REPORT ON
REGIONAL TRAINING ON THE DEMAND AND DISTRIBUTION OF WATER
SAINT LUCIA, July 1st to 4th 2019

Introduction
A Regional Training Program on the Demand and Distribution of Water was organized from 1 – 4 July 2019 in Rodney Bay, Saint Lucia, in close collaboration between the Project Institutional and Organizational Strengthening of WASCO Saint Lucia and Regional Water Utilities, the Caribbean Water and Sewerage Association (CAWASA), the Water and Sewerage Company of Saint Lucia, WASCO and the Caribbean Aqua Terrestrial Solutions Program (CATS) and the German International Development Agency GIZ.

Proceedings
The workshop was attended by 12 staff members of WASCO and 6 staff of utilities in the Caribbean Region. A list of participants is attached as Annex 1.

The training course lasted 4 days and the program is attached as Annex 2 to this report. The first two days and the last day of the course the Senior Hydraulic Expert of the project acted as the trainer. The third day of the course, on demand forecasting, was conducted by the senior Institutional Expert. A field trip was organized in the afternoon of day 2 of the program.

Training Materials

Water Loss Reduction and Water Balance Calculation

The trainers’ notes for the first two days and the last day of this course are attached as Annex 4 to this report. The PP presentations on Water Loss Reduction and Water Balance Calculation are attached as Annex 5 and 6. The exercises were provided as handouts including their solutions (attached as Annex 7)

District Metered Areas (DMAs)

The PP presentation on District Metered Areas (DMAs) and the slides used for the exercise are attached as Annex 8 and 9. The introduction to the pilot zone Babonneau for the field trip visiting the pilot zone is attached as Annex 10.
Demand Forecasting and Analysis

A PP presentation and the trainers’ notes for the course are attached as Annex 11 and 12 to this report. All trainees received copies of the Handouts as well as the results of the case study, which have been made available to WASCO.

Hydraulic Analysis

The PP presentation on Hydraulic Analysis of Transport Systems is attached as Annex 13. The corresponding exercise on Head Loss Calculation is attached as Annex 14. The PP presentation introducing SCADA systems is attached as Annex 15.

Evaluation

All participants were asked to complete a short evaluation form and 16 forms were received back. A summary of the feedback is provided in Annex 3 to this report. Most of the questionnaires handed out were filled in in full; one was left empty. Most of the participants had a positive impression about the workshop and the trainers. The average response is 4+ out of 5 in all relevant answers. Suggestions for changes that were mentioned multiple times were, e.g. more field trips, more exercises and a closer relation to the Caribbean context (e.g. in the case studies).
## Annex 1: List of Participants Regional Training Program 1-4 July 2019

<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
<th>Contact/Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthony Reece</td>
<td>WASCO</td>
<td><a href="mailto:Reece.anthony@gmail.com">Reece.anthony@gmail.com</a></td>
</tr>
<tr>
<td>Lester Daniel</td>
<td>DOWASCO, Dominica</td>
<td><a href="mailto:lsterdaniel@gmail.com">lsterdaniel@gmail.com</a></td>
</tr>
<tr>
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<td>CWSA, Saint Vincent &amp; the Grenadines</td>
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<tr>
<td>Anthony Joseph</td>
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<tr>
<td>Adrian Medard</td>
<td>WASCO</td>
<td><a href="mailto:adrianmedard@wascosaintlucia.com">adrianmedard@wascosaintlucia.com</a></td>
</tr>
<tr>
<td>Jermaine Jackson</td>
<td>NWC (National Water Commission), Jamaica</td>
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</tr>
<tr>
<td>Dave Marquez</td>
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</tr>
<tr>
<td>Timothy James</td>
<td>WASCO</td>
<td><a href="mailto:timmywasco@gmail.com">timmywasco@gmail.com</a></td>
</tr>
<tr>
<td>Karim Thompson</td>
<td>BWS, Belize</td>
<td><a href="mailto:Karim.thompson@bwsl.com.bz">Karim.thompson@bwsl.com.bz</a></td>
</tr>
<tr>
<td>Ervin Flores</td>
<td>BWS, Belize</td>
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</tr>
<tr>
<td>Lester Arnold</td>
<td>Consultant</td>
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<tr>
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<td>WASCO</td>
<td><a href="mailto:fevriuslouisernest@gmail.com">fevriuslouisernest@gmail.com</a></td>
</tr>
<tr>
<td>Kelvin Emilien</td>
<td>WASCO</td>
<td><a href="mailto:kelvinemilien@wascosaintlucia.com">kelvinemilien@wascosaintlucia.com</a></td>
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<tr>
<td>Hemish Joseph</td>
<td>WASCO</td>
<td><a href="mailto:hemishjoseph@wascosaintlucia.com">hemishjoseph@wascosaintlucia.com</a></td>
</tr>
<tr>
<td>Nicholai Hyacinth</td>
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</tr>
<tr>
<td>Timo Schirmer</td>
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<tr>
<td>Kees de Jong</td>
<td>Consultant</td>
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<tr>
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<tr>
<td>Ignatius Jean</td>
<td>CAWASA</td>
<td><a href="mailto:ijean@cawasa.org">ijean@cawasa.org</a></td>
</tr>
<tr>
<td>Jan Overbeek</td>
<td>Consultant</td>
<td><a href="mailto:Jw.overbeek@gmail.com">Jw.overbeek@gmail.com</a></td>
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<tr>
<td>Matthew Francis</td>
<td>WASCO</td>
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Annex 2: Training Program

### Day 01 – Introduction to Water Loss Reduction and Water Balance Calculation

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
<th>Description</th>
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<tbody>
<tr>
<td>09:00</td>
<td>Welcome and Introduction</td>
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<tr>
<td>09:30</td>
<td>Presentation</td>
<td>Introduction to Water Loss Reduction</td>
</tr>
<tr>
<td>10:00</td>
<td>Presentation</td>
<td>Calculating a Water Balance (a)</td>
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<tr>
<td>10:15</td>
<td>Coffee break</td>
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</tr>
<tr>
<td>10:30</td>
<td>Exercise</td>
<td>Categorization of Water Use</td>
</tr>
<tr>
<td>11:30</td>
<td>Presentation</td>
<td>Calculating a Water Balance (b)</td>
</tr>
<tr>
<td>12:00</td>
<td>Lunch</td>
<td></td>
</tr>
<tr>
<td>13:00</td>
<td>Exercise</td>
<td>Water Balance Calculation</td>
</tr>
<tr>
<td>14:30</td>
<td>Coffee break</td>
<td></td>
</tr>
<tr>
<td>14:45</td>
<td>Discussion</td>
<td>Water Balance Calculation</td>
</tr>
<tr>
<td>15:30</td>
<td>Wrap up of day 01</td>
<td></td>
</tr>
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### Day 02 – District Metered Areas (DMAs)

<table>
<thead>
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<th>Time</th>
<th>Activity</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>09:00</td>
<td>Presentation</td>
<td>District Metered Areas (DMAs)</td>
</tr>
<tr>
<td>09:45</td>
<td>Exercise</td>
<td>Establishing DMAs</td>
</tr>
<tr>
<td>11:00</td>
<td>Coffee break</td>
<td></td>
</tr>
<tr>
<td>11:15</td>
<td>Exercise</td>
<td>Establishing DMAs</td>
</tr>
<tr>
<td>12:15</td>
<td>Lunch</td>
<td></td>
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<tr>
<td>13:15</td>
<td>Introduction</td>
<td>DMA Pilot Zone Babonneau</td>
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<tr>
<td>13:30</td>
<td>Field trip</td>
<td>Pilot Zone Babonneau</td>
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<tr>
<td>16:00</td>
<td>Wrap up of day 02</td>
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### Day 03 – Demand Analysis and Forecasting

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<th>Time</th>
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<th>Description</th>
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<tbody>
<tr>
<td>09:00</td>
<td>Q&amp;A</td>
<td>Identify key factors which determine demand</td>
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<tr>
<td>09:45</td>
<td>Presentation</td>
<td>The need &amp; instruments to manage the demand for water</td>
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<tr>
<td>10:30</td>
<td></td>
<td>Coffee break</td>
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<tr>
<td>10:45</td>
<td>Discussion</td>
<td>How to effectively manage water demand</td>
</tr>
<tr>
<td>11:15</td>
<td>Group Work</td>
<td>Sources for obtaining data for water demand forecasting</td>
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<tr>
<td>11:45</td>
<td>Presentation</td>
<td>Willingness and Ability to Pay</td>
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<td>12:15</td>
<td></td>
<td>Lunch</td>
</tr>
<tr>
<td>13:15</td>
<td>Group Work</td>
<td>Case Study in Demand Forecasting</td>
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<tr>
<td>15:30</td>
<td></td>
<td>Wrap up of day 03</td>
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### Day 04 – Hydraulic Analysis / Design & Evaluation of Transport Systems

<table>
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<tr>
<th>Time</th>
<th>Activity</th>
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<tr>
<td>09:00</td>
<td>Presentation</td>
<td>Introduction to Hydraulic Analysis</td>
</tr>
<tr>
<td>09:45</td>
<td>Exercise</td>
<td>Head Loss Calculation</td>
</tr>
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<td>10:30</td>
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<td>Coffee break</td>
</tr>
<tr>
<td>10:45</td>
<td>Exercise</td>
<td>Head Loss Calculation</td>
</tr>
<tr>
<td>12:00</td>
<td></td>
<td>Lunch</td>
</tr>
<tr>
<td>13:00</td>
<td>Presentation</td>
<td>Introduction to SCADA</td>
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<tr>
<td>14:00</td>
<td>Feedback on training event</td>
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<tr>
<td>14:30</td>
<td></td>
<td>Wrap up of day 04 and clarification of open questions</td>
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## Annex 3: Results of the Evaluation

### Question Answers given in questionnaire

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<th>General Information</th>
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<th>4</th>
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<th>13</th>
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<tbody>
<tr>
<td>Employee of</td>
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<td>Time worked in the water sector</td>
<td>&gt;15 years</td>
<td>&gt;15 years</td>
<td>&gt;15 years</td>
<td>&gt;2...&lt;5</td>
<td>&gt;15 years</td>
<td>&lt;2 years</td>
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<td>&gt;15 years</td>
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<td>&gt;15 years</td>
<td>&gt;15 years</td>
<td>&gt;15 years</td>
<td>&gt;15 years</td>
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<tr>
<td>In my utility, I’m currently actively involved in activities related to reduction of non-revenue water</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
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<tr>
<td>Feedback on the training</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>The presentations provided were relevant to my current work assignment</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>4</td>
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<td>1</td>
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<td>5</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>The time allocated to presentations was enough to follow and understand the content conveyed</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>4</td>
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<td>5</td>
<td>5</td>
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<tr>
<td>The content provided through the presentations was informative and helpful</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>5</td>
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<td>4</td>
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<tr>
<td>The group exercises helped me to fully understand the subject introduced by the presentations</td>
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<td>4</td>
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<td>4</td>
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<tr>
<td>The field trip to WASCOs Pilot Implementation Zones was a helpful exercise to understand the practical application of the theoretical knowledge</td>
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<td>4</td>
<td>3</td>
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<td>3</td>
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<td>4</td>
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<tr>
<td>What could have been improved in the contents and format of the training?</td>
<td>- field trip could have been better organised - the facilitators were not properly informed and didn't have the necessary info - a more indepth tour of WASCO</td>
<td>- setting up DMA - water demand examples @ WASCO</td>
<td>- more exercises - include videos from different utilities in the region</td>
<td>- another field trip - some work on hydraulics software - field trip could have been more clearly delineated prior</td>
<td>- information on automatic meter reading - another field trip - more practical exercises</td>
<td>- more calculations with exercises - more field trip demonstrations</td>
<td>cannot read the remark</td>
<td>- the worksheet grammar was not clear</td>
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### Feedback on the trainers

<table>
<thead>
<tr>
<th>Feedback</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>The trainers demonstrated sound knowledge in their field of expertise</td>
<td>3</td>
</tr>
<tr>
<td>The trainers conveyed the contents professionally and appropriately to my level of experience</td>
<td></td>
</tr>
<tr>
<td>In my opinion, questions were addressed appropriately and to my satisfaction</td>
<td>4</td>
</tr>
<tr>
<td>What can be improved by the trainers to convey their input even better?</td>
<td></td>
</tr>
<tr>
<td>- use of more regional materials as opposed to 1st world materials</td>
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<tr>
<td>- more field visit</td>
<td></td>
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<td>- more hydraulic scenarios at WASCO</td>
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<td>- provision of links for research</td>
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<tr>
<td>- more field visit</td>
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<tr>
<td>- photos of WASCO</td>
<td></td>
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<tr>
<td>- use of regional materials as opposed to 1st world materials</td>
<td></td>
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<tr>
<td>- a more direct interaction</td>
<td></td>
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<tr>
<td>- clearer communication</td>
<td></td>
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<td>- photographs of other regions</td>
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<td>- more slides</td>
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<td>- more case studies</td>
<td></td>
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<td>- more calculative exercises</td>
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<tr>
<td>It was well carried out</td>
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### Conclusion

<table>
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<tr>
<th>Conclusion</th>
<th>Rating</th>
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<tbody>
<tr>
<td>Please rate your overall satisfaction with the accommodation and services provided.</td>
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</tr>
<tr>
<td>- excellent approach</td>
<td></td>
</tr>
<tr>
<td>- involve more regional utilities</td>
<td></td>
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<tr>
<td>- ensure persons present have technical background</td>
<td></td>
</tr>
<tr>
<td>- the structure is good and should be kept</td>
<td></td>
</tr>
<tr>
<td>- generally a good workshop</td>
<td></td>
</tr>
<tr>
<td>- examples of how NRW strategies worked to reduce figures</td>
<td></td>
</tr>
<tr>
<td>- overall this was a very informative and interactive workshop</td>
<td></td>
</tr>
<tr>
<td>- case studies from regional utilities can be presented</td>
<td></td>
</tr>
<tr>
<td>- incorporate cultural exchange using tour</td>
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</table>
Annex 4: Trainers’ Notes

Course name: Training on DMA’s, Water Balances & Advanced Hydraulics

Time: July 1st, 2nd & 4th 2019

Objective: At the end of the workshop participants will be able to

- Make use of the IWA water balance model and understand the used terminology
- Quantify real and apparent water losses of their utility by means of a water balance
- Question the reliability of used data and water balances
- Understand the concept and objectives of DMAs and know prerequisites for their implementation
- Know about the infrastructure leakage index
- Determine different types of DMAs and apply general design rules for DMAs
- Establish easy hydraulic network analysis

Duration: Three days: Day 1 Water Balance, Day 2 DMA, Day 3 Hydraulic Analysis (all sessions include aspects on hydraulic modeling)

Training methods: Short input presentations (ppt), group discussions, group work, exercises

Handout: Presentations, Exercises, FAQ on water balance calculation

Target Group: 1. Utility and government staff involved in the planning and design of new water supply systems or extensions of existing water supply systems

2. Staff working with regulatory authorities supervising water utilities

Trainer: Kees de Jong, hydraulic expert, head of CAH International Department

Tentative Program: DAY 1

1. Short introduction session on objectives, background of participants and expectations
2. Presentation: Introduction to Water Loss Reduction (ppt)
3. Presentation: Calculating a Water Balance (ppt)
4. Group work: Categorization of Water Use
5. Group work: Water Balance Calculation for Vieux Fort
   - Introduction to exercise
   - Group work in 2-3 groups
   - Presentation of solutions and discussion in plenary
   - Discussion on reliability of WB data
DAY 2
1. Presentation: District metered areas (DMAs) (ppt)
2. Group work: Establishing DMAs
   - Identifying steps for implementation of DMAs
   - Identifying methods for effective NRW reduction through DMAs
3. Field trip: Pilot zone Babonneau
   - Implementation of a DMA

DAY 3
1. Presentation: Introduction to Hydraulic Analysis (ppt)
2. Group work: Head Loss Calculation
   - Exercise Pumping System
   - Exercise Gravity Transport System
3. Presentation: Introduction to SCADA (ppt)

Exercise

Water Balance calculation Vieux Fort
Objectives of the exercise

The objective of the exercise is to become acquainted with a structured method for the establishment of a water balance, targeting the assessment of the level of Non-Revenue Water within a complex water distribution system. In order to achieve this aim, a standardised IWA (International Water Association) water balance covering all components of water production, water consumption as well as real and apparent losses shall be established. The following text summarises all available information regarding the water distribution system of the example city of Vieux Fort.

The International Water Association (IWA) water balance model shows different, standardized categories of water production, consumption and loss.

<table>
<thead>
<tr>
<th>System input volume</th>
<th>Authorised consumption</th>
<th>Billed authorised consumption</th>
<th>Billed metered consumption (including water exported)</th>
<th>Revenue water</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>(2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(3) Billed unmetered consumption</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unbilled authorised consumption</td>
<td>(4) Unbilled metered consumption</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(5) Unbilled unmetered consumption</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Apparent losses</td>
<td></td>
<td>(6) Unauthorised consumption</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Water losses</td>
<td></td>
<td>(7) Customer metering inaccuracies</td>
<td>Non-revenue water (NRW)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Real losses</td>
<td>(8) Leakage on transmission and/or distribution mains</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(9) Leakage and overflow at utility’s storage tanks</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(10) Leakage on service connections up to the point of customer metering</td>
<td></td>
</tr>
</tbody>
</table>
Pilot zone Babonneau (St. Lucia) and Action planning

Objectives of the exercise

The objective of the exercise is to show usage of DMAs and action planning for effective NRW reduction.

Introduction

Reliable and accurate information are a prerequisite for efficient water loss management. Information is best managed by means of information systems. A network register and a hydraulic model are very useful tools during the development of a leakage reduction strategy.

DMAs

The key principle behind DMAs is to continuously measure flows into discrete parts of the network via remote meter reading and to analyse the flow, particularly at night, to estimate the level of leakage. DMAs can be defined as a discrete area of a water distribution network. They are usually created by closing boundary valves, in order to keep them flexible to changing demands, but it is also possible to permanently disconnect pipes to neighbouring areas. Different arrangements of DMAs are shown in Figure 1.

![Figure 1: Components and arrangements of DMAs](image)
Hydraulic Analysis

Objectives of the exercise

The objective of the exercise is to introduce the use of hydraulic analysis, which is essential for hydraulic network models used for the correct planning of DMAs.

Hydraulic network models

Hydraulic network models are used to simulate the behaviour of existing or planned systems under a wide range of conditions. They are valuable tools for improving the operational efficiency and can be used to:

- verify system capacities (analysis of pressures and flows)
- select zone boundaries for district metered areas (DMAs)
- plan pressure management measures (e.g. dimensioning of valves, revision of fire flow conditions, detection of pressure shortcomings) or to
- analyse system vulnerability and supply security.

Prerequisites for the set-up of DMAs

For the set-up of DMAs, detailed knowledge on the network is required. Before the definition of a DMA, a number of prerequisites should be fulfilled, such as:

- existence of a complete, up-to-date network register with topographic information
- availability of information on water consumption patterns and operational data about flows and pressure
- a calibrated hydraulic model to determine the impacts of the sectorisation (optional)
- sustainability of the DMA implementation process, ensured by the operator, as the set-up of DMAs is not a one-time job, but needs continuous monitoring and maintenance!
Annex 5: Presentation on Water Loss Reduction

M1.1 Introduction to water loss reduction

Training on water loss reduction
Module 1: Understanding water losses

Content
- Water losses – a global problem
- Basic terms and definitions
- Real water losses
- Apparent water losses
- Why reduce water losses?
- Intervention methods
Water losses – a global problem

Basic terms and definitions

**Water losses**: The volume of water lost between the point of supply and the customer due to various reasons.

- **Real losses**
  - Volume of water lost between the point of supply and the customer meter due to physical leaks from mains, pipes and valves and due to tank overflow.

- **Apparent losses**
  - Volume of water lost due to other factors, such as unauthorised consumption, metering inaccuracies and data handling errors.
**Water balance**: The sum of all water quantities that go into the water supply system compared with the sum of all water quantities that leave the system. ‘Input’ minus ‘output’ should be equal to zero.

**Basic terms and definitions**

**Own sources**

**Water supply**

**Water exports**

**Unbilled consumption**

**Non Revenue**

**Real losses**

**Real water losses**

Real losses can be classified according to:

- **Size and runtime**
  - Background leakage
  - Unreported (or hidden) leaks
  - Reported (or visible) leaks

- **Location**
  - Transmission and distribution mains
  - Service connections
  - Storage tanks
Real water losses

Leakage on transmission and distribution mains may occur at:
- pipes (bursts due to extraneous causes or corrosion),
- joints (disconnection, damaged gaskets) and
- valves (operational or maintenance failure)

They usually have medium to high flow rates and short to medium run times.
Leakage may occur on **service connections** (up to the customer meter):

- Service connections are weak points, joints and fittings have high failure rates.
- Leaks are difficult to detect due to low flow rates leading to long runtimes.

Leakage and overflows from storage tanks:

- Leakage is caused by lacking or damaged level controls or seepage from untight masonry or concrete walls.
- Losses are easy to detect, but often underestimated.
- Repair works are usually elaborate and expensive.
Potentially Recoverable Real Losses

- Due to background losses and hidden leaks, real losses $Q_{RL}$ can never be totally eliminated.
- The remaining amount of losses is known as Unavoidable Annual Real Losses (UARL).
- Potentially recoverable losses can be expressed by subtracting the Unavoidable Annual Real Losses (UARL) from the Current Annual Real Losses (CARL).

Apparent water losses

Apparent losses can be classified into:

a) **Meter inaccuracies** due to broken or incorrect customer and bulk water meters.

b) **Data handling**, accounting errors and poor customer accountability in billing systems.

c) **Unauthorised consumption** due to water theft and illegal connections.
Apparent water losses

Importance of apparent losses

- Apparent losses play a major role in many water utilities in developing and emerging countries.
- They cause additional production and capital costs for the utility without generating revenue.

Reduction of apparent losses

- can be achieved in most cases at relatively low costs.
- presents a good starting point for water loss reduction activities.
- usually pays off quickly.

Why reduce water losses?

Proportions of water utilities

Range of NRW levels
Why reduce water losses?

The World Bank estimated in 2006:

- The annual volume of NRW in developing countries amounts to \( \approx 2.67 \) billion \( \text{m}^3 \).
- This represents a financial loss of \( \approx 5.9 \) billion US\$ every year.

Reducing the amount of water losses by half would generate enough water to supply additional 90 million people in the developing countries.

<table>
<thead>
<tr>
<th>Hole ( a = 6 \text{ mm} )</th>
<th>Equivalent</th>
<th>Olympic size swimming pool ( V = 2500 \text{ m}^3 )</th>
<th>Per capita consumption ( = 138 \text{ l/cap/d} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure = 50 m</td>
<td></td>
<td>Filled in less than 2 months</td>
<td>( 317 \times 138 \text{ l/cap/d} = 43.2 \text{ m}^3/d )</td>
</tr>
<tr>
<td>Leakage = 43.2 l/d</td>
<td></td>
<td></td>
<td>( \approx ) Water for 317 persons</td>
</tr>
</tbody>
</table>
Why reduce water losses?

Technical, social and environmental impacts of water losses:

- **Technical:**
  - Service breakdowns up to intermittent supply
  - Overload of wastewater and storm water collection

- **Social:**
  - Increased health risk
  - Low customer satisfaction

- **Environmental:**
  - Increased stress on surface and subterranean water bodies
  - Energy wastage, increased consumption of chemicals for water treatment

---

Water loss reduction should be the aim of every water utility since it alleviates economic, technical and social and ecological problems:

- Improved operational efficiency.
- Improved metering and billing.
- Reduced health risk.
- Increased security of supply.
- Reduced infrastructure damages.
- Reduced sewer load.
- Improved customer satisfaction.
- Improved publicity and willingness to pay.
- Reduced ecologic stress.
Intervention methods

Since many factors influence water losses, some steps have to be taken before intervention methods can be chosen.

- Creating an encouraging political framework
  - Binding regulations,
  - incentives,
  - benchmarking and
  - target setting for leakage levels.

- Analysing the particular system
  - Identifying all types of losses and their proportion, and
  - understanding the factors that attribute to real water losses.
References

Annex 6: Presentation on Water Balance Calculation

M1.2.1 Calculating a water balance

Training on water loss reduction
Zimbabwe 2017

<table>
<thead>
<tr>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective of a water balance</td>
</tr>
<tr>
<td>The IWA water balance model (Exercise)</td>
</tr>
<tr>
<td>Water balance calculation step by step</td>
</tr>
<tr>
<td>Quantifying real water losses</td>
</tr>
<tr>
<td>Exercise: Water Balance Calculation</td>
</tr>
</tbody>
</table>

Water loss reduction | Calculating a water balance 2
Objective of a water balance

Water Production → Water Utility → Billed Water → Revenue

Water loss reduction | Calculating a water balance

Objective of a water balance

Consumer → Water Production → Technical Water losses → Illegal Consumption

Water Production → Water Utility → Billed Water → Revenue

Water loss reduction | Calculating a water balance
Objective of a water balance

- Raw Water Production: 124.1
- Treated Water Production: 115.1
- Operational Consumption: 4.4
- Water Losses: 3.9
- Distributed Water: 114.2

Water losses:
- Domestic Use: 87.7
- Industry: 7.0
- Authorities: 1.3
- Bulk Supply: 13.4
- Firefighting/Flush: 0.2

Water loss reduction | Calculating a water balance
## The IWA water balance model

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Billed authorized consumption $Q_{a}$</td>
<td>Billed water exported</td>
</tr>
<tr>
<td>Billed metered consumption $Q_{m}$</td>
<td>Billed metered consumption</td>
</tr>
<tr>
<td>Billed unmetered consumption $Q_{u}$</td>
<td>Billed unmetered consumption</td>
</tr>
<tr>
<td>Unauthorized consumption $Q_{u}$</td>
<td>Unauthorized consumption</td>
</tr>
<tr>
<td>Apparent losses $L_{a}$</td>
<td>Customer meter inaccuracies and data handling errors.</td>
</tr>
<tr>
<td>Real losses $L_{r}$</td>
<td>Leakage in transmission and distribution mains</td>
</tr>
<tr>
<td></td>
<td>Leakage and overflows at storage tanks</td>
</tr>
<tr>
<td></td>
<td>Leakage in service connections up to point of customer meter</td>
</tr>
</tbody>
</table>

### Water loss reduction | Calculating a water balance

### Exercise: “Categorization of water use”
Basic terms and definitions

A water balance tracks every component of water that is delivered to and subtracted from a supply system within a defined period of time.

Approaches:
- Annual water balance,
- Real loss assessment.

Highest reliability will be achieved when both approaches are combined.

Calculating a Water Balance

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Step 4</th>
<th>Step 2</th>
<th>Step 5</th>
<th>Step 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Custom input volume $Q_i$</td>
<td>Authorised consumption $Q_a$</td>
<td>Billed authorised consumption $Q_{a,b}$</td>
<td>Unauthorised consumption $Q_u$</td>
<td>Leakage on transmission and distribution mains</td>
</tr>
<tr>
<td></td>
<td>Water losses $Q_L$</td>
<td>Billed metered consumption $Q_{b,m}$</td>
<td>Customer meter inaccuracy and data handling errors</td>
<td>Leakage and overflows at storage tanks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Billed unmetered consumption $Q_{b,m}$</td>
<td></td>
<td>Leakage on service connections up to point of customer meter</td>
</tr>
</tbody>
</table>

Water loss reduction | Calculating a water balance
**Water balance calculation step by step**

**Step 1:** Determine 'system input volume Q_{i}'

**Requirements:**
- Bulk meters on water treatments plants and pumping stations
- Regular reading and maintenance of bulk meters
- Standardized work flows for data collection

If bulk meters are not available or out of order:

→ Estimations based on sample measurements and pump running hours

---

**Sample measurement with portable US meter**
### Water balance calculation step by step

#### Step 1

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Authorised consumption $Q_a$</th>
<th>Billed authorised consumption $Q_{a,b}$</th>
<th>Billed metered consumption</th>
<th>Billed unmetered consumption</th>
<th>Revenue Water</th>
<th>Non-revenue Water</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Billed metered consumption</td>
<td>Billed unmetered consumption</td>
<td>Revenue Water</td>
<td>Non-revenue Water</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Unbillclimated consumption</td>
<td>Unbillclimated consumption</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Apparent losses $L_a$</td>
<td>Unauthorised consumption</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Customer meter inaccuracies and data handling errors</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Real losses $L_r$</td>
<td>Leakage transmission and distribution mains</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Leakage and overflows at storage tanks</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Leakage at service connections up to point of customer meter</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Step 2-4: Determine ‘Authorised consumption’

**Requirements:**
- Up to date customer register
- Customer data align with the balance boundaries
- Customer meters installed and read on a regular basis
- Meter management concept
- Flat rate volumes proofed by sample measurements
- Officially unbilled customers (e.g. authorities)
### Water balance calculation step by step

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Step 4</th>
<th>Step 2</th>
<th>Step 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>System input volume $Q_L$</td>
<td>Authorised consumption $Q_a$</td>
<td>Billed authorised consumption $Q_{b, a}$</td>
<td>Unbilled authorised consumption $Q_{u, a}$</td>
</tr>
<tr>
<td>Water issues $Q_L$</td>
<td>Apparent losses $Q_h$</td>
<td>Unauthorised consumption</td>
<td>Leakage in transmission and distribution mains</td>
</tr>
<tr>
<td>Real losses $Q_L$</td>
<td></td>
<td>Customer meter inaccuracies and data-handling errors</td>
<td>Leakage and overflows at storage tanks</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Leakage at service connections up to point of customer meter</td>
</tr>
</tbody>
</table>

#### Step 5: Estimate apparent losses $Q_{al}$
- Break down into various components.
- Estimate each component.
Water balance calculation step by step

**Step 5:** Estimate apparent losses $Q_{AL}$
- Break down into various components.
- Estimate each component.

E.g.: Illegal connections, meter inaccuracies, data handling errors, ...

**By:** surveys, pilot areas, ..
Water balance calculation step by step

**Step 6:** Calculate real losses $Q_{RL}$
- By sample measurements
- Values from other areas
- Abstraction from apparent losses (if applicable)
### Real losses assessment

<table>
<thead>
<tr>
<th>Location</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage tank</td>
<td>Drop test</td>
</tr>
<tr>
<td>Transmission mains</td>
<td>Portable flow meters, simultaneous measurement up- and downstream</td>
</tr>
<tr>
<td>Distribution network</td>
<td>Continuous supply: Minimum night flow</td>
</tr>
<tr>
<td></td>
<td>Intermittent supply: Stop tap method</td>
</tr>
</tbody>
</table>

Rightarrow: **CONTINUOUS MONITORING**

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### Quantifying real water losses: Minimum Night Flow Analysis

![Graph showing different water loss components: Minimum flow, Burst leakage, Varying customer use, Background/leakage, and Customer night use.](image)

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### Water balance calculation step by step

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Step 4</th>
<th>Step 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Authorised consumption $Q_a$</td>
<td>Billed authorised consumption $Q_{bl}$</td>
<td>Billed water exported</td>
</tr>
<tr>
<td>System input volume $Q_i$</td>
<td>Billed metered consumption</td>
<td>Billed unmetered consumption</td>
</tr>
<tr>
<td>Water usage $Q_u$</td>
<td>Step 3</td>
<td>Unbilled authorised consumption £u</td>
</tr>
<tr>
<td></td>
<td>Step 5</td>
<td>Unauthorised consumption</td>
</tr>
<tr>
<td></td>
<td>Step 6</td>
<td>Leakage in transmission and distribution mains</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leakage in service connections up to point of customer meter</td>
</tr>
</tbody>
</table>

#### Exercise “Water Balance Calculation”

[Diagram of exercise]
References

Management
Decision based on information

O & M Department
- Organisation of Meter Repair and Maintenance
- Inscription of DMA, Separation (closed boundary valves)
- Assistance with temporarily flow and pressure measurements

Planning Department
- Monthly analysis of bulk meter data
- Organization of temporarily flow measurements
- Nightflow analysis
- Water Balance Calculation
- Calculation of Performance Indicators

Commercial Department
- Extraction of the billing data according to the balance zone boundary
- Determining billed and unbilled volumes
- Estimation unrecorded volumes

Customer Meter Reader

Water loss reduction | Calculating a water balance
Annex 7: Exercises Water Balance

Water balance components of a utility

Target group: Participants without in-depth knowledge and/or practical experience in establishing a water balance according to the IWA standard. Water utilities having a different terminology than the official one from IWA.

Trainers: 2 trainers; resource persons or trainees can be integrated.

Duration: approx. 1 hour

Objective: Participants understand which components of the IWA water balance correspond to which component used in their daily business terminology. Participants know where to find the data and are sensitised to data availability and quality.

Preparation

Needed material: Pin board prepared with different categories (e.g. see template below)

Handouts: -

### Procedure

<table>
<thead>
<tr>
<th>Step</th>
<th>Procedure</th>
<th>Time</th>
<th>Materials</th>
</tr>
</thead>
</table>
| 1)   | ✓ Introduce and explain the exercise (in plenary):  
  o Present the different components prepared on a pin board (see template below)  
  o Explain that every participant should come up with “water balance components”, write them on cards and pin them at the right place, under the correct category. The participant should indicate where he can obtain the data in his water utility and estimate the data reliability (e.g., is it measured, estimated, what is the uncertainty?)  
  o Start with one component and do the exercise: e.g.: Domestic consumption, fire hydrants, under-metering  
  ✓ Ask if the task is understood and let the participant start adding components | ~15' | ✓ Pin board prepared with different categories (e.g. see template below)  
✓ Cards  
✓ Marker pens |
| 2)   | ✓ Encourage participants to come up with water balance components using their **own words** and start a discussion in plenary for each component.  
✓ Use following questions for discussion: ‘are you sure that this component is in this category?’; ‘does everybody agree?’; ‘is this data available in your WU? If yes: how reliable is it?’  
✓ The trainers should help participants to have a dynamic exercise. | ~30' |
| 3)   | ✓ Present the final pin board and address the expected difficulties to get the needed numbers and the quality of data.  
✓ Highlight the fact that data collection is one of the biggest challenges. | ~5' |

### Template to be prepared on a pinboard before the exercise

<table>
<thead>
<tr>
<th>Nº</th>
<th>Component</th>
<th>Cards to be pinned here</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Billed Metered Consumption</td>
<td>e.g. Domestic consumption</td>
</tr>
<tr>
<td>2</td>
<td>Billed Unmetered Consumption</td>
<td>e.g. Not readable meters</td>
</tr>
<tr>
<td>3</td>
<td>Unbilled Metered Consumption</td>
<td>e.g. water distributed during water shortage</td>
</tr>
<tr>
<td>4</td>
<td>Unbilled Unmetered Consumption</td>
<td>e.g. fire hydrants</td>
</tr>
<tr>
<td>5</td>
<td>Unauthorised Consumption</td>
<td>e.g. illegal connections</td>
</tr>
<tr>
<td>6</td>
<td>Metering Inaccuracies</td>
<td>e.g. under-metering</td>
</tr>
<tr>
<td>7</td>
<td>Real Losses</td>
<td>e.g. bursts</td>
</tr>
</tbody>
</table>

It is also possible to use numbers directly on the IWA water balance and to use these component numbers on the pin board.
Water Balance calculation “Vieux Fort” for 2017

Objectives of the exercise
The objective of this exercise is to become familiar with a structured method for the establishment of a water balance. The level of Non-Revenue Water of a complex water distribution system shall be determined using available figures as well as estimations. In order to achieve this aim, a standardised IWA (International Water Association) water balance is used, that covers all components of water production, water consumption as well as real and apparent losses. The following text summarises all available information regarding the water distribution system of the example city of Vieux Fort.

Introduction

Water consumption in Vieux Fort
The water utility (WU) provides water to Vieux Fort, which has 5,684 domestic and 373 light commercial customers. The water distribution system of Vieux Fort is divided into five hydraulically independent supply zones, so-called District Metered Areas (DMA). The number of inhabitants of the DMAs as well as the metered domestic water consumption of each DMA is shown in Table 1.

Table 1: Inhabitants per DMA and billed metered water consumption

<table>
<thead>
<tr>
<th>Supply zone</th>
<th>Total domestic customers</th>
<th>Total light commercial customers</th>
<th>Customers without water meters</th>
<th>Metered water consumption [m³/a]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vieux Fort South</td>
<td>1,299</td>
<td>228</td>
<td>225</td>
<td>144,832</td>
</tr>
<tr>
<td>Vieux Fort North</td>
<td>2,710</td>
<td>110</td>
<td>712</td>
<td>302,138</td>
</tr>
<tr>
<td>Laborie</td>
<td>1,280</td>
<td>19</td>
<td>503</td>
<td>69,457</td>
</tr>
<tr>
<td>Grace</td>
<td>457</td>
<td>2</td>
<td>139</td>
<td>31,290</td>
</tr>
<tr>
<td>Pierrot</td>
<td>1,114</td>
<td>14</td>
<td>304</td>
<td>89,512</td>
</tr>
</tbody>
</table>

Some customers don’t have water meters. These customers are billed with a flat-rate, regardless of their consumption. The average consumption per customer in Vieux Fort is 461 l/day (derived from metered customers).

In addition to domestic water consumption, a certain amount of operational and public water consumption is needed for flushing of mains, irrigation of parks, public buildings, fire fighting, etc. This part of water consumption has been authorized by the WU but cannot be metered. The unbilled unmetered water consumption is estimated to be 1,25 % of the system input volume.

Furthermore, in addition to the domestic and light commercial customers, there are 101 major customers (hotels, major commercial, industry and governmental consumers), which have consumed and have been billed for 451,359 m³/year.
Water production

Water supply of Vieux Fort region relies on various sources. The Vieux Fort water supply system is mainly supplied by two intake sites and subsequent treatment plants – Grace (upper) and Beausejour (lower). Currently, the main supply is covered by the two Grace intakes (see Figure 5) from where the collected raw water is delivered through a transmission main by gravity to the Grace WTP. The Beausejour WTP is included as part of water production mainly during the dry season with reduced or minimum river flows.

During the dry season or other scenarios that lead to a lack of water in parts of Vieux Fort, customers receive water by water trucks. In this case, the water is imported from outside resources in Soufriere or Choiseul and thereby must be counted as imported water.

The measured and estimated flow data of the Grace WTP, the Beausejour WTP and the water trucks is shown in Table 2.

Table 2: Flow measurements from bulk water meters and estimates

<table>
<thead>
<tr>
<th>Volume supplied [m³/a]</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Grace WTP</td>
<td>2,188,296</td>
</tr>
<tr>
<td>Beausejour WTP</td>
<td>251,595</td>
</tr>
<tr>
<td>Water trucks</td>
<td>6,262</td>
</tr>
</tbody>
</table>

Water losses

It can be assumed that neither leakage nor overflows are occurring at the storage tanks.

Apparent losses caused by customer-metering inaccuracies is estimated to be equal to 5 % of the system input volume. Data handling errors are estimated to sum up to an amount equal to 2 % of the system input volume. Unauthorized consumption due to illegal connections is estimated to be equal to 10 % of the system input volume.
Working instructions

General instructions
Please work in small groups and prepare a water balance for Vieux Fort. Take into account:

- the background information about Vieux Fort – sketch, description and data
- the IWA standardised water balance as shown in Figure 2
- the prepared tables and calculators

The working time for this exercise is 70 minutes. Please prepare for the discussion of results in the plenary.

<table>
<thead>
<tr>
<th>System Input Volume [m³/a]</th>
<th>Authorised Consumption [m³/a]</th>
<th>Billed Authorised Consumption</th>
<th>Revenue Water [m³/a]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Billed Metered Consumption (including water exported)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Billed Unmetered Consumption</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unbilled Authorised Consumption [m³/a]</td>
<td>Unbilled Metered Consumption</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unbilled Unmetered Consumption</td>
<td></td>
</tr>
<tr>
<td>Water Losses [m³/a]</td>
<td>Apparent Losses [m³/a]</td>
<td>Unauthorised Consumption</td>
<td>Non-Revenue Water [m³/a]</td>
</tr>
<tr>
<td></td>
<td>Real Losses [m³/a]</td>
<td>Metering Inaccuracies</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leakage on Transmission and/or Distribution Mains</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leakage and Overflows at Utility’s Storage Tanks</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Leakage on Service Connections up to point of Customer metering</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2: Standard terminology for the water balance according to IWA

Calculation procedure
It is recommended to proceed according to the following approach:

1. Assess the overall system input volume (by taking into account all water entering the system).
2. Calculate the billed authorised consumption, the so-called ‘revenue water’, by
   a. Determining the billed metered consumption
   b. Determining the billed unmetered consumption (estimation).
3. Calculate the amount of non-revenue water (by subtracting the billed authorised consumption from the system input).
4. Identify the unbilled authorised consumption (part of NRW). Therefore, define unbilled metered consumption (if existent) and unbilled unmetered consumption.
5. Calculate the amount of water losses.
6. Assess the volumes of *apparent* and *real losses* occurring in the water distribution system.

**note:** not all sub-values, e.g. like Leakage on Transmission, etc. can be determined in this exercise

**Hints for calculation**
- Be careful to use consistent units.
- Follow the IWA scheme to establish a standardised water balance.
- In order to get the billed authorised consumption, identify the different positions contributing to the billed metered consumption and estimate the billed unmetered consumption based on the average metered data.
- To assess the unbilled authorised consumption calculate the unbilled unmetered consumption.
- To assess the real losses first identify apparent losses.

**Results**

**Overall water balance for the Newtown water utility**

Please use the following table to insert your results for the overall water balance. Please note that not all components of the water balance can be determined by means of the available information.

<table>
<thead>
<tr>
<th>System Input Volume [m³/a]</th>
<th>Billed Authorised Consumption [m³/a]</th>
<th>Billed Metered Consumption (including water exported) [m³/a]</th>
<th>Revenue Water [m³/a]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Billed Unmetered Consumption [m³/a]</td>
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<td></td>
<td></td>
<td>Unbilled Authorised Consumption [m³/a]</td>
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<td>Unbilled Metered Consumption [m³/a]</td>
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<td>Unbilled Unmetered Consumption [m³/a]</td>
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<td></td>
<td>Unauthorised Consumption [m³/a]</td>
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<td></td>
<td></td>
<td>Metering Inaccuracies [m³/a]</td>
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<td>Non-Revenue Water [m³/a]</td>
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<td></td>
<td></td>
<td>Leakage on Transmission and/or Distribution Mains [m³/a]</td>
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<td></td>
<td></td>
<td>Leakage and Overflows at Utility’s Storage Tanks [m³/a]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leakage on Service Connections up to point of Customer metering [m³/a]</td>
<td></td>
</tr>
</tbody>
</table>
Frequently asked questions (FAQs)

(1) Why is it usually not recommended to estimate the item ‘billed unmetered consumption’ by using the average consumption figures from metered users?

For billed customers who are not equipped with water meters, it is not recommended to simply assign the consumption figures of metered users, because metered tariffs usually create different consumption behaviour than flat-rate tariffs. In case of flat-rate tariffs, consumption can be significantly higher.

(2) How can the item ‘billed unmetered consumption’ be estimated properly?

The average unmetered domestic consumption should be determined using individual household monitors (IHMs) on a random sample of users. An alternative method is the use of small area monitors (AMs), if the area under investigation is not subject to large volumes of undetected leakage.

(3) How can the amount of “unbilled unmetered consumption” be quantified properly?

Unbilled unmetered consumption relates to all types of customer groups, such as domestic, commercial, industrial and other authorised consumption (e.g. slum areas, squatters, public parks or fire service). First, all customer groups have to be identified. Then, surveys have to be carried out, such as individual household monitors (IHMs) or area monitors (AMs).

(4) How is the percentage of water losses influenced if losses at the transmission main from the well field to the treatment plant are not considered?

Water losses at the transmission main (from the well field to the treatment plant) amount to 56,414 m$^3$/a. If this amount is subtracted from the system input, real water losses are reduced from 28.5% to 27% and NRW is reduced from 38% to 36.5%.

(5) How is the percentage of water losses influenced if the ‘unbilled metered authorised consumption’ at the water treatment plant as well as the ‘water exported’ are not considered in the water balance?

36,500 m$^3$/a are used for the backwashing at the treatment plant and 180,000 m$^3$/a are exported. If those authorised consumptions are not considered in the water balance, water losses will rise from 34.5% to 38% and NRW from 38% to 40%.
(6) ‘Unbilled unmetered consumption’ and ‘apparent losses’ were given as a ratio of the total system input (1.25% and 7% of the system’s input volume). If a water balance for each DMA is done, ‘unbilled unmetered consumption’ and ‘apparent losses’ have to be estimated for each DMA. How can this be done?

There are different possibilities: One approach is to weight ‘unbilled unmetered consumption’ and ‘apparent losses’ according to the volumes of domestic consumption of each DMA (e.g. if Vieux Fort North received 12.4% of the total system input then Unbilled unmetered consumption of Vieux Fort North = Overall unbilled unmetered consumption * 0.124). In general it can be said that no ‘correct’ method exist, since the distribution of the ‘unbilled unmetered consumption’ and the ‘apparent losses’ will always be an estimate.

(7) How can apparent losses be further broken down into single components?

Within the framework of this exercise, only an estimate for the total apparent losses is given. Thus, it is not possible to make a statement on the share of its components ‘unauthorised consumption’ and ‘metering inaccuracies’. To get to know more about the components of apparent losses, field surveys have to be carried out.
## Water Balance calculation “Newtown”

**System Input Volume**
- Grace WTP: 2,188,296 [m$^3$/a]
- Beausejour WTP: 251,595 [m$^3$/a]
- Water import: 6,262 [m$^3$/a]
- **Total**: 2,446,153 [m$^3$/a]

**Authorised Consumption**
- grace: 1,436,008 [m$^3$/a]
- **Total**: 1,405,431 [m$^3$/a]

**Billed Authorised Consumption**
- 1,405,431 [m$^3$/a]

**Billed Metered Consumption (including water exported)**
- Vieux Fort South: 144,832 [m$^3$/a]
- Vieux Fort North: 302,138 [m$^3$/a]
- Laborie: 69,457 [m$^3$/a]
- Grace: 31,290 [m$^3$/a]
- Pierrot: 89,512 [m$^3$/a]
- Industry: 451,359 [m$^3$/a]
- **Total**: 1,088,588 [m$^3$/a]

**Unbilled Authorised Consumption**
- 30,577 [m$^3$/a]

**Unbilled Metered Consumption**
- 0 [m$^3$/a]

**Revenue Water**
- 1,405,431 [m$^3$/a]

**Unbilled Unmetered Consumption**
- Public consumption: 30,577 [m$^3$/a]

**Apparent Losses**
- Illegal consumption and metering errors: 415,846 [m$^3$/a]

**Real Losses**
- Leakage on Transmission and/or Distribution Mains: n.a. [m$^3$/a]
- Leakage and Overflows at Utility’s Storage Tanks: n.a. [m$^3$/a]
- Leakage on Service Connections up to point of Customer metering: n.a. [m$^3$/a]

**Non-Revenue Water**
- 1,040,722 [m$^3$/a]
Annex 8: Presentation on District Metered Areas (DMAs)

**M2.2 District metered areas (DMAs)**

Training on water loss reduction  
Module 2: Information systems and hydraulic modelling

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**Table of content**

- Definition and objectives
- Types of district metered areas
- Prerequisites for implementing DMAs
- General design rules for DMAs
- Implementation of DMAs
- Operation and maintenance of DMAs
**DMAs – Definition and objectives**

**District metered areas (DMAs)** are discrete areas of a water distribution network, where in- and outflows are continuously measured.

**Objectives:**
- Monitoring of the level of leakage
- Locally limited NRW assessments
- Prioritisation of problem areas

→ Prerequisite for water loss management/pressure management

---

**Types of district metered areas**

[Diagram showing different types of district metered areas]
Prerequisites for implementing DMAs

**In-depth knowledge of the water supply system**
- complete, up-to-date network register, incl. topographical data
- information on water consumption patterns
- information on flows and pressure in the network
- calibrated hydraulic model to determine the impacts of zoning

General design rules for DMAs

- Separation of the trunk system from the distribution network
- Preferably single inlet DMAs
- DMA size: 500-3,000 connections or 4-30 km pipe length
- Minimal variations in ground elevation across the DMA
- Easily identifiable and robust DMA boundaries
- Minimisation of potential zones of stagnation
Implementation of DMAs

- Closure of existing boundary valves and installation of new valves where necessary, according to DMA design
- Test for tightness of boundary valves
- Selection and installation of appropriate flow meter at the inlet point.
- Performance of a zero pressure test
- Verification of flow meters
- Verification of existence of pressure or supply shortages

Operation and maintenance of DMAs

After DMA set-up, it is necessary to:
- determine the level of leakage
- eliminate backlog of detected and undetected leaks
- implement routine operations
- identify the pressure management capability
Operation and maintenance of DMAs

Implementing and maintaining routine operations:
- Recording and updating of key information for each DMA
- Regularly check of all boundary valves
- Documentation of pipe flushing or opening of boundary valves for operational reasons
- Maintenance of flow meters
- Monitoring of customer complaints
Conclusions

- DMAs are isolated areas of the distribution network where all in and outflows are continuously measured.
- DMAs are important tools for the monitoring of water losses and a prerequisite for pressure management.
- The set-up of DMAs requires an up-to-date network register, information about consumption patterns, flows and pressures in the network and, ideally, a calibrated hydraulic model.
- Necessary maintenance activities include: regular check of boundary valves, maintenance of flow meters and monitoring of customer complaints.

References

Annex 9: Exercise DMAs

DMAs Roadmap

1. Network Mapping
   - Strategic Planning (GIS Unit)
2. Definition of DMA boundaries
   - Water Services
3. Creation of DMA boundary layer
   - Strategic Planning (GIS Unit)
4. Mapping of customers
   - Strategic Planning (GIS Unit)
5. Assign DMA ID to customers
   - Customer Service
6. Identify customers within DMA
   - Customer Service
7. Calculate water balance for each DMA
8. Separate commercial & physical losses
9. Implement corrective measures in real time
10. Monitoring per DMA
Annex 10: Field trip pilot zone Babonneau
Institutional and Organisational Strengthening of WASCO Saint Lucia and Regional Water Utilities

Saint Lucia

DEMAND FORECASTING
March 2019

DETERMINANTS

A. Domestic Demand
   • Number and size of households
   • Population growth
   • Family income and income distribution
   • Costs of water presently used
   • Cost of future water used
   • Connection charges
   • Availability and quality of service
   • Cost and availability of water using devices
   • Availability of alternative water sources
   • Present water consumption
   • Legal requirements
   • Population density
   • Cultural influences
DETERMINANTS OF DEMAND - 2

B. Commercial Demand

- Sales and turnover
- Costs and volume of water presently used
- Price of future water used
- Connection charges
- Costs of water using appliances
- Quality and reliability of service
- Working hours of various types of commercial establishments
- Legal requirements

C. Industrial Demand

- Present and future costs of water
- Type of industry and water use intensity
- Relative price of alternative sources
- Quality and reliability of supply
- Costs of treatment and disposal of waste water
- Legal requirements

DETERMINANTS OF DEMAND - 3

D. Agricultural Demand (for [non] piped water supply)

- Present and future costs of water
- Availability of other sources
- Quality and reliability of supply
- Supply cost of alternative water systems
- Number of cattle
- Legal requirements

E. Public Services Demand

- Present and future costs of water
- Revenue of local governments
- Number and size of public schools, hospitals, ministries, etc.
- Legal requirements

F. Technical requirements

- Unaccounted for Water (leakage)
- Peak factors
- Seasonal fluctuations
DEFINITION OF DEMAND

The demand for water is the quantity of water demanded at a given service level and at a specified price.
FUTURE COSTS OF WATER

DEMAND MANAGEMENT IN MELBOURNE

about six years. The potential in investment was various at different locations. The figure below.

DEMAND MANAGEMENT MEASURES

Reduce demand by increasing tariffs
- Increase average tariff
- Introduce progressive tariff
- Introduce tariffs for wastewater
- Provide fiscal incentives (investments water saving)

Reduce demand without price changes
- Introduce water saving devices
- Educational programs (change behavior)
- Legal measures (use of groundwater)
- Industrial water audits
- Increase efficiency of utilities

EXERCISE

You are to prepare a demand forecast for Castries for the next 25 years. Please answer the following questions:

1. What is the estimated current demand for water?
2. What is the estimated demand for water in 2024?
Annex 12: Trainers Notes

Course name: Demand Analysis and Forecasting

Time: To coincide with CAWASA Seminar

Objective: At the end of the workshop participants will be able to
- Identify the various factors which determine the demand for water
- Explain the need to manage the demand for water
- Describe the various instruments to manage the demand for water
- List the types of data needed to forecast the demand for water
- Identify the main sources for data collection
- Explain the concepts Willingness and Ability to Pay
- Carry out a simple exercise in forecasting water demand

Duration: One day

Training methods: Short lectures, group discussions, group work, various exercises


Target Group: 1. Utility and government staff involved in the planning and design of new water supply systems or extensions of existing water supply systems
2. Staff working with regulatory authorities supervising water utilities

Trainer: J.W. Overbeek, Institutional Expert and Economist

Tentative Program:

6. Introduction
7. Group work to identify the various factors which determine the demand for water
8. Introduction on the various instruments to manage water demand
9. Group discussion on the effectiveness and feasibility of the identified instruments
10. Group work to identify potential sources of data needed for demand forecasting
11. Introduction on Willingness and Ability to Pay followed by discussion
12. Carry out a simple case study in estimating water demand
Session Guide

A. The Determinants of the Demand for Water

1. Divide participants in groups of two (sitting next to one another). Ask all groups to take 10 minutes and list the factors that determine the future demand for water and make a distinction between domestic and industrial/commercial demand.

2. After 10 minutes ask the first group to mention the first three factors. Ask group 2 to add another three factors. Continue the exercise until participants have listed most of the determinants of the demand for water mentioned below.

3. Write down the definition of the demand for water, as follows:
   
   The demand for water is the quantity of water demanded of a given service level and at a specified price.

   Explain that the demand is always related to a specific product or service level and the price paid for the product or service level.

B. Some Concepts

4. What is the difference between the “demand” for water and the “consumption” of water? Elicit the concept of “constrained” demand, i.e. that the actual demand is higher as consumption, but e.g. the water utility cannot provide enough water.

5. Ask participants if all water that WASCO produces represents additional demand for water? Elicit by questioning and discussion the difference between non-incremental demand and incremental demand for water. The difference is relevant, because non-incremental demand does not generate benefits for a water supply project, as it just replaces water. Incremental demand represents a benefit for a water supply project.

6. Ask participants what they can say about the relationship between the price and the volume of water demanded. Participants may suggest that the higher the price the lower demand. Suggest that in case supply of water is very limited, e.g. only a few liters per day, consumers may be willing to pay very high prices for water, for drinking. However, for the next few liters, e.g. for cooking, they will be prepared to pay less, and for the next 10 liters (for washing) they will be prepared to pay even less. Draw a demand curve on the board (nonlinear and linear) The downward slope of the demand curve indicates the decreasing marginal value of water. For practical purposes the linear demand curve is often used, whereas the non-linear version probably is a better representation of actual consumer behavior.

7. Draw a demand curve for a consumer who uses water from a public tap. Ask participants where the demand curve for water from a consumer with water from a house connection would lay. Probably the HC demand curve would lay higher and to the right of the PT demand curve indicating that consumers are willing to pay a higher price for the same quantity of water with a quality that they perceive as higher.
8. Introduce the concept of **price elasticity**. Price elasticity is the relative change in the quantity of water demanded divided by a relative change in the price of water. If the price elasticity is <1, we call demand inelastic, and if price elasticity is >1, we call demand elastic. Studies of the World Bank show, that the average demand for water is rather inelastic and ranges between -0.2 and -0.8. This means that if the Price increases with 10% the demand for water will decrease with 2% - 8%.

9. Explain to participants that it would actually be very useful to know the actual shape of the demand curve. For that purpose, sometimes Willingness to Pay surveys are being carried out in the course of forecasting demands and planning for system development. In such WTP surveys, consumers are being asked how much they are willing to pay for a connection and/or for water. Such surveys often make use of the Contingency Valuation Method.

10. Another important determinant of the demand for water deals with income. Ask participants what will happen to the demand for water if income increases. Participants may guess that when income increases, customers are willing to pay more for the same quantity of water. This is called **income elasticity**, which represents the relative change in the quantity of water demanded divided by the relative change in income. Income elasticity for water is rather inelastic and estimated at between 0.4 and 0.5, which means that e.g. an increase in income with 10% will lead to an increase in water demand of 4%.

11. Ask participants what they know about Ability to Pay which is defined as the ratio of the monthly household water consumption expenditure to the monthly household income. World Bank and other organizations apply a standard whereby ability to pay for water should not exceed 5%, which means that households should not be asked to spend more than 5% of their income for water supply.

**C. Data needed and sources of information for water demand forecasting**

12. Ask participants what sources are available to collect the necessary data for forecasting demand:
   
   (i) collection of secondary data from existing studies, water enterprises, government agencies, etc.;
   
   (ii) conducting reconnaissance surveys in the area to observe the actual field situation; and
   
   (iii) collection of primary data through field observations and household surveys.

Household surveys normally provide:

   (i) data about family size, occupation, income etc.;
   
   (ii) data about the quantity, quality and costs related to the current water supply (and sanitation) situation; and
   
   (iii) data about the future use of water supply and sanitation: the preferences of respondents about the future level of service, type of facility and what they are willing to pay for the preferred level of service.
D. The need to manage water demand

13. Is there a need to manage the demand for water? Elicit various reasons from participants why it is useful to consider demand management:
   a. Limited availability of water
   b. The need to share water among various sectors (agriculture, hydropower, tourism, nature, etc)
   c. The future costs of water

14. What can we say about the future costs of water supply? Will it be more expensive or less expensive as compared to our current supply. Elicit by questioning that the future costs of water, in the long run, will tend to be more expensive as compared to the current water source, because water will need to be transported, treated, etc. The following figure demonstrates this effect:

![Future Cost vs Current Cost Diagram]

- Explain the concepts Willingness and Ability to Pay

E. Various instruments to manage the demand for water

15. Draw a demand curve on the whiteboard, and ask participants how they would go about reducing demand: Elicit the following answers:

   a. reduce the quantity demanded by increasing the price of (excessive) water use. This will result in a reduction of demand through a movement along the same demand curve. At a higher price, a smaller quantity of water is demanded. By introducing financial incentives, consumers (domestic and nondomestic) can be expected to reduce their
water consumption. Often, the objectives and reasons for such a policy will have to be thoroughly explained to the users through public education programs. Examples of introducing financial measures include:
   i. increasing the average water tariff;
   ii. introducing progressive water tariff structures, aiming at reduction of excessive water use;
   iii. increasing tariffs for wastewater discharge: (industries will be particularly sensitive to this measure);
   iv. introducing ground water abstraction fees;
   v. fiscal incentives (e.g. for investments in water saving devices or treatment plants);
   vi. utilization of water markets: experience from water markets in the United States and Gujarat, India indicates that water markets create a framework which contributes to the efficient use of water.

b. Move the demand curve to the left, resulting in a reduction in the quantity demanded and moving the demand curve to the left. This means that at the same price level, the quantity of water demanded will be reduced. This can be achieved through:
   i. introduction of water saving devices;
   ii. changing consumer behavior through educational programs;
   iii. legal measures (e.g. regulating the use of groundwater);
   iv. industrial “water-audit” programs. This entails a review of the use of water and waste water in industrial plants, with the purpose of reducing the use of water.
   v. save the use of water or avoid waste of water resources on the supply side.

Such measures could include:
   • increase in efficiency at the utility level (reduction of production losses, UFW); and
   • institutional changes (merger of utilities may create economies of scale).

16. In most cases, water demand management and conservation policies will consist of a comprehensive set of measures to be carried out over a longer period to achieve the desired results. However, in the long run, it may save millions of dollars in deferred investment, like the case study Melbourne (hand out the example).

F. Carry out a simple exercise in forecasting water demand

17. Tell trainees that now they will apply what they have learned in the sessions today. Divide participants in groups of 3-4 persons. Each group has that task to prepare a Demand Forecast for Babonneau (Hill 20 System) for the next 25 years. Each group has about 30 minutes to answer the following questions:

   a. What type of data do you need?
   b. How are you going to obtain the data?
   c. Which measures do you think could be considered to manage demand?
Reconvene the groups and ask each group to give a short presentation the answers to the three questions. Compare the three presentations and conclude the session.
Handout 1: The Determinants of the Demand for Water

A. Domestic Demand

- Number and size of households
- Population growth
- Family income and income distribution
- Costs of water presently used
- Cost of future water used
- Connection charges
- Availability and quality of service
- Cost and availability of water using devices
- Availability of alternative water sources
- Present water consumption
- Legal requirements
- Population density
- Cultural influences

B. Commercial Demand

- Sales or value added of non-subsistence commercial sector
- Costs and volume of water presently used
- Price of future water used
- Connection charges
- Costs of water using appliances
- Quality and reliability of service
- Working hours of various types of commercial establishments
- Legal requirements

C. Industrial Demand

- Present and future costs of water
- Type of industry and water use intensity
- Relative price of alternative sources
- Quality and reliability of supply
- Costs of treatment and disposal of waste water
- Legal requirements

D. Agricultural Demand (for [non] piped water supply)

- Present and future costs of water
- Availability of other sources
- Quality and reliability of supply
- Supply cost of alternative water systems
- Number of cattle
- Legal requirements
E. Public Services Demand

- Present and future costs of water
- Per capita revenue of local governments
- Number and size of public schools, hospitals etc.
- Legal requirements

F. Technical requirements

- Unaccounted for Water (leakage)
- Peak factors
- Seasonal fluctuations
Handout 2:

*Demand Forecasting: Chapter 3 and Annex 1 of the ADB Handbook for the Economic Analysis of Water Supply Projects.*
Handout 3: Case Study Demand Analysis for Castries, Saint Lucia

WASCO needs to upgrade the so-called Northern Line, which supplies the Northern half of Saint Lucia and to determine the necessary future capacity of the main pipes, WASCO wants to carry out a demand forecast for Castries, the capital of Saint Lucia.

In 2018 Castries had an estimated population of 25,000 persons. It is the capital and largest city of Saint Lucia. In 2013, the region with the same name had a population of 70,000 and stretches over an area of 80 km² (31 sq mi). The average size of a household is 4.8 persons. Average population growth in Saint Lucia is estimated at 1.2% per year, but for Castries the population is expected to grow with an average of 3 % per year for the next 10 - 20 years. The average water consumption per day per person in Saint Lucia is estimated at 60 gallons and currently almost all houses in Castries are connected to the water supply system.

Castries is in a flood gut and is built on reclaimed land. It houses the seat of government and the head offices of many foreign and local businesses. The city’s design is in a grid pattern. Its sheltered harbor receives cargo vessels, ferry boats, and cruise ships. It houses duty-free shopping facilities such as Point Seraphine and La Place Carenage. There are many local restaurants. Supermarkets and other shopping facilities provide goods. It is estimated that the commercial sector consumes 23% of total domestic consumption.

Castries has about 20 hotels with a total capacity of 650 beds with an average occupation rate of 65% throughout the year. Based on current experience it is estimated that water consumption in hotels equals some 25% of domestic consumption.

In addition, Castries is visited by an average number of 450 cruise ships per year. The average cruise ship carries some 2,250 persons (including crew) and WASCO provides these ships with water. The volume of water sold to cruise ships equals about 2% of domestic consumption.

Castries is the location of a great number of government offices. Water consumption of the government sector over the past decade amounted to 19% of domestic water consumption.

WASCO has recently submitted a tariff review to the National Utility Regulatory Authority and has proposed a tariff increase of 1.2% in real terms for the next 5 years. This is needed because WASCO currently is not able to recover its operational and capital costs. The NURC is expected to approve the tariff proposals later this year and WASCO plans to introduce it 1 January 2020.

The Bureau of Statistics is rather optimistic about economic growth in Saint Lucia, which is estimated at some 3% for the next 3-5 years. This is partly due to recent direct investments in sectors such as offshore banking, transshipment and tourism, which are expected to continue this level of growth for the foreseeable future. Average Income per capita amounts to USD 14,450 and is expected to grow with an average of 2% per year over the coming 5-10 years.

The current level of Non-Revenue Water for WASCO is estimated at 45% of water distributed and recent investigations carried out by the Water Services Department show that this consists of actual leakage (25%), production losses (8%) and illegal connections (12%).

Recent studies of the World Bank and the IADB for Saint Lucia estimate price elasticity for the demand for water in Saint Lucia at -0.6 and income elasticity for the same at 0.5.

Task:
Estimate the demand for drinking water in Castries for 2019 and for 2024 and demonstrate the methodology you applied to estimate the volume of water demanded.
## Handout 4: Calculations related to the Case Study

### Case Study Calculations

<table>
<thead>
<tr>
<th>Unit</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>2023</th>
<th>2024</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population growth</td>
<td>%</td>
<td>3%</td>
<td>3,0%</td>
<td>3,0%</td>
<td>3,0%</td>
<td>3,0%</td>
<td>3,0%</td>
</tr>
<tr>
<td>Price increase</td>
<td>%</td>
<td>0,00%</td>
<td>1,20%</td>
<td>1,20%</td>
<td>1,20%</td>
<td>1,20%</td>
<td>1,20%</td>
</tr>
<tr>
<td>Price elasticity</td>
<td>nr</td>
<td>-0,60</td>
<td>-0,60</td>
<td>-0,60</td>
<td>-0,60</td>
<td>-0,60</td>
<td>-0,60</td>
</tr>
<tr>
<td>Daily water use 1</td>
<td>gpd</td>
<td>60,000</td>
<td>59,568</td>
<td>59,139</td>
<td>58,713</td>
<td>58,291</td>
<td>57,871</td>
</tr>
<tr>
<td>Increase in Income</td>
<td>%</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>Income elasticity</td>
<td>nr</td>
<td>0,50</td>
<td>0,50</td>
<td>0,50</td>
<td>0,50</td>
<td>0,50</td>
<td>0,50</td>
</tr>
<tr>
<td>Daily water use 2</td>
<td>gpd</td>
<td>60,60</td>
<td>60,77</td>
<td>60,95</td>
<td>61,14</td>
<td>61,33</td>
<td>61,52</td>
</tr>
<tr>
<td>Total Domestic use</td>
<td>gpd/day</td>
<td>1.560.450</td>
<td>1.611.878</td>
<td>1.665.121</td>
<td>1.720.244</td>
<td>1.777.318</td>
<td>1.836.416</td>
</tr>
<tr>
<td>Total Domestic use</td>
<td>gpd/year</td>
<td>569.564.250</td>
<td>588.335.621</td>
<td>607.769.031</td>
<td>627.889.027</td>
<td>648.721.096</td>
<td>670.291.706</td>
</tr>
<tr>
<td>Commercial Use (23%)</td>
<td>gpd/year</td>
<td>130.999.778</td>
<td>135.317.193</td>
<td>139.786.877</td>
<td>144.414.476</td>
<td>149.205.852</td>
<td>154.167.092</td>
</tr>
<tr>
<td>Hotels (25%)</td>
<td>gpd/year</td>
<td>142.391.063</td>
<td>147.083.905</td>
<td>151.942.258</td>
<td>156.972.257</td>
<td>162.180.274</td>
<td>167.572.926</td>
</tr>
<tr>
<td>Government (19%)</td>
<td>gpd/year</td>
<td>108.217.208</td>
<td>111.783.768</td>
<td>115.476.116</td>
<td>119.298.915</td>
<td>123.257.008</td>
<td>127.355.424</td>
</tr>
<tr>
<td>Total Water Use</td>
<td>gpd/year</td>
<td>962.563.583</td>
<td>994.287.200</td>
<td>1.027.129.663</td>
<td>1.061.132.455</td>
<td>1.096.338.653</td>
<td>1.132.792.982</td>
</tr>
<tr>
<td>Leakage (25%)</td>
<td>gpd/year</td>
<td>359.165.516</td>
<td>371.002.687</td>
<td>383.257.337</td>
<td>395.944.946</td>
<td>409.081.587</td>
<td>422.683.949</td>
</tr>
<tr>
<td>Production Losses (8%)</td>
<td>gpd/year</td>
<td>114.932.965</td>
<td>118.720.860</td>
<td>122.642.348</td>
<td>126.702.383</td>
<td>130.906.108</td>
<td>135.258.864</td>
</tr>
<tr>
<td>Total Water Demand</td>
<td>gpd/year</td>
<td>1.436.662.063</td>
<td>1.484.010.747</td>
<td>1.533.029.348</td>
<td>1.583.779.784</td>
<td>1.636.326.347</td>
<td>1.690.735.795</td>
</tr>
</tbody>
</table>

### Formulas

- $d_5 = c_5 \times d_4$
- $d_9 = d_7 \times d_8 \times c_10$
- $d_10 = c_10 + d_9$
- $d_14 = d_12 \times d_13 \times c_15$
- $d_15 = c_15 + d_9 + d_14$
- $d_17 = d_5 \times d_15$
- $d_18 = d_17 \times 365$
- $d_20 = d_18 \times 23\%$
- $d_21 = d_18 \times 25\%$
- $d_22 = d_18 \times 2\%$
- $d_23 = d_18 \times 19\%$
- $d_25 = d_20 + d_21 + d_22 + d_23$
- $d_26 = \frac{d_25 \times 25}{67}$
- $d_27 = \frac{d_25 \times 8}{67}$
- $d_29 = d_25 + d_26 + d_27$

### Leaks (25%)

- $d_25 = d_20 + d_21 + d_22 + d_23$

### Production Losses (8%)

- $d_27 = \frac{d_25 \times 8}{67}$

### Total Water Demand

- $d_29 = d_25 + d_26 + d_27$
Annex 13: Presentation on Hydraulic Analysis of Transport Systems

Institutional and Organisational Strengthening of WASCO Saint Lucia and Regional Water Utilities

Saint Lucia

Hydraulic Analysis of Transport Systems

Ivera de Jong
July 2019

1. Purpose of Hydraulic analysis
2. Centralised Water Supply Systems (CWSS)
3. Head Loss Calculation - Theory
4. Exercise
In fluid dynamics, hydraulic analysis is the analysis of the fluid flow through a network. The aim is to determine the flow rates and pressure drops in the individual sections of the network.

1. Use for design by design department for extension of transport & distribution system (sizing of the pipe diameters)

2. Calculation of fire fighting demand

3. Simulation (and calibration) of the actual operation of the transport and distribution system and based on this restructuring of the network and improvement of the operation, e.g. by creating pressure zones or by installing PRV’s or break pressure tanks (by service department supported by strategic planning department)
1. Purpose of Hydraulic analysis

2. Centralised Water Supply Systems (CWSS)

3. Head Loss Calculation - Theory

4. Exercise

5 Elements of Centralized Water Supply Systems:

- Collection
- Transport
- Treatment
- Storage
- Distribution
**INTRODUCTION**

**Distance** between source and consumption → water transmission

**Many individual consumers** → water distribution

Two general systems
- flow by gravity
- pumped flow

---

**EXAMPLE GRAVITY SYSTEM (FREE-FLOW)**

Can I supply all customers?

How much water can flow through?
1. Purpose of Hydraulic analysis

2. Centralised Water Supply Systems (CWSS)

3. **Head Loss Calculation - Theory**

4. Exercise
Water pumped from **lower to higher** water level.

**Or:** pumped (or gravity) from low reservoir into a network.

All head parts (static head, head losses in pipeline and in a pumping station) have to be determined.
Local losses in PS can be calculated in detail.

**Simplification:** assume an additional loss of 2.0 m

---

**Determination of Head Losses in Pipeline**

**Formula of Darcy** can be used to calculate losses in pipes.

The run of the pipeline and its dimension and length has to be known.
Formula of Darcy

\[ h_f = \frac{\lambda}{D} \cdot \frac{L \cdot v^2}{2g} \]

- \( h_f \) = Hydraulic Losses [m]
- \( \lambda \) = Friction coefficient [-]
- \( L \) = length of pipe [m]
- \( D \) = Diameter [m]
- \( v \) = Flow velocity [m/s]
- \( g \) = Gravity acceleration (9.81 m/s\(^2\))

Formula of Colebrook

\[
\frac{1}{\sqrt{\lambda}} = -2 \cdot \ln \left( \frac{2.51}{Re \cdot \sqrt{\lambda}} + \frac{k}{3.71 \cdot d} \right)
\]

- \( \lambda \) = Head loss coefficient [-]
- \( \ln \) = Natural logarithm
- \( Re \) = Reynolds number [-]
- \( k \) = Roughness of pipe [mm]
- \( d \) = Inner diameter of pipe [mm]
### Pipe roughness $k$ for new pipes

<table>
<thead>
<tr>
<th>Pipe Material</th>
<th>Roughness $k$ (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>0.05</td>
</tr>
<tr>
<td>PVC / PE</td>
<td>0.05</td>
</tr>
<tr>
<td>Ductile cast iron (DCI)</td>
<td>0.25</td>
</tr>
<tr>
<td>Asbestos cement</td>
<td>0.10</td>
</tr>
<tr>
<td>Pre-stressed concrete</td>
<td>0.80</td>
</tr>
<tr>
<td>Cement lining</td>
<td>0.20</td>
</tr>
</tbody>
</table>

### Pipe roughness $k$ for practical calculation including local losses and incrustation

<table>
<thead>
<tr>
<th>Pipe Material</th>
<th>Roughness $k$ (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel or ductile cast iron pipes without lining</td>
<td>1.6 - 2.0</td>
</tr>
<tr>
<td>PVC / PE pipes</td>
<td>0.1</td>
</tr>
<tr>
<td>Asbestos cement pipes</td>
<td>0.4</td>
</tr>
<tr>
<td>Pre-stressed concrete pipes</td>
<td>1.0</td>
</tr>
<tr>
<td>Pipes with cement lining</td>
<td>0.4</td>
</tr>
</tbody>
</table>
1. Purpose of Hydraulic analysis

2. Centralised Water Supply Systems (CWSS)

3. Head Loss Calculation - Theory

4. Break → Exercise
Annex 14: Exercise Head Loss Calculation

Head loss of a pipe

### 1. Input

<table>
<thead>
<tr>
<th>Water Temperature</th>
<th>Roughness</th>
<th>Inner Diameter</th>
<th>Length</th>
<th>Flow</th>
<th>Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>°C</td>
<td>(mm)</td>
<td>(mm)</td>
<td>(km)</td>
<td>(m³/h)</td>
<td>(l/s)</td>
</tr>
<tr>
<td>0</td>
<td>0,01</td>
<td>81,4</td>
<td>1,00</td>
<td>0,0</td>
<td>0,0</td>
</tr>
</tbody>
</table>

### 2. Results (according to head loss formula of Darcy-Colebrook)

<table>
<thead>
<tr>
<th>Kinematic Viscosity</th>
<th>Pipe cross section</th>
<th>Velocity of flow</th>
<th>Reynolds Number</th>
<th>Head loss coefficient</th>
<th>Head loss</th>
<th>Specific head loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>ν</td>
<td>A</td>
<td>v</td>
<td>Re</td>
<td>λ</td>
<td>h&lt;sub&gt;v&lt;/sub&gt;</td>
<td>h&lt;sub&gt;v,s&lt;/sub&gt;</td>
</tr>
<tr>
<td>(10⁻⁶ m²/s)</td>
<td>(m²)</td>
<td>(m/s)</td>
<td>-</td>
<td>-</td>
<td>(m)</td>
<td>(m/km)</td>
</tr>
<tr>
<td>1,793</td>
<td>0,01</td>
<td>0,00</td>
<td>0</td>
<td>0,0129</td>
<td>0,00</td>
<td>0,00</td>
</tr>
</tbody>
</table>

Capacity of a pipe

### 1. Input

<table>
<thead>
<tr>
<th>Water Temperature</th>
<th>Roughness</th>
<th>Inner Diameter</th>
<th>Length</th>
<th>Available head</th>
</tr>
</thead>
<tbody>
<tr>
<td>°C</td>
<td>(mm)</td>
<td>(mm)</td>
<td>(km)</td>
<td>(m)</td>
</tr>
<tr>
<td>10</td>
<td>0,01</td>
<td>81,4</td>
<td>1,00</td>
<td>27,80</td>
</tr>
</tbody>
</table>

### 2. Results (according to head loss formula of Darcy-Colebrook)

<table>
<thead>
<tr>
<th>Kinematic Viscosity</th>
<th>Pipe cross section</th>
<th>Velocity of flow</th>
<th>Flow</th>
<th>Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>ν</td>
<td>A</td>
<td>v</td>
<td>Q</td>
<td>Q</td>
</tr>
<tr>
<td>(10⁻⁶ m²/s)</td>
<td>(m²)</td>
<td>(m/s)</td>
<td>(m³/h)</td>
<td>(l/s)</td>
</tr>
<tr>
<td>1,311</td>
<td>0,01</td>
<td>1,54</td>
<td>29</td>
<td>8</td>
</tr>
</tbody>
</table>
Calculation of a System Curve

1. Input Data

<table>
<thead>
<tr>
<th>Water Temperature</th>
<th>Roughness Coefficient</th>
<th>Inner Diameter</th>
<th>Pipe Length</th>
<th>Static Head</th>
</tr>
</thead>
<tbody>
<tr>
<td>g (°C)</td>
<td>k (mm)</td>
<td>di (mm)</td>
<td>l (km)</td>
<td>h_s (m)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0,01</td>
<td>200</td>
<td>1,00</td>
<td>0,0</td>
</tr>
</tbody>
</table>

2. Calculated Values

<table>
<thead>
<tr>
<th>Kinematic Viscosity</th>
<th>Pipe Cross Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>v (10^-6 m²/s)</td>
<td>A (m²)</td>
</tr>
<tr>
<td>1,311</td>
<td>0,03</td>
</tr>
</tbody>
</table>

3. Calculation Table (according to the headloss formula of Darcy-Weissbach und Prandl-Colebrook)

<table>
<thead>
<tr>
<th>Flow</th>
<th>Flow Rate</th>
<th>Reynolds Number</th>
<th>Headloss Coefficient</th>
<th>Dynamic Headloss</th>
<th>Total Head</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>v</td>
<td>Re</td>
<td>λ</td>
<td>h_D (mWC)</td>
<td>h_T (mWC)</td>
</tr>
<tr>
<td>(m³/h)</td>
<td>(m/s)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>0,18</td>
<td>26.988</td>
<td>0,0242</td>
<td>0,19</td>
<td>0,2</td>
</tr>
<tr>
<td>40</td>
<td>0,35</td>
<td>53.975</td>
<td>0,0207</td>
<td>0,66</td>
<td>0,7</td>
</tr>
<tr>
<td>60</td>
<td>0,53</td>
<td>80.963</td>
<td>0,0190</td>
<td>1,37</td>
<td>1,4</td>
</tr>
<tr>
<td>80</td>
<td>0,71</td>
<td>107.950</td>
<td>0,0180</td>
<td>2,29</td>
<td>2,3</td>
</tr>
<tr>
<td>100</td>
<td>0,88</td>
<td>134.938</td>
<td>0,0172</td>
<td>3,43</td>
<td>3,4</td>
</tr>
<tr>
<td>120</td>
<td>1,06</td>
<td>161.925</td>
<td>0,0167</td>
<td>4,78</td>
<td>4,8</td>
</tr>
<tr>
<td>140</td>
<td>1,24</td>
<td>188.913</td>
<td>0,0162</td>
<td>6,33</td>
<td>6,3</td>
</tr>
</tbody>
</table>
Annex 15: Presentation on SCADA Systems

1. Definition and Purpose of SCADA System

2. Various Measurements for Flow, Pressure & Level

3. Example of SCADA Vieux Fort

4. Appropriate Design Principles
Supervisory Control and Data Acquisition (SCADA) is a control system architecture that uses computers, networked data communications and graphical user interfaces for high-level process supervisory management, but uses other peripheral devices such as programmable logic controller (PLC) and discrete PID controllers to interface with the process plant or machinery.

**WHY SCADA?**
- Better understanding of system behaviour
- Optimisation of tank and pump management
- Reduction of required manpower in field (bulk meter reading, pump operation, ...) ➔ cost saving
1. Definition and Purpose of SCADA System

2. Various Measurements for Flow, Pressure & Level

3. Example of SCADA Vieux Fort

4. Appropriate Design Principles
RESERVOIR & DISTRIBUTION ZONE / DMA

LT: Level Indicator Transmitter  PIT: Pressure Indicator Transmitter  FIT: Flow Indicator Transmitter

PRESSURE REDUCING VALVE (PRV)

ΔP

PIT: Pressure Indicator Transmitter  FIT: Flow Indicator Transmitter
1. Definition and Purpose of SCADA System

2. Various Measurements for Flow, Pressure & Level

3. Example of SCADA Vieux Fort

4. Appropriate Design Principles
SCADA facilities Vieux Fort WSS

Monitor and control the project water supply system, including two WTPs, pumping stations and three storage tanks.

The SCADA system will consist of the following sub-systems:

- A human–machine interface (HMI) presenting process data to the operator to monitor and control the process.
- A supervisory computerized system, gathering (acquiring) data on the process and sending commands (controlling) to the process.
- Programmable logic controllers (PLCs).
- Various process and analytical instrumentation with remote terminal units (RTUs) connected to sensors in the process, converting sensor signals to digital data and sending digital data to the supervisory system.
1. Definition and Purpose of SCADA System

2. Various Measurements for Flow, Pressure & Level

3. Example of SCADA Vieux Fort

4. Appropriate Design Principles
Use an uniform SCADA system for the Utility

Keep the SCADA system as simple as possible, the more I/O signals the higher the cost for programming and hardware

Start the SCADA system with the most needed control functions only

Select a modular design, start with main system components

Using fiber optic cable is the most reliable communication system with GSM as back-up