STATE OF MAINE DEPARTMENT OF TRANSPORTATION

Culvert Rehabilitation Guidance

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This document provides guidance on creating a plan set for culvert rehabilitation. Described will be methods of rehabilitation, when they are appropriate, and general construction practices.

1. INTRODUCTION

Culvert rehabilitation is the practice of extending or restoring the service life of a culvert without removal of the existing culvert. Generally preference is given to methods that avoid open-cut trenching. The benefits of this approach are many, including reduced construction time, lower social impact, and cost savings. This document will guide you through the process of creating a plan set for a variety of rehabilitation techniques that MaineDOT employs. Although this document is intended to assist in stand-alone rehab projects, the principles may be applied to treat culverts as part of another project.

1.1. Special Provisions

The following Special Provisions can be found in the appendix:

Section 502: Structural Concrete Culvert Invert Lining (Cast-in-place Method)
Section 502: Structural Concrete Culvert Invert Lining (Shotcrete Method)
Section 502: Structural Culvert Invert Lining (Composites Method)
Section 502: Annular Space Grouting
Section 502: Structural Concrete (Fish Weirs)
Section 509: High Density Polyethylene Fish Weirs
Section 603: Pipe Culverts and Storm Drains (Cured in Place pipe)
Section 603: Pipe Culverts and Storm Drains (Culvert Sliplining)

1.2. Definitions

- Sliplining: Placing of a smaller diameter liner culvert into a larger diameter host pipe. The liner may be either a culvert or a product specifically manufactured for sliplining. The annular space between the new pipe and host pipe must be grouted to facilitate soil-structure interaction.
- Pipe Invert: The bottom section of a culvert that sees flow. As a general rule, the lower 50% of the pipe.
- Annular Space: The space between a rehabilitation structure and the host structure. Sometimes referred to as the “annulus.”
- Invert Liner: A rehabilitation technique where a new pipe invert is provided over the existing invert.
- Fiber Reinforced Polymer (FRP): A manufactured product comprised of glass fibers in a polymer resin matrix. Commonly referred to as fiberglass.
- Shotcrete: Concrete that is placed by using a pneumatic gun, producing a rough finish.

1.3. Limitations of Guidance

This document does not take into consideration the individual situation of each project. With the environmental concerns of MaineDOT projects continually evolving, the scope

of this document is limited to detailing the techniques that have been used by the Department and how to create a plan set for each of them in order to create consistency between designers and Regions. Selection of the proper treatment will most likely be a negotiation process between Project Development, the Environmental Office, and the environmental agencies such as Inland Fisheries and Wildlife and the Department of Marine Resources. This guidance is not intended to replace good engineering judgment or Stream-Smart culvert design.

2. DESCRIPTION OF METHODS

This chapter of the Guidance will describe how each method of culvert rehabilitation is constructed and state the advantages and disadvantages of each method to help a designer decide between different options.

2.1. Sliplining

Sliplining is the practice of placing a new pipe inside the old host pipe. This section will describe the materials that have been used across the United States and list some advantages and disadvantages of each. The general construction guidelines will also be presented.

2.1.1. Materials

Sliplining projects may be completed using a variety of materials. The following is a list of materials and their characteristics, although others may be available:

- Corrugated Metal Pipe (CMP): This material is inexpensive relative to the others. It is, however, very subject to corrosion and abrasion. Service life is relatively short and has been seen as short as 20 years in abrasive and corrosive environments. It is available in either steel or aluminum.
- High-Density Polyethylene (HDPE): Somewhat inexpensive, although suppliers for larger diameters are limited. Very resistant to corrosion and abrasion, however, if unreinforced, low stiffness and creep deformation become concerns. HDPE pipe is generally smooth-lined, which brings up a concern of high water velocities. This material also, if solid wall, has a thinner wall section as compared to CMP. May be a good alternative to CMP in an abrasive environment.
- Fiber Reinforced Polymer (FRP): This material has not been used as a sliplining material at the time this guidance was written. Other State DOT's have stated that the pipe is easier to handle than RCP while providing many of the same benefits. It is, generally, much more expensive than other possible options.
- Polypropylene (PP): Polypropylene pipe is a relatively new technology. Manufacturers of this product claim that the pipe is significantly more stiff than HDPE pipe, allowing it to be used under conditions where higher loading is expected. This product is available in a triple-wall construction, which is both stiffer than the double-wall construction pipe and has a smooth exterior for ease of installation.
- Any other material approved for use by the Department as Option III.

2.1.2. Construction

Sliplinings may be constructed in two ways: segmental or continuous construction. Continuous construction consists of connecting the sections of the liner pipe outside of the construction area and slid into the host pipe as a single unit. Segmental construction is performed by placing one section into the host pipe at a time and connecting the segments as they are placed into the culvert. For larger diameter pipes, segmental may be the only method that will work due to space and weight restrictions. For smaller pipes, either may be used. This option should be left to the contractor.

Figure 2.1.2.a: Proper Grout Application

Figure 2.1.2.b: Incorrect grouting

Once the liner is placed in the pipe, the annular space must be filled with grout. This is done in order to facilitate soil-structure interaction. A minimum of 1” of grout must be between the liner and the host pipe at any location around the pipe. The method used to do this should be left to the contractor, but acceptable methods include utilization of grout ports in the liner pipe and a system of grouting pipes of various lengths.

The above photos show two sliplined pipes in Maine. Figure 2.1.2.a shows a proper grouting finished product. The grout is uniform around the entire circumference of the pipe. In figure 2.1.2.b, the liner pipe rests on the host pipe, which may result in point loads on the liner in the future. Also take note of the voids in the grouting. This must be avoided to help ensure the longevity of the sliplining.

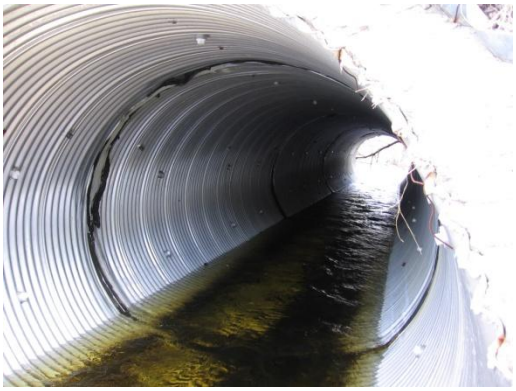


Figure 2.1.2.c: Proper Grout Method

Figure 2.1.2.d: Incorrect Grouting Method

Figures 2.1.2.c and 2.1.2.d show two methods of grouting. In figure 2.1.2.c, grout ports can be seen throughout the length of the barrel of the culvert. This helps to ensure uniformity of the grout and reduces the likelihood that voids are created. In figure 2.1.2.d, a hole has been cut in the existing pipe. This was done at both ends of the culvert and grout was pumped from either end. With this method, the condition of the grout in the center of the culvert is unknown. If the grout was not as flowable as requested, then the likelihood that voids are present under the center of the roadway is high.

The number of methods that create a proper product is extensive, but a good plan is one that has grout entry points at varying locations along the length of the culvert. Placing in lifts or blocking of the culvert may also be necessary to prevent the culvert from "floating" in the grout. A grouting plan must be submitted to, and approved by, the Department before any grouting may begin.

Care should be used during construction to ensure that the length of the flow line does not change during the sliplining process. This includes extension of the flow line as well as lateral translation of it. This may violate conditions of the permits.

2.2. Invert Liners

Invert liners are essentially a replacement contact surface of the most worn part of a pipe, the part that sees water. It can be constructed from either FRP or concrete, each with its own advantages and disadvantages.

2.2.1. Fiber Reinforced Polymer Composite

This method of creating an invert liner is relatively new and has only been used a few times across the country. There is only one manufacturer of the material as of the date this guidance was written. It was developed by a joint effort between

the University of Maine, who helped develop the technology, and Kenway, who manufactures the product. It is a thin, yet strong liner that does not greatly change the invert elevation of the pipe when installed properly, however, it does present some issues of its own.

Figure 2.2.1.a: High water velocity in FRP lined pipe

Figure 2.2.1.a shows a pipe that was rehabilitated with an FRP liner. Because of the smoothness of the pipe, the water velocity is greatly increased as compared to before treatment. This leads to issues with stream conductivity and erosion control.

Figure 2.2.1.b: Weir inclusion in an FRP liner

The high water velocity can be combatted as shown in figure 2.2.1.b. This photo shows the inclusion of weirs in the FRP liner. These must be carefully designed to slow water while still allowing wildlife to pass through the culvert. A poor design could easily fail to accomplish either of these goals.

FRP liners, like sliplinings, have an annular space that must be filled. For this application the grout must have a 28 day compressive strength of 3,000 PSI. This is because the grout for FRP liners serves two purposes: to connect the liner to the culvert and to provide resistance to buckling because of the thinness of the liner.

Another concern with FRP liners is the corrosion of the fasteners. Although they are galvanized steel, the coating wears away quickly and the fasteners begin to corrode if they are below the ordinary high water mark. Use of stainless steel fasteners is the preferred solution. If this isn't possible, the panels should be carefully designed to prevent fasteners from being located below this mark.

2.2.2. Concrete

Concrete invert liners are generally one of the least expensive forms of rehabilitation and have a very short service life, only about 15-25 years depending on site conditions. They may be constructed using one of two methods: Shotcrete or cast-in-place concrete.

Figure 2.2.2.a: A concrete liner nearing the end of service life

In both instances, the original flow line of the culvert must be restored prior to installation of the liner itself. This work is performed by means of a preliminary concrete placement anyplace where the invert has corroded away and voids have formed in the soil.

Before the placement of the actual liner, rows of shear connectors are welded to the side of the culvert. Generally 3 rows of connectors spaced 8” apart will be

adequate. The area to receive the liner is 6" above the highest row of shear connectors and lower.

Reinforcing steel is also placed. #5 bars spaced at 12" has worked well. This allows field cutting and bending if it becomes necessary while still providing adequate strength. Rebar should be paid separately from the liner.

The final step of the liner is the placement of the concrete. This is the only variation between the two methods. Regardless of how the concrete is placed, a minimum of 5 inches of concrete is to be placed with a minimum cover over the reinforcing steel of 2 inches and no bolt lines of the original culvert within one foot of the top of the liner. The finish of the liner should be rough, meaning either leaving a gun finish or, in the case of cast-in-place, providing a broom finish. Before the culvert is allowed to pass water again, asphalt emulsion is placed on the top edges of the liner to facilitate draining. Any internal weirs are incidental to the placement of the liner.

Figure 2.2.2.b: Asphalt emulsion on a concrete liner

External weirs for this type of liner are not incidental. They may become complex and, to avoid problems, the Department has concluded that in this case it is best to pay for weirs separately.

2.3. Cured-in-Place Pipe (CIPP)

This method of treatment is still in its infancy in Maine. There are very few suppliers for this method and it tends to be expensive as compared to the other methods, though the advantages that it provides are unmatched. It is an excellent choice where excavation and social impacts are not permitted at all, perhaps making it a good option

to rehabilitate underdrain in urban areas such as Portland or Bangor. Existing access, for example a catch basin, is adequate for the placement of CIPP.

The CIPP is installed by feeding a thermosetting resin-soaked sleeve through the host pipe and expanding it using either water or compressed air. The feeding may be done by either pulling the sleeve into place or inverting it. Inversion is a better option for tight spaces and variation in cross section of the host pipe. The water or air used to expand the sleeve is then heated in order to cure the resin. The ends of the sleeve are then cut to match the existing pipe and service is allowed to continue. The entire process may be completed in as little as one day.
The design calculations for the liner itself are left to the contractor, who shall submit them for approval to the Department.

2.4. Spray-on Treatments

A spray-on treatment is to culvert rehabilitation as a hot mix asphalt overlay is to paving. The intent is to preserve the culvert rather than to extend the service life of it. This has not been used in Maine yet for good reason. The state of our infrastructure system forces our focus to be on extending service life rather than preventing degradation of a structure already in good condition. The hope is to include this treatment method for future use, when the infrastructure system has improved to the point where prevention can be utilized over repair.

To apply a spray-on treatment a contractor may either use a Shotcrete type applicator or a centrifuge type gun. The concept is to apply a thin layer of mortar across the entire inside surface of a culvert. The idea behind the treatment is to prevent corrosion and abrasion before it starts to take place and to provide a sacrificial surface that does not contribute to the function of the structure that can wear before the culvert itself.

3. CULVERT EVALUATION

The first step in determining whether or not a culvert will need treatment, be it rehabilitation or replacement, is to evaluate the condition of the culvert. This work is done by Maintenance and Operations (M&O), but having an understanding of the ratings may help in making an informed decision. This section will expose you to the rating systems used by M&O and help in determining possible causes of deterioration.

3.1. FHWA Culvert Inspection Rating Guidelines

The Federal Highway Association (FHWA) has established a set of guidelines that rates culvert conditions on a scale from 0 to 9, with 9 being a newly installed culvert and 0 being total failure of the culvert. These ratings were deemed conservative by the Department and were modified, however, the essence of the system remains. The ratings still range from 0 to 9, but superficial issues no longer result in a poor rating. The following is a description of the ratings from section 4.1.1 of the Bridge Inspection Guide:

Code	Description
N	NOT APPLICABLE
9	EXCELLENT CONDITION – no defects at initial inspection
8	VERY GOOD – no noteworthy deficiencies
7	GOOD – shape is smooth and symmetrical Galvanizing is gone (usually below low water elevation) allowing surface rust, but no pitting. Minor scouring near pipe.
6	SATISFACTORY – shape has smooth curvature, but non-symmetrical shape. Pitting up to ½ of plate thickness. Local minor scour at pipe end(s); may have some undermining.
5	FAIR – shape has significant distortion and deflection in one section. Pitting is deeper than ½ plate thickness, but no holes. Scour/erosion has partially to totally exposed a moderate portion of the pipe end(s); roadway width unaffected
4	POOR – shape has significant distortion and deflection throughout. Individual holes through the pipe walls. Scour/erosion has significantly undermined the end(s)or exposed the ends sufficiently to allow distortion to occur; minor roadway shoulder loss
3	SERIOUS – shape has extreme distortion and deflection. Holes are continuous for partial section, but unlikely to collapse under roadway. Scour/erosion has caused severe loss of full travel lane(s) is narrowed or unstable @ edges
2	CRITICAL – shape has extreme distortion and deflection throughout; roadway possibly settled. Extreme section loss could allow collapse under roadway (unzipped); Scour/erosion has reduced roadway to 1 lane
1	CLOSED – partial failure

0 TOTAL FAILURE

Note that these ratings only apply to corrugated metal culverts. In this system, a rating of 3 (Serious) and lower insinuates that the structural integrity of the culvert may have become compromised, meaning that a treatment to restore this capacity must be used. A rating greater than 3 may require evaluation of integrity, but failure at the current condition is unlikely. A culvert that has lost structural capacity, regardless of the level of loss, is considered fully deteriorated. Otherwise, it is to be considered partially deteriorated and non-structural methods may be used.

3.2. Identifying the Problem

There are many reasons that a culvert may be degrading. Determining the reason a culvert is degrading can allow a designer to make an informed decision on the treatment method and material to be used to best use the resources of the Department. The following table may help to determine the causes of common problems:

Problem	Possible Cause
Loss of Invert	• Abrasion caused by stream • Corrosion from pH of water • Low resistivity soils • Chemical attack
Large deflections	• Loading exceeding design capacity • Unexpected changes in loading (eg. Groundwater elevation changes.) • Insufficient compaction of soils under haunches • Voids in soil around culvert • Insufficient cover
Joint Separation	• Improper installation • Freeze-thaw interaction • Settlement • Movement from structural deterioration
Voids in surrounding soil	• Water flow around holes in culvert causing particle migration • Improper soil placement and compaction

This table is by no means complete, but it does provide a starting point for designers. Deterioration caused by corrosion or abrasion may be the simplest to determine and rehabilitate. It is also the most common. In this case, the designer should choose a rehabilitation material that is different from the existing material. For example, a corroded invert on a corrugated metal pipe may be repaired by sliplining with a

high density polyethylene, a material that is not subject to the oxidation that caused the corrosion in the host pipe.

3.3. Feasibility of Rehabilitation

Not all culverts can be rehabilitated. There are many reasons why a culvert may not be rehabilitated. The following list contains some of those reasons:

- Invert elevation sensitivity (stream connectivity)
- Culvert was previously rehabilitated
- Too much pipe deflection or joint separation
- Significant errors in installation or design
- Reduction in capacity not allowable

If deterioration is caused by an issue from either design or installation, it may be difficult to correct. An example of this would be misaligned pipe segments, incorrect inlet or outlet elevation, etc. In these cases, a better option would be to replace the culvert. If rehabilitation is attempted, the underlying issues may still be present, possibly compromising the effectiveness of the rehabilitation technique.

4. ENVIRONMENTAL AND HYDRAULIC CONSIDERATION

Some of the biggest issues that must be addressed with regard to culvert rehabilitation do not involve the structure itself, but rather how it works. In order to be a feasible option, the new condition of the system must allow the passage of water during high water conditions and the conductivity of aquatic organisms at the opposite end of the spectrum: low water conditions. This section of the guide will explain how these challenges are handled.

4.1. Weir Inclusion

Weirs can most easily be described as a method of flow regulation. Essentially, they act as mini dams within a culvert system. For our purposes, there are two types of weirs: substrate retention weirs and stream connectivity weirs. Both will be discussed in this section and can be made from concrete, HDPE, or composites.

4.1.1. Stream Connectivity

This kind of weir can be more accurately described as a stream connectivity weir. Depending on the site in question, species that must be able to pass through the culvert may include Atlantic salmon, eastern brook trout, alewife, smelt, or other aquatic animals. Final determination of passage requirements, as well as the efficacy of an engineered weir approach to fish passage, is the responsibility of MaineDOT's Environmental Office.

The design of this kind of weir is performed by a hydraulic engineer or hydrologist, but it is worth noting in this manual the general characteristics. The design should serve several purposes. Two of the most important of these purposes are, firstly, to slow the water in the pipe to levels that will reduce scour and erosion and allow weak-swimming species to pass through the culvert and, secondly, to increase the water level in the culvert so that even during dry times and low water conditions the system will allow passage.

The design possibilities are nearly limitless, but some characteristics remain in most designs. Modern practice for external grade control is to build with rock and other natural materials. Most weirs have a notch in them where water and aquatic organisms may pass through. This notch may either be in the center of the weir or alternate left and right along the culvert. The other characteristic that weir systems have is increasing top elevation as they progress upstream.

In some cases, a site may require a more complex system of weirs that may extend to external weirs. The properties of this type of weir system are beyond the scope of this guidance.

4.1.2. Substrate Retention

Often, a requirement of permitting is to provide a natural stream bed in an effort to make the structure "invisible" to wildlife. When the scope of a project is pipe replacement, there are many more options than with culvert rehabilitation. In a replacement project, a natural stream bed can be achieved by either constructing an open bottom arch or by placing soil retention sills in a standard box or pipe. The design for these, like wildlife conductivity weirs, is generally handled by a hydraulic engineer.

Because this technique increases the invert elevation dramatically, it is not used in culvert rehabilitation and therefore beyond the scope of this document.

4.2. Hydraulic Consideration

A consequence of culvert rehabilitation many times is decreasing of the cross-sectional area of a culvert. This brings into play the issues of hydraulic capacity. It is important to make sure that after rehabilitation a culvert can pass a high water event. If it cannot, the impacts on both infrastructure and public safety can be catastrophic.

Hydraulic analysis is performed by a hydraulic engineer, although, unless an error was made in sizing the host pipe, the decrease in cross-sectional area does not greatly affect the performance of a culvert. This may be from either conservative calculations or limited sizing options at the time of installation.

5. REHABILITATION PLAN DEVELOPMENT

Our method of conveying information on how we would like projects constructed is generally by using a plan set. This is a set of documents that tells a contractor where the project is located and what we expect the finished product to be. This section will tell you the recommended format for plan sets on culvert rehabilitation projects.

5.1. Sliplining

In the appendix you will find a sample plan set for a sliplining project. You may notice the order of the sheets. In general, the higher the sheet number, the more specific are the requirements and provided information. For example, the first sheet tells the general location, while the last sheets show elevations on the cross-sections. A good order of plans is as follows:

- Title sheet
- General notes and estimate
- Culvert Details
- Plan view
- Cross-sections

Although there are many ways to prepare a plan set, one goal of the Department is consistency. For this reason, the order stated above should be followed. The required information for each sheet will be discussed in the following table:

Sheet	Required Information
Title Sheet	• Follow "Title Sheet Development" in Microstation manual.
General Notes and Estimate	• Note stating that contractor is responsible for measurement to ensure fit of proposed liner • Estimate with item numbers • Any other appropriate notes
Culvert Details	• Existing pipe diameter • Proposed lining diameter • Proposed pipe length • Riprap, if applicable
Plan View	• "Install XX" Sliplining" • Riprap, if applicable • Start and end of project
Cross-Sections	• "Existing roadway to remain" • Flow direction • Existing culvert annotation • Riprap, if applicable • "Proposed XX" sliplining"

5.2. Invert Liners

Plan sets for concrete invert liners are somewhat more complicated as compared to a plan set for a full sliplining. This is because it is necessary to detail the rebar used in the liner. Generally, #5 bars spaced 12" OC in each direction will be sufficient. The proper order of sheets for this type of plan set, for both an FRP liner and a concrete liner, is as follows:

- Title Sheet
- General Notes and Estimate
- Culvert Details
- Plan View

For this type of rehabilitation, no cross-section is necessary. The required information is the same as stated in Section 5.1 above.

5.3. Cured-in-Place Pipe

The rehabilitation method of cured-in-place pipe is seldom used in Maine. In this instance, a plan set was not used. Generally, these projects tend to be difficult to develop in this sense. This may be because CIPP is generally used on closed drainage systems, where a survey is not obtainable. The best course of action on this type of project is to create an accurate estimate and bid book package.

5.4. Spray-on Treatments

Spray-on treatments have not been used as a rehabilitation technique in Maine, although they hopefully will be in the future. In the event that it is used, the easiest, and perhaps the best, course of action to prepare the project for bidding would be to follow the model used for CIPP projects. This method is straight forward enough that no plan set will be required.

6. APPENDIX

SPECIAL PROVISION
SECTION 502
STRUCTURAL CONCRETE CULVERT INVERT LINING
(Cast-in-place Method)

Description The work shall include preparation of existing surfaces, installation of machine bolts or studs, spot painting of corroded areas, placement of concrete, and the application of emulsified asphalt.

The Contractor has the option of using either a shotcrete lining method or a composite lining method for this culvert repair in lieu of this cast in place method. If the Contractor chooses a shotcrete or composite method, the appropriate special provision must be followed.

Materials Concrete for the culvert repair shall be Class "A" Concrete. The concrete mix shall include a chemical accelerator and shall be submitted to the Resident for prior approval.

Construction Requirements All work shall be in conformity with applicable requirements of Section 502.

Stud welded shear connectors or machine bolts meeting ASTM A307 shall be installed in accordance with Section 505 of the Standard Specifications with the following changes, Section 505.04 shall be ignored and the first paragraph of Section 505.05 is replaced in with the following:

Studs shall be inspected for a full 360 degree weld. Any stud that is found not to have the full weld shall be marked for re-welding.

All reinforcement shall be secured in place to prevent displacement during the concrete placement.

Finish the entire length of the invert with a broom surface finish.

The horizontal interfaces (joint between the top of the concrete invert lining and the corrugated metal culvert) shall be sealed with an asphalt emulsion (roofing tar) which extends onto the metal culvert at least 25 mm [1 in].

All areas of steel section loss above the concrete liner shall be sandblasted and painted with a MC Zinc Primer and a MC Urethane with Mox Tar Topcoat.

The Contractor shall sandblast all areas from 25 mm [1 in] below the top of concrete lining to 150 mm [6 in] below lowest row of shear connectors. The Contractor shall remove all loose materials, rust, scale, oil and deleterious material from all remaining surfaces to receive concrete by methods acceptable to the Resident. In areas where the metal is non-existent, a preliminary concrete placement shall be made utilizing forms where required, to fill voids and establish the former extremity lines of the metal. The final placement is to be made over this preliminary placement. No concrete shall be placed on frozen surfaces.

An approved curing cover (or compound) shall be applied within 18 hours after finishing. Finished concrete shall be cured for a minimum of 48 hours before flushed with water, unless otherwise directed by the Resident, and flush water must be collected as per Section 656.

Method of Measurement The structural concrete for the culvert invert lining, satisfactorily placed and accepted in accordance with the dimensions shown on the plans, will be measured as one lump sum unit.

Basis of Payment The accepted structural concrete for the culvert invert lining will be paid for at the contract lump sum price for Structural Concrete Culvert Invert Lining. The contract lump sum price shall be full compensation for preparing surfaces, installing machine bolts or studs, spot painting of corroded areas with an MC Zinc Primer and MC Urethane with a Mox Tar Topcoat, placing concrete, applying of asphalt emulsion and furnishing all materials except reinforcing steel, equipment, labor and incidentals necessary to complete the work. Reinforcing steel fabrication, delivery and placing shall be paid for under their respective pay items.

Concrete admixtures including silica fume will not be paid for directly, but shall be incidental to the related contract item.

The containment and disposal of pollutants during surface preparation will not be paid for directly, but shall be incidental to the related contract item and included in the Contractor's SEWPCP.

Payment will be made under:

Pay Item		Pay Unit
502.325	Structural Concrete Culvert Invert Lining	Lump Sum

SPECIAL PROVISION
SECTION 502
STRUCTURAL CONCRETE CULVERT INVERT LINING
(Shotcrete Method)

Description The work shall include preparation of existing surfaces, installation of machine bolts or studs, spot painting of corroded areas, application by pneumatic pressure of a shotcrete mix, furnishing test panels, extracting cores, and application of asphalt emulsion as indicated on the plans, and in accordance with this specification.

The Contractor has the option of using either a cast in place lining method or a composite lining method for this culvert repair in lieu of this shotcrete method. If the Contractor chooses a cast in place or composite method, the appropriate special provision must be followed.

Shotcrete shall conform to all requirements of ACI 506.2 "Specifications for Materials, Proportioning, and Application of Shotcrete", published by the American Concrete Institute, Detroit, Michigan, except as modified by the requirements of this project specification. Shotcrete shall consist of an application of one or more layers of mortar or concrete conveyed through a hose and pneumatically projected at a high velocity against a prepared surface.

Shotcrete shall be produced by either a dry-mix or a wet-mix process. The wet-mix process consists of thoroughly mixing all the ingredients except accelerating admixtures but including the mixing water, introducing the mixture into the delivery equipment and delivering it, by positive displacement, to the nozzle. The wet-mix shotcrete shall then be air jetted from the nozzle at high velocity onto the surface. Dry-mix process is shotcrete without mixing water which is conveyed through the hose pneumatically and the mixing water is introduced at the nozzle. For additional descriptive information, the Contractor's attention is directed to the American Concrete Institute Standard "Guide to Shotcrete (ACI 506R-90)".

Qualifications The work shall be performed by fully qualified personnel experienced in this type of work.

1. The foreman shall have at least five years of shotcrete experience and at least two years as a nozzleman.
2. The nozzleman shall have at least two years recent experience of satisfactory work as a nozzleman.
3. Evidence of the foreman and nozzleman's experience of satisfactory work in similar capacities elsewhere shall be provided.

Materials All materials for shotcrete shall conform to the following requirements.

Cement	AASHTO M-85, ASTM C150, Type I, II, III or IV.
Fine Aggregate	AASHTO M-6, ASTM C33 clean, natural.
Coarse Aggregate	AASHTO M-80, Class B for quality.
Water	Potable, clean, and free from substances deleterious to concrete and steel or elements that would stain.

Chemical Admixtures	ASTM C1141 and the following: Water-
reducer	AASHTO M-194, Type A, D, F, G or
Superplasticizer	ASTM C494 Type A, D, F, G Air-
Entraining Agent	AASHTO M-194/ASTM C260
Plasticizers	AASHTO M-194 Type A, D, F, G or ASTM C494
Mineral Admixtures	
Fly Ash	AASHTO M-295, ASTM C618 Type F or C
Silica Fume	ASTM C1240, 90% minimum silicon dioxide solids content, not to exceed 12% by weight of cement. In addition, silica fume shall conform to the requirements of Section 502.
Polypropylene Fibers	ACI Standard, Polypropylene Fibers, 1 inches in length, 1½ lb/yd^3
Steel Fibers	ASTM A820 Type I, II, or III, Deformed, Steel Fibers, 1 in to 1 ⅜ inches in length, minimum aspect ratio of 60.
Curing Compounds	AASHTO M-148 Type 1 D of Type 2 Pre-
packaged Shotcrete	ASTM C928

The use of other admixtures shall not be used unless approved by the Resident. Admixtures used to entrain air, to reduce water-cement ratio, to retard or accelerate setting time, or to accelerate the development of strength, shall be thoroughly mixed into the shotcrete at the rate specified by the manufacturer unless specified otherwise. Accelerating additives shall be compatible with the cement used, be non-corrosive to steel and shall not promote other detrimental effects such as cracking or excessive shrinkage. The maximum allowable chloride ion content of all ingredients shall not exceed 0.10% when tested to AASHTO T260.

Premixed and pre-packaged concrete products specifically manufactured as a shotcrete product may be provided for on-site mixed shotcrete if approved by the Resident. The packages shall contain materials conforming to the materials portion of this specification.

Stud welded shear connectors or machine bolts meeting ASTM A307 shall be installed in accordance with Section 505 of the Standard Specifications with the following changes, Section 505.04 shall be ignored and the first paragraph of Section 505.05 is replaced in with the following:

Studs shall be inspected for a full 360 degree weld. Any stud that is found not to have the full weld shall be marked for re-welding.

Materials Storage and Handling Materials shall be delivered, stored, and handled to prevent contamination, segregation, corrosion, or damage. Liquid admixtures shall be stored to prevent evaporation and freezing.

Cement shall be adequately stored to prevent moisture degradation and partial hydration. Cement that has become caked or lumpy shall not be used.

Aggregates shall be stored so that segregation and the inclusion of foreign materials are prevented. The bottom 6 in of aggregate piles in contact with the ground shall not be used.

Submittals The following submittals shall be provided by the Contractor for the Resident's review and approval. The Contractor will not be allowed to begin culvert repairs until all submittal requirements are satisfied and found acceptable to the Resident. Changes or deviations from the approved submittals must be resubmitted for approval. Adjustments in contract time will not be allowed for incomplete submittals.

At least 21 calendar days prior to initiating the work, the Contractor shall submit to the Resident the following:

1. Written documentation of the foreman's and nozzleman's qualifications and the proposed method of shotcrete placement.
2. Shotcrete mix design including:
   a) Brand and type of Portland Cement used.
   b) Source, gradation, and quality of aggregates as specified herein.
   c) Proportions of mix by weight.
   d) Proposed admixture, manufacturer, dosage, technical literature (when admixture allowed).
   e) Compressive strength test results from the manufacturer's records, no older than six months, verifying the 28 day compressive strength.

Shotcrete Mix Design Aggregate for shotcrete shall meet the strength and durability requirement of AASHTO M-80 and M-43 and shall meet the following gradation requirements.

Sieve Size	% Passing by Weight
3/8 in	100
No. 4	95 – 100
No. 8	80 – 100
No. 16	50 – 85
No. 30	25– 60
No. 50	10 – 30
No. 100	2 – 10
No. 200	0-5
FM	2.3 to 3.1

A. Proportioning Shotcrete shall be proportioned and delivered with a minimum cement content of 650 lb/yd^3.

B. Strength Requirements Shotcrete shall be proportioned to produce a mix capable of attaining 5000 psi compressive strength in 28 days. The average compressive strength of each set of three cores extracted from the test panels shall equal or exceed the specified compressive strength, with no individual core less than 75 percent of the specified compressive strength, in accordance with ACI 506.2R-95.

Mixing and Batching Mixing equipment shall be capable of thoroughly mixing the materials in sufficient quantity to maintain the placing continuity. Shotcrete shall be batched, delivered and placed within 90 minutes of mixing.

Field Quality Control Production test panels shall be required. Qualified personnel shall perform shotcreting and coring of the test panels with the Department's personnel present. The Contractor shall provide equipment, materials and personnel as necessary to obtain shotcrete cores for testing including construction of test panel boxes, field curing requirements and coring. The Department will perform compressive strength testing. Shotcrete final acceptance will be based on obtaining the specified 28 day compressive strength.

Shotcreting may commence upon initial approval of the design mix and nozzlemen.

Production Test Panels At least one production test panel shall be furnished during each day of production of shotcrete. The production test panels shall be constructed simultaneously with the shotcrete facing installation at times designated by the Resident. Production test panels shall be made with the minimum dimensions of 18 x 18 inch and at least 6 inch thick.

Test Panel Curing, Test Specimen Extraction and Testing Immediately after shooting, the test panels shall be field moist cured by covering and tightly wrapping with a sheet of material meeting the requirements of ASTM C 171 until test specimens are extracted. The test panels shall not be immersed in water. The test panels for the first 24 hours after shooting shall not be disturbed.

At least three 3 inch diameter core samples shall be cut from each unreinforced production test panel for compressive strength testing. The Contractor shall extract the test specimens from test panels in the field within 48 hours of shooting the panel.

Cores shall not be taken from the outer 6 inch of test panels measured in from the outside edges of the panel's form.

The cores and container shall be clearly marked to identify the core locations. For production testing, the production section of the unformed superstructure repair represented by the production test panel cores shall be marked on the cores and the container. Immediately wrap cores in wet burlap or material in accordance with the requirements of ASTM C 171 and seal in a plastic bag. The Department shall take possession of the cores immediately after extraction. The remainder of the panels shall become the property of the Contractor. The Department will perform the compressive strength testing.

Upon delivery to the testing lab, samples will be placed in the moist room until the time of test. When the test length of a core is less than twice the diameter, the correction factors given in AASHTO T 24/ASTM C 42 will be applied to obtain the compressive strength of individual cores. Three cores will be tested at 28 days for compressive strength per AASHTO T 24/ASTM C 42.

Construction Requirements

The construction sequence shall be in accordance with the approved submittal, unless otherwise approved by the Resident.

A. Equipment

1. The shotcreting equipment selected must be capable of metering the mix through a hose to the nozzle for projecting at high velocity onto the surface to be shotcreted.

2. The gun shall be either the double chamber or the rotary type capable of continuous delivery of material. Gaskets in the equipment must be kept in good condition to avoid reduced pressure and consequent reduced velocity of material through the hose.

3. The air compressor may be any standard type capable of sufficient pressures and volume of air to convey the material through the longest hose delivery. The air compressor capacity must have allowance for air used in removing rebound and other incidental work. The air hose shall be equipped with filters to prevent any oil or grease from contaminating the shotcrete.

4. Water pressure shall be maintained at a minimum 15 psi higher than the highest air pressure required for placing the material. Both air and water pressure shall be uniformly steady.

B. Surface Preparation The Contractor shall remove all loose materials, rust, scale, oil, and deleterious material from all surfaces to receive shotcrete by methods acceptable to the Resident. The removal shall be accomplished in such a manner as not to loosen, crack, or shatter the surfaces to receive the shotcrete. Any surface material, which in the opinion of the Resident, is so loosened or damaged shall be removed to a sufficient depth to provide a base that is suitable to receive the shotcrete. The Contractor shall clean all surfaces to receive shotcrete by methods acceptable to the Resident. Material that loosens as the shotcrete is applied shall be removed. No shotcrete shall be placed on frozen surfaces.

All areas of section loss above the concrete liner shall be sandblasted and painted with a MC Zinc Primer and a MC Urethane with Mox Tar Topcoat.

C. Shotcrete Alignment Control The Contractor shall ensure that the thickness of shotcrete satisfies the minimum thickness shown on the design drawings using alignment wires, thickness control pins, or other means acceptable to the Resident.

D. Delivery and Application In the areas of the culvert where voids are present a preliminary placement of shotcrete shall be made to fill all voids adjacent to the extremity of the lines of the structure face. The final placement is to be made over this preliminary placement to full depth.

The shotcrete shall be applied from the lower part of the work area upwards to prevent accumulation of rebound on uncovered surfaces. Rebound shall not be worked back into the placement nor shall the rebound be salvaged. Rebound which does not fall clear of the working area shall be removed. The nozzle shall be held at an angle approximately

perpendicular to the working face and at a distance so that rebound will be minimal and compaction will be maximized. Thickness, methods of support, air pressure, and rate of placement of shotcrete shall be controlled to prevent sagging or sloughing of freshly applied shotcrete.

The shotcreting procedure may be corrected by adjusting the nozzle distance and orientation perpendicular to the surface, adjusting the water content of the shotcrete mix or other means acceptable to the Resident. Retempering of the mix will not be permitted. The shotcreted surface shall be broomed and roughened to insure proper bond of subsequent layers.

All horizontal edges of exposed concrete (joint between the top of the concrete invert lining and the corrugated metal culvert) shall be sealed with an asphalt emulsion (roofing tar) which extends onto the culvert at least 1 in.

E. Defective Shotcrete Surface defects shall be repaired as soon as possible after initial placement of the shotcrete. All shotcrete which lacks uniformity, which exhibits segregation, sagging, honeycombing, or lamination, or which contains any voids of sand pockets shall be removed and replaced with fresh shotcrete by the Contractor in accordance with this specification and to the satisfaction of the Resident.

A clearly defined pattern of continuous horizontal or vertical ridges or depressions at the reinforcing elements after they are covered will be considered an indication of insufficient cover of reinforcement or poor application and probable void. In this case, the application of shotcrete shall be immediately suspended and the work carefully inspected by the Resident. The Contractor shall implement and complete corrective measures prior to resuming the shotcrete operations.

Reinforcement All reinforcement shall be secured in place to prevent displacement during the shotcrete application.

F. Finish Shotcrete finish shall be a natural gun finish. Scraping or cutting to remove high spots shall not be done until the shotcrete has become stiff enough to withstand the pull of the cutting device.

G. Weather Limitations Shotcrete shall not be placed without cold weather protection when the ambient temperature is below 40° F and falling and/or when the shotcrete is likely to be subjected to freezing temperatures before a minimum strength of 700 psi is attained. Cold weather protection shall be maintained until the strength of the in-place shotcrete is greater than 750 psi. Cold weather protection shall include heating under tents, blankets, or other means acceptable to the Resident. The temperature of the shotcrete, when deposited, shall be above 50° F but less than 90° F.

Shotcrete application shall also be suspended during high winds and heavy rains when, in the opinion of the Resident, the quality of the application is not acceptable. Newly placed shotcrete exposed to rain that washes out cement or otherwise makes the shotcrete unacceptable to the Resident shall be removed and replaced. The Contractor shall

provide adequately secured polyethylene sheeting or equivalent when adverse exposure to weather is anticipated.

H. Curing An approved curing cover (or compound) shall be applied within 18 hours after finishing. After surface water has evaporated from the finished surface, shotcrete exposed to sunlight shall be immediately treated for curing. Finished shotcrete shall be cured for a minimum of 48 hours before flushed with water, unless otherwise directed by the Resident, and flush water must be collected as per Section 656.

Safety Requirements Appropriate eye and dust protection equipment shall be used during shotcrete application. Cement and other admixtures are caustic and may cause eye, skin, and respiratory irritation unless safety measures are taken. Adequate ventilation shall be required. Nozzlemen and helpers shall as a minimum be equipped with gloves, respirators, eye protection and adequate protective clothing during the application of shotcrete. The Contractor is responsible for meeting all Federal, State, and Local Safety Code Requirements.

Method of Measurement The shotcrete for the culvert invert lining, satisfactorily applied and accepted in accordance with the dimensions shown on the plans, will be measured as one lump sum unit.

Basis of Payment The accepted shotcrete for the culvert invert lining will be paid for at the contract lump sum price for Structural Concrete Culvert Invert Lining. The contract lump sum price shall be full compensation for preparing surfaces, installing machine bolts or studs, spot painting of corroded areas with an Zinc rich Primer and MC Urethane with a Mox Tar Topcoat, applying shotcrete, applying of asphalt emulsion, constructing test panels, extracting cores, and furnishing all materials, equipment, labor, and incidentals necessary to complete the work.

Shotcrete admixtures including silica fume will not be paid for directly, but shall be incidental to the related contract item.

72

The containment and disposal of pollutants during surface preparation and during shotcrete application will not be paid for directly, but shall be incidental to the related contract item and included in the Contractor's SEWPCP.

Payment will be made under:

Pay Item	Pay Unit
502.325 Structural Concrete Culvert Invert Lining	Lump Sum

SPECIAL PROVISION
SECTION 502.325
STRUCTURAL CULVERT INVERT LINING
(Composites Method)

Introduction This specification covers the rehabilitation and fish weirs for culvert structures through the use of glass fiber reinforced polymer (FRP) liner segments.

The Contractor has the option of using either a shotcrete lining method or a cast in place lining method for this culvert repair in lieu of this composites method. If the Contractor chooses a shotcrete or cast in place method, the appropriate special provision must be followed.

DEFINITIONS

For the purpose of this specification, the following definitions apply:

E-glass Alumo-borosilicate glass with an alkali content of maximum one weight percent, when expressed as sodium oxide (Na_2O)

Effective length of unit

The distance between planes normal to the unit axis and passing through the end points of the lining unit

Liner segment A discrete length of culvert lining which may be either a single pipe lining unit or a combined pair of segmental lining units

Vinyl ester resin

A resin produced by the esterification of an epoxy resin with an unsaturated monocarboxylic acid – the reaction product is then dissolved in a reactive solvent, such as styrene, to a 35 - 50 percent content by weight

MATERIALS

Glass Mat A layer of E-glass fiber constructed as either chopped strand mat (CSM) or continuous filament mat (CFM) that provides a resin rich FRP layer near the corrosion/erosion exposed surface. All glass fiber reinforcement shall have a surface treatment (binder) compatible with the lining manufacturing process and the matrix resins. A stitched material laminate is also acceptable.

Glass fiber Reinforcement All glass fiber reinforcement shall be E-glass or better and have a surface treatment compatible with the lining manufacturing process and the matrix resins.

Unidirectional (UD) reinforcement areal weight shall not exceed 55 oz/yd^2 in any single ply. A layer of CSM or CFM shall separate layers of UD fabric where applicable to maintain laminar shear strength. The E-glass material shall not contain more than 0.2% moisture by weight as supplied; it shall be uncontaminated and protected to the point of use.

Grout Grout having a 28-day compressive strength of at least 3,000 psi at the desired water content for optimum placement shall be used. The permissible mixing and placement temperature range per the manufacturer's recommendations shall not be lower than 40°F or higher than 90°F. The non-shrink grout shall have a Hardened Height Change per ASTM C1090 of 0.0 to 0.3%.

Resin Vinyl ester or vinyl ester blend corrosion resistant resin shall be used with a catalyzation process applied in accordance with the resin manufacturer's instructions. The resin shall have a viscosity suitable for manufacturing method. The gel time shall be adequate for the given environmental conditions present during the manufacturing process. The gel time must allow for the elimination of wedging within the part. Resin promotion should allow for adequate cure during manufacture. Resin must achieve 80+% of manufacturer's Barcol value without post curing.

Cured resins, as cast singly without reinforcement, shall have an elongation at break greater than 1.4% when tested in accordance with ASTM D790. In addition, the Barcol Hardness as determined by ASTM D2503 shall be at least 30. Resins "flexibilised" by the addition of plasticisers shall not be used.

Coating Dyes, pigments, or additives shall be introduced as necessary in the resin to provide resistance to ultra-violet light degradation and a uniform, muted appearance.

Fasteners Carbon steel fasteners and washers with a minimum 0.2 mil zinc coating or stainless steel fasteners and washers shall be used. Fasteners shall have a minimum shank diameter of 0.138 inches and washers shall have a diameter of between ¾ to 1 inch.

CONSTRUCTION REQUIREMENTS

General All culvert linings shall be manufactured with the following elements:

4. A corrosion and abrasion resistant barrier layer
5. A reinforcement layer comprised of double bias and unidirectional fabric
6. A rough backing to provide a bond between the lining and annular grout
7. A nailing flange that is offset from the general liner radius

The manufacturing facility shall have a Certified Composites Technician (CCT) certified in Open Molding or Vacuum Infusion Process (VIP) on staff to supervise or perform the manufacturing of all composite components. The design of the composite liner shall be completed by a composites engineer and be verified by a Professional Engineer.

Barrier Layer (BL) The BL shall be manufactured from a vinyl ester resin system reinforced with E-glass CSM or CFM between 30-50% content by weight. The BL shall be a minimum of 0.10 inches thick.

Glass reinforcement The structural layer shall be made from a vinyl ester resin system impregnated layers of E-glass fiber. At least one ply shall be double bias (±45) stitched or woven fabric having an areal weight of at least 24 oz/yd^2. At least one ply shall be made up of unidirectional (UD) E-glass with the fiber direction oriented in the circumferential (hoop) direction of the liner. The areal weight of the UD plies shall be selected by analysis and/or

test to satisfy strength and stiffness requirements. The structural layer shall have a fiber content of between 50%-70% by weight.

Liner fabrication Each fabric layer comprising the FRP liner shall be placed in a mold having the same nominal inner radius as the culvert minus 1 inch to avoid contact with the culvert bolts. A nailing flange shall transition outward to the nominal inner radius of the culvert extending a minimum of 2 times the number of fastener rows plus 1 inch. A gradual transition shall exist between the two liner radii extending between 3 to 6 inches depending on liner radius. The extent of the liner in the circumferential dimension shall be as shown on the Plans.

Rough backing A clean, dry aggregate shall be bonded to the back of the FRP liner to promote a mechanical bond between the liner and grout filler. It shall consist of an angular, inert material, such as crushed granite, nominally 1/8 to 1/4 inch in size uniformly distributed over the external surface. A CSM layer with an areal weight at least 1.5 oz/ft^2 shall be hand laid on to the back of the liner using a vinyl ester resin system and rollers to provide a resin- rich embedment layer for the aggregate. Once the resin has cured, a stiff broom shall be passed over the surface to remove any loose or poorly bonded aggregate. The aggregate must uniformly cover 50% or more of the total surface area of the back of the panel.

Weir Fabrication Weirs shall be fabricated from E-glass fabric and a vinyl ester resin system using the materials described above. The size, shape, and elevation of the weir features shall be as shown on the Plans. Wall thickness shall be at least ½ inch. Wall thickness may need to increase based on panel radius. Allowable stresses as per RTP1-2011.

Edges and ends The edges and ends of all trimmed lining segments and sections shall be sealed with a vinyl ester resin system to prevent the exposure of glass fibers. The resin shall be pigmented to match the color and performance of the laminating resin.

INSTALLATION

General

Flow Diversion Flow shall be rerouted or dammed prior to culvert cleaning and until after the liner, grout, and weirs have been installed. The presence of some groundwater is acceptable as long as flow is prevented along the length of the culvert. Any water

propagating through the corroded invert of the culver must be contained prior to panel installation. No grout dilution is allowable.

Cleaning and Preparation Debris shall be removed from the culvert and disposed of in accordance with state and local environmental requirements. The invert shall be pressure washed to remove soil and loose, corroded material from the culvert. All debris should be removed by mechanical means. Any holes in the steel culvert shall be sealed with hydraulic cement. Bolts that protrude more than 1.25 inches above the crest of corrugations shall be trimmed prior to placing the FRP liner. Bolts should be cut off flush with the top of the nut. The nut must not be compromised.

All areas of culvert section loss above the composite liner shall be sandblasted and painted with a MC Zinc Primer and a MC Urethane with a Mox Tar Topcoat.

LINERS

Attachment The exact position of the first liner segment placed at one end of the culvert shall be determined based on the segment length and the overall length of the culvert such that the first and last liner segments shall be at least 5 feet long.

Liner segments shall be secured to sound steel using powder-actuated galvanized steel fasteners. The frequency and spacing of the fasteners shall be determined by engineering analysis of the seam strength requirements. Fasteners shall be driven with enough energy to ensure the head and washer are seated tight against the FRP and that contact is maintained between the FRP and steel while avoiding excess force that may cause cupping of the washer or damage to the FRP. Jacking poles may be used to hold the FRP against the steel in places where sudden geometry changes prevent contact under dead weight. The allowance of any gap between the FRP and steel is at the discretion of the engineer and shall be minimized.

Trimming Liner segments placed at the culvert ends shall be trimmed to match the taper of the existing steel culvert. The ends shall be sealed with a mixture of resin and fiber to contain the annular grout. The edges and ends of all trimmed lining segments and sections shall be sealed with a vinyl ester resin system to prevent the exposure of glass fibers. The resin shall be pigmented to match the color and performance of the laminating resin.

Joining All joining of panels shall be designed as per RTP1-2011 standards and specifications. Reference sections 3A-800 Secondary Bond Shear Stress and subpart 3B Design by Stress Analysis sections 3B-100 through 3B-700 to determine proper joint design. Refer to RTP1-2011 Mandatory Appendix M-5 Qualification of Laminators and Secondary Bonders for the required standards and practices. See section M-5 for required procedures to properly manufacture and test shear bond strength specimens.

FISH WEIRS

Size and Location The number, size, geometry, and location/elevation of all fish weirs internal and external shall be as shown on the plans.

Fitting Each fish weir shall be fabricated oversized and trimmed to fit in the required location. All trimmed edges shall be treated in accordance with the Construction Requirements above. The final weir channel elevation of the trimmed part shall be verified by the Resident prior to attachment.

Attachment The internal weirs shall be attached to the liner through the use of a methacrylate adhesive capable of bridging a gap of at least 0.250". The weir must be 100% edge sealed with the adhesive. The adhesive must be allowed to completely cure prior to installing the final weld kit. The final weld kit shall be installed on the upstream side of the weir and across

the top seams on both sides. The weld kit shall be in accordance with ASME RTP-1 specifications. Glass used shall be E-glass and consist of a combination of 1.5 oz CSM and 24 oz Woven Roving. All weld kits must be final coated and leave no exposed areas.

External Fish Weirs External fish weirs should be pre-assembled on a jig and placed as a complete unit in the prepared location. The Site should be excavated to a depth as shown on the Plans to allow for the installation of a Geotextile stabilization fabric followed by a minimum of 12" of ¾" stone. The entire stone bed must be leveled to within ¼" of an inch prior to placement. The top of the stone must allow for the critical surfaces of the weirs and spouts to be at the proper final elevation.

Forming of the weirs must allow for the complete encapsulation of the weirs and spouts. Installation and placement of rebar shall be in accordance with all customer specifications. External edges must be softened to assure that there are no 90° drop offs.

QUALITY ASSURANCE

As part of the quality assurance procedures, the manufacturer shall keep records of the following against each batch of output product:

3. raw material batch details, including source, acceptance test records, purchase dates and shelf-life at time of use
4. resin mixing records
5. initiator level
6. mold pressure at commencement of infusion
7. mold temperature
8. resin temperature
9. ambient temperature of the shop
10. infusion start and stop time
11. visual inspection results of the cured part
12. final Barcol readings

13. technician names and date of manufacture

Appearance and surface condition The surface of the lining material shall be free from tackiness and defects such as protruding fibers, air voids, crazes, cracks, blisters or foreign matter that might impair the performance in service. The internal surface of the lining shall be textured. The surface of the panels shall be finished with a pigmented UV resistant final coat. Pigment must be compatible with the resin system.

Joints The liner and joint shall be designed so that the resulting lap joint is flush with the interior surface of the liner segments. The flexible or rigid joints are required to provide a permanent seal between liner segments to protect the integrity of the grout and prevent water ingress. Rigid setting or flexible compounds used to caulk or seal the gap between liner segments shall be resistant to the environment for which they are intended, and shall be suitable for installation within a confined space taking safety aspects into consideration.

Upon complete cure of the sealing compound the joint should be finished with a weld kit designed in accordance with ASME RTP-1 specifications and final coated.

Performance requirements A composites engineer shall determine the appropriate reinforcing ply thickness to satisfy all strength, stiffness, and seam strength requirements assuming the corroded invert does not provide any residual strength to the system. Mechanical testing performed by a certified (ISO 9000 or equivalent) testing laboratory shall be conducted to verify predicted material properties for final design and provide quality control data. All calculations supporting the design shall be submitted for approval by the Department prior to beginning construction.

Type tests Coupon tests to verify predicted mechanical properties used during preliminary design shall be performed before completing the detail design. These tests shall include flexural strength and modulus per ASTM D790 and compressive strength and modulus per ASTM D6641. Component level tests shall be performed to verify the predicted buckling strength of the FRP/grout system and the shear capacity of the connection. The acceptable design value for strength is the mean minus two standard deviations. The acceptable design value for modulus is the mean.

QUALITY CONTROL TESTS

General The following test requirements are necessary in order to demonstrate a continuing satisfactory level of production quality in day to day production. The manufacturer shall establish a quality system to meet the requirements of ISO 9001 or ASME RTP-1. Witness panels fabricated at the same time using the same materials as the liner or cut-outs from the liner segment shall be used to conduct verification tests for every tenth panel fabricated.

Dimensions Wall thickness and resin rich layer thickness shall be determined at a minimum of three locations in each test sample using a method of measurement accurate to the nearest

- inches by measuring cut surfaces through the lining wall. The cut surfaces shall be smoothed sufficiently for the different layers to be delineated. Generally the locations of cores shall include:
    - A point towards the center of the test sample and points near each end of the test sample, but not at a joint.

Resin cure The surfaces shall not be tacky to the touch. Each test specimen shall be tested in accordance with the method described in ASTM D2503 at a minimum of three points and shall have a hardness not less than the minimum declared in the material subsection for resin. Post curing is permissible if necessary to achieve the desired results.

Analysis of construction The disposition of the laminates or layers and the constituents within them shall correspond to those of the type tested liners. The percentage by weight of the constituents and the weight of glass per unit area shall not deviate from the declared control values by more than ±10% (of each numerical value).

Appearance The internal and external surfaces of each lining unit shall be examined visually and be free from defects. Where practicable this shall occur prior to application of any bed mat backing or pigmented, UV resistant final surface coating.

Mechanical Properties The coupon tests described in 6.4 shall be conducted on test samples. The Quality Control Test results are acceptable if the calculated design values (as described in 6.4) are not less than 95% of the Type Test values.

CONTROL OF TEST CONDITIONS

Test conditions Unless otherwise required by this specification the test measurements shall be conducted at a temperature of 72 ±10°F and relative humidity of 50 ±10%.

Specimen conditioning For Type Testing, specimens shall be kept in air 72 ±10°F and 50
±10% RH for not less than 72 hours prior to testing.

For Quality Control Testing, specimens shall be kept in air at 72 ±10°F and 50 ±10% RH for not less than 24 hours after they are considered to be cured.

NOTE The preferred temperature for conditioning and testing composite materials is 72°F and 50% RH.

Test specimen preparation Test specimens shall be prepared in accordance with the applicable ASTM standards.

WORKMANSHIP, INSPECTION AND CERTIFICATION

Manufacturing Process FRP liners shall be manufactured using vacuum assisted resin transfer molding (VARTM) or open molding to ensure the production of high quality components and repeatability of physical and mechanical properties.

All raw materials shall be tested at a frequency sufficient to ensure consistency and compliance with this specification. The manufacturer shall adequately supervise all stages of production and keep records of the raw material batches used and products made each work shift or day. Manufacture shall be under environmental conditions compatible with producing satisfactory liners and raw materials shall be stored and used in compliance with the recommendations of their manufacturers.

Reinforcement materials shall be stored in dry conditions. The liner manufacturer shall be familiar with the changes in viscosity, gel times, etc., which may occur during storage of the resin, and make appropriate allowances in the lining manufacturing process. Resin stored in original unopened containers shall not be used after the resin manufacturer's stated expiration date.

Inspection In addition to the manufacturer's own inspection and supervision, the purchaser or his appointed inspecting authority shall have access at all reasonable times to inspect parts and all relevant test records.

Certification The manufacturer shall, on request, furnish the purchaser or purchaser's representative, with copies of a signed certificate for each size of liner stating that the construction and testing of liner segments supplied comply with the requirements of this specification and given details of minimum performance parameters agreed with the purchaser. If required by the purchaser, the quality control test results or a suitable summary shall be provided with the certificate.

PROTECTION OF LINING UNITS

Liner segments shall be handled, stored and transported in such a way as to prevent damage before receipt by the purchaser.

METHOD OF MEASUREMENT

Composite invert lining and/or fish weirs satisfactorily placed and accepted in accordance with the dimensions shown on the plans, will be measured as one lump sum unit.

BASIS OF PAYMENT

The accepted structural composite invert lining and/or composite fish weirs will be paid for at the contract lump sum price under the related Structural Concrete Culvert Invert Lining and Structural Concrete Fish Weir items. The contract lump sum price shall be full compensation for preparing surfaces, spot painting of corroded areas with a MC Zinc Primer and a MC Urethane with a Mox Tar Topcoat, placing composite segments and furnishing all other materials, equipment, labor and incidentals necessary to complete the work.

The containment and disposal of pollutants during surface preparation will not be paid for directly, but shall be incidental to the related contract item and included in the Contractor's SEWPCP.

Payment will be made under:

Pay Items		Pay Unit
502.325	Structural Concrete Culvert Invert Lining	Lump Sum

SPECIAL PROVISION
SECTION 502
ANNULAR SPACE GROUTING

Description This work shall consist of providing and placing non-shrink grout as described below. The annular space (void between the host and liner pipes) shall be completely grouted to support the liner and provide long-term stability. The Contractor shall provide testing of the materials and methods for compliance with the following requirements. Prior to any work the Contractor shall furnish an acceptable plan for performing and testing the grouting.

Preparation After slip liner installation but prior to grouting, bulk heading of the ends and venting shall be constructed.

After bulk heading of the ends and venting, test the integrity of the installed liner pipe and constructed bulkheads for any leaks.

Grouting Plan: The Contractor shall also submit a grouting plan to the Resident. This shall contain locations of vents and grout entry points. The Resident shall have at least 10 working days to review the grouting plan.

Materials The grout material shall consist of portland cement (portland cement and fly ash) and/or additives as described in the following Subsections of Division 700 - Materials:

Portland Cement	701.01
Water	701.02
Air-Entraining Admixtures	701.03
Fine Aggregate	701.01
Fly Ash	701.10 Type F or C
Chemical Admixtures	701.04
Accelerating Admixtures	AASHTO M-194 Type “C”

8. Compressive Strength The grout shall have a minimum penetration resistance of 100 psi in 24 hours when tested in accordance with ASTM C403 and a minimum compressive strength of 500 psi in 28 days when tested in accordance with ASTM C495 or C109.

9. Performance Requirements The Contractor shall submit the proposed grout mix, methods, plans and criteria of the grouting operations. The grouting system shall have sufficient gauges, monitoring devices and tests to determine the effectiveness of the grouting operation and to ensure compliance with the liner pipe specifications and design parameters.

14. Mix Designs One or more mixes shall be developed to completely fill the annular space based on the following requirements:
    a) Size of annular void
    b) Void (size) of the surrounding soil
    c) Absence or presence or groundwater
    d) Sufficient strength and durability to prevent movement of the liner pipe, and
    e) Provide adequate retardation.

Qualifications The Contractor shall demonstrate to the Resident its worker's capabilities of filling the annular space and performing their work in conformance with the Plans and the Specifications.

Grouting Equipment The materials shall be mixed in equipment of sufficient size and capacity to provide the desired amount of grout material for each stage in a single operation. The equipment shall be capable of mixing the grout at densities required for the approved procedure and shall also be capable of changing density as dictated by field conditions any time during the grouting operation.

Injection Procedure and Pressure The gauged pumping pressure shall not exceed the liner pipe Manufacturer's approved recommendations. Pumping equipment shall be of a size sufficient to inject grout at velocity and pressure relative to the size of the annular space. Gauges to monitor grout pressure shall be attached immediately adjacent to each injection port. The gauge shall conform to an accuracy of not more than one-half percent error over the full range of the gauge. The range of the gauge shall be not more than 100 percent greater than the design grout pressure. Pressure gauges shall be instrument oil filled and attached to a saddle type diaphragm seal (gauge saver) to prevent slogging with grout. All gauges shall be certified and calibrated in accordance with ANSI B40 Grade 2A.

Test Section The Contractor shall be required to perform a test on each type of grout and grout system proposed to be used.

Submittals and Required Calculations The Contractor shall submit the following to the Resident for his review and approval at least 30 working days prior to the start of the grouting operation:

C. The proposed grouting mix
D. The proposed densities and viscosities
E. Initial set time of the grout
F. The proposed grouting method
G. The maximum of injection pressures

C. The 24-hour and 28 day compressive strengths
D. Proposed grout stage volumes

E. Bulkhead designs
F. Buoyant force calculations
G. Flow control
H. Provisions for service connections
I. Pressure gauge certification
J. Vent location plans
K. Certification that grouting plan conforms with all provisions, cautions and restrictions or the liner manufacturer.

These shall be submitted as a complete package for a single or sample section only. The Contractor shall notify the Resident of any changes to be made in grouting. Any damage caused by the grouting operation shall be repaired by the contractor at no expense to the Department.

Method of Measurement Grout satisfactorily placed and accepted will be measured by the cubic yard, in accordance with the pay limits established, if such limits have been established. In the absence of pay limits, the Resident may use discretion to accept the delivered quantity as the measurement for payment.

Basis of Payment The accepted work done under Annular Space Grouting including all forms, berms, bulkheads, pumping, and incidentals necessary will be **considered incidental to Item 509.202 Culvert Slip-lining.**

SPECIAL PROVISION
SECTION 502
STRUCTURAL CONCRETE
(Fish Weirs)

Description This work shall consist of forming and placing reinforced concrete fish weirs inside and outside the culvert and any incidental construction in accordance with these specifications, as called for on the plans, or as designated by the Resident. All work shall be in conformity with the Standard Specifications and other Special Provisions.

Materials Concrete shall be Class A using Testing Method C; Reinforcing Steel shall be ASTM A615/A615M Grade 60. Any required anchor Bolts, washers and anchor rods shall conform to ASTM A307 and all fastener components shall be galvanized.

If required on the Plans, high density polyethylene (HDPE) plate baffles shall be furnished with the following for each plate:

1. 5/8 inch diameter by 16 inch long threaded rod – quantity 4
2. 5/8 inch flat washer - quantity 8
3. 5/8 inch hex nuts – quantity 8

The HDPE plates shall be solid wall HDPE with the Cell Classification meeting ASTM D-3350-02 and shall have the Plastic Pipe Institute ASTM Material Designation PE3408

Composites may be used in lieu of concrete for the internal fish weirs upon approval of the Project Resident. If the fish weirs are made from composite material, the requirements of Special Provision 509.73 Composite Invert Lining Option shall be followed.

CONSTRUCTION REQUIREMENTS

General The fish weir(s), including the vertical walls and channel bottom for the entire length between the weirs as shown on the plans shall be formed, cast, and stripped in the conventional manner; the use of shotcrete will not be allowed for construction of the external fish weir structure. If required on the plans, HDPE baffle plates shall be drilled and cut to the shape as shown on the plans or as directed unless the Plans call for the plates to be furnished to DOT for cutting by others.

Method of Measurement Reinforced concrete fish weirs satisfactorily placed and accepted will be measured for payment as one lump sum unit acceptably covered in accordance with the plans and this special provision.

Basis of Payment Reinforced concrete fish weirs will be paid for at the contract lump sum price. Payment shall be full compensation for forming, placing and finishing the concrete; fabrication, delivery and placing reinforcing steel; furnishing and installing anchor rods, furnishing and installing pvc sleeves, furnishing and installation of HDPE plates all equipment and labor, and all other incidentals necessary to complete the work.

Payment will be made under:

Pay Item		Pay Unit
502.326	Structural Concrete Fish Weirs	Lump Sum

SPECIAL PROVISION
SECTION 509
High Density Polyethylene
(Fish Weirs)

Description This work shall consist of fabricating, and extrusion welding High Density Polyethylene (HDPE) Fish Weirs into culverts sliplined with HDPE.

Materials Materials for Fish Weirs shall be compatible for welding into the existing slipliners and shall meet the following requirements:

HDPE sheet stock shall be black material formulated for the pipe industry and conform to the requirements of ASTM D3350. HDPE welding rod shall meet or exceed the requirements of ASTM D3350.

Submittals The Contractor shall make one weir available to the Environmental Office representative for review and approval prior to final fabrication, delivery and installation of all remaining weirs. The Department shall be allowed a minimum of 5 working days to review the Contractor's submittal.

Construction Requirements Fish Weirs shall be fabricated from 1½-inch thick pieces of HDPE sheet stock. The dimensions shall be cut as shown on the contract documents. If baffle plates are required, mounting holes shall be drilled into the plates as shown on the Plans. The contractor will not be required to supply or install the baffle plates unless otherwise stated in the Plans.

The seams between the weir plates and the buttresses shall be extrusion welded to form one solid unit. Each unit shall be attached to the existing HDPE liner, with all seams extrusion welded in place.

The Contractor shall be responsible for any required inspecting, drying and cleaning the culvert where the Fish Weirs will be attached to ensure a solid weld.

Any damage to the existing slipliners caused by the Contractor's equipment, personnel, or operation shall be repaired to the satisfaction of the Department. All work, equipment, and materials required to make the repairs shall be at the Contractor's expense.

Method of Measurement HDPE Fish Weirs satisfactorily placed and accepted will be measured and paid for as one lump sum unit.

Basis of Payment Payment for HDPE Fish Weirs will be full compensation for furnishing all labor, materials, and equipment necessary to manufacture and install the fish weirs complete and in place, including, but not limited to dewatering, pipe surface inspecting, drying, and surface cleaning, providing and cutting notch plates, and all site cleanup. **Payment shall be considered incidental to item 509.202 – Culvert Sliplining**.

SPECIAL PROVISON
Section 603
Pipe Culverts and Storm Drains
(Cured in Place Pipe)

Description: This work shall consist of the reconstruction of pipeline by the installation of a Cured in Place Pipe (CIPP) in accordance with this specification and in reasonably close conformity with the lines and grades shown on the plans and in the project specifications, or as approved by the Department's Resident.

Materials:
The Cured in Place Pipe system shall consist of a resin-impregnated flexible tube that is either inverted or
pulled into the original pipe and expanded to fit tightly against the pipe using water or air pressure. The curing of the resin shall be accomplished by raising the temperature of the water or air used to inflate the pipe to the level required to effect a thermosetting reaction of the initiators in the resin.

The resin impregnated pipe shall meet the Requirements of ASTM D5813.

The resin system and installation shall meet the requirements of either ASTM F1216 or ASTM F1743. Using test method ASTM D790 the Flexural Modulus of Elasticity shall be a minimum of 250,000 psi, and the Flexural Strength shall be a minimum of 4,500 psi.

Submittals and Qualification:

A resume showing that the CIPP installer has at least five years of continuous experience in the installation of the CIPP system used shall be submitted prior to any work on the CIPP installation.

A list of at least 5 satisfactory similar installations of the CIPP system shall be documented, listing locations, owners and contact information.

Design:
The liner thickness and the design of the CIPP system shall be sealed by an Engineer Licensed in the
State of Maine.

1. Existing pipe diameter	36 and 48 in
2. Design Factor of Safety	2.0 min
3. Retention Factor of Long-term Flexural Modulus	50%
4. Groundwater Depth (above invert of existing pipe)	4 ft
5. Soil Depth (above top of existing pipe)	7 ft
6. Soil Modulus	45,000 psi
7. Soil Density	130 pcf

The Cured in Place Pipe shall be designed using ASTM F1216, Appendix X.1, using the required properties and the following design parameters for the fully deteriorated pipe condition.

10. Live Load	AASHTO – H20
11. Design Condition	Fully Deteriorated

Initial nominal tube thickness and resin allowances shall allow for resin migration onto the existing pipe while providing the final thickness as specified by the design.

Construction Requirements:

Product Handling

The following procedures shall be adhered to unless otherwise approved by the Project Resident.

A. Prior to entering access areas such as manholes, and performing inspection or cleaning operations, an evaluation of the atmosphere to determine the presence of toxic or flammable vapors or lack of oxygen must be undertaken in accordance with local, state, or federal safety regulations.
B. Cleaning of pipeline: All internal debris should be removed from the original pipeline. Gravity pipes should be cleaned with hydraulically powered equipment, high velocity jet cleaners, or mechanically powered equipment as per NASSCO recommended specifications for sewer collection system rehabilitation. Pressure pipelines should be cleaned with cable attached devices or fluid propelled devices as per AWWA manual on cleaning and lining water mains, m28.
C. Inspection of pipelines: Inspection of pipelines should be performed by experienced personnel trained in locating breaks, obstacles, and service connections by closed circuit television or man entry. The interior of the pipeline should be carefully inspected to determine the location of any conditions that may prevent proper installation of the impregnated tube, such as protruding service taps, collapsed or crushed pipe, and reductions in the cross sectional area of more than forty percent. These conditions should be noted so that they can be corrected.
D. Line obstructions: The original pipeline should be clear of obstructions such as solids, dropped joints, protruding service connections, crushed or collapsed pipe, and reductions in the cross sectional area of more that forty percent that may hinder or prevent the installation of the resin impregnated fabric tube. If inspection reveals an obstruction that cannot be removed by conventional sewer cleaning equipment, then a point repair excavation should be made to uncover and remove or repair the obstruction.

E. Bypassing: If bypassing of the flow is required around the sections of pipe designated for reconstruction, the bypass should be made by plugging the line at a point upstream of the pipe to be reconstructed and pumping the flow to a downstream point or adjacent system. The pump and bypass lines should be of adequate capacity and size to handle the flow. Services within this reach will be temporarily out of service.

Installation of Product:

1. The contractor shall designate a location where the tube will be impregnated with resin using a vacuum and distribution roller system to thoroughly saturate the tube prior to installation. The contractor shall allow the owner to inspect the materials and the "wet out" procedure.
2. Perforation of resin impregnated tube: Prior to pulling the resin saturated tube in place, the outer impermeable plastic coating may be perforated to permit resin to be forced through the perforations and out against the existing conduit by the force of the hydrostatic head or air pressure against the inner wall of the calibration hose. The perforation may be done after fabric tube impregnation with a perforating roller device at the point of manufacture or at the jobsite.
3. Pulling resin impregnated tube into position: The wet out tube shall be pulled into place using a power winch. The saturated tube shall be pulled through an existing manhole or other approved access to fully extend it to the next designated manhole or termination point.
4. Hydrostatic head calibration hose inversion: The calibration hose shall be inserted into the vertical inversion standpipe and attached at the lower end of the inversion standpipe so that a leak proof seal is created. The resin impregnated tube should also be attached to the standpipe so that the calibration hose can invert into the center of the resin impregnated tube. The inversion head should be adjusted to be of sufficient height to cause the calibration hose to invert through the entire length of tube and hold the resin impregnated tube tight to the pipe wall, producing dimples at side connections.
5. After installation is completed, suitable heat source and water circulation equipment are required to circulate heated water throughout the section to uniformly raise the water temperature above the temperature required to affect a cure of the resin.
6. The heat source should be fitted with suitable monitors to measure the temperature of the incoming and outgoing water supply. Temperature sensors should also be placed between the resin impregnated tube and the host pipe invert at both termination points to monitor the temperatures during cure.
7. Initial cure will occur during temperature heat up and is completed when exposed portions of the CIPP appear to be hard and sound and the remote temperature

sensor indicates that the temperature is of a magnitude to realize an exotherm or cure in the resin. After initial cure is reached, the temperature should be raised to the post-cure temperature and held there for a period recommended by the resin manufacturer or CIPP manufactured. The curing of the CIPP must take into account the existing pipe material, the resin system, and ground conditions (temperature, moisture level, and thermal conductivity of soil).

8. The new pipe shall be cooled to a temperature below 100-deg. F. (38-deg. C.) Before relieving the static head in the inversion standpipe. Cool-down may be accomplished by the introduction of cool water into the inversion standpipe to replace water being drained from a small hole made in the downstream end. Care should be taken so as to cool down the CIPP in a controlled manner as recommended by the resin manufacturer of CIPP manufacturer.
9. The finished pipe shall be continuous over the entire length of an installation and be free of dry spots, lifts, and delaminations. If these conditions are present, the CIPP will be evaluated for its ability to meet applicable physical requirements. Where the CIPP does not meet specifically stated requirements of the client or engineer the affected portions of CIPP will be removed and replaced with an equivalent repair mutually agreed upon by the client and contractor.
10. After the new pipe has been cured in place, the existing active (or inactive) service connections should be reinstated. This should generally be done without excavation, and in the case of non-man entry pipes, from the interior of the pipeline by means of television camera and a remote control cutting device.

Method of Measurement: The accepted quantities of pipe for Cured in Place Pipe will be paid for at the contract unit price per linear foot, complete and in place. All labor, materials, equipment, and incidentals
necessary for the instillation of Cured in Place Pipe shall be considered incidental to the Cured in Place Pipe item.

Television inspection both prior to installation and post rehabilitation, any necessary cleaning, and all submittals shall be incidental to this item.

Basis of Payment

Pay Item		Pay Unit
603.2195	CIPP Liner for 36” Pipe	Linear Foot

SPECIAL PROVISION
SECTION 603
PIPE CULVERTS AND STORM DRAINS
(Culvert Sliplining)

Description: This work shall consist of inserting a new pipe into an existing culvert, constructing seals at the ends of the new pipe and filling the voids between the new and existing culvert pipe with grout in accordance with the plans and specifications. The Contractor shall utilize the material shown on the contract Plans for lining. If no material is specified, any pipe meeting the materials section of this Special Provision at the required nominal diameter may be used.

General Construction Requirements: Handle and assemble all elements of the structure in accordance with the manufacturer's instructions, except as modified herein, on the plans or as ordered by the Resident in writing. The Contractor shall submit fabrication details including assembly drawings, pipe insertion methods, internal joint coupling and bracing details, to the Resident for approval. The Resident will be allowed a minimum of 10 working days to review the Contractor's submittal.

The Contractor shall be responsible for field measurement of the existing culvert pipe to ensure that the correct sized liner is ordered and will fit in the existing conditions.

The Contractor will dewater, inspect, and clean the existing culvert. The Contractor shall provide strutting and bracing to ensure the stability of the existing culvert during this operation.

The Contractor may push or pull or use a combination of both to get the new pipe sections into place. When pushing is used, the jacking force must be uniformly distributed around the perimeter of the liner pipe to avoid the possibility of damaging the pipe due to a concentrated jacking load. The Contractor shall utilize skids in the existing culvert to facilitate placement of the pipe sections. The displacement between adjacent pipe ends shall not exceed 13 mm [1/2 in].

The pipe sections shall be braced against the existing culvert so that the new pipe shall remain in place during grouting operations. The Contractor is responsible for assuring that the pipe does not "float" during the grouting operation. A minimum 25 mm [1 in] of grout shall be between the new and existing culverts. Bracing material shall not significantly impede grout flow into the annular space between the culverts.

Seals: Place plywood or material of equivalent strength, in the annular space at each end of the culvert, to retain grout. Seals may be left in place providing they do not interfere with bank protection and/or fish passage.

Materials

Materials required to complete the work of sliplining shall meet the requirements in Division 700 - Sections 706.06, 706.08, 706.10, 707.06, and 707.08 of the Standard Specifications, as applicable. See Section 700 for specific Standards. Lining materials shall also meet the requirements of ASTM F894 and AASHTO M326, as applicable, except as modified herein. No perforated pipe shall be permitted:

1.) Polyethylene material shall contain a minimum of 2%, well dispersed, carbon black. Additives, which can be conclusively proven not to be detrimental to the pipe, may also be used, provided the pipe produced meets the requirements of this Standard.

2.) Polyethylene and polypropylene pipe shall contain no recycled compound except that generated in the manufacturer's own plant from resin of the same specification and from the same raw material supplier as the virgin material.

3.) Compliance with the requirements of this paragraph shall be certified in writing by the pipe supplier.

Pipe Design

The pipe shall be designed as a stand-alone direct burial pipe. The pipe shall be able to support the earth and live load by itself with no additional capacity from the existing pipe or the annular space grout. Any design calculations shall be performed by the Contractor and reviewed by the Resident. The Resident shall have at least 10 working days to review the calculations. For solid wall polyethylene pipe, a Standard Dimension Ratio of 26 shall be used.

Joining Methods:

The liner pipe shall be joined in accordance with the manufacturer's recommendations. The pipe manufacturer shall provide an outline of recommended field quality control procedures to be performed on system components.

Construction Requirements: The sections of pipe may be assembled and joined together prior to insertion into the existing culvert or may be joined segmentally upon insertion into the host pipe. If welding is used to join the pipe segments, the pipe shall be welded on both the interior and exterior.

The liner pipe may be inserted into the existing pipe with a power winch and steel cable connected to the end of the pipe in an appropriate manner. The pipe manufacturer's recommendations should be followed regarding the most appropriate method of attaching the cable to the liner pipe. If required, a special pulling head may be attached to the end of the liner pipe to facilitate easy connection of the pulling cable.

Basis of Payment: Payment for culvert slip-lining will be paid for at the contract lump sum price. Culvert slip-lining includes full compensation for furnishing all labor, materials, equipment necessary to manufacture, assemble and install the pipe/culvert complete and in place, including: but not limited to dewatering, cleaning, inspecting, strutting, bracing, ovalizing of the liner, skids, sliplining material, concrete grout filler, joint bands, seals, installing grout ports, plugs, fittings, hardware, and damaged pipe repair. Grout used to fill the annular space and backfill voids will be completed according to Special Provision Section 502, Annular Space Grouting.

Payment will be made under:

Pay Item	Pay Unit
509.202 Culvert Slip Lining	Linear Foot/Lump Sum

LIST OF PRODUCTS AND SUPPLIERS

Below you will find a list of potential suppliers and products for the materials mentioned in this guidance as well as several others of interest. This is by no means a complete list.

Sliplining:

Product:	Manufacturer	Website:
Weholite	KWH Pipe	www.weholite.com/North_America
Snap-tite	ISCO Industries	www.culvert-rehab.com
Polypropylene Pipe	ADS	www.ads-pipe.com
Duromaxx	Contech	www.conteches.com
Culvert Renew	Poly Profiles Technology	www.culvertrenew.com

Invert Liner:

Product:	Manufacturer	Website:
FRP Invert Liner	Kenway	www.kenway.com

Cured-in-Place Pipe:

Product:	Manufacturer	Website:
Insituform	Aegion Corporation	www.insituform.com

Spray on Liners:

Product:	Manufacturer	Website:
Centripipe (Cementitious liner)	AP/M Permaform	www.centripipe.com
Spraywall	Sprayroq	www.sprayroq.com
PolySpray F-250	Hydratech	www.hyrdratechllc.com

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

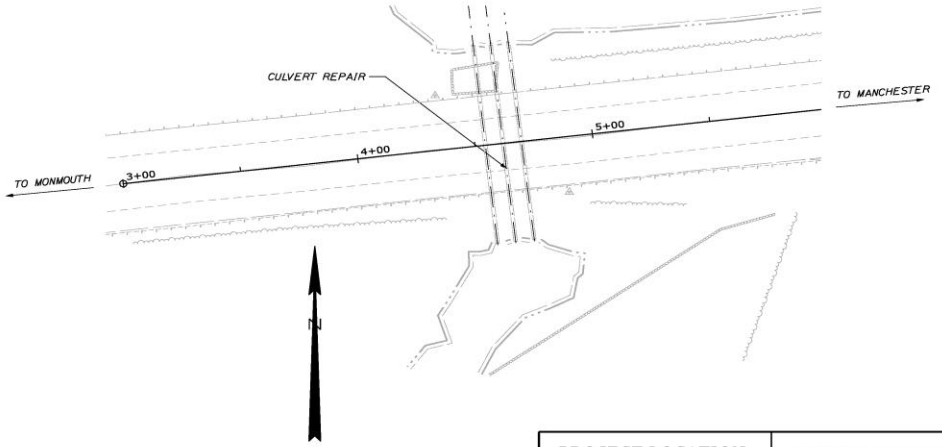
PLAN LEGEND

Town, County, State
Property Lines
R/W Lines-Existing
R/W Lines-Proposed
Culvert-Existing
Culvert Proposed
Curbing Existing Proposed
Type 1
Type 3
Type 5
Outline of Bodies of Water
Ledge
Buildings
Trees Conifer Deciduous
Tree Line
Clearing Limit Line CLL

Centerline-Existing
Centerline-Proposed
Travelway-Existing
Travelway-Proposed
Railroad
Catch Basins Existing Proposed
Manholes Existing Proposed
Proposed Underdrain
Proposed Ditch
Existing Ditch
Utility Poles Existing Proposed
Fire Hydrants Existing Proposed
Existing Water Line
Existing San. Sewer
Existing San. Sewer Manhole
Guardrail-Existing
Guardrail-Proposed
Guardrail-Cable, Other

WINTHROP
KENNEBEC COUNTY
ROUTE 202
STATE PROJECT NO. 20338.00
PROJECT LENGTH : 0.01 MILES

INDEX OF SHEETS



LAYOUT SCALE
25 0 25 50
Scale In Feet

TRAFFIC DATA

Current (2014) AADT 13910
Design Speed (mph) 45
Functional Class ..... Minor Arterial
Corridor Priority 1

PROJECT LOCATION:	RTE 202, 1.0 MILE WESTERLY OF MANCHESTER/WINTHROP TL
PROGRAM AREA:	HIGHWAY
SCOPE OF WORK:	LARGE CULVERT REHABILITATION: SLIP LINING

WIN 20338.00 20338.00

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION
APPROVED DATE
COMMISSIONER:
CHIEF ENGINEER:

PROJECT INFORMATION

PROGRAM	HIGHWAY	SIGNATURE	
PROJECT MANAGER	SHAWN SMITH		
DESIGNER	N. HARTLEY	P.E. NUMBER	
CONSULTANT			
PROJECT RESIDENT			
CONTRACTOR		DATE	
PROJECT COMPLETION DATE			

WINTHROP
ROUTE 202
TITLE SHEET

SHEET NUMBER
1
OF 7

Filename: ...\DOT\HIGHWAY\MSTA\001_Title.dgn Division: HIGHWAY Username: Nicholas.W.Hartley Date:6/17/2014

GENERAL NOTES

1. EXISTING INSLOPES STEEPER THAN 2:1 IN PROPOSED FILL AREAS SHALL BE BENCHED AS DIRECTED BY THE RESIDENT.

2. THE FOLLOWING SHALL BE CONSIDERED INCIDENTAL TO ITEM 509.202 SLIP LINING:
   A) ANY CUTTING OF EXISTING CULVERTS AND/OR CONNECTORS NECESSARY TO INSTALL NEW CULVERT REPLACEMENTS OR EXTENSIONS.

   B) ALL PIPE EXCAVATION INCLUDING ANY CUTTING AND REMOVING OF PAVEMENT.

   C) FURNISHING, PLACING, GRADING, AND COMPACTING OF ANY NEW GRAVEL AND FOR TEMPORARY DETOURS TO MAINTAIN TRAFFIC DURING PIPE INSTALLATION.

   D) FLOW LINES MAY BE CHANGED BY UP TO 1.5 FT.

   E) ANY NECESSARY CLEARING OF BRUSH AND NON-PAY TREES WITHIN 10' OF CULVERT ENDS.

   F) FURNISHING, PLACING, GRADING, AND COMPACTING OF ANY NEW GRAVEL AND/OR FILL MATERIAL. THIS ALSO INCLUDES GRANULAR BORROW USED UNDER THE PIPES AND FOR TEMPORARY DETOURS TO MAINTAIN TRAFFIC DURING PIPE INSTALLATION. EXCAVATION OF MAINTENANCE OF TRAFFIC MATERIAL IS ALSO INCIDENTAL.

3. NO EXISTING DRAINAGE SHALL BE ABANDONED, REMOVED, OR PLUGGED WITHOUT PRIOR APPROVAL OF THE RESIDENT.

4. EXISTING ABANDONED WATER MAINS BROKEN BY THE CONTRACTOR DURING CONSTRUCTION SHALL HAVE THE ENDS PLUGGED WITH BRICK AND MORTAR. COST FOR ALL LABOR AND MATERIAL WILL BE CONSIDERED INCIDENTAL TO CONTRACT ITEMS.

5. ANY DAMAGE TO THE SLOPES CAUSED BY THE CONTRACTOR'S EQUIPMENT, PERSONNEL OR OPERATION SHALL BE REPAIRED TO THE SATISFACTION OF THE RESIDENT. ALL WORK, EQUIPMENT, AND MATERIALS REQUIRED TO MAKE REPAIRS SHALL BE AT THE CONTRACTOR'S EXPENSE.

6. NO SEPARATE PAYMENT FOR SUPERINTENDENT OR FOREMAN WILL BE MADE FOR THE SUPERVISION OF EQUIPMENT BEING PAID FOR UNDER THE EQUIPMENT RENTAL ITEMS.

7. EROSION CONTROL GEOTEXTILE SHALL BE PLACED AT ALL RIPRAP LOCATIONS. PAYMENT WILL BE MADE UNDER ITEM 620.58 EROSION CONTROL GEOTEXTILE.

8. "UNDETERMINED LOCATIONS" SHALL BE DETERMINED BY THE RESIDENT.

9. STATIONS REFERENCED ARE APPROXIMATE.

10. ALL WORK SHALL BE DONE IN ACCORDANCE WITH THE MAINE DEPARTMENT OF TRANSPORTATION'S BEST MANAGEMENT PRACTICES FOR EROSION CONTROL & SEDIMENT CONTROL, FEBRUARY 2008.

11. THE CONTRACTOR WILL PERFORM FIELD MEASUREMENTS BEFORE FABRICATION TO ENSURE THE SLIP LINE WILL FIT IN THE CURRENT PIPE CONDITIONS.

12. QUANTITIES INCLUDED FOR PAY ITEMS MEASURED AND PAID FOR BY LUMP SUM ARE ESTIMATED QUANTITIES AND ARE PROVIDED BY MAINEDOT FOR INFORMATIONAL PURPOSES ONLY. LUMP SUM PAY ITEMS WILL BE PAID FOR AT THE CONTRACT BID AMOUNT WITH NO ADDITION OR REDUCTION IN PAYMENT TO THE CONTRACTOR IF THE ACTUAL FINAL QUANTITIES ARE DIFFERENT FROM MAINEDOT PROVIDED ESTIMATED QUANTITIES EXCEPT AS FOLLOWS:

   A) IF A LUMP SUM PAY ITEM IS ELIMINATED THE REQUIREMENTS OF STANDARD SPECIFICATIONS SECTION 109.2 ELIMINATION OF ITEMS WILL TAKE PRECEDENCE.

   B) IF OTHER CONTRACT DOCUMENTS SPECIFICALLY ALLOW A CHANGE IN PAYMENT OF A LUMP SUM PAY ITEM THOSE REQUIREMENTS WILL BE AS FOLLOWED.

   C) IF A DESIGN CHANGE RESULTS IN A CHANGE TO ESTIMATED QUANTITIES FOR LUMP SUM PAY ITEMS, PRICE ADJUSTMENTS WILL BE MADE IN ACCORDANCE WITH STANDARD SPECIFICATION SECTION 109.7 EQUITABLE ADJUSTMENTS TO COMPENSATION.

CONSTRUCTION NOTES

AREAS AND STATIONS AS DIRECTED ON PLANS.

509.202 CULVERT SLIP LINING
THIS ITEM SHALL INCLUDE ALL WORK AND MATERIALS NECESSARY TO COMPLETE THE SLIPPING. THIS INCLUDES, BUT IS NOT LIMITED TO, DEWATERING, CLEANING THE EXISTING STRUCTURE, FURNISHING AND PLACING APPROXIMATELY 280' OF NEW 54" INSIDE DIAMETER CULVERT, BRACING THE CULVERT, AND ANNULAR SPACE GROUT.

511.07 COFFERDAM
THIS ITEM SHALL INCLUDE ALL WORK NECESSARY TO CONSTRUCT COFFERDAMS IN ACCORDANCE WITH SECTION 511 OF THE STANDARD SPECIFICATIONS. SEPARATE PAYMENT SHALL BE MADE FOR UPSTREAM AND DOWNSTREAM COFFERDAMS.

610.08 PLAIN RIPRAP
STATION 4+43 LT TO STATION 4+86 LEFT
STATION 4+43 RT TO STATION 4+91 RT

SEEDING - INCIDENTAL TO CONTRACT ITEMS
METHOD #2 - SEEDING MAY BE DONE BY HAND

ESTIMATED QUANTITIES

ITEM NO.	DESCRIPTION	QUANTITY	UNIT
203.20	COMMON EXCAVATION	10	CY
203.24	GRANULAR BORROW	10	CY
509.202	CULVERT SLIPLINING	280	LF
511.07	COFFERDAM: UPSTREAM	1	LS
511.07	COFFERDAM: DOWNSTREAM	1	LS
610.08	PLAIN RIPRAP	260	CY
620.58	EROSION CONTROL GEOTEXTILE	310	SY
629.05	HAND LABOR - STRAIGHT TIME	20	HR
631.12	ALL PURPOSE EXCAVATOR (INC. OPERATOR)	10	HR
631.172	TRUCK - LARGE (INC. OPERATOR)	10	HR
631.18	CHAIN SAW RENTAL (INC. OPERATOR)	10	HR
639.19	FIELD OFFICE TYPE B	1	EA
652.33	DRUM	10	EA
652.34	CONE	20	EA
652.35	CONSTRUCITON SIGN	300	SF
652.361	MAINTENANCE OF TRAFFIC CONTROL DEVICES	60	CD/LS
652.38	FLAGGER	240	HR
656.75	TEMPORARY SOOIL EROSION AND WATER POLLUTION CONTROL	1	LS
659.10	MOBILIZATION	1	LS

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION
020338.00
WIN 20338.00
HIGHWAY PLANS

PROJ. MANAGER SHAWN SMITH
DESIGN DETAILED IN HARTLEY
CHECKED/REVIEWED
DESIGN DETAILED
DESIGN DETAILED
REVISIONS 1
REVISIONS 2
REVISIONS 3
REVISIONS 4
FIELD CHANGES

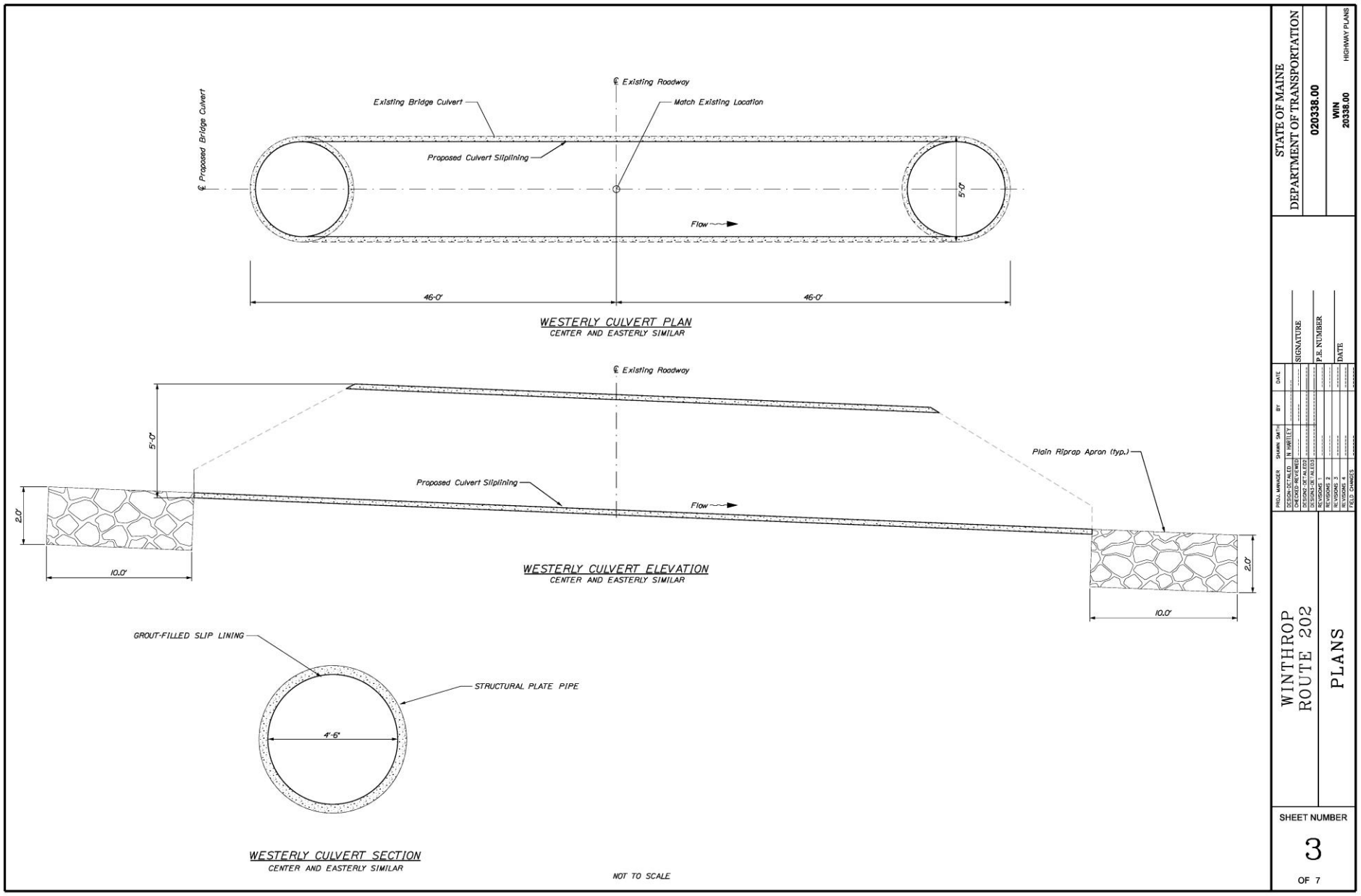
BY DATE SIGNATURE
P.E. NUMBER
DATE

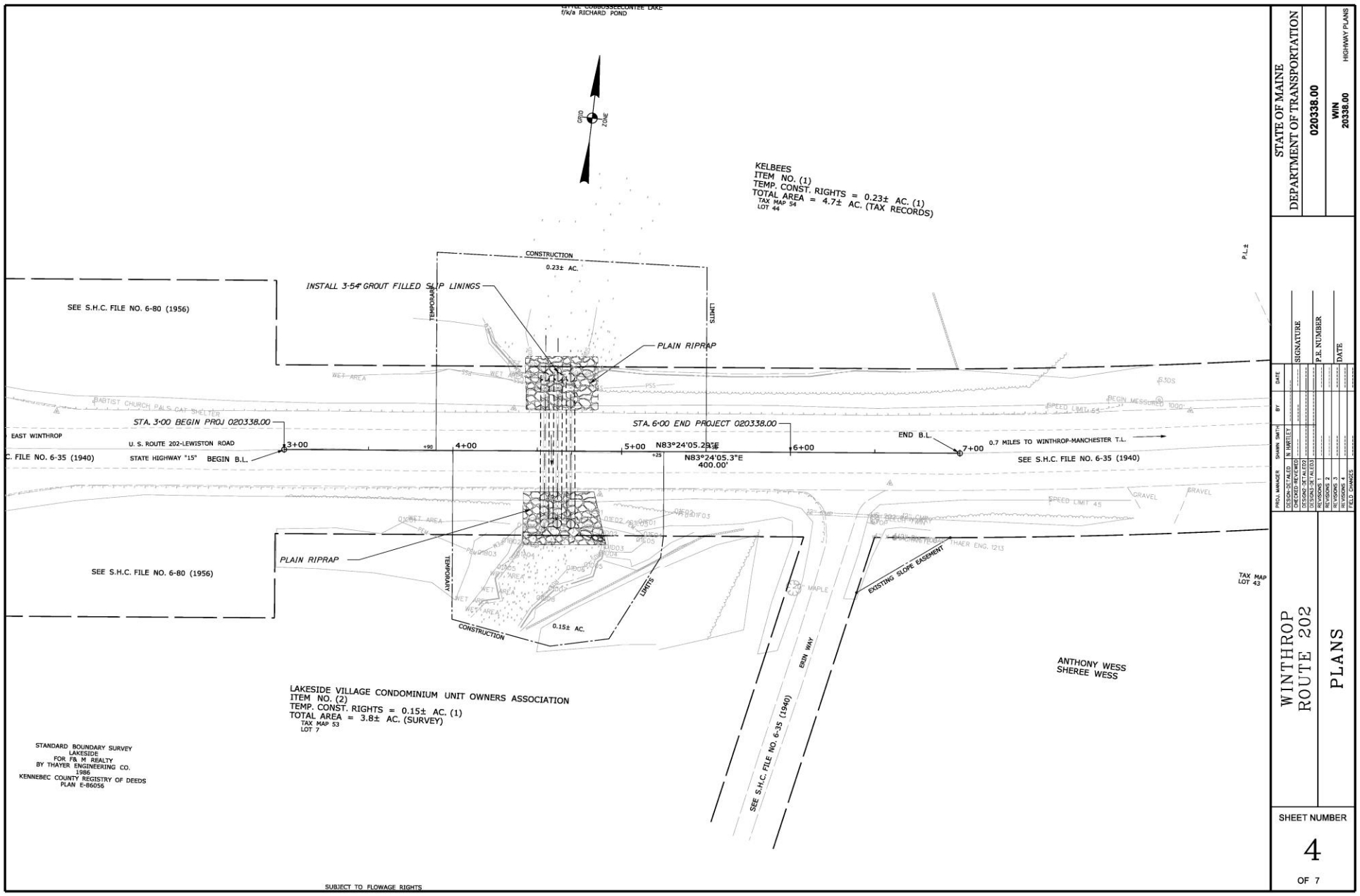
WINTHROP
ROUTE 202

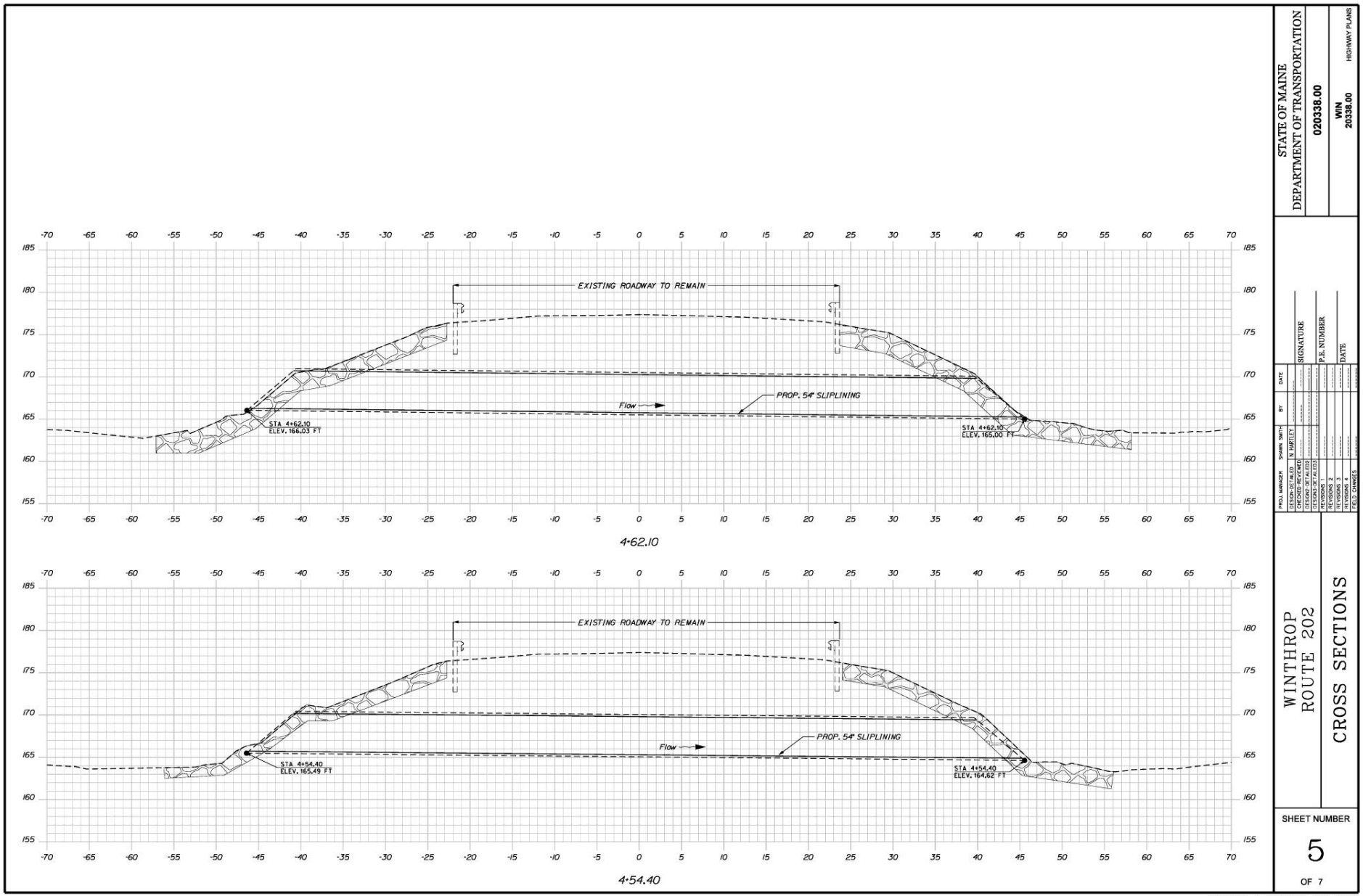
GENERAL NOTES/ESTIMATE

SHEET NUMBER
2
OF 7

Filename: ...\MSTA\002_GeneralNotes.dgn Division: HIGHWAY Username: Nicholas.W.Hartley Date:6/17/2014

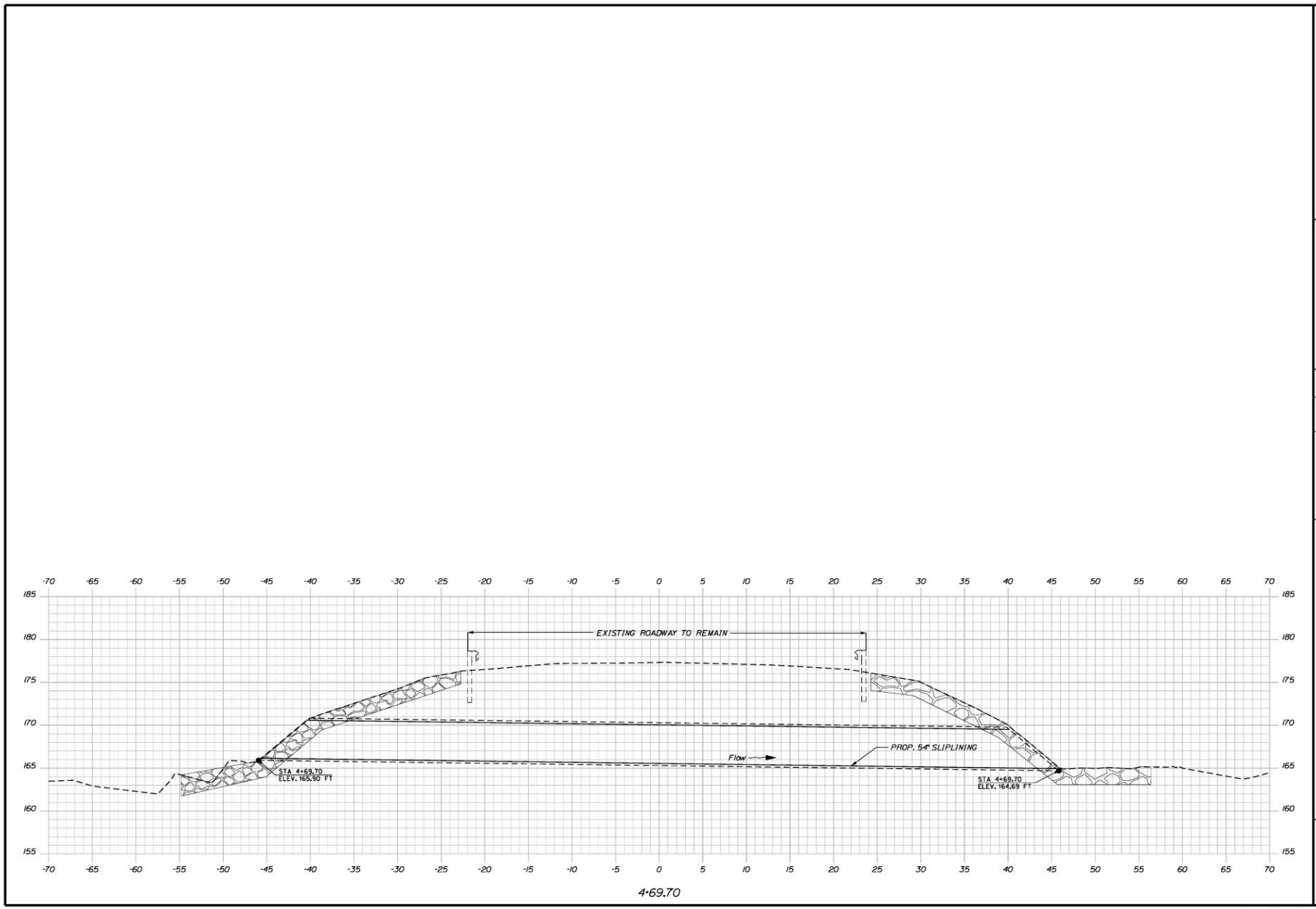

℄ Existing Roadway
Existing Bridge Culvert
Match Existing Location
℄ Proposed Bridge Culvert
Proposed Culvert Sliplining
5'-0"
Flow
46'-0"
46'-0"
WESTERLY CULVERT PLAN
CENTER AND EASTERLY SIMILAR
℄ Existing Roadway
5'-0"
Plain Riprap Apron (typ.)
Proposed Culvert Sliplining
Flow
2.0'
2.0'
10.0'
10.0'
WESTERLY CULVERT ELEVATION
CENTER AND EASTERLY SIMILAR
GROUT-FILLED SLIP LINING
STRUCTURAL PLATE PIPE
4'-6"
WESTERLY CULVERT SECTION
CENTER AND EASTERLY SIMILAR
NOT TO SCALE
STATE OF MAINE
DEPARTMENT OF TRANSPORTATION
020338.00
WIN
20338.00
HIGHWAY PLANS
PROJ. MANAGER
DESIGN DETAILED
PROJECT MANAGER
DESIGN CHECKED
DESIGN QC'ED
REVISIONS 1
REVISIONS 2
REVISIONS 3
REVISIONS 4
FIELD CHANGES
SHAWN SMITH
N. HARTLEY
BY
DATE
SIGNATURE
P.E. NUMBER
DATE
WINTHROP
ROUTE 202
PLANS
SHEET NUMBER
3
OF 7
Filename: ...\MSTA\003_Pipedetails.dgn
Division: HIGHWAY
Username: Nicholas.W.Hartley
Date:6/17/2014


KELBEES
ITEM NO. (1)
TEMP. CONST. RIGHTS = 0.23± AC. (1)
TOTAL AREA = 4.7± AC. (TAX RECORDS)
TAX MAP 54
LOT 44
CONSTRUCTION
0.23± AC.
INSTALL 3-54" GROUT FILLED SLIP LININGS
PLAIN RIPRAP
SEE S.H.C. FILE NO. 6-80 (1956)
STA. 3+00 BEGIN PROJ 020338.00
STA. 6+00 END PROJECT 020338.00
EAST WINTHROP
U. S. ROUTE 202-LEWISTON ROAD
STATE HIGHWAY "15" BEGIN B.L.
END B.L.
0.7 MILES TO WINTHROP-MANCHESTER T.L.
N83°24'05.3"E
400.00'
SEE S.H.C. FILE NO. 6-35 (1940)
PLAIN RIPRAP
SEE S.H.C. FILE NO. 6-80 (1956)
0.15± AC.
CONSTRUCTION
LAKESIDE VILLAGE CONDOMINIUM UNIT OWNERS ASSOCIATION
ITEM NO. (2)
TEMP. CONST. RIGHTS = 0.15± AC. (1)
TOTAL AREA = 3.8± AC. (SURVEY)
TAX MAP 53
LOT 7
STANDARD BOUNDARY SURVEY
LAKESIDE
FOR F& M REALTY
BY THAYER ENGINEERING CO.
1986
KENNEBEC COUNTY REGISTRY OF DEEDS
PLAN E-86056
ANTHONY WESS
SHEREE WESS
TAX MAP
LOT 43
EXISTING SLOPE EASEMENT
ERIN WAY
SEE S.H.C. FILE NO. 6-35 (1940)
SUBJECT TO FLOWAGE RIGHTS
STATE OF MAINE
DEPARTMENT OF TRANSPORTATION
020338.00
WIN
20338.00
HIGHWAY PLANS
WINTHROP
ROUTE 202
PLANS
SHEET NUMBER
4
OF 7



Sta. 4+54.40 to Sta. 4+62.10

Filename: ...\MSTA\006_Xsect_4+69_002.dgn Division: HIGHWAY Username: Nicholas.W.Hartley Date:6/17/2014



STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

020338.00

WIN
20338.00

HIGHWAY PLANS

PROJ. MANAGER	SHAWN SMITH	BY	DATE
DESIGN DETAILED	N HARTLEY	------	------
CHECKED/REVIEWED	------	------	SIGNATURE
DESIGN DETAILED	------	------	------
DESIGN DETAILED	------	------	P.E. NUMBER
REVISIONS 1	------	------	------
REVISIONS 2	------	------	------
REVISIONS 3	------	------	DATE
REVISIONS 4	------	------	------
FIELD CHANGES	------	------	------

WINTHROP
ROUTE 202

CROSS SECTIONS

SHEET NUMBER
6
OF 7

Sta. 4+69.70 to Sta. 4+69.70