Real Loss Component Analysis: A Tool for Economic Water Loss Control
Project Team

TECHNICAL TEAM

- Reinhard Sturm, Water Systems Optimization
- Kate Gasner, Water Systems Optimization

OUTREACH TEAM

- Mary Ann Dickinson, Alliance for Water Efficiency
- Jeffrey Hughes, Alliance for Water Efficiency
Downloading the 4372 Materials

www.waterrf.org, then search for 4372 or real losses

Water Audits and Real Loss Component Analysis - 4372

Completion Year
2013

Research Value
$544,023

Research Manager
Maureen Hodgins

Contractor
Water Systems Optimization Inc.

The purpose of this project is to help the North American water industry design efficient and sustainable leakage control programs. The project has been divided into two segments. Real Loss Component Analysis: A Tool for Economic Water Loss Control (Order #4372a) provides water utilities with an analysis tool to better understand the sources of their real losses (reported, un-reported, or background) and a means of analyzing their economic intervention strategies. This project improves the quality of standard leakage component analysis and compliments the AWWA Water Audits and Loss Control Program (M36), 3rd edition. In addition to the research report, the project produced two spreadsheet tools: a Component Analysis Model and the Leak Repair Data Collection Guide, which are available on this project page under Project Resources/Web Tools. 4372a was published in June 2014. Analysis of U.S. Water Audits (Order #4372b) will provide a national snapshot of IWA/AWWA water audit results including key performance indicators and benchmarks and summarize state regulations as of 2013. Data sources include approximately 2,500 water audits submitted to the California Urban Water Conservation Council, Georgia EPA, Texas Water Development Board, Tennessee Comptroller of the Treasury, and the Delaware River Basin Commission from 2011-2013. 4372b will be available in Fall 2015. Research partner: EPA.

Report Name
Real Loss Component Analysis: A Tool for Economic Water Loss Control

Report #
4372a

Available
5/30/2014

Order Report

Download PDF

Executive Summary

Project Resources

- Webcasts (1)
  - What are the Best Economic Options for Managing Leakage?

- Web Tools (2)
  - Leak Repair Data Collection Guide
  - Component Analysis Of Real Losses Software Model
Real Loss Component Analysis: A Tool for Economic Water Loss Control

PROJECT BASICS:
- Funded by the WRF and EPA
- Webinar on June 19 2014

PROJECT GOALS:
- Provide utilities software model for component analysis of real losses
- Provide informative context for performance indicator results
- Develop the software model to optimize use (prioritizing accessibility & adoption)

PARTICIPATING UTILITIES:
- Eastern Municipal Water District
- Metro Water Services, Nashville TN
- Halifax Regional Water Commission
- City of Folsom Utilities Dept
- San Antonio Water System
- Lake Arrowhead Community Services District
- S. Central CT Regional Water Authority
- City of Phoenix Water Services Dept
- Austin Water Utility
- Water & Wastewater Authority of Wilson County
Results of Utility Questionnaire

Water Loss Control Experience

<table>
<thead>
<tr>
<th>Stage of Water Loss Control Experience</th>
<th>% of Participating Utilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introductory</td>
<td></td>
</tr>
<tr>
<td>Beginner</td>
<td>45%</td>
</tr>
<tr>
<td>Intermediate</td>
<td>45%</td>
</tr>
<tr>
<td>Advanced</td>
<td>10%</td>
</tr>
</tbody>
</table>

% of Participating Utilities
Results of Utility Questionnaire

![Bar Chart showing model priorities]

Model Priorities

- Short Term Economic Level of Leakage Analysis
- Performance Indicator Comparison
- Break Frequency Analysis
- Component Analysis of Real Losses

% of Participating Utilities
# The AWWA Water Balance

<table>
<thead>
<tr>
<th>System Input Volume</th>
<th>Billed Authorized Consumption</th>
<th>Billed Metered Authorized Consumption</th>
<th>Billed Unmetered Authorized Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Authorized Consumption</td>
<td>Unbilled Authorized Consumption</td>
<td>Unbilled Metered Authorized Consumption</td>
<td>Unbilled Unmetered Authorized Consumption</td>
</tr>
<tr>
<td>Water Losses</td>
<td>Apparent Losses</td>
<td>Consumption Metering Errors</td>
<td>Unauthorized Consumption</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Systematic Data Handling Errors</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Real Losses</td>
<td>Leakage/Overflow at Reservoirs</td>
<td>Leakage from Trunk Mains</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leakage from Distribution Mains</td>
<td>Leakage from Service Connections</td>
</tr>
</tbody>
</table>
Water Loss Control Program Next Steps

With A Completed AWWA Water Balance:

✓ Volume of Apparent Losses
✓ Volume of Real Losses
✓ Performance Indicators
✓ Data Validity Score

Remaining Assessments:

➡ Understanding of Real Loss Breakdown (where are these losses occurring? what types of leakage?)
➡ Evaluation of Cost-Effective Real Loss Intervention Strategies
Component Analysis of Real Losses

Background leakage
Un-reported and un-detectable using traditional acoustic equipment.

Tool:
- Pressure reduction
- Main and service replacement
- Reduction in the number of joints and fittings

Un-reported leakage
Often does not surface but is detectable using traditional acoustic equipment.

Tool:
- Pressure reduction
- Main and service replacement
- Reduction in the number of joints and fittings
- Proactive leak detection

Reported leakage
Often surfaces and is reported by the public or utility workers.

Tool:
- Pressure reduction
- Main and service replacement
- Optimized repair time

Image of ruptured pipes and water spraying.
Participating Utility Insight

- Integrity and completeness of failure data
- Readiness of average utility
- Presentation of software as a TOOL not a REPORT!
- Estimation/ assumption comfort
Component Analysis of Real Losses

Volume Determination

Model Example Work
## Component Analysis of Real Losses

<table>
<thead>
<tr>
<th>SYSTEM INPUT VOLUME</th>
<th>Authorized Consumption</th>
<th>Billed Authorized Consumption</th>
<th>Billed Metered Authorized Consumption</th>
<th>Billed Unmetered Authorized Consumption</th>
<th>Unbilled Authorized Consumption</th>
<th>Unbilled Metered Authorized Consumption</th>
<th>Unbilled Unmetered Authorized Consumption</th>
<th>Apparent Losses</th>
<th>Consumption Metering Errors</th>
<th>Unauthorized Consumption</th>
<th>Systematic Data Handling Errors</th>
<th>Water Losses</th>
<th>Leaked/Overflow at Reservoirs</th>
<th>Leakage from Trunk Mains</th>
<th>Leakage from Distribution Mains</th>
<th>Leakage from Service Connections</th>
</tr>
</thead>
</table>
Component Analysis of Real Losses

**Background leakage**
- Un-reported and un-detectable using traditional acoustic equipment.
- Tools:
  - Pressure reduction
  - Main and service replacement
  - Reduction in the number of joints and fittings

**Un-reported leakage**
- Often does not surface but is detectable using traditional acoustic equipment.
- Tools:
  - Pressure reduction
  - Main and service replacement
  - Reduction in the number of joints and fittings
  - Proactive leak detection

**Reported leakage**
- Often surfaces and is reported by the public or utility workers.
- Tools:
  - Pressure reduction
  - Main and service replacement
  - Optimized repair time
Reported Leakage: the water utility became aware of the event because it came about as a complaint or report of a problem caused by visible water from the leak

Reported by:
• Customer
• Public Safety personnel – police, streets/highway, fire dept, etc.
• Meter Reader
• Sewer Inspection, or Other
Un-Reported Leakage

Un-reported Leakage: the water utility became aware of the event by its own proactive work to seek out and identify hidden leakage

Reported by:
• Leak Detection Crew
• Leak Detection Service
Determining Leakage Volumes

**Reported Leakage and Un-reported Leakage**
requires the following data:

- # of reported leaks by size
- average Awareness – Location - Repair (ALR) time per leak size group
- average leak flow rate
- average system pressure
Real Losses Calculation for Reported & Un-Reported Leakage

Annual Real Loss Volume from Reported Leaks =

\[ \text{# of leaks by size} \times \text{average run time} \times \text{average flow rate (at average system pressure)} \]

<table>
<thead>
<tr>
<th>Leakage Occurrence</th>
<th>Pipe Diameter</th>
<th># of Events</th>
<th>Flow Rate (gpm)</th>
<th>Average Run Time (hrs)</th>
<th>Annual Leakage (MG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mains Breaks</td>
<td>8”</td>
<td>6</td>
<td>46</td>
<td>8.25</td>
<td>3.3</td>
</tr>
</tbody>
</table>

Failure Repair Records

Estimated based on pipe size using BABE methodology

Awareness Time Estimation + Failure Repair Records for Location & Repair Time
Break Frequency Research

- Focus on Predictive Models
- Terminology
- Data Collection Completeness
MODEL!
Background Losses

Background Losses: weeps & seeps at joints & fittings

• Cannot be detected via traditional acoustic leak detection
• Depends on the condition of the infrastructure
• Very pressure sensitive

• Calculated using:
  • Length of mains, # of Service Connections, Avrg. System Pressure
  • Unavoidable Annual Real Losses (UARL)
  • Infrastructure Condition Factor (ICF)
Calculation of Background Losses

Background Loss Allowances - UARL Formula

<table>
<thead>
<tr>
<th>Infrastructure Component</th>
<th>Background Leakage</th>
<th>Reported Leaks and Breaks</th>
<th>Unreported Leaks and Breaks</th>
<th>UARL Total</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mains, gal/mile of main/day/psi</td>
<td>2.87</td>
<td>1.75</td>
<td>0.77</td>
<td>5.4</td>
<td>Gals/mile of main/day/psi</td>
</tr>
<tr>
<td>Service Connections, main to curb-stop,</td>
<td>0.112</td>
<td>0.007</td>
<td>0.030</td>
<td>0.15</td>
<td>Gals/service connection/day/psi</td>
</tr>
<tr>
<td>gal/service connection/day/psi</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Service Connections, curb-stop to meter,</td>
<td>4.78</td>
<td>0.57</td>
<td>2.12</td>
<td>7.5</td>
<td>Gals/mile of service connection/day/psi</td>
</tr>
<tr>
<td>gal/service connection/day/psi</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: AWWA
MODEL!
Component Analysis of Real Losses

- **Background leakage**
  - Un-reported and un-detectable using traditional acoustic equipment
  - Tools:
    - Pressure reduction
    - Main and service replacement
    - Reduction in the number of joints and fittings

- **Un-reported leakage**
  - Often does not surface but is detectable using traditional acoustic equipment
  - Tools:
    - Pressure reduction
    - Main and service replacement
    - Reduction in the number of joints and fittings
    - Proactive leak detection

- **Reported leakage**
  - Often surfaces and is reported by the public or utility workers
  - Tools:
    - Pressure reduction
    - Main and service replacement
    - Optimized repair time
### Hidden Losses

<table>
<thead>
<tr>
<th>Component of Real Losses</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background Losses</td>
<td>A</td>
</tr>
<tr>
<td>Reported Leakage</td>
<td>B</td>
</tr>
<tr>
<td>Unreported Leakage (filed from leak detection)</td>
<td>C</td>
</tr>
<tr>
<td>Hidden Losses = remaining unreported leakage the continues to run in the system</td>
<td>D</td>
</tr>
</tbody>
</table>

**Total Real Losses** *determined by Water Balance

\[
\text{Hidden Losses} = \text{Water Balance Total} - (A + B + C)
\]
## Real Loss Component Analysis Results

### Water Audit: City of Austin, TX, USA, 2011

**REAL LOSSES COMPONENT ANALYSIS**

### SUMMARY: REAL LOSS COMPONENT ANALYSIS

<table>
<thead>
<tr>
<th>System Component</th>
<th>Background Leakage (MG)</th>
<th>Reported Failures (MG)</th>
<th>Unreported Failures (MG)</th>
<th>Total (MG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reservoirs</td>
<td>22.08</td>
<td>-</td>
<td>-</td>
<td>22.08</td>
</tr>
<tr>
<td>Mains and Appurtenances</td>
<td>372.61</td>
<td>217.12</td>
<td>173.49</td>
<td>763.22</td>
</tr>
<tr>
<td>Service Connections</td>
<td>844.15</td>
<td>39.55</td>
<td>17.46</td>
<td>901.15</td>
</tr>
<tr>
<td>Total Annual Real Loss</td>
<td><strong>1,238.83</strong></td>
<td><strong>256.66</strong></td>
<td><strong>190.95</strong></td>
<td><strong>1,686.44</strong></td>
</tr>
</tbody>
</table>

**Real Losses as Calculated by Water Audit**

**Hidden Losses/Unreported Leakage Currently Running Undetected**
Real Loss Component Analysis Results

- **Reported Leakage**
  - Background Leakage: 28.6%

- **Unreported Leakage**
  - 65.5%

- **Leak Detection Un-Reported Leakage**

- **Ongoing Unreported Leakage**
  - “Hidden”
MODEL!
Real Losses Component Analysis

Real Losses Intervention
Leakage Management Strategies

- Potentially Recoverable Real Losses
- Unavoidable Annual Real Losses
- Economic Level of Real Losses
- Pipeline and Asset Management: Selection, Installation, Maintenance, Renewal, Replacement
- Pressure Management
- Speed and Quality of Repairs
- Active Leakage Control
- Current Annual Real Losses
Economics

- Real losses have real value – they are a hidden cost for the utility
- Leakage control is primarily an operational cost
- The economic optimum is achieved when the combined cost of real losses plus the cost of leakage control is at a minimum
What Volume of Real Losses is Economic??

Cost of Leakage Control and Water Lost

LOSSES (MGD)

COST OF LEAKAGE CONTROL AND WATER LOST

Background Leakage and Reported Breaks

Where the total cost is at a minimum

Economic Leakage Level

Cost of Water Lost

Cost of Leakage Control
Active Leakage Control Tools

- Economic Intervention Frequency for Leak Detection
- Repair Time Improvement
- Pressure Management
Economic Intervention Frequency for Leak Detection
Real Loss Component Analysis Results

- **REPORTED LEAKAGE**
  - Background Leakage, 28.6%

- **UNREPORTED LEAKAGE**
  - 65.5%

- **LEAK DETECTION UN-REPORTED LEAKAGE**
  - ONGOING UNREPORTED LEAKAGE “HIDDEN”
Economic Intervention Frequency for Leak Detection

<table>
<thead>
<tr>
<th>Economic Intervention Frequency</th>
<th>Retail Cost Valuation of Real Losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of System to be Surveyed Annually</td>
<td>18.0 month</td>
</tr>
<tr>
<td>Annual Budget for Intervention</td>
<td>67%</td>
</tr>
<tr>
<td>Economic Unreported Real Losses</td>
<td>$288,127</td>
</tr>
<tr>
<td>Potential Recoverable Leakage</td>
<td>126 MG/Year</td>
</tr>
<tr>
<td></td>
<td>543 MG/Year</td>
</tr>
</tbody>
</table>
MODEL!
Active Leakage Control Tools

- Economic Intervention Frequency for Leak Detection
- Repair Time Improvement
- Pressure Management
Real Loss Component Analysis Results

- REPORTED LEAKAGE
- BACKGROUND LEAKAGE, 28.6%
- BACKGROUND LEAKAGE
- UNREPORTED LEAKAGE, 65.5%
- LEAK DETECTION UN-REPORTED LEAKAGE
- ONGOING UNREPORTED LEAKAGE "HIDDEN"
Time Impacts Leakage

14 gpm

REPORTED MAINS BREAK
22,000 Gallons

4.5 gpm

REPORTED UTILITY SIDE SERVICE BREAK
104,000 Gallons

4.5 gpm

REPORTED CUSTOMER SIDE SERVICE BREAK
299,000 Gallons
Improving Repair Time

Assess Repair Times

• Do you accurately capture:
  • Reporting Time?
  • Completion of Repair Time?

Improve Repair Times

• Target repair time programs
• Increased repair crews
• Change system operations for tracking by zone
  • DMA Work
  • Frequent Water Balancing

TIME

Leak Starts  Report Initiated  Flow Contained  Repair “Complete”
MODEL!
Active Leakage Control Tools

- Economic Intervention Frequency for Leak Detection
- Repair Time Improvement
- Pressure Management
Pressure and Leakage Relationship

![Graph showing the relationship between ratio of pressures and ratio of leakage rates with different values of N1.](image)

- Ratio of Pressures $P_1/P_0$
- Ratio of Leakage Rates $L_1/L_0$

Key:
- $N_1 = 0.50$
- $N_1 = 1.00$
- $N_1 = 1.15$
- $N_1 = 1.50$
- $N_1 = 2.50$
Real Loss Component Analysis Results

- REPORTED LEAKAGE
- BACKGROUND LEAKAGE (28.6%)
- UNREPORTED LEAKAGE
- LEAK DETECTION UN-REPORTED LEAKAGE
- ONGOING UNREPORTED LEAKAGE "HIDDEN"

Background Leakage, 28.6%

65.5%
Benefits of Pressure Management

- Reduction of Real Losses when switching from no control to fixed outlet and/or advanced pressure control

- Reduction of new leaks/breaks = extended infrastructure life!

- Can serve a water conservation tool – if appropriate

- Can improve energy efficiency

- Ensured minimum standards are met
Pressure Management Tools

- Introduction of pressure controlled areas (pressure zones)
- Fixed outlet pressure control
- Advanced flow-modulated pressure control
- Transient control
Fixed Outlet Pressure

EID Flow Modulation Profile - Initial and New

<table>
<thead>
<tr>
<th>Inflow</th>
<th>Outlet Pressure Initial</th>
<th>Outlet Pressure New</th>
</tr>
</thead>
<tbody>
<tr>
<td>gpm</td>
<td>psi</td>
<td>psi</td>
</tr>
<tr>
<td>250.00</td>
<td>70.00</td>
<td>79.00</td>
</tr>
<tr>
<td>140.00</td>
<td>60.00</td>
<td>50.00</td>
</tr>
</tbody>
</table>
Fixed & Modulated Pressure Control

Dartmouth Central DMA Flow and AZP Pressure @ no control - fixed outlet control - flow modulated control

Fixed & Modulated Pressure Control
Lowered Break Frequency & Extended Infrastructure
DMA5 – Background Leakage Reduction

DMA5 - Reduction in Background Leakage between April 2005 and December 2009

- Background Leakage Component from April 5th 2005 MNF Analysis [gpm]
- Background Leakage Component from December 15th 2009 MNF Analysis [gpm]
- Average DMA5 pressure from April 5th 2005 MNF Analysis [PSI]
- Average DMA5 pressure from December 15th 2009 MNF Analysis [PSI]
Pressure Surges

Zone 4 High Frequency Logging Results at Galston Ct - April 19-20, 2011

- Min
- Avg
- Max

-Time

-Pressure (PSI)
MODEL!