Northern California Pipe Users Group

5th Annual Sharing Technologies Seminar

Berkeley, California - February 27, 1997

PIPE USERS GROUP

SHARING TECHNOLOGIES

THE NORTHERN CALIFORNIA PIPE USERS GROUP WAY

Abstract

The Northern California Pipe Users Group (PUG) is a group of public agencies and consulting engineers which meet to discuss common concerns and issues related to the design, construction, and maintenance of pipeline systems. The group works together to resolve common problems; to improve specifications, inspection, and testing; and to evaluate new products and rehabilitation methods, especially in the rapidly changing area of trenchless technology.

PUG has developed a unique process for exchanging information among neighboring agencies and consultants related to the design, construction, and maintenance of pipeline systems. By applying a stepped approach to evaluating new pipeline replacement and rehabilitation methods, group members learn in an atmosphere which promotes a better understanding of conventional and trenchless technologies. The end product of the stepped process provides a technical specification that addresses the concerns of the group. Technical specifications have been developed for the trenchless technologies of cured-in-place pipe (CIPP), folded pipe liner (FFP), microtunneling, and pipe bursting. Key elements of the specifications will be presented along descriptions of construction projects where the PUG specifications were used.

Introduction

The Northern California Pipe Users Group was formed in 1991. Current membership includes 11 public agencies and 11 consulting engineering firms. PUG works together to evaluate new pipe construction and rehabilitation technologies, develop specifications, and improve design, inspection, and testing of pipeline systems.

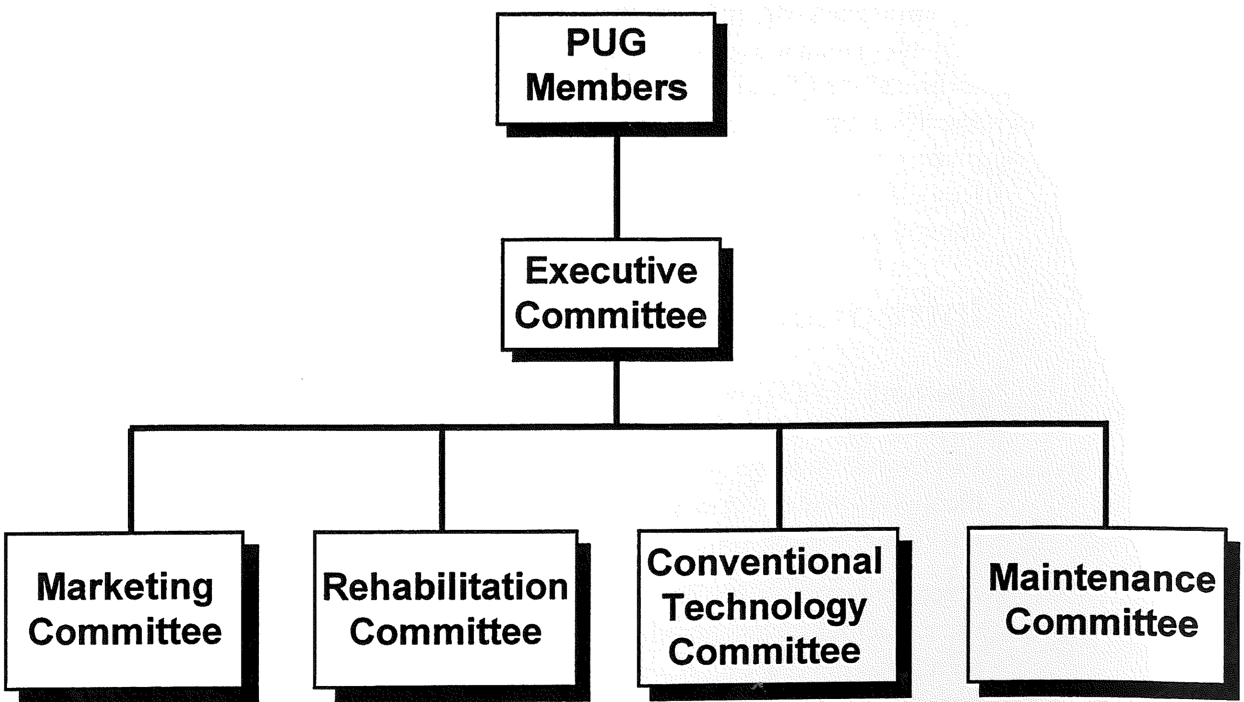
Over the last 10 to 15 years, trenchless technology for installing and rehabilitating sewer and other pipeline systems has changed and increased significantly. The original developers of trenchless technology have improved and expanded their systems. More and more competitors have entered the trenchless technology market. The increased competition has reduced prices and fostered technology and product improvements.

The rapid growth of the trenchless technology industry was one of the reasons for the formation of PUG. PUG members recognized the advantages of sharing information about the many trenchless technologies. This paper will present the approach used by PUG for evaluating trenchless technologies and developing specifications for their use

PUG Organization

PUG is organized into committees as shown below. The Executive Committee manages the organization. The Marketing Committee promotes the organization, encourages membership, and puts on an annual seminar. The Rehabilitation, Conventional Technology, and Maintenance Committees evaluate new technologies; recommend improvements for conventional and trenchless technologies; prepare specifications; and develop testing, inspection, and maintenance procedures.

PUG members have made use of many trenchless construction and rehabilitation technologies (see Table 1). Information is shared, and work products are prepared at monthly committee meetings and a monthly general membership meeting. In addition PUG sponsors an annual one-day workshop that presents information or case studies about innovative or emerging pipeline technologies.



PUG Organization

Technical Specifications

PUG has embarked on a stepped procedure for evaluating the various rehabilitation and/or replacement methods available to the design engineer. The four steps of the procedure are:

Step 1 - Educate Group Members. The program begins by selecting a rehabilitation or replacement method and learning about how the method is applied, the materials used, and how the finished product is maintained by the collection system operators.

Step 2 - Identification and Discussion of Concerns. Issues related to the application of the method, cost, the materials used, and maintenance issues are identified and documented.

Step 3 - Presentation by Technical Expert. The concerns identified in Step 2 are used to establish an agenda for a technical expert from either the manufacturer or academia to make a presentation to the group. The presentations are limited to the concerns expressed by the group.

Step 4 - Preparation of Technical Specifications. The fourth step of the process involves the development of technical specifications for the method. These specifications allow the participating agencies to have uniform standards and to require consistent performance from contractors.

PUG has developed the following guide specifications:

Trenchless Technology

- Cured-in-Place Pipe (CIPP)
- Fold and Form Pipe (FFP)
- Microtunneling, Jacking and Boring
- Pipe Bursting and High Density Polyethylene Pipe

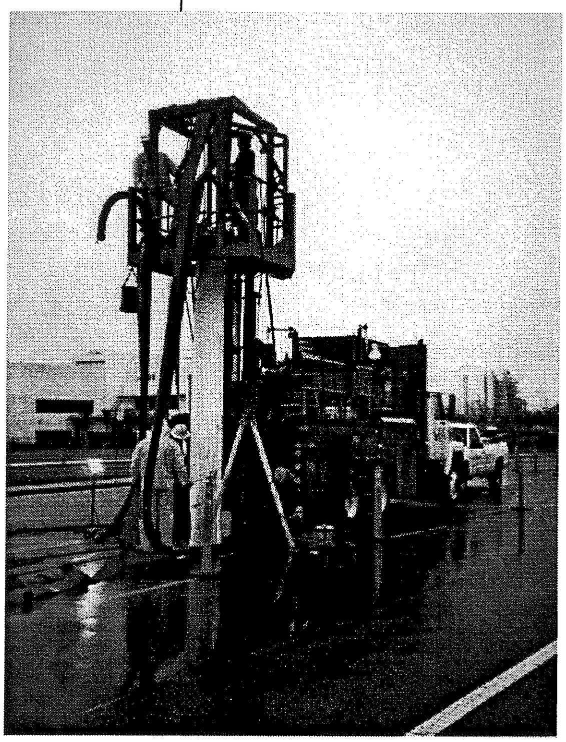
Conventional Trench Materials

- Controlled Low Strength Material
- Low Density Concrete Backfill
- Recycled Aggregate Material
- Reinforced-Concrete Gravity Piping

Specifications currently being prepared are for directional drilling and manhole rehabilitation. These specifications will be reviewed and revised on a regular basis to reflect changes in the technology and the experience from use on construction projects.

Cured-in-Place Liner

The CIPP specification is for gravity pipes and covers all related work, including bypass pumping, sewer cleaning and inspection, lining installation and curing, lateral reconnections, and point repairs. The required liner thickness and other design parameters for each pipe segment are to be listed in the specification. Design parameters include pipe diameter, pipe depth, enhancement factor K, groundwater level, resin type, ovality, soils modules, amount of excess resin, and liner thickness. Possible resin types are epoxy, vinylester, polyester, and enhanced polyester. The minimum liner thickness is to be 6 mm for all pipes, except for 6-inch sewers where the minimum thickness is 4.5 mm. Testing for corrosion resistance of the liner and exfiltration are part of the specification. Requirements and correction of wrinkles in the cured liner are also included in the specification. Service lateral reconnections can be made using either external saddles bonded to the liner or internally using a remotely operated cutter.



Sacramento County CIPP

The Lawrence Livermore National Laboratory made use of the PUG CIPP specification for a project to line approximately 24,000 feet of sewer mains and sewer laterals. The diameters for the Lawrence Livermore sewer system range from 4 inches to 6 inches for the laterals and 6 inches for the sewer mains. Prior to installation of the CIPP liner, 130 point repairs were made to the collection system. Sewer laterals were reinstated using an internal cutter.

In 1996, the County of Sacramento discovered that approximately 22,000 feet of 21-inch, vitrified-clay sewer was severely cracked. This sewer receives an industrial discharge of approximately 1 million gallons per day. The discharge has a high concentration of methanol and fatty acids and has a temperature of approximately 130° degrees Fahrenheit.

Sacramento County was able to divert flow from approximately 21,000 out of the 22,000 feet of deteriorated sewer. The remaining 1,000 feet of damaged sewer was repaired using CIPP liner. Sacramento County selected CIPP liner as the repair method because of the composition of the industrial discharge and the need to accomplish a repair in a short time period. Sacramento County used the PUG CIPP specification for this project and specified a vinylester resin because of the nature of industrial discharge. The repair work was completed within ten days. Cost for CIPP installation, including bypass pumping, was $124,000.

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Folded Pipe Liner

The folded plastic liner specification provides for reconstruction of gravity pipe by the installation of a folded thermoplastic pipe that is heated and pressured internally causing it to unfold and expand against the interior surface of the original pipe. The FFP specification applies to all fold and form PVC liners and deformed and reformed HDPE pipe liners. In addition to liner installation, the specification covers bypass pumping, sewer cleaning and inspection, point repairs, and lateral reconnections.

The FFP specification includes design parameters calculated or determined by the design engineer. Design parameters include pipe diameter, pipe depth, groundwater level, liner type, liner thickness, pipe ovality, and soil modulus. Reforming of the FFP liner and placement of end seals are covered under the execution section of the specification. Internal and external lateral reconnections are both addressed also.

Folded Liner in Lafayette, CA

The PUG specification was used for a project by Central Contra Costa Sanitary District to line approximately 2,700 feet of deteriorated sewer in Lafayette, California. The specified liner was a white HDPE pipe with an SDR of 26. Overall, installation of the HDPE liner in the existing 10-inch, vitrified-clay sewer was successful. The installation was relatively fast and caused little disruption to the public and neighborhood. The installation did require two more weeks than the originally planned three-week schedule due to equipment breakdowns, difficulties in pulling the liner into the existing pipe due to bends, and disruption to the planned work sequence due to required point repairs.

One surprise was the amount of point repairs to the old clay sewer that were necessary before the liner could be installed. During design, approximately 60 feet of point repairs were estimated. The actual length of point repairs was 200 feet. Some of these additional repairs were due to unsound pipe encountered during construction. However, approximately half of the repairs were the result of recommendations by the liner subcontractor so that the liner could be installed.

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Most of the lateral service reconnections on the liner pipe were accomplished externally with strap-on saddles. However, because of buildings adjacent to, or other surface improvements over the sewer, internal lateral reinstatements were made at ten locations using a television camera and remotely operated grinder. The specifications called for the lateral reinstatements to be circular and between 95 percent and 100 percent of the lateral opening. The subcontractor had difficulty locating the lateral openings and did not achieve specification. The actual lateral openings are significantly greater than the 4-inch diameter laterals and were more square shaped than circular.

Pipe Bursting

Pipe bursting provides for replacement of existing pipelines by bursting the existing pipe and inserting an HDPE pipe. The PUG specification for pipe bursting is intended for projects utilizing hydraulic or pneumatic bursting devices. The specifications can be modified when the use of cone cracking is desired. Cone cracking is less expensive than either hydraulic or pneumatic bursting devices; however, it has limitations in terms of pulling length and upsizing greater than one pipe size.

Under the PUG specification, the designer determines the HDPE pipe thickness based on ultimate and installation conditions. The minimum HDPE wall thickness is SDR 17. The interior color of the HDPE pipe must be white, natural, light green, or light red to allow easier television inspection. All sewer laterals must be exposed and disconnected prior to pipe bursting. Lateral sewers are reconnected using heat-fused saddles. The internal weld bead at the fused HDPE joints is required to be removed prior to installation. This requirement is to allow mandrel testing of the new pipeline for deflection and to prevent problems with maintenance and cleaning equipment.

14 -inch Pipe Bursting Head

The pipe-bursting specification was used for a project by Central Contra Costa Sanitary District in 1994 to replace approximately 1,700 feet of undersized vitrified-clay sewer located in Lafayette, California. The use of pipe bursting to increase the sewer size from 10-inch inside diameter to 14-inch diameter was accomplished. Upsizing in this pipe size had only been attempted once before in California and in different soil conditions. In this case the decision to use only a pipe-bursting system with a hydraulically or pneumatically operated bursting head was prudent.

The pipe-bursting segment of the project was accomplished within one month. Overall, there was much less disruption to the neighborhood and to the public than if conventional open-cut construction had occurred.

With the two pipe size increase, there was a potential for surface displacement from the bursting operation. However, the surface displacement was greater than expected. In reaches where the sewer was 5 to 7 feet deep, vertical surface heave of 1 to 3 inches was observed. A crack, approximately 1 to 3 inches wide, developed along the pipe alignment as the bursting head progressed. The vertical displacement was limited to the area right above the newly installed pipe and did not extend more than 24 inches from the center line on either side. In most areas of the project, the displacement occurred in landscaped areas and did not have any adverse impact. In one reach, approximately 150 feet long, a badly deteriorated asphalt driveway was cracked and was replaced. In another area where the sewer was only 5 feet deep, a brick and mortar sidewalk was removed prior to pipe bursting, and a 6-inch deep by 18-inch wide trench was dug along the pipe alignment, prior to pipe bursting, to prevent damage to an adjacent tennis court. This mitigation was successful. The brick and mortar sidewalk was replaced after pipe bursting.

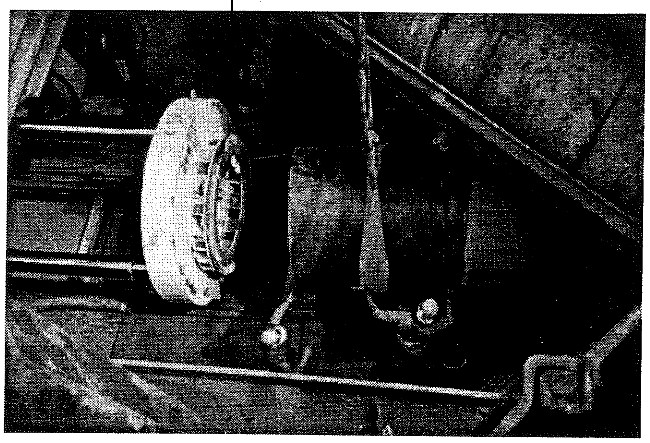
In areas where the pipe depth was 7 to 12 feet deep, the vertical displacement from pipe bursting was not observed. Surface cracking of the ground or pavement areas did not occur.

Another "learning experience" was the laydown or staging area requirements for the 14-inch inside diameter, SDR 17, HDPE pipe prior to installation. Central Contra Costa Sanitary District has pipe bursted extensively with smaller diameter HDPE pipe, both SDR 17 and SDR 35. In these sizes, the HDPE pipes are more flexible than the larger sizes. The larger HDPE pipes require a straight laydown area directly behind the installation pit. Two of the six original laydown areas could not be used. Fortunately, alternate straight laydown areas were available.

Microtunneling

The PUG specification for microtunneling includes both conventional jacking and boring and microtunneling. Microtunneling, as defined in the specification, is a process of installing a pipe underground behind a remotely controlled, closed-face, steerable, laser-guided, articulated microtunnel boring machine (MTBM) that exerts a continuous, controllable pressure at the microtunnel heading to prevent groundwater and soil movement inflow. The MTBM is connected to and followed by pipe, which is installed by jacking. Both the cases of installing a steel casing pipe or direct installation of a carrier pipe are covered by the specification.

Minimum design requirements for microtunneling and jacking and boring cover the thrust block, ground surface settlement or heave, dewatering, overcut, and jacking stations. The thrust block must be able to withstand the maximum jacking pressure with a factor of safety of at least 2. Ground surface settlement or heave is limited to 1 inch or less. Dewatering for groundwater control can only be utilized at the jacking and receiving shafts or pits. The maximum allowable overcut shall be less than 1 inch larger in radius that the outside diameter of the pipe. The annular space created by the overcut must be completely filled with a bentonite lubricant. Intermediate jacking stations must be used when primary jacking forces exceed specified acceptable bearing stresses on the pipe.



CCCSD Microtunnel Project

For microtunneling, only an MTBM system manufactured by a company that specializes in design and fabrication of this type of equipment for at least five years can be used. The MTBM must have a remotely controlled, articulated, full-face shield with the capability of continuously measuring the earth pressure at the face of the microtunnel. It must also continuously exert a controllable, stabilizing pressure at the face, as required to balance soil and groundwater pressures. The MTBM is to be laser guided and must be monitored continuously with a closed-circuit television system. Each owner must select his/her own horizontal and vertical tolerances. The recommended tolerances are 2 inches for horizontal line and 1 inch for vertical grade. Any deviation with respect to line or grade must be recorded at least once per foot. If the excavation is off liner grade, necessary corrections must be made to return to the designed alignment at the rate of not more than 1 inch per 25 feet.

The owner must specify the type or types of pipe that are allowed. Possible carrier pipes for direct installation by microtunneling or jacking and boring are Hobas pipe, vitrified-clay pipe, and reinforced-concrete pipe (RCP). Steel pipe is specified where casing pipe is to be installed.

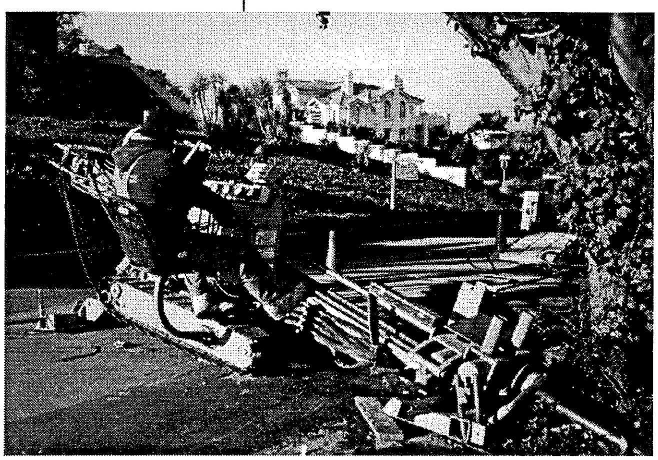
The PUG specification was developed under a project constructed by Central Contra Costa Sanitary District. The project involved installation of approximately 5,000 feet of 48-inch diameter RCP. The RCP carrier pipe was directly installed using an MTBM manufactured by Ackerman. The pipe depth ranged from 18 to 25 feet. The alignment of the microtunneled sewer passed under school yards, an athletic playing field, a shopping center, and adjacent to a flood control channel.

Installation of the sewer by microtunneling using the PUG specification went very well. The sewer was installed on time and without impact to local businesses, schools, or traffic. Only one major problem was encountered. While microtunneling adjacent to the flood control channel, the MTBM encountered tree stumps that had been used as fill in a former quarry site adjacent to the flood control channel. The fibrous wood material plugged the cutting ports. The cutting ports could not be cleaned in time, and the MTBM had to be excavated and removed. Improvements to the PUG specification are being made in the areas of line and grade monitoring, sound control, and slurry pressure control. At some locations along the alignment adjacent to the flood control channel, slurry blowouts were experienced.

Directional Drilling

A specification for horizontal directional drilling is currently being developed by PUG. PUG member agencies are using prototype specifications before an official draft specification is issued. The specification covers the three steps involved in directional drilling: pilot-hole drilling, reaming, and pipeline insertion.

Because the ability to make changes is limited with directional drilling and the grade of gravity sewers is critical, the ability to locate and track the drilling head is very important. The PUG specification calls for an electronic tracking and guidance system to be located within the drilling head, with feedback to a laptop computer located in the field. The drilling head location is monitored and corrections made every foot. Surface tracking devices are required to check the accuracy of the in-line locating device. The reaming operation is required to be done in at least two steps depending on the diameter of the pipe to be installed. The enlarged hole must be at least 1.15 to 1.5 times the outside diameter of the pipe to be installed. During the pipe insertion step, the specification requires the installed pipeline to displace the drilling mud and that the drilling mud be removed by a vacuum truck or pump. Under the PUG specification, the contractor must determine the size of the pipeline to be installed. The minimum acceptable pipeline is an HDPE pipeline with an SDR of 17. Because of the stresses involved in the installation of the pipeline by directional drilling, a wall thickness of an SDR of 15.5 or 11 is usually required.



Directional Drilling at Castlewood Country Club

Harris & Associates used the PUG specification for directional drilling on a sewer rehabilitation and waterline construction project for Alameda Public Works at Castlewood Country Club in Pleasanton, California. Part of the work involved constructing new 8" watermain, 6" sewer main, and 4" sewer laterals under existing driveways, walkways, mature landscaping, and golf course fairways. Directional drilling was an economical choice to install these facilities with minimal disruption to the existing surface features. For watermain directional drilling, HDPE pipe was used with SDR=7 because of the 150+ psi working pressures in this area. Sanitary sewer directional drilling was completed with HDPE pipe with SDR = 11. Overall, the direction drilling was very successful but not without some glitches. There was one case of striking an underground electrical service and one broken water service which flooded the garage at the same location.

Because of the efficiency of the process the Contractor elected to do much more directional drilling than anticipated. Directional drilling was used instead of pipe bursting when the Contractor was concerned that the surface might be displaced by pipe bursting. The Contractor also elected to directional drill a 6" watermain in a street where open cut was allowed in order to reduce traffic disruption.

Central Contra Costa Sanitary District has tested the PUG specifications for directional drilling on a busy street in a commercial area of downtown Martinez, California. Approximately 500 feet of new, 12-inch diameter, HDPE sewer was installed at a depth of 6 to 8 feet. The horizontal drilling contractor selected HDPE pipe with a wall thickness of SDR 15.5. Guiding and tracking of the drill rod and drilling head were accomplished by an in-line inclinometer with a direct feedback to a laptop computer with a preprogrammed alignment and grade. A surface locator was also used to track and verify the position of the drilling head. The pilot hole was kept within 1 inch of the preprogrammed grade and alignment by advancing the drilling head in 1 to 2 foot advances, checking and then making any vertical or horizontal corrections. The pipeline was installed along the design grade and alignment. The only problem encountered with this project was damage to a water main by the drilling head. The water main was lower than information provided by the water company.

Conclusion

The joint efforts of the PUG members to evaluate trenchless technologies and develop specifications for use of these technologies in public construction projects have been efficien/t and successful. The shared experience of agencies, cities, counties, and consultants allows trenchless technologies to be used in the appropriate circumstances and location. Improvements to specifications can be made in a shorter time frame. The PUG specifications are also beneficial to contractors and suppliers. It is easier to deal with a common specification, rather than separate and different specifications from each public agency.

TABLE 1

NORTHERN CALIFORNIA PIPE USERS GROUP

Member Rehabilitation Experience Matrix

Agency & Contact	Micro Tunneling	Slip-lining	CIPP	Pipe Bursting	Danby Liner	Lateral Rehab	Directional Drilling	Folded Pipe	MH Rehab	Piercing	Ramming	Direct Auger Boring
Central Contra Costa Sanitary District Tad Pilecki (510) 229-7273	✓	✓	✓	✓			✓	✓				✓
City of Sacramento-Dept. of Utilities Bruce Barboza (916) 433-6639		✓	✓	✓				✓	✓			✓
City of San Jose Richard Lucas (408) 277-4638		✓	✓	✓	✓			✓	✓			
City of Santa Rosa Larry Brown (707) 543-3930		✓	✓									
Sacramento County-Dept Of Public Wrk Mike Maggi (916) 855-8279		✓	✓				✓					
Union Sanitary District Richard Davis (510) 790-0100	✓	✓	✓				✓	✓				
West Valley Sanitation District Jonathan Lee (408) 378-2407		✓	✓	✓	✓							
City of Oakland - Public Works Gus Amirzehni (510) 238-3437		✓	✓	✓		✓		✓				✓
City of Stockton Charlie Swimley (209)□937-8701		✓										
Lawrence Livermore National Lab Jill Farrell (510) 423-8442			✓			✓			✓			

NEWS FROM THE NORTH AMERICAN SOCIETY FOR TRENCHLESS TECHNOLOGY AND THE OLIVER STREET UTILITY CROSSING

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Pipe Users Group
Annual Seminar
February 27, 1997

NEWS FROM THE NORTH AMERICAN SOCIETY FOR TRENCHLESS TECHNOLOGY AND THE OLIVER STREET UTILITY CROSSING

Introduction

Trenchless Technology is the installation or rehabilitation of infrastructure by non-person entry methodologies. Infrastructure includes all of the service facilities constructed beneath the ground that provide for the quality of life that we enjoy in our cities today. These include the sanitary and storm sewers, forcemains, watermains, gas lines, electrical conduits, telephone cables and television cables.

The Trenchless Technology Societies

The North American Society for Trenchless Technology is six years old. The Society has grown to more than 600 members in that time. When many engineers, municipalities, contractors and people in general are still unaware either of the technology or of details of No-Dig, then this is an exciting beginning.

NASTT is an affiliated member of the International Society for Trenchless Technology (ISTT) which is headquartered in London, England. ISTT is ten years old. It is fitting to note, especially as we are in the Province of Quebec for this meeting, that the first Chairman of ISTT was Ted Flaxman, from Britain, and the second Chairman was Michel Mermet, of France. These two gentlemen, together with the current Chairman, Rolf Bielecki from Germany and the vice Chairman, Gert Fischer from Scandinavia have provided great leadership to the Societies. In that time, the Trenchless family has been established in eighteen countries with two pending. The Member countries are as follows:

> Argentina, Australia, Austria, China-Taipei, Czech, France, Germany, Hungary, India, Italy, Netherlands, North America, Russia, Scandinavia, Slovak, South Africa, Spain/Portugal, Switzerland and Venezuela.

One of the rapidly developing benefits of Society membership is this worldwide link with all the other Societies. Up to the present time this has been done through the International No-Dig conferences, specialized meetings and the Trenchless magazines. Three of the International No-Dig conferences have been held in North America to assist in the spread of knowledge of the Technology. There will be additional means in the near future as the Trenchless Societies develop their Home Pages and provide greater detail of the particular activity of each Society. This will allow ISTT and the member Societies to assist in the continuous sharing of ideas and knowledge. NASTT is preparing to host an international teleconference in the fall of this year.

The Internet

At the present time, NASTT and GSTT have home pages. When the ISTT home page begins, these Societies will join in the Trenchless Internet. There is much basic information available today on the NASTT home page. The data is generally in two areas. One of these areas gives the necessary information on the upcoming No-Dig '97 Conference which will be held in Seattle from April 18th to the 21st. This includes details of the program, the exhibition and registration. The other area offers details on Society membership, outlines features of the ISTT affiliation, explains the Memorandum of Understanding and presents reports from the various NASTT committees.

It is good to see this continuing development of international togetherness in the technology transfer. As was indicated during my remarks as Chairman of NASTT at the International No-Dig conference in New Orleans this year, it is important that we work with a Spirit of Cooperation to continue the development of Trenchless Technology.

Construction Industry Congress

An example of such cooperation in the construction industry was evidenced in Washington in April of this year. This was the second meeting of the Construction Industry Congress. There were 35 Societies in attendance, including the National Society of Professional Engineers, the American Association of Architects and the Association of General Contractors. It was an honor to be present at this meeting, especially representing NASTT.

After the appropriate introductions on the first afternoon, the signing of the historic Dispute Avoidance Resolution document took place. The 35 Associations present to sign represented all aspects of the construction industry. This document indicated the desire of all to endeavor to work together for the common good and to try to prevent the losses in efficiency, time and cost that can occur without such a rapport.

On the second day, this group prepared a statement on the position of the gathering on the Environment. This document indicated that the 35 Associations present represented 8.5% of the workforce of America, and, as planners, designers and contractors, were the protectors of the natural environment and the purveyors of the developed environment. The document indicated that regulators required to recognize this expertise and capability to work in the environment.

The Memorandum of Understanding

Again, in the necessary Spirit of Cooperation, NASTT developed a Memorandum of Understanding in its earlier years. This is an important document, as it identified that all who signed were willing to work together for the betterment of the Technology. This is a most important concept, as again, we can prevent duplication of effort and, in so doing, also prevent the development of lower standards or the creation of problems caused by the provision of poorer quality trenchless materials or methods. The Organizations participating in this MOU are:

- American Public Works Association
- American Underground Construction Association
- American Water Works Association
- Associated General Contractors
- National Association of Sewer Service Companies
- National Utility Contractors Association
- Trenchless Technology Center
- Water Environment Federation

The MOU generally indicated that Trenchless Technology was the area of expertise of interest to NASTT, and that the other Associations would cooperate with NASTT in this field. This strategy has been successful because although there have been papers or work presented in various areas of Trenchless within those Associations, in most cases, NASTT has been a sponsor or NASTT members have been part of the effort. This cooperation is most valuable as it helps to maintain a constant level of development in the technology transfer.

Development of Standards

Another area of cooperation is in the development of standards for materials used in the trenchless industry. This type of work is done by the Canadian Standards Association or the American Society for Testing and Materials for most of the materials used in construction. Consider the case of pipe rehabilitation where the pipe is not to be replaced. If the existing pipe is out of round, then a standard for the material of choice to reline that pipe is necessary. A designer can then use this information to prepare a specification for the rehabilitation of the pipe and be able to satisfy the client that the design is correct.

This is an important development as it can take some time for an agency, municipality or industry to decide to use a trenchless method. It is important that the application be appropriate and long-serving.

The Pipe Rehabilitation Council is forming under the auspices of the Society of the Plastics Industry, Inc. This Council will be primarily composed of those in the manufacture of plastics and use of that product base in pipe rehabilitation. The Council is working closely with NASTT and will continue to do so as the effort in developing the standards for rehabilitation materials begins.

The Gas Rehabilitation Institute (GRI) is also involved in research in methods of pipeline rehabilitation. This work has been coordinated with the Gas Committee of NASTT.

Committees

This is an important area of the work done by NASTT. Due to the amount of fragmentation in the industry, it is necessary that we coordinate activities and effort. This is a major thrust of each of these committees. The committees are in three basic families. Since Trenchless Technology includes both installation of new and rehabilitation of old infrastructure, then the committees follow the same path. The third family includes those areas which are not directly associated with construction and rehabilitation. The committees are:

- Directional Drilling
- Microtunnelling
- Pipe Jacking
- Horizontal Earth Boring

- Water Rehabilitation
- Sewer Rehabilitation
- Gas

- Safety
- Education/Public Relations
- Program

These committees are involved in a broad spectrum of activity. The Directional Drilling Committee is working on specifications.

The Microtunnelling Committee is working with ASCE on a pipe-jacking and microtunnelling standard, preparing a bibliography on the technology and completing a final review of the Glossary of Terms.

The Pipe Jacking Committee is working on specifications.
The Horizontal Earth Boring Committee is finalizing a specification on auger boring and working on pipe ramming specifications.

The Water Rehabilitation Committee has been working with others within the MOU on reports identifying renewal techniques. Joseph Loiacono has been involved in this committee with the Diagnostic Tools Survey Report. The Sewer Rehabilitation Committee is finalizing a Glossary of Terms which will apply to all rehabilitation work and is developing fact sheets that apply to sewer rehabilitation methods and sewer inspection technology. The Gas Committee is working on the identification of and solutions to problems with rehabilitation. An example of a problem is that approvals and regulation create difficulties due to rigidity on acceptance of certain materials and the approval process.

The Safety Committee is reviewing the safety programs of the various regulatory agencies and developing an understanding of the effects of definition of trenchless procedures on classification of those procedures by the regulators. This can affect the cost of doing business. The Education/Public Relations Committee is involved in the Home Page maintenance as well as coordinating and developing trenchless advisory programs. The Program Committee is responsible for the annual No-Dig Conference.

Chapters

Chapters are a vital part of the growth of NASTT and of the continuing development of the knowledge and use of Trenchless Technology. NASTT considers that seminars and valuable meetings such as this one should be organized by the chapter with whatever assistance is required from the Society as a whole. In the near future, one of the ways that the Society can help is by providing the latest information on No-Dig from the other member Societies.

At this time, there are three Chapters and two Student Chapters in NASTT. The Chapters include:

1. The Northeast Trenchless Technology Society

   This Society has members in the States of Pennsylvania, New Jersey, New York, Connecticut, Rhode Island, Massachusetts, Vermont, New Hampshire and Maine. This chapter has been successful due to a vibrant leadership, led by Joe Vellano, and has held four meetings to date since its inauguration just over a year ago. NETTS recently held its Board meeting in New York on Thursday, November 7, 1996 in New York City.

2. The Great Lakes and St. Lawrence Chapter

   This Chapter indicates the interest in the technology in Canada. It is good to note that the third Chairman of NASTT is from Canada. It may also be recorded that the fourth NASTT chairman will also be from Canada, from the west coast. One of the exciting features of GLAST is that its present geographic area is based on a historic one in that it includes both lower and upper Canada as a base while serving the large area of Ontario and Quebec. The first GLAST Chapter meeting was held in Scarborough, Ontario on Friday, November 1, 1996. This forum offered various points of view on the Technology and had a roundtable discussion on how to remove the barriers to the use of Trenchless. This meeting in Montreal, although not a Chapter meeting, is more than complimentary to the efforts of the Great lakes and St. Lawrence Chapter and, again, identifies the necessary Spirit of Cooperation necessary in the industry.

3. The Rocky Mountain Trenchless Society

   This Chapter covers part of the exciting western area of the States, Colorado, Utah, Arizona, New Mexico and Wyoming. Under the leadership of Tim Coss, this Chapter is involved in the Internet, coordinating with NASTT, and with the Colorado School of Mines in advancing the knowledge of microtunnelling.

The Student Chapters are:

1. Louisiana Tech Student Chapter

   The students at Louisiana have been of great assistance at No-Dig '96 in New Orleans, where they met many of the people in the industry. The students also are involved in the work at the Trenchless Technology Center where they receive hands-on training and experience.

2. University of Waterloo Student Chapter

   Just as their counterparts in the South, the students at Waterloo were of invaluable assistance at No-Dig '95 in Toronto and also receive important experience with their involvement with CATT, the Centre for the Advancement of Trenchless Technology. They are planning to assist in No-Dig '97 in Seattle.

These Student Chapters are a most important part of the NASTT family as they allow the younger members to fully understand the technology and see where it can be a professional career for their future. If we are to maintain the quality of life that we presently enjoy, then our younger people must learn that the infrastructure business is a glamorous and rewarding career. All of the NASTT Chapters are working closely with the universities and colleges.

At the present time, meetings have been held for the inception of the Northwest Chapter which will serve Alberta, British Columbia, Washington, Oregon and Idaho. Likewise, discussions are underway for the inauguration of the Mid-Atlantic Chapter which will serve the area around Washington, D.C. We are always ready to discuss the formation of a student chapter with any interested institution.

<u>Publications</u>

There is a broad spectrum of material available from or through NASTT. Although many aspects of the technology are improving or changing, there are still past procedures that are satisfactory. An attendee at a No-Dig conference receives a copy of the papers to be presented, but there may be a topic given at an earlier conference which is appropriate for use today. NASTT carries all of the past papers presented, both at North American and International No-Digs for sale.

NASTT also offers the Mini-Horizontal Directional Drilling Manual as well as other information produced by the Association or its affiliates. NASTT offers all the publications of the WRc from U.K. to those in the field of rehabilitation and also offers the work of the Trenchless Technology Center.

<u>No-Dig Conferences</u>

The No-Dig Conferences are designed to further the knowledge of Trenchless Technology and to broaden its use. These conferences have been located in those geographic areas which offered details of the Technology to as many people as possible. The first conferences were in Washington D.C. where the technology was in use. This helped the Society to start. Since then No-Dig has been held in Kansas City, San Jose, Dallas, Toronto, New Orleans and will be in Seattle in 1997. It is planned that the conference be in Albuquerque, Orlando and Anaheim in future years.

This year's conference will have meetings of all of the Committees, workshops on rehabilitation, environmental remediation by HDD and highway crossing case histories. A major purpose of the workshops is to review and discuss matters such as critical buckling behavior of rehab pipe liners. The technical sessions will cover all aspects of the Technology. An important session this year is one on the Owner's Perspective on Trenchless Technology. This is an important area as use of the Technology will only continue to grow if the owners wish to use it.

There will also be an exhibition of all aspects of Trenchless Technology where attendees can see physical evidence of available equipment and materials. There will be a Field Demonstration day when slurry boring, pipe ramming, pipe bursting and mapping/ locating technologies will be displayed in place in the field.

Due to the busy schedules of people, this years No-Dig conference is being held over a weekend. The conference will be held from Friday, April 18, 1997 to Monday, April 21, 1997. The schedule is as follows:

Friday	Committee Meetings Exhibition Opening
Saturday	Opening Session Exhibition
Sunday	Workshops Technical Sessions Exhibition Social Evening
Monday	Technical Sessions Field Demonstrations

It is considered that this timing may permit more municipal people to attend as budget constraints are a concern to all. As before, the content of the conference is good and offers a keen learning experience to those who attend.

Conclusion

Trenchless Technology is one of the most exciting happenings in the infrastructure business today. It holds great promise for the future. There are designs that are possible with this technology that have not yet been attempted. Present and future users of No-Dig will be more willing to consider these technologies once that more procedures have a proven history in place. NASTT has an important role to play, both in advancing knowledge in North America, and in providing proven methodologies from the other Societies overseas. It will be of interest to compare the Trenchless Industry in 1996 to that in 2001.

OLIVER STREET UTILITY CROSSING

Background

A major component of the $7.9 billion Central Artery / Tunnel (CA/T) Project in Boston is the relocation of existing utilities and drainage facilities. The CA/T expands two interstate highways by replacing the existing elevated section of the I-93 Central Artery in the downtown business district with a new 8 to 10 lane roadway, mostly underground; and by extending the existing I-90 Massachusetts Turnpike from downtown Boston to Logan International Airport, under Boston Harbor with a new 4 lane immersed tube tunnel.

Since much of this work is within existing streets with multiple active utilities, the Project had to develop an extensive utilities relocation plan to provide continuous utility service to the various commercial buildings adjacent to the highway construction. The general plan for the relocation of existing utilities is to establish north/south longitudinal corridors outside of and parallel to the new highway tunnel right-of-way (R.O.W.) in City streets, and to install several east/west transverse utility crossings at selected locations perpendicular to the highway. The new utilities at these transverse crossings will be supported in place, under a temporary traffic deck, as the highway tunnel structures are constructed below.

Oliver Street Utility Crossing

One of the more complicated and interesting pieces of utilities relocation work occurs at a transverse crossing between Purchase Street and Atlantic Avenue, where a portion of Oliver Street had been discontinued for the construction of the original Central Artery in the 1950's. As part of the final surface street traffic circulation plan, Oliver Street will be restored as a City street with new utilities, above the highway tunnel, and extended across the recently constructed Northern Avenue Bridge over the Fort Point Channel into South Boston. New buildings are planned on both sides of the future Oliver Street.

What makes the work more difficult at this location is the fact that all of the new utility systems must be installed below the active I-93 surface highway and above the future highway tunnel. This means that the pipes and conduits must be installed by either jacking or microtunnelling methods. The jacking and receiving pits for this operation are 25-ft wide by 110-ft long and 30-ft deep. The distance across the highway R.O.W., between the jacking and receiving pits in Purchase Street and Atlantic Avenue, is about 250-ft.

These utilities have to be constructed in advance of the highway tunnel because they must be installed through the new slurry walls that will serve as the excavation support for the new tunnel structures between Atlantic Avenue and Purchase Street.

The new systems required at the Oliver Street Utility Crossing include a combined sewer and a sanitary sewer to be installed by direct jacking, and seven 48-inch steel casing pipes to be microtunnelled and then used as sleeves. The utilities involved are listed below.

Utility	Size	Material
Combined Sewer	72-in	P.C.C.P.
Sanitary Sewer	66-in	P.C.C.P.
Low Service Water	20-in	C.L.D.I.
High Service Water	20-in	C.L.D.I.
High Pressure Fire	20-in	C.L.D.I.
Electrical	(9-5")	P.V.C.
Electrical	(15-5")	P.V.C.
Electrical	(4-8.6")	Steel
Signal	(26-4")	P.V.C.

The three water 20-inch water mains each will have a separate sleeve. The two sets of electrical distribution system ductbanks E(9-5") and E(15-5") will be in separate sleeves. The four oil insulated 115 kV electrical transmission conduits are in one sleeve. The remaining 48-inch sleeve will contain twenty-six 4-inch communication and signal conduits belonging to NYNEX, Teleport, MFS/McCourt, Cablevision, ATS/Western Union and the Boston Public Works Dept.

All of the utilities at the Oliver Street Crossing will be activated, then supported in-place under a temporary roadway decking system during construction of the highway tunnel below. After the tunnel structure is completed, the area above it, including the utility crossing, will be backfilled; and the new Oliver Street will be constructed as part of the surface restoration plan.

This paper will summarize and explain the design and construction requirements for the Oliver Street Utility Crossing, including construction staging and utility company coordination issues. It will also describe the materials, methods and equipment used to perform this work.

Design Requirements

The final design of the Oliver Street Crossing complied with the design standards of each utility company and the CA/T "Project Design Criteria" (PDC). The Utilties Section of the PDC includes detailed requirements for the design of water mains, sewers, drains, steam mains, gas mains, telecommunication facilities and electric power systems.

Because of the co-operative design review process, the utility companies have been able to modernize their systems and reduce the number of locations where they have to cross the highway. The Boston Water & Sewer Commission (BWSC) for example has requested two large diameter pipes at Oliver Street, a 66-inch for sanitary sewer flows and a 72-inch for combined sewer flows that will be separated later by BWSC and eventually carry storm water flows only. The local telephone company NYNEX by comparison has been able to reduce the number of conduits it needs by using fiber optics instead of traditional copper cables.

Construction Staging

The most important requirement for construction staging was to maintain traffic flow in the contract area. The Atlantic Avenue Jacking Pit required the relocation of an I-93 northbound off-ramp. On the other side of the highway, a new traffic detour plan had to be implemented on several streets to redirect City traffic around Oliver Street Receiving Pit. The construction staging plan at both pit areas had to be approved by the City of Boston Traffic Department and all of the affected utiltity companies.

The actual pipe and conduit installations had to be staged in a sequence that allowed for the activation of a new utility system and the discontinuance of adjacent, existing systems to provide space within the corridor for the next new system. This restraint required the contractor to interrupt its work while the local utility companies performed their work.

Utility Company Coordination

Since the utility work at Oliver Street involves nine separate crossings with three major utilities (BWSC, NYNEX and BECo), and four telecommunication companies, construction coordination must be a continuous process. This planning effort is accomlished through regular construction coordination meetings, attended by utility company representatives.

Materials, Methods and Materials

The large pipes used for the sanitary sewer and combined sewers are prestressed concrete cylinder pipe (P.C.C.P.) because they will be eventually be supported from above in a future highway tunnel contract. All other pipes and conduits will be inside of 48-inch steel casing pipes.

Both the 72-inch and 66-inch P.C.C.P. will be direct jacked. All seven 48-inch steel casing pipes will be microtunnelled. Several of the 48-inch steel pipes have already been microtunnelled across the 250-ft work area under the existing highway. The accuracy of these installations has been within the contract tolerance limits.

Summary

Due to the difficult conditions associated with the Oliver Street Utility Crossing, there was no possibility of installing the various utility systems by open cut trenching methods. By using the trenchless methods of direct jacking and microtunnelling, the Project has been able to solve a multitude of problems anticipated in this particular construction contract. The microtunnelling operation has been so successful that it is now being considered for use in several other adjacent contracts with similar complicated utility installations. As the construction of the Central Artery / Tunnel Project progresses in the Downtown area of Boston, it is certain that direct jacking and microtunnelling will become more routine and used more frequently.

PIPE USERS GROUP OF NORTHERN CALIFORNIA

SHARING TECHNOLOGIES SEMINAR

"The American Trenchless Technology Scene, An Independent Perspective"

Ray Hutchinson is an engineer originally from UK with over 20 years experience in Sewerage Rehabilitation Technology. Ray has worked in the US for 12 months and having attended the NO-DIG 96 and WEFTEC 96 as well as being a member of the Ad Hoc Committee for the newly formed Pipe Rehabilitation Council has developed a perspective that will be of interest to the PUG. Ray has a wealth of experience in Consultancy, especially overseas in the Middle East and Asia, but he was also formerly Chief Assistant Engineer in the Main Drainage Department of Manchester City Council, the second largest City in UK.

* Investigative technology - what works and what doesn't ? Innovations in this field of the pipeline rehabilitation industry have been appreciable and yet Engineers in America still appear to be confined to conventional CCTV and not much more. There is much that can help Engineers come to terms with the pipeline and its environs. This paper reviews the key complimentary Investigative technologies (CIT'S) currently available including sonar, impulse radar, seismic refraction/transmission, radio electromagnetic as well as conventional CCTV, lightline profiling and much more, that can assist in completing the picture.
* Lining Pipes, especially large diameter ones, what is out there ? What can go wrong ? The author reflects on how $100 000 can be lost in 6 minutes when a 4'-0" lining job went wrong.
* When it comes to design, testing and adoption/acceptance of the rehabilitated pipe are we all singing off the same hymn sheet? This aspect of the paper reflects on some of the imponderables out there and explores what can be regarded as the consensus part of current approaches as opposed to that part that reflects dissention.
* The various themes that run throughout this presentation are brought together in this concluding part. The author notes the independent spirited approach to NO DIG that is so much a characteristic ingredient of the American scene but countenances the view that sharing technologies should lead to standardization, quality control and a consolidated knowledge base

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Pipe Users Group of Northern California
1997 Sharing Technologies Seminar

Charles W. Joyce, P.E., Brown and Caldwell
Bob Whiteley, Ph.D., Coffey Partners International

Seismic Tomographic Imaging - Part of a Complete Pipe Condition Assessment

ABSTRACT

Nobody likes it when a sinkhole forms in their street. Nor do they enjoy the emergency work that often goes through the night to repair the results of a pipe collapse and the accompanying sinkhole. Until now the location of a potential collapse could not be determined through conventional pipe condition assessment techniques.

An important aspect of pipeline condition assessment is to obtain a complete understanding of the the soils surrounding the pipe. Normally any investigative work performed around a pipeline is in the form of random borehole samples (soil penetration testing) along an alignment. Borehole sampling is costly and destructive to the area being tested and provides results limited to the diameter of the boring. The results of borehole testing may or may not provide the needed information for an accurate picture of the soil conditions throughout a pipe alignment.

Seismic Tomographic Imaging (STI) is a non-destructive screening method that allows engineers to identify areas of loose or voided soils around sewers. STI provides a continuous profile image of the seismic velocity distribution of the soils between a pipeline and the ground surface. These profiles reveal key information about soil densities and relative strengths and are used to focus additional field investigation and rehabilitation of the affected area.

Use of STI allows a condition assessment to prioritize the overall condition of the sewers in a collection system. There are three testing methods used for STI to meet the needs of differing field conditions. Each of these methods have been used on recent projects in California and Oregon. The techniques and how the results of the tests are used in the condition assessment process will be the focus of this paper.

INTRODUCTION

Seismic Tomographic Imaging (STI) is an innovative application of technology first developed in the petroleum industry to determine the subsurface characteristics of geological formations. STI when applied to underground piping systems establishes the subsurface characteristics of soils surrounding pipes, appurtenances, and buried structures. This technology uses seismic waves to give an overall "view" of the subsurface conditions.

The information obtained from STI can identify the need for more in-depth testing of a particular area, including the best location to drill truthing boreholes. Identifying the best locations for boreholes prevents costly incorrectly placed boreholes and can optimize soil information received.

Brown and Caldwell and Coffey Partners International, a geophysical and geotechnical consulting firm based in Australia, have teamed together to bring STI to the United States as a new tool in the condition assessment of aging collection systems.

CONDITION ASSESSMENT

Condition assessment of sewers typically involves a six-element investigation to establish the condition and the need for corrective measures for sewers. These elements are:

- **Historical Data.** These data include collecting and reviewing any construction and maintenance related information associated with the segments of sewer being evaluated.
- **Internal Inspection**. This element is dependent on the size of the pipe being evaluated and local conditions. Small diameter pipes (less-than 60-inch diameter) television inspection normally provides excellent images of internal conditions. For larger pipes, this investigation often includes a walk-through inspection to collect specific information on the internal condition of the pipe. Other technology including sonar scanning can be used for siphons and force mains to obtain information on the internal condition.
- **Hydraulics**. Anticipated dry and wet weather flows are developed and modeled for the pipe segments being evaluated and areas of surcharge are noted. Rehabilitation recommendations are also modeled to determine impacts from changing pipe materials and potential reduction of pipe cross sectional area.
- **Structural Condition**. Depending on pipe material and size a structural analysis is performed to compare stresses on the pipe to the remaining structural wall section of the pipe. Stresses due to critical loading conditions are determined using computer models. Actual loading conditions are then compared to calculated values to develop the various combinations of loads to represent field conditions and determine whether the pipe can structurally support the identified loads.
- **Corrosion Potential**. Corrosion of concrete, ductile iron, or asbestos cement pipe causes structural weaknesses, which in severe cases can cause collapse or holes to form in the pipe. These allow soils to enter the sewer causing loose areas and voids above and around the pipe. Sulfide measurements and modeling are performed to establish areas of the collection system where corrosion levels may exist. Also, at designated sites, depending on pipe size, corings of the pipe wall are made to physically measure the remaining wall thickness and the level of corrosion.
- **Geotechnical Conditions**. This part of the evaluation involves an analysis of background geotechnical information and traditionally included drilling a series of exploratory borings along the alignment of the sewer to define soil and groundwater conditions. Corings performed as part of the corrosion potential also provide access to the outside of the pipe where samples can be collected for laboratory testing. Where problems indicate, a more detailed program of geotechnical investigation may be developed to more fully define subsurface conditions. The geotechnical component of the condition assessment can be one of the most labor intensive and costly. The information obtained from a geotechnical

analysis is point-specific and does not necessarily reflect conditions elsewhere along the pipe alignment. Depending on the location of the sampling program, the actual condition over and adjacent to the pipe is often missed as most drillers do not drill directly over a pipe.

SEISMIC TESTING

Seismic testing was originally developed and utilized in the exploration for petroleum products and mineral resources. Beginning in 1994 seismic testing was first used in Melbourne Australia by Coffey Partners International to assist in identifying the extent of a major sewer collapse. Since then the technology has evolved into three separate field methods that have been applied to many miles of sewer as part of condition assessment programs.

Most subsurface investigations rely on a combination of conventional tests, such as SPT (soil penetration testing) and drilling. These procedures are destructive and provide limited disturbed data on the subsurface condition. As a result engineering design relies on a soil condition analysis that does not fully cover the entire site.

Techniques employed in geophysical seismic testing have advanced in recent years and are becoming more widely used and available. The information obtained from this form of subsurface testing is a non-destructive means of providing a continuous image of conditions at any specific site and does not require the engineer to rely solely on published historical or spot samples during evaluation and design of a project.

In general terms, seismic methods measure the dynamic elastic properties of earth and sewer materials. This response is contained within subsurface distribution of seismic velocities together with geometric and spectral character distribution of specially-generated seismic waves. Three new seismic technologies are available for inspection of various types of pipelines and are used individually or in combination, depending on the particular conditions and problems encountered at each site. The technologies, described in more detail below, are called Seismic Resonance Testing (SRT©), SEWREEL© testing, and Site Uniformity Borehole Seismic Testing (SUBS©). Variations on these basic techniques are used to accommodate specific field conditions.

Seismic Resonance Testing (SRT©)

SRT© is a seismic screening technique specifically designed for a rapid initial investigation of the geotechnical conditions around and above the sewer where entry along the length of pipe is not possible or permitted. A specially-constructed impact source (the Hiss Hammer©) is lowered down an access hole and placed on the invert of the sewer. A drop-weight enclosed within this source is raised with pneumatic rams and released to impact an anvil on the invert. This impact causes seismic waves to travel along the sewer re-radiating from the sewer traveling through the soil. These waves have travel times, characteristics, modes or resonances that are influenced by the integrity of the sewer and by actual geological conditions surrounding the sewer. Refraction and other wave propagation processes allow a large portion of the radiated seismic energy to travel to the surface and to be detected with a linear array of closely-spaced geophones that are deployed on the ground surface directly above the sewer alignment.

SRT© work can be performed quickly; and provided the invert is relatively intact, a continuous visual seismic tomographic image can be produced at a rate of up to 4,000 feet per day between manholes up to about 900 feet apart. SRT can be operated in live or surcharged sewers. Suspect conditions can normally be readily identified, and locations can then be selected for further investigation. The resolution of SRT© for the delineation of subsurface features, including potentially voided and weak or loose regions, is plus or minus 15 feet horizontally and plus or minus 15 percent of the depth to the sewer invert vertically. Figure 1 shows a typical field layout for SRT testing.

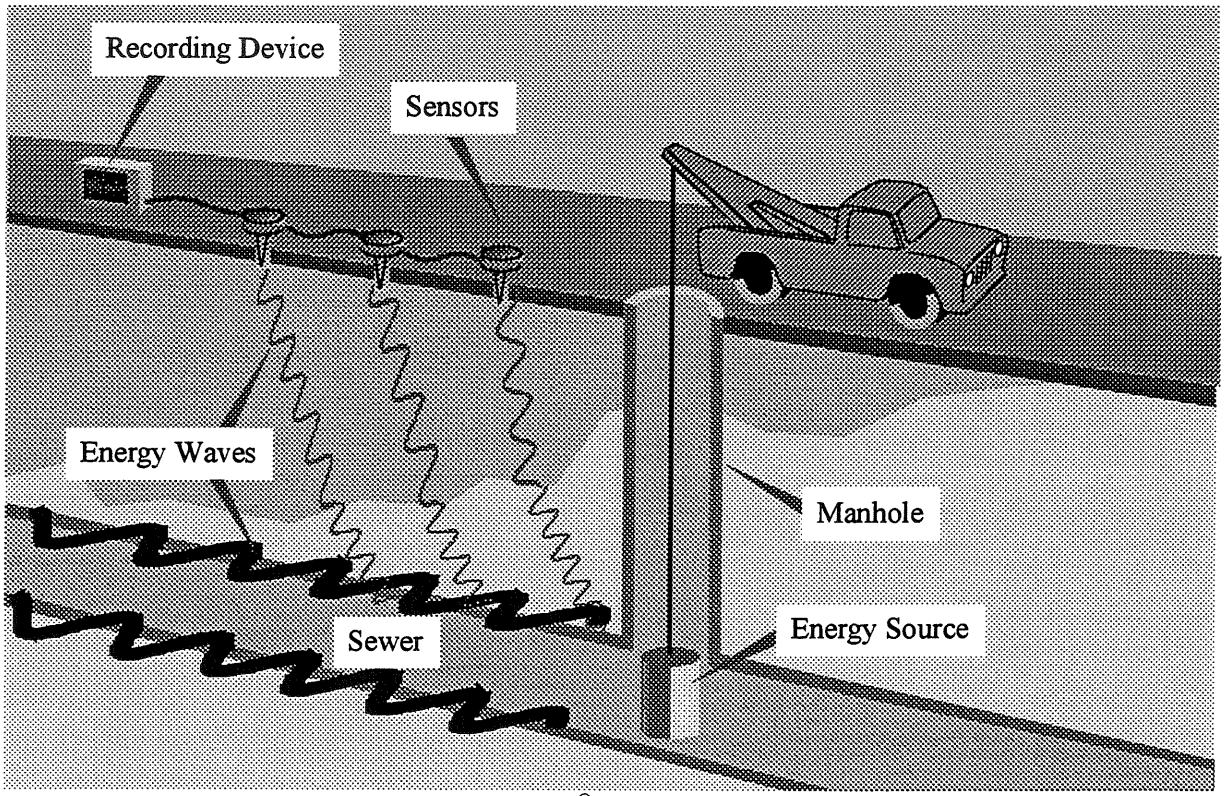


Figure 1 - SRT© Equipment Setup

SEWREEL© Testing

SEWREEL© was developed to provide detailed information about the soils between the sewer and the ground surface where access to the length of sewer pipe is available. SEWREEL© is often used in conjunction with closed circuit television inspection to provide comprehensive information on the internal and external sewer conditions. In the SEWREEL© test an array of closely-spaced hydrophones encased in an oil-filled tube, called an "eel," is placed along the invert of the sewer. Seismic coupling is provided by wastewater in the sewer. The eel remains stationary while the seismic energy source (Hiss Hammer©) is deployed on the surface above the sewer at close spacing along the sewer alignment.

A crew can perform SEWREEL© testing in live sewers to a depth of about 120 feet at a rate up to 600 feet per day. SEWREEL© requires a considerable amount of data reduction and processing. It is therefore best suited to detailed investigation or in situations where the invert is in poor condition. SEWREEL© can be used for monitoring changes in conditions produced by grouting, construction, or changing groundwater elevation.

Continuous seismic tomographic images produced for the seismic data allow high resolution definition of subsurface features along the sewer alignment. The resolution of SEWREEL© is plus or minus three-feet horizontally and plus or minus five percent of depth to the sewer invert vertically.

Figure 2 shows a typical field layout for SEWREEL© testing.

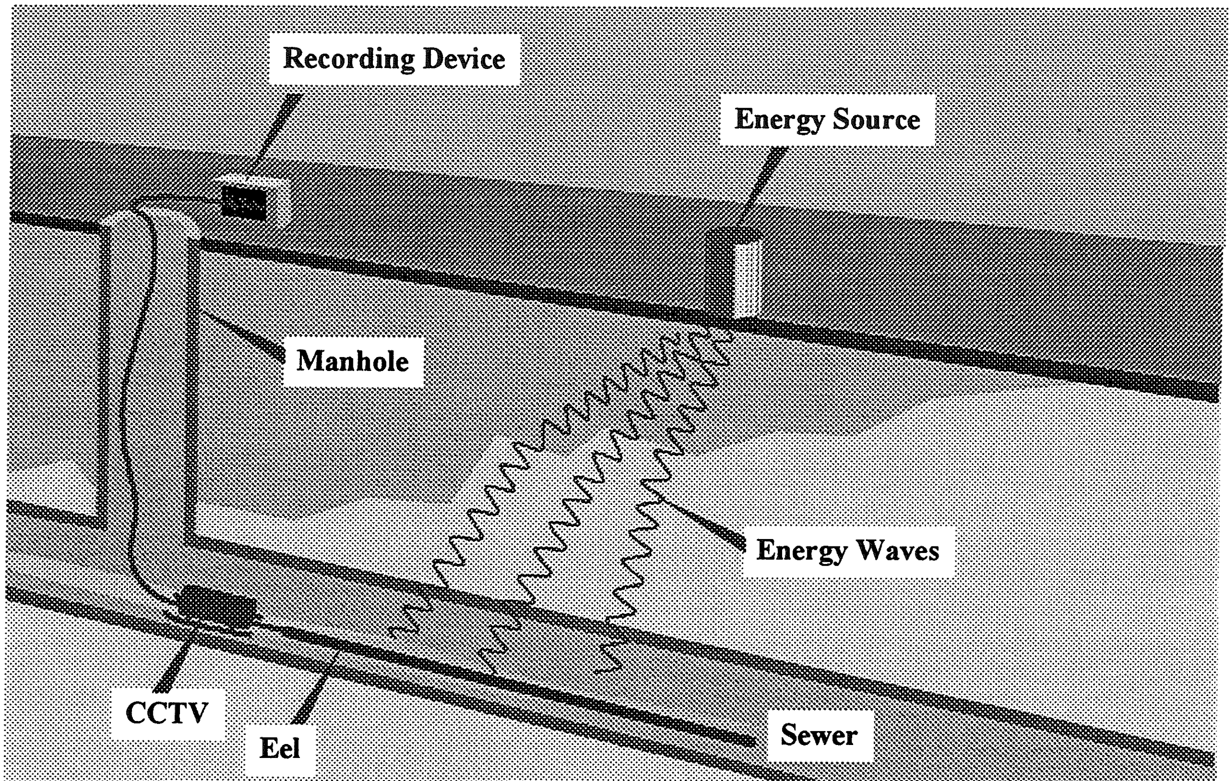


Figure 2 - SEWREEL© Equipment Setup

Site Uniformity Borehole Seismic Testing (SUBS©)

SUBS© testing is specifically designed for detailed follow-up investigation after SRT© and SEWREEL© surveys have identified possible problem conditions or for pre-design and pre-construction planning. Sewer entry or the presence of a pipeline is not used. A borehole is located in or near the site to be tested. An array of closely spaced hydrophone detectors encased in an oil-filled tube or eel, is lowered into a water tight PVC-cased and carefully filled borehole with a 2 ½-inch inside diameter. Seismic coupling of this array to the earth is achieved by filling the hole with water or drilliig fluid. The in-hole detector array has a length of about 65 feet, and the borehole may be tested by multiple sensor placements, to depths in excess of 300 feet.

Seismic energy is generated by the Hiss Hammer© on the ground surface around the borehole at varying distances from the hole. A maximum horizontal investigation radius to two or three times the depth of the hydrophones is possible, depending on local conditions. The horizontal range extends the effective radius of investigation of the borehole considerably and allows detailed calibration with geotechnical and geological information at the borehole. Seismic waves that travel from each surface-impact point to the detector array are modified by the ground conditions around the borehole within an effective volume of investigation (shaped like a cone). In particular, the first arrival compressional wave travel times are controlled by the elastic properties of the materials and the distribution of elastic interfaces. Should the subsurface conditions or elastic properties of these materials vary laterally around the borehole, the travel times to each subsurface detector will be different for identical source offsets around the borehole. Any significant condition that weakens the material will scatter the seismic energy and delay its travel time. Seismic tomographic imaging allows detailed definition of subsurface features around a borehole. Additionally, SUBS© can be used for monitoring changes in those conditions produced by grouting, construction, or changing groundwater elevation. The resolution of SUBS© is plus or minus three feet vertically and varies from plus or minus five feet horizontally near the hole to plus or minus ten feet at the greatest distance from the hole. Up to 4 SUBS© holes to 80 feet depth can be completed in one day.

Figure 3 shows a typical field layout for SUBS© testing.

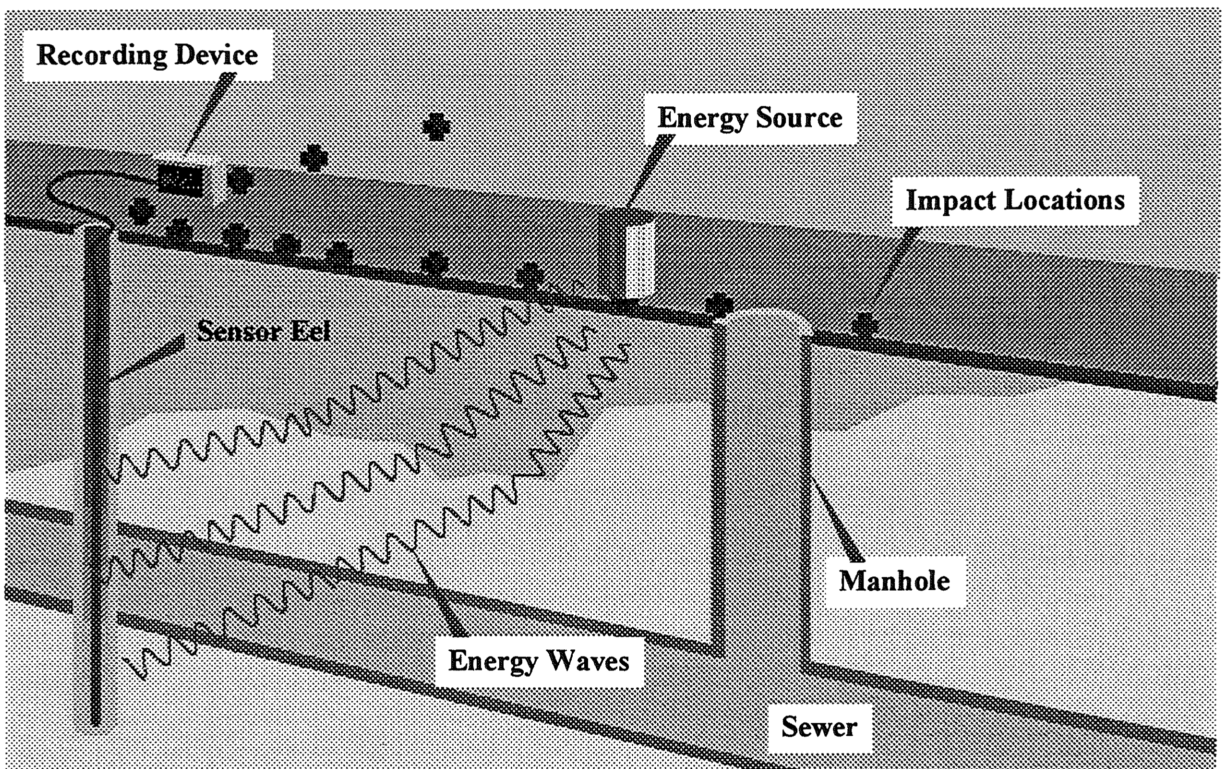


Figure 3 - SUBS© Equipment Setup

SEISMIC VELOCITY AND SOIL DENSITY

On each STI produced from a scan, a color grading is developed and used to display the seismic velocities and ranges. This color range depicts the changing seismic velocity, which provides information on how the soil density changes in the area of the test. Higher density soils allow higher seismic velocities, while less dense soils and voids exhibit lower velocities.

In areas of high ground water the seismic velocity range reflects higher average velocities due to the saturated soils.

The following table provides a guide to assist the interpretation of STI based on our experience in sandy soil conditions above the water table. This table may be used to assist in relating the seismic velocities and their distribution to the materials present. A similar table is completed for each project to aid the engineer in comparing data between conventional geotechnical investigations and STI. It should be noted that the seismic results obtained relate strictly to the time when the fieldwork is carried.

Guide to the Interpretation of STI in Sands Above the Water Table

SPT N-value	Geotechnical Classification	Seismic velocity (kft/s)	Seismic velocity classification	STI Color Range
0 to 4	very loose	1.1 to 1.4	very low	white to magenta
4 to 10	loose	1.4 to 1.7	low	magneta to red
10 to 30	medium dense	1.7 to 2.4	moderate	red to light green
30 to 50	dense	2.4 to 5.5	high	light green to light blue
> 50	very dense	> 5.5	very high	light blue to dark blue

Information from work completed for City of Los Angeles, 1996.

STI BENEFITS

The use of STI as part of a condition assessment program provides a means of establishing the subsurface condition of the soils around the pipe in a reproducible, timely, and efficient manner.

- **Non-Destructive**. Both SRT and SEWREEL testing methods use existing access to the sewer to collect data, so no damage to the ground surface or the pipe takes place.
- **Reproducible Results**. The use of a non-destructive test method allows a field crew to retest a site to establish changes in the subsurface condition around the pipe without impacting the pipe or potentially causing damage to the ground surface.
- **Productivity**. The use of SRT for initial screening will allow for production of 4,000 feet per day of data collection of a continuous image. If traditional borings were placed on a 200 ft spacing, an average of 20 feet deep, a total of 27 borings are required and could take two to three weeks to collect the field data.

STI APPLICATIONS

Typical objectives of using STI on a project range from siting a new pipeline alignment, to establishing the soil condition around the remaining portion of a sewer after a catastrophic failure. Projects completed to date have had the following objectives when using STI as part of the project:

- **Existing Sewer Condition Assessment**. Use of SRT, SEWREEL, and SUBS depending on site constraints provides the engineer with continuous information on the subsurface condition of a pipe alignment.
- **Predesign and Design Alignment Selection**. Use of SUBS provides key information to augment conventional geotechnical data to determine location and extent of soils/rock boundaries, abandoned and filled quarries, and other underground features that can impact tunneling or open cut construction.
- **Structural Settlement Evaluation**. Use of SUBS or SEWREEL, where a pipeline is available under a building, can be used to provide information on the location of subsidence zones under the foundation of a building.
- **Pre- and Post-Construction Evaluation**. Use of STI on construction projects can provide information related to the site conditions before and after construction. Projects with soil strengthening around a pipeline using grout are an excellent type of application of STI methods.

CONCLUSIONS

Seismic Tomographic Imaging technology provides significant information about subsurface conditions related to densities and passive soil support for the sewer. STI represents a substantial improvement over the tools previously available for determining conditions that may put an underground pipeline, particularly tunnels at risk of failure. Before now, engineers were limited to information on subsurface conditions provided by conventional geotechnical borings, which are slow, costly, and subject to interpretation between boring locations. Large scale geotechnical boring programs have normally been limited to areas where severe defects in the sewer have already occurred.

With STI, an alignment can be quickly scanned without drilling and suspect areas can be readily located for more intensive investigation. Costs for using SRT are low relative to borings or the construction cost of rehabilitation and the results are invaluable as a tool for locating potential problems prior to sewer damage.

The most important aspect of this technology is the ability to locate defects or conditions that will eventually threaten the pipeline before distress has progressed to being a concern to public safety. STI allows observation of subsurface conditions prior to problems occurring at the ground surface or inside the pipeline, allowing the engineer to practice preventive engineering rather than reactive restoration.

Brown and Caldwell has been involved with the evaluation and rehabilitation of sewers for over 25 years. We believe we now have a tool that when used as part of pipeline inspection and maintenance program, can prevent the expenditure of capital budgets for emergency restoration projects. Accordingly, we recommend consideration of a comprehensive survey program that uses STI technology as a key component in a preventive engineering and risk assessment and reduction program.

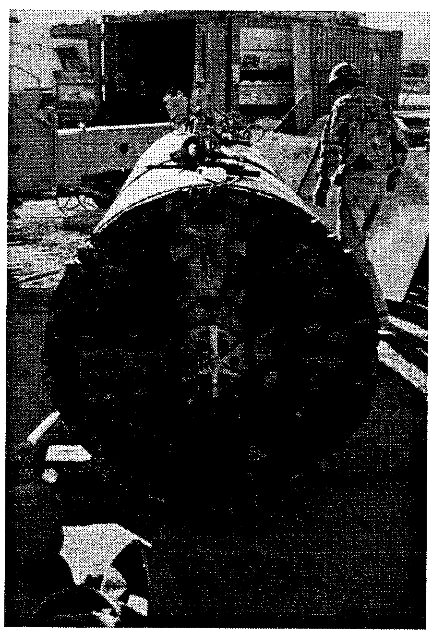
Monte Cristo/Cheyenne Sewer Interceptor Project

Presented by Dennis Anderson, City Engineer-City of Las Vegas, Dave Seevers, Assistant City Engineer-City of Las Vegas, and Jim Morrris, Construction Manager-Harris & Associates

Introduction

Greetings from the City of Las Vegas, City Engineer Division. We are pleased to submit this report on the Monte Cristo/Cheyenne Sewer Interceptor Project. Like many of our projects, the fast paced growth which is occurring in the City of Las Vegas has determined the need for this project.

The City's first burst of growth occurred on May 15, 1905, when 110 acres of land in the downtown area was auctioned off. On March 16, 1911, the City was incorporated, encompassing 19.18 square miles with a population of approximately 800. In 1956, the City of Las Vegas annexed one square mile of land, the first addition since incorporation 45 years earlier. By 1960, the City encompassed 25 square miles and had a population of 64,405. Even in 1960, no one would have predicted that in July, 1996, the City would have grown to 93.4 square miles and hosted a City population of 398,110 and 1,115,940 population county wide.



Microtunnel Machine

Currently, there are more than 88,000 hotel rooms in the Las Vegas Valley with another 10,000 under construction and due to open in 1997. The Center for Business and Economic Research at the University of Nevada Las Vegas, estimates that new hotels create one job per room internally and 1.5 jobs per room externally for a net of 2.5 jobs per new hotel room.

This and other industrial growth translated into approximately 7,820 new single family homes built within the city limits. The Building and Safety Department issued 9,900 residential permits and 227 commercial permits between July, 1994 and June, 1995. These permits are valued at $650 million for residential construction and $131 million for commercial construction . The new home construction along with commercial construction led to approximately 85 miles of new roads and of course under those new roads, we have our new sewer lines.

Design Phase

The Monte Cristo/Cheyenne Sewer Interceptor (MCCSI) project was identified as part of the City of Las Vegas (CLV) "Wastewater Collection System Master Plan" prepared by Greeley and Hansen in 1994. The primary purpose of the MCCSI is to convey wastewater from the rapidly growing area of Northwest Las Vegas (specifically the area west of Highway 95 off Lone Mountain and the area surrounding the intersection of Jones and Lone Mountain) to the Westside Interceptor Sewer collection system beginning at the intersection of Cheyenne Avenue and Decatur Boulevard.

In February 1995, the CLV retained Black and Veatch (B&V) to provide engineering services for the MCCSI. The CLV established the capacity of the interceptor to be 15 million gallons per day (mgd) in the segment between Monte Cristo Way and the intersection of Lone Mountain Road and Jones Boulevard and 20 mgd downstream of the intersection. The tie-in points were determined to be the existing manholes located at 1) the intersection of Monte Cristo Way and Lone Mountain Road; 2) the intersection of Jones Boulevard and Lone Mountain Road; and 3) the existing manhole on the south side of the intersection of Cheyenne Avenue and Decatur Boulevard.

Black & Veatch submitted a study report to the CLV in March which provided recommended alignments and a preliminary cost estimate. Due to the CLV need to pick up flows on Lone Mountain Road at the intersections of Monte Cristo Way and Jones Boulevard, the portion of the route between these intersections is fixed. From the intersection of Jones Boulevard and Lone Mountain Road, the sewer needed to be routed to the intersection of Decatur Boulevard and Cheyenne Avenue for termination. The selection of feasible routes from Jones Boulevard and Lone Mountain Road was limited by the number of constraints, both horizontally and vertically, along possible route. B&V identified the following constraints affecting selection of feasible horizontal alignments:

- Required connection at the intersection of Jones Boulevard and Lone Mountain Road.
- No cut pavement policy in effect for:
    - Lone Mountain Road, east of Jones Boulevard to Decatur Boulevard
    - Decatur Boulevard, from Lone Mountain Road to Rancho Road
    - Craig Road, from Highway 95 to Decatur Boulevard
    - Cheyenne Avenue
    - Rancho Road

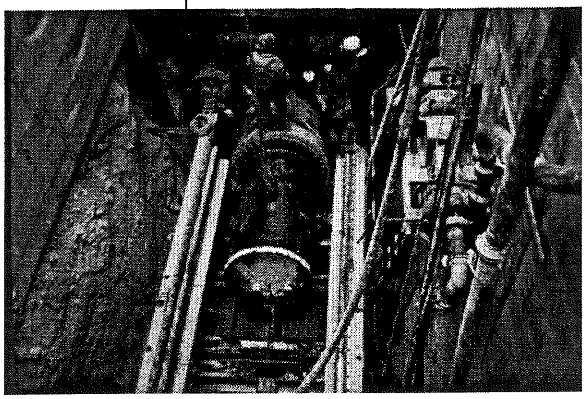
- NDOT Encroachment Permits required for highway 95, Rancho Road, and Cheyenne Avenue.
- Heavy traffic requiring extensive traffic control measures on Craig Road, Ranch Road, Highway 95, Cheyenne Avenue, Jones Boule vard, and Decatur Boulevard.
- Amount of pavement replacement.
- Public disruption and acceptance along potential routes.
- Required connection at Cheyenne Avenue and Decatur Boulevard.

Black & Veatch also identified the following constraints affecting the vertical profile:

- Invert elevation of the tie-in at Monte Cristo Way and Lone Moun tain Road.
- Proposed construction of an interchange at Highway 95 and Lone Mountain Road.
- Proposed storm drain channel along Highway 95.
- The capacity of conveying sewers near Cheyenne Avenue and Decatur Boulevard and the invert elevation of the end connection.
- Existing utilities that have to be crossed, specifically an 8' x 5' box culvert on Gowan Road, and a 60-inch storm drain on Craig Road.

The potential routes from the intersection of Jones Boulevard and Lone Mountain Road were evaluated and the most feasible alignment was determined. The preferred alignment turns south on Jones Boulevard to Hickam Avenue, east on Hickam Avenue to Bradley Road, south on Bradley Road to Gowan Road, east on Gowan Road to Thom Boulevard, south on Thom Boulevard to Donnie Avenue, east on Donnie Avenue to Decatur Boulevard, then south on Decatur Boulevard to the terminus south of Cheyenne. The preferred alignment routed the sewer through low density, fairly open and unimproved residential areas and avoided heavily traveled major arterials, Parsons Elementary School and existing densely developed residential areas.

Following the selection of the preferred routing, B&V began the collection of data required to develop the design. Data collection included right-of-way and utility research, a geotechnical investigation and survey of the alignment. In June B&V made their first design submittal to the CLV. During the review process several major design issues were identified. Due to the existing topography along the selected alignment, excavation depths varied from approximately 5 to 45 feet to maintain gravity flow. Shallow cover over the pipe in the vicinity of Bradley Road and Hickam Avenue would require encasement of approximately 350 linear feed (lf) of the interceptor. In order to maintain the design capacity of 20 mgd and minimize the excavation depth south of the Bradley Road and Hickam Avenue intersection, the pipe slope was reduced to 0.0019 ft/ft resulting in the need to upsize the diameter of the pipe. With the design criteria issues satisfied, questions turned to constructibility.



Starting the Drive

Since the alignment of the sewer was entirely within the public right-of-way, no private property would need to be acquired. The location of the proposed pipeline within the right-of-way varied along the route from centerline to within 10 feet of right-of-way. The location of the sewer with respect to private property and the depth of excavation presented significant concern in numerous locations. A majority of the proposed sewer would require excavation to depths ranging from 5 to 30 feet. It was determined that the excavation could be accomplished by open-cut methods with conventional excavation equipment. Due to the presence of caliche along the alignment, some heavy ripping, hoe ramming, demolition ball or other special method would need to be employed in isolated areas to facilitate the removal of these cemented materials. This type of construction methodology is considered normal for pipeline construction in the Las Vegas area. Typically, the largest hydraulic excavator used in the valley is a Caterpillar 245 or equivalent; therefore, excavation to depths in excess of 30 to 35 feet were deemed not to be feasible with standard equipment. Approximately 6,000 lf of the proposed sewer would require excavation to a depth in excess of 30 to 35 feet with maximum depth expected to be on the order of 45 feet. Alternative construction methods were evaluated and it was determined that microtunneling should be utilized for depths over 35 feet. Since microtunneling was considered to be a relatively new technology and had never been utilized in the Las Vegas valley, some obstacles had to be overcome.

In the weeks following the initial design review, additional borings were performed along the proposed microtunneling portion of the route to confirm the existing geotechnical conditions in the vicinity of the pipe zone, B&V presented a seminar on the microtunneling process and applications to the CLV design and construction management team, and finally a joint CLV and B&V presentation was made to the Sanitation District.

From the geotechnical information collected it was determined that microtunneling was feasible. It was anticipated that mixed-face conditions and groundwater would be encountered. The microtunneling seminar that B&V provided to CLV personnel provided a level of comfort that microtunneling was the right solution to the deep sewer concerns. The presentation to the Sanitation District, primary funding source for the project, occurred on June 28,

1995. Somewhat reluctant to be funding the initial microtunneling in the valley, the District understood the advantages microtunneling had over a 45 foot deep open-cut excavation within a residential street with a 60' right-of-way. With these obstacles out of the way, B&V continued to refine the design.

In August the CLV received the 90 percent plans, specifications and cost estimate from B&V for final comments. Plans were submitted to various groups within the CLV for comments prior to final corrections. The only significant comment that was received was from the head of the Engineering Planning Division, who questioned the "need for over a mile of microtunneling." The reluctance to utilize a "new" technology had risen again. In order to satisfy the comments of Engineering Planning and evaluate the direct cost or savings associated with microtunneling, B&V was directed to prepare a bid form that would allow the comparison of costs for microtunneling and open-cut.

The final issue that needed to be addressed prior to completing the contract documents was the type of pipe materials to be specified. B&V had identified a variety of materials that were acceptable to the District and satisfied the design criteria. To ensure competitive bidding, eliminate post-award substitutions and allow the contractors the maximum flexibility in preparing its bid, the CLV directed B&V to prepare a bid form that required the contractor to identify the material bid from a predetermined list specified in the bid documents.

The contract as bid required the contractor to submit a "Base Bid" for the 16,700 lf of 30 and 36-inch open-cut sewer and all appurtenances, an "Additive Alternate 1" bid for the microtunneling of 5,800 lf of 36-inch sewer, and an "Additive Alternate 2" bid for the open-cut of the same scope of work identified in alternate 1. The bid form required the contractor to select either RCP or HDPE material for open-cut and either CCRFP, RCP or VCP for microtunneling. The bid documents stated that the bid will be awarded to the lowest responsive and responsible bidder based on the Base Bid plus Additive Alternate 1 or Base Bid plus Additive Alternate 2.

Final PS&E were completed in November 1995 and advertisement of the project began December. Bids were received and opened on January 25, 1996. An analysis of the bids submitted indicated that the microtunneling alternative provided a direct cost savings to the CLV. The construction contract with the microtunneling option was awarded to Contri Construction. The only obstacle that remained would be the construction of the project.

Construction Phase

The City of Las Vegas Contract No. 96.1730.01RH was awarded to Contri Construction Co. on April 1, 1996. The total contract amount was $9,441,130 with $4,311,020 being earmarked for the microtunneling portion. Contri's tunneling subcontractor was Elmore Pipe Jacking Inc. from Sylmar, California.

The total footage of pipe for the project was 23,216 feet, with the microtunneling portion accounting for 5,810 feet of 36-inch pipe (Elmore actually installed 42-inch diameter pipe). The total contract time for the project was 365 calendar days. Notice to proceed was given on May 15, 1996.

The project also included two other bore and jack installations under the State of Nevada right-of-ways. These bores were 235 feet and 275 feet in length and 42-inches in diameter.

Forty-three manholes were installed along the right-of-way, all of which were lined with T-lock lining from Ameron. The manholes varied in depth from 10 feet to 46 feet and in size, from 60-inch diameter to 96-inch diameter.

Elmore Pipe Jacking elected to use Ackerman Equipment Inc. Microtunneling equipment. Ackerman's MTBM's are pressure balanced slurry removal machines that are well equipped for long drives. Ackerman guidance systems, slurry circulation systems and separation systems were also utilized by Elmore for the project.

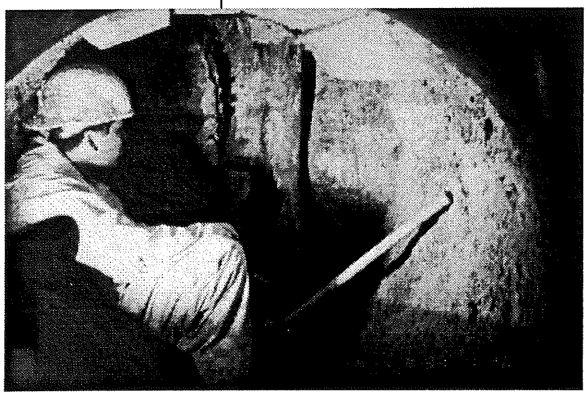
Elmore requested to substituted 42-inch diameter pipe in lieu of the specified 36-inch diameter piping due to the fact that Elmore's conventional tunneling equipment is 42-inch. Should something happen to the Ackerman microtunneling equipment, Elmore would be able to mobilize its conventional equipment and mitigate the potential delays. As the project turned out, this was very good planning on Elmore's behalf.

The receiving pits for the tunneling operation were installed using a vertical drilling machine custom made by Anderson Drilling from Southern California. The shafts were 10-feet in diameter and lined with 10 gauge corrugated steel pipe. The corrugated pipe was shipped in quarter sections which was bolted together on the project site. The jacking pits were installed utilizing I-Beams and 1/4-inch steel sheet lagging. The beams were set in pre-drilled holes with the lagging installed during excavation for the pit.

During construction, the contractor, Elmore Pipe Jacking, had several issues to deal with in order to keep the project on schedule. The first of those issues was the shearing off of transmission bolts during the drilling of the first tunnel section. The tunneling equipment had drilled the first 200-feet when all control of the equipment was lost. After consulting with the equipment manufacturer, Ackerman, Elmore began excavating on the alignment to retrieve the MTBM and make the necessary repairs. During the shut down, Elmore mobilized its conventional tunneling equipment and began drilling at another jacking pit in order to maintain the project schedule.

The second issue to face the Contractor was the installation of two separate tunnels which had been installed at the incorrect grade. The Ackerman laser guidance equipment was set with the wrong slope during the initial tunneling operations. The Contractor set the slope with one to many decimal points which resulted in the tunnels being installed at a much flatter grade.

Due to the fact that the design slopes for these two tunnels were already at the minimum slope, the tunnels had to be reinstalled. Elmore designed a jacking shield which would push out the incorrect pipe and cut the new slope at the same time. Elmore was able to reuse the existing piping after being pushed out at the retrieving pit. The annular space left by the existing pipe was filled with a grout slurry. The new piping floated somewhat during the grouting operation, but was much closer to the design slope than the original tunnels.



Well, Oh Well - Hitting Casing 40' Deep

The third issue to develop during the project was the discovery of an existing 14-inch well casing. The casing had been abandoned in accordance with the State of Nevada requirements, therefore it was cut off below the existing grade and filled with concrete.

Hitting this casing with the MTBM caused damage to the cutting head by shearing off most of the cutting teeth. The impact also caused some damage to the transmission which is under question, but repairs were made to the gear pins.

The casing was hit after only tunneling 50-feet from the jacking pit. The decision was made to pull the piping and tunneling equipment out of the tunnel with the jacking unit in reverse. After removal of the equipment all repairs were made and the equipment and piping were reinstalled into the tunnel and drilling resumed.

Project Higlights

Monte Cristo/Cheyenne Sewer Interceptor - Design Phase

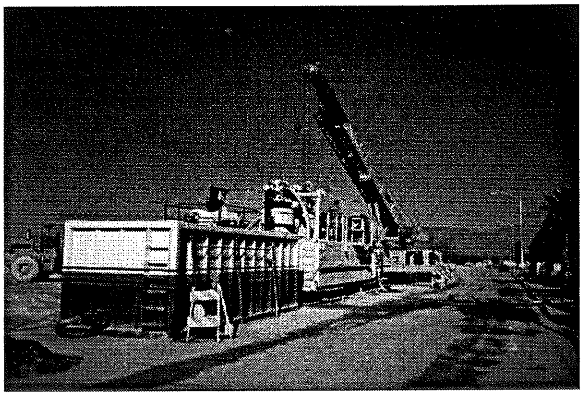
Predesign

Design Consultant Selection

Timeline (start 2/95 finish 3/95)

Design Requirements

- Connection Points
  - Monte Cristo/Lone Mountain - Collection
  - Jones/Lone Mountain - Collection
  - Decatur/Cheyenne - Discharge
- Capacity Requirements
  - 15 MGD between Monte Cristo and Jones
  - 20 MGD between Jones and Cheyenne



Ancillary Equipment on City Street

Design Requirements vs. Master Plan

Design Constraints

- Horizontal Alignment
  - Required connection at Jones/Lone Mountain
  - No cut pavement policy
  - NDOT Right-of-Way crossings
  - Heavy Traffic
  - Amount of pavement replacement

- Public disruption and acceptance along route
- Required connection at Cheyenne/Decatur

- Vertical Profile
  - Invert Elevation at Monte Cristo/Lone Mountain
  - NDOT Interchange at Highway 95/Lone Mountain
  - NDOT Storm Channel at Highway 95
  - Capacity of conveying sewers near Cheyenne/Decatur
  - Invert Elevation of end Connection
  - Existing Utilities

Alternate Alignments

Alignment Evaluation and the Selected Alignment

Final Design

Timeline

- Start Data Collection - March 1995
- 70% Submittal - June 1995
- 90% Submittal - August 1995
- Final PS&E - November 1995

Data Collection

- Utility Information
- Survey

70% Design Submittal

- Issues Raised
  - Depth to Invert for Gravity main from 7 to 43 feet
  - Deepest Excavation in 60' and 80' Right-of-Way
  - Horizontal Alignment 20' off Centerline
  - Minimal Slope Available (0.0019 ft/ft)
  - Minimum Slope Occurs at Deepest Excavation
  - Pipe Diameter Needs to be Increased due to slope

- Alternate Solutions
  - Redesign for Lift Station and Force Main
  - Evaluate Alternate Methods for Construction of Deep Segments
- Recommended Solution
  - Obtain Additional Geotechnical Information
  - Evaluate Microtunneling as Alternative to Open Cut
  - Presentation to Funding Source

Preparation of Construction Documents

- Alternates
  - Base Bid - Open Cut 16,700 lf of 30 and 36-inch
  - Additive Alternate 1 - Microtunnel 5,800 lf of 36-inch
  - Additive Alternate 2 - Open Cut 5,800 lf of 36-inch
- Alternate Pipe Materials
  - Open Cut
    - RCP
    - HDPE
  - Microtunneling
    - CCRFP
    - RCP
    - VCP
- Basis of Award

Bid/Award

Timeline

- Begin Advertisement - December 1995
- Pre Bid Conference - January 9, 1996
- Bid Opening - January 25, 1996
- Five Bidders

SHORT LENGTH SEGMENTED PVC LINER PIPE INSTALLED THROUGH AN EXISTING MANHOLE

Kenneth L. Salvail, P.E., Assoc. Civil Engineer, City of San Jose, CA
Dave Gellings, Principal, Trenchless Resources Int., Bellingham, WA

ABSTRACT

Sanitary sewers have been rehabilitated with liner pipe in the United States for over twenty years. Generally, a substantial excavation pit is required to provide access to the existing pipeline for installation of liner pipe. This presentation focuses on the rehabilitation of approximately 760 linear feet of 30-inch reinforced concrete pipe with short length flush-jointed 12-inch Polyvinyl Chloride (PVC) liner pipe for the City of San Jose's Senter-Monterey Sanitary Sewer Rehabilitation Phase II project.

Due to the location of this reach of sewer to be rehabilitated, the location of standard access pits would have severely disrupted the surrounding neighborhood and limited access to a mobile home park. Based on these circumstances, short length liner pipe was furnished and installed from within an existing manhole with little disruption.

PROJECT BACKGROUND

The Senter-Monterey sanitary sewer system was originally constructed from 1963 to 1968 within the City of San Jose. The Senter-Monterey sanitary sewer was identified for rehabilitation by the City's Sewer Management System Condition Assessment component of the Infrastructure Management System. Internal pipe video inspection revealed areas of moderate to severe corrosion of the reinforced concrete pipe (RCP).

The Senter-Monterey Sanitary Sewer Rehabilitation Phase II project sewer originally served an area of approximately 4,000 acres of residential, commercial, and industrial development. However, a sanitary sewer supplement was constructed that reduced the service area significantly. Based on a hydraulic capacity analysis, it was determined that a significant reduction in the existing pipe diameter from 27 and 30-inches to 12-inches was required to provide minimum self-cleansing velocities for the service area being served. Rehabilitation methods that fulfill this requirement are sliplining with 14-inch High Density Polyethylene (HDPE) butt-fussed solid wall and 12-inch PVC gasketed joint solid wall liner pipes.

Both rehabilitation methods involve installing a significantly smaller-diameter liner pipe within the existing sewer and filling the annular space between the two pipes with grout. While HDPE and PVC liner pipes in conjunction with grout are common rehabilitation systems, the use of a much smaller liner pipe and correspondingly, larger grout area, is unique.

In May 1996 the City of San Jose Department of Public Works bid the Senter-Monterey Sanitary Sewer Rehabilitation Phase II project, which included rehabilitating approximately 2,000 linear feet of 27-inch and 5,300 feet of 30-inch diameter RCP including approximately 760 linear feet of 30-inch RCP within an easement through the County Fair Mobile Estates mobile home park. Detrick Corporation, Inc. submitted the lowest bid of $523,537 and was awarded the project. Detrick Corporation bid utilized Lamson Vylon Pipe PVC solid wall liner pipe. A bid of $668,000 was submitted for the alternate rehabilitation process, HDPE solid wall liner pipe.

INSTALLATION

Several standard access pits were excavated to install the majority of the liner pipe used on the Senter-Monterey Sanitary Sewer Rehabilitation Phase II project. However, 760 linear feet of sewer within the easement area was sliplined through an existing manhole.

Standard Access Pits

The standard access pits excavated for the project were approximately 10 feet wide by 20 feet long. The top of the 27 and 30-inch diameter RCP were sawcut and removed to the springline to allow the liner pipe to be lowered and pushed into the host pipe, while maintaining sewage flow. To prevent the liner pipe from wedging against offset or badly mortared host pipe joints during pushing, the contractor fabricated a chamfered nose section as shown in Figure 1. Pushing of the liner pipe was performed utilizing a cable and pulley system. Cables were connected to a pushing ring and routed through pulleys anchored into the host pipe, and a T-9 crane was used to pull up on the cable to exert a horizontal force on the end of the liner pipe. The pushing head was fabricated using the same pipe material as the liner pipe as shown in Figure 2.

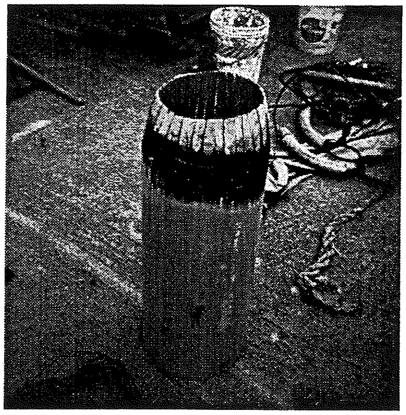


FIGURE 1 12" PVC Liner Pipe Nose Section.

FIGURE 2 12" PVC Liner Pipe Pushing Head.

Insertion Through a Manhole

The project specifications originally prohibited the contractor from excavating any access pits within the easement area to minimize disruption to the mobile home park residents. Additionally, due to an angle point located within the easement, a substantial excavation would have been required to slipline the sewer upstream and downstream from this point. Therefore, any access pits required for liner installation would have had to be located at both ends of the easement. One end of the easement is located at the mobile home park driveway, which accesses a heavily traveled thoroughfare.

However, prior to sliplining the sewer within the mobile home park, the contractor submitted a cost reduction proposal to eliminate excavating access pits at both ends of the easement and substitute sliplining of the existing pipe through a manhole opening. The cost reduction proposal was accepted and a net savings of $34,281 was realized.

The manhole used to slipline the sewer within the mobile home park was located at the angle point approximately 640 linear feet from the driveway entrance. This manhole was used to slipline the sewer in both directions. Figure 3 shows the special three-foot lengths of sliplining pipe being lowered into the manhole. Since the manufacturing plant is setup to produce standard 15-foot lengths of liner pipe, the joints for the non-standard three foot length liner pipe had to be routed by hand. Since this method of sliplining limits the impact to the surrounding neighborhood, requires no excavation, and provides a cost savings; provisions are currently being implemented at the plant to have the ability to manufacture any length of pipe without having to route the joints by hand.

The joint assembly and jacking process utilized within the manhole was similar to the system used in the standard access pits. However, due to the limited working area as shown in Figure 4, special rigging was fabricated.

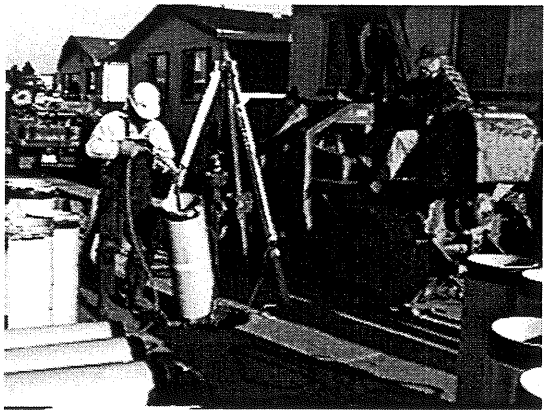


FIGURE 3 Insertion of 3' Length Liner Pipe at Manhole

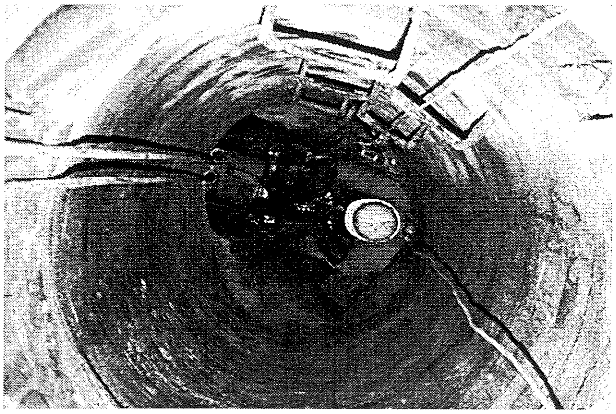


FIGURE 4 Limited Working Area Inside Manhole

Figure 5 shows the clamping system used to hold the liner pipe in-place to assemble the joints. The liner pipe was then released and inserted into the host pipe with the pushing head. Similar to the standard access pit, a cable and pulley system was utilized to exert a horizontal force on the sliplining pipe. The assembly of a joint and the pushing of a three-foot liner pipe section was accomplished on the average every minute as compared to two minutes being required to install a 15-foot section of liner pipe through a standard access pit.

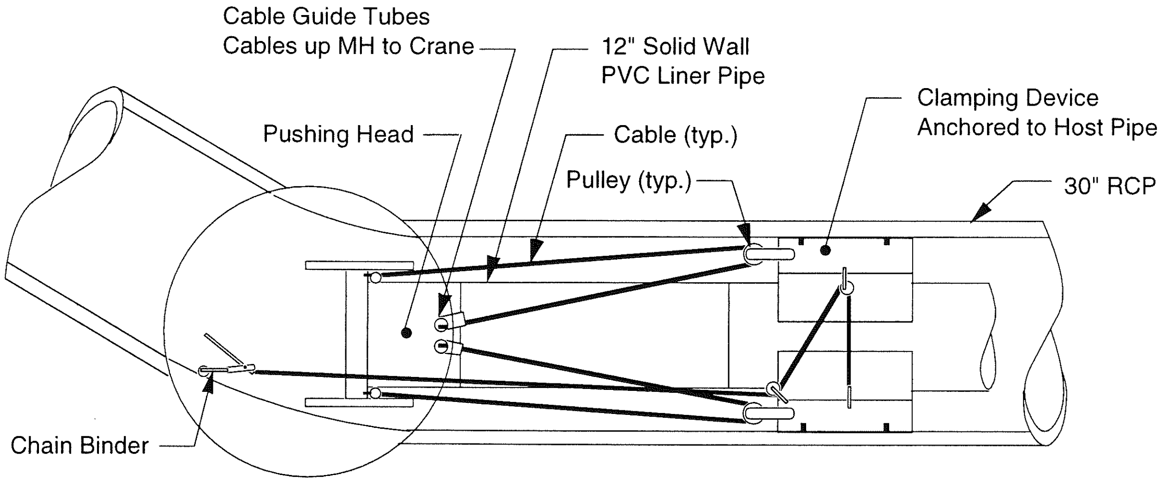


FIGURE 5 Joint Assembly and Pushing Rigging within Manhole

GROUTING

Figure 6 shows the large annular space that needed to be grouted. Since the annular space is quite large, collapsing of the PVC pipe was a concern due to the exorbitant amount of heat that could be released and the accompanied thermal expansion as the grout hydrates. The softening point of PVC occurs at approximately 140°F, whereas the normal grout mix design peak hydration temperature is approximately 230°F, resulting in a temperature differential of approximately 90° for a period of 3 to 6 hours.

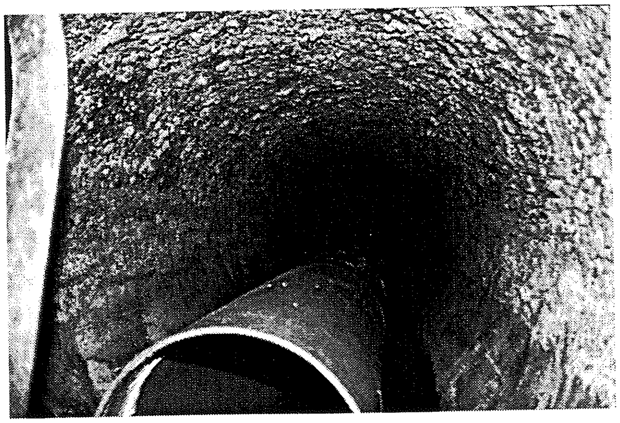


FIGURE 6 Annular Space Between 12" PVC Liner Pipe and 30" RCP

Therefore, the grout mix was modified to have a lower hydration temperature. As a result, the compressive strength was reduced from 300 psi to an amount between 200 and 250 psi and the initial set and hydration completion period expanded from 3 to 6 hours to a period between 6 and 24 hours. However, based on the following variables: ambient temperature, water temperature inside the liner pipe, and heat dissipation qualities of the PVC liner pipe, a 48 hour grout set time was established. This set time was used to establish the time required to keep the liner pipe full of sewage to prevent flotation.

SUMMARY

Using the Lamson Vylon Pipe short length PVC liner pipe provided a viable cost-effective solution and limit the impact to the surrounding neighborhood. This also produced substantial cost savings for the City of San Jose and tangible quality-of-life benefits for the community. The use of short length PVC liner pipe provides an effective solution for areas with limited access and an economic solution for rehabilitating short segments of sewers.

ACKNOWLEDGMENTS

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This paper was prepared using Corel® WordPerfect for Macintosh. Figure was drwan in Claris® Claris CAD; photos were modified in Adobe™ Photoshop. Text type is Palatino® and display type Avant Garde.

PIPE USERS GROUP OF NORTHERN CALIFORNIA
SHARING TECHNOLOGIES SEMINAR

The Sanitary Sewer Evaluation Study
or
How to Turn Your O&M Headaches to CIP Projects

Mr. Mike Evert, City of Petaluma
Ms. Gisa Ju, Montgomery Watson
Mr. Marc Solomon, Winzler & Kelly

ABSTRACT

Infiltration and Inflow (I/I) is a common problem in sanitary sewer systems that can create surcharging, overflows, pipeline failures, sinkholes and deteriorating pavements. Because the problem occurs during winter months and coincides with major storm events when staff is already busy, it wreaks havoc on street and sewer crews, the operation of the treatment plant and any agency's attempt to control budget and cost.

The City of Petaluma has completed a Sanitary Sewer Evaluation Study (SSES) quantifying flows, developing a model, and identifying capital improvement projects that will correct key system deficiencies under peak wet weather flows. The study included flow monitoring in 10 locations from January through March 1995. Two different flow meter types were used to monitor sewers in surcharged and nonsurcharged conditions and to allow the City to evaluate different technologies for eventual purchase. The results of the monitoring program were used to develop a HYDRA model of the collection system. While the model was built by the engineering team, it will become a tool for the City's long term use in planning and operating the collection system.

The system model identified three areas of surcharging under five year storm conditions, which coincided with field observations. A cost-effectiveness analysis looked at 1) a comprehensive rehabilitation program and 2) two specific projects to increase the capacity of the trunk sewer system. The two specific projects were found to be more cost effective for providing immediate relief for overflows and surcharging and the City is including funding in its CIP for these projects; an upgrade to the headworks pump station and construction of a new relief sewer. The study also provided recommendations and budget figures for field investigations and I/I repairs that will be used by the City to develop a future I/I monitoring program to continue to address problem areas within the collection system.

PROJECT HISTORY

The City of Petaluma is located in Southern Sonoma County, approximately 45 miles north of San Francisco. Petaluma is located on the banks of the Petaluma River, a navigable channel that drains to San Pablo Bay. Because of this location, the City is one of the oldest in the Bay Area and a portion of its infrastructure is nearly one hundred years old. The City maintains approximately 120 miles of sanitary sewer collection system varying in diameter from 6 to 48 inches. Some of these sewers, particularly those located into the city's historic districts, are brick and were originally part of a combined sanitary and storm sewer system.

The collection system drains to the City's Wastewater Treatment Plant (WWTP), located adjacent to the Petaluma River in the southeast area of town. Petaluma is in the process of upgrading this facility and this project was influenced by the City's hope that an I/I correction program could translate into potential savings at the WWTP.

While long term capital planning for the WWTP did influence the City's decision to quantify the peak wet weather flow through their collection system, the immediate impetus for the project was a history of surcharging and an occasional sewer overflow storm events. The collection system is divided into five major basins known as the East, Northeast, North, West and Southwest Basins. Each basin is divided into several smaller subbasins. The City has experienced manhole overflows and discharges of sewage into streets from four of its eleven subbasins. Four high priority trunk sewer systems were identified based on a history of surcharging and a 1985 Sewer Collection System Master Plan. These areas included:

- Lindberg Lane sewer
- Magnolia/Liberty sewer
- Mountain View Avenue sewer
- Madison Street sewer.

The basins and locations of these priority trunk sewer systems are illustrated in Figure 1.

These I/I problems, when they occur, do create a significant burden on maintenance staff and operations at the treatment plant. The City of Petaluma's collection system maintenance crews typically respond to 2 to 4 surcharging events in a given winter season. When a surcharging event begins, crews are typically required in 2 to 4 locations for approximately 8 hours. In addition, the collection system supervisor must carefully document any overflow event and inform the San Francisco Bay Regional Water Quality Control Board of the dates, times, locations and estimated quantities of discharge. This emergency response work is in addition to the normal crew duties and frequently requires the expenditure of overtime budgets. The City's careful and

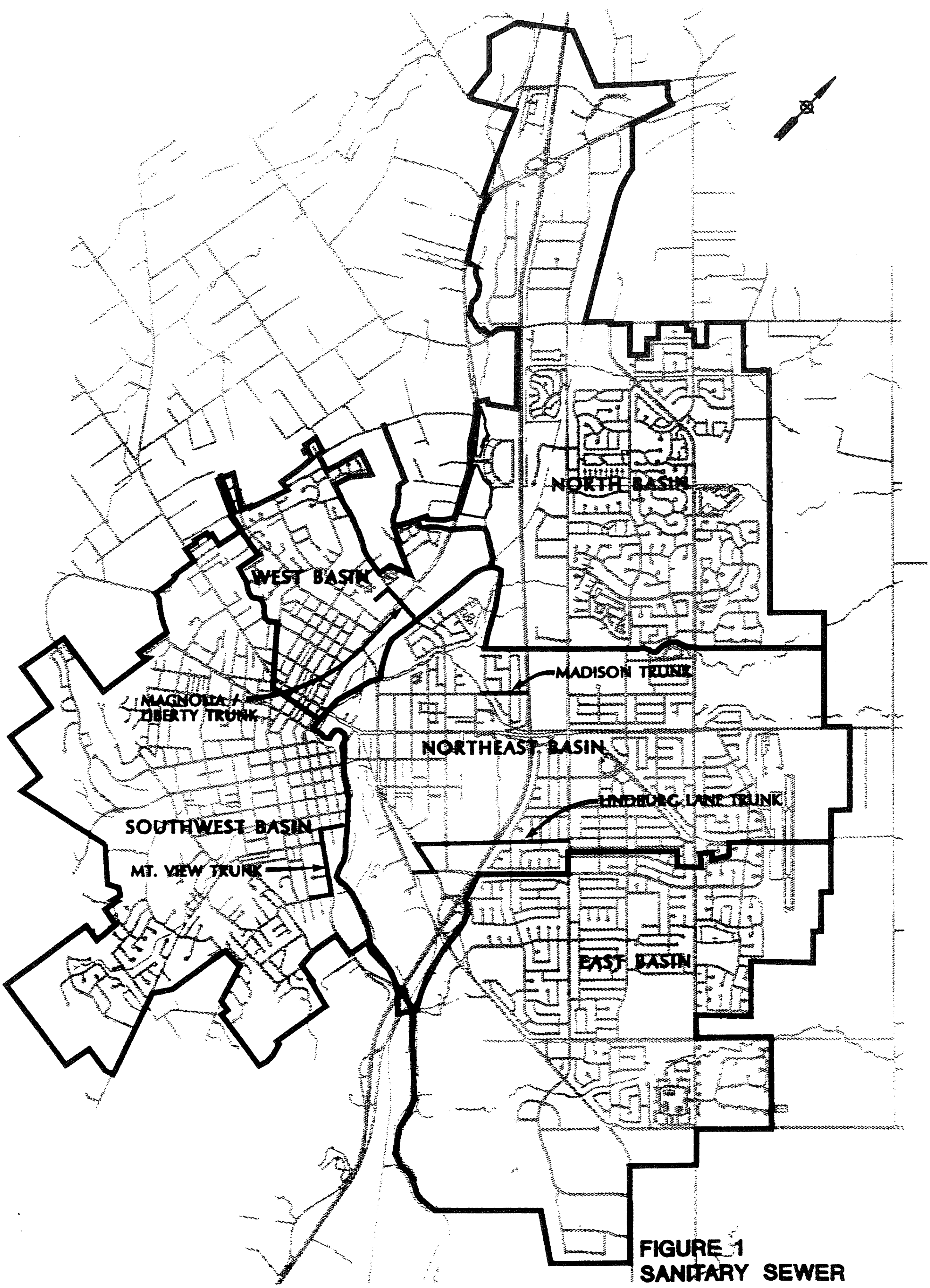

FIGURE 1
SANITARY SEWER
COLLECTION SYSTEM BASIN &
PRIORITY TRUNK SEWERS
PUG "SHARING TECHNOLOGIES"
EVERT, JU, SOLOMON

a: \CF\PRESENT\POWERPNT\P7220002\FIG1.DWG 2/13/97 consistent reporting and ongoing efforts to improve their facilities have resulted in a solid working relationship with the Regional Board. The Sanitary Sewer Evaluation Study is among these efforts.

THE SANITARY SEWER EVALUATION STUDY (SSES) APPROACH

The City of Petaluma's Sanitary Sewer Evaluation Study (SSES) documented the magnitude of the sanitary sewer system I/I, recommended approaches to reduce I/I flows, and identified system capacity improvements that would allow for the conveyance of peak wet weather flows that could not be easily reduced. These study objectives were augmented with one further objective--development of a partnering program that would allow City maintenance staff to participate in the data collection and model development phases so that they could continue to maintain the model and the sanitary sewer evaluation program after the consultant contract was complete. Although capital improvements can help mitigate sever I/I impacts, management of infiltration and inflow is frequently a maintenance function and Petaluma's SSES provides valuable tools to the City staff responsible for this function.

While the City was well aware of the most problematic of their trunk sewers, they elected to invest in a study of the entire collection system. The City-wide study was valuable in that it compared I/I for the entire City during the same storm frequencies. This investment allowed for better comparisons and identification of the I/I problems within the entire system and provided for some flexibility in the final design solutions.

The SSES method used included the following steps:

Flow Monitoring: In order to quantify the I/I flows into the sanitary sewer collection system, flow monitoring was conducted from January through March of 1995. The monitoring program was conducted jointly by City staff and representatives from the Winzler & Kelly/Montgomery Watson consultant team. Ten rented flow meters were used in conjunction with three rain gauges in the tributary basins. The rented meters included ISCO 4110 Ultrasonic Flow Loggers, which measure flow depth and ISCO 4150 Submerged Flow Loggers which measure flow depth and velocity. Utilizing two styles of meters allowed City staff to work in both surcharged and nonsurcharged conditions and to evaluate which style best met their needs. At the conclusion of the Study, the City purchased five meters to utilize in future flow monitoring efforts. The location of the flow monitors and rain gauges are shown in Figure 2.

The data collected during the monitoring program was analyzed to quantify average and peak dry weather flows (ADWF and PDWF), groundwater infiltration (GWI) and rainfall-dependent I/I (RDI/I). The results of the flow monitoring indicated that I/I rates vary throughout the City and that the highest rates were found in the meter areas which generally representing the oldest areas of the City. These results correlated well the

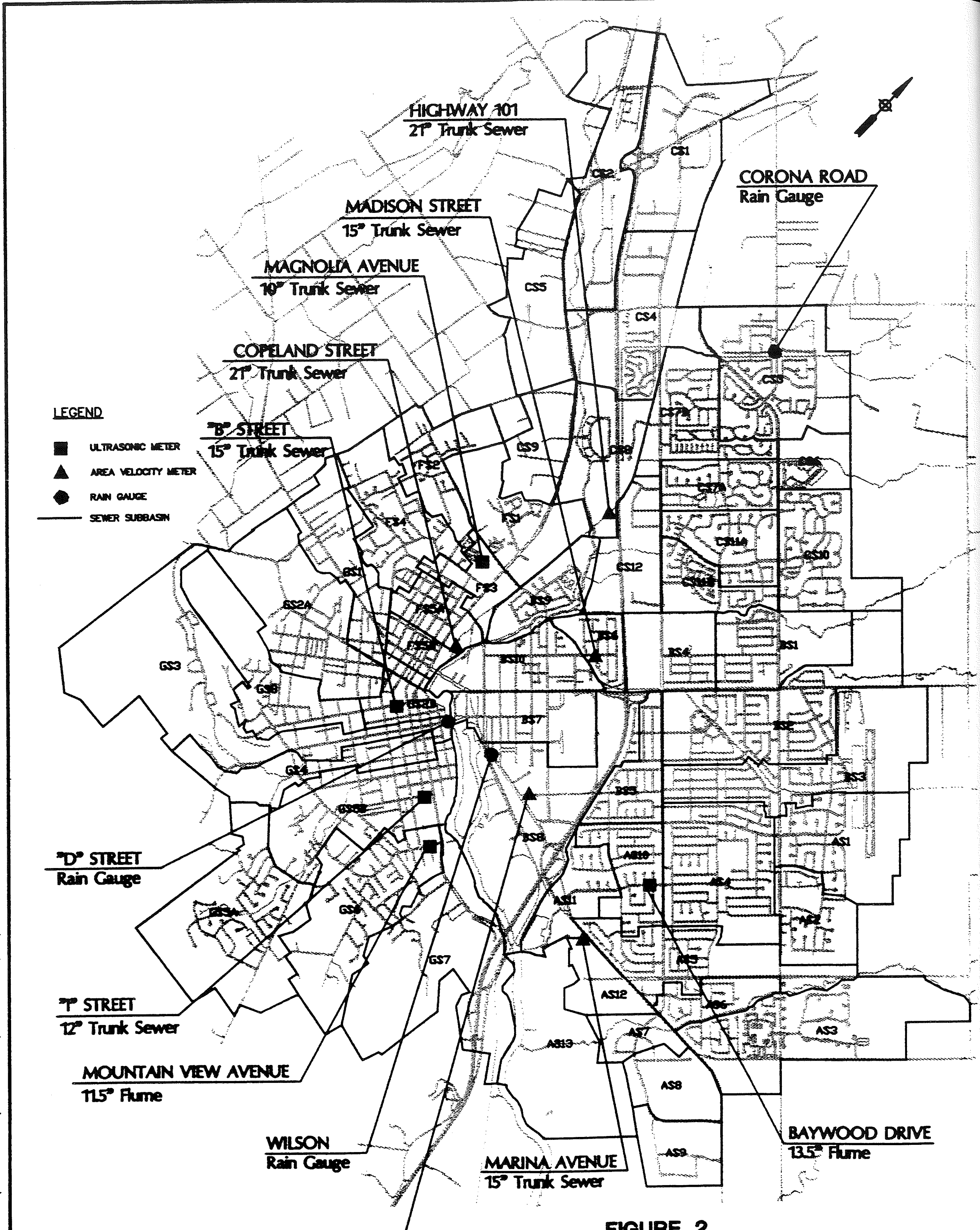

FIGURE 2
METER & RAIN GAUGE LOCATIONS
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Q:\CF\PRESENT\POWERPNT\P7220002\FIG3.DWG 2/11/97

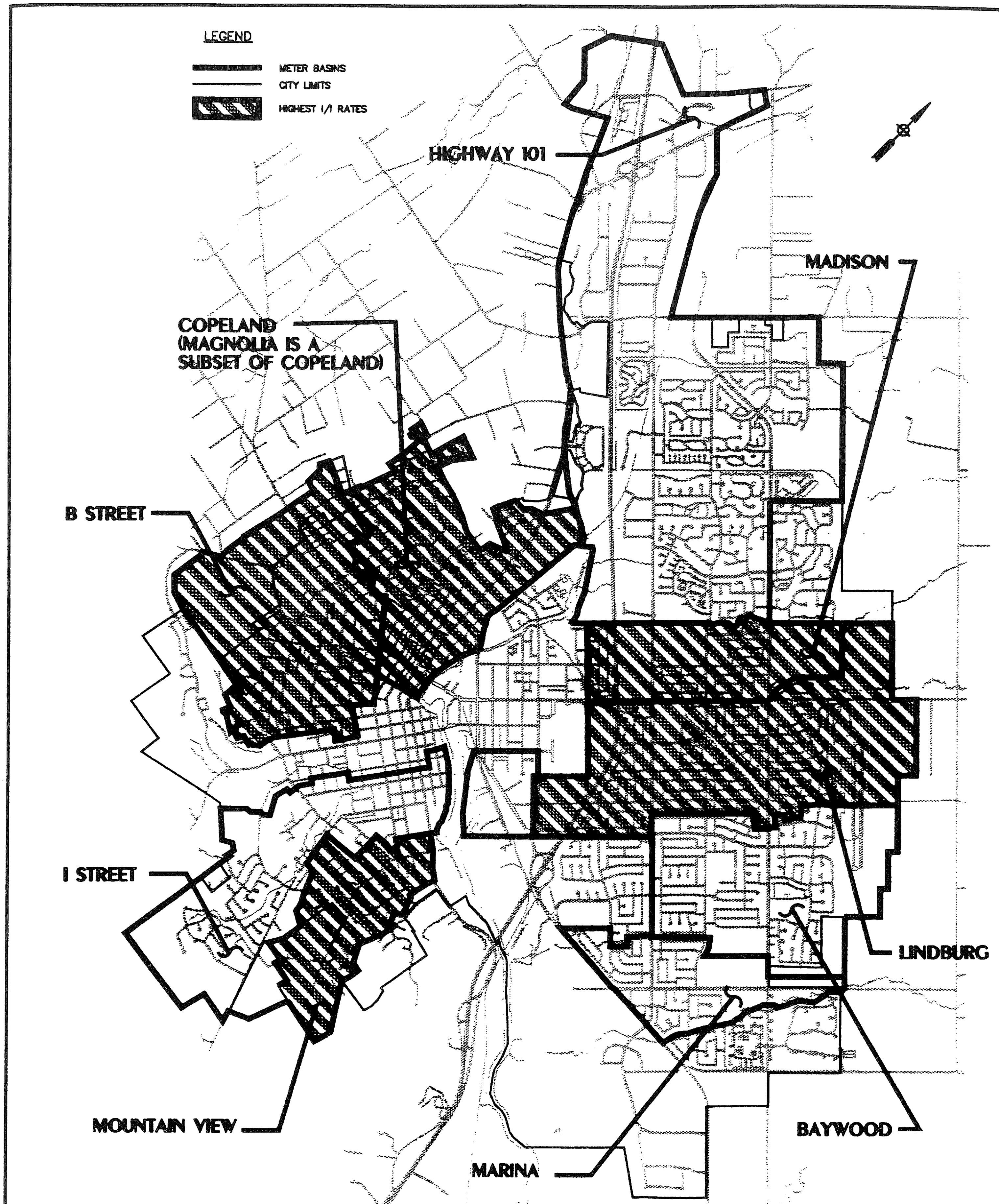

FIGURE 3
HIGH 1/1 SUBBASIN
PUG "SHARING TECHNOLOGIES"
EVERT, JU, SOLOMON

G:\CF\PRESENT\POWERPNT\P7220002\FIG3.DWG 2/11/97 experience of the City's maintenance staff. The highest rates were associated with the sewers in the Mountain View Avenue, B Street, Copeland Street, Lindberg Lane and Madison Street subbasins. The location of these subbasins are shown on Figure 3, which also shows the location of the four priority trunk sewer systems identified prior to the project.

Design Flow Development: Design flow estimates were developed to evaluate the existing and future capacity requirements of the trunk sewer systems. The base sanitary sewer flow estimates were based on land use projections from the City's General Plan and unit flow factors for different types of land uses. Peak wet weather flows were calculated by adding estimated peak I/I flows to the base flow. Peak I/I estimates were developed using a 6-hour duration, 5-year frequency storm. The rainfall generated by this storm was used to develop a "synthetic" hydrograph for each flow meter based on the volume, peak and shape of the RDI/I hydrographs measured for actual storms during the 1995 flow monitoring program. This methodology allows projected design flows to be compared with the observed behavior of the sewer collection system. This provided a data check and resulted in more accurately calibrated models of the Sanitary Sewer Collection System.

Capacity Analysis: The capacity of the City's sanitary sewer system was analyzed using a computerized hydraulic model. The model included those sewers 10 inches in diameter and larger. These larger diameter pipelines constitute approximately 10 percent of the total footage in the sanitary sewer system and most of its peak carrying capacity. The model also simulated the influent conditions to the City's WWTP. Hydraulic limitations at the WWTP cause flow to back up into the sewer system and force periodic shutdown of the "C" Street lift station.

The model simulated flows in the system under existing and future peak flow conditions. System components were identified as deficient if the model predicted that the design flows would result in an overflow in the system under 5-year design storm PWWF. The model predicted overflows in three locations given the current WWTP configuration and the present day system flows:

- Along the 15-inch Lindberg Lane trunk sewer and upstream tributary sewers.
- In the 24-inch trunk sewer downstream of the "C" Street lift station force main.
- Along Petaluma Boulevard, upstream of the "C" Street lift station, between H Street and Mountain View Avenue.

These locations coincide fairly well with the locations of surcharging observed during major storm events.

The model was also run under the hypothetical condition of no hydraulic limitations at the WWTP. Under current conditions, daily flows in excess of 8 million gallons per day (mgd) bypass the primary treatment units at the WWTP and are conveyed directly to the Pond Influent Pump Station, which pumps flows to the City's oxidation ponds. Under extreme peak flow conditions, the gates to the influent junction structure of this pump station must be closed to prevent flooding. When this happens, the flow back up into the sewer system and forces the shutdown of the "C" Street lift station. This hydraulic limitation was eliminated during one of the model run and an assumption was made that the "C" Street lift station continued to operate during peak storm conditions. Under this assumption, the only model-predicted overflow locations are along the Lindberg Lane sewer. In several other areas, the model predicted surcharging but not overflows. These results indicate that the overflow problems in the system are primarily due to the limitations of the WWTP. The ability to separate WWTP problems from I/I induced collection system problems was critical to guiding the recommended correction program.

The City of Petaluma began their SSES study with a perception that four trunk sewers were impacted by I/I related capacity problems. However, by choosing to document and model existing conditions in a Sanitary Sewer Evaluation Study, the City was able to identify that all but one of their perceived I/I problems may be directly attributable to other causes. The SSES analysis helped the City to clarify the appropriate capital improvement projects to correct the surcharging and sanitary sewer overflows that they were experiencing.

THE SSES RESULTS

The flow monitoring, capacity analysis and hydraulic modeling efforts identified that a project to remove hydraulic constrictions at the WWTP and the project to correct capacity problems in the Lindberg Lane trunk sewer were the most appropriate ways to address the problems that the City of Petaluma has been experiencing. The SSES results included a comparative study of several different methods for correcting the identified deficiencies.

Comprehensive Rehabilitation: One alternative for eliminating surcharging from the Lindberg Lane trunk sewer would be to reduce the peak wet weather flow through the sewer by reducing the I/I component. An I/I reduction of 35 to 50 percent would reduce peak wet weather flow to levels that could be carried by the existing trunk sewer. However, achieving such a substantial level of I/I reduction requires a comprehensive rehabilitation approach which includes both the public sewer mains and the private house laterals. The Lindberg Lane subbasins contain approximately 90,000 feet of pubic sewers and 1,800 lateral connections. Achieving the required reduction in peak I/I flows would require rehabilitation of approximately one half of these mains and laterals. The estimated cost of this work is $4 to $5 million. While a reduction in peak wet weather flow through the Lindberg Lane subbasin would also reduce the peak wet weather flow to the WWTP, the reduction would not be sufficient to eliminate the need for improvements to plant influent hydraulics. A comprehensive rehabilitation program, no matter how effective, will still require a WWTP upgrade project to eliminate all of the observed and predicted sanitary sewer overflows.

Relief Sewer: A relief sewer for the Lindberg Lane trunk would require installing 4,000 feet of 18- and 21- inch diameter pipe to replace the existing 15-inch trunk sewer. The estimated capital cost for the relief sewer is approximately $1.7 million. The relief sewer would not provide any reduction of Peak Wet Weather Flow into the WWTP. This project alternative will require a WWTP upgrade project to eliminate all of the observed and predicted sanitary sewer overflows.

WWTP Upgrades: Correction of the influent hydraulic constrictions at the WWTP can be achieved by replacing an influent pump station known as the Pond Influent Pump Station. This 20 year old station is overwhelmed when I/I is high and City crews elect to throttle back the station and use the collection system as a storage reservoir (or flow equalization basin). While this effectively manages capacity at the plant, it is a major contributor to surcharging in the collection system. A new, adequately designed station could provide the capacity for projected future flows and eliminate the collection system surcharging and predicted overflows in the 24-inch trunk sewer downstream of the "C" Street lift station and along Petaluma Boulevard between H Street and Mountain View Avenue. The estimated cost of this station is $1.7 million.

Long Term Maintenance and I/I Control Program: While the near term capital improvements described above would address the immediate capacity problems in the sewer system, these capital improvements need to be supplemented by an on-going maintenance and rehabilitation program that ensures that the sewers do not deteriorate further and cause I/I to increase in the future. As result the City has begun budgeting for a long term program that would include the following components:

- Continued monitoring of areas suspected of contributing high I/I flows particularly within the Copeland, "B" Street, Mountain View, Madison and Lindberg areas.

- Field investigations such as smoke testing and manhole inspection to identify major sources of I/I including direct storm or surface drainage connection to the sanitary sewer system and deteriorated manholes subject to inflow during storm periods. Highest priority for these field investigations will be in the five basins identified as having the highest I/I contributions as well as the other older areas of the City.

- Continued television inspection of the sewers on a cyclic basis to assess their physical condition and identify rehabilitation needs. The television inspection work would identify projects for lining or replacement of sewer in poor structural condition.

- Permanent metering and telemetry improvements to optimize the operation of the system and enable the City to monitor long term flow trends. This can be accomplished by telemetering flow data from the lift stations and installing metering station at strategic location on the trunk sewers.

The study estimated that the flow monitoring and field inspection activities will require about 150 crew days per year. The City's staff currently includes an equivalent of 7 positions dedicated to the sanitary sewer system. A fully implemented program could involve the addition of 2 staff positions or augmentation by outside contractors. The City's budgeting efforts will focus first on accomplishing major field investigations with outside contractors. The effectiveness of the program and future budgeting needs will be reevaluated each year.

Comparative Cost Estimates: Table 1 below indicates the comparative costs of the various program alternatives investigated as part of the SSES. The table illustrates capital and annual costs. The recommendations from the SSES represent a focused method for attacking problems that were already costing the City of Petaluma money and resources. The SSES reveals that, in Petaluma's case, the most cost effective way to deal with I/I is for the City to develop an active program to contain I/I at its current level.

Table 1
Summary of Costs

Project Component	Capital Cost	Annual Cost
Lindberg Lane Corrections		
Alt 1 Comprehensive Rehabilitation	$4,000,000	
Alt 2 Lindberg Lane Relief Sewer	$1,700,000	
Pond Influent Pump Station	$1,700,000	
Programmatic Field Investigations		$100,000

SUMMARY

The SSES showed clearly that two projects solved the immediate problems associated with high I/I in the City of Petaluma's trunk sewer system. These two project were a more efficient use of funds than comprehensive rehabilitation in one subbasin. The City focused on immediate projects that would prevent potential overflows. Even with the projects, some areas of the collection system will be subject to surcharging. Long term efforts will focus on correcting surcharging and managing I/I at its current levels. In an era of tighter budgets, agencies must make decisions based on the overall value received from expenditures. The SSES approach gave the City of Petaluma's engineering staff tools for clearly comparing the benefits of collection system repairs. In addition, by partnering with Consultants during the initial monitoring efforts, the City has been able to train staff to continue the evaluation of our collection system. These ongoing efforts will allow further quantification of problem areas within the system so that the City can continue to identify cost effective Capital Improvement Projects.

Q:\CF\PRESENT\POWERPNT\P7220002\FIG4.DWG 2/13/97

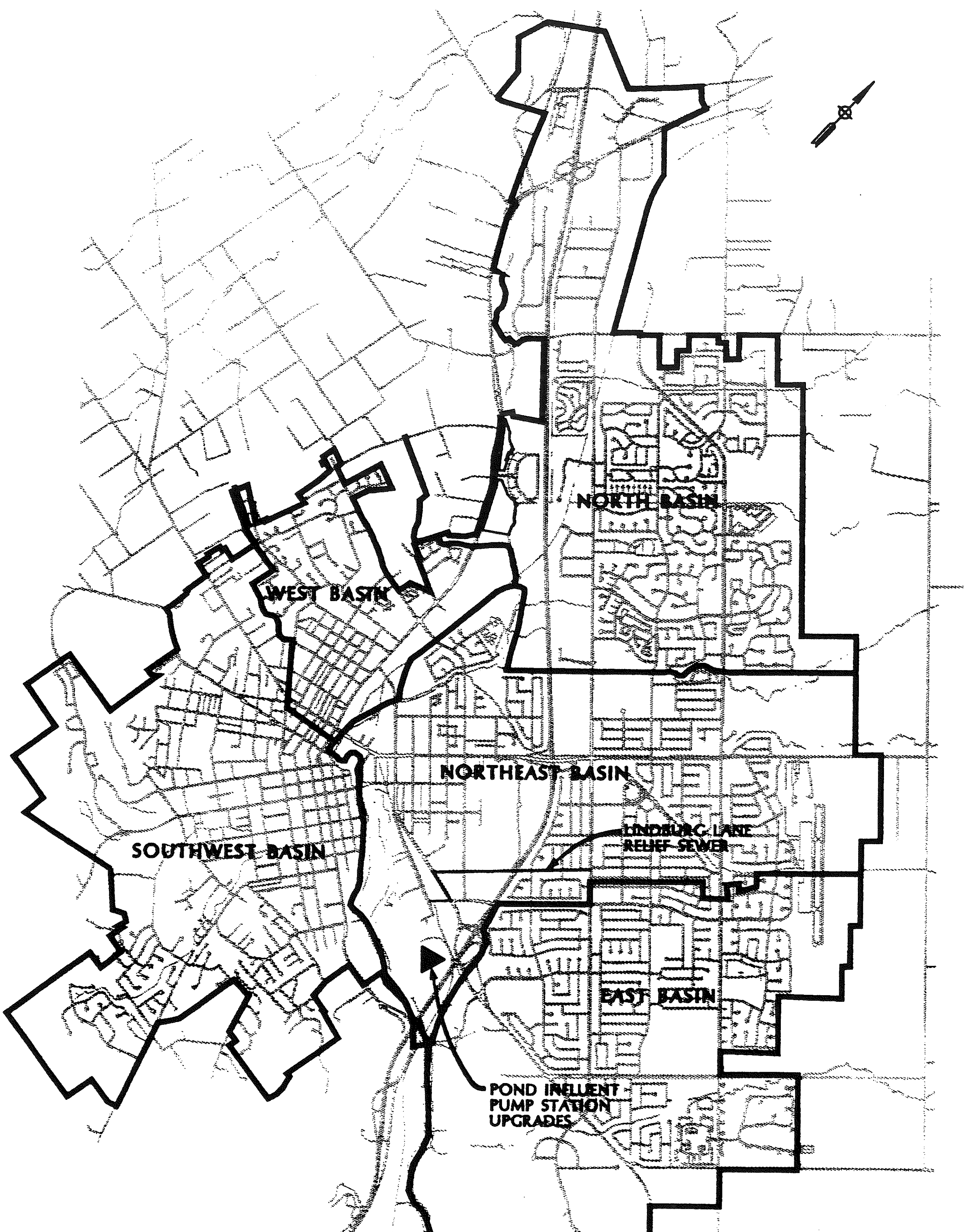

FIGURE 4
SSES PROJECT
RECOMMENDATIONS
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G:\CF\PRESENT\POWERPNT\P7220002\FIG4.DWG 2/13/97

PLANNING AND DESIGN CONSIDERATIONS FOR MICROTUNNELING

By

David Mathy, President, DCM/Joyal Engineering
Tad Pilecki, Senior Engineer, Central Contra Costa Sanitary District

The use of microtunneling as an attractive alternative to conventional open cut is gaining momentum, especially in the Western United States. Not only can microtunneling reduce overall noise, vibration, and other disturbances to residents and business, but it can be less expensive depending on site conditions, pipe depths, soil, bedrock, and groundwater conditions.

Central Contra Costa Sanitary District (CCCSD) is contemplating using microtunneling to replace 8,000 LF of 15-inch to 36-inch trunk sewer in Moraga Way that serves the southern half of Orinda, California. The existing sewer parallels San Pablo Creek, which is a tributary to San Pablo Reservoir, an East Bay Municipal Utility District drinking water reservoir. During major storm events, this trunk sewer and its tributaries surcharge and may overflow into the creek creating a potential public health issue. Complexities of the project include variable soil conditions, high traffic volumes on Moraga Way, a two lane commute corridor, numerous utilities including deep culverts, limited areas for staging and a very affluent/sensitive neighborhood.

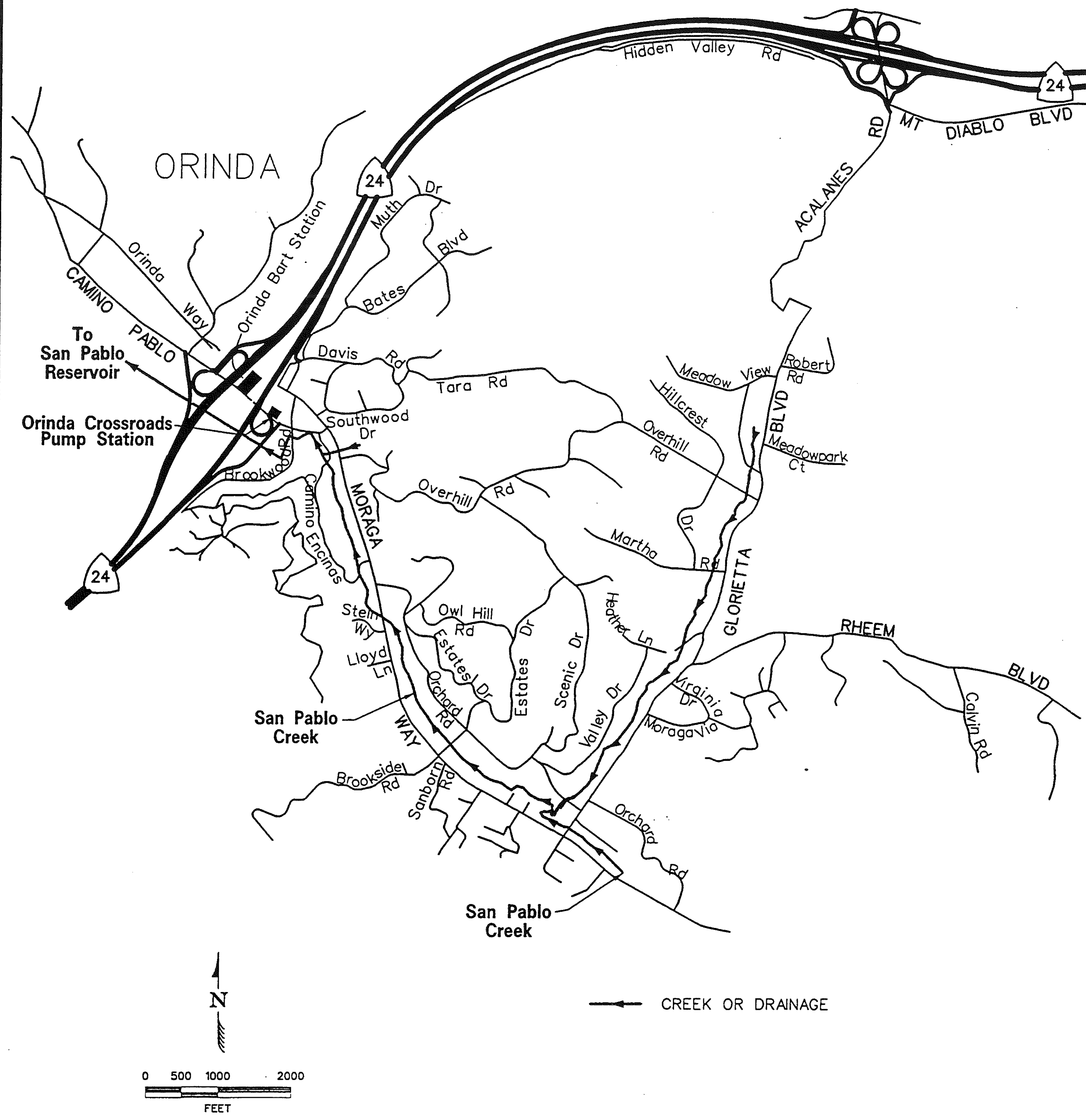
This paper explores a number of considerations that the District and its consultants have utilized when planning and designing the Moraga Way microtunneling project. These considerations include alignment investigations, alignment characterizations, geotechnical issues, equipment/material considerations, environmental issues, and miscellaneous issues.

The District is the agency responsible for wastewater collection, treatment and disposal for 400,000 constituents located in Central Contra Costa County. Its 126 square mile service area is located in the eastern part of the San Francisco Bay Area. The District maintains over 1,300 miles of collection system.

Due to extensive urban development and the ever increasing public awareness of construction impacts on their quality of life, the District has been very active in pursuing and implementing new trenchless alternatives to open cut. One of the promising alternatives has been microtunneling. To date, the District has successfully installed over 7,000 linear feet of pipe ranging in size from 36 inches to 78 inches internal diameter utilizing microtunneling equipment manufactured by Herrenknecht, Iseki, and Akkerman. Currently, over 25,000 feet of pipe (ranging in size from 24 to 42 inches) under design is expected to be installed utilizing microtunneling technology. This experience has proved invaluable in planning and designing the Moraga Way Microtunneling Project.

ALIGNMENT INVESTIGATIONS

The existing trunk sewer serving the south Orinda area starts at the Orinda Crossroads Pump Station located in Downtown Orinda and follows Moraga Way for approximately 8,000 feet to the intersection with Glorietta Boulevard (see Figure 1). Moraga Way is located in the



Central Contra Costa Sanitary District

SOUTH ORINDA VICINITY MAP

FIGURE 1

bore/receiving pit locations on private property resulted in the need for temporary and permanent easements from approximately 40 properties, but before the right-of-way acquisition process could begin, the District first needed to do an alignment characterization.

ALIGNMENT CHARACTERIZATION

Alignment characterization looks for obstructions that may create problems for microtunneling. Sources for identifying these obstructions include historical development, review of historic aerial photos, creek crossings, fills and buried debris, trees, and basement and foundation tiebacks.

Alignment characterization is a very important task that can save a designer many headaches at a later date. For example, on a recent District microtunneling project with a 48-inch machine, the contractor lost steering control of the cutting head approximately 500 feet into a 725 foot push. The jacking pressures had reached the upper limit of the concrete pipe being jacked and the contractor had to shut down the operation and dig up the cutting head. Apparently the microtunneling machine had run into some redwood tree stumps, which were shredded by the cutting face. The shredded redwood then proceeded to block the slurry return ports, thus the soil cuttings/slurry mixture could not be removed from the face of the machine, effectively shutting down the microtunneling process. The remainder of the run was completed by open cut.

A review of historic aerial photos of the area where the cutting head got stuck showed an old quarry with numerous trees visible (Figure 2). If this information had been provided to the contractor, the problem with the wood may have been avoided. On a subsequent bore, the contractor ran into more stumps, but by removing some of the high pressure nozzles on the front of the cutting head, the contractor was able to create a back flushing action on the slurry screen which prevented the redwood shreds from blocking the slurry return ports.

Review of the aerial photos of the Orinda area showed that some of the creeks in the vicinity of downtown Orinda had been realigned and that Moraga Way had been realigned over the old creek beds (Figure 3). This indicated that we should expect to find fill material and some creek bed deposits in this area. This is discussed further under geotechnical issues.

Records from construction of buildings can also be a valuable source of information for alignment characterization. Several of the buildings in downtown Moraga had been constructed with basement and foundation tiebacks and needed to be accounted for (i.e., avoided) in final alignment selection.

Creek crossings on the preliminary alignment developed for the Moraga Way microtunneling project were a major issue. Many of these creeks were very deep. In some cases the separation between the bottom of the creek (or culvert if under a roadway) and the top of the pipe was less than 4 feet. Careful evaluation of the creek beds was required to determine whether slurry blowout would be an issue. In one case the District is considering placing over-burden on the alignment crossing a creek bed to prevent slurry blowout problems. Other alternatives such as grout curtains are also being considered.

Trees present a different type of challenge with respect to alignment finalization. Due to the depth of pipe (20-35 feet), roots would not be an issue. However, the City of Orinda does have a large number of heritage Oaks (Valley and Live Oaks) throughout the Moraga Way area.

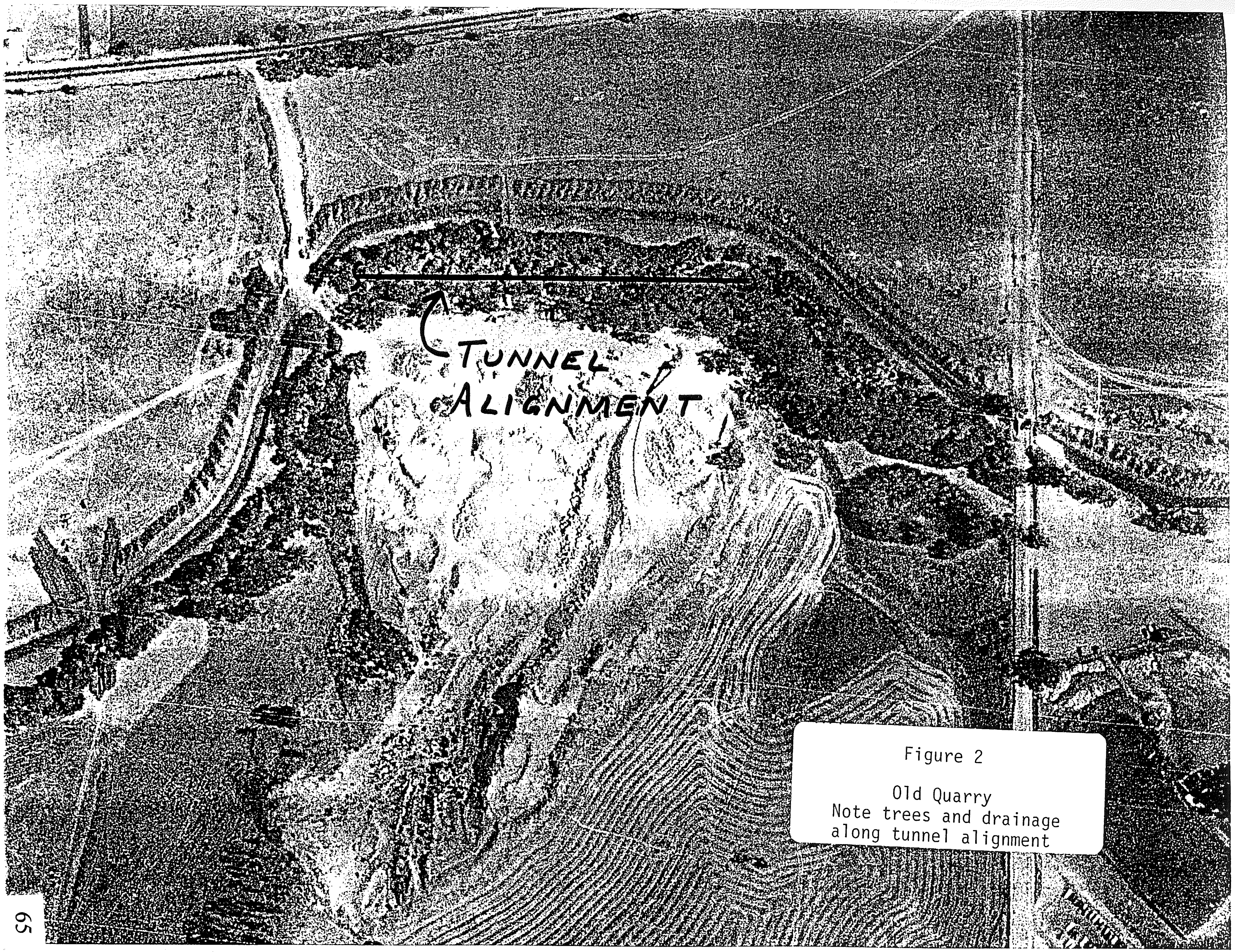
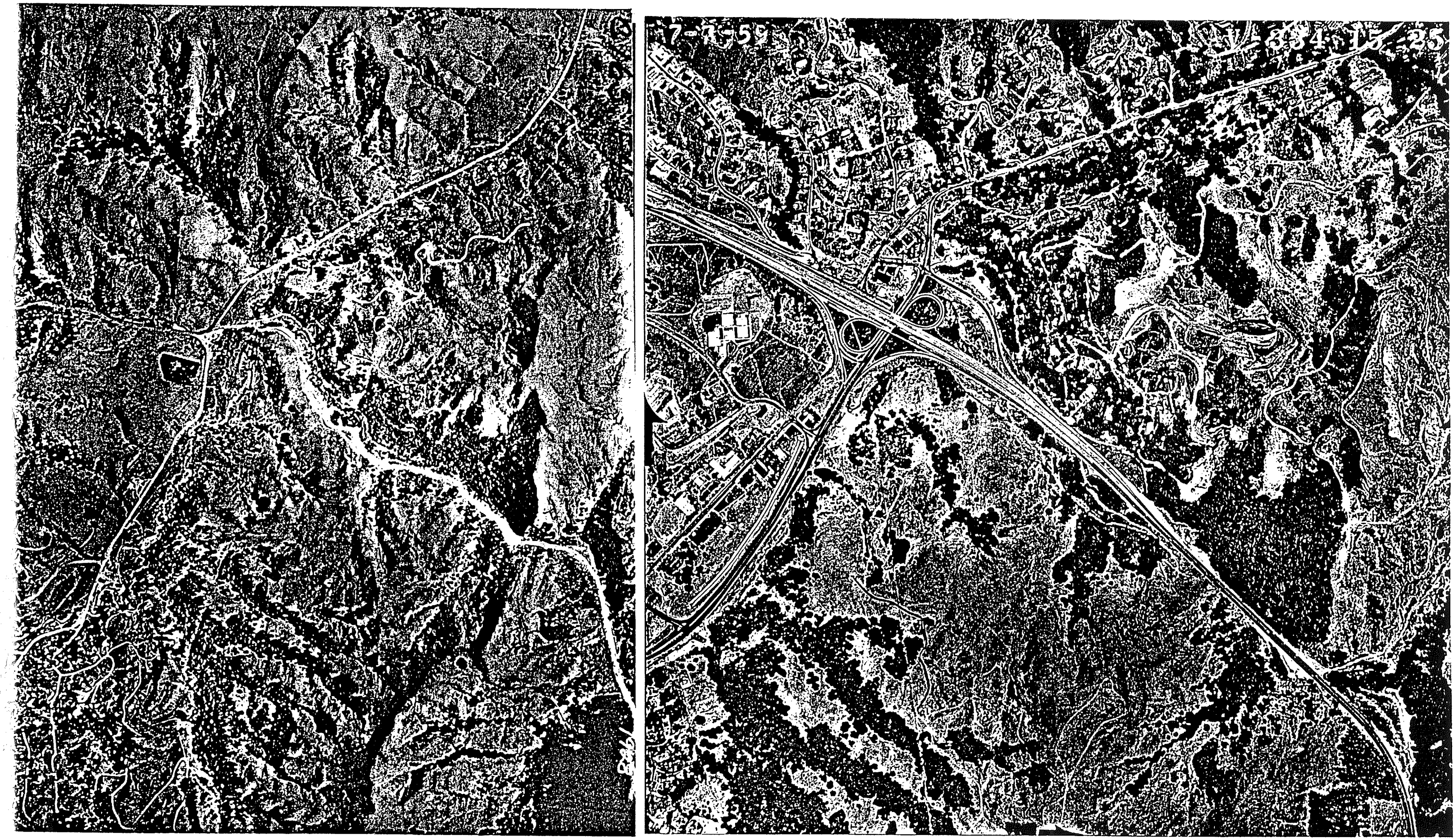


Figure 2

Old Quarry
Note trees and drainage
along tunnel alignment

Figure 3
Aerials of Moraga Way - Note realignment of Moraga Way over old creek bed in downtown area



These trees range in size from 24 to 60 inches in trunk diameter. Bore/receiving pits and the associated operations had to be situated so as to not impact these trees. Several good pit locations had to be dropped from consideration on account of trees.

Once preliminary locations of the bore/receiving pits have been chosen, the geotechnical and equipment/material considerations need to be evaluated.

GEOTECHNICAL ISSUES

The Moraga Way project is located on the east side of the Berkeley hills in the City of Orinda. The Berkeley hills consist of a belt of faulted anticlinal and synclinal folds that are part of the Northern Coast Range Geomorphic Province, a series of north to northwest trending mountains and valleys bordered by the Great Valley to the east and the Pacific Ocean to the west. The Coast Ranges continue to be shaped in the San Francisco Bay region as a result of displacement across the north-northwestward trending San Andreas Fault system. The nearest known active fault to the pipeline alignment is the Hayward Fault located approximately 4 miles to the west.

The pipeline alignment is located along the side slopes of the drainage valley formed by San Pablo Creek which flows from south to north into San Pablo Reservoir. The bedrock within this drainage valley typically is covered by Quartenary alluvium and/or colluvium. However, in the downtown area, the bedrock is also overlain by fill and backfill placed during realignment of San Pablo Creek and downtown development. Locally, the pipeline alignment is also crossed by ancient slide debris generated from landslides on either side of the valley.

Following is a brief description of the alluvium, colluvium, fills, bedrock and landslide deposits along the pipeline alignment. Alluvial deposits include irregularly stratified, poorly consolidated deposits of mud, silt, sand, and gravel deposited in creek beds and on adjoining flood plains. Colluvial deposits include unstratified and poorly stratified, unconsolidated to poorly consolidated deposits composed of fresh and weathered rock fragments, organic material, silts and clays, or irregular mixtures of these materials that accumulate by the slow downslope movement of surficial material, predominantly by the action of gravity, but assisted by running water that is not concentrated into channels. Fills consist of mixed native soils placed in the downtown area of Orinda (north end of alignment) in the 1940's to 1950's with potential oversize material and construction debris. Bedrock underlying the alluvium and/or colluvium along the proposed pipeline alignment is a non-marine sequence of sedimentary rocks called the Contra Costa Group. These rocks predominantly include thick sequences of claystone and siltstone with less frequent sandstone and conglomerate.

Some of the engineering characteristics of the Contra Costa Group bedrock as described by USGS mapping are:

- Poorly consolidated
- Weathered rock soft, clayey
- Contains montmorillonite clay
- Prominent and widespread jointing
- Can be moved with power equipment
- Poor slope stability

Regional mapping of landslides and other surficial deposits in the Orinda area by USGS and the City of Orinda indicates that the pipeline alignment is crossed by ancient landslide deposits. Typical of the ancient landslides is a mapped deposit at the south end of the pipeline alignment where an ancient landslide (approximately 1,600 feet long by 700 feet wide) is located on the west side of the valley. The toe of this landslide deposit is in San Pablo Creek and has locally changed the alignment of the creek. Based on borings drilled within this landslide deposit, the depth of sliding appears to be as deep as 25 feet below present ground surface.

In summary, regional and local geologic mapping indicates that the pipeline alignment will encounter a variety of subsurface materials including the following:

- fill
- alluvium
- colluvium
- bedrock
- landslide deposits

The subsurface investigation for the Moraga Way project included 21 test borings, 3 piezometers, and 3 seismic image profiles. Sixteen borings were drilled at bore and receiving pits with the balance of 5 borings drilled at selected mid-drive locations. In order to evaluate equilibrium groundwater conditions, three of the test borings at pit locations were completed as open standpipe piezometers.

As anticipated by the geologic research, test borings encountered a variety of subsurface materials both within pit excavations and tunnel drives. The subsurface materials encountered within borings included:

- Fill - mixed native soils varying from clays to sands and gravels with occasional debris including asphalt, concrete, wood, and roots. Fill was deepest in the downtown area at the north end of the alignment.

- Undisturbed native soils - predominantly low to moderate plasticity clays (colluvium and alluvium) either directly overlying bedrock or overlying mixtures of sand, gravel and cobble creek bed deposits (alluvium). The gravels and cobbles of the creek bed deposits were derived from basalt flows at the top of the Berkeley hills. The maximum cobble size as measured in the bed of San Pablo Creek was 12 inches. Unconfined compression testing on cores taken from these creek bed cobbles ranged from 7,000 to 21,000 psi.

- Landslide debris - consists of native soils and fragmented bedrock transported downhill through landslide activity. The landslide deposits were locally softer in consistency than undisturbed native soils with generally higher groundwater levels.

- Bedrock - siltstone/claystone bedrock of moderate plasticity. The bedrock is closely fractured and jointed and soft to very soft in rock hardness. The type, consistency and quality of bedrock was relatively uniform along the project alignment.

- Groundwater - Groundwater levels varied considerably along the alignment depending on proximity to San Pablo Creek, its tributaries and ancient landslide deposits. Groundwater was encountered during drilling at depths ranging from 15 to 25 feet. Three borings were completed as open standpipe piezometers to allow an evaluation of the seasonal effect on groundwater levels. These piezometers will be monitored and reported up to the time of final plans and specifications.

Figure 4 presents a general summary of subsurface conditions encountered along the pipeline alignment.

Based on the results of geologic research and test borings, it became apparent that the most consistent target zone for the tunnel alignment would be the siltstone/claystone bedrock. Maintaining as much of the tunnel as possible in bedrock will accomplish the following:

- tunnel below the depth of fills placed in the downtown area and possible obstructions within the fill;

- tunnel below creek bed deposits and possible oversize material; and

- tunnel below landslide deposits and possible weak or otherwise unstable slide debris.

Maintaining as much of the tunnel in bedrock as possible required deepening the pipeline to the maximum extent allowed by the existing downstream Orinda Crossroads Pump Station connection in downtown Orinda. The depth of tunneling was therefore set at 20 to 35 feet below the existing ground surface.

In order to evaluate the lateral consistency of the bedrock layer, seismic imaging field tests were performed. The seismic imaging technique establishes soil and bedrock stratigraphy based on seismic compression wave velocity measurements, and is used to extend the radius of investigation of a borehole. At three locations along the project alignment, 60-foot deep boreholes were equipped with a vertical series of seismic detectors. An impact source (140 lb. hammer dropped 24-inches) is applied to the ground surface at regular interval distances away from the borehole. A subsurface seismic compression wave profile is generated from these measurements for a distance of approximately 180 feet to either side of each borehole in the direction of the tunnel alignment. As shown in Figure 5, the seismic imaging technique provides an extension of the bedrock laterally away form the borehole. The results of the three seismic images indicated a high degree of variability in the upper soils and fill with more uniformity in the bedrock.

With the majority of the tunnel planned to be within the siltstone/claystone bedrock, additional laboratory testing was undertaken to help evaluate the bedrock performance within the tunnel. These additional tests included:

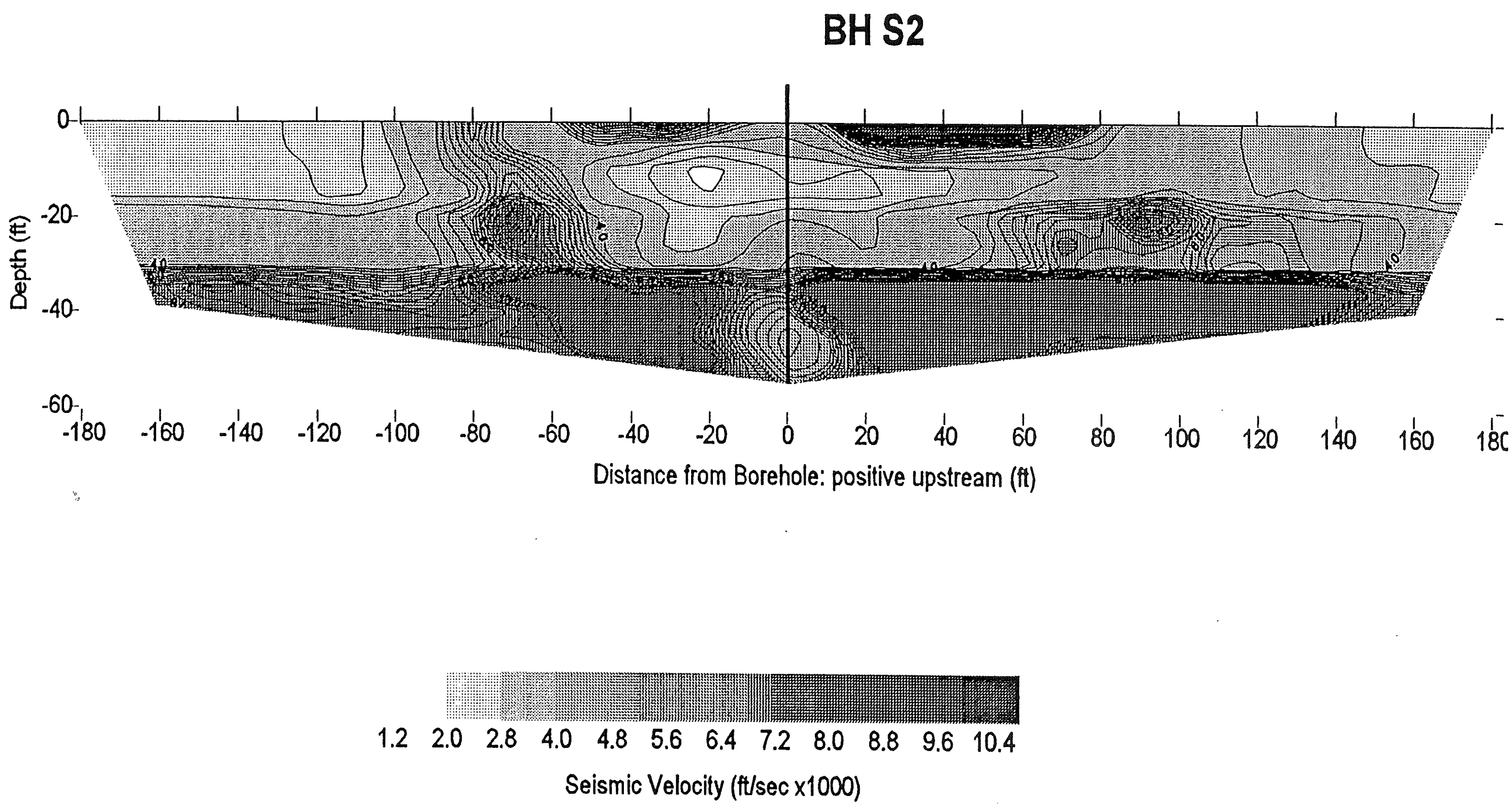
- confined and unconfined compression;
- grain size distribution;
- swell testing (to evaluate the effect of squeezing on the pipe); and
- slake durability testing (to evaluate the effect of different slurry fluid on bedrock cuttings).

FIGURE 4

SUMMARY OF SUBSURFACE CONDITIONS						
SUBSURFACE MATERIAL	USCS[1]	AVG. DEPTH INTERVAL (ft.)	MAXIMUM GRAIN SIZE (in.)	AVG. BLOW COUNT RANGE "N"	AVG. SEISMIC VELOCITY (fps x 1000)	AVG. COMPRESSIVE STRENGTH
FILL	CL CL/CH	0-8	<3"	10-25	2-3	1.0+ksf (q_u)
NATIVE SOILS	CL, CH, SC	8-15	<3"	10-25	2-3	1-3 ksf (q_u)
CREEK DEPOSITS	SM, GM, GW-GM	15-20	12"	8-20	2-3	7-21 ksi (q_u) (Cobble cores)
SILTSTONE/ CLAYSTONE	-	20-25+	-	40->100	4-10	3-9 ksf (UU)
GROUNDWATER	-	15-25	-	-	-	-

[1]USCS - Unified Soil Classification System
CL - Low to Medium Plasticity Clays
CH - High Plasticity Clays
SC - Clayey Sands
SM - Silty Sands
GM - Silty Gravels
GW - Well Graded Gravels

Figure No. 5



BH S2
Depth (ft)
0
-20
-40
-60
-180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160 180
Distance from Borehole: positive upstream (ft)
1.2 2.0 2.8 4.0 4.8 5.6 6.4 7.2 8.0 8.8 9.6 10.4
Seismic Velocity (ft/sec x1000)

Results of bedrock grain size distribution, bedrock swell testing and bedrock slake durability testing are summarized on Figure Nos. 6, 7, and 8, respectively. The grain size distribution tests indicate the relative uniformity of the bedrock. Swell testing indicates relatively minor free swell upon release of overburden and saturation. This is consistent with the low to moderate plasticity of the bedrock. Spoils handling is a critical concern on this project, given the limited topside equipment space. The results of slake durability tests indicate a significant increase in slake durability index (I_d) with the addition of slurry fluid polymers. The larger particle size survivability will minimize thickening of the slurry via the clay content of the bedrock cuttings, and will maximize sedimentation and solids separation of the slurry in the topside equipment.

EQUIPMENT/MATERIAL CONSIDERATIONS

Since most of the tunnel alignment will be located in the siltstone/claystone bedrock, the cutter head must be capable of boring through this bedrock with an unconfined compressive strength of 3,000 to 9,000 psf. Given the number of tributary drainages entering San Pablo Creek and landslide deposits along the 8,000 foot long pipeline alignment, there is a high probability that localized portions of some microtunnel drives will transition from bedrock to creek bed deposits or landslide debris. Therefore the cutter head must also be capable of boring through occasional softer clay soils and sands, gravels, and cobbles under mixed-face conditions. The cutter head must be capable of crushing cobbles up to 12 inches in diameter with relatively high unconfined compressive strengths of 7,000 to 21,000 psi. Given that the tunnel will be as much as 15 feet below the groundwater table, the tunneling machine must also be capable of balancing hydrostatic (as well as earth) pressures. Therefore, a slurry microtunneling system will be required.

Given the limited available topside area at each pit location, specifically bore pits, the spoil removal system is a critical aspect of construction. The slurry machine will mix excavated cuttings into a slurry chamber behind the cutting head and hydraulically pump the spoils to the topside equipment (sedimentation tanks). The siltstone/claystone has a high percentage of fines (90 to 100% passing a No. 200 sieve) which can cause significant problems with slurry thickening in the slurry chamber and hydraulic system and difficulty with separation in the topside sedimentation tanks. As indicated by laboratory slake durability testing (see Figure 8), polymers added to the slurry can significantly improve the behavior of the cuttings by reducing slaking thereby reducing thickening effects and increasing the rate of sedimentation.

A pipe lubrication system will be required to reduce friction loads on the driven pipe. The pipe lubricant will be injected into an overcut annular space around the outside of the pipe. Polymers will also be added to the lubricating fluid to reduce the loss of water into the bedrock and minimize swelling. Bedrock swelling and resultant increases in normal stress and friction load on the driven pipe will be further avoided by overcutting the tunnel diameter. Overcuts of 2 to 3 inches on diameter will be allowed depending on the specifics of the microtunnel machine (e.g., steering limits).

The individual drive lengths range from about 320 to 700 feet. Given the relatively long drive lengths, intermediate jacking stations will be required and used as necessary to advance the pipe. Locating an intermediate jacking station in the first 100 to 200 feet of the drive is a good practice with additional interjacks being installed when the jacking forces reach 80 percent of the safe jacking of the pipe being used. The pipe itself must be capable of handling

Figure 6

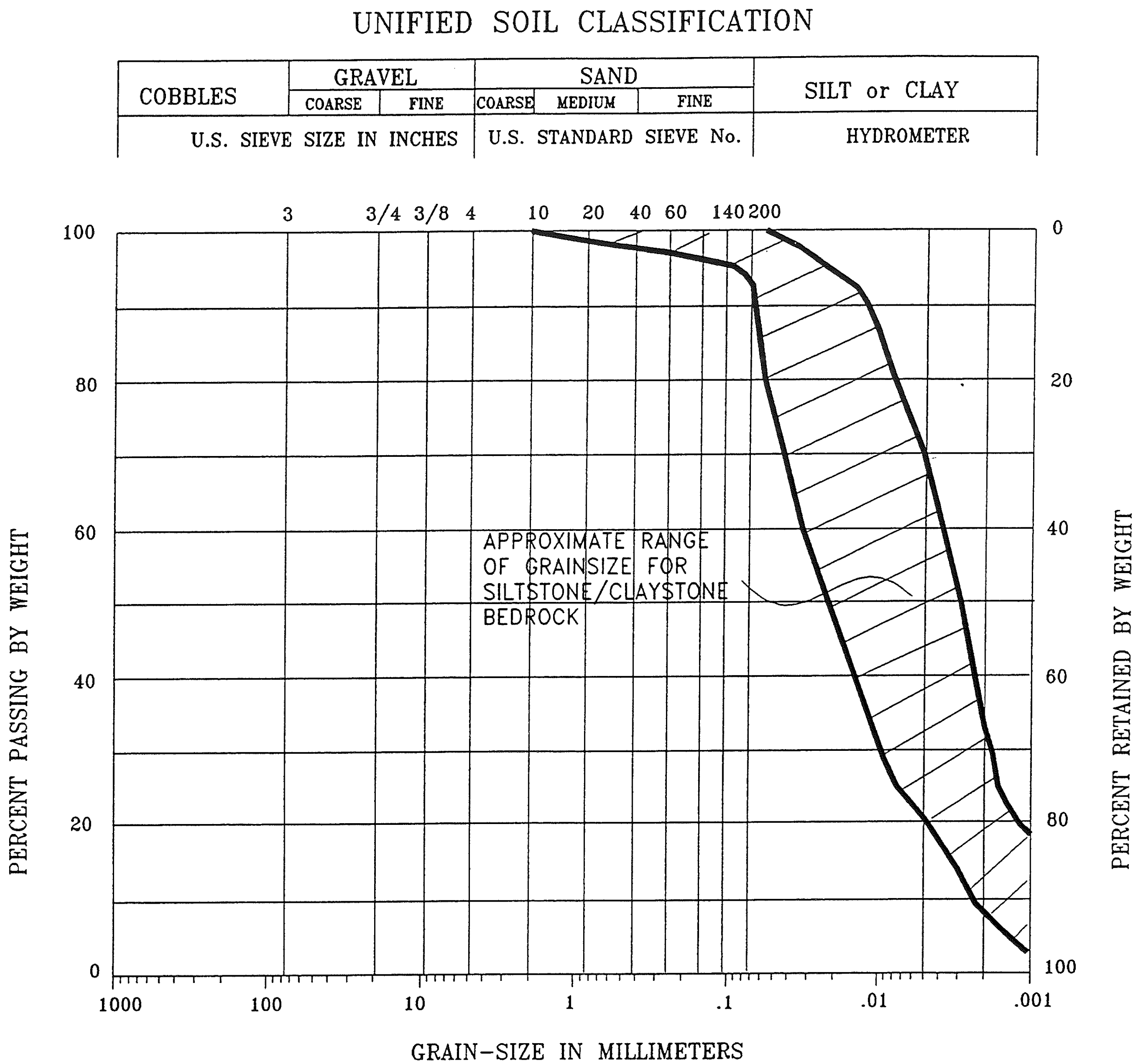

UNIFIED SOIL CLASSIFICATION
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT or CLAY
U.S. SIEVE SIZE IN INCHES
U.S. STANDARD SIEVE No.
HYDROMETER
3
3/4
3/8
4
10
20
40
60
140
200
APPROXIMATE RANGE
OF GRAINSIZE FOR
SILTSTONE/CLAYSTONE
BEDROCK
PERCENT PASSING BY WEIGHT
PERCENT RETAINED BY WEIGHT
100
80
60
40
20
0
0
20
40
60
80
100
1000
100
10
1
.1
.01
.001
GRAIN-SIZE IN MILLIMETERS

FIGURE NO. 7

SUMMARY OF SWELL AND ATTERBERG LIMIT TESTS ON SILTSTONE/CLAYSTONE BEDROCK					
SWELL TEST RESULTS (ASTM D 4546)				ATTERBERG LIMITS	
INSITU MOISTURE CONTENT	SWELL MOISTURE CONTENT	INITIAL DRY DENSITY	FREE SWELL (%)	LIQUID LIMIT	PLASTICITY INDEX
10-20%	11-22%	110-130 pcf	1.7 to 4.9	37-47	18-27

FIGURE NO. 8

SLAKE DURABILITY INDEX $I_d(2)$
A.S.T.M. D4644

BORING No.	SAMPLE No.	DEPTH (feet)	INITIAL MOISTURE CONTENT (%)	TYPE OF LIQUID IN TROUGH [1]	TYPE OF FRAGMENTS RETAINED [2]	$I_d(2)$ [3]
DCM-5	5-13	32-32.5	20	H_2O	None	0.0
DCM-5	5-13	32-32.5	20	A (75%)	II	28.7
DCM-10	10-9	23-23.5	16	H_2O	III	7.2
DCM-10	10-9	23-23.5	16	A (75%)	II	26.7
DCM-11	11-4	23.5-24	16	A (25%)	II	69.3
DCM-18	18-10	22.5-24	10	A (25%)	II	77.9
DCM-19	19-8	32-33	14	H_2O	II	2.4
DCM-19	19-8	32-33	14	B (75%)	II	54.3
DCM-19	19-7	31.5-32	19	B (25%)	II	52.8
DCM-20	20-9	33-33.5	13	H_2O	II	17.8
DCM-20	20-9	33-33.5	13	B (75%)	II	74.3
DCM-20	20-9	33.5-34	15	B (25%)	II	87.1

[1] LIQUID A - 1 Qt. EZ MUD PLUS*/100 Gallons WATER
LIQUID B - 1 Qt. EZ MUD PLUS and 2 Qt. CONDET**/100 Gallons WATER
75% - Liquid diluted 75% (i.e., 1 Gallon LIQUID with 3/4 Gallon WATER)
25% - Liquid diluted 25% (i.e., 1 Gallon LIQUID with 1/4 Gallon WATER)

* EZ MUD PLUS - Anionic Polymer produced by Baroid Drilling Fluids, Inc.
** CONDET - Wetting Agent produced by Baroid Drilling Fluids, Inc.

[2] TYPE I - Retained pieces remain virtually unchanged
TYPE II - Retained material consists of large and small pieces
TYPE III - Retained material is exclusively small fragments

[3] $I_d(2)$ - Slake Durability Index (second cycle)

jacking forces. Since jacking forces are anticipated to be relatively high, concrete pipe or polymer concrete pipe are likely candidates for this project.

Bore pits and receiving pits will be excavated through a variety of materials including fill, landslide debris, colluvium, alluvium, and creek bed deposits. Soil types will range from clays to sands and gravels. Pits will be excavated as much as 15 feet below the groundwater table. In general, soils are stiff and dense in place; however, loose fills and soft landslide debris are expected. Creek bed deposits and other granular alluvium are water bearing and will produce significant groundwater inflow. Since pits are located on private properties and often in close proximity to homes, driveways, streets and utilities, ground surface settlements produced by unsupported cuts and/or groundwater drawdown must be avoided. In order to minimize adverse impacts of pit excavations on adjacent properties, all pits will be "water-tight" and continuously and positively shored. Caisson style pit construction is preferable. High thrust block capacities are available for thrust blocks bearing on bedrock.

A special construction concern is the tunnel crossing beneath San Pablo Creek with very shallow cover. In order to prevent slurry blowout into the creek, pre-grouting of the creek bed deposits and/or temporary surcharging (i.e., creek infilling) are being considered.

Since the details of the microtunneling process are dependent on the specifics of the machine used, the contractor will be required to provide submittals prior to construction for a variety of items including the overall construction process and equipment, pit design, thrust block design, cutter head, slurry and spoil handling system, pipe, lubrication, maximum jacking forces, and laser guidance control. Record of construction submittals will include machine performance records and complete jacking force records.

ENVIRONMENTAL ISSUES

Environmental issues also play a significant role in the microtunneling project. Issues such as preconstruction contamination can cause costly delays to projects. Other environmental issues such as noise, hours of construction, and slurry spills can not only be financially costly, but they can also turn the public and the jurisdictional agencies off when it comes to microtunneling on future projects.

Preconstruction contamination can be identified by a number of different ways. Soils boring rigs should be equipped with an OVA (organic vapor analyzer), and the operators should be on the lookout for hydrocarbon contamination. Operator awareness is very important. On one of the borings for the project, the operator detected hydrocarbon odors, but the OVA did not. Other sources for leads on potential preconstruction contamination include past aerials as well as your local health department's records of known contaminated areas. Past aerials for the Orinda downtown area showed an old gas station at a present bank building site. Hydrocarbons were found in the soil borings in the general vicinity of this former gas station. Fortunately the levels were very low. Information such as this can be valuable. On a recent project, the District was able to adjust the microtunnel alignment to avoid the majority of the contamination and provide the contractor with specifications on how to deal with the situation so the contractor could adjust their bid accordingly.

Noise and work hours are two factors that go hand in hand. Typically, open cut construction occurs during daylight hours on weekdays and results in intense periods of noise when the contractor is near or in front of a home or business. With microtunneling, the homes or businesses immediately adjacent to the bore pits can be subjected to prolonged periods of constant noise because once a boring operation starts, the contractor typically wants to minimize the amount of down time and restarting the tunnel operation. Adding to the problem is weekend work. Once a boring operation has started, especially long pushes, the contractor wants to keep the pipe moving, otherwise it might freeze over a weekend. District sound measurements show that late hour ambient noise levels in a residential neighborhood are between 40 and 50 decibels. Microtunneling operations can generate noise levels on the order of 90 plus decibels. Continuing these noise levels into the night and/or over weekends, ruining the residents sleep, and scaring their pets results in calls and complaints to the police, the City Engineer, elected officials, and your boss.

The issue of noise and work hours can be effectively addressed through the specifications and an effective public relations program. Items the specifications can address are mufflers on equipment, ground mufflers on boom trucks, sound enclosures on generators (or utility company power drop if available), placement of tanks to deflect sound, and sound barriers. In one case, the District's contractor placed sound blankets over portable classrooms to allow class to go on. Utility drops are effective in reducing noise, but on the Moraga Way project, they cost approximately $25,000 each. Part of this is due to the power requirements needed, 700 KVA at 460 Volt, three phase.

Restricted work hours are also important. Limiting construction hours (during the actual pushing operation) to 7 a.m. to 10 p.m. (9 a.m. where children live) on Monday through Friday, 9 a.m. to 6 p.m. Saturdays and, if absolutely necessary (i.e., jacking pressures are high), 12 p.m. to 6 p.m. Sundays can also make residents more tolerant. Digging the pits, setting the equipment up, and getting ready to push should be restricted to Monday through Friday, 7 a.m. to 7 p.m. only. Restricting the contractor to initial start up of the pushing operations to Monday (Tuesday on short runs) helps to reduce the need for weekend work except for very long pushes. The restricted hours also apply to maintenance and fueling vehicles. The District imposes a monetary fine, up to $500, if the work hour restrictions are not complied with. These restrictions need to be clearly identified in the contract so that the contractor can take them into account in preparing their bid.

To ensure homeowner, business, and jurisdictional entity buy-in, an effective public relations program is necessary. Each of the entities impacted needs to be contacted and provided with the microtunneling details. Weekend work should only proceed with advance notice. The benefits of the longer hours should be stressed, i.e., shorter overall duration of the project. Tours of the microtunneling operation are effective ways to work with the public. Providing access to a community relations liaison assigned to the project is also important. Sometimes special arrangements need to be made, such as kenneling pets. People will work with you if you are honest and work with them.

High slurry pressures represent another nuisance problem. High daily production rates translate to higher profits for the contractor. If the work hours are shorter, and weekend work restricted, one way to increase daily production is to push faster. Pushing faster results in higher slurry pressures. If these pressures get too high, the ground near the cutting head may experience slurry blowouts at the surface. This not only creates the obvious mess at the surface, but the more difficult situation of trying to explain to the agency having jurisdiction that the roadway, levee, etc., is not damaged. It is very difficult to set a specific criteria in the specifications to deal with this situation since each piece of equipment/system configuration is different. Some of the best ways to deal with this situation is to prequalify the contractor, superintendent and equipment operator, and set specific requirements on the equipment such as the use of variable speed slurry pumps, pressure control values, and a flow meter. Receiving and reviewing daily reports on the equipment operation is also helpful. Good dewatering and settling characteristics of the cuttings are important. If the cuttings do not settle out, the viscosity of the slurry increases, resulting in higher slurry pressures. In this case, a polymer to enhance settling may be necessary (see Figure 8).

MISCELLANEOUS ISSUES

Other issues that need to be considered in designing a microtunneling project include, prequalification of tunnelers, safety, alignment control, and the use of Partnering or a Disputes Review Board (DRB). Prequalification is a useful tool to restrict contractors without prior microtunneling experience, or experience in similar geotechnical conditions, or experience with intermediate jacking stations (if required for a particular project) from bidding the project. It also eliminates contractors (with no prior experience) who want to get into the microtunneling business by utilizing a manufacturers equipment and crew. Prequalification of microtunneling contractors improves your chance of success.

Safety is a very important issue that needs to be addressed, both from the public and the contractor's employees perspective. Microtunneling pits are generally very deep (20 feet plus). Adequate protection must be taken to ensure that the public, especially children, do not fall in. In special circumstances, 24-hour security around the bore and receiving pits, in addition to fencing, may be warranted. Night construction creates its own set of safety issues for the public. The specifications again need to be very clear in identifying special safety precautions, such as around the clock security.

Another area of safety deals with contractor safety. OSHA already does a pretty good job of setting safety requirements for construction workers. Contractors are also required to develop their own safety manuals and have weekly safety tailgate meetings. Even the tunneling equipment is equipped with OVAs. One area of concern the District has, however, is how to assist/rescue workers who are injured or unable to move inside the microtunnel. Although microtunneling is a remote controlled operation, the reality is that contractor employees need to make trips to the tunneling head for various reasons. It would be very difficult to assist an injured worker inside a 36- to 48-inch tunnel with all the piping, interjacks, and ventilation ducts in place. The District is considering requiring contractors to work with local health and safety organizations to come up with a contingency plan for these types of situations.

Alignment control is one of the recurring problems the District has experienced with the microtunneling operation. Alignment control, especially vertical, is important to the District since most of its lines flow by gravity. The first item to note is that the manufacturer's claims of plus or minus 1/4 inch have not been verified by field data. Generally, the District's microtunneling projects have come in at plus or minus 2 to 3 inches. Most of the alignment problems relate to the laser set-up and machine targeting. The laser cannot be supported from the pit floor or thrust wall or the interconnected shoring system because these have a tendency to move. The laser needs to be supported independently of the pit support system. The targets on the microtunneling machine also need to be properly set-up. A shifting laser coupled with a poor target set-up resulted in one run being off almost 1 foot in the horizontal before it was caught. Also, as the distance from the laser to the target increases, heat generated in the tunnel can distort the laser beam.

To ensure proper alignment for gravity facilities, the laser positioning and targeting should be checked once per shift by a licensed surveyor. The surveyor can be supplied by the contractor, but the owner should also consider an independent verification. Microtunneling support equipment around the pit should be positioned such that a line of sight from control points some distance from the pit can be utilized. The requirement to check the laser and targeting once per shift needs to be clearly spelled out in the contract documents. The checking operation takes anywhere from 30 to 90 minutes which, if not coordinated with the contractor's operations, is a significant amount of down time.

One last issue the designer should consider for a microtunneling project is a tool for dispute resolution. Two tools the District is familiar with are Partnering and a Disputes Resolution Board (DRB). A DRB is a three member panel of experts in the particular field of construction. One member is selected by the owner, one member by the contractor, and the two selected members pick the third member. The DRB keeps apprised on project progress and recommends solutions/compromises to the situations brought before the DRB by the contractor or owner. An alternative to the DRB is to use a tool known as Partnering. Partnering establishes joint goals between the owner and the contractor in order to establish a cooperative atmosphere in executing construction of the project and to avoid disputes. Anytime a tunnel project is contemplated, the owner should seriously consider utilizing either a DRB or Partnering. (As a practical limit, an agency may want to set a dollar limit such as $5 million as a cutoff for deciding whether or not to use a DRB.) Having the specifications require the contractor to enter into an agreement utilizing a DRB or Partnering usually results in more favorable bids to the owner since some of the inherent risk associated with tunneling is being shared by the owner and the contractor. Either tool provides the contractor with some assurances that if unforeseen circumstances occur (such as changed site conditions or the equipment gets stuck), there is a mechanism in place to see that he can get financially compensated. From the agency perspective, these tools cut down on claims without merit and reduces the need to go to court. The District has utilized both methods of dispute resolution successfully on several projects.

Microtunneling is a useful tool for installing pipes in congested areas such as the Moraga Way project. Alignment investigation, alignment characterization, geotechnical issues, equipment/material considerations, environmental issues, and the other miscellaneous issues described above are considerations that need to be addressed to improve the chances for a successful project.

PIPE USERS GROUP OF NORTHERN CALIFORNIA
SHARING TECHNOLOGIES SEMINAR

Learning from Disaster:
The City of Livermore's Trunk Sewer Rehabilitation Project

Mr. Bill Adams, City of Livermore
Ms. Laura Johnson, City of Livermore
Mr. Marc Solomon, Winzler & Kelly

ABSTRACT

In 1994, the City of Livermore experienced a catastrophic failure when internal pipeline corrosion led a reinforced concrete trunk sewer to collapse. The situation presented enormous hazard and required bypass pumping until a repair could be completed. The event triggered a comprehensive evaluation of the East Trunk Sewer system, with the intent of affecting necessary repairs ahead of the sinkholes.

A corrosion evaluation of the East Trunk Sewer system offered the City the ability to see the internal condition of the pipeline, much like CCTV, and the ability to measure the inside profile using the Sonex Caliper. This measurement device detected internal corrosion before cracks and breaks appeared. The evaluation guided the City's repair strategy based on a known pattern of failure.

With the results of the corrosion survey, the City and their consultant designed a mile of large diameter trunk sewer improvements. The City faced typical urban construction conditions; busy streets, little room for relocation and the need to maintain service. The final design solution employed a variety of trenchless technologies, including PVC sliplining and grouting. For one reach, a 29.5-inch PVC pipe was sliplined into a 33-inch RCP trunk sewer. Special grout specifications were developed for grouting long distances with tight annular spaces.

To minimize the impacts of bypassing large flows (7,000 gpm), an innovative solution was developed. The bypass piping was slipped into an adjacent 30-inch storm drain and then routed to a downstream sanitary sewer.

PROJECT HISTORY

The City of Livermore is located east of San Francisco in eastern Alameda County. The City is situated along Highway 580 between Highways 680 and 5. The City operates and maintains 207 miles of sanitary sewer collection system. The collector sewers drain to three major trunk systems, the North, South and East trunks, which drain to the City's Water Reclamation Plant located on at the northwest edge of the City limits. The majority of the sewer system is constructed of reinforced concrete pipeline. Much of the trunk sewer system is forty years old. In 1994, the City experienced a catastrophic failure of its East Trunk Sewer system at the intersection of Pine Street and Rincon Avenue. Internal corrosion of the 24-inch reinforced concrete pipeline (RCP) installed in late 1950s resulted in collapse of the pipeline and the street section above. As a result of this the City developed a proactive maintenance program aimed at assessing the condition of its trunk sewer system, identifying high risk areas, increasing preventive maintenance and programing planned capital expenditures for sewer system rehabilitation.

The City of Livermore's Trunk Sewer Rehabilitation Program has three main goals:

- To correct a series of collection system layout problems that had contributed to failures, such as the collapse at Pine Street and Rincon Avenue

- To assess the condition of the remainder of the East Trunk sewer and take proactive measures to prevent failure, and

- To use the lessons learned from the East Trunk sewer to schedule preventive maintenance in the remainder of the trunk system.

Achieving these three goals resulted in the development of an innovative monitoring and maintenance program and rehabilitation of 5,000 feet of RCP varying in diameter from 24 to 39 inches in 1996. The City of Livermore teamed with Winzler & Kelly Consulting Engineers of San Francisco and Sonex, LTD of Seattle, Washington to develop an innovative approach to this challenging rehabilitation project.

THE SONIC CALIPER STUDY

Evaluating a sewer line for evidence of internal corrosion required application of a unique technology that allowed the City to see a "map" of the internal diameter of the pipeline. Conventional CCTV technology allows an operator to see existing cracks, breaks and root intrusion. The "map" produced by sonic caliper technology allows the City to predict areas that may fail soon based on reduction of the internal diameter of the pipeline and potential exposure of reinforcing steel.

The City of Livermore began their sewer assessment on the East Trunk Sewer. The failure at Pine and Rincon Streets had highlighted that this system was vulnerable to internal corrosion. The assessment of Livermore's East Trunk Sewer involved the use of the ROTATOR Sonic Caliper, operated by Sonex, LTD. This device has an ultrasonic transducer that rotates 360 degrees for every linear foot of pipeline. The

ROTATOR uses sonic distance measurements to map the inside circumference of the pipeline. This technology typically takes 50 readings per foot and can resolve distance measurement to within 0.05 feet. The raw data is reduced and can be plotted showing a profile of the crown or springline of the pipeline or a cross section of the pipeline at chosen intervals. Figure 1 illustrates two types of plots. For the City of Livermore's study, a CCTV camera was mounted on a skid with the sonic caliper. This allowed the City to evaluate both the television images and the sonic caliper data. This type of mounting presented some minor difficulties during the field work, but proved to be a valuable way to assess anomalies in the sonic caliper plots.

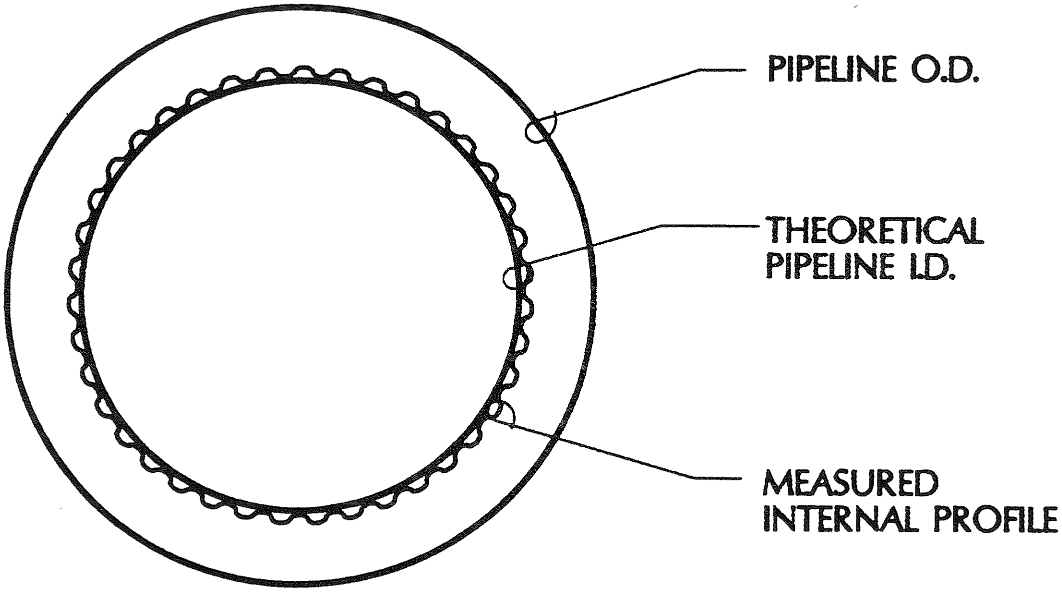
The assessment of the East Trunk Sewer provided more than valuable information on pipe condition. Conducted over a two week period, the study phase served to train City staff in the use of the sonic caliper tools. The City plans to continue condition assessments into the North and South Trunk sewers as an important part of its preventive maintenance. The lessons learned in the East Trunk assessment will assist in budgeting, scheduling and executing future maintenance activity.

CONDITION ASSESSMENTS

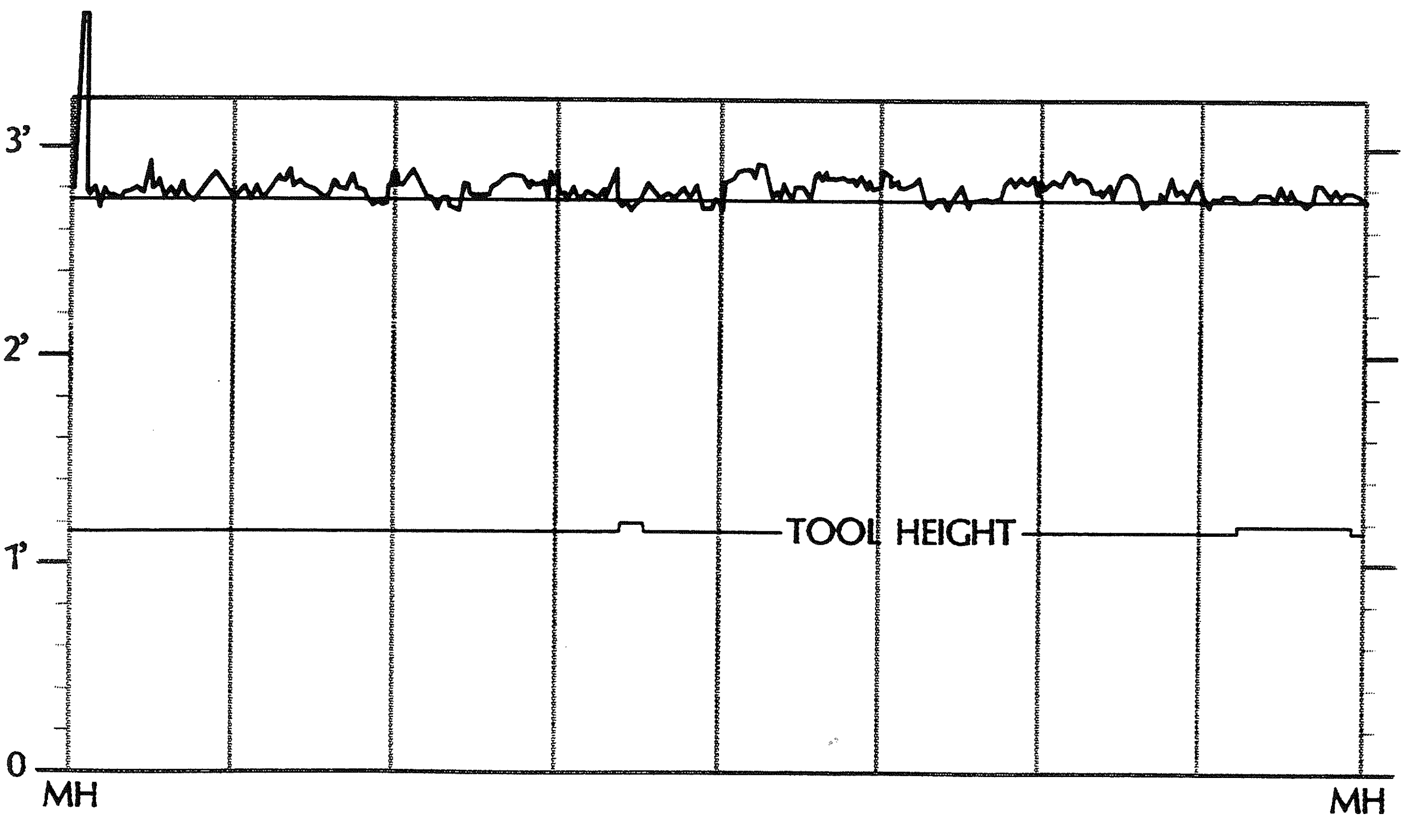
The sonic caliper study provided the City with very high quality raw data on which to base a "Condition Assessment" of its trunk sewer. In general the pipelines presented a uniform pattern of corrosion equally distributed from springline to springline. The City was fortunate that the study did not reveal more disasters waiting to happen. However the lack of immediately obvious problems made the task of condition assessment more challenging. In order to prioritize rehabilitation projects and schedule maintenance activities, three categories of pipeline condition were established:

> Pipes in "Fair Condition" displayed little or no corrosion. Routine cleaning and inspection of these sewers will allow them to provide reliable service.
>
> Pipes in "Moderate Condition" displayed some corrosion or structural defects but do not require immediate rehabilitation. These defects can include moderate roots and closed cracks. Pipelines in moderate condition will be subject to more frequent CCTV inspections as well as routine cleaning.
>
> Pipes in "Poor Condition" display severe corrosion. These sewers require rehabilitation to prevent collapse.

The RCP used for sewer construction in Livermore has a typical cover of 1" over its reinforcing steel. When the sonic caliper study detected loss of more than 3/4-inch of this cover, the pipeline was a candidate for rehabilitation. Of the 5000 feet of trunk sewer studied, Livermore found approximately 650 feet in three locations in Poor Condition. Another 875 feet was considered in Moderate Condition. Figure 2



PIPELINE CROSS SECTION



PROFILE OF PIPELINE REACH

FIGURE 1
TYPICAL SONIC CALIPER OUTPUT
PUG "SHARING TECHNOLOGIES"
ADAMS, JOHNSON, SOLOMON

illustrates the Condition Assessment through the study reach.

Livermore was also able to utilize the SONEX data to predict the remaining life of its sewer pipeline. By dividing the observed corrosion over the 40-year service life of the sewer, an annual corrosion rate could be calculated. By interpreting this annual rate, one can predict when the 3/4-inch cover loss is most likely to occur. Based on these predictions, the City can accelerate its routine observations in vulnerable reaches and predict its capital repair needs.

Clearly the sonic caliper technology can be useful in many applications. It augments the information provided by a CCTV study and allows careful evaluation of the remaining service life of sewer trunk lines. When the data is utilized to calculate an annual corrosion rate, sewer planning and operation staff gain a valuable tool for predicting the "weak spots" in their collection system, intensifying their regular maintenance and observation work and budgeting their capital improvement needs.

PINE STREET AND RINCON AVENUE CORRECTION

The East Trunk sewer immediately adjacent to the Pine Street and Rincon Avenue intersection is a 24-inch RCP installed in the late 1950s. The downstream pipeline includes a 33-inch diameter stretch, reducing to a 30-inch diameter stretch and increasing again to a 39-inch diameter stretch. The system was installed cross country, as necessary, to keep up with planned development. When this development occurred, a stretch of the East Trunk sewer ended up in backyard easements, surrounded (and sometimes directly beneath) swimming pools, landscaping, decks, fences and walls. This irregular installation resulted in more than a few problems including the loss of several manholes (all above ground evidence has simply been obliterated by zealous landscapers) and difficult maintenance.

The internal corrosion failure at Pine and Rincon was attributed to a series of bends at the intersection necessitating five manholes and an 11-foot drop through one of these manholes. These conditions resulted in very turbulent flow which released hydrogen sulfide gas. In the presence of oxygen, the gas forms sulfuric acid which tends to corrode the crown of the unprotected RCP trunk. Correction of the situation focused on achieving the following objectives:

- Improved hydraulics by improving steady-state flow conditions. This included minimizing bends in the trunk sewer and eliminating "counter" merging collector flow. The mainstream flow (flow in the trunk sewer) should have the least bend and the smallest turning angle. Merging flows should be at an acute angle (less than 90 degrees and preferably less than 45 degrees).

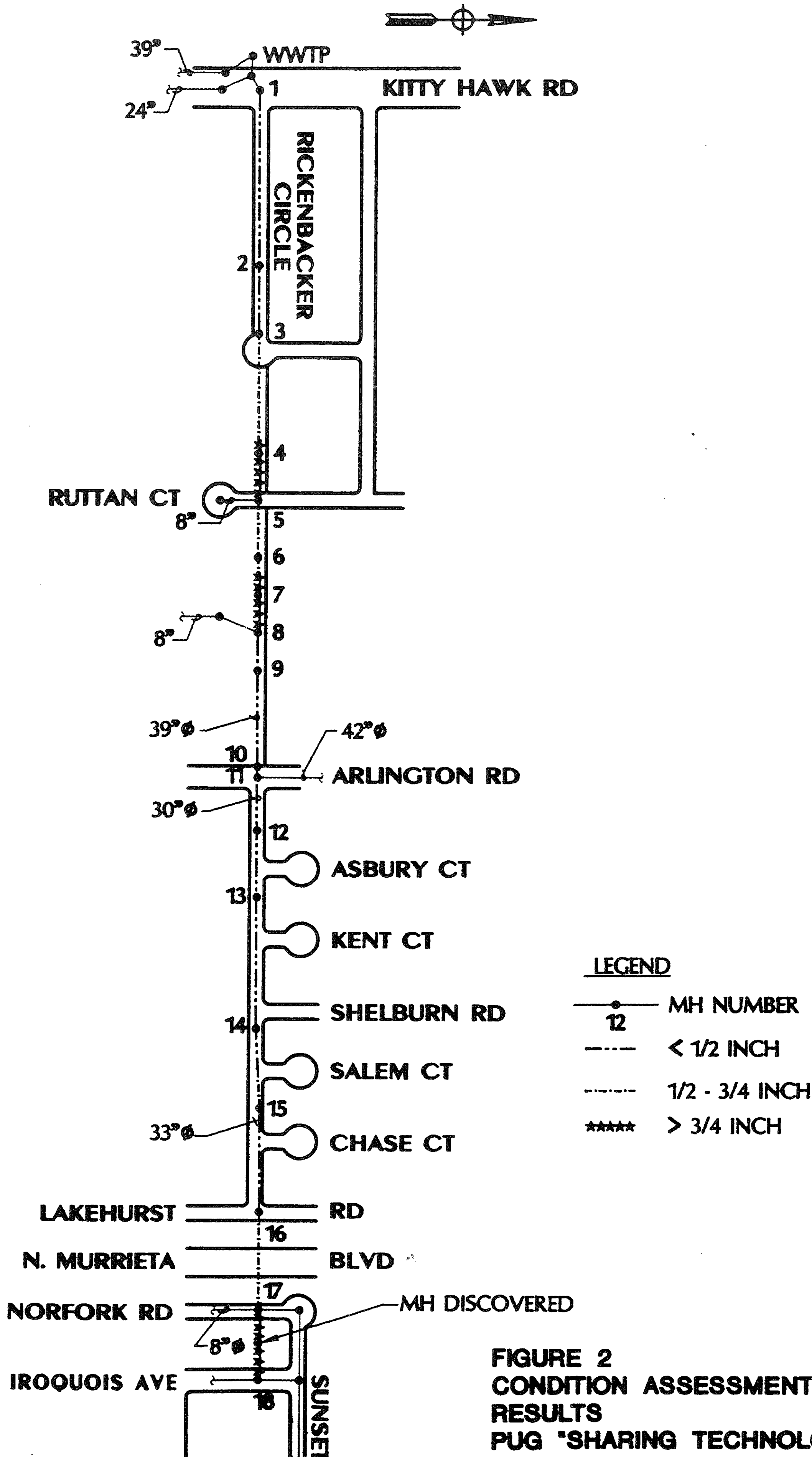


FIGURE 2
CONDITION ASSESSMENT RESULTS
PUG "SHARING TECHNOLOGIES"
ADAMS, JOHNSON, SOLOMON

Q:\CF\PRESENT\POWERPNT\P7220002\PWRFIG2.DWG 2/13/97

- Reduced vertical manhole drops. The 11-foot free fall drop in the current collection system configuration was a direct contributor to release of hydrogen sulfide.

- Reduced number of manholes

- Minimal interferences with existing utilities. Any sewer trunk and collector had to clear existing utilities in the intersection including 24-inch and 18-inch RCP storm drains and 8-inch water line.

- Constructability and cost. The ability to construct while maintaining flow affected the construction cost and public convenience. The emergency repair work at the Pine and Rincon intersection required several days of round the clock pumping, which hadn't endeared the City to the neighborhood. Minimizing bypass pumping was an important public relations concern.

- Compatibility with the East Trunk Sewer Masterplan. The City of Livermore wished to eliminate the cross country sewer lines and standardize the sizing of the East Trunk Sewer. Work in the Pine and Rincon intersection needed to be consistent with this goal.

Based on these goals, three main conceptual alternatives were developed to correct flow conditions through the intersection. The first alternative used the existing alignment and reduced the number of horizontal bends from 3 to 2. The second and third alternatives utilized new pipeline alignments and reduced the number of horizontal bends from 3 to 1. All alternatives reduced the vertical drop. The alternatives were evaluated based on the five criteria listed above and construction cost . The Ranking Matrix is illustrated in Table 1.

THE RECOMMENDED PROJECT

The results of the Pine and Rincon analysis were combined with the results of the sonic caliper analysis to develop a project which greatly assisted the City in implementing its East Trunk Sewer Master Plan. A project was developed that implemented Alternative 3 from the Pine and Rincon analysis, rerouted the main East Trunk Sewer out of the back yards and sliplined a vulnerable piece of the old East Trunk Sewer to serve as a collector sewer.

In addition, because a portion of the East Trunk Sewer has been rerouted, the capacity requirements for several other vulnerable sections of pipeline have been reduced. This allows the City to consider sliplining, cured-in-place or other trenchless technologies as options for rehabilitating the reach, since trunk main size is no longer a critical concern. As neatly as the eventual project came together, there were still several challenges for

TABLE 1

CITY OF LIVERMORE TRUNK SEWER REHABILITATION PROJECT

Evaluation Matrix
Pine Street and Rincon Avenue Correction

Evaluation Criteria	Evaluation Sub-Criteria	Alternative 1		Alternative 2		Alternative 3	
		Rating	Score	Rating	Score	Rating	Score
Improve Hydraulics	Eliminate Vertical Drop	Good	2	Good	2	Good	2
	Number of Bends	2 Bends	1	1 Bend	2	1 Bend	2
	Merging Angle of Collector	110 deg	0	40 deg	3	60 deg	2
Minimize Manholes	Resulting Number of Manholes	5	1	6	0	4	3
Minimize Rerouting	Number of Utility Relocations	0	1	0	1	0	1
Constructability	Need Temp Bypass in Trunk	Yes	1	No	3	No	2
	Need Temp Bypass in Collector	No		No		Yes	
	Estimated Construction Cost	15000	2	36000	1	29000	1
	Area of Road Closed	2450 sf		4450 sf	0	2400 sf	0
	Duration of Road Closed	4 wks		8 wks		8 wks	
Compatible to Master Plan	Consistent with Trunk Line Alignment	No	1	Yes	2	Yes	2
TOTAL SCORE			11		14		15

Score: 3 = Excellent; 2 = Good; 1= Fair; 0= Poor the design team, the operations staff and the construction contractor.

CONSTRUCTION EXPERIENCE

Construction of the East Trunk Sewer Rehabilitation project involved resolving several technical challenges in a manner that was cost-effective and minimally disruptive to the surrounding neighborhood. Trenchless technology was employed to minimize the disruption related to rehabilitating a piece of the 33-inch trunk sewer. Careful analysis showed that the pipe in question could provide adequate capacity with an inside diameter of 29.5 inches. Both sliplining and cured-in-place technologies provided feasible construction alternates.

The sliplining alternate required careful specification of a grout mix that could seal the annular space between the 29.5 inch liner pipeline and the 33-inch trunk sewer. Because of the logistics of the project, the grout needed to be placed in continuous runs of up to 1000 feet. The final performance-based specification for the project included a grout mix that met these stringent criteria. The specification is now available to the Pipe Users Group.

In order to obtain the best value for the City of Livermore, several trenchless technologies were bid against one another. The construction contractors were allowed to use cured-in-place lining, sliplining with PVC or sliplining with HDPE. The low bidder used sliplining with flushbell PVC pipe. This material had the advantage of lowest first cost and also minimized the bypass pumping requirements. A majority of the sliplining operation was conducted in live sewer mains. Installing the PVC liner in this manner simplified the construction contractor's operation and minimized neighborhood disruptions.

Even with the advantages of the PVC slipliner, a certain amount of by-pass pumping was necessary and an innovative technique was employed. Typically bypass pumping requires the installation of above ground hose, which infringes on either the working area or the traveled way. In Livermore, we were able to use a variation of trenchless technology to avoid this situation and make the best use of a nearby storm drain utility. Bypass sewer flows were pumped through a 10-inch HDPE pipe which was slipped down a catch basin into a 30-inch diameter storm drain. The bypass pipe ran several thousand feet through the storm drain and was slipped out a catch basin and back into the sewer at the termination of the project. This solution allowed the bypass piping to be well protected during the entire construction operation, provided clear working areas and minimized traffic impacts.

The final construction costs for the trunk sewer rehabilitation project averaged $200 per linear foot. This included all traffic control, bypass pumping and tributary pipeline modifications as well as the rehabilitation of a large diameter trunk sewer and overlays of the neighborhood streets. In this application, the trenchless rehabilitation method compared very favorably with a dig and replace situation. In addition, the City of Livermore was able to minimize traffic impacts and neighborhood disruption and avoid utility conflicts by reusing the existing trunk line.

SUMMARY

Sonic Caliper technology allowed the City of Livermore to see pipe failure prior to its occurrence. Because of this, trenchless technologies that utilized the existing pipe structure could be cost effectively employed to achieve the City's goals for its East Trunk Sewer. In addition, the analysis allowed the City to calculate its anticipated annual corrosion rate along the full reach of the East Trunk Sewer. The predicted corrosion rate provides a valuable tool for directing maintenance activities and for planning future capital needs.

Livermore will be continuing a program of sonic caliper assessment in its North and South Trunk sewer system. The program will augment the tools the City has for providing efficient, effective preventive maintenance in its collection system. The Livermore Trunk Sewer project can be used as a model for any service area where long reaches of sewer collection system sized for future development present a risk of internal corrosion failure.

Northern California Pipe Users Group

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Delta Diablo Sanitation District
Dublin/San Ramon Services District
Lawrence Livermore National Laboratory
City of Oakland
County of Sacramento
City of San Francisco
City of San Jose
City of Santa Rosa
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