

---

# Culvert Rehabilitation Practices

---



**UtahState**  
UNIVERSITY

**UTDOT**  
CONNECTING COMMUNITIES

## TABLE OF CONTENTS

Report Objective .....	1
Introduction .....	1
General Culvert Rehabilitation .....	3
Culvert Cleaning.....	3
Grouting.....	4

## REHABILITATION METHODS

Slip Lining.....	5
Spiral Wound Lining.....	6
Cured-In-Place Lining.....	8
Fold-And-Form PVC Lining.....	10
Deformed-Reformed HDPE Lining .....	11
Cement-Mortar-Spray-On Lining.....	12
Trenchless rehabilitation methods table.....	14
References .....	16
Glossary .....	17

---

---

## Report Objective

The purpose of this report is to provide pertinent information regarding culvert rehabilitation (repair) methods that may be applicable in Utah. This manual is not meant to replace the installation manual provided by the manufacturer, but rather to provide a brief description of each method and its installation procedure and highlight the advantages and disadvantages of each method. This manual was developed based on the *General Culvert Barrel Rehabilitation Techniques* (Caltrans, 2003), *Culvert pipe liner guide and specification* (Central Federal Lands Highway Division, 2005), a literature review and interaction with the Utah Department of Transportation.

## INTRODUCTION

Many aging culverts in the State of Utah have deteriorated to the point where replacement or repair is warranted. When deciding whether to replace or repair, it is typically more cost effective, as a rule-of-thumb, to repair when the Average Daily Traffic exceeds 1000 vehicles, the maximum cover over a culvert is more than 4 feet, and the detour route for the work area is greater than 20 minutes.

Prior to deciding whether to replace or rehabilitate the culvert, a determination of the structural integrity of the host pipe must be made. If the existing pipe is incapable of sustaining design loads, it should be replaced rather repaired (see *Figure 1*).



**Figure 1. Example of collapsed culvert**  
([www.mnr.gov.on.ca/images](http://www.mnr.gov.on.ca/images))

In other cases the existing culvert may be deformed as shown in *Figure 2A*. It is still possible to repair this culvert with a drawback that the diameter of the new “**liner**” pipe will have to be smaller (assuming a rigid-wall liner were used), relative to a non-deformed pipe (see *Figure 2B*).



**Figure 2A: Deformed culvert**



**Figure 2B: Round culvert with rusted invert**

Like traditional culverts, rehabilitated culverts can operate under inlet or outlet control depending on the culvert slope, end treatments and flow conditions. When a culvert is rehabilitated, the cross-sectional area decreases because a smaller diameter liner pipe is inserted into the old pipe. If the slip-lined culvert is hydraulically smoother than the old pipe and operates under outlet control, the decreased flow area will likely be offset by the reduction in flow resistance, resulting in a similar discharge capacity. If the slip-lined culvert operates under inlet control, then an improved end treatment may be required to minimize the amount of culvert capacity flow reduction associated with the smaller diameter inlet. Currently, most slip-lined culverts have projecting end treatments with squared off ends. Little information is currently available regarding the hydraulic characteristics of end treatments specific to slip-lined culverts, however, in many cases, they may not be considerably different from traditional projecting inlets (see *figure 3*).



**Figure 3. Inlet of slip-lined culvert**

---

## General Culvert Rehabilitation

Culvert rehabilitation is typically much faster and easier than removing and replacing the old culvert, particularly where there are deep fills or where trenching would cause extensive traffic disruptions. Generally, deteriorated culverts are rehabilitated by inserting a rigid-wall or flexible liner pipe that is held in place by either grout (rigid-wall liner) or a pressure and heat based curing process (flexible liner). The following six (6) methods are current rehabilitation techniques used for deteriorated culverts.

1. Slip lining
2. Spiral wound lining
3. Cured-in-place lining
4. Fold-and-form PVC lining
5. Deformed-reformed HDPE lining
6. Cement-mortar spray-on lining

A generic summary of each method will be provided in this manual and a quick reference for the specifications, materials, advantages, and disadvantages of each technique are discussed in Table 1.

### *Cleaning the culvert*

Before installing a new liner pipe, the existing culvert must be cleaned of all debris. Where available, a vacuum truck is used for most culvert cleaning operations, otherwise a small section of pipe attached at three points and plugged is assembled and pulled through the old culvert to remove debris (see *Figure 4*). If man entry is possible a visual inspection is recommended to check for any metal pieces the new liner may get caught on. A hammer can be used to bend these pieces back. Cleaning of the existing culvert should take place a few days prior to installation of new liner to prevent further debris from entering the existing culvert.



**Figure 4. Optional cleaning device for culverts**  
([www.culvert-rehab.com](http://www.culvert-rehab.com))

## Grouting

Grouting of the **annular space** between the old culvert and rigid-walled liner pipe is recommended to reduce seepage, deterioration, and soil migration. Grouting also establishes a structural connection between the liner, the host pipe, and the soil. Prior to grouting, the annular space must be sealed at both ends by **bulkheads** in order to contain the grout and keep the water out if present (see *Figure 6*). Cement bulkheads are the most common. It is best to let the cement set up for a day or two before grouting. When water is present (i.e., live stream or wetlands) within the culvert, fabricating the bulkheads of Oakum soaked in water-activated urethane sealant represents a good alternative (see *Figures 5A and 5B*). When the **Oakum** is in place it sets up within minutes.

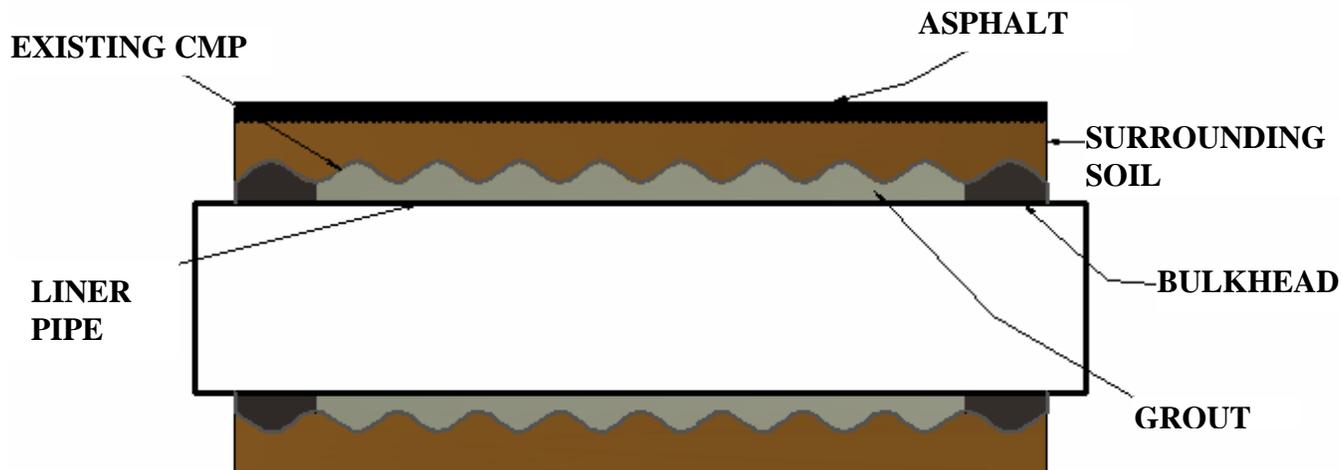


**Figures 5A: Oakum being soaked in urethane sealant**



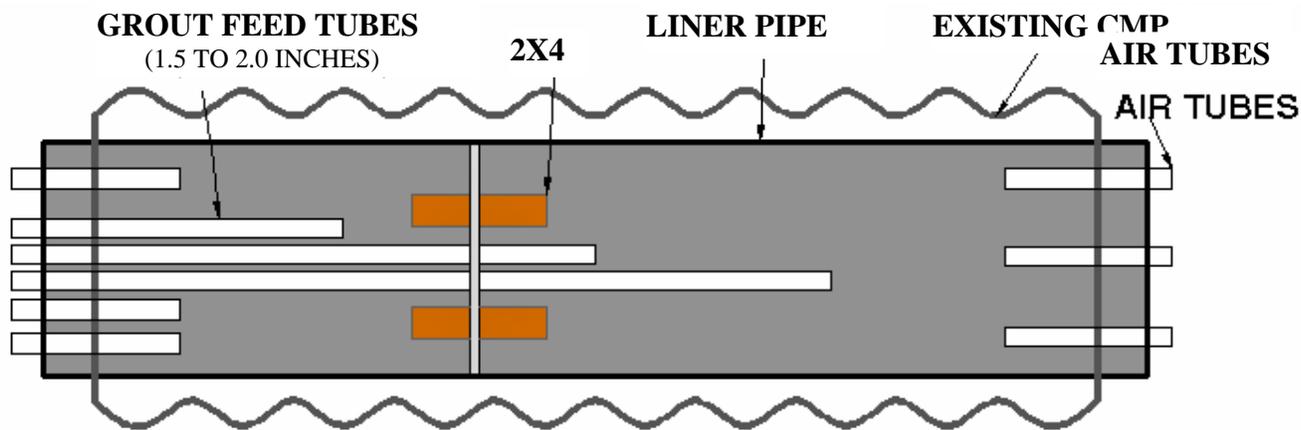
**Figure 5B: Inlet sealed with Oakum**

Grout may be either gravity fed or pumped through a hose or small diameter pipe (1-1/2 inch to 2 inch PVC) laid in the annular space. The grout should be a low-density foam concrete consisting of portland cement and **fly ash**. This mix allows the grout to flow easily and should fill the entire annular space (see *Figure 6*). A high-density grout maybe required to displace the water and fill the annular space if standing water is present. Grouting in lifts is recommended when using high-density grout or when grouting a culvert with a significant change in elevation between inlet and outlet. Grouting in lifts will prevent the liner from collapsing. If voids exist in the surrounding soil of the existing culvert, grout should fill the voids to provide a uniform support and prevent sinkhole from forming.



**Figure 6: Model of CMP lined with HDPE liner**

When preparing to pump grout, these steps are recommended: The 3 grout feed tubes running 75%, 50%, and 25% of the total length of the liner are installed. Strap the grout feed tubes to the liner every 20 feet using metal banding. 2x4 blocks are placed adjacent to the tubes to minimize direct pressure from the banding. Air tubes are placed at three, nine and twelve o'clock in each bulkhead. The air and grout feed tubes are capped when the grout begins to ooze out (see *Figure 3*). For all steps listed above refer to *Figure 7*. (This is only an example, designs may vary.)



**Figure 7. Plan view of model setup for grouting process.**

## REHABILITATION METHODS

### Sliplining

Rigid-walled liner pipes are inserted into host pipe for the sliplining method. The liner pipe is moved into the culvert either one section at a time or as an entire unit after being butt-fused. The liner is pushed or pulled with jacks or construction machinery. Rigid-walled liner pipes with smooth exteriors usually will allow for easier insertion, particularly if the host pipe has a corrugated wall profile. If there are alignment

changes in the old host pipe it can reduce the slip liner diameter significantly. Also, any deflections in the culvert walls will become control or pinch points. In this case a “pulling head” or “nose cone” is recommended (see *Figure 8A and 8B*). When the liner is in place, the space between the new and old culvert (annular space) and any voids that exist within the old culvert are grouted. Bulkheads must be installed before grouting to seal the ends of the pipe. Almost any type of culvert can be slip lined with an appropriately sized liner pipe. The specifications, materials, advantages, and disadvantages of slip lining are summarized in Table 1.



**Figure 8A: Cutting out nose cone**

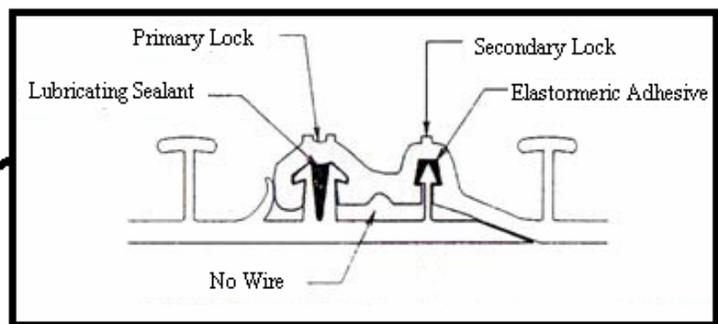


**Figure 8B: Nose cone**

([www.culvert-rehab.com](http://www.culvert-rehab.com))

## Spiral Wound Method

To line a culvert with the spiral wound method, interlocking profile strips are coiled through a winding machine that mechanically forces the strips to interlock and form a smooth, continuous, spirally wound liner (see *Figure 9*). During the interlocking process, a sealant is applied to each joint to form a watertight seam. As the material is wound and snapped together, it is forced into the existing culvert.



**Figure 9: Rib Loc lining system**

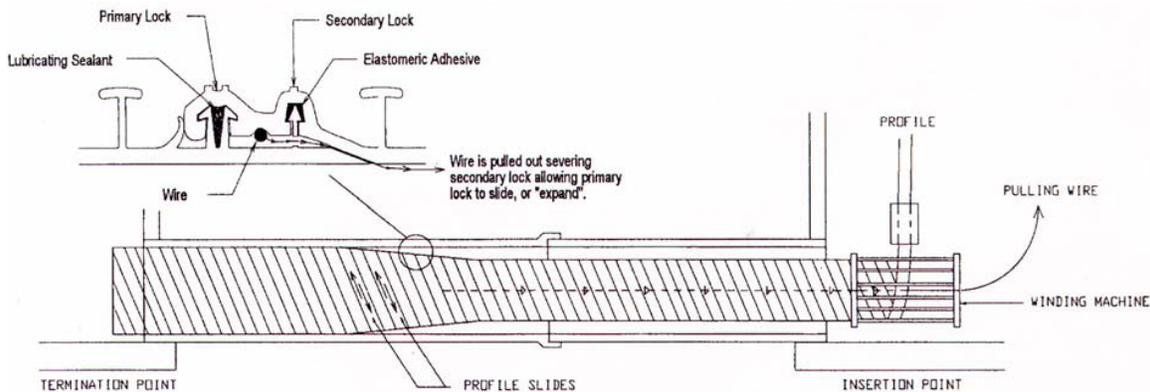
Left: ([www.dot.ca.gov](http://www.dot.ca.gov)), Right: ([www.cflhd.gov](http://www.cflhd.gov))

During installation, the spiral wound PVC liner pipe is either:

- A) Inserted at a fixed diameter and then expanded until it presses against the interior surface of the existing pipe; or,
- B) Inserted at a fixed diameter into the existing pipe and then grouted; or,
- C) Wound against the host pipe walls by a machine that travels down the pipe.

## A. Expanding liner

The expanding liner system calls for a continuous plastic strip that is spiral wound into the existing deteriorated host pipe. The male and female edges of the strip are securely locked together by the winding machine. Once a section is installed, it is expanded against the wall of the host pipe (see *Figure 10*). Both flexible and rigid pipes can be rehabilitated with this system. This lining system is similar to the fixed diameter process except that the continuous spiral joint utilizes a water activated polyurethane adhesive for sealing and no annular space grouting is required (but the pipe ends are usually grouted).



**Figure 10. Spiral wound expanding system**

(www.cflhd.gov)

## B. Fixed-Diameter Liner (PVC or Steel Reinforced)

The fixed-diameter liner system creates a ribbed profile of PVC, requiring the annular space to be grouted. This produces an integrated structure with the PVC liner "tied" to the original pipe through the grout similar to a slip liner.

For the steel reinforced PVC lining system, a continuous strip of profiled reinforcing steel is added to the outside of the plastic pipe when specified (see *Figure 11B*). The resulting liner has a smooth plastic internal surface with increased stiffness from the steel reinforcing profile. The liner's annular space is grouted. Both flexible and rigid pipes can be rehabilitated with this system.

## C. Full Bore Expanding Liner Machine

The full bore, traveling machine system creates a continuous plastic strip that is spiral wound into the existing deteriorated host pipe by a machine that rotates and lays the profile against the host pipe walls as it travels through the host pipe (see *Figure 11A*). This system has the option of a steel reinforcing section for increased load carrying

capacity. The specifications, materials, advantages, and disadvantages of spiral wound lining are discussed in *Table 1*.



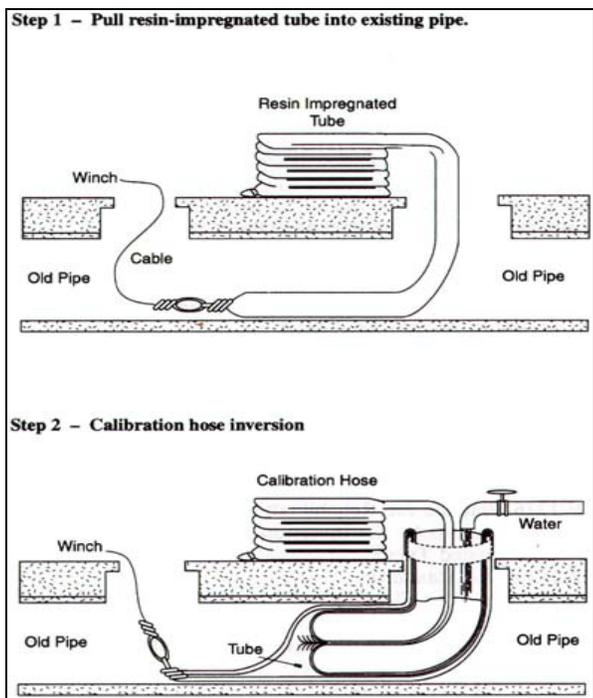
**Figure 11A: Full Bore travel expanding machine**  
(www.dot.ca.gov)



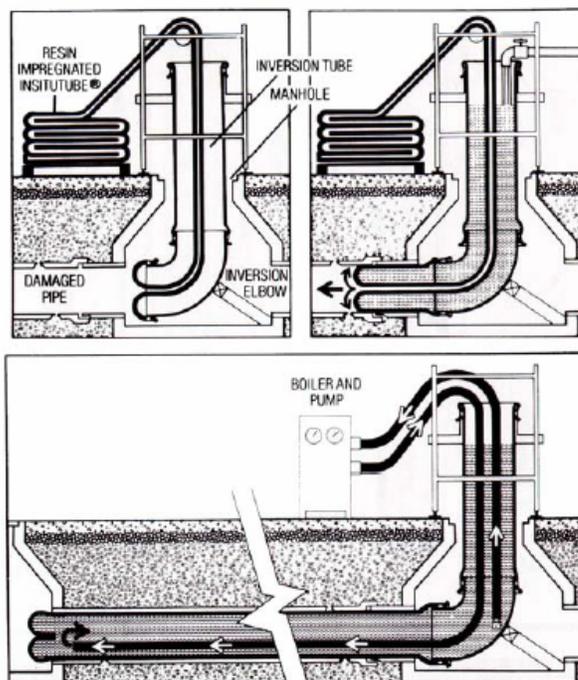
**Figure 11B: Steel Reinforce Lining**  
(www.prsrohrganierung.de)

**Cured-In-Place Lining**

Cured-in-place lining installations involve the insertion of a flexible fiber tube coated with a thermosetting resin into an existing culvert. The tube is inserted either by inverting it into place using water or compressed air or by pulling it in place with a winch.



**Figure 12A. Pulled in place method**



**Figure 12B: Inverted method**

(www.cflhd.gov)

For the pulled-in-place installation method, a winched cable is placed inside the existing pipe. The resin-impregnated liner is connected to the free end of the cable and then pulled into place between drainage structures or culvert ends. The cable is disconnected, the ends are plugged, and the liner is inflated and cured with hot water or steam (see *Figure 12A*).

For the inverted installation method, the tube is inserted inside out (inverted) and filled with water or compressed air as shown in *Figure 12B*. Generally, a polyester felt tube saturated with a liquid thermosetting resin material is used. During the process, the lining tube inverts as it travels down the pipeline. This results in the plastic outer sleeve surface becoming the inner surface of the repaired pipe and puts the resin system in contact with the existing culvert wall. Pressure inside the inverted tube, due to the water or compressed air, presses the tube against the carrier pipe wall (see *Figure 13*). Once the tube has reached the far end of the pipe section under repair, either heated water or steam is fed into the inverted tube to cure the thermosetting resin.



**Figure 13. Outlet end of inverted liner**

Once installed, the resin is cured under ambient conditions or through applied heat (circulating stream or hot water) throughout the tube. Unlike other lining methods, the flexible fiber lining tube is manufactured to suit specific existing culvert dimensions.

Resins, when heated, become the primary structural component of the cured-in-place system and are categorized as unsaturated polyester, vinyl ester or epoxy. Unsaturated polyester resins are the most widely used resins in cured-in-place lining systems.

Cured-in-place linings are available in felt-based, woven hose, and membrane type tubes. Felt-based lining tubes are produced from nonwoven polyester felt and coated on one face with a layer of elastomer. Felt-based tubes offer solutions to a wide range

of design requirements since they can be manufactured in varying thicknesses to match individual pipe diameters. Woven hose systems, manufactured out of a circular woven, seamless, polyester fiber hose and coated on one face with a layer of elastomer, are primarily designed to rehabilitate pressure pipelines suffering from corrosion and leakage. Membrane linings are composed of very thin elastomers designed for the rehabilitation of leaking, low pressure gas mains and offer internal corrosion protection.

If water is used for curing the liner, the water must be heated continually and circulated during the curing process. Additionally, the water source to fill the tube must be accessible to the site. The application of heat hardens the resin after a few hours, forming a jointless pipe-within-a-pipe. Once set, remote controlled cutters are used to reinstate junctions and laterals.

Due to potential environmental concerns including the capture and disposal of styrene-contaminated process water, using cured-in-place lining method should generally be limited to urban drainage systems that discharge to treatment plants, otherwise all residual water will need to be captured for proper disposal. Styrene-contaminated water is fatal to fish. The specifications, materials, advantages, and disadvantages of cured-in-place lining are discussed in *Table 1*.

### **Fold-and-Form Lining**

The fold-and-formed lining method uses a PVC pipeliner coiled on reels, which is supplied at project-specific lengths. 4- to 12-inch diameter liners are coiled in a *flat shape* as shown in *Figure 14A*. 15- to 30-inch diameter liners are coiled in an “*H*” shape as shown in *Figure 14B*.



**Figure 14A. Flat shape liner**  
(4- to 12-inch) ([www.ultraliner.com](http://www.ultraliner.com))



**Figure 14B. "H" shape liner**  
(15- to 30-inch)

The liner is inserted as follows: A winch cable is fed through the host pipe and attached to the end of the pipeliner. The coiled liner is covered with a tarp and pre-heated with steam until malleable. The tarp is then removed and the liner is pulled through the host pipe. The liner is pulled through at a rate of 40 to 50 feet per minute depending on field conditions. After the liner is pulled through it is cut and sealed on both ends with pneumatic plugs (see *Figure 15A* and *15B*).



**Figure 15A. Cutting liner**



**Figure 15B. Pneumatic plug with steam and air supply line**

With both ends of the liner plugged, the liner is re-heated (over several hours) and pressured using steam and air until the liner expands tightly against inside of the host pipe. The steam is replaced by compressed air to cool the liner while maintaining its shape. Once cooled, the ends of the liner are trimmed to the desired length (typically projecting some distance beyond the end of the host pipe) (see *Figure 16*). This overall process typically requires just less than a full work day per installation. The time required to heat the liner (twice) will vary with ambient temperature conditions.



**Figure 16. Inlet of fold-and-form rehabilitated culvert**

## **Deformed-Reformed HDPE Lining**

During deformed-reformed lining, a HDPE solid wall pipe is deformed by mechanical force. If the nominal diameter of the HDPE liner is 18 inches or smaller, it is delivered to the job site folded on a spool (see *Figure 17A*). Larger diameters are brought to the job site in individual sections and then butt-fused and deformed on site by means of thermo-mechanical deforming equipment into a “U” shape (see *Figure 17B*).



**Figure 17A: Liner installed through a drainage inlet**



**Figure 17B: On-site deforming equipment**

(www.htliners.com)

After the liner is pulled or pushed through the existing culvert, heat is introduced into the folded liner using pressurized steam to conform the new liner to the existing culvert wall (see *Figure 18*). A remote controlled cutter reconnects laterals without excavation. The specifications, materials, advantages, and disadvantages of deformed-reformed lining are discussed in *Table 1*.



**Figure 18. Steam being introduced into a 30 inch HDPE liner**

(www.htliners.com)

## **Cement-Mortar Spray-On Lining Method**

Cement-mortar spray-on liners are usually applied to existing steel and iron culverts to provide protection against corrosion. Lining is applied by the rotating head of an electric or air-powered machine (see *Figure 19A*). Mortar is supplied to the machine through a system of high-pressure hoses. A uniform thickness liner is applied as the machine moves through the existing culvert at a constant speed. The thickness of the liner applied is directly related to the speed at which the machine moves. After the liner has been applied, rotating or conical drag trowels provided a smooth troweled finish. Unless reinforced, cement-mortar spray-on lining adds little or no structural integrity to the existing culvert.

## CULVERT REHABILITATION PRACTICES



**Figure 19A: Lining machine for non-man entry culverts**

(www.dot.ca)



**Figure 19B: Large diameter cement-mortar lining**

(www.cflhd.gov)

Reinforced cement-mortar spray-on lining is limited to large diameter culverts (see *Figure 19B*). Installations are limited by pipe diameter, valve locations, bends, and length of supply hose. The specifications, materials, advantages, and disadvantages of cement-mortar lining are discussed in *Table 1*.

### *Conclusion*

Rehabilitating rather than replacing culverts, will become more common in Utah because of the existing aging culverts are failing and population growths makes traffic control more difficult. A survey of existing culverts and site conditions and cost considerations will help determine which rehabilitation method is most appropriate.

# CULVERT REHABILITATION PRACTICES

**TABLE 1. SUMMARY OF TRENCHLESS REHABILITATION METHODS.**<sup>a</sup>

<b>Method</b>	<b>Diameter (inches)</b>	<b>Length (feet)</b>	<b>Material</b>	<b>Advantages*</b>	<b>Disadvantages**</b>
Slip lining	4 to 158	Up to 5248	HDPE, PE, PP, PVC, GRP	<ul style="list-style-type: none"> <li>-Capable of large radius bends</li> <li>-Flow diversion not necessary during installation</li> <li>-Simplistic method</li> <li>-Low cost/less training</li> <li>-Applicable to all types of existing culvert materials</li> </ul>	<ul style="list-style-type: none"> <li>- Excavation required for access pits</li> <li>-Grouting necessary for annular space</li> <li>-Existing culvert must be longitudinally uniform</li> </ul>
Cured-in-place pipe	4 to 108	Up to 3000	Thermoset Resin/Fabric Composite	<ul style="list-style-type: none"> <li>-Access pits not required</li> <li>-Capable of bends and varying diameters within the pipe</li> <li>-Grouting not required</li> <li>-Minimal or no reduction in flow capacity</li> <li>-Non-circular shapes possible</li> <li>-No joints</li> </ul>	<ul style="list-style-type: none"> <li>-Flow bypass is required</li> <li>-High material and training cost</li> <li>-Tubing must be specifically constructed for each project</li> <li>-Styrene monomer-based resins used in curing the liner are toxic to fish when discharged</li> </ul>
Fold-and-Form	4 to 18 spool 19 to 60 onsite	300 to 400	HDPE	<ul style="list-style-type: none"> <li>-Little excavation</li> <li>-Minimal or no reduction in flow capacity</li> <li>-Few or no joints</li> <li>-Fast installation</li> <li>-No grouting required</li> <li>-Capable of large bends</li> </ul>	<ul style="list-style-type: none"> <li>-Flow bypass is required</li> <li>-High material and training cost</li> <li>-Pipe must be specifically constructed for each project</li> </ul>
Cement-mortar spray-on lining	3 to 276	Up to 1476	Cement, Mortar	<ul style="list-style-type: none"> <li>-Does not block lateral and service connections</li> <li>-Protects against corrosion</li> <li>-Low cost</li> </ul>	<ul style="list-style-type: none"> <li>-Flow bypass is required</li> <li>-Existing culvert must be completely dry prior to applying the cement</li> <li>-Long curing time (up to seven days)</li> <li>-Generally fails to enhance the structural integrity of the existing pipe</li> <li>-Application of cement-mortar may be inconsistent</li> </ul>
Spiral-Wound Liner	4 to 120	Up to 1000	PE, PVC, PP PVDF	<ul style="list-style-type: none"> <li>-Liner formed on site</li> <li>-No or little excavation</li> <li>-Flow bypass may not be necessary</li> <li>-Accommodates diameter changes</li> <li>-Grouting not required if expandable liner is used</li> </ul>	<ul style="list-style-type: none"> <li>-Trained personnel required</li> <li>-Grouting may be required if fixed diameter is used</li> <li>-High material and training cost</li> <li>-Continuous fusion or sealant for joints required</li> </ul>

# CULVERT REHABILITATION PRACTICES

---

α Based on sources: -Diane Purdy, Penn State. *Trenchless Technology Alternatives for Pipe Rehabilitation*. LTAP Technical Information Sheet #116, Spring 2005.  
-Central Federal Lands Highway Division, *CULVERT PIPE LINER GUIDE AND SPECIFICATIONS*. July 2005  
-Caltrans

\* All methods restore structural integrity.

\*\* All methods increase flow velocity which may cause scouring at outlets.

Abbreviations:

CIP:	Cast Iron Pipe	PE:	Polyethylene	PVDF:	Poly-Vinylidene Chloride
GRP:	Glass-Fiber-Reinforced Polyester	PP:	Polypropylene	RCP:	Reinforced Concrete Pipe
HDPE:	High-Density Polyethylene	PVC:	Poly-Vinyl Chloride	VCP:	Vitrified Clay Pipe

Note: Given continually changing techniques, materials and equipment, the information provided here is at best a snapshot of industry practice.

## References

Caltrans. (2003). "General Culvert Barrel Rehabilitation Techniques." DIB 83-01 – 6.1-6.1.3.8 <[www.dot.ca.gov/hq/oppd/dib/dib83-01-6.htm](http://www.dot.ca.gov/hq/oppd/dib/dib83-01-6.htm)>

Central Federal Lands Highway Division. (2005). "Culvert Pipe Liner Guide and Specifications."  
<[www.cflhd.gov/techDevelopment/completed\\_projects/hydraulics/culvert-pipe-liner/](http://www.cflhd.gov/techDevelopment/completed_projects/hydraulics/culvert-pipe-liner/)>

Hydro Tech Inc. <[www.htliners.com](http://www.htliners.com)>

Isco Industries Inc. Snap-Tite. <[www.culvert-rehab.com](http://www.culvert-rehab.com)>

Ultraliner Inc. <[www.ultraliner.com](http://www.ultraliner.com)>

## *Glossary*

**Annular space** – Space between two nested pipes.

**Bulkhead** – Walls that are placed at the end(s) of a culvert to seal the annular space.

**Cured-in-place-pipe** – A resin-impregnated flexible tube cured with heat.

**Deformed-reformed** – A HPDE pipe folded that is reformed by heat.

**Fly ash** – The powdery residue of matter that remains after burning coal in a power plant. It is a fine residue that, when dry, literally flies in air.

**Laterals** – Small pipes that flow into larger pipes.

**Liner** – A material that serves as a lining inside of an existing pipe.

**Oakum** - Loosely twisted hemp or jute fiber for caulking seams.