ADB

Technical Assistance Consultant's Report

Project Number: 45148
February 2014

Sri Lanka: Capacity Development for Non-Revenue Water Reduction Project
(Financed by the Water Financing Partnership Facility)

Prepared by:

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For the Ministry of Urban Development, Water Supply and Drainage

Asian Development Bank

TA 45148 SRI – Capacity Development for Non-Revenue Water Reduction Project

FINAL REPORT (FEBRUARY 2014)

Project Number 120816

Prepared for National Water Supply and Drainage Board FEBRUARY 2014

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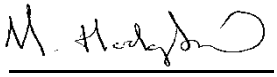
	Draft		Signature	
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EXECUTIVE SUMMARY

Colombo City has been operating with a persistently high level of Non- Revenue Water (NRW). In response the Board, with support from the Asian Development Bank (ADB), is preparing a major investment programme with the aim of reducing NRW to below 18% by the year 2020.

In May 2013, ADB commissioned NRW Specialists to undertake a 'capacity development' project. Outcomes from the project can be summarised as follows:

Colombo City 'Supply Zone':

System input for the city is reported by 16 bulk flow meters including:

Ultrasonic meters (large transmission mains): The majority of these meters were installed in recent years however a few older generation (Flutech) meters are still in use remote from the city boundary.

Mechanical meters (smaller distribution mains): Generally in very poor condition and past their useful asset life.

A programme of meter replacements to improve the measurement of system input has been incorporated into the investment programme and is expected to be implemented in 2014.

The city boundary is largely defined by waterways and is consequently generally robust. However there are a number of areas were problems with the boundary have been identified:

1. The hydraulic boundary is not completely secure;
2. The billing system is not aligned with the hydraulic boundary; and
3. There is considerable uncertainty about the GIS data.

The issues and preliminary corrective actions have been identified.

Baseline NRW:

A water balance has been completed using the best available data and based on the current understanding of network configuration. Issues affecting confidence in the outcomes of the balance have been clearly documented.

The calculation of NRW is believed to be reasonably robust with **NRW estimated at 50,984Ml per annum or 48% of Water Into Supply**.

This is in line with the official estimate of NRW reported by NWSDB for the same period (49%).

Analysis of the NRW concludes that Real Losses (leakage) is the predominant component accounting for nearly three quarters of NRW. Typical performance indicators based on the analysis are:

Infrastructure Leakage Index (ILI):	47
Burst Losses:	820 l/connection/day

However Apparent Losses are also significant accounting for over one quarter of NRW.

DMA Design:

The DMA have been re-designed under the project to exclude trunk mains and relocate the district meters onto the branch lines. None the less the DMA design should be viewed as preliminary and further design work is required. In particular;

1. Undertaking site surveys of the critical meter locations; and
2. Reviewing boundary design to minimise potential network impacts.

It is important that confidence in the DMA design is improved prior to beginning detailed pipe design.

Strategy Issues:

Under the investment programme Active Leak Control (ALC) is generally deferred until late in the programme after DMA setup. It is recommended that an earlier and wider response is considered.

A customer meter replacement policy based on economic replacement frequencies should be included in the investment programme.

The current strategy is over reliant on the use of %NRW to measure progress. Key Performance Indicators (KPI) should be adopted to give a more meaningful measure of progress and support project management decisions.

Change Management Issues:

The Operations Group 'roles and responsibilities' (with respect to NRW) have been clarified and some resource issues identified to support change management.

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1.0 INTRODUCTION

1.1 BACKGROUND

Colombo City has been operating with a persistently high level of Non- Revenue Water (NRW). Approximately half of system input is currently lost to NRW. In response the Board has undertaken a series of initiatives and, with support from the Asian Development Bank (ADB), is preparing a major investment programme with the aim of reducing NRW below 18% by the year 2020.

In May 2013 ADB commissioned NRW Specialists to undertake a capacity development project. The "Capacity Development for NRW Reduction Project" has five distinct outputs which can be briefly described as follows:

Baseline NRW level: A 'baseline' Water Balance has been prepared based on the best available information and the current understanding of network configuration (Section 3). NRW has been calculated and analysed and recommendations have been made for improving confidence in future balances (Section 4);

Review of DMA design: The original (Master Plan) DMA design has been reviewed and revised. Comment and recommendations on the 'revised' design are presented in Section 5;

Training workshops: Training workshops were provided on the IWA Water Balance, DMA concepts and change management awareness (Section 6);

Document review: A review of existing project documentation was undertaken with particular emphasis on the tender documentation for the future investment programme. Comments on NRW strategy are included in Section 7; and

Change management issues: A number of change management issues were identified and comments and recommendations are included in Section 8.

The project has a nominal 9 month programme and commenced in June 2013.

1.2 KEY PROJECT DATA

Assignment:	TA45148-SRI: Capacity Development for NRW Reduction Project
Key Officers Reporting:	Project Director – Mr S. A. Rasheed Team Leader - Mr Mark Hodgson ADB Coordinator - Mr Mingyuan Fan
Mobilization Date:	3rd June 2013
Length of Services:	9 months
Value:	US$ 154,904 (Variation 1)
PMU Office:	Project Management Unit Office 37 Kirulapone Avenue Colombo 05 Sri Lanka

1.3 PURPOSE OF REPORT

The Final Report summarises the conclusions and outcomes of the project.

2.0 PROJECT DELIVERY

2.1 INTRODUCTION

The project commenced in July 2013 and was delivered by a small project team located in the local Project Management Unit (PMU) office. Co-location with the PMU allowed a high degree of integration with good lines of communication. Local staff provided support throughout the project assisting with project coordination as well as providing technical support in areas such as GIS.

In the early stages of the project a number of formal meetings was arranged to clarify the TOR and coordinate day to day activities. The later stages of the project were managed by more informal discussions with the Project Director, Mr S.A. Rasheed and facilitated by the routine daily contact with and members of his team.

Meetings were conducted with a wide range of NWSDB staff to collect information and discuss issues arising under the project. The RSC-WC Operations Group participated in meetings and discussions throughout the project with particular support coming from the NRW Unit.

Aspects of project delivery relating to specific tasks are discussed in the following sections.

2.2 BASELINE NRW

Establishing a 'baseline' NRW level was seen as the primary output of the project.

The assessment of NRW is a simple calculation which has been routinely undertaken and reported by NWSDB for a number of years. Although the establishment of the 'baseline NRW' is a simple arithmetic calculation, the accuracy of the input data is critical. Consequently work focused on the validity of the applied water balance and the understanding of the data that supports it. The intention was to address two questions:

How confident are we that the figure reported is accurate?

What steps need to be taken to improve confidence in that accuracy?

A range of investigations were undertaken focused on three areas;

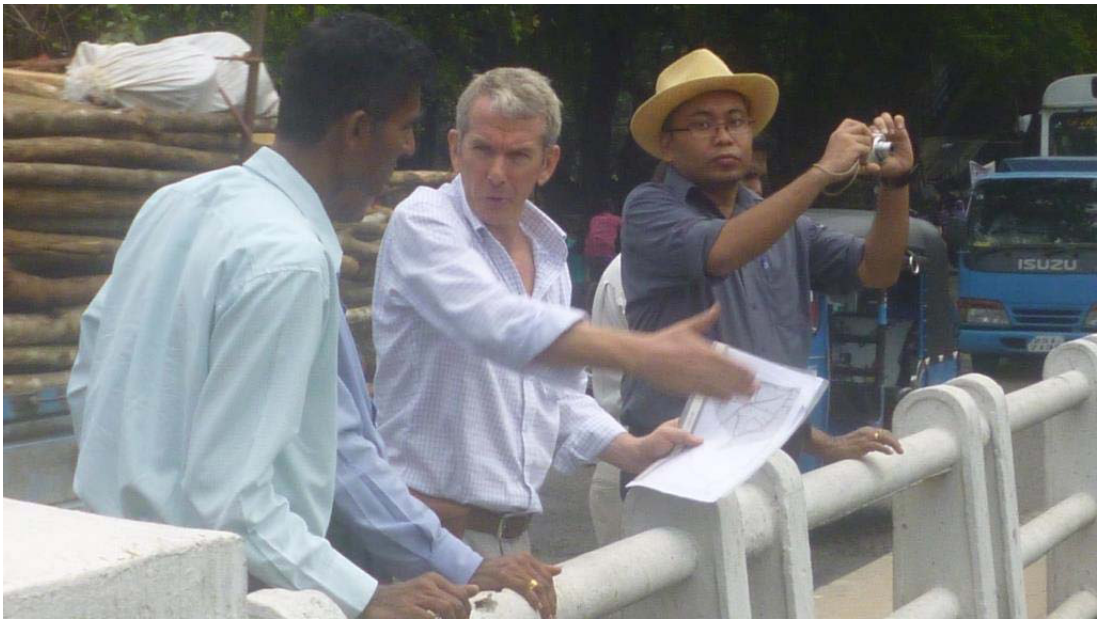
1. The accuracy of 'System Input Volume';
2. The security (and definition) of the Supply Zone boundary; and
3. The assessment of 'Authorised Billed Consumption'

Particular tasks undertaken included:

Meetings were held with the NRW Manager, Mr Rajkumar, and the NRW team to discuss their approach to the water balance (NRW calculation) and to confirm the understanding of system input meter configuration. A number of meetings were also held with the Commercial Manager, Mr ADGC Kariyapperuma, to discuss customer billing and data handling.

A joint site visit was arranged with the NRW team to inspect the system input meters. The visit focused primarily on the condition of flow meters and was used to assess the validity of data for water balance as well as confirming the bid document for proposed meter replacement (CWSSIP/ADB/SIM/ICB/05).

Site Visit to Inspect System Input Meters



Joint meter readings were undertaken with the NRW team from June to September to confirm the validity of the readings and gather a consistent data set for use in the 'baseline' water balance.

A GIS study was undertaken to identify the key features of the Colombo City Water Supply Zone including System Input meters and the boundary valves and to identify any breeches in the boundary. A series of meeting was arranged with the relevant Officers In Charge (OIC) to discuss the findings and access local knowledge. This work is on-going.

A discussion of the conclusions is presented in Section 3 and a detailed water balance is presented in Section 4.

2.3 REVIEW OF DMA DESIGN

The original 'Master Plan' DMA design was reviewed early in the project and preliminary outcomes were discussed in the Inception Report. A number of significant issues were identified and, as a result, the design was substantially reworked.

The revised design has been the subject of a high level review based on the statistics available at the current time. It must be stressed that a detailed (DMA by DMA) review of the design has not been undertaken under the current contract. The detailed review of individual DMA forms part of the TOR for the MASC.

A brief discussion of the outcomes is presented in Section 5.

2.4 TRAINING

The purpose of the training was to support the change management process and facilitate smooth implementation of the investment programme. Training needs were assessed following discussions with various stakeholders including meetings with the AGM for training Mr Jaliya Seekkuge. The training was focused on two key areas:

1. Technical awareness: NRW and DMA concepts and associated technologies
2. Change awareness: sensitisation to change and change management concepts

Participant Profile: a total of 137 persons have participated in training programme to date. Participants were predominantly drawn from the RSC-WC Operations Group but also included personnel from the wider NWSDB organisation and a small number of local ADB consultants and staff.

Trainers and Facilitators: principal trainers were:

Technical Training:	Mr Mark Hodgson (Team Leader & NRW Specialist)
Change Management:	Mr Gamini Kudaliyanage (Change Management & Training Specialist)
	Co Trainer Mr Darsana Ranatunga.

Additional support and facilitation on the change management programme was provided by the Mr. S.A. Rasheed (Project Director of CDTA) and Mr. Thilina Wijethunga (DGM / ADB Project).

Training programmes were conducted on a participatory framework. Presentations were made in both English and Sinhala. Participants were encouraged to ask questions in Sinhala.

Discussion Session at Change Awareness Workshop

An outline of the workshops and a summary of recommendations for further training are provided in Section 6.

2.5 DOCUMENT REVIEW

A full list of the documents supplied to the project team is given in Table 2-1.

The documents supplied were used to provide general background information and data for other aspects of the project. The primary focus of the review was the critical bid documents, in particular;

- Supply and Installation of SIV Meters etc;
- Supply and Delivery of Equipment for ALC Activities; and
- System Rehabilitation for NRW Reduction

Technical feedback and advice on the bid documents was provided to the relevant engineers. In addition the project team leader has been extensively engaged in meetings and discussions on the tender process. The outcomes of the review were incorporated into the tender documentation.

Recommendations on strategy are included in Section 7.

2.6 CHANGE MANAGEMENT

A series of meetings have been held with various stakeholders to discuss the change management impacts of the investment programme with particular emphasis on the 'Operation Group' for Colombo City and the need for reorganisation during and after DMA implementation.

Some comments and recommendations on change management issues are included in Section 8.

Table 2-1 Project Document Register

Item	Received	Main Title	Sub Title	Volume	Issued	Type
1	7 Jun 2013	Western Province Water Supply Master Plan Update	Master Plan Draft Final Report	Vol I to VIII	Mar 2013	Report
2	7 Jun 2013	Colombo Water Supply Service Improvement Project (Project 1)	Main Report	Vol 1	Nov 2012	Report
			Appendices & Annexes	Vol 2	Nov 2012	Report
3	7 Jun 2013	Supply and Delivery of Equipment for ALC Activities			May 2013	Bid
4	7 Jun 2013	Supply and Installation of SIV Meters			May 2013	Bid
6	12 Jun 2013	System Rehabilitation for NRW Reduction in North of Colombo City	Employers Requirements	Vol 11 of IV		Bid
			Bill of Quantities	Vol 111 of IV		Bid
7	17 Jun 2013	Consultancy Services for NRW Engineering Study, Master Plan Update and Institutional Development Project	NRW Engineering Study Main Report	Vol 1	May 2013	Report
			Development of Water Loss Management Strategies	Vol 2	May 2013	Report
			Leak Detection and Pipe Repair Manual	Vol 3.1	May 2013	Report
			New Connection Procedure Manual	Vol 3.2	May 2013	Report
			Water Meter Selection Manual	Vol 3.3	May 2013	Report
			Pipe Selection Manual	Vol 3.4	May 2013	Report
8	18 Jun 2013	Capacity Development project for NRW in Colombo City (JICA)	Project Completion Report		Nov 2012	Report
9	19 Jun 2013	Colombo Water Supply Service Improvement Project (Project 2)	Main Report	Vol 1	May 2013	Report
			Appendices & Annexes	Vol 2	May 2013	Report
10	20 Jun 2013	Greater Colombo Water and Wastewater Management Improvement Program –Project 2	Project Administration Manual		June 2013	Report
11	1 Jul 2013	Master Plan Update and Institutional Development Project	HR Management & Role Effectiveness of NRW Staff	Chapter 7		Report
12	31 Jul 2013	USAID: Impact Evaluation of Water and Sanitation Sector Project			Nov 1993	Report

3.0 COLOMBO CITY SUPPLY ZONE

3.1 OVERVIEW OF COLOMBO CITY ZONE

The Colombo City 'supply' zone is effectively an administrative area based on the Colombo Municipal Council (CMC) boundary. The boundary is essentially geographic in nature being largely defined by water with the coastline to the west and the Kalani River to the east.

All major system inputs are metered and there are no bulk exports. However the zone is not hydraulically discrete with various distribution lines crossing the boundary. None the less the boundary is reasonably robust as the geographic features restrict mixing with adjacent zones.

The boundary is defined by a number of key features as illustrated in Figure 3-1 including:

- System Input Meters (see Section 3.2); and
- Boundary Valves (See Section 3.4)

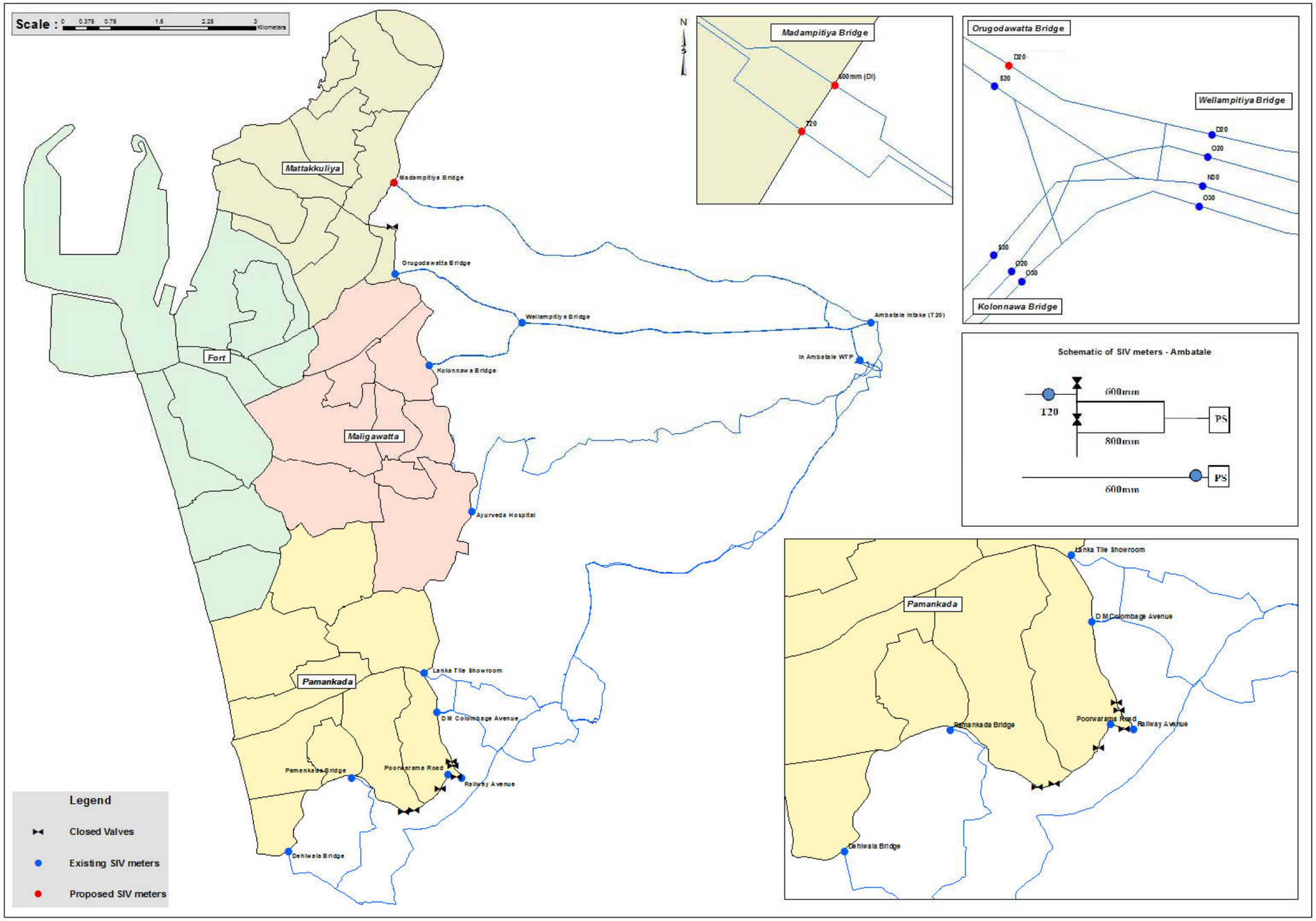
The zone is managed as four autonomous areas (with distinct and coincident billing areas) each administered from a separate Area Office:

1. Mattakkuliya;
2. Maligawatta;
3. Pamankada; and
4. Fort

The four areas are heavily interconnected with no metering of bulk flows in or out.

The NRW for Colombo City is calculated monthly using a rolling 12 month balance based on data supplied by the NRW Team (SIV) and the Commercial Team (Billed Consumption). The DGM for Corporate Planning, Mr George, maintains and publishes 'island wide' NRW figures, including the figure for Colombo Metropolitan City (CMC), in the MI Report. NRW is typically expressed as a percentage.

Figure 3-1 Key Features of Colombo City Water Balance



3.2 COLOMBO CITY SYSTEM INPUT METERS

3.2.1 Condition of System Input Meters

The system inputs can be viewed as a mixture of large diameter transmission lines (feeding the service reservoirs) and smaller diameter distribution mains. Flow measurement for Colombo City currently utilises three distinct types of meter:

1. In-line Ultrasonic Meters: these are mains powered and situated on pipe bridges on the larger diameter transmission mains (typically >500mm);
2. Mechanical (helix) Meters: installed in chambers on the smaller diameter distribution mains (typically <300mm); and
3. Electromagnetic (EM) Meters: a single mains powered EM meter is used to report production from the new 600mm line at Ambatele treatment plant.

A site inspection of the system input meters was undertaken on 13th June 2013 with follow up site visit to Ambatele on 27th June. The inspection was primarily focused on meter condition. Key observations and recommendations are summarised in the following section. Details of the meters are summarised in Table 3-1.

Ultrasonic Meters: Two makes have been utilised:

1. PicoSonic - installed by the NRW team since 2008 with the most recent installed this year; and
2. Flutech – installation dates are not available however these are significantly older than the PicoSonic meters and are remote from the city boundary. These meters have been steadily superseded by the newer PicoSonic meters.

It should be noted that 'in-line' Ultrasonic meters do not represent the most accurate metering option available. These meters are highly sensitive to installation effects and meter accuracy is dependent on the precision of the installation of the Ultrasonic probes. At some sites controlling the installation to maintain optimum accuracy will be challenging and it is essential that experienced engineers are employed for this work. However the use of full bore EM meters on large diameter transmission mains is both very costly and disruptive. Consequently the use of Ultrasonic probes at these locations represents a reasonable meter selection and the meters should be considered fit for purpose.

It is recommended that an annual verification procedure is put in place to confirm and maintain performance of the Ultrasonic meters. It is understood that all sites have insertion points suitable for use with insertion probes which could provide a suitable basis for a verification procedure. Verification should be based on a direct comparison utilising a minimum of 24 hours data logged at 15 minute intervals.

The older Flutech meters are remote form the Colombo City boundary and consequently do not provide a direct measurement of flow into the zone. The NRW Team has been installing new ultrasonic meters directly on the city boundary to eliminate the risk of errors resulting from un-metered connections off the transmission lines distorting the water balance. Only two of the older Flutech meters are still used in the CC Water Balance and plans to replace and relocate these meters are well advanced. **It is recommended that new Ultrasonic meters are installed on the city boundary as proposed by the NRW team**.

Table 3-1 System Input Meters

Name (location)	Pipe Details	Meter Type	Make & Model	Flow (m^3/hour)	Comments
Dehiwala Bridge	10 CI	Mechanical	Kent Helix 3000	118	
Pamankada Bridge	30 CI	Ultra Sonic	Pico Sonic	1,070	
Railway Avenue	6 CI	Mechanical	Elster	9	Reporting very low flow
Poorvarama Road	250 CI	Mechanical	Kent Helix 3000	68	Subject to routine flooding
DM Colombage Mawatha	300 DI	Mechanical	Elster	60	
Lanka Tile (Nawala Road)	700 DI	Ultra Sonic	Pico Sonic	1,659	
Ayurwedic Hospital - Point A	200 DI	Mechanical	Schlumberger	21	
Ayurwedic Hospital - Maragasmulla	200 DI	Mechanical	Schlumberger	39	
Wellampitiya Bridge D20	20	Ultra Sonic	Flutec	932	
Wellampitiya Bridge O20	20	Ultra Sonic	Flutec	807	Superseded by Kolonnawa Bridge (see 3.2.2)
Wellampitiya Bridge N30	30	Ultra Sonic	Flutec	3,186	Superseded by Kolonnawa Bridge (see 3.2.2)
Wellampitiya Bridge O30	30	Ultra Sonic	Flutec	2,478	Superseded by Kolonnawa Bridge (see 3.2.2)
Kolonnawa Bridge N30	30	Ultra Sonic	Pico Sonic	2,469	
Kolonnawa Bridge O20	20	Ultra Sonic	Pico Sonic	579	
Kolonnawa Bridge O30	30	Ultra Sonic	Pico Sonic	2,231	
Orugodawatta Bridge S20	20	Ultra Sonic	Pico Sonic	597	
Orugodawatta Bridge D20	20	Ultra Sonic	Pico Sonic		Recent installation – no data available
Elie house supply from Ambatale T20	20	Ultra Sonic	Flutec	972	
Elie house supply from Ambatale PS N600	600	Electro Magnetic (EM)	Endress Hauser	1,363	

Mechanical Meters: A number of different models are being utilised (for details see Table 3-1) with a wide range of installation dates. It is noted that all of these meters have been installed in line (without out bypasses) and there was no evidence of any routine maintenance being carried out.

With the exception of the two Elster meters which were manufactured in 2008 the mechanical meters are generally in poor condition. Installation dates are not available however visual inspection and the meter types (H3000 ceased to be manufactured in the mid 1990's) suggests these meters are at least 20 years old and should be considered beyond the end of their asset life. Meter accuracy will have been impaired with the meters subject to significant levels of under recording.

Dehiwalla Bridge Kent H3000

It was noted that one of the Schlumberger meters was visibly and severely stalling during the site visit.

Of the two newer Elster meters; the meter on Colombage Road shows a clear installation defect. All meters are required to be installed on straight pipe and any distortion in the pipe in close proximity to the meter will inevitably result in impaired performance.

Colombage Road - Installation defect

The remaining Elster meter is installed on a 6" distribution line at Railway Avenue with relatively low flow. It is desirable to close and ultimately eliminate distribution lines crossing the boundary. **It is recommended that this meter is removed following re-design of the Pamankada boundary (see 3.4.3).**

Otherwise all mechanical meters should be replaced with modern full bore EM meters.

Electromagnetic (EM) Meters: A mains powered Endress Hauser meter is utilised to report flow on the 600mm line from Ambetele treatment plant. In general mains powered EM meters represent the most accurate metering option commonly in use in the water industry. However to deliver the optimum accuracy these meters must be installed correctly with the required minimum straight lengths (typically 5D and 2D). As can be seen below the meter at Ambetele is attached directly into the outlet of the surge vessel and consequently there will inevitably be some loss of accuracy.

Ambatele Production Meter – Installed without necessary straight lengths

As previously noted this meter is remote from the city boundary and under current proposals will be replaced in the Colombo City Water Balance with a new ultrasonic installation at Sedawatta Bridge. Consequently no further action is required under the investment programme.

3.2.2 Configuration of System Input Meters

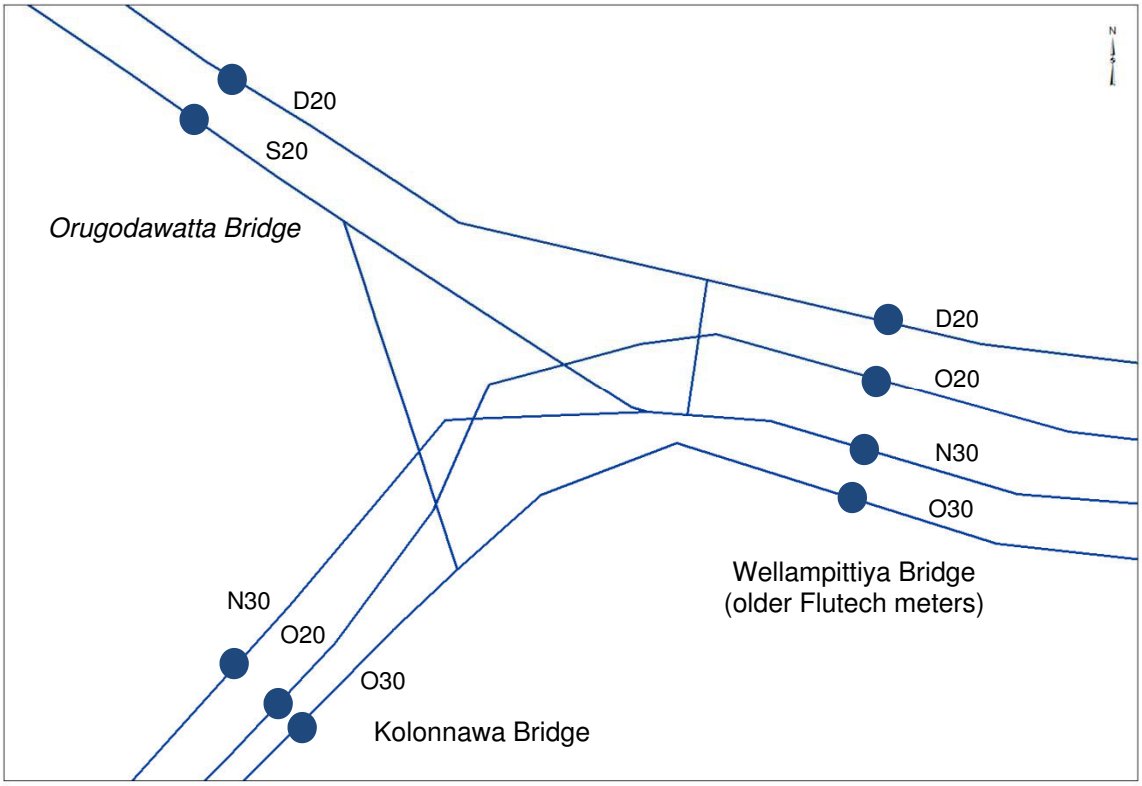
Historically the system input was derived from a total of 22 meters. Over recent years the NRW team has been refining the calculation of system input by

- Relocating some of the larger meters to positions coincident with the city boundary; and
- Eliminating some of the smaller diameter meters and replacing with closed valves.

As a result the calculation of SIV has been changing as new meters have been introduced and some older small diameter meters have been eliminated. At the beginning of 2013 system input was derived from a total of 15 meters.

At the time of the current study the calculation of system input is in a state of transition. In particular the older Wellampittiya Bridge meters are currently being superseded by new installations at Kolonnawa Bridge and Orugodawatta Bridge as illustrated in Figure 3-2.

Figure 3-2 Wellampittiya Transmission Lines & Meter Configuration



Consequently the reporting of system input through the Wellampittiya transmission lines has changed since the beginning of 2013 as the new meters were brought on line. The different meter configurations can be summarised as follows:

Original Configuration	*Current Configuration*	*Final Configuration*
Wellampittiya bridge D20	Wellampittiya bridge D20	~~Wellampittiya bridge D20~~
Wellampittiya bridge O20	~~Wellampittiya bridge O20~~	~~Wellampittiya bridge O20~~
Wellampittiya bridge N30	~~Wellampittiya bridge N30~~	~~Wellampittiya bridge N30~~
Wellampittiya bridge O30	~~Wellampittiya bridge O30~~	~~Wellampittiya bridge O30~~
	Kolonawwa Bridge N30	Kolonawwa Bridge N30
	Kolonawwa Bridge O20	Kolonawwa Bridge O20
	Kolonawwa Bridge O30	Kolonawwa Bridge O30
	Orugodawatta Bridge S20	Orugodawatta Bridge D20
		Orugodawatta Bridge S20

Under the original configuration a total of 15 input meters were required to calculate system input. Under the current (and final) configuration System Input Volume is the sum of 16 system input meters.

Moving the system input meters onto the city boundary will eliminate any errors in the calculation of SIV resulting from un-metered connections off the transmission lines before Colombo City.

Two further meters are included under the investment programme for installation at Sedewatta Bridge. These installations will supersede the Ambetale meters allowing flow on the T20 and N600 lines to be recorded directly at the city boundary.

All meters are manually read every month to provide the System Input Volume for the Water Balance. Manual reading has two inherent sources of error:

1. As the readings are taken over the course of a working day the period is not precisely aligned with the period of the water balance; and
2. Manual readings are prone to meter reading and data handling errors as data is transferred from site to the Water Balance

It is recommended that all SIV meters are fitted with GSM enabled data loggers to facilitate automatic meter reading and improve the calculation of System Input Volume.

3.3 COLOMBO CITY BILLING

3.3.1 Condition of Customer Meters

Customer meters are known to be generally in poor condition (see Master Plan Update).

Currently NWSDB does not have a customer meter replacement strategy with meters only being replaced on failure. In practise the performance of any mechanical meter will deteriorate with use resulting in under registration and loss of revenue to the board.

It is recommended that a meter replacement policy is implemented to manage customer meter under registration and maximise revenue to the board.

3.3.2 Configuration of Billing Areas

Meter reading for Colombo City is undertaken in four areas and further sub-divided into priority and non-priority customers as follows:

Non-priority

- 10/11 Mattakkuliya non-priority
- 10/12 Maligawatta non-priority
- 10/13 Pamankada non priority
- 10/14 Fort non priority

Priority

- 11/31 Mattakkuliya
- 11/32 Maligawatta
- 11/33 Pamankada

The meter reading areas are exactly coincident with the city “administrative’ boundary. The sum of the seven billing areas has historically been used to calculate total consumption for the city. However, as discussed in Section 3.4 there are significant discrepancies between the ‘administrative’ boundary and the hydraulic boundary and consequently the calculation needs to be refined to provide a more accurate assessment of Authorised Consumption for use in the Water Balance (see Section 4.4).

3.4 COLOMBO CITY BOUNDARY ISSUES

3.4.1 Background

The assessment of NRW requires a water balance to be applied to a specific 'supply' zone. For an accurate balance the zone must have three features:

1. All bulk flows in and out of the zone should be metered;
2. The zone should be hydraulically discrete with no un-metered flow across the boundary; and
3. The boundary must be clearly defined so that customers can be confidently allocated to the correct zone

As noted previously the boundary for Colombo City is effectively the boundary of an administrative area. Whilst it does have a high degree of hydraulic integrity due to the various water features around the city it does not represent a fully isolated and discrete supply zone.

A review of available GIS data has been undertaken to investigate the hydraulic integrity of the city boundary. The review was based on the city boundary and GIS data as supplied by the Master Plan team. A preliminary study was undertaken to identify all mains crossing the boundary. These mains where then individually queried with the relevant OIC to confirm:

1. If the information in the GIS was correct; and
2. If the main was open or closed.

A few general issues where noted during these discussions:

- The knowledge of boundary conditions was patchy. Some OIC were very well informed whilst others had only limited knowledge and at times were uncertain about the location and status of the city boundary;
- Responsibility for maintaining the boundary was not clearly defined and furthermore was not seen as a high priority;
- There is no official documentation or marking of boundary valves either on the ground or in the mains records. It should be noted that the OIC do not have access to GIS and rely on paper records only; and
- A significant number of GIS errors where identified.

Maintaining the city boundary is critical for the accurate assessment of NRW. Furthermore knowledge, documentation and control of boundary conditions will be crucial for successful DMA operation. **It is recommended that NWSDB improve awareness of boundary control and implement BV management procedures.**

The results of the discussions and required actions are summarised in Table 3-2 and discussed in the following pages. It must be stressed that work is on-going and that the actions identified are preliminary. Further follow up work will be required as investigations progress.

Table 3-2 Boundary Issues & Actions

Item	Draw'g No	Main Type	Assumed Status	Feature	City Area	Location	Comments and Actions
1	04	Various	Open		Pamankada	Area around Raymond Road	Considerable uncertainty about network configuration in this area complicated by GIS errors. There is general consensus that the boundary is breeched. **Action: Site investigation to confirm configuration followed by redesign to establish viable boundary**
2	05	3 inch C.I.	Closed	Boundary Valve	Pamankada	High Level Road Near Anula College	Both valves reported closed by O&M. One valve confirmed on site. The other valve is buried. **Action: Consider as part of general redesign of Pamankada East boundary**
3	05	3 inch C.I.	Closed	Boundary Valve	Pamankada	High Level Road Near Anula College	
4	08	63 mm PVC	Open		Pamankada	Kandewatta Road	Both mains reported open by O&M. These mains by-pass the existing Poorwarama Road meter. **Action: Consider as part of general redesign of Pamankada East boundary**
5	08	3 inch C.I.	Open		Pamankada	D.W. Rupasingha Road	
6	09	63 mm PVC	Closed	Cap End	Pamankada	Kandewatta Terrace	Reported closed (capped) by O&M. **Action: Confirm on site and document**
7	10	150 mm D.I.	Closed	Cap End or BV	Pamankada	Colombage Mawatha	Reported closed by O&M. However unclear whether boundary is defined by a closed valve or a cap end. **Action: Confirm on site and document**
8	11	200 mm C.I.	Closed	Cap End or BV	Pamankada	Nawala Road Near Lanka Tile Showroom	Reported closed by O&M. However unclear whether boundary is defined by a closed valve or a cap end. **Action: Confirm on site and document**

Item	Draw'g No	Main Type	Assumed Status	Feature	City Area	Location	Comments and Actions
9	13	4 inch C.I.	Open		Maligawatta	Kolonnawa Road	Reported closed by O&M. **Action: Confirm and document**
10	14	100mm	Open		Mattakkuliya	Baseline Road Junc. Avissawella Road	Undocumented (not shown on GIS) 100mm connection between Colombo City & Kolonnawa distribution systems reported by O&M. **Action: Close valve, confirm and document**.
11		2 inch	Open		Mattakkuliya	Avissawella Road	Undocumented 2" tapping off D20 reported by O&M. Understood to be in front of the new System Input meter site at Orugodawatta Bridge. **Action: Disconnect, confirm and document.**
12	15	100mm	Closed	GIS anomaly	Mattakkuliya	Baseline Road	X-connection from Colombo City 225mm to Kolonnawa 100mm shown on GIS. This is disputed by O&M and is not shown on original mains records where a hydrant is recorded. **Action: Confirm on site and document**.
15	16	600mm	Closed	GIS anomaly	Mattakkuliya	Madampitiya Bridge Sedawatta Road	Transmission line in the mains records does not exist. Confirmed by O&M and visual inspection. **Action: Update mains records and GIS**

Drawings illustrating the boundary features (including System Input meters) and associated issues are included in Appendix A.

3.4.2 Overview of Issues

There are essentially three overlapping issues:

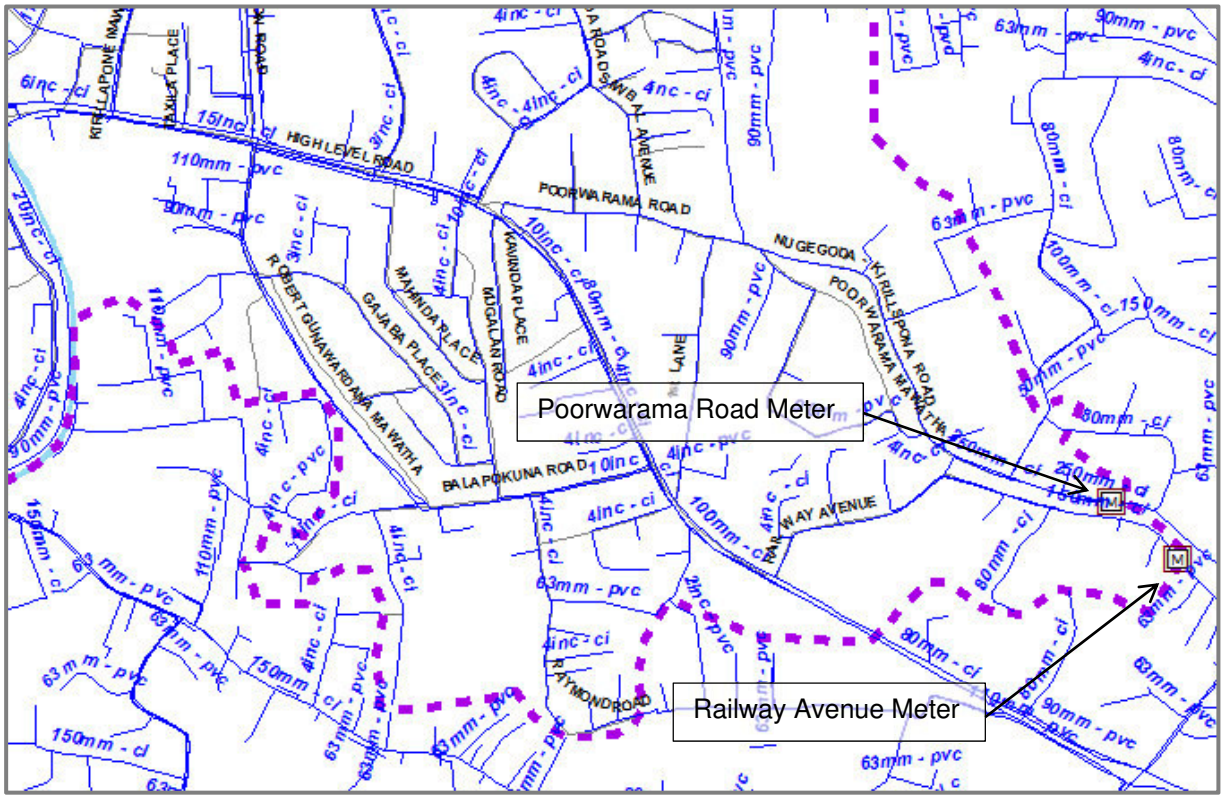
1. The hydraulic boundary is not secure and consequently the Colombo distribution system is mixing with the adjacent networks thus distorting the measurement of SIV;
2. The billing system is not aligned with the hydraulic boundary and therefore the billing records do not accurately reflect the Billed Consumption for the city; and
3. There is considerable uncertainty about the GIS data which makes it difficult to interpret network configuration in some areas.

As previously noted the city boundary is largely defined by water. Consequently the boundary is generally robust and where issues do arise they are generally simple and transparent as pipework crossing the boundary is restricted to a limited number of pipe bridges and consequently visible. However there are two areas (Pamankada East and Baseline Road) that are not defined by waterways where the network configuration is more complex. Specific areas are discussed individually in the following sections.

3.4.3 Pamankada East Boundary

The majority of the issues identified (items 1 – 6) are in the Pamankada East area. The boundary of the city around Pamankada East crosses a fully developed residential area and is therefore complex.

Figure 3-3 Pamankada East Boundary



In discussions with local OIC it was generally accepted that the boundary in Pamankada East is breached in a number of places. In addition it was noted that:

- There is considerable doubt about the configuration of the network in this area. A number of mains are believed to have been "pieced through" in response to local pressure problems;
- The mains records are not believed to be complete or accurate and there is some difficulty in determining which properties are supplied from which main; and
- The old city boundary is irrational with respect to the current housing estates, topography and network configuration

It is recommended that the boundary in Pamankada is redesigned to provide a clear and robust boundary for the future measurement of NRW.

The following should be taken into account:

- The review and redesign should be comprehensive for the Pamankada East area between the System Input meters at Pamankada Bridge and DM Colombage;
- Following the 'old' city boundary in this area is inappropriate and consequently the boundary needs to be redesigned based on hydraulic principles;
- The area suffers from low pressure and it has been noted that there are a number of areas of high ground which may be pressure sensitive. This will need to be taken into consideration when designing the new boundary; and
- Poorwarama Road & Railway Avenue meters form part of the current "boundary". Both meters are due for replacement. It has been previously recommended that Railway Avenue is abandoned due to the low flows in this line and that Poorwarama Road is relocated due to flooding. Redesign of this boundary provides an opportunity to relocate and rationalise these meters thus **providing an immediate cost saving to the board**.

To avoid unnecessary construction work the final and complete 'lock in' of the new boundary will be deferred until a new meter has been installed (relocated) at Poorwarama under the investment programme. It should be recognised therefore that this issue may not finally be resolved until the middle of 2014.

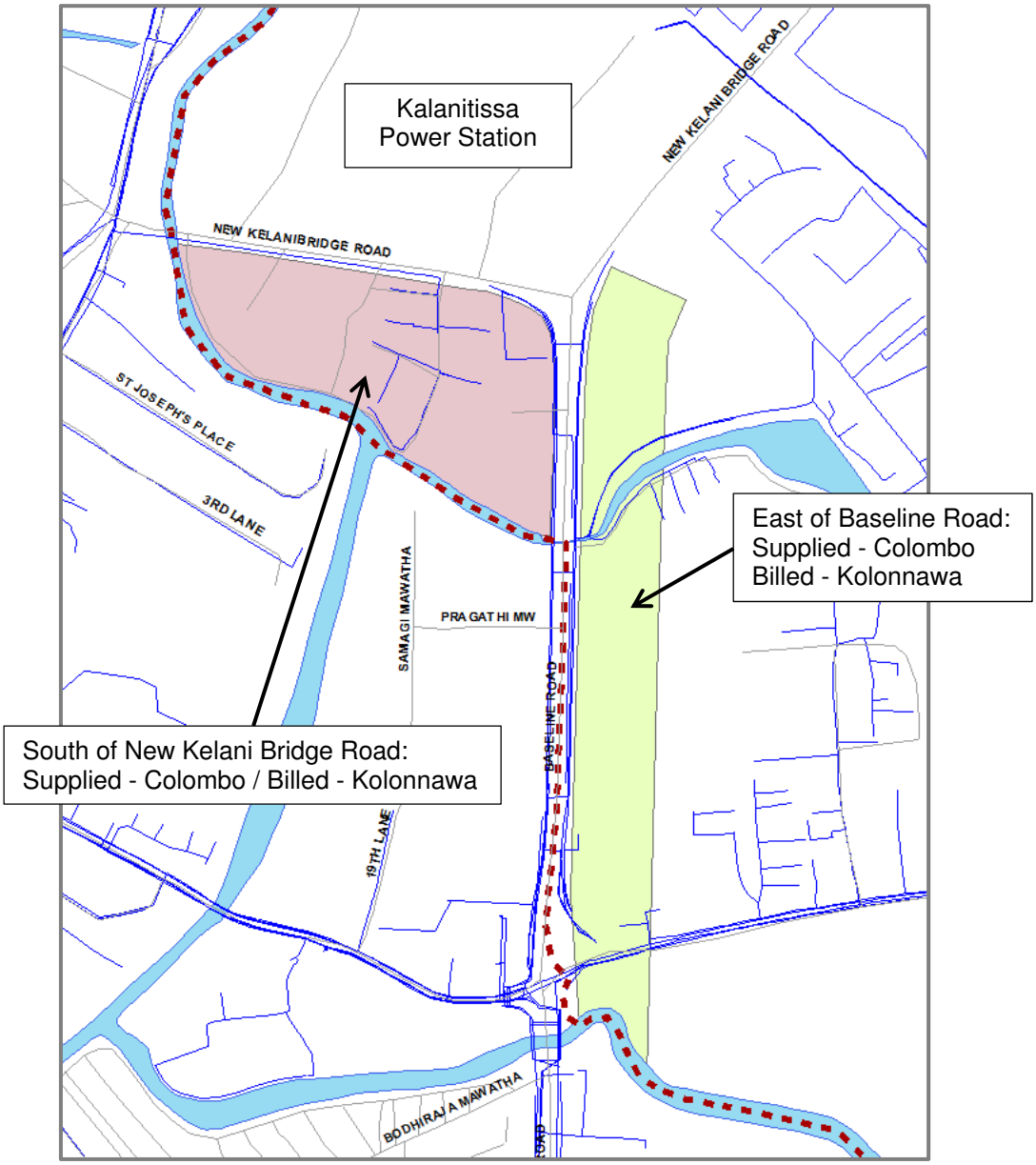
3.4.4 Baseline Road

The administrative boundary for Colombo City runs along Baseline Road. The administrative boundary at this point is not aligned with the hydraulic boundary and consequently water supplied by Colombo City is currently being billed by Kolonnawa. There are three distinct billing issues as shown in Figure 3-4:

1. **Kalanitissa Power Station**: the priority meters for the power station are supplied from the city but allocated to Kolonnawa in the billing system;
2. **South of New Kalani Bridge Road**: this area is clearly supplied by the Colombo distribution system but billed by Kolonnawa; and

3. **East of Baseline Road**: this area is billed by Kolonnawa but believed to be (at least in part) supplied by Colombo City. However it must be stressed that there is significant uncertainty about the GIS data in this area and therefore the network configuration is open to interpretation.

Figure 3-4 Colombo City & Kolonnawa Billing Discrepancies



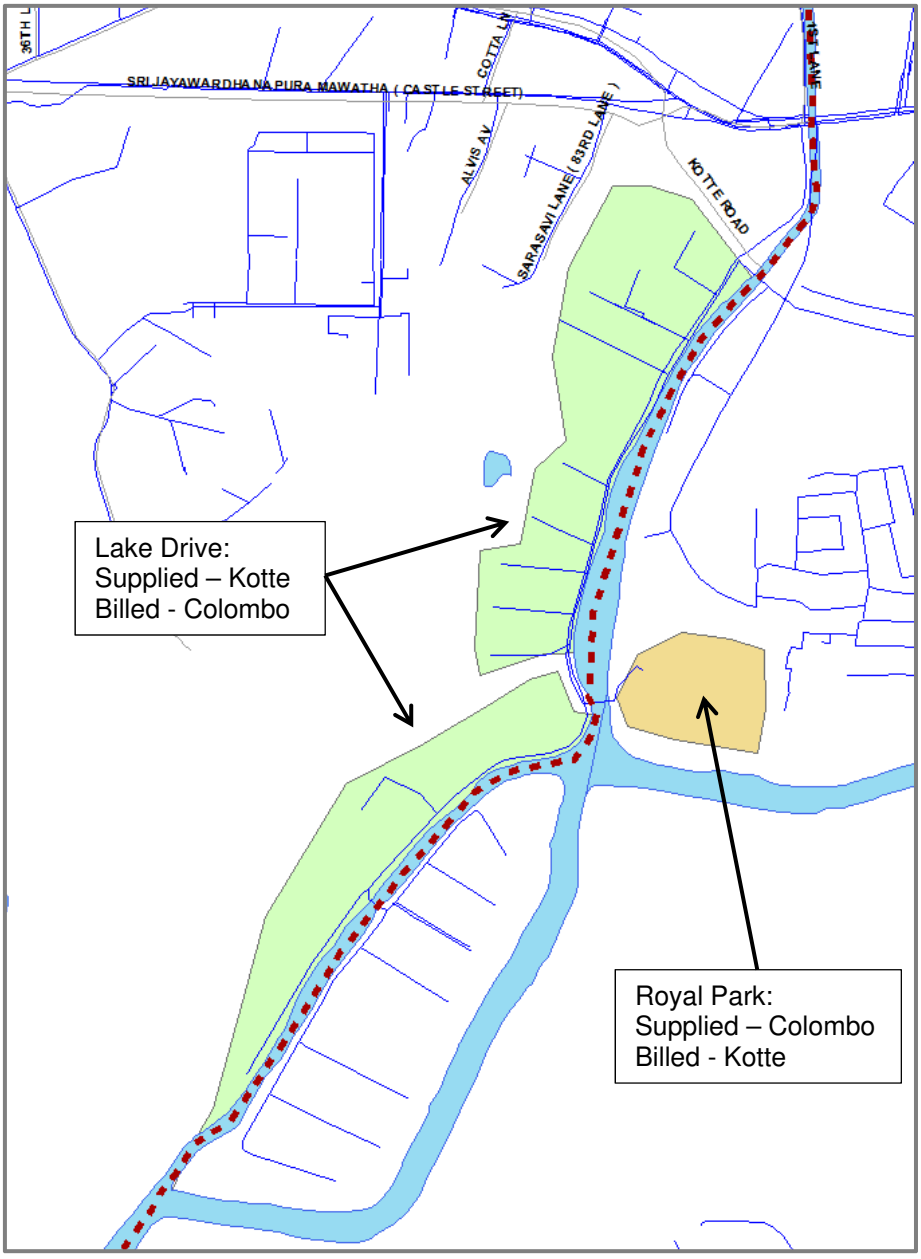
Further investigations are required to clarify the situation on Baseline Road. In particular to confirm the extent to which the Colombo and Kolonnawa distribution networks are mixing. It should be noted that the boundary may need to be significantly redesigned in this area. **Following investigations it is recommended that a secure and well defined hydraulic boundary is established to separate the two distribution networks.**

It is recommended that the billing areas are reallocated in the water balance in line with the current best understanding of network configuration.

3.4.5 Lake Drive and Royal Park

As shown in Figure 3-5 the administrative boundary between Colombo and Kotte follows the canal. However the hydraulic boundary crosses the canal in two places and as a result the billing system is misaligned with the hydraulic boundary.

Figure 3-5 Colombo City & Kotte Billing Discrepancies



There are two distinct billing anomalies:

1. **Lake Drive** is supplied by Kotte but billed by Colombo; and conversely
2. **Royal Park** is supplied by Colombo but billed by Kotte

It is recommended that Billed Consumption is corrected in the water balance accordingly.

3.4.6 Other Boundary Issues

Three other distribution lines were identified crossing the boundary into Colombo City via pipe bridges (items 7, 8 & 9). These lines are understood to be closed however exact details and location of boundary valves (if any) are difficult to confirm.

It is recommended that all boundary valves are confirmed closed (and sounded). Appropriate records should be kept and a boundary valve management procedure put in place to maintain the Colombo City boundary in the future.

3.4.7 Management of Billing Area Discrepancies

The immediate issue arising from the discrepancies between the administrative boundary and the hydraulic boundary is the misallocation of billing data when calculating NRW. This can most readily be corrected in the short term by making adjustments to the calculation of Billed Consumption in the water balance.

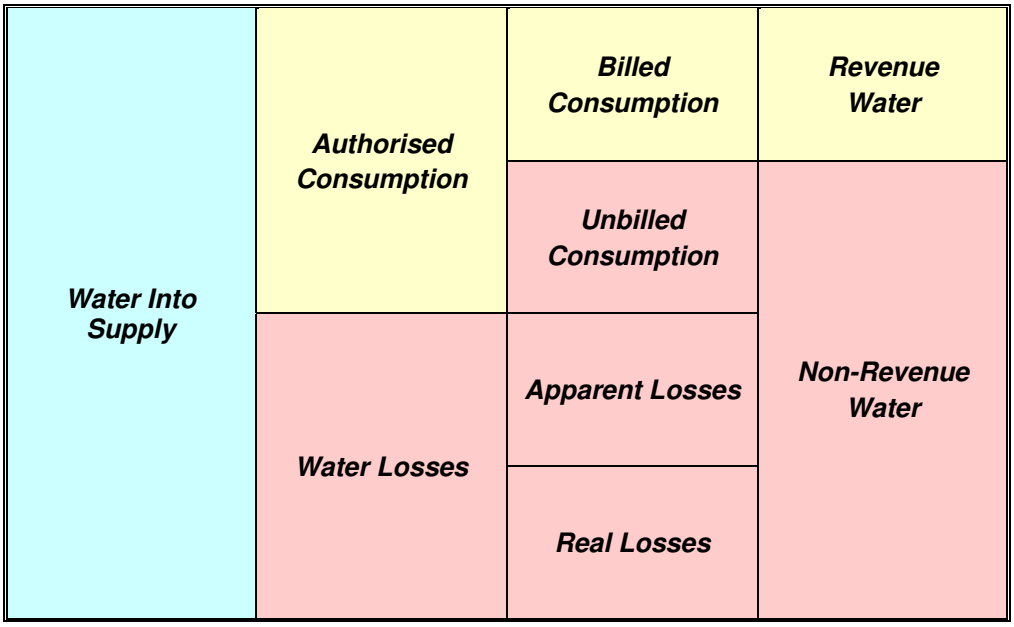
In the **long term** it is desirable to align the administrative areas with the hydraulic 'supply zone' boundary as this will provide a more rational basis for network operations in the future. Consequently **it is recommended that the billing system is brought into line with the hydraulic boundary.** However it is recognised that this will require significant adjustments to current operations as well as corrections to the billing system. Consequently any realignment must be based on a firm and 'final' understanding of the supply zone boundary.

4.0 WATER BALANCE AND NRW CALCULATION

4.1 COMPONENTS OF THE IWA WATER BALANCE

The major components of the IWA Water Balance for Colombo City are illustrated below:

Figure 4-1 Major Components of the Water Balance



Note: simplified format excluding 'System Input Volume' & 'Bulk Exports'

The main components of the balance can be defined as follows:

System Input Volume: bulk flow into the supply zone typically read from the system input meters

Water Into Supply: net flow into the supply zone given by:

Water Into Supply = System Input Volume - Bulk Exports

Note: For Colombo City "System Input Volume" is equivalent to "Water Into Supply" as there are no bulk exports to adjacent supply zones. However it should be noted that this is an important distinction which will need to be taken into consideration for other supply zones.

Authorised Consumption: consumption within the zone derived from two components as follows:

1. **Billed Authorised Consumption:** total of all billed consumption (metered & unmetered) recorded in the billing records (excluding bulk exports).

2. **Unbilled Authorised Consumption:** comprising the free water programme, operational use, firefighting and any other approved unbilled use.

Water Losses: total losses on the network derived from;

Water Losses	=	Water Into Supply	-	Authorised Consumption

Water Losses is divided into two main components both of which are **estimated** based on a detailed understanding of system performance;

1. **Real Losses** comprises all real physical losses (leakage) form the network including losses from transmission lines, reservoirs and the distribution system; and

2. **Apparent Losses** comprises paper (commercial) losses primarily resulting from metering (and billing) errors and illegal use

4.2 AVAILABLE DATA

Historical data from 2010 has been supplied by the NRW team.

It should be noted that the monthly volumes supplied are derived from average flow rates rather than direct readings of volume. The use of average flow rates to derive volume is necessary to compensate for the non-synchronous and erratic nature of manual meter readings. Direct (and synchronous) measurement of System Input Volume will become available once data loggers are installed on all System Input meters.

Historical meter readings have been provided from 2012 to date. The archive from early 2012 is incomplete but shows steady improvement reflecting improved meter reading practises. A near complete data set is available from August 2012 with only the Lanka Tile meter out of commission (see Appendix B).

Meter readings from July to October 2013 were confirmed on site during joint meter reading with the NRW team.

Customer Billing data has been collected from the Commercial Team. Summary data for Colombo City has been made available from 2009 with more detailed data, taken directly from the MIS data sheets, since 2012.

The available data sets are summarised in Table 4-1.

Table 4-1 Summary of Available Data

Data Set	From	To
System Input Volume		
Summary	Jan 2010	May 2013
Meter Readings	Jan 2012	Sep 2013
Customer Billing		
Summary	Oct 2009	Sep 2013
Detailed (MIS)	Jan 2012	Aug 2013

4.3 CALCULATION OF NRW

Non Revenue Water (NRW) is calculated as follows:

NRW = Water Into Supply - Billed Consumption

Where:

'Water Into Supply' is the **net flow** of the supply zone measured at bulk meters; and

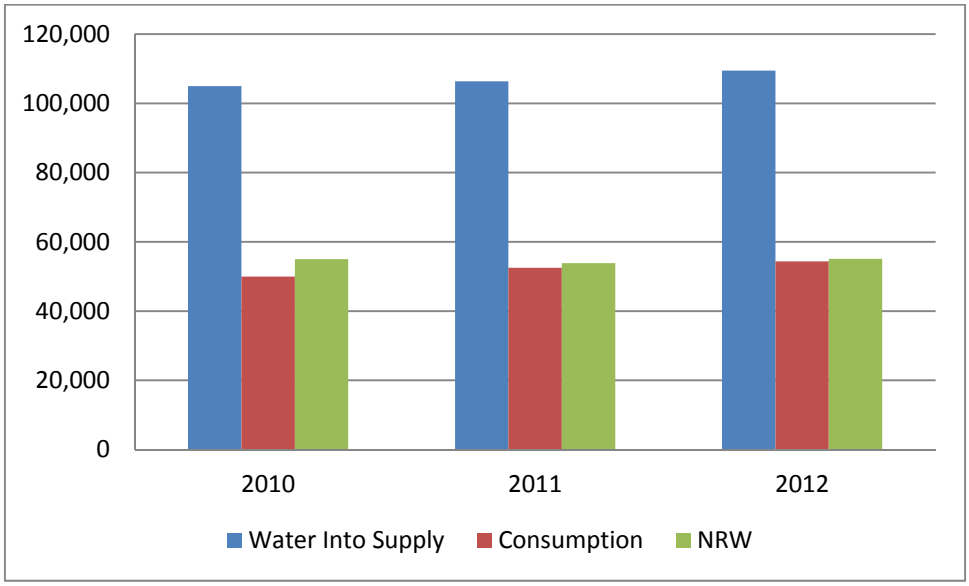
'Billed Consumption' is derived from the corporate billing records.

A simple NRW calculation based on the 'summary' data is presented in Table 4-2 and illustrated graphically in Figure 4-2 below:

Table 4-2 NRW 2010 - 2012

	2010	2011	2012
Water Into Supply (Ml)	104,993	106,387	109,461
Consumption (Ml)	49,989	52,527	54,371
NRW (Ml)	55,004	53,860	55,090
NRW (%)	52%	51%	50%

Figure 4-2 NRW 2010 - 2012



It can be seen that, in volumetric terms, the NRW has remained stable over the period with the marginal decline in percentage NRW reflecting the steady increase in demand.

It is commonly recognised that %age NRW can be misleading due to its susceptibility to fluctuations in demand. It is important that all stakeholders are aware of this issue so that a correct understanding of changes in %NRW is achieved.

4.4 DETAILED WATER BALANCE

It is generally recommended to undertake Water Balance over a 12 month period to eliminate any possible errors due to seasonal fluctuation in demand and to minimise the negative impacts of meter reading lag. The water balance presented in the following section covers the 12 month period up to September 2013.

4.4.1 Calculation of Water Into Supply

The System Input meters are read on a monthly basis by the NRW team. Available meter readings for the 15 months to October 2013 are included in Appendix B for reference.

The period to September 2013 provides a nearly complete data set thus allowing the annual volume to be derived directly from the meter readings with the minimal amount of manipulation and extrapolation.

The calculated 'annually adjusted' volume and associated flow rates is shown in Table 4-3.

It should be noted that annual volumes for two meters have been extrapolated from reduced data sets:

1. Lanka Tile meter has only been providing reliable data from April 2013 and consequently the volume for this meter has been extrapolated from a 5 month data set
2. Ayurwedic Hospital - point A meter was removed due to construction work in October 2013 and consequently the volume for this meter has been extrapolated from an 11 month data set.

Otherwise all volumes are based on a full 12 month cycle with only minor adjustments of a few days.

As noted in previously a number of system input meters are remote from the city boundary. The relevant transmission lines are understood to supply a limited number of connections outside the city boundary. The measured SIV has therefore been corrected, based on estimates supplied by the NRW team, to compensate for 'off-takes' and losses from the following transmission lines:

Ambatele to Colombo City (600mm & T20)	100 m^3/hour
Wellampittiya Bridge to Colombo City (O20, D30, O30 & D20)	500 m^3/hour
Total correction	600 m^3/hour

The corrected annual total is given by:

Annually Adjusted System Input (Table 4-3)	111,979,453	m^3
Correction for transmission lines	5,256,000	m^3
Water Into Supply	**106,723,453**	**m^3**

The correction represents approximately 5% of total SIV.

Table 4-3 System Input Volume September 2012 – August 2013

Meter Location	Units (m^3)	Initial Reading		Final Reading		Total Volume (m^3)	Elapsed Days	Flow Rate (m^3/hour)	Annually Adjusted Volume (m^3)
		Date	Reading	Date	Reading				
Dehiwala Bridge	1	28/08/12	726,867	03/09/13	1,780,528	1,053,661	371	**118**	**1,036,621**
Pamankada Bridge	1	28/08/12	2,256,375	03/09/13	11,784,111	9,527,736	371	**1,070**	**9,373,649**
Poorwarama Road	1	28/08/12	8,532,835	03/09/13	9,139,093	606,258	371	**68**	**596,453**
Railway Avenue	1	28/08/12	253,660	03/09/13	334,440	80,780	371	**9**	**79,474**
Nawala Road (Lanka Tile) Note 1	1	02/04/13	1,781,891	03/09/13	7,913,003	6,131,112	154	**1,659**	**14,531,532**
DM Colombage Mawatha	1	28/08/12	1,084,850	03/09/13	1,617,480	532,630	371	**60**	**524,016**
Ayurwedic Hosp - Point A Note 2	1	28/08/12	932,978	02/08/13	1,103,072	170,094	339	**21**	**183,140**
Ayurwedic Hosp - Maragasmulla	1	28/08/12	767,918	03/09/13	1,118,853	350,935	371	**39**	**345,260**
Wellampitiya - O20	100	03/09/12	938,235	03/09/13	1,008,967	7,073,200	365	**807**	**7,073,200**
Wellampitiya - N30	100	03/09/12	4,735	03/09/13	283,848	27,911,300	365	**3,186**	**27,911,300**
Wellampitiya - O30	100	03/09/12	566,766	03/09/13	783,848	21,708,200	365	**2,478**	**21,708,200**
Wellampitiya - D20	100	03/09/12	79,886	03/09/13	161,537	8,165,100	365	**932**	**8,165,100**
Eli House - T20	1	07/09/12	669,202	03/09/13	753,387	8,418,500	361	**972**	**8,511,780**
Ambatele PS (New) Note 3	1	01/09/12		01/09/13		11,939,731	365	**1,363**	**11,939,731**
Annually adjusted total:							365	**12,783**	**111,979,453**

Note: 1 Nawala Road (Lanka Tile) meter out of commission until April 2013

2 Ayurwedic Hospital – Point A meter removed in October 2013 due to construction work on the bridge

3 Volumes for Ambatele PS extracted directly from production records

4.4.2 Calculation of Billed Consumption

The administrative area of Colombo City is made up of 7 billing areas. However as the hydraulic boundary is not completely coincident with the administrative boundary, in order to achieve a more accurate assessment of billed consumption it is necessary to compensate for water consumed in other billing areas.

The adjustments made to the Colombo City billing are based on discussions with the relevant local Commercial Officer and can be summarised as follows:

Colombo City Non-priority Billing:		
	10/11	Mattakkuliya non-priority
	10/12	Maligawatta non-priority
	10/13	Pamankada non priority
	10/14	Fort non priority
Colombo City Priority Billing:		
	11/31	Mattakkuliya priority
	11/32	Maligawatta priority
	11/33	Pamankada priority
Colombo City Non-priority Billing supplied from Kotte:		
	10/12/666	Lake Drive
Kotte Non-priority Billing supplied from Colombo City:		
	10/21/047/001/11	
	10/21/047/250/19	Royal Park bulk meters
	10/21/047/251/18	
Kolonnawa Non-priority Billing supplied from Colombo City:		
	10/25/267	
	10/25/339	South of New Kelani Bridge Road
	10/25/368	
	10/25/378	
	10/25/280	East side of Baseline Road
	10/25/497	
Kolonnawa Priority Billing supplied from Colombo City:		
	11/25/300/003/17	
	11/25/300/002/18	Kelanitissa Power Station
	11/25/300/001/19	

Monthly billing summary for the year to September 2013 are included in Table 4-4.

The additional consumption identified represents an increase of 1% in Colombo City Billed Consumption.

Table 4-4 Billed Consumption (m^3) September 2012 – August 2013

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Colombo City Non-priority Billing												
10/11: Mattakkuliya	717,966	693,062	728,247	754,185	725,927	806,891	721,943	720,200	746,000	632,752	643,353	738,265
10/12: Maligawatta	682,173	710,521	713,531	710,882	772,290	739,617	713,976	797,289	828,820	713,094	775,083	795,839
10/13: Pamankada	817,163	772,660	806,040	785,110	802,334	785,539	756,011	817,760	821,530	775,892	784,717	803,662
10/14: Fort	677,192	632,700	673,180	655,917	703,145	662,316	634,470	710,755	742,698	698,291	676,135	734,050
Colombo City Priority Billing												
11/31: Mattakkuliya	623,587	618,860	606,467	557,264	654,527	572,238	546,789	597,320	548,095	570,233	552,336	629,523
11/32: Maligawatta	623,528	584,305	617,343	587,442	671,752	572,332	563,150	626,185	580,268	587,200	585,909	626,143
11/33: Pamankada	502,416	469,090	487,419	482,731	539,152	407,763	449,951	493,359	460,263	469,332	412,569	439,348
Sub-total	**4,644,025**	**4,481,198**	**4,632,227**	**4,533,531**	**4,869,127**	**4,546,696**	**4,386,290**	**4,762,868**	**4,727,674**	**4,446,794**	**4,430,102**	**4,766,830**
Total for Colombo City Billing September 2012 to August 2013:												**55,227,362 m^3**
Colombo City Non-priority Billing supplied from Kotte												
10/12/666	8,211	8,460	7,772	8,119	7,396	8,886	7,880	9,261	6,991	7,474	8,239	7,799
Kotte Non-priority Billing supplied from Colombo City												
10/21/047/001/11	125	121	139	188	166	118	293	183	351	403	350	294
10/21/047/250/19	2,237	2,639	2,466	2,764	2,955	2,372	2,570	2,612	2,440	3,645	3,347	2,734
10/21/047/251/18	2,600	2,388	2,214	2,607	2,599	2,065	2,424	2,486	2,545	3,185	2,946	2,588
Sub-total	***4,962***	***5,148***	***4,819***	***5,559***	***5,720***	***4,555***	***5,287***	***5,281***	***5,336***	***7,233***	***6,643***	***5,616***

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Kolonnawa Non-priority Billing supplied from Colombo City												
10/25/267	1,456	1,390	1,784	1,547	1,612	1,670	2,202	1,839	2,197	1,852	1,713	1,889
10/25/339	5,737	5,704	6,222	5,279	5,910	5,690	5,910	6,745	6,244	5,161	5,033	5,991
10/25/368	8,504	7,450	7,927	7,337	9,084	8,307	7,738	9,250	8,834	9,429	7,994	8,438
10/25/378	5,903	5,578	6,053	6,069	6,936	5,680	6,932	6,202	5,948	6,187	5,214	6,095
10/25/280	8,400	8,615	9,528	9,157	9,810	7,984	9,710	10,505	9,842	8,663	8,010	8,134
10/25/497	4,314	4,510	4,904	4,495	4,834	4,649	4,811	5,695	5,214	4,059	4,804	5,037
Sub-total	**34,314**	**33,247**	**36,418**	**33,884**	**38,186**	**33,980**	**37,303**	**40,236**	**38,279**	**35,351**	**32,768**	**35,584**
Kolonnawa Priority Billing supplied from Colombo City – Kalanitissa Power Station												
11/25/300/003/17	66	0	132	79	62	16	454	192	0	0	28	0
11/25/300/002/18	3,360	10,130	2,700	1,810	1,080	5,930	13,310	9,520	7,240	1,620	1,160	1,720
11/25/300/001/19	4,712	5,579	4,637	4,008	3,455	4,450	4,190	4,917	4,323	4,147	3,550	3,851
Sub-total	**8,138**	**15,709**	**7,469**	**5,897**	**4,597**	**10,396**	**17,954**	**14,629**	**11,563**	**5,767**	**4,738**	**5,571**
Total Billed Consumption September 2012 to August 2013:											**55,739,011 m^3**	

4.4.3 Estimating the Components of NRW

Whereas Water Into Supply and Billed Consumption are measured volumes derived from bulk meters and the corporate billing system the individual components of NRW are necessarily estimated. Furthermore, in the early stages of NRW management these estimates are inevitably course. The basis for the estimation used for the current analysis is outlined in the following section.

Authorised Unbilled Consumption:

Authorised unbilled consumption is divided into two categories; metered and unmetered. It is understood that all authorised unbilled consumption in unmetered and comprises the following components:

1. Free Water
2. Operational Use
3. Fire Fighting

Free water (Tenement Gardens): the consumption of free water has been the subject of a major programme of work by the NRW team. The programme has been systematically replacing all free water taps identified in the Colombo City "Tenement Garden Directory" with individual billed connections and metered stand posts. The programme was completed in October with all known free water supplies in Colombo City now included in the billing.

Free water consumption was estimated at 6.7% of SIV in December 2012 (ref Master Plan Update). Assuming linear progress to zero in October would give a median estimate of 5% of SIV (5,336,173m3) for the period of the water balance.

No data is available to estimate operational use or firefighting. In the absence of auditable data it is generally recommended (IWA) that an allowance of 0.5% of SIV (533,617m3) is adopted.

No other authorised unbilled users have been identified.

Unauthorised Consumption (illegal use):

Survey work undertaken by the NRW team in areas of suspected high illegal use found an average of 8% (ref Master Plan Update p3-33) of properties surveyed in 2012 had illegal connections. As these activities are targeted the results do not provide a representative estimate of the wider network but does provide a useful benchmark on the upper limits of illegal connections.

The JICA "Capacity Development Project" published in November 2012 reported that illegal use accounted for 1.88% of SIV. The study was based on a number of representative pilot areas which were comprehensively surveyed for illegal connections. However as the study is based on the number of connections it will overlook transient or ad hoc illegal use, for instance theft from fire hydrants or temporary by-passes of customer meters, which in any case is likely to be supressed during the period of the survey. Consequently it would be prudent to adopt a higher figure for the water balance and an estimate of 3% of SIV (3,201,704m3) has been used in line with the estimate adopted in the 'Master Plan Update'.

Customer Meter Errors:

Customer meter error can be regarded as comprising three components:

1. Meter under-registration
2. Data handling errors
3. Corrupt meter reading

Two studies investigating meter under-registration have been reported

- Kula Ganaga Water Supply project reported 7% (ref Master Plan Update)
- JICA "Capacity Development Project" reported 5.45%.

The use of flow rigs to test meter accuracy will tend to understate the level of meter under-registration so it is prudent to take the higher figure.

Some data handling errors are inevitable in any system which involves the manual reading and data entry of over 100,000 customers. However most data handling errors are random and will therefore have no net effect on the water balance.

Similarly the use of robust estimates, whilst undesirable, will have no net effect on the balance. Only systematic over or under estimation will have an impact on the assessment of NRW

In the absence of any evidence of systematic errors this component is assumed to be zero.

Corrupt meter reading has not been studied or analysed previously. However in the absence of rigorous systems to eliminate such practices it is prudent to assume that corrupt meter reading makes some contribution to NRW. For the purposes of the current analysis a notional allowance of 1% of Billed Consumption has been allowed.

Real Losses:

Real Losses is a derived value and is effectively the output of the Water Balance.

A detailed water balance for Colombo City derived on this basis is presented in Figure 4-3.

Figure 4-3 Colombo City Water Balance (Sept 2012 – Aug 2013)

<table>
<tr><td rowspan="6">Water Into Supply
106,723 Ml
(100%)</td><td rowspan="3">Authorised Consumption
61,609 Ml
(58%)</td><td rowspan="2">Billed Consumption
55,739 Ml
(52%)</td><td>Billed Metered
55,739 Ml (52%)</td><td rowspan="2">Revenue Water
55,739 Ml
(52%)</td></tr>
<tr><td>Billed Unmetered
0 Ml (0%)</td></tr>
<tr><td rowspan="2">Unbilled Consumption
5,870 Ml
(6%)</td><td>Unbilled Metered
0 Ml (0%)</td><td rowspan="4">Non-Revenue Water
50,984 Ml
(48%)</td></tr>
<tr><td>Unbilled Unmetered
5,870 Ml (6%)</td></tr>
<tr><td rowspan="3">Water Losses
45,115 Ml
(42%)</td><td rowspan="2">Apparent Losses
7,661 Ml
(7%)</td><td>Unauthorised Consumption
3,202 Ml (3%)</td></tr>
<tr><td>Customer Meter Error
4,459 Ml (4%)</td></tr>
<tr><td colspan="2">Real Losses
37,454 Ml
(35%)</td></tr>
</table>

4.5 DISCUSSION

4.5.1 Correct Application of the Water Balance

When correctly applied, to a hydraulically discrete and fully metered system with a regime of routine meter reading, the annual water balance represents the most reliable and accurate mechanism for assessing NRW.

However it must be remembered that the water balance contains a number of inherent inaccuracies which need to be minimised to provide a robust and reliable measure of NRW. In order to manage these inaccuracies the balance should be applied to large areas comprising discrete supply zones over long time periods. It is generally recommended that the water balance is applied for a 12 month period.

It must be understood that all the components of the water balance are subject to errors and inaccuracies and that some components are estimated based on assumptions or extrapolated from pilot studies. It is important therefore, when interpreting the results of a water balance, for stakeholders to have an understanding of the reliability of the assumptions that underpin it if they are to have confidence in the outcomes.

In the early stages of NRW management it will be necessary to collect data and put in place specific programmes to improve confidence in the balance. Improving and maintaining confidence in the balance should be seen as a continuous process subject to on-going review.

In this respect it is useful to think of the 'detailed' Water balance as a modelling exercise rather than a calculation and to view the results in terms of confidence in the outcomes. As with all modelling, where accurate data is not available simplicity and transparency in the underlying assumptions is to be desired if the results are to be useful and not mislead stakeholders with a less sophisticated understanding of the process.

Specific issues relating to 'confidence' in the current balance are discussed in the following sections.

4.5.2 Sources of Error in System Input Volume

System Input Volume is the largest and therefore the most critical figure in the water balance. There are three significant sources of error in the current SIV:

1. Meter accuracy;
2. Un-metered flows through distribution mains; and
3. Un-metered flows from transmission lines.

Meter Accuracy is a function of meter type, age and installation effects. As discussed in Section 3.2 the system input meters fall into three distinct categories:

Ultrasonic meters are being utilised on all the larger transmission lines and currently report 90% of flow into the city. As previously noted these meters are capable of a high degree of accuracy but are highly susceptible to installation effects. At present data is restricted to monthly meter readings with no access to detailed (15 minute interval) data. It is recommended that data loggers are installed.

It is noted that the Ultrasonic meters have historically been validated against bulk flow data from insertion probes. It is recommended that meter validation is revisited once logged data becomes available as the detailed data available will greatly improve confidence in these critical meters.

Mechanical meters are currently recording 2% of system input. As noted in Section 4.2 the condition of these meters is generally very poor and it is likely that some of the meters will be substantially under reporting flow. The meters are included for replacement with high accuracy EM meters under the early stages of the investment programme so no further action is required.

The EM meter at Ambetale represents the most accurate metering system but as noted in Section 3.2 will be subject some loss of accuracy due to installation effects. The size of the error is unknown however this meter will be superseded in the Colombo City water balance by a new ultra sonic meter at Sedewatta Bridge during the early stages of the investment programme.

Un-metered flows through distribution mains are crossing the Colombo City boundary at a number of locations as described in Section 3.4. Whilst the flows through individual distribution mains are likely to be small in comparison with the SIV the combined effect is potentially significant and the security of the boundary will need to be addressed to improve confidence in the assessment of NRW.

Some investigations into the city boundary have been completed however complete isolation of the Colombo City supply zone may take some time. In particular providing an optimum solution for Pamankada will entail relocation of the system input meters.

It should also be noted that, once established, the key to maintaining confidence in the supply zone integrity is a robust boundary valve management procedure.

Un-metered flows from transmission lines are estimated by the NRW team based on a combination of field surveys and direct meter readings of some of the larger customers supplied.

As noted previously the system input meters at Wellampittiya Bridge are being superseded by new installations at Kolonnawa Bridge and Orugodawatta Bridge. The transition is only partially complete and only limited data is available from the new meters however an analysis of the difference in flow rates between the two sets of meters suggests that the estimate for the Wellampittiya transmission lines is robust.

The installation of the final three ultrasonic meters in 2014 under the investment programme will eliminate this error entirely.

Summary: The early stages of the investment programme will deliver a significant improvement in the measurement of system input (and therefore confidence in NRW) which should start to feed through into the balance by the end of 2014.

4.5.3 Billed Consumption

The authorised consumption as derived from the billing system is inherently in-precise. Customer meters in any given area are read over a period of time (typically one month in line with the billing cycle) and consequently the

billed volume reported is never precisely aligned with the period of the water balance. This discrepancy is known as meter reading lag.

With a one month billing cycle and a conventional 12 month water balance meter reading lag represents an acceptable statistical error however over shorter periods it can be much more significant. With a modern billing system it is possible to partially adjust for meter reading lag however it should be stressed that this error can never be completely eliminated.

It is recommended that NWSDB continue to report NRW based on rolling 12 month balance. In the event that shorter time periods are used the results should be treated with lower confidence to reflect the impact of meter reading lag.

A summary of the billing statistics for the period of the water balance is shown below:

Table 4-5 Billing Statistics September 2012 – August 2013

	Domestic	Non Domestic	Total
Normal	108,461	12,732	121,193
Unmetered	0	0	0
Estimated	966 (0.89%)	100 (0.78%)	1,065 (0.88%)
Disconnected	4,883	2,374	7,257
Inactive Accounts	934	280	1,214
Sub Total	115,244	15,485	130,730

There are two other inherent sources of error in the billing system which should be noted:

1. Billed Estimates: generally low - typically 1%for the period; and
2. Billed Un-metered: no unmetered connections are reported in Colombo City

Only systematic errors in the estimating process will impact on NRW. Provided a robust and fair system of estimation is in place the errors generated will be random. Over the timeframe of the balance most short term estimates will self correct and with a large sample (zone) any outstanding estimates will statistically average to zero.

Consequently the use of estimates is not regarded as an issue at current levels. None the less the number of estimates should be kept under review and in particular long running estimates should be discouraged.

4.5.4 Billing Area Discrepancies

As discussed in Section 3.4 the current billing zones are not completely coincident with the supply zone boundary. Whilst the revised allocation of Billed Consumption described in Section 4.4 is regarded as an improvement it must be remembered that it is still underpinned by some assumptions about network configuration which are unproven.

In particular the redistribution of billing zones along Baseline Road is based on an assumed understanding of the network configuration which remains under investigation. Consequently the allocation of billing to the city supply zone may need further refinement in light of improved understanding of network configuration particularly in the Baseline Road area.

In addition billing in the Pamankada area will also require some reassignment once the supply zone boundary has been finalised and secured.

It should be stressed that the error is regarded as small when compared to total Billed Consumption. However the correct allocation of customers to supply zones is entirely feasible and will eliminate any error in Billed Consumption thus improving confidence in the balance.

4.5.5 Unbilled Consumption

Free water supplied to Tenement Gardens represents the largest component of unbilled consumption. The quantification of water supplied is inevitably crude and subject to significant error. However as the programme to eliminate free water in Colombo City is now complete this error is diminishing and will be completely eliminated from the water balance in 2014 thus greatly improving confidence in the estimation of unbilled consumption.

Operational use and firefighting have been estimated as a percentage of SIV. Whilst based on a standard IWA recommendation for use in the absence of auditable data this is none the less crude. **It is recommended that the Operations Group undertake routine audits of operational use and make an annual estimate of firefighting consumption for use with future balances**.

It is noted that operational use and firefighting are small components of the water balance however they will become increasingly significant as NRW is reduced.

4.5.6 Unauthorised Consumption (Illegal Use)

Illegal use is by its nature difficult to quantify. The current estimation of illegal use is an extrapolation from pilot studies and therefore based on limited data sets.

An early task under the investment is to undertake a house by house survey to identify illegal connections. This will have two impacts:

1. Provide an opportunity to substantially eliminate illegal connections from the city thus minimising the significance of this component in the future; and

2. Provide a wider data set which will greatly improve the understanding of illegal use in Colombo City thus delivering improved confidence in future estimations of illegal use.

It should be stressed that illegal use will not be completely illuminated by the investment programme.

4.5.7 Meter Under Registration

The estimation of customer meter under registration has been extrapolated from pilot studies and is therefore based on a limited data set.

At present there is only limited information available on the customer meter stock and this is inhibiting a more rigorous analysis of the situation. As with illegal use work, under the investment programme will have a twofold impact:

1. Street surveys will provide the necessary information to improve the understanding (and estimating) of under registration and form the basis of a meter replacement policy; and

2. Implementing the meter replacement policy will reduce the level of under-registration and as well as further improving the understanding thus improving the confidence in future estimates.

The aim of a meter replacement programme is to reduce under registration to economic levels. Consequently whilst level of under registration will be greatly reduced in the future this will remain a significant component of Apparent Losses and estimates will need to be kept under continual review.

4.5.8 Corrupt Meter Reading

No prior studies on corrupt meter reading practices are available for reference. Consequently the estimate employed is inevitably course and is deliberately simplistic with the intention of being transparent rather than making any pretence at accuracy.

It should be noted that there is no clear evidence of such practices however in the absence of rigorous systems to prevent corrupt meter readings it is prudent to assume that some level of malpractice exists.

It is recommended that systems are implemented to eliminate corrupt meter readings in the future. Recommendations have been made elsewhere for appropriate systems such as:

- Analysing the billing system for anomalous readings;
- Conducting randomised audits; and
- Rotating meter readers.

In addition it should be remembered that corruption is essentially a cultural and behavioural issue and as such requires a HR response including trainings and motivational programmes.

4.6 CONCLUSIONS

The balance uses the best available data and is based on the current understanding of network configuration. The calculation is believed to be reasonably robust with **NRW estimated at 50,984Ml for the period or 48% of Water Into Supply**.

The official estimate of NRW reported by NWSDB for the 12 months to September 2013 is 49%. The analysis is consistent with the NWSDB figure with the discrepancy (1%) being due to the additional consumption applied in the current balance. **The reporting of NRW by NWSDB is fair and reasonable.**

However a number of issues affecting confidence in the reporting and analysis of NRW have been identified.

Key factors which directly affect the calculation of NRW are:

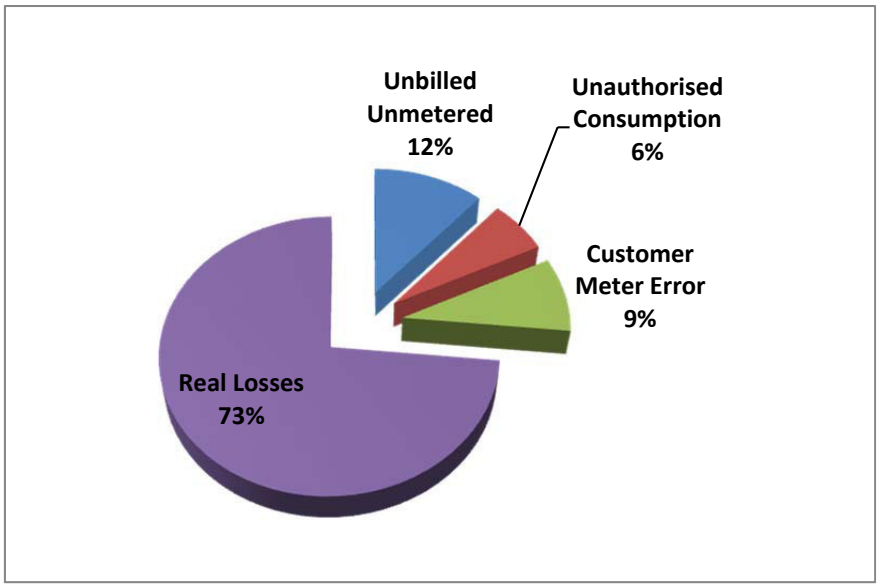
- Accuracy of SIV;
- Security of the hydraulic boundary; and
- Correct allocation of customer billing

Corrective actions have been identified which are expected to be implemented in 2014. These actions will significantly improve confidence in the measurement of NRW in Colombo City.

The analysis of the components of NRW is based on the best estimates available at the current time but should, none the less, be regarded as course. Data collection during the early stages of the investment programme will deliver a better understanding of the various estimates underpinning the analysis of NRW. Consequently confidence in the outcomes of the water balance should be greatly improved.

The analysis of the components of NRW is summarised in Figure 4-4.

Figure 4-4 Components of NRW



It can be concluded that Real Losses (leakage) is the predominant component accounting for nearly three quarters of NRW. Typical performance indicators based on the analysis are:

Infrastructure Leakage Index (ILI):	47
Burst Losses:	820 l/connection/day

However Apparent Losses are also significant accounting for over one quarter of NRW.

4.7 ESTABLISHING BASELINE NRW

It is proposed to establish a baseline NRW level for performance monitoring at the commencement of the implementation phase. Contracts are currently under negotiation and therefore it is assumed that the baseline will be set later in the year. In addition it may be desirable to benchmark progress at a number of other strategic intervals throughout the contract.

The official NRW level for Colombo City is calculated on a rolling 12 month balance and reported monthly by the DGM for Corporate Planning. The current study has found the reporting of NRW by NWSDB to be fair and reasonable.

It would be undesirable (and unhelpful) to establish a parallel water balance for the investment programme. Consequently **it is recommended that the official NWSDB figure is adopted as the baseline and for any subsequent benchmarks.**

To ensure confidence in the baseline, particularly for stake holders outside NWSDB, **it is recommended that the baseline and any subsequent benchmarks are subjected to audit.**

The basis of the NRW calculation will be under revision throughout 2014 as the various programmes to improve confidence in the calculation are rolled out. Consequently the audit would need to include the basis of the calculation to provide stakeholders with a full understanding and confidence in the NRW level.

The audit will therefore be two-fold:

1. Verification of the calculation; and
2. A review of the basis of calculation.

As noted previously the baseline NRW and any subsequent benchmarks should be reported as both volume and percentage. The percentage figure should be quoted to the nearest round number.

Serious discrepancies will need to be investigated and resolved and where specific errors are identified the official estimate of NRW should be revised. However some minor discrepancies due to differences of interpretation should be anticipated and this should not be considered an issue.

It should be noted that the baseline figure has no contractual (monetary) significance. The purpose is rather to provide stakeholders with an agreed start point against which to measure the overall performance of the investment programme.

The data sets (System Input & Billed Consumption) collected for the current study have been passed to the PMU and it is recommended that these data sets are maintained to allow future audits to undertaken with minimum additional effort.

5.0 REVIEW OF DMA DESIGN

5.1 REVISION OF MASTERPLAN DESIGN

A review of the original (Master Plan) DMA design was undertaken early in the project and the results were summarised in the Inception Report. A number of significant issues were identified and recommendations for corrective actions were made.

The DMA have now undergone a substantial redesign in line with the recommendations. In particular the DMA have been redesigned to exclude trunk mains and relocate the district meters onto the branch lines. The impacts of the redesign are summarised below:

1. District Meter Size: District meters have been relocated from the trunk mains to the main branch lines resulting in a significant reduction in the average diameter of the district meters. A comparison of the district meter sizes from the original and the revised design is given in Table 5-1.

Table 5-1 Comparison of District Meter Sizes

	Original Design	Revised Design
Maximum Diameter (mm)	1000	400
Minimum Diameter (mm)	150	150
Average Diameter (mm)	470	270

In addition to improving the design, the smaller meter sizes allow more flexibility during implementation and **represent a substantial cost saving to NWSDB**.

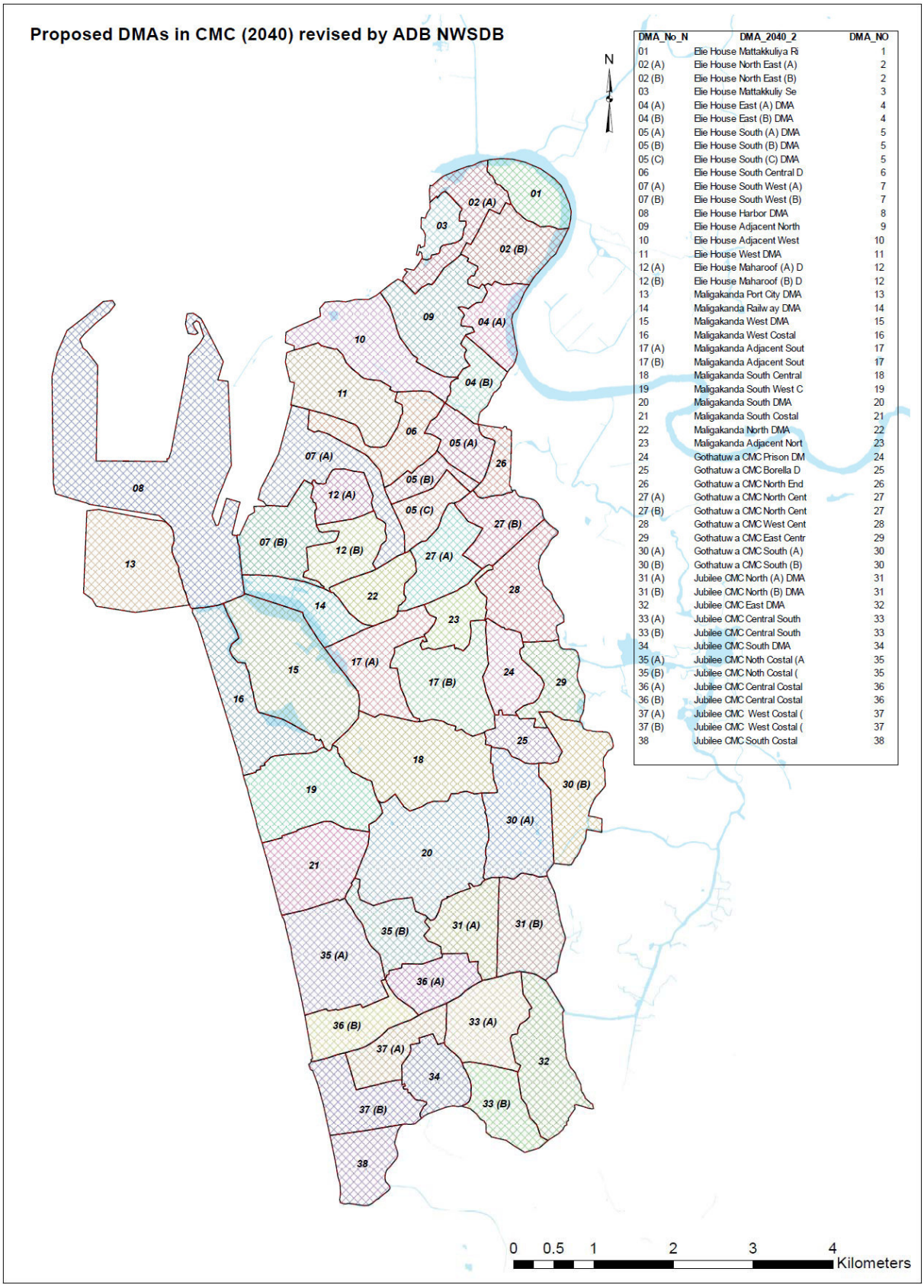
2. DMA Size: The number of DMA has increased from 32 to 51 giving an average size of approximately 2,500 connections. All DMA are now below 5,000 connections.

5.2 REVISED DMA DESIGN

The revised design is illustrated in Figure 5-1.

A full DMA by DMA review is outside the scope of the current contract. Consequently comments in the following section are based on the available statistical data for the overall design. A summary of available data is provided in Table 5-2.

Figure 5-1 Revised DMA Layout



DMA_No_N	DMA_2040_2	DMA_NO
01	Elie House Mattakkuliya Ri	1
02 (A)	Elie House North East (A)	2
02 (B)	Elie House North East (B)	2
03	Elie House Mattakkuliy Se	3
04 (A)	Elie House East (A) DMA	4
04 (B)	Elie House East (B) DMA	4
05 (A)	Elie House South (A) DMA	5
05 (B)	Elie House South (B) DMA	5
05 (C)	Elie House South (C) DMA	5
06	Elie House South Central D	6
07 (A)	Elie House South West (A)	7
07 (B)	Elie House South West (B)	7
08	Elie House Harbor DMA	8
09	Elie House Adjacent North	9
10	Elie House Adjacent West	10
11	Elie House West DMA	11
12 (A)	Elie House Maharoof (A) D	12
12 (B)	Elie House Maharoof (B) D	12
13	Maligakanda Port City DMA	13
14	Maligakanda Railw ay DMA	14
15	Maligakanda West DMA	15
16	Maligakanda West Costal	16
17 (A)	Maligakanda Adjacent Sout	17
17 (B)	Maligakanda Adjacent Sout	17
18	Maligakanda South Central	18
19	Maligakanda South West C	19
20	Maligakanda South DMA	20
21	Maligakanda South Costal	21
22	Maligakanda North DMA	22
23	Maligakanda Adjacent Nort	23
24	Gothatuw a CMC Prison DM	24
25	Gothatuw a CMC Borella D	25
26	Gothatuw a CMC North End	26
27 (A)	Gothatuw a CMC North Cent	27
27 (B)	Gothatuw a CMC North Cent	27
28	Gothatuw a CMC West Cent	28
29	Gothatuw a CMC East Centr	29
30 (A)	Gothatuw a CMC South (A)	30
30 (B)	Gothatuw a CMC South (B)	30
31 (A)	Jubilee CMC North (A) DMA	31
31 (B)	Jubilee CMC North (B) DMA	31
32	Jubilee CMC East DMA	32
33 (A)	Jubilee CMC Central South	33
33 (B)	Jubilee CMC Central South	33
34	Jubilee CMC South DMA	34
35 (A)	Jubilee CMC Noth Costal (A	35
35 (B)	Jubilee CMC Noth Costal (	35
36 (A)	Jubilee CMC Central Costal	36
36 (B)	Jubilee CMC Central Costal	36
37 (A)	Jubilee CMC West Costal (	37
37 (B)	Jubilee CMC West Costal (	37
38	Jubilee CMC South Costal	38

Table 5-2 DMA Summary Data

DMA No.	DMA Name	Meter Size (mm)	Mains Length (m)	No of Connections	Base Demand (m^3/hour)	Ave Pressure (m)	Boundary Valves
1	Elie House Mattakkuliya Riverside	250	9,977	2168	196	14.8	4
02 (A)	Elie House North East (A)	250	14,430	5508	184	16.61	17
02 (B)	Elie House North East (B)	250	16,367		186		13
3	Elie House Mattakkuliya Seaside	150	3,654	469	68	21.2	3
04 (A)	Elie House East (A)	250	12,262	5076	211	17.72	7
04 (B)	Elie House East (B)	150	9,044		116		3
05 (A)	Elie House South (A)	300	9,773	6657	317	10.94	16
05 (B)	Elie House South (B)	250	10,138		195		29
05 (C)	Elie House South (C)	200	8,051		144		17
6	Elie House South Central	300	15,216	2049	277	16.94	27
07 (A)	Elie House South West (A)	300	15,591	6008	570	16.11	30
07 (B)	Elie House South West (B)	300	21,298		586		22
8	Elie House Harbour	400	23,669	108	806	17.11	15
9	Elie House Adjacent North	250	30,607	4974	384	25.82	27
10	Elie House Adjacent West	250	22,300	3311	297	22.85	15
11	Elie House West	250	17,865	2563	278	23.84	16
12 (A)	Elie House Maharoof (A)	300	13,572	7539	473	24.38	19
12 (B)	Elie House Maharoof (B)	300	17,246		623		14

DMA No.	DMA Name	Meter Size (mm)	Mains Length (m)	No of Connections	Base Demand (m^3/hour)	Ave Pressure (m)	Boundary Valves
13	Maligakanda Port City	400	66	0	938	21.23	
14	Maligakanda Railway	200	12,080	31	234	19.77	6
15	Maligakanda West	400	34,692	4358	1123	15.43	16
16	Maligakanda West Coastal	400	18,856	1181	976	13.85	17
17 (A)	Maligakanda Adjacent South West (A)	300	17,452	6,151	495	14.71	35
17 (B)	Maligakanda Adjacent South West (B)	300	30,260		367		44
18	Maligakanda South Central	300	29,786	1,980	412	3.2	21
19	Maligakanda South West Coastal	300	31,278	1,810	342	14.09	20
20	Maligakanda South	300	25,301	1,145	432	14.67	16
21	Maligakanda South Coastal	300	8,595	1,593	241	13.8	16
22	Maligakanda North	300	11,995	2,407	449	25.34	7
23	Maligakanda Adjacent North	250	19,138	2,071	206	13.21	21
24	Gothotuwa CMC Prison	300	15,461	633	333	12.99	16
25	Gothotuwa CMC Borrella	200	11,825	1,137	144	19.94	21
26	Gothotuwa CMC North End	200	6,204	1,712	177	13.41	16
27 (A)	Gothotuwa CMC North Central (A)	300	19,533	8,427	333	16.03	7
27 (B)	Gothotuwa CMC North Central (B)	250	9,230		408		8
28	Gothotuwa CMC West Central	300	23,339	4,615	394	17.5	9
29	Gothotuwa CMC East Central	300	16,138	4,143	367	17.39	2

DMA No.	DMA Name	Meter Size (mm)	Mains Length (m)	No of Connections	Base Demand (m^3/hour)	Ave Pressure (m)	Boundary Valves
30 (A)	Gothotuwa CMC South (A)	300	21,355	4,282	318	18.4	11
30 (B)	Gothotuwa CMC South (B)	250	20,587		163		10
31 (A)	Jubilee CMC North (A)	300	17,240	4,842	507	38.41	11
31 (B)	Jubilee CMC North (B)	300	16,467		201		1
32	Jubilee CMC East	250	19,399	2,164	308	23.11	16
33 (A)	Jubilee CMC Central South (A)	300	22,485	5,646	288	32.07	11
33 (B)	Jubilee CMC Central South (B)	200	12,087		160		15
34	Jubilee CMC South	250	16,572	2,249	199	30.08	10
35 (A)	Jubilee CMC North Coastal (A)	200	30,693	4,934	285	18.71	22
35 (B)	Jubilee CMC North Coastal (B)	200	12,742		202		19
36 (A)	Jubilee CMC Central Coastal (A)	250	21,208	3,443	546	19.83	17
37 (A)	Jubilee CMC West Coastal (A)	250	13,361	5,363	230	19.14	16
37 (B)	Jubilee CMC West Coastal (B)	250	17,781		235		16
38	Jubilee CMC South Coastal	250	13,520	2,457	230	17.74	2
	City-wide		**867,786**	**125,204**	**18,154**	**18.75**	

Notes: Mains length and connections taken from GIS with mains length based on rehabilitated system.

Hydraulic data taken from Master Plan based on 2040 modelling scenario

Full statistics for the new DMA not yet available – connections and pressure based on the old 'combined' DMA

5.2.1 Meter Size

All DMA in the revised design are single feed with supply from medium to large diameter distribution mains. The distribution of the assessed district meter sizes is summarised below:

Table 5-3 Distribution of District Meter Sizes

150mm	200mm	250mm	300mm	400mm
2	7	17	21	4

The current district meter selection is based on a desktop analysis of the feed points and does not take into account 'constructability' of the meter site. Site inspections of the proposed meter locations are required to confirm the suitability of the proposed site and allow a detailed design to be developed. It should be expected that some changes to both meter location and the meter size will result from site inspections.

Clearly any revision to the proposed meter size will require a corresponding adjustment to the meter order. However the meter tender has now been revised in such a way as to provide the necessary flexibility to allow revisions to the meter order to be managed with minimal disruption. None the less, **site inspections of the proposed meter sites should be undertaken at the earliest opportunity to allow the detailed design to be completed and the critical meter order to be finalised.**

5.2.2 DMA Size

Full statistics for the revised design were not available at the time of reporting. However the average DMA size is now 2,500 with the largest DMA comprising 4,974 connections. There are four DMA with in excess of 4,000 connections.

In general smaller DMA allow more aggressive leakage management as smaller leaks become visible on the night line and detection times are reduced. However this improved leakage performance is offset by increased construction and maintenance costs. Ultimately, therefore, DMA size is a function of the economic level of leakage which is currently unknown.

None the less the DMA size can be regarded as reasonable for the local cost base. In the event that leakage management costs are higher than expected some of the larger DMA may be considered for 'splitting' in the future.

5.2.3 DMA Boundaries

The primary objective of boundary design is to minimise negative impacts of DMA establishment on network performance. The number and diameter of pipes in the existing network which need to be closed to establish the boundary is indicative of the impact on network performance and reflects of the degree of difficulty which is likely to be encountered in DMA establishment.

Table 6-2 shows the number of boundary valves required to establish a given DMA.

It should be noted that in advance of detailed design it is not possible to specify the number of actual valves required as it will be appropriate to cap some of the smaller diameter lines. The statistics at this stage should

therefore be seen as a measure of the number of interventions in the network required to establish the DMA and the term boundary 'valve' should not be taken literally.

The distribution of boundary 'valve' diameters is summarised in Table 5-4.

Table 5-4 Diameters of Boundary 'Valves'

150mm<	150 – 300mm	>300mm
180	184	19

The following observations should be made:

1. Some DMA require excessive numbers of boundary 'valves' to establish the DMA. Whilst this may be a reflection of the high level of network connectivity it is, none the less, a cause for concern; and

2. Some of the boundaries require large diameter pipes to be closed which may have significant network impacts and will give rise to water quality issues in the future.

It is recommended that the boundaries are subjected to a detailed review. Where possible, boundaries should be redesigned to minimise the number of boundary valves required. The following guidelines should be applied during detailed design:

- All pipes should be 'looped' within the DMA where practicable;
- End caps should be preferred for smaller diameter pipes (typically less than 150mm); and
- Boundary valves should be preferred for larger diameter pipes (typically greater than 150mm) which are retained for strategic reasons

The impacts of closing larger diameter pipes should be considered on a pipe by pipe basis.

Many of the medium and large diameter pipes which are proposed for closure to secure the boundary are included in the mains rehabilitation programme. These pipes should be considered for down-sizing. **Down-sizing redundant capacity offers considerable scope for cost savings in the rehabilitation budget**. However it should be noted that the final pipe size must balance any potential cost savings from down-sizing against the strategic importance of the main.

5.2.4 System Pressure and DMA Establishment

System pressures are very low with a citywide average of less than 20m head based on 2040 modelling scenarios. It should be noted that low pressures will have two direct impacts on NRW activities:

1. The establishment of DMA boundaries (lock in) may be problematic at low pressures. Any valve closure results in a redistribution of network pressure and, where pressures are close to the standard of service, establishing DMA boundaries can cause significant problems; and

2. Leak detection may be more challenging at low pressures. All commonly used leak detection techniques are acoustic in nature and work better at higher pressures. Night time detection is clearly preferable with such low system pressures.

5.2.5 Pressure Monitoring Points

It is noted that, with the exclusion of the district meter, Pressure Monitoring Points (PMP) have not been included in the design. It is conventional to install a PMP within the DMA typically at the critical point (lowest pressure) to monitor network performance. Whilst it should be noted that the PMP is not required for NRW management it does provide a powerful tool for network managers and is particularly useful in larger DMA were low pressure is a factor. **It is recommended that PMP are installed to facilitate network management.**

5.3 DISCUSSION

It should be recognised that the DMA design is very high level 'planning' design based on a very limited specification. The key specification of the DMA design was to establish zones of less than 5,000 connections whilst maintaining minimum pressures of 10m under 2040 demand conditions.

The output of the design is essentially a zone boundary with an identified feed point which has been used to derive the proposed meter diameter. No detailed meter design has been undertaken.

Significant improvements have been made to the design during the current project. None the less it must be recognised that DMA design is an on-going process that will be subject to revision throughout the construction phase as better information becomes available. The current design should therefore be viewed as a preliminary desktop design and further changes should be anticipated as the design process proceeds.

It is recommended that the design is progressed by;

3. Undertaking site surveys of the critical meter locations; and
4. Reviewing boundary design to minimise potential network impacts.

It is important that confidence in the DMA design is improved prior to beginning detailed pipe design.

6.0 TRAINING

6.1 SUMMARY OF TRAINING PROGRAMMES

The following workshops and presentations were delivered through the course of the project:

	Participants:	*Date:*
DMA Design, Operation & Maintenance	64	10th September 12th September
Change Awareness & DMA Concepts	65	19th November 21st November
Training Design & Presentation Techniques	28	27th November
Use and Interpretation of IWA Water Balance	*26*	22nd January

DMA Design, Operation and Maintenance:

Description: a full day workshop for RSC-WC engineers and managers. The workshop was built around a series of technical presentations and question and answer sessions covering all aspects of DMA from basic theory through to design, operation and maintenance. The workshop was delivered by the team leader Mark Hodgson.

Objective: to provide an overview of DMA concepts for managers and engineers in RSC-WC to facilitate delivery of the investment programme.

Change Awareness & DMA Concepts:

Description: a full day workshop for RSC-WC engineering assistants and technicians. The workshop was delivered in two distinct sessions. Session 1 comprised a participatory session including group discussions and presentations by the participants on the general "need for change". Session 2 was an introduction to basic DMA concepts. The workshop was led by the training specialist Gamini Kudalyanage with support from team leader Mark Hodgson.

Objective: to provide an awareness of the need for change in the context of the Colombo City NRW project and give an overview of DMA concepts for OIC and Zone Officers in RSC-WC.

Training Design & Presentation Techniques:

Description: a full day workshop for the training of trainers in training design and presentation techniques. The workshop was interactive with participants taking part in group activities, discussions and practice sessions. The workshop was led by the training specialist Gamini Kudalyanage with support from Mr Darsana Ranatunga.

Objective: to provide overview of training design and improve the presentation techniques of prospective trainers within RSC-WC who can provide peer to peer training during the investment programme.

IWA Water Balance:

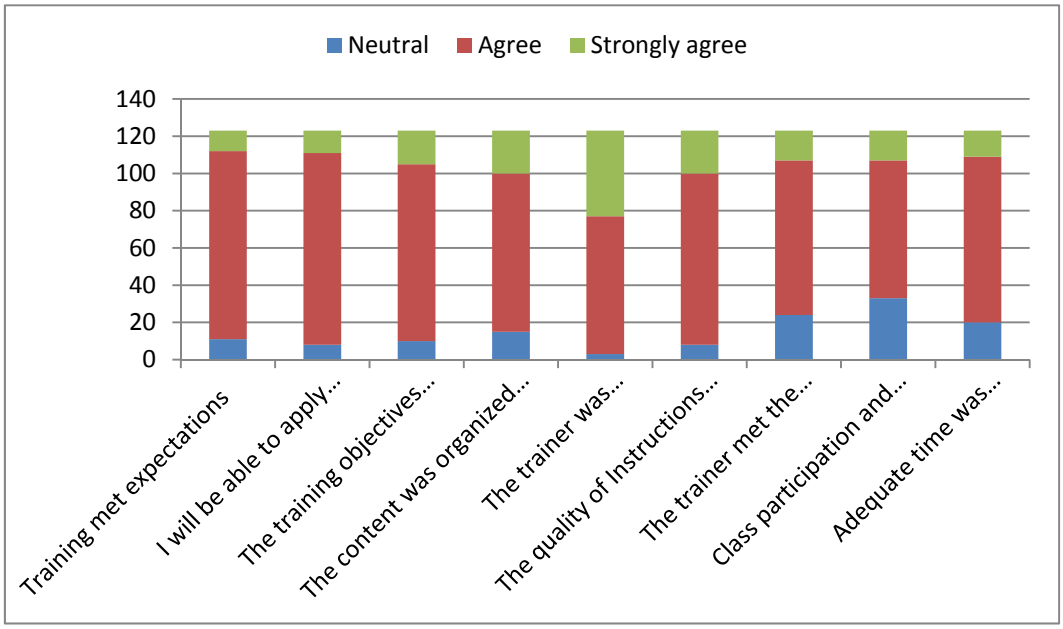
Description: a short presentation on the correct application and interpretation of the IWA water balance. Participants included engineers and managers involved in the production of water balance and the reporting of NRW. The presentation will be delivered by the team leader Mark Hodgson.

Objective: to provide an improved understanding on the correct application and interpretation of the standard IWA Water Balance.

6.2 TRAINING EVALUATION

Participants were asked to complete a training evaluation sheet after each training workshop. The responses were analysed and detailed results are presented in Appendix C. Overall training response is above average with one negative response and over 80 % of respondents expressing positive views. A graphical summary of the overall responses is presented below:

Figure 6-1 Overall Training Assessment Responses



Comments from Training Specialist Mr Gamini Kudaliyanage:

- The training provided basic skill transfer of the main change management and technical concepts.
- Change Management training was a success in terms of participant satisfaction and interaction during the training. Training participants maintained attention throughout the sessions and participation in the training was very high;
- While participants had little prior experience in change management and best practices of NRW, their performance during workshops was highly satisfactory. The participants contributed immensely to the success of the programme;

- The technical training succeeded in raising awareness of the technical changes associated with the investment programme and the likely impacts on the Operations Group. However further practical (On the Job) training will be required for specific skills training;

- Experience sharing though, was the lowlight of the technical training due to the language barrier. In addition there was no real life cases or issues that trainees could have provided due to lack of experience in NRW; and

- Understanding of the training cycle and the importance of making effective presentations as trainers were very well accepted by the trainees. The participants showed a marked improvement in presentation technique following the session; and

Comments from participants:

- Participants requested that the Change Management programme be extended to the wider workforce; and

- Participants were keen to learn about management training re leadership, team building, communication, strategic planning areas.

6.3 RECOMMENDATIONS

6.3.1 Change Management Training

Change management training to date has been focused on the middle ranked Operations staff. It is recommended that the programme is extended to cover the wider RSC-WC workforce in preparation for the investment programme.

Change management is a continuous process. Consequently training needs will have to be kept under review throughout the investment programme. It is recommended that regular 'awareness' programmes are held to keep all staff informed of progress and current issues. This will help to maintain 'buy in' from the workforce as well as providing a forum for accessing useful feedback.

Managing the structural changes in the workforce will be challenging. It is recommended that a capacity building programme is considered to expose senior management and operational staff to modern management techniques and theory.

6.3.2 Skills Training

There is a need for a wide range of skills training both to reinforce existing skills and to train staff in new work practices and the use of new equipment required in NRW management. Skills training is essentially based on demonstration and supervised practice and as such is best delivered by 'on the job' experience.

The investment programme offers a unique opportunity to have NWSDB staff trained by international specialists.

There is a need to identify suitable candidates for secondment to MASC and/or the Contractor to work in areas such as leak detection, repair and DMA maintenance. Key secondments should be aligned with particular

training needs and suitable candidates should have the necessary qualities to act as trainers and be prepared to roll out new skills to their peer group within RSC-WC.

It should be noted that the new GIS team may have very specific training requirements however this will be dependent on the skill and experience of the staff recruited.

6.3.3 Knowledge Transfer

Similarly **senior engineers should be mentored by the MASC experts** for key positions. These engineers should be ear marked to assume responsibility for operating systems at the end of the implementation phase. Allowing senior engineers to shadow key consultants and contractors will also ensure smooth transfer at the end of the implementation period.

7.0 COMMENTS ON NRW REDUCTION STRATEGY

7.1 ACTIVE LEAK CONTROL (ALC)

7.1.1 Early Investment Programme

NWSDB has initiated a number of programmes in recent years to address the high level of NRW. Awareness of NRW has improved with weekly monitoring introduced by the chairman's Monday morning meeting. Reported year end (December) NRW figures for Colombo City are given below:

Table 7-1 Reported ('year end') NRW

2008	2009	2010	2011	2012
53.96%	53.05%	52.03%	49.97%	49.19%

The data shows a modest but steady reduction in NRW accounting for approximately 1% per annum. This reduction is largely attributable to increasing demand with a significant contribution coming from the successful free water and illegal use programmes conducted by the NRW team. However as the free water programme is now complete and the number of illegal users is declining the ability of the NRW team to apply downward pressure to the NRW level is diminished.

There is currently no city wide ALC programme with activities restricted to small pilot areas. Under the strategy ALC activities are deferred until after the network refurbishment and DMA establishment. Consequently in the early stages of the investment programme there is a significant risk that the NRW will begin to increase again as unreported bursts accumulate on the network in the absence of ALC.

It is tacitly assumed that the majority of the leakage is on the cast iron pipes however this is not proven. Consequently while the condition of the PVC pipes remains an unknown there is a risk that residual leakage at the end of the mains refurbishment will remain high. Early collection of burst statistics from the PVC pipes will therefore deliver greater certainty in the outcomes of the project.

It is recommended that a programme of ALC targeted at the PVC pipes is implemented early in the investment programme.

Key experts to lead ALC programmes are available under MASC. **It is recommended that a leakage team is drawn from existing Operations staff to support the MASC expert**. Exposure to the MASC leakage specialist will deliver good skills transfer and provide excellent training. However it is recognised that this proposal is dependent on the availability of resources and must be balanced against the other demands on the RSC-WC Operations Group.

7.1.2 Post DMA Establishment

Current strategy documentation over promotes the use of step testing as a first option leak detection method. Step testing is problematic in urban environments and inefficient in back log situations. **It is recommended that a simple leakage sweep based on the manual sounding of all fittings and connections is undertaken as the first approach**.

The contract requires ALC to be continued until a target level of 18% NRW is achieved at which point the DMA is handed over to Operations. The use of % NRW as a target for ALC activities is inappropriate and inherently unreliable at DMA level. **It is recommended that the more meaningful measure of 'burst losses' as derived from the Minimum Night Flow (MNF) is adopted as the target measure for ALC**.

Ceasing ALC at a notional level of 18% NRW is potentially inefficient as it may be wasteful of easy gains. **It is recommended that ALC is continued by the Operations Group after DMA handover to drive burst losses down to optimum levels based on a night line analysis**.

7.2 CUSTOMER METER REPLACEMENT POLICY

Currently NWSDB does not have a customer meter replacement strategy with meters only being replaced on failure. **It is recommended that a meter replacement policy based on economic replacement frequency is implemented under the investment programme.**

An effective meter replacement policy will need to address two related issues:

1. Meter Selection: Current procurement policies focus on unit purchase price. A more sophisticated approach to procurement should be adopted with selection of quality meters from suppliers with proven track record **based on whole life costs**.

2. 'Age' of meter: Meters will initially be replaced based on age. However as more data becomes available NWSDB should move to a more sophisticated analysis based on age and volume to better reflect meter condition.

7.3 STREET SURVEYS

Under the investment programme the contractor is required to undertake a number of surveys to support different aspects of the work including customer meter surveys and property surveys to support illegal use activities. As far as possible these surveys should be merged into a single street by street survey and undertaken early in the contract period.

The information collected represents valuable data which will be required by NWSDB for future operation and management of the network. **It is recommended that NWSDB identify an end user for the various data sets collected to ensure a smooth transfer of data to NWSDB without loss of valuable information**.

7.4 DMA ESTABLISHMENT

Under the current strategy DMA Establishment is deferred until after mains refurbishment. Consequently DMA will typically only be established in the later phases of the investment programme. **It is recommended that DMA with limited mains replacement are prioritised for establishment early in the investment programme to act as pilot areas.**

7.5 PROGRESS MONITORING & KPI

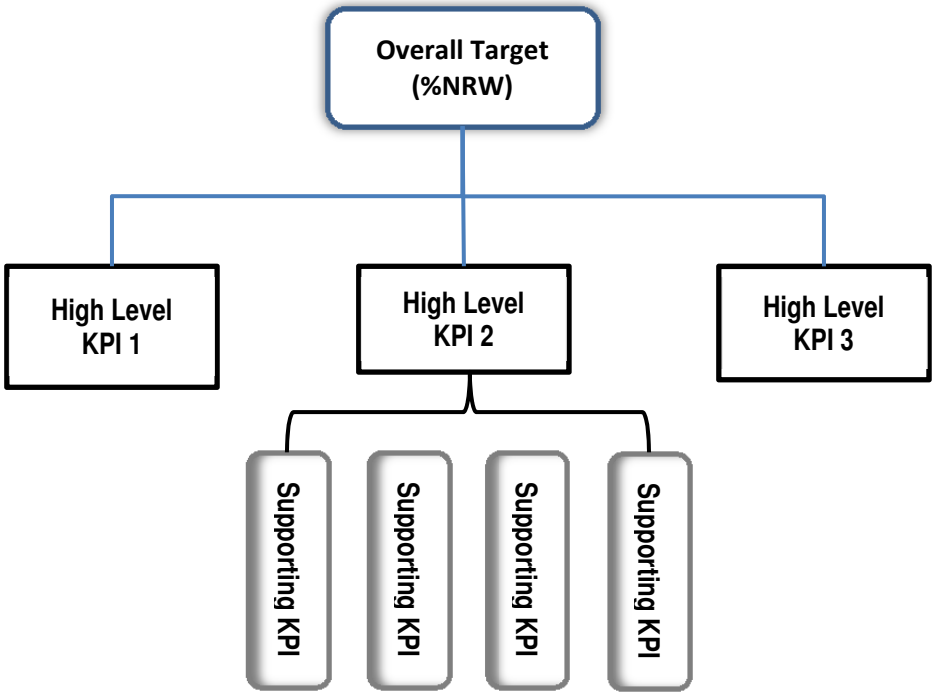
The current strategy is over reliant on the use of %NRW to monitor progress and performance. As previously noted %NRW is an unreliable indicator of NRW performance due to its susceptiblilty to fluctuations in demand. **It is recommended that %NRW is quoted in conjunction with the volume to avoid misleading stakeholders.**

There are a number of additional problems with this approach:

- NRW is a composite measure and provides no information on the progress of the component activities thus making it a poor tool for project management;
- Delivery is attributed to a wide group of stakeholders therefore NRW does not reflect performance of any one party thus making it a poor tool for performance monitoring;
- Monitoring NRW alone does not offer any insight into the performance (or failure) of a particular activity or party. Successful delivery in one task could mask under performance in another thus preventing managers from taking corrective action; and
- In the early stages of the contract (particularly the design stage) progress will not be reflected in the NRW. As noted previously NRW may initially increase in response to the Natural Rate of Rise (NRR) regardless of good progress being made under the required contract activities.

Progress under the contract will therefore need to be measured for the individual programmes of work and performance assessed against a number of Key Performance Indicators (KPI). For a complex project with multiple stakeholders performance monitoring will need to be layered with 'high level' KPI underpinned by a basket of supporting KPI as illustrated below.

Figure 7-1 Approach to Performance Monitoring



It is recommended that the following areas are considered for high level KPI:

Design: *Objective:* deliver a fully detailed and staged design for each package (DMA) approved by PMU	No of packages (DMA) complete
Network Refurbishment: *Objective:* refurbish network as per design including final reinstatement and handover to Operations	Km complete %age of total
DMA Establishment: *Objective:* establish fully operable DMA reporting to control room and ready for ALC	No of operable DMA
Apparent Losses – Illegal use: *Objective:* fully surveyed network with all detected illegal use eliminated	%age of network complete No of illegal users disconnected
Apparent Losses – Meter under registration: *Objective:* all customer meters operating in line with adopted meter replacement policy	%age of network under meter replacement policy No of meters replaced
Real Losses – ALC inside DMA: *Objective:* maintain all operable DMA at or below target level based on MNF	No of DMA at or below target No of leaks repaired
Real Losses – ALC outside DMA: *Objective:* maintain downward pressure on NRW	No of leaks repaired
Real Losses – Passive leak control: *Objective:* timely customer response and maintain downward pressure on NRW.	Time to repair

It is recommended that a 'basket' of appropriate supporting KPI is developed for use with the investment programme and with the long term maintenance of NRW. To be effective KPI need to be reliable, transparent and targeted at specific tasks and parties.

KPI will need to be applied early in the implementation phase. Initial responsibility for delivering KPI will largely fall with MASC and the Contractor however it should be noted that some critical functions will be retained by the Operations Group. As DMA are handed over the responsibility for maintaining KPI will be progressively transferred to NWSDB staff.

It is important that KPI are accepted as reasonable by all stakeholders (including the contractor). **It is recommended that a workshop is held early in the investment programme to agree and allocate supporting KPI to all stakeholders.**

8.0 COMMENTS ON CHANGE MANAGEMENT

8.1 INTRODUCTION

The implementation phase of the "Colombo Water Supply Service Improvement Project" is due to commence in 2014. This will result in a number of significant changes in the performance and operation of the Colombo City network. There is a need therefore for NWSDB and in particular RSC-WC to plan for the short term impacts and to prepare a strategy to manage change in the medium to long term.

It should be recognised that change management is a continuous process which should be kept under review. This Section highlights some critical issues and makes a few preliminary recommendations on 'change management'. It is not intended to provide a comprehensive or definitive solution to the issues but is hoped to provide a basis for moving forward.

8.2 OVERVIEW OF CHANGES

The objective of the investment programme is to reduce NRW to below 18% of Water Into Supply.

The programme can be considered as comprising three components:

1. A major network refurbishment programme covering 60% of network; and
2. A number of NRW programmes primarily ALC based on DMA concepts.
3. Introduction of new data management systems including GIS

The impacts of these components are summarised in Table 8-1.

Table 8-1 Impacts of Investment Programme

Current Position	Project Implementation	Post Project Implementation (2020)
Network Refurbishment		
The current network performance is very poor with significant proportion of the infrastructure operating beyond its useful asset life and subject to repeat failures. The Operations team are essentially firefighting with little or no positive impacts on performance.	Implementation will result in large scale construction works concentrated in highly developed urban areas. The number of operational sites will dependant on contractor deployment. The immediate impact will result in a localised deterioration of network performance as shut offs have a negative impact. Customer complaints (contacts) will inevitably increase. Performance should begin to improve during later stages of implementation as new assets come on line. There will be no change to NWSDB core functions however NWSDB (Ops) workload will increase during early stages of project roll out due to the need to manage shut offs and customer contacts.	Network performance will be substantially improved with corresponding reduction in NWSDB (Operations) workload. There should be a general move from "fire-fighting" to network management focused on delivering a continuous planned improvement in performance.
NRW Components		
The O&M unit spend significant time and resources addressing passive leakage control (in response to customer complaints). NRW unit run a number of projects targeted at 'active' NRW reduction but no comprehensive citywide response. Projects include • ALC pilot studies; • Targeted sweeps for illegal use	Implementation will result in the steady reduction in NRW as the new infrastructure comes on line. Specific NRW programmes will be rolled out city wide to address specific components of NRW including: • Illegal use – early • Customer meter replacements • DMA establishment & ALC Areas will be handed back to NWSDB control on a DMA by DMA basis once all refurbishment works are	NRW will be below 18% with systems and programmes in place to maintain or reduce NRW levels into the future. O&M unit will see significant reduction in leakage work (passive leak response and repairs) NRW unit will see significant reduction in all work programmes within the city: • Introduction of DMA will substantially reduce

Current Position	Project Implementation	Post Project Implementation (2020)
• Free water programme NRW has remained persistently high at 50% despite various NRW reduction projects.	completed and target NRW levels (18%) have been achieved. NWSDB will need to restructure to accommodate DMA infrastructure. NRW team will take over responsibility for DMA operation and maintenance. NWSDB workload should reduce as implementation progresses with both passive (O&M) and active (NRW) NRW activities being reduced	the amount of manpower required for ALC • Illegal use will be largely eliminated • 'Free Water' programme will be complete NRW team will refocus activities outside the city. NWSDB should plan to reduce NRW to economic levels which may be lower than 18%.
Systems		
Mains records are currently maintained by the Mapping Section. RSC-WC Operations are largely reliant on paper plans though a digital GIS has been made available to the PMU. There are no comprehensive NRW management systems. The Water Balance is undertaken citywide. System Input meters are manually read. No comprehensive property records and the billing system have not been spatially referenced.	Development and roll out of new systems will be on-going throughout implementation including: • GIS • Data logging systems • NRW management systems • Water Balance by supply zone • Improved billing system and property data NWSDB will need to progressively take over management of these systems throughout the later stages of implementation. A new GIS unit will need to be established. NRW unit will take over ALC & data logging systems Commercial will take over management of the customer meter stock.	NWSDB will be responsible for operation and maintenance of all systems. The new GIS unit will take over responsibility for maintaining mains records from the Mapping Section. All systems should be rolled out across RSC-WC and access widened to all relevant staff. In general the introduction of the new systems should be neutral with respect to work load as need for new specialist staff is off-set by operating efficiencies in other areas.

8.3 CHANGE MANAGEMENT ISSUES

8.3.1 Restructuring

Some organisational restructuring will be required to accommodate the new systems and DMA structure within the city. In particular:

- A new GIS unit will need to be established;
- The O&M unit will restructure to align with new DMA boundaries; and
- The NRW unit will restructure to set up ALC for Colombo City and wind up other programmes as they become redundant.

The GIS unit will comprise technical staff with specialist skills which will naturally form a 'stand alone' unit with a clear division of roles and responsibilities from the remainder of the Operations Group. The line management and in particular the relationship with the Mapping Section will need to be confirmed. **The key action will be to appoint a specialist engineer for the team leader position**.

8.3.2 Roles and Responsibilities

Successful delivery of the investment programme will rely heavily on the integration of the various parties involved in implementation; NWSDB/PMU/MASC/Contractor. Successful integration will in turn rely on a clear understanding of roles and responsibilities.

The RSC-WC Operations Group comprises four distinct and largely autonomous units (including GIS). The proposed division of responsibilities between the four Operations Units is summarised in Table 8-2.

Roles and responsibilities for specific NRW activities within the Operations Group are summarised in Table 8-3.

The investment programme will be largely delivered by the MASC and the Contractor. There is some overlap in expertise and function between these two parties. **Consequently roles and responsibilities will need to be further clarified with the MASC and the Contractor once appointed.**

8.3.3 Communications

Delivery of the programme will only be achieved with the coordinated efforts of all parties and the support of all stakeholders. Consequently good communications will be essential.

The PMU will be responsible for general communications, progress reporting and notifying stakeholders of planned works. However there is a particular need for strong and clear lines of communication between the Contractor(s) and the O&M unit to manage day to day network operations.

Table 8-2 Operations Group - High Level Responsibilities

	GIS Unit (future)	Current Operations Group		
		Commercial Unit	O&M Unit	NRW Unit
IT System Owner	GIS	Billing	Customer Complaints	NRW Management System
Asset Owner		Customer meters	All other fixed assets (SR, PS, pipes & fittings etc.)	District meters (and associated data loggers)
Roles *Note: italics indicates future role*	*Maintain and operate GIS and provide mapping and GIS analysis to support other RSC-WC units*	Maintain and operate the billing system. Manage customer meter reading *Manage customer meter stock*	Operation and maintenance of the network First response to all customer complaints All physical works on the network including meter replacements All valve operations Passive NRW management Maintain Supply Zone boundaries *Maintain DMA boundaries*	NRW reporting Active NRW management Maintenance of system input *and district meters and associated data loggers*
Key Performance Area	Initially: Construction of GIS Ultimately: Accuracy of GIS	Correct & timely billing	Network performance	NRW

Table 8-3 Specific NRW Roles and Responsibilities

Component of NRW	Responsible Unit	Comment
Unbilled Authorised Consumption – Unbilled Unmetered		
Free Water (Tenement Gardens)	NRW	Reduction of free water (Tenement Garden) usage within Colombo City has been on-going since 1990 and is now nearing completion. Staff currently employed on this programme will need to be redeployed outside the city or onto Active Leakage Control as the programme winds down.
Operational Use	O & M	Operational use is a minor component of the water balance and consequently often overlooked. However as NRW is reduced this will become increasingly significant and the need to improve the management and reporting of Operational Use will become more important.
Apparent Losses – Unauthorised (illegal) Consumption		
Passive Control of Illegal Connections	Commercial O & M	Illegal connections will continue to be identified on an ad-hoc basis by the Commercial and O&M units during the course of their day to day activities. Responsibility for reporting illegal use should rest with all staff of NWSDB however it should be expected that a particular responsibility would lie with the meter readers.
Active Control of Illegal Connections	NRW	Responsibility for targeted sweeps will remain with the NRW unit however it is assumed that only limited illegal use will remain in Colombo City following completion of the investment programme. Consequently activity is likely to be reduced and will be refocused outside the city area.
Management Systems & Records	GIS	Sustainable reductions in illegal use will require continuous monitoring of the situation. The investment programme requires consultants to develop data base of all properties in Colombo City and check the status all “non-customers”. Going forward it is important that the data collected is maintained to ensure that the reductions in illegal use are sustained. All properties (including those who are not currently connected to the network) should be monitored to encourage the legal connection of new customers and ensure that new illegal connections are not established. Property records should be included and maintained in the GIS system.

Component of NRW	Responsible Unit	Comment
Apparent Losses – Customer Meter Errors		
Meter under-registration	Commercial	The investment programme will implement a proactive replacement policy for customer meters within the city based on the economic replacement frequency. Following the initial meter replacements the Commercial section will need to assume responsibility for maintaining the policy in Colombo City as well as rolling out the policy to the wider RSC-WC area.
Data handling errors	Commercial	The management and minimisation of data handling errors (including billing estimates) will remain with the commercial unit
Corrupt Meter Reading	Commercial	The management of corrupt meter reading practises will be the responsibility of the commercial unit.
Real Losses		
Passive Leak Control	O & M	The O&M unit will have responsibility for managing reported (passive) leakage. Following the extensive mains rehabilitation undertaken in investment programme it is expected that burst frequency will be dramatically reduced and therefore the general level of activity within the city will be greatly reduced.
Active Leak Control	NRW	The NRW unit have responsibility for managing unreported (active) leakage. Following the extensive mains rehabilitation undertaken in investment programme it is expected that burst frequency will be dramatically reduced and therefore the general level of activity within CC will be greatly reduced. Consequently whilst ALC is an on-going activity network wide it should be expected that the intervention frequency within the city will be greatly reduced and activities will refocus outside of the Colombo City area.
Leak Repair	O & M	O&M will manage all repairs (including repairs out sourced to contractors)

It is inevitable that O&M staff will find themselves working in close proximity to the Contractor. Good communication and coordination of valve operations will be essential to avoid unintended consequences particularly where unplanned work by O&M staff is concerned.

Boundary Valve management procedures are essential to the maintenance of DMA. Unless these procedures are applied to all parties from the outset there is a significant risk that DMA established by one party could be undone by another resulting in abortive work with the obvious impacts on progress.

Customer complaints will need to be notified to all relevant parties and the response will need to be coordinated. For instance the lock in of a DMA may result in complaints of 'no water' which require immediate action. It is assumed that primary responsibility for responding to customer complaints will be retained by O&M staff however the response may need to be delegated to the Contractor.

It is recommended that a coordination group is established for each area and that regular stakeholder meetings are set up to manage communications for the following activities:

- General valve operations;
- Notifications and shut offs;
- Customer complaints;
- Progress monitoring; and
- Forward planning.

It is recommended to identify an experienced engineer to act in the critical role of Coordination Officer for each area.

8.3.4 Resource Issues

Manpower impacts will be in two phases. Initially additional manpower will be required to support implementation however on completion the improved performance should allow staffing levels to be reduced.

Long term resource levels will need to be reassessed at the end of the implementation period. Both the O&M and NRW Units should be able to operate with reduced levels of resources within the city due to improved performance of the refurbished network.

However the additional workload generated by the implementation programme in general and the construction phase in particular will clearly generate significant resource pressures. Specific areas of concern where workload will clearly increase are:

- Customer Complaints;
- Notifications & Shut Offs; and
- Contractor Communications.

It is recommended that a resource strategy is established to meet the increased workload.

The strategy should consider both Operations and contract staff by:

- Deploying existing operations staff to roles where experienced network operators and specialist local knowledge is required; and
- Using contract staff (from MASC/Contractor) to backfill for Operations staff and to undertake administrative and routine tasks.

8.3.5 Leakage Management

Leakage management will be a key part of the NRW reduction strategy. As already noted a clear division of responsibilities between 'passive' and 'active' leakage management is required for efficient delivery of leakage management.

However during the investment programme additional leakage detection teams will be active and, in addition, responsibility for ALC will be transferred between parties depending on the status of a particular DMA. Potentially there are four distinct teams in operation:

O&M unit	Passive leak detection across the city;
NRW unit	Active leak detection - currently only in pilot areas;
Contractor	Active leak detection within established DMA (over 18%NRW);
MASC	Leak detection specialists available but no supporting staff or delegated role;

Current contract arrangements restrict leak detection activities by the contractor to ALC inside established DMA which are reporting NRW over a threshold level of 18%. The actual number and timing of leakage sweeps will be at the discretion of the PMU.

The MASC Specialists are required to work with NWSDB and PMU staff to provide training and support ALC activities but no specific area of operation has been identified at the current time.

There is a need to develop a clear policy towards leakage management during the investment programme which will make the best use of the available resources and delivers the maximum benefit across the city.

9.0 PMU PRIORITY ACTIVITIES FOR 2014

The PMU will have a pivotal role in ensuring a smooth transition into the implementation phase of the investment programme. Activities within the scope of the current study have been identified throughout the report. The following section outlines some additional tasks and provides a summary of the tasks already discussed.

At the time of reporting, the tender process to secure goods and services for the investment programme is on-going. Key contracts for equipment supply and civil works are expected to be in place by the middle of 2014. The Management Advisory and Supervision Consultant (MASC) is not expected to be in place until 2015 following difficulties with the tender process.

The detailed programme for the early stages of the investment programme is still therefore subject to contract negotiation and may need to be revised to accommodate the reduced resources available following the delay to the deployment of the MASC.

9.1 RESOURCE PLANNING

The delay to the MASC has resulted in a substantial loss of resources for the PMU. **There is a clear and urgent need to review the current resource levels, identify any resource gaps and develop an alternative resource strategy.** Some areas of immediate concern include:

> **DMA Design**: the DMA design is under review and it is anticipated that a significant redesign will be required. This area has proved problematic in the past and there is a clear need for expert support to deliver a robust design before moving to implementation.
>
> **GIS Capacity**: the capacity for processing GIS work is restricted by the number of qualified operators and GIS work stations. The design and implementation phases will require substantial GIS input and additional capacity in this area is critical if the programme is not to be constrained.
>
> **NRW Expertise**: to date advice on NRW issues has been provided by external consultants. There is an on-going need to provide support in this area. In particular contract negotiations may raise specific queries over product specifications and implementation methodologies which require expert advice.

It must be stressed that the resource situation remains highly fluid. The situation with the MASC tender remains unresolved and other contracts are still under negotiation. As noted previously the interface with the contractor requires further clarification and, as many of the tasks are collaborative, the capability of the contractors will also need to be taken into consideration. The stakeholders will need to develop a comprehensive resource plan for the PMU based on a full understanding of the situation once the contractual position has been clarified.

9.2 IMPLEMENTATION STAGING

It is currently assumed that the civil works will be rolled out on a DMA by DMA basis. The staging of the individual DMA for construction will need to take into account:

> **Impacts on the Surrounding Network:** construction works in one area should not unduly undermine the performance of other areas of the network. Typically this will favour construction start in upstream DMA or in 'isolated' DMA with minimal connectivity;

Ease of Construction: sequencing needs to take into account customer and environmental impacts and in particular restrictions due to traffic sensitivity. Areas with particular sensitivities should be deferred to allow time for planning, notifications and permissions; and

Current Design Status: the current DMA design is subject to review and some areas may require significant redesign. The staging should favour DMA with no significant design issues to allow designers time to work on more complex issues in other areas.

In addition some critical mains will need to be refurbished out of step with the wider DMA for operational reasons or due to the sensitivity of construction works in a given road. It may be necessary to bring forward or defer some individual mains in the programme to accommodate other utility operators, road resurfacing or environmental and social sensitivities.

Contractor deployment for large scale construction projects is inevitably challenging and will need to be ramped up over a period of time. **It is recommended that a 'soft' area based on ease of construction is identified for contractor start up**. This area can then be used to trial procedures and establish a robust interface with NWSDB and the PMU before ramping up deployment.

As noted previously pilot DMA should also be identified for early establishment.

It is recommended that the PMU develop a high level implementation staging for the refurbishment of DMA and critical mains. Immediate activities should be focused on the first contract package.

9.3 DMA DOCUMENTATION

The DMA design is currently documented within the GIS (and network model) and effectively comprises a boundary line over-layed across the network. Detailed information is limited and difficult to manipulate. Access to information is restricted to GIS operators.

In the early stages of the investment programme the proposed DMA will be the subject of discussion by planners and designers and will need to be submitted to other stakeholders for comment and approval. **It is recommended that the PMU develop a standard DMA pack comprising pertinent data to facilitate the design and planning process**. A typical pack would include:

- A large scale drawing(s) of the DMA clearly indicating:
  - Network configuration and structure;
  - DMA boundary with clear details of all boundary features; and
  - Detailed drawing of proposed meter installation.
- Statistical information such as mains length, property counts etc; and
- Identification of all priority and sensitive customers

Immediate activities should be focused on the first contract package.

9.4 OTHER ACTIVITIES

The current report is focused on NRW activities and highlights some priority issues requiring short term action. It must be stressed that the tasks identified are not intended to be comprehensive and that the PMU will need to undertake a wide range other activities to ensure smooth delivery of the investment programme.

It is currently assumed that construction will begin in 2015. Consequently preparation for construction will need to begin towards the end of the year. Preparation will include activities such as:

- Collecting utility data;
- Preparing public awareness materials; and
- Establishing procedures for construction supervision.

The resource allocation and programming for construction preparation will be critically dependent on the outcome of contract negotiations and consequently the situation will need to be kept under review.

9.5 SUMMARY OF PMU ACTIVITIES FOR 2014

A summary of PMU activities identified in the report is given in Table 9-1.

The notional start period is based on assumed outcomes of the contract negotiations (see foot note)

Table 9-1 PMU Activities in 2014

Activities	Other Stakeholders	Notional Start Period	Comment
Tender Process			
Contract negotiations		Q1	Complete tender negotiations for Civil Works, SI Meters and NRW Equipment contracts.
MASC		Q1	Clarify position with respect to MASC
Resource Planning		Q1	Assess impacts of delay to MASC tender and develop alternative resource strategy.
DMA Design (activities focused on first contract package)			
DMA Documentation		Q1	Produce DMA documentation packs for DMA design and implementation planning.
Review DMA Design		Q1	1. Review DMA design as discussed in Section 5. 2. Update boundary and revise meter locations as necessary. 3. Pass 'reviewed' DMA to Contractor for detailed design.
Implementation planning (activities focused on first contract package)			
High Level Implementation Staging	O&M Contractor	Q2	Develop high level implementation staging and agree with all stakeholders.
Set Up Coordination Group	O&M	Q2	Set up 'Coordination Group' (Section 8.3.3) and establish routine coordination meetings
Establish progress reporting	Operations Contractor	Q3	Establish progress reporting format and develop supporting KPI (Section 7.5) and agree with all stakeholders

Activities	Other Stakeholders	Notional Start Period	Comment
NRW Calculation - System Input Meters			
Install data loggers and software	NRW & Contractor	Q2	Work to be carried out under the meter supply contract. Software will initially be located with the NRW unit but eventually be rolled out to other stakeholders.
Upgrade SI meter stock	O&M, NRW & Contractor	Q3	Upgrade and relocate System Input meter stock as described in Section 3.0. All physical works and commissioning are included under the meter supply contract. PMU & Operations will provide support throughout planning and implementation.
NRW Calculation - Supply Zone Boundary			
General boundary issues	O&M	Q1	Complete investigation and documentation of supply zone boundary (Table 3-2).
Pamankada East Boundary	O&M	Q1	1. Develop design for Pamamkada East boundary in collaboration with local O&M as described in Section 3.4.3. 2. Install any new pipework or valves required by design (excluding meters). O&M to undertake construction if required. 3. Install pressure loggers, lock in and field test proposed boundary. 4. Poorwarama and Railway Avenue meters to be abandoned and/or relocated in line with proposed design. Work to be carried out under meter supply contract (Q3).
Boundary Valve Management	Operations	Q3	Develop a BV management procedure (Section 3.4.6) in agreement with the operations team. Apply procedure to supply zone boundary.
Establish NRW Baseline	NRW	Q3	Undertake audit of NWSDB NRW figure as required (Section 4.7).
Establish ALC strategy	Operations	Q3	Liaise with stakeholders to review resources for early adoption of ALC (Section 7.1).
Street Surveys	Contractor	Q3	Develop data collection procedure for street surveys (Section 7.3)

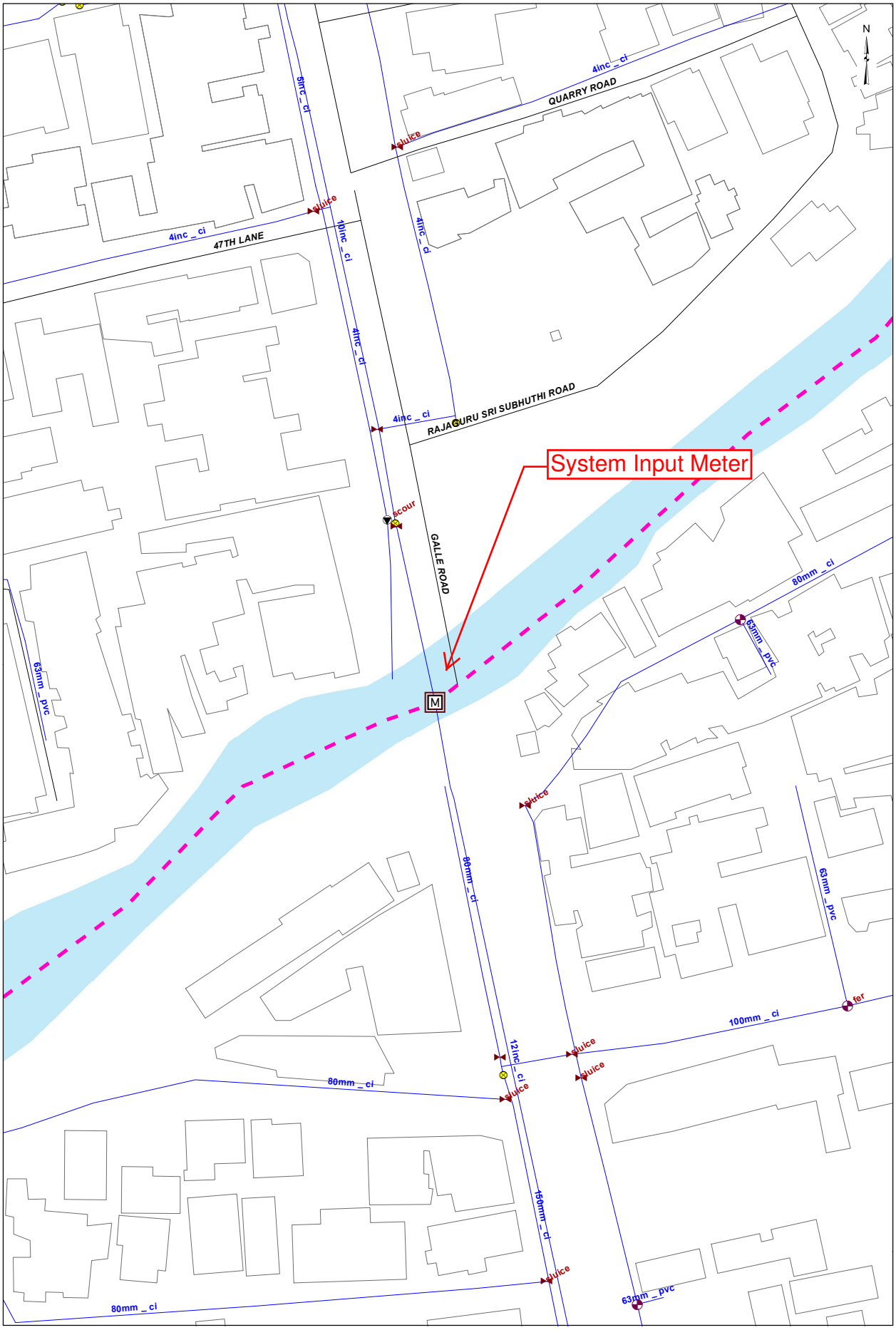
Note: Notional start period assumes the following outcomes of the on-going contract negotiations:

Civil Works Contract:	*Awarded end of Q2*	*Construction Start 2015*	
Meter Installation Contract:	*Awarded end of Q1*	*Logger delivery Q2*	*Meter delivery Q3 (assuming typical 3 month lead in time)*

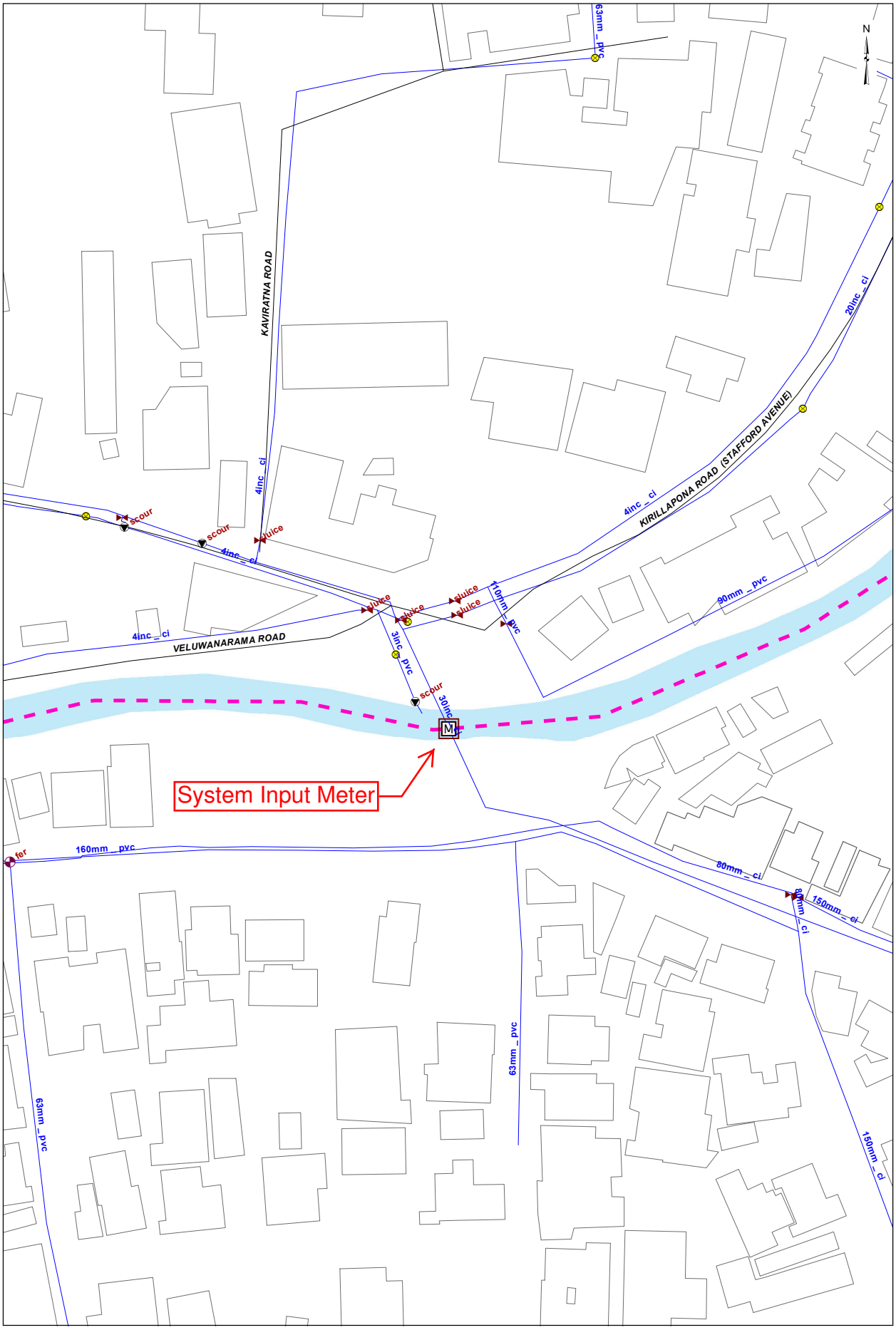
APPENDIX A

Boundary Features & Issues

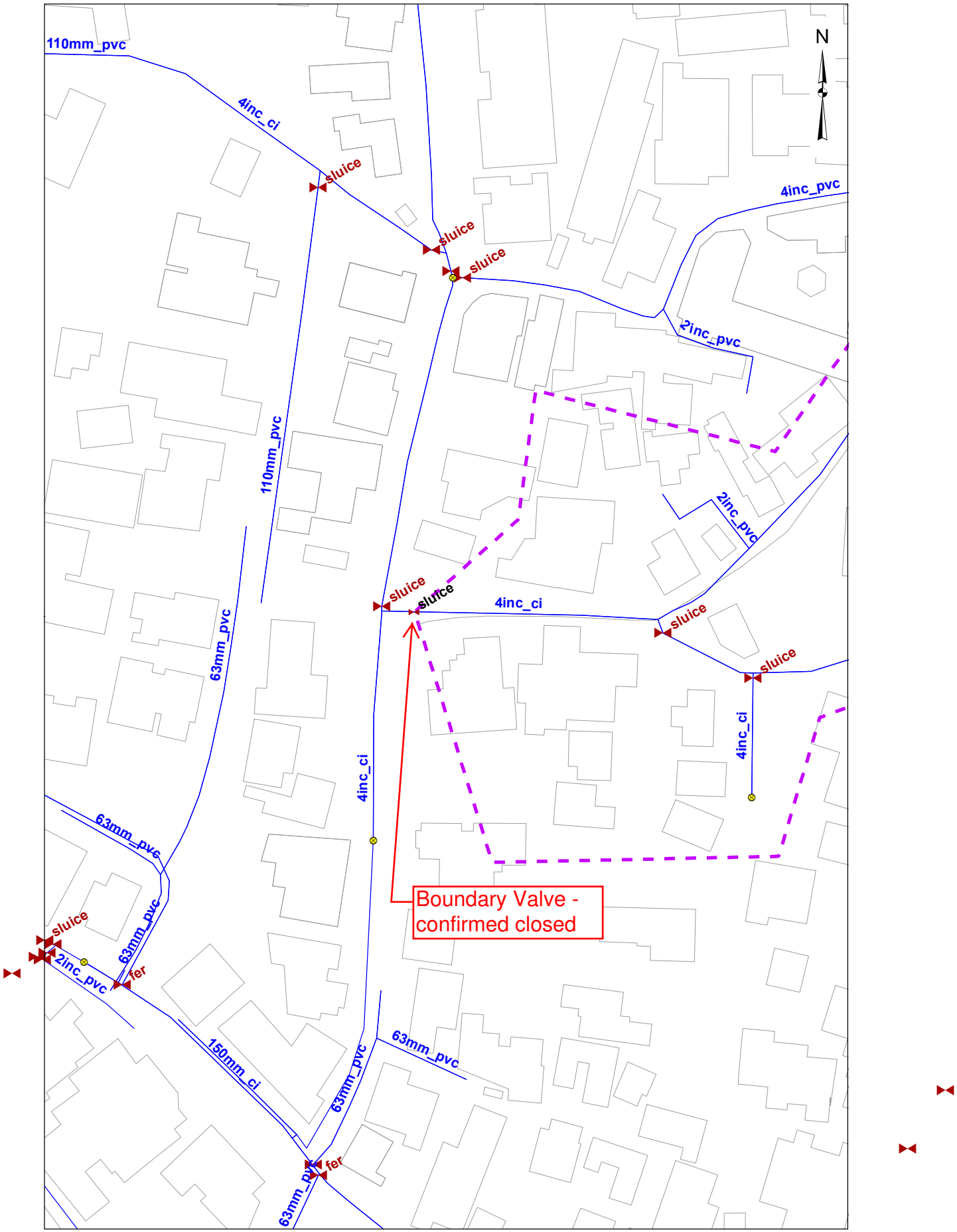
01. Dehiwala Bridge



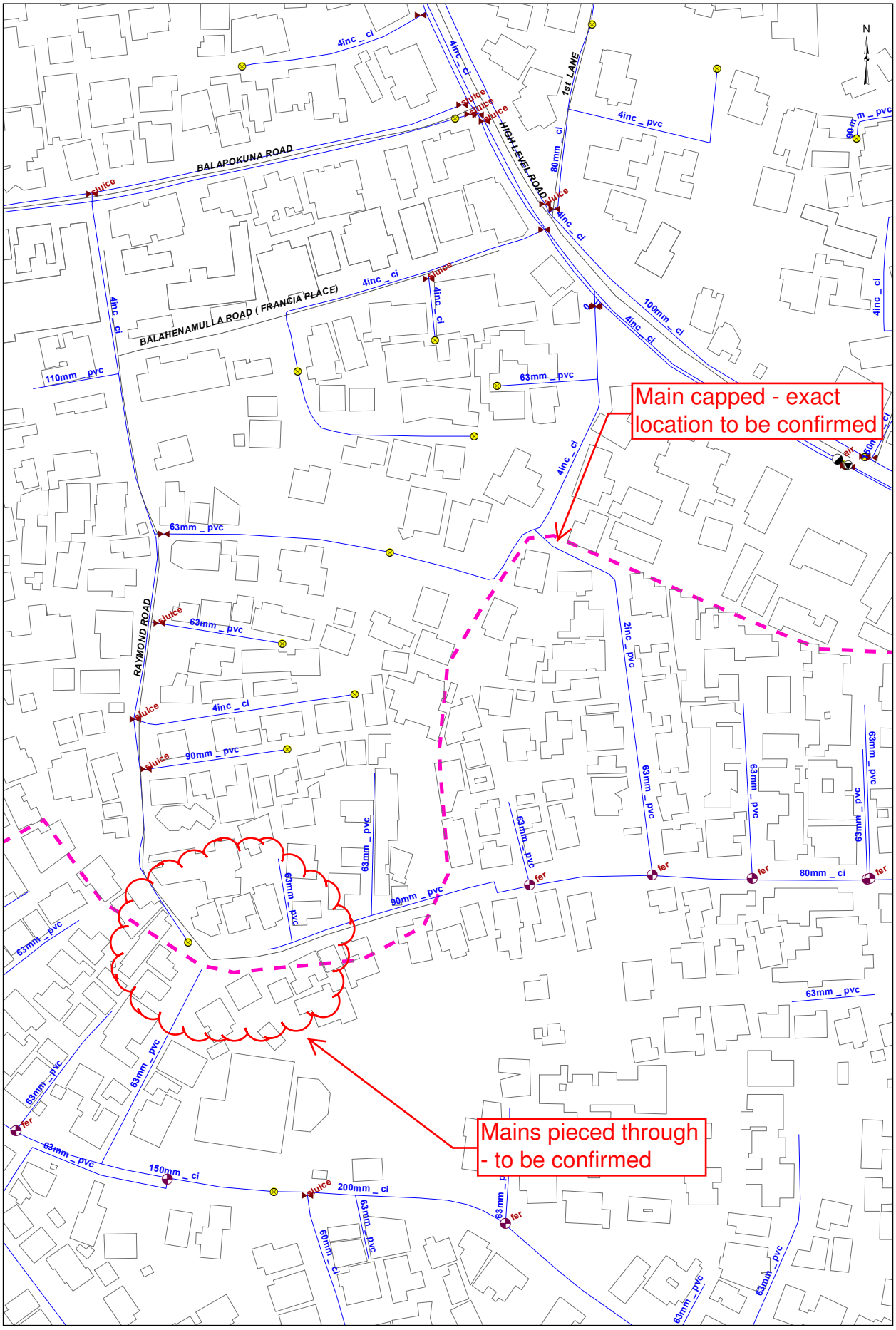
02 Pamankada Bridge



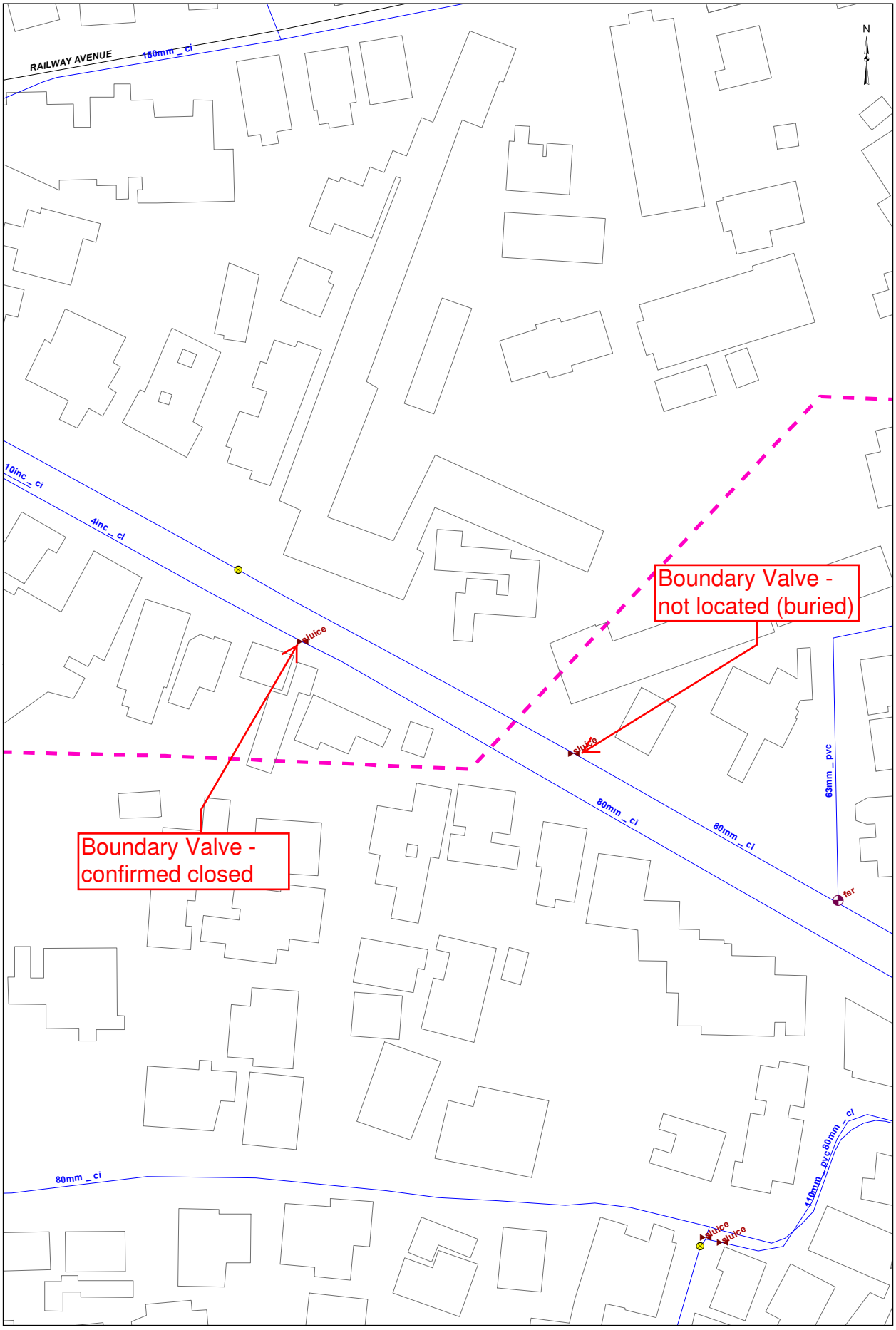
03 Halgaswatta Road



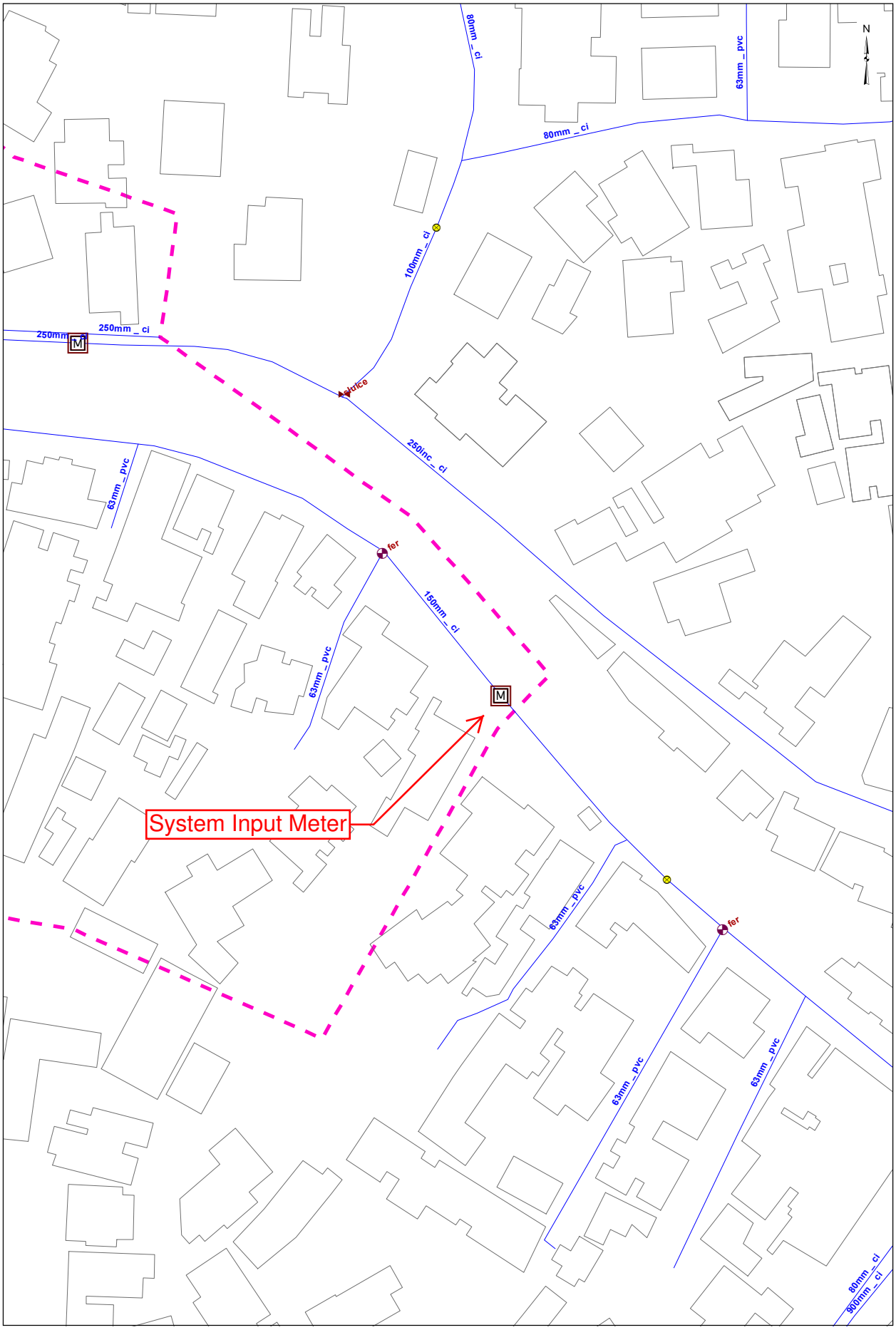
04 Raymond Road



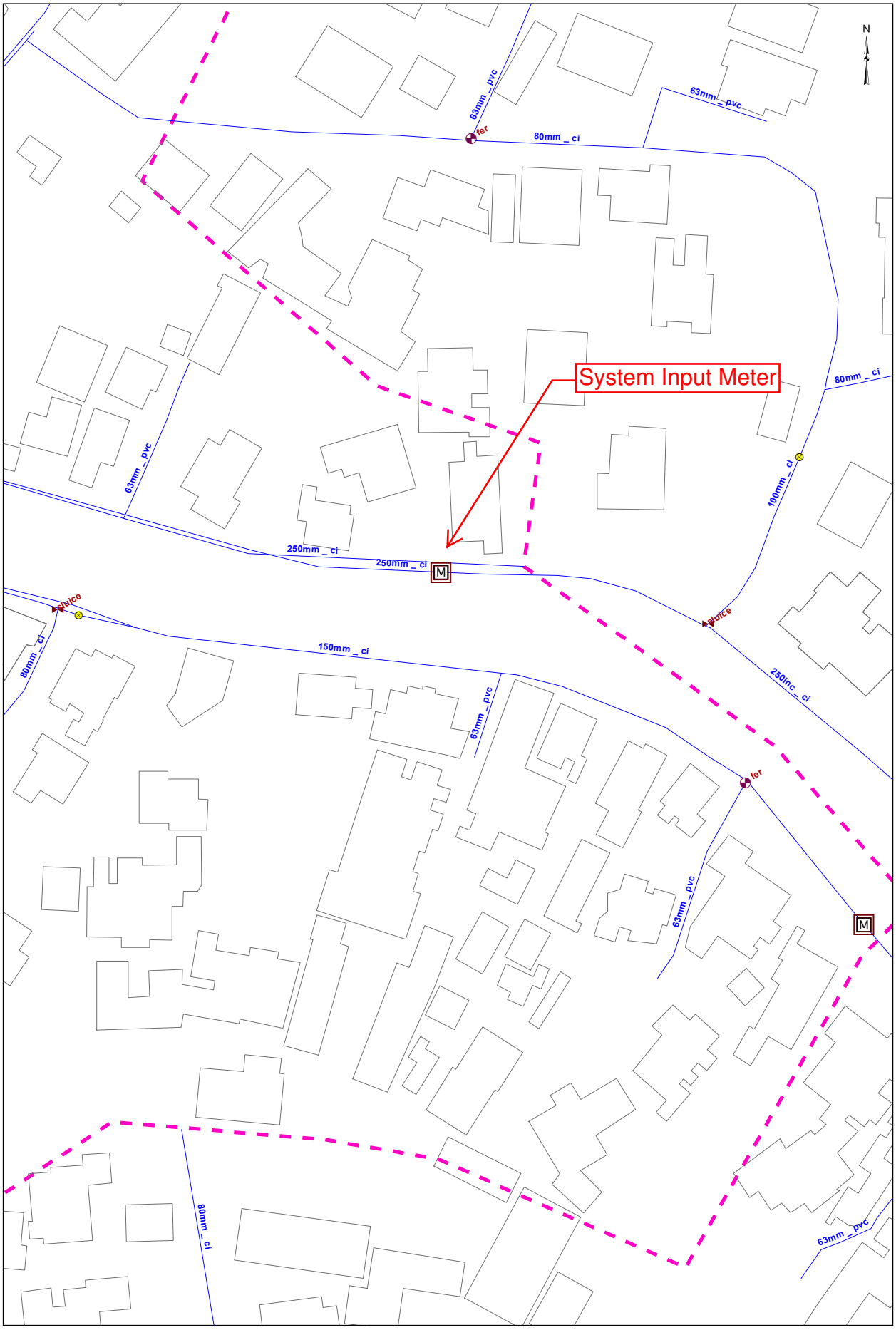
05 High Level Road (Close to Annula College)



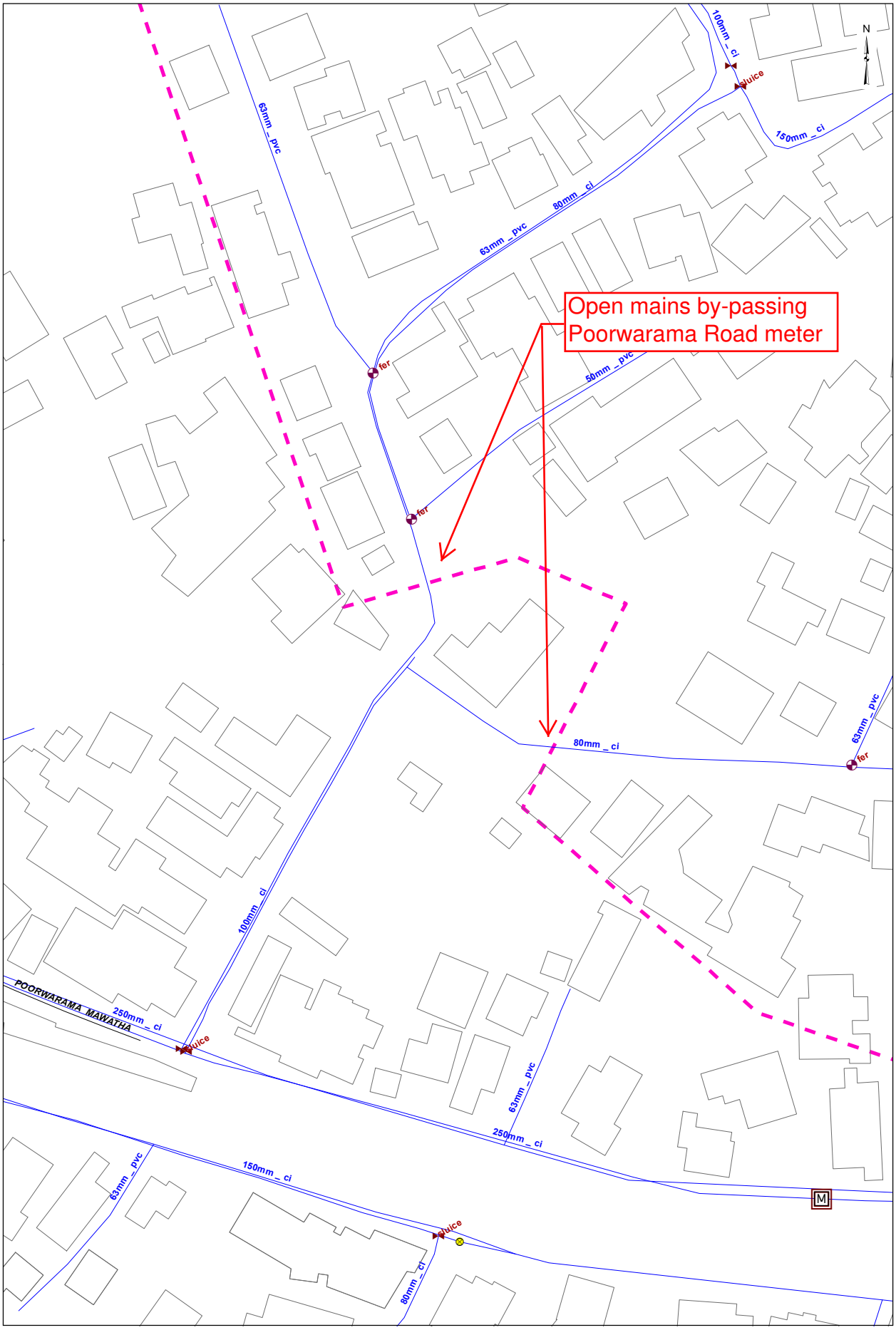
06 Railway Avenue



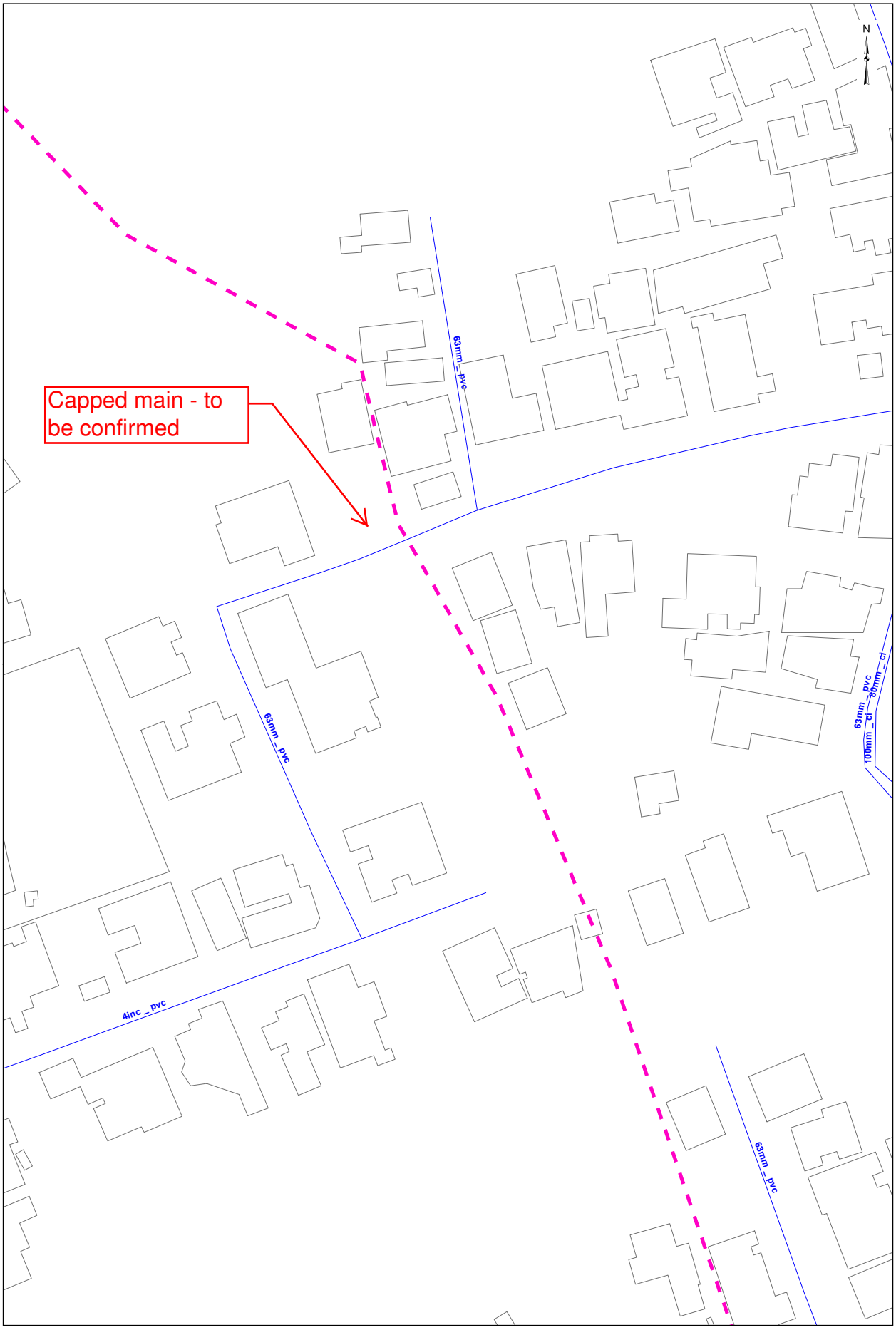
07 Poorwarama Road



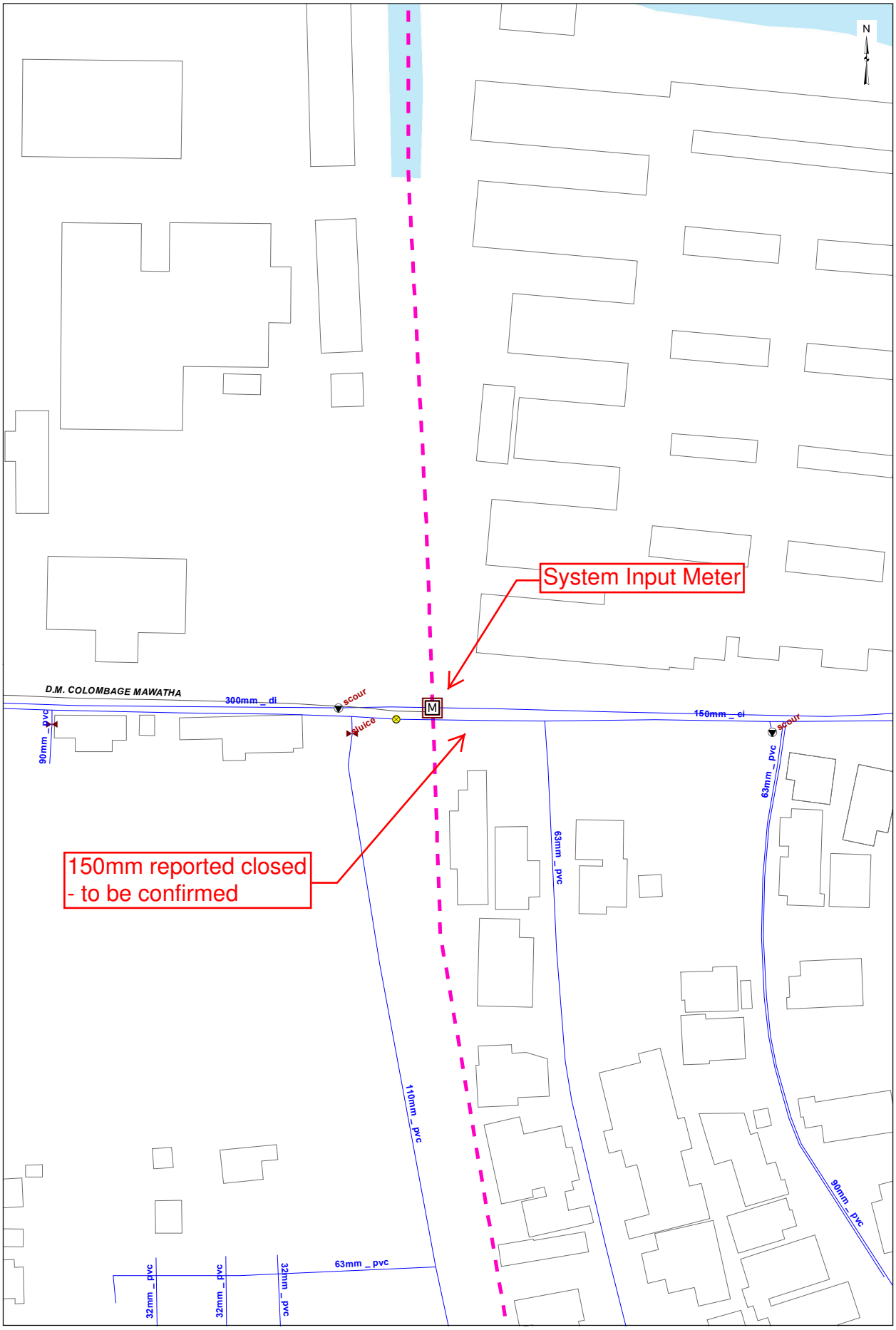
08 Kandewatta Road



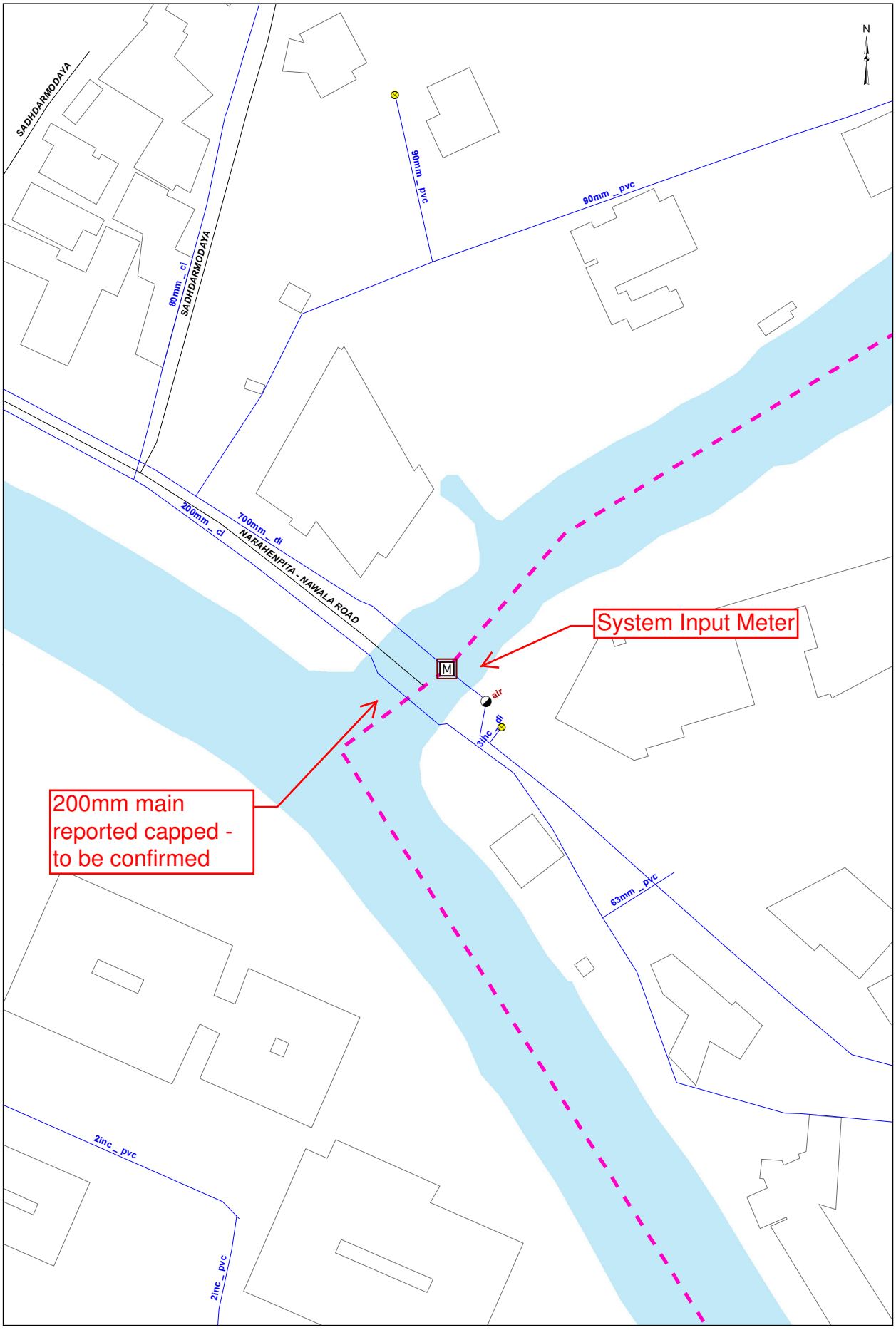
09 Kandewatta Terrace



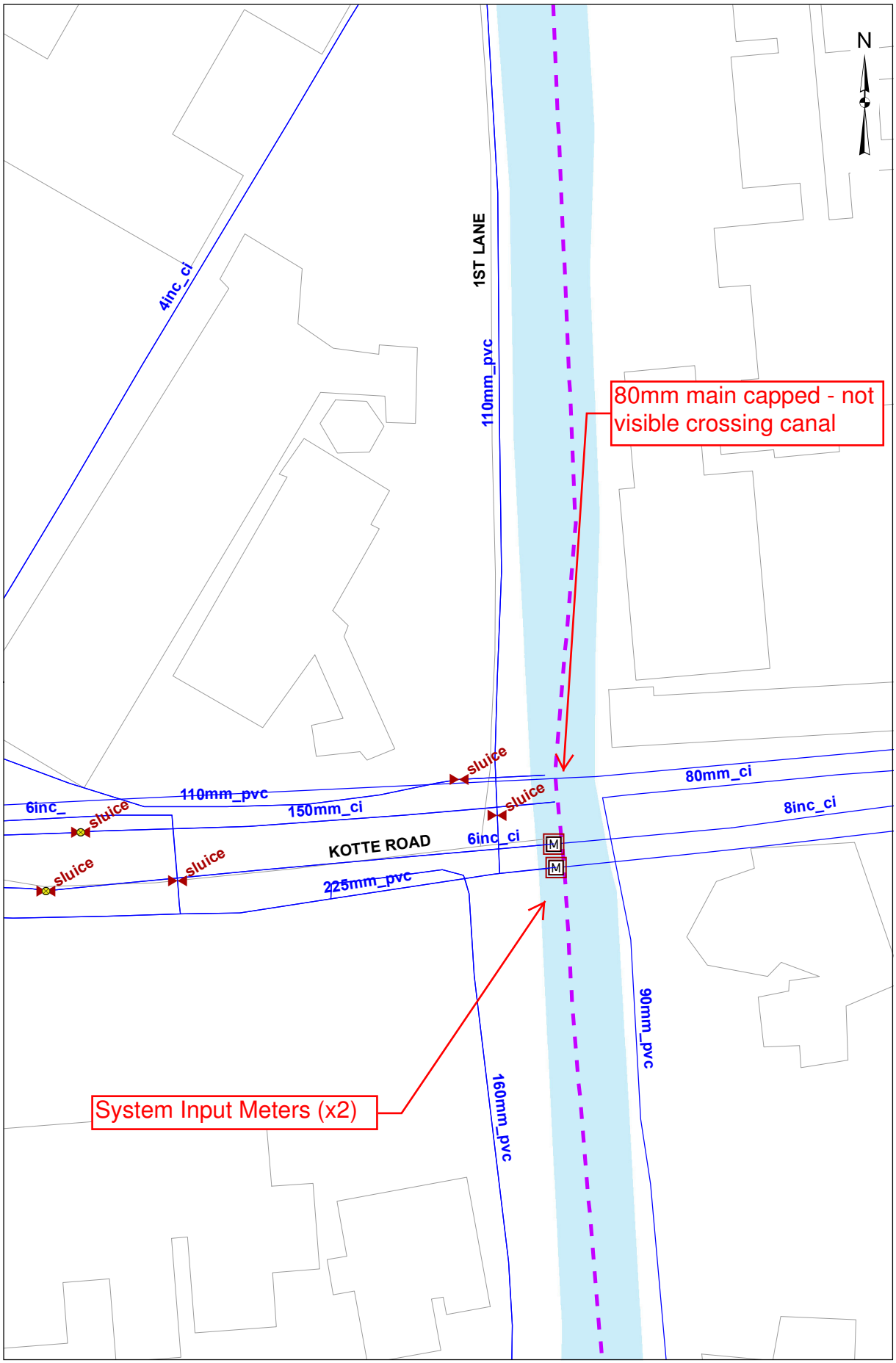
10 D M Colombage Mawatha



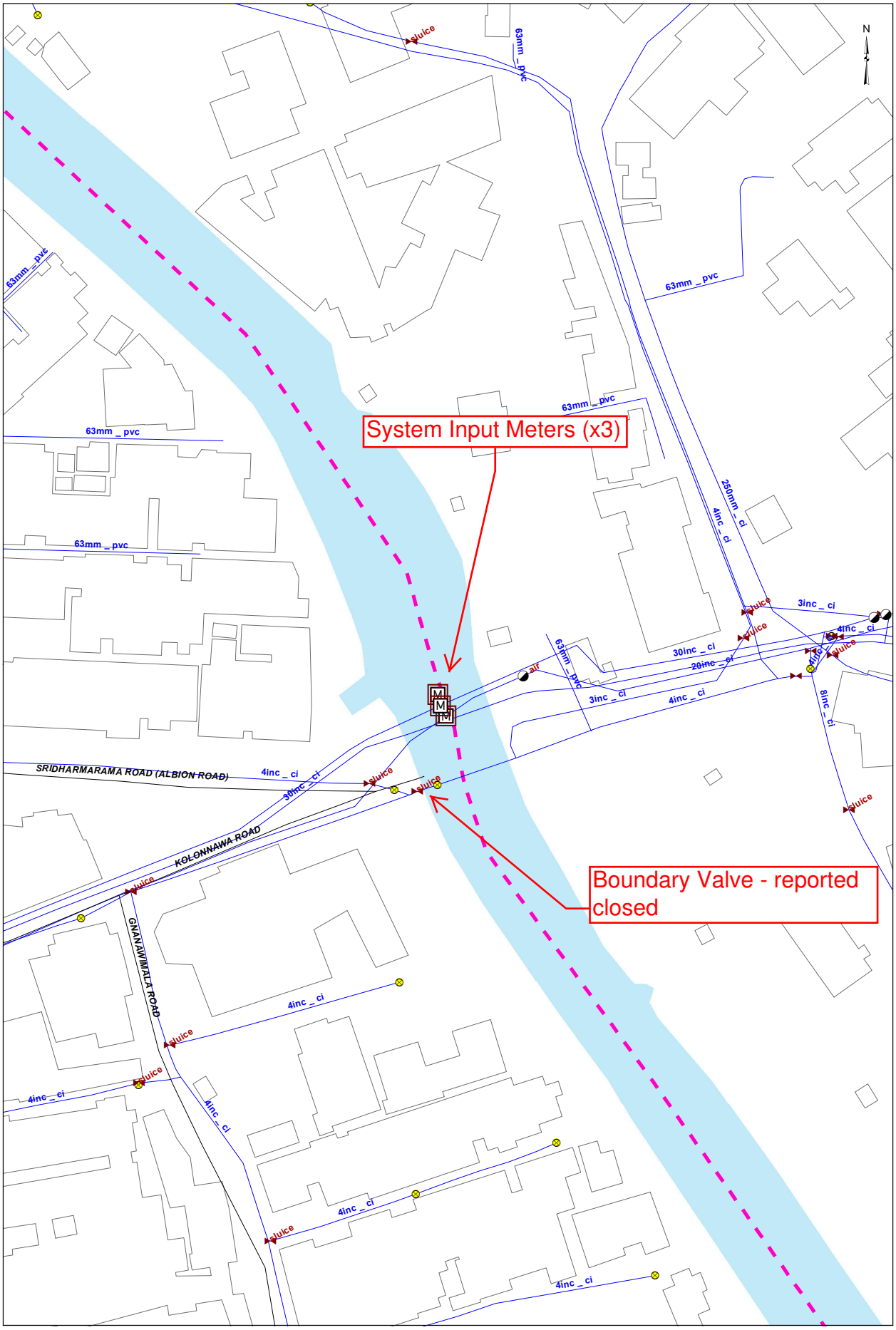
11 Nawala Road (Lanka Tiles Showroom)



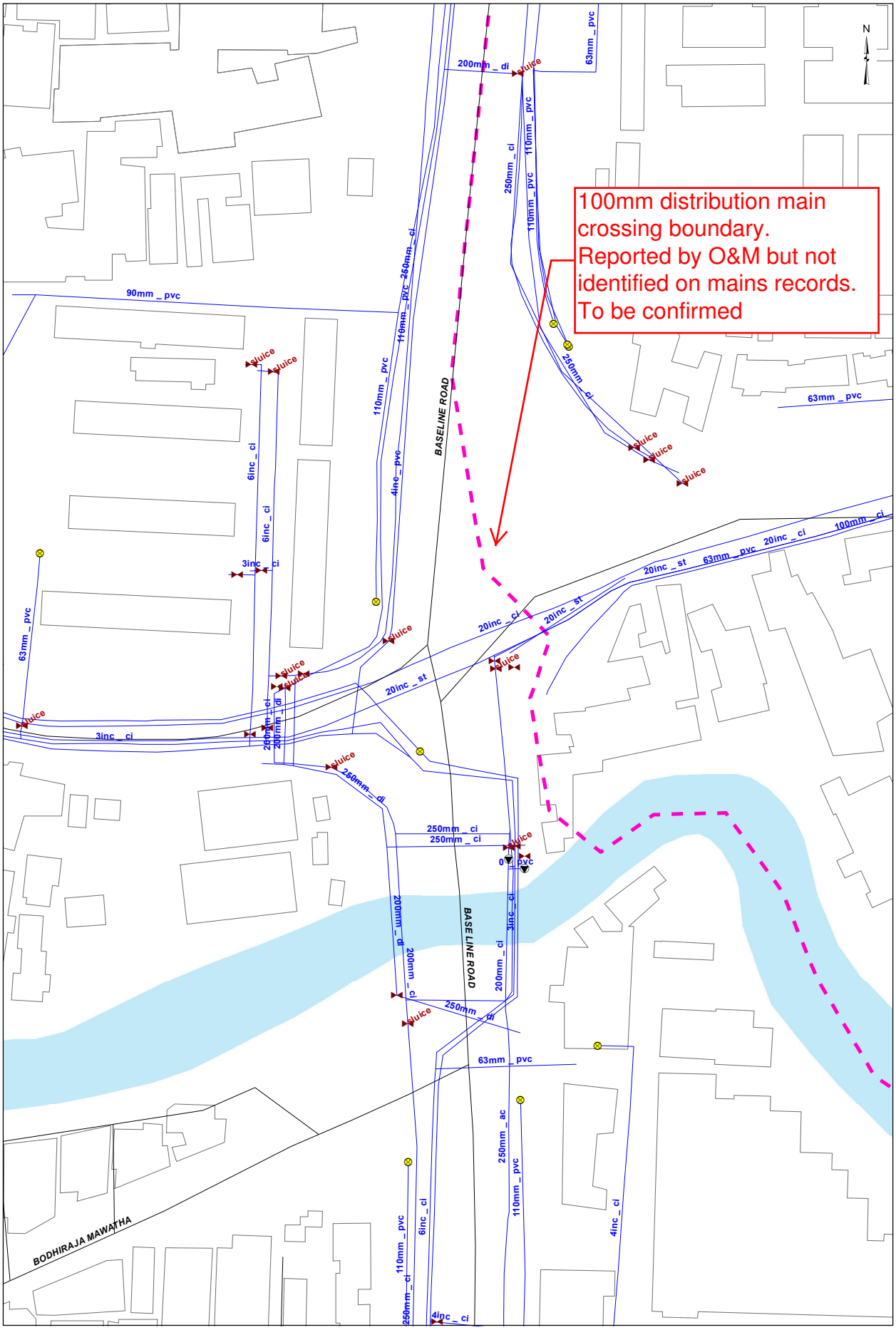
12 Kotta Road (Aurveda Hospital)



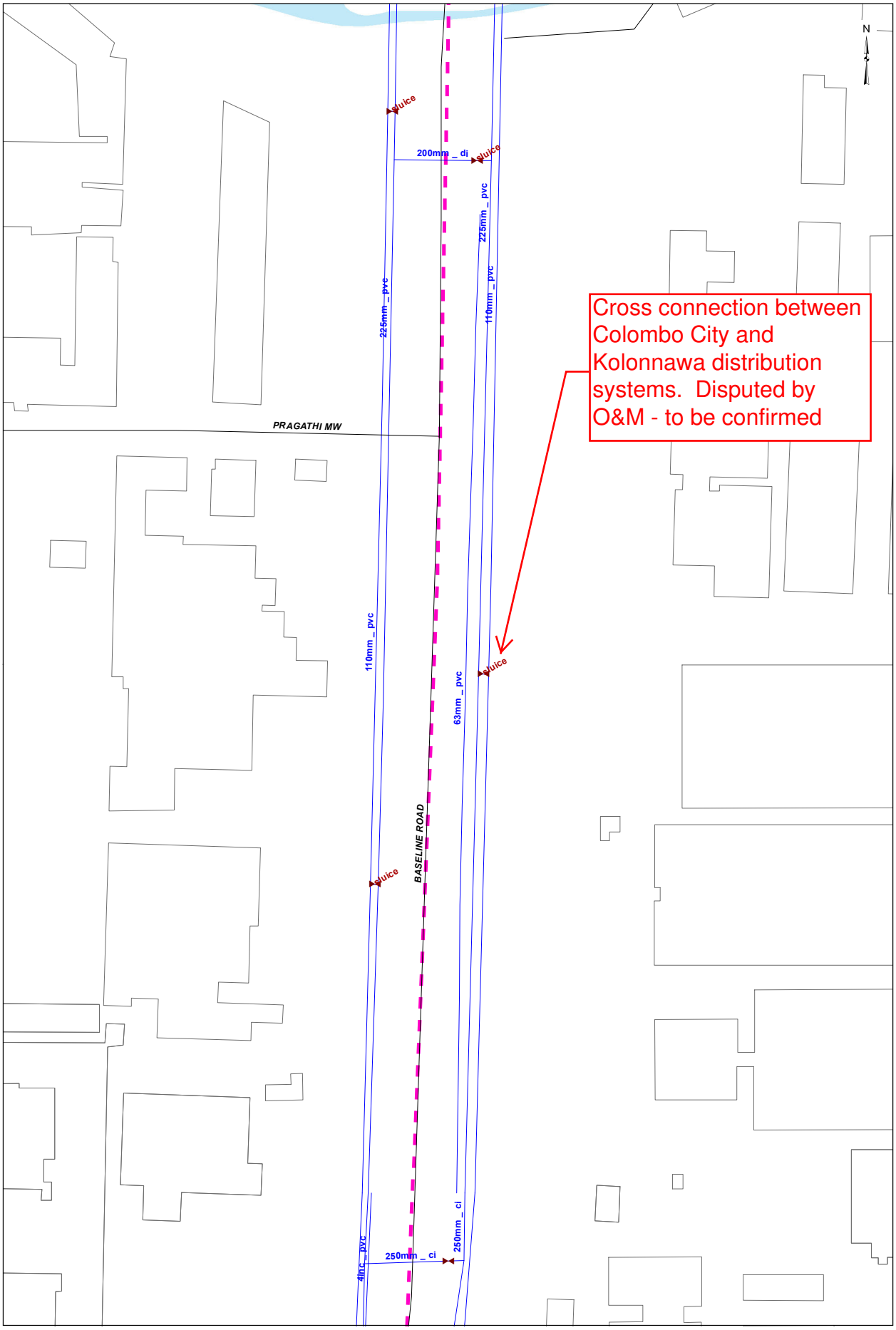
13 Kolonnawa Bridge



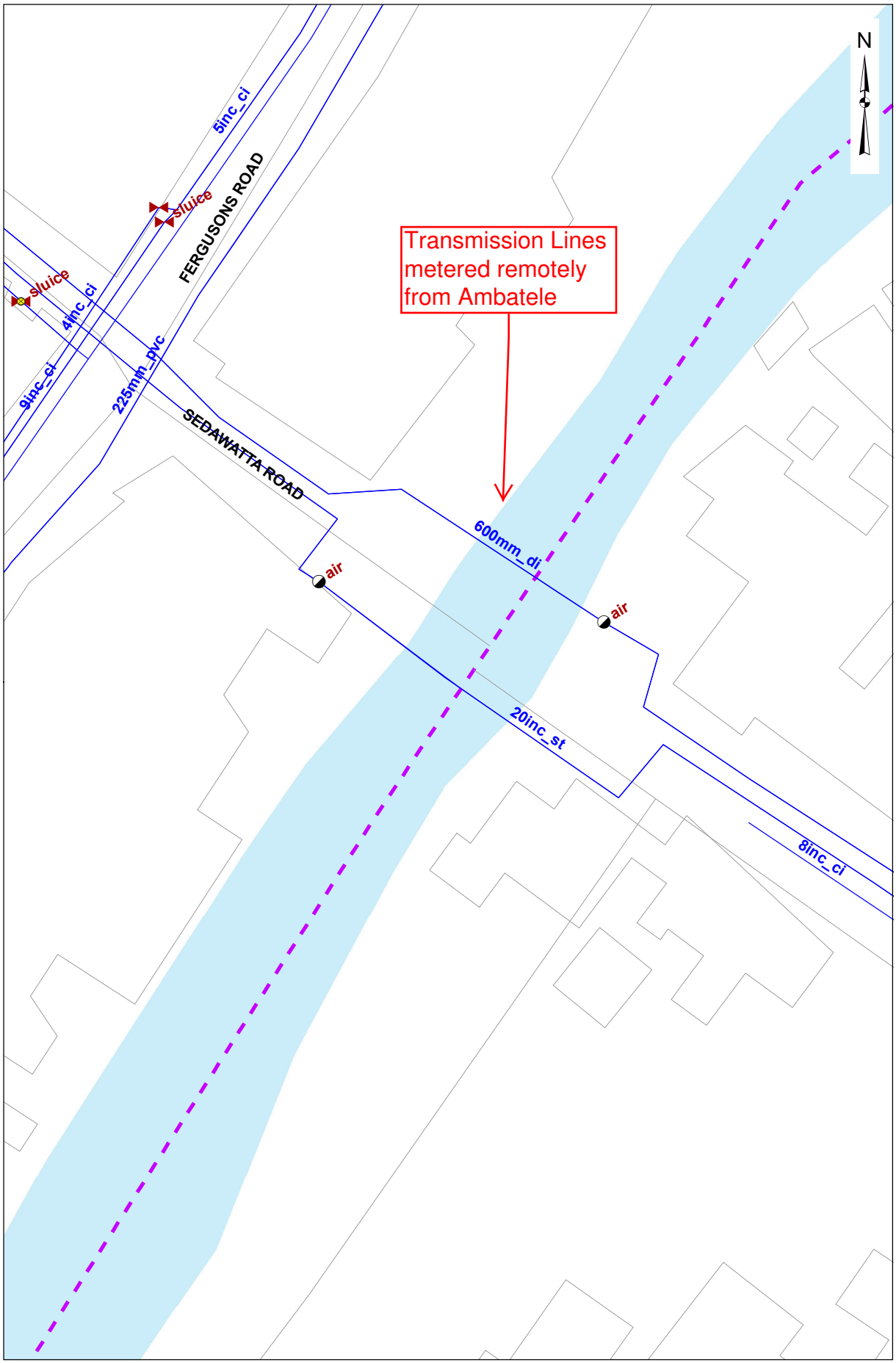
14 Avissawella Road - Baseline Road Junction



15 Baseline Road



16 Madampitiya Bridge



APPENDIX B

SIV Meter Readings

System Input Meter Readings: August 2012 to December 2012

Meter Location	Units (m^3)	August 2012			September			October			November			December		
		Date	Reading	Flow Rate (m^3/hr)	Date	Reading	Flow Rate (m^3/hr)	Date	Reading	Flow Rate (m^3/hr)	Date	Reading	Flow Rate (m^3/hr)	Date	Reading	Flow Rate (m^3/hr)
Dehiwala Bridge	1	28/08/12	726,867	**103.09**				01/10/12	810,945	**103.04**	06/11/12	899,296	**102.26**	07/12/12	976,010	**103.11**
Pamankada Bridge	1	28/08/12	2,256,375	**521.07**	24/09/12	2,948,752	**1,068.48**	01/10/12	3,125,453	**1,051.79**	06/11/12	4,058,698	**1,080.14**	07/12/12	4,857,777	**1,074.03**
Poorwarama Road	1	28/08/12	8,532,835	**65.43**				01/10/12	8,584,899	**63.80**	06/11/12	8,642,251	**66.38**	07/12/12	8,692,324	**67.30**
Railway Avenue	1	28/08/12	253,660	**10.11**				01/10/12	262,110	**10.36**	06/11/12	270,950	**10.23**	07/12/12	278,780	**10.52**
Nawala Road (Lanka Tile)	1	No data available - meter inoperable														
Colombage Mawatha	1	28/08/12	1,084,850	**78.40**				01/10/12	1,127,920	**52.78**	06/11/12	1,180,360	**60.69**	07/12/12	1,223,000	**57.31**
Ayurwedic Hosp - point A	1	28/08/12	932,978	**28.52**				24/09/12	946,140	**20.31**	31/10/12	970,938	**27.93**			
Ayurwedic Hosp - Maragasmulla	1	28/08/12	767,918	**40.21**				24/09/12	796,645	**44.33**	31/10/12	836,430	**44.80**			
Wellampitiya - O20	100	02/08/12	932,046	**393.21**	03/09/12	938,235	**805.86**	08/10/12	945,127	**820.48**	08/11/12	950,492	**721.10**	10/12/12	956,186	**741.41**
Wellampitiya - N30	100	02/08/12	977,737	**1,775.74**	03/09/12	4,735	**3,515.36**	08/10/12	33,653	**3,442.62**	08/11/12	58,517	**3,341.94**	10/12/12	84,296	**3,356.64**
Wellampitiya - O30	100	02/08/12	548,184	**1,145.09**	03/09/12	566,766	**2,419.53**	08/10/12	587,791	**2,502.98**	08/11/12	604,786	**2,284.27**	10/12/12	622,920	**2,361.20**
Wellampitiya - D20	100	02/08/12	72,589	**462.16**	03/09/12	79,886	**950.13**	08/10/12	88,010	**967.14**	08/11/12	94,978	**936.56**	10/12/12	102,337	**958.20**
Eli House - T20	1	03/08/12	660,373	**1,054.61**	07/09/12	669,202	**1,051.07**	24/09/12	673,469	**1,045.83**	01/11/12	683,099	**1,055.92**	03/12/12	690,734	**994.14**
Ambatele PS (New)	1	01/08/12		**1,345.77**	01/09/12		**1,363.80**	01/10/12		**1,375.40**	01/11/12		**1,364.93**	01/12/12		**1,358.45**
Kolonnawa Bridge - N30	1															
Kolonnawa Bridge - O30	1															
Kolonnawa Bridge - O20	1															
Urugodawatta Flyover - S20	1															

System Input Meter Readings: January 2013 to May 2013

Meter Location	Units (m^3)	January 2013			February			March			April			May		
		Date	Reading	Flow Rate (m^3/hr)	Date	Reading	Flow Rate (m^3/hr)	Date	Reading	Flow Rate (m^3/hr)	Date	Reading	Flow Rate (m^3/hr)	Date	Reading	Flow Rate (m^3/hr)
Dehiwala Bridge	1	08/01/13	1,054,625	**102.36**	27/02/13	1,216,729	**135.09**	28/03/13	1,313,408	**138.91**	10/04/13	1,347,167	**108.20**			
Pamankada Bridge	1	08/01/13	5,688,290	**1,081.40**	27/02/13	6,972,458	**1,070.14**	28/03/13	7,721,385	**1,076.04**	10/04/13	8,057,586	**1,077.57**			
Poorwarama Road	1				27/02/13	8,827,646	**68.76**	28/03/13	8,877,240	**71.26**						
Railway Avenue	1							28/03/13	303,180	**9.16**	10/04/13	305,830	**8.49**			
Nawala Road (Lanka Tile)	1	01/01/13	1,983,375		01/02/13	2,005,326	**29.50**	28/03/13	1,611,297	**-298.51**	02/04/13	1,781,891	**1,421.62**	20/05/13	3,733,622	**1,694.21**
Colombage Mawatha	1	08/01/13	1,262,250	**51.11**	27/02/13	1,328,020	**54.81**	28/03/13	1,367,930	**57.34**	10/04/13	1,385,820	**57.34**			
Ayurwedic Hosp - point A	1	16/01/13	1,008,094	**20.11**	27/02/13	1,035,840	**27.53**	28/03/13	1,056,429	**29.58**	30/04/13	1,079,164	**28.71**			
Ayurwedic Hosp - Maragasmulla	1	16/01/13	899,818	**34.30**	27/02/13	940,362	**40.22**	28/03/13	966,181	**37.10**	18/04/13	986,334	**39.99**	30/04/13	995,871	**33.11**
Wellampitiya - O20	100	01/01/13	960,325	**783.90**	27/02/13	971,300	**802.27**	28/03/13	977,185	**845.55**	30/04/13	983,724	**825.63**	27/05/13	989,066	**824.38**
Wellampitiya - N30	100	01/01/13	102,270	**3,404.17**	27/02/13	145,900	**3,189.33**	28/03/13	167,526	**3,107.18**	30/04/13	191,909	**3,078.66**	27/05/13	211,851	**3,077.47**
Wellampitiya - O30	100	01/01/13	636,795	**2,627.84**	27/02/13	671,234	**2,517.47**	28/03/13	688,305	**2,452.73**	30/04/13	708,086	**2,497.60**	27/05/13	724,296	**2,501.54**
Wellampitiya - D20	100	01/01/13	109,335	**1,325.38**	27/02/13	120,015	**780.70**	28/03/13	126,435	**922.41**	30/04/13	133,620	**907.20**	27/05/13	139,822	**957.10**
Eli House - T20	1	17/01/13	702,140	**1,056.11**				28/03/13	719,336	**1,023.57**	30/04/13	727,663	**1,051.39**			
Ambatele PS (New)	1	01/01/13		**1,360.85**	01/02/13		**1,349.48**	01/03/13		**1,371.83**	01/04/13		**1,334.38**	01/05/13		**1,379.00**
Kolonnawa Bridge - N30	1															
Kolonnawa Bridge - O30	1															
Kolonnawa Bridge - O20	1															
Urugodawatta Flyover - S20	1															

System Input Meter Readings: June 2013 to October 2013

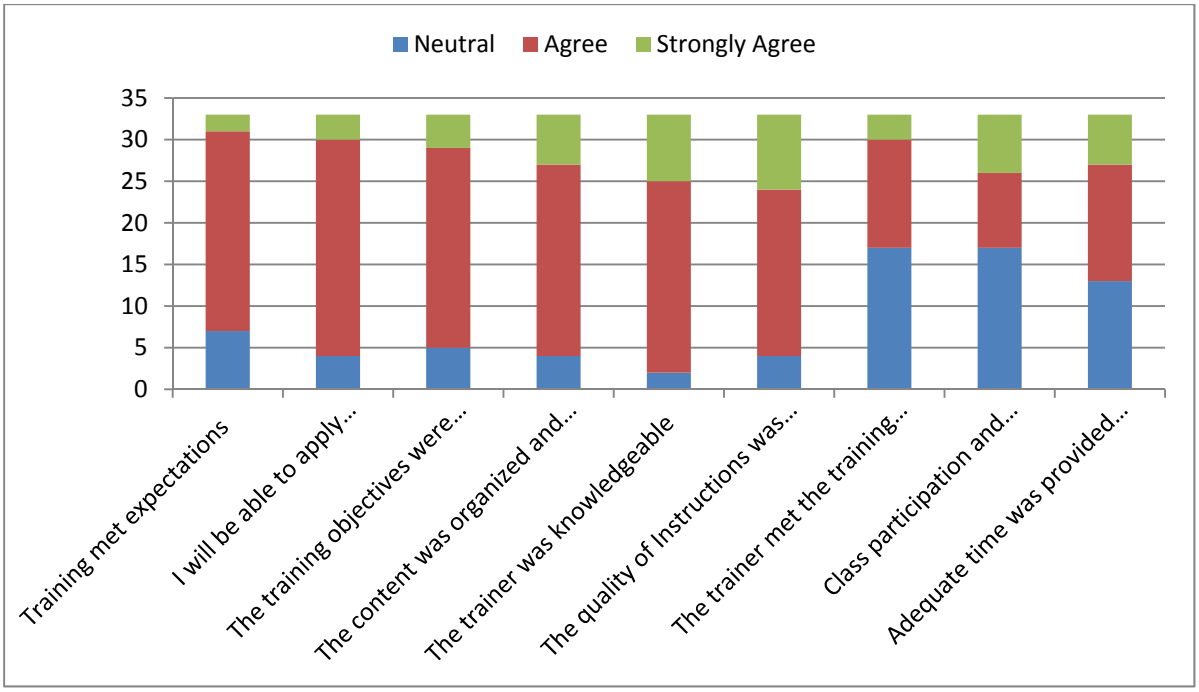
Meter Location	Units (m^3)	June 2013			July			August			September			October		
		Date	Reading	Flow Rate (m^3/hr)	Date	Reading	Flow Rate (m^3/hr)	Date	Reading	Flow Rate (m^3/hr)	Date	Reading	Flow Rate (m^3/hr)	Date	Reading	Flow Rate (m^3/hr)
Dehiwala Bridge	1	13/06/13	1,558,397	**137.52**	02/07/13	1,615,992	**126.30**	02/08/13	1,694,719	**105.82**	03/09/13	1,780,528	**111.73**	2/10/2013	1,859,070	**112.85**
Pamankada Bridge	1	13/06/13	9,705,199	**1,072.66**	02/07/13	10,191,324	**1,066.06**	02/08/13	10,991,517	**1,075.53**	03/09/13	11,784,111	**1,032.02**	No data – meter failure		
Poorwarama Road	1				02/07/13	9,038,392	**69.94**	02/08/13	9,088,123	**66.84**	03/09/13	9,139,093	**66.37**	2/10/2013	9,188,877	**71.53**
Railway Avenue	1	13/06/13	318,000	**7.92**	02/07/13	321,840	**8.42**	02/08/13	328,370	**8.78**	03/09/13	334,440	**7.90**	2/10/2013	340,340	**8.48**
Nawala Road (Lanka Tile)	1	13/06/13	4,734,951	**1,738.42**	02/07/13	5,430,535	**1,525.40**	02/08/13	6,668,899	**1,664.47**	03/09/13	7,913,003	**1,619.93**	2/10/2013	8,939,976	**1,475.54**
Colombage Mawatha	1	13/06/13	1,498,120	**73.11**	02/07/13	1,522,100	**52.59**	02/08/13	1,568,360	**62.18**	03/09/13	1,617,480	**63.96**	2/10/2013	1,651,890	**49.44**
Ayurwedic Hosp - point A	1	13/06/13	1,088,139	**8.50**	02/07/13	1,088,950	**1.78**	02/08/13	1,103,072	**18.98**	Meter removed due to construction work					
Ayurwedic Hosp - Maragasmulla	1	13/06/13	1,038,788	**40.64**	02/07/13	1,058,206	**42.58**	02/08/13	1,088,933	**41.30**	03/09/13	1,118,853	**38.96**	Meter removed - construction		
Wellampitiya - O20	100				02/07/13	996,271	**833.91**	02/08/13	1,002,520	**839.92**	03/09/13	1,008,967	**839.45**	2/10/2013	1,014,724	**827.16**
Wellampitiya - N30	100				02/07/13	238,476	**3,081.60**	02/08/13	261,468	**3,090.32**	03/09/13	283,848	**2,914.06**	2/10/2013	306,529	**3,258.76**
Wellampitiya - O30	100				02/07/13	745,667	**2,473.50**	02/08/13	764,232	**2,495.30**	03/09/13	783,848	**2,554.17**	2/10/2013	800,954	**2,457.76**
Wellampitiya - D20	100				02/07/13	147,780	**921.06**	02/08/13	154,537	**908.20**	03/09/13	161,537	**911.46**	2/10/2013	167,768	**895.26**
Eli House - T20	1				02/07/13	737,229	**632.67**	02/08/13	745,477	**1,108.60**	03/09/13	753,387	**1,029.95**	2/10/2013	760,481	**1,019.25**
Ambatele PS (New)	1	01/06/13		**1,366.75**	01/07/13		**1,354.60**	01/08/13		**1,368.15**	01/09/13		**1,373.33**	01/10/13		**1,377.86**
Kolonnawa Bridge - N30	1				02/07/13	62,096,696		02/08/13	63,938,632	**2,475.72**	03/09/13	65,830,096	**2,462.84**	2/10/2013	67,508,082	**2,410.90**
Kolonnawa Bridge - O30	1				02/07/13	53,724,174		02/08/13	55,380,378	**2,226.08**	03/09/13	57,097,720	**2,236.12**	2/10/2013	58,595,133	**2,151.46**
Kolonnawa Bridge - O20	1				02/07/13	11,762,598		02/08/13	12,066,832	**408.92**	03/09/13	12,638,286	**744.08**	2/10/2013	12,914,116	**396.31**
Urugodawatta Flyover - S20	1				02/07/13	349,888		02/08/13	753,109	**541.96**	03/09/13	1,252,496	**650.24**	2/10/2013	1,776,064	**752.25**

APPENDIX C

Training Assessment Responses

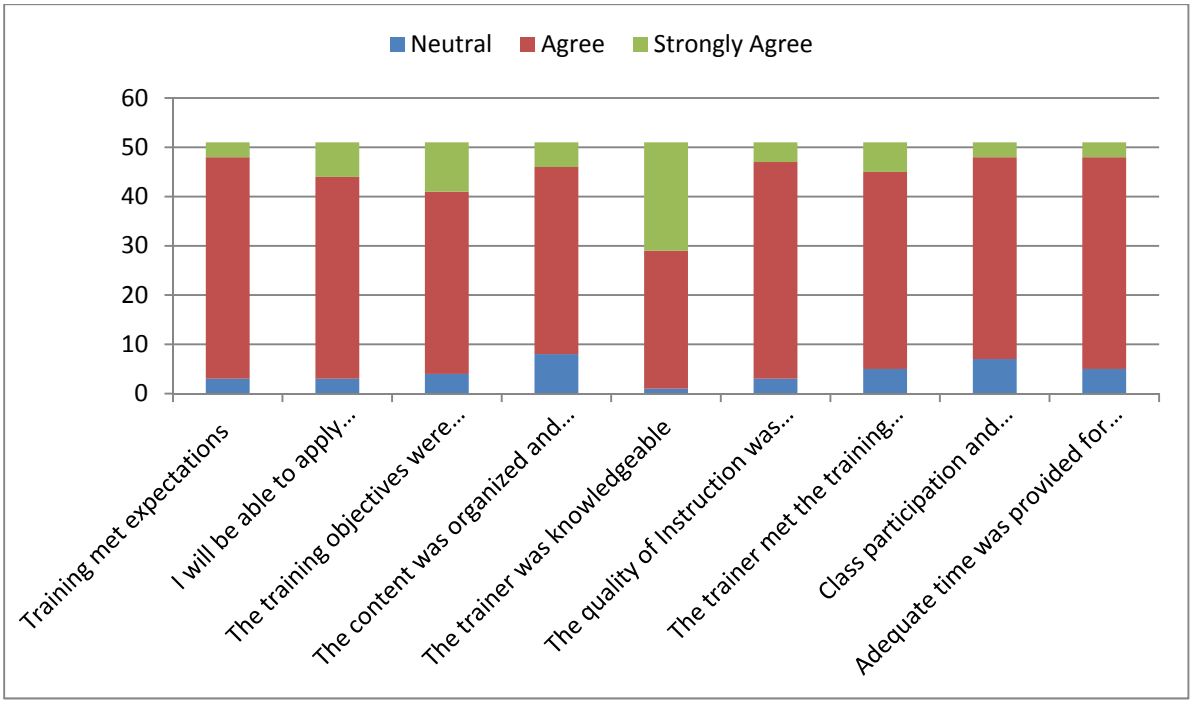
DMA Design, Operation & Maintenance held on 10th & 12th August 2013

	Neutral	Agree	Strongly Agree
Training met expectations	7	24	2
I will be able to apply knowledge learned	4	26	3
The training objectives were identified	5	24	4
The content was organized and easy to follow	4	23	6
The trainer was knowledgeable	2	23	8
The quality of Instructions was good	4	20	9
The trainer met the training objectives	17	13	3
Class participation and interactions were encouraged	17	9	7
Adequate time was provided for questions and discussions	13	14	6



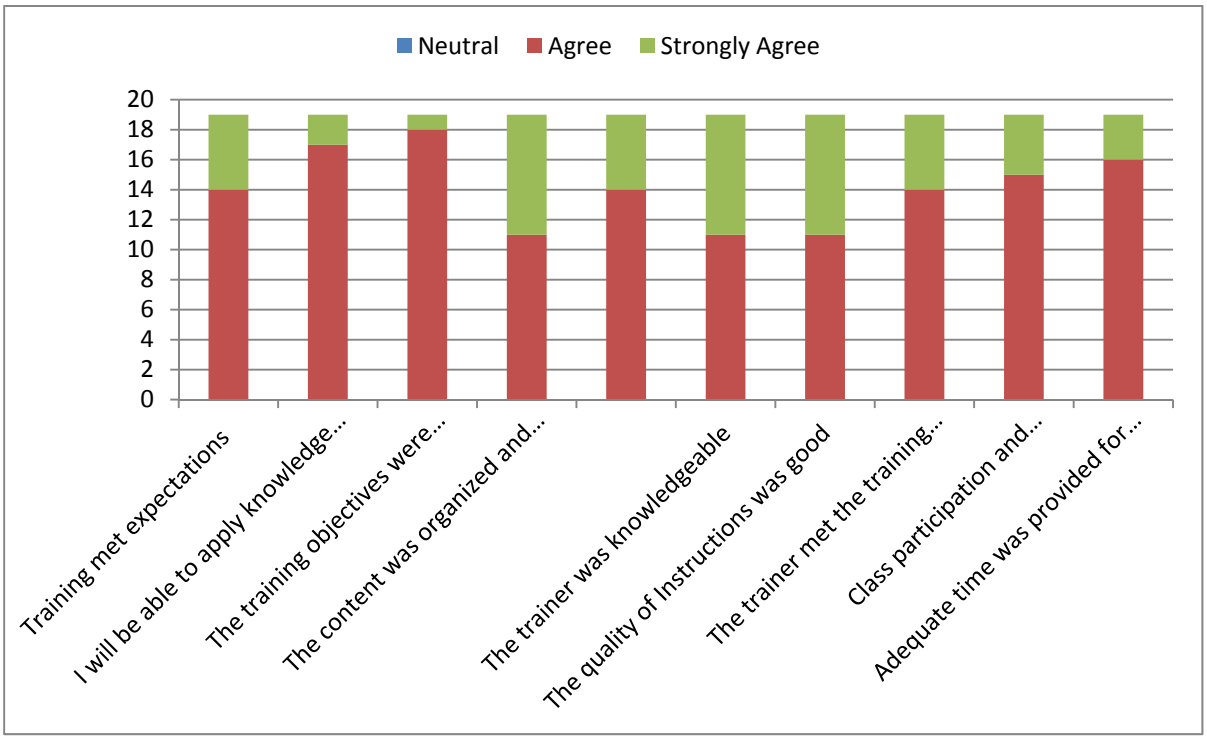
Change Awareness & DMA Concepts held on 19th & 21st November 2013

	Neutral	Agree	Strongly Agree
Training met expectations	5	67	5
I will be able to apply knowledge learned	5	58	14
The training objectives were identified	6	54	17
The content was organized and easy to follow	10	57	10
The trainer was knowledgeable	2	35	40
The quality of Instruction was good	3	68	6
The trainer met the training objectives	6	63	8
Class participation and interactions were encouraged	10	63	4
Adequate time was provided for questions and discussions	6	67	4



Training Design & Presentation Techniques held on 27th November 2013

	Neutral	Agree	Strongly Agree
Training met expectations	0	14	5
I will be able to apply knowledge learned	0	17	2
The training objectives were identified	0	18	1
The content was organized and easy to follow	0	11	8
The materials distributed were pertinent and useful	0	14	5
The trainer was knowledgeable	0	11	8
The quality of Instructions was good	0	11	8
The trainer met the training objectives	0	14	5
Class participation and interactions were encouraged	0	15	4
Adequate time was provided for questions and discussions	0	16	3



Water Balance Training held on 22nd January 2014

	Neutral	Agree	Strongly Agree
Training met expectations	1	18	1
I will be able to apply knowledge learned	1	19	0
The training objectives were identified	1	16	3
The content was organized and easy to follow	3	13	4
The trainer was knowledgeable	0	12	8
The quality of Instructions was good	1	17	2
The trainer met the training objectives	2	16	2
Class participation and interactions were encouraged	9	9	2
Adequate time was provided for questions and discussions	2	16	2