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CIVIL ENGINEERING

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DEPARTMENT OF TRANSPORTATION

JOINT HIGHWAY RESEARCH PROJECT
Final Report
FHWA/IN/JHRP - 91/14

REPAIR/REHABILITATION OF
DETERIORATED DRAINAGE PIPE

B.G. McCullouch

PURDUE UNIVERSITY

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DETERIORATED DRAINAGE PIPE

B.G. McCullouch

TO: Kumares Sinha
Joint Highway Research Project

April 30, 1992
Project:C-36-62H

From: Bob G. McCullouch
Research Engineer

File: 9-8-8

This letter serves as a transmittal for the Final Report titled "Repair/Rehabilitation of Deteriorated Drainage Pipe." It was prepared by Bob G. McCullouch and represents the work of the study advisory committee and Bob G. McCullouch.

This report serves as a study document for various methods and techniques for repairing drainage pipe. The report contains four chapters. Chapter 1 contains background information on the problem and describes the scope of the study. Chapter 2 describes the various rehabilitation and replacement methods currently used. Chapter 3 is a summary and analysis of the DOT Rehab survey performed. Chapter 4 is a discussion on INDOT rehabilitation options and considerations for expanding current capabilities. The Appendix contains summaries for the state survey responses.

This report has been reviewed by the committee with their comments incorporated within.

Sincerely,

Bob G. McCullouch
Research Engineer

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Final Report

Repair/Rehabilitation of Deteriorated Drainage Pipe

by

Bob G. McCullouch

Joint Highway Research Project

Project No.: C-36-62H

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Prepared for an Investigation
Conducted by the

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Purdue University

In cooperation with the
Indiana Department of Transportation
and the
Federal Highway Administration

The opinion, findings and conclusions expressed in this publication are those of the author and not necessarily those of the Indiana Department of Transportation or the Federal Highway Administration

Purdue University
West Lafayette, Indiana

April 30, 1992
Final Report

TABLE OF CONTENTS

LIST OF TABLES	ii
LIST OF FIGURES	iii
Chapter 1 Introduction	1
1.1 Study Objectives	1
1.2 Study Activities	3
Chapter 2 Rehabilitation Methods	4
2.1 Open Trench Replacement	4
2.2 Chemical Grouting	6
2.2.1 Application Methods	7
2.3 Cement Mortar Lining	9
2.3.1 Application Method	9
2.4 Reinforced Shotcrete	11
2.4.1 Application Method	11
2.4.2 Pipe Problem Applicability	12
2.5 Pipe Insertion - Slip Lining	12
2.5.1 Pipe Insertion Material	13
2.5.2 Application Method	15
2.5.3 INDOT Slip Lining Procedure	17
2.6 Resin Impregnated Fabric	21
2.6.1 Insertion Material	22
2.6.2 Installation Procedure	22
2.7 Micro-Tunneling	23
2.8 INDOT Pipe Rehabilitation Capabilities	25
Chapter 3 DOT Pipe Rehab Survey Analysis	26
3.1 Rehab Costs	26
3.2 Replacement Costs	27
Chapter 4 INDOT Rehabilitation Options	30
References	32
Appendix	33
Technical Summary	72

LIST OF TABLES

Table

2.1	Methods Summary	5
2.2	Rehabilitation Equipment Needs	25
4.1	Rehabilitation/Pipe Material Matrix	31

LIST OF FIGURES

Figure

2.1	Chemical Grouting Procedure	7
2.2	Remote Grouting Procedure	8
2.3	Remote Grouting Setup	8
2.4	Cement Lining Operation for Small Diameter Pipes . . .	10
2.5	Cement Lining Operation for Larger Diameter Pipes . . .	10
2.6	Pull Technique	16
2.7	Push Technique	16
2.8	Insituform Process	23
2.9	Microtunneling Pipe Replacement	24

Chapter 1

Introduction

Deteriorated, damaged drainage pipe poses a potentially serious threat to the roadway, right-of-way, and adjacent areas affected by improper drainage. In these cases either replacement or rehabilitation is necessary to insure continued drainage control and serviceability of the roadway. Traditionally the most common repair method has been replacement requiring an open trench. This method causes a disruption in the normal traffic pattern and inconveniences to roadway users. Other repair and rehabilitation methods exist that are performed in-place, allow for continued roadway use and should be considered before a decision is made on pipe repair.

Currently the Indiana Department of Transportation (INDOT) has a comprehensive annual pipe inspection program that identifies troublesome drainage pipe. Some of this pipe is being rehabilitated in-placed with a plastic slip liner product by INDOT maintenance crews. This method is described later in this report. Other in-place methods exist and should be considered by INDOT. This report describes current technologies that are being used for in-place pipe rehabilitation.

1.1 Study Objectives

To guide the study several objectives were established by a

Study Advisory Committee and followed. Members that comprised this committee were:

Professor Bob McCullouch, Chairman, Purdue;

Mr. Richard K. Smutzer, INDOT;

Mr. Timothy D. Bertram, INDOT;

Mr. Doug Lawrence, INDOT;

Mr. Yi Jiang, INDOT, and;

Mr. Steve Toillion, Federal Highway Administration
(FHWA).

Objectives established by this committee were:

1. Identify the current technologies, methods, and materials in drainage pipe rehabilitation and replacement;
2. Determine the suitable pipe types for each method;
3. Develop cost comparisons between the various methods;
4. Determine what methods can be performed by INDOT personnel and equipment, and requirements for special equipment, and;
5. Recommend methods for various pipe types based on applicability, cost, and constructability.

1.2 Study Activities

To accomplish these objectives two activities were performed.

They were:

1. Accumulate technical and cost information on current pipe rehabilitation methods, and;
2. Survey and review other Department of Transportation (DOT) pipe rehabilitation programs.

For the first activity, a search of various technical publications, organizations, and related companies was performed. This information was accumulated, studied, and promising contacts followed up on.

The second activity consisted of a written survey of other DOT organizations within the United States. Fifty organizations were contacted(49 states plus D.C.) and thirty-five responded to the survey. Survey results were recorded in a dBase III+ database for analysis. A summary of the survey responses along with the survey response form is located in the Appendix.

Chapter 2

Rehabilitation Methods

The current available rehabilitation methods fall into one of the following methods:

- Open Trench/Replacement
- Chemical Grouting
- Cement Mortar Linings
- Reinforced Shotcrete
- Pipe Insertion
- Resin-impregnated Fabric
- Micro-tunneling

Each of these methods will be explained and described. Table 1 summarizes their applicability, advantages, and disadvantages.

2.1 Open Trench/Replacement

In this method the existing damaged/deteriorated pipe is removed by opening up a trench; new pipe is set in-place and covered with fill material; and, road pavement is patched at the trench area. Traffic disruption occurs because of either a road or lane closure. Because of these disruptions and the presence of an open trench, a potentially dangerous site exists. Utilities and other services are often encountered by the open trench creating further complications with this method. This method is usually performed by a DOT crew or contractor with costs dependent on trench size and depth . This is the only method appropriate for all pipe types

Method	Description	Application	Advantages	Disadvantages
Excavation and replacement	Total Replacement in original trench.	Any pipe with major structural defects.	Increase pipe capacity.	Most disruptive method physically and time-wise.
Chemical grouting	Application of grout to patch leaky joints and, in some cases, cracked pipe. Usually injected behind a packer.	Used to control infiltration/inflow	Cost less than replacement. No excavation needed. Low flows tolerated.	Does not improve structural strength; can fail if dehydrated. Difficult to seal packers where surface is irregular. Point repairs may be required.
Cement mortar linings (several application methods)	Cement mortar is applied, either by spraying or with a mandrel. In larger lines reinforcement is recommended.	Leading method for water pipe rehab. Also used for concrete sewer pipe.	Improves structural integrity.	Not recommended for corrosive liquids.
Reinforced shotcrete	After placement of steel reinforcement, a mixture of fine aggregate cement and water is applied by air pressure.	Large pipes needing structural repair.	Higher strength than cement mortar linings. Variations in cross-section readily accommodated.	Only suitable for larger pipes. Control of infiltration is required.
Pipe insertion (slip lining)	A liner pipe of slightly smaller diameter is inserted into existing pipe, then connected to service laterals.	Used where no major alignment distortions are present.	Less time, lower cost than excavation and replacement; minimum excavation and disruption.	Reduced cross-section.
Resin-impregnated fabric	Flexible liner installed, thermally hardened, cut by remote control.	Pipes of any geometry	Provides structural reinforcement. No excavation required.	Patented system handled by relatively few contractors. Site set-up costs are high. Not economical for small projects.
Microtunneling	On-line pipe renewal by using special tunneling shield equipment.	Can excavate, remove, and replace existing pipes made of concrete, clay, asbestos, and cement.	Removal and replacement performed in-place. Increase pipe capacity	Requires special tunneling equipment that is costly to operate.

Table 2.1
Methods
Summary

2.2 Chemical Grouting

Grouting with chemical grouts is the most efficient way to seal leaky joints and circumferential cracks in pipes. This method is used to control infiltration through the joints and cracks. Two types of grouts are used in this method; foam and gel grouts.

Foam grouts form an in-place gasket and cures to a rubber-like material. The injection pressure causes the grout to expand into the joint, thereby minimizing penetration to the area outside of the pipe. During the injection process the grout is catalyzed by water. Foam grout is more expensive and difficult to apply than gel grout.

Gel grouts flow through the joint and forms an exterior seal around the pipe. This allows for filling external voids that may have occurred due to infiltration. If large voids are suspected to exist then foam grouts should be used. One problem with this type of grout is that it is susceptible to dehydration and cracking caused by alternating wet and dry cycles. This can be mitigated to a certain extent by using the additive ethylene glycol.

Both grouts cannot improve the structural characteristics of a pipeline. So, this method should not be used when the pipe has shifted or settled. This method should be viewed as a quick fix rehabilitation to seal leaky joints and cracked sections.

2.2.1 Application Methods

Chemical grouting can be performed on a wide range of pipe sizes starting as small as 6 inch diameter. For the larger diameters where manned entry is available the application procedure is illustrated in Figure 2.1.

Figure 2.1. Chemical Grouting Procedure

In the smaller diameter pipes grouting is performed by using a piece of equipment called a packer with a TV monitoring system to locate the problem areas.. The procedure is illustrated and explained in Figure 2.2.

In both application methods a small amount of pipe flow is permissible. This repair method does not improve the structural pipe strength and can fail if the grouts become dehydrated. It becomes very difficult to seal with a packer if the inside surfaces are irregular. In that case manned entry is required for point patching.

STEP 1

STEP 2

STEP 3

STEP 4

1. The packer is pulled into the pipe to the leaky joint or crack.

2. The sleeves at each end are inflated to create a seal around the cracks.

3. Compressed air is pumped in to test the joint or crack. If it fails the test then grout is pumped under pressure to fill the void.

4. Packer sleeves are deflated and it is moved to the next suspect area.

Figure 2.2. Remote Grouting Procedure

Figure 2.3 shows an overall view of how the packer system operates.

Figure 2.3. Remote grouting setup

2.3 Cement Mortar Lining

Deteriorated interior surfaces of concrete pipe can be rehabilitated by using a cement mortar lining. This lining procedure is especially effective if pipe corrosion is a problem. It can be performed on a wide range of pipe diameters starting as small as 8 inch diameter.

Before the lining can be applied, the pipe must be thoroughly prepared by dewatering and cleaning and flow must be rerouted during the application of the cement lining material. The cleaning process removes debris and corrosive elements from the pipe.

2.3.1 Application Methods

Cement mortar can be applied either by a manual process or by using a centrifugal process. The most common method is centrifugal.

This process uses a lining machine that dispenses and trowels mortar onto the interior surface of the pipe. In small diameter pipes the machine is pulled through the pipe by a winch. Figure 2.4 illustrates this process.

Typical Cement Mortar Lining Operation in Pipes Less Than 24 Inches Diameter.
Courtesy Raymond International Builders.

■ LINING between access openings proceeds after the section of water main has been thoroughly cleaned.

Figure 2.4. Cement Lining Operation for Small Diameter Pipes

For larger diameter pipes, the process is the same but is usually controlled by a person on the lining machine. Figure 2.5 illustrates this process for larger diameter pipes.

Typical Cement Mortar Lining Operation in Pipes 24-Inches Diameter and Greater.
Courtesy Raymond International Builders.

Figure 2.5. Cement Lining Operation for Larger Diameter Pipes

Because this method restores the pipe interior it does improve its structural integrity. This method is not recommended if corrosive liquids may exist.

2.4 Reinforced Shotcrete

This effort requires manned entry, therefore it is limited to larger pipe sizes. Pipes should be larger than 36 inch diameter or clearance. Irregular pipe sizes can be rehabilitate in this method. This method restores structural integrity to deteriorated pipe by essentially constructing a new pipe within the existing one.

2.4.1 Application Method

The procedure consists of:

- a. The rehabilitate segment is isolated and all flow is diverted around the segment.
- b. Deteriorated materials, rust, oil, and scale are removed. The interior surface of the pipe is prepared for the reinforcing steel.
- c. Reinforcing steel is put in-place.
- d. Surfaces are dampened prior to shotcreteing to improve bonding and reduce the effect of shrinkage cracking.
- e. Shotcrete is applied behind the reinforcement before it accumulates on it.
- f. One layer of reinforcement is covered with the shotcrete per application.
- g. Shotcrete cover of the reinforcement is a minimum of 2

inches.

h. Finish is applied to the surface (gun, broom, float, trowel, etc.).

i. Curing - For the first 24 hours a moist condition must be maintained. Total curing time is 7 days, during which the temperature must be maintained above 40 degrees. Curing time can be reduced for early-strength cement.

2.4.2 Pipe Problem Applicability

This method should be considered for the following pipe problems:

- Pipe crown sag
- Reinforcing steel corroded or deteriorated
- Pipe joints defective
- Pipe joints leaking or offset
- Pipe cracked
- Pipe cement corroded

2.5 Pipe Insertion - Slip Lining

In this method, new liner material is pushed or pulled through the deteriorated pipe to form a new pipe within the existing one. Liner materials successfully used in this method are: extruded polyethylene, spiral-ribbed polyethylene, extruded polybutylene, reinforced plastic mortar, reinforced thermosetting resin, and ductile iron. Insertion material selection is based on application design needs, economics, and space requirements.

This method can be used to repair a variety of pipe problems.

However, this method cannot be used when the pipe has alignment distortions or is severely crushed or collapsed causing the inside of the pipe to be altered or reduced. This condition causes a restriction that prevents the liner material from being installed.

A major concern in this method is the effect of the reduced pipe cross-section on flow capacity. However, the insertion material usually provides improved surface smoothness that promotes better flow rates. The reduced pipe flow capacity should be analyzed before utilizing this method.

This method provides a minimum disruption to traffic and can be performed very quickly. See INDOT example in the next section. It can be cost effective depending on the application(see cost information section) and the type of liner material chosen. The liner material can be very expensive and may be the determining factor in choosing this rehabilitataion option.

2.5.1 Pipe Insertion Material

Extruded Polyethylene

This type of pipe material is normally available in 40 foot lengths. Available size ranges from 2 to 48 inches in diameter. It has excellent resistance to chemical and acid attack, however some chemicals such as gasoline, phenolics, and aromatic hydrocarbons can cause softening of the pipe walls.

Spiral-Ribbed Polyethylene

This pipe generally behaves the same as extruded. But there are some differences. These are:

- Diameters range between 4 and 144 inches and can come in varying lengths to meet installation requirements;
- Cross-section strength can be modified by varying the wall thickness and rib spacing thus providing differing pipe strengths.

Extruded Polybutylene

This pipe has basically the same characteristics as extruded polyethylene. The basic differences are:

- it has higher stress capacity (i.e. stronger);
- it retains more of its strength at higher temperatures;
- and, availability of different diameters is less.

Reinforced Plastic Mortar

The material is composed of resin-saturated strands of fiberglass and sand bound together by resin. This pipe usually comes in standard lengths of 20 feet and diameters between 18 and 66 inches. It possesses good resistance to chemicals and corrosion. It has a smooth surface which reduces friction losses and has high strength when compared to the previous pipe types.

Reinforced Thermosetting Resin

This pipe is very similar to reinforced plastic mortar. The material is different in that no sand is used. It is available in a wide range of sizes (4 - 192 inches in diameter) and lengths (up to 80 ft.). It has good structural strength and resistance to corrosion, erosion, and abrasion.

Ductile Iron

It has proven to be a very successful liner because of its strength which allows it to be pushed longer distances. It comes in a wide range of sizes (4 to 60 inches) and normally in 20 foot lengths.

2.5.2 Application Method

The slip lining procedure consists of:

- a. Clean the section of pipe to be rehabilitated by removing deposits, debris, and protrusions.
- b. Insert liner material either with the pull or push technique.
- c. Fill annular space between liner pipe and the existing pipe. Grout material is usually used.

The two insertion methods used are the "pull" and "push" methods.

The "pull" technique pulls the liner material through the pipe by a winch and cable system attached to a pulling head which the

liner pipe attaches to. Figure 2.6 illustrates this procedure.

Figure 2.6. - Pull Technique

The "push" technique can utilize either a backhoe, winch and cable assembly, or a jacking machine to insert the liner pipe. Figure 2.7 illustrates this method utilizing the backhoe and the winch assembly.

Figure 2.7. - Push Technique

After the pipe liner is inserted, then annular space between the liner and the existing pipe is filled with grout. A cement grout mixture is typically used to completely fill this void space. Manifolds are constructed at each end and grout is pumped into this from the upstream or high end. This continues until the grout exits at the lower end, indicating the annular space has been filled.

2.5.3 INDOT Slip-Lining Procedure

INDOT has successfully used this pipe rehabilitation method and realized its benefits. But unfortunately it has only gained popular acceptance in one district, the Vincennes district. To assist in promoting this method to the other districts, an explanation of it is described below by documenting an actual project.

The pipe rehabilitation job occurred on September 12 at a location on SR 231 approximately 1-1/2 miles south of Haysville, IN. The pipe to be rehabilitated was approximately 60' long, 15" in diameter, concrete at one end and steel at the other end. The probable reason for the different pipe material was the road had been widened so the new pipe extension was steel. The work started at 8:00 A.M. with a 6 man crew. A 4 man crew could have sufficed for this particular application. The liner pipe material used was extruded polyethylene 12" diameter with snap tite ends. The following pictures show the sequencing of the operations and the corresponding text describe it.

The required length of lining pipe is delivered to the job site either on a dump truck or on the flat bed carrying the backhoe. This photo shows the pipe at the site before the rehabilitation operations start.

In this photo INDOT maintenance personnel are using a backhoe to prepare the pipe adjacent to the headwall for a grout stand pipe. A hole is made in the top of the pipe. For concrete pipe this is done by using a pointed steel rod driven to puncture the pipe. For steel pipe a cutting torch is used to form a hole in the top. The grout stand pipe is inserted into this hole and grouted in. The stand pipe should be of sufficient height to accommodate the delivery and pouring of grout.

This next picture shows the grout stand pipe in place. A stand pipe is installed at each end.

This photo shows the workers manually pushing the first liner section in.

Pipe sections are joined by using chains and a come-a-long to snap the pieces together. This photo shows this process.

When the liner pipe cannot be pushed manually, a chain is placed around the pipe and tied to the backhoe. This picture shows the backhoe pushing in the liner pipe. At the completion of pushing, the liner should project out from the end 1' to 2' to allow for possible future expansion.

This final photo shows the packing of grout between the existing pipe and the liner pipe. This is allowed to cure for a couple of hours before the grout is placed into the stand pipe. This seals off the ends of the annular space and allows it to be filled with grout.

The final step in the process is to fill the space between the pipe sections with grout. The grout is ordered from a local concrete supplier and delivered to the job site. The grout is poured into the up-stream or high end stand pipe and continues until it starts rising in the lower one. After the grout has cured sufficiently the stand pipes are removed and the lining process is essentially complete.

2.6 Resin Impregnated Fabric

This process involves inserting a resin impregnated fabric into the rehabilitate section and cured in-place. This process was first called the "Insituform process" after the company that introduced it. Other companies have developed similar products and processes.

This method is a quick and clean way to rehabilitate most pipe problems. According to some publications, some structural problems, such as crushed, collapsed, or sagged pipe, cannot be corrected with this method due to the structural capacity of the

inserted material. However, a testing program conducted at Utah State University revealed some interesting structural information on this material. In 1988 field load tests on Insituform pipe were performed. Results from these tests revealed two interesting structural facts. One test compared two cracked concrete pipes under load with one pipe having been rehabilitated with the Insituform material. The rehabilitated pipe capacity was 150% of the cracked concrete pipe. Another test buried an Insituform pipe to determine its load capacity in its natural state. Test results indicated that a 5% deflection occurred under a load equivalent to a 40' burial depth. Most pipe designs require a minimum of 5% deflection at 30' depth, so Insituform pipe alone appears to possess significant structural strength capacity.

2.6.1 Insertion Material

The lining material consists of polyester felt with a bonded - on membrane backing impregnated with either a polyester or epoxy resin. Both are liquid thermosetting. Resin is typically applied to the felt within 24 hours of field installation and kept at low temperatures to prevent the resin from prematurely curing. This material is made into a tube the same diameter as the interior diameter of the rehabilitated pipe. Diameter capabilities range from 8" to 72".

2.6.2 Installation Procedure

Prior to inserting the lining material, the pipe is cleared of debris and the water flow is rerouted. The insertion process for the liner is described in the below Figure 2.8.

Figure 2.8. The Insituform Process

2.7 Micro-Tunneling

In this method a microtunneling machine removes the deteriorated pipe in-place and replaces it with new pipe material. Pipe that can be removed in this method include: reinforced concrete, clay, asbestos, cement, and glass reinforced plastic. The machines come in sizes ranging from eight to 36 inch diameters for removing and replacing different pipe sizes. A visual picture of this process is found in Figure 2.9.

The microtunnelling machines use rotary cutting heads to grind the old pipe and cut into the surrounding soil. The machines can operate in a wide range of soil types, clay to soft rock, because of a counterbalancing technique used. This technique maintains a constant pressure at the cutting head to prevent collapse by

utilizing slurry under pressure. The broken up old pipe and any surrounding soil is mixed into the slurry which is pumped to the surface where it is settled out in tanks. Then the slurry is circulated to the cutting head in the process.

The machine is moved ahead by pushing in new pipe behind it. Powerful hydraulic jacks in the push pit do the pushing. Depending on soil conditions, up to 1000 feet of pipe can be pushed from one pit before utilizing a new push pit.

Figure 2.9. Microtunneling Pipe Replacement

One unique advantage associated with this method is new pipe is being installed and pipe capacity can be increased. None of the other in-place rehabilitation methods can provide this.

2.8 INDOT Pipe Rehabilitation Capabilities

Seven rehabilitation methods have been described in this chapter. In each of these at least one application method has been described along with the required equipment. The following table summarizes the equipment requirements and INDOT capabilities.

Rehabilitation Method	Special Equipment	INDOT Capability
Open Trench Replacement	Backhoe, Excavator, Compactor, Paving	Yes
Chemical Grouting	Hand-held probe, packer device	No
Cement Mortar Linings	Special Lining Equipment	No
Reinforced Shotcrete	Applicator - Grout mixer, pump, hose, and cement gun	No
Pipe Insertion	Backhoe, torch, come-a-long	Yes
Resin-Impregnated Fabric	Special truck equipped to pump cold water into the liner that installs it and then circulates warm water to set the resin.	No
Microtunneling	Microtunneling Pipe replacer	No

Table 2.2 Rehabilitation Equipment Needs

Chapter 3

DOT Pipe Rehabilitation Survey Analysis

Summaries of the state DOT responses are in Appendix A. All states were contacted and thirty-five responded. Analyzing these responses provides some useful information in this study.

One is that even though these rehabilitation technologies have been in existence for some time, approximately half the states still only replace with no rehabilitation program in-place. The other half both replace and rehabilitate in-place with some of the methods described in this report. The most commonly cited in-place rehabilitation methods used are the slip-lined and the instituform process or the resin-impregnated process.

Reviewing the cost information reported on the surveys reveals some cost consistency among the various rehabilitation methods. This cost information is summarized by using the following facts:

3.1 Rehabilitation Costs

1. Plastic slip-liner

12"	-	\$15/LF	-	Polyethylene
14"	-	\$32/LF	-	Polyethylene
15"	-	\$25/LF	-	\$30/LF
18"	-	\$39/LF	-	Polyethylene
20"	-	\$30/LF	-	\$48/LF
22"	-	\$44/LF		
24"	-	\$50/LF		
36"	-	\$91/LF	-	\$146/LF
42"	-	\$75/LF	-	\$145/LF - Polyethylene
48"	-	\$140/LF		

2. Metal Insert pipe

24"	-	\$55/LF
36"	-	\$62/LF

3. Steel Arch Pipe

\$400/LF - No size indicated
Replacement cost = Pipe material cost(PMC) + 2.5*PMC

4. Small Culvert

24"	-	\$46/LF	-	Butt fused
30"	-	\$67/LF	-	Butt fused
36"	-	\$88/LF	-	Butt fused
42"	-	\$83/LF		

3.2 Replacement Costs

<u>Pipe Type</u>	<u>SIZE(Inches)</u>	<u>COST/LF</u>
Concrete	12	\$10
	15	\$26
	18	\$24-\$28
	24	\$21-\$31
	30	\$43
	36	\$33-\$57
	42	\$64
	48	\$45-\$75
	60	\$78
	72	\$103
Clay	15	\$26
	18	\$28
	36	\$57
	48	\$75
Coated Metal	12	\$12
	15	\$26
	18	\$26-\$28
	24	\$20-\$28
	30	\$26-\$43
	36	\$33-\$57
	42	\$35-\$108
	48	\$40-\$141
	54	\$46
Noncoated metal	12	\$16
	15	\$18
	18	\$17-\$21
	24	\$18-\$27
	30	\$30
	36	\$28-\$36
	48	\$38
Plastic	8	\$7
	12	\$11
	18	\$12
	24	\$22
Steel Arch Pipe	15	\$24
	18	\$34
	36	\$65
	48	\$103
	17x13	\$18
	24x18	\$22
	28x20	\$19
	42x29	\$29
	57x38	\$39
	35x24	\$21
	50sf waterway	\$400
	100sf waterway	\$600
	125sf waterway	\$720
Small Culverts	36	\$80
	48	\$90-\$150 (plate, box)
	5'x3'	\$93
	6'x4'	\$115
	7'x4'	\$143

Comparing costs between rehabilitation and replacement reveals that replacement costs are lower for each similar size comparison. The %cost differential varies from 10-300%. Why then consider rehabilitation at all if the cost differential is this much? The reason is that several other factors should be considered before basing the decision strictly on these unit cost figures.

These factors are related to site conditions and impact factors caused by replacement. One site condition is the depth of pipe below roadway. Certainly at greater depths unit costs will increase. Greater depths means a wider trench at road surface which poses a greater safety hazard while opened. An open trench means either a road or lane closure which impacts traffic flow and motorist plans and habits. This could also affect local businesses because changes to driving patterns could deter or alter customer habits and access. Another important consideration is that pavement settlement will most likely occur at the trench location creating a possible long term maintenance problem and roadway hazard. Another major consideration is the extra time involved in replacement. A replacement project that takes several days or a week could be performed in one day by some of these replacement methods. These larger replacement projects usually go out to contract so there is extra time involved in the bidding and document preparation. And the larger projects are usually not performed by state maintenance personnel. Whereas the same project rehabilitated could employ state maintenance forces.

The only rehabilitation method that has sufficient historical cost information is slip lining. Costs for the other methods

described in this report were not obtained. One explanation for this is that these methods require specialized equipment whose operating costs determine installed unit costs. Unit costs would depend upon project size and length. For small specialized applications unit costs would be significantly higher than on large projects with long or many sections. Some of these specialized vendors were contacted to obtain unit cost information and they refused to do so for these reasons.

Some of the newer methods, such as the "Instituform process" or the microtunneling pipe replacer utilize specialized expensive equipment. Unit costs vary significantly depending on how long the equipment is utilized. For example, the microtunneling machines cost between \$500,000 to \$1,000,000. Utilizing these expensive machines may cause unit costs in this method to be as much as five times that for open trench. However, in some cases it may be less expensive.

Chapter 4

INDOT Rehabilitation Options

Table 4.1 is a matrix that indicates the appropriate rehabilitation method for the various pipe material types.

Rehabilitation Method	1	2	3	4	5	6	7
Pipe Type							
Concrete	x	x	x	x	x	x	x
Clay	x	x	x		x	x	x
Coated Metal	x	x			x	x	
Non Coated Metal	x	x			x	x	
Plastic	x	x			x	x	
Steel Arch Pipe	x			x			
Small Culverts	x		x	x	x		

Table 4.1 - Rehabilitation Method/Pipe Material Matrix

Key

1. Replacement
2. Chemical Grouting
3. Cement Mortar Linings
4. Reinforced Shotcrete
5. Pipe Insertion
6. Resin-impregnated Fabric
7. Micro-tunneling

Table 2.2 points out that INDOT currently can only perform the

replacement and pipe insertion or slip lining options. This is limiting INDOT capability and options on performing pipe rehabilitation. Perhaps INDOT needs to consider developing the capability in some of the other options, particularly chemical grouting, mortar linings, and reinforced shotcrete. These do not require the investment in expensive equipment as the "institufarm" and microtunneling processes. INDOT should look into these options and perform an economic analysis on each to determine their feasibility. In chapter 3 there are no costs for these options and the reason is explained. When comparing replacement versus slip lining the cost differential can be considerable. Having other capabilities may provide a more economical solution.

These other options will require equipment investment. One way to achieve a return on this investment is to train a crew and provide it equipment that can be used on a statewide basis. If there is considerable pipe rehabilitation ahead for INDOT options other than replacement and slip lining should be investigated further to determine their economic and practical viability.

References

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Appendix

HIGHWAY DRAINAGE PIPE & CULVERT REHABILITATION

SURVEY FORM

State: _____

Person of Contact:

Name _____

Title _____

Address _____

Phone _____

Please Return to:

Bob McCullouch

Dept. of Civil Engineering

Civil Engineering Bldg.

Purdue University

West Lafayette, IN 47907

317/494-0643

Drainage Pipe
Material:

Current Rehab
Method (Note
Special Equipment):

Installation Cost
(Unit Cost):

Concrete

Clay

Coated Metal

Noncoated Metal

Plastic

Steel Arch Pipe

Other

Small Culverts

Dear Sir:

Currently I am performing a study for the Indiana Department of Transportation to investigate rehabilitation methods and associated costs for highway drainage pipe and small culverts. This study will ultimately provide a comparison of the various rehab methods in terms of economy and efficiency.

As part of my study, I am conducting a nationwide survey of state highway or transportation departments to determine the rehab methods currently used in each state.

Please indicate on the enclosed form a person of contact, the rehab method for each type of drainage pipe material and small culverts, and the installation costs associated with each method and material type.

Your response is greatly appreciated and will be most beneficial if returned by February 1, 1991. Thank you.

Sincerely,

Bob McCullouch, Ph.D.
Assistant Professor

Enclosure

STATE: AK

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE	None		0.00 0.00 0.00 0.00 0.00
CLAY	None		0.00 0.00 0.00 0.00
COATED METAL	Replace		0.00 0.00 0.00 0.00 0.00 0.00
NONCOATED METAL	None		0.00 0.00 0.00 0.00
PLASTIC	None		0.00 0.00 0.00 0.00
STEEL ARCH PIPE	Replace		0.00 0.00 0.00 0.00
SMALL CULVERTS	Replace		0.00 0.00 0.00 0.00

NOTES

STATE: AL

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE			0.00 0.00 0.00 0.00 0.00
CLAY			0.00 0.00 0.00 0.00
COATED METAL			0.00 0.00 0.00 0.00 0.00 0.00
NONCOATED METAL			0.00 0.00 0.00 0.00
PLASTIC			0.00 0.00 0.00 0.00
STEEL ARCH PIPE			0.00 0.00 0.00 0.00
SMALL CULVERTS			0.00 0.00 0.00 0.00

NOTES

* No rehab, replacement when unserviceable.

STATE: AR

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE	Replace		0.00 0.00 0.00 0.00 0.00
CLAY	Replace		0.00 0.00 0.00 0.00
COATED METAL	Replace		0.00 0.00 0.00 0.00 0.00 0.00
NONCOATED METAL	Replace		0.00 0.00 0.00 0.00
PLASTIC	Replace		0.00 0.00 0.00 0.00
STEEL ARCH PIPE	Replace		0.00 0.00 0.00 0.00
SMALL CULVERTS	Replace		0.00 0.00 0.00 0.00

NOTES

* A.L. Holmes, State Const. and Maint. Engr. sent
cover letter.

* REPLACEMENT COST SHEET ATTACHED W/ LETTER

STATE: CA

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF. -----
CONCRETE	Paved Invert 30"	Welded Wire Fabric	9.00
	Paved Invert 36"	Welded Wire Fabric	17.00
	Liner 15"	Plastic Pipe HDPE	25.00
	Liner 20"	Plastic Pipe HDPE	30.00
	Centerlining	Special Machine req'd	0.00
CLAY	Do Not Use		0.00
			0.00
			0.00
			0.00
COATED METAL	Liner	Plastic Pipe HDPE	0.00
	Liner	Plastic Pipe PVC	0.00
	Insituform		0.00
	Bitumen Dipped 18"		10.00
			0.00
			0.00
NONCOATED METAL	Do Not Use		0.00
			0.00
			0.00
			0.00
PLASTIC	No Need to Repair Yet		0.00
			0.00
			0.00
			0.00
STEEL ARCH PIPE	Repair Inverts		0.00
			0.00
			0.00
			0.00
SMALL CULVERTS	Abandon & Bore New Hole		0.00
			0.00
			0.00
			0.00

NOTES

* Pete Zaniewski, Associate M & R Engr.
916/739-3926 filled out survey form and is doing
similar research.

STATE: CO

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE			0.00 0.00 0.00 0.00 0.00
CLAY			0.00 0.00 0.00 0.00
COATED METAL			0.00 0.00 0.00 0.00 0.00 0.00
NONCOATED METAL			0.00 0.00 0.00 0.00
PLASTIC			0.00 0.00 0.00 0.00
STEEL ARCH PIPE			0.00 0.00 0.00 0.00
SMALL CULVERTS	Replace during reconst. Insituform	Metal Cross Culvert	0.00 0.00 0.00 0.00

NOTES

- * Several pipes have been lined w/ smaller dia. pipes and grouted voids.
- * Recommend FHWA study by Craig Ballinger, Wilbur Smith Associates, 703/698-9780

STATE: CT

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE	Replace 18"		24.37
	Replace 24"		30.65
	Replace 30"		42.99
	Replace 36"		50.26
	Replace 42"		63.62
CLAY			0.00
			0.00
			0.00
			0.00
COATED METAL	Replace 18"	Class B	26.00
	Replace 24"	Class B	28.10
	Replace 30"	Class B	42.50
	Replace 36"	Class B	45.00
	Replace 42"	Class B	108.00
	Replace 48"	Class B	141.00
NONCOATED METAL	Replace 18"		17.31
	Replace 24"		26.84
	Replace 30"		30.20
	Replace 36"		36.42
PLASTIC	Replace 12"		10.49
	Replace 18"		11.50
	Replace 24"		22.00
			0.00
STEEL ARCH PIPE	Replace 17"X13"		18.00
	Replace 24"X18"		22.20
	Replace 35"X24"		21.32
			0.00
SMALL CULVERTS			0.00
			0.00
			0.00
			0.00

NOTES

- * Rehab not done, deficiencies corrected by replacement.
- * Class C prices given also for coated metal.
- * Materials vary and are generally part of bid.

STATE: DC

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE	Replace in kind 15"	Reinforced PCC	35.00 0.00 0.00 0.00 0.00
CLAY	Replace 6"	PVC	25.00 0.00 0.00 0.00
COATED METAL			0.00 0.00 0.00 0.00 0.00 0.00
NONCOATED METAL			0.00 0.00 0.00 0.00
PLASTIC			0.00 0.00 0.00 0.00
STEEL ARCH PIPE			0.00 0.00 0.00 0.00
SMALL CULVERTS			0.00 0.00 0.00 0.00

NOTES

* Also contacted Leonard Benson from the Water and
Sewer Utility Administration. Reported no rehab
within last ten years.

* Prices above are per LF

STATE: GA

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE	Replace		0.00 0.00 0.00 0.00 0.00
CLAY	Replace		0.00 0.00 0.00 0.00
COATED METAL	Reline	Metal Pipe Liners	0.00 0.00 0.00 0.00 0.00 0.00
NONCOATED METAL	Reline		0.00 0.00 0.00 0.00
PLASTIC			0.00 0.00 0.00 0.00
STEEL ARCH PIPE	Replace Reline		0.00 0.00 0.00 0.00
SMALL CULVERTS	Replace Reline		0.00 0.00 0.00 0.00

NOTES

* Cost of relining is controlled by terrain and size of pipe.

STATE: IA

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE	Replace Culvert Liner	12" 2000D Conc. Pipe & Flow Mortar	10.11 0.00 0.00 0.00
CLAY	Replace	12" Coated Metal	12.12 0.00 0.00 0.00
COATED METAL	Replace	12" Coated Metal	12.12 0.00 0.00 0.00 0.00
NONCOATED METAL	Replace	12" Noncoated Metal	15.97 0.00 0.00 0.00
PLASTIC	Replace	8"	7.34 0.00 0.00 0.00
STEEL ARCH PIPE	Culvert Liner	Metal Pipe & Flow Mortar	400.00 0.00 0.00 0.00
SMALL CULVERTS	Culvert Liner	42" Conc. Pipe & Flow Mor	82.82 0.00 0.00 0.00

NOTES

* Cost per foot

* Steel Arch replacement cost is approximate

STATE: ID

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE	Replace		0.00 0.00 0.00 0.00 0.00
CLAY			0.00 0.00 0.00 0.00
COATED METAL	Replace		0.00 0.00 0.00 0.00 0.00
NONCOATED METAL	Replace		0.00 0.00 0.00 0.00
PLASTIC	Replace		0.00 0.00 0.00 0.00
STEEL ARCH PIPE	Replace		0.00 0.00 0.00 0.00
SMALL CULVERTS	Replace		38.48 0.00 0.00 0.00

NOTES

* Plastic pipe insertion used for temporary fix.
* Cost per LF for culvert is average for 4125 LF
per year and includes initial signing to final
restoration.

STATE: IL

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE			0.00 0.00 0.00 0.00 0.00
CLAY			0.00 0.00 0.00 0.00
COATED METAL			0.00 0.00 0.00 0.00 0.00 0.00
NONCOATED METAL			0.00 0.00 0.00 0.00
PLASTIC			0.00 0.00 0.00 0.00
STEEL ARCH PIPE			0.00 0.00 0.00 0.00
SMALL CULVERTS			0.00 0.00 0.00 0.00

NOTES

- * Contact on staff of D. L. Wolaver, Engr. of Des.
- * Specs for pipe culverts and insertion liners given.
- * Installed liner ranges from \$44/FT for 22" liner to \$140/FT for 48" liner.

STATE: KS

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE			0.00 0.00 0.00 0.00 0.00
CLAY			0.00 0.00 0.00 0.00
COATED METAL			0.00 0.00 0.00 0.00 0.00 0.00
NONCOATED METAL			0.00 0.00 0.00 0.00
PLASTIC			0.00 0.00 0.00 0.00
STEEL ARCH PIPE			0.00 0.00 0.00 0.00
SMALL CULVERTS			0.00 0.00 0.00 0.00

NOTES

* Dean M. Testa, P.E., Chief of Const. & Maint.
also on letter.

* No rehab program, replacement at end of life.

STATE: KY

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE	Remove and Relay for 15"		16.00
	Replace 15"	Pipe	26.00
	Replace 18"	Pipe	28.00
	Replace 36"	Pipe	57.00
	Replace 48"	Pipe	75.00
CLAY	Replace 15"	Pipe	26.00
	Replace 18"	Pipe	28.00
	Replace 36"	Pipe	57.00
	Replace 48"	Pipe	75.00
COATED METAL	Replace 15"	Pipe	26.00
	Replace 18"	Pipe	28.00
	Replace 36"	Pipe	57.00
	Replace 48"	Pipe	75.00
			0.00
			0.00
NONCOATED METAL	Replace 15"	Pipe	18.00
	Replace 18"	Pipe	21.00
			0.00
			0.00
PLASTIC			0.00
			0.00
			0.00
			0.00
STEEL ARCH PIPE	Replace 15"		24.00
	Replace 18"		34.00
	Replace 36"		65.00
	Replace 48"		103.00
SMALL CULVERTS	Replace 48"	Precast Concrete Box	150.00
	Replace 36"	Multi Plate	80.00
	Replace 48"	Multi Plate	90.00
			0.00

NOTES

- * Costs per foot
- * Concrete 18" also replaced at 28.00 per foot
- * Small Culverts also replaced with pipe for same cost and diameter as Clay and Coated Metal

STATE: MD

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE			0.00 0.00 0.00 0.00 0.00
CLAY			0.00 0.00 0.00 0.00
COATED METAL			0.00 0.00 0.00 0.00 0.00 0.00
NONCOATED METAL			0.00 0.00 0.00 0.00
PLASTIC			0.00 0.00 0.00 0.00
STEEL ARCH PIPE			0.00 0.00 0.00 0.00
SMALL CULVERTS			0.00 0.00 0.00 0.00

NOTES

- * Replacement used when possible; when not, slip lined or supplemented w/ jacked pipe.
- * Recent rehabs w/ 72" and 96" culverts.
- * Robert D. Douglass, Deputy Chief Engineer, Office of Highway Development wrote cover letter.

STATE: ME

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE	Slip Line	Metal Pipe, Grout Between	0.00 0.00 0.00 0.00 0.00
CLAY	Replace		0.00 0.00 0.00 0.00
COATED METAL	Replace		0.00 0.00 0.00 0.00 0.00 0.00
NONCOATED METAL	Replace		0.00 0.00 0.00 0.00
PLASTIC	Replace		0.00 0.00 0.00 0.00
STEEL ARCH PIPE	Replace		0.00 0.00 0.00 0.00
SMALL CULVERTS	Replace		0.00 0.00 0.00 0.00

NOTES

* Slip line rehab done once in the 1960's at
unknown cost.

STATE: MI

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE	Relayed & Joints Wrapped	Non-Woven Geotextile (Jt)	0.00
	Replace		0.00
	Slip Line	Plastic	0.00
	Slip Line	Steel	0.00
			0.00
CLAY	Replace	Plastic	0.00
			0.00
			0.00
			0.00
COATED METAL	Seldom used		0.00
			0.00
			0.00
			0.00
			0.00
NONCOATED METAL	Replace		0.00
			0.00
			0.00
			0.00
PLASTIC	No Problems To Date		0.00
			0.00
			0.00
			0.00
STEEL ARCH PIPE	Replace		0.00
	Slip Line		0.00
			0.00
			0.00
SMALL CULVERTS	Replace		0.00
			0.00
			0.00
			0.00

NOTES

* MDOT 4th quarter report on Average Unit Contract
Prices included.

STATE: MN

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE			0.00 0.00 0.00 0.00 0.00
CLAY			0.00 0.00 0.00 0.00
COATED METAL			0.00 0.00 0.00 0.00 0.00 0.00
NONCOATED METAL			0.00 0.00 0.00 0.00
PLASTIC			0.00 0.00 0.00 0.00
STEEL ARCH PIPE			0.00 0.00 0.00 0.00
SMALL CULVERTS	Slip Line for 24"	Polyethylene (butt fused)	46.00
	Slip Line for 30"	Polyethylene (butt fused)	67.00
	Slip Line for 36"	Polyethylene (butt fused)	88.00
			0.00

NOTES

- * Cost based on average for 1990.
- * Round concrete and metal culverts were lined.

STATE: MO

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE			0.00 0.00 0.00 0.00 0.00
CLAY			0.00 0.00 0.00 0.00
COATED METAL	Insertion Liner on 12.75"	Plastic Pipe	28.09
	Insertion Liners on 14"	Plastic Pipe	29.88
	Insertion Liners on 20"	Plastic Pipe	47.98
	Insertion Liners on 36"	Plastic Pipe	146.33
			0.00 0.00
NONCOATED METAL			0.00 0.00 0.00 0.00
PLASTIC			0.00 0.00 0.00 0.00
STEEL ARCH PIPE			0.00 0.00 0.00 0.00
SMALL CULVERTS			0.00 0.00 0.00 0.00

NOTES

- * Cost per LF based on average for 1988.
- * Coated metal pipe is corrugated metal.
- * Gary Chullino, Division Engineer, Construction sent cover letter.

STATE: MT

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE			0.00 0.00 0.00 0.00 0.00
CLAY			0.00 0.00 0.00 0.00
COATED METAL			0.00 0.00 0.00 0.00 0.00 0.00
NONCOATED METAL	Insert, grout gap 24"	CSPMetal	55.00
	Insert, grout gap 36"	CSPMetal	62.00
			0.00 0.00
PLASTIC			0.00 0.00 0.00 0.00
STEEL ARCH PIPE			0.00 0.00 0.00 0.00
SMALL CULVERTS			0.00 0.00 0.00 0.00
NOTES -----			

STATE: NC

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE			0.00 0.00 0.00 0.00 0.00
CLAY			0.00 0.00 0.00 0.00
COATED METAL			0.00 0.00 0.00 0.00 0.00 0.00
NONCOATED METAL			0.00 0.00 0.00 0.00
PLASTIC			0.00 0.00 0.00 0.00
STEEL ARCH PIPE			0.00 0.00 0.00 0.00
SMALL CULVERTS			0.00 0.00 0.00 0.00

NOTES

- * Replacement is primary repair method.
- * Occasional addition of concrete invert to large metal structures.

STATE: NE

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE			0.00 0.00 0.00 0.00 0.00
CLAY			0.00 0.00 0.00 0.00
COATED METAL			0.00 0.00 0.00 0.00 0.00 0.00
NONCOATED METAL			0.00 0.00 0.00 0.00
PLASTIC			0.00 0.00 0.00 0.00
STEEL ARCH PIPE			0.00 0.00 0.00 0.00
SMALL CULVERTS			0.00 0.00 0.00 0.00

NOTES

- * No experience w/ rehab of drainage pipes
- * Survey not marked

STATE: NJ

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE			0.00 0.00 0.00 0.00 0.00
CLAY			0.00 0.00 0.00 0.00
COATED METAL			0.00 0.00 0.00 0.00 0.00 0.00
NONCOATED METAL			0.00 0.00 0.00 0.00
PLASTIC			0.00 0.00 0.00 0.00
STEEL ARCH PIPE			0.00 0.00 0.00 0.00
SMALL CULVERTS			0.00 0.00 0.00 0.00

NOTES

* Other contact - John Pezik, Bureau of Maint.
Engr., 609/530-3850

* Attached was storm drainage pipe liner specs &
bid tabulation from contractor

STATE: NM

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE	Replace		0.00 0.00 0.00 0.00 0.00
CLAY	Replace		0.00 0.00 0.00 0.00
COATED METAL	Replace		0.00 0.00 0.00 0.00 0.00 0.00
NONCOATED METAL	Replace		0.00 0.00 0.00 0.00
PLASTIC	Replace		0.00 0.00 0.00 0.00
STEEL ARCH PIPE	Replace		0.00 0.00 0.00 0.00
SMALL CULVERTS	Replace		0.00 0.00 0.00 0.00

NOTES

- * Requests final report
- * See letter for further address and phone info

STATE: NY

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE	Replace		0.00
	Pipe Jack		0.00
	Reline		0.00
			0.00
			0.00
CLAY	Replace		0.00
	Pipe Jack		0.00
	Insituform		0.00
			0.00
COATED METAL	Replace		0.00
	Pipe Jack		0.00
	Reline		0.00
	Insituform		0.00
	Pave Invert		0.00
			0.00
NONCOATED METAL	Replace		0.00
	Pipe Jack		0.00
	Reline		0.00
	Insituform		0.00
PLASTIC	Replace		0.00
	Pipe Jack		0.00
	Reline		0.00
	Insituform		0.00
STEEL ARCH PIPE	Replace		0.00
	Pipe Jack		0.00
	Reline		0.00
	Insituform		0.00
SMALL CULVERTS	Replace		0.00
	Pipe Jack		0.00
	Insituform		0.00
			0.00

NOTES

-
- * Plastic pipe is new & has needed rehab.
 - * Steel or concrete is used for pipe jack next to existing culvert.
 - * Liners include insituform for 12,15,18&24" pipe and corrugated plastic, steel, or aluminum for larger pipe w/ grout between.

STATE: OH

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE			0.00 0.00 0.00 0.00 0.00
CLAY			0.00 0.00 0.00 0.00
COATED METAL	Reline (large dia.)	Tunnel Liner Plates	0.00 0.00 0.00 0.00 0.00 0.00
NONCOATED METAL	Replace	Various Conduit	0.00 0.00 0.00 0.00
PLASTIC			0.00 0.00 0.00 0.00
STEEL ARCH PIPE	Replace Replace	3-Sided Precast Boxes 4-Sided Precast Boxes	0.00 0.00 0.00 0.00
SMALL CULVERTS	Insituform (12",15",18")		0.00 0.00 0.00 0.00

NOTES

* Insituform used on experimental site.

STATE: OK

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE	Replace 24"		21.00
	Replace 36"		33.00
	Replace 48"		45.00
			0.00
			0.00
CLAY			0.00
			0.00
			0.00
			0.00
COATED METAL	Replace 24"		20.00
	Replace 36"		30.00
	Replace 48"		40.00
			0.00
			0.00
NONCOATED METAL	Replace 24"		18.00
	Replace 36"		28.00
	Replace 48"		38.00
			0.00
PLASTIC			0.00
			0.00
			0.00
			0.00
STEEL ARCH PIPE	Replace 28"X20"		19.00
	Replace 42"X29"		29.00
	Replace 57"X38"		39.00
			0.00
SMALL CULVERTS			0.00
			0.00
			0.00
			0.00

NOTES

* Bruce E. Taylor, P.E., Urban Design Engineer on cover letter.

* Costs of culverts is broken into material quantities for concrete and steel and varies by quantity amounts.

STATE: PA

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE	Replace in kind (low)		26.45
	Replace in kind (high)		144.00
			0.00
			0.00
			0.00
CLAY	No info		0.00
			0.00
			0.00
			0.00
COATED METAL	Replace in kind (low)		17.92
	Replace in kind (high)		275.00
			0.00
			0.00
			0.00
NONCOATED METAL	Replace in kind (low)		25.76
	Replace in kind (high)		90.00
			0.00
			0.00
PLASTIC	Replace in kind 4" (low)		4.94
	Replace in kind 4" (high)		8.00
	Replace in kind 8" (low)		5.13
	Replace in kind 8" (high)		5.83
STEEL ARCH PIPE	Replace in kind (low)		25.11
	Replace in kind (high)		82.50
			0.00
			0.00
SMALL CULVERTS	Replace	Precast units	0.00
			0.00
			0.00
			0.00

NOTES

* Precast units are bid individually by lump sum

STATE: RI

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE			0.00 0.00 0.00 0.00 0.00
CLAY			0.00 0.00 0.00 0.00
COATED METAL			0.00 0.00 0.00 0.00 0.00 0.00
NONCOATED METAL			0.00 0.00 0.00 0.00
PLASTIC			0.00 0.00 0.00 0.00
STEEL ARCH PIPE			0.00 0.00 0.00 0.00
SMALL CULVERTS			0.00 0.00 0.00 0.00

NOTES

* Do not have a rehab program; replaced under a state highway contract.

STATE: SD

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE	Replace		0.00 0.00 0.00 0.00 0.00
CLAY	Replace		0.00 0.00 0.00 0.00
COATED METAL	Replace		0.00 0.00 0.00 0.00 0.00 0.00
NONCOATED METAL	Replace		0.00 0.00 0.00 0.00
PLASTIC	Replace		0.00 0.00 0.00 0.00
STEEL ARCH PIPE	Replace		0.00 0.00 0.00 0.00
SMALL CULVERTS	Replace		0.00 0.00 0.00 0.00

NOTES

STATE: TN

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE	Stabilizing Outfall @ endw/ 2" for larger stone		11.00 0.00 0.00 0.00 0.00
CLAY			0.00 0.00 0.00 0.00
COATED METAL	Slip Line for 12" Slip Line for 42"	Polyetheline Pipe Polyetheline Pipe	15.00 75.00 0.00 0.00 0.00 0.00
NONCOATED METAL	Slip Line for 12" Slip Line for 42"	Polyetheline Pipe Polyetheline Pipe	15.00 75.00 0.00 0.00
PLASTIC			0.00 0.00 0.00 0.00
STEEL ARCH PIPE	Replacing in-kind		0.00 0.00 0.00 0.00
SMALL CULVERTS	Replace Replace	Precast Reinforced Cast-in-Place	0.00 0.00 0.00 0.00

NOTES

- * Replacement pipe for steel arch pipe is cost of pipe + 2.5 cost of pipe for installation.
- * Culverts (< 20' Spans), Cast-in-place concrete is 2.00/yd, reinforce is 0.40/lb, cast-in-place is 50% higher for mat cost, but less for user cost.

STATE: TX

PIPE TYPE	FIX METHOD	FIX MATERIAL	COST/LF
-----	-----	-----	-----
CONCRETE			0.00
			0.00
			0.00
			0.00
			0.00
CLAY			0.00
			0.00
			0.00
			0.00
COATED METAL	Replace 24"	CMP Gal Stl	19.79
	Replace 30"	CMP Gal Stl	26.08
	Replace 36"	CMP Gal Stl	31.92
	Replace 42"	CMP Gal Stl	35.00
	Replace 48"	CMP Gal Stl	40.00
	Replace 54"	CMP Gal Stl	46.00
NONCOATED METAL			0.00
			0.00
			0.00
			0.00
PLASTIC			0.00
			0.00
			0.00
			0.00
STEEL ARCH PIPE			0.00
			0.00
			0.00
			0.00
SMALL CULVERTS	Replace	3' X 2'	300.00
	Replace	5' X 3'	92.67
	Replace	6' X 4'	115.00
	Replace	7' X 4'	143.00

NOTES

* Defective pipes/culverts are replaced, no rehab methods used.

* Prices given are average bid.

STATE: UT

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE			0.00 0.00 0.00 0.00 0.00
CLAY			0.00 0.00 0.00 0.00
COATED METAL			0.00 0.00 0.00 0.00 0.00 0.00
NONCOATED METAL			0.00 0.00 0.00 0.00
PLASTIC			0.00 0.00 0.00 0.00
STEEL ARCH PIPE			0.00 0.00 0.00 0.00
SMALL CULVERTS			0.00 0.00 0.00 0.00
NOTES -----			

STATE: VT

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE	Replace in kind 18"		26.00
	Replace in kind 36"		42.00
	Replace in kind 48"		57.00
	Replace in kind 60"		78.00
	Replace in kind 72"		103.00
CLAY	Replace	Metal Culvert	0.00
			0.00
			0.00
			0.00
COATED METAL	Replace	Uncoated Metal Pipe	0.00
			0.00
			0.00
			0.00
			0.00
NONCOATED METAL	Replace in kind 12"		17.00
	Replace in kind 18"		19.00
	Replace in kind 24"		22.00
	Replace in kind 36"		35.00
PLASTIC	No Failures to date		0.00
			0.00
			0.00
			0.00
STEEL ARCH PIPE	Replace in kind	50SF Waterway	400.00
	Replace in kind	100SF Waterway	600.00
	Replace in kind	125SF Waterway	720.00
			0.00
SMALL CULVERTS	Total Replace in kind		0.00
			0.00
			0.00
			0.00

NOTES

* Other drainage material - Multi Plates - Repair
invert w/ 6" concrete OR install tunnel liner. For
Replacement: 50SF Waterway . . . 330.00/LF
100SF Waterway. . . 490.00/LF
125SF Waterway. . . 560.00/LF

STATE: WI

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE	Reline 14"	High Density Polyethylene	31.50
	Reline 18"	High Density Polyethylene	39.00
	Reline 24"	High Density Polyethylene	50.00
	Reline 36"	High Density Polyethylene	91.00
	Reline 42"	High Density Polyethylene	145.00
CLAY	Don't Use		0.00
			0.00
			0.00
			0.00
COATED METAL	Reline (Same as Above)		0.00
			0.00
			0.00
			0.00
			0.00
NONCOATED METAL	Don't Use		0.00
			0.00
			0.00
			0.00
PLASTIC	No Experience		0.00
			0.00
			0.00
			0.00
STEEL ARCH PIPE	Reline (Same as Above)		0.00
			0.00
			0.00
			0.00
SMALL CULVERTS	Replace		0.00
			0.00
			0.00
			0.00

NOTES

- * Other Reline pipe sizes given.
- * Engineer's Estimate costs used, bid costs are lower and are also given.

STATE: WV

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE	Replace		0.00 0.00 0.00 0.00 0.00
CLAY	Replace		0.00 0.00 0.00 0.00
COATED METAL	In Situ Method	Plastic Inter Sleeve	0.00 0.00 0.00 0.00 0.00 0.00
NONCOATED METAL	Replace		0.00 0.00 0.00 0.00
PLASTIC	Replace		0.00 0.00 0.00 0.00
STEEL ARCH PIPE	Replace		0.00 0.00 0.00 0.00
SMALL CULVERTS	Replace		0.00 0.00 0.00 0.00

NOTES

* Expensive, variable cost for in situ method.

STATE: WY

PIPE TYPE -----	FIX METHOD -----	FIX MATERIAL -----	COST/LF -----
CONCRETE	Replace		0.00 0.00 0.00 0.00 0.00
CLAY			0.00 0.00 0.00 0.00
COATED METAL	Replace		0.00 0.00 0.00 0.00 0.00
NONCOATED METAL	Replace		0.00 0.00 0.00 0.00
PLASTIC			0.00 0.00 0.00 0.00
STEEL ARCH PIPE	Replacement		0.00 0.00 0.00 0.00
SMALL CULVERTS			0.00 0.00 0.00 0.00

NOTES

- * Clay not used, very small amt of Plastic used.
- * Cost dependent on size and based on labor, mat, and equip when done by state forces.

TECHNICAL SUMMARY

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Repair/
Rehabilitation
of Deteriorated
Drainage Pipe
April 30, 1992

Background

Deteriorated , damaged drainage pipe poses a potentially serious threat to the roadway, right-of-way, and adjacent areas affected by improper drainage. In these cases either replacement or rehabilitation is necessary to insure continued drainage control and serviceability of the roadway. Traditionally the repair method has been replacement requiring an open trench. This causes a disruption in the normal traffic pattern and inconveniences to roadway users. This report describes the existing methods for rehabbing drainage pipe in-place that allow for continued roadway use.

Results

This report describes the current technologies, methods and materials used in drainage pipe rehab and replacement. It also identifies which of these technologies can be applied for the various pipe material types. Installed cost information was obtained from the states in the survey and from vendors for the various methods. In describing each method, equipment requirements and limitations are reported. From this report, one should be able to understand what method is appropriate for the various repair problems and pipe types.

Conclusions

This is a synthesis study conducted to develop an information base on the state-of-practice in pipe rehab methods. No conclusions are reported.

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