Minnesota Pollution Control Agency

Polyvinyl Chloride Liner Guidelines

I. General

Scope

These guidelines describe the materials, installation, and testing of Polyvinyl Chloride (PVC) liners. These guidelines have been developed by the Minnesota Pollution Control Agency (MPCA) and are intended to service as recommended minimum requirements for the design, installation, and testing of PVC for containment applications and groundwater protection. These guidelines are not, however, intended to replace competent engineering documents and practices produced and undertaken by qualified and experienced engineering designers and inspectors. Specifications issued by the engineer that deviate from these guidelines may be allowed, however, justification for these changes will be required by the MPCA. The intended use of these guidelines is for applications involving municipal sewage and approved industrial wastes.

For synthetic liners, the MPCA only allows PVC and High Density Polyethylene (HDPE) liners for wastewater stabilization ponds. Clay-lined ponds are also allowed.

For more information on this please see the MPCA Recommended Pond Design Criteria at:
http://www.pca.state.mn.us/index.php/view-document.html?gid=11503.

These guidelines do not guarantee that the liner, when installed, will not fail during initial operation or at any time in the future. However, the information contained within should provide the engineer a firm basis for designing, specifying, and inspecting a PVC liner.

II. Materials/Handling

1. Liner materials should consist of PVC, manufacturing of new first quality raw materials. Recycling of manufactured PVC products and/or materials shall not occur. Additives may be used provided they do not interfere with the intended use of the product and are used according to the manufacturer's recommendation.

   The final product shall be suitably formulated for the intended use to meet full compliance with warranty conditions.

2. Liner material should be produced as single, homogenous sheets free of holes, blisters, roughness, striations, and contamination by foreign matter, undispersed raw materials, or any other defect which may cause the liner to deviate from the minimum material requirements. If such conditions are found to exist, the engineer has the option to reject the roll, or ask the material supplier to repair the defective area. Where excessive damage or a repeating pattern of damage to the liner has occurred, the engineer shall reject the roll.

   Flaws in the liner may indicate material and/or manufacturing problems, which may ultimately result in failure of the liner. The engineer should be cautious about accepting a liner that appears defective.

3. Liner material should be supplied as panels to the site or on containers designed to prevent handling damage. Labels on the packaging shall identify the thickness, length, width, date of manufacture, lot number, deployment directions and shall identify any additional information deemed necessary by the engineer or manufacturer.

   This basic information will allow the inspector to quickly check and verify that the correct material is being delivered.

4. Liner material stored on site should be protected to keep PVC sheeting clean and dry. Storage should minimize exposure to excessive heat or sunlight. The manufacturer should provide specific information regarding allowable exposure conditions.

   Dirt and wetness are two common causes for seam failures. Additional cleaning/drying should be required at the time of field seaming if the material is not kept clean and dry during storage.

5. Prior to delivery of the synthetic liner to the job site, manufacturer certified test results, showing that liner made from each new batch of raw material meets all specification requirements, should be supplied to the engineer. Additional random samples should be taken from liner rolls shipped to the site according to the following rate:
   - A minimum of three random samples or one random sample for every ten acres of lined surface, whichever is greater.

These samples should be tested by an independent testing laboratory for thickness, elongation, and tensile properties. Test results shall be reported to the engineer and contractor.

Certified test results from the manufacturer should show that all material properties are in conformance with the specifications.

Testing of random samples provides a check that shows if the material that was supposed to be supplied to the site is, in fact, being installed.

Payment of these tests should be determined by the engineer and included in the contract documents as appropriate.

6. Liner materials shall meet the following minimum requirements from ASTM Standard D7176*:

Property	ASTM Test Method	30 mil PVC
Thickness (mils)	D5199	30 ± 1.5
Tensile Properties (minimum)		
Strength at Break	D882	73 lb/in
Elongation		380 %
Modulus at 100%		30 lb/in
Tear Strength (min)	D1004	8 lb
Dimensional Stability (max change)	D1204	3%
Low Temperature Impact	D1790	-20°F
Specific Gravity (min)	D792	1.2
Water Extraction (max loss)	D1239	0.15%
Volatile Loss (max loss)	D1203	0.70%
Soil Burial (max change)	G160	
Break Strength		5%
Elongation		20%
Modulus at 100%		20%
Hydrostatic Resistance (min)	D751	100 psi
Minimum Average Molecular Weight	D2124	400

*ASTM Standard D7176, 2006, "Specification for Non-Reinforced Polyvinyl Chloride (PVC) Geomembranes used in Buried Applications, ASTM International, West Conshohocken, PA, 2006, DOI: 10.1520/D7176-06, http://www.astm.org.

7. Factory seams shall meet the following minimum requirements:

Property	Test Method	Value
Bonded Seam Strength (factory seam, breaking factor, ppi width)	ASTM D3083	55.2
Peel Adhesion (lbs/in. minimum)	ASTM D413	10
Resistance to Soil Burial (max % Change in original value)	ASTM D3083	
1. Peel adhesion		-20
2. Bonded Seam Strength		-20

III. Installation

A. General

Prior to placement of the liner, a preliner inspection must be performed by the MPCA. See Prefill and Water Balance Guidance for requirements (http://www.pca.state.mn.us/index.php/view-document.html?gid=11503.

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The intent of this section is to define the work and responsibilities related to the installation of PVC for containment applications and ground water protection. Liner installation includes, but it not limited to, preparation of the subgrade, placement and seaming of liner panels, sealing around all appurtenances, patching and repairs to the liner, seam and materials testing, covering of the liner and any other procedures necessary to attain proper installation of the liner.

1. With the bid, the contractor shall name the proposed manufacturer and fabricator of the PVC liner. At the time of shop drawing submittal, the contractor should provide a certification from the manufacturer stating that the subgrade preparation and cover material specifications will meet or exceed the requirements of the manufacturer, and will adequately protect the manufacturer's product from damage.

   It is desirable that the manufacturer states that the subgrade specifications meet their requirements so that they will not reject the site when it is ready for liner placement. Warranties should not be voided by the subgrade or cover materials.

2. At the time of shop drawing submittal, the liner manufacturer/contractor should furnish to the engineer a liner panel layout as required for liner installation.

   Liner layout should minimize the amount of seams located on the dikes running parallel to the dikes. All seams shall be accurately shown on the "as built" drawings.

   Horizontal seams on dike slopes are more likely to be in a stressed condition if unequal settlement occurs, which could lead to seam failure. Horizontal field seams should not be allowed or at least minimized. It is also suggested that transverse seams on the pond bottom should be staggered so they do not line up.

3. Subgrade should be inspected by the liner installer prior to placement of the liner. Upon completion of the workmanship and/or materials which are believed to not be in compliance with the project plans and specifications, or if subgrade is found to be adequate, issue a certification to that effect to the contractor. The contractor shall forward this certification to the owner/engineer. As noted previously, a preliner inspection by the MPCA is required prior to liner placement.

4. Liner installation must be performed under the direction of a full time experienced installer. Installer must possess the technical expertise and authority to direct and certify all work related to the installation of the liner. The installer should identify in writing substandard workmanship and/or materials to the engineer

   In the specifications the engineer shall identify the amount of experience the installer must have. Directing the installation of at least three similar jobs or posting a bond for inexperienced installers is considered minimal.

B. Subgrade

Any soil in contact with the liner must meet the following requirement:

The six inches of soil immediately beneath the liner shall be inorganic, free of all rocks, stones, sticks, and debris of any kind, with no particle larger than three-eighths inch diameter. Not more than 50 percent by weight of this material shall be between one-fourth and three-eighths inch diameter. Angular, sharp material is not allowed in the subgrade, regardless of diameter.

In addition, the underlying soils should be stable and relatively incompressible. Unsuitable underlying soil conditions should be corrected.

The determination of conformance to the subgrade requirement should be made by the engineer in consultation with a geotechnical firm during the preparation of plans and specifications. The engineer should select an appropriate type of subgrade to meet specific job requirements. The Minnesota Department of Transportation (MN/DOT) specification No. 3149 for fine filter aggregate is an acceptable subgrade/cover requirement.

The following are three examples of subgrades for installation of a synthetic liner:

1. If native soil at the liner elevation meets subgrade requirements, no additional work is needed except for compaction.
   a. Surfaces to be lined should be excavated to the elevation of the liner, and compacted to 95 percent of the standard proctor density.

      If there is any uncertainty about the acceptability of onsite native soils for direct contact with the liner, the engineer should consider a bid item for importing acceptable subgrade material. An estimate of the quantity of material needed and identification borrow sites, or other known sources of material should be included in the specifications.

If subgrade material is needed and has to be hauled to the pond site, the inclusion of the bid item will help avoid an unexpected cost increase for hauling subgrade material. If a sufficient quantity of acceptable native soil is on site, the imported material can be deducted from the contract.

2. If native soil at liner elevation does not meet subgrade requirements, replace top six inches of soil in areas to receive liner with soil that will meet subgrade requirements and compact.

   a. Surfaces to be lined must be excavated to a depth six inches below the elevation of the liner, and compacted to 95 percent of the standard proctor density.

   b. Six inches of fill material meeting the subgrade requirements must be backfilled in areas to be lined. This layer will also be compacted to 95 percent of the standard proctor density.

   c. Where excavation greater than six inches is required, as determined by the engineer or geotechnical firm, fill material must be placed according to the engineer or geotechnical firm's recommendation and compacted to 95 percent of the standard proctor density. The top six inches of this fill shall meet the subgrade requirements.

      If the engineer has determined that native soil will not meet subgrade requirements, then consideration should be given to bidding items two and three as alternatives. The haul distance and/or screening cost will influence where the breakeven point between the two alternatives is.

3. If native soil at liner elevation does not meet subgrade requirements, place a geotextile fabric above and below the liner to protect it from punctures. No additional work is needed except for compaction, and possibly, some rock removal.

   a. Surfaces to be lined will be excavated to the liner elevation, and compacted to 95 percent standard proctor density to provide a smooth flat surface. All rounded rocks protruding more than one inch, and all sharp protruding rocks must be removed.

   b. A nonwoven geotexile fabric must be installed at all locations to receive liner. The fabric shall be a minimum of 7 oz/sq yd or 200 gm/sq m. The liner shall be placed directly upon the fabric.

   c. Following the liner placement, a second layer of nonwoven geotextile fabric (min 7 oz/sq yd) must be placed above the liner. Soil cover material will be placed on the fabric containing rocks no larger than four inches in diameter.

      - Studies have shown that a seven oz/sq yd nonwoven geotextile fabric on both sides of a 30 mil liner is equivalent to about 100 mil liner in respect to puncture resistance. REF: Third International Conference on Geotextiles, 1986, Vienna, Austria.

Subgrade General Requirements:

1. The subgrade must be graded or rolled to provide a smooth flat surface for placing the liner to within (+,-) 0.2 feet. No abrupt changes in grade shall occur, such as vehicular ruts.

   Ruts force the liner to span the gap unless the liner perfectly conforms to the rut. When cover material is applied, the liner will stretch and may fail.

2. Liner must be sloped to avoid gas buildup below the liner. Consideration may also be given to providing a method of gas venting.

   The venting of air or other gases from under the liner is generally not necessary for a pond system with at least four feet of separation from the seasonal high water table and the liner. The bottom of a properly designed pond and the liner itself are sloped in the range of 0.5 to 2.5 percent from the center of the pond to the dikes to ensure that air cannot be trapped under the liner. If the ground water table is highly variable, or large areas of organic material are present, venting may be considered.

   All vent outlets must be at least 2 feet above the high water elevation. Surface vents shall be placed with the vent flap facing down slope so that no surface water runoff can enter the vent opening.

   Vent pipes or drain tile shall not be placed directly under the pond liner. If piping is used for vents, they shall be placed around the perimeter of the pond so that if a pipe failure were to occur, it will not compromise the liner integrity

3. During liner placing and seaming, the subgrade must be kept free of standing water. If subgrade below the liner becomes wet and unstable, it must be dried and re-compacted.

C. Placement

1. Liner panels should be laid out according to plans supplied by the manufacturer, and no deviation will be allowed except with approval of the engineer.
2. Only those panels that can be seamed that day will be deployed. All loose panels will be protected from wind lift.
3. Liner panels must be secured in an anchor trench, as determined by the engineer.

   Anchor trench size and location may be determined empirically or with design calculations. Anchor trench will vary depending on liner thickness, dike slope, etc. Design Calc. Ref. ***Designing with Geosynthetics***, Robert M. Koerner, 1986.
4. Liner panels shall be overlapping according to manufacturers' recommendation. Overlap distance must be sufficient so that all seam tests can be performed as stated in the various test procedures.

   Typical overlaps are three to six inches. There shall be no loose flap on the top side of the completed seam, resulting from the overlap, to avoid catching during covering.
5. At no time during liner placement shall any vehicle be allowed directly on the exposed liner.

   There is a high probability of liner damage regardless of the subgrade.
6. All workers, inspectors, and supervisors must wear soft-soled shoes.

D. Seaming

1. All seaming of PVC panels should be made according to the manufacturer's recommendations. Ambient temperatures for seaming should be in the range of 50 to 95°F. Seaming should not occur on wet or damp PVC bonding areas. In addition, interfaces should be cleaned of all dust and dirt.

   Any method is acceptable as long as it can consistently produce a seam that passes all seam tests. Liner materials stored over winter or for long periods of time may be difficult to bond. Consult the manufacturer for potential seaming difficulties.
2. The type of adhesive and method of application should be according to the manufacturer's recommendation.

   Paint rollers shall not be used as they cannot reach the "v" area formed by the last seamed area.
3. Following adhesive application, seams shall be closed immediately to prevent excessive solvent evaporation.

   A dull or cloudy adhesive film appearance, prior to closing the seam, may indicate a high rate of evaporation.
4. All solvent or cleaning agents should be stored away from PVC material to prevent degradation of the materials from spills. Any spills of solvent or cleaning agents on the liner should be wiped up immediately.
5. The final product seam should be capable of producing a continuous homogenous bond at every location, meeting seam strength requirements.

   Poorly constructed liner seams have a high potential of being a cause of liner failure.
4. Fish mouths are not allowed. A fish mouth is defined as an area in the seam where one liner panel is first folded over on itself and a second liner panel is placed and welded over this fold. Where fish mouths occur, the liner must be cut, overlapped and covered with a patch.

   Fish mouths that are not properly repaired will leak.

E. Patching/Repairs

1. All repairs shall be noted on the "as built" drawings.

   Proper documentation of repairs will make any follow-up work easier.
2. Patches and repairs on the liner should be made within 48 hours of discovery of the defect.

   Patches should be placed as soon as possible to avoid missing them.
3. Patches will be made from the same material as the liner and have a continuous rounded edge with indistinct corners. In addition, overlap distance and adhesives shall meet all previous seam requirements. A minimum overlap of three inches is recommended beyond the damaged area.

   Patches shall be rounded to avoid corners that could catch during covering and rip off.

F. Seam Testing

1. Seam Strength Requirements – All general welds, repair welds, and patches shall meet the following seam strength requirements.

   a. The bonded seam strength test will indicate seam strength and, if excessive damage to the liner has occurred during the seaming process. See the table on page 2 for testing requirements.

      Field seams should meet the minimum factory seam requirements as indicated on pages two and three.

   b. The peel adhesion test will indicate seam strength, and reflects the quality of the welds. See the table on page two for testing requirements.

2. Non-Destructive Testing

   a. Non-destructive tests should be performed by the contractor or engineer on all field and factory seams, patches, and repair bonds.

      Every weld is suspect when considering leaks.

   b. This test should be performed by using air lancing to find obvious un-bonded areas.

      This testing technique provides a quick and easy method of finding obvious bad seams that cannot be detected by eye. This test provides no indication of seam strength. Refer to ASTM D4437-84 for acceptable air lancing techniques.

   c. It is also recommended that vacuum box testing be performed on every inch of every field seam and patch.

      Vacuum box testing will locate pinholes in the liner seams. Seam intersections and “T” welds at dike toes are always likely locations for pinholes.

3. Destructive Testing

   a. Destructive testing of the liner should be performed on all field seams. Destructive testing may be done on all patches and repair bonds as required by the engineer.

      Destructive testing is the only way to get an indication of seam strength. Destructive tests done on scrap samples should not be allowed to fulfill this requirement, since they cannot be made under the same conditions as seams.

   b. A tensionmeter should be provided on the construction site during liner installation for the purpose of testing samples. Samples should be tested by the inspector as soon as the bond cures. The inspector should maintain a log of all sampling events. The log should include location, date, and time of the sampling events and include the outcome of all tests including numerical values. Upon completion of the liner installation, copy of this log should be forwarded to the owner.

      The tensionmeter should be supplied by whichever party the engineer deems appropriate and included in the contract documents.

   c. Samples for destructive testing should be cut by the contractor at locations identified by the inspector.

      Test samples shall be of sufficient size to fulfill the requirements of the intended testing procedure(s).

      - Independent testing laboratories may require different size samples to run seam tests. This should be checked beforehand.

   d. Upon removal of sample, a patch made from the same material as the liner should be placed over the hole and bonded to the liner.

   e. Samples should be taken at the following frequency:

1. One sample per 500 feet of seam or one sample per each seam length, whichever provides for the greatest number of samples. At least one of these samples per day should be divided in half with one half being tested with the onsite tensionmeter and the other being sent to an independent testing laboratory for testing of shear and peel strength.

   Sampling frequency will be increased by the engineer if seaming problems are being encountered.

   Checking field and lab tests will allow for a comparison of the accuracy of the onsite tensionmeter against the laboratory tests, lab tests are assumed to be more accurate.

2. Two samples per dike face should be tested by both the onsite tensionmeter and independent testing laboratory. Any remaining field sample should be labeled and saved until lab test results are received.
3. Additional samples shall be taken at any location as directed by the engineer.

   The most difficult areas to seam can be around structures, liner penetrations, and dike. Sampling and testing shall be done at the frequency which will ensure that good seams are being produced.

   f. Field samples should be tested for both shear and peel strength. Failure of either test should cause the weld to be rejected at this location.

   g. Upon rejection of the original sample, two new test samples should be removed and tested. These samples should be taken at a maximum of ten feet on each side of the original sample. Subsequent failure of these samples will cause the testing to move further down the seam until the extent of the faulty seam has been determined. All faulty seam areas should be bounded by two passing test samples.

   h. Faulty seams should be repaired by placing a patch over the entire faulty seam area and welded.

G. Cover

1. As a minimum, a uniform 12-inch layer of cover material should be placed on the liner. The party responsible for warranty coverage should verify, in writing, that installation techniques will not void the warranty.

   Cover material depth will be greater in the center of the pond due to the slope on the subgrade. This is a good location for haul roads if used.
2. The six inches of soil immediately on top of the liner shall be inorganic, free of all rocks, stones, sticks, and debris of any kind, with no particle larger than three-eighths inch diameter. Not more than 50 percent by weight of this material shall be between one-fourth and three-eighths inch diameter. Angular, sharp material is not allowed in the subgrade, regardless of diameter.
3. MN/DOT specification No. 3149 is acceptable for cover.
4. Placement of cover material should be done in such a manner as to preclude any damage to the liner.

   Sharp turning by equipment on the liner cover soil can cause damage to the liner. No equipment is allowed directly on the liner.
5. Upon completion of the covering operation, the cover material should be smoothed to the required elevation (+,-) 0.2 feet.
6. The PVC liner should be covered as soon as possible or at least within two weeks to minimize exposure to sunlight, wind, and animals.

IV. Boots

Effective seams and seals around pipes penetrating through the liner or around other structures are critical to preventing leaks. Pipe boots are frequently found to be the cause of leakage at ponds that do not pass the water balance test.

Boots around pipe penetrations should be of the same material and thickness as the specified liner. Manufacturer's recommendations for attaching the boot to the pipe and seaming the boot to the liner shall be followed. All pipe boots shall be appropriately sized to the dimensions of the pipe and fit snugly with no wrinkles or fishmouths. The liner under the boot must remain in contact with the subgrade surface.

When stainless steel pipe bands are used to clamp the boot to the pipe, the straps shall not be placed in direct contact with the pipe boot material. A neoprene gasket, or other material specified by the manufacturer shall be placed between the liner and pipe band.

V. Certification

Upon completion of the covering operation, the contractor will certify, in writing, to the owner that all materials, equipment and construction has been completed in conformance with the plans and specifications.

VI. Water Balance Test

After completion of the liner installation, and before any water may be added to the pond, a prefill inspection must be completed by the MPCA. If the completed construction passes inspection, authorization will be granted to begin filling the pond with enough water to perform a water balance test. Prefill inspections and water balance testing shall be in accordance with the MPCA's Prefill and Water Balance Criteria, which can be found at http://www.pca.state.mn.us/index.php/view-document.html?gid=15336.

VII. Warranty

Upon acceptance of the project, the owner should be provided with a liner system warranty and/or performance bond which cover all appropriate items that would cause the pond to leak beyond the 500 gal/acre/day leakage requirement, i.e. Rocks, abrasion, settlement, seaming, construction technique, ice, etc. This warranty or bond should be of sufficient dollar value to cover labor and materials to fully repair the liner and remedy the problem. This should include, but not limited to detection of the leak, removal and replacement of the riprap, geotextile fabric, cover material, liner, subgrade, etc. ***The terms of the warranty and length of coverage should be specified in the contract documents to assure comparable bids. Manufacturers typically provide prorated material warranties ranging from 1to 30 years depending on the specific application. Installation warranties are generally specified as one– to- five years in length.***

Bonding for the liner installation is at the discretion of the owner. The engineer should determine a specific dollar value for this bond sufficient to cover those items listed.