ADMINISTRATIVE INFORMATION:

- Effective Date: This Engineering Instruction (EI) is effective for projects submitted for Letting on or after 09/01/11.
- Superseded Issuance: EI 01-029 Design Guidelines for Rehabilitation of Culvert and Storm Drain Pipe.

PURPOSE: To issue a limited revision to the Highway Design Manual (HDM) Chapter 8 to revise design guidance on the selection and use of the various rehabilitation items for culverts and storm drains.

TECHNICAL INFORMATION:

- This EB is being issued concurrently with EI 11-002 Revisions to Standard Specifications 602 – REHABILITATION OF CULVERT AND STORM DRAIN PIPE.
- Cost Impact: Substantial savings will be realized in the capital program if the most cost effective culvert rehabilitation method is selected. Depending on site conditions and material selection, rehabilitation may be more cost effective than replacement. The key is always to use the lowest cost/benefit ratio rehabilitation methodology unless unique conditions dictate otherwise.
- This Issuance provides structured and concise guidance on how to select the most appropriate rehabilitation scheme for a particular culvert based on site conditions.
- Provides guidance on how to properly specify the two new HDPE relining items (smooth and profile wall).
- Provides guidance on when to specify and how to properly execute Cured in Place Pipe (CIPP) applications.
- HDM Chapter 8 Section 8.6.7 is the only section revised by this issuance.

TRANSMITTED MATERIALS: None.

- Design details for structural invert paving of culverts spanning up to 10 feet and bearing up to 20 feet of fill over the crown are available in .dgn format under “Resource Links” at: https://www.nysdot.gov/divisions/engineering/design/dqab/hdm/chapter-8
- Revised Chapter 8 is available at: https://www.nysdot.gov/divisions/engineering/design/dqab/hdm

BACKGROUND: Section 602 of the Standard Specifications was created in 2001. Since then, advances in materials and technologies utilized in culvert rehabilitation, have resulted in methodologies with a high quality end product. These methodologies can be delivered in a speedy and in a non-interfering way.
with traffic and the travelling public and can be implemented in environmentally sensitive areas. The current issuance aims to provide designers with the most current information and clear guidance on materials and methodologies in culvert and storm drain pipe rehabilitation. It also aims at delivering the safest and highest quality rehabilitated culvert and storm drain pipes with the lowest cost/benefit ratio possible, thereby resulting in substantial life cycle cost savings. The intent of the specification language and the history behind the specifications development is provided in the concurrently issued EI 11-002 Revisions to Standard Specifications 602 Rehabilitation of Culverts and Storm Drains.

CONTACT: Direct questions on this EB to Ed Lucas or Michael Mathioudakis of the Materials Bureau via e-mail at elucas@dot.state.ny.us or mmathioudakis@dot.state.ny.us.
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8.6.6 **Safety - Roadside Design**

Decisions regarding roadside design should be made consistent with Chapter 10. In general:

1. Any unnecessary drainage structures that would be hazardous to an errant vehicle should be eliminated. Examples might include: headwalls protruding above embankments; non-traversable ditches, particularly those perpendicular to traffic; check dams in ditches; etc.
2. Potentially hazardous drainage structures that are necessary should be relocated farther from the roadway, if practical, and if doing so would result in an adequate clear zone. Relocating drainage structures should not result in a discontinuous embankment.
3. Drainage structures which cannot be eliminated or relocated, should be modified to reduce the hazard, if such modification can be made without adversely affecting hydraulic performance.
4. Designers should refer to EI 06-015 and Chapter 10, Sections 10.2.1.2 and 10.3.2.2 for design guidance for culvert-end safety grates.
5. If the above four measures, considered in combination, will not be able to produce an adequate clear zone, than that roadside area should be shielded from traffic with an appropriate barrier system.

**8.6.7 Rehabilitation of Culverts and Storm Drains**

See Page 8-65A
8.6.7 **Rehabilitation of Culverts and Storm Drains**

8.6.7.1 General

Replacement of a buried pipe system will seldom be a viable alternative in locations where long detours or extensive disruption to traffic will occur. When replacement is not viable or economically desirable, existing pipes may be rehabilitated by one of the following options:

8.6.7.1.A Structural paving of the invert with Portland Concrete Cement (PCC).

This is an excellent rehabilitation methodology when the culvert has maintained its original shape, even if it exhibits considerable invert deterioration. Structural invert paving should be the predominant choice for rehabilitating large diameter arches and culverts, where using a new pipe lining method is cost prohibitive. Invert and barrel deterioration are the prime considerations when deciding on the extent and boundaries of the structural invert paving operation. These boundaries should be clearly shown on the contract documents. For worker access safety reasons, structural paving of the invert should not be specified in culverts with diameters smaller than 48”, except when no other option is feasible.

Design details on structural invert paving along with extended guidance can be found in Section 8.6.7.6. Structural invert paving may also be used in conjunction with shotcreting of the entire remaining culvert barrel (i.e. beyond the structural paving limits) further improving the structural capacity of the rehabilitated culvert. This hybrid rehabilitation scheme is recommended when the circumferential integrity of the culvert is questionable.

8.6.7.1.B Lining with Shotcrete.

This is a cost effective solution for large size culverts and arches that are experiencing distress in sidewalls, roof, and invert. The culvert should not display any significant structural deficiencies, buckling or other forms of deformation. It can also be used in combination with paving inverts. The plans need to indicate the reinforcement details and its limits along the culvert periphery. Utilizing welding or stainless steel mechanical anchors in reinforcement anchoring are the only options allowed. Lining with shotcrete could encompass the entire barrel of the pipe. A minimum cover of 2 inches over the corrugation crests is recommended. If for other reasons a designer would like to specify a thicker cover this must be clearly indicated on the plans. To accommodate the proper installation and application equipment, the item can only be used in culverts with a minimum diameter of 48 inches.

8.6.7.1.C Lining with Cured in Place Pipe (CIPP).

This consists of a CIPP lining inserted into an existing culvert. When lining with CIPP, the designer must provide on the plans all necessary information so that the bidding Approved List installers are able to calculate the design (dead and live) loads on each liner based on the same critical design input parameters. The provided information must at minimum include, but it is not limited to, the culvert maximum depth of cover, estimated modulus of soil reaction E’ and estimated water table elevation above culvert invert for the site. This information should be clearly
noted on the plans, as: “The maximum depth of cover is estimated from the top of the pipe to…”; or “The estimated water table elevation is measured from the culvert invert”. By providing this information on the plans, we improve the uniformity of bidding, since all submitted bids will be relying on the same design input parameters. Subcontractors mobilization cost should also be considered when selecting relining methodologies. For example, if CIPP lining has been selected for twelve culverts with bends while HDPE lining has been proposed for three straight run culverts, unless the three straight run culverts were of very large diameter (approaching 42” in diameter), it may be cost prohibitive to mobilize another subcontractor (HDPE lining) when the CIPP one will already be on site. Designers should be selecting the most cost effective repair scheme.

8.6.7.1.D Lining with New Pipe.

This rehabilitation technique can restore both structural and hydraulic capacity of a pipe. It is appropriate for culverts ranging in diameters from 12 through 120 inches. The existing (host) pipe should be relatively free of large bulges and in relatively good alignment. If bulges, alignment issues or other obstructions exist, they should be (if possible) eliminated in order to accommodate the unobstructed insertion of the new liner pipe. Lining pipe generally comes in 20 foot lengths and requires adequate end access space to accommodate insertion. When end access is limited, shorter pipe lengths may be utilized but they have to be special ordered. Designers should contact lining pipe manufacturers or suppliers in advance to determine availability of short lengths. All available pipe rehabilitation materials are presented in Section 8.6.7.6.

When end access of an existing large pipe (72 inches or larger) is limited, Galvanized Steel Plate, Steel Structural Plate and Galvanized Steel Tunnel Liner Plate may be cost effective pipe lining options. This is true only if structural paving is not an option. These methodologies will also restore a culvert’s structural integrity.

Designers should never specify the grout mix design used to fill the annular space between the existing pipe and the lining pipe. It is the manufacturer's representative’s responsibility to recommend a suitable grout compatible with the lining material used. The grout material recommendation must be included in the submitted written proposal to the EIC, in accordance to the specifications. The compressive strength of the grout is completely ignored (it is assumed that it carries no load and it does not contribute to the structural capacity of the composite “old pipe-grout-liner pipe” structure) in the liner thickness design calculations. Completely deteriorated conditions (i.e. it possesses zero remaining structural capacity) are assumed for the existing pipe during these calculations. Consequently, the proposed liner is required to possess adequate structural capacity to carry the entire calculated dead and live load. The maximum depth of cover for the culvert to be relined, estimated modulus of soil reaction E’, and the estimated water table elevation should be clearly noted on the plans.

Due to the potential for adverse environmental impacts associated with culvert rehabilitation activities (e.g. in-stream habitat, sediment dynamics, water/air quality), it is essential that designers coordinate the project development with the Regional Environmental Unit at an early stage in order to identify potential impacts and opportunities for mitigation.

The reader is strongly encouraged to review Section 8.6.7.6 for a detailed presentation of the above
mentioned rehabilitation techniques. Additional guidance regarding the rehabilitation of culverts is provided in AASHTO’s Highway Drainage Guidelines, Volume XIV.

8.6.7.2 Evaluating the existing culvert and site conditions

During hydraulic calculations to determine the minimum required diameter which satisfies the facility’s hydraulic demand, the proposed lining pipe’s wall thickness and/or the corrugation pattern may dictate the choice of lining materials.

It is imperative that the existing (host) culvert is thoroughly inspected in order determine the most appropriate type of rehabilitation. The inspection should determine culvert’s dimensions, material type, overall condition and structural integrity as well as site and/or existing pipe end accessibility for inserting lining pipe. Inspectors should clearly map the location and extent of distressed areas as well as all existing obstructions/buckles which may impact the size and insertion of the proposed lining pipe. Buckled pipes can be jacked near to their original shape provided that working room and proper access are available. However, excessive buckling of the existing pipe may severely obstruct and consequently preclude the use of any lining pipe. If visual inspection of the existing pipe is not feasible, a robotic or other remote inspection method is warranted.

Special order lining pipe lengths may be available for some types of lining pipes. If needed and as it was recommended in the “Lining with a new pipe” section, Designers should contact the pipe manufacturer or supplier to determine availability of shorter lining pipe lengths and approximate material costs.

If significant pipe perforations and/or backfill subsidence has been observed, consult with the Regional Geotechnical Engineer to determine the extent of any voids that may exist in the backfill material in the area above and immediately adjacent to the culvert.

8.6.7.3 Hydraulics & Service Life

All material used in culvert and storm drain rehabilitation should meet structural, hydraulic and service life requirements as identified in Chapter 8 of the Highway Design Manual. For design calculation purposes, the existing culvert and any annular fill material (e.g. grout) used in the lining application are assumed to provide no additional service life nor contribute to the structural capacity of the lining pipe.

8.6.7.4 Geotechnical Issues

Consult with the Regional Geotechnical Engineer to determine and map the extent of any voids that may exist in the backfill material adjacent to the culvert. Voids not immediately adjacent to the culvert, which may have developed via infiltration of backfill fines into the culvert, are typically filled from above using a series of drill holes. For the sake of uniform bidding purposes, when voids are present, the Plans should include the following details: general site conditions, access, proposed end treatments, profiles and grade staging, voids mapping, any special situations, relevant restrictions, etc. The Regional Geotechnical Engineer should be contacted for selecting the voids filling material in the backfill.
Very rarely culvert bearing embankments require grouting immediately prior to culvert rehabilitation. Extensive embankment grouting (filling of voids beyond culvert vicinity) is pursued only when the Designer and/or a Geotechnical Engineer decide(s) that the observed settlement poses a serious and immediate threat to the embankment integrity. Established practice for most cases dictates completing the lining work prior to addressing any settlement related issues.

8.6.7.5 Cost

Each rehabilitation methodology has its own pay item which includes all labor and materials cost necessary to complete the installation. The depth of cover (or fill height above the culvert) and ground water table elevation impact the bidding price of a liner. The fill material in the backfill area above the pipe is paid for under a separate item provided by the Geotechnical Engineer.

8.6.7.6 Available lining methodologies and recommended conditions for use:

8.6.7.6.A Adequate Structural Capacity.

If the culvert possesses reduced but adequate structural capacity and the culvert has maintained its original shape some structural capacity can be restored by rehabilitating the barrel. Under these conditions, the culvert could be effectively rehabilitated by selecting one of the following two methodologies:

8.6.7.6.A.1 Structural Paving of Inverts with Portland Cement Concrete (PCC)

This is a relatively low cost solution for rehabilitating circular culverts and arches experiencing invert distress, primarily caused by abrasion or a combination of abrasion and corrosion. Generally, if the pipe or arch has maintained its original shape and does not experience other major structural deficiencies except the invert loss, the culvert can be rehabilitated by structurally paving the invert, regardless if the invert shows considerable deterioration. Due to the higher cost of lining pipes using other approved rehabilitation methodologies, the effectiveness of invert paving for invert distressed drainage facilities should be explored first. Structural invert paving is appropriate when there are no other major structural deficiencies in the culvert besides the invert deterioration, and the pipe is also of sufficient size (a minimum culvert diameter of 48” is recommended) to accommodate safe execution of this work. The designer should clearly indicate in the plans the concrete cover over the corrugation crests, the type and layout of the concrete reinforcement, and the paving area limits along the periphery of the culvert. Note that the periphery paving limits should always extend beyond the area of significant corrosion loss, allowing reinforcement to be attached onto sound metal locations on both sides of the invert. The 602 standard specification requires that all reinforcement details shall be shown on the plans.

Design details for structural invert paving of culverts spanning up to 10 feet and bearing up to 20 feet of fill over the crown are available in .dgn format under “Resource Links” at: https://www.nysdot.gov/divisions/engineering/design/dqab/hdm/chapter-8. Repairs for culverts falling outside these parameters need to be designed on an individual basis and the Office of Structures can be consulted for assistance. Welded wire fabric reinforcement embedded in a 4” deep/thick concrete slab over the corrugation crest is recommended for structural invert paving of
round pipes and arches spanning up to 6 feet. The welded wire fabric reinforcement can be attached directly onto the corrugations by welding or utilizing stainless steel mechanical anchors. These are the only two anchoring options allowed for welded wire fabric reinforcement embedded in 4” thick concrete slab for culverts spanning less than 6 feet.

Reinforcement bars are recommended for all arches (regardless of span) and also for all round pipes spanning between 6 and 10 feet. The reinforcement is embedded in a 6” or 8” thick concrete slab, depending on the culvert’s span, with a minimum of 2” reinforcement cover. Shear transfer is achieved by anchoring (welding) shear studs to sound metal on the corrugation crests (see relevant drawing detail Figure 2). Reinforcement bars shall only be attached to shear studs (never directly to the culvert walls) by wire tying (see relevant drawing detail Figure 1). Reinforcement bar sizes will be selected based on the recommendations established by the Office of Structures (see Figure 3). All reinforcement and shear studs should be covered with concrete and the concrete should be sloped in such a way as to prevent water ponding on the side walls. Small areas of suspected metal loss around culverts circumference do not necessarily preclude the use of this item as an effective rehabilitation technique, since the remaining circumference above the structurally paved invert area could also be lined with shotcrete. Since these treatments modify culverts hydraulics characteristics, designers must consult with the Hydraulics Design section on this topic. Designers are directed to use a Manning's “n” value of 0.013 for hydraulic calculations in the paved area of the culvert. Structural paving of corrugated pipe inverts with PCC results in reduced roughness, leading to increased flow velocity and sediment transport competence. This may in turn negatively affect aquatic habitat connectivity as the barrel will retain less streambed sediment than it did in its prior unpaved condition. It is recommended that surface roughening techniques (e.g. raking the fresh concrete perpendicular to the flow) be considered for use where appropriate and practicable. Designers are also reminded that a culvert with a previously paved invert could be re-rehabilitated with concrete lining.

8.6.7.6.A.2 Lining with Shotcrete

If the entire culvert circumference (or even when an area beyond the extent of structural invert paving but less than 20% of the total corroded area) exhibits signs of minor corrosion, lining with shotcrete is a viable option. Designers may utilize the Design Standard details for structural paving developed by the Office of Structures Design which are available in .dgn format under “Resource Links” at: https://www.nysdot.gov/divisions/engineering/design/dqab/hdm/chapter-8, after simply substituting the concrete with the appropriate shotcrete item. As mentioned in the previous section, shotcrete can be used in conjunction with structural invert paving to address corrosion beyond the extent of paving. Shotcrete can also be used for localized rehabilitation of a distressed culvert section. If properly specified, this method can also restore culvert structural capacity. Designers are directed to use a Manning's “n” value of 0.013 for hydraulic calculations in the shotcreted area of the culvert. For worker access safety reasons, this lining methodology should not be utilized in culverts with diameters smaller than 48”.

8.6.7.6.B Inadequate Structural Capacity.

If the structural integrity of the culvert is questionable, the following six lining options may be considered:
8.6.7.6.B.1 Lining with High Density Polyethylene Pipe (HDPE)

High Density Polyethylene Pipe meeting ASTM F894 (Profile Wall) or ASTM F714 (Smooth Wall) may be used in association with the height of cover table provided below. There are two types of HDPE liners: a profile wall often without exterior corrugations, and a smooth solid wall pipe. The exterior and interior diameters of these liners vary among manufacturers. Considerable confusion has been generated when specifying the required size of these two lining pipes. Profile wall pipe is specified by the inside diameter, and as the required load increases, the wall profile thickens. Smooth wall pipe is specified by the outside diameter and the actual inside diameter diminishes with greater loads, as the wall thickens. Smooth wall HDPE lining pipe has a much higher material cost because of the larger resin volume required for its fabrication compared to the profile wall. For good grouting practice purposes Standard Specification 602 requires a minimum annular space of 1 inch between the host pipe and the liner. Therefore the outside diameter of the liner pipe must be a minimum of 2 inches smaller than the diameter of the existing (host) pipe. This is an important size constraint when calculating the hydraulic capacity of the relined installation. As a result of these dimensional constraints, designers are at times forced to specify the more expensive smooth wall liner pipe instead of the less expensive profile wall. This is the case, because for the same load carrying capacity, the smooth wall liner pipe possesses a thinner wall section, allowing for more interstitial space between the proposed liner and the host pipe. To prevent problems during construction between the two wall types, both types have their own specification and the Designers’ wall selection should be clearly indicated in the plans. The original specification has been retained as an optional item. It can be used when abundant interstitial/annular space exists and the consequences of a potentially arbitrary swap in the field are not a major concern. Currently available diameters for these pipes range from 18 to 60 inches for solid wall pipe, and 18 to 96 inches for profile wall pipe.

Various joint types can be specified to hold the liner segments aligned and firmly together through the liner insertion process and until the grout sets in place. The issue of joint type selection for HDPE liners is addressed in the revised 602 specification as: “Perform all butt fusion and extrusion welding of HDPE pipe in accordance with the Manufacturer’s recommendation” and “Alternate joining methods will be subject to approval by the Director, Materials Bureau”. Two mechanical joints are currently approved, a threaded joint and a smooth exterior bell and spigot joint. A mechanical joint wrap process has been evaluated and approved with some dimensional restrictions associated with its use at this time. However, butt fusion and extrusion welding are still the most durable joining methods, effectively creating a continuous liner pipe but they are also more labor intensive and hence more expensive than other joining methods. When alignment breaks or pinch points are encountered in a project, designers should only consider butt fusion and extrusion welding as the joining methods of choice, as they provide the most reliable joints for these challenging site conditions. Designer choices should be clearly stated in the notes and placed in a very prominent spot in the contract documents. The notes should also explicitly state that these joint selection restrictions solely apply to the host pipes possessing these challenging morphological conditions. Again, the maximum depth of cover for the culvert to be relined, estimated modulus of soil reaction E’, and the estimated water table elevation should be clearly noted on the plans.
8.6.7.6.B.2 Lining with Cured in Place Pipe (CIPP)

Lining with Cured in Place Pipe (CIPP) is an option for round pipes when end access is limited, pipe alignment includes bends, or when other lining methods would seriously reduce culvert hydraulic capacity. CIPP can restore both the structural and the hydraulic capacity of a pipe. Although this item is relatively expensive compared to other relining items, it could be the best rehabilitation alternative if all or some of the above site conditions exist. Designers are responsible for making this selection decision based on site conditions and associated regional installation cost. This item should very rarely be considered as a viable rehabilitation method for arches or rectangular culverts. CIPP is best suited for circular drainage facilities with limited access to and ranging in diameter from 12 to 42 inches. CIPP technology can be applied to lining larger diameter culverts, but in these cases, the installation cost is usually prohibitive and CIPP lining should only be considered for very short lengths. The ability to prepare (“wet”) the liner off site as opposed to “wet” it on site (near the culvert’s access point) greatly impacts operational cost. High depths of cover and elevated water tables demand thicker CIPP liners. These adverse site conditions coupled with large diameter and/or long host culverts, result in very heavy liners, which forces the installer to perform the “wetting” operation over the culvert’s access point. This additional cost may render the overall cost of this operation prohibitive. Consult with the Materials Bureau when dealing with large diameter and/or excessively long liners.

Lining Concrete Pipe with Cured in Place Pipe (CIPP) is an option created to utilize a partially deteriorated design methodology and can ONLY be used for lining concrete pipes. This item should ONLY be used when the concrete pipe still possesses some measurable structural capacity but inspections have raised some concerns, which can be alleviated by lining. These concerns may include, but are not limited to, damaged or separated joints, infiltration of ground water from faulty joints or incipient cracks (cracks not threatening the structural capacity of the concrete pipe) or as a precautionary measure for abrasion protection. The designer may follow the same guidance as with CIPP (see above), but this concrete pipe pay item should be selected. It is anticipated that invoking the partially deteriorated design methodology, ONLY where warranted, will result in substantial material cost savings and reduced overall bid prices.

A Manning's coefficient “n” value of 0.013 should be used for hydraulic calculations in all CIPP sections. The CIPP relining item is often selected by designers as a result of two very important features. The usually improved Manning’s coefficient of the rehabilitated culvert coupled with the smallest cross section reduction possible as a result of selecting CIPP vs. any other relining

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| Maximum Allowable Cover (feet)
  | 30 | 30 | 33 | 26 | 26 | 26 | 23 | 23 | 26 | 26 | 26 | 26 | 33 | 36 |    |

1 Maximum vertical distance between the top of the pipe and the top of pavement.
methodology. Once again, only round culverts should be lined with this method. The anticipated service life of this treatment is 70 years.

It is imperative that all obstructions in the culvert are removed prior to initiating the CIPP lining procedure. The bid price for the CIPP item includes the cost of removing any obstructions, along with re-establishing culvert to secondary pipe connections and the removal of any protruding pipes as required. It should be noted that Department policy for storm drainage allows addition of pipe connections onto a pipe only within a structure (e.g. manhole, drop chamber, etc.) and never in between such structures, so finding all pipe to pipe connections should be a straightforward process. A thorough culvert inspection is required to determine the number of existing “pipe to pipe” connections and the extent, if any, of obstruction removal. If the culvert opening (36” in diameter or less) prohibits a human-led visual inspection, a closed circuit television inspection should be performed by experienced personnel trained in locating breaks, obstacles and service connections during the design phase of the project. This information should be made available to all bidders to assist them in preparing an accurate bid.

Designers should be aware that in the field, the liner is inverted and filled with water, which pushes the liner through the culvert. The water also holds the resin-impregnated liner in position and in contact with the host pipe. The water is circulated through a mobile boiler which raises its temperature in excess of 160°F. The heat of the circulating water cures the resin and transforms the formerly flexible liner into a solid continuous conduit. The liner curing process typically lasts several hours. Once the liner is completely cured, the curing water is removed, then, all (if any) service connections are restored, using robotic cutting devices, especially for culverts less than 36” in diameter. The completed liner should be inspected, often using a closed circuit television, especially for culverts less than 36” in diameter.

Environmental impact concerns and information gathered from the extensive use of CIPP, have led to a series of new product developments as well as amendments to installation procedures. Curing water from CIPP installations utilizing a styrene-based resin contains some styrene residual. NYS Surface Water and Groundwater Quality Standards and Groundwater Effluent Limitations (6 New York State Department of Codes, Rules and Regulations (NYCRR) Part 703) set quantitative and qualitative standards for effluents to NYS water bodies. These standards may vary for different classes of receiving waters or for discharging it to groundwater. NYS Water Quality Standards include specific limit guidelines for discharging certain pollutants (including styrene) to various surface water classes and groundwater. The limit of 0.05 ppm applies to surface water bodies with classifications A, A-S, AA and AA-S while the limit of 0.005 ppm applies to groundwater with GA (fresh groundwater) classification. The general conditions listed in 6 NYCRR Part 701 apply to all water classifications. They dictate that discharges shall not cause impairment of the best usages of the receiving water (as specified by the water classifications) both at the location of discharge or at any other location which may be affected by such discharge. Note that thermal loading considerations (6 NYCRR Part 704) are directly related to the release temperature and discharge rate of the curing water. Provisions for handling and/or disposal alternatives as well as other control procedures are included in the specifications to address the presence of styrene in the curing water and other potential releases to water and air from the byproducts of the CIPP installation. These provisions include:
Some procedural changes to enhance control of the CIPP process and leakage of resin, including utilizing a preliner bag and excavating a temporary resin control pit at the outlet.

- Allowing the use of non-styrene based resins containing less than five percent volatile organic compounds (VOCs) with less than 0.1 percent hazardous air pollutants (HAPs). These resins are now included in the 602 Standard Specifications and can be used by the Contractor in any CIPP site. The cured liner should also contain less than 0.1 percent of water quality pollutants (as listed in 6 NYCRR Parts 700-705). NYSDOT may determine and dictate that at certain areas of greater environmental concern (i.e. in the vicinity of class A, A-S, AA and AA-S water sources or at other locations presenting other needs) non-styrene based resins MUST be used. If the Department requires the use of only a designated resin type, the resin type requirements shall be clearly noted in the contract documents; otherwise, the Contractor may select the resin type from the resin approved list included in the CIPP Approved Installer’s Materials Procedure document, which is kept on file at the Main Office, Materials Bureau.

- In all CIPP installations utilizing a styrene based resin, it is required to collect the curing water for:
  - Reuse in another curing operation
  - Treatment or disposal at an off-site facility; or
  - Release on site after treatment to standards dictated by NYSDEC and with approvals from NYSDEC.

**Summarizing**, the resin type alternatives for CIPP work are to either use a non-styrene based resin or follow additional controls when using a styrene-based resin.

Areas of environmental concern may include, but are not limited to, wetlands, fishing streams and ponds, upstream of public water sources, densely populated urban areas where residents are concerned about the short lasting odor of the styrene during curing, etc. Waters classified as Class A are: a source of water supply for drinking, culinary or food processing purposes; primary and secondary contact recreation; and fishing (i.e. waters suitable for fish, shellfish, and wildlife propagation and survival). Although numerical standards are not listed for other classes of streams in 6NYCRR Part 703, the general requirements of Part 701 apply (i.e. discharge must not cause impairment of the best usages of the receiving water).

The designer shall determine the location of each installation in respect to environmental resources including the classes of streams/watercourses in the vicinity of the project. The regional environmental unit and/or “Environmental Viewer” (A GIS application currently available at the Office of the Environment Intradot site and under the manual / applications tab, subsection GIS Application) shall be consulted for stream classification and other relevant environmental information. For installations close to and presenting the potential for curing water releases to class A, A-S, AA and AA-S streams or releases of other concern, the requirement for using a non-styrene based resin should be considered.

If designers determine that a non-styrene based resin shall be used in a specific CIPP installation, then the relining project’s contract documents have to clearly and unambiguously specify that “a resin containing less than five percent volatile organic compounds (VOCs) with less than 0.1 percent hazardous air pollutants (HAPs) must be used”. It should also clearly state that “the cured liner should contain less than 0.1 percent of water quality pollutants (as listed in 6 NYCRR Parts
Use of these resins will result in a significant increase to the rehabilitation cost, approximately double to the materials cost of using regular styrene based resins in 2009 market prices. Therefore the decision to specify non-styrene based resins should not be made lightly and never prior to evaluating whether the use of styrene based resins combined with other alternative provisions to control the release of the curing water provide both enough site environmental protection and project cost savings. These provisions (listed now in the 602 Standard Specification) include, but they should not be limited to: removal (pumping out) of the curing water at the end of the CIPP installation, transporting it to an appropriate disposal facility instead of free draining it at the outlet, providing for a resin catchment pit excavated right at the culvert’s outlet to create ideal conditions for the collection of the trace amounts of styrene, temperature control of the released curing water, as well as combinations of the above. Again, designer’s stipulations on environmental protection provisions should be clearly indicated on the plans as they may substantially impact the operational cost. These stipulations should be limited to the class of the neighboring stream or water course class which may be impacted by the release of the curing water, the need for utilizing a styrene or a non-styrene based resin, the maximum allowed release temperature of the curing water and the size of the resin catchment pit. It is recommended that the resin catchment pit dimensions are: 12 to 15 feet long, twice the culvert diameter wide and one foot deep. If a rip-rap layer has been installed at the culvert outlet (potentially even in the stream bed), the proposed depth of the catchment pit will be equal to the thickness of the rip rap layer (it could even be over a foot deep) and as indicated on the record plans. If the natural bedrock is encountered near the culvert invert elevation, the catchment pit bottom elevation must be just (at least) below the culvert invert, so that the CIPP installer is able to create the proposed temporary catchment pit. CIPP installers will decide as to the catchment pit lining, as they are responsible for preventing the liner curing process byproducts and waste from reaching the surrounding ground and percolate / leach into the groundwater. The excavation, temporary storage of the fill and restoration of the downstream channel will be paid for under pay item 206.04 Trench and Culvert Excavation – O.G.

The majority of the environmental controls in any CIPP project are dictated by the written agreement (Materials Procedure) between the Approved List manufacturer / installer and the Materials Bureau. If designers have any concerns about using the CIPP relining item at a specific location, especially when styrene based resins are employed, they should first consult with the Materials Bureau.

Current designs address fill heights up to a maximum of 50 feet. If the fill height over the CIPP installation exceeds 50 feet at any point along the culvert alignment, contact the Materials Bureau to coordinate an evaluation of the proposed CIPP liner design.

8.6.7.6.B.3 Lining with Polyvinyl Chloride Pipe

The 602 relining specification also allows the contractor to use PVC pipe meeting ASTM F1803, ASTM F949, and two new standards, ASTM F679 or ASTM D3034 (small diameters 12" or 15") as relining material. PVC pipe is currently available in diameters ranging from 12 inches through 36 inches on the current Approved List. Designers must consult the Approved List for the addition of new manufacturers and/or products as well as for the currently approved sizes for each PVC material. PVC lining pipes are corrosion and abrasive resistant. A Manning's coefficient value of 0.013 should be used for all hydraulic capacity calculations related to PVC pipes.
Some PVC pipes are more brittle than other flexible relining materials. Therefore, designers should determine prior to specifying it, that the condition and shape of the host culvert will allow for an unobstructed insertion of the PVC lining pipe.

Since the 602 relining specification requires a minimum annular space of 1" for effective grouting, the outside diameter of the liner pipe needs to be a minimum of 2" smaller than the inside diameter of the existing (host) pipe when calculating the hydraulic capacity of the new installation. Profile wall pipe (ASTM F949) is specified by the pipe's nominal inside diameter while the respective outside diameters can be found in ASTM F949. ASTM F1803 lists only the nominal inside diameter of these respective materials, therefore designers must consult with the pipe manufacturer to obtain the outside diameter information. Both ASTM F949 and ASTM F1803 pipes possess joints that are flush with the outside diameter. However, ASTM F679 and ASTM D3034 pipes do not have a joint flush with the outside diameter of the pipe but rather a bell and spigot joint protruding from the outer pipe shell. Therefore, for ASTM F679 & ASTM D3034 pipes, it is the outside diameter of the joint and not the outside diameter of the pipe which dictates the maximum allowable liner diameter for a particular application. Because of this confusion, the lack of readily available info for some PVC pipes and in order to properly evaluate selected PVC pipe size compliance with the minimum required annular space for effective grouting, designers are strongly encouraged to consult with the Materials Bureau about the maximum outside dimension of any PVC pipe, if this information is not available to them.

The table below provides the allowable fill heights for each size of PVC liner pipe. If the fill height exceeds 50 feet at any point along the pipe alignment, contact the Materials Bureau for approval of the proposed liner design. The anticipated service life of a PVC liner is 70 years.

<table>
<thead>
<tr>
<th>PVC Liner Diameter (inches)</th>
<th>12</th>
<th>15</th>
<th>18</th>
<th>21</th>
<th>24</th>
<th>30</th>
<th>36</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Allowable Cover (feet)</td>
<td>50</td>
<td>46</td>
<td>33</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>26</td>
</tr>
</tbody>
</table>

Maximum vertical distance between the top of the pipe and the top of pavement.

8.6.7.6.B.4 Lining with Tunnel Liner Plate

In some closed drainage systems, space constraints may limit lining options which involve installing full lengths of pipe sections. In these cases, galvanized tunnel liner plate may be a viable option. Tunnel liner plate can be inserted and assembled within the host culvert as the laying length of individual sections is 18 inches. Galvanized Tunnel Liner Plate requires a PCC invert to provide the required service life and hydraulic performance.

Structural paving of the invert improves the hydraulic efficiency of the culvert and protects the tunnel liner bolt flanges from abrasion caused by bedload. When site conditions dictate that only tunnel liner plates can accommodate the structural demand of the culvert, but hydraulics analysis dictates that a low Manning material must be used, shotcreting the invert or HDPE lining is a valid
solution. Consult the Materials Bureau for further guidance when such cases arise.

8.6.7.6.B.5 Lining with Polymer Coated Corrugated Steel Pipe (CSP)

If the rehabilitated pipe is anticipated to be subjected to potentially abrasive bed loads or to be exposed to high concentrations of industrial waste, the Polymer Coated CSP item is a suitable relining material for these conditions. The suggested Manning’s coefficient “n” value will range from 0.013 to 0.026, depending on the corrugation pattern selected. The recommended Manning coefficient “n” values for all drainage materials are provided in Section 8.6.3.1.

The height of fill tables provided in Appendix A shall be used to determine if the 12 gauge steel pipe meets the site’s height of fill requirements.

8.6.7.6.B.6 Lining with Steel Structural Plate Pipe or Pipe Arches with PCC Paved Invert

Steel structural plate can be partially or fully assembled and pushed or pulled into place within the pipe. This lining option should be considered for large diameters where other items are unavailable. If the plate sections are too large to be inserted into the host culvert through the exposed ends, then an excavation and a field cut through the culvert roof would be required. Every effort should be made to ensure that the excavation and field cut are located where it will be the least disruptive to traffic.

Designers must clearly indicate in the plans how to pave the invert of the plate pipe or arch. The minimum extent of the invert paving will be the bottom 30 percent of the inside circumference for round pipes, the bottom 35 percent of the inside periphery for arch spans up to 3 m and the bottom 40 percent of the inside periphery for arch spans greater than 3 m. If this paving coverage encompasses (with some margin of safety) at least 150 mm circumferentially beyond the limits of the culvert’s wetted perimeter for mean flow conditions, then this paving coverage will be sufficient. If it does not, then a greater percentage of coverage should be used. A minimum cover of 50 mm over the crests of the corrugation and the steel fabric reinforcement should also be noted on the plans.
HIGHWAY DESIGN MANUAL

Chapter 8 HIGHWAY DRAINAGE

Revision 61- Metric
(Limited Revision)

March 25, 2011
<table>
<thead>
<tr>
<th>Section</th>
<th>Changes</th>
</tr>
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<tbody>
<tr>
<td>8.6.7</td>
<td>Section updated by EB 11-008.</td>
</tr>
</tbody>
</table>
8.6.7 Rehabilitation of Culverts and Storm Drains

8.6.7.1 General

Replacement of a buried pipe system will seldom be a viable alternative in locations where long detours or extensive disruption to traffic will occur. When replacement is neither viable nor economically desirable, existing pipes may be rehabilitated by one of the following options:

8.6.7.1.A Structural paving of the invert with Portland Concrete Cement (PCC).

This is an excellent rehabilitation methodology when the culvert has maintained its original shape, even if it exhibits considerable invert deterioration. Structural invert paving should be the predominant choice for rehabilitating large diameter arches and culverts, where using a new pipe lining method is cost prohibitive. Invert and barrel deterioration are the prime considerations when deciding on the extent and boundaries of the structural invert paving operation. These boundaries should be clearly shown on the contract documents. For worker access safety reasons, structural paving of the invert should not be specified in culverts with diameters smaller than 1200 mm, except when no other option is feasible.

Design details on structural invert paving along with extended guidance can be found in Section 8.6.7.6. Structural invert paving may also be used in conjunction with shotcreting of the entire remaining culvert barrel (i.e. beyond the structural paving limits) further improving the structural capacity of the rehabilitated culvert. This hybrid rehabilitation scheme is recommended when the circumferential integrity of the culvert is questionable.

8.6.7.1.B Lining with Shotcrete.

This is a cost effective solution for large size culverts and arches that are experiencing distress in sidewalls, roof, and invert. The culvert should not display any significant structural deficiencies, buckling or other forms of deformation. It can also be used in combination with paving inverts. The plans need to indicate the reinforcement details and its limits along the culvert periphery. Utilizing welding or stainless steel mechanical anchors in reinforcement anchoring are the only options allowed. Lining with shotcrete could encompass the entire barrel of the pipe. A minimum cover of 50 mm over the corrugation crests is recommended. If for other reasons a designer would like to specify a thicker cover this must be clearly indicated on the plans. To accommodate the proper installation and application equipment, the item can only be used in culverts with a minimum diameter of 1200 mm.

8.6.7.1.C Lining with Cured in Place Pipe (CIPP).

This consists of a CIPP lining inserted into an existing culvert. When lining with CIPP, the designer must provide on the plans all necessary information so that the bidding Approved List installers are able to calculate the design (dead and live) loads on each liner based on the same critical design input parameters. The provided information must at minimum include, but it is not limited to, the culvert maximum depth of cover, estimated modulus of soil...
reaction E’ and estimated water table elevation above culvert invert for the site. This information should be clearly noted on the plans, as: “The maximum depth of cover is estimated from the top of the pipe to…”, or “The estimated water table elevation is measured from the culvert invert”. By providing this information on the plans, we improve the uniformity of the bidding, since all submitted bids will be relying on the same design input parameters. Subcontractors mobilization cost should also be considered when selecting relining methodologies. For example, if CIPP lining has been selected for twelve culverts with bends while HDPE lining has been proposed for three straight run culverts, unless the three straight run culverts were of very large diameter (approaching 1050 mm in diameter), it may be cost prohibitive to mobilize another subcontractor (HDPE lining) when the CIPP one will already be on site. Designers should be selecting the most cost effective repair scheme.

8.6.7.1.D Lining with a New Liner Pipe.

This rehabilitation technique can restore both structural and hydraulic capacity of a pipe. It is appropriate for culverts ranging in diameters from 300 through 3000 mm. The existing (host) pipe should be relatively free of large bulges and in relatively good alignment. If bulges, alignment issues or other obstructions exist, they should be (if possible) eliminated in order to accommodate the unobstructed insertion of the new liner pipe. Lining pipe generally comes in 6 m lengths and requires adequate end access space to accommodate insertion. When end access is limited, shorter pipe lengths may be utilized but they have to be special ordered. Designers should contact lining pipe manufacturers or suppliers in advance to determine availability of short lengths. All available pipe rehabilitation materials are presented in Section 8.6.7.6.

When end access of an existing large pipe (1800 mm or larger) is limited, Galvanized Steel Plate, Steel Structural Plate and Galvanized Steel Tunnel Liner Plate may be cost effective pipe lining options. This is true, only if structural paving is not an option. These methodologies will also restore a culvert’s structural integrity.

Designers should never specify the grout mix design used to fill the annular space between the existing pipe and the lining pipe. It is the manufacturer's representative’s responsibility to recommend a suitable grout compatible with the lining material used. The grout material recommendation must be included in the submitted written proposal to the EIC, in accordance to the specifications. The compressive strength of the grout is completely ignored (it is assumed that it carries no load and it does not contribute to the structural capacity of the composite “old pipe-grout-liner pipe” structure) in the liner thickness design calculations. Completely deteriorated conditions (i.e. it possesses zero remaining structural capacity) are assumed for the existing pipe during these calculations. Consequently, the proposed liner is required to possess adequate structural capacity to carry the entire calculated dead and live load.

Due to the potential for adverse environmental impacts associated with culvert rehabilitation activities (e.g. in-stream habitat, sediment dynamics, water/air quality), it is
essential that designers coordinate the project development with the Regional Environmental Unit at an early stage in order to identify potential impacts and opportunities for mitigation.

The reader is strongly encouraged to review Section 8.6.7.6 for a detailed presentation of the above mentioned rehabilitation techniques. Additional guidance regarding the rehabilitation of culverts is provided in AASHTO’s Highway Drainage Guidelines, Volume XIV.

8.6.7.2 Evaluating the existing culvert and site conditions

During hydraulic calculations to determine the minimum required diameter which satisfies the facility’s hydraulic demand, the proposed lining pipe’s wall thickness and/or the corrugation pattern may dictate the choice of lining materials.

It is imperative that the existing (host) culvert is thoroughly inspected in order determine the most appropriate type of rehabilitation. The inspection should determine culvert’s dimensions, material type, overall condition and structural integrity as well as site and/ or existing pipe end accessibility for inserting lining pipe. Inspectors should clearly map the location and extent of distressed areas as well as all existing obstructions / buckles which may impact the size and insertion of the proposed lining pipe. Buckled pipes can be jacked near to their original shape provided that working room and proper access are available. However, excessive buckling of the existing pipe may severely obstruct and consequently preclude the use of any lining pipe. If visual inspection of the existing pipe for whatever reason is not feasible, a robotic or other remote means inspection method is warranted.

Special order lining pipe lengths may be available for some types of lining pipes. If needed and as it was recommended in the “Lining with a new pipe” section, Designers should contact the pipe manufacturer or supplier to determine availability of shorter lining pipe lengths and approximate material costs.

If significant pipe perforations and/or backfill subsidence has been observed, consult with the Regional Geotechnical Engineer to determine the extent of any voids that may exist in the backfill material in the area above and immediately adjacent to the culvert.

8.6.7.3 Hydraulics & Service Life

All material used in culvert and storm drain rehabilitation should meet structural, hydraulic and service life requirements as identified in Chapter 8 of the Highway Design Manual. For design calculation purposes, the existing culvert and any annular fill material (e.g. grout) used in the lining application are assumed to provide no additional service life nor contribute to the structural capacity of the lining pipe.

8.6.7.4 Geotechnical Issues

Consult with the Regional Geotechnical Engineer to determine and map the extent of any voids that may exist in the backfill material adjacent to the culvert. Voids not immediately adjacent to
the culvert, which may have developed via infiltration of backfill fines into the culvert, are typically filled from above using a series of drill holes. For the sake of uniform bidding purposes, when voids are present, the Plans should include the following details: general site conditions, access, proposed end treatments, profiles and grade staging, voids mapping, any special situations, relevant restrictions, etc. The Regional Geotechnical Engineer should be contacted for selecting the voids filling material in the backfill.

Very rarely culvert bearing embankments require grouting immediately prior to culvert rehabilitation. Extensive embankment grouting (filling of voids beyond culvert vicinity) is pursued only when the Designer and/or a Geotechnical Engineer decide(s) that the observed settlement poses a serious and immediate threat to the embankment integrity. Established practice for most cases dictates completing the lining work prior to addressing any settlement related issues.

8.6.7.5 Cost

Each rehabilitation methodology has its own pay item which includes all labor and materials cost necessary to complete the installation. The depth of cover (or fill height above the culvert) and ground water table elevation impact the bidding price of a liner. The fill material in the backfill area above the pipe is paid for under a separate item provided by the Geotechnical Engineer.

8.6.7.6 Available lining methodologies and recommended conditions for use:

8.6.7.6.A Adequate Structural Capacity

If the culvert possesses reduced but adequate structural capacity and the culvert has maintained its original shape some structural capacity can be restored by rehabilitating the barrel. Under these conditions, the culvert could be effectively rehabilitated by selecting one of the following two methodologies:

8.6.7.6.A.1 Structural Paving of Inverts with Portland Cement Concrete (PCC)

This is a relatively low cost solution for rehabilitating circular culverts and arches experiencing invert distress, primarily caused by abrasion or a combination of abrasion and corrosion. Generally, if the pipe or arch has maintained its original shape and does not experience other major structural deficiencies except the invert loss, the culvert can be rehabilitated by structurally paving the invert, regardless if the invert shows considerable deterioration. Due to the higher cost of lining pipes using other approved rehabilitation methodologies, the effectiveness of invert paving for invert distressed drainage facilities should be explored first. Structural invert paving is appropriate when there are no other major structural deficiencies in the culvert besides the invert deterioration, and the pipe is also of sufficient size (a minimum culvert diameter of 1200 mm is recommended) to accommodate safe execution of this work. The designer should clearly indicate in the plans the concrete cover over the corrugation crests, the type and layout of the concrete reinforcement, and the paving area limits along the periphery of the culvert. Note that the periphery paving limits
should always extend beyond the area of significant corrosion loss, allowing reinforcement to be attached onto sound metal locations on both sides of the invert. The 602 standard specification requires that all reinforcement details shall be shown on the plans.

Design Standard details of structural invert paving of culverts spanning up to 3000 mm and bearing up to 6 m of fill over the crown are available in .dgn format under “Resource Links” at: https://www.nysdot.gov/divisions/engineering/design/dqab/hdm/chapter-8. Electronic copies of these details can be provided upon request. Repairs for culverts falling outside these parameters need to be designed on an individual basis and the Office of Structures can be consulted for assistance. Welded wire fabric reinforcement embedded in a 100 mm deep/thick concrete slab over the corrugation crest is recommended for structural invert paving of round pipes and arches spanning up to 1800 mm. The welded wire fabric reinforcement can be attached directly onto the corrugations by welding or utilizing stainless steel mechanical anchors. These are the only two anchoring options allowed for welded wire fabric reinforcement embedded in 100 mm thick concrete slab for culverts spanning less than 1800 mm.

Reinforcement bars are recommended for all arches (regardless of span) and also for all round pipes spanning between 1800 and 3000 mm. The reinforcement is embedded in a 150 mm or 200 mm thick concrete slab, depending on the culvert’s span, with a minimum of 50 mm reinforcement cover. Shear transfer is achieved by anchoring (welding) shear studs to sound metal on the corrugation crests (see relevant drawing detail Figure 2). Reinforcement bars shall only be attached to shear studs (never directly to the culvert walls) by wire tying (see relevant drawing detail Figure 1). Reinforcement bar sizes will be selected based on the recommendations established by the Office of Structures (DCES) (see Figure 3). All reinforcement and shear studs should be covered with concrete and the concrete should be sloped in such a way as to prevent water ponding on the side walls. Small areas of suspected metal loss around culverts circumference do not necessarily preclude the use of this item as an effective rehabilitation technique, since the remaining circumference above the structurally paved invert area could also be lined with shotcrete. Since these treatments modify culverts hydraulics characteristics, designers must consult with the Hydraulics Design section on this topic. Designers are directed to use a Manning’s “n” value of 0.013 for hydraulic calculations in the paved area of the culvert. Structural paving of corrugated pipe inverts with PCC results in reduced roughness, leading to increased flow velocity and sediment transport competence. This may in turn negatively affect aquatic habitat connectivity as the barrel will retain less streambed sediment than it did in its prior unpaved condition. It is recommended that surface roughening techniques (e.g. raking the fresh concrete perpendicular to the flow) be considered for use where appropriate and practicable. Designers are also reminded that a culvert with a previously paved invert could be re-rehabilitated with concrete lining.

8.6.7.6.A.2 Lining with Shotcrete

If the entire culvert circumference (or even when an area beyond the extent of structural invert paving but less than 20% of the total corroded area) exhibits signs of minor corrosion, lining with shotcrete is a viable option. Designers may utilize the Design Standard details for
structural paving developed by the Office of Structures Design which are available in .dgn format under “Resource Links” at: https://www.nysdot.gov/divisions/engineering/design/dqab/hdm/chapter-8, after simply substituting the concrete with the appropriate shotcrete item. As mentioned in the previous section, shotcrete can be used in conjunction with structural invert paving to address corrosion beyond the extent of paving. Shotcrete can also be used for localized rehabilitation of a distressed culvert section. If properly specified, this method can also restore culvert structural capacity. Designers are directed to use a Manning’s “n” value of 0.013 for hydraulic calculations in the shotcreted area of the culvert. For worker access safety reasons, this lining methodology should not be utilized in culverts with diameters smaller than 1200 mm.

8.6.7.6.B Inadequate Structural Capacity

If the structural integrity of the culvert is questionable, the following six lining options may be considered:

8.6.7.6.B.1 Lining with High Density Polyethylene Pipe (HDPE)

High Density Polyethylene Pipe meeting ASTM F894 (Profile Wall) or ASTM F714 (Smooth Wall) may be used in association with the height of cover table provided below. There are two types of HDPE liners: a profile wall often without exterior corrugations, and a smooth solid wall pipe. The exterior and interior diameters of these liners vary among manufacturers. Considerable confusion has been generated when specifying the required size of these two lining pipes. Profile wall pipe is specified by the inside diameter, and as the required load increases, the wall profile thickens. Smooth wall pipe is specified by the outside diameter and the actual inside diameter diminishes with greater loads, as the wall thickens. Smooth wall HDPE lining pipe has a much higher material cost because of the larger resin volume required for its fabrication compared to the profile wall. For good grouting practice purposes Standard Specification 602 requires a minimum annular space of 25 mm between the host pipe and the liner. Therefore the outside diameter of the liner pipe must be a minimum of 50 mm smaller than the diameter of the existing (host) pipe. This is an important size constraint when calculating the hydraulic capacity of the relined installation. As a result of these dimensional constraints, designers are at times forced to specify the more expensive smooth wall liner pipe vs. the cheaper profile wall. When this is the case, because for the same load carrying capacity, the smooth wall liner pipe possesses a thinner wall section, allowing for more interstitial space between the proposed liner and the host pipe. To prevent problems during construction between the two wall types, both types have there own specification and the Designers’ wall selection should be clearly indicated in the plans. The original specification has been retained as an optional item. It can be used when abundant interstitial / annular space exists and the consequences of a potentially arbitrary swap in the field are not a major concern. Currently available diameters for these pipes range from 45 to 1500 mm for solid wall pipe, and 45 to 2400 mm for profile wall pipe.
Various joint types can be specified to hold the liner segments aligned and firmly together through the liner insertion process and until the grout sets in place. The issue of joint type selection for HDPE liners is addressed in the revised 602 specification as: “*Perform all butt fusion and extrusion welding of HDPE pipe in accordance with the Manufacturer’s recommendation*” and “*Alternate joining methods will be subject to approval by the Director, Materials Bureau*”. Two mechanical joints are currently approved, a threaded joint and a smooth exterior bell and spigot joint. A mechanical joint wrap process has been evaluated and approved with some dimensional restrictions associated with its use at this time. However, butt fusion and extrusion welding are still the most durable joining methods, effectively creating a continuous liner pipe but they are also more labor intensive and hence more expensive than other joining methods. When alignment breaks or pinch points are encountered in a project, designers should only consider butt fusion and extrusion welding as the joining methods of choice, as they provide the most reliable joints for these challenging site conditions. Designer choices as such, should be clearly stated in the notes and placed in a very prominent spot in the contract documents. The notes should also explicitly state that these joint selection restrictions solely apply to the host pipes possessing these challenging morphological conditions.

<table>
<thead>
<tr>
<th>HDPE Liner Diameter (mm)</th>
<th>450</th>
<th>525</th>
<th>600</th>
<th>675</th>
<th>750</th>
<th>825</th>
<th>900</th>
<th>1050</th>
<th>1200</th>
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<tbody>
<tr>
<td>Maximum Allowable Cover¹ (m)</td>
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<td>10</td>
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<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>10</td>
<td>11</td>
</tr>
</tbody>
</table>

¹ *Maximum vertical distance between the top of the pipe and the top of pavement.*

8.6.7.6.B.2 Lining with Cured in Place Pipe (CIPP)

Lining with Cured in Place Pipe (CIPP) is an option for round pipes when end access is limited, pipe alignment includes bends, or when other lining methods would seriously reduce culvert hydraulic capacity. CIPP can restore both the structural and the hydraulic capacity of a pipe. Although this item is relatively expensive compared to other relining items, it could be the best rehabilitation alternative if all or some of the above site conditions exist. Designers bear the sole responsibility in making this selection decision based on site conditions and associated regional installation cost. This item should very rarely be considered as a viable rehabilitation method for arches or rectangular culverts. CIPP is best suited for circular drainage facilities with limited access to and ranging in diameter from 300 to 1050 mm. CIPP technology can be applied to lining larger diameter culverts, but in these cases, the installation cost is usually prohibitive and CIPP lining should only be considered for very short lengths. The ability to prepare (“wet”) the liner off site as opposed to “wet” it on site (near the culvert’s access point) greatly impacts operational cost. High depths of cover and elevated water tables demand thicker CIPP liners. These adverse site conditions coupled with large diameter and/or long host culverts, result in very heavy liners, which forces the installer to perform the “wetting” operation over the culvert’s access point. This additional cost may render the overall cost of this operation prohibitive. Consult with the Materials Bureau when dealing with large diameter and/or excessively long liners.
Lining Concrete Pipe with Cured in Place Pipe (CIPP) is an option created to utilize a partially deteriorated design methodology and can ONLY be used for lining concrete pipes. This item should ONLY be used when the concrete pipe still possesses some measurable structural capacity but inspections have raised some concerns, which can be alleviated by lining. These concerns may include, but are not limited to, damaged or separated joints, infiltration of ground water from faulty joints or incipient cracks (cracks not threatening the structural capacity of the concrete pipe) or as a precautionary measure for abrasion protection. The designer may follow the same guidance as with CIPP (see above), but this concrete pipe pay item should be selected. It is anticipated that invoking the partially deteriorated design methodology, ONLY where warranted, will result in substantial material cost savings and reduced overall bid prices.

A Manning's coefficient “n” value of 0.013 should be used for hydraulic calculations in all CIPP sections. The CIPP relining item is often selected by designers as a result of two very important features. The usually improved Manning’s coefficient of the rehabilitated culvert coupled with the smallest cross section reduction possible as a result of selecting CIPP vs. any other relining methodology. Once again, only round culverts should be lined with this method. The anticipated service life of this treatment is 70 years.

It is imperative that all obstructions in the culvert are removed prior to initiating the CIPP lining procedure. The bid price for the CIPP item includes the cost of removing any obstructions, along with re-establishing culvert to secondary pipe connections and the removal of any protruding pipes as required. It should be noted that Department policy for storm drainage allows addition of pipe connections onto a pipe only within a structure (e.g. manhole, drop chamber, etc.) and never in between such structures, so finding all pipe to pipe connections should be a fairly straight forward process. A thorough culvert inspection is required to determine the number of existing “pipe to pipe” connections and the extent, if any, of obstruction removal. If the culvert opening (900 mm in diameter or less) prohibits a direct human visual inspection, a closed circuit television inspection should be performed by experienced personnel trained in locating breaks, obstacles and service connections during the design phase of the project. This information should be made available to all bidders to assist them in preparing an accurate bid.

Designers should be aware that in the field, the liner is inverted and filled with water, which pushes the liner through the culvert. The water also holds the resin-impregnated liner in position and in contact with the host pipe. The water is circulated through a mobile boiler which raises its temperature in excess of 71°C. The heat of the circulating water cures the resin and transforms the formerly flexible liner into a solid continuous conduit. The liner curing process typically lasts several hours. Once the liner is completely cured, the curing water is removed, then, all (if any) service connections are restored using robotic cutting devices, especially for culverts less than 900 mm in diameter. The completed liner should then be inspected, often using a closed circuit television, especially for culverts less than 900 mm in diameter.

Environmental impact concerns and information gathered from the extensive use of CIPP, have led to a series of new product developments as well as amendments to installation
procedures. Curing water from CIPP installations utilizing a styrene-based resin contains some styrene residual. NYS Surface Water and Groundwater Quality Standards and Groundwater Effluent Limitations (6 New York State Department of Codes, Rules and Regulations (NYCRR) Part 703) set quantitative and qualitative standards for effluents to NYS water bodies. These standards may vary for different classes of receiving waters or for discharging it to groundwater. NYS Water Quality Standards include specific limit guidelines for discharging certain pollutants (including styrene) to various surface water classes and groundwater. Namely the limit of 0.05 ppm applies to surface water bodies with classifications A, A-S, AA and AA-S while the limit of 0.005 ppm applies to groundwater with GA (fresh groundwater) classification. The general conditions listed in 6 NYCRR Part 701 apply to all water classifications. They dictate that discharges shall not cause impairment of the best usages of the receiving water (as specified by the water classifications) both at the location of discharge or at any other location which may be affected by such discharge. Note that thermal loading considerations (6 NYCRR Part 704) are directly related to the release temperature and discharge rate of the curing water. Provisions for handling and/or disposal alternatives as well as other control procedures are included in the specifications to address the presence of styrene in the curing water and other potential releases to water and air from the by-products of the CIPP installation. These provisions include:

- Some procedural changes to enhance control of the CIPP process and leakage of resin, including utilizing a preliner bag and excavating a temporary resin control pit at the outlet.
- Allowing the use of non-styrene based resins containing less than five percent volatile organic compounds (VOCs) with less than 0.1 percent hazardous air pollutants (HAPs). These resins are now included in the 602 Standard Specifications and can be used by the Contractor in any CIPP site. The cured liner should also contain less than 0.1 percent of water quality pollutants (as listed in 6 NYCRR Parts 700-705). NYSDOT may determine and dictate that at certain areas of greater environmental concern (i.e. in the vicinity of class A, A-S, AA and AA-S water sources or at other locations presenting other needs) non-styrene based resins MUST be used. If the Department requires the use of only a designated resin type, the resin type requirements shall be clearly noted in the contract documents; otherwise, the Contractor may select the resin type from the resin approved list included in the CIPP Approved Installer’s Materials Procedure document, which is kept on file at the Main Office, Materials Bureau.
- In all CIPP installations utilizing a styrene based resin, it is required to collect the curing water for:
  - Reuse in another curing operation
  - Treatment or disposal at an off-site facility; or
  - Release on site after treatment to standards dictated by NYSDEC and with approvals from NYSDEC.

**Summarizing**, the resin type alternatives for CIPP work are to either use a non-styrene based resin or follow additional controls when using a styrene-based resin.

Areas of environmental concern may include, but are not limited to, wetlands, fishing streams and ponds, upstream of public water sources, densely populated urban areas where residents
are concerned about the short lasting odor of the styrene during curing, etc. Waters classified as Class A are: a source of water supply for drinking, culinary or food processing purposes; primary and secondary contact recreation; and fishing (i.e. waters suitable for fish, shellfish, and wildlife propagation and survival). Although numerical standards are not listed for other classes of streams in 6NYCRR Part 703, the general requirements of Part 701 apply (i.e. discharge must not cause impairment of the best usages of the receiving water).

The designer shall determine the location of each installation in respect to environmental resources including the classes of streams/watercourses in the vicinity of the project. The regional environmental unit and/or “Environmental Viewer” (A GIS application currently available at the Office of the Environment Intradot site and under the manual / applications tab, subsection GIS Application) shall be consulted for stream classification and other relevant environmental information. For installations close to and presenting the potential for curing water releases to class A, A-S, AA and AA-S streams or releases of other concern, the requirement for using a non-styrene based resin should be considered.

If designers determine that a non-styrene based resin shall be used in a specific CIPP installation, then the relining project’s contract documents have to clearly and unambiguously specify that “a resin containing less than five percent volatile organic compounds (VOCs) with less than 0.1 percent hazardous air pollutants (HAPs) must be used”. It should also clearly state that “the cured liner should contain less than 0.1 percent of water quality pollutants (as listed in 6 NYCRR Parts 700-705)”. Use of these resins will result in a significant increase to the rehabilitation cost, approximately double to the materials cost of using regular styrene based resins in 2009 market prices. Therefore the decision to specify non-styrene based resins should not be made lightly and never prior to evaluating whether the use of styrene based resins combined with other alternative provisions to control the release of the curing water provide both enough site environmental protection and project cost savings. These provisions (listed now in the 602 Standard Specification) include but they should not be limited to: removal (pumping out) of the curing water at the end of the CIPP installation and transporting it to an appropriate disposal facility instead of free draining it at the outlet, providing for a resin catchment pit excavated right at the culvert’s outlet to create ideal conditions for the collection of the trace amounts of styrene, temperature control of the released curing water, as well as combinations of the above. Again, designer’s stipulations on environmental protection provisions should be clearly indicated on the plans as they may substantially impact the operational cost. These stipulations should be limited to the class of the neighboring stream or water course class which may be impacted by the release of the curing water, the need for utilizing a styrene or a non-styrene based resin, the maximum allowed release temperature of the curing water and the size of the resin catchment pit. It is recommended that the resin catchment pit dimensions are: 4 to 5 m long, twice the culvert diameter wide and 300 mm deep. If a rip-rap layer has been installed at the culvert outlet (potentially even in the stream bed), the proposed depth of the catchment pit will be equal to the thickness of the rip rap layer (it could even be over 300 mm deep) and as indicated on the record plans. If the natural bedrock is encountered near the culvert invert elevation, the catchment pit bottom elevation must be just (at least) below the culvert invert, so that the CIPP installer is
able to create the proposed temporary catchment pit. CIPP installers will decide as to the
catchment pit lining, as they are responsible for preventing the liner curing process byproducts
and waste from reaching the surrounding ground and percolate / leach into the groundwater.
The excavation, temporary storage of the fill and restoration of the downstream channel will be
paid for under pay item 206.04 Trench and Culvert Excavation –O.G.

The majority of the environmental controls in any CIPP project are dictated by the written
agreement (Materials Procedure) between the Approved List manufacturer / installer and the
Materials Bureau. If designers have any concerns about using the CIPP relining item at a
specific location, especially when styrene based resins are employed, they should first consult
with the Materials Bureau.

Current designs address fill heights up to a maximum of 15 m. If the fill height over the CIPP
installation exceeds 15 m at any point along the culvert alignment, contact the Materials
Bureau to coordinate an evaluation of the proposed CIPP liner design.

8.6.7.6.B.3  Lining with Polyvinyl Chloride Pipe

The 602 relining specification also allows the contractor to use PVC pipe meeting ASTM
F1803, ASTM F949, and two new standards, ASTM F679 or ASTM D3034 (small diameters
300 or 375 mm) as relining material. PVC pipe is currently available in diameters ranging from
300 through 900 mm on the current Approved List. Please always consult the Approved List
for the addition of new manufacturers and/or products as well as for the currently approved
sizes for each PVC material. PVC lining pipes are corrosion and abrasive resistant. A
Manning's coefficient value of 0.013 should be used for all hydraulic capacity calculations
related to PVC pipes.

Some PVC pipes are more brittle than other flexible relining materials. Therefore, designers
should determine prior to specifying it, that the condition and shape of the host culvert will
allow for an unobstructed insertion of the PVC lining pipe.

Since the 602 relining specification requires a minimum annular space of 25 mm for effective
grouting, the outside diameter of the liner pipe needs to be a minimum of 50 mm smaller than
the inside diameter of the existing (host) pipe when calculating the hydraulic capacity of the
new installation. Profile wall pipe (ASTM F949) is specified by the pipe's nominal inside
diameter while the respective outside diameters can be found in ASTM F949. ASTM F1803
lists only the nominal inside diameter of these respective materials, therefore designers must
consult with the pipe manufacturer to obtain the outside diameter information. Both ASTM
F949 and ASTM F1803 pipes possess joints that are flush with the outside diameter. However,
ASTM F679 and ASTM D3034 pipes do not have a joint flush with the outside diameter of the
pipe but rather a bell and spigot joint protruding from the outer pipe shell. Therefore, for
ASTM F679 & ASTM D3034 pipes, it is the outside diameter of the joint and not the
outside diameter of the pipe which dictates the maximum allowable liner diameter for a
particular application. Because of this confusion, the lack of readily available info for some
PVC pipes and in order to properly evaluate selected PVC pipe size compliance with the
minimum required annular space for effective grouting, designers are strongly encouraged to
consult with the Materials Bureau about the maximum outside dimension of any PVC pipe, if this information is not available to them.

The table below provides the allowable fill heights for each size of PVC liner pipe. If the fill height exceeds 15 m at any point along the pipe alignment, contact the Materials Bureau for approval of the proposed liner design. The anticipated service life of a PVC liner is 70 years.

<table>
<thead>
<tr>
<th>PVC Liner Diameter (mm)</th>
<th>300</th>
<th>375</th>
<th>450</th>
<th>525</th>
<th>600</th>
<th>750</th>
<th>900</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Allowable Cover (m$^1$)</td>
<td>15</td>
<td>14</td>
<td>10</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>8</td>
</tr>
</tbody>
</table>

*$^1$ Maximum vertical distance between the top of the pipe and the top of pavement.

8.6.7.6.B.4 Lining with Tunnel Liner Plate

In some closed drainage systems, space constraints may limit lining options which involve installing full lengths of pipe sections. In these cases, galvanized tunnel liner plate may be a viable option. Tunnel liner plate can be inserted and assembled within the host culvert as the laying length of individual sections is 450 mm. Galvanized Tunnel Liner Plate requires a PCC invert to provide the required service life and hydraulic performance.

Structural paving of the invert improves the hydraulic efficiency of the culvert and protects the tunnel liner bolt flanges from abrasion caused by bedload. When site conditions dictate that only tunnel liner plates can accommodate the structural demand of the culvert, but hydraulics analysis dictates that a low Manning material must be used, shotcreting the invert or HDPE lining is a valid solution. Consult the Materials Bureau for further guidance when such cases arise.

8.6.7.6.B.5 Lining with Polymer Coated Corrugated Steel Pipe (CSP)

If the rehabilitated pipe is anticipated to be subjected to potentially abrasive bed loads or to be exposed to high concentrations of industrial waste, the Polymer Coated CSP item is a suitable relining material for these conditions. The suggested Manning’s coefficient “n” value will range from 0.013 to 0.026, depending on the corrugation pattern selected. The recommended Manning coefficient “n” values for all drainage materials are provided in Section 8.6.3.1.

The height of fill tables provided in Appendix A shall be used to determine if the 12 gauge steel pipe meets the site’s height of fill requirements.

8.6.7.6.B.6 Lining with Steel Structural Plate Pipe or Pipe Arches with PCC Paved Invert

Steel structural plate can be partially or fully assembled and pushed or pulled into place within the pipe. This lining option should be considered for large diameters where other items are unavailable. If the plate sections are too large to be inserted into the host culvert
through the exposed ends, then an excavation and a field cut through the culvert roof would be required. Every effort should be made to ensure that the excavation and field cut are located where it will be the least disruptive to traffic.

Designers must clearly indicate in the plans how to pave the invert of the plate pipe or arch. The minimum extent of the invert paving will be the bottom 30 percent of the inside circumference for round pipes, the bottom 35 percent of the inside periphery for arch spans up to 3 m and the bottom 40 percent of the inside periphery for arch spans greater than 3 m.

If this paving coverage encompasses (with some margin of safety) at least 150 mm circumferentially beyond the limits of the culvert’s wetted perimeter for mean flow conditions, then this paving coverage will be sufficient. If it does not, then a greater percentage of coverage should be used. A minimum cover of 50 mm over the crests of the corrugation and the steel fabric reinforcement should also be noted on the plans.