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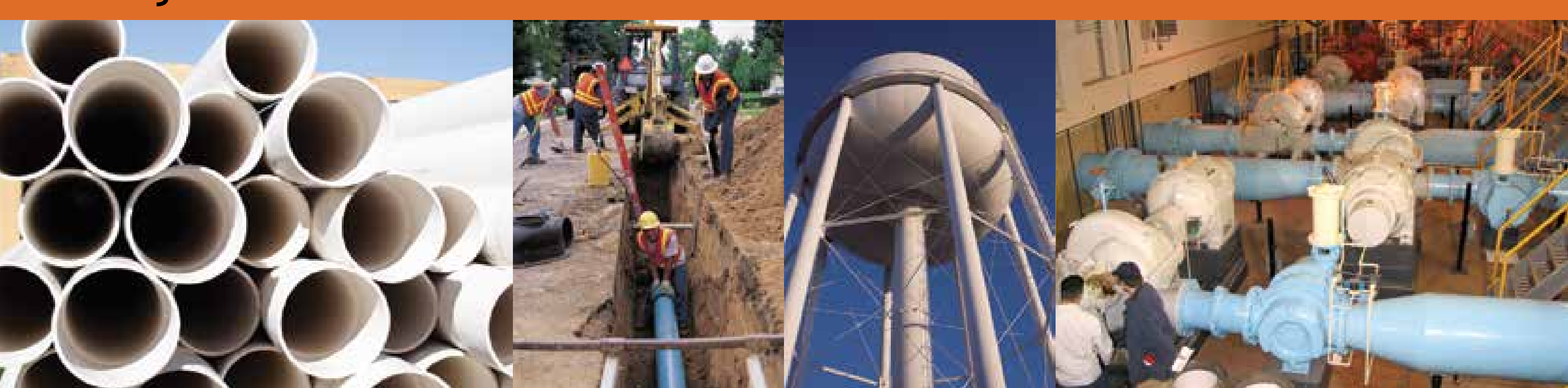
Environmental Impact of Asbestos Cement Pipe Renewal Technologies

Web Report #4465

Subject Area: Infrastructure



Environmental Impact of Asbestos Cement Pipe Renewal Technologies

About the Water Research Foundation

The Water Research Foundation (WRF) is a member-supported, international, 501(c)3 nonprofit organization that sponsors research that enables water utilities, public health agencies, and other professionals to provide safe and affordable drinking water to consumers.

WRF's mission is to advance the science of water to improve the quality of life. To achieve this mission, WRF sponsors studies on all aspects of drinking water, including resources, treatment, and distribution. Nearly 1,000 water utilities, consulting firms, and manufacturers in North America and abroad contribute subscription payments to support WRF's work. Additional funding comes from collaborative partnerships with other national and international organizations and the U.S. federal government, allowing for resources to be leveraged, expertise to be shared, and broad-based knowledge to be developed and disseminated.

From its headquarters in Denver, Colorado, WRF's staff directs and supports the efforts of more than 800 volunteers who serve on the board of trustees and various committees. These volunteers represent many facets of the water industry, and contribute their expertise to select and monitor research studies that benefit the entire drinking water community.

Research results are disseminated through a number of channels, including reports, the Website, Webcasts, workshops, and periodicals.

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More information about WRF and how to become a subscriber is available at www.WaterRF.org.

Environmental Impact of Asbestos Cement Pipe Renewal Technologies

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U.S. Environmental Protection Agency
Washington, D.C.

Published by:
Water Research Foundation℠

DISCLAIMER

This study was jointly funded by the Water Research Foundation (WRF), the U.S. Environmental Protection Agency (EPA), and the Water Environment Research Foundation (WERF) under Cooperative Agreement No. CR-83419201. WRF, EPA, and WERF assume no responsibility for the content of the research study reported in this publication or for the opinions or statements of fact expressed in the report. The mention of trade names for commercial products does not represent or imply the approval or endorsement of WRF, EPA, and WERF. This report is presented solely for informational purposes.

Printed in the U.S.A.

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FOREWORD

The Water Research Foundation (Foundation) is a nonprofit corporation that is dedicated to the implementation of a research effort to help drinking water utilities respond to regulatory requirements and address high-priority concerns of the water sector. The research agenda is developed through a process of consultation with Foundation subscribers and other drinking water professionals. Under the umbrella of a Strategic Research Plan, the Board of Trustees and Board-appointed volunteer committees prioritize and select research projects for funding based upon current and future needs, applicability, and past work. The Foundation sponsors research projects through the Focus Area, Emerging Opportunities, and Tailored Collaboration programs, as well as various joint research efforts with organizations such as the U.S. Environmental Protection Agency and the U.S. Bureau of Reclamation.

This publication is a result of one of the Focus Area sponsored studies, and it is hoped that its findings will be applied in communities throughout the world. The following report serves not only as a means of communicating the results of the water industry's centralized research program but also as a tool to enlist the further support of the nonmember utilities and individuals.

Projects are managed closely from their inception to the final report by the Foundation's staff and large cadre of volunteers who willingly contribute their time and expertise. The Foundation serves a planning and management function and awards contracts to other institutions such as water utilities, universities, and engineering firms. The funding for this research effort comes primarily from the Subscription Program, through which water utilities subscribe to the research program and make an annual payment proportionate to the volume of water they deliver and consultants and manufacturers subscribe based on their annual billings. The program offers a cost-effective and fair method for funding research in the public interest.

A broad spectrum of water supply issues is addressed by the Foundation's research agenda: resources, treatment and operations, distribution and storage, water quality and analysis, toxicology, economics, and management. The ultimate purpose of the coordinated effort is to assist water suppliers to provide the highest possible quality of water economically and reliably. The true benefits are realized when the results are implemented at the utility level. The Foundation's trustees are pleased to offer this publication as a contribution toward that end.

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Chair, Board of Trustees
Water Research Foundation

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Executive Director
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ACKNOWLEDGMENTS

The authors of this report would like to thank the following water utilities and individuals who contributed to this project their data, experience, and project sites:

Supporting Utilities and Active Webinar Participants:

City of Casselberry (Alan Ambler), Casselberry, FL, USA
HDR (Kent Von Aspern), California, USA
Internal Lining Alternatives (Jim Baglier), Macomb, MI, USA
Las Vegas Valley Water District (Miles Davies, Ryan Benner, Ryan Pearson, and Charles Scott), Las Vegas, NV, USA
Louisville Water Company (Keith Coombs), Louisville, KY, USA
Monroe County Water Authority (Ann Ziki), Rochester, NY, USA
Sacramento Suburban Water District (John Valdes), Sacramento, CA, USA
Ted Berry Company (Matt Timberlake), Livermore, ME, USA
TT Technologies (Collins Orton), California, USA

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EXECUTIVE SUMMARY

OBJECTIVE

The primary objective of this project was to provide drinking water utilities with reliable performance, cost, and environmental data related to asbestos cement (AC) pipe renewal practices. This was accomplished through an investigation of renewal practices and regulatory standards, demonstration of innovative renewal technologies, and evaluation of the environmental impact of techniques related to the rehabilitation and renewal of AC pipe. The research for this project was conducted in three phases: (1) data needs assessment and review; (2) technology demonstration and evaluation; and (3) project reporting and information dissemination. Phase 1 identified research and data needs by conducting a literature search, interviews, consultations with stakeholders, and a webinar. Phase 2 investigated the performance, environmental impact, and cost of both cured-in-place pipe (CIPP) and pipe bursting on AC water mains. The environmental impact of both technologies was evaluated through the collection of air, soil, and water samples that were analyzed for asbestos. The final report, which documents the findings of Phases 1 and 2, was produced during Phase 3, as were accompanying papers designed to reach the widest audience possible. The results of the asbestos sampling performed at the demonstration sites are included as Appendices A and B (on the #4465 project page under Project Resources/Project Papers).

BACKGROUND

AC pipe accounts for approximately 15% of water main pipe material in North America (AWWA 2004). Renewal activities, which are needed to maintain these pipes as they deteriorate, can result in impaired water quality, reduced hydraulic capacity, and higher leakage rates (Hu et al. 2009). Water main renewal has historically been performed by open cut replacement, but with a current annual replacement rate of 0.5%, pipe that was designed to last 50 to 100 years is now relied upon to last 200 years (Morrison et al. 2013). Concerns over the environmental impact of AC pipe renewal and the associated regulations are an area of confusion for most water utility managers (Griffin 2009). This confusion led the Water Research Foundation (WRF) to commission project #4093, *Long-Term Performance of AC Pipe*, which included a study of renewal approaches (Hu et al. 2013). This study identified a need for environmental assessments of various renewal approaches. The industry is still struggling with regulations and practices for renewing AC pipes, and requires help establishing reasonable regulations based on actual data (Salvo et al. 2012). Several available technologies such as CIPP lining, sprayed-in-place pipe (SIPP) lining, pipe bursting, and pipe reaming have been adopted (primarily from the wastewater rehabilitation market) for use in water distribution systems. There is concern that when these technologies are used on AC pipe, asbestos fibers may become friable, causing a potential health hazard to workers and the public. This report addresses concerns with AC pipe renewal technologies and regulatory standards as well as existing knowledge and data gaps.

APPROACH

This report summarizes asbestos regulations within the United States and presents current practices from a select number of utilities in North America and Australia. In addition, two real-world renewal demonstrations are presented as case studies to examine the environmental impact of pipe bursting and CIPP. Input and data were gathered from the following sources:

- Literature review: legislative documents, research papers, and technical reports were reviewed and synthesized.
- Consultation with state regulatory agencies: State and regional regulatory agencies contributed to the project by responding to requests and providing feedback on asbestos regulations.
- Facilitated webinar: Utility operators, consultants, and industry experts attended a webinar to discuss their experience with AC pipe and provide recommendations for the demonstration.
- Technology demonstrations: Actual demonstration and evaluation of two rehabilitation technologies on AC pipes.

RESULTS AND CONCLUSIONS

Asbestos is regulated at the federal level by the U.S. Environmental Protection Agency (EPA) under the National Emission Standards for Hazardous Air Pollutants (NESHAP). Although AC pipe renewal activities are not specifically regulated under NESHAP, AC pipe can become regulated asbestos containing material (RACM) if it becomes friable or has a high probability of becoming crumbled, pulverized, or reduced to powder by forces expected to act on the material during the course of renovation, potentially pipe rehabilitation or replacement.

The enforcement and interpretation of NESHAP has largely been left to the state regulatory agencies. A survey of 50 state asbestos regulatory agencies conducted by Battelle found that the majority of states adhere to NESHAP regulations and conclude that any process that makes asbestos fibers friable would be regulated and requires either licensed contractors or should not be attempted at all.

Utility practices with regards to AC pipe were examined and found to vary state by state and from utility to utility. Most utilities preferred to abandon AC pipe in-place when possible, or replace it by excavating. Although other methods of AC pipe renewal exist, such as CIPP, SIPP, pipe reaming, and pipe bursting, utilities were hesitant to employ them based on their understanding and interpretation of NESHAP and state regulations.

Real-world demonstration and evaluation of two rehabilitation technologies was conducted in Florida (pipe bursting) and Nevada (CIPP). Air, soil, and water samples were collected from each site and analyzed for asbestos by a certified laboratory. The results from the analyses showed the following:

- The level of airborne asbestos was always below the eight-hour time-weighted average (TWA) permissible exposure limit (PEL) of 0.1 fiber structures per cubic centimeter (s/cc) of air set by the Occupational Health and Safety Administration and posed no threat to the workers' health (OSHA 2014).

- Soil samples collected at each site indicated only trace amounts of asbestos in the soil surrounding the pipe. With no increase in asbestos following the completion of the renewal activities (especially in the case of pipe bursting) it was determined that neither renewal method adversely impacted the soil environment.
- The results from the water samples collected from each site showed that the renewal technologies had no negative impact on the water quality, and in one instance, reduced the asbestos detected after bursting compared to before bursting.

APPLICATIONS/RECOMMENDATIONS

Report Findings

The report can be used by water utilities when planning future rehabilitation projects on AC pipe in their distribution system. The background on federal/state/local regulations provides a clearer picture of what is typically allowable. In addition, the document contains detailed case studies of practical AC pipe rehabilitation projects, and an idea of what types of data can be collected to ensure the projects are environmentally safe. Based upon the results of the air samples collected at each site, neither pipe bursting nor CIPP lining of AC pipe was found to have a negative impact on the surrounding air environment or the heath of the workers. Overall, the results from the soil samples collected at each site indicate only trace amounts of asbestos in the soil surrounding the pipe. With no increase in asbestos following the completion of the renewal activities (especially in the case of pipe bursting) it was determined that neither renewal method adversely impacted the soil environment. The results from the water samples collected from each site showed that the renewal technologies had no negative impact on the water quality and, in one instance, reduced the asbestos detected after bursting compared to before bursting. Therefore, these technologies did not have an adverse impact on the water environment.

Recommendations for Further Study

Very little real-world data exists on how the AC rehabilitation technologies studied in this report impact the environment. It is recommended that regulatory agencies review the data presented in this report and consider reevaluating the allowance of such methods, particularly pipe bursting, which has been the cause of much regulatory confusion. When proper procedures were followed in the pipe bursting demonstration, the environmental impact was negligible and the requirements of NESHAP were met. It is recommended that an EPA Administrator Approved Alternative (AAA) be pursued for pipe bursting, which would allow the use of pipe bursting on AC pipe when proper procedures are followed. To benefit future studies, it is recommended that baseline soil samples be collected prior to AC pipe bursting projects, which would allow for retrospective testing and future data comparisons. In cases where additional oversight is required by regulatory agencies, air sampling can be conducted using the procedures used during this project.

RESEARCH PARTNERS

- U.S. Environmental Protection Agency (EPA)
- Water Environment Research Foundation (WERF)

PARTICIPANTS

- City of Casselberry, FL
- Monroe County Water Authority
- Las Vegas Valley Water District
- Louisville Water Company
- Sacramento Suburban Water District
- HDR, Inc.
- Perkasie Regional Authority
- TT Technologies, Inc.
- Internal Lining Alternatives
- Murphy Pipeline
  Ted Berry Company, Inc.

CHAPTER 1
INTRODUCTION

PROJECT PURPOSE

The primary objective of this project was to provide water utilities with reliable performance, cost, and environmental impact data relating to asbestos cement (AC) pipe renewal practices. This was accomplished through an investigation of renewal practices and regulatory standards, demonstration of innovative renewal technologies, and evaluation of the environmental impact of water distribution rehabilitation techniques related to the rehabilitation and renewal of AC pipe. The research for this project was conducted in three phases: (1) Data Needs Assessment and Review; (2) Technology Demonstration and Evaluation; and (3) Project Reporting and Information Dissemination. Phase 1 identified research and data needs by conducting a literature search, interviews, and consultations with stakeholders, and a webinar conducted on May 29th, 2013. Phase 2 of this project investigated the performance, environmental impact, and cost of both pipe bursting and cured-in-place pipe (CIPP) on AC water mains. The environmental impact of both technologies was evaluated through the collection of air, soil, and water samples that were analyzed for asbestos. The Final Report, which documents the findings of Phases 1 and 2, was produced during Phase 3 as were accompanying papers designed to reach the widest audience possible.

SCOPE

This report summarizes asbestos regulations within the United States and presents current utility practices for a select number of utilities in North America and Australia. In addition, two real-world renewal demonstrations are presented as case studies examining the impact of pipe bursting and CIPP on the environment. Input and data were gathered from the following sources of information:

- Literature: legislative documents, research papers, and technical reports were reviewed and synthesized.
- Consultation with state regulatory agencies: state and regional regulatory agencies contributed to the project by responding to requests and providing feedback on asbestos regulations.
- Facilitated webinar: utility operators, consultants, and industry experts attended a webinar to discuss their experience with AC pipe and provide recommendations for the demonstration.
- Technology demonstrations: actual demonstration and evaluation of two rehabilitation technologies on AC pipes.

BACKGROUND

AC pipe accounts for approximately 15% of the water main pipe materials in North America (AWWA 2004). Renewal activities are needed to maintain these pipes as they deteriorate, which results in impaired water quality, reduced hydraulic capacity, and higher leakage rates (Hu et al. 2009). Water main renewal has historically been performed by open cut replacement, but with a current annual replacement rate of 0.5%, pipe that is designed to last 50 to 100 years is being expected to last 200 years (Morrison et al. 2013). Concerns over the environmental impact of AC pipe renewal and the associated regulations are an area of confusion for most water utility managers (Griffin 2009). Confusion around these issues partly led the Water Research Foundation (WRF) to commission a project to study the *Long-Term Performance of AC Pipe,* including a study of approaches for renewal (Hu et al. 2013). This study in part identified the need to conduct environmental assessments of these renewal approaches. The industry was still struggling with regulations and practices for renewing AC pipes and in is need of help to establish reasonable regulations based on actual data (Salvo et al. 2012). Several available technologies such as CIPP lining, sprayed-in-place pipe (SIPP) lining, pipe bursting, and pipe reaming have been adopted primarily from the wastewater rehabilitation market for use in water distribution systems. There is concern that when these technologies are used on AC pipe, asbestos fibers may become friable causing a potential health hazard to workers and the public. This report addresses concerns with AC pipe renewal technologies and regulatory standards as well as existing knowledge and data gaps.

CHAPTER 2
PHASE I: DATA NEEDS ASSESSMENT AND REVIEW

This section presents the project findings from Phase I, which identified needs by conducting a literature search, interviews, and consultations with stakeholders, and a webinar in May 2013. Phase I resulted in the publication of a conference paper (Matthews et al. 2013) and a peer-reviewed journal paper (Matthews and Stowe 2015), which were intended to educate a wider audience on the current regulations and data needs associated with AC pipe renewal.

ASBESTOS REGULATIONS

Asbestos is regulated at the Federal level by the U.S. Environmental Protection Agency (EPA) under the National Emission Standards for Hazardous Air Pollutants (NESHAP). NESHAP regulates the two main types of asbestos containing material (ACM): friable and non-friable. Under NESHAP, AC pipe is a Category II non-friable material, which means it cannot be crumbled, pulverized, or reduced to powder by hand pressure when dry. Although AC pipe renewal activities are not specifically regulated under NESHAP, AC pipe can become regulated asbestos containing material (RACM) if it either became friable or have a high probability of becoming crumbled, pulverized, or reduced to powder by forces expected to act on the material during the course of renovation (i.e., renewal, rehabilitation, or replacement). In July 1991, 18 years after NESHAP, the EPA provided clarification on NESHAP regulations pertaining to the crushing of excavated AC pipe in the form of a letter (Von Aspern 2011). The letter, which was a response to an earlier inquiry, contained the following key points:

- *"…the crushing of asbestos cement pipe with mechanical equipment would cause this material to become RACM."*
- *"The backfilling and burial of the crushed asbestos cement pipe in place would cause these locations to become active waste disposal sites…"*
- *"If the pipe is left in place or removed in such a way that it is not crumbled, pulverized, or reduced to powder, it would not be subject to the NESHAP."*

The letter does not address any other forms of pipe renewal (e.g., CIPP, SIPP, etc.) besides the crushing of excavated AC pipe by mechanical equipment. The crushing of AC pipe in-situ (i.e., pipe bursting or pipe reaming) is not discussed by EPA in their response and still, some 20 years later, it is not fully clear if it is an acceptable method for renewal.

The enforcement and interpretation of NESHAP has largely been left to the state regulatory agencies. In an effort to understand how individual states were regulating AC pipe renewal, each state agency was contacted via email for clarification and the following observations were made (as of survey completion in early 2013):

- Few agencies prohibited renewal activities by name (i.e., pipe bursting, pipe reaming, and/or pipe lining).
- Most agencies stated any activity that rendered the AC pipe as RACM would require appropriate local, state, or federal procedures to be followed.

- Most states adhere to NESHAP regulations and conclude that any process that makes asbestos fibers friable would be regulated and requires either licensed contractors or should not be attempted at all.

Table 2-1 below summarizes the state policies on renewal of AC pipe.

Table 2-1 Summary of state regulatory agency policies

Typical Policy	States
Rehabilitation methods were not prohibited by name, AC pipe removal was typically recommended, but notification forms are required and EPA requirements for removal must be met for RACM.	AK, AL, AR, AZ, CA, FL, GA, HI, ID, IA, IL, IN, KY, LA, MD, ME, MI, MN, MO, MS, NC, ND, NE, NH, NM, NV, OH, OK, OR, PA, RI, SD, TX, VT, VA, WA, WI, WV
Rehabilitation methods were not prohibited by name, and the AC pipe was typically abandoned.	CT, KS, MT, NJ
Pipe Bursting was prohibited by name.	CO, MA, NY, SC, UT
Pipe Bursting not prohibited by name, but it is discouraged.	DE, TN, WY

Some examples include the State of Maine, much like many other states (see Table 2-1), does not specifically prohibit the rehabilitation of AC pipe by name. Maine's Department of Environmental Protection (DEP) details all rules and regulations pertaining to asbestos in *Chapter 425: Asbestos Management Regulations* (Maine DEP 2011). Some key points include:

- AC pipe not in use can be buried in place as long as it remains in-tact.
- Best management practices (BMPs) must be used to minimize breakage during removal.
- If removal includes sanding, grinding, or cutting the work must be performed by a licensed contractor and is subject to Chapter 425 rules.

In contrast, the State of Massachusetts specifically prohibits certain AC pipe renewal activities by name. The Massachusetts Department of Environmental Protection (MassDEP) states in their *Asbestos Cement Pipe Guidance Document* (MassDEP 2011) that pipe reaming, pipe bursting, and the crushing of AC pipe in the trench is not allowed. The reasoning provided by MassDEP in the document is as follows:

- *"…crushing of an ACM is prohibited… Further, USEPA has determined that backfilling and burial of the crushed asbestos cement pipe would cause these locations to be considered active disposal sites…"*
- *"…if no additional asbestos-containing waste material is buried at the location for a year, the site would become an inactive waste disposal site…"*
- *"…the owner of the land would be required to comply with the requirements for active and inactive waste disposal sites."*
- *"…reaming or pipe bursting through an existing asbestos cement pipe would cause the existing asbestos cement pipe to become crushed and friable."*

In the State of California, AC pipe renewal activities are not regulated at the state level (i.e., California Environmental Protection Agency), but instead are regulated at the regional level (e.g., Bay Area Air Quality Management District [BAAQMD]). In an advisory (BAAQMD 2006) issued to all Bay Area Building, Planning, and Public Works departments, it addressed asbestos control requirements for pipe bursting and reaming. The key points of the advisory are included below. It should be noted that these requirements do not apply to emergency repairs.

- *"Pipe reaming and pipe bursting are processes which can be subject to the notification and emission control requirements…"*
- *"These two processes become regulated activities when the existing pipe contains greater than 1% asbestos content."*
- *"These activities require notice to the Air District when 100 linear feet or greater is disturbed."*
- *"…any future tie-ins, right of way work, or any soil disturbance would require 45 day notification…"*

WATER UTILITY PRACTICES

Utility practices with regards to AC pipe were examined and were found to vary state by state and from utility to utility. Information was collected during consultations with water utilities from the United States, Canada, and Australia. The results from the consultations with utilities are presented in Table 2-2 for seven selected water utilities.

Table 2-2 Current utility practices

Utility Name	AC Pipe in System	Current Practices
City of Phoenix, AZ, USA	54%	• Prefer to abandon-in-place and keep record of location • If cannot be abandoned, pipe will be dug up and replaced with ductile iron • Allowed by ADEQ to crush AC pipe in-situ • No formal guidance document for crushing AC pipe
Sacramento Suburban Water District, CA, USA	53%	• Replacing 7-8 miles/year (abatement required) • Interested in using pipe bursting, but unsure of the regulations
City of Houston, TX, USA	21%	• Repair breaks using a wrap or band-type fitting • Special precautions used to remove and discard AC pipe • Replacing AC with PVC or abandoning in place
City of Edmonton, AB, Canada	29%	• Contractor have code of practice for the disposal of AC pipe • Tough to work with and cut
City of Dubbo, NSW, Australia	2%	• Abandon-in-place when possible • Replacement protocols require wet cutting and masks
Goulburn Valley Water, Victoria, Australia	40%	• Replacing 7.5 to 10 km/year (up from previous years of 3 km/year) • Typically install a new pipe on new alignment and abandon main (80%) • Pipe bursting of the other 20% (as high as 70% in previous years) • Improved practices for handling AC from repairs including sorting spoil to remove all hard waste, including any AC missed.
EBMUD	30%	• Abandon-in-place when possible • Increasing its AC replacement from 2 miles/year to 5 miles/year and eventually to 20 miles/year by 2030

RENEWAL OPTIONS

Several options currently exist for the renewal of AC pipe. The most common renewal methods are replacement via open-cut and abandon-in-place. Trenchless technologies, such as CIPP, SIPP, and pipe busting, are also becoming more common in the drinking water industry and gaining support by utilities.

Dig and Replace (Open Cut)

For years, the primary way to renew AC pipe was to dig it up and replace it. A trench is dug to expose the AC pipe (Figure 2-1), which is then cut into manageable-size pieces, placed into containers or wrapped in plastic (Figure 2-2), and transported to a landfill that accepts asbestos waste. During the cutting process, the asbestos in the pipe has a high probability of becoming friable and, therefore, is regulated under NESHAP. Wetting of the pipe during cutting is needed to prevent the asbestos fibers from becoming airborne. All the activities are typically performed by certified asbestos abatement contractors. To help owners and operators of facilities with asbestos cement products, EPA (2013) has provided the following statement on the removal of asbestos cement products and their applicability to NESHAP:

> *"Whether asbestos-cement products are subject to the asbestos NESHAP should be determined by the owner or operator on a case-by-case basis based on the demolition techniques to be used. In general, if contractors carefully remove asbestos-cement materials using tools that do not cause significant damage, the materials are not considered RACM and can be disposed of with other construction debris."*

Therefore, according to the above EPA statement, AC pipe would not become RACM and would not be subject to NESHAP if tools used during the removal do not cause significant damage. In addition, the asbestos waste that would be generated could be disposed of with other construction debris.

Source: Courtesy of EBMUD

Figure 2-1 Typical open cut installation site

Figure 2-2 AC pipe being wrapped in plastic for disposal

Abandon-In-Place

In lieu of AC pipe replacement, many water utilities have elected to abandon the pipe in place and install a new water main of a different material (e.g., ductile iron, PVC, etc.) on a parallel alignment. AC pipe that is abandoned-in-place is not subject to NESHAP, as stated in the EPA

(1991) letter, since the pipeline is left in-tact. The location of the abandoned pipe should be recorded in as-built plans or a geographic information system (GIS) to minimize the chance of breakage in the future due to activities in area. EPA has also suggested pumping grout into buried lines that are no longer in service.

Cured-In-Place Pipe (CIPP)

CIPP is a well-established lining method for wastewater pipe rehabilitation and over the past decade modified versions have been adapted to pressure applications and water distribution systems. CIPP uses a resin-saturated tube that is inserted into a cleaned pipe by inversion or with a winch, and expanded using air or water pressure (Figure 2-3). For water applications, the tube can be made from polyethylene (PE) or polyurethane (PU) coated fabric of woven polyester or glass-fiber, or non-woven felt and glass reinforcement. The resin used for water applications is typically epoxy, and the product must be certified to meet NSF/ANSI Standard 61 requirements for contact with potable water. Equipment used for the installation is dedicated for the water application to minimize risks of cross-contamination from other non-drinking water pipeline applications (Morrison et al. 2013).

Figure 2-3 CIPP used to renew a 6-in water main

Examples of CIPP on AC water mains have been conducted in the past. For example, CIPP was used to renew 3,460 ft of a 6-in. cast iron and AC pipe in the housing area of Joint Base Elmendorf-Richardson in Alaska (Yunis 2010). The base has approximately 350,000 ft of water infrastructure that is over 70 years old and frequently experiences breaks and leaks which cause shut downs (up to 12 hours) due to repairs. CIPP was selected due to the depth of the pipes (i.e., 10 ft.) and the width of the trenches (i.e., 40 ft.) that would have been needed if a traditional method like dig and replace was used. After the pipe was lined, 34 service connections were reinstated from inside the pipe using robotic equipment.

Spray-In-Place Pipe (SIPP)

Polymeric SIPP is an innovative alternative for water main rehabilitation capable of achieving AWWA semi-structural properties. In this process, polymeric materials (i.e., polyurea or polyurethane) are pumped through a hose to a rotating spray head that directly applies it onto the interior of a cleaned pipe (Figure 2-4). The thickness of the applied layer is controlled by the flowrate of material and the speed of the lining rig through the pipe. After inspection by camera, the main is disinfected and flushed, and service connections are reopened. The pipe is then returned to service (Kulkarni et al. 2010). This technology has been used predominately in the U.K., Australia, and Canada, but initial demonstrations and pilot projects haves begun in the United States over the past few years (Matthews et al. 2012).

Figure 2-4 SIPP used to renew a 10-in water main

In a project for the City of Syracuse, SIPP was used to line 1,342 ft. of a 10-in. cast iron main with polymeric SIPP (Natwig and Murdock 2010). The main was installed in 1928 and had a significant history of breaks over the past decade and significant tuberculation. In addition, the pipeline was located under a busy turnpike that traverses hills and closing it would have resulted in a massive detour for motorists. Benefits from the lining the pipeline included increased flow through the pipe due to the removal of tuberculation, enhanced structural performance of the main, and prevention of future tuberculation. No literature currently exists on the application of SIPP on AC pipe, but there is no reason that the liner could not be applied to cleaned AC.

Pipe Bursting

Pipe bursting uses specialized equipment to fracture brittle pipes and displace the existing pipe into the soil while forming a cavity in the soil large enough to place a new pipe of equivalent or larger size in the ground (Morrison et al. 2013). Pipe bursting has the advantage of the installation of a new pipe, often an upsized diameter, and eliminates any need for detailed condition assessment (Figure 2-5). However, prior to pipe bursting, a good deal of information about the old pipe and its construction, in particular the placement and surroundings including the existence of other buried utilities and adjacent building foundations, is required. Removal of service connections is required before bursting to minimize collateral damage and the service connections will often be replaced by trenching or, if lengthy and under the road pavement, by impact moling. While pipe bursting has become a popular method of trenchless replacement of water mains (Deb et al. 1999), concerns over the environmental impact has limited its use on AC pipes.

Figure 2-5 Pipe bursting used to renew an 8-in AC water main

In Casselberry, FL the use of pipe bursting to replace AC pipe was approved by the Drinking Water State Revolving Fund Program as a qualified Green Project Reserve project (Thomas and Ambler 2012). With grant funding through the American Recovery and Reinvestment Act, over 30 miles of AC pipe has been replaced via pipe bursting while meeting all NESHAP criteria. Industry representatives worked closely with Florida Department of Environmental Protection to determine how NESHAP applies to the bursting of AC pipe and how to comply with these regulations. Observed time-weighted averages (TWA) for the employees performing the work and work area were determined using NIOSH Method 7400. The results for the employees and work area were below the permissible exposure level (PEL) of 0.1 fiber structures per cubic centimeter (s/cc) of air as established by the U.S. Occupational Safety and Health Administration (OSHA). The TWA results (Jonsson 2011) established a negative exposure assessment (NEA) for future pipe bursting activities, which assumes that the pipe conditions closely resemble the process, type of material, control methods, work practices, environmental conditions, and employee training encountered during the project. Due to the success and activity of this program, Casselberry was used as a test site for the pipe busting demonstration and environmental impact evaluation for this project.

The key steps taken on the Casselberry project to ensure NESHAP compliance are presented below (Ambler et al. 2014).

1. *File a Notice to EPA or Its Designee (61.145(b))*
   NESHAP specifies salient information that must be included on the notice. Florida DEP has a form 62-257.900(1) (see Appendix C) that requires this information. The form is one page and has to be signed only by the utility owner (Thomas et al. 2012).
2. *Provide for Emission Control during Renovation and Disposal (61.145(c) / 61.150)*
   There can be no visible emissions from the work per 61.150(a). With pipe bursting, this can be accomplished because the AC pipe is wetted within any excavation, and non-power saw tools are used to cut the pipe (chain cutter, handsaw) (Thomas et al. 2012).
3. *Comply with Inactive/Active Waste Disposal Site Requirements (61.151 / 61.154)*
   NESHAP provides for disposing of RACM on the site of the demolition/renovation work or at a waste disposal site. Currently regulators interpret NESHAP such that the work site is considered a waste disposal site for pipe bursting projects. Numerous options are provided in NESHAP to prevent asbestos exposure. These options include: no visible emissions from the site, fencing and posting signs around the site, have a natural barrier (cliffs, lakes or other large bodies of water, deep and wide ravines, and mountains) around the site, or cover the RACM with two feet of compacted non-asbestos containing material. With pipe bursting, the two feet of cover is virtually always provided because most all buried AC pipeline maintain greater than 2 ft depth of cover (Thomas et al. 2012).
4. *Comply with Inactive Waste Disposal Site Deed Notation and Alternative (61.151(e))*
   NESHAP requires that a notation to the deed of a facility property be recorded within 60 days of a waste disposal site becoming inactive. A site is deemed inactive when disposal of RACM is completed. Applying this to pipe bursting projects, a site is deemed inactive when the project is completed. The notation is to contain the following information (Thomas et al. 2012):

   - The land has been used for the disposal of asbestos-containing waste material;
   - The survey plot and record of the location and quantity of asbestos-containing waste disposed of within the disposal site required in Sec. 61.154(f) have been filed; and
   - The site is subject to 40 CFR part 61, subpart M.

Most of the buried AC pipes owned by utility providers in the United States lie within public right-of-ways. However, public right-of-ways do not maintain a property deed where the restrictions NESHAP references can be directly met. A modification to the existing NESHAP regulations would require an Act of Congress to complete. EPA officials recommended industry representatives present the EPA Administrator with an “Administrator Approved Alternate” process that can cover AC pipe bursting. To date, there has never been an “Administrator Approved Alternate” process approved to supersede NESHAP nor has any guidance been given to prepare the Administrator Approved Alternate. Industry representatives are currently working through the Administrator Approved Alternate Task Force to develop a suitable document to submit to EPA (Ambler et al. 2014).

DATA NEEDS

Through the course of Phase I of this project, several data needs were identified. The interpretation of NESHAP and lack of understanding of trenchless rehabilitation technologies has caused many state regulatory agencies to prohibit or discourage the use of some techniques. This has created a need for research on the actual environmental impact of these technologies. Studies to date, such Hu et al. (2013), have expressed the same concerns many regulatory agencies and water utilities have, but have not provided actual environmental impact data to base these concerns on that real world job sites can provide. It is believed that this data will help to clarify the impact AC pipe renewal projects have on the air, water, and soil. Phase II of this project gathered data from two real world field sites to help further the understanding of the actual impact. Two types of data parameters were collected during the demonstrations – general and environmental. General parameters included:

- Pipe Characteristics: Pipe material, diameter, length, installation date, depth, number of service connections, condition, etc.
- Technology Maturity: Innovative (e.g., CIPP or SIPP for water main rehabilitation) or more common (e.g., pipe bursting of water mains).
- Technology Feasibility: Potential for addressing the nature of the problem faced in the pipe such as a Class IV fully-structural solution (e.g., pipe bursting or reinforced CIPP).
- Technology Complexity: Level of training required for the installer and the maintenance staff to use the technique or maintains the material/liner.
- Technology Performance: Capabilities and limitations of the technology and materials used for the rehabilitation.
- Cost: Cost of installation including direct costs and the associated restoration costs and the estimated costs for periodic operation and maintenance (O&M).

Environmental parameters included air, water, and soil samples in addition to the estimated carbon footprint. Air, water, and soil samples were collected during each major activity during the demonstrations and were analyzed using the following methods:

- International Organization for Standardization (ISO) 10312 (1995): Determination of Asbestos Fibers in Ambient Air by transmission electron microscopy (TEM)
- EPA Method 100.2 (1994): Determination of Asbestos Structures over 10 µm in Length in Drinking Water
- EPA Method 600/R-93/116 (1993): (Polarized Light Microscopy [PLM]): Determination of Asbestos in Bulk Building Materials (Followed by gravimetric reduction and mass of fibers/gram soil results)

WEBINAR FEEDBACK

On May 29, 2013, a project webinar was held to present the findings through Phase 1 and to gather feedback from the participants on the following three questions:

1. Are there any additional data that needs to be gathered besides those listed above?

2. Are there potential demonstrations sites that should be considered for pipe bursting, CIPP, and/or SIPP?
3. Are there any additional technologies that should be considered for demonstration?

Key comments from the webinar participants are presented below along with responses from the Project Team (***in bold italics***) and are organized by attendee.

- **Florida Utility**
  - Conducted negative exposure assessment (NEA) during AC pipe bursting project.
    - Asbestos fibers on workers and environment (air) were measured using NIOSH Method 7400 and were found to be less than permissible exposure limit.
    - Did not conduct soil or water sampling during pipe bursting project.
    - Will provide results of NEA to the Project Team.
  - The cost of pipe bursting was found to be 3.5 times cheaper than replacement via open-cut.
  - Larger diameter (12-in & 14-in) AC pipe tend to hold up better than smaller diameter AC pipe (< 12-in).
  - Offered up their pipe bursting project as a potential demonstration site.
  - ***Our Team followed-up to obtain the NEA results and to organize a demonstration.***
- **Texas Utility**
  - The Utility participated in a pipe bursting project through AWWARF in 1999.
  - Pipe bursting was found to cost more than replacement at the time.
  - ***Our Team located the results of the study from Deb et al. (1999).***
- **Industry Representative 1**
  - Inquired as to whether water quality was the driver for renewal/replacement of AC pipe or just the overall reduction of asbestos.
    - Participants cited the reduction of asbestos along with structural and reliability issues encountered as the driving forces.
  - Recommended isolating the rehabilitated section(s) of pipe to accurately determine any reduction in asbestos in the water as the current method of measurement may not be reflective of the reduction experienced in the rehabilitated section(s).
  - ***Our Team collected water samples from the same location in the pipe before and after rehabilitation. It was difficult to isolate only rehabilitated sections of the pipe, but the team attempted this when possible.***
- **Nevada Utility**
  - Condition assessment identified approximately 2,500 ft. of 16-in. AC pipeline that has up to 30% degradation.
    - The pipeline is around 40 years old and is located within a major thoroughfare and is also close to a hospital.
    - The pipeline will be renewed using CIPP and sections of pipe will be removed and undergo Phenolphthalein dye testing and additional tests to verify the results of the condition assessment.
  - Offered up their CIPP project as a potential demonstration site.
  - ***Our Team followed-up to organize a demonstration.***

- **Equipment Manufacturer**
  - Germany conducted extensive air studies on the bursting of AC pipe in the field approximately 10 years ago.
    - Will provide the data from the studies to the Project Team
  - ***Our Team followed-up to obtain the data (see Appendix D).***
- **Engineering Consultant**
  - Inquired as to whether soil samples would be collected from legacy sites where pipe busting of AC has occurred to determine if the fibers migrate over time This is not in the scope of the project, but was be discussed with PAC.
  - Inquired as to when soil samples would be collected from pipe bursting demonstration sites.
  - ***Our Team collected soil samples before and after the demonstrations if possible.***
- **Industry Representative 2** (Post-Webinar)
  - Expressed interest in using their technology for a SIPP demonstration.
  - ***Our Team followed-up, but did not organize a demonstration.***
- **California Utility** (Post-Webinar)
  - Interested in case studies using rehabilitation methods on AC pipe.
  - ***Our Team provided contact info for various case studies cited in the webinar.***
- **Summary of Responses to Specific Questions**
  - Are there any additional data that needs to be gathered?
    - Legacy soils samples from renewal sites (added to project scope by PAC).
    - Water samples from isolated rehabilitated sections (not deemed possible).
  - Are there potential demonstrations sites that should be considered for pipe bursting, CIPP, and/or SIPP?
    - Florida Utility offered a pipe bursting site (served as Demonstration #1).
    - Nevada Utility offered a CIPP site (served as Demonstration #2).
    - Industry Representatives expressed interest in a SIPP site (this was not pursued as the activities that could release asbestos were very similar to the CIPP site).
  - Are there any additional technologies that should be considered for demonstration?
    - None were brought up.

CHAPTER 3
DEMONSTRATION 1: PIPE BURSTING

DEMONSTRATION APPROACH

This section outlines the overall of approach of the first field demonstration of Phase II and includes the site description, characteristics of the existing asbestos cement pipe, the design approach, and data collection protocol. One peer-reviewed journal paper will be submitted based on the findings of this demonstration.

Site Description

The first demonstration site was the City of Casselberry which is located in central Florida, approximately 15 miles northwest of the City of Orlando. The City was incorporated on October 10, 1940 and has a population of 26,566 (Census 2015).

The Water Production Division of the City is responsible for the operation of water treatment plants and distribution system. The potable water system includes three water treatment plants, six ground storage tanks, three elevated storage tanks, and a water distribution network of various pipe sizes and materials. The total storage capacity is approximately 3.35 million gallons (MG). Water is drawn from the Floridian Aquifer and the average daily demand is 5.0 MG per day (MGD).

Each treatment plant has three wells with a production capacity of 19.4 MGD. The treatment at each plant consists of aeration, addition of a corrosion inhibitor, and disinfection. Table 3-1 summarizes all of the drinking water and reclamation facilities and their respective capacities. The City has one reclamation facility (see Table 3-1) that is operated by the Water Reclamation Division, which reuses a 100% of the wastewater.

Table 3-1 Drinking water and wastewater facility capacities

Facility Name	Facility Type	Capacity (MGD)
North Water Plant	Drinking Water	5.256
Howell Park Plant	Drinking Water	4.030
South Water Plant	Drinking Water	4.948
Reclamation Facility	Wastewater Reuse	2.200

Physical/Operating Characteristics of the Burst AC Pipe

The pipe bursting demonstration was performed on a section of AC distribution main running underneath and alongside the entirety of Derbyshire Road in the City of Casselberry (Figure 3-2). Characteristics (i.e., historical, operational, and environmental) of the AC pipe that was burst underneath Derbyshire Road is presented in Table 3-2.

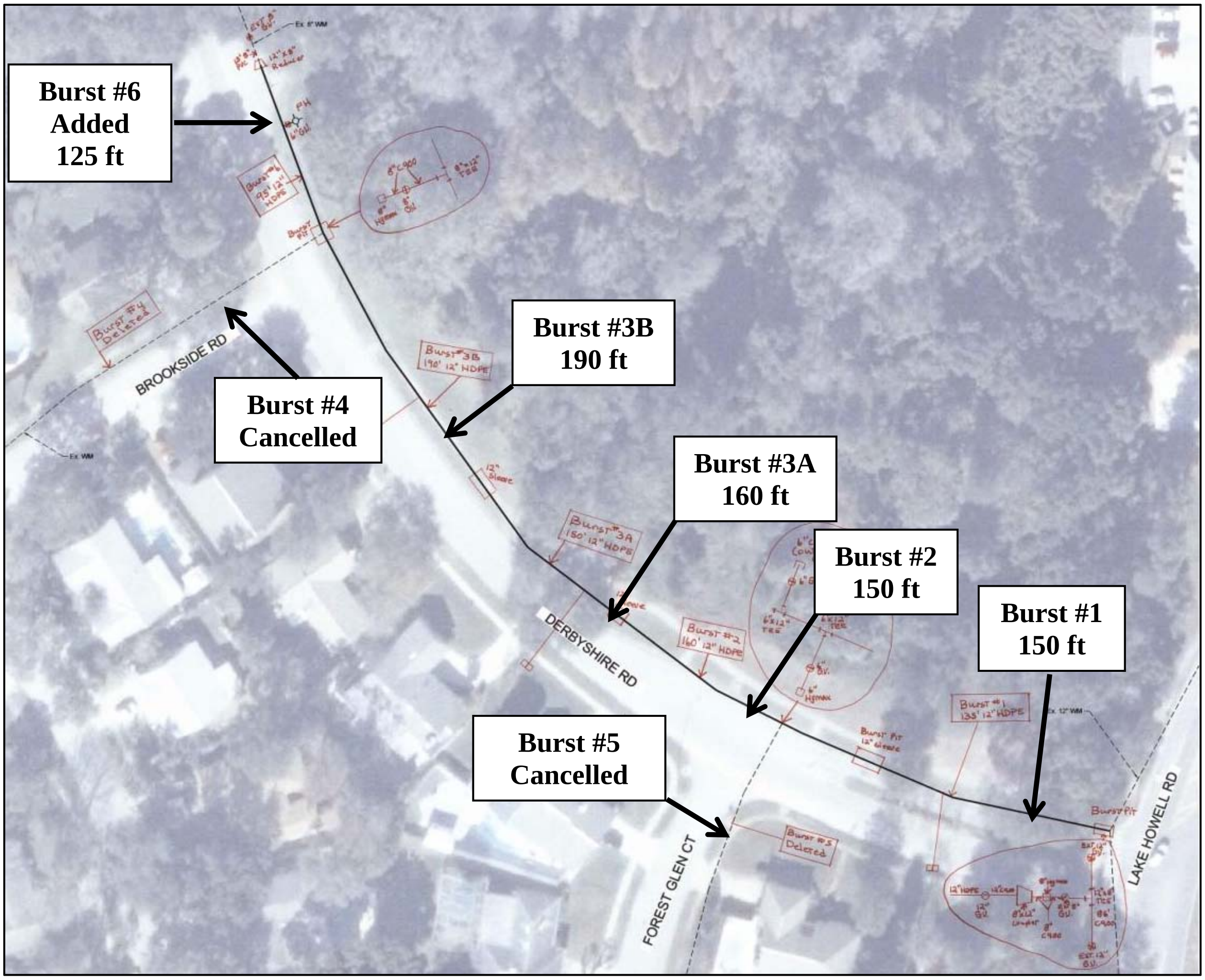
Table 3-2 Characteristics of the AC pipe

Historical	
Pipe ID and Material	8-in and 12-in AC Pipe
Installation Date	Approximately 1972
Pipe Joint-to-Joint Length (ft)	13
Pipe Outer Diameter (in.)	9.5
Pipe Class	150
Pipe Wall Thickness (in.)	0.50
Approximate Total Pipe Length (ft)	775
Burial Depth (ft below ground surface)	5
Type of Joints	Spigot and Coupling
Land Use over Main	Grassed Right-of-Way
Operational	
Typical Operating Flow (MGD)	Unknown
Typical Operating Pressure (psi)	60-65 psi
Water pH (S.U.)	7.8-8.0
Environmental	
Soil pH	Unknown
Average Monthly Temperatures (°F)/ Humidity (%) for August 2013[a]	High/Low: 91°F /75°F; Min/Max: 53%/95%

[a] Based on data from Weather Underground (www.wunderground.com)

Design Approach

A total of five bursts across Derbyshire Road, Brookside Road, and Forest Glen Court were originally planned for a total length of 1,020 ft. The size of the existing AC ranged in diameter from 8-in to 12-in and was entirely replaced with 12-in high-density polyethylene (HDPE) pipe. Due to unforeseen circumstances in the field, modifications to the original plans had to be made. Bursts #4 (185 ft) and #5 (185 ft) on Brookside Road and Forest Glen Court, respectively, were cancelled and Burst #6 (125 ft) along Derbyshire Road was added (see Figure 3-2). Burst #3 was divided into two (2) runs – #3A (160 ft) and #3B (190 ft) – due to difficult soil conditions experienced while performing runs #1 and #2. To accommodate runs #3A and #3B an additional pit (#4A) between pits #4 and #5 had to be excavated. As a result of the modifications, the total length of AC pipe burst and replaced decreased from 1,020 ft. to 775 ft. The locations of the actual five bursts that occurred in the field are shown in Figure 3-1 and summarized in Table 3-3.



Source: Courtesy of the City of Casselberry, FL

Figure 3-1 Map of pipe bursting locations in Casselberry, FL

Table 3-3 Bursting run length summary

Burst No.	Length (ft)	AC Size (in)	New Pipe	Start/End Pit
1	150	8	12-in HDPE	#1/#2
2	150	8		#2/#4; #3 (Tie-in)
3A	160	12		#4A/#4
3B	190	12		#4A/#5
6	125	8		#5/#8; #9 (Hydrant Pit)
Total	**775**			

The pipe bursting procedure outlined below, which uses pre-disinfected/pre-chlorinated pipe, was followed by the contractor (Killebrew) for the City of Casselberry. More details follow in the Pipe Bursting Demonstration section. Pre-chlorinated pipe bursting is innovative since the pipe segments are pre-disinfected, the water line can be put back into service once the ends are reconnected after bursting. This eliminates the need to install temporary bypass service, which can be costly, therefore residents are only without water during the daytime on the day their main lines are burst. This has resulted in a reduction of project by as much as 50% in some cases (Rockaway and Ball, 2007). Other examples of pre-chlorinated pipe bursting projects can be in the North American Society for Trenchless Technology (NASTT) technical paper library (www.nastt.org/technicalpapers).

1. Notify residents of upcoming service interruption (2 week notice)
2. Fuse HDPE pipe string
3. Swab the pipe string clean with a polyswab (pigging)
4. Pressure test the pipe string per manufacturer's requirements
5. Chlorinate the pipe string per Florida Administrative Code (F.A.C.) Rule 62-555-330
6. Flush super-chlorinated water from HDPE, which is passed through a dechlorinator.
7. Bacteriologically sample/test pipe string per F.A.C. requirements
8. Set up maintenance of traffic (one lane of traffic was shutdown)
9. Notify residents two days in advance of service interruption
10. Locate existing valves, fittings, & service connections
11. Isolate existing section of line to be rehabilitated
12. Excavate pits for machine, pipe insertion, fittings, & services
13. Remove existing fittings as needed
14. Insert rod string, attach bursting head to HDPE pipe & machine
15. Rehabilitate existing pipe via pipe bursting
16. Reconnect services to newly installed HDPE pipe string
17. Connect new main to existing water system and inspect for leaks
18. Backfill, compact, and restore pits

Data Collection Protocol

The site-specific quality assurance project plan (QAPP) included multiple data parameters across five categories – Technology Application, Time, Labor, and Equipment Requirement, Waste Volumes, Cost, and Environmental Impact – that were collected in the field. Air, drinking water, and soil samples were collected during the demonstration to better understand the environmental impact of pipe bursting. A summary of the parameters that were to be collected is presented in Table 3-4.

Table 3-4 Summary of field data collected

Parameter	Description	Method or Standard	Frequency	Party
Technology Application Parameters				
Host Pipe Characteristics	Length, number of services measured prior to rehabilitation (if applicable).	Parameters checked via CCTV or on as-builts during pre-rehab inspection.	Once per section	Contractor/ Utility
Raw Materials	Visual inspection of materials, including quantities and packaging.	Inspection conducted visually prior to rehabilitation activities.	Once per application	Battelle Team
Safety Requirements	Safety requirements associated with rehabilitation equipment and installation practices.	On-site staff will document requirements for comparison with traditional methods.	Daily	
Rehabilitation Application	Documentation of application timeline from installation to final reconnection.	Time and associated parameters from beginning to end of application.	Multiple times during installation	Battelle Team
Time, Labor, and Equipment Requirements				
Time and Labor	A record of the time, level of effort, and number of workers for each major feature of work.	On-site staff will maintain records of the time and number of workers.	Daily	Battelle Team
Equipment Operational Data	The carbon footprint of the demonstration was estimated based on equipment usage.	On-site staff will maintain records of the equipment types and use duration.		
Service Reconnections	Report difficulties encountered in reinstating service connections.	On-site staff will maintain records of the issues encountered.	During service reconnections	
Waste Volumes				
Excavation Pit Dimensions	Record the size of each pit, the amount of backfill soil, and the volume disposed of off-site.	On-site staff will maintain records of the excavations and soil uses.	Once per pit	Battelle Team
Cost				
Cost	Cost of installation including direct costs and associated restoration costs.	Cost per unit foot ($/ft.) calculated from bid docs and actual pipe length renewed.	Once	Contractor/ Utility
Environmental Impact				
Asbestos (Air)	Determine the level of asbestos contamination in the air during various activities.	ISO 10312 (1995)	Five per site (during rehab)	Battelle Team/ Reservoirs Lab
Asbestos (DW)	Quantify the level of asbestos contamination by the number of asbestos structures in water.	EPA Method 100.1 & 100.2 (1994)	Three pre-rehab Three post-rehab	
Asbestos (Soil)	Determine the presence of asbestos in soil, both pre and post-rehabilitation.	EPA Method 600/R-93/116 (1993)	Three pre-rehab Three post-rehab	

PIPE BURSTING DEMONSTRATION

This section outlines the activities involved with the pipe bursting field demonstration including site preparation, pipeline preparation, technology application, and site restoration.

Site Preparation

Prior to rehabilitation of the pipe via bursting, various site preparation activities were required. These activities included: resident notification, installation of new service connections, installation of dewatering systems, pipe fusing and pre-chlorination, and excavation of pits and pipe removal.

Resident Notification

For this project a bypass system was not used, so an interruption to a resident's water service for the day would be required. The affected residents were first notified by the contractor, about the interruption to their service two weeks in advance. A second notification was sent out two days before the start of construction. The water service was always reconnected at the end of the day (6:00 PM) so no residents are without water in the evening. In this particular instance, due to bi-directional flow within the pipe, only the residents whose service connection was located on the pipe section undergoing rehabilitation was interrupted.

Safety and Logistics

Throughout the demonstration project, individual excavation areas along Derbyshire Road were secured. Open pits were marked with orange barrels and all pits were backfilled at the end of each day to avoid accidents during the evenings and on weekends. The contractor was responsible for traffic control.

The Florida Department of Environmental Protection (FDEP) does not require permits when using the pre-chlorinated pipe bursting method for pipes up to two times larger size in diameter. Therefore, only approval from the City Engineer was required to perform pipe bursting work within the City's right-of-way where all the pipe was located.

The demonstration took place over two work weeks (weeks of August 12 and August 19, 2013). A typical day began around 7:00 AM and activities were normally completed by 6:00 PM. The Battelle team typically had two staff members onsite during bursting activities and at least one staff member onsite during restoration activities. The Battelle team maintained constant coordination with the City and its contractors throughout the demonstration project to ensure that all field data was collected as planned in the site-specific QAPP. Level D personal protective equipment, including hard hats, safety glasses, steel-toed shoes and safety vests, were required for all personnel while onsite

Dewatering Systems

Due to the sandy soil conditions in the area, dewatering systems were installed near each pit. One week prior to the start of work, a crew drilled a series of 1.5-in holes approximately 2-3 ft apart beside the planned pit locations. A section of slotted 1.5-in. diameter polyvinyl chloride (PVC) was inserted into each hole and connected to a larger PVC pipe (i.e., 6-in diameter x 10 ft length) by a short hose (Figure 3-2). Approximately five 1.5-in slotted PVC sections were connected to each 12 ft section of 6-in PVC. The 12 ft section was connected to a pump, which pumped the water to a nearby storm sewer that has been fitted with an external filter to prevent sand and debris from entering.

Figure 3-2 Dewatering system (left) and pump (right)

Service Connections

As a result of the bursting process, new service connections for each residence had to be installed. Had open cut been used to replace the main in the same trench, the existing services would likely have been used and re-tapped into the new main. A week prior to the start of scheduled work, existing service connections were located and new service connections (i.e., 1-in. HDPE) were directionally drilled using a micro rig (Figure 3-3). The new services were connected after the existing AC pipe had been burst and the new HDPE pipe was inserted. More than one residence could be supplied by a single connection, which reduces the number of taps into the main.

Figure 3-3 New HDPE service (left) and service connected to new HDPE main (right)

Pipe Fusing, Pressure Testing, and Pre-Chlorination

HDPE was selected by the City as the replacement pipe for the current AC water line. The pipe string for each burst run was prepared at the site up to two weeks in advance. Specialized equipment was used to fuse the sections of HDPE pipe. The equipment first shaved down each end of the pipes to be fused to ensure they were perfectly flush. Next, a flat iron larger than the diameter of the pipe was heated to 400°F (Figure 3-4) and inserted between the two sections of pipe that were to be fused. The pipe ends were pulled together against the iron to heat up. After the ends heated up, becoming deformable, the iron was removed and the pipe ends were pulled together and locked in place causing the ends to fuse while simultaneously cooling down (Figure 3-4).

Figure 3-4 Flat iron with heating element (left) and pipe fuser (right)

After all required sections of HDPE pipe were fused the string of pipe was rinsed with clean water and pressure tested to 150 psi for two hours as instructed by the manufacturer to check for any leaks at the fused seams. Upon successful completion of the pressure test, the string of pipe was completely filled with super-chlorinated water (approximately 2% by weight as hypochlorite [$^{-}$OCl]). The super-chlorinated water was made by putting approximately eight ounces of calcium hypochlorite ($Ca(OCl)_2$) powder (65% available chlorine) into five gallons of water (Figure 3-5). The super-chlorinated water remained in the pipe up until the time the string was to be used. The water was then drained prior to insertion.

Figure 3-5 Buckets of super-chlorinated water (left) and calcium hypochlorite (right)

Pit Excavation and Pipe Removal

A total of eight pits were excavated over the course of the two week demonstration. Six pits served as machine and/or pipe insertion pits; one pit was needed for the connection of the water main that runs underneath Forest Glen Court (see Figure 3-1); and one pit was required for the removal and installation of a new fire hydrant. Only the pits required for that day's scheduled bursting run are excavated. The average dimensions of the eight pits were approximately 14 ft (L) x 10 ft (W) x 5 ft (D). The pits were outlined and "de-rocked" by cutting through the pavement with a demolition saw (Figure 3-6) and removing the pavement above the soil with an excavator. The broken-up pavement was place in a temporary debris pile prior to being loaded into a truck for disposal. After the pits were "de-rocked", an excavator was used to excavate the soil and gain access to the pipe (Figure 3-6). All excavated soil was kept onsite and used to backfill the pits at the end of each day.

Figure 3-6 Pavement cutting (left) and pit excavation (right)

The section of AC pipe exposed in each pit was removed so the crew could gain internal access to the pipe. To remove the exposed pipe, a cut was made near each pipe and pit wall interface. The cuts were made either using a small sledgehammer or hammer and chisel, depending if a clean edge (result of using a chisel) was needed or not (result of using a sledgehammer). Clean edges were needed to make the temporary connections between the newly inserted HDPE pipe and existing AC pipe. The cutting process involved two workers with dust masks – one worker was responsible for making the cut while the other worker maintained a wet cutting area using a sprayer (Figure 3-7).

Figure 3-7 Workers cutting AC pipe

The City and its contractor follow the practices in *Work Practices for Asbestos-Cement Pipe* (AWWA 1995). In addition, the cutting area on the pipe was wrapped with wet rags to prevent of pieces of the pipe becoming airborne and potentially causing injury. Once the cuts were finished, the pipe was connected to the boom of the excavator with a chain and lifted out of the pit. The AC pipe was then lowered on to a large plastic sheet on the ground where it was completely wrapped and tapped by a worker (Figure 3-8). The exposed ends of the AC pipe protruding into the pit were also wrapped with plastic until the start of bursting. If the section of pipe being removed contained a joint or a valve, only the exposed ends of the pipe were wrapped with plastic and tapped – not the entire piece. The wrapped section of pipe was loaded onto a truck for transport to a landfill that accepted asbestos waste.

Figure 3-8 Wrapping and taping of the AC pipe

Technology Application

After completion of the site preparation activities, the machine and insertion pits were prepared followed by rehabilitation of the pipe section via pipe bursting. Additional activities associated with the technology application included service reconnection, pipe swabbing, and water main connections. This process is described below for completeness, but it is not unique to AC pipe bursting.

Pit Preparation Activities

Of the two pits excavated to isolate the section of pipe for rehabilitation, one pit served as a machine or extraction pit while the other served as an insertion pit. Activities that occurred at each pit just prior to bursting are discussed below.

Machine Pit. This pit contained the hydraulic bursting equipment that was responsible for pulling the new HDPE pipe from the insertion pit and to the machine or extraction pit. A bed of gravel was laid in the pit prior to the introduction of equipment to provide a relatively level and stable base. The equipment (i.e., hydraulic bursting machine, linkage basket, pin basket, and steel plate) was then lowered into the pit using the boom of the excavator. The steel plate was positioned against the pit wall and contained a hole that allowed access to the pipe to be burst. The hydraulic bursting machine was placed against the plate for stability. The hydraulic bursting machine (A), linkage basket (B), pin basket (C), and steel plate (D) are shown in Figure 3-9.

Power to the bursting machine was provided by a large hydraulic pump located on a nearby flatbed trailer and was connected by two (2) hoses (Figure 3-10). A three-person crew was required in the machine pit. The roles of the crew were as follows:

- One worker loaded the linkages into the bursting machine
- One worker connected the linkages using a hammer and pin
- One worker outside the pit operated the hydraulic pump to push or pull the linkages

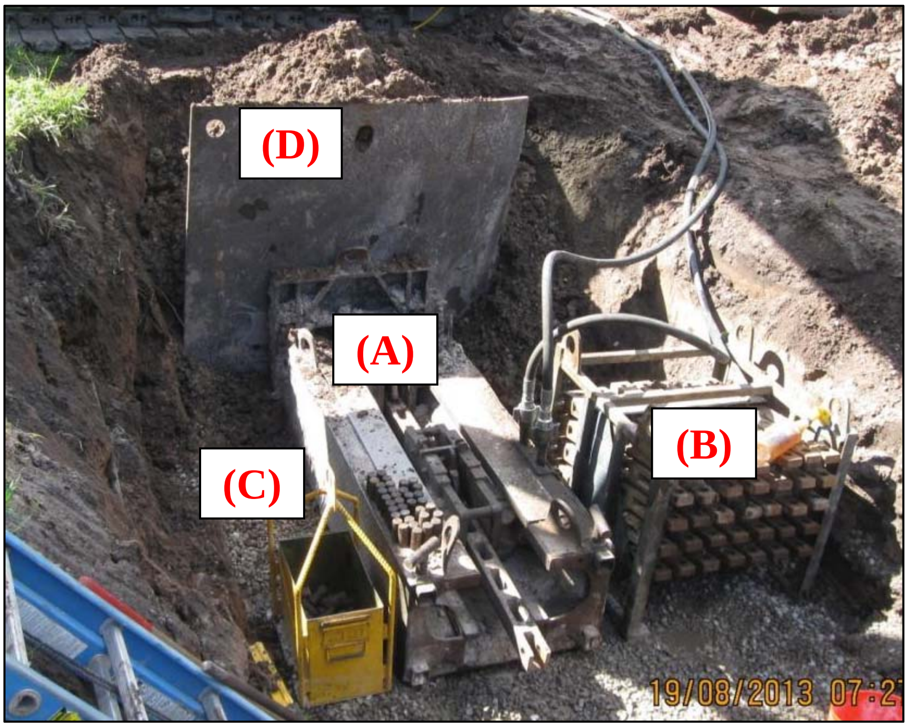


Figure 3-9 Machine pit containing bursting equipment

Figure 3-10 Hydraulic pump and linkages on a trailer

Each linkage was approximately 3 ft in length and was connected to another linkage using a pin. The linkages were stored in baskets that held approximately 30 linkages. Prior to being connected, each end of the linkage was sprayed with oil to prevent sticking while disconnecting during the bursting process.

After the bursting machine was properly positioned in the pit and connected to the hydraulic pump, the two workers in the pit began loading the linkages and pushing them through to the insertion pit. When pushing through to the insertion pit, the first linkage was fitted to a rounded head to minimize the chance of snags while traveling through the pipe and any pits.

Insertion Pit. This pit would serve as the insertion point for the new HDPE pipe that was outfitted with bursting and expander heads. Prior to insertion of the pipe, the water supply was shut off. This was accomplished one of two ways:

1. If the new HDPE pipe was going to be connected to a water main that was <u>not</u> going to be rehabilitated, a valve was turned off to isolate the existing pipe section.
2. If the new HDPE pipe was going to be connected to another section of new HDPE pipe from a previous burst, a large hydraulic clamp was used (Figure 3-11).

Figure 3-11 Hydraulic pipe clamp

Since one burst run was performed per day and runs were made consecutively, temporary connections were made between new HDPE pipe and the existing AC pipe. Temporary connections were typically made in the machine pit while permanent connections were made in the insertion pit. Because a pit that served as a machine pit on one run would serve as the insertion pit on the next run, the temporary connection established when the pit was a machine pit was removed using a chainsaw to allow access to the AC pipe. Figure 3-12 shows a worker starting to make a cut in the HDPE side of the connection.

Figure 3-12. Removal of temporary connection

Once the temporary connection was removed, the string of pipe to be used for the run was lined up with the insertion pit using an excavator and a front-end loader with equipped with forks. Next, the bursting head was connected to the front-end of the pipe string. The bursting head (Figure 3-13) consisted of four (4) distinct elements:

1. Connector Head – round metal cap with a connection that was fused to the front of the pipe.
2. Extender Rod – metal rod (approximately 3 ft) that connected to the connector head with a pin.
3. Expander Head – metal cylinder with a conical front slightly used to create the void space the new pipe will occupy. Slid over the extender rod and connector head.
4. Splitter Head – metal rod with two joints that allowed for horizontal and vertical movement and two fins on each side used to split the existing pipe. The rear connected to the extender rod while the front connects to the linkages. Both connections used pins.

Figure 3-13 Elements of the bursting head

Pipe Bursting

Upon connection of the bursting head to the linkage at the insertion pit (Figure 3-14), the crew in the machine pit began pulling the pipe string and bursting the AC pipe. The pipe string was moved in a series of short pulls as the bursting machine pulled back the linkages. The average pull rate was approximately 6 ft/min. This equates to one basket (30 linkages) every 15 minutes. As the linkages returned to the machine pit they were disconnected by the workers in the pit and placed in the basket. When the bursting head reached the machine pit, the splitter head, extender rod, and expander head were removed, leaving only the connector head still attached. The equipment (i.e., bursting machine, linkage basket, pin basket, and steel plate) was then raised from the machine pit. The connector head was chained to the boom of the excavator, which finished pulling through the pipe string.

Figure 3-14 Fully-assembled bursting head connected to linkage at insertion pit

During the demonstration, instances of upheaval were observed on bursting runs #2 and #6. Figure 3-15 shows the upheaval at run #2 and #6, respectively. In both instances the shallow depth of the pipes (i.e., approximately 2.5-3 ft) combined with enlargement of the original pipe (i.e., 8-in to 12 in) resulted in the upward displacement of soil and roadway/sidewalk. Any damage to roadways, sidewalks, and/or grass was repaired during site restoration.

Figure 3-15 Upheaval of roadways and sidewalks during runs #2 (left) and #6 (right)

Water Main Connection and Pipe Swabbing

After the pipe was in place and cut to length, connections to the existing water mains were made in each pit. Typically, a temporary connection was made at the machine pit and a permanent connection was made at the insertion pit. A temporary connection was one that was made between the new HDPE pipe and the existing AC pipe. This connection consisted of a ductile iron reducer that connected the 12-in HDPE to an 8-in PVC section, which was connected the existing 8-in AC pipe using a coupling. The HDPE and PVC were connected to the reducer by Megalug® mechanical joints. When temporary connections were made between pipes of the same diameter, a ductile iron sleeve was used instead of a reducer. Note that an aluminum insert was placed in each pipe end connected to the sleeve to ensure a proper connection between the sleeve and Megalug®. The temporary connection was removed in order to gain access to the AC pipe for the next bursting run. Figure 3-16 shows two finished temporary connections – one with a ductile iron reducer and one with a ductile iron sleeve.

Figure 3-16 Connection between HDPE and AC with reducer (left) and sleeve (right)

A permanent connection was one that was made between two new HDPE pipe ends. The two sections of the same diameter (i.e., 12-in) were connected using a ductile iron sleeve and Megalug® mechanical joints. A permanent connection between HDPE pipes is shown in Figure 3-17. Note that an aluminum insert was placed in each pipe end connected to the sleeve to ensure a proper connection between the sleeve and Megalug®. To prevent the introduction of bacteria into the super-chlorinated, clean HDPE pipe, all tools, pipe sections, and fittings were thoroughly washed in chlorinated water before being used.

Figure 3-17 Permanent connection between HDPE pipes

Prior to making the temporary connection, super-chlorinated water was loaded into the HDPE pipe followed by a polyswab (also known as a pig). After the temporary connection was complete, but before the permanent connection was made, water was introduced to the pipe by opening a valve on the AC side. The water propelled the polyswab and the slug of super-chlorinated water through the new pipe cleaning it as it travelled along. The polyswab was recovered from the other end of the pipe located at the machine pit, as shown in Figure 3-18. Following the polyswab, the permanent connection was then made using chlorinated tools and fittings.

Figure 3-18 Cleaning of HDPE pipe using super-chlorinated water and polyswab

Site Restoration

Site restoration activities customarily took place on Thursdays and Fridays (i.e., August 15-16 and August 22-23, 2013) while bursting activities occurred Mondays through Wednesdays (i.e., August 12-14 and August 19-21, 2013). Restoration activities were performed by the same contractor, but a different crew. Backfilling of the excavation pits was performed by the bursting crew. All excavated soil was used to backfill the pits at the end of each work day (Figure 3-19).

Figure 3-19 Backfilled excavation pit

Activities performed by the restoration crew included the repaving of asphalt roadways, pouring of concrete curbs and sidewalks, and the replanting of grass. The preparation and repaving of Pit #1 is shown below in Figure 3-20.

Figure 3-20 Preparation and repaving of pit #1 by restoration crew

The broken pieces of host AC pipe not removed during accessing the pipe (which stay under soil cover throughout the pipe bursting process) are left in the ground as with all pipe bursting projects. This is similar to abandoning the AC in place. A couple attempts have been made to determine if there is any impact to the soil in areas where AC pipes are located or have previously been burst. Goulburn Valley Water conducted an assessment in June 2014 on an AC pipe that had not been burst. One soil sample, which was approximately 2-inches from the side of the pipe was found to contain asbestos. Other samples located above the crown did not show any asbestos.

For comparison, the team also collected soil samples from an AC pipe that was previously pipe burst in Florida from the same Casselberry program. A 12-in. AC pipe that was installed in 1973, was pipe burst in July 2009. The team collected soil samples from two pits locations in

September 2014, with one sample near the crown and one sample 2 to 3 ft above the crown in each pit (Figure 3-21). All four samples showed either trace levels of asbestos or were non-detectable, which suggests there has been no increase in asbestos released in the ground since the pipe bursting occurred five years ago.

Figure 3-21 Retrospective soil samples from AC pipe bursting site

ENVIRONMENTAL SAMPLING RESULTS

This section presents the results of the air, soil, and water samples collected during the pipe bursting demonstration.

Air Sampling

A total of eight air samples were collected during the demonstration on two separate days, including two field blanks (a minimum of five samples were recommended in the QAPP). Air samples were collected by a Battelle staff member using two SKC AirChek® XR5000 personal air sampling pumps with approximate flow rates of 2 liters per min (LPM). The pumps were calibrated in the field prior to sample collection using a Bios Defender Model 510M flow calibrator. Note the Bios Defender is a primary calibration standard. Table 3-5 summarizes the air samples collected.

Table 3-5 Summary of collected air samples

Sample No.	Burst Run No.	Average Flow Rate (LPM)	Run Time (min)	Volume (L)
1	#2	2.0181	278	561
2	#2	2.0113	278	559
3	#2	2.0577	182	374
4	#2	2.0381	182	371
5	#6	2.0113	181	364
6	#6	1.9933	192	383
Field Blank-1	#2	N/A	N/A	N/A
Field Blank-2	#6	N/A	N/A	N/A

N/A = not available

Air sample analysis was performed by Reservoirs Environmental, Inc. (REI) laboratories located in Denver, Colorado. The samples were analyzed using TEM following ISO method 10312 (1995). The results of the air sample analyses are presented in Table 3-6.

Table 3-6 Asbestos air sample results summary

Sample No.	Number of Asbestos Structures Detected	Analytical Sensitivity (s/cc)	Asbestos Concentration (s/cc)
1	ND	0.0038	BAS
2	ND	0.0036	BAS
3	ND	0.0041	BAS
4	ND	0.0042	BAS
5	ND	0.0042	BAS
6	ND	0.0040	BAS
Field Blank-1	ND	N/A	BAS
Field Blank-2	ND	N/A	BAS

s/cc = structures per cm^3; ND = none detected; N/A = not available; BAS = below analytical sensitivity

As shown in Table 3-6, the asbestos concentration of each sample is below the analytical sensitivity. The analytical sensitivity of each sample is below the 8-hr TWA-PEL of 0.1 s/cc set by OSHA. These results match well with NEA previously conducted in Casselberry (Jonsson 2011) and with the air studies conducted in Germany that showed asbestos did not exceed the detection limit during pipe bursting (Appendix D). This is a key finding in the study as there were not any positive exposure results found in the literature or testing to show pipe bursting posed a threat to works or the public.

The air sample results are representative of all activities that occurred onsite on the specific day of sampling. Note the Battelle staff member was not present in the machine pit or insertion pit at the time of bursting, but on the surface at the edge of the pit due to space restrictions and worker safety. During the bursting operation, the staff member traveled between the machine and insertion pit in an attempt to collect representative samples.

Soil Sampling

Six pre-rehabilitation soil samples were collected during the demonstration from two different excavation pits over two days (a minimum of three samples were recommended in the QAPP). Each soil sample was collected from the pit walls at different depths. Table 3-7 summarizes the soil samples collected.

Soil sample analysis was performed by REI laboratories. Each sample was analyzed using PLM in accordance with EPA Method 600/R-93/116 (1993). In addition, samples 2 and 5 underwent a 400 point count utilizing PLM. Table 3-8 presents the results of the baseline soil sample analyses.

Table 3-7 Summary of collected soil samples

Sample No.	Burst Run No.	Location	Depth from Surface (ft)	Notes
1	#2	Pit#4-West Side	4.5	Pipe crown to 1ft above
2	#2	Pit#4-East Side	4.5	Pipe crown to 1ft above
3	#2	Pit#4-West Side	3	2-3 ft above pipe crown
4	#2	Pit#4-East Side	3	2-3 ft above pipe crown
5	#6	Hydrant Pit-South Side	3	Pipe crown
6	#6	Hydrant Pit-South Side	2	1 ft above pipe crown

Table 3-8 Baseline asbestos soil sample results summary

Sample No.	Asbestos Content		Non-Asbestos Fibrous Component (%)	Non-Fibrous Components (%)
	Mineral	Visual Estimate (%)		
1	–	ND	0	100
2	Chrysotile: Crocidolite:	TR<0.25 TR<0.25	2	98
3	–	ND	TR	100
4	–	ND	1	99
5	Chrysotile: Crocidolite:	TR<0.25 TR<0.25	1	99
6	–	ND	TR	100

ND = none detected; TR = trace, <1% visual estimate

No asbestos was detected in soil samples 1, 3, 4, and 6. Soil samples 2 and 5 each had trace amounts of Chrysotile and Crocidolite at <0.25%. The results indicate essentially no asbestos was released by the pipe to the surrounding soil since its installation over 40 years ago.

Post-rehabilitation soil samples were collected by the City approximately five months after the baseline samples. A total of six samples were collected (a minimum of three samples were recommended in the QAPP) from the same locations (see Table 3-9) and analyzed by REI laboratories using PLM in accordance with EPA Method 600/R-93/116. In addition, samples 1, 2, 4, and 6 underwent a 400 point count utilizing PLM. The results of the post-rehabilitation soil samples are presented in Table 3-9.

Table 3-9 Post-rehabilitation asbestos soil sample results summary

Sample No.	Asbestos Content		Non-Asbestos Fibrous Component (%)	Non-Fibrous Components (%)
	Mineral	Visual Estimate (%)		
1	Chrysotile: Crocidolite:	TR<0.25 TR<0.25	TR	100
2	Chrysotile: Crocidolite:	TR<0.25 TR<0.25	TR	100
3	–	ND	TR	100
4	Chrysotile:	TR<0.25	TR	100
5	–	ND	TR	100
6	Chrysotile:	TR<0.25	TR	100

ND = none detected; TR = trace, <1% visual estimate

No asbestos was detected in soil samples 3 and 5. Soil samples 1 and 2 each had trace amounts of Chrysotile and Crocidolite at <0.25% while soil samples 4 and 6 each had trace amounts of Chrysotile at <0.25%. Comparison between the baseline and post-rehabilitation soil sample results are summarized below in Table 3-10.

Table 3-10 Comparison summary of soil sample results

Sample No.	Baseline	Post-Rehabilitation	Comparison Findings
1	None Detected	Trace Amount (Chyrsotile & Crocidolite)	Increase in asbestos concentration by trace amount
2	Trace Amount (Chyrsotile & Crocidolite)	Trace Amount (Chyrsotile & Crocidolite)	No change in asbestos concentration
3	None Detected	None Detected	No change in asbestos concentration
4	None Detected	Trace Amount (Chyrsotile)	Increase in asbestos concentration by trace amount
5	Trace Amount (Chyrsotile & Crocidolite)	None Detected	Decrease in asbestos concentration by trace amount
6	None Detected	Trace Amount (Chyrsotile)	Increase in asbestos concentration by trace amount

An increase in asbestos concentration was observed in three of the six soil samples (i.e., Samples 1, 4, and 6). The increase observed was only by trace amounts for all three samples. The asbestos minerals present were Chyrsotile and Crocidolite. No change in asbestos concentration was seen in two of the soil samples (i.e., Samples 2 and 3). Sample 2 contained trace amounts of Chyrsotile and Crocidolite in both the baseline and post-rehabilitation samples, and Sample 3 was found to be non-detect in each of the two samples collected. A decrease in asbestos concentration was noted in Sample 5. The baseline results for Sample 5 showed traced amounts of Chrysotile and Crocidolite, while the post-rehabilitation sample was non-detect. This result which shows little impact on the soil could be expected in the short term. Over a longer period, it would be beneficial to know whether asbestos fibers migrate in soil after pipe bursting.

Water Sampling

During the demonstration, pre- and post-rehabilitation water samples were collected from a residential service line and a fire hydrant connected to the water main. Samples were collected in clean, 1-L HDPE bottles. A total of five samples were collected in including one blank sample that contained deionized (DI) water (a minimum of three samples were recommended in the QAPP). A summary of the water samples collected is presented in Table 3-11.

Water sample analysis was performed by REI laboratories. The samples were analyzed using TEM following EPA method 100.2 (1994). The results of the water sample analyses are presented in Table 3-12.

Table 3-11 Summary of collected water samples

Sample No.	Burst Run No.	Sample Location	Sample Type	Sample Volume (L)
1	1	Service Line	Pre-Rehab	1
2	6	Hydrant	Pre-Rehab	1
3	1	Service Line	Post-Rehab	1
4	6	Hydrant	Post-Rehab	1
5	N/A	N/A	Blank	1

N/A = not available

Table 3-12 Water sample results summary

Sample No.	Asbestos Structures Detected	Analytical Sensitivity (msl)	Asbestos Concentration (msl)
1	5	0.17	0.87
2	58	0.35	20.07
3	1	0.09	0.09
4	12	0.08	0.94
5	ND	0.07	BAS

ND = none detected; BAS = below analytical sensitivity; msl = million structure/liter

Only one sample (Sample 2) was above the EPA maximum contaminate level (MCL) for asbestos in drinking water of 7 million structures per liter (msl). A decrease in asbestos concentration was observed at both locations between the pre- and post-rehabilitation samples. An 89.7% decrease in asbestos concentration occurred at the residential service line (i.e., Samples 1 and 3) while a 95.3% decrease in asbestos concentration was observed at the hydrant location (i.e., Samples 2 and 4). Since the new HDPE line is still connected to AC lines at three locations, the presence of asbestos in the drinking water is likely to continue, albeit at lower concentrations than before. Even though water utilities monitor for asbestos under their water quality programs to ensure levels are below the EPA MCL, it would be valuable to study the asbestos levels closer to areas with lots of AC pipe as the sample sites may not always be near AC pipe locations.

CHAPTER 4
DEMONSTRATION 2: CIPP

DEMONSTRATION APPROACH

This section outlines the overall of approach of the second field demonstration of Phase II and includes the site description, characteristics of the existing asbestos cement pipe, the design approach, and data collection protocol. One peer-reviewed journal paper will be submitted based on the findings of this demonstration.

Site Description

The demonstration was conducted by Las Vegas Valley Water District. Approximately 90% of its water is supplied by a river and 10% by a deep aquifer. The aquifer is primarily used in the summer months to meet peak demand. The water is treated using ozonation, aeration, flocculation, and filtration. Then the water is chlorinated upon leaving the treatment plant.

Physical/Operating Characteristics of the Host Pipe

The host pipe, which was installed in 1963, is 3,100 linear feet (LF) of 16-in AC pipe. The pipe typically operates at a pressure of approximately 75 psi while transmitting approximately 1.0 and 2.2 MGD in the winter and summer, respectively. Table 4-1 summarizes the historical, operational, and environmental characteristics of the host pipe.

Table 4-1 Characteristics of the host pipe

Historical	
Pipe ID and Material	16-in AC Pipe
Installation Date	October 1963
Pipe Joint-to-Joint Length (ft.)	20
Pipe Outer Diameter (in.)	19
Pipe Class and Wall Thickness	150 and 1.5-in
Approximate Total Pipe Length (ft.)	3,100
Burial Depth (ft. below ground surface)	4
Type of Joints	AC Coupling with Rubber Sealing Rings
Land Use over Main	Heavy Traffic – Truck, Bus, etc.
Operational	
Typical Operating Flow (gpm/(MGD)	700/1.0 (winter) to 1,500/2.2 (summer)
Typical Operating Pressure (psi)	~75
Water pH (S.U.)	7.8
Environmental	
Soil pH (S.U.)	8.1
Avg. Temp. (°F)/Humidity-Dec. 2013[a]	47°F/37%

[a] Based on data from National Weather Service (www.weather.gov).

Design Approach

A total of 14 runs and 20 insertion pits were required to complete the lining of the 3,100-ft of AC pipe. The CIPP technology that was installed was NORDIPIPE™. During the course of the lining operation, only one of the 31 services had to be reinstated by excavation – the remaining 30 were robotically reinstated. In addition, 14 fire hydrants were reconnected. Prior to the start of construction, a 10-in bypass was installed to continue water service to customers during construction. The pipe lining procedure outlined below was followed by the contractor and subcontractor.

1. Excavate pits and cut AC pipe for internal access
2. Setup of 10-in HDPE bypass
3. Camera (CCTV) and clean (i.e., water jet and swab) lines
4. Plug service connections
5. Install and cure CIPP liner
6. Install end seals on lined pipe
7. Pressure test each segment
8. Remove service plugs
9. Install pipe fittings (i.e., couplings and tees) and gate valves (hydrant locations only)
10. Reconnect water service
11. Remove bypass and backfill insertion pits
12. Pour concrete for curbs, gutters, sidewalks, and pads
13. Pave insertion pits
14. Repave roadway

Data Collection Protocol

Multiple data parameters across seven categories – Rehabilitated Pipe QA/QC Measurements, Technology Application, Time, Labor, and Equipment Requirement, Waste Volumes, Material Properties, Cost, and Environmental Impact – were collected in the field. Air, drinking water, and soil samples were collected during the demonstration to better understand the environmental impact of pipe lining. All samples were sent to REI laboratories (Denver, CO) for asbestos analysis. A summary of the parameters that were collected is presented in Table 4-2.

Table 4-2 Summary of field data collected

Parameter	Description	Method or Standard	Frequency	Party
Field QA/QC Measurements Made on Rehabilitated Pipe				
Pipe Condition	Closed circuit television (CCTV) inspections of interior pipe surface.	CCTV used for the pre and post-rehab inspections to document observations.	Twice (pre and post-lining)	Contractor
Pipe Diameter	The outer (OD)/inner diameter (ID) will be verified.	OD/ID measured with a tape measure.	Four positions per cross-section	Battelle Team
Lining Thickness	Liner thickness measured manually with a micrometer in the field.	Measured at 3, 6, 9, and 12 o'clock at each opening.		
Technology Application Parameters				
Host Pipe Characteristics	Pipe cleanliness, length, number of services measured prior to rehabilitation.	Parameters checked via CCTV during pre-rehabilitation inspection.	Once per section	Contractor
Raw Materials	Visual inspection of materials, including quantities and packaging.	Inspection conducted visually prior to rehabilitation activities.	Once per application	Battelle Team
Safety Requirements	Safety requirements associated with rehabilitation equipment and installation practices.	On-site staff will document requirements for comparison with traditional methods.	Daily	
Rehabilitation Application	Documentation of application timeline from initial installation to final reconnection.	Time and associated parameters from beginning to end of application.	Multiple times during installation	Contractor/ Battelle

(continued)

Table 4-2 (Continued)

Time, Labor, and Equipment Requirements				
Time and Labor	A record of the time, level of effort, and number of workers for each major feature of work.	On-site staff will maintain records of the time and number of workers.	Daily	Battelle Team
Equipment Operational Data	The carbon footprint of the demonstration was estimated based on equipment usage.	On-site staff will maintain records of the equipment types and use duration.		
Service Reconnections	Report difficulties encountered in reinstating service connections.	On-site staff will maintain records of the issues encountered.	During service reconnections	
Waste Volumes				
Pre-Rehabilitation	Record the time and estimate the volume of water used for pipe cleaning.	Time and volume to be estimated from durations in field log book.	Once per section	Battelle
Excavation Pit Dimensions	Record the size of each pit, the amount of backfill, and the volume disposed of off-site.	On-site staff will maintain records of the excavations and soil uses.	Once per pit	
Material Properties				
Various Material Parameters	Various QA/QC tests required by the utility (i.e., flexural and tensile strength, hardness tests, etc.).	ASTM D638; ASTM D790; ASTM D2240	Various	Third-Party Lab
Cost				
Cost	Cost of installation including direct costs and associated restoration costs.	Cost per unit foot ($/ft.) calculated from bid docs and actual pipe length renewed.	Once	Battelle

(continued)

Table 4-2 (Continued)

Environmental Impact				
Asbestos (Air)	Determine the level of asbestos contamination in the air during various activities.	ISO 10312 (1995)	Five per site (during rehab)	Battelle/ Reservoirs Lab
Asbestos (DW)	Quantify the level of asbestos contamination by the number of asbestos structures in water.	EPA Method 100.1 & 100.2 (1994)	Three pre-rehab Three post-rehab	
Asbestos (Soil)	Determine the presence of asbestos in soil, both pre and post-rehabilitation.	EPA Method 600/R-93/116 (1993)	Three pre-rehab Three post-rehab	

PIPE LINING DEMONSTRATION

This section outlines the activities involved with the CIPP pipe lining field demonstration including site preparation, pipeline preparation, technology application, post-lining activities, and site restoration.

Site Preparation

Prior to pipe lining, various site preparation activities were required. These activities included: safety and logistics, installation of a bypass, and excavation of insertion pits for pipe access.

Safety and Logistics

Throughout the lining project, individual excavation areas were secured. The contractor for was responsible for traffic control. The lining portion of the project was scheduled to take place over approximately three weeks (December 2 through December 24, 2013) with work occurring Monday through Thursday. Due to delays, lining did not start until December 6, 2013 and, therefore, would occur Monday through Saturday to keep on schedule. A typical day began around 7:30 AM and activities were normally completed by 3:00 PM. The permits required included fire hydrants, air quality (dust control and asbestos), and stormwater protection.

In addition to the permits, the utility also coordinated with the local natural gas, phone, cable, and sewer utilities that had infrastructure in the area. Open pits (i.e., pits in use) were marked with orange barricades, fencing, and signs. All other pits not in use were covered with steel plates or barricaded. At the end of each work day, all open pits were either covered with steel plates or barricaded and fenced off (see Figure 4-1) to avoid accidents during the evenings and weekends.

Figure 4-1 Access pit along roadway barricaded and fenced off

To ensure all activities associated with the lining operation were covered, two Battelle teams were utilized. The first team documented lining activities and collected environmental samples (i.e., air, soil, and water) during the week of December 9, 2013. The second team continued to document the lining activities and make any additional observations. The Battelle teams maintained constant coordination with utility and its contractors while onsite to ensure that all field data was collected as planned in the site specific QAPP. Level D personal protective equipment, including hard hats, safety glasses, steel-toed shoes and safety vests, were required for all personnel while onsite.

Excavation of Pits

A total of 20 pits were excavated in the weeks prior to the start of lining to gain access to the 16-in AC pipe and any tie-ins and/or appurtenances. Dimensions of three pits that were measured while onsite and are presented in Table 4-3 along with the approximate volume excavated.

Table 4-3 Excavation pit measurements and calculated volumes

Pit No.[(a)]	Pit Dimension (ft)			Approximate Volume (ft^3)
	Length	Width	Depth	
1	22.0	10.0	5.5	1,210
2	8.5	9.5	5.6	451
8	17.3	8.9	6.0	927
Average	**15.9**	**9.5**	**5.7**	**863**
Standard Deviation	**6.9**	**0.5**	**0.3**	**384**

(a) Number corresponds to a specific pit from the project plans

The width and depth of the pits measured varied little and were 9.5 and 5.7-ft on average. Pit length varied greatly ranging from 8.5 to 22-ft. Pit length was dependent upon the presence of any tie-ins and/or appurtenances, which increased the length of the pit.

Installation of Bypass and Pipe Access

To continue uninterrupted water service to customers during the course of the project a bypass was installed. The bypass started on the south side of the southernmost pit and ended at the north side of the northernmost pit, and was constructed of approximately 3,100-ft of 10-in HDPE. The bypass had 31 service and 14 fire hydrant connections, and, per code, was buried below grade at all roadway entrances and exits. Figure 4-2 shows elements of the bypass.

Figure 4-2 Bypass system: hydrant (left), service (center), and buried entrance (right)

Following the installation of the bypass, the pipe was drained and the sections of AC pipe exposed during the pit excavations were removed to gain access to the inside of the pipe. The exposed AC pipe was removed using a wet-cutting technique to prevent the unintentional release of asbestos fibers to the air and surrounding soil. The AC pipe sections removed from the pits were wrapped in plastic and disposed of according to applicable regulations. For convenience, approximately 1-ft of AC pipe was left protruding from the end of each pit wall (Figure 4-3).

Figure 4-3 Cut AC pipe protruding from the pit wall

Pipe Line Preparation

Once the inside of the pipe was accessible, it underwent the following activities in preparation for the liner: a pre-lining inspection, cleaning by water jet, and the plugging of existing service connections.

Pre-Lining Inspection and Cleaning

The AC pipe line was inspected using a robotic camera and CCTV to determine its condition and locate all service connections. The robot was tethered by an umbilical to a truck where it was controlled by an operator. All CCTV footage was recorded. After inspection the interior of the pipe line was cleaned using pressurized water and dried using a squeegee. A water jet was connected to a hose which was connected to a truck, which provided the pressurized water. The water jet was inserted at one end of the pipe and travelled down the pipe spraying water in the opposite direction of travel until it reached the other end of the pipe in the next pit. The water jet was then shut off and a squeegee, slightly larger than the inner diameter of the pipe, was attached to it. The water jet hose was then retracted by the truck pulling the squeegee back through pipe to the pit where the water jet was originally inserted. Figure 4-4 shows the camera, water jet, and squeegee equipment used to inspect and prepare the pipe for lining.

Figure 4-4 Equipment: camera (left), water jet (center), and squeegee (right)

Plugging of Service Connections

The final step in preparing the inside of the pipe for lining was plugging the existing service connections. All service connections up to 2-in could be plugged using a robot equipped with a camera and controllable arm. The plugs were assembled onsite and were comprised of four pieces: (1) a large plug; (2) a flange; (3) a small plug; and (4) a screw. All pieces of the assembled plug are shown and identified in Figure 4-5.

Figure 4-5 Typical service connection plug

An adhesive sealing compound was put on the side of the flange that would be against the pipe wall (i.e., the side with the large plug) to keep the plug attached and to prevent any resin from getting into the service and potentially clogging it. The plug assembly was then attached to the robot by fitting the small plug over an adapter at the end of the robotic arm. The adapter allowed the plug to stay firmly in place using only friction. The robot was inserted into the pipe and travelled to the service connection that had been located during the pre-lining inspection. The plug was then placed into the service connection hole by the operator controlling the robotic arm. To ensure a secure fit, the operator would keep the arm pressed against the plug for approximately seven minutes so the adhesive sealing compound would set. Once the compound was set, the robotic arm could be removed from the small plug and the robot could return.

Technology Application

After completion of the site and pipeline preparation activities the AC pipe was ready to undergo lining via CIPP. Additional activities associated with the technology application included the installation of end seals and pressure testing.

Technology Description

NORDIPIPE™ is an AWWA (2014) Class IV structural liner that is NSF 61 approved for potable water. The liner can be manufactured in lengths up to 1,000 ft and can be used in pipe ranging from 6 to 48-in in diameter. The glass-fiber-reinforced liner is applied by impregnating it with epoxy resin. The thickness of the pipe liner ranges from 0.22 to 0.79-in (5.5 to 20 mm) based up the number of felt and glass-fiber reinforcement layers and the thickness of the internal PE-coating. The design gives the pipe liner static, self-supporting properties and allows it to withstand high internal and external loads. The liner design selected for this project consisted of two layers of glass-fiber reinforcement and one layer of felt. The final nominal thickness of the liner was 7.3 mm with a nominal operating pressure rating of 190 psi.

Installation of CIPP Liner

A staging area was setup off-sit where the section of liner was prepared for that day's run. The liner was impregnated with epoxy resin and the end was tied-off with a black rope which connected to a yellow strap that was used to reel the liner onto a spool inside a pressure vessel mounted on the back of the inversion truck (Figure 4-6). In addition, a short length of yellow nylon rope (3-4 ft) was tied to the same end as the black rope, but was put inside the liner. The yellow rope was used as a gauge in the field to know when the end of the liner had completely made it through the pipe. The truck then headed to location where the liner was to be installed.

Figure 4-6 Pressure vessel mounted on the inversion truck

Insertion of the Liner. The pit where the liner was inserted into the pipe from the inversion truck was designated as Station A. When the inversion truck arrived at Station A, it was positioned at the pit end opposite the end of the pipe segment to be lined. Once in position, a short length of liner was pulled through the opening of the pressure vessel, inverted, and attached to the sidewalls of the opening using screw clamps (Figure 4-7). A sleeve was used between the pressure vessel and pipe to protect the liner from dirt and ultraviolet (UV) light, which can prematurely activate the resin causing it to harden. The protective sleeve was slid over the liner end that was attached the sidewalls of the pressure vessel opening and secured in place with screw clamps. The unattached end was put inside the end of the pipe segment where it acted like a guide for the liner (Figure 4-8).

Figure 4-7 Inverted liner end attached to pressure vessel opening

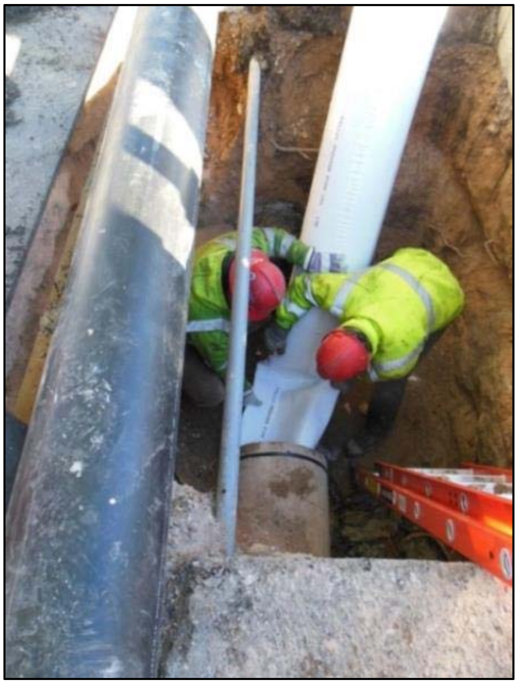


Figure 4-8 Protective sleeve and pressure vessel (left) and guiding the liner in (right)

After the sleeve was in place, the pressure vessel was pressurized with air to 10 psi. The pressurized air pushed the liner out of the vessel into the protective sleeve and through the pipe to the other pit, known as Station B. As the liner left the vessel it was inverted, which allowed the resin impregnated inside to now be on the outside where it would contact the interior of the pipe when cured. As the liner traveled through the pipe it unwound from the spool inside the pressure vessel. The rate of travel by the liner was regulated by the black rope and yellow strap connected to the spool. Regulating the speed also helped prevent unnecessary stretching of the liner. Once approximately 3-ft of the yellow nylon rope that was attached to the liner end was visible at Station B the entire liner for that pipe segment was in place. Figure 4-9 shows a worker measuring the length of the yellow nylon rope.

Figure 4-9 End of liner with rope arriving at Station B

Curing of Liner. The liner was cured with steam generated onsite by a steam truck connected to the inversion truck and pumped into the liner via the pressure vessel (Figure 4-10). The steam was delivered into the liner at a pressure of 10 psi with the temperature ranging between 180 and 210°F. Curing typically took around three hours once the temperature at Station B was the same as the delivery temperature at Station A. After curing, the liner required a one hour cooling period.

Figure 4-10 Steam truck (foreground) connected to inversion truck (background)

To prepare the liner for curing, two metal spikes, also known as “stingers”, were first inserted into the section of liner protruding from the pipe at Station B as shown in Figure 4-11. Each spike was connected by a hose to the input side of an apparatus containing pressure and temperature gauges (Figure 4-12).

Figure 4-11 End of liner with stingers at Station B

Figure 4-12 Pressure and temperature apparatuses with gauges

Valves located on the output side of each pressure and temperature apparatus were adjusted to maintain steam pressure at 10 psi inside in the liner. Hoses connected to the output side of the pressure and temperature apparatuses were used to vent the steam (Figure 4-13).

Figure 4-13 Hoses used to vent steam during the curing process

Prior to the insertion of the liner, thermocouple wires were temporarily affixed to the inside bottom of each pipe end. As shown in Figure 4-14, each set of wires were connected to a digital thermometer, which was used as the official temperature measurement at each pipe end. The 3-hour curing time did not start until the temperature at Station B was approximately the same as the delivery temperature (i.e., 180-210°F) at Station A.

To remove any condensation (i.e., water) that formed during the curing process, a small diameter pipe with a 90-degree elbow was inserted into the liner at Station B (Figure 4-15). The end of the pipe rested on the bottom of the liner and provided a pathway for the water out of the liner.

Figure 4-14 Yellow thermocouple wire inside pipe (left) and digital thermometer (right)

Figure 4-15 Condensation vent extending from the liner at Station B

Following the three hour curing, the liner underwent cooling for approximately one hour. Cooling occurred at ambient temperature and was the final step in the curing process. The two metal spikes that vented the steam and the condensation vent were removed after the liner had cooled. After the spikes and condensation vent were removed, a section of the protruding liner was cut out to gain access inside the liner and cut the black rope from the yellow strap, which was then reeled back onto the spool in the pressure vessel. Figure 4-16 shows the section of liner removed and the remaining piece of black rope tied to the end of the liner.

Figure 4-16 Cured liner with section removed to gain internal access to black rope

End Seal Installation

End seals were installed at each end of the lined pipe to prevent water from getting behind the liner once the pipe was back in service. The seals were installed the day after the pipe was lined and consisted of a 1-ft wide rubber gasket and two stainless steel rings (Figure 4-17).

Figure 4-17 End seal consists of a rubber gasket and steel rings

To install the seals, the liner had to be cut back 6-inches from the edge of the pipe. Next, the outside of the rubber gasket (i.e., the side to be against the inside pipe wall) was coated with pipe lube and worked into place. The gasket set flush with the edge of the pipe and overlapped the liner approximately 6-inches. To lock the gasket in place two steel rings were positioned on each side of the gasket (i.e., first 6-inches and second 6-inches of the gasket) and locked in place with tension. The outside of the rings were lightly coated with pipe lube and installed one at time starting first with the ring positioned on the back 6-inches of the gasket (i.e., inner ring). As shown in

Figure 4-17, the rings were not closed, but open. Once the ring is correctly positioned on the gasket, a hydraulic ring opener is used to open the ring and put it under the correct tension (Figure 4-18). A precisely cut piece of steel is then fitted into the space between the ring ends locking the ring securely into place (Figure 4-18). The same process is then followed for the outer ring. Once both rings are installed the end seal is complete.

Figure 4-18 Hydraulic ring opener (left) and finished inner ring on end seal (right)

Pressure Test

Once the end seals were installed on each end of a pipe segment the liner was pressure tested to ensure it was free of leaks or defects. To perform the pressure test, each end of the pipe was capped then the pipe was filled with water and pressurized to 150 psi for approximately one hour.

The caps, which came to the site already assembled, consisted of a section of iron pipe bolted to a metal cap that was fitted with a hose connection at the center (Figure 4-19). The outer diameter of the iron pipe was slightly smaller than the inner diameter of the AC pipe to allow for insertion into the AC pipe.

Figure 4-19 End cap assembly used for pressure testing

Before the end caps could be attached connection fittings were installed on each end of the pipe. The connection fittings included a blue metal sleeve, a gray metal flange, and a black rubber gasket which held the flange in place. The parts are shown individually and assembled in Figure 4-20.

Figure 4-20 Sleeve and flange (left); rubber gasket (center); connection fitting (right)

To connect the end caps to the pipe end, each one was fitted with a blue metal flange and a black rubber gasket. The iron pipe portion of the cap was inserted into the AC pipe and then bolted together through the openings in the flanges. The connected end cap assembly is shown in Figure 4-21.

Due to the high pressure of the pressure test (i.e., 150 psi) reinforcement was need to prevent the end cap from dislodging from the AC pipe. Two pieces of wood (2-in x 4-in) were positioned between the end cap and a round steel plate that rested up against the AC pipe on the other side of the pit. This setup provided enough reinforcing strength to the end cap to prevent dislodgement.

Figure 4-21 End cap assembly connected to AC pipe for a pressure test

When both end caps were securely connected and reinforced, water was pumped from a small tanker truck at approximately 50 psi into the pipe via the end cap with the 1-¾ in hose connection (Figure 4-22). The size of the hose connection on each cap was different. One end cap had a 1-¾ in connection while the other end cap had a standard garden hose connection (Figure 4-23).

Figure 4-22 Truck pumping water in the pipe through an end cap for a pressure test

Just before the pipe was completely full, the tanker truck stopped pumping water. A small electric pump was then connected to other end cap with the standard garden hose connection and used to bring the pressure inside the pipe to 150 psi (Figure 4-23). Once the pressure reached 150 psi inside the pipe, the pump was stopped and the one hour pressure test was started. If no pressure loss was observed after an hour the liner was deemed free of leaks.

Figure 4-23 End cap with garden hose connection (left) and small electric pump (right)

Post-Lining Activities

Post-lining activities commenced with the completion of pressure testing and included reinstatement of water services, installation of pipe fitting and valves, disinfection, reconnection of the water main, and the removal of the bypass.

Reinstatement of Service Connections

Water service connections were reinstated robotically using the same robot that installed the plugs. The robot's arm was outfitted with a cutting tool that allowed it to cut out the plastic service plugs. Of the 31 service connections, all but one was able to be reinstated robotically. The one service connection that was not reinstated robotically had to be excavated and a new service installed. This service could not be located from inside the pipe.

Installation of Pipe Connections, Fittings, and Valves

The lined sections of AC pipe were connected using 16-in DR-18 PVC pipe that are NSF-61 certified. The AC pipe was connected to the new PVC pipe using metal collars with rubber gaskets that were bolted together. The connected AC pipe sections are shown in Figure 4-24.

Figure 4-24 Lined AC pipe sections connected by a 16-inch PVC pipe

Reconnection of Water Main and Removal of Bypass

After all the AC pipe sections were connected with 16-in DR-18 PVC pipe, the lined pipe was disinfected prior to being reconnected to the water main and put back into service. Once the main was put back into service the bypass was removed and site restoration commenced.

Site Restoration

Due to scheduling delays, the Battelle Team was not present during the site restoration. Site restoration activities included the backfilling of the access pits, concrete repair/replacement, asphalt paving of the roadway, and restoration of any green space that was disturbed.

ENVIRONMENTAL SAMPLING RESULTS

This section presents the results of the air, soil, and water samples collected during the CIPP lining demonstration. The results were used to determine the impact of the demonstrated technology on the environment.

Air Sampling

A total of nine air samples were collected during the demonstration on three separate days, including three field blanks (a minimum of five samples were recommended in the QAPP). Due to an inadequate volume of air sampled on the first day, only six samples, including two field blanks, were analyzed. Air samples were collected by two Battelle staff members each using a SKC AirChek® XR5000 personal air sampling pump with an approximate flow rate of two LPM. The pumps were calibrated in the field prior to sample collection using a Bios Defender Model 510M flow calibrator. Note the Bios Defender 510M is a primary calibration standard. Table 4-4 summarizes the air samples collected.

Table 4-4 Summary of collected air samples

Sample No.	Lining Run No.	Average Flow Rate (LPM)	Run Time (min)	Volume Collected (L)
3	#5	1.9847	259	514
4	#6	1.9822	244	484
5	#6	2.0352	280	570
6	#6	2.0427	252	515
Field Blank-2	#5	N/A	N/A	N/A
Field Blank-3	#6	N/A	N/A	N/A

N/A = not available

Air sample analysis was performed by REI laboratories (Denver, CO). The samples were analyzed using TEM following the ISO method 10312 (1995). The results of the air sample analyses are presented in Table 4-5.

Table 4-5 Asbestos air sample results summary

Sample No.	Number of Asbestos Structures Detected	Analytical Sensitivity (s/cc)	Asbestos Concentration (s/cc)
3	ND	0.0050	BAS
4	ND	0.0050	BAS
5	1	0.0048	0.0048
6	ND	0.0050	BAS
Field Blank-2	ND	N/A	BAS
Field Blank-3	ND	N/A	BAS

s/cc = structures per cm^3; ND = none detected; N/A = not available; BAS = below analytical sensitivity

As shown in Table 4-5, the asbestos concentration of all but one sample (i.e., Sample 5) is below analytical sensitivity. The analytical sensitivity of Samples 3, 4, and 6 is below the 8-hr TWA-PEL of 0.1 s/cc set by OSHA. The asbestos concentration of sample 5 (i.e., 0.0048 s/cc) is also below the OSHA TWA-PEL.

The air sample results are representative of all activities that occurred onsite on the day of sampling. Prior to the arrival of Battelle staff, all access pits had been excavated and all AC pipe sections had been cut and removed at the site. It is assumed that the results from those activities would mirror the results from other studies that follow similar procedures. It is assumed that methods that use similar practices to access the pipe, like SIPP, would have similar results.

Note the Battelle staff members were not present in the pits at the time of lining, but on the surface at the edge of the pit due to space restrictions and worker safety. During the lining operation, the staff members traveled between the insertion pit (Station A) and the end pit (Station B) in an attempt to collect representative samples.

Soil Sampling

Six baseline soil samples were collected by Battelle staff during the demonstration from three different excavation pits over two days (a minimum of five samples were recommended in the QAPP). Each soil sample was collected from the pit walls at different depths and/or locations around the host pipe. Follow-up soil samples were not collected due to the paving of the access pits at the completion of the project. Table 4-6 summarizes the soil samples collected.

Table 4-6 Summary of collected soil samples

Sample No.	Pit No.	Location	Notes
1	8	North Side of Pit	Pipe Crown
2	8	North Side of Pit	1.5-ft above Pipe Crown
3	1	North Side of Pit	Pipe Crown
4	1	North Side of Pit	3 O'clock Position
5	2	South Side of Pit	Pipe Crown
6	2	South Side of Pit	3 O'clock Position

Soil sample analysis was performed by REI laboratories. Each sample was analyzed using PLM in accordance with EPA Method 600/R-93/116 (1993). In addition, Samples 1, 2, and 3 underwent a 400 point count. Table 4-7 presents the results of the soil sample analyses.

Table 4-7 Asbestos soil sample results summary

Sample No.	Asbestos Content		Non-Asbestos Fibrous Component (%)	Non-Fibrous Components (%)
	Mineral	Visual Estimate (%)		
1	Chrysotile:	TR<0.25	TR	100
2	Chrysotile:	TR<0.25	TR	100
3	Chrysotile:	TR<0.25	TR	100
4	–	ND	TR	100
5	–	ND	TR	100
6	–	ND	TR	100

ND = none detected; TR = trace, <1% visual estimate

No asbestos was detected in Soil samples 4, 5 and 6. Soil samples 1, 2, and 3 each contained trace amounts (i.e., <1% visual estimate) of Chrysotile. The point count performed on Samples 1, 2, and 3 further characterize the trace amount of Chrysotile as being less than 0.25% visual estimate. The results indicate essentially no asbestos has been released by the pipe to the surrounding soil since its installation nearly 50 years ago. Although post-rehabilitation samples were not able to be collected, it can be assumed that the asbestos would not increase as the external portion of the pipe is not disturbed during CIPP lining. Future retrospective sampling could provide more insight into whether asbestos fibers migrate through soil over time.

Water Sampling

Prior to the arrival of Battelle staff onsite, water had been drained from the host pipe and a bypass system installed. Due to this, baseline water samples from services connected to the section of the host pipe undergoing rehabilitation were not able to be collected. Instead, two water samples were collected from services downstream of the lining operation. Both samples were collected from backflow preventers located above ground in front of each location. Samples were collected in clean, 1-L HDPE bottles. A summary of the water samples collected is presented in Table 4-8.

Table 4-8 Summary of collected water samples

Sample No.	Sample Type	Sample Volume (L)
1	Backflow Preventer	1
2	Backflow Preventer	1

Water sample analysis was performed by REI laboratories. The samples were analyzed using TEM following EPA method 100.2 (1994). The results of the water sample analyses are presented in Table 4-9.

Table 4-9 Water sample results summary

Sample No.	Asbestos Structures Detected	Analytical Sensitivity (msl)	Asbestos Concentration (msl)
1	ND	0.03	BAS
2	ND	0.03	BAS

ND = none detected; BAS = below analytical sensitivity; msl = million structure/liter

Both downstream water samples were found to be non-detect and, therefore, the asbestos concentration was below analytical sensitivity of 0.03 million structures per liter. The EPA MCL for asbestos in drinking water is 7 million structures per liter.

Following completion of the lining project and reinstatement of the main, two additional water samples were collected from the same locations shown in Table 4-8. The results from the follow-up water samples are presented in Table 4-10.

Table 4-10 Follow-up water sample results summary

Sample No.	Asbestos Structures Detected	Analytical Sensitivity (msl)	Asbestos Concentration (msl)
1	ND	0.03	BAS
2	ND	0.03	BAS

ND = none detected; BAS = below analytical sensitivity; msl = million structure/liter

Both follow-up water samples were found to be non-detect and, therefore, the asbestos concentration was below analytical sensitivity of 0.03 million structures per liter. As previously mentioned, the EPA MCL for asbestos in drinking water is 7 million structures per liter. The team did not expect the asbestos limit to increase after lining so this result was no surprise.

CHAPTER 5
CONCLUSIONS

This section outlines the conclusions. It is expected that one peer-reviewed journal paper will be submitted based on the overall findings of this project. During each demonstration, air, water, and soil samples were collected to determine if the activities associated with the renewal technology had any negative impacts on the environment, which was the key objective of this project. The samples were sent to REI laboratories in Denver, Colorado for asbestos analysis. Table 5-1 presents a summary of all the samples analyzed for both demonstrations.

Table 5-1 Sample summary

Sample Type	Analytical Method	Site	No. of Samples
Air	ISO Method 10312 (1995)	Pipe Bursting	8[a]
		CIPP	9[b]
		Total	**17**
Soil	EPA Method 600/R-93/116 (1993)	Pipe Bursting	12[c]
		CIPP	6[d]
		Total	**18**
Water	EPA Method 100.2 (1994)	Pipe Bursting	5[e]
		CIPP	4[f]
		Total	**9**

(a) Includes two field blanks
(b) Includes three field blanks
(c) Includes six baseline samples and six follow-up samples
(d) Includes only downstream samples; follow-up samples were not able to be collected
(e) Includes one blank
(f) Includes two samples collected downstream of lining and two follow-up samples

AIR SAMPLING CONCLUSIONS

Individual air sample results from the pipe bursting and CIPP demonstrations can be found in chapters 3 and 4, respectively. A total of 17 air samples (see Table 5-1) were collected and analyzed across the two demonstration sites (including five field blanks). Of all the samples analyzed, only one (CIPP Site, Sample 3) had a detectable amount of asbestos structures (i.e., 1 s/cm), which yielded a concentration of 0.0048 s/cc (see Table 4-5). The other 16 samples had no detectable asbestos structures giving them asbestos concentrations below their respective analytical sensitivity. The analytical sensitivity of each sample (including CIPP Site, Sample 3) was also below the OSHA 8-hr time-TWA-PEL of 0.1 s/cc. Based upon the results of the air samples collected at each site, neither pipe bursting nor CIPP lining of AC pipe was found to have a negative impact on the surrounding air environment or the heath of the workers performing the work. This matched well with other air sampling studies conducted on similar projects (Jonsson 2011 and Appendix D).

SOIL SAMPLING CONCLUSIONS

Individual soil sample results from the pipe bursting and CIPP demonstrations can be found in chapters 3 and 4, respectively. A total of 18 soil samples (see Table 5-1) were collected and analyzed – 12 soil samples from the pipe bursting site and six soil samples from the CIPP lining site.

The 12 soil samples collected from pipe bursting site included six baseline samples collected from the pit walls near the pipe prior to pipe bursting and six post-rehabilitation samples collected months later from the same locations. When the baseline samples were compared to the post-rehabilitation samples (see Table 3-10), three samples were found to increase in asbestos concentration by a trace amount, two samples were found to stay the same, and one sample was found to decrease in asbestos concentration by a trace amount. Any asbestos found in the samples was present in trace amounts (i.e., <0.25% visual estimate) and contained either Chrysotile or Crocidolite, or a combination of the two. While this is a negligible impact after a few months, we also confirmed retrospective samples from a site where pipe bursting was conducted five years earlier to see if the asbestos amounts are greater. This aspect was recommended by the PAC and the samples collected showed only trace or non-detectable levels of asbestos. This suggests there has been no increase in asbestos released in the ground since the pipe bursting occurred five years ago.

The six soil samples collected from the CIPP demonstration site consisted of only baseline samples, which were collected from the access pit walls near the pipe. Since all the access pits were located in the roadway, follow-up samples were not able to be collected. Of the six samples collected, three were found to contain trace amounts (i.e., <0.25% visual estimate) of asbestos in the form of Chrysotile. The remaining three samples contained no asbestos. This is a negligible impact and although post-lining samples could not be collected, it would be expected that those results would also be negligible since the exterior of the AC pipe is not disturbed by CIPP. There are no efforts underway to collect any additional post-lining or retrospective soil samples.

Overall, the results from the soil samples collected at each site indicate only trace amounts of asbestos in the soil surrounding the pipe. With no increase in asbestos following the completion of the renewal activities (especially in the case of pipe bursting) it was determined that neither renewal method adversely impacted the soil environment.

WATER SAMPLING RESULTS

Individual water sample results from the pipe bursting and CIPP demonstrations can be found in chapters 3 and 4, respectively. A total of nine water samples (see Table 5-1) were collected and analyzed – five water samples from the pipe bursting site, including one blank, and four water samples from the CIPP site.

Water samples collected at the pipe bursting demonstration site consisted of two baseline samples, which were collected prior to pipe bursting, two post-rehabilitation samples collected from the same locations following pipe bursting, and one blank. Of the two baseline samples analyzed, one (Sample 2) contained 20.07 million structure/liter, which is almost three times the EPA's asbestos MCL of 7 million structure/liter. The sample was collected from a hydrant and was most likely not adequately flushed prior to sample collection resulting in a concentration not representative of the pipeline. The two post-rehabilitation samples showed an average decrease in asbestos concentration of 92.5%. Both samples were also below the EPA MCL. The presence of asbestos in the drinking water is likely to continue, albeit at lower concentrations than before, since the new HDPE line is still connected to AC lines.

A total of four water samples were collected from the CIPP demonstration site. Prior to the arrival of Battelle staff onsite, water had been drained from the host pipe and a bypass system installed. Due to this, water samples could not be collected from the pipe section that was to be lined. Instead, samples were collected from two backflow preventers located downstream on an unlined portion of the same pipeline. Following completion of the lining activities water samples were collected again from the same locations. All four water samples were found to contain no asbestos and had a concentration below the analytical sensitivity of 0.03 million structure/liter.

The results from the water samples collected from each site showed that the renewal technologies had no negative impact on the water quality and, in one instance, reduced the asbestos detected after bursting compared to before bursting. Therefore these technologies did not have an adverse impact on the water environment. Even though water utilities monitor for asbestos under their water quality programs to ensure levels are below the EPA MCL, it would be valuable to study the asbestos levels closer to areas with lots of AC pipe as the sample sites may not always be near AC pipe locations.

RECOMMENDATIONS

No negative environmental impacts were observed as a result of either pipe bursting or CIPP lining of AC pipe based on the results from the air, soil, and water samples that were collected. It is recommended that regulatory agencies review these data presented and consider reevaluating the allowance of such methods, particularly pipe bursting which has been the cause of much regulation confusion. When proper procedures were followed, as were in the pipe bursting demonstration in Casselberry, FL (Ambler et al. 2014), the environmental impact was negligible and the requirements of NESHAP were met. It is recommended that an EPA Administrator Approved Alternative (AAA) be pursued for pipe bursting, which would allow the use of pipe bursting on AC pipe when proper procedures are followed. To benefit future studies, it is recommended baseline soil samples are collected prior to future AC pipe bursting projects, which would allow for retrospective testing and for future data comparisons. In cases where additional oversight is required by regulatory agencies, air sampling can be conducted using the procedures used during this project. It is also recommended that a study be conducted to determine the impact sampling locations have on monitoring for asbestos in water quality programs.

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ABBREVIATIONS

AC	asbestos cement
ACM	asbestos containing material
ADEQ	Arizona Department of Environmental Quality
AHERA	Asbestos Hazard Emergency Response Act
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
AWWA	American Water Works Association
AWWARF	American Water Works Association Research Foundation (now WRF)
BAAQMD	Bay Area
BAS	below analytical sensitivity
BMP	best management practices
CCTV	closed-circuit television
CIPP	cured-in-place pipe
DI	deionized
EPA	U.S. Environmental Protection Agency
FAC	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
GIS	geographical information system
gpm	gallon per minute
HDPE	high-density polyethylene
HESHAP	National Emissions Standards for Hazardous Air Pollutants
ID	inner diameter
ISO	International Organization for Standardization
L	liter
LF	linear feet
LPM	liter per minute
MassDEP	Massachusetts Department of Environmental Protection
MCL	maximum contaminant level
MG	million gallons
MGD	millions gallons per day
mV	millivolt
NA	not available
NASTT	North American Society for Trenchless Technology

ND	none detected
NEA	negative exposure assessment
NIOSH	National Institute for Occupational Safety and Health
NSF	Nation Sanitation Foundation
OD	outer diameter
OSHA	Occupational Health and Safety Administration
O&M	operation and maintenance
PAC	project advisory committee
PE	polyethylene
PEL	permissible exposure limit
PLM	polarized light microscopy
psi	pound per square inch
PU	polyurethane
PVC	polyvinyl chloride
QAPP	quality assurance project plan
QA/QC	quality assurance/quality control
RACAM	regulated asbestos containing material
REI	Reservoirs Environmental, Inc.
SIPP	sprayed-in-place pipe
S.U.	Standard Unit (pH)
TEM	transmission electron microscopy
TWA	time-weighted average
UV	ultraviolet
WRF	Water Research Foundation