlet	Aluva 48 MLD WTP	Vert Turbine
KPS06	Aluva	Outlet	Aluva 72 MLD WTP	Vert Turbine
KPS07	Aluva	Outlet	Aluva 70 & 35 WTP MLD	Vert Turbine
KPS08	Pazhoor	Inlet	Maradu 100 MLD WTP Raw Water	Vert Turbine
KPS09	Maradu	Outlet	Maradu 100 MLD WTP Clear Water	HSC
KPS10	Karuvelipady	Booster	Karuvelipady Service Area	HSC
KPS11	Thoppumpady	Booster	Thopumpady Service Area	HSC

PS No	Pump Station Location	Pump Station Type	Inlet to/Outlet from/Booster to	Type of Pump
KPS12	Palluruthy	Booster	Palluruthy Service Area	HSC
KPS13	Thammanam	Booster	Thammanam Service Area – 1	HSC
KPS14	Thammanam	Booster	Thammanam Service Area - 2	HSC
KPS15	Pallimukku	Booster	Pallimukku Service Area - 1	HSC
KPS16	Pallimukku	Booster	Pallimukku Service Area – 2	HSC
KPS17	Pallimukku	Booster	Pallimukku Service Area– 3	HSC
KPS18	Elamkulam	Booster	Elamkulam Service Area	HSC

Pump Stations are referred to by their respective pump station numbers.

7.2 Pump Station Condition Assessments

The basic function of a pump station is to reliably pump its design volume of water. In reviewing a pump station, the key aspects to consider are as follows.

1. Can the pump station pump its design volume of water?
2. Is the pump station being required to pump more than its design volume?
3. Are the required number of duty and standby pumps available?
4. Are the velocities within the pipelines within the pump station less than the maximum acceptable velocity[9]?
5. Are there any water or oil leaks?
6. Is any of the equipment rusting?
7. Are all the instruments working?
8. Is the pump station safe for operations and maintenance personnel?
9. Is there a pump station maintenance plan available?

Using this as a guide a condition assessment was undertaken for each pump station. An initial walk through yielded the following observations.

1. Some pump stations are operating above maximum capacities
2. There appears to be high velocities in some pipework
3. Some pumps are reaching end of their operational lives
4. Standby pumps are often missing
5. Valves are leaking
6. Oil is seeping from some pumps
7. There are significant safety hazards
8. Monitoring equipment not working
9. Amenities require upgrading
10. Pumps are not connected to a SCADA system
11. There is insufficient workspace around some pumps

A more detailed condition assessment involved hydraulic calculations (no design or as-built drawings were available). In addition, the pump stations were compared to a ‘reference pump station’ in

[9] This can be calculated using the Reynolds Number but can be taken to be less than 2.5 m/s.

terms of equipment and layout to determine any deficiencies. The reference pump station is shown in Figure 6.

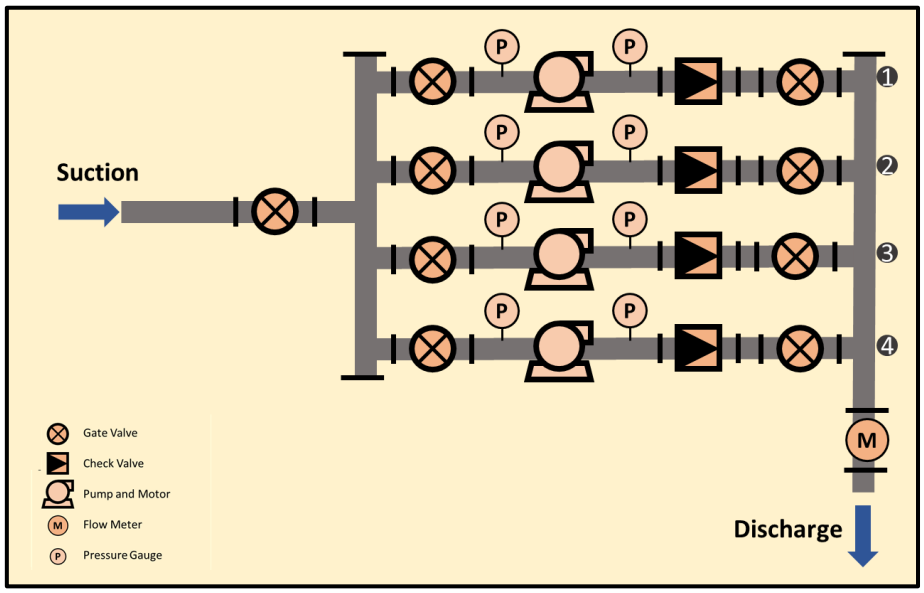
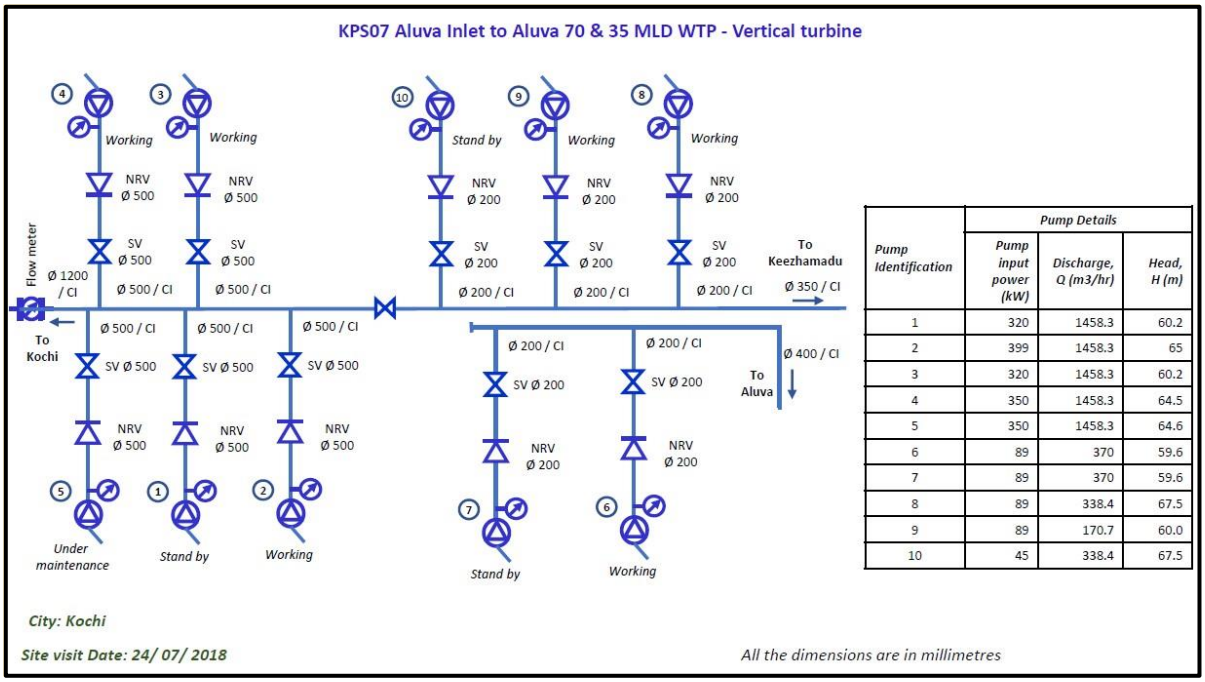


Figure 6 Reference Pump Station

A detailed schematic of each pump station was produced together with an accompanying spreadsheet detailing the various equipment and parameters of each pumping station. Figure 7 contains an example of a pump station schematic, while Table 19 contains an example of a spreadsheet. The schematics will form part of the bidding documents.



Pump Identification	Pump Details		
	Pump input power (kW)	Discharge, Q (m3/hr)	Head, H (m)
1	320	1458.3	60.2
2	399	1458.3	65
3	320	1458.3	60.2
4	350	1458.3	64.5
5	350	1458.3	64.6
6	89	370	59.6
7	89	370	59.6
8	89	338.4	67.5
9	89	170.7	60.0
10	45	338.4	67.5

Figure 7 Schematic of Pump Station

Table 19 Example of the Pump Station Spreadsheet

Asset Description	Unit	Pump Line 1	Pump Line 2	Pump Line 3	Pump Line 4	Pump Line 5	Pump Line 6
KPS01 Aluva Inlet to Aluva 48 MLD WTP – Vertical turbine							
Pump - rate	m^3/hr	1502	1502	1502			
Pump - head	m	38	38	38			
Motor - size	kW	160	160	160			
KPS02 Aluva Inlet to Aluva 72 MLD WTP – Vertical turbine							
Pump - rate	m^3/hr	1894	1894	1894	1894		
Pump - head	m	20	20	20	20		
Motor - size	kW	150	160	150	150		
KPS03 Aluva Inlet to Aluva 105 MLD (70+35) WTP – Vertical turbine							
Pump - rate	m^3/hr	1875	1875	1875	1875		
Pump - head	m	27	27	27	27		
Motor - size	kW	239	239	239	239		

A photographic record of each pump station was also made and will be made available as part of the bidding documents.

7.3 Pump Station Replacement

Pump stations to replace all existing pumps (4 No's) in KPS02 (Aluva RWPH-2) are located in the Aluva pump house at the Aluva raw water inlet. A photograph of this pump house is shown in Figure 8.

It is not possible refurbish this pump station and it is recommended to replace it with a new pump station built adjacent to it. Once built and commissioned, the new pump station will take over the supply to the water treatment plants and the old pump station will be decommissioned and removed.

Figure 8 KPS02 Aluva 72 MLD WTP Inlet

7.4 Pipeline Velocities

The flow velocities in the pipelines and their associated fittings were calculated. Flow velocities should be kept under an upper limit to prevent the flow from becoming turbulent and reducing the efficiency of operation and minimise the impact of water hammer. This velocity depends upon the pipeline concerned but in general it is unwise to exceed a velocity of 2.5 metres per second. Figure 9 provides a sample of the calculations made with the excessive velocities highlighted in red. The options available are to change the operating regime of the pumps (that is pump less water) or to change the pipelines and fittings to cater for higher flows. For example, Figure 9 shows that PS05 (all pump lines) is operating beyond its design capacity and requires refurbishment to address this condition.

Asset Description	Rated Discharge (m^3/hr)	Pump Line 1		Pump Line 2		Pump Line 3		Pump Line 4		Pump Line 5		Pump Line 6		Pump Line 7		Pump Line 8	
		DN (mm)	V (m/s)	DN (mm)	V (m/s)	DN (mm)	V (m/s)	DN (mm)	V (m/s)	DN (mm)	V (m/s)	DN (mm)	V (m/s)	DN (mm)	V (m/s)	DN (mm)	V (m/s)
K1 Aluva Raw Water Pump House - 1																	
Suction pipe			NA		NA		NA										
Suction stop valve			NA		NA		NA										
Delivery NRV	1502	400	3.32	400	3.32	400	3.32										
Delivery stop valve	1502	400	3.32	400	3.32	400	3.32										
Delivery pipe	1502	400	3.32	400	3.32	400	3.32										
K10 Karuvelipady Pump House (Mattanchery, Fort Kochin)																	
Suction pipe	510	350	1.47	350	1.47	350	1.47	350	1.47								
Suction stop valve	510	250	2.89	250	2.89	250	2.89	250	2.89								
Delivery NRV	510	200	4.51	200	4.51	200	4.51	200	4.51								
Delivery stop valve	510	200	4.51	200	4.51	200	4.51	200	4.51								
Delivery pipe	510	200	4.51	200	4.51	200	4.51	200	4.51								
K10 Karuvelipady Pump House (Pallurthy)																	
Suction pipe	510									350	1.47	350	1.47				
Suction stop valve	510									250	2.89	250	2.89				
Delivery NRV	510									200	4.51	200	4.51				
Delivery stop valve	510									200	4.51	200	4.51				
Delivery pipe	510									200	4.51	200	4.51				
K10 Karuvelipady Pump House (Naval Quarters)																	
Suction pipe	85													250	0.48	250	0.48
Suction stop valve	85													150	1.34	150	1.34
Delivery NRV	85													100	3.01	150	1.34
Delivery stop valve	85													100	3.01	150	1.34
Delivery pipe	85													100	3.01	150	1.34

Figure 9 Calculation of Flow Velocities (Excessive Velocities Highlighted in Red)

7.5 Pumping Station Refurbishment Program

7.5.1 Pump Station Major Works Program

A pump station refurbishment program has been compiled from the pumping station condition assessments. An example of the pump station refurbishment program is contained in Table 20.

Table 20 Pumping Station Refurbishment Program

Action	Asset Description			Qty	Unit
K1 Aluva Raw Water Pump House - 1 - VT					
Maintain	Pump - flow	m3/h	1502	3	No.
	- head	m	38		
Replace (upsize)	Motors	kW	250	3	No.
Maintain	Switchboard			1	Item
Replace	Delivery stop valve	DN	400	3	No.
Install	Air valve			1	No.
Install	SCADA			1	Item
Install	Outlet Flowmeter	DN	900	1	No.
K2 Aluva Raw Water Pump House - 2- VT					

Action	Asset Description			Qty	Unit
Re-install	Pump - flow	m3/h	1894	1	No.
	- head	m	20		
Install	Motors	kW	160	1	No.
Maintain	Pump - flow	m3/h	1894	3	No.
	- head	m	20		
Maintain	Motors	kW	149	3	No.
Maintain	Switchboard			1	Item
Install	Pressure Gauge	m		4	No.
Install	Delivery stop valve	DN	500	1	No.
Maintain	Delivery stop valve	DN	500	3	No.
Install	Air valve			1	No.
Install	SCADA			1	Item
Install	Outlet Flowmeter	DN	900	1	No.
K3 Aluva Raw Water Pump House - 3 - VT					
Re-install	Pump - flow	m3/h	1875	1	No.
	- head	m	27		
Install	Motors	kW	200	1	No.
Install	Pressure Gauge (PL1)			1	No.
Install	Delivery NRV (PL1)	DN	500	1	No.
Install	Delivery stop valve (PL1)	DN	500	1	No.
Install	Delivery pipe (PL1)	DN	500	1	No.
Install	Air valve			1	No.
Install	SCADA			1	Item
Install	Outlet Flowmeter	DN	900	1	No.
K5 Aluva Clear Water Pump House - 1 (new) - VT					
Install	Air valve			1	No.
Install	SCADA			1	Item
K6 Aluva Clear Water Pump House - 2 - VT					
Install	Air valve			1	No.
Install	SCADA			1	Item

7.5.2 Pump Station Minor Works Program

A pump station refurbishment minor works program has also been developed and is shown in **Error! Reference source not found.**1. These works may be included in a refurbishment contract or may be undertaken separately by the KWA. Many of these items should become part of a regular pump station maintenance program.

In some cases, it is a matter of cleaning up the sites, removing discarded or disused materials, restoring and painting buildings and improving safety.

Table 21: Pumping Station minor works Program

Asset description	Risk	Minor Works Required
K1 Aluva Raw Water Pump House - 1 - VT		
Site Amenity	5	Remove all surplus and disused material from site
Safety	5	Erect safety signs. Conduct a site hazard assessment and remove safety hazards. Issue staff with PPE.
Structure	4	Arrange electrical cables properly. Paint
K2 Aluva Raw Water Pump House - 2- VT		
Site Amenity	4	Remove all material not required for operation
Safety	5	Erect safety signs. Conduct a site hazard assessment and remove safety hazards. Issue staff with PPE.
Structure	4	Arrange electrical cables properly. Paint
K3 Aluva Raw Water Pump House - 3 - VT		
Delivery NRV	3	Paint
Site Amenity	2	Remove all material not required for operation
Safety	4	Erect safety signs. Conduct a site hazard assessment and remove safety hazards. Issue staff with PPE.

7.6 SCADA System

Table 20 includes references to the connection of the pump stations to a SCADA system. It is recommended to install a new SCADA system across all pump stations (and water treatment plants – referred to as the 'Production SCADA System').

The SCADA system is to record the following parameters.

1. Water level in the pump wet well (or equivalent where relevant – not applicable to booster pump stations)
2. Suction and discharge pressures across each pump
3. Start and stop time of each pump
4. Run time for each pump (from 3)
5. Flow rate exiting the pump station
6. Voltage and current at the pump station switchboard

Event alarms required are as follows.

1. High water level in the wet well (or equivalent and where relevant)
2. Low water level in the wet well (or equivalent and where relevant)
3. Pump Failure
4. Power Failure

It is not proposed to use the supervisory control features of the SCADA system for pump stations at this stage.

7.7 Mechanical and Electrical Maintenance

A note is included here on mechanical and electrical maintenance. This maintenance also includes the maintenance of instrumentation and the SCADA system.

The KWA manages a large number of treatment plants and pump stations all of which rely on the ongoing performance of mechanical and electrical equipment. Furthermore, as time

progresses the KWA will become more and more reliant on SCADA and associated instruments to help monitor and control this equipment. A case in point is this project which has recommended increased instrumentation in treatment plants, pump stations and networks and ongoing monitoring and reporting using a comprehensive SCADA system.

To manage and service the mechanical and electrical assets and associated instruments and control systems it is recommended that the KWA establishes a Mechanical and Electrical Section within its organization headed by a Chief Mechanical and Electrical Engineer and staffed by mechanical engineers and technicians, electrical engineers and technicians, instrumentation technicians and SCADA and PLC programmers. The role of such a section would be as follows.

- To monitor the performance of the KWAs mechanical and electrical assets and undertake preventive maintenance on these assets to ensure their operability and reliability
- To recommend the replacement of the KWA's mechanical and electrical assets when either they present an unacceptable risk to the KW's service delivery performance or it is efficient to do so
- To ensure that the KWA carries and efficient quantity of mechanical and electrical and instrumentation spares
- To provide a mechanical and electrical and instrument breakdown service to the operational units of the KWA including a 24/7 response capability
- To provide, manage and maintain a corporate SCADA system and act as the SCADA system administrator
- Ensure the KWAs has the resources and competencies is require to efficiently and effectively manage its mechanical and electrical assets and associated instrumentation and hardware and software control systems

This function should not be outsourced although routine maintenance can be let to subcontractors.

7.8 Pumping Station Refurbishment and Upgrade Program Implementation

Kochi has nine inlet and outlet pump stations supplying water to and from treatment plants and ten booster pump stations supplying elevated distribution areas.

Clearly these cannot all be refurbished at the same time and a carefully planned program of works coupled to detailed work method statements is required to ensure the impact of the pump station refurbishment and upgrade works on the supply of water is minimised. The planned works also need to be coordinated with the water treatment plant refurbishment and upgrade works to ensure that water treatment plants and the pump stations that service them are worked on at the same time.

For this reason, a separate pump station refurbishment and upgrade program is not produced but is included in that of the water treatment plants.

7.9 Pump Station Buildings and Amenity

The refurbishment of pump station buildings and the improvement of the pump station site amenity is discussed later in this report.

8 TREATMENT PLANTS

8.1 KWA Water Treatment Plants

8.1.1 Introduction

The drinking water distribution system supplies drinking water treated to meet the quality limits set by IS 10500:2012[10] and which apply at the customer taps. The source water is surface water extracted from rivers and lakes, which in turn are fed from open catchments[11]. The source water contains inorganic and organic substances, dissolved and suspended solids and biological contaminants including viruses, pathogenic bacteria, protozoa, oocysts, amoeba, helminth and helminth ova. To make the source water suitable for drinking, the water is treated close to its source to remove these contaminants and is then disinfected before entering the transmission and distribution networks.

The Water Treatment Plants have been built and upgraded over time as the demand for water has exceeded the total production capacity. The upgrades were made to meet the Indian water quality standard available at the time of upgrade. However, the standard has become more stringent with each new edition (1991, 2004, and 2012). Hence the quality of the treated water at some plants that were built or upgraded before 2012 falls short of the quality targets stipulated in the current water quality standard IS10500 (2012).

As Kerala source water is extracted from the rivers and lakes and is mainly rain water it has very low alkalinity. During heavy rains the microbiological contamination of the surface source water is high as shown by KWA river water composition monitoring data. The water treatment plant processes are adjusted for this increased health hazard posed by the high turbidity river water however extreme deviations of raw water quality cannot be managed without upgrading the current treatment processes.

The average mean temperature of Kerala of 27 degrees Celsius is creating optimum environmental conditions for biological growth including the growth and multiplication of pathogenic organisms. The Kerala water treatment plants produce drinking water that during some weather conditions does not meet the quality targets of the IS 10500:2012 in respect to turbidity, colour, pH and iron.

The low alkalinity of the source water makes the water very corrosive to the water treatment plants and downstream water transmission and distribution assets. Also, the high corrosivity of the water presents a health risk associated with the leaching of toxic heavy metals such as copper, lead and zinc from the customers' plumbing and the KWA's metallic water pipes and metallic fittings (such as pumps and valves).

Sometimes the free residual chlorine in the distribution system completely disappears from the drinking water due to the combined effect of high turbidity and high temperature of the water.

The major finding of this study is that the KWA water treatment plant processes must be upgraded to permit effective treatment plant monitoring, control and process adjustment in a range of ambient conditions to ensure that the drinking water produced always meets health and asset protection requirements.

[10] http://cgwb.gov.in/documents/wq-standards.pdf

[11] Open catchments is a term used to refer to water supply catchments that include human activities such as urbanisation and farming

8.1.2 KWA Water Treatment Plants

The water supply systems of Kochi include treatment plants, which operate on the same principles but differ in details. These treatment plants together with their respective treatment capacities are contained in Table 222.

Table 22 Water Treatment Plants Supplying Kochi

Location	Capacity (MLD)	Capacity (GL/Y)	Year	Source Water
Maradu	100	36.5	2016	Muvattupuzha River
Aluva I	48	17.5	1965	Periyar River
Aluva II	72	26.3	1975	Periyar River
Aluva III	70	25.6	1992	Periyar River
Aluva IV	35	12.8	2002	Periyar River
Total	**325**	**118.6**	**1993**	(Weighted Age)

A condition assessment was carried out for all water treatment plants except the 74mld plant which is new and currently being operated by the original process engineering contractor (Suez) and the findings and recommendations which follow exclude this plant.

8.2 Drinking Water Quality Guidelines

The drinking water guidelines used in this study were the following.

1. IS 10500:2012, Indian Drinking Water Standard, Revised Second Edition, Amended June 2015
2. World Health Organisation, Guidelines for Drinking Water Quality, Fourth Edition[12]

It is noticeable that over time the drinking water standards and guidelines used around the world have become more stringent as knowledge on the health impacts of various water contaminants has improved while the water quality of source waters has deteriorated. In examining treatment process regard has been given to the likely changes in water quality parameter limits. In particular, while the upper limit for turbidity given in IS 100500 is NTU ≤ 1 this study has adopted a value of NTU ≤ 0.1. The nature of the catchments and water sources serving Kochi suggest that reducing this parameter is particularly important to protect the health of consumers.

For this study four different aspects of water quality have been considered and these are as follows.

1. **Safe Drinking Water:** consuming the water will not have an adverse effect on the health of the consumer
2. **Healthy Drinking Water:** consuming the water will have a beneficial effect on the health of the consumer
3. **Robust Water:** the water quality will enhance the persistence of free chlorine by resisting the impacts from external influences

[12] http://www.who.int/water_sanitation_health/publications/turbidity-information-200217.pdf

4. **Inert Water:** the water quality will be such that it will not have an adverse impact on the infrastructure use to transfer the water to customers

The main water quality parameters and limits for water leaving the treatment plants that have been adopted for this study are shown in Table 233.

Table 23 Main Water Quality Parameters and Limits

Parameter	Measure	Target
Water Production – Quality	Percentage compliance with IS100500 (as at June 2015) at the outlet	100%
	Alkalinity at outlet	50 < X < 100 mg/l
	pH at outlet	7.2 < X < 8.5
	Chlorine concentration at outlet	2.5 < X < 4.0 mg/l
	Turbidity at outlet	NTU < 0.15
	Corrosion inhibitors at outlet	0.5 to 3.0 mg/l
Water Production – Reliability	Water Treatment Plant availability	99.5% 99.5%

8.3 New Drinking Water Safety Benchmarks

8.3.1 Introduction

While there is no published historical data on water borne diseases in particular to Kochi, there is for the State of Kerala and this is shown in Figure 10[13]. There had been an evident increasing trend of water borne diseases in the State.

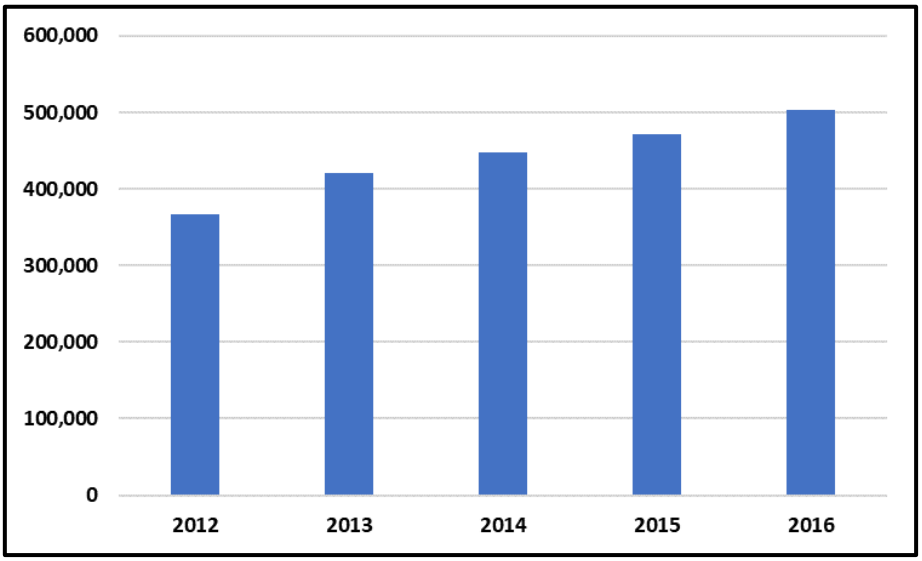


Figure 10 Water Borne Disease Numbers in Kerala

[13] Economic Review, 2016; http://spb.kerala.gov.in/EconomicReview2016/web/chapter04_12.php

Due to local conditions, there is a high probability of contamination of the source water with the ubiquitous parasite Cryptosporidium. Cryptosporidium resists chlorination and the only way to make water free of this pathogenic organism is physical removal. Cryptosporidium oocysts are between 3µm and 6 µm in size. Adequate coagulation and flocculation are critical process steps in the removal of small sized pathogens. The flocs will incorporate the suspended solids down to colloidal size and the microorganisms including chlorination resistant pathogens such as oocysts and helminths eggs which permits their removal during subsequent clarification and filtration process steps. To keep the treated water safe, the flocs must be removed to below 0.15 NTU[14] according to research data.

Drinking water safety has been the subject of numerous research studies. These research studies were the basis for tightening the drinking water treatment processes parameter limits to reflect the new findings[15]. To prevent water borne disease outbreaks, the limits for the turbidity of the filtered water produced in water treatment plants are included in the WHO drinking water guidelines.

The major finding of this treatment plant condition assessment is that the KWA water treatment plant processes must be upgraded to permit the effective treatment and treatment plant monitoring and control and treatment process adjustment to suit a range of ambient conditions to ensure that the drinking water produced always meets health and asset protection requirements.

8.3.2 Turbidity

The generic raw water treatment at all KWA water treatment plants consists of raw water pre-treatment, chemical treatment followed by clarification, filtration and disinfection.

It is proposed for KWA to adopt the following filtered water turbidity maximum limits for all drinking water treatment plants:

- 95th percentile of all turbidity readings of the filtrate produced by each individual filter should be ≤0.15 NTU
- Turbidity should never exceed 0.3 NTU in two consecutive samples taken from the filters' effluents combined flow[16] [17]
- To achieve the current generic water treatment processes depicted in Figure 11 must be converted into the generic water treatment processes depicted in Figure 12.

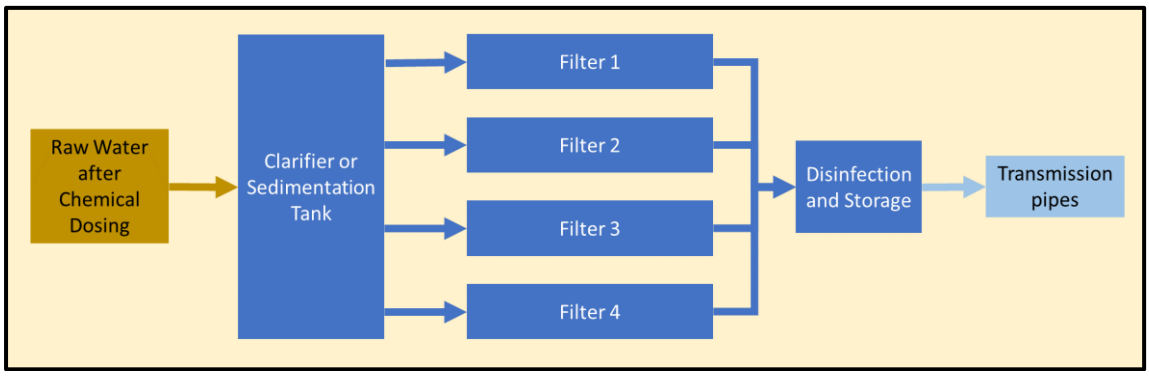


Figure 11 Current General Water Treatment Process at KWA

[14] https://www.tceq.texas.gov/assets/public/permitting/watersupply/pdw/SG-TROT-Meeting_Minimum_Treatment_Reqs.pdf
[15] https://www.gpo.gov/fdsys/pkg/FR-2006-01-05/pdf/06-4.pdf
[16] https://www.gpo.gov/fdsys/pkg/FR-2006-01-05/pdf/06-4.pdf
[17] https://www.clarence.nsw.gov.au/page.asp?f=RES-YDP-77-62-43

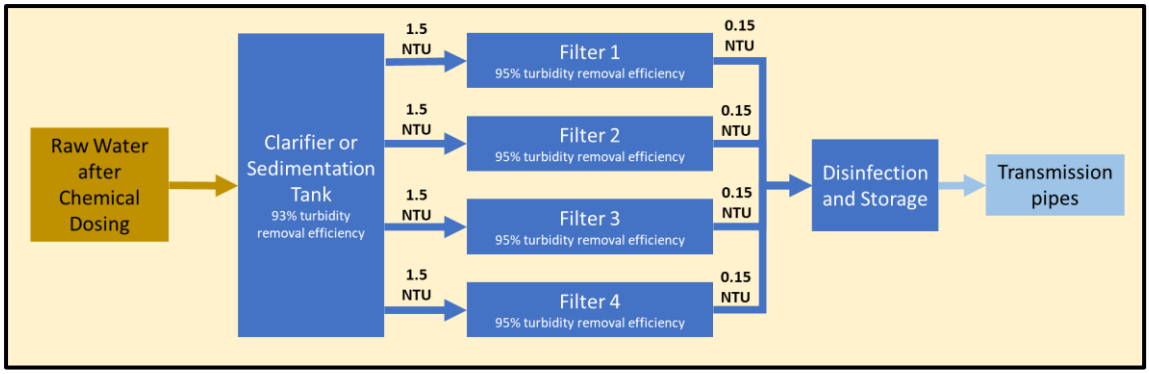


Figure 12 Proposed General Water Treatment Process at KWA

To achieve solids removal to the above recommended turbidity targets, the process units need to be upgraded to achieve better than 95% solids removal efficiency. Depending on the duration and frequency of high turbidity events, 95% removal efficiency of turbidity might not be enough to meet consistently the biological safety of the clear water. Therefore, it is recommended to upgrade the physical contaminants removal process units to achieve a minimum 95% separation efficiency to ensure meeting the best practice drinking water quality benchmark.

The new turbidity target will ensure that:

- No sedimentation occurs in the clear water sumps and transmission lines
- The chlorine demand will be lower
- The Trihalomethanes (THMs) concentration in the treated water will reduce
- The biological contamination of the drinking will decrease for all types of biological contaminants.

Table 244 shows the difference in the turbidity removal between clarifiers and filters.

Table 24 Calculated Filter Effluent Turbidity and Clarifier Turbidity Removal Efficiencies

Turbidity Removal Efficiency	Turbidity			Comments
	Raw Water	Clarifier Effluent	Filter Effluent	
Units	[NTU]	[NTU]	[NTU]	
80%	10	2	0.4	Insufficient treatment efficacy
90%	10	1	0.1	Satisfactory treatment efficacy
90%	15	1.5	0.15	Satisfactory treatment efficacy
90%	20	2	0.2	Marginal treatment efficacy
90%	30	3	0.3	Exceedance during heavy rains
90%	40	4	0.4	Exceedance during heavy rains
90%	50	5	0.5	Exceedance during heavy rains
90%	60	6	0.6	Exceedance during heavy rains
90%	70	7	0.7	Exceedance during heavy rains

95%	70	3.5	0.175	Marginal during heavy rains
95%	100	5	0.25	Marginal during heavy rains
95%	150	7.5	0.375	Plants to be shut down if raw water turbidity exceeds 150 NTU

Trihalomethanes (THMs) are formed during the chlorine disinfection process during reaction between the organic matter contained in the water and chlorine. The THMs concentration in drinking water is tightly regulated (US EPA max. allowable level of THMs is 0.1 mg/l) due to their carcinogenic potential. The IS 10500:2012 has the targets on trihalomethane contaminants shown in Table 255.

Table 25 IS 10500:2012 THMs targets

Trihalomethanes	**Units**	**Requirement, Maximum Acceptable Limit**	**Permissible Limit in the Absence of an Alternate Source**
Bromoform	mg/l	0.1	No Relaxation
Dibromochloromethane	mg/l	0.1	No Relaxation
Bromodichloromethane	mg/l	0.06	No Relaxation
Chloroform	mg/l	0.2	No Relaxation

Following waterborne disease outbreaks[18] around the world among the drinking water consumers, the WHO, USEPA [19]and other similar organizations, updated their drinking water quality guidelines, rules and regulations for the drinking water produced from surface waters, based on the latest research findings. Water utilities on a global scale are using the new turbidity maximum limit established by the USEPA SWTR[20] (2006) as a benchmark for surface water treatment to produce safe drinking water.

The surface waters typically have high concentrations of pathogenic organisms. The protozoan, amoeba, virus and microbe contamination are difficult to remove from water unless the treatment process has efficient pre-treatment and chemical treatment, solids separation and disinfection processes.

It has been demonstrated by research studies[21] that the protozoan oocyst cannot be removed from the drinking water unless the filtered water is processed to have less than 0.15 NTU 95% of the time with a maximum of 0.3 NTU.

Chlorine disinfection of the drinking water has limited effect on protozoan pathogens due to the oocyst that pass easily through the filter bed and resist chlorination. The best barrier for protozoan contamination of the drinking water is effective coagulation, flocculation, clarification and filtration.

Due to seasonal high turbidity of the raw water, the treatment plants have to upgrade the clarification processes with sludge scrapers, to ensure fast removal of sludge during processing of high turbidity source water. If sludge is not removed fast enough, it will accumulate in the clarifiers

[18] https://www.cdc.gov/healthywater/surveillance/pdf/mm6431.pdf
[19] https://www.epa.gov/sites/production/files/documents/SWTR_Fact_Sheet.pdf
[20] https://www.epa.gov/dwreginfo/surface-water-treatment-rules
[21] https://www.jstor.org/stable/jamewatworass.104.12.e653?seq=1#page_scan_tab_contents

and eventually will be carried over to the filters causing fast clogging of the filters and frequent backwashing requirements reducing the overall clear water output of the treatment plant.

8.3.3 Disinfection

Disinfection has the purpose of killing pathogenic organisms from the filtered water and provides a disinfectant residual in the distribution system to prevent re-growth of the pathogenic organisms and to prevent biofilm induced corrosion in cast iron pipes.

The disinfection and residual disinfectant are most efficient if the water is pre-treated to an advanced level as measured by colour and turbidity. Any residual colour and turbidity will increase the chlorine demand, will cause formation of carcinogenic halogenated organic compounds and will provide shielding and a food source for pathogen re-growth in the distribution system.

From the analytical test reports provided, it is not clear which type of residual chlorine was determined and monitored: free residual chlorine or total residual chlorine. It was assumed that the parameter measured and monitored was free residual chlorine as per IS 10500:2012 requirements.

To make the surface water safe to drink, the water treatment process must remove and destroy all disease-causing organisms that typically live in the surface source water. Some of the pathogenic organisms are highly resistant to chlorine and only physical removal methods of treatment will work. The physical removal methods using conventional treatment can be successful only if the organisms are clumped into large flocs by coagulation to a size that will be bulky enough to be physically removed by sedimentation and filtration. Turbidity of the filtered water plays an important role in disinfection efficacy due to shielding effect of flocs on the pathogenic organisms residing inside the flocs.

IS 10500:2012 recommends minimum free residual chlorine of 0.2 mg/l at customers end, with the remark that '*when protection against viral infection is required, it should be minimum 0.5 mg/l* '. The common pathogenic organisms that are living in surface waters used as source water for drinking water production are listed in
Table 266.

Table 26 Common Pathogens Transmitted through Drinking Water[22]

Pathogen		Resistance to chlorine	Persistence in water supplies	Health significance	Relative infectivity
Bacteria	Burkholderiapseudomallei	Low	May multiply	High	Low
	Campylobacter jejuni/coli	Low	Moderate	High	Moderate
	Escherichia coli-Pathogenic	Low	Moderate	High	Low
	E.coli-Enterohaemorrhagic	Low	Moderate	High	High
	Francisellatularensis	Moderate	Long	High	High
	Legionella spp.	Low	May multiply	High	Moderate
	Leptospira	Low	Long	High	High
	Mycobacteria(nontuberculous)	High	May multiply	Low	Low
	Salmonella Typhi	Low	Moderate	High	Low
	Other salmonellae	Low	May multiply	High	Low
	Shigella Spp.	Low	Short	High	High

[22] https://dyuthi.cusat.ac.in/xmlui/bitstream/handle/purl/5121/Dyuthi-T%202186.pdf?sequence=1

Pathogen		Resistance to chlorine	Persistence in water supplies	Health significance	Relative infectivity
	Vibrio cholerae	Low	Short to long	High	Low
Viruses	Adenoviruses	Moderate	Long	Moderate	High
	Astroviruses	Moderate	Long	Moderate	High
	Enteroviruses	Moderate	Long	High	High
	Hepatitis A virus	Moderate	Long	High	High
	Hepatitis E virus	Moderate	Long	High	High
	Noroviruses	Moderate	Long	High	High
	Rotoviruses	Moderate	Long	High	High
	Sapoviruses	Moderate	Long	High	High
Protozoa	Acanthamoebaspp.	High	May multiply	High	High
	Cryptosporidium hominis /Cryptosporidium parvum	High	Long	High	High
	Cyclosporacayetanensis	High	Long	High	High
	Entamoebahistolytica	High	Moderate	High	High
	Giardia intestinalis	High	Moderate	High	High
	Naegleria fowleri	Low	May multiply	High	Moderate
Helminths	Dracunculus medinensis	Moderate	Moderate	High	High
	Schistosoma spp.	Moderate	Short	High	High

To mitigate the virus survival risk in the drinking water it is recommended the range 0.3 mg/l to 0.5 mg/l free residual chlorine in tap water to be adopted by KWA. Higher than 0.3 mg/l free residual chlorine can be tasted in the drinking water, however water safety is considered to override the aesthetic quality of drinking water.

A better alternative to chlorination for extensive distribution systems is Chloramination. Chloramination is a more complex chemical disinfection process and requires greater operator training to be successfully used and is not proposed here.

The best way to ensure the safety of the drinking water is advanced suspended solids and soluble organic matter removal, resulting in low turbidity, colour and low chlorine demand. In clean water the residual disinfectant is easy to maintain and requires less disinfectant to maintain the minimum of 0.5 mg/l residual chlorine required at customers' taps.

8.3.4 pH and Alkalinity

Final pH adjustment of the disinfected water to above 7.2 is recommended to reduce the water corrosivity and prevent damage to water assets and leaching of toxic heavy metals into the drinking water.

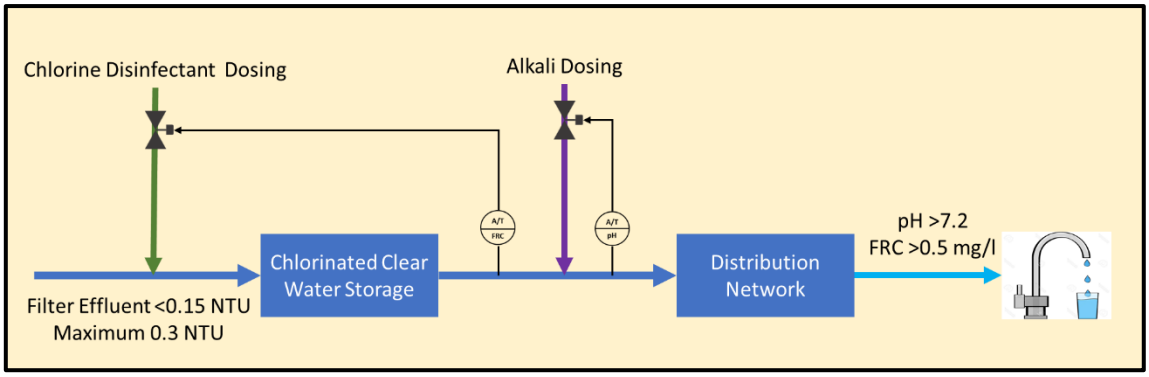


Figure 13 pH and Alkalinity Adjustment using Alkali and Carbon Dioxide Dosing

The adjustments required for full assets protection are pH 8, alkalinity 100 mg/l and calcium concentration 50 mg/l. Figure 13 shows a typical pH and alkalinity adjustment system.

The current natural water alkalinity of the source water at most KWA plants is on average below 20 mg/l while calcium concentration is below 6 mg/l. To increase the alkalinity to 50 mg/l to provide corrosion protection of the water assets the lime dosage at the current plants should be increased five fold while calcium concentration increase from 6 mg/l to 50 mg/l would require an eight-fold increase of the current lime dosage rates. The large increase in lime addition will require carbon dioxide injection into the water for buffering against pH upside excursion above the standard maximum limit of 8.2. Additionally, the high-water pH of 8 is close to the limit of organoleptic acceptability of the drinking water making this option unfeasible. The large increase in lime usage to provide corrosion protection makes the lime option unattractive. To provide corrosion protection of the assets the use of corrosion inhibitors is recommended.

For final polishing step to increase pH and alkalinity of the disinfected water limestone contactors[23] could be employed. Such a process is shown in Figure 14.

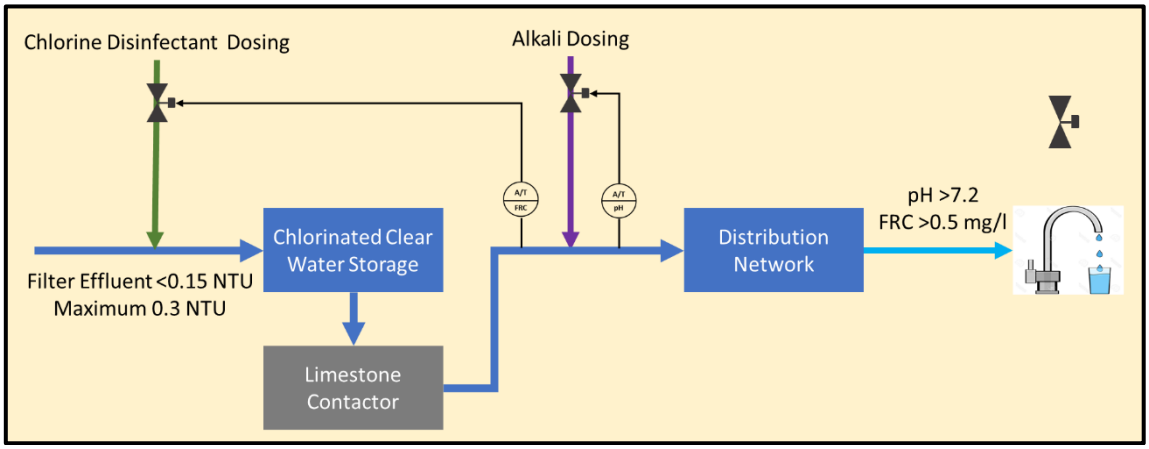


Figure 14 pH and Alkalinity Adjustment using Limestone Contactors

8.3.5 Corrosion Mitigation

Heavy metals contamination at customers' taps has to be measured and corrosion mitigation action must be taken if this form of contamination is occurring. If the tap water contains more than 0.015 mg/l lead or more than 1.3 mg/l copper the clear water has to be treated with corrosion inhibitors. If

[23] https://pdfs.semanticscholar.org/0591/2f8aa6da547a03ff97251e32f9ebcd7e93f4.pdf

the iron concentration in the tap water is higher than in the disinfected clear water supply tank, it is recommended to use corrosion inhibitors to protect KWA drinking water transmission assets. [24]

8.4 Treatment Plant Condition Assessments

8.4.1 Introduction

A condition assessment was undertaken of each water treatment plant. The condition assessment comprised a visual inspection, analysing the raw and product water quality and process engineering calculations. In addition, the treatment plants were compared to a 'reference treatment plant' in terms of equipment and process flows to determine any deficiencies. The reference water treatment plant is shown in Figure 15.

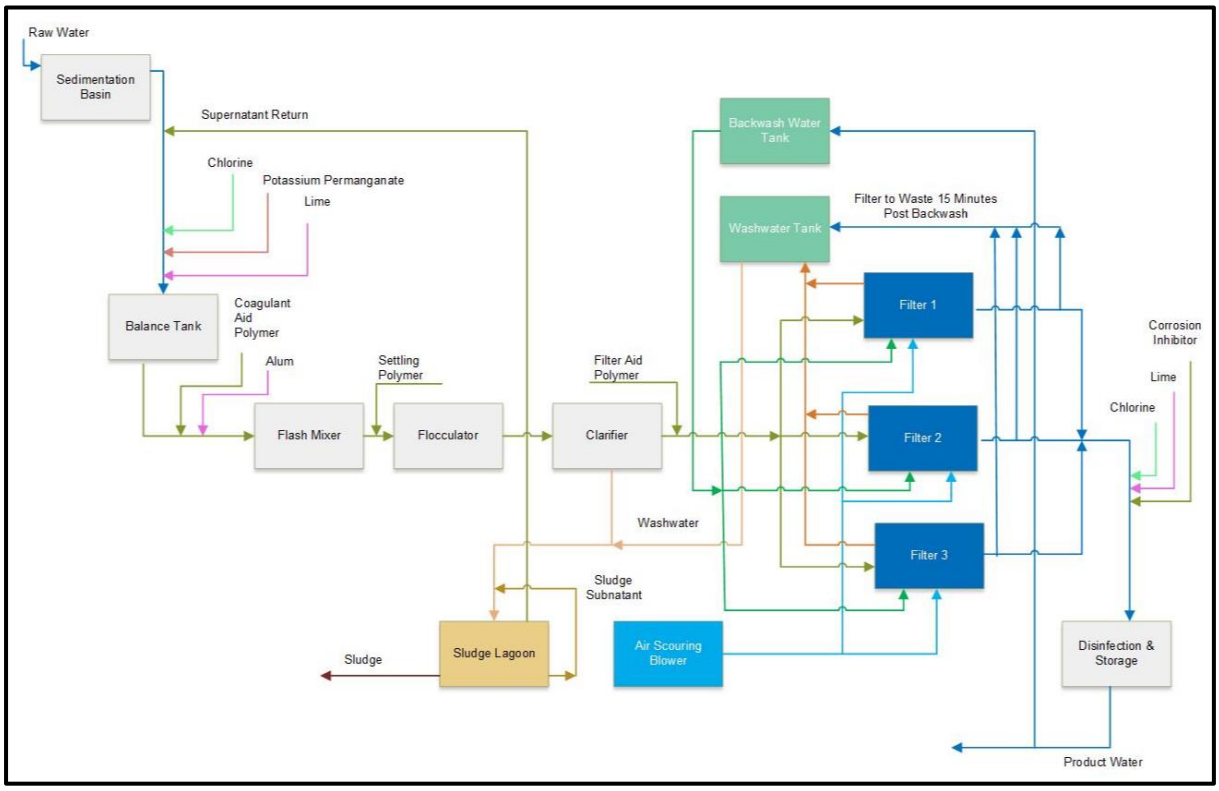


Figure 15 Reference Water Treatment Plant

8.4.2 Power Supply

A number of water treatment plants include transformers for stepping down the voltage. A number of these are old and need replacing these replacements have been included in this project.

8.4.3 Corrosion

A general observation applicable to all KWA water treatment plants and water distribution assets is the advanced corrosion of all metal and masonry components. The reason for fast breakdown of these assets is the quality of the water, both raw and the treated clear water alike. The KWA water (based on Langelier Index[25]) causes serious corrosion to water treatment and distribution assets. To reduce water corrosivity, the water has to be treated to increase calcium bicarbonate alkalinity and

[24] https://www.epa.gov/sites/production/files/2016-03/documents/occtmarch2016.pdf
[25] https://www.lenntech.com/calculators/langelier/index/langelier.htm

pH using hydrated lime and carbon dioxide post disinfection or alternatively use limestone contactors[26].

8.4.4 Water Treatment Plant Physical Review

The following observations were made during the WTP physical inspections.

- All water treatment plants assets including the recently built water treatment plants showed advanced corrosion to metal and masonry components
- Most valves were leaking
- Cast Iron pipes are not painted for corrosion protection
- At some plants the feed water to the filters is contaminated with lubrication oil seen as an oil slick on the surface of the water of the operating filter, potentially causing treated water non-compliance to IS 10500:1012 in respect to Polynuclear Aromatic Hydrocarbons concentration of maximum 0.0001 mg/l.
- Treated water channels coming from the filters product lines at most plants are open and at risk of re-contamination.
- Filtered water from each individual filter is not monitored for turbidity leaving the clear water vulnerable to protozoa, helminths[27] and amoeba contamination during filter breakthrough or during a backwashed filter ripening *(See Glossary of Terms)* after the filter is returned to service.
- Most of the original covers on filtered water collection pits made from cast iron are completely corroded or broken and are left open or replaced in an unsatisfactory manner.
- The treatment plant buildings have broken windows or open windows with no insect mesh leaving the process vulnerable to wildlife contamination.
- Most electrical assets are in an advanced state of breakdown due to the high humidity environment.
- Most plants have electrical cables that are laying on wet floors instead of being in cable trays, representing a safety hazard for the operational staff.
- Some plants have unsafe switchboards that are corroded and, in some cases, are live presenting an unacceptable hazard to plant operators
- Redundant assets are not removed from sites causing safety hazards to operational personnel and water safety issues due to potential faecal contamination from wild life.
- The operations personnel are not wearing safety equipment while handling corrosive chemicals
- No safety signage is displayed on the inspected sites
- Most sites lack adequate security, leaving the plants vulnerable to general public access and putting both KWA assets and the safety of intruders at risk.
- The product water tanks and channels are not sealed from wildlife, leaving the treated water vulnerable to recontamination.
- The chemical handling is unsatisfactory when assessed against handling requirements specified in the material safety data sheets (MSDS) of the handled products.
- The dosing procedures of the chemicals are uncontrolled leaving the treatment process vulnerable to a failure to remove dangerous biological contaminants from the raw water.

8.4.5 Water Treatment Plants Process Review

The following observations were made during the WTP process inspections.

[26] https://pdfs.semanticscholar.org/0591/2f8aa6da547a03ff97251e32f9ebcd7e93f4.pdf
[27] http://parasite.org.au/para-site/contents/helminth-intoduction.html

- Most treatment plants are affected by algae growth in the aeration structures and the sedimentation tanks. Algae cells can by killed by oxidation with potassium permanganate.
- Most plants have coagulation and flocculation jar testing equipment. However, the equipment might not be used as often as required by fast changing water quality. Some plants have the equipment but lack adequately trained personnel to do the tests and adjust the process based on test results. Other plants have equipment but no reagents or batteries to power the analysers.
- None of the water treatment plants inspected is recovering the filter backwash water, potentially reducing the plant output by up to 4%. The backwash water recovery is only recommended if pre-oxidation with strong oxidants is part of the raw water treatment process.
- None of the treatment plants has sludge drying lagoons. The sludge drying lagoons serve the purpose of dewatering and drying the sludge produced in the sedimentation tanks, filters and backwash recovery tanks for safe and easy disposal. The sludge contains high concentration of pathogenic organism and heavy metals removed from the source water during the water treatment process. The sludge is currently discharged into a receiving water resulting in long term contamination of the receiving water and downstream environments which cannot be repaired at some future time.
- All plants have manual filter backwash systems. Some plants are using water only and some are using air scouring and water backwash. The backwash water required is higher when the filters are backwashed with water only. Air scouring improves contaminants removal from the media and reduces the backwash time and the water loss during backwash. Air scouring of the filters during filters cleaning must be added to all treatment plants to improve treatment plants efficiency.
- None of the treatment plants monitor turbidity of the water produced by individual filters to diagnose early actionable filter operation issues. The operators are not aware of filtered water recontamination with unfiltered water that typically occurs:
    - At the restart of filtration after filter cleaning during the filter ripening period (see glossary of terms)
    - Or during filter breakthrough that typically occurs due to preferential channels formation in the filter bed caused by inefficient filter bed backwash.
- None of the inspected treatment plants have pH adjustment system of the treated water after chlorine disinfection causing very corrosive low pH and low alkalinity water to be distributed into the transmission system.
- None of the inspected treatment plants treat the product water with corrosion inhibitors to protect the product water transmission and distribution assets and prevent leaching of toxic metals from the metal infrastructure elements and customers tap water system.

8.4.6 Water Treatment Plants Water Quality Review

The following observations were made during the WTP quality inspections.

- Most treatment plants are exceeding on regular bases the turbidity target of maximum 1 NTU and colour limit of 5 Hazen units as per IS 10500:2012. Some water treatment plants also produce drinking water that occasionally has a pH lower than the minimum of 6.5 as per IS 10500:2012.
- Aluminium in the clear water is not tested to troubleshoot coagulation issues that lead to aluminium residues in the product water and incomplete coagulation.

- Alkalinity of the water at most plants is less than 50 mg/L and pH of the water most of the time is bordering the lower acceptable treated water pH range causing serious corrosion to the water treatment, transmission and distribution assets.
- E-coli are sometimes detected at some customers' taps and could be related to incomplete disinfection of the organisms embedded in the suspended solids measured as turbidity.
- Full testing is required as per IS 10500:2012 to assess the impact of any of industrial wastewater discharges into the surface waters upstream of a raw water intake.

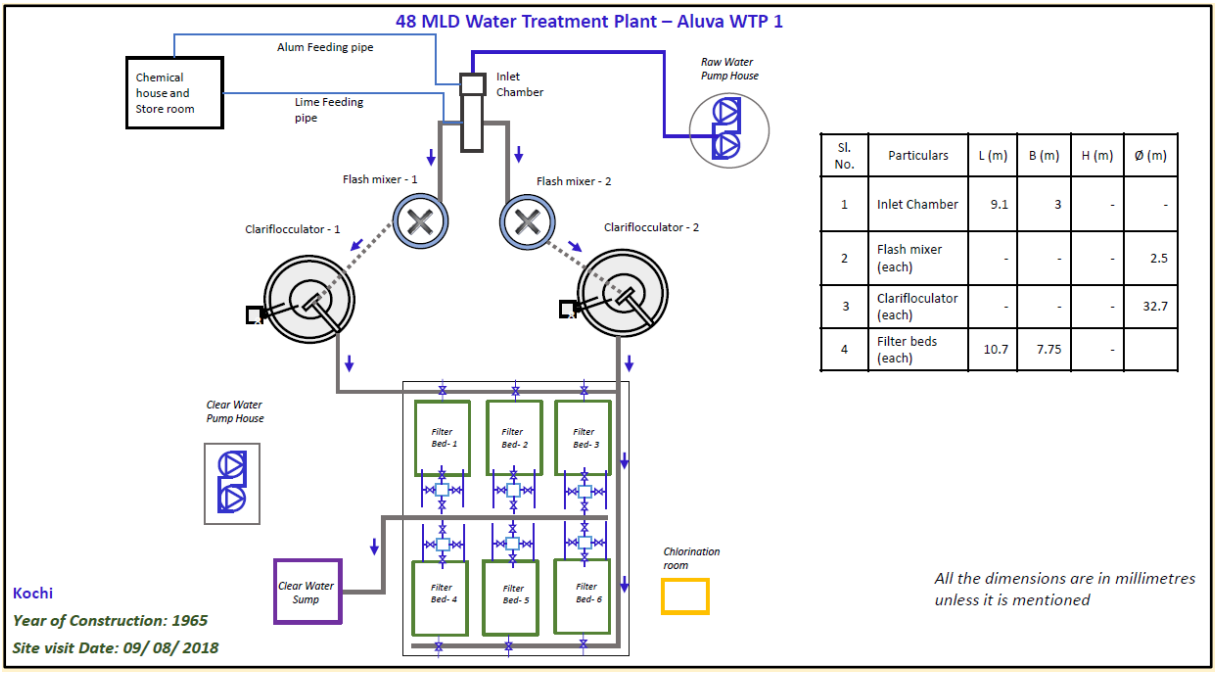
8.4.7 Water Treatment Plant Design Inspection

Water treatment plant drawings were not available therefore only general design comments can be provided at this time. Pipe and Instrument Diagrams (P&IDs) of the treatment plants were also not available for inspection. A set of P&IDs will be prepared as part of this review.

8.5 Treatment Plant Refurbishment and Upgrade Program

8.5.1 Introduction

The condition assessment found that the water treatment plants servicing the Kochi corporation areas are not able to reliably treat water to the water quality standards adopted for this project. To assist in determining the required works and inform bidders of what is required a schematic of each water treatment plant has been prepared. An example is given in Figure 16.



Sl. No.	Particulars	L (m)	B (m)	H (m)	Ø (m)
1	Inlet Chamber	9.1	3	-	-
2	Flash mixer (each)	-	-	-	2.5
3	Clarifloculator (each)	-	-	-	32.7
4	Filter beds (each)	10.7	7.75	-	

Figure 16 Schematic of Water Treatment Plant

A treatment plant refurbishment and upgrade program has been developed to address issues found during the condition assessment. This refurbishment program takes the following form.

1. Upgrade the treatment processes
2. Upgrade the dosing of chemicals during the treatment process
3. Upgrade the post treatment conditioning of the treated water
4. Improve the monitoring of the treatment process
5. Improve the skills of the treatment plant operators
6. Upgrade the amenity of the sites and buildings

These are now briefly discussed.

8.5.2 Upgrade of Treatment Processes

8.5.2.1 Raw Water Pre-oxidation

The raw water is to be dosed with a chemical oxidant such as chlorine and/or potassium permanganate ($KMnO_4$) to ensure the full oxidation of colour causing components of the raw water such as iron.

8.5.2.2 Flow Balancing Tank

A flow balancing tank with ten minutes residence time is to be installed at the inlet and designed to ensure a constant flow is delivered to the subsequent treatment process steps. Several water streams will be returned to the plant inlet including the recovered backwash water and the filtered water produced in the first 15 minutes after a clean filter restart. These streams are to be returned to this flow balancing tank. The balance tank outlet valve is to be controlled by a downstream flowmeter to ensure constant flow to the flash mixers.

8.5.2.3 Flash Mixers

The chemically dosed and balanced raw water will next be sent to the flash mixer(s). The flow from the flash mixers is to be sent to clarifier/ clariflocculator depending upon the particular treatment plant. If there is more than one clarifier/clariflocculator the flow must be spilt in equal proportions. The mixer type will depend on the flow direction as shown in Figure 17. The flash mixers will have a detention time of 20 seconds and velocity gradient G = 750 s^{-1} for optimum chemicals mixing.

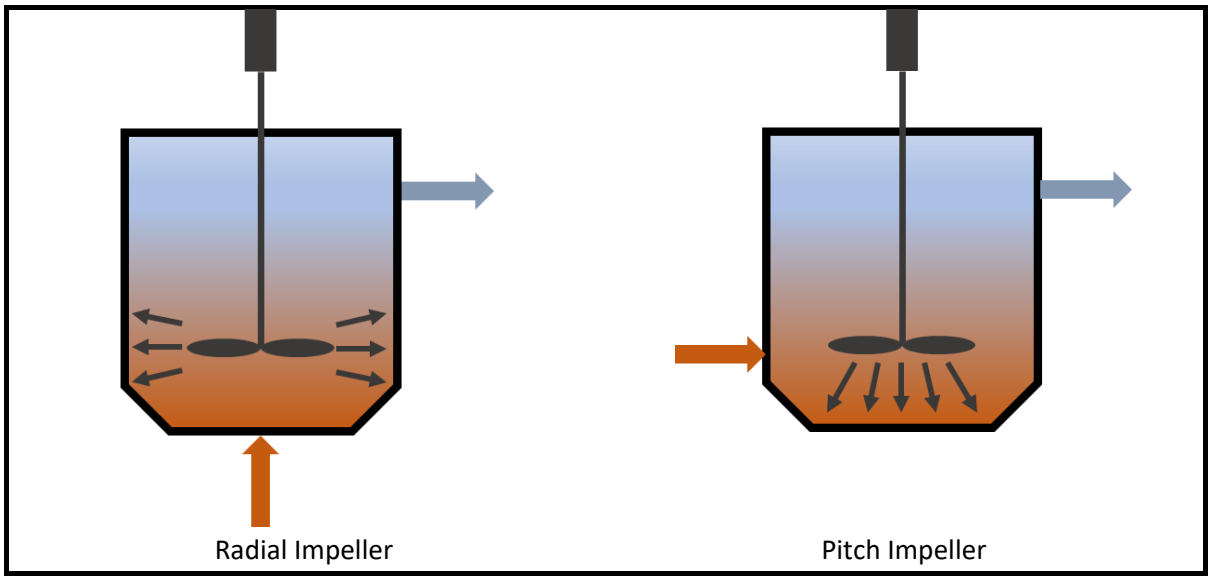


Figure 17 Flash Mixer Impellers

8.5.2.4 Flocculation

The flocculation tanks are currently part of the clariflocculator. The flocculators' mixer motors are to be fitted with variable speed drives (VSD) to allow operators to adjust the mixer speed for optimum flocculation.

8.5.2.5 Clarification

Tube settlers and vacuum sludge removal systems are to be installed.

8.5.2.6 Filtration

The existing underdrain system is to be replaced with a Vee Wire type underdrain of the type shown in Figure 18.

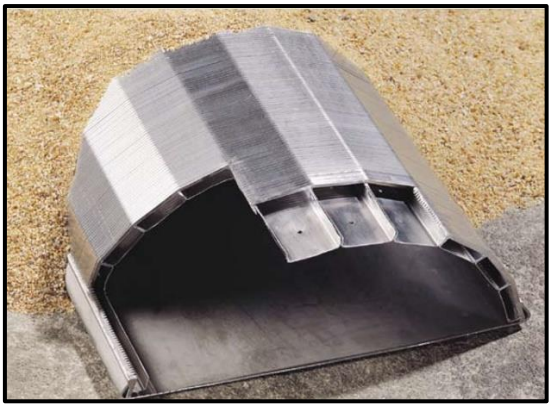


Figure 18 Type of Vee Wire Underdrain Required

The existing single media filters are to be changed to dual media filters comprising sand then granular activated carbon (GAC). The depth of 400 mm occupied currently by gravel is to be replaced by granular activated carbon.

8.5.2.7 Filter Backwash

The filters' backwash is to be automated. The filter backwash water and the first 15 minutes of filtered water following a backwash are to be collected in a wash water tank (see next paragraph).

8.5.2.8 Backwash Recovery and Sludge Treatment

A backwash water recovery system is to be installed comprising a backwash water tank, back wash water transfer pumps, sludge drying beds, supernatant transfer pumps and subnatent transfer pumps and associated pipes and fittings. The supernatant is to be transferred to the balancing tank at the inlet of the treatment plant while the subnatent is to be transferred to the top of the sludge drying bed, as shown in Figure 15.

The number of drying beds will be different for each plant and will comprise beds in duty mode, beds in drying mode and one spare bed for wet weather conditions. The beds on duty are to be fed sequentially at set time intervals to allow for the suspended solids to settle to a low turbidity making the supernatant suitable to be returned to the head of the plant. The beds in drying mode is to start the cycle when sludge of minimum 5% w/v solids reaches 1 m depth. The beds are to be designed for six month drying time.

8.5.2.9 Clear Water pH Adjustment

The disinfected water will be dosed with hydrated lime and carbon dioxide to increase the carbonate alkalinity of the treated water to above 50 mg/L.

8.5.2.10 Air Blower System

The air blower system is used to supply low pressure air for the air scouring process on the filters backwash cycle.

The air scouring system is to be upgraded to meet the requirements of the newly upgraded filter and backwash system.

8.5.2.11 Compressed Air System

The compressed air system will supply compressed air to various services in the plant. There will be two air compressors in a standby/duty arrangement. The air compressors will be self-contained packaged units that will feed compressed air to the system on demand. Each package will consist of intake air filter, air compressor, air filter, air dryer and air receiver.

8.5.2.12 Treated Water Service

A treated water service to the site will be supplied from a clear water sump to several on-site supply points through a booster pump system with three variable speed centrifugal pumps.

From the common pipework, four treated water service streams will be directed to the following areas:

- Potable water to for toilets, amenities and laboratory
- Hose taps through a reduced pressure zone backflow preventer, pumps, filters, backwash water holding tanks, chemical building, clear water sump, clariflocculators and aerators
- Site safety showers
- A separate reduced pressure zone backflow preventer that branches out into five streams, each with a check valve, supplying treated service water to the chemical dosing systems (corrosion inhibitor, lime, alum, polymers and potassium permanganate)

8.5.2.13 SCADA and Historical Data Storage

The treatment plants with a supervisory control and data acquisition (SCADA) system and historical data storage system is to be upgraded or replaced.

8.5.2.14 Electrical Equipment and Electrical Wiring

A separate air-conditioned enclosure for all electrical panels and switchboards is to be provided. All electrical wiring is to be placed in cable trays.

8.5.3 Water Treatment Plant Laboratory

The chemicals and laboratory equipment required to do regular in-process testing as per Indian standard test methods requirements are to be supplied. It must be a unique and secure room.

The plant laboratories are to contain the following as a minimum.

- Laboratory benches and a desk and suitable chairs
- Cabinets for storage of equipment, glassware, chemical reagents and other consumables
- Shelving
- Power outlets, and adequate lighting
- Running water and sink
- Laboratory glassware drying rack
- Water distillation unit
- Fridge for the storage of samples and some chemicals
- Adequate power outlets

Upgrade the plant laboratory with a spectrophotometric analyser and testing reagents for fast process control testing of essential water quality parameters such as iron, manganese, aluminium, colour, alkalinity and calcium.

Each laboratory is to have a computer connected to the KWA's LIMS system to be used by operators for data recording, storage and reporting. The operators are to be provided with a hand-held turbidity and level indicator transmitter for sedimentation tanks and clarifiers sludge level monitoring. This equipment is for checking that the in-line equipment is working. [28]

[28] Many of the existing water treatment plants have sludge floating on top of clariflocculator which is an indicator that there is old sludge at the bottom of the clariflocculator that has started to breakdown and the

All chemicals used in the laboratory should have current materials safety data sheet (MSDS) kept in the laboratory.

The site laboratories should have first aid kits, safety showers and eye washes and should be airconditioned so that testing may be undertaken in the correct controlled conditions.

8.5.4 Upgrade and New Chemical Dosing

8.5.4.1 Alum Batching and Dosing

The existing alum blocks batching system is to be replaced with liquid dosing system serviced by importing by road tanker a ready-made alum solution (8% as Al_2O_3, Grade 5 as per IS 299). The liquid alum transfer station is to have a chemical wastewater collection pit to collect wastewater and any alum solution that leaks during transfer. A safety eyewash and shower station are to be located next to the alum transfer station.

The alum from the road tanker is to be transferred into a new alum solution storage tank. The storage tank will have a capacity to store enough alum for 15 days of operation at maximum alum dose rate of 50 mg/l as $Al_2(SO_4)_3.18H_2O$.

The dosing of alum is to be undertaken using programmable variable speed dosing pumps in a duty/standby arrangement. The dosing pumps skid will be placed in a chemical bund to collect any chemicals that escape during breakdowns and maintenance. A safety shower and eyewash station are to be located next to the alum dosing skid.

8.5.4.2 Hydrated Lime Batching and Dosing System

The existing hydrated lime batching system is to be replaced with a batching system similar to the existing 74 MLD plant batching system. The batching system will consist of a lime silo, lime slurry preparation tank and lime slurry storage tank. The batching system is to be a supplier-package and have all equipment and instruments included in the package and supplied by the chemical vendor.

The dosing of the lime slurry is to have programmable variable speed peristaltic hose pumps in duty/standby arrangement to allow for maintenance and operator intervention to adjust lime dosing rates as a function of water quality. The lime silo and dosing pumps skid will be placed in chemical bunds to collect any chemicals lost during breakdowns and maintenance. A safety shower and eyewash station are to be located next to the alum dosing skid.

8.5.4.3 Polymer Batching and Dosing System

The granular polymer batching system will be a vendor package supplied by the polymer vendor with all equipment and instruments included in the package.

The polymer solutions will be stored in tanks with storage capacity designed to store enough polymer to supply the production requirement for 15 days at the maximum dose rate.

The dosing of the polymer solutions is to have programmable variable speed diaphragm pumps in a duty/standby arrangement to allow for maintenance and operator intervention to adjust polymer dosing rates as a function of raw water quality. The polymer batching systems and the dosing pump skids are to be placed in chemical bunds to collect any chemicals lost during breakdowns and maintenance. A safety shower and eyewash station are to be located next to the alum dosing skid.

gases formed as a result have lifted up the sludge. There should be no standing sludge at the bottom of the clariflocculator.

8.5.4.4 Potassium Permanganate Batching and Dosing Systems

The potassium permanganate stored on site should allow for the plant production requirements for 15 days at the maximum dosing rate.

The potassium permanganate batching system should be a supplier-package with all equipment and instruments included in the package.

The potassium permanganate solution should be stored in a tank with storage capacity designed to store sufficient potassium permanganate to cover production requirement for one day at the maximum dose rate.

The dosing of the potassium permanganate solution is to be undertaken using programmable variable speed diaphragm pumps in duty/standby arrangement to allow for maintenance and operator intervention to adjust potassium permanganate dosing rates as a function of raw water quality. The potassium permanganate batching system and the dosing pumps skids are to be placed in chemical bunds to collect any chemicals lost during breakdowns and maintenance. A safety shower and eyewash station are to be located next to the alum dosing skid.

8.5.4.5 Corrosion Inhibitor Dosing

The corrosion inhibitor stored on site should cover plant production requirements for 15 days at maximum dosing rate.

The corrosion inhibitor batching system will be a supplier-package with all equipment and instruments included in the package.

The corrosion inhibitor solution should be stored in a day tank with storage capacity designed to store sufficient corrosion inhibitor to cover the production requirement for one day at maximum dose rate.

The dosing of the corrosion inhibitor solution is to come with programmable variable speed diaphragm pumps in a duty/standby arrangement to allow for maintenance and operator intervention to adjust corrosion inhibitor dosing rates as a function of raw water quality. The corrosion inhibitor batching system and the dosing pumps skids will be placed in chemical bunds to collect any chemicals lost during breakdowns and maintenance. A safety shower and eyewash station are to be located next to the alum dosing skid.

8.5.4.6 Chlorine Dosing System

The chloride dosing system is to be upgraded to meet the Indian health and safety standards. Material of construction used within the chlorine building should be chemically compatible with dilute hydrochloric acid.

8.5.4.7 Post Treatment Dosing

The post-treatment dosing shall consist of:

- Automated final pH adjustment system using lime and carbon dioxide injection.
- Automated corrosion inhibitor dosing system

8.5.4.8 Summary

The chemical dosing used for this project and the reasons for undertaking the dosing are summarised in Table 277. Figure 15 also contains a summary in schematic form.

Table 27 Dosing Used in Water Treatment Plant Upgrades

Chemical Dosed	Dosing Point	Purpose of Dosing
Potassium Permanganate	Raw Water Inlet Pipe	Oxidize and Disinfect Raw Water
Chlorine	Raw Water Inlet Pipe	Oxidize and Disinfect Raw Water and Reduce the Cost of Oxidation Treatment
Lime	Raw Water Inlet Pipe	Adjust Raw Water pH to Ensure Optimum Coagulation Conditions
Coagulant Aid Polymer	Dosed Raw Water Flash Mixer Inlet Pipe	Improve coagulation and reduction of coagulant dosing rate, hence reduction of sludge production
Coagulant (Alum)	Dosed Raw Water Flash Mixer Inlet Pipe	To coagulate the colloidal contaminants from the raw water
Settling Polymer	Dosed Raw Water Flash Mixer Outlet Pipe	To improve flocs strength and size to ensure fast settling in the clarifier
Filter Aid Polymer	Clariflocculator outlet pipe/channel	The further improve the flocculation of the remaining suspended solids not removed in the clarifier to improve solids separation during filtration
Chlorine	Filters Outlet, Filtered Water Combined Channel/Pipe Header	Disinfection of the filtered water and meet the free residual chlorine regulatory requirements
Lime	Clear Water Pipe Post Chlorination	To adjust pH to the optimum range required for corrosion inhibitor to work
Corrosion Inhibitor	Clear Water Pipe after Chlorination and pH Adjustment	To protect water infrastructure assets against corrosion and leaking of copper and lead into the drinking water from older type of water transmission components

8.5.5 Improvements to Treatment Plant Monitoring

8.5.5.1 Flow Measuring and Monitoring

The following are required to permit the flows in the water treatment plant to be monitored.

- Install flow switches connected to SCADA to trigger alarms on all pump delivery lines.
- Install flow switch pressure relief valves on pump delivery pipes
- Install electromagnetic flow meters on the raw water inlet pipe and clear water outlet pipe
- Install an electromagnetic flow meter on the backwash pumps delivery line and connected to SCADA as part of the filters automated backwash system.
- Install variable area flow meters (rotameters) on all sampling lines.

8.5.5.2 Pressure measuring and monitoring

All chemical dosing pumps discharge lines will be fitted with pressure gauges and pressure switches connected to SCADA system. All filters will have differential pressure transmitters connected to SCADA system as part of the automated filters operation.

8.5.5.3 Level measuring and monitoring

All tanks will have level indicators and level switches connected to SCADA and interlocked with other instruments as part of the plant semi-automation system.

8.5.5.4 Water Sampling and Testing

The following process streams will be automatically sampled by a sampling system, analysed by in-line analysers and the results stored in the SCADA System:

- Raw Water
- Dosed Raw Water
- Clarified Water
- Filtered Water
- Treated Water

The following parameters will be continually measured by the in-line analysers and the results stored in SCADA:

- pH
- Temperature
- Turbidity
- Free Chlorine Residual

The test results will be reviewed daily by the technical staff charting software for troubleshooting and process improvement.

8.5.6 Improvements to Operator Skills

All staff involved in the production of potable water, testing and control shall undertake professional improvement training covering the following areas:

- Plant operations
- Operations and quality troubleshooting and solutions
- Plant and laboratory equipment maintenance
- Basic water chemistry and microbiology
- Samples collection, storage and testing
- Jar testing
- Test results processing and interpretation
- How to adjust plant parameters to bring the water quality into the targeted range
- Health and safety rules and regulations applicable in the laboratory, in the water treatment plants and during water sampling
- Plant automation and SCADA after upgrades

8.5.7 Upgrade of the Amenity of Sites and Buildings

The upgrade of the Amenity of the sites and buildings is covered later in this report.

8.6 Treatment Plant Refurbishment and Upgrade Program Scheduling

The following assumptions and nomenclature are used.

1. KPS04 will be abandoned and no works are required
2. The prefix ‘K’ means Kochi
3. A water treatment plant and its associated inlet and outlet pump stations will be refurbished and upgraded at the same some to minimise disruption to water supplies

Table 288 has been structured to show the works sub-packages that will be required to refurbish and upgrade all the water treatment plants and pump stations. There are 14 works sub-packages in Kochi. The detailed programming of these sub-packages will require careful and detailed planning

involving both the Employer and Contractor and this is expected to be undertaken during the first year of the project ('Project Establishment Phase').
Altogether there are 13 water treatment plant and pump station (WTP/PS) sub-packages and 15 booster pump station (BPS) sub-packages. Each sub-package will require a detailed design before construction commences. For the water treatment plants, the detailed design is to include both the process design and the hydraulic design.

In the case of the WTP/PS sub-packages, the detailed design is expected to take six months and the construction another eighteen months. In the case of BPS sub-packages, the design is expected to take one month and the construction four months. Works are to spread out over time to minimise disruption to water supplies and all works are expected to be completed by the end of the seventh year.

Table 28 Water Treatment Plant and Pump Station Works Sub-Packages

Combined Pump Stations and Treatment Plants						
SubP	PS	MLD	WTP	MLD	PS	MLD
Kochi						
K1	KPS01	48.0	Aluva I	48.0	KPS05	48.0
K2	KPS02	72.0	Aluva II	72.0	KPS06	72.0
K3	KPS03	105.0	Aluva III	70.0	KPS07	105.0
K4			Aluva IV	35.0		
K5	KPS08	100.0	Maradu	100.0	KPS09	100.0
Booster Pump Stations						
Task	PS	MLD	WTP	MLD	PS	MLD
K6	KPS10	28.6	Karuvelipady	NA	NA	NA
K7	KPS11	11.8	Thoppumpady	NA	NA	NA
K8	KPS12	14.2	Palluruthy	NA	NA	NA
K9	KPS13	33.8	Thammanam	NA	NA	NA
K10	KPS14	28.8	Thammanam	NA	NA	NA
K11	KPS15	60.5	Pallimukku	NA	NA	NA
K12	KPS16	12.1	Pallimukku	NA	NA	NA
K13	KPS17	1.7	Pallimukku	NA	NA	NA
K14	KPS18	41.7	Elamkulam	NA	NA	NA

Figure 19 shows one possible schedule for the implementation of the water treatment plant and pump station refurbishment and upgrade program. A schedule of this ilk will be included in the bidding document but can only be finalised after detailed discussions with both the Employer and the Contractor.

Combined Pump Stations and Treatment Plants							1	2	3	4	5	6	7	8	9	10	11	12
Task	PS	MLD	WTP	MLD	PS	MLD	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Trivandrum																		
T1	TPS01	86.0	Aruvikkara	86.0	TPS02	86.0												
T2	TPS03	74.0	Aruvikkara (Suez)	74.0	TPS04	74.0												
T3	TPS05	72.0	Aruvikkara	48.0	TPS06	72.0												
T4			Aruvikkara	24.0														
T5	TPS07	5.0	Adimadakkukayam	5.0	NA	NA												
T6	TPS08	16.0	PTP Nagar	16.0	NA	NA												
T7	TPS09	13.5	PTP Nagar	13.5	NA	NA												
T8	TPS10	21.9	Vellayani	21.9	TPS11	21.9												
T9	TPS12	36.0	Vellayambulam	36.0	TPS13	36.0												
Kochi																		
K1	KPS01	48.0	Aluva I	48.0	KPS05	48.0												
K2	KPS02	72.0	Aluva II	72.0	KPS06	72.0												
K3	KPS03	105.0	Aluva III	70.0	KPS07	105.0												
K4			Aluva IV	35.0														
K5	KPS08	100.0	Maradu	100.0	KPS09	100.0												
Booster Pump Stations																		
Task	PS	MLD	WTP	MLD	PS	MLD												
Trivandrum																		
T10	TPS14	7.8	Kudappanakunnu	NA	NA	NA												
T11	TPS15	4.3	Peroorkada	NA	NA	NA												
T12	TPS16		Powdikonam	NA	NA	NA												
T13	TPS17	18.6	Powdikonam	NA	NA	NA												
T14	TPS18	1.7	Nettayam	NA	NA	NA												
T15	TPS19	13.6	Iranimuttom	NA	NA	NA												
Kochi																		
K6	KPS10	28.6	Karuvelipady	NA	NA	NA												
K7	KPS11	11.8	Thoppumpady	NA	NA	NA												
K8	KPS12	14.2	Palluruthy	NA	NA	NA												
K9	KPS13	33.8	Thamanam	NA	NA	NA												
K10	KPS14	28.8	Thamanam	NA	NA	NA												
K11	KPS15	60.5	Pallimukku	NA	NA	NA												
K12	KPS16	12.1	Pallimukku	NA	NA	NA												
K13	KPS17	1.7	Pallimukku	NA	NA	NA												
K14	KPS18	41.7	Elamkulam	NA	NA	NA												

Figure 19 Water Treatment Plant and Pump Station Refurbishment and Upgrade Schedule

8.7 Treatment Plant Buildings and Amenity

The refurbishment of treatment plant buildings and the improvement of the treatment plant sites and amenities are discussed later in this report.

9 DISTRIBUTION PIPELINES

9.1 Pipeline Data

A summary of the data collected is listed in Table 299. As with all data sets this data contains errors and these errors have been taken into account when making recommendations based upon data analyses.

Table 29 Summary of Data Collected

Data Item	Description
Locations	The locations refer to: (1) The Project Area for each City (2) The Sections within each Project Area. Only the sections within the Project Area are included. This report has used the Section as the basis for analysing the pipeline data. The Sections are as follows. **Kochi** Kaloor-Sec 1 Kaloor-Sec 2 Karuvelypady-Sec 1 Karuvelypady-Sec 2 Pallimukku-Sec 1 Pallimukku-Sec 2 Pallimukku-Sec 3 Vyttila-Sec 1 Vyttila-Sec 2

Pipeline Materials

The materials used for the manufacture of the pipelines installed within each project area.
The pipeline materials that have been used are as follows.

Kochi
AC
ASTM
CI
DI
HDPE
GI
MS
PREMO
PSC
PVC

Pipeline Diameters

The diameters selected for the pipelines installed within each Project Area.

Range 1	10 mm	32 mm
Range 2	40 mm	180 mm
Range 3	200 mm	500 mm
Range 4	600 mm	900 mm

Pipeline Ages

The ages of the pipelines (measured from the date of the commissioning of the pipeline). This data is not available for any of the Project Areas. The date ranges when particular pipeline materials were used is known and these ranges have been included in this report for completeness It has not been used in the pipeline analysis as it is too generic.

Material	**Start Date**	**End Date**
Cast Iron	1933	1990
Ductile Iron	1990	Ongoing
Polyvinyl Chloride	1970	Ongoing
Prestressed Concrete	1970	1988
Mild Steel	2003	Ongoing
Galvanised Iron	Not Used	
Glass Reinforced Plastic	Not Used	
High Density Polyethylene	2000	Ongoing

Pipe Lengths

The lengths of the pipelines broken down into:

(1) Lengths of pipelines by locations
(2) Lengths of pipelines by materials
(3) Lengths of pipelines by diameters

This data forms a three-dimensional matrix.

Activities

The number of maintenance activities broken down into several maintenance activity categories and by location.
The activity categories that have been used are as follows.

House Service Connection (HSC)	Elbow
	Union
	Ferrule
	MTA
	RFTA
	FTA/FT
	Adaptor
	Disconnection
Pipeline (Pipe)	Plug
	Reducer
	Tee
	Coupler
	Socket
	End Cap
Joints	Saddle
	Bend
	CID Cast Iron Detachable Joint
	CIR

<table>
<tr><td></td><td><table>
<tr><td></td><td>Public Taps</td></tr>
<tr><td></td><td>NA</td></tr>
<tr><td>Valves</td><td></td></tr>
<tr><td>Public Taps</td><td></td></tr>
<tr><td>Not Applicable</td><td></td></tr>
</table></td></tr>
<tr><td>Customer Complaints</td><td>The number of customer complaints broken down into several complaint categories and by location.
The customer complaints that have been used are as follows.<table>
<tr><td rowspan="3">Leakage</td><td>Pipe Leak minor</td></tr>
<tr><td>Pipe Leak major</td></tr>
<tr><td>Others</td></tr>
<tr><td rowspan="3">Quality</td><td>Coloured Water</td></tr>
<tr><td>Bad Odour</td></tr>
<tr><td>Others</td></tr>
<tr><td rowspan="4">Special</td><td>Illegal Consumption</td></tr>
<tr><td>Misuse of Water</td></tr>
<tr><td>Others</td></tr>
<tr><td>Water Theft</td></tr>
<tr><td rowspan="5">Supply</td><td>No supply</td></tr>
<tr><td>Short Supply</td></tr>
<tr><td>Low Pressure</td></tr>
<tr><td>High Pressure</td></tr>
<tr><td>Others</td></tr>
<tr><td rowspan="6">Status of Complaint</td><td>Received</td></tr>
<tr><td>Assigned</td></tr>
<tr><td>Closed</td></tr>
<tr><td>Returned</td></tr>
<tr><td>Hold</td></tr>
<tr><td>Out Standing</td></tr>
</table></td></tr>
<tr><td>Connections</td><td>The number of connections broken down into several customer types and by location.
The customer types used are as follows.<table>
<tr><td>Domestic</td><td>Residential Entities</td></tr>
<tr><td>Non-Domestic</td><td>Commercial and Institutional</td></tr>
<tr><td>Industrial</td><td>Supply and Bulk Supply</td></tr>
<tr><td>Special</td><td>Construction</td></tr>
</table></td></tr>
<tr><td>Supply (Quantity)</td><td>The volume of water sold broken down into several customer types (see connections) and by location.</td></tr>
<tr><td>Supply (Reliability)</td><td>There is no firm data on the reliability of supply to customers. However assistant engineers in the subdivisions were interviewed in regard to this topic and the resulting data has been included in the analysis.</td></tr>
<tr><td>Supply (Quality)</td><td>The results of testing the quality of water at consumer taps.</td></tr>
<tr><td>Populations</td><td>The number of resident people broken down into locations. This data uses data reported from censuses downloaded from the Office of the Registrar, General & Census Commissioner, Ministry of Home Affairs, Government of India and calculations and projections based on other parameters.</td></tr>
</table>

Investigations were carried out into the distribution pipelines. It was clear that early assessments of the lengths of pipelines had grossly underestimated the reality. Map bases were produced onto which were plotted pipelines identified from previous studies. These were then manually updated by local water supply operations and maintenance staff to produce a final set of drawings of the network layout together with pipeline diameters and materials. Pipeline ages were not known and could not be estimated. These maps were used in this study but will need further refinement and regular updating in the future.

Field inspections were undertaken to gain a first-hand experience of the condition of the pipelines and the maintenance work carried out. Figure 20 refers to one such inspection. Also, a large amount of data was collected from Section offices as well as interviews with Section staff. Figure 21 shows two such data collection exercises.

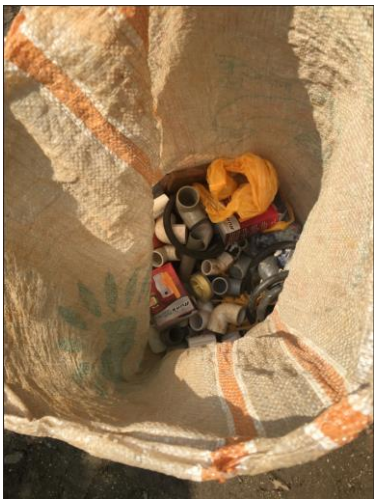
		
Hand excavation of pipeline – estimated depth thought to be 2.5 m as advised by local person who observed pipe laying many years ago. No personal protection equipment.	Discussions with contractor – ground conditions were 120 mm concrete over stiff clay. Pipe location and depth were unknown. This was the second excavation attempt to find the pipe.	Contractors spare parts used for repairs – a number of fittings were in degraded condition. Rubber rings had expired. Cause of leak unknown meaning additional spares may need to obtained.

Figure 20 Field Inspection of Pipelines and Maintenance Work

Figure 21 Collecting Data in Kochi

Summaries of the pipeline data for Kochi are contained in Table 3030 below for each section.

Table 30 Pipeline Length by Section for Kochi

Section	Length (m)	Percent	Percent	Length (m)	Subdivision
Kaloor S1	131,071	10.4%	23.0%	290,102	Kaloor
Kaloor S2	159,030	12.6%			
Karuvelipady S1	132,639	10.5%	20.2%	254,734	Karuvelipady
Karuvelipady S2	122,095	9.7%			
Pallimukku S1	92,009	7.3%	27.8%	350,585	Pallimukku

Pallimukku S2	106,800	8.5%			
Pallimukku S3	151,775	12.0%			
Vyttila S1	104,618	8.3%	29.0%	367,286	Vyttila
Vyttila S2	262,667	20.8%			
Total	1,262,706	100.0%	100%	1,262,706	Total

A range of pipeline materials have been used in developing Kochi's water supply networks. The lengths of these materials for Kochi are shown in Table 311 below.

Table 31 Pipeline Length by Pipeline Material for Kochi

Material	Length (m)	Percent
AC	290,842	23.0%
CI	192,307	15.2%
DI	4,826	0.4%
HDPE	25,986	2.1%
GI	2,825	0.2%
MS	0	0.0%
PREMO	10,925	0.9%
PVC	731,729	57.9%
ASTM	0	0.0%
VITROLI	3,266	0.3%
Total	1,262,706	100.0%

9.2 Pipeline Faults

The KWA records pipeline faults in its Customer Redressal System. Data from the CDR has been extracted for 2017 and analysed. Faults on the KWA's pipeline systems are assigned to one of the following categories.

- HSC: House Service Connections
- Pipe: Pipeline perforation or related matter
- Joint: Pipeline joint leak or related matter
- Valve: Valve leak or operational issue or related matter
- Public Taps: Public Tap malfunction, leak or related matter
- Not Available: Fault cannot be assigned to any of the above categories

When a fault is recorded the material and diameter of the pipe are also recorded and this data has been used to determine the fault rates for different materials and diameters of pipes. Some fault data is recorded incorrectly which means the pipeline in question cannot be identified. This data has been excluded from the pipeline fault analysis.

For the pipeline fault analysis, the data has been grouped as follows.

- **Known Fault**: HSC, Pipe, Joint and Valve Faults – this make up the pipeline system for the supply of water
- **Public Tap Fault**: These are considered to be separate from the pipeline system

- **Unknown Fault**: Not Available – this category may have arisen because when the fault data was recorded but a fault type or fault location was not entered. However, there are also other fault types which exist outside of the above categories. Therefore, while these faults were acknowledged they were excluded from the analysis.

Table 322 show the number of pipeline faults for Kochi for each section.

Table 32 Pipeline Faults for Kochi

Section	Known	Public Taps	Unknown	Total Faults
Kaloor S1	488	0	0	488
Kaloor S2	685	9	0	694
Karuvelipady S1	473	7	0	480
Karuvelipady S2	804	0	0	804
Pallimukku S1	305	0	0	305
Pallimukku S2	123	0	0	123
Pallimukku S3	336	0	0	336
Vyttila S1	183	17	0	200
Vyttila S2	328	1	0	329
Total	3725	34	0	3759
Percentage	100%	0.0%	0.0%	100%

9.3 Pipeline Fault Analysis and Refurbishment Program

The analysis that was undertaken involved the calculation of the number of faults per kilometre of pipeline for each pipeline diameter and material and for each section. A summary of the results may be found in

Table 33 for Kochi city.

The cells in each table have been coloured as follows.

1. Orange: Fault rate is high and corresponding pipelines should be replaced
2. Yellow: Fault rate is approaching high and corresponding pipelines are likely to need replacement within the next seven years
3. Green: Fault rate is medium but corresponding pipelines should be closely monitored
4. Blue: No faults have been recorded
5. Grey: There are no pipelines in this category

It is proposed to replace all pipelines in the red and yellow categories within the first six years of the project. All pipes with a fault rate greater than 2.5 faults per kilometre will be replaced.

Table 33 Summary of the Pipeline Fault Analysis for Kochi (Faults per Kilometre)

Dia	AC	CI	DI	HDPE	GI	MS	PREMO	PVC	ASTM	VITROLI	Length (m)
40								3.3			909
50					245.6			59.1			2,022
63								4.2			488,999
75								10.0			42,130
80	3.0	2.0									11,766
90								6.1			64,088
100	1.0	0.7			0.7						257,012
110				82.4				0.6			78,162
125	0.9	0.1			5.2						20,571
140								0.2			10,987
150	0.7	1.8									49,955
160								0.4			53,636
175		23.0									1,612
180											0
200	0.1			4.5				0.5			31,715
225	1.3	0.1									11,919
250	0.3	0.3									25,800
280											0
300		0.5									45,519
315				0.4							14,325
350		0.1									14,828
375											4,637
400		0.5					0.5				13,983
450											7,861
500							0.3				10,271
Total	290,842	192,307	4,826	25,986	25,986	0	10,925	731,729	0	3,266	1,262,706

The results from

Table 33 have been subjected to a further level of analysis and an example of this analysis follows.

9.4 Replacing Asbestos Cement Pipelines

It is proposed to replace all asbestos cement pipelines. Asbestos cement pipelines present an ongoing occupational health and safety risk to maintenance staff when repairing water mains or making new property service connections and it is proposed to mitigate this risk.

Asbestos pipelines will be left in situ and a new pipeline will be laid along the same route as the old pipeline and care would be taken to ensure a different trench as far as feasible subject to availability of right of way. Asbestos pipelines cannot be replaced using pipe-bursting, pipe-cutting or slip-lining replacement techniques. The property service connection from the pipeline tapping to the edge of the roadway is also to be left in situ, and a new property service connection installed from a tapping in the newly laid pipeline.

A procedure will be developed for replacing asbestos pipelines complying to environmental safeguards and will be included in the bidding documents.

An alternative exists should the KWA consider the full replacement of asbestos cement pipes excessive. In this case the KWA may choose to only replace poorly performing pipes which will reduce the costs of the project. For this study it has been assumed that all asbestos cement pipes will be replaced.

9.5 Pipeline Refurbishment Program Implementation

9.5.1 Pipelines to be Replaced

Combining the pipelines that experience high fault rates and are to be replaced with the replacement of all asbestos cement pipelines results in the proposed pipeline replacement program.

The pipelines to be replaced for Kochi are listed in Table 344. No other pipelines are to be replaced within the first six years of the project.

Table 34 Pipelines to be Replaced in Kochi

Diam (mm)	Material	Section	Faults	Length (m)	Faults/km
Poor Performance Removal					
50	All	All	174	2,022	86.1
75	All	All	418	42,130	9.9
175	All	All	37	1,612	23.0
80	AC	All	25	8,394	3.0
125	GI	All	3	580	5.2
110	HDPE	All	150	1,820	82.4
200	HDPE	All	3	660	4.5
40	PVC	All	3	909	3.3
63	PVC	Kaloor S2	409	73,595	5.6
63	PVC	Karuvelipady S1	181	15,478	11.7
63	PVC	Karuvelipady S2	412	25,403	16.2
90	PVC	All	384	62,871	6.1
63	PVC	Kaloor S1	264	71,171	3.7
63	PVC	Pallimukku S1	189	43,149	4.4
63	PVC	Pallimukku S2	56	15,012	3.7
63	PVC	Pallimukku S3	242	58,704	4.1
Total			2,950	423,510	7.0
AC Pipeline Removal					
90	AC	All	0.0	1,217	0.0
100	AC	All	229.0	225,602	1.0
125	AC	All	4.0	4,372	0.9
150	AC	All	23.0	31,521	0.7
200	AC	All	1.0	8,420	0.1
225	AC	All	3.0	2,327	1.3
250	AC	All	1.0	3,143	0.3
300	AC	All	0.0	1,256	0.0
500	AC	All	0.0	4,398	0.0
Total			261	282,255	0.9

A summary of the pipeline replacement program is given in Table 355.

Table 35 Summary of Pipeline Replacement Program

Item	Kochi
Total Length of Pipeline (m)	1,262,706
Total Number of Faults	3,725

Performance	
Pipeline Replaced (m)	423,510
Percentage	33.5%
Faults Removed	2,950
Percentage	79.2%
AC Removal	
Pipeline Replaced (m)	282,255
Percentage	22.4%
Faults Removed	261
Percentage	7.0%
Total	
Pipeline Replaced (m)	705,765
Percentage	55.9%
Faults Removed	3,211
Percentage	86.2%

9.5.2 Road Openings and Road Reinstatements

The success of the pipeline replacement program is full dependent on the ability of the pipeline replacement contractors to:

1. Cut the roads and excavate trenches for pipelines
2. Cut the roads and excavate trenches for property service connections
3. Lay the pipelines make the tappings and lay the property service connections
4. Backfill and compact the trenches
5. Resurface the roads
6. Work on multiple fronts across the municipal areas
7. Have sufficient continuity of time to efficiently undertake this work

Road openings and road reinstatements are the most critical factor in pipeline replacement programs and a blanket road opening approval (with conditions) will be require prior to the advertising of the bid, as this will be a critical factor in a bidder's pricing.

1. The need for pipe bridges and culverts
2. The impact of construction activities on neighbouring areas and restrictions to working hours
3. Provision of temporary supplies while connections are being changed from old to new pipes
4. The requirement for traffic management and dust mitigation
5. Additional feeder pipes to ensure adequate pressure
6. The temporary patching and subsequent permanent reinstatement of road surfaces after three months
7. Pressure testing of newly constructed pipelines and property services
8. Relevant adjustments to labour rates to allow for the various working conditions experienced.

9. Quality control by the PMC including factory inspection and testing of pipes, the use of approved vendors, plant and equipment, and the mandatory training of staff undertaking various pipeline construction activities
10. Continuous process of pipeline construction community consultation, advanced notice of proposed pipeline construction activities and consultation on pipeline alignments

It is assumed that property service connections will be made at the time a new pipeline is constructed.

It is assumed that property service connections will be made at the time a new pipeline is constructed.

9.5.3 Other Factors

This study has included a number of factors in estimating the cost of pipeline renewals. These factors include the following.

i. The need for pipe bridges and culverts
ii. The impact of construction activities on neighbouring areas and restrictions to working hours
iii. Provision of temporary supplies while connections are being changed from old to new pipes
iv. The requirement for traffic management and dust mitigation
v. Additional feeder pipes to ensure adequate pressure
vi. The temporary patching and subsequent permanent reinstatement of road surfaces after three months
vii. Pressure testing of newly constructed pipelines and property services
viii. Relevant adjustments to labour rates to allow for the various working conditions experienced.
ix. Quality control by the PMC including factory inspection and testing of pipes, the use of approved vendors, plant and equipment, and the mandatory training of staff undertaking various pipeline construction activities
x. Continuous process of pipeline construction community consultation, advanced notice of proposed pipeline construction activities and consultation on pipeline alignments

9.6 Pipeline Materials and Joints

The permitted pipeline materials and joints for pipeline renewals are listed in Table 366 and Table 377.

Table 36 Permitted Pipeline Materials

Pipeline	Material	Specification
Property Service Connections	Medium Density Poly Ethylene	PN10, PE100
Diameters < 250 mm	High Density Poly Ethylene	PN 12.5, PE 100
Diameters ≥ 250 mm	Ductile Iron Cement Lined	Class 125

Table 37 Permitted Pipeline Joints

Pipeline	Joint	Specification

Property Service Connections	Compression	PN16
Tappings	Strap on tapping bands that fully encompass the water main – mechanical or fusion Must contain a valve for controlling the pressure and flow	
Diameters < 50mm	Compression	PN 12.5
Diameters ≥ 50 mm	Butt Welding[29]	PN 12.5
Diameters ≥ 250 mm	Spigot and Socket ('Push-On')	

It is recommended that pipe diameters in the distribution network be standardised.

Table 388 contains a list of HDPE pipes available in the market and the highlighted rows show the recommended sizes to use. A minimum size of DN63 is recommended. Standardising pipe sizes reduces the need to carry large stocks of repairs and simplifies and speeds up maintenance activities.

Table 38 PE Pipeline Diameters

DN[30]	SDR[31]	Wall Thickness (mm)	Internal Diameter (mm)	PN[32]	Material	Max Manufactured Length (m)
20	13.6	1.6	17	12.5	PE100	200
25	13.6	1.9	21	12.5	PE100	200
32	13.6	2.4	27	12.5	PE100	200
40	13.6	3.0	34	12.5	PE100	150
50	13.6	3.7	42	12.5	PE100	150
63	13.6	4.7	53	12.5	PE100	100
75	13.6	5.5	63	12.5	PE100	100
90	13.6	6.6	76	12.5	PE100	100
110	13.6	8.1	93	12.5	PE100	100

The nominal pressure rating of the high-density polyethylene pipe has been recommended to be 12.5 The other option is to select 10.0. The reason PE12.5 has been selected is that it is a stronger pipe. Table 39 shows the maximum allowable pressure for a range of temperatures for the two different nominal pressure ratings. It is acknowledged that the buried pipe is not subject to the same temperature ranges as it would be if it was on the surface. Nevertheless Table 3939 shows that the pressure rating of 12.5 adds a factor of safety to the operation of the pipeline, particularly at higher temperatures.

Table 39 Comparison of PN10 and PN12.5 HDPE Pipe

[29] Butt welding machines must be able to print out the results of a weld and be operated by a person trained and certified in the use of the machine

[30] DN in the nominal diameter in millimetres

[31] SDR is the standard dimension ratio and is the ratio of the outside pipe diameter to the minimum wall thickness

[32] PN is the nominal pressure rating in bars (12.5 is approximately 125 m)

Maximum Allowable Head (PE100)		
Temp (°C)	PN10	PN12.5
20	100	127
25	91	115
30	91	115
35	83	106
40	83	106
45	77	99
50	71	91

9.7 Property Service Connections

9.7.1 Property Service Connection Standard Design

A standard design for a property connection is required and will be developed as part of the bidding documents. Standard designs ensure that the items of work are carried out correctly and minimise maintenance costs. Figure 22 contains two possible standard designs. A standard design will be finalised in consultation with the KWA.

The property service connection comprises four main components which are as follows.

1. Water Main Tapping: the connection of the communication pipe to the water pipeline
2. Communications Pipe: the pipe connecting the water pipeline to the meter assembly
3. Meter Assembly: the infrastructure that connects the communications pipe to a customer's in-property plumbing, supports the meter and facilities the meter reading and the meter replacement
4. Meter: the water meter used to periodically measure the volume of water used

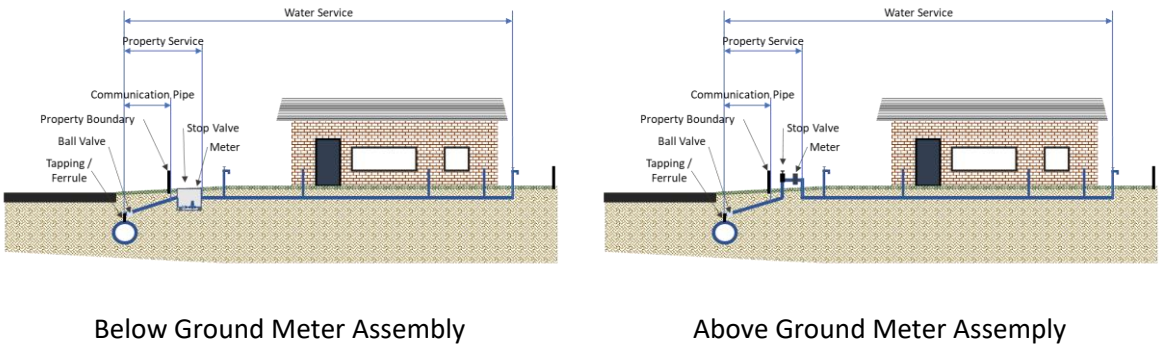


Figure 22 Two Possible Configurations for Property Service Connections

9.7.2 Property Service Connection Replacement Program

The property service connection replacement program comprises three components. These are as follows.

9.7.2.1 Component 1: Water Pipeline Replacement Program

The property service connections (including the water main tapping, communications pipe, meter assembly and meter) are also to be replaced at the time the water pipelines are replaced. The section of the old property service connection from the downstream side of the meter assembly to the edge of the roadway is to be removed. The new property service connection is to be installed up to the proposed new meter assembly at the time the new water pipeline is installed. The transfer from the old property service connection to the new property service connection is to take place

towards the end of the commissioning of the new water pipeline to minimise the interruption of the water supply to customers.

9.7.2.2 Component 2: Meter Replacement Program

For pipelines that are not being replaced the water meter that forms part of the existing property service connection is to be replaced.

9.7.2.3 Component 3: Property Service Connection Maintenance Program

Where a property service connection is not replaced the old property service connection is to continue to be maintained. For example, leaks on the old property service connection are to be repaired. Where a property connection continues to leak despite being repaired several times, or where the property service connection is unable to deliver the required volume of water due to the internal corrosion of the communication pipe, it is to be replaced as part of the ongoing network maintenance program. Eventually all property service connections are to be replaced and a ten-year period from the start of the project has been set to complete these replacements

The number of property connections to be replaced in Kochi is shown in Table 40.

Table 40 Number of Property Service Connections to be Replaced in Kochi

Pipeline Length (m)	1,262,706
Connections (m)	146,564
Length per Connection	8.62
Performance Pipe Replacement (m)	423,510
PSC[33] Replacement	49,157
AC Pipe Replacement (m)	282,255
PSC Replacement	32,762
Total PSC Replacement	81,919
Balance Unreplaced	64,645

Property Service connections are a major source of leaks which contribute significantly to non-revenue water. For example, an early study[34] in Chennai, India found that *the main findings of the Phase II study are that there prevailed 39 percent leaks in ferrules, 31 percent leaks in communication pipes and 39 percent leaks in the mains*. A 'rule-of-thumb' used by non-revenue water specialists is that *up to 80 percent of leaks are in the property service connections[35]*. Hence this project includes a full replacement of all property service connections (over a ten-year period).

9.7.3 Meter Replacement

There are numerous studies that have shown the degree of customer meter under-registration. Figure 4 contained the results of one such study while, to amplify the point Table 41 reports on the

[33] PSC = Property Service Connection

[34] https://books.google.ki/books?id=H_3E2cTUTaUC&pg=PA101&lpg=PA101&dq=leaks+from+property+service+connections&source=bl&ots=_uNC0VepeI&sig=ACfU3U2HgALhMuDhSpr5xu18CT5-xm3p_w&hl=en&sa=X&ved=2ahUKEwj79PCM3J7iAhWYvZ4KHUIaDnYQ6AEwEHoECAgQAQ#v=onepage&q=leaks%20from%20property%20service%20connections&f=false

[35] Personal correspondence

results from a second study[36]. As reported earlier the age profile of Kochi's is not known although interviews with staff members suggest that meters are not replaced at regular intervals. It is proposed to replace all customer meters over the first six years of the project as follows.

1. Meters will be replaced when property service connections are replaced
2. Where a property service connection is not proposed to be replaced for at least one year the meter will be replaced and reused when the property service connection is replaced.

Each meter must contain a unique identifier, be stamped with the date of its manufacture and must achieve the required recording accuracy.

Table 41 Results of a Study into Meter Age and Meter Under-Registration

Meter Age		Number Tested	Error at 35 l/h (%)
0	5	20	-2.6
5	10	20	-8.8
10	15	20	-8.9
15	20	20	-7.9
20	25	20	-19.5
25	30	20	-7.9
30	35	20	-45.1
35	40	20	-36.8
40	45	20	-83.1

When meters are replaced, it is proposed to replace all meters in all commercial, industrial and apartment connections with smart meters.

The types of meters to be used are as follows.

- Domestic Properties: mechanical meters
- Non-Domestic Properties: smart meters
- Bulk Supplies: electromagnetic meters

9.8 Pipeline and Property Service Asset Management

The practice of asset management is the most effective way of ensuring the outcomes from this project are maintained. Asset management is a planning activity and its role is to ensure that the required functionality of the water supply system is efficiently maintained. The two principal outputs from asset management are (1) an asset replacement program and (2) a preventative maintenance program.

The results of this study are essentially asset management results in that the project is aimed at returning the required functionality to the water supply system, which means delivery the required services to the customers in an efficient manner.

All assets must be included in an asset management system. Because it is not proposed to replace all pipes asset management practices become very important in the management of the pipes not

[36] https://www.researchgate.net/publication/38078298_Evaluation_of_the_Apparent_Losses_Caused_by_Water_Meter_Under-Registration_in_Intermittent_Water_Supply

replaced. For example, the analysis if the pipeline and fault data has shown that while some pipes are not recommended for replacement at this stage, they warrant ongoing monitoring. These pipes are listed in Table 422 for Kochi City.

Table 42 Potential Problem Pipes for Kochi

Kaloor S1	110	PVC	2,751
Karuvelipady S1	250	CI	1,182
	90	PVC	11,160
Pallimukku S1	80	CI	705
Pallimukku S3	315	HDPE	1,342
Vyttila S1	63	PVC	43,558
Total			60,700

Asset management involves the ongoing monitoring of asset performance, data collection and analysis and the development of interventions before problems become manifest.

Asset management is the role of the Employer and it is proposed to include an asset management procedure and training as part of this project.

Pipeline and Property Service Scheduling

Table below show the proposed pipeline and property service scheduling for Kochi City. The first year is used to establish the project and put the various information management system in place. The proposed capital works are delivered over the next six years with the aim of achieving a non-revenue water target of 20% by the end of the seventh year. It must be remembered that the first seven years not only undertake the works required to achieve this non-revenue water target but also the processes to ensure it is maintained over the long term.

The estimated reduction in non-revenue water each year is also shown in the two tables. This number may be used as a performance measure. After the target of 20% is achieved in 2026 the non-revenue water volume actually increases again each year. This is the result of the water use increasing while holding the non-revenue water at 20%. An alternative approach is to hold the non-revenue water at a defined volume of water, in which case it will continue to decline as the water use increases. This second approach is not included in this project.

Table 43: Pipeline and Property Service Connection Scheduling for Kochi

PSC = Property Service Connection		1	2	3	4	5	6	7	8	9	10	11	12
Kochi		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Pipeline Replacement (m)	705,765		117,628	117,628	117,628	117,628	117,628	117,628	15,175	15,175	15,175	15,175	
PSC Replacement													
- With Pipeline Replacement	81,919		13,653	13,653	13,653	13,653	13,653	13,653					
- Stand Alone Program	64,645		6,465	6,465	6,465	6,465	6,465	6,465	6,465	6,465	6,465	6,465	
- Total	146,564		20,118	20,118	20,118	20,118	20,118	20,118	6,465	6,465	6,465	6,465	
Customer Meter Replacement													
- With PSC Replacement	81,919		13,653	13,653	13,653	13,653	13,653	13,653					
- Stand Alone Program	64,645		10,774	10,774	10,774	10,774	10,774	10,774					
- Total	146,564		24,427	24,427	24,427	24,427	24,427	24,427					

10 CUSTOMER SERVICES

10.1 Customer Service Processes and Data Collection

The KWA already has in place good customer service facilities. Customer service here includes receiving and resolving enquiries and complaints, connections and disconnections, meter reading and billing, revenue collection and the management of unpaid bills. For this project revenue collection and the management of unpaid bills are not included.

Figure 23 shows the hand held recording and bill issuing device used by the KWA. This is a very efficient way to manage this aspect of KWA's work is not developed further. It is understood that the KWA is updating its hand-held device which is commendable and is not commented on further. The two aspects that are most relevant to this project are as follows.

1. The collection of customer inquiries and complaints, and following up actions, in a manner that that enables this data to be used to inform future asset management activities
2. The collection of water-use records in a manner that enables this data to be used to measure the performance of the water supply system and its assets and to develop interventions as needed

The term 'in a manner' is used to describe both the ability to identify various aspects of the issue in question (such as property address), the ability to process the data and the elimination of data recording errors and to spatially locate the complaint. This is an important set of data to asset managers which can use it to track common issues and adverse trends and develop remedial interventions.

Figure 23 Meter Read Logger and Bill Issued

Figure 24 shows customers queuing up to pay water bills. The process of paying bills, either manually or electronically, are outside of the scope of this project.

Figure 24 Paying Water Bills in Kochi

Given the large amounts of data it is efficient to use computer systems to management customer related work flows. There are many utilities in the world (water, electricity, gas, telephone) all managing customers and there are readily available software packages, now located in the cloud, which can be easily configured and used.

Three process flow diagrams have been prepared and these are shown in Figure 25, Figure 26 and Figure 27. Figure 25 shows how a customer contact is managed. Importantly it shows how this contact feeds through to responsive maintenance. Figure 26 shows how responsive maintenance is managed and importantly how the customer contact is accepted and processed. Figure 26 also shows how the results of the contact feed through to maintenance planning (or asset management). Figure 27 shows the meter reading and billing process and how the data from here also feeds into maintenance planning (or asset management).

The improvement that is recommended in regard to customer service is to ensure the current and future software can perform these functions. This is covered later in this report.

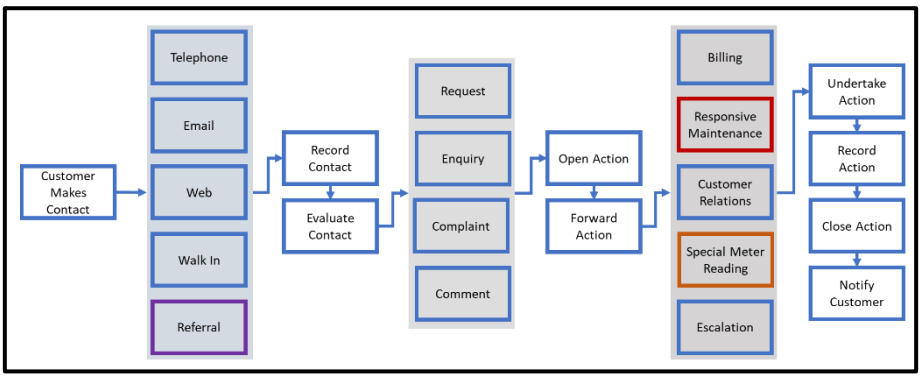


Figure 25 Customer Contact Process Flow

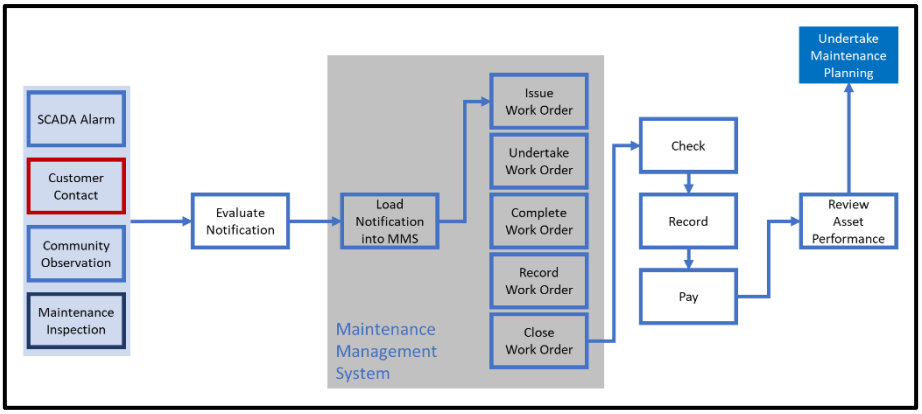


Figure 26 Responsive Maintenance Process Flow

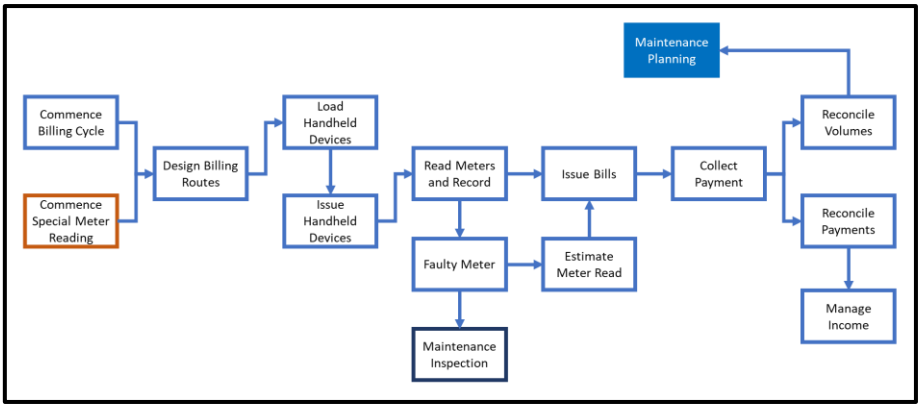


Figure 27 Meter Reading and Billing Process Flow

Although at first appearing a minor part of this project the upgrading of the Customer Redressal System (CDR) forms a critical part of this project. Evidence of this is found on the pipeline analysis found earlier on this report.

10.2 Number and Distribution of Customer Service Centres

Customer service centres play an important role in a water utility as they are a main and direct interface with customers, although the trend is to decrease the number of centres due to their high running cost and to now use the web as the major interface. Figure 28 show the distribution of the customer service centres in Kochi.

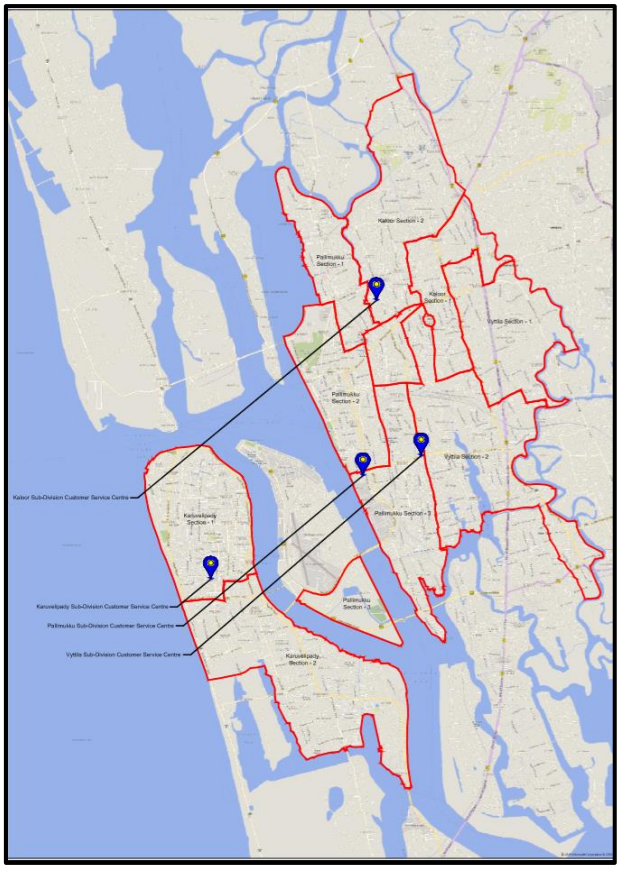


Figure 28 Kochi Customer Service Centres

Table contains a list of the Kochi customer service centres.

Table 44 Customer Service Centres

Customer Service Centre	Sub-Division	Section
Kochi		
Pallimukku	Pallimukku Sub Division	Pallimukku 1, 2 & 3
Karuvelipady	Karuvelipady Sub Division	Karuvelipady 1 & 2
Vyttilla	Vyttilla Sub Division	Vyttilla 1 & 2
Kaloor	Kaloor Sub Division	Kaloor 1 & 2

Table 455 contains a number of customer service centre ratios. Kochi centres can expect to be more congested with approximately 50% more visits however this can be accommodated with greater counter space and service staff, which is an operational issue. From this project's perspective there is no need to increase the number of service centres in either corporation area.

Table 45 Customer Service Centre Ratios

Item	Kochi
Number	4
Population	669,432
Connections	126,026
Area (km^2)	95
People per Centre	167,358

Connections per Centre	31,506
Area per Centre (km^2)	23.8
People per Area	7,047
Connections per Area	1,327

11 Information Management Systems

11.1 Introduction

A study of the KWAs information management systems has been undertaken to determine their ability to support this project. The project requires the following computer-based information management systems.

1. Geographic information system (GIS)
2. Supervisory control and data acquisition system (SCADA)
3. Maintenance management system (MMS)
4. Customer contact management system (CCMS)
5. Meter reading and billing system (MRBS)
6. Laboratory information management system (LIMS)

Of these the KWA has a SCADA, CCMS (CRS), MRBS (eAbacus) and a LIMS.

It was noted that the digital communications between the KWA's section offices and depots and head office was very poor, with computer systems dropping out for extended periods of time. Staff compensated by keeping both computer and paper records, and updating the computer records when at times the computer systems were available. The KWA is obliged to use the Kerala State Wide Area Network (KSWAN) but this network is unable to meet the needs of the water utility.

These information management systems are fundamental to the operation of a contemporary water utility and will greatly assist in controlled non-revenue water. The relationship between these information management systems and the meeting of performance measures if shown in Figure 29.

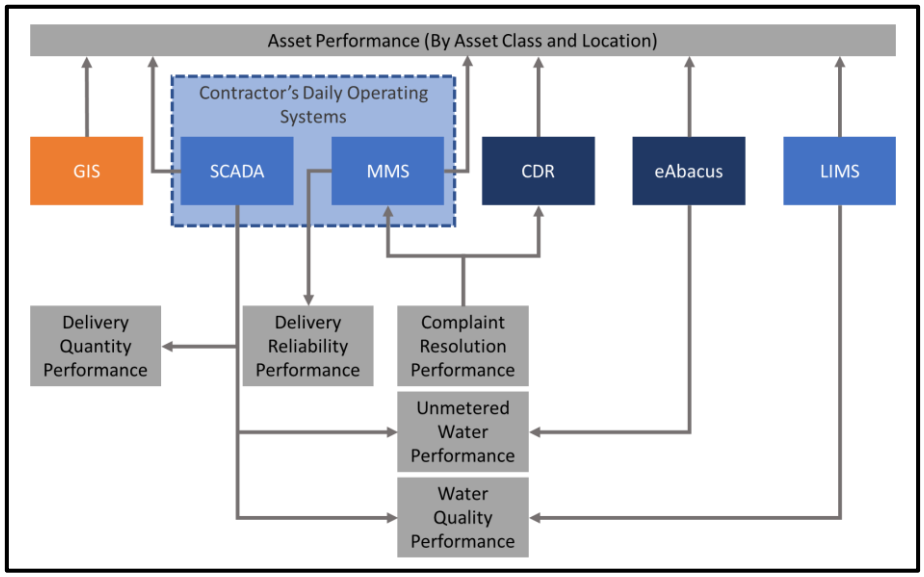


Figure 29 Relationship Between Performance Measures and Information Management Systems

11.2 IMS Investigations

The information management systems were studied to determine whether their respective functionalities and data management routines could support the ambitions of the project. All systems were viewed and background documentation read. Users were also interviewed regarding their experience with the information management systems and opportunities for improvement.

The outcomes of this work and recommendation are summarised as follows.

1. The KWA purchases a maintenance management system.
   The KWA does not currently have a maintenance management system and one must be purchased and configured as a stand-alone MMS preferably as 'software-as-a-service' (SaaS). The MMS should initially be purchased and developed by a maintenance contractor engaged under the KUWSIP. The maintenance contractor should not be permitted to use its own system. When proven and fully operational the MMS can be introduced into the other KWA areas. It is expected that it will take up to twelve months to fully develop a functional MMS aligned the KWA's work flows and procedures, and to train people in its use. This is commensurate with the scope of the KUWSIP. These requirements would be included in the maintenance component of a proposed maintenance contract. The MMS would absorb the KWA's OMS (Operations and Maintenance System used for contractor payments) and most likely its CMS (Contract Management System).
2. The KWA continues to use its Compliant Redressal System (CRS).
   The CRS must be upgraded by modifying its data entry screens and the underlying database structure. The CRS is well used in the KWA and already goes some way to meeting the needs of the KUWSIP. However, a smart data entry system is required, data formats must be refined and the underlying database tables amended to achieve the data storage, retrieval and reporting requirements. A link must be established between the CRS and MMS so that specific information can be exchanged between the two systems. This link may use simple batching, with data transfers occurring several times a day. The maintenance contractor could be given the task of undertaking the CRS upgrade work and establishing the CRS-MMS data exchange system, or it could form a separate package. For reference the CRS is also referred to in the industry as a Customer Contract Management System (CCMS) or a Customer Relationship Management System (CRMS). Modifications made to this system would necessarily apply to all KWA water supply are that use CRS.
3. The KWA continues to use the eAbacus system for meter reading and billing.
   It is understood the KWA is upgrading the meter reading aspect of this system. However, steps should be taken to improve the accuracy of the data by implementing smart data entry and post data entry reconciliations. In addition, the extraction of data and the automated delivery of performance reports should be upgraded. The work should be undertaken with the requirements of the KUWSIP in mind. This work may be undertaken by the maintenance contractor or by the KWA. In the latter case the timing must match that of the KUWSIP. Modifications made to this system would necessarily apply to all KWA water supply areas which use eAbacus.
4. The KWA purchases and implements a new SCADA system.
   The new SCADA system should be a well-recognised and supported brand. It must be an enterprise SCADA system and meet the needs of treatment plant operators, pump station operators, network operators and meter readers. The enterprise SCADA system should first be deployed within the KUWSIP and developed to the extent that it can be subsequently rolled out to other areas of the KWA. This is a key piece of water supply infrastructure that offers many potential benefits and utilising the KUWSIP and the skills of a maintenance

contractor to develop and deploy a new fully functional SCADA system offers an efficient method of achieving a good result.

5. The KWA purchases a new laboratory information management system (LIMS).
   Again, it is recommended that this work be included on that of the new maintenance contractor in a similar manner to the SCADA. This new system would be used by the KWA's laboratories and apply to all of KWAs areas which use the KWA's laboratories. This new system would be very helpful to the water treatment plant operations and the monitoring of water quality delivered to customers.
6. The KWA pursues implementing a GIS over time.
   The matter of a GIS has been examined and it has been recommended that a bureau service be used. A GIS is a major undertaking and has not been included in the KUWSIP. The implementation of a GIS would slow the KUWSIP and not permit it to meet its timeframes. However, what is important is the collection of asset and activity data and it is recommended that this is included in the KUWSIP (many new pipelines will be laid, meters installed and maintenance activities undertaken; all of these will be geo-tagged). This data must be stored in a properly structured database and it is recommended that this work be undertaken by the maintenance contractor.
7. The KWA does not continue with the development of an Enterprise Resource Planning (ERP) system.
   ERPs have a notorious history which is littered with many failures and many disputed contracts. The KWA does not have the prerequisites which are required to design and operate an ERP and the current budgets for time and cost grossly underestimate what are needed. Finally, an ERP is likely to divert funds from much more pressing needs such as those highlighted in these KUWSIP reports. It recommended that the KWA does what it has done in the past and that is to pursue a policy of 'best-in-breed' such as the SCADA and MMS recommended above.
8. The Kerala State Wide Area Network (KSWAN) cannot support the KUWSIP as it is. However, it is recognised that there is an imperative to use this system. Therefore, it is recommended that the information management systems referred to be supported locally by software that both provides a continuous interface to the user while managing interruptions in the background (data held on site and in a corporate location is synchronised). To begin with it is proposed to deploy this in the KUWSIP project area as a pilot and when considered mature the KWA can expand to other areas.
9. One cause of the poor performance of computer systems in subdistrict offices has been identified as the lack of a suitable environment to house information technology infrastructure. It is proposed to provide a suitably equipped computer room in each district and subdistrict office to overcome this deficiency and improve the information systems uptime.

A summary of the required information management systems is contained in Table 466.

Table 46 Summary of Information Management Systems Scope of Works

IMS	GIS	SCADA	MMS	CRS	eAbacus	LIMS
Information Management System	Geographic Information System	Supervisory Control and Data Acquisition	Maintenance Management System	Customer Contact Management System	Meter Reading and Billing System	Water Quality Testing Management System
Function	Capture, store, manipulate,	Monitor and/or control operating	Manage the maintenance of	Manage the process of receiving and	Manage meter reading and the	Manage laboratory test results

	analyse, manage and display spatial	equipment and store and report on operational data	infrastructure and maintenance contractors	resolving complaints and enquiries from the public	subsequent issue of a bill	
Data	Asset Database	Asset Performance Database	Maintenance Activity Database	Customer Enquiries and Complaints Database	Customer Database	Water Quality Database
KUWSIP	New	New	New	Upgrade	Upgrade	New
Software	Bureau Service	Owned	Owned or SaaS	Owned	Owned	Owned or SaaS
Developer	Maintenance Contractor	Maintenance Contractor	Maintenance Contractor	Maintenance Contractor or KWA	Maintenance Contractor or KWA	Maintenance Contractor
Initial Principal User	Maintenance Contractor	Maintenance Contractor	Maintenance Contractor	KWA	Maintenance Contractor	Maintenance Contractor
Roll Out	(1) KUWSIP (2) KWA	(1) KUWSIP (2) KWA	(1) KUWSIP (2) KWA	(1) KWA	(1) KWA	(1) KUWSIP (2) KWA
Hardware Upgrade	KUWSIP Project Areas	KUWSIP Project Areas	KUWSIP Project Areas	KUWSIP Project Areas	KUWSIP Project Areas	KUWSIP Project Areas
Computer Room	Required	Required	Required	Required	Required	Required
KSWAN Augment Software	KSWAN Augment Software	KSWAN Augment Software	KSWAN Augment Software	KSWAN Augment Software	KSWAN Augment Software	KSWAN Augment Software

11.3 Information Management System Scheduling

The first year of the project has been set aside for the establishment of the project. The deployment of these information management systems is included in this establishment. This is an ambitious timeframe and its achievement will require a good working relationship between the Employer and Contractor, and Information Management System suppliers.

One aspect that has to be managed is the tendency to over-specify the functionality to include every potential possibility. One good discipline is to permit only what is referred to as commercial-off-the-shelf (COTS) software and prohibit is customisation. This discipline has proven to deliver software solutions on time and on budget, which is a rarity in the Information Technology world.

Consideration has been given to the likely timeframes required and the schedule shown in Figure 30 is the result.

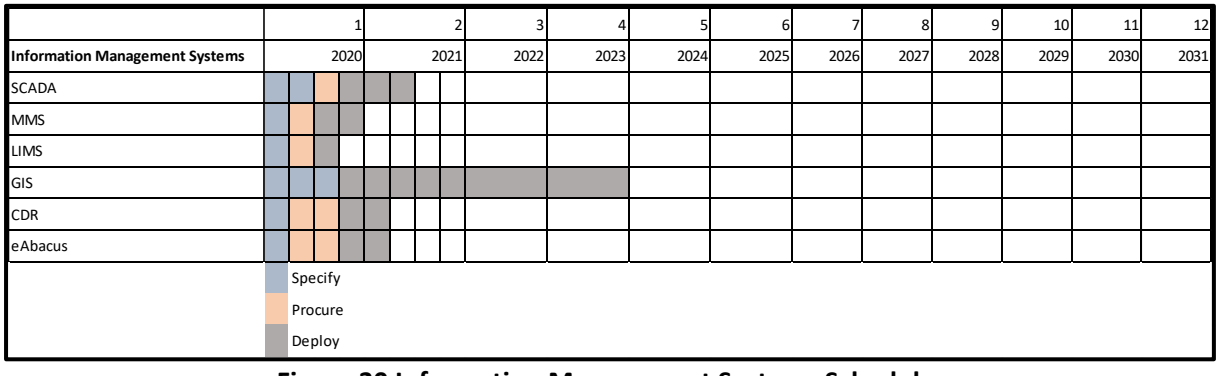


Figure 30 Information Management Systems Schedule

12 SITE IMPROVEMENT WORKS

Generally, the pump station and water treatment plant sites are in poor repair and require refurbishing. There is a significant amount of disused material and equipment found on the sites which is a hazard to personnel using the sites and attracts vermin and snakes. These are not compatible with treatment plants producing drinking water and are not conducive to good quality work.

It is recommended to undertake the site improvement works listed in below Table.

Table 47 Site Improvement Works

Boundary	Fences to be repaired to prevent public access
	Gates to be repaired – must working and lockable
	CCTV at entrance to be installed and connected to SCADA system
	Guard box to be installed
	Roadways to permit good all-weather access
Grounds	Disused material and equipment to be removed
	A proper store is to be provided for spare parts
	Excess vegetation is to be removed
	Pathways are to be upgraded, clearly marked, trip hazards removed
	Lighting to permit safe night access and egress to be installed
	Designated areas for parking to be delineated
	Pedestrian and vehicle movements to be separated
	Shed to be proved for ground maintenance tools
	Rubbish bins and waste management to be provided
Offices	Offices to be cleaned and painted
	Industrial standard floor covering to be installed
	Windows to be repaired, able to open and shut and coated with reflective material
	Offices to be property furnished
	Offices to be air conditioned as appropriate
	Secure vermin proof document store to be provided
	Rubbish bins to be provided
	Offices to be fitted with electrical outlets
	Offices to be fitted with WIFI (4G standard)
Laboratory	Each water treatment plant is to have a secure and laboratory for operational testing
	Each laboratory is to properly equipped and linked to the new LIMS for data recording
	Each laboratory must have associated with it at least two staff training in using the equipment
Amenities	Each site is to have a working laundry and a clothes-drying area
	Each site is to have separate and secure male and female change rooms, showers and toilets
	Each site of to have a clean lunch room and a basic kitchen, refrigerator and cupboards

	Each site is to have enough secure lockers to provide one for each person on site
Buildings	Buildings are to be cleaned and painted inside and outside
	Roofs are to be repaired and sealed
	Minor repairs to walls and doors are to be carried
	Windows are to be repaired and fitted with reflective material and insect proof screens
	Floors are to covered with industrial proof material (as appropriate) and trip hazards removed
	Doors are to be made secure where appropriate
	Guard rails are to be installed in places which are subject to falls
	Chemical storage areas are to be designated and secured from common access
	Rooms contained plant are to be marked as such and access limited to authorised personnel
	Access areas containing chemicals, operating plant or product water to be restricted
Electrical	All electrical installations are to be made safe
	Switchboards are to be fitted with circuit breakers and alarmed
	Old or non-standard switchboards are to be replaced
	Old or non-standard wiring is to be replaced
	Wiring is to be contained in cable trays as appropriate
Communications	Each site is to be fitted with Wi-Fi
	Each site is to have a secure air-conditioned computer room

Figure 31 contains some examples of facilities to be upgraded.

Many trip hazards plus lack of working space

Live switchboard which can only be operated using an insulated tool

Access to dose tank presents a fall from heights hazard

Figure 31 Examples from Field Inspections of Hazardous Working Conditions

12.1 Site Improvement Works Scheduling

Site improvement works are to be carried out in conjunction with pump station and water treatment plant refurbishment and upgrade works.

13 PROJECT BENEFITS

13.1 Tangible Benefits

The tangible benefits come from the following sources.

1. Reduced operating costs as less water has to be treatment and pumped
2. Reduced maintenance costs as network faults are reduced
3. Increased water sales as customer meters better measure the water used
4. Increased water sales as customer use more water as a result of a 24/7 supply and improved water quality
5. Increased water sales as the number of unregistered connections is reduced

Given that it is targeted to reduce non-revenue water from 51% to 20% for Kochi these benefits are substantial. Table 48 show the tangible benefits that come from reducing non-revenue water for Kochi City. The total amount saved for Kochi amounts to Rs 217,005,670 which is an annual saving.

Table 48 Tangible Benefits of Reducing Non-Revenue Water – Kochi

COC Benefit		Current State	Future State	Change	Rate	Benefit (Rs)
System Input Volume	kl	73,564,508	51,470,398	-22,094,110	6.95	153,554,063
Billed Metered Consumption	kl	36,046,609	41,176,319	5,129,710	11.11	56,991,075
Maintenance Items	#	3,725	514	3,211	2012	6,460,532
Total						217,005,670

Another financial benefit not calculated here is the deferment of new capital works (both treatment and transmission works). The above two tables show that the volume of water freed up from having a lower non-revenue water would be 22.1 GL for Kochi per annum. This is enough water service an additional 111,000 household in Kochi.

13.2 Intangible Benefits

The intangible benefits from reducing non-revenue include the following.

- Improved customer service (24/7 pressurised supply)
- Improved water quality (especially in areas of intermittent supply)
- Lower greenhouse gas emissions (less water treatment and pumping)
- Reduction in the use of chemicals (less treatment)
- Reduction in water taken from the environment
- Reduced water in drains and sewers (water leaking from pipes often finds it was into sewers and drains)

There is also a view that actively reducing non-revenue water and celebrating good results improves staff engagement and general well-being.

14 PACKAGING OF WORKS

Five works pages have been developed under the KUWSIP out of which two packages pertain to Kochi City which are listed in table. These works packages may be advertised concurrently or consecutively. Separate bidding documents will be prepared for each of the packages.

Table 49 KUWSIP Works Packages for Kochi City

Package	City	Scope
Works Package 3 Rs. 117.03 Cr	COC	Maintain water treatment plants and associated pump stations and storages Design and build refurbishment work for water treatment plants and associated pumping stations and storages Develop and deploy a Laboratory Information Management System and a SCADA system for the water treatment plants and associated pumping stations and storages
Works Package 4 Rs. 1135.37 Cr	COC	Operate and maintain the water supply networks from downstream of the water treatment plants up to and including the property service connections Design and build refurbishment work for the water supply networks, booster pump stations and storages from downstream of the water treatment plants up to and including the property service connections Read water meters and issue bills Develop and deploy a Geographic Information System, a Maintenance Management System and a SCADA system for the Networks

Cost details for each component and city are presented in Volume II of this report and the drawings are presented as Volume III.

15 APPENDIX A SECTIONAL DATA

Kochi Levels of Service

		Kaloor-Sub division		Karuvelypady Sub division		Pallimukku Sub division			Vyttila Sub division	
Sl No	Parameters	Kaloor-section 1	Kaloor-section 2	Karuvelypady-section 1	Karuvelypady-section 2	Pallimukku-section 1	Pallimukku-section 2	Pallimukku-section 3	Vyttila-section 1	Vyttila-section 2
	Water supply service levels									
1	24 Hours a day	25%		30%	35%	95%	80%	75%	83%	25%
2	18-24 Hours a day	50%	60%	26%	15%		-	20%		5%
3	12-18 hours a day	25%	40%	33%	40%	5%	20%			
4	less than 6 hours a day			11%	10%					
5	Alternate days (22 Hours)							5%	17%	
6	Alternate days (15 Hours)									70%
		100%	100%	100%	100%	100%	100%	100%	100%	100%

Kochi Complaints

	Type	Kaloor-Sub division	Karuvelipady Sub division	Pallimukku Sub division	Vyttila Sub division	Kochi city Total
		Kaloor-section 1 & 2	Karuvelypady-section 1 & 2	Pallimukku-section 1, 2 & 3	Vyttila-section 1 & 2	Total
Leakage	Leaks	67	31	121	62	281
Quality	Bad water	0	2	2	0	4
	Coloured water & Bad smell	0	0	0	1	1
	Contaminated water	0	0	1	0	1
Special	Illegal Consumption of water	1	0	1	0	2
	Misuse of Water	3	2	5	1	11
	Water Theft	2	2	1	3	8
Supply	No supply	1	0	0	0	1
	Short Supply	83	20	189	45	337
	Others	9	14	13	10	46
Sub total	Leakages	67	31	121	62	281
Grand Total	All compalints	166	71	333	122	692

Kochi Materials

		Kaloor-Sub division		Karuvelipady Sub division		Pallimukku Sub division			Vyttila Sub division	
	Materials	Kaloor-section 1	Kaloor-section 2	Karuvelypady-section 1	Karuvelypady-section 2	Pallimukku-section 1	Pallimukku-section 2	Pallimukku-section 3	Vyttila-section 1	Vyttila-section 2
	AC	30847	38150	17424	36752	16132	36951	42830	28351	33392
	CI	7566	12021	57027	20109	12270	49564	25431	5263	13450
	DI	320	0	2783	0	0	0	111	625	315
	HDPE	0	0	0	0	0	296	1525	4068	5067
	GI	0	0	0	0	0	836	1898	0	0
	MS	453	2791	0	0	991	0	26	0	0
	PREMO	1990	3571	0	0	714	229	4035	0	3076
	PVC	36704	78462	36500	55341	42836	15245	56442	70678	137077
Subtotal	AC	30847	38150	17424	36752	16132	36951	42830	28351	33392
Subtotal	HDPE+PVC	36704	78462	36500	55341	42836	15542	57966	74746	142144
Subtotal	CI+DI+MS	8340	14813	59810	20109	13261	49564	25568	5888	13765
Subtotal	PREMO	1990	3571	0	0	714	229	4035	0	3076
Subtotal	GI	0	0	0	0	0	836	1898	0	0

Kochi Pipe Lengths

Diameter	Material	Kaloor-Sub division		Karuvelipady Sub division		Pallimukku Sub division			Vyttila Sub division	
		Kaloor-section 1	Kaloor-section 2	Karuvelypady-section 1	Karuvelypady-section 2	Pallimukku-section 1	Pallimukku-section 2	Pallimukku-section 3	Vyttila-section 1	Vyttila-section 2
Subtotal	40 to180	67,001	115,221	87,703	94,233	55,003	71,358	98,798	97,757	171,078
Subtotal	200 to 315	7,398	12,986	12,255	9,994	10,351	19,928	19,199	9,945	8,793
Subtotal	350 to 900	3,482	6,789	13,775	7,975	7,590	11,834	14,299	1,283	12,505
Total	40 to 900	77,881	134,997	113,734	112,202	72,943	103,121	132,297	108,986	192,377

Kochi Diameters

	Diameter (mm)	Kaloor-Sub division		Karuvelipady Sub division		Pallimukku Sub division			Vyttila Sub division	
		Kaloor-section 1	Kaloor-section 2	Karuvelypady-section 1	Karuvelypady-section 2	Pallimukku-section 1	Pallimukku-section 2	Pallimukku-section 3	Vyttila-section 1	Vyttila-section 2
	40	0	228	0	0	0	0	307	134	0
	50	140	521	0	0	0	0	0	159	427
	63	28,097	53,803	16,292	23,734	29,562	7,618	42,660	38,426	90,741
	75	1,700	1,948	6,072	10,398	2,226	1,678	2,516	1,524	6,488
	80	0	0	5,453	2,294	153	3,182	758	0	187
	90	3,073	7,213	9,516	5,290	3,065	2,055	2,066	11,540	11,168
	100	28,093	33,184	31,084	30,964	12,935	37,620	32,777	20,086	23,917
	110	1,752	6,883	3,562	7,230	3,976	3,575	7,172	10,365	11,600
	125	0	2,137	10,777	0	1,398	6,296	579	404	542
	140	0	0	638	6,499	0	0	257	0	393
	150	2,205	2,960	3,889	5,635	0	8,603	8,204	6,810	6,687
	160	1,942	6,345	420	2,188	1,688	731	1,503	8,308	16,604
	175	0	0	0	0	0	0	0	0	2,324
	180	0	0	0	0	0	0	0	0	0
	200	3,019	4,731	2,686	1,437	3,188	3,392	6,177	1,146	1,881
	225	0	1,069	0	1,530	2,115	2,673	2,393	0	0
	250	1,726	2,319	2,961	4,509	0	1,409	5,002	3,274	1,581
	280	0	0	0	0	0	0	0	0	0
	300	2,653	4,866	6,608	2,518	5,049	12,455	4,103	843	51
	315	0	0	0	0	0	0	1,525	4,683	5,281
	350	257	427	3,327	631	4,273	0	1,181	0	1,596
	360	0	0	0	0	0	490	98	0	0
	375	0	0	3,295	1,898	0	0	0	0	0
	400	565	1,199	0	74	1,193	1,595	1,092	0	4,375
	450	57	0	770	754	586	5,684	3,718	0	59
	500	0	2,372	1,473	0	0	0	789	1,283	5,633
	525	0	0	3,037	0	547	907	3,132	0	0
	600	0	0	1,541	3,648	0	0	0	0	0
	700	1,745	0	330	969	0	0	2,847	0	0
	711	0	0	0	0	0	0	0	0	0
	750	0	0	0	0	0	0	0	0	0
	800	453	2,791	0	0	991	0	26	0	0
	825	0	0	0	0	0	1,529	104	0	0
	900	405	0	0	0	0	1,630	1,313	0	844
Subtotal	40 to180	67,001	115,221	87,703	94,233	55,003	71,358	98,798	97,757	171,078
Subtotal	200 to 315	7,398	12,986	12,255	9,994	10,351	19,928	19,199	9,945	8,793
Subtotal	350 to 900	3,482	6,789	13,775	7,975	7,590	11,834	14,299	1,283	12,505
Total	40 to 900	77,881	134,997	113,734	112,202	72,943	103,121	132,297	108,986	192,377

Kochi Historic Population

Population of Kochi										
1911	1921	1931	1941	1951	1961	1971	1981	1991	2001	2011
14%	7%	25%	19%	19%	22%	27%	17%	11%	9%	6%
135,151	145,084	180,746	215,576	256,341	312,557	398,478	467,933	521,371	570,119	602,046

Kochi Water Use 2017

		Kaloor	Karuvelypady	Pallimukku	Vyttila	Total
Connections	Industrial	11	152	49	17	229
	Domestic	27,181	42,174	25,920	30,810	126,085
	Non-Domestic	3,986	3,046	8,833	4,384	20,249
	Special	0	0	1	0	1
	Total	31,178	45,372	34,803	35,211	146,564
Water Use (kl)	Industrial	17,275	225,888	66,307	11,427	320,897
	Domestic	5,531,818	7,511,928	6,005,500	6,740,383	25,789,629
	Non-Domestic	1,673,129	1,128,860	5,478,833	1,654,541	9,935,363
	Special	0	0	720	0	720
	Total	7,222,222	8,866,676	11,551,360	8,406,351	36,046,609
Water Use per Connection (kl)	Industrial	1,570	1,486	1,353	2	1,401
	Domestic	204	178	232	1	205
	Non-Domestic	420	371	620	1	491
	Special	-	-	720	-	720
	Total	232	195	332	239	246

Kochi Water Charges

Item		Pallimukku	Karuvelpady	Kaloor	Vyttila	Total
Connections	I	11	152	49	17	230
	D	27,178	42,187	25,904	30,756	126,026
	N	4,181	3,036	8,836	4,376	20,429
	S	0	0	1	0	1
	T	31,371	45,375	34,790	35,149	146,685
Water Rate Charge	I	2,066,845	6,121,036	717,583	495,939	9,401,403
	D	70,202,969	66,123,121	74,404,339	75,728,042	286,458,471
	N	252,618,858	42,211,662	83,094,196	67,011,815	444,936,531
	S	2,535	0	0	0	2,535
	T	324,891,207	114,455,819	158,216,118	143,235,796	740,798,940
Fixed Charge	I					
	D					
	N					
	S					
	T					
Water Rate Charge Per Connection	I	182,369	40,182	14,720	28,750	40,935
	D	2,583	1,567	2,872	2,462	2,273
	N	60,418	13,905	9,404	15,314	21,780
	S	0	0	0	0	2,535
Total Water Charge Per Connection	**I**	182,369	40,182	14,720	28,750	40,935
	D	2,583	1,567	2,872	2,462	2,273
	N	60,418	13,905	9,404	15,314	21,780
	S	0	0	0	0	2,535
	T	10,357	2,522	4,548	4,075	5,050
Water Use (kl)	I	66,307	225,888	17,275	11,427	320,897
	D	6,005,500	7,511,928	5,531,818	6,740,383	25,789,629
	N	5,478,833	1,128,860	1,673,129	1,654,541	9,935,363
	S	720	0	0	0	720
	T	11,551,360	8,866,676	7,222,222	8,406,351	36,046,609
Total Water Charge Per Water Use	**I**	31.17	27.10	41.54	43.40	29.30
	D	11.69	8.80	13.45	11.23	11.11
	N	46.11	37.39	49.66	40.50	44.78
	S	3.52	0.00	0.00	0.00	3.52
	T	28.13	12.91	21.91	17.04	20.55

Kochi Compliance with Minimum Chlorine Levels

Karuvelipady	Kaloor	Vyttila	Pallimukku	Total
91%	77%	84%	100%	89%