Quantifying Leaks with Acoustic Loggers

2008-2010

Prepared for:

New Mexico Office of the State Engineer Water Use and
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EXECUTIVE SUMMARY

Every day in the United States over six billion gallons of water withdrawn from rivers, lakes and wells slated for public use never reach a billed customer. Much of this water is lost due to leakage from over 250,000 water main ruptures that occur in distribution systems in the United States every year (AWWA, 2009). As operational costs and the price of developing new water supplies increase, alternative options to supply communities with water have become critically important. Distribution system leakage not only results in the loss of water, but also in lost revenue. A leak detection program is a logical first step in minimizing the loss of this water and revenue.

In order to investigate emerging technologies in leak detection, the New Mexico Office of the State Engineer (NMOSE) applied for and received a grant from the 2008 Governor's Water Innovation Fund. The grant, *Quantifying Leaks with Acoustic Loggers*, involved a partnership with three New Mexico cities: Ruidoso, Las Vegas, and Rio Rancho. Each city was provided with passive leak detection equipment[1] and training on how to implement a passive leak detection program. In exchange, each city agreed to provide the necessary data to complete an American Water Works Association (AWWA) standard water loss audit. The AWWA audit methodology is quickly becoming the accepted standard for accounting for water. Several government agencies are considering or have already implemented the AWWA audit as their best management practice; these include California, Pennsylvania's Department of Environmental Protection, Delaware River Basin Commission, New Mexico and Alberta, Canada.

Quantifying Leaks with Acoustic Loggers ran from March 2009 through May 2010. The equipment for the program consisted of 300 self-contained acoustic loggers (100 for each city), three personal digital assistants (PDA's), three receivers and three ground microphones. The installation and training for all three cities occurred between August 2009 and January 2010. Follow up visits were conducted as needed through the winter and spring of 2010.

The *Quantifying Leaks with Acoustic Loggers* grant project provided insights to the utilities involved and the NMOSE. All parties came away with a better understanding of the capabilities and limitations of a leak detection system. Although the implementation in each city was similar, the results varied widely. The main difference was how the individual cities responded to leaks and potential leaks. The response plans varied from leaks that were repaired within 24 hours to not recognizing the potential leak. The volume of water lost to these leaks is hard to quantify because it is unclear how long they had been in place and how long they would have gone undetected without use of the loggers. The NMOSE will attempt to quantify the volume of water lost through the conducting of a water audit one year after implementation of the acoustic logger project. In addition, each city is keeping a record of the leaks discovered with the loggers and an estimate of the volume of water lost.

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[1] For the purpose of this project, passive leak detection is defined as automated devices that are placed on pipe contact points and programmed to listen for leaks.

The passive acoustic logger program does have its limitations. A common issue was the lack of sufficient valves or points to place loggers. The loggers are limited in acoustic range by the piping material; metal pipes have a greater range while the plastic pipes have a shorter range. Long distances between listening points, particularly on plastic pipe result in these areas being difficult to assess with a passive leak detection program. However, the acoustic loggers are only one of the tools in the leak detection tool box. When used in conjunction with the ground microphone, correlation devices, night flow analysis, and pressure testing, the likelihood of finding leaks is increased. In addition, the utility must receive the appropriate training and technical assistance on the use of all the equipment and the analysis of the data produced.

The cost effectiveness of implementing a leak detection program should be assessed by each utility. This assessment will aid in determining the type and amount of equipment needed as well as how much time and manpower should be dedicated to a program. A helpful tool to assess a utility's water system is the American Water Works Association (AWWA) standard water loss audit. This method for estimating non-revenue water and real water loss (water specifically lost to leaks) provides the volume of water lost along with an estimated annual cost of this water loss. The second step is to evaluate the capital cost and debt that would be incurred for additional treatment plants and storage facilities needed to accommodate the additional supply. A final consideration must include from where additional water could be obtained if it was not recovered from leaks. In New Mexico, this means acquiring water rights. Cities searching for additional water resources are realizing that conservation of the water they currently have rights to is less expensive than purchasing additional water rights.

This New Mexico leak detection program is still in its infancy; it has been only eight months from the installation of the first loggers until the writing of this report. The last installation began only five months prior to reporting. In this short timeframe, NMOSE and the partnering cities have seen tremendous growth in the experience and knowledge regarding the equipment. Each lift and shift, patrol and data download is providing new information. As this program matures, both NMOSE and the cities anticipate better results.

NMOSE will continue to work with the partner cities to determine the best technologies and methodologies for leak detection in New Mexico. In addition NMOSE is expanding the program to include a partnership with the New Mexico Rural Water Association (NMRWA). NMOSE will supply equipment and training to NMRWA to set up an ongoing leak detection program for small and medium rural New Mexico water systems.

1. INTRODUCTION

Every day in the United States over six billion gallons of water withdrawn from rivers, lakes and wells slated for public use never reach a billed customer. Much of this water is lost due to leakage from over 250,000 water main ruptures that occur in distribution systems in the United States every year (AWWA, 2009). Because of increasing demands on already limited water resources utilities managing water distribution systems are beginning to shift their thinking from only repairing major leaks and ruptures when they occur to proactively looking for unseen/unnoticed leaks and repairing them before they evolve into a large break.

As operational costs and the price of developing new water supplies increase, alternative options to supply communities with water have become critically important. Cities searching for additional water resources are realizing that conservation of the water they currently have rights to is less expensive than purchasing additional water rights. Distribution system leakage not only results in the loss of water, but also in lost revenue. The lost revenue is associated with the operational costs of pumping and treating water that is never delivered for beneficial use. Therefore, a leak detection program is a reasonable first step in minimizing the loss of this water. The cost effectiveness of implementing a leak detection program should be assessed by each utility.

The New Mexico Office of the State Engineer (NMOSE) received a grant from the 2008 Governor's Water Innovation Fund. The grant involves a partnership with three New Mexico cities that had identified problems with real water losses or had large volumes of non-revenue water. Through the grant, each city was provided with passive leak detection equipment[2] and training on how to implement a passive leak detection program. In exchange, each city agreed to provide the data necessary to complete an American Water Works Association (AWWA) standard water loss audit and sign an MOU stating that they would continue the program for three years. The leak detection programs were deployed in the fall and winter of 2009-2010.

1.1 Supply Issues in New Mexico

Concerns about water availability are becoming increasingly more important as the population in the Southwest continues to grow. The southwestern portion of the United States continues to experience the highest growth rate in the country. New Mexico and its neighboring states rank in the top ten for growth (NMOSE, 2008). The United States Census Bureau's population growth projections for New Mexico add an additional 800,000 people to the state by 2030 (U.S. Census, 2000). This is an increase of 40 percent over the State's population in 2000. Seventy percent of the increasing population is expected in the Rio Grande Basin. This growth is estimated to increase the water supply demand in the Rio Grande Basin by approximately 10 percent of the historical average flow of the river. However, in conjunction with the increasing demand, water supplies are not increasing. In fact, between interstate compacts, groundwater level declines, and over-allocations of existing water rights, the Rio Grande Basin is already under stress.

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[2] For the purpose of this project, passive leak detection is defined as automated devices that are placed on pipe contact points and programmed to listen for leaks.

New Mexico drinking water suppliers are faced with finding that next unit of water to supply their growing communities. Their options include purchasing additional water rights, most likely from agricultural uses, investing in new technologies, such as desalination or deep wells, and/or conserving the water they have. In 1986, the New Mexico implemented statute that required that all permitted uses of water cannot be contrary to conservation. Following in 1997, the State Engineer mandated that drinking water supply permits should include the following: Permittee "shall utilize highest and best technology available to ensure conservation of water to the maximum extent (practical/economically feasible)". The reduction of water use when implementing a relevant water conservation plan is evidenced by the City of Albuquerque's per capita reduction over the last 15 years. Since 1994, the city has dropped system-wide daily per capita consumption from 250 gallons (1994) to 205 gallons (2001). Their single-family residential consumption reduced from 183 to 135 gallons per capita per day. Albuquerque's water conservation plan was implemented in 1997 (Western Resource Advocates, 2003).

A relevant water conservation plan must include programs for the demand side and the supply side. Demand side programs affect the customers' use. They include education programs, retrofits, ordinances, and audits. Supply side programs impact how the utility delivers water. They include leak detection, metering, and efficiency improvements such as reducing water treatment waste. Albuquerque's water conservation plan includes both supply-side and demand-side programs.

1.2 Overview of Grant

The New Mexico Office of the State Engineer applied for and received a 2008 Governor's Innovation Fund grant to implement a program titled *Quantifying Leaks with Acoustic Loggers*. The grant utilized a combination of new technology and a 2003 methodology to identify and track non-revenue water discovered through a leak detection program. The program utilized a two-phased method consisting of an AWWA top-down water audit and an on-the-ground leak detection program. The AWWA top-down audit, also known as a paper audit, tracks water through the production and billing data to estimate how much water is lost through leakage in the distribution system. To find leaks in a distribution system, a passive acoustic leak detection program was deployed. This approach provides daily feedback on noise levels surrounding a chosen water pipe, but does not require daily vigilance from utility staff.

Passive leak detection technology is relatively new in the United States. The technology was tested on a large-scale in El Paso, Texas and in Las Vegas, Nevada starting in 2004. The first round of the Governor's Innovation Fund financed the City of Albuquerque's water utility's (now called Albuquerque Bernalillo County Water Utility Authority's (ABCWUA)), research comparing passive acoustic loggers to active leak detection methods. ABCWUA's research determined that passive, acoustic loggers found leaks earlier than traditional, active methods and recommended coupling the process with the AWWA audit for tracking purposes (NMEFC, 2007).

NMOSE partnered with three New Mexico cities, Ruidoso, Las Vegas and Rio Rancho (Figure 1) that have identified problems with real losses or large volumes of non-revenue water. Each city had previously completed an AWWA audit and had data available for review and assessment. In 2005, Ruidoso had an estimated 28.5 percent real water loss equal to 177 million gallons (MG) per year or approximately 66.8 gallons per connection per day (DBS&A, 2007). In 2006, Las Vegas had an estimated 20.4 percent real water losses which equaled 131 MG per year or approximately 55.6 gallons per connection per day (Hydrosphere, 2007). In 2006, Rio Rancho has an estimated 10.5 percent real water losses which equates to 417 MG per year or 40.9 gallons per connection per day (WPRC, 2007).

As part of the grant, each city received passive leak detection equipment in which they could initiate a more proactive approach to finding leaks within their distribution system. The equipment included: 100 loggers that will cover five to 20 miles of pipeline (depending on pipe material), a personal data assistant (PDA), a receiver that communicates between the loggers and the PDA, and an acoustic ground microphone. Another element of the program required that each city provide the data to complete a pre-water audit.

In order to receive the highest benefit possible from the program, the NMOSE trained the utility personnel on the use, maintenance and 'lift and shift' capabilities of the loggers and on how to interpret the data received. After the pilot period, NMOSE will leave the complete leak detection system with each utility to manage. In return for the equipment and training, each city will keep leak records for the duration of the pilot period and fix leaks where appropriate. It is recommended that future documentation on the program by the cities should include: tracking leaks found with new equipment, the number of leaks fixed, estimated volume of water saved, and the number of personnel hours required to maintain and operate the program. They also provided assurance regarding monitoring and long term maintenance of the leak detection equipment.

1.3 Accountability

Unaccounted-for water has long been used by utilities as a performance measure for their drinking-water supply systems. The nominal definition of unaccounted-for water was produced water minus billed water. However, research found that the practices of calculating 'unaccounted-for' water varied so widely in utilities around the world that the term had no consistent meaning (Beecher, 2002). The advancements in the field of water accountability come from the International Water Association (IWA), and the AWWA.

The AWWA Water Loss Control Committee developed, in conjunction with the IWA, a best management approach to water audits. The water audit accounts for all water used leaving no water 'unaccounted-for'. The categories in the audit include revenue water (billed) and non-revenue water. Non-revenue water includes real losses (leaks and overflows), apparent losses (metering inaccuracies, data handling errors, and theft), and unbilled authorized consumption (fire fighting, line flushing etc.). Billed authorized consumption is the only revenue water. AWWA provides free software to assist drinking water suppliers with their audit. The software also provides a cost estimate, by category, for non-revenue water.

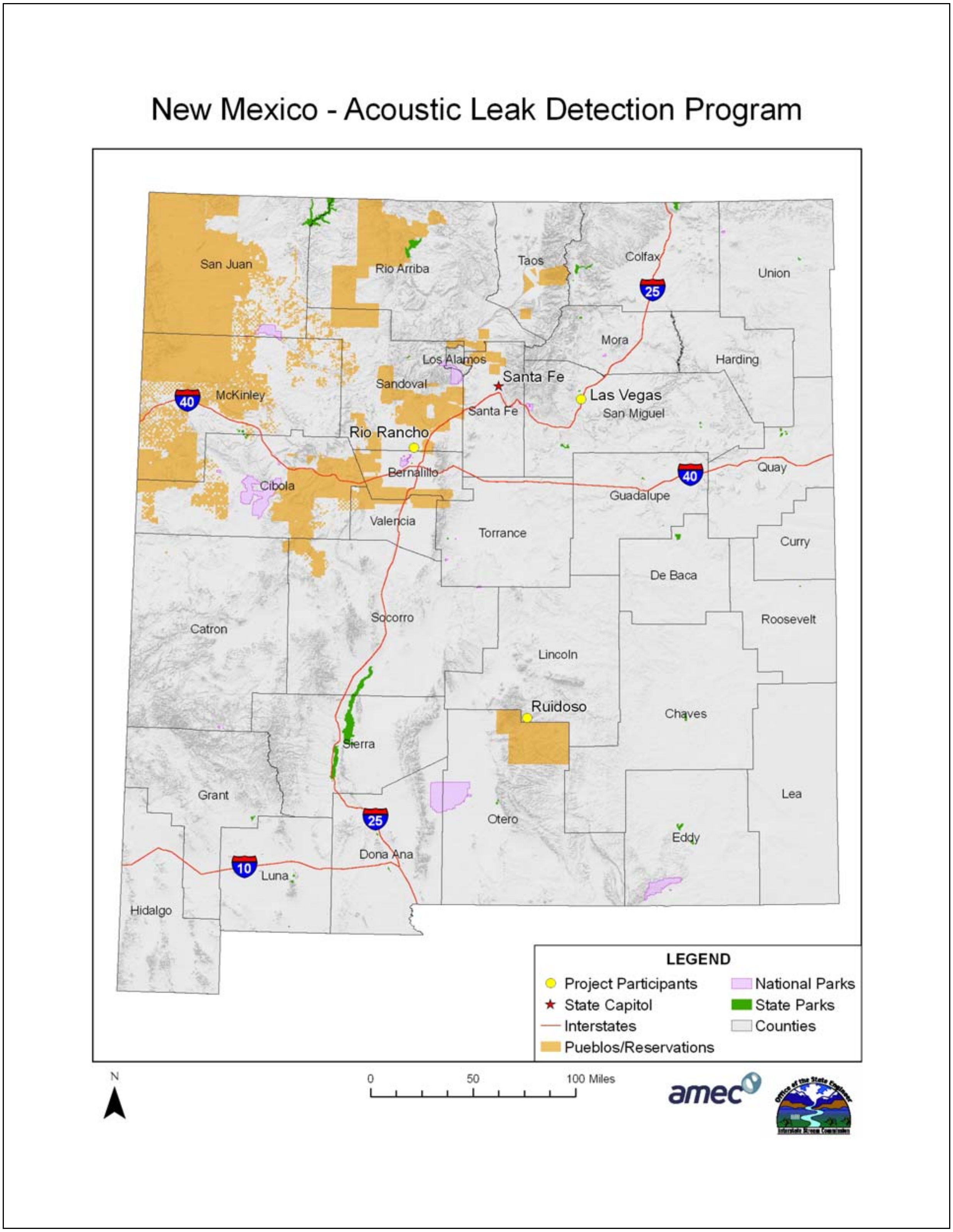


Figure 1: State map depicting the locations of the cities involved in the project.

The AWWA audit methodology is quickly becoming the accepted standard for accounting for water. Several government agencies are considering or have already implemented the AWWA audit as their best management practice; these include California, Pennsylvania's Department of Environmental Protection, Delaware River Basin Commission, New Mexico and Alberta, Canada.

1.4 Leak Detection Technologies

Water conservation specialists have teamed with utility engineers to advance the field of leak detection and water system accountability. The objectives of proactive leak detections programs are to locate hidden leaks that have not surfaced or may never have a surface expression and to find small leaks so they can be repaired before they evolve into large emergency breaks.

The science of leak detection has evolved into two general methods: active and passive. Active acoustic leak detection requires a person/s using sonic ground listening devices, correlators, and probes to carry out the listening phase of the program. This is performed by walking along main lines and listening at valves, fire hydrants and key junctures. This method can be time- and labor-intensive, and requires highly trained staff, or contractors.

Passive leak detection programs utilize permanent and semi-permanent acoustic leak detection devices or 'loggers' to do the listening. The loggers are small-scale, self contained devices that magnetically attach to distribution valves, fire hydrants, and key junctures. At night or during low ambient noise (often low use) periods they activate and listen for unusual vibrations that could represent a leak in the pipe. They transmit the data via radio telemetry to a receiver, located in a maintenance or meter reader truck, which can access the data via a drive-by mode when the logger and receiver are in close proximity. If a logger detects an abnormal noise vibration during the listening period, the logger will send an alert to the receiver. These alerts are then investigated by utilities to substantiate or dismiss a possible leak.

Generally, cities recognize cost savings with leak detection programs in the form of lower operational and treatment costs. Since the implementation of a leak detection program in Hilo, Hawaii, the Hawaii County Department of Water Supply is saving more than $30,000 per month on electricity after 251 leaks were located and repaired (Armstrong, 2006). The El Paso Water Utility estimates that they are saving 5.8 million gallons of water per day since deployment of a leak detection system in 2004 (Valdez, 2006). The Las Vegas Valley Water Department's (Nevada) leak detection program located 540 leaks from service lines between January 2004 and December 2005 with an estimated water loss of 286.4 acre-ft valued at $1,291,500.00 (Jones, 2006). All three systems are utilizing the same passive leak detection technology as the NMOSE program. Saving water by identifying and repairing leaks allows utilities to lower their operating costs for treating, pumping and storing water, and reduces wear on equipment, thus postponing the need for costly infrastructure replacement (DOH, 2008). There could be cost savings to the city in the form of reduced insurance costs, reduced property damage and legal liability because leaks are found before they become catastrophic (Lahlou, 2002). The most significant savings will often be in delaying capital improvements needed to meet customer demand such as finding new water sources, connecting existing permitted supplies, or drilling new wells and building new storage facilities (Lahlou, 2002).

Deploying a leak detection program includes many other benefits. It results in an increased knowledge of the distribution system and assessment of its condition, which can be used to set priorities for pipe line replacement or rehabilitation programs and make response to emergencies more effective. Systems with leaks are more likely to fail bacteria or water quality tests because a leaky pipe creates another connection that could allow contaminants into the water system (DOH, 2008). Relations between the public and utilities are improved as the system becomes more efficient and reliable. Also, if the public sees the utility personnel engaged in an active leak detection program, this might encourage people to conserve water and cooperate in conservation efforts (Lahlou, Z.M, 2002).

1.5 Partners

In addition to the partnerships with the three cities, NMOSE hired AMEC as the primary contractor through a competitive bid process. Miya Water was subcontracted through AMEC as a specialist in the acoustic logging process. A competitive bid was also held for the purchase of all equipment. Fluid Conservation Services (FCS) had the lowest bid and was awarded the contract to provide 300 acoustic loggers, three personal digital assistants, three receivers and three ground microphones to divide between the three cities.

2.0 AWWA WATER AUDITS

An AWWA water audit was conducted for all three cities. In Ruidoso and Las Vegas, the audits were conducted by NMOSE with data supplied by the utilities for July 2008 through June 2009. Rio Rancho supplied a completed audit for calendar year 2008. The categories used in the audit are shown in Table 1:

The AWWA water audit method standardizes equations and definitions used. The following equations and definitions are used in all AWWA audits (AWWA WASv4.0, 2010):

Water Supplied - volume of water generated to be delivered to the distribution system. This includes any water imported from other sources and excludes any water exported to other systems.

Equation 1

Water supplied= volume of water from own sources – meter error + imported water – exported water

Authorized Consumption - volume of metered or unmetered water used by registered customers for residential, commercial, institutional or industrial use. Does not include exported water.

Equation 2

Authorized consumption= billed metered + billed unmetered + unbilled metered + unbilled unmetered

Table 1: AWWA standard categories used in the audit process (modified from AWWA website).

WATER SUPPLIED	Authorized Consumption	Billed-Authorized	Billed, Metered Consumption	Revenue Water
			Billed, Unmetered Consumption	
		Unbilled-Authorized	Unbilled, Metered Consumption	Non-Revenue Water
			Unbilled, Unmetered Consumption	
	Water Losses	Apparent Losses	Unauthorized Consumption	
			Customer Metering Inaccuracies	
			Systematic Data Handling Errors	
		Real Losses	Leakage on Transmission and Distribution Lines	
			Leakage and Overflows at Storage Tank Sites	
			Leakage on Transmission and Distribution Mains	

Total Losses – water supplied minus authorized consumption, includes both apparent and real losses.
Equation 3
Total Losses = Water Supplied – Authorized Consumption

Apparent Losses - includes all types of inaccuracies associated with customer metering as well as data handling errors (meter reading and billing), plus unauthorized consumption (theft or illegal uses).
Equation 4
Apparent Losses= unauthorized consumption + customer meter inaccuracies + data handling errors

Real Losses – are the physical water losses from the pressurized system and the utility's service tanks, up to the point of customer consumption. However, it is calculated within the AWWA spreadsheet as everything left over, or water supplied – authorized consumption – apparent losses. This means that if any of the other categories have been estimated or miscalculated it will reflect in the real water losses.
Equation 5
Real Losses= water losses – apparent losses

Non-revenue water is defined as water that does not provide any revenue to the city.
Equation 6
Non-Revenue water= apparent losses + real losses + unbilled metered + unbilled unmetered

In addition to the standardized definitions and equations, the AWWA method standardizes the output in performance indicators. There are both financial and operational performance indicators. The financial indicators include non-revenue water as percentage of volume of water supplied and percentage of cost of the operating system. The annual costs of real losses and apparent losses are also calculated. The real losses are calculated using variable costs while the apparent costs are calculated using the customer retail costs.

The main operational indicators are the apparent losses and the real losses as volume per connection per day. Because they are calculated by connection, they provide the most equitable means of comparing utilities. Although it is recommended that they only be used to track changes within the utility over time. The other main operational performance indicator is the infrastructure leakage index (ILI). The ILI is the ratio of unavoidable annual real losses (UARL) to current annual real losses. The AWWA spreadsheet defines the UARL as the theoretical reference value representing the technical low limit of leakage that could be achieved if all of today's best technology could be successfully applied. These numbers are calculated using the length of mains, the operating pressure, and number of connections. The software does not calculate either value if the pressure is below 25 psi or the number of connections is below 3,000. The ILI is a ratio defining where the system currently stands compared to where it could be in terms of real losses. However, the capability and the costs associated with finding the next unit of real losses are subjective. It will depend largely on whether there are options for the next unit of water. In areas without additional supplies, actively targeting real losses becomes more viable, regardless of the calculated ILI.

Due to the short time frame of the grant (March 2009 through June 2010), NMOSE decided to start the AWWA water audits in each city at the same time as the leak detection programs. At the beginning of the project, data on real losses was used from previously conducted audits. Ruidoso's existing data was from 2005, while both Las Vegas and Rio Rancho's data was from 2006. When comparing the previous audits to the new audits, NMOSE prefers to look at gallons per connection per day rather than percentages. Percentages are subjective and vary depending on the water demand for a specific year. The updated audits, when completed, showed that Ruidoso's real losses have gone down from 66.70 gallons per connection per day in 2005 to 37.81 gallons per connection per day in FY 2009. This decrease was due to a shift on paper of non-revenue water from real losses into apparent losses. Although this data has not been validated due to master meter errors, Ruidoso's expectations of lost water found with the loggers would have been lower if they used 2009 data. Las Vegas saw an increase in real losses (from 55 to 87 gallons per connection per day) while Rio Rancho's numbers have stayed fairly steady (41 to 45 gallons per connection per day). All three current audits can be found in the appendices. It is important that management understand their real loss numbers prior to investing time and money in leak detection equipment. They should also evaluate the cost of their real losses and the cost of obtaining the next unit of water.

2.1 Village of Ruidoso

Ruidoso is a fast growing mountain resort community located at an elevation of 6,920 feet in the Sierra Blanca mountain range in south central New Mexico, Lincoln County (Figure 2). The city has a resort-style population with many second homes and vacation rentals. They have a single family residential home vacancy rate over 50 percent. Their year round population is approximately 8,000 persons. Area attractions include Ruidoso Downs horse racing track, Inn of the Mountain Gods casino, Ski Apache ski resort, music festivals, and outdoor activities.

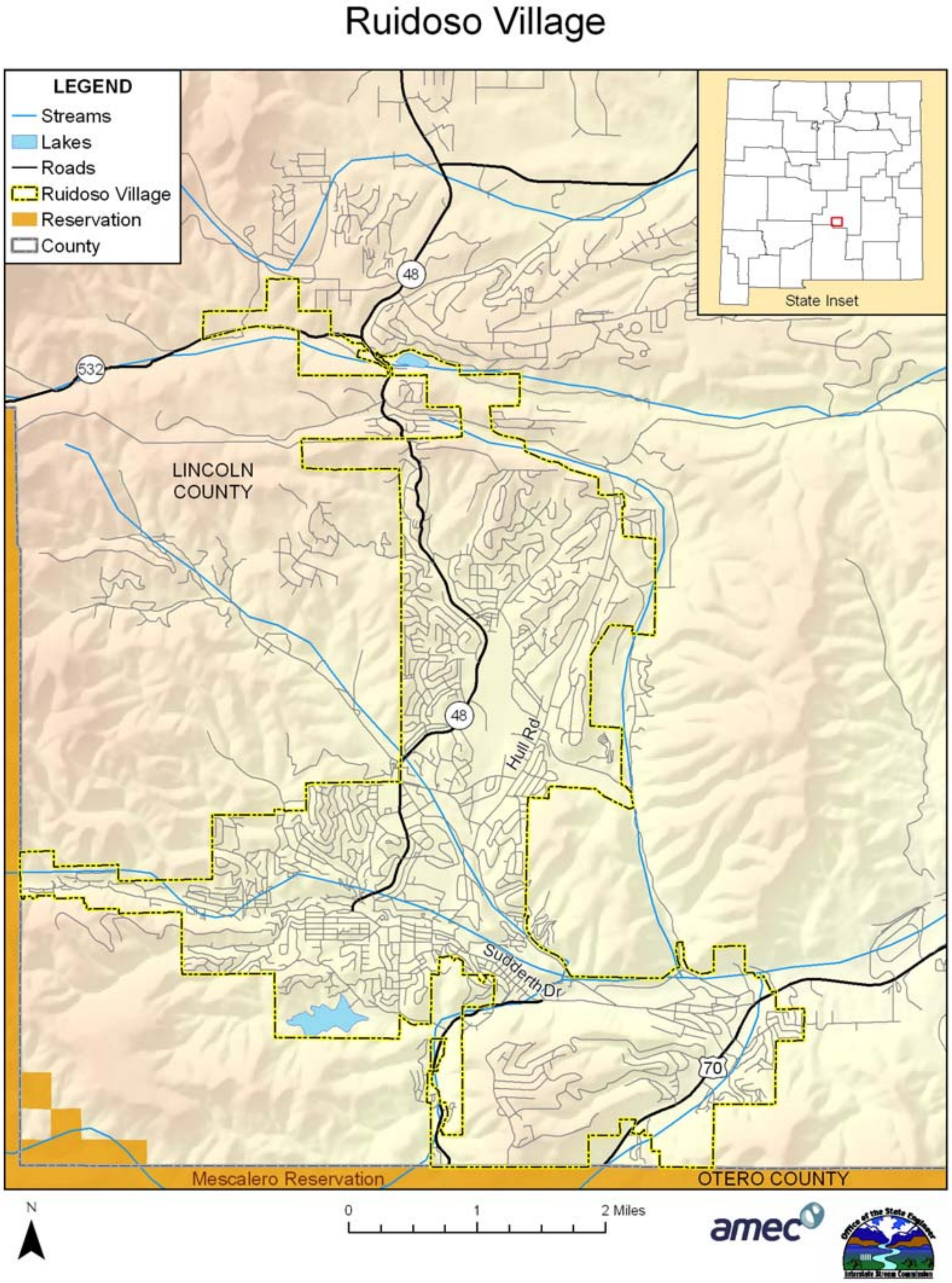


Figure 2: Map of Ruidoso, New Mexico

Highest water usage occurs on the peak summer weekends, which reflect water consumption that approximates 30,000 to 35,000 people. On a yearly basis, water consumption averages about 2.2 million gallons per day, with peak usage at about 6.3 million gallons per day on summer weekends (Brand and Wilt, 2003). Additional demand spikes come in the winter holidays when the area's ski resort has snow.

2.1.1 Ruidoso Water System

Primary water supplies for Ruidoso consist of two surface watershed basins: the Southern Grindstone-Rio Ruidoso basin and the Northern basin known as the North Fork-Eagle Creek basin. The southern Grindstone-Rio Ruidoso supply system consists of surface water diversions from the Rio Ruidoso that are transferred by a pipeline into a storage reservoir known as Grindstone Reservoir (Brand and Wilt, 2003). Two supplemental wells, Cherokee and Hollywood, provide both supply augmentation and drought-relief water supply to this system. The northern North Fork-Eagle Creek basin, consists of a combination of surface water diversions from Eagle Creek, augmented by eight groundwater wells, all carry water via a pipeline into a storage reservoir (Alto Lake) or directly into the Alto Crest Water Treatment Plant (Brand and Wilt, 2003). The two water supply systems operate independently and have no inter-connections prior to treatment and distribution (Brand and Wilt, 2003). In years of high precipitation 70 percent of the village's supply is from surface water; in dry years the supply is primarily from groundwater (DBS&A, 2007).

2.1.2 Ruidoso AWWA Audit

NMOSE completed an AWWA audit for FY09 (7/2008 – 6/2009) with data supplied by the utility. The entire AWWA audit and reporting worksheet can be found in Appendix A. The water balance worksheet is shown in Table 2.

For the purpose of this leak detection project, the NMOSE and the utility focused on the system's losses. Total water losses were calculated by using equation 3 and totaled 141,060,000 gallons. This amount represents apparent losses totaling 39,143,000 gallons (equation 4) and real losses totaling 101,917,000 gallons (equation 5). The real losses comprise 17.4 percent of all water supplied or 37.81 gallons per connection per day. These real losses are suspect due to the validity question of the master meter error adjustment. Without the error adjustment, real losses would be closer to 57 gallons per connection per day. Ruidoso has purchased a second meter to install for calibration purposes. This meter is scheduled for installation in the summer of 2010. Ruidoso documented main break losses of 1,119,963 during this same time frame. These losses were estimated by field staff that responded to breaks and repaired them. This includes a line break as the result of the July 27-28, 2008 flood. The estimates of leak volumes recorded by the crews sent to repair the leaks are outlined in Table 12 in Appendix A.

Table 2: Ruidoso's water balance worksheet.

WATER SUPPLIED (585.881 MG)	Authorized Consumption (444.821 MG)	Billed-Authorized (411.608 MG)	Billed, Metered Consumption (411.608 MG)	Revenue Water (411.608 MG)
			Billed, Unmetered Consumption 0	
		Unbilled-Authorized (33.213 MG)	Unbilled, Metered Consumption (16.813 MG)	Non-Revenue Water (174.273 MG)
			Unbilled, Unmetered Consumption (16.400 MG)	
	Water Losses (141.060 MG)	Apparent Losses (39.143 MG)	Unauthorized Consumption (1.465 MG)	
			Customer Metering Inaccuracies (22.548 MG)	
			Systematic Data Handling Errors (15.130 MG)	
		Real Losses (101.917)	Leakage on Transmission and Distribution Lines	
			Leakage and Overflows at Storage Tank Sites	
			Leakage on Transmission and Distribution Mains	

2.2 City of Las Vegas

Las Vegas was founded in 1835 by settlers, whose family roots go back to the early 1600's when the Spanish arrived. Las Vegas was an important stop on the Santa Fe Trail and became a booming railroad community in the late 1880's. Located 65 miles east from Santa Fe off I-25, Las Vegas is a high plains desert community located at an elevation of 6,430 feet on the Great Plains where the prairie meets the Rocky Mountains in San Miguel County (Figure 3). The population of Las Vegas was 13,818 in July 2008, a 5.1 percent decrease since the 2000 census showed a population of 14,565 *(http://www.city-data.com/city/Las-Vegas-New-Mexico).* Enrollments at Highlands University, Luna College and the Armand Hammer United World College of the American West cause the city's populations to fluctuate through the year (Hydrosphere, 2007).

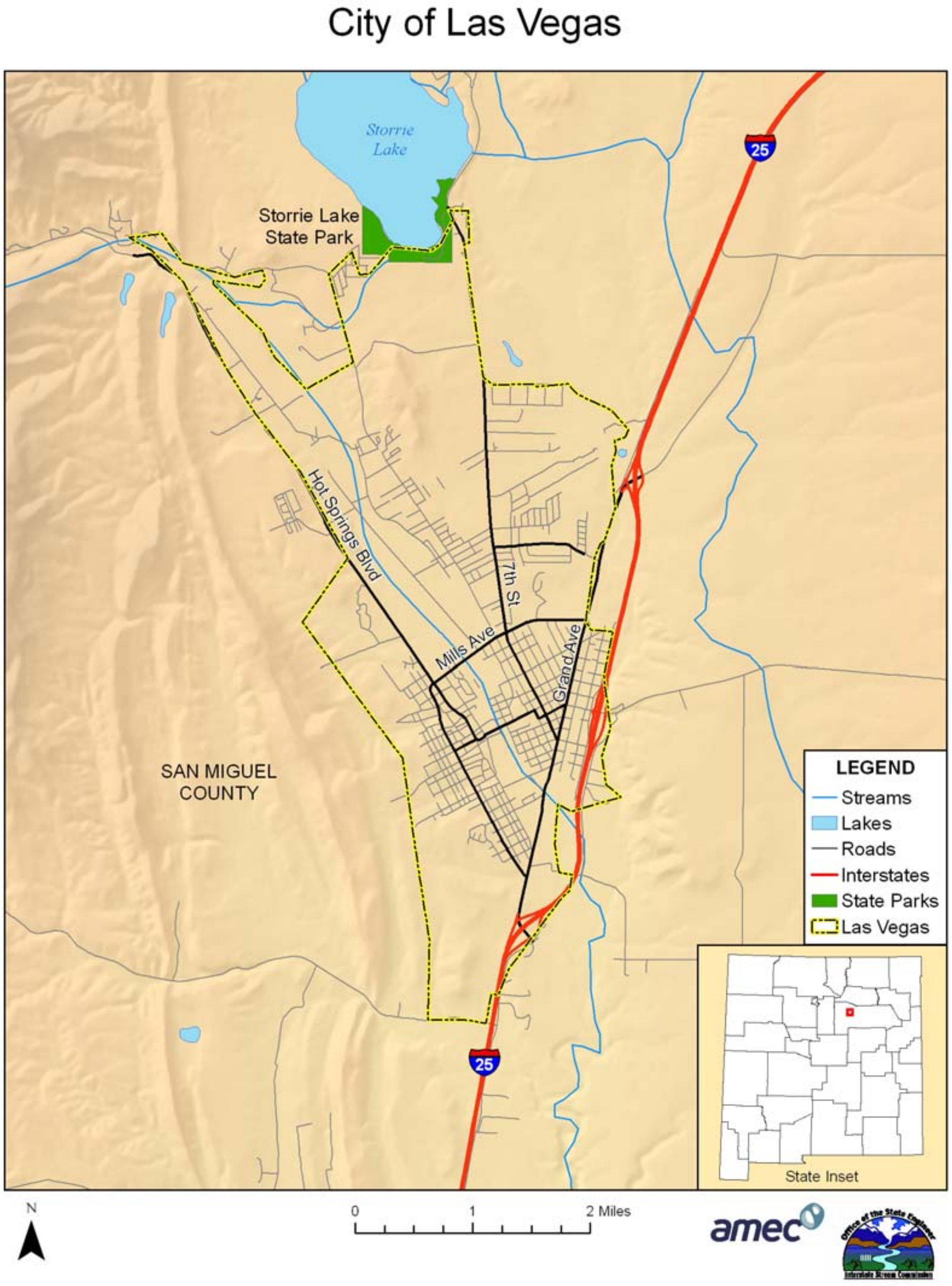


Figure 3: Map of Las Vegas, New Mexico

2.2.1 Las Vegas Water System

The Gallinas River is the primary source of water for Las Vegas providing 95 percent of its domestic water supply (Evans and Lindline, 2004). The Gallinas River originates in the southern Sangre de Cristo Mountains and flows southeast towards Las Vegas, where a large percentage of the surface flow is diverted to the Storrie Lake Water Project and divided among multiple users, including the city of Las Vegas, Las Vegas National Wildlife Refuge, farmers and ranchers. Water from groundwater wells located in the Taylor well field supplement surface water supplies.

2.2.2 Las Vegas AWWA Audit

NMOSE completed an AWWA audit for the year FY09 (7/2008 – 6/2009) with data supplied by the utility. The entire AWWA audit and reporting worksheet can be found in Appendix B.

Table 3: Las Vegas's water balance worksheet.

WATER SUPPLIED (792.156 MG)	Authorized Consumption (544.284 MG)	Billed-Authorized (516.122 MG)	Billed, Metered Consumption (516.122 MG)	Revenue Water (516.122 MG)
			Billed, Unmetered Consumption 0	
		Unbilled-Authorized (28.162 MG)	Unbilled, Metered Consumption (18.260 MG)	Non-Revenue Water (276.034 MG)
			Unbilled, Unmetered Consumption (9.902 MG)	
	Water Losses (247.872 MG)	Apparent Losses (38.243 MG)	Unauthorized Consumption (1.980 MG)	
			Customer Metering Inaccuracies (31.102 MG)	
			Systematic Data Handling Errors (5.161 MG)	
		Real Losses (209.629 MG)	Leakage on Transmission and Distribution Lines	
			Leakage and Overflows at Storage Tank Sites	
			Leakage on Transmission and Distribution Mains	

Water losses amounted to 247,872,000 gallons for FY 2009 (equation 3). This amount represents apparent losses totaling 38,243,000 gallons (equation 4) and real losses totaling

209,629,000 gallons (equation 5). The real losses comprise 26.5 percent of all water supplied or 87.4 gallons per connection per day. The city did not provide documentation on losses estimates due to leaks or overflows. Anecdotal information from staff revealed that a tank overflow occurred in the summer of 2008 that went uncorrected for approximately one month. Although this is undocumented, this overflow is suspected to have contributed to the real loss volume.

2.3 City of Rio Rancho

The city of Rio Rancho is located at an elevation of 5,282 feet on the west side of the Rio Grande River in the Rio Grande Valley in Sandoval County with a small portion of the city extending into Bernalillo County (Figure 4). Rio Rancho is located in a region considered high desert with an average annual rainfall of less than nine inches. It is considered part of the Albuquerque metropolitan area. It is the fastest-growing and third-largest city in New Mexico. The city population was 51,765 for the 2000 census. As of the 2007 census estimate, it has risen to 75,978. *http://www.rredc.org/rrprofile/demographics.html*

2.3.1 Rio Rancho Water System

Rio Rancho has no surface water rights and groundwater from the Santa Fe Group Aquifer is its only water source. The aquifer stretches 100 miles north to south from Cochiti at the north to Socorro in the south and from Tijeras Canyon on the east to the Rio Puerco on the west. There are 19 wells listed on the City’s 2008 production spreadsheet, however only16 wells were producing water during 2008. There are 21 surface storage tanks with a holding capacity of 31 million gallons per day currently available within the system (WPRC, 2007).

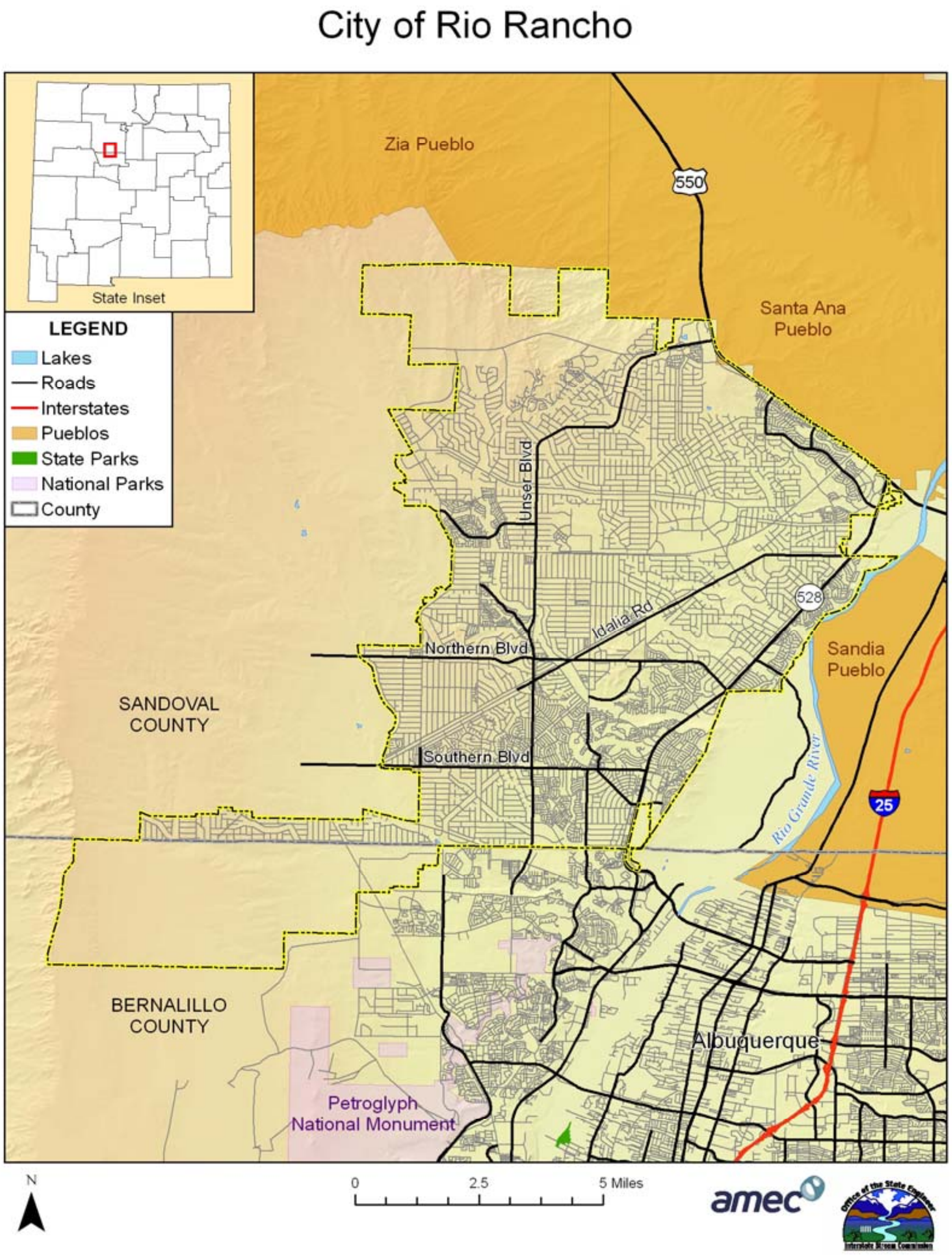


Figure 4: Map of Rio Rancho, New Mexico

2.3.2 Rio Rancho AWWA Audit

Rio Rancho is in its third year of completing an AWWA audit. They have supplied the NMOSE with a completed audit and an explanation of each of the audit categories. Their audit is based on the 2008 calendar year from January through December 2008. The entire AWWA audit can be found in Appendix C. Their water balance worksheet is shown in Table 4.

Table 4: Rio Rancho water balance worksheet

WATER SUPPLIED (4,352.480 MG)	Authorized Consumption (3,638.274 MG)	Billed-Authorized (3,630.336 MG)	Billed, Metered Consumption (3,630.336 MG)	Revenue Water (3,630.336 MG)
			Billed, Unmetered Consumption 0	
		Unbilled-Authorized (7.938 MG)	Unbilled, Metered Consumption 0	Non-Revenue Water (722.144 MG)
			Unbilled, Unmetered Consumption (7.938 MG)	
	Water Losses (714.206 MG)	Apparent Losses (118.539 MG)	Unauthorized Consumption (10.881 MG)	
			Customer Metering Inaccuracies (102.657 MG)	
			Systematic Data Handling Errors (5.000 MG)	
		Real Losses (595.667 MG)	Leakage on Transmission and Distribution Lines	
			Leakage and Overflows at Storage Tank Sites	
			Leakage on Transmission and Distribution Mains	

Water losses for 2008 amounted to 714,206,000 gallons, with apparent losses totaling 118,539,000 gallons and real losses totaling 595,667,000 gallons (equation 5). The real losses comprise 13.7 percent of total production or 55 gallons per connection per day. Rio Rancho documented main break losses of 2,966,201 during this same time frame (Table 19, Appendix C). These losses were estimated by field staff that responded to breaks and repaired them.

3.0 PASSIVE LEAK DETECTION PROGRAM

Leak detection is a problem-solving process that requires utilities to analyze their system and determine a strategy for the best use of a leak detection program. By reviewing their system and taking into consideration the reasons for leakage such as aging infrastructure, corrosion, poor installation and lack of maintenance and external factors, such as earthquakes and ground subsidence, utilities can create a systematic approach to survey their distribution system. An active system requires trained professionals walking water lines using listening equipment. A passive leak detection program is designed to let automated loggers do the 'listening' part of surveying a system for potential leaks instead of a trained professional.

3.1 Theory

Water escaping from a hole or rupture in a pipe that is transmitting water under pressure will produce a noise vibration (Figure 5). Depending on subsurface conditions the water from a leak either moves upward to the surface where it can be observed or flows downward into a permeable sub-surface layer and is not visible or observed.

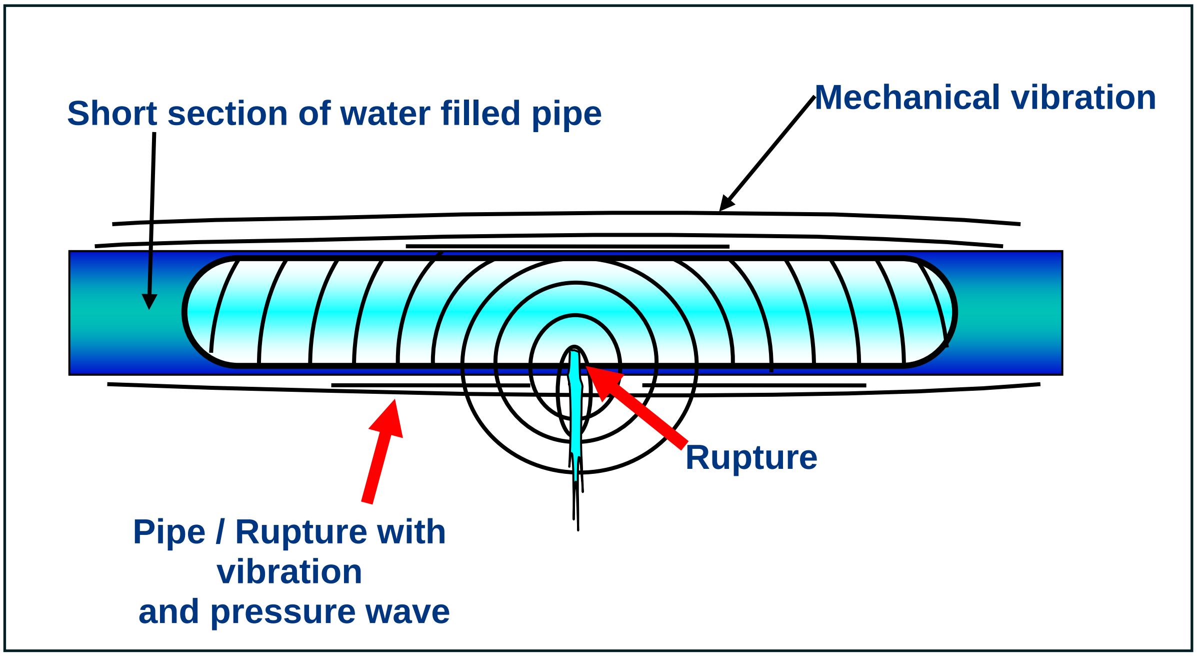


Figure 5: Diagram showing vibrations a leak makes (modified from FCS, 2009)

The acoustic loggers attached to a connection point have the ability to audibly detect the pressure or mechanical vibrations emitted by the leaking pipe and record them. The data is transmitted via radio signals to a receiver that then transmits the data via blue-tooth technology to the personal digital assistant (PDA) or computer. The data are then placed into a database (see example in Table 5). The information identifies the logger, a location, the date of the reading, the status of leak mode and the level and spread of the noise heard. Each system on the market handles the data reading and output slightly differently, but they are all fundamentally the same.

Table 5: Example of generalized data obtained from logger.

Serial	Comment	Deployed	Read	Status	Level	Spread
0000111	100 3rd St	10/1/2009	10/14/2009	N	4	2
0000112	108 3rd St	10/1/2009	10/14/2009	L	36	7
0000113	112 3rd St	10/1/2009	10/14/2009	N	10	3

3.2 Equipment

The loggers are small-scale, self contained devices that magnetically attach to distribution valves, fire hydrants, and key junctures on the water main (Figure 6). At night or during slow water use periods they activate, listen for and 'pick up' vibrations that occur in the pipeline. The preset program within the logger analyzes the data to evaluate whether a leak is possible. If no leak is apparent, the signal transmitted indicates normal background conditions and shows no alert. If a suspect leak is detected, an alert is displayed notifying utility personnel of a possible leak condition.

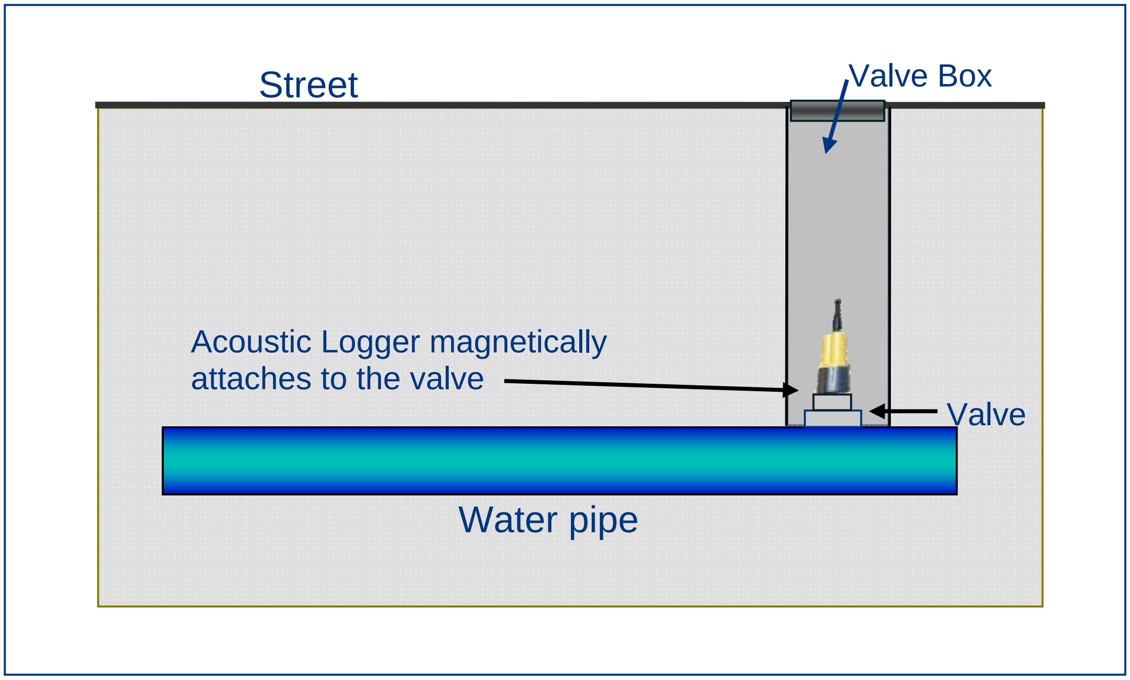


Figure 6: Diagram depicting placement of logger on a valve (Modified from FCS, 2009)

The loggers transmit the data via radio signals to a receiver, located in either maintenance or meter reader truck as they drive along their route (Figure 7). The truck's drive-by schedule can be set according to the community's water system needs. When evaluating schedule options, utilities should consider the estimated quantity of leaks, the availability of staff and the need to recover lost water. Patrolling can be done daily, weekly, bi-monthly etc; communities with large losses or older systems can conduct frequent patrolling, while other cities under normal circumstances might rely on the regular meter reading routes. The transmitted data from each logger can then be viewed on a PDA or downloaded to a computer depending on which system is purchased. If an area has been cleared of leaks the loggers can be picked up and moved to a new locality. This technique is known as a 'lift and shift'.

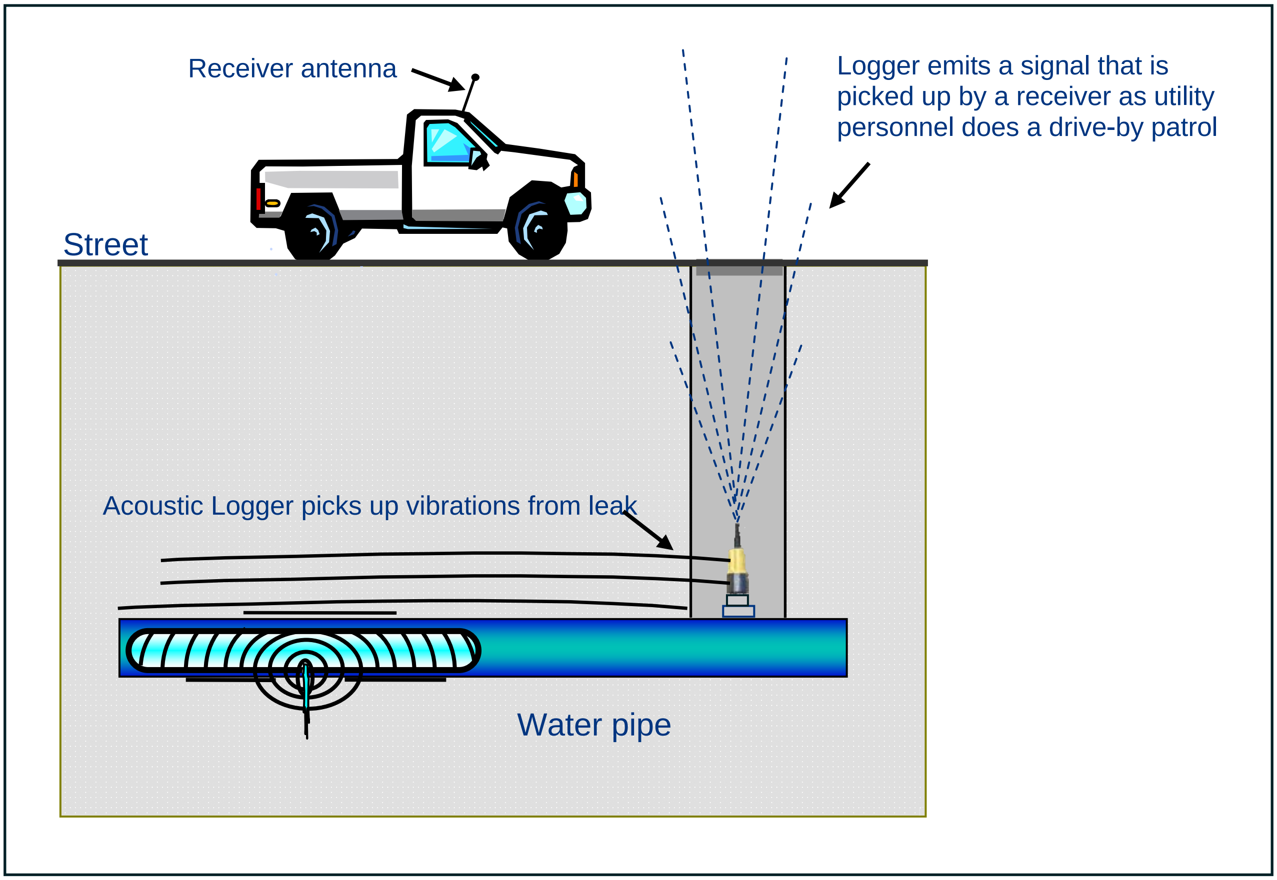


Figure 7: Diagram of how a receiver picks up the data from the logger as utility personnel drive by

3.3 Leak noise factors

There are many factors that influence the type and quality of noise that a leaking pipe emits. The type of material the pipe is composed of is one of the prime factors; generally the harder the material the better it is at transmitting the noise a leak produces. The amount of pressure in the line is another factor that can affect the noise quality; lower pressure generally causes less noise to be generated. Smaller diameter pipes have a smaller surface area, so the noise is not as greatly attenuated as with larger diameter pipes. This acoustic logger technology is not usually used on large-diameter transmission mains (24-inch and larger) for this reason. A list of factors that affect the quality of audio are listed in Table 6.

Table 6: Factors that affect the quality of the noise that a leak makes (FCS, 2009)

Factors producing good quality leak noise	Factors producing poor quality leak noise
Metallic pipes	Soft/Lined pipes
Small diameter pipes	Large diameter pipes
Clean pipes	Encrusted pipes
High water pressure	Low water pressure
Hard backfill	Soft backfill
Small rupture	Split mains

The distance between deployed loggers is another critical factor in how effective they will be in identifying leaks. The recommended spacing is determined by pipe material. However, actual spacing is determined by available valves, fire hydrants or meter locations. If there are few locations available to listen for leaks the chances of detection are greatly reduced. Loggers spaced with large distances between them will be less effective than loggers that are optimally spaced (Table 7).

Table 7: Ideal distance between logger placements based on pipe material (FCS, 2009)

Type of pipe material	Distance between loggers (feet)
Steel	1000
Iron	1000
Asbestos Cement	250-500
PVC	50-250
Polyethylene	50-250

Additional, system features and outside influences can contribute to problems hearing leaks. System features such as changes in pipe diameter, presence of pressure reducing valves, partially closed valves (throttled or passing) and running meters will result in noises that could cause a logger to give an alert (FCS, 2009). External noises such as traffic, electrical interference from transformers or street lights are common sources that affect the data. Loggers located in close proximity to sewer mains, culvert pipe or gas lines will also pick up these extra background noises. Off hour water pumping and usage such as early morning irrigation also produce problematic noises (FCS, 2009). When a logger program is being planned, these influences should be taken into account. A visual scan of the site can help with appropriate placement or noting potential problems. An audible scan can be conducted with a ground microphone to see if background noise will be a constant.

These noises can often be separated out of the data. Reviewing multiple data sets from a site with a known problem will provide background information on the level and spread of that particular problem. For example, a ground based electrical transformer within 100 feet could provide a leak signal, but the level and spread is 40,1 for every read on consecutive days. Therefore it is determined to be only the electrical hum and not a leak.

3.4 Locating a Leak

When the logger detects a leak in an underground pipeline, the next step is to locate its position. There are several options to locate the leak 1. use of a ground microphone, 2. cross correlators, and 3. pressure, or step testing. For this project the ground microphone was chosen. To use the ground microphone, an operator places the microphone on adjacent valves, meters, and fire hydrants in addition to placing it on the ground above the pipeline to listen for leak noise. The volume should increase closer to the leak. It is up to the user to make a determination of the location of the leak. The use of cross-correlators requires the use of accelerometers placed on either side of the suspected leak and by measuring the time it takes the leak “noise’ to reach each device the location can be mathematically determined (Fantozzi, 2000). The benefits of using correlators to locate the leak are that they offer a more accurate location of the leak, less dependence on operator interpretation, and can be used in noisy conditions (Fantozzi, 2000). There are loggers available that include a correlation component. If correlation capacity is desired, both built in and stand alone models are worth pricing.

Pressure testing is another way to determine if a leak is present in the system. The test introduces a certain amount of water at a known pressure into an isolated section of pipe for a specified time period. During this time frame, the pressure is observed. If the pressure drops this probably signifies a leak, whereas if the pipeline holds the pressure then a leak can probably be ruled out. The drawbacks of pressure testing are that it doesn’t pinpoint the location of a leak, takes time and manpower to do the test and creates safety issues.

3.5 Advantages of Passive Leak Detection Programs

The advantages of passive leak detection programs over other methods are the versatility of how a water distribution system can be surveyed and the relatively low amount of manpower to do the survey. Depending on budgetary concerns, a city may opt for full deployment over their entire distribution system or purchase a small number of loggers to survey their system in sections by performing a ‘lift and shift’. The loggers are compact and battery operated. They are designed for rapid deployment and can be programmed to listen for leaks when conditions are optimal with low background noise. The loggers analyze the noise vibrations that are picked up, so only basic leak detection experience is required. The loggers magnetically attach to valves so water supplies are not affected. Once deployment is complete, a system can be monitored or ‘patrolled’ in a short period of time. The main goal is to find small leaks before they become large breaks. The passive systems require an initial investment in equipment and training. However, labor efforts and percentage of system covered can then be set to meet the needs of the utility.

3.6 Disadvantages of Passive Leak Detection Programs

The disadvantages of using a passive leak detection program include the upfront capital expenses, the need for valves or accessible contact points and the fact that they do not pinpoint the exact location of a leak. The loggers range in price from $500 - $800 each. For utilities choosing to cover large areas, this can add up quickly. The receiver is a separate cost, ranging from $5,000 to $7,000 and may or may not come with the communication link (PDA or computer). In addition, the leak will need to be pinpointed with a correlator that can range from $16,000 - $24,000 or a ground microphone with costs in the $1,000 - $5,600 range. All of the listed costs are based on quotes that were received by the NMOSE during this project. Cost can and will vary depending on the options chosen.

The valve or access points for placing loggers tend to be a problem for systems that are not on a grid. Long distances between valves can be caused by improper infrastructure installation, changing elevations and distance between customer connections. Piping material dictates the spacing of the loggers, but doesn't always correlate to the spacing of the valves. This can eliminate areas from surveying by a passive leak detection method.

The loggers do not give an exact location of a leak in a pipe, other methods described above are required to pinpoint the location of a leak. It also must be noted that the loggers will not identify and give an alert for all leaks. Several reasons for this are provided in Table 6. Experts on acoustic leak detectors state that utilities can anticipate approximately 60-70 percent of the leaks in their system will be identified by a logger.

4.0 NMOSE LEAK DETECTION PROGRAM

The NMOSE program was implemented using the same basic formula in all three cities. An initial meeting was set up with utility management to discuss how the equipment works, what options the utility had for placement and management of the equipment and to address any questions. Ruidoso, as the first city in the project did not receive an initial visit. NMOSE team adjusted to provide this in the remaining two cities. This was followed by two scheduled implementation visits (Figure 8) that included meetings to discuss the AWWA audit. Trouble shooting visits were arranged as needed. In addition, a final closing interview was conducted in each city.

Figure 8: Ruidoso staff, OSE coordinator and consultants implementing the leak detection program.

The equipment for the program consisted of 300 self-contained acoustic loggers (100 for each city), three personal digital assistants (PDA's), three receivers and three ground microphones. Permalog® Plus acoustic noise loggers and the accompanying Patroller II made by Palmer Environmental were chosen for the project. The ground microphones chosen were a L-mic ground-microphone system, which includes a geophone, listening stick and a tripod-listening foot. Fluid Conservation Systems (FCS) won the contract to provide this equipment.

4.1 Implementation of the System

The implementation of the program occurred in the Fall and Winter of 2009-2010 with a two-day field visit to each of the cities. The initial visit involved training the utility personnel assigned to the project. The training included: education on acoustic logger leak detection, programming the equipment, deployment of the acoustic loggers, patrolling to determine how the system was operating and collecting, downloading, and assessing data. It is estimated that a couple of hours were spent on each of the training areas. The most time was spent on deployment, with the least time spent on assessing data. NMOSE and contractors presented a short introduction to utility field staff involved in the project. The majority of the training occurred in the field as the loggers were deployed. An effort was made to allow all interested staff a chance to work the PDA and to program and deploy loggers (Figure 9).

Figure 9: Rio Rancho staff programming data into the PDA and placing a logger on a water valve.

The loggers were programmed prior to deployment to 'listen' for leaks from 2:00 am to 4:00 am. The time interval for the loggers to emit the signal to be picked up by the receiver was programmed from 6:00 am to 6:00 pm. The primary utility staff members were trained on the programming; however, the majority of the 300 loggers were programmed by contractors in advance in order to reduce confusion at the beginning of the project and to speed up deployments.

The system deployment consisted of four integral tasks: 1. prepare for logger deployment by locating and cleaning out valve boxes (Figure 10), 2. program and deploy the acoustic loggers with a quality assurance/quality control check to determine if the antenna is transmitting to receiver and that the logger is working properly, 3. perform a drive-by patrol of the system to collect data, and 4. review the data noting any areas where there is a leak alert or where a change in the level and spread show a potential problem. If an alert is given or a leak is suspected, the next step includes pinpointing the location of the leak and ultimately repairing or replacing the pipe.

Both Ruidoso and Rio Rancho had GIS capabilities and were able to produce maps depicting the valve locations and pipelines. In Las Vegas, copies of the field maps were provided. The location and unique serial number of the loggers were noted on the maps as they were deployed. These maps were then used by the utilities to create the routes for the drive-by patrolling.

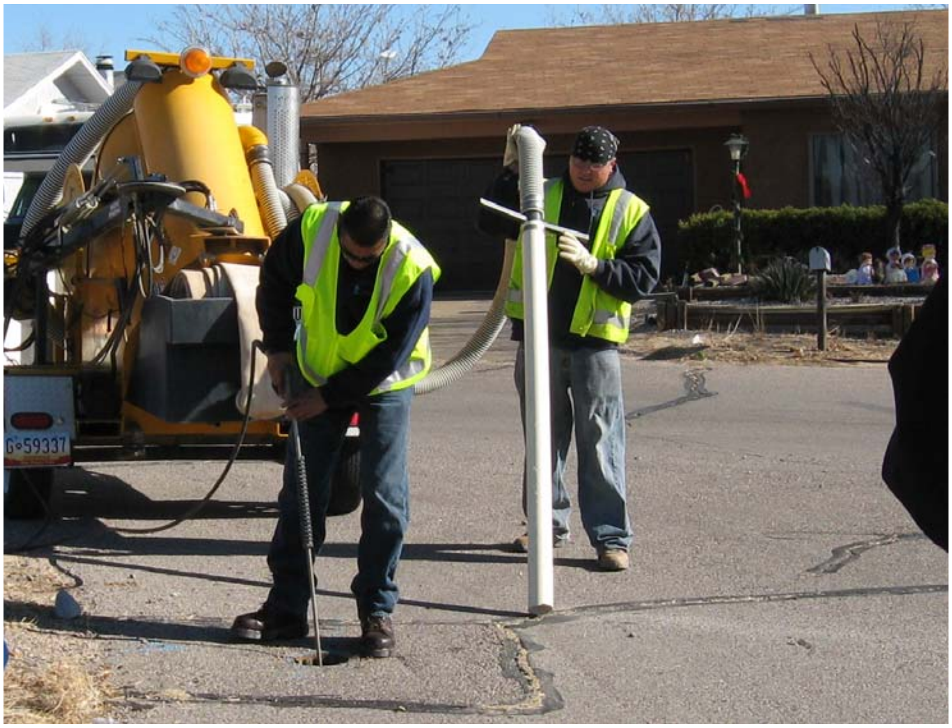


Figure 10: Personnel cleaning out valves prior to logger deployment

Locations selected for the initial deployment of the leak detection system were in known problem areas determined by each city. Over the two day period, each city installed 33-60 of the 100 loggers. Ruidoso staff consulted with the contracted specialists to determine the appropriate placement of the loggers in their areas of concern. This was done prior to the visit; therefore the utility had cleaned the valve boxes before the installation team arrived onsite. The Las Vegas utility and Rio Rancho’s Environmental Programs Manager created maps and delineated their own areas of concern. During the initial field visit to Las Vegas the valve boxes were cleaned out by a field crew just ahead of the personnel deploying loggers. However, in Rio Rancho, the two-man crew cleaned the valve box out as a location was chosen. This same crew was also involved in the deployment of the loggers, and the associated training on the PDA. This tended to slow the installation process slightly, although it may be more efficient in terms of total time spent, as in the other utilities two crews were necessary.

In both Ruidoso and Las Vegas, office staff downloaded and maintained the data collected by the loggers. Both these programs are overseen by the utility manager. In Las Vegas, the daily management of the program is conducted by the water conservation employee and is run by one primary field staff. The water conservation employee also does all of the data management. They do not have a GIS program. In Rio Rancho, the program is run by the Environmental Programs manager and one staff member. The distribution system is managed by a contractor. The Rio Rancho staff has to work through the utility's contractor to gain access to the distribution system. The contractor provided two personnel for cleaning valve boxes and training on the equipment. The Environmental Programs Manager and City staff member do all the patrolling, manage all data and work with a GIS department for mapping needs.

The supplemental visits included additional deployment of the remaining loggers, patrolling assistance, questions concerning database management, work with data interpretation, site investigations, ground microphone work (Figure 11) and general trouble shooting.

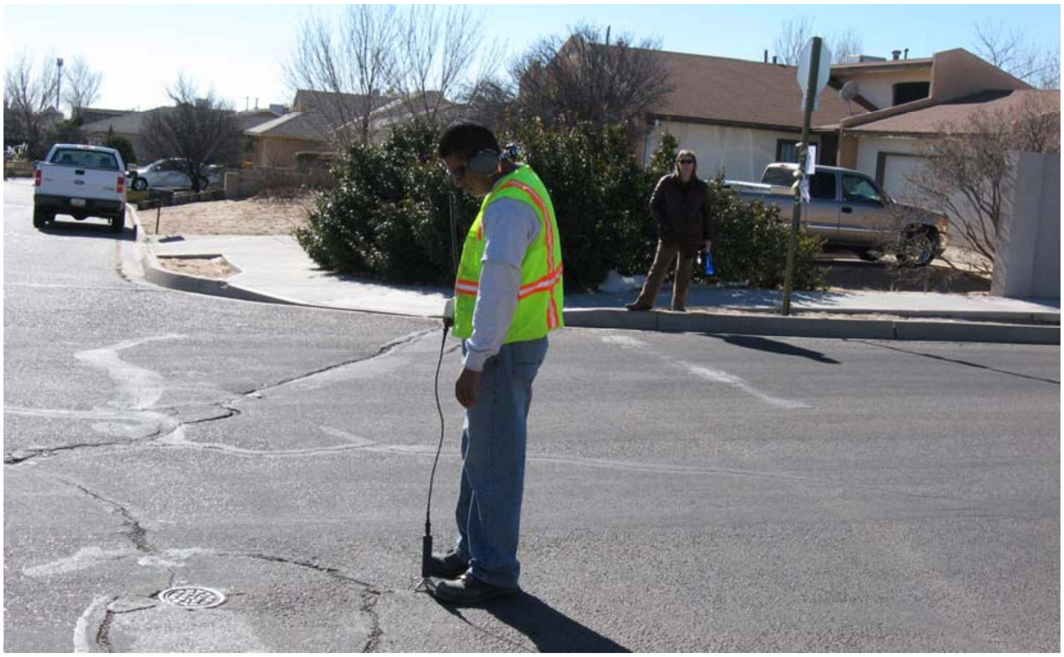


Figure 11: Rio Rancho personnel using ground microphone to listen for leak.

4.2 Modifications

Problems occurred in both the implementation process chosen by NMOSE and with the logger equipment. The implementation process was reviewed and updated as the NMOSE team moved from city to city. Some of the adjustments helped the process while others did not. Many of the equipment problems were resolved through trial and error. Generally, as everyone became more proficient with the equipment and software, difficulties were reduced.

4.2.1 Implementation Process

A critical factor to the success of the program is the support and skill set of upper management as well as field staff. Upper management must provide time for the field staff to train on equipment use, conduct the patrols, interpret data and ultimately repair leaks. In turn, the field team needs to have good knowledge of the water distribution system, be flexible and know how to troubleshoot and problem solve when problems arise. The database manager should have a good eye for reviewing and studying data so he/she can make sound interpretations based on how the level and spread numbers are changing in each subsequent patrol. Working together the field team and database manager can identify potential leaks and problems in the water supply system. Identifying an appropriate ‘in house’ team and resources to manage the system is critical.

When implementing leak detection programs, the training must be geared to the skill level of the primary staff involved. Each city participating in the NMOSE project provided a solid field crew, however each posed different training needs. Their comfort levels with the PDA ranged from not willing to touch it to master level. This was a very obvious generational issue. The field crews that were not brought up on cell phones, touch screens and computers needed extra training on the PDA interface and programming. Extra training was also needed when field crews were asked to download databases and organize spreadsheets. Training and experience was also the biggest factor in the use of the ground microphones. This is a specialized skill and required practice. When possible, staff was taken to an area with a known leak to listen from various access points. Over time, staff can become very efficient with this equipment.

It is important to recognize that the loggers only identify the leaks. It is up to the utilities to repair them. A response plan should be put into place prior to deployment of the loggers. In all three cases, the respond and repair plans was left up to the utility. One city placed all leaks found with the loggers onto their emergency response list. These leaks were addressed within two hours. The same city implemented a fire hydrant program with the ground microphone that placed all leaks found onto their 48 hour repair list. The other two cities involved in the project did not implement a follow up plan. These cities are addressing the found leaks on an ad hoc basis. Several leaks have gone months without being addressed. It must also be noted the bulk of this project was implemented during the winter months. At least one utility had to wait until the ground thawed prior to digging up lines.

4.2.2 Equipment Limitations

The passive leak detection equipment does have limitations. These include: pipe material, valve placement, interference (electrical, traffic), pinpointing leaks, and the number of available loggers. The ability of the loggers to hear leak noise is restricted by the type of pipes in the system, as discussed earlier plastic pipes do not conduct sound as well as metal pipes. All three of the City’s systems in this study were predominately PVC pipe. Therefore, for maximum listening coverage, the loggers should be placed within 50 to 250 feet from one another. However, several areas in all three cities did not have this advantageous distance between valves. The lack of valves or connections on PVC pipe makes these areas difficult or non-conducive to survey with only a passive leak detection program.

Background noise can interfere with logger reading. Electrical hums from ground transformers and street lights as well as noise generated by traffic and gas lines all created issues at various locations. If during deployment these obstacles were observed and entered into the PDA, staff would be able to review the data with a wary eye when a leak alert is given from a logger in the vicinity. Gas line noise and electrical interference tends to be consistent, with little or no variations in the level or spread. This consistency should be flagged during the data review process. Traffic also proved to be a problem. A logger placed adjacent to major intersection continued to signal an alert. Traffic noise was an issue even at the early hours of 2:00-4:00 am, therefore it was removed for redeployment elsewhere.

The loggers only identify if a noise that could be a leak is within its range, in the case of units connected to PVC mains that could mean up to 250 feet in either direction. The loggers do not pinpoint the exact location of the leak. An additional step must be taken. The options discussed earlier included ground microphones, correlators and pressure testing. All of these require additional time and additional training. In one of the pilot cities a leak had been identified with the loggers, so staff walked the main line with the ground microphone. They were unable to pinpoint the leak or provide an area to be excavated by the back hoe. Within one week that main line leak had progressed to a main break. This city is discussing the option of adding a correlator to their leak detection program. It should be noted that some acoustic loggers do come with correlators imbedded.

NMOSE limited the number of loggers purchased for each city to 100. This provided its own set of problems. Cities had to prioritize the areas for deployment, set a time limitation and then reset or lift and shift the loggers to the next location. Passive logger programs in both El Paso, Texas and Las Vegas, Nevada have purchased enough loggers to blanket their areas of concern and leave the equipment in place. For Ruidoso, with 7,385 connections in 160 miles of line and Las Vegas, NM with 6,445 connections in 124 miles of lines, it is reasonable to expect a lift and shift program to work. However, Rio Rancho has 29,689 connections and 524 miles of line. With only 100 loggers and limited staff time, it would take several years to examine their entire system.

4.2.3 Equipment Problems

The NMOSE program also encountered some problems with the equipment during the implementation process. For the most part these were due to the normal learning curve and were corrected as NMOSE and the cities gained more experience with the equipment. These included: logger programming, reception from loggers, communication between receiver and PDA, and loggers turning off.

The first problem encountered was the inability to pick up the transmitted signal from the acoustic loggers during the drive-by patrolling. Troubleshooting revealed that there were two issues: one was misunderstanding the programming software and the second was a hardware issue. The software within the PDA allows for the user to set the time interval when the loggers are to ‘listen’ and record sounds and to transmit the signal to be received. The default programming was set to Pacific Standard Time. However, New Mexico is in Mountain Standard Time, therefore time intervals were not correctly correlated. When the NMOSE staff tried to patrol the first deployment, it was outside of the default timeframe. In addition, the loggers were not always preset with the default read and send times. Each of the 300 loggers needed to be checked for the correct programming. The utility staff was given a little extra training on how to program the loggers and the problem lessened. This occurred in the first utility to receive the loggers where the deployment occurred prior to discovery of the programming issues. Subsequently, the loggers were programmed in the contractor's office prior to the field visit.

The equipment problem was centered on the standard antennas. These antennas are about 3 inches long and attach directly to the logger. The loggers are placed on valves which are located in vaults one to four feet below the ground surface. A large percentage of the radio signals did not make it out of the valve box. The antenna problem was resolved by removing the antennas from the loggers and attaching them to long extension cables (10 feet). The cables connected the loggers to the antennas so the antennas could be placed closer to the ground surface, just beneath the valve lid (Figure 12). The antennas are also unable to transmit if they are under water. The higher position in the valve box limited the reception problem to all but the most severe weather events. Ruidoso's heavy snow pack provided for a couple of snow melt events that put even the raised antennas under water for a short period of time. Utility personnel also improved drive-by reception by placing the receiving antenna on the roof of the patrolling vehicle instead of on the hood. This worked well when driving slowly and directly over a valve box. On occasion, it was still necessary to stop, get out and lift valve box lids in order to get a reading. This was usually due to soils becoming hard packed around the lid and sealing it from transmissions.

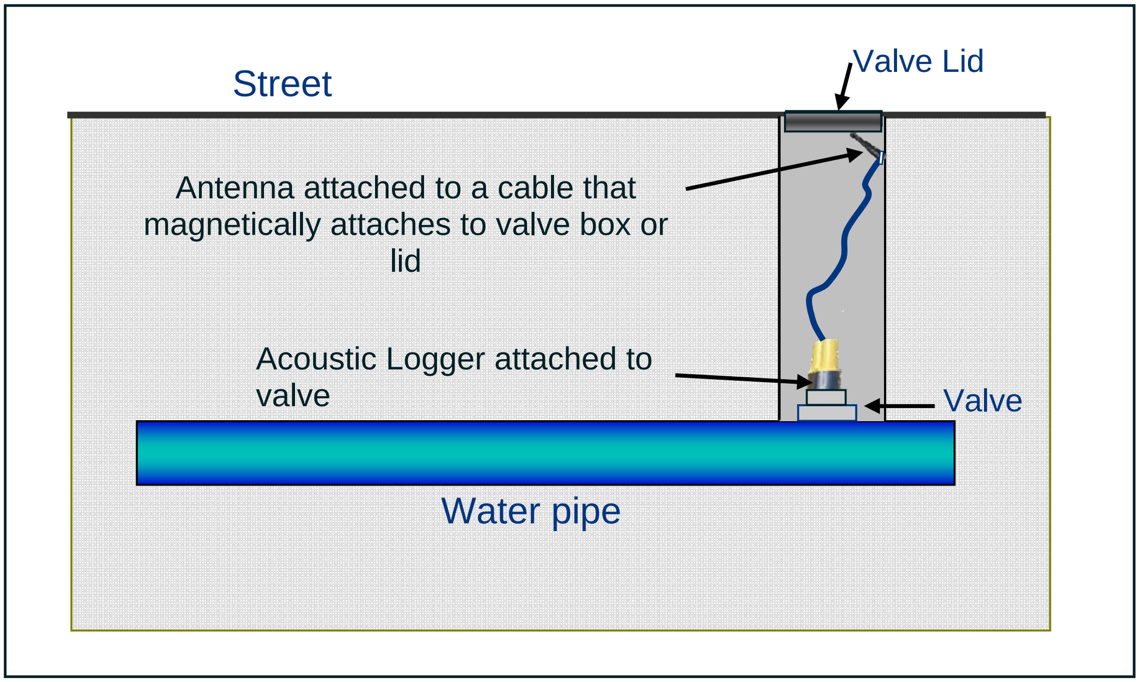


Figure 12: Diagram showing the antenna attached to logger with a cable and placed under valve lid.

Modifications have also been made for the PDA and the receiver. The PDA and receiver communicate through a Bluetooth connection. This connection could be tenuous at times.

Dropped or lost connections between the PDA and the receiver cause frustration and lost time. It has been discovered through trial and error that if both pieces are turned on and left alone for several minutes, the connection will re-establish. Problems occur most often when the user tries to hurry the connection. It has also been reported that residential WiFi systems have been causing interference with the Bluetooth. A couple of other complaints from the field staff regarding the PDA were also noted. The screen is difficult to read outdoors due to the sun's glare. During logger deployment or reprogramming, staff is often chasing the shade in order to input data on the PDA. Secondly, the PDA has a battery saving default that turns the screen dark after a short period of time if the PDA does not perceive use. This dark screen has become an issue during patrols because the driver cannot see if the data from a logger has been received and has to pull over and stop to turn the PDA back on. This is especially problematic and unsafe if one person is doing the patrolling. Attempts to change these settings have not been successful. A new field PDA (Archer Field PC) has been purchased for each city in an attempt to alleviate these problems. Early results are promising.

Finally, it has been reported in two of the three cities that about four to six months into the program the majority of the loggers have either turned themselves off or had a programming shift on the read times. Field crews reported that they would receive signals for 90 to 100 percent of the loggers during one patrol and then the next patrol only get 5 or 10 percent. The loggers that were not sending signals were pulled and swiped to be restarted and redeployed. This resets the loggers, deleting accumulated data. However, the loggers are working once again. At this time it is unknown why this is happening. Both cities experiencing this problem had extremely cold, harsh winters (Figure 13). NMOSE and the cities involved will continue to investigate this issue. An early hypothesis is that the cold weather weakens the battery causing the unit to shut off to preserve the data.

Figure 13: Ice filled valve box in Las Vegas, NM

4.3 Results

Although the implementation in each city was relatively similar, the results varied widely. One issue that all three cities had in common is that they all have portions of their distribution system that lack sufficient valves or points to place loggers. The lack of listening points results in these areas being difficult to assess with a passive leak detection program only.

4.3.1 Ruidoso

Area Covered

Since the program was implemented in September 2009, the utility has surveyed approximately 20 percent of their system (Figure 14). Sixty loggers were deployed in the initial two day visit. Utility staff followed up by installing 35 more. The project was initiated in areas that had the oldest pipelines and where the underground strata are highly permeable. Approximately six weeks later, when the original locations were considered completed, the utility did a lift and shift and redeployed 95 loggers to a second location. A third deployment included 54 loggers and was implemented approximately four weeks later when the second area was cleared.

The utility estimates that thirty percent of the system is not appropriate for the program primarily because these areas have long distances of PVC pipe with no valve or location to place a logger.

Staff Time and Involvement

After the initial training and deployment of the loggers, Ruidoso utility estimates that they spend an average of four hours a week on the program. This includes patrolling, database management and any troubleshooting that is needed. During a lift and shift operation, the utility dedicated two field personnel for two days to clean out valves boxes ahead of the deployment crew. The number of loggers deployed by one staff member was approximately 30 a day.

According to the AWWA water audit, Ruidoso's system is experiencing approximately 30 percent non-revenue water with 17 percent real losses. The real loss equates to 37.81 gallons per connection per day. At this level of loss, utility management would like to dedicate staff level and time at two days per month for logger deployment, one day per week in the field (patrolling) and two hours per week in office for database management. This does not include time needed for cleaning valves or for pinpointing any suspected leaks. Current staffing situations have not allowed for full commitment at this time. If real losses can be reduced to 10 percent, management would like two days per month allocated to the program for deployment, patrolling and data management. Management would also like to eventually cross train more field personnel instead of having one person devoted to the program. Again, staffing levels have prevented this from happening to date. GIS personnel are also a vital element to this program. Keeping this staff close by and providing them hands on training is highly recommended.

Leaks Found and Repaired

Ruidoso found 13 small leaks either directly or indirectly as a result of the program. The first leak was identified by a logger on Third Street. However, field personnel using the ground microphone, were unable to pinpoint the exact location of the leak. Within one week, this leak had advanced to a main break. An estimated 50,000 gallons of water were lost.

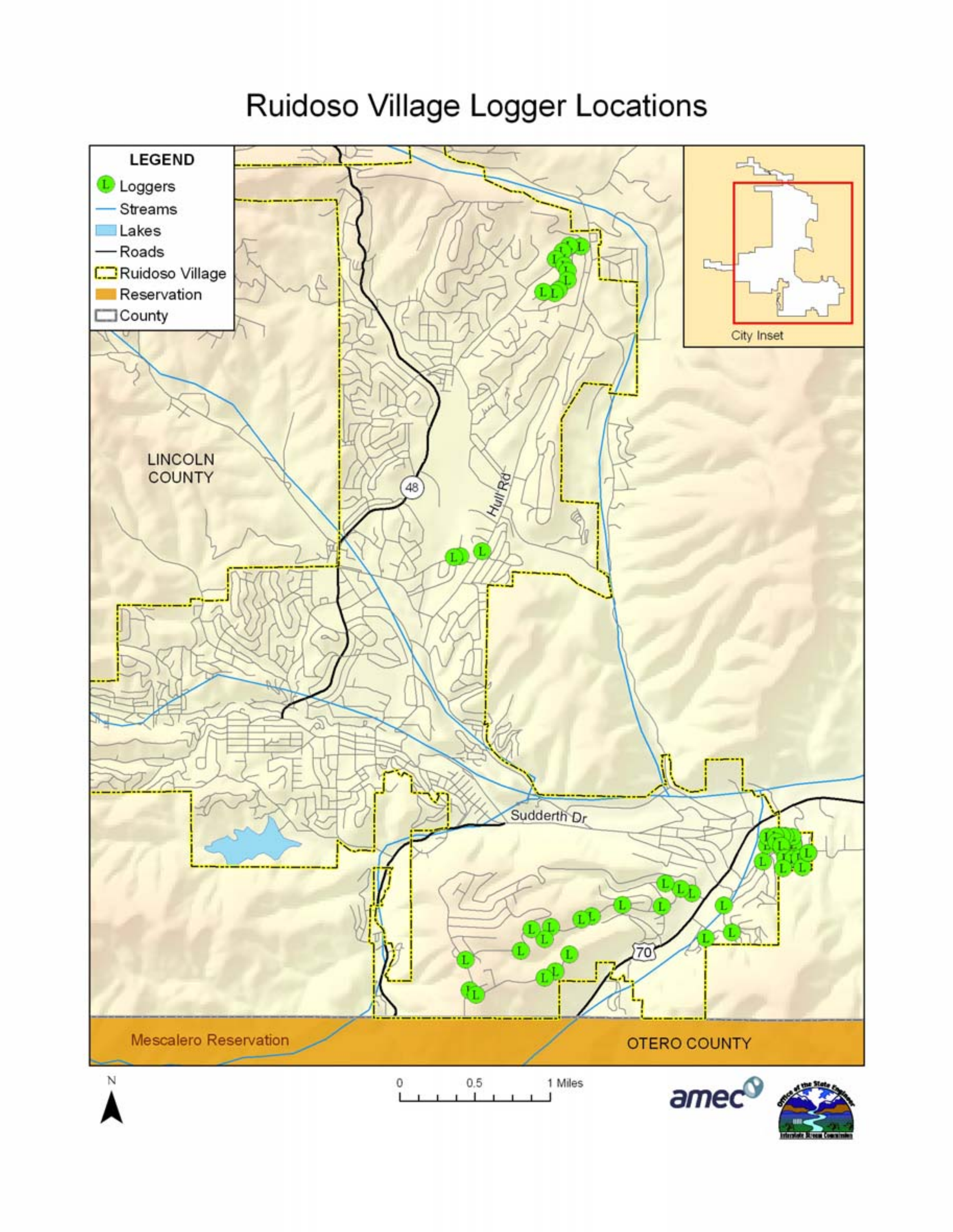


Figure 14: Locations of logger placement during the initial and subsequent deployments in Ruidoso, NM.

Two additional leaks detected by loggers were estimated to be leaking about 10 gallons per minute. These leaks were called in as emergencies with a response time of less than two hours and were pinpointed and repaired. Ten additional leaks were discovered with the ground microphone during routine maintenance of fire hydrants. To date over 80 leak noises have been reported for investigation. These were found because through this grant program field staff had access to and had been trained on the use of the ground microphone. The volume of these leaks was not estimated. The repair crews' response was within 48 hours.

In the short time that the logger program has been in Ruidoso, staff has expressed some concern over the effectiveness of the equipment. In one case personnel could see and hear a leak but the logger 100 feet away did not give an alert. In addition, the winter weather has affected the use of the system. Snow and ice on the streets prevented access to the loggers and a couple of loggers were damaged by a snowplow and water intrusion. Snow melt caused flooding in the valve boxes and in several cases the antennas were temporarily submerged which prevents radio transmissions. The staff's main concern is that there are multiple, small leaks in many parts of the distribution system and not one or two large leaks that will solve the water loss problems. This appears to be borne out by the amount and type of leaks found during the program.

Benefits

The utility has benefited from the exposure to the new technology and is now looking into the purchase of a correlator that could aid in pinpointing the location of possible leaks. The incorporation of the ground microphone into the fire hydrant program has assisted in finding leaks and partially open valves. The utility is investigating a new, more systematic approach to using the leak detection equipment by using a grid system as part of their leak detection methodology. It would be a combination of an active and passive approach. They would survey the lines through subdivisions, on a street by street approach. Their vision is to use valves, fire hydrants and meters to provide the appropriate coverage.

4.3.2 Las Vegas

Area Covered

The leak detection program was initiated in Las Vegas in October 2009. Over a two day period approximately 40 loggers were deployed primarily in areas that were suspected of having multiple leaks, but no leaks could be identified. Over the next couple of weeks, the remaining 60 loggers where deployed by Las Vegas staff. Approximately two months later, the utility shifted all the loggers to new locations. Both the new and original locations were in areas that have aging infrastructure. The Las Vegas field staff stated that the two deployments covered 80 percent of the available valves, and approximately 40 percent of the main lines. Similar to Ruidoso, the utility stated that 20 percent of their system is not appropriate for this passive method of leak detection because the main lines do not have enough valves or locations to place the loggers.

Staff Time and Involvement

During the initial deployment, the program was introduced to all field staff. Some took a more active role with the programming and deployment of the loggers, while others located and cleaned out the valve boxes. Currently, the utility has allocated two staff members to manage the program. The water conservation manager spends approximately 2 to 4 hours per week overseeing the program, downloading data and managing the database. The other field staff member conducts a drive-by patrol twice a week.

Leaks Found and Repaired

By April 7, 2010 the utility had reported finding seven possible leaks with the leak detection equipment (Table 8). These leaks were mainly on older, cast iron pipelines. They have recognized that the next step is to go out during the early hours of the morning with the ground microphone in order to try to pinpoint the leak before digging. The Reynolds alley leak had three loggers in the same area reporting a leak. Using the ground microphone staff could hear noise, but close proximity to a gas line made pinpointing the leak difficult. The noise level did attenuate with distance from the valve with the highest noise level suggesting that a leak was close to the valve. The area was dug up within 20 feet of the valve but no leak was found and the soil was dry. This pipe line is on a priority list to be replaced during spring 2010 so no further action was taken. Another logger alerted that was adjacent to a school. After talking to school staff, the utility discovered that the school uses a boiler to heat the building and water was probably being used during off hours. This “leak” was taken off the list for further investigation.

Table 8: Las Vegas, suspected leaks found with loggers

Location	Pipe Installation Date	Main Size	Notes
Reynolds Alley	1953	6” Cast Iron	Alley behind Sonic, Area dug up within 20” of valve, no leak found,
Reynolds and 7th	1955	2” Galvanized	water main scheduled to be replaced with 2” PVC
Washington	1956	4” Cast Iron	Suspected to be noise from a gas line that shares bore hole
Gallinas	1946	3” Cast Iron	Leak went to main break, Fixed April 2010
Colonias	1956	4” Cast Iron	No action to date
Colonias	1960	6” Cast Iron	Fire Hydrant, valve properly closed
Blanchard	1974	6” Cast Iron	No action to date

At the time of this report, the remaining potential leaks had not been investigated. Staff was inhibited by winter weather and by priority given to 6,000 feet of main line (cast iron) being replaced with PVC.

Benefits

Unrelated to this project, the City of Las Vegas has decided to purchase and test 620 automatic meter readers (AMR) for both gas and water meters. The new AMR system will be placed directly on the meters and will transmit data on the meter reading, leak detection, and theft or tampering. This will expand and compliment the passive leak detection program.

4.3.3 Rio Rancho

Area Covered

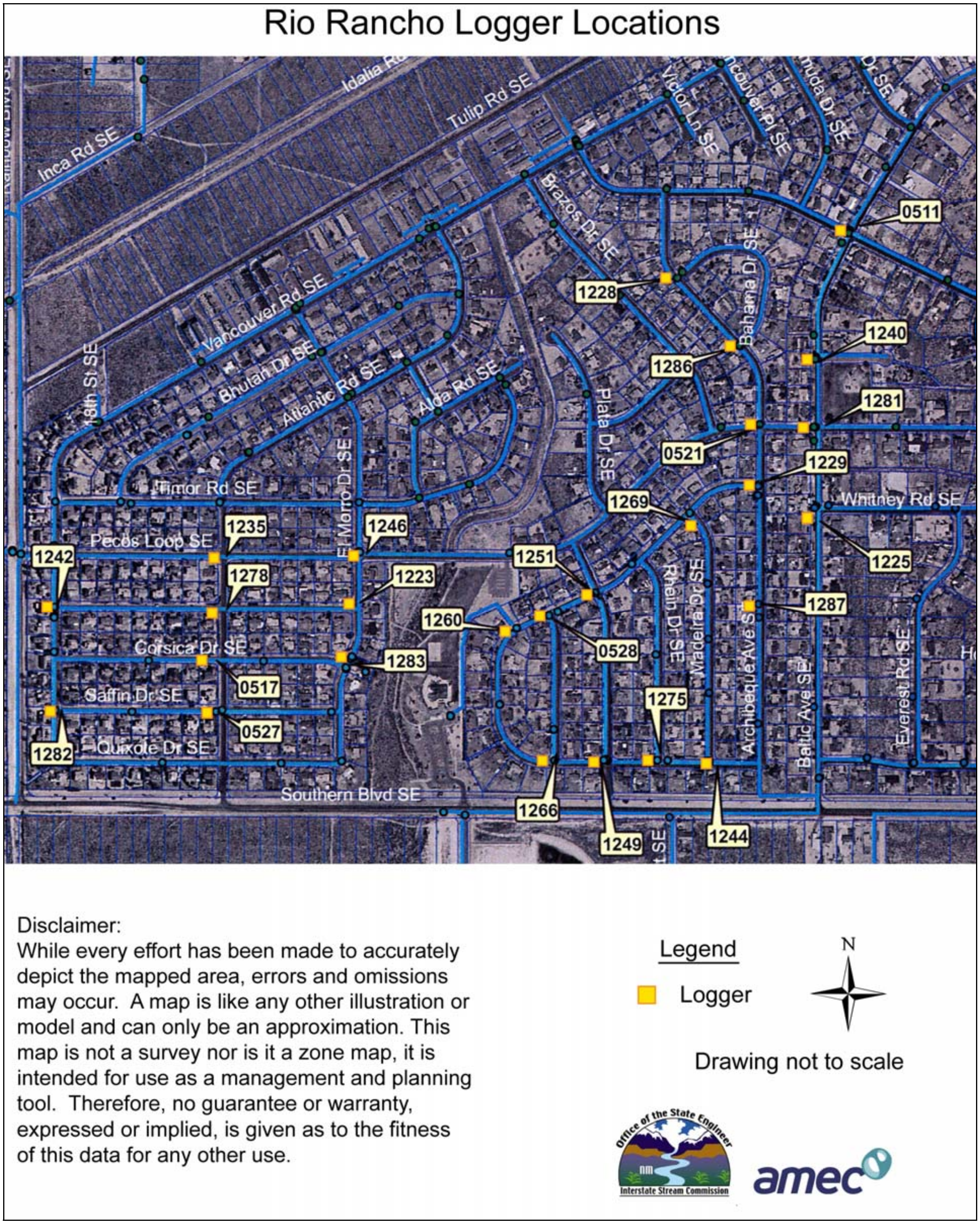
Since the program was implemented in December 2009, approximately 10 percent of the system has been surveyed. The original deployment included placing approximately 90 loggers in areas that historically have had problems with leaks (Figure 15). One lift and shift redeployment has been completed to a similar problem area. These areas had little inspection and oversight during pipeline installation and have problems with piping material and valve placements. The developer at that time installed SDR26 PVC pipe for the distribution lines. This grade of pipe is in a category not accepted by most utilities today. The utility estimates that about 90 percent of the earliest installations done by this developer or about 50 percent of the current system used SDR26 pipe. In addition, earlier developments had sparse installation of water control gate valves and do not have valves on all fire hydrants. This leaves long distances of PVC pipe with no point to place a logger. The City has a long-term plan for replacement of these lines. The City’s Environmental Programs Manager estimates that 30 percent of the system is not appropriate for the program primarily because the valves are not spaced close enough.

Staff Time and Involvement

The utility has dedicated two persons working a total of three to four hours per week doing the drive-by patrolling with approximately 15 minutes spent downloading and reviewing the data. ‘Lift and shift’ redeployment takes about three hours for one person to retrieve 87 loggers and four personnel two days to redeploy the loggers in a new location. At this time budgetary concerns will not allow for a full-time person to be dedicated to the program. However, the city is planning to continue with the current labor/time level.

Leaks Found and Repaired

Rio Rancho found leaks both while installing the loggers and as a result of the acoustic logging equipment. During the original deployment in December 2009, utility staff observed water leaking from a recent asphalt patch. This was called in to be placed on the utility’s leak reporting ‘board’. Four other leaks were identified with the equipment. A logger detected the first leak on Zaragoza Road and Wagontrain Road. The utility used a ground microphone for pinpointing and the leak was located in a meter box. At a second location, the Environmental Programs Manager recognized downloaded data that looked suspicious (level was at a mid-range) but it did not alert as a leak (L) and decided to investigate the area. The second leak was discovered also in a meter box.   For the third leak at a third location, the level data looked suspicious with subsequent readings showed the level decreasing. The leak surfaced prior to further investigation. It was determined that as the leak grew larger the noise level decreased resulting in no alert by the logger. The fourth leak was on a service line and surfaced two days following deployment. The leaks that have surfaced have been repaired. Additional leaks continue to be found by the loggers but have not yet been categorized. A leak detected in December has not yet been repaired by the date of this report.



Rio Rancho Logger Locations

Disclaimer:
While every effort has been made to accurately depict the mapped area, errors and omissions may occur. A map is like any other illustration or model and can only be an approximation. This map is not a survey nor is it a zone map, it is intended for use as a management and planning tool. Therefore, no guarantee or warranty, expressed or implied, is given as to the fitness of this data for any other use.

Legend

🟨 Logger

Drawing not to scale

Figure 15: Locations of logger placement in Rio Rancho, NM

Benefits

Rio Rancho has written a new contract for water maintenance services. It now includes explicit language regarding the locating and repairing of leaks. Two additional benefits are that the public has noticed the leak detection effort and is encouraged and previously unmapped pipelines and valves have been added to the city's water atlas (mapping system). The city does not plan to increase the program or purchase new leak detection equipment in the near future due to budgetary constraints. The existing loggers and equipment should keep the City and CH2M-Hill OMI staff busy for the next several years.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The *Quantifying Leaks with Acoustic Loggers* grant project provided insights to the utilities involved and the NMOSE. All parties came away with a better understanding of the capabilities and limitations of a leak detection system. The utility perspectives were provided by both utility management and field staff during program operation and through closing interviews conducted by NMOSE. The NMOSE perspectives encompass insights from the state and the contractors involved in the project.

5.1 Utility Perspective

The AWWA Audit

The AWWA audit is a valuable tool for cities to evaluate their systems. As one utility manager stated "the inability to find 30 percent of produced water is eye opening". As personnel become familiar with the data needed for the audit and where it originated, the procedure of completing the audit becomes simpler. Data was found, reorganized and clarified for inclusion in the audit. In several cases, procedures are being modified to provide better data acquisition for future audits. All three cities plan to continue completing annual audits, however one city requested additional assistance from NMOSE. Two of the three cities understand the value of the data validity score and are looking for ways to increase this number.

There was mixed confidence in the results of the audit. One city questioned their breakdown of apparent and real losses. This utility manager has stated that next year's audit will produce better numbers. They plan on investigating both their billing procedures and customer metering accuracy to determine a more accurate volume of apparent losses and improve their validation score. Two of the three cities are considering programs to check the reliability of customer meters, especially for large water users. These programs would include verifying and tracking meter installation dates, validating the volume that has passed through the meter, and checking for proper installation. The third city already has a program in place to validate the meters of large water users. One city is in the process of updating their billing software. Although this was not a result of the audits, the utility hopes that it will provide more accurate data for future audits.

All three cities questioned their own production numbers, yet only one city had tested their master meters within the last two years. As a direct result of this project, all three cities are planning to test and calibrate their master meters. These timelines vary. One city has calibrated two out of four meters and is setting up a permanent dual meter system at their main treatment plant. A second city wants to implement testing on an annual basis and plans to start by 2011. The third city has not set a timeline.

Acoustic Logger Leak Detection Program

In all three cases, the cities would not have implemented a leak detection program without the Governor's grant and the NMOSE's assistance. The most common reason provided was the lack of staff time and money, although two of the cities had also debated their confidence in the technology. Each city had their reasons for participating in the audit and leak detection program; the most common reason was the belief that the majority of their non-revenue water was due to leaks. As the program progressed, the technology won over the majority of the field staff. However, some skeptics remain both at the field level and in utility management. The bulk of the skepticism came from placing loggers in areas thought to have leakage problems, yet not finding any leaks. The most faith was put in the ground microphone. It provided the users with instant results, hearing the leak, and became the tool of choice in one city.

All three cities agreed that the training on the use of the equipment and analysis of the data was essential. Only one city felt that the training provided was adequate. The other two felt that the initial training session did not provide enough information and would have liked some follow up sessions. One city wanted more training on the equipment, the other more training on the data analysis. All three cities agreed that if additional training could be provided in the future, it would be useful.

5.2 NMOSE perspective

As operational costs and the price of developing new water supplies increase, alternative options to supply communities with water have become critically important. Cities searching for additional water resources are realizing that conservation of the water they currently have rights to can be less expensive than purchasing additional water rights. In order to conserve water it is imperative that drinking water suppliers understand how their water is used and what the best water conservation technologies and methodologies available to them are.

The AWWA Audit

The AWWA water audit's method of detailing a utility's revenue/non-revenue water and authorized/unauthorized use along with its financial and operational performance indicators provides the appropriate information to begin making water conservation and water management decisions. In order to make good decisions, the audit must have reliable data. The AWWA spreadsheet provides a method by which a utility can evaluate the reliability of their data. A validity grade is requested when a value is entered. When the utility receives a grade of less than 50, it is highly recommended that data validity be the priority. Recommendations for improving the score can be found within the audit spreadsheet on the *Loss Control Planning* worksheet.

It is highly recommended that utilities complete audits annually.

Acoustic Logger Leak Detection Program

The NMOSE implemented the acoustic logger project to test the technology and its relevance in New Mexico. In all three cities, it was proven that the loggers find leaks before they surface.

It was also proven that the loggers worked in a variety of New Mexico cities. In addition to actually finding leaks, the process resulted in providing valuable feedback on how to best implement future leak detection efforts. The benefits from the use of an acoustic logger program are dependent on the manner in which it is managed and operated. The upfront costs, the volume of staff time, appropriate placements, and the repair plan all contribute to the costs and benefits. However, the amount of time devoted to the program also relates to the benefits seen. In general, the more effort applied the better the results. Management has to find the balance with the most appropriate use of staff time within the leak detection program. This knowledge only comes with trial and error. In addition, the utility must receive the appropriate training and technical assistance on the use of the equipment as well as on the analysis and interpretation of the resulting data. With proper training and technical support, the effectiveness of the program is significantly improved.

It is also important to note, that the acoustic loggers are only one of the tools in the leak detection tool box. When used in conjunction with the ground microphone, correlation devices, night flow analysis, and pressure testing, the likelihood of finding leaks increases. In addition, water audits can be conducted at the pressure zone levels to try to quantify losses by zone. This would require a ‘master meter’ for the zone being tested. The tool box also includes the level of the staff expertise and time devoted to the program. The more training personnel receive the better they will be at finding leaks. “More is better” does not necessarily hold true for time dedicated to a program. The cost benefit must be considered when determining the appropriate amount of time to devote to the program. In general, the more aggressive programs tend to find the most leaks. However, time should not exceed the monetary value associated with the real losses. These tools should all be evaluated and adjusted as the utility’s leak detection program and skills progress. The more tools used, the better trained the personnel, and more valid the data, the better the results.

The cost and benefits of a leak detection program should be considered when determining the amount of equipment and the amount of staff time to dedicate to a program. The first level of review is the Annual Cost of Real Losses from the AWWA audit spreadsheet. This value is calculated using the variable costs (electrical and chemical) of providing the next unit of water to its customers. A second level of review that must be considered is avoided cost such as capital and debt for building new treatment plants to accommodate additional supplies. A final consideration must include where the next unit of water is coming from. In New Mexico, this will include available water rights. The purchase cost of additional water rights will vary across the state depending on population growth, hydrology, and the willingness of seller. Given that the majority of New Mexico is a fully appropriated, both surface water and groundwater, acquiring new water supplies is becoming increasingly complicated and costly.

6.0 NEXT STEPS

The NMOSE will continue working with its three partners cities on the acoustic logger leak detection program. Technical assistance on the existing equipment will be provided when requested. Several cities have stated a desire to explore the use of new equipment and technologies. These cities have been invited to attend a training class on correlators and correlating loggers scheduled for May 2010. NMOSE will provide expertise where appropriate and facilitate communication between the cities on knowledge gained. NMOSE will also provide assistance on a post audit to be completed one year after the acoustic loggers were installed. All three cities have agreed to provide annual updates to the NMOSE on the progress and findings of this project. NMOSE anticipates publishing a follow up report on the post audits and progress of the cities.

New Partnership

As a final product of the Governor's Innovation Fund grant, NMOSE is partnering with the New Mexico Rural Water Association (NMRWA) to set up an ongoing leak detection program for small and medium rural water systems. The grant will provide NMRWA with leak detection equipment and the appropriate training. In return, NMRWA will integrate the passive leak detection program into their existing field services program. NMRWA will provide staff time, a notebook computer for communicating with the loggers and analyzing data, as well as a ground microphone to assist with pinpointing leaks. NMWRA will set up an application process to prioritize systems in need of leak detection. NMOSE is requesting that the AWWA audit be included in the application process. This partnership is scheduled to begin in June 2010.

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Appendix A: Ruidoso Water Audit

A.1 Water Supplied

Total metered production by the system for the year 2009 was 585,881,000 gallons (Table 9). Master meters are read daily and the data are manually entered into the spreadsheet, Monthly Water Production Reports, are then transferred into a master database. The data in the Monthly Water Production Reports did not always match the data in the spreadsheets. Master meter testing was performed in March 2010 on meters in the Grindstone Treatment Plant and the Hollywood well. Both sites were tested with the *Controlotron 1010,* an ultrasonic 'strap-on' flow meter. Results from the *Controlotron 1010* comparison test of the Grindstone master meter estimated that the meter is over reporting the amount of water flow by 2.9 percent. Testing of the main meter at the Hollywood well revealed that the well was under reporting the water volume by 5 percent. The City utility manager estimates that the 16" master meter on the Alto Treatment Plant is over reporting production by 15 percent. This is because the meter is not set to the manufacturer's recommended calibration and it is suspected that staff is adjusting the calibration themselves. Testing was attempted on the Alto meter, but due to the concrete lining of the pipes, a test could not be performed with the *Controlotron 1010*. The Alto meter is a magnetoflow (mag) meter that was installed in 2003. A third party consultant did recognize that the installation looked sound and should not be contributing to misreading (Burke, 2010). However, the electrodes on mag meters should be pulled after six months for cleaning. The manufacturer states that high concentrations of conductive solids will affect the accuracy of these meters (Burke, 2010). Because testing could not be completed, the master meter error remains suspect. Ruidoso has purchased a second meter to install at Alto for calibration purposes. This meter is scheduled for installation in the summer of 2010.

Table 9: Monthly water production totals for Ruidoso in FY 2009.

Water Production in Gallons **July 1, 2008 - June 30, 2009**						
Month	**WTPS (Alto)**	**WEP4 (Grindstone)**	**High School**	**Cherokee**	**Hollywood**	**Total**
July, 2008	31,063,000	14,421,000		4,518,000	9,266,000	59,268,000
	36,443,000	15,672,000		2,978,500	3,102,000	58,195,500
	31,339,000	16,402,000		3,884,000		51,625,000
	34,531,000	16,669,000		3,300,000	591,000	55,091,000
	30,566,000	15,331,000		2,830,000	100,000	48,827,000
	27,923,000	17,028,000		3,645,200	3,133,000	51,729,200
	25,277,000	17,702,000		4,833,000	4,838,000	52,650,000
	22,013,000	15,921,000		4,306,000	4,983,000	47,223,000
	22,494,000	17,190,000		5,123,000	963,000	45,770,000
	25,574,000	15,757,000		4,296,000	5,221,000	50,848,000
	22,009,000	17,571,000		4,388,000	16,180,000	60,148,000
	22,667,000	18,870,000	2500	4,684,000	10,863,000	57,086,500
Total	**331,899,00**	**198,534,000**		**48,785,700**	**59,240,000**	**638,461,200**
Meter error from Controlotron Testing	15% (not confirmed)	2.90%		not tested	-5%	
Estimated Master Meter Error	49,784,850	5,757,486			2,962,000	
Difference	-49,784,850	-5,757,486	0	0	2,962,000	-52,580,336
Adjusted Totals	**282,114,150**	**192,776,514**	**2,500**	**48,757,700**	**62,202,000**	**585,880,864**

A.2 Authorized Consumption

Authorized consumption includes billed metered, unbilled metered, billed unmetered and unbilled unmetered accounts. Ruidoso does not have billed unmetered use, but the utilities billing department maintains records for the remaining three categories (Table 10). The Ruidoso Utility billed customers for 411,607,991 gallons in FY 2009. During the audit process unbilled, metered accounts that totaled 2,415,350 gallons were discovered in the billed metered spreadsheet. These accounts were moved to the appropriate unbilled metered spreadsheet and the total was adjusted up to 16,813,220 gallons. A spreadsheet is also kept for estimates of backwashing and plant use, line flushing and miscellaneous village and project uses. This is categorized as unbilled unmetered and totaled 16,401,650 gallons.

Table 10: Ruidoso Authorized Consumption

Month	Billed Metered	UnBilled Metered	UnBilled UnMetered
July 2008	37,948,416	1,145,320	1,505,650
August	44,623,670	870,910	1,231,600
September	31,626,399	855,770	1,248,600
October	32,248,472	949,680	1,735,320
November	29,271,211	1,048,310	1,616,600
December	42,028,587	1,330,540	1,035,260
January 2009	18,071,905	1,822,580	745,590
February	33,671,680	912,490	685,010
March	27,450,836	716,191	1,516,520
April	25,880,861	1,086,219	1,529,620
May	51,226,580	1,712,850	1,840,060
June	39,977,724	1,944,010	1,711,820
Total	**414,026,341**	**14,394,870**	**16,401,650**
errors	-2,418,350	+2,418,350	--
Adjusted Totals	**411,607,991**	**16,813,220**	**16,401,650**

A.3 Water Losses

Total water losses were calculated by using equation 3 and totaled 141,060,000 gallons. This amount represents apparent losses from unauthorized use, end user metering inaccuracies, data handling errors, as well as real losses. The apparent losses totaled 39,143,000 gallons (equation 4). Unauthorized consumption (theft) was calculated using the AWWA default value of 0.25 percent of water supplied. The systematic data handling errors were determined by a month-by-month comparison of the end user meter reporting database versus the billing database. The differences totaled 15,103,084 gallons for the year.

Utility personnel believe that both the systematic data handling errors and the meter inaccuracies could be more of a problem than represented here. The billing software is old and antiquated and makes correlating billing changes/edits difficult to follow. Review of the databases found meters not previously included in the database and placed in the wrong spreadsheet. There are currently no annual audits or reviews performed. Customer metering inaccuracies totaled 31,102,000 gallons. The meter database shows a relatively new system of end-use meters and NMOSE estimated meter accuracy using an equation that determines meter degradation by age (Westerling and Hart, 1995). The estimated meter accuracy is 95 percent (Equation 7) with meter error estimated to be 5 percent for the city's end use meters (Table 11). Field staff stated that there are still finding old meters in the systems that need replacing.

Eq 7: Accuracy (%) = -0.466%* (Age of meter in years) + 97.4%

Ruidoso estimate = $(0.86 \times 95.07) + (0.13 \times 97.4) = 95\%$

Table 11: Ruidoso age distribution of end-use meters and meter accuracy percentage.

2009	Year	Number of Meters	Percent	Age correction co-efficient	Accuracy of meters (weighted ave)
Meters Older than 20 Years	1989	0	0	NA	
Meters Older than 15 Years	1994	2	0.0	NA	
Meters Older than 10 Years	1999	16	0.2	NA	
Meters Older than 5 Years	2004	6383	86.4	95.07	82
Meters Older than 1 Years	2008	984	13.3	97.4	13
Total Number of Meters:		**7385**			**95%**

The remaining 101,917,000 gallons are deemed real losses (equation 5). This comprises 17.4 percent of all water supplied or 37.81 gallons per connection per day. These real losses are suspect due to the validity question of the master meter error adjustment. Without the error adjustment, real losses would be closer to 57 gallons per connection per day. Ruidoso has purchased a second meter to install for calibration purposes. This meter is scheduled for installation in the summer of 2010. Ruidoso documented main break losses of 1,119,963 during this same time frame. These losses were estimated by field staff who responded to breaks and repaired them. This includes a line break as the result of the July 27-28, 2008 flood. The estimates of leak volumes recorded by the crews sent to repair the leaks are outlined in Table 12. It should be noted that due to the estimates in the water supplied, master meter error, the real losses could be significantly higher.

Table 12: Ruidoso estimated water losses from pipeline leaks.

Month	*Main Break Losses (gallons)
July	75,250
August	60,500
September	6,500
October	20,200
November	32,000
December	30,000
January	47,200
February	82,500
March	64,600
April	287,200
May	132,263
June	281,750
TOTAL	**1,119,963**

A.4 Non-Revenue Water

Non-Revenue water is water the utility produces from which it does not receive payment. This includes both authorized (i.e. fire fighting) and unauthorized (i.e. real and apparent losses). Approximately 174,273,000 gallons (29.7 percent) or 64.65 gallons per connection per day of non-revenue water were produced in 2009 using equation 6.

A.5 System Data

The Ruidoso system has approximately 160 miles of distribution line with 7,385 connections. The large number of connections compared to the year round population represents a vacancy rate over 50 percent. This is due to the resort nature of the city, including second homes and vacation rentals. The utility places the meters at the curb which according to the AWWA spreadsheet results in a 0 feet for the average length of a customer meter line. The average operating pressure of the system is estimated to be 75 pounds per square inch (psi). However, this represents a highly variable range of pressure throughout the system, 35 psi – 260 psi. The high pressure areas are needed due to the large elevation changes within the city (DBS&A, 2007).

A.6 Cost Data

Cost data included in the AWWA audit includes annual operating costs, annual variable costs, and an average for customer rates. Operating and variable costs were taken from the Financial Management Budget Performance Report dated 6/30/09 supplied by the utility (Fund 02: Utility and Account Classification and Fund 711: Personnel). Variable costs included utilities and chemicals, and are $405.00 per million gallons of produced water. All other costs were placed in operating costs which equaled $2,518,819 for the year. The customer unit cost or customer rate is $2.23 per 1,000 gallons using a weighted average by volume of water sold and average customer rates for residential and commercial (Table 13).

Table 13: Ruidoso's charge fee per use and type with weighted average cost by volume.

Current Water Commodity Charges (Fee per 1,000 Gallons ($)		
Range	Residential	Commercial, Industrial, Institutional
4,001 – 25, 000	$2.00	$2.00
25,001 – 35,000	$4.00	$2.75
35,001 – 55,000	$8.00	$3.50
55,001 – 75,000	$16.00	$4.25
75,001 – 100,000	$32.00	$5.00
100,001 – 125,000	$64.00	$5.75
125,001 – 150,000	- -	$6.50
150,001 – 1,000,000	- -	$18.75
(0.70 x $2.00) + (0.30 x $2.75) = $2.23 The weighted average cost per volume unit of water (1,000 gallons)		

A.7 Performance Indicators

The performance indicators are tracked as both financial indicators and operational efficiency indicators. The Ruidoso system's non-revenue water as percentage by volume of water supplied is 29.7 percent or 64.6 gallons per connection per day. This means that almost 30 percent of the water placed into the distribution system is not billed. It includes real losses, apparent losses and unbilled authorized consumption. If this were billable water, it would represent 5.6 percent of the annual operating costs of the system. The estimated annual cost of apparent losses is $87,289.00. Apparent loss costs are calculated using the customer retail unit cost per 1,000 gallons. The estimated annual cost of real losses is $41,276.00. Real loss costs are calculated using the variable production costs. The operational performance indicators show that apparent losses are 14.52 gallons per connection per day and the real losses are 37.81 gallons per connection per day. It should be noted that without the master meter error adjustment, the real losses per connection per day would be closer to 57 gallons.

A.8 Data Validity/Priority Areas

The AWWA water audit spreadsheet (WASv4.0) includes a data validity score and priority areas for attention. Ruidoso received 41 out of 100 for their data validity score. This is a weighted value based on the importance of the various data values requested. Ruidoso provided a rating for each of the data values provided in the report. The ratings are based on the AWWA Grading Matrix provided within the water audit spreadsheet. The Grading Matrix also provides recommendations on the actions that can be taken by the utility to increase their scores. Due to the low validity score, it is highly recommended that Ruidoso focuses on improving their data.

The audit spreadsheet prioritized the following areas for attention as follows:

1. Volume from own sources
2. Master meter error adjustment, and
3. Unbilled metered

A.9 Audit Recommendations

Upon reviewing the AWWA audit, the NMOSE recognized the primary issues in conducting the audit were:

1. The accuracy of the main production meters
2. The inconsistencies between the utilities database system (both production and end-users) and billing departments database system and
3. The inconsistent or questionable data regarding the age of the billing meters.

The following recommendations from NMOSE on improving data validity are:

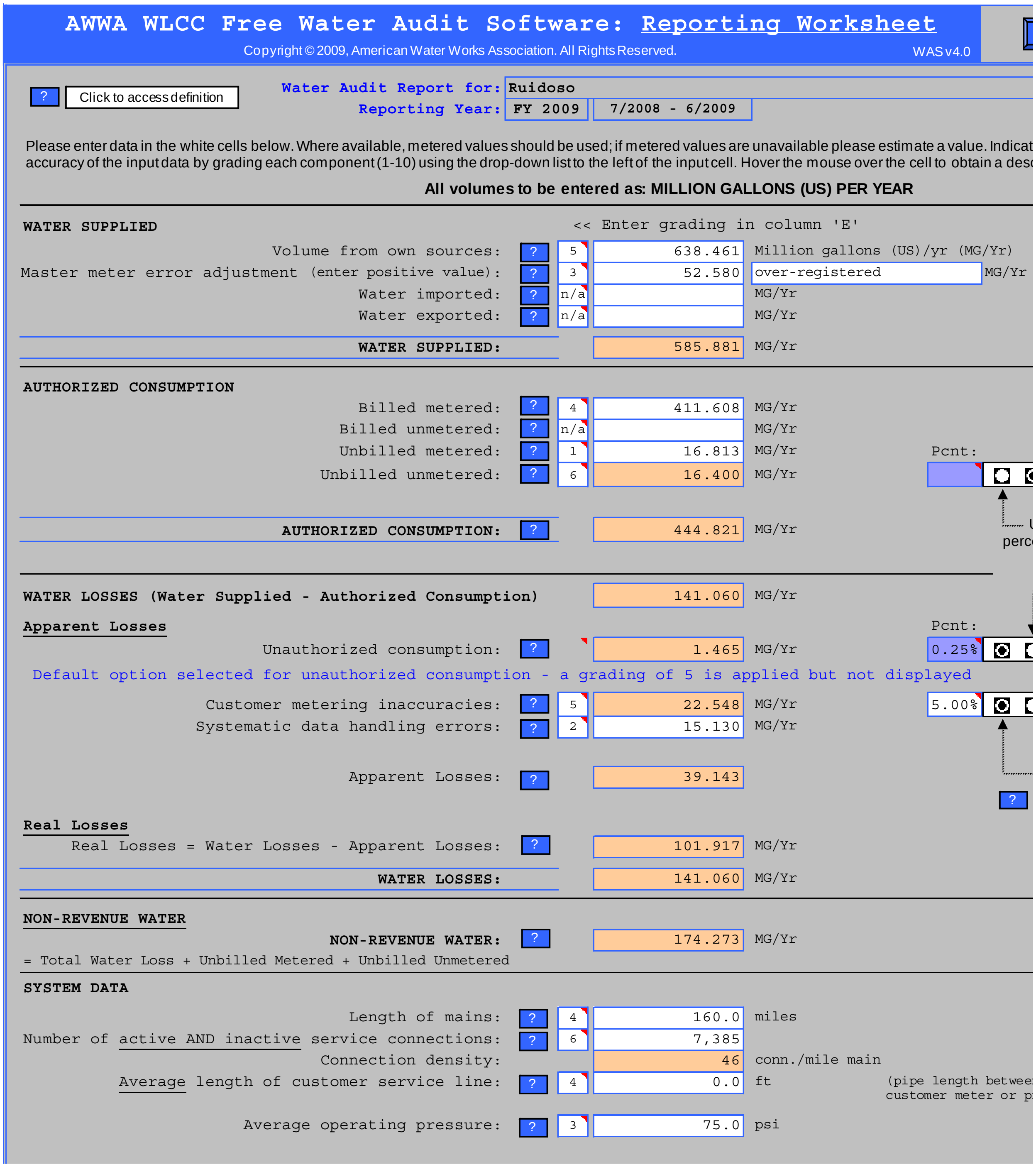
- Calibrate and test the meter at the Alto Treatment Plant and testing of the meter at Cherokee well. Development of a routine testing and calibration program for all master meters. The current audit is suspect due to estimates on Alto master meter overages provided by the utility but not confirmed.
- Initiate a protocol on how master meters are read and transferred into database. Consider quality control of data using the existing supervisory control and data acquisition (SCADA) system.

- Update billing database to clean up the billed and unbilled accounts. Initiate a protocol on how changes/corrections are made in the billing database so transactions are easily tracked and treated uniformly.
- Confirm the ages and installation dates of all end-use meters.
- Designate a responsible person to assemble, review, and analyze the water audit data on at least an annual basis to determine water losses and implement reductions in water loss.
- Evaluate the grading scale from the AWWA software, improve the level of validation for the three most important data inputs.

The following are recommendations from the NMOSE on reducing the volume of non-revenue water:

- Conduct a top down audit of the largest users in the system. Determine if the users are in the appropriate range of use. If not, conduct a meter test.
- Replace older meters that are outside of the warranty time frame or volume limits.
- Continue the leak detection program at current staffing levels allowing flexibility to reorganize the program in a way that works best for the unique conditions of the City.

A.10 Ruidoso’s AWWA Reporting Worksheet



AWWA WLCC Free Water Audit Software: Reporting Worksheet

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WAS v4.0

Water Audit Report for: Ruidoso

Reporting Year: FY 2009 7/2008 - 6/2009

Please enter data in the white cells below. Where available, metered values should be used; if metered values are unavailable please estimate a value. Indicat accuracy of the input data by grading each component (1-10) using the drop-down list to the left of the input cell. Hover the mouse over the cell to obtain a desc

All volumes to be entered as: MILLION GALLONS (US) PER YEAR

WATER SUPPLIED << Enter grading in column 'E'

Volume from own sources:	5	638.461	Million gallons (US)/yr (MG/Yr)
Master meter error adjustment (enter positive value):	3	52.580	over-registered MG/Yr
Water imported:	n/a		MG/Yr
Water exported:	n/a		MG/Yr
WATER SUPPLIED:		585.881	MG/Yr

AUTHORIZED CONSUMPTION

Billed metered:	4	411.608	MG/Yr
Billed unmetered:	n/a		MG/Yr
Unbilled metered:	1	16.813	MG/Yr
Unbilled unmetered:	6	16.400	MG/Yr
AUTHORIZED CONSUMPTION:		444.821	MG/Yr

Pcnt:

perc

WATER LOSSES (Water Supplied - Authorized Consumption) 141.060 MG/Yr

Apparent Losses

Pcnt:

Unauthorized consumption:		1.465	MG/Yr	0.25%

Default option selected for unauthorized consumption - a grading of 5 is applied but not displayed

Customer metering inaccuracies:	5	22.548	MG/Yr	5.00%
Systematic data handling errors:	2	15.130	MG/Yr	
Apparent Losses:		39.143		

Real Losses

Real Losses = Water Losses - Apparent Losses: 101.917 MG/Yr

WATER LOSSES: 141.060 MG/Yr

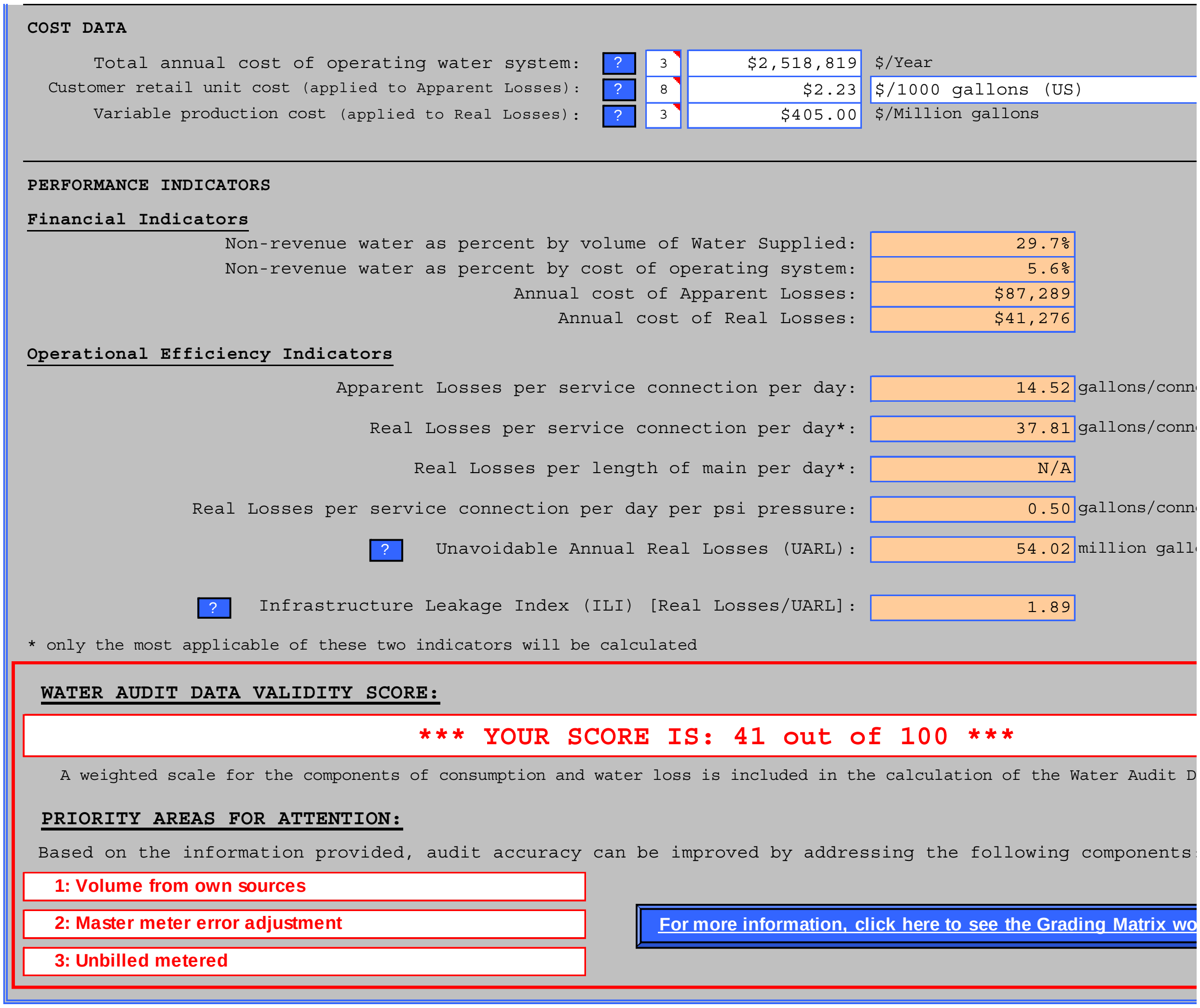
NON-REVENUE WATER

NON-REVENUE WATER: 174.273 MG/Yr

= Total Water Loss + Unbilled Metered + Unbilled Unmetered

SYSTEM DATA

Length of mains:	4	160.0	miles
Number of active AND inactive service connections:	6	7,385	
Connection density:		46	conn./mile main
Average length of customer service line:	4	0.0	ft (pipe length betwee customer meter or p
Average operating pressure:	3	75.0	psi



COST DATA

Total annual cost of operating water system:	?	3	$2,518,819	$/Year
Customer retail unit cost (applied to Apparent Losses):	?	8	$2.23	$/1000 gallons (US)
Variable production cost (applied to Real Losses):	?	3	$405.00	$/Million gallons

PERFORMANCE INDICATORS

Financial Indicators

Non-revenue water as percent by volume of Water Supplied:	29.7%
Non-revenue water as percent by cost of operating system:	5.6%
Annual cost of Apparent Losses:	$87,289
Annual cost of Real Losses:	$41,276

Operational Efficiency Indicators

	Apparent Losses per service connection per day:	14.52	gallons/conn
	Real Losses per service connection per day*:	37.81	gallons/conn
	Real Losses per length of main per day*:	N/A	
	Real Losses per service connection per day per psi pressure:	0.50	gallons/conn
?	Unavoidable Annual Real Losses (UARL):	54.02	million gall
?	Infrastructure Leakage Index (ILI) [Real Losses/UARL]:	1.89	

* only the most applicable of these two indicators will be calculated

WATER AUDIT DATA VALIDITY SCORE:

*** YOUR SCORE IS: 41 out of 100 ***

A weighted scale for the components of consumption and water loss is included in the calculation of the Water Audit D

PRIORITY AREAS FOR ATTENTION:

Based on the information provided, audit accuracy can be improved by addressing the following components

1: Volume from own sources

2: Master meter error adjustment

3: Unbilled metered

For more information, click here to see the Grading Matrix wo

Appendix B: Las Vegas Water Audit

B.1 Water Supplied

Total metered production by the Las Vegas system for the year FY 2009 was 792,156,000 gallons (Table 14). The data was supplied by the utility from their production reports. The water treatment plant production meter has a remote totalizing read-out that is read by operating staff and meter readings are recorded every day. The water treatment meter is an 18" Endress @Hauser Promag 53 F (Hydrosphere, 2007). The Taylor well field is measured by an eight-inch DanFoss MAGFLO 5100 meter and the totalizer value is read daily (Hydrosphere, 2007). These production meters have not been calibrated since installation; staff indicated that installation of both meters occurred approximately six years ago. Access to the water treatment production meter is limited due to its location in an underground vault. Visual inspection for proper installation was not conducted. Therefore, a master meter error adjustment was not calculated.

Table 14: Las Vegas water production in gallons from July 1, 2008 - June 30, 2009

Water Production in Gallons
July 1, 2008 - June 30, 2009

Month	Filter Plant	Taylor Wells	Total
July, 2008	55,963,000	4,475,000	60,438,000
August	61,552,000	2,239,000	63,791,000
September	63,468,000	0	63,468,000
October	59,253,000	0	59,253,000
November	56,951,000	2,087,000	59,038,000
December	65,461,000	1,551,000	67,012,000
January	65,174,000	5,728,000	70,902,000
February	62,504,000	3,128,000	65,632,000
March	68,711,000	0	68,711,000
April	70,233,000	0	70,233,000
May	72,845,000	1,015,000	73,860,000
June, 2009	62,400,000	7,418,000	69,818,000
Total	**764,515,000**	**27,641,000**	**792,156,000**

B.2 Authorized Consumption

Authorized consumption was 544,284,000 gallons for FY2009. The Las Vegas Utility billed customers for 516,122,000 gallons. Billing data were compiled from revenue reports that are categorized by commercial, large commercial, livestock, residential, small commercial and stand pipe (Table 15). The City reportedly does not have any billed unmetered use. The unbilled metered water constitutes some of the use at the water treatment plant and is estimated to be 18,260,000 gallons per year. There are additional unbilled, metered connections used for livestock near the Taylor Well field. These connections were discussed during the audit process and were added to the unbilled metered database. Unbilled, unmetered was estimated using the default value of 1.25 percent or 9,902,000 gallons for the year. Firefighting data was provided by the city, however, the default value was used because the city did not provide estimates for water used during fire hydrant, water main, and sewer flushing and street sweeping.

Table 15: Las Vegas total amount of authorized consumption that was billed in FY 2009.

Authorized Consumption (gallons)
July 1, 2008 - June 30, 2009

Month	Commercial	Large Commercial	Livestock	Residential	Small Commercial	Stand Pipe	Total
July 2008	11,200	15,862,580	3,400	31,708,894	4,679,464	23,550	52,289,088
August	11,640	13,838,133	4,000	26,882,587	4,708,441	20,650	45,465,451
September	14,870	13,816,025	1,700	26,615,154	4,594,979	24,000	45,066,728
October	8,680	13,083,080	7,300	24,576,312	4,341,447	20,250	42,037,069
November	7,550	11,580,800	62,100	23,251,011	3,984,387	19,850	38,905,698
December	6,988	12,992,753	4,700	23,459,633	3,912,745	20,575	40,397,394
January	13,562	12,176,608	166,500	26,276,627	4,067,872	19,575	42,720,744
February	10,970	10,482,225	171,000	23,727,219	3,796,140	16,000	38,203,554
March	10,740	10,768,730	6,400	21,750,240	3,289,855	19,900	35,845,865
April	11,810	12,248,714	7,600	23,443,964	3,547,619	27,855	39,287,562
May	12,200	16,028,805	13,700	27,460,648	4,015,420	25,670	47,566,433
June 2009	17,110	16,501,181	21,700	27,527,715	4,249,602	29,300	48,346,608
Total	**137,320**	**159,379,634**	**470,100**	**306,680,004**	**49,187,971**	**267,175**	**516,132,194**

B.3 Water Losses

Water losses amounted to 247,872,000 gallons for FY 2009 (equation 3). This amount represents apparent losses from unauthorized use, end user metering inaccuracies, data handling errors, as well as real losses. Apparent losses totaled 38,243,000 gallons (equation 4). Unauthorized consumption (theft) was calculated using the AWWA default value of 0.25 percent of water supplied or 1,980,000 gallons. In order to determine how much water loss resulted from systematic data handling errors an estimate of 1 percent of billed water was used based on the audit performed by Hydrosphere in 2007. This amount totaled 5,161,000 gallons. The utility did supply spreadsheets from their database system for review; however, the format was such that NMOSE was unable to evaluate the accuracy, therefore, the above mentioned number was used. The final category in apparent losses is customer metering inaccuracies. 5,000 meters were purchased in 2004 of which 4800 have been installed. This means that approximately 73 percent of consumer meters are less than 10 years old. Using equation 7 by Westerling and Hart, 1995, the estimated meter accuracy is 94.5 percent with meter error estimated to be 5.5 percent for the city’s end use meters (Table 16). Customer metering inaccuracies totaled 31,102,000 gallons.

Las Vegas Estimate =

$$(0.12 \times 88.08) + (0.10 \times 90.41) + (0.05 \times 92.74) + (0.37 \times 95.07) + (0.36 \times 97.4) = 94.55\%$$

Table 16: Las Vegas summary of the age of customer meters and meter accuracy

2009	Year	Number of Meters	Percent	Age correction co-efficient	Accuracy of meters (%)
Meters older than 20 years	1989	807	12.4	88.08	10.9
Meters older than 15 years	1994	642	9.8	90.41	8.9
Meters older than 10 years	1999	302	4.6	92.74	4.3
Meters older than 5 year	2004	2407	36.9	95.07	35.1
Meters older than 1 year	2008	2364	36.2	97.4	35.3
Total Number of Meters		**6522**			**94.5%**

The remaining 209,629,000 gallons are calculated real losses (equation 5). This comprises 26.5 percent of all water supplied or 87.4 gallons per connection per day. The city did not provide documentation on loss estimates due to leaks or overflows. Anecdotal information from staff revealed that a tank overflow occurred in the summer of 2008 that went uncorrected for approximately one month. Although this is undocumented, this overflow is suspected to have contributed to the real loss volume.

B.4 Non-Revenue Water

Non-revenue water is water the utility produces from which it does not receive payment. This includes both authorized (i.e. fire fighting) and unauthorized (i.e. real and apparent losses). Approximately 276,034,000 gallons (34.8 percent of total production) or 115 gallons per connection per day of non-revenue water were produced in FY2009.

B.5 System Data

According to information provided by City utility there are approximately 124.2 miles of main pipe lines ranging in diameter from 18 inches to ½ inch. They are divided into three pressure zones: Zone 1 ranges from 50-100 psi, Zone 2 ranges from 45-100 psi and Zone 3 ranges from 40-90 psi. An average of 75 psi was used for this audit. There are 6,445 active and inactive service connections with a connection density of 52 connections per mile. The average customer service line is 0 feet in length.

B.6 Cost Data

Cost data included in the AWWA audit includes annual operating costs, annual variable costs, and an average for customer rates. All cost data was provided by the Utility in a report titled *Fund 640 Detailed Budget Report, Fiscal Year 2009.* Variable costs, which included utilities and chemicals, totaled $202,000.00 or $255.00 per million gallons of produced water. All other costs were placed in operating costs which equaled $3,998,597. The average for customer rates or cost per unit of water is $2.29. This weighted average was determined by the volume of water sold to residential and commercial customers and their corresponding rates (Table 17).

Table 17: Las Vegas cost per unit fee with percentage of use.

Current Water Commodity Charges (Fee per 1,000 Gallons ($))			
Type of Use	**Average amount Used (gallons)**	**Rate at average use**	**Percentage of Use**
Residential	4,600	$2.02	60%
Commercial, Industrial, Institutional	22,740	$2.69	40%
(0.60 x $2.02) + (0.40 x $2.69) = $2.29 The weighted average cost per volume unit of water (1,000 gallons)			

B.7 Performance Indicators

The performance indicators are tracked as both financial and operational efficiency indicators. The Las Vegas system's non-revenue water as percentage by volume of water supplied is 34.8 percent or 115.8 gallons per connection per day. This means that almost 35 percent of the water placed into the distribution system is not billable water. It includes real losses, apparent losses and unbilled authorized consumption. If this were billed water, it would represent 3.7 percent of the annual operating costs of the system. The annual cost of apparent losses is $87,576.00. Apparent loss costs are calculated using the customer retail unit cost per 1,000 gallons. The annual cost of real losses is $53,455.00. Real loss costs are calculated using the variable production costs. The operational performance indicators show that apparent losses are 15.95 gallons per connection per day and the real losses are 87.4 gallons per connection per day.

B.8 Data Validity/Priority Areas

The AWWA water audit spreadsheet (WASv4.0) includes a data validity score and priority areas for attention. Las Vegas received 53 out of 100 for their data validity score. This is a weighted value based on the importance of the various data values requested. The data validity was estimated by NMOSE and contractors and has not been confirmed by the utility.
The ratings system is provided in the AWWA Grading Matrix within the water audit spreadsheet. The Grading Matrix also provides recommendations on the actions that can be taken by the utility to increase their scores.

The audit spreadsheet prioritized the following areas for attention as follows:

1. Volume from own sources
2. Unbilled metered
3. Customer metering inaccuracies

B.9 Audit Recommendations

Upon reviewing the AWWA audit, the following actions are recommended by the NMOSE to improve water accountability and conservation. The primary issues of concern are:

1. The accuracy of the main production meters
2. Lack of ability to review and track data in the utilities database system, and
3. The inconsistent data regarding end-user meters

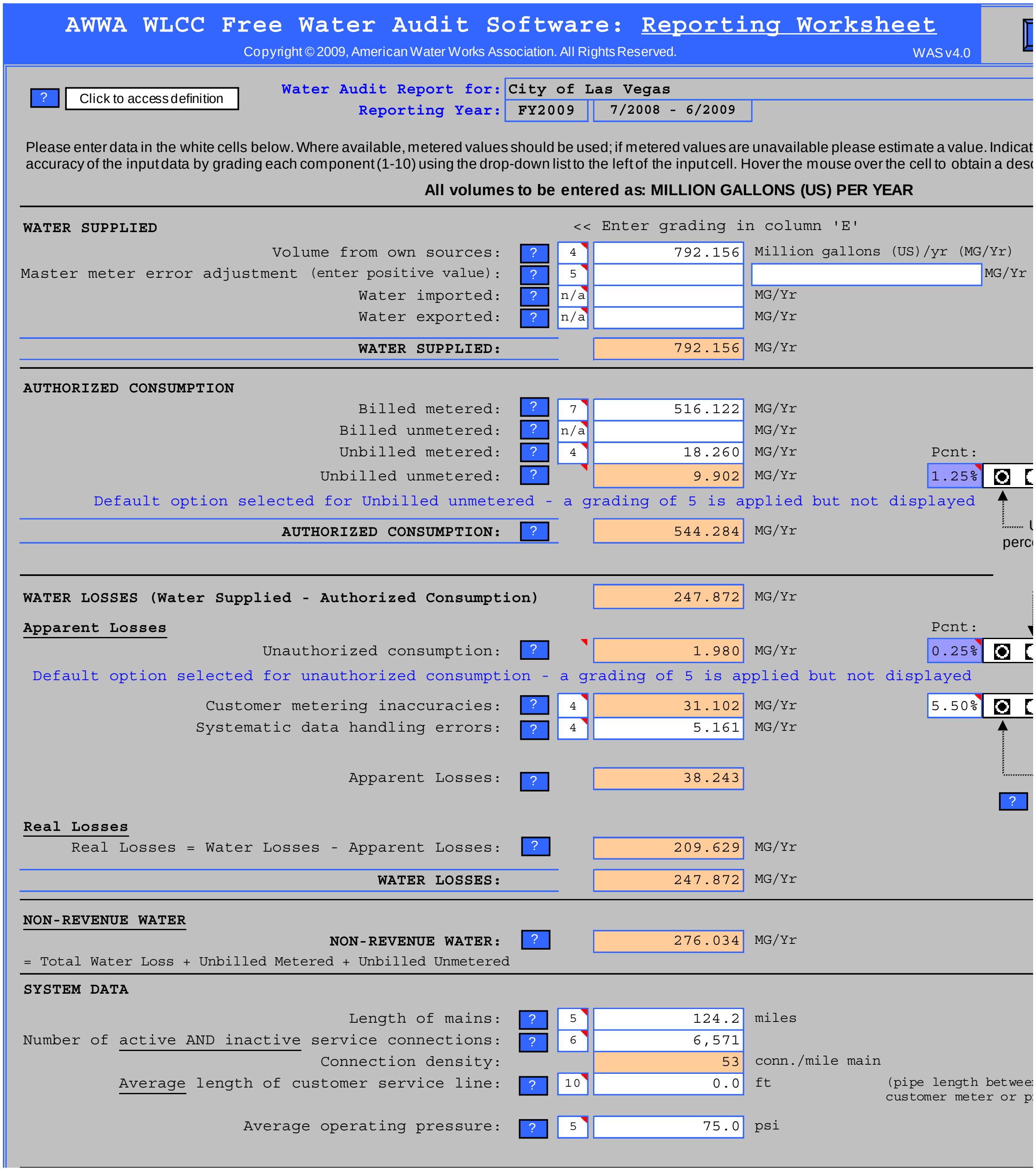
The following are recommendations by NMOSE in order to improve data validity:

- Review Grading Matrix and scores assigned by NMOSE and update where appropriate.
- Perform regular testing and calibration of the production meters and meters on the Taylor Wells.
- Obtain an estimated error on the master meters and proceed with an adjustment in the AWWA audit.
- Review data handing methods and update or revise software to track billing adjustments and changes to simplify the review process.
- Review and improve the data validation scores as presented on the AWWA software.

The following are recommendations by the NMOSE to reduce the volume of non-revenue water:

- Conduct a top down or paper audit of the largest users in the system to determine if these users are in the appropriate range of use. If not, conduct a meter test.
- There are numerous issues related to the structure of the metering system that should be investigated and corrected if a problem is discovered. Some of these issues are:
    - Check that the meters are the correct size for the job: small meter with large amounts of water going through it will not spin fast enough to meter the correct water amount and vice versa a large meter with a low flow will not spin and no water usage will be recorded.
    - If a line is double metered are they being properly recorded and billed?
    - Large commercial properties that have old meters should be replaced.
    - Are meter rollovers properly recorded?
- Continue the leak detection program and develop a protocol on how to repair leaks.
- Consider reallocating a technician full-time, to run the pro-active leak detection program.

B.10 Las Vegas AWWA Reporting Worksheet



AWWA WLCC Free Water Audit Software: Reporting Worksheet

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WAS v4.0

Water Audit Report for: City of Las Vegas

Reporting Year: FY2009 7/2008 - 6/2009

Please enter data in the white cells below. Where available, metered values should be used; if metered values are unavailable please estimate a value. Indicat
accuracy of the input data by grading each component (1-10) using the drop-down list to the left of the input cell. Hover the mouse over the cell to obtain a desc

All volumes to be entered as: MILLION GALLONS (US) PER YEAR

WATER SUPPLIED

<< Enter grading in column 'E'

Volume from own sources: 4 792.156 Million gallons (US)/yr (MG/Yr)
Master meter error adjustment (enter positive value): 5 MG/Yr
Water imported: n/a MG/Yr
Water exported: n/a MG/Yr

WATER SUPPLIED: 792.156 MG/Yr

AUTHORIZED CONSUMPTION

Billed metered: 7 516.122 MG/Yr
Billed unmetered: n/a MG/Yr
Unbilled metered: 4 18.260 MG/Yr
Unbilled unmetered: 9.902 MG/Yr Pcnt: 1.25%

Default option selected for Unbilled unmetered - a grading of 5 is applied but not displayed

AUTHORIZED CONSUMPTION: 544.284 MG/Yr

U
perc

WATER LOSSES (Water Supplied - Authorized Consumption) 247.872 MG/Yr

Apparent Losses Pcnt:

Unauthorized consumption: 1.980 MG/Yr 0.25%

Default option selected for unauthorized consumption - a grading of 5 is applied but not displayed

Customer metering inaccuracies: 4 31.102 MG/Yr 5.50%
Systematic data handling errors: 4 5.161 MG/Yr

Apparent Losses: 38.243

Real Losses

Real Losses = Water Losses - Apparent Losses: 209.629 MG/Yr

WATER LOSSES: 247.872 MG/Yr

NON-REVENUE WATER

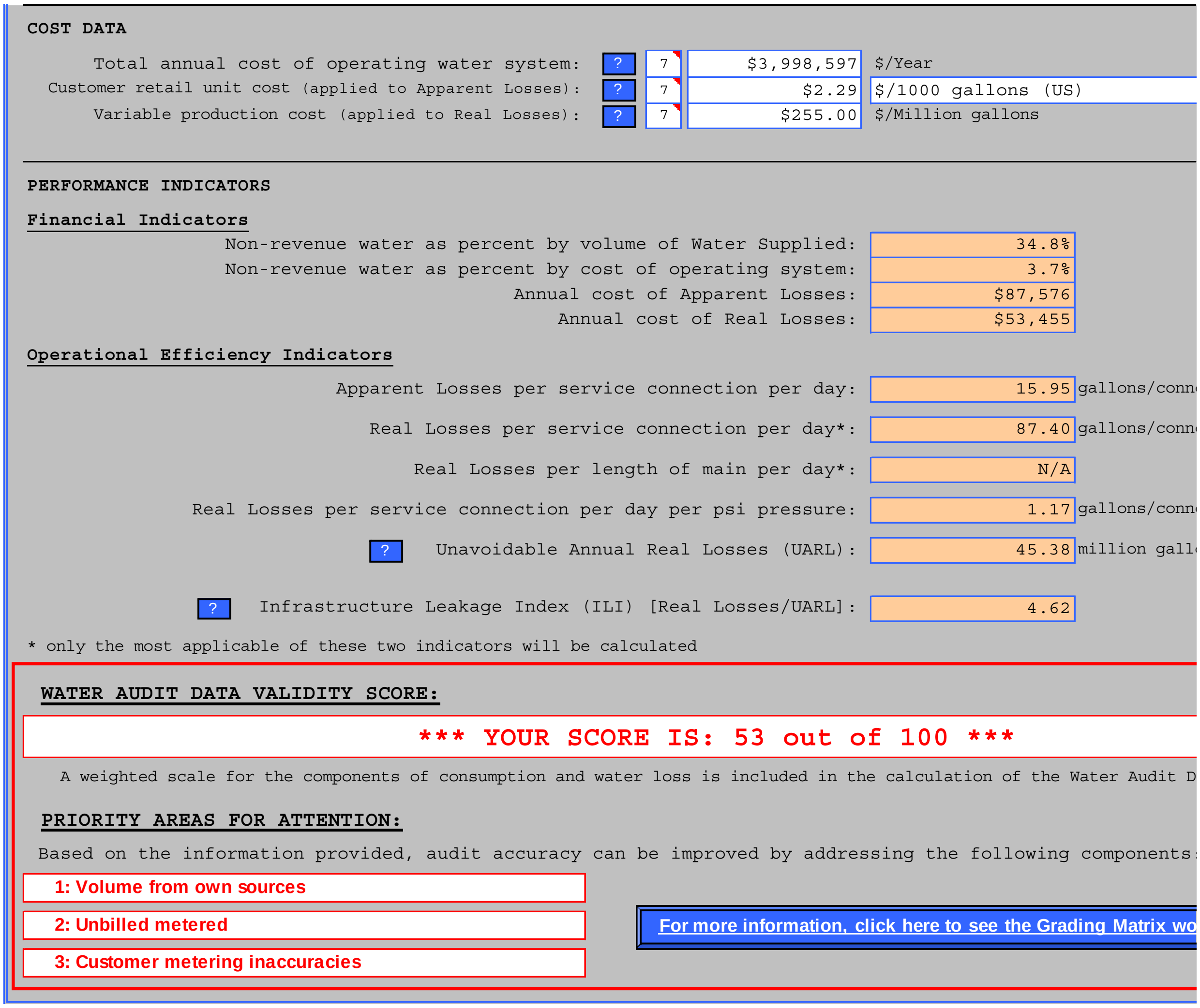
NON-REVENUE WATER: 276.034 MG/Yr

= Total Water Loss + Unbilled Metered + Unbilled Unmetered

SYSTEM DATA

Length of mains: 5 124.2 miles
Number of active AND inactive service connections: 6 6,571
Connection density: 53 conn./mile main
Average length of customer service line: 10 0.0 ft (pipe length betwee customer meter or p

Average operating pressure: 5 75.0 psi



COST DATA

Total annual cost of operating water system:	?	7	$3,998,597	$/Year
Customer retail unit cost (applied to Apparent Losses):	?	7	$2.29	$/1000 gallons (US)
Variable production cost (applied to Real Losses):	?	7	$255.00	$/Million gallons

PERFORMANCE INDICATORS

Financial Indicators

Non-revenue water as percent by volume of Water Supplied:	34.8%
Non-revenue water as percent by cost of operating system:	3.7%
Annual cost of Apparent Losses:	$87,576
Annual cost of Real Losses:	$53,455

Operational Efficiency Indicators

Apparent Losses per service connection per day:	15.95	gallons/conn
Real Losses per service connection per day*:	87.40	gallons/conn
Real Losses per length of main per day*:	N/A	
Real Losses per service connection per day per psi pressure:	1.17	gallons/conn
? Unavoidable Annual Real Losses (UARL):	45.38	million gall
? Infrastructure Leakage Index (ILI) [Real Losses/UARL]:	4.62	

* only the most applicable of these two indicators will be calculated

WATER AUDIT DATA VALIDITY SCORE:

***** YOUR SCORE IS: 53 out of 100 *****

A weighted scale for the components of consumption and water loss is included in the calculation of the Water Audit D

PRIORITY AREAS FOR ATTENTION:

Based on the information provided, audit accuracy can be improved by addressing the following components

1: Volume from own sources

2: Unbilled metered

3: Customer metering inaccuracies

For more information, click here to see the Grading Matrix wo

Appendix C: Rio Rancho Water Audit

C.1 Water Supplied

Totaled meter production for the City in 2008 was 4,267,140,772 gallons. The data was supplied by the operations contractor CH2M-Hill OMIfrom their production reports. A supervisory control and data acquisition (SCADA) system is in place to collect data, however, manual reads are also conducted daily and totaled monthly for inclusion into the Utility Commission Report and the NMOSE reports. No water is imported or exported. All the production well meters are Krohne ECONO MAG meters except one that is a McCrometer Ultra Mag meter (WPRC, 2007). Selected master meters were tested in early 2007 with a clamped on portable meter and the average of all the master meters tested were underreporting by approximately one percent. For this audit, a master meter error of two percent under registering was used due to an assumed drift in meter accuracy over time. This amounts to an additional 85,340,000 gallons added to the metered production value to calculate the total water supplied value of 4,352,480,000 gallons.

C.2 Authorized Consumption

Authorized consumption was 3,638,274,000 gallons for 2008. The City billed customers for 3,630,336,000 gallons. Billing data were compiled from reports that are categorized by single-family residential, multi-family residential (2-4 units), commercial (including multi-family residential (>4 units), industrial, city, and irrigation. Customer meters are read on a 28 day cycle. Forty percent of the system is Automatic Meter Read (AMR), with the expectation that the entire system will be AMR by 2012. The City does not have any billed unmetered or unbilled metered use. As there were no significant changes in the last two years, Rio Rancho choose to use the unbilled, unmetered estimate for fire fighting and street cleaning from the 2007 report. However, the method for fire hydrant flushing significantly changed in 2008, reducing that amount of water used. In addition, the ditch witch value has been added to the 2008 value. The total unbilled, unmetered for 2008 is 7,938,000 gallons (Table 18).

Table 18: Rio Rancho unbilled, unmetered water

Category	Volume (gallons)
Fire fighting	5,870,000
Street cleaning	1,200,000
Flushing	844,551
Ditch witch	23,440
Total	**7,938,000**

C.3 Water Losses

Water losses for 2008 amounted to 714,206,000 gallons, with apparent losses totaling 118,539,000 gallons. This amount represents apparent losses from unauthorized use, end user metering inaccuracies, data handling errors, as well as real losses. Unauthorized consumption or theft was calculated using a default value of 0.25 percent which totaled 10,881,000 gallons. Previous reports had unauthorized consumption values almost as high as two percent of water produced. A good percentage of unauthorized consumption had previously come from unauthorized diversions during construction activities. This amount has decreased as development and construction in the area has slowed. Also, the City has increased enforcement of regulations of the fire hydrant meter program improving the measurement of the water used through this program. Customer metering inaccuracies were the largest source of apparent losses and totaled 102,657,000 gallons. The amount was estimated using a rate of 2.75 percent meter inaccuracy. This rate was determined by Rio Rancho using the number of meters over 20 years old. The age of most 2 inch meters and larger are less than 2 years old with 40 percent of the 5/8 inch meters being less than 4 years old. The majority of this information was duplicated from the 2007 audit. Losses due to systematic data handling errors were estimated at 5,000,000 gallons. Recommendations in the 2006 audit were implemented in 2007 and have vastly improved the 2008 database. They have a fairly sophisticated DOS-based billing system that allows for rereads and rebilling without changing meter values.

The remaining 595,667,000 gallons are deemed real losses (equation 5). This comprises 13.7 percent of total production or 55 gallons per connection per day. Rio Rancho documented main break losses of 2,966,201gallons during this same time frame. These losses were estimated by field staff who responded to breaks and repaired them (Table 19).

Table 19: Rio Rancho's Documented Leaks, 2008

Month	Leaks (gal)
January	150,232
February	123,020
March	300,570
April	291,760
May	178,740
June	536,424
July	208,200
August	265,500
September	415,800
October	220,740
November	128,294
December	146,921
Totals (gal)	**2,966,201**

C.4 Non-Revenue Water

Non-revenue water is water that is produced and put into the system for which the City does not receive payment. This includes both authorized and unauthorized uses. The audit revealed that the city is not being paid for 722,144,000 gallons or 16.6 percent of the produced water. This amounts to losses of approximately 66.6 gallons per connection per day.

C.5 System Data

The City has approximately 524 miles of distribution lines and 29,689 inactive/active connections with a connection density of 57 connections per mile of water pipe (City of Rio

Rancho 2008 audit). The City's system has nine pressure zones ranging from 45 to 150 psi, with the average system pressure estimated to be 65 psi (WPRC, 2007).

Rio Rancho differs from Ruidoso and Las Vegas in that it does not have city water utility staff, instead it subcontracts its water works department to an outside company. Currently the contract is held by CH2M-Hill OMI.

C.6 Cost Data

Cost data included in the AWWA audit includes annual operating costs, annual variable costs, and an average for customer rates. Rio Rancho pulled the cost of the operating system from their Public Works Accounting budget, $29,979,950.00 for calendar year 2008. From the same report the variable cost of water (electricity and chemicals) for 2008 was calculated at $200.94 per million gallons.

The fiscal year change on July 1, 2008 initiated new, higher customer water rates. Therefore, the two rates were averaged. Residential customer retail unit rates were changed from $2.90 to $3.06 for the first tier of use (0-10,000 gallons) and commercial rates were increased from $3.08 to $3.24. An average base rate of $2.98 was used for the residential up to 10,000 gallons/month and $3.16 commercial (no tiers). The remaining averages are listed below (Table 20). To determine an average customer retail unit cost for the AWWA audit, Rio Rancho used 80 percent by volume residential and 20 percent by volume commercial. This calculated to a unit cost rate of $3.02.

Table 20: Rio Rancho cost per unit fee.

2008 Water Commodity Charges (Fee per 1,000 gallons($))*						
Range	**Residential**	**Multi-Family Residential**	**Commercial**	**City**	**Irrigation**	**Industrial**
0-10,000	$2.98	--	--	--	--	--
10,001-19,999	$3.25	--	--	--	--	--
Over 20,000	$3.49	--	--	--	--	--
No multi-tiered rate		$3.04	$3.16	$3.00	$3.49	$3.00
(0.80 x $2.98) + (0.20 x $3.16) = $3.02 the weighted average cost per volume of water (1,000)						

*The rates are an average of two FY rates.

C.7 Performance Indicators

The performance indicators are tracked as both financial and operational efficiency indicators. The Rio Rancho system's non-revenue water as percentage by volume of water supplied is 16.6 percent or 66.6 gallons per connection per day. If this were billable water, it would represent 1.6 percent of the annual operating costs of the system. The annual cost of apparent losses is $357,986.00. Apparent loss costs are calculated using the customer retail unit cost per 1,000 gallons. The annual cost of real losses is $119,694.00. Real loss costs are calculated using the variable production costs. The operational performance indicators show that apparent losses are 10.94 gallons per connection per day and the real losses are 54.97 gallons per connection per day.

C.8 Data Validity/Priority Areas

The AWWA water audit spreadsheet (WASv4.0) includes a data validity score and priority areas for attention. Rio Rancho received 77 out of 100 for their data validity score. This is a weighted value based on the importance of the various data values requested. Rio Rancho provided a rating for each of the data values provided in the report. The ratings are based on the AWWA Grading Matrix provided within the water audit spreadsheet. The Grading Matrix also provides recommendations on the actions that can be taken by the utility to increase their scores.

The audit spreadsheet prioritized the following areas for attention as follows:

1. Volume from own sources
2. Customer metering inaccuracies
3. Customer retail unit cost (applied to apparent losses)

C.9 Audit Recommendations

Upon reviewing the AWWA audit, the NMOSE recognized the primary issues in conducting the audit were

1. Calibration of the master meters.
2. Lack of tiered rate structure in non-residential customers.

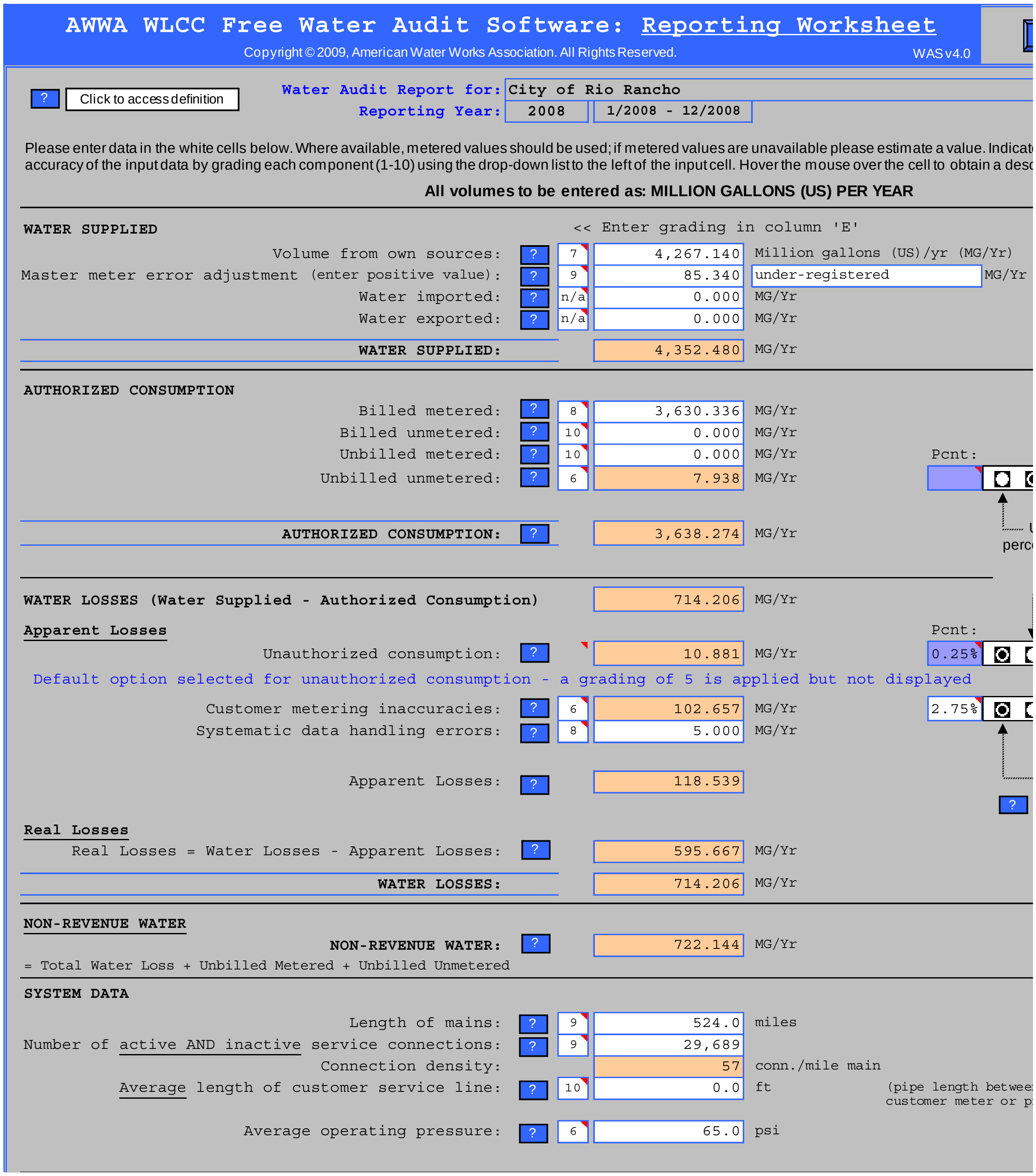
The following recommendations from NMOSE on improving data validity are:

- Development of a routine testing and calibration program for all master meters.
- Designate a responsible person to assemble, review, and analyze the water audit data on at least an annual basis (preferably monthly), to determine water losses and implement reductions in water loss.

The following are recommendations from the NMOSE on reducing the volume of non-revenue water:

- Conduct a top down audit of the largest users in the system. Determine if the users are in the appropriate range of use. If not, conduct a meter test.
- Set up procedures to track the age and volume of use for all customer meters and change out those approaching warranty.
- Continue the leak detection program and consider expanding the leak program to include additional loggers.

C.10 Rio Rancho AWWA Reporting Worksheet



AWWA WLCC Free Water Audit Software: Reporting Worksheet

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WAS v4.0

? Click to access definition

Water Audit Report for: City of Rio Rancho

Reporting Year: 2008 1/2008 - 12/2008

Please enter data in the white cells below. Where available, metered values should be used; if metered values are unavailable please estimate a value. Indicat accuracy of the input data by grading each component (1-10) using the drop-down list to the left of the input cell. Hover the mouse over the cell to obtain a desc

All volumes to be entered as: MILLION GALLONS (US) PER YEAR

WATER SUPPLIED << Enter grading in column 'E'

Volume from own sources:	7	4,267.140	Million gallons (US)/yr (MG/Yr)	
Master meter error adjustment (enter positive value):	9	85.340	under-registered	MG/Yr
Water imported:	n/a	0.000	MG/Yr	
Water exported:	n/a	0.000	MG/Yr	
WATER SUPPLIED:		4,352.480	MG/Yr	

AUTHORIZED CONSUMPTION

Billed metered:	8	3,630.336	MG/Yr	
Billed unmetered:	10	0.000	MG/Yr	
Unbilled metered:	10	0.000	MG/Yr	Pcnt:
Unbilled unmetered:	6	7.938	MG/Yr	
AUTHORIZED CONSUMPTION:		3,638.274	MG/Yr	

U

perc

WATER LOSSES (Water Supplied - Authorized Consumption)		714.206	MG/Yr	

Apparent Losses Pcnt:

Unauthorized consumption:		10.881	MG/Yr	0.25%

Default option selected for unauthorized consumption - a grading of 5 is applied but not displayed

Customer metering inaccuracies:	6	102.657	MG/Yr	2.75%
Systematic data handling errors:	8	5.000	MG/Yr	
Apparent Losses:		118.539		

Real Losses

Real Losses = Water Losses - Apparent Losses:		595.667	MG/Yr
WATER LOSSES:		714.206	MG/Yr

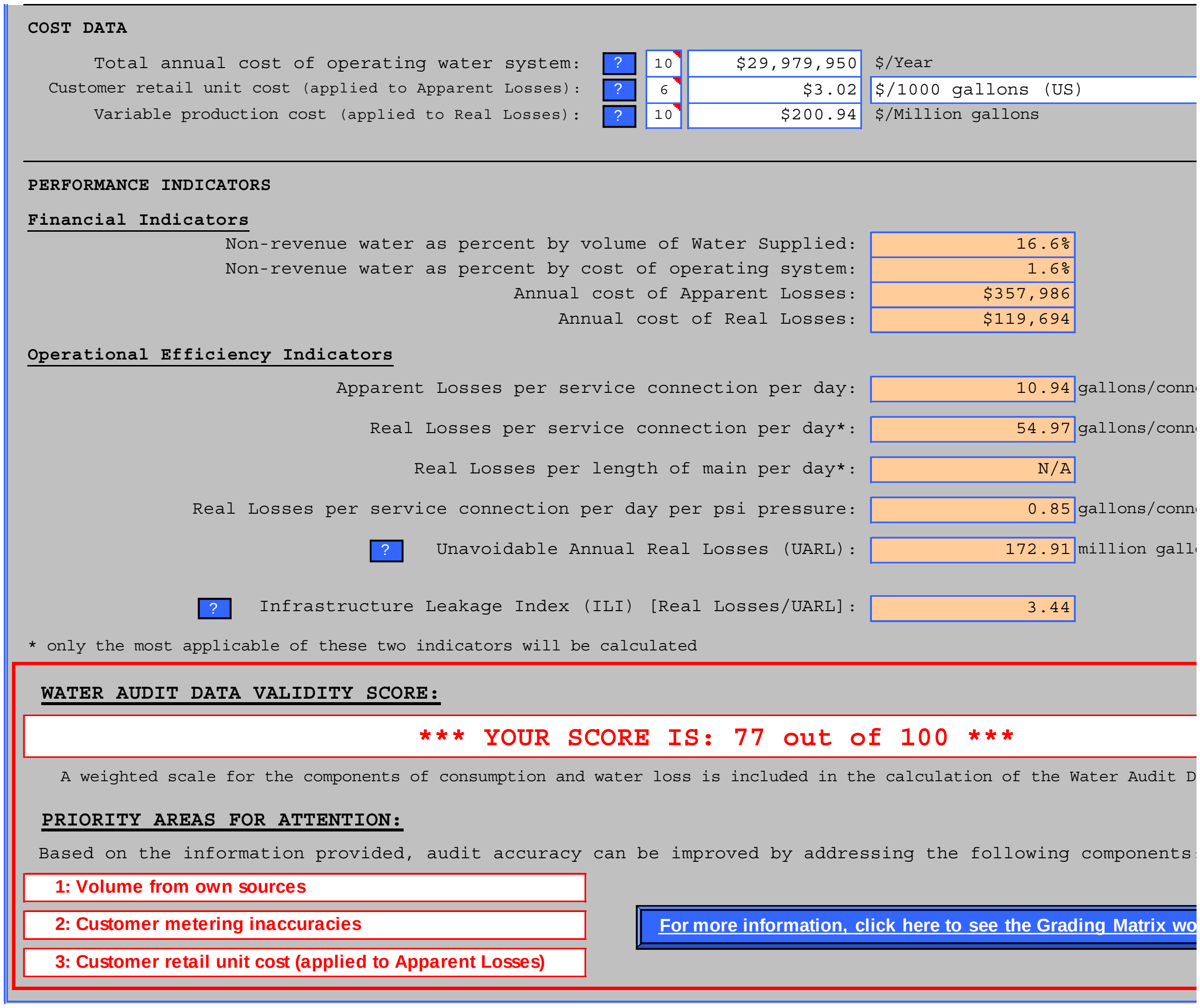
NON-REVENUE WATER

NON-REVENUE WATER:		722.144	MG/Yr

= Total Water Loss + Unbilled Metered + Unbilled Unmetered

SYSTEM DATA

Length of mains:	9	524.0	miles	
Number of active AND inactive service connections:	9	29,689		
Connection density:		57	conn./mile main	
Average length of customer service line:	10	0.0	ft	(pipe length betwee customer meter or p
Average operating pressure:	6	65.0	psi	



COST DATA

Total annual cost of operating water system:	?	10	$29,979,950	$/Year
Customer retail unit cost (applied to Apparent Losses):	?	6	$3.02	$/1000 gallons (US)
Variable production cost (applied to Real Losses):	?	10	$200.94	$/Million gallons

PERFORMANCE INDICATORS

Financial Indicators

Non-revenue water as percent by volume of Water Supplied:	16.6%
Non-revenue water as percent by cost of operating system:	1.6%
Annual cost of Apparent Losses:	$357,986
Annual cost of Real Losses:	$119,694

Operational Efficiency Indicators

	Apparent Losses per service connection per day:	10.94	gallons/conn
	Real Losses per service connection per day*:	54.97	gallons/conn
	Real Losses per length of main per day*:	N/A	
	Real Losses per service connection per day per psi pressure:	0.85	gallons/conn
?	Unavoidable Annual Real Losses (UARL):	172.91	million gall
?	Infrastructure Leakage Index (ILI) [Real Losses/UARL]:	3.44	

* only the most applicable of these two indicators will be calculated

WATER AUDIT DATA VALIDITY SCORE:

***** YOUR SCORE IS: 77 out of 100 *****

A weighted scale for the components of consumption and water loss is included in the calculation of the Water Audit D

PRIORITY AREAS FOR ATTENTION:

Based on the information provided, audit accuracy can be improved by addressing the following components

1: Volume from own sources

2: Customer metering inaccuracies

3: Customer retail unit cost (applied to Apparent Losses)