USDA United States Department of Agriculture

Natural Resources Conservation Service

WISCONSIN FIELD OFFICE TECHNICAL GUIDE
450 – 11 – TECHNICAL GUIDE
FOTG NOTICE WI-92

April 18, 2018

Purpose. Revisions to Wisconsin Conservation Practice Standards and Specifications.

Effective Date. This notice is effective upon receipt.

Explanation of Changes. The waste management standard update meetings held around the state following the release in October, and the first designs using the released standards pointed out a number of minor revisions and clarifications that were appropriate minor revisions. The NRCS National Technical Guide Committee is utilizing a date designation of "R" (e.g. 2017R) to a released standard where minor changes are made. The standards in this notice will have the designation of October 2017R.

Section IV: Conservation Practice Standards and Specifications:

Pond Sealing or Lining – Compacted Soil Treatment (Code 520) – Cleaned up formatting, English language use and punctuation issues. The following changes were also made:

General Criteria Applicable to All Soil Liners:

- Liner thickness – added "required by state regulation" to specific discharge bullet.

Additional Criteria for Waste Storage Facilities (WI CPS 313):

- Labeled columns in tables to help with design and documentations and communication. (e.g. Sub-liner design uses table 3 column A)

Additional Criteria for Compacted Soil Lined Clean Water Applications:

- Cleaned up confusion in additional criteria for soil disbursement and bentonite sections.

Pond Sealing or Lining – Concrete (Code 522) – Cleaned up formatting, English language use and punctuation issues. Criteria moved to the appropriate standard headings (e.g. additional criteria, etc.). The following changes were also made:

General Criteria Applicable to All Concrete Liners:

- Moved Table 1 to within the reduced seepage concrete section.
- Table 1 name now includes "for reduced seepage concrete with waterstop".
- Only two major types of joints are referenced in the standard "construction and control. (Definitions and drawing revisions will follow this reference).

Additional Criteria for Waste Storage Facilities (WI CPS 313):

- Labeled columns in tables to help with design and documentations and communication. (e.g. Sub-liner design uses table 2a column A)
- Labeled rows of table 2 and 3 - these are liner systems consisting of two components, concrete and soil liner component. Wording now consistent between standards.
- Table 3 now includes a drainage layer row.

DIST: Wisconsin Statewide

Sensitive Environmental Settings:

- Added "Evaluate the effects of outletting to perennial or intermittent waterways" to the paragraph on secondary liquid containment.
- Added "Pre-engineered structures may contain specific additional requirements which are included in the approval letters for the manufacturer, written by the SCE."

Pond Sealing or Lining – Geomembrane or Geosynthetic Clay Liner (Code 521) – Cleaned up formatting, English language use and punctuation issues. The following changes were also made:

Additional Criteria for Waste Storage Facilities:

- Labeled columns in tables to help with design and documentations and communication. (e.g. Subliner design uses table 3 column A)
- Labeled rows of table 5 and 6 – these are liner systems consisting of two components, Geo and soil liner component. Wording now consistent between standards.

References:

- Added AWMFH.

Waste Storage Facility (Code 313) – Cleaned up formatting, English language use and punctuation issues. The following changes were also made:

Site Assessment:

- Reduced the number of tests required for PI and P200 from 1 per 15,000 sq. ft. to 1 per 30,000 sq. ft.
- Reduced the number of test pits in the borrow area from 1 per 15,000 sq. ft. to 1 per 30,000 sq. ft.

Additional criteria for liquid waste storage impoundment:

- Embankment/liner construction in body of the standard instead of table 1. Specified construction dimensions.

Additional criteria for fabricated structures:

- Removed table 5, Waste Storage Structure Separation Distances
- Added language that makes it clear wall control joints with embedded waterstop spacing of 100 feet is not applicable to ACI-350 designs.

Definitions:

- Reworded Impoundments definition.
- Reworded "Perched Conditions" definition.

Page 21:

- Updated Figure 1.

Clay Liner (WCS 300) – Removed and updated references to the Jan 2014 version of 313, and ASTM references to the current published ASATM standards.

The following revisions have been posted on the Wisconsin eFOTG website:

Remove the following outdated Standards and Specifications from any printed copies of the WI FOTG:

- Index
- Pond Sealing or Lining – Compacted Soil Treatment (Code 520)
- Pond Sealing or Lining – Concrete (Code 522)
- Pond Sealing or Lining – Geomembrane or Geosynthetic Clay Liner (Code 521)
- Waste Storage Facility (Code 313)
- Clay Liner (WCS 300)

Add the following Standards and Specifications to any printed copies of the WI FOTG:

- Index
- Pond Sealing or Lining – Compacted Soil Treatment (Code 520)
- Pond Sealing or Lining – Concrete (Code 522)
- Pond Sealing or Lining – Geomembrane or Geosynthetic Clay Liner (Code 521)
- Waste Storage Facility (Code 313)
- Clay Liner (WCS 300)

A link to the Wisconsin FOTG is located on the NRCS website at:
https://www.nrcs.usda.gov/wps/portal/nrcs/main/wi/technical/cp/

ANGELA L. BIGGS
Wisconsin State Conservationist

Attachments

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NATURAL RESOURCES CONSERVATION SERVICE
CONSERVATION PRACTICE STANDARD

POND SEALING OR LINING – COMPACTED SOIL TREATMENT

CODE 520

(Ft.^{2})

DEFINITION

A liner for an impoundment constructed using compacted soil with or without soil amendments.

PURPOSE

This practice is installed to reduce seepage losses from impoundments constructed for water conservation and environmental protection.

CONDITIONS WHERE PRACTICE APPLIES

This practice applies where:

- In-place natural soils have excessive seepage rates, and
- An adequate quantity and type of soil suitable for constructing a compacted soil liner without amendments is available, or
- An adequate quantity and type of soil suitable for treatment with a soil dispersant or bentonite amendment is available for an amended soil liner.

CRITERIA

General Criteria Applicable to All Soil Liners

Design Seepage Requirements. Design a compacted soil liner for a waste storage impoundment to reduce specific discharge (unit seepage) to rates specified in the National Engineering Handbook (NEH), Part 651, Agricultural Waste Management Field Handbook (AWMFH), Chapter 10, Appendix 10D, or rates mandated in State regulations, if more restrictive. Lower specific discharge rates must be used if required by regulatory authorities, and may be used at the discretion of the designer even if no such lower limit exists. Tables 1 and 2 of this standard achieve the specific discharge requirements referenced in the AWMFH.

Laboratory testing of compacted soil liner material for a waste storage impoundment is required to document the specific discharge to meet the design seepage threshold.

Design a compacted soil liner for a clean water pond to reduce seepage to a rate that will allow the pond to function as intended.

Liner filter compatibility. Design a compacted soil liner that is filter-compatible with the subgrade on to which it is placed to prevent loss of the liner soil into larger openings in the subgrade material. NEH, Part 633, Chapter 26, Gradation Design of Sand and Gravel Filters, provides criteria on filter compatibility.

Liner Thickness. The minimum thickness of the finished compacted liner must be the greater of:

- The liner thickness required to achieve a specific discharge (unit seepage) design value required by State regulations, or
- A liner thickness required by State regulations, or
- The minimum liner thickness as shown in Table 1 (manure storage) or Table 4 (clean water)

Liner Construction. Use methods described in the AWMFH, Appendix 10D, for liner construction. Properly seal all penetrations through the liner (e.g. pipes)

Liner Protection. Protect the soil liner against damage caused by the effects of waste or water surface fluctuations, desiccation and cracking, wave action, rainfall during periods when the liner is exposed, water falling onto the liner from pipe outlets, agitation equipment, solids and sludge removal activity, animal activity, penetrations through the liner, and any other activity capable of causing physical damage to the liner.

A protective soil cover may be used to protect the soil liner from desiccation or erosion. The soil cover will be of a soil type, thickness, and density that is resistant to erosion and desiccation. Under severe conditions, a protective soil cover may not adequately protect the liner from desiccation. For example during long periods, of hot, low-humidity condition, a soil cover constructed with very high plasticity soils may experience damage. Under severe conditions, additional design measures such as installation of a geomembrane in conjunction with the soil cover may be required. The side slope liner thickness listed in Table 1 includes an additional two feet to act as a protective soil cover for desiccation (No additional measure is required). Additional erosion or agitation protection may still be needed based on the management assessment performed for waste storage facilities.

Side Slopes. The side slopes of the impoundment should be 3H (horizontal) to 1V (vertical) or flatter to facilitate compaction of soil on the slopes when the "bathtub" method of construction is used, as described in AWMFH, Appendix 10D. Slopes as steep as 2H to 1V can be considered if the "stair-step" method of construction as described in appendix 10D of the AWMFH is used.

Foundation. Evaluate the foundation for conditions such as karstic bedrock, joints, and other discontinuities of the underlying bedrock to determine the appropriateness for a compacted soil liner.

Additional Criteria for Waste Storage Facilities (WI CPS 313)

Tables 1 and 2 summarize the liner and separation distance requirements for waste storage facilities.

Determine the plasticity index (PI) in accordance with ASTM D4318 and the percent fines in accordance with ASTM D1140. Permeability shall be determined by ASTM D5084 from undisturbed samples of the compacted liner. Additional soil testing requirements are found in WI FOTG Construction Specification 300, Clay Liner.

All waste storage facilities shall also meet the requirements of Wisconsin NRCS Conservation Practice Standard (WI CPS) 313, Waste Storage Facility (WI CPS 313).

Use WI CPS 313 criteria to determine subsurface saturation and bedrock depth.

Table 1. Soil Liner Criteria for Waste Storage Facility Impoundments Note 1

Soil Liner	
Thickness, Bottom	As specified in Table 2
Thickness, Sides Note 2	≥ 5 feet
% Fines	≥ 50%
Plasticity Index	≥ 12
Permeability	≤ 1x10
WI FOTG Construction Specification	Spec 300
Sub-Liner	**See Table 3**
Separation Distances	
Wells Note 3	≥ 250 feet
Sinkholes or other Karst Features	≥ 400 feet
Subsurface Saturation	As specified in Table 2
Bedrock	As specified in Table 2
Liner Protection Required	
Agitation and Pumping Locations	Minimum 20 feet wide x 30 feet long x 4 inches thick concrete pad or sump in bottom and 20 feet wide ramp or a 16 feet wide ramp with 12 inches high curbs to the top of the facility.
Scraping and Other Mechanical Means of Removing Solids and Sand	Protect with hard surfacing designed for the expected conditions and loads, a minimum of 4 inches thick.

Note 1 This liner may be used to meet the requirements of Wisconsin Administrative Code, Chapter NR 213 (NR 213), with additional restrictions (e.g. soils investigations, separation distances, liner properties, maintenance requirements). See NR 213 and WI AWMFH 313 companion documents.

Note 2 Thickness measured perpendicular to slope.

Note 3 Community water system wells may require larger separation distances (see Wisconsin Administrative Code, Chapter NR 811 (NR 811)).

Table 2. Soil Liner Thickness (Bottom) and Separations for Waste Storage Facility Impoundments Note 1

Impoundment Depth Note 2	Liner Thickness (feet)	Separation to Subsurface Saturation (feet)
0 – 13	≥ 3.0	≥ 5.0
13.1 – 14	≥ 3.2	≥ 5.2
14.1 – 16	≥ 3.6	≥ 5.6
16.1 – 18	≥ 4.1	≥ 6.1
18.1 – 20	≥ 4.5	≥ 6.5
20.1 – 22	≥ 5.0	≥ 7.0
22.1 – 24	≥ 5.4	≥ 7.4
24.1 - 25	≥ 5.7	≥ 7.7

Note 1 Thickness is calculated based on a maximum permeability of $1x10^{-7}$ cm/sec.

Note 2 Depth is the distance from the bottom of the impoundment up to the maximum operating level (M.O.L.).

Sub-Liner Soils. Sub-liner soil requirements are listed in Table 3. These sub-liner soils can be placed or be in situ materials. There is no compaction requirement for in situ materials. Sub-liner soil is required under the footprint of all waste storage facilities. For structures, the sub-liner soil must be wrapped around to the top of the footing to provide continuous protection. For pre-engineered structures, requirements for sub-liner soil configurations are included in the approval letter for the manufacture, written by the SCE.

Sub-liner soil thickness is in addition to any liner thickness requirement.

Table 3. Sub-Liner Soil Requirements for Waste Storage Facility Impoundments

	Minimum Soil Requirements			
	A	B	C	D
% Fines	≥ 20%	≥ 20%	≥ 40%	Foundry Sand [Note 1]
Plasticity Index (PI)	≥ 7	—	≥ 12	—
Thickness (bottom and sides)	≥ 1.5 feet	≥ 2 feet	≥ 8 inches	≥ 1.5 feet
Compaction of Placed Material	WI Spec 204	WI Spec 204	WI Spec 300	WI Spec 204

[Note 1] The foundry sand must be ferrous foundry sand with only minimal concentrations of hazardous constituents, cores and other over-size materials crushed or removed, and at least 5% bentonite content. A site specific WDNR approval is required under Wisconsin Administrative Code, Chapter NR 538 (NR 538) that may specify greater separation distances and parameters not addressed by this standard. An NR 538 Category I or II ferrous foundry sand may be appropriate.

Additional Criteria for Compacted Soil Lined Clean Water Applications

Table 4 lists required liner thickness for clean water applications.

Table 4. Minimum Liner Thickness For Clean Water

Design Storage Depth (feet)	Liner Thickness (inches)
≤16	12
16.1–24	18
24.1–30	24

Additional Criteria for Soil Dispersant Treatment for Clean Water Applications

This liner treatment does not meet the requirements for a waste storage facility liner.

Dispersant Materials. The dispersant must be tetrasodium pyrophosphate (TSPP), sodium tripolyphosphate (STPP), or soda ash unless laboratory tests using other dispersant types are used in the design.

Application Rate. Laboratory permeability tests may be conducted using a dispersant of the same quality and fineness as that proposed for use. To meet the liner design threshold, use the application rate and the number and thickness of compacted soil lifts specified in the geotechnical laboratory report. In the absence of laboratory tests or field performance data on soils similar to those to be treated, apply dispersant at a rate equal to or greater than the amount listed in Table 5. Install the liner with a maximum 6-inch-lift thickness.

Safety. During dispersant handling, application and mixing, personnel on-site must wear masks and goggles for protection against dispersant dust.

Table 5. Minimum Dispersant Application Rates for Clean Water Ponds

Dispersant Type	Minimum Application Rate per 6-inch lift thickness (pounds/100 square feet)
Polyphosphate (TSPP, STPP)	7.5
Soda Ash	15

Additional Criteria for Bentonite Treatment for Clean Water Applications

This liner treatment does not meet the requirements for a waste storage facility liner.

Bentonite Material. The bentonite must be a sodium bentonite with a free swell of at least 22 milliliters as measured by ASTM Standard Test Method D5890, unless laboratory tests using other bentonite types are used for design.

Application Rate. Laboratory permeability tests may be conducted using a bentonite of the same quality and fineness as that proposed for use. To meet the liner design threshold, use the application rate and the number and thickness of compacted soil lifts specified in the geotechnical laboratory report. In the absence of laboratory tests or field performance data on soils similar to those to be treated, apply bentonite at a rate equal to or greater than the amount listed in Table 6. Install the liner with a maximum 6-inch-lift thickness.

Table 6. Minimum Bentonite Application Rates for Clean Water Ponds

Pervious Soil Description	Minimum Application Rate (pounds/square foot) per 1-inch lift thickness
Silts (ML, CL-ML)	0.375
Silty Sands (SM, SC-SM, SP-SM)	0.5
Clean Sand (SP, SW)	0.625

Safety. During bentonite handling, application and mixing, personnel on site must wear masks and goggles for protection against bentonite dust.

CONSIDERATIONS

Consider maintenance access safety and slope stability when selecting inside side slopes for design.

Consider using a composite liner system, including a geomembrane and/or geosynthetic clay liner (GCL) for sites that have liquid depths greater than 24 feet.

Consider installing a 12-inch protective soil cover over the compacted soil liner.

In areas where the liner can potentially be damaged or scoured by agitation, pumping, or other equipment access, consider installing a concrete pad over the liner.

PLANS AND SPECIFICATIONS

Prepare plans and specifications for a compacted soil liner for a pond or a waste storage impoundment that describe the requirements for applying the practice to achieve its intended purpose. As a minimum, include:

- Soils investigation, including subgrade.
- Soil amendment requirements, as needed.
- Quantities of soil liner material and soil cover material, as needed.
- Quantity and gradation of filter material, as needed.
- Compaction requirements.
- Supplemental practices, such as geomembrane, as needed.
- Construction and material specifications.
- Safety requirements.
- Applicable Wisconsin Construction Specifications

OPERATION AND MAINTENANCE

Maintenance activities required for this practice consist of those operations necessary to prevent and/or repair damage to the compacted soil liner. This includes, but is not limited to:

- Excluding animals and equipment from the treated area.
- Repairing damage to the liner; restoring the liner to its original thickness and condition.
- Removing roots from trees and large shrubs at first appearance.

REFERENCES

USDA Natural Resources Conservation Service. 2012. Agricultural Waste Management Field Handbook (AWMFH). USDA-NRCS, Washington, D.C.

National Engineering Handbook, Part 633, Chapter 26 – Gradation Design of Sand and Gravel Filters.

DEFINITIONS

Bedrock – The solid or consolidated rock formation typically underlying loose surficial material such as soil, alluvium or glacial drift. Bedrock includes but is not limited to limestone, dolomite, sandstone, shale and igneous and metamorphic rock.

Note: Although solid or consolidated bedrock can sometimes be removed with typical excavation equipment, these materials are included in the above definition.

Clean Water – Water that has not been mixed with manure, wastewater or other contaminants.

Geomembrane – Very low permeability synthetic membrane liner or barrier used with any geotechnical engineering related material so as to control fluid migration in a man-made project, structure or system (ASTM D 4439).

Geosynthetic Clay Liner (GCL) – A manufactured hydraulic barrier consisting of clay bonded to a layer or layers of geosynthetic materials.

Karst features – Refers to areas of land underlain by carbonate bedrock (limestone or dolomite). Typical land features in karst areas include sinkholes, network of interconnected fissures, fractures, disappearing streams, closed depressions, blind valleys, caves, and springs. See the companion document in Chapter 10 of the AWMFH for additional discussion of karst features.

Leachate – Concentrated liquid waste which has percolated through or drained by gravity from a pile of manure, manure processing derivative, or animal feed. It contains much higher concentrations of contaminants than Contaminated Runoff.

Percent Fines (% Fines) – Percentage of given sample of soil which passes through a #200 sieve.

Permeability – The coefficient of permeability (K) is a measure of the ability of soil to transmit liquids. It is used to compute the flow rate of liquid through a soil liner for specific conditions of soil thickness and fluid head (e.g., $1x10^{-7}$ cm/s).

Plasticity Index, PI – A soil property indicating moldability. Measured by ASTM D4318.

Sinkholes – Closed, usually circular depressions which form in karst areas. Sinkholes are formed by the downward migration of unconsolidated deposits into solutionally enlarged openings in the top of bedrock.

Structure – A waste storage facility consisting of constructed surfaces, tanks, or walls for the purpose of storing waste above or below the ground surface.

Sub-Liner Soil – The soil directly below the bottom of the liner. This may be placed or in situ material.

Wastewater – Milking center waste, flush water, leachate from feed holding areas, and similar waste materials generated at the animal production area.

NATURAL RESOURCES CONSERVATION SERVICE
CONSERVATION PRACTICE STANDARD

POND SEALING OR LINING – CONCRETE

CODE 522

(Ft.^{2})

DEFINITION

A liner for an impoundment constructed using reinforced or non-reinforced concrete.

PURPOSE

This practice is installed to reduce seepage losses from impoundments constructed for water conservation and environmental protection.

CONDITIONS WHERE PRACTICE APPLIES

This practice applies where:

- In-place natural soils have excessive seepage rates.
- Construction of a compacted soil liner is not feasible with available soils.
- Use of impoundment requires concrete both as a liner and a protective subgrade cover.

CRITERIA

General Criteria Applicable to All Concrete Liners

Select the concrete liner design for either ‘reduced seepage’ or ‘liquid tight’ criteria, depending on the site conditions and management needs.

Liquid Tight. Where liquid tightness is required to provide an additional level of protection for sensitive environmental settings (SES), geologic concerns, groundwater resources and risk factors as described in the Agricultural Waste Management Field Handbook (AWMFH), Chapter 10, building code requirements must be one of the following:

- Structural Engineering, NRCS National Engineering Manual (NEM) Part 536, Structural Engineering.
- Requirements for Environmental Concrete Structures, Slabs-on-Soil, American Concrete Institute (ACI) 350 Appendix H.

Reduced Seepage. Where liquid tightness is not required, building code requirements must be one of the following:

- ACI 318, Building Code Requirements for Reinforced Concrete
- ACI 330R, Guide for the Design and Construction of Concrete Parking Lots
- ACI 360R, Guide to Design of Slabs-on-Ground
- Concrete Floors on Ground, Chapter 5, Portland Cement Association (PCA)

Include temperature and shrinkage reinforcing steel equal to or greater than shown in Table 1 in floors and slabs.

Table 1. Reinforcing Steel Size (Grade 60) and Spacing for Temperature and Shrinkage Control for Reduced Seepage Concrete with Waterstop

Concrete Thickness	Spacing Between Control Joints			
	< 100 feet	< 125 feet	< 150 feet	< 175 feet
≤ 5"	#4 @ 18"	#4 @ 15"	#4 @ 15"	#5 @ 18"
< 6"	#4 @ 18"	#4 @ 12"	#5 @ 18"	#5 @ 15"
< 7"	#4 @ 15"	#5 @ 18"	#5 @ 15"	#5 @ 12"
< 8"	#5 @ 18"	#5 @ 15"	#5 @ 15"	#5 @ 12"

Joints. Design construction joints and control joints to meet the appropriate ACI code specified above.

Side Slopes. Design side slopes of the pond or impoundment to be stable during construction. Design liners to withstand all anticipated internal and external loads, and resist agitation scouring, as specified in Table 2 or 3. Proportion the concrete mixture for a sufficiently stiff mix that can be installed on the slope without slumping or bulging.

Foundation and Liner Protection. Design floors and slabs used as a liner for anticipated loads including crack control and joint treatments stated below. Penetrations through the liner, such as pipes, must be properly sealed. Design slabs on ground that will be subject to heavy truck or heavy equipment loads in accordance with ACI 360R, Guide to Design of Slabs-on-Ground, Concrete Floors on Ground, Chapter 5, Portland Cement Association (PCA), or ACI 330R, Guide for the Design and Construction of Concrete Parking Lots.

- Concrete with waterstop – Include distributed reinforcing steel within the concrete, and include embedded waterstop in all joints in accordance with Wisconsin FOTG Construction Specification 004-WS, Waterstop.

  Place steel in the top ½ of the slab thickness with a minimum clear distance from the top of the slab of 1.5 inches.

- Include a waterstop joint plan in the construction plans and include the following: location of joints; cross- section details of joint(s); waterstop materials including factory fabricated corners, intersections, and transitions; and installation specifications.
- Plan additional waterstop control joints where stresses can be predicted to exceed the reinforcing steel's ability to restrain cracking and minimize leakage.
- All waterstop joints in areas subject to equipment traffic shall be designed with a dowel system to transfer the load across the joint. Slab thickness changes at these joints shall be made with a minimum transition ratio of one inch of thickness change over ten inches of run (10:1).
- Concrete used as part of a liner is required to meet WI Construction Specification 4 Concrete.

Additional Criteria for Waste Storage Facilities (WI CPS 313).

For waste storage facilities, design foundation conditions for concrete liners in accordance with Tables 2 and 3. All waste storage facilities shall also meet the requirements of WI CPS Waste Storage Facility (WI CPS 313). Use WI CPS 313 criteria to determine subsurface saturation and bedrock depth.

Reduced seepage concrete soil composite (Table 2) – Determine the plasticity index (PI) in accordance with ASTM D4318 and the percent fines in accordance with ASTM D1140. Place the concrete in intimate contact with the foundation soil. Design floors and slabs to be a minimum of 5 inches thick with reinforcing consisting of #4 bars spaced at 18 inches on center each way. No control joints are required. Maintain continuous reinforcing steel through all construction joints. Drain tile and/or drain fill material may not be installed within the soil liner component of the composite liner.

Table 2. Concrete Liner System Criteria for Waste Storage Facility Structure Floors and Impoundments Note 1

	Reduced Seepage Concrete with Waterstop	Reduced Seepage Concrete - Soil Composite			
	A	B	C	D	E
Concrete Component	Design Requirement: ACI-318, ACI-330R, or ACI-360R				
Soil Component					
% Fines	N/A Concrete Component Only	20%	20%	40%	Foundry Sand Note 2
Plasticity Index (PI)		≥ 7	—	≥ 12	—
Thickness (bottom and sides)		≥ 1.5 feet	≥ 3 feet	≥ 8 inches	≥ 1.5 feet
Compaction of Placed Material		WI Spec 204	WI Spec 204	WI Spec 204	WI Spec 204
Sub-Liner Soils (Soil Directly Below Concrete or Soil Component)	See Table 2A for Options				
Separation Distances					
Sinkholes Or Other Karst Features					
Impoundment or Structure below ground	≥ 400 feet	≥ 400 feet	≥ 400 feet	≥ 400 feet	≥ 400 feet
Structure above ground	≥ 200 feet	≥ 200 feet	≥ 200 feet	≥ 200 feet	≥ 200 feet
Well Distance	≥ 100 feet	≥ 100 feet	≥ 100 feet	≥ 100 feet	≥ 100 feet
Subsurface Saturation	≥ 2.5 feet (1.5 feet for sump)	≥ 4.0 feet (3.0 feet for sump)	≥ 5.5 feet (4.5 feet for sump)	≥ 3.5 feet (2.5 feet for sump)	≥ 4.0 feet (3.0 feet for sump)
Bedrock	≥ 2.5 feet (1.5 feet for sump)	≥ 4.0 feet (3.0 feet for sump)	≥ 5.5 feet (4.5 feet for sump)	≥ 3.5 feet (2.5 feet for sump)	≥ 4.0 feet (3.0 feet for sump)
Impoundment					
Inside Side Slopes	2.5:1 or flatter	2:1 or flatter			

Note 1 This liner may be used to meet the requirements of Wisconsin Administrative Code, Chapter NR 213 (NR 213), with additional restrictions (e.g. soils investigations, separation distances, liner properties, maintenance requirements). See NR 213 and WI AWMFH 313 companion document.

Note 2 The foundry sand must be ferrous foundry sand with only minimal concentrations of hazardous constituents, cores and other over-size materials crushed or removed, and at least 5% bentonite content. A site specific WDNR approval is required under NR 538 that may specify greater separation distances and parameters not addressed by this standard. An NR 538 Category I or II ferrous foundry sand may be appropriate.

Sub-Liner Soils. Sub-liner soil requirements are listed in Table 2A. These sub-liner soils can be placed or in situ materials. There is no compaction requirement for in situ materials. Sub-liner soil, if required, must be under the entire footprint of all waste storage facilities. For structures, the sub-liner soil must be wrapped around to the top of the footing to provide continuous protection. For pre-engineered structures, requirements for sub-liner soil configurations are included in the approval letter for the manufacture, written by the SCE. Determine the PI in accordance with ASTM D4318 and the percent fines in accordance with ASTM D1140.

Sand or gravel is allowed between the concrete with waterstop liner or structure and the sub-liner soil. The sub-liner soil thickness must be present below the sand or gravel.

Sub-liner soil thickness is in addition to any concrete or concrete-soil composite thickness requirement.

Table 2A. Sub-Liner Soil Requirements for Waste Storage Facility Impoundments

	Minimum Soil Requirements			
	A	**B**	**C**	**D**
% Fines	≥ 20%	≥ 20%	≥ 40%	Foundry Sand [Note 1]
Plasticity Index (PI)	≥ 7	—	≥ 12	—
Thickness (bottom and sides)	≥ 1.5 feet	≥ 2 feet	≥ 8 inches	≥ 1.5 feet
Compaction of Placed Material	WI Spec 204	WI Spec 204	WI Spec 300	WI Spec 204

[Note 1] The foundry sand must be ferrous foundry sand with only minimal concentrations of hazardous constituents, cores and other over-size materials crushed or removed, and at least 5% bentonite content. A site specific WDNR approval is required under NR 538 that may specify greater separation distances and parameters not addressed by this standard. An NR 538 Category I or II ferrous foundry sand may be appropriate.

Sensitive Environmental Settings. Table 3 contains the criteria for constructing liquid waste storage facilities in Wisconsin's sensitive environmental settings, as defined in WI CPS 313. Determine the PI in accordance with ASTM D4318 and the percent fines in accordance with ASTM D1140.

Design the storage facility as a reinforced concrete hydraulic or environmental structure according to NRCS NEM, Part 536, Structural Design with liquid tight concrete. (Concrete with waterstop ACI 350 or 350 Appendix H)

Alternatively, construct a facility with reduced seepage concrete and secondary liquid containment. Three components must be present for this system, a concrete liner, a drainage layer, and a secondary liquid containment liner. Design the concrete liner to meet the reduced seepage liner requirements contained within this standard. The drainage layer will consist of a minimum of twelve (12) inches of clean stone, with a drainage system that enters into an observation and pumping port with gravity outlet discharging to the surface. This port must be monitored for discharge for flow depth and pollutants. If pollutants are identified, the gravity outlet must be blocked and the port pumped until the source is identified and repairs can be completed. Evaluate the effects of outletting to perennial or intermittent waterways.

Pre-engineered structures may contain specific additional requirements which are included in the approval letters for the manufacture, written by the SCE.

Table 3. Structural Concrete and Concrete Liners with Secondary Liquid Containment System for Waste Storage Facilities in Sensitive Environmental Settings

	Liquid Tight Concrete with Waterstop	Reduced Seepage Concrete with waterstop PLUS Secondary Liquid Containment-Soil Liner	Reduced Seepage Concrete with waterstop PLUS Secondary Liquid Containment-Geomembrane Liner Note 2	Reduced Seepage Concrete with waterstop PLUS Secondary Liquid Containment-Foundry Sand Liner
	A	B	C	D
Concrete Component	ACI-350	Design Requirement: ACI-318, ACI-330R, or ACI-360R		
Drainage Layer	—	Drainage layer with a minimum of twelve (12) inches of clean stone between the concrete liner and the secondary liquid containment liner.		
Soils of the Secondary Liquid Containment				
Fines	—	40%	**No Soil Component or Sub-liner is required for secondary containment system**	Foundry sand
Plasticity Index (PI)	—	12		—
Thickness (bottom and sides)	—	1.5 feet		1.5 feet
Compaction of Placed Material	—	WI Spec 204		WI Spec 204
Separation Distances				
Sinkhole or other Karst Features	250 feet	250 feet	250 feet	250 feet
Well	100 feet	100 feet	100 feet	100 feet
Subsurface Saturation	2 feet	4 feet	3 feet	4 feet
Bedrock	1.5 feet	3 feet	2 feet	3 feet
Impoundment				
Inside Side Slopes	2.5:1 or flatter	2.5:1 or flatter	2.5:1 or flatter	2.5:1 or flatter

Note 1 Separation distance assumes a concrete thickness of 6 inches. Increase separation distance when slab thickness is greater than 6 inches by an equal amount.

Note 2 Design geomembrane secondary containment with the Design, Materials, Subgrade Preparation, Penetrations, and Cover Soil sections of WI NRCS CPS 521- Pond Sealing or Lining- Geomembrane or Geosynthetic Clay Liner (Additional Criteria for Waste Storage Facilities of CPS-521 does not apply)

Additional Criteria for Clean Water Applications

Liners for clean water applications shall be according to Table 2, Reduced Seepage Concrete with waterstop or Reduced Seepage Concrete - soil composite. No sub-liner soil is required.

Determine the plasticity index (PI) in accordance with ASTM D4318 and the percent fines in accordance with ASTM D1140. Place the concrete in intimate contact with the foundation soil. Design floors and slabs to be a minimum of 5 inches thick with reinforcing consisting of #4 bars spaced at 18 inches on center each way. No control or expansion joints are required. Maintain continuous reinforcing steel through all construction joints.

CONSIDERATIONS

Consider texturing concrete surfaces to provide traction for rubber-tired equipment. Texturing may not compromise the integrity of the liner.

PLANS AND SPECIFICATIONS

Prepare plans and specifications for a concrete liner for a pond or a waste storage impoundment that describe the requirements for applying the practice to achieve its intended purpose. As a minimum, include:

- Soils investigation, including subgrade.
- Concrete and reinforcing requirements.
- Quantities of concrete and reinforcement as specified.
- Subgrade preparation, materials and compaction.
- Construction and material specifications.
- Safety requirements.
- Applicable Wisconsin Construction Specifications

OPERATION AND MAINTENANCE

Maintenance activities required for this practice consist of those operations necessary to prevent and/or repair damage to the concrete liner. This includes, but is not limited to:

- Visually inspecting liner annually.
- Excluding animals.
- Repairing damage to concrete liner, as necessary. Repairing liner to its original condition.
- Preventing damage from roots of tree and large shrubs by removing such vegetation at first appearance.
- Preventing and/or repairing rodent damage to concrete subgrade.

REFERENCES

American Concrete Institute (ACI), Farmington Hills, MI

ACI 318, Building Code Requirements for Reinforced Concrete

ACI 330R, Guide for the Design and Construction of Concrete Parking Lots

ACI 350, Appendix H, Requirements for Environmental Concrete Structures, Slab-on-Soil

ACI 360, Design of Slabs on Grade

DEFINITIONS

Bedrock – The solid or consolidated rock formation typically underlying loose surficial material such as soil, alluvium or glacial drift. Bedrock includes but is not limited to limestone, dolomite, sandstone, shale and igneous and metamorphic rock. Although solid or consolidated bedrock can sometimes be removed with typical excavation equipment, these materials are included in this definition of bedrock.

Construction Joints – These joints are used where a fresh pour of concrete abuts an existing recent pour. Construction joints where the steel is continuous through the joint are considered to be monolithic if constructed properly.

Control Joints – Control joints are used to control the location of cracks caused by concrete shrinkage during setting and thermal changes. Steel reinforcement is interrupted in control joints with embedded waterstop. (Includes expansion, construction, and isolation joints.)

Environmental Structure – Any structure intended for conveying, storing, or treating water, wastewater, or other liquids and nonhazardous materials, such as solid waste, and for secondary containment of hazardous liquids or solid waste and designed to be liquid-tight, with minimal leakage under normal service conditions.

Expansion Joints (Expansion or contraction joints) – These joints are used to prevent crushing of abutting concrete or other structural units due to compressive forces developed during expansion caused by high temperature.

Hydraulic structure – Any structure subjected to hydrostatic or hydrodynamic pressures, either externally or internally.

Impoundment – A waste storage facility constructed of earthen embankments and/or excavations for the purpose of storing waste. An impoundment may be lined or unlined.

Intimate Contact – Direct contact between liner materials (concrete, GCL, and geomembrane) and soil.

Isolation Joint – Joint installed to separate one section of concrete from another. Isolation joints prevent transfer of loading from one section to another, and allow movement to occur between a concrete slab and adjoining columns or walls. They also separate new concrete from existing or adjacent construction which might expand, contract, or settle at different rates.

Karst features – Refers to areas of land underlain by carbonate bedrock (limestone or dolomite). Typical land features in karst areas include sinkholes, network of interconnected fissures, fractures, disappearing streams, closed depressions, blind valleys, caves, and springs. See the companion document in Chapter 10 of the AWMFH for additional discussion of karst features.

Sinkholes – Closed, usually circular depressions which form in karst areas. Sinkholes are formed by the downward migration of unconsolidated deposits into solutionally enlarged openings in the top of bedrock.

Structure – A waste storage facility consisting of constructed surfaces, tanks, or walls for the purpose of storing waste above or below the ground surface. Structures may be constructed of concrete, steel, wood or other construction materials.

Sub-Liner Soil – The soil directly below the bottom of the liner. This may be placed or in situ material.

NATURAL RESOURCES CONSERVATION SERVICE
CONSERVATION PRACTICE STANDARD

POND SEALING OR LINING – GEOMEMBRANE OR GEOSYNTHETIC CLAY LINER

CODE 521

(Ft.^{2})

DEFINITION

A liner for an impoundment constructed using a geomembrane or a geosynthetic clay material.

PURPOSE

This practice is applied to:

- Reduce seepage losses from an impoundment for water conservation.
- Protect soil and water from contaminants.

CONDITIONS WHERE PRACTICE APPLIES

This practice applies where in-place natural soils have excessive seepage rates.

CRITERIA

General Criteria Applicable to all Purposes

Design. The facility to be lined must meet all applicable NRCS standards. All inlets, outlets, ramps, and other appurtenances may be installed before, during, or after the liner placement, but must be done in a manner that does not damage or impair the proper operation of the liner.

Design and install the liner in accordance with manufacturer's recommendations and applicable specifications, found in Tables 3 and 4.

Follow manufacturer's recommendations with regard to protection from weather and ultraviolet exposure.

Design liners to withstand all anticipated internal and external loads, and resist agitation scouring.

Materials. Geomembrane and geosynthetic clay liner (GCL) materials must meet the requirements in Tables 1 – 4.

Safety. Include appropriate safety features in the design to minimize the hazards of the completed pond facility. Use warning signs, fences, ladders, ropes, bars, rails, and other devices, as appropriate, to ensure the safety of humans, wildlife, and livestock.

Underliner Drainage and Venting. Design the drainage and venting system beneath the geomembrane liner based on subsurface conditions such as soil type and groundwater levels. Liners used for waste storage require venting at the top of slope. For clean water applications, incorporate a drainage and venting system when conditions exist that may result in floating of the geomembrane liner. Ponds with an underliner drainage system must have a bottom slope of at least 1 percent.

Do not install a drainage layer or venting system beneath a GCL, as they could compromise the liner.

Table 1. Minimum Geomembrane Thickness Criteria

Type	Name	Minimum Thickness	
		Manure & Wastewater	Clean Water
HDPE	High Density Polyethylene	60 mil [Note 1]	30 mil
LLDPE	Linear Low Density Polyethylene	60 mil	30 mil
LLDPE-R	Reinforced Linear Low Density Polyethylene	Not Applicable	24 mil
PVC	Polyvinyl Chloride	Not Applicable	30 mil
EPDM	Ethylene Propylene Diene Terpolymer	60 mil	45 mil
FPP	Flexible Polypropylene	Not Applicable	30 mil
FPP-R	Reinforced Flexible Polypropylene	Not Applicable	24 mil
PE-R	Reinforced, Slit – Film, Woven Polyethylene	Not Applicable	24 mil

[Note 1] 1 mil = 1/1000 of an inch

Table 2. Minimum Bentonite Content for Geosynthetic Clay Liners

Type	Minimum Bentonite Content	
	Manure & Wastewater	Clean Water
GCL	0.75	

Table 3. Reference Specifications for Geomembranes

Type	Applicable Specification
HDPE	WI FOTG Construction Specification 202, Polyethylene Geomembrane Lining
LLDPE	WI FOTG Construction Specification 202, Polyethylene Geomembrane Lining
LLDPE-R	NRCS Material Specification 594, Geomembrane Liner
PVC	NRCS Material Specification 594, Geomembrane Liner
EPDM	WI FOTG Construction Specification 205, Ethyl Propylene Diene Monomer (EPDM) Geomembrane Lining
FPP	NRCS Material Specification 594, Geomembrane Liner
FPP-R	NRCS Material Specification 594, Geomembrane Liner
PE-R	NRCS Material Specification 594, Geomembrane Liner

Table 4. Reference Specifications for Geosynthetic Clay Liners

Reference Specifications for Geosynthetic Clay Liners	
Type	**Applicable Specification**
GCL	WI FOTG Construction Specification 203, Geosynthetic Clay Liner

Groundwater and Leakage Drainage. If a soil investigation indicates that the groundwater level may be near the invert elevation of the pond, install groundwater monitoring wells to verify the expected water table location. Use NRCS Conservation Practice Standard (CPS) Monitoring Well (CPS 353). In some situations, monitoring wells may need to be installed for a year or more to determine the groundwater levels and gather enough information to properly determine the required flow capacity of the drainage system. If the monitoring wells indicate a seasonal high water table within 2 feet of the pond bottom, install subsurface or other type of drainage to control the potential uplift pressures.

Gas Venting. All pond liners with anchor trenches require venting near the top of the side slopes. Design and install venting in accordance with the manufacturer's recommendations, with a spacing not to exceed 20 feet between vents. Investigate the need for additional venting beneath wastewater pond liners as part of the design. If the investigation determines the potential of gas buildup under the liner, the liner must be vented in accordance to the manufacturer's recommendations. Site conditions conducive to gas production include sites which have been subject to long-term seepage of animal waste into the foundation soil, sites with naturally occurring organics in the soil, or fine-grained foundation soils where fluctuating groundwater levels may trap gases present in the soil. If site conditions are determined to be conducive to gas production, the bottom of the liner must include features to allow gas to flow along the bottom and up the side slopes to the liner vents in the crown.

Subgrade Preparation. Prepare the subgrade to conform to manufacturer's recommendations. The subgrade materials must be free from sharp, angular stones, and the surface free from oversized particles, or any objects that could damage the liner. The subgrade surface must provide a smooth, flat, and unyielding foundation for the liner. Do not use sub-liner soil that contains sharp, angular stones or any objects that could damage the liner. No standing water, mud, vegetation, snow, frozen subgrade, or excessive moisture may be present at the time of liner placement. The maximum allowable particle size of sub-liner soil is 3/8 inch for geomembrane liners and 1/2 inch for GCLs.

Liner protection. Protect liners from mechanical damage from all sources, including equipment access points and agitation operations. If pond management plans indicate locations where agitation operations may result in abrasion or other mechanical damage to the liner, provide protective measures. Measures to ensure the integrity of the liner include increasing the liner thickness above the minimum values listed in table 1 or providing protective ramps and aprons at agitation locations. For GCL liners, analyze the wastewater, subgrade soil, and cover soil to ensure that undesirable cation exchange (calcium and magnesium for sodium) will not occur in the GCL.

Anchorage. Anchor the liner to prevent uplift due to wind or slippage down the side slope, in accordance with manufacturer's recommendations.

Penetrations. Install penetrations through the liner in accordance with manufacturer's recommendations. Penetrations associated with waste storage must be watertight.

Cover Soil. PVC and GCL liners shall be covered with a minimum of 12 inches of soil, with an additional 12 inches on side slopes, unless protected from erosion for a total of 24 inches of soil measured perpendicular to the finished surface (see Table 6). Cover soil may be used on other liners but is not required unless essential for the proper performance, protection, and durability of the installation. Do not use cover soil that contains sharp, angular stones or any objects that could damage the liner. The maximum allowable particle size of soil cover material is 3/8 inch for geomembrane liners and 1/2 inch for GCLs. Use cover materials that are stable against slippage down the slope under all operational and exposure conditions, such as rapid drawdown or saturation by precipitation or snowmelt.

Place cover soil within 24 hours after placement of the liner to minimize the potential for damage from various sources, including precipitation, wind, and ultraviolet light exposure.

Cover soil for GCLs must provide uniform confinement pressure as recommended by the manufacturer.

Additional Criteria for Waste Storage Facilities.

Table 5 and 6 summarizes the liner and separation distance requirements for waste storage facilities. Table 7 describes sub-liner soil requirements. All waste storage facilities shall also meet the requirements of Wisconsin Conservation Practice Standard (WI CPS) Waste Storage Facility (WI CPS 313). Wisconsin Construction Specifications 202, 203, 204 and 205 contain construction requirements for geomembrane and geosynthetic clay liners. All designs must meet these requirements.

The geomembrane shall be installed with intimate contact to the soil below. Intimate contact does not exclude the use of trenches for gas venting or leak detection. The plasticity index (PI) shall be determined in accordance with ASTM D4318 and the percent fines in accordance with ASTM D1140.

Poured-in-place concrete slabs shall meet requirements of WI CPS Pond Sealing or Lining – Concrete (WI CPS 522), if the geomembrane will be joined to the concrete. All connections between the geomembrane and concrete shall be liquid tight and structurally sound.

Liner protection installation over the geomembrane shall be completed by methods that will maintain the integrity and performance of the liner. Liner protection placed on top of the geomembrane shall be structurally sound, but liquid-tightness is not required. Concrete liner protection poured on top of the geomembrane shall be separated from the geomembrane by a sacrificial layer of the same weight geomembrane and a cushioning layer of 10 oz/sy non-woven geotextile. The sacrificial layer shall not be welded to the geomembrane liner. Liner protection placed on slopes shall be designed with provisions to ensure stability.

Sand bedding may be used in conjunction with a geomembrane liner, but the design must include a method to remove sand from the waste stream before it enters the waste storage facility. Multiple liners may be installed to address the accumulation of sand in the waste storage facility.

Use WI CPS 313 criteria to determine subsurface saturation and bedrock depth.

Sub-Liner Soils. Sub-liner soil requirements are listed in Table 7. These sub-liner soils can be placed or in situ materials. There is no compaction requirement for in situ materials. Sub-liner soil is required under the footprint of all waste storage facilities. For structures, the sub-liner soil must be wrapped around to the top of the footing to provide continuous protection. For pre-engineered structures, requirements for sub-liner soil configurations are included in the approval letter for the manufacture, written by the SCE.

Sub-liner soil thickness is in addition to any soil liner or soil cover requirement.

Table 5. Geomembrane Liner System Criteria for Waste Storage Facility Impoundments Note 1

Liner Material		
Geomembrane Component	See Table 1	
Soil Component		
% Fines	≥ 40%	≥ 40%
Plasticity Index (PI)	≥ 7	—
Thickness	≥ 2 feet	≥ 4 feet
Compaction of Placed Material	WI FOTG Construction Specification 204, Earthfill for Waste Storage Facilities	
Subgrade preparation requirements	WI FOTG Construction Specification 202, Polyethylene Geomembrane Lining and 205, Ethyl Propylene Diene Monomer (EPDM) Geomembrane Lining	
Sub-Liner Soil (Soil Directly Below Soil Component)		**See Table 7**
Separation Distances		
Well Distance Note 2	≥ 250 feet	≥ 250 feet
Sinkholes or Other Karst Features	≥ 400 feet	≥ 400 feet
Subsurface Saturation	≥ 4 feet	≥ 6 feet
Bedrock	≥ 4 feet	≥ 6 feet
Impoundment		
Inside Slope	2.5:1 or flatter.	
Other		
Liner Protection Required	Agitation and pumping locations	Minimum dimension of 20 feet wide x 30 feet long x 4 inches thick concrete pad or sump in bottom and 20 feet wide ramp with 18-inch curb to the top of the facility with provisions for liner integrity. Ramps shall be located to be accessible to the agitation equipment used.
	Scraping and other mechanical means of removing solids and sand	Protect with hard surfacing designed for the expected conditions and loads.
Vent system	Required for all facilities. The system shall be designed in such a manner to vent gas from the system. Waste and runoff shall be prevented from entering the venting system. Liquid detection points may be installed as part of the system.	
Liner Installation	WI FOTG Construction Specification 202, Polyethylene Geomembrane Lining and 205, Ethyl Propylene Diene Monomer (EPDM) Geomembrane Lining	

Note 1 This liner may be used to meet the requirements of Wisconsin Administrative Code, Chapter NR 213 (NR 213), with additional restrictions (e.g. soils investigations, separation distances, liner properties, maintenance requirements). See NR 213 and WI AWMFH 313 companion document.

Note 2 Community water system wells may require larger separation distances (see Wisconsin Administrative Code, Chapter NR 811 (NR 811)).

Table 6. Geosynthetic Clay Liner (GCL) System Criteria for Waste Storage Facility Impoundments Note 1

Liner Material		
Geosynthetic Clay Liner Component	See Table 2 and 4. Non-woven needle punched. Manufacturer's specifications and WI FOTG Construction Specification 203, Geosynthetic Clay Liner.	
Soils Component		
% Fines	≥ 40%	≥ 40%
Plasticity Index (PI)	≥ 7	—
Thickness (from bottom and sides)	≥ 2 feet	≥ 4 feet
Compaction of placed material	WI FOTG Construction Specification 203, Geosynthetic Clay Liner	
Liner Cover Material Thickness		
Bottom	≥ 1 foot	≥ 1 foot
Side Slopes	≥ 2 feet	≥ 2 feet
Compaction of Placed Materials	WI FOTG Construction Specification 203, Geosynthetic Clay Liner	
Sub-Liner Soil (Soil Directly Below Soil Component)		**See Table 7**
Separation Distances		
Well Distance Note 2	≥ 250 feet	≥ 250 feet
Sinkholes or Other Karst Features	≥ 400 feet	≥ 400 feet
Subsurface Saturation	≥ 4 feet	≥ 6 feet
Bedrock	≥ 4 feet	≥ 6 feet
Impoundment		
Inside Slope Note 3	3:1 or flatter	
Other		
Liner Protection	Agitation and Pumping Locations	Minimum dimension of 20 feet wide x 30 feet long x 4 inches thick concrete pad or sump in bottom and 20 feet wide ramp or a 16 feet wide ramp with 18-inch high curb to top of facility. GCL continues under the concrete pad or sump. Poured in place concrete slabs shall meet requirements of WI CPS 522.
	Scraping and Other Mechanical Means of Removing Solids and Sand	Sand bedding may be used in conjunction with a geosynthetic clay liner, but the design must include a method to remove sand from the waste stream before the waste is stored in the liner or the liner must be protected to allow mechanical removal of the sand. Poured in place concrete slabs shall meet requirements of WI CPS 522.
Liner Installation	WI FOTG Construction Specification 203, Geosynthetic Clay Liner.	

Note 1 This liner may be used to meet the requirements of NR 213, with additional restrictions (e.g. soils investigations, separation distances, liner properties, maintenance requirements). See NR 213 and WI AWMFH 313 companion document.

Note 2 Community water system wells may require larger separation distances (see NR 811).

Note 3 The GCL and soil cover shall be stable at the designed side slope.

Table 7. Sub-Liner Soil Requirements for Waste Storage Facility Impoundments

	Minimum Soil Requirements			
	A	B	C	D
% Fines	≥ 20%	≥ 20%	≥ 40%	Foundry Sand [Note 1]
Plasticity Index (PI)	≥ 7	—	≥ 12	—
Thickness (bottom and sides)	≥ 1.5 feet	≥ 2 feet	≥ 8 inches	≥ 1.5 feet
Compaction of Placed Material	WI Spec 204	WI Spec 204	WI Spec 300	WI Spec 204

[Note 1] The foundry sand must be ferrous foundry sand with only minimal concentrations of hazardous constituents, cores and other over-size materials crushed or removed, and at least 5% bentonite content. A site specific WDNR approval is required under Wisconsin Administrative Code, Chapter NR 538 (NR 538) that may specify greater separation distances and parameters not addressed by this standard. An NR 538 Category I or II ferrous foundry sand may be appropriate.

CONSIDERATIONS

Designs for waste storage facilities should consider leakage through the liner due to liner damage. Giroud and Bonaparte (1989) recommends designing the drainage system based on a frequency of one hole (0.16 square-inch) per acre of surface area. Therefore, drainage and venting systems are strongly recommended for all waste storage facilities.

Minimize the number of penetrations through the liner for pond management appurtenances. Detail the trenching and backfilling of pipes to prevent charging of the underside of the liner with subsurface water.

For HDPE liners associated with waste water with penetrations over 2 inches in diameter, consider using concrete pads matching the slope with embedded channels to connect the liner, instead of manufactured boots.

PVC geomembranes are not recommended for aquatic production. The stabilizers in the PVC liner material leach out and may be harmful to aquatic species. Consult with manufacturers before selecting a geomembrane material used for aquatic production.

Where access is needed, consider installing concrete ramps with embedded channels to connect the liner. Pond corners are typically good locations for concrete ramps due to the flatter slopes. Consider placing the access ramp at a corner location.

If the entire waste storage pond is lined and access is needed on the bottom, consider placing concrete over the liner, bedded with geotextile.

Consider the use of a geosynthetic such as a geonet or geocomposite under the liner to facilitate collection, drainage of liquids, and venting of gas. If geocomposite materials are used for drainage and/or venting, use materials recommended by the manufacturer in the system design. Use Geosynthetic Research Institute (GRI) Standard GC8, "Standard Guide for the Allowable Flow Rate of a Drainage Geocomposite" to determine the allowable flow rate of the geocomposite. Slope the pond bottom a minimum of 1 percent to permit positive flow of the liquids or gases. In most cases, the geocomposite will serve both purposes of drainage and venting. For large impoundments, the bottom may need to be sloped in multiple directions in order to decrease the required drainage and venting flow travel distances.

PLANS AND SPECIFICATIONS

Prepare plans and specifications for a geomembrane or GCL for a pond or a waste storage impoundment that describe the requirements for applying the practice to achieve its intended purpose. As a minimum, include:

- Layout of the containment facility, collection points, waste transfer locations or pipelines, and topography of the site.
- Soils investigation and subgrade details, including tolerances on smoothness of the finished grade.
- Required properties of selected liner, geosynthetics, and cushion materials.
- Quantities of liner materials, cover soil, and geosynthetic materials as needed.
- Subsurface drainage and venting details.
- Construction and material specifications.
- Safety requirements for installed liner.
- Details of liner installation, seaming requirements, and requirements for attachments and appurtenances.
- Minimum qualifications of installers and quality control testing requirements.
- Warranty requirements, if desired.
- Fence and signage requirements, if required.
- Applicable Wisconsin Construction Specifications

OPERATION AND MAINTENANCE

Prepare a plan for O&M of the liner and facility consistent with the purposes of the type of liner chosen, intended life, safety requirements, and design criteria. Include site-specific information regarding design capacity and liquid level of the facility and repair procedures for liner material. Maintenance activities required for this practice consist of those operations necessary to prevent and repair damage to the geomembrane or GCL. These include, but are not limited to:

- Excluding animals and equipment from the treated area.
- Repairing damage to the liner and restoring the liner and cover to its original thickness and condition.
- Removing roots from trees and large shrubs at first appearance.
- Monitoring leak-detection system.
- Protecting the liner during filling and agitation procedures.
- Provide guidance on items to inspect periodically, including:
- Visible portions of the liner for tears, punctures, or other damage.
- Liner interface with inlets, outlets, ramps, or other appurtenances for damage.
- Liquid level in the facility.
- Ballooning of the liner indicating presence of gas beneath the liner.

REFERENCES

ASTM D 5887, Test Method for Measurement of Index Flux Through Saturated Geosynthetic Clay Liner Specimens Using a Flexible Wall Permeameter.

ASTM D 5890, Test Method for Swell Index of Clay Mineral Component of Geosynthetic Clay Liners.

ASTM D 5891, Test Method for Fluid Loss of Clay Component of Geosynthetic Clay Liners.

ASTM D 5993, Test Method for Measuring of Mass Per Unit of Geosynthetic Clay Liners.

ASTM D 6102, Guide for Installation of Geosynthetic Clay Liners.

ASTM D 6214, Test Method for Determining the Integrity of Field Seams Used in Joining Geomembranes by Chemical Fusion Methods.

ASTM D 6392, Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods.

ASTM D 6497, Guide for Mechanical Attachment of Geomembrane to Penetrations or Structures.

ASTM D 7176, Specification for Non-Reinforced Polyvinyl Chloride (PVC) Geomembranes Used in Buried Applications.

ASTM D 7272, Test Method for Determining the Integrity of Seams Used in Joining Geomembranes by Pre-manufactured Taped Methods.

ASTM D 7408, Specification for Non Reinforced PVC (Polyvinyl Chloride) Geomembrane Seams.

ASTM D 7465, Specification for Ethylene Propylene Diene Terpolymer (EPDM) Sheet Used in Geomembrane Applications.

Daniel, D.E., and R.M. Koerner. 1993. Technical Guidance Document: Quality Assurance and Quality Control for Waste Containment Facilities. EPA/600/R-93/182 (NTIS PB94-159100).

Geosynthetic Research Institute, GRI Standard GC8, Standard Guide for the Allowable Flow Rate of a Drainage Geocomposite.

Geosynthetic Research Institute, GRI Test Method GT12(a) – ASTM Version, Test Methods and Properties for Nonwoven Geotextiles Used as Protection (or Cushioning) Materials.

Geosynthetic Research Institute, GRI Test Method GM13, Standard Specification for Test Methods, Test Properties and Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes.

Geosynthetic Research Institute, GRI Test Method GM17, Standard Specification for Test Methods, Test Properties and Testing Frequency for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes.

Geosynthetic Research Institute, GRI Standard GM18, Standard Specification for Test Methods, Test Properties and Testing Frequencies for Flexible Polypropylene (fPP and fPP-R) Nonreinforced and Reinforced Geomembranes.

Geosynthetic Research Institute, GRI Test Method GM19, Standard Specification for Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes.

Geosynthetic Research Institute, GRI Test Method GM21, Standard Specification for Test Methods, Properties, and Frequencies for Ethylene Propylene Diene Terpolymer (EPDM) Nonreinforced and Scrim Reinforced Geomembranes.

Geosynthetic Research Institute, GRI Test Method GM25, Standard Specification for Test Methods, Test Properties and Testing Frequency for Reinforced Linear Low Density Polyethylene (LLDPE-R) Geomembranes.

Giroud, J.P., and R. Bonaparte. 1989. Leakage through liners constructed with geomembranes—Part 1. Geomembrane Liners. In Geotextiles and Geomembranes, vol. 8, pgs. 27–67.

Koerner, R.M. 2005. Designing with Geosynthetics, 5th ed. Pearson Prentice Hall, Upper Saddle River, NJ.

U.S. Department of Agriculture, Natural Resources Conservation Service. National Engineering Handbook, Part 642, Specifications for Construction Contracts.

U.S. Department of Agriculture, Natural Resources Conservation Service. National Engineering Handbook, Part 651, Agricultural Waste Management Field Handbook. (AWMFH)

U.S. Department of Agriculture, Natural Resources Conservation Service. Conservation Practice Standard Monitoring Well (Code 353).

DEFINITIONS

Bedrock – The solid or consolidated rock formation typically underlying loose surficial material such as soil, alluvium or glacial drift. Bedrock includes but is not limited to limestone, dolomite, sandstone, shale and igneous and metamorphic rock.

Note: Although solid or consolidated bedrock can sometimes be removed with typical excavation equipment, these materials are included in the above definition.

Clean Water – Water that has not been mixed with manure, wastewater or other contaminants

Geomembrane – Very low permeability synthetic membrane liner or barrier used with any geotechnical engineering related material so as to control fluid migration in a man-made project, structure or system. (ASTM D 4439)

Geosynthetic Clay Liner (GCL) – A manufactured hydraulic barrier consisting of clay bonded to a layer or layers of geosynthetic materials.

Impoundment – A waste storage facility constructed of earthen embankments and/or excavations for the purpose of storing waste. An impoundment may be lined or unlined.

Intimate Contact – Direct contact between liner materials (concrete, GCL, and geomembrane) and soil.

Karst features – Refers to areas of land underlain by carbonate bedrock (limestone or dolomite). Typical land features in karst areas include sinkholes, network of interconnected fissures, fractures, disappearing streams, closed depressions, blind valleys, caves, and springs. See the companion document in Chapter 10 of the AWMFH for additional discussion of karst features.

Percent Fines (% Fines) – Percentage of given sample of soil which passes through a #200 sieve.

Permeability – The coefficient of permeability (K) is a measure of the ability of soil to transmit liquids. It is used to compute the flow rate of liquid through a soil liner for specific conditions of soil thickness and fluid head (e.g., $1x10^{-7}$ cm/s).

Plasticity Index, (PI) – A soil property indicating moldability. Measured by ASTM D4318.

Sinkholes – Closed, usually circular depressions which form in karst areas. Sinkholes are formed by the downward migration of unconsolidated deposits into solutionally enlarged openings in the top of bedrock.

Sub-Liner Soil – The soil directly below the bottom of the liner, having at least 20% fines. This may be placed or in situ material.

Structure – A waste storage facility consisting of constructed surfaces, tanks, or walls for the purpose of storing waste above or below the ground surface.

Wastewater – Milking center waste, flush water, leachate from feed holding areas, and similar waste materials generated at the animal production area.

NATURAL RESOURCES CONSERVATION SERVICE
CONSERVATION PRACTICE STANDARD

WASTE STORAGE FACILITY

CODE 313

(No.)

DEFINITION

An agricultural waste storage impoundment or containment made by constructing an embankment, excavating a pit or dugout, or by fabricating a structure.

PURPOSE

To store manure, agricultural by-products, wastewater, manure processing derivatives, leachate, and contaminated runoff to provide the agricultural operation management flexibility for waste utilization.

CONDITIONS WHERE PRACTICE APPLIES

Use where regular storage is needed for wastes generated by agricultural production or processing, where soils, geology, and topography are suitable for construction of the facility, and where the construction, operation, and maintenance will protect the soil and water resources.

For structures and conduits used to transfer waste and other byproducts, use the Wisconsin NRCS Conservation Practice Standard (WI NRCS CPS) Waste Transfer (Code 634).

For liquid waste storage facilities implemented with an embankment, this practice applies only to low hazard facilities as defined in the NRCS National Engineering Manual (NEM), Part 520 subpart C with a maximum effective height of 25 feet.

This standard applies to:

- Waste storage impoundments or structures up to 25 feet of impoundment depth; and
- Facilities that are part of a planned agriculture waste management system intended to meet the facility management goals, regulatory requirements, or nutrient management plans by providing storage of waste.

For the purposes of this standard, liquid waste is used to describe any waste that is too wet to stack. It includes both liquid and slurry waste.

This practice does not apply to the storage of human waste, routine animal mortality, the unstacked waste that accumulates in animal housing units (barns) or animal production areas not intended to store waste (animal confinement/feed areas).

CRITERIA

General Criteria Applicable to All Waste Storage Facilities.

The following criteria establish minimum allowable limits for design parameters, acceptable installation processes, or performance requirements for all waste storage facilities (impoundments and structures).

Laws and Regulations. Plan, design, and construct the waste storage facility to meet all Federal, Tribal, State, and local laws and regulations. This standard does not contain the text of the federal, tribal, state, or local laws governing waste storage facilities. Regulatory approval may be needed prior to accepting off-site material(s) or adding chemicals to the waste storage facility. The operator is responsible for securing required permits.

Location. Locate and design the waste storage facility such that it is outside the 100-year floodplain unless site restrictions require locating it within the floodplain. Where waste storage facilities are located in flood prone areas, protect these facilities from inundation, structural damage, and instability. Design these facilities to accommodate any additional loading resulting from static water levels or saturated soils. The lowest point at which floodwater could potentially enter the waste storage facility must be 2 feet above the maximum flood elevation resulting from a 100-year, 24-hour rainfall event. Additionally, follow the policy found in the NRCS General Manual (GM) 190, Part 410.25, Flood Plain Management.

Management Assessment

Conduct, document, and incorporate a management assessment into the design. Perform the assessment with the owner/operator to explore options and to determine the purpose of storage components, available resources, manure disposal schemes, sand and manure solids separation methods, and waste characteristics.

The management assessment shall address the following as appropriate to the system being designed:

- Waste Characterization
  - Sources, volumes, and consistency of manure, contaminated runoff, manure processing derivatives, leachate, wastewater, and other inputs to the waste storage facility
  - Animal type, size, number and weight
  - Bedding types and quantity
  - Chemical characteristics which may impact facility design
- Land base available for utilization of waste
- Method of distribution of manure onto the land base
- Planned storage period
- Waste handling and transfer methods from the waste source to the storage facility
- Facility waste removal methods
- Storage facility liner possibilities and preferences
- Access needs and limitations
- Safety needs, including those to address the hazards of manure gases
- Labor and equipment needs
- Potential odor concerns
- Provisions for facility expansion

When the intent of the owner/operator is to process and/or treat the various waste streams within the animal production area, provide a narrative describing the system. The description will include the intent and purpose of the processing or treatment strategies relative to land spreading or waste distribution strategies, stabilization of organic by-products, separation of sand bedding, reducing pollutant loads, nutrient concentration, waste consistencies, odor control, energy production, and volume reduction.

Site Assessment

Conduct, document, and incorporate a site assessment into the design. Perform the assessment to determine physical site characteristics that will influence the placement, construction, maintenance, and environmental integrity of a proposed waste storage facility, liner(s) and transfer components. Include input from the owner/operator in the site assessment. The site assessment shall include:

- Locations and elevations of buildings, roads, lanes, soil investigations, property lines, setbacks, easements, wells, springs, floodplains, surface waters, surface drains, subsurface drains, utilities, overhead lines, cultural resources, and wetlands.
- The location of sinkholes and other karst features and conduits to groundwater within 1,000 feet of the facility. Features within 1,000 feet of the facility must be further analyzed per WI NRCS Engineering Field Handbook Supplement Chapter 4, Exhibit A (Chapter 4, Exhibit A) to determine if they pose a hazard to the facility or environment.
- Log subsurface investigations for all waste storage facilities sufficient in detail and analysis to support the design in accordance with Chapter 4, Exhibit A. Describe the soil material encountered, location of any seeps, depth to subsurface saturation, and depth to bedrock (Note: Chapter 4, Exhibit A follows NRCS NEM Part 531, Geology, by utilizing ASTM D2488 procedures).
    - » Document the location of test pits or soil borings, soil test results, photos taken during the soils investigation, and a narrative describing the design parameters that have been derived from the soils data. Note the bedrock type, if encountered, such as sandstone, limestone, dolomite, or granite.
    - » Locate test pits and borings used to meet the criteria within the footprint or no more than 100 feet from the footprint. A minimum of one test pit or boring per 15,000 square feet of facility footprint, with a minimum of two per facility, is required. Extend these test pits/soil borings to bedrock, a free water surface, or to a minimum depth to ensure subsurface saturation and bedrock separation distances required in this standard or associated Pond Sealing or Lining standards are achieved.
    - » Complete soil tests for soils (in-place), sub-soil or sub-liner soils in a laboratory on representative samples of soil beneath the proposed grade at a rate of 1 test per 30,000 square feet of facility footprint, with a minimum of two tests. The Plasticity Index (PI) shall be determined in accordance with ASTM D4318 and the percent fines (% fines) in accordance with ASTM D1140.
    - » Increase the number and distribution of test pits and soil borings needed to characterize the subsurface (soils, saturation, and bedrock) if there is inconsistency within or between test pits or borings.

» Characterize soil for liners and sub-liners according to Chapter 4, Exhibit A. Soils for liners and sub-liners may be located within the footprint of the storage, on site, or off site and transported to the site for construction. Include locations, dimensions and elevations, soil volumes, soil samples, testing results, and reclamation plans of any borrow areas. Complete soil characterization at a rate of one test per 30,000 square feet of borrow source, with a minimum of two tests per area. Distribute the test pit or borings evenly across the borrow source. Additional soils testing may be needed to meet the requirements of the selected liner type. See the appropriate Pond Sealing or Lining standards and Wisconsin construction specifications for additional criteria.

Separation from Subsurface Saturation or Bedrock. The separation is determined to be the closest distance from any point on the inside surface (bottom and sides) of the storage facility to the feature from which separation is required.

For the purposes of this standard, factors used to identify subsurface saturation shall include observed saturation, gleyed soil, gray redoximorphic features, and soil color in conjunction with nearby surface water features. The highest subsurface saturation elevation in a test pit/soil boring will be identified by any of the following soil properties:

- Free water or wet soil identified by glistening, due to the slow release of water
- Gleyed soil, that may extend uninterrupted from an observed free water surface.
- The presence of distinct gray redoximorphic features with a chroma of 2 or less based on Munsell color charts.
- Depleted matrices having a value of 4 or more and chroma of 2 or less based on Munsell color charts. In some cases soil parent materials have a natural color with a chroma of 2 or less or gleyed color that is not due to saturation. In these cases other indicators may be used such as landscape position, relative elevation or soils in relation to nearby water features.

In soils not conducive to mottling, such as sand, establish the subsurface saturation elevation by evaluating the soil morphology of the soil profile. Other indicators that may be considered in making the determination are the position of the soil in the landscape, topography, nearby wetlands and well construction logs. In sites susceptible to groundwater contamination or complex hydrogeological sites, additional saturation verification methods may be required. Verification methods could include but are not limited to groundwater monitoring wells, piezometers, and soil test pits conducted during the wet season. Other information to consider includes historic precipitation and groundwater elevation records from nearby locations, which can indicate whether or not the area is experiencing a local high or low trend in groundwater elevation.

If the site assessment indicates artesian features, complete a hydrogeologic and geotechnical evaluation of the site to determine the site suitability for an in-ground waste storage facility. Include a groundwater monitoring well or piezometer below the apparent confining layer and a water table observation monitoring well in the evaluation. Monitor the site through the wettest portion of the annual groundwater recharge cycle.

Construct and develop groundwater monitoring wells and piezometers according to WI NRCS CPS Monitoring Well (Code 353) or appropriate state monitoring well construction requirements.

Subsurface saturation, pockets of sand and gravel, or water-bearing materials, if encountered, shall not be removed or drained except for perched conditions. Include documentation to demonstrate that subsurface saturation is perched and its effects can be eliminated.

Excavation of bedrock is permitted to achieve the required separation distance as specified in Table 5 of this standard and tables in associated Pond Sealing or Lining standards. Do not remove bedrock by blasting. Evaluate the exposed bedrock surface to ensure a structurally sound base for a liner or other soil material. Treat fractures or voids to prevent migration of soil material. The entire surface of the excavated bedrock shall have a positive grade, minimum of 1 percent, under and away from the storage facility, as to prevent any significant ponding on the rock surface. If bedrock is excavated, the material placed between the liner and the bedrock shall meet the requirements of sub-liner soil in the appropriate Pond Sealing or Lining standards.

Perched Conditions. Pockets of sand and gravel, or other water-bearing materials may be removed or drained to achieve separation distances in Tables 1 and 5 within this standard, or tables in associated Pond Sealing or Lining standards, and to relieve hydrostatic loads on the facility and its liner(s). All drainage systems shall drain to the ground surface or surface water by gravity. Evaluate the effect of temporary tailwater on the structure or liner and the effects of outletting to perennial and intermittent waterways. Locate a drainage system around the outside perimeter of the facility footprint and drain to a surface outlet. Protect outlets against erosion and undermining of the conduit, entry of vegetation, damaging periods of submergences, and entry of rodents or other animals into the subsurface drain. A drainage system may also be located around the outside perimeter of an impoundment floor within the facility footprint if the drainage system enters an observation and pumping port and then continues by gravity to a surface outlet. Design the port such that the outlet can be blocked and a pump can be utilized to remove the polluted liquids until the source is identified and repairs can be completed.

Sensitive Environmental Settings. Wisconsin Sensitive Environmental Settings are sites where one or more of the following conditions are met:

- Bedrock or subsurface saturation separation distances are less than those listed in Tables 1 of this standard, Table 1 of WI NRCS CPS Pond Sealing or Lining – Compacted Soil Treatment (Code 520), Tables 5 and 6 of WI NRCS CPS Pond Sealing or Lining – Geomembrane or Geosynthetic Clay Liner (Code 521), or Table 2 of WI NRCS CPS Pond Sealing or Lining – Concrete (Code 522);
- Sub-liner soils do not meet both the required thickness and percent fines listed in Table 1 of WI NRCS CPS 520, Tables 5 and 6 of WI NRCS CPS 521, or Table 2 of WI NRCS CPS 522;
- For facilities with one or more sloped sides or structures with vertical sides with any part of the storage floor below existing ground surface, a sinkhole or other karst feature is present within 400 feet horizontally from the footprint of the proposed storage facility; or
- For above ground structures where the storage floor is entirely above existing ground surface, a sinkhole or other karst feature is present within 200 feet horizontally from the footprint of the proposed storage facility.

In-situ soils that do not meet both the sub-liner required thickness and percent fines listed in the applicable liner standard can be removed and replaced with compliant materials. When designed and constructed in this manner, the site is no longer classified as Wisconsin Sensitive Environmental Settings.

Where liquid-storage is to be provided in sensitive environmental settings, design according to WI NRCS CPS Pond Sealing or Lining – Concrete (Code 522), Sensitive Environmental Settings.

Storage Period. The storage period is the maximum length of time anticipated between emptying events. Base the minimum storage period on the timing required for environmentally safe waste utilization considering the climate, crops, soils, equipment, in accordance with the operations and maintenance plan, nutrient management plan and Federal, State, and local regulations.

Design Storage Volume. Calculate design storage volumes with the procedures and default values found in the Wisconsin supplement to Chapter 10 of the NRCS Agricultural Waste Management Field Handbook (AWMFH) or site-specific estimates and measurements documented in the design. Include the sum of the following during the storage period in the design volume:

The maximum operating level (MOL) for liquid storage facilities is the level that provides the operational volume (Figure 1 contains a diagram of this information). This includes the following:

- Manure, wastewater, bedding, and all other wastes accumulated during the storage period.
- For liquid storage facilities, include normal precipitation (omit diverted roof runoff) less evaporation during the storage period.
- Normal runoff from the facility's drainage area during the storage period. Exclude clean water from the facility to the fullest extent practical except where including the runoff is advantageous to the operation of the agricultural waste management system.
- Additional storage when required to meet management goals or regulatory requirements.

Emergency Volume (liquid storages only) includes the following:

- 25-year, 24-hour precipitation on the surface of the liquid storage facility at the maximum level of the required design storage.
- 25-year, 24-hour runoff from the facility's drainage area.

Remaining Waste. Add a minimum of two feet to storage depth for facilities with side slopes and one foot for vertical walled facilities for planned maximum remaining waste. The additional storage depth can be reduced if a sump is installed or other provisions to empty the facility have been made. The anticipated method for solids removal must be accommodated in design, particularly in determining the configuration of impoundments and the type of liner to be used and maintained.

Freeboard Volume. This volume applies to liquid waste storage exposed to precipitation. Add a minimum of one foot of depth to the design storage volume to reduce the risk of overtopping. This depth is not intended to add storage capacity.

Inlet. Design inlets to resist corrosion, plugging, freeze damage, and ultraviolet deterioration. Incorporate erosion protection for in-place earth (Table 1 of this standard), soil liner (WI NRCS CPS 520, Table 1), and geosynthetic clay liners (WI NRCS CPS 521, Table 6).

Waste Removal. Provide components for removing waste such as gates, pipes, docks, wet wells, pumping platforms, retaining walls, or ramps. Incorporate features to protect against erosion, tampering, and accidental release of stored waste as necessary. Design ramp slopes to accommodate anticipated equipment and traction available. Use WI NRCS CPS Nutrient Management (Code 590) for land application of stored material or follow other disposal options outlined in a Comprehensive Nutrient Management Plan (CNMP).

Outlet. An outlet that can automatically release stored material is not permitted except for outlets leading to another storage facility with adequate capacity for releases due to accident or system component failure. Design a permanent outlet that will resist corrosion and plugging. Provide a backflow prevention measure for an outlet that pumps wastewater to secondary storage located at a higher elevations.

Staff Gauge. Place a staff gauge or other permanent marker that does not compromise the integrity of the liner in the liquid storage facility to clearly indicate the following elevations:

- Maximum operating level (top of the operational volume)
- Emergency level (top of the design storage volume)
- State or local codes may require additional markers

For storages where the contents or staff gage are not visible, such as below a slatted floor, identify the method for the operator to measure the depth of stored waste.

Safety. Identify and minimize the hazards to animals and people in the safety design. In particular, waste storage facility designs may create confined spaces, which may pose significant hazards in terms of the inhalation of poisonous gases, asphyxiation, or explosion. At a minimum, the safety design shall include the following:

- Include appropriate safety features to minimize the hazards of the facility (refer to American Society of Agricultural and Biological Engineers (ASABE) Standard EP470, Manure Storage Safety for guidance, as needed). Design and operate confined spaces where human entry might occur in compliance with the provisions contained in ASABE EP470, Manure Storage Safety.
- Characterize and identify any combination of effluent and amendments currently in use that may have the potential to create hazardous conditions.
- Provide warning signs, fences, ladders, ropes, bars, rails, and other devices as appropriate, to ensure the safety of humans and livestock. Provide ventilation and warning signs for covered waste holding facilities, as necessary, to prevent explosion, poisoning, or asphyxiation.
- Install safety stops, gates, or both at push-off ramps and load-out areas of impoundments and structures to reduce the potential for accidental entry of machinery.
- Ensure equipment access ramps and embankment slopes are compatible with the equipment intended to be used.
- Design covers and grating over openings such that livestock or humans cannot accidentally displace them and fall into the facility.
- Design pipelines with a water-sealed trap and vent, or similar device, if there is a potential for gases from the pipe to accumulate in confined spaces.
- Place a fence around impoundments and uncovered tanks which have exposed walls less than 5 feet above ground surface. Use the WI NRCS CPS Fence (Code 382) for design of a fence that will restrict access to safety hazards by people and animals likely to be on-site.
- Post universal warning signs to warn children and others from entering liquid waste storage facilities.
- Safety features should be added to the Operation and Maintenance Plan.

Roofs and Covers. Use WI NRCS CPS Roofs and Covers (Code 367) for design of waste storage facility covers or roofs, as needed.

Failure Analysis. Evaluate the overall functionality of the waste storage facility for possible malfunctions which could lead to sudden breach of embankment or accidental release of waste from the storage facility under normal operational conditions. Identified failure modes should be addressed in the design phase, the operation and maintenance plan, and the emergency action plan.

The Failure Analysis should include features, safeguards, and/or management measures to minimize the risk of failure or accidental release, or to mitigate impact of this type of failure when any of the features listed below might be significantly affected:

- Human safety
- Surface water bodies – perennial and intermittent streams, lakes, wetlands and estuaries
- Conduits to groundwater
- Artesian well features
- Critical habitat for threatened and endangered species
- Riparian areas
- Farmstead, or other areas of habitation
- Off-farm property
- Historical and archaeological sites or structures

Seeding and Mulching. Seed and mulch disturbed areas and embankments in accordance with WI NRCS CPS Critical Area Planting (Code 342).

Additional Criteria for Liquid Waste Storage Impoundments

The following criteria establish additional design parameters, acceptable installation processes, or performance requirements for liquid waste storage impoundments.

Foundation. Locate the impoundment in soils with a permeability that meets all applicable regulations (Table 1 meets the specific discharge requirements specified in the National Engineering Handbook (NEH), Part 651, Agricultural Waste Management Field Handbook (AWMFH), Chapter 10, Appendix 10D). Alternately, line the impoundment with suitable material. If a liner is needed, use liners which meet or exceed WI NRCS CPS 520, 521, or 522. Construction shall not occur on or with organic soils.

A combination of liners is acceptable. Join the liners so as to preserve the performance and integrity of all liner types. Concrete walls used within impoundments shall maintain the integrity of any liner. Construct and maintain any penetration and overfall/outfalls of the liner to maintain the performance and integrity of the liner used.

Waste storage impoundments that store milkhouse waste or feed storage runoff may be subject to the requirements of Wisconsin Administrative Code, Chapter NR 213 (NR 213) if the operation is considered a concentrated animal feeding operation or if compliance with NR 213 is required by other NRCS standards. NR 213 contains requirements not contained within this standard. If the waste storage impoundment is regulated under NR 213, the design must meet the requirements of both NR 213 and this standard.

Embankments. Non liner components of an impoundment embankment shall be constructed with mineral soil material compacted to WCS-204 requirements. The impoundment embankment shall be lined with (CPS 313) Table 1 Soils (In Place) material, a soil liner (CPS 520), or the selected liner component and soil component (WI NRCS CPS 521 or 522). The soil component shall be compacted following the Wisconsin Construction Specification listed in the applicable standard. The bottom of the liner shall be extended until it daylights the embankment. Minimum embankment top widths are shown in Table 2. Design the combined side slopes of the settled embankment to be equal to or flatter than 5 horizontal to 1 vertical. Interior side slopes must meet the design requirements listed in either Table 1 or the selected liner requirements, found in the pond liner standards (WI NRCS CPS 520, 521, and 522). Exterior side slopes may be no steeper than 2 horizontal to 1 vertical.

The top of the embankment may be constructed to drain, either toward or away from the stored waste, as desired by the designer. Add additional material above the required top width to accommodate desired drainage.

Increase the constructed embankment height by at least 5 percent to allow for settlement. After settlement, the top of the embankment shall be greater than or equal to 1 foot above the surrounding grade. Stabilize all embankments to prevent erosion or deterioration. Compact according to WI FOTG Construction Specification 204, Earthfill for Waste Storage Facilities or Construction Specification 300, Clay Liner, as applicable. For an impoundment with greater than one acre of surface area and where wave action is a concern, increase the embankment height to account for calculated wave height.

Any diversion or waterway along the embankment shall have a capacity for 25-year, 24-hour storm plus 0.5 feet of freeboard, with a minimum depth of 1 foot.

Construct a core trench whenever the settled embankment fill height at the centerline is greater than or equal to 10 feet. Minimum dimensions of the core trench shall be 8-foot bottom width, 2-foot depth, and 1 horizontal to 1 vertical or flatter side slopes.

Spillway or Equivalent Protection. For a facility having an effective height greater than 20 feet, construct an auxiliary (emergency) spillway designed to handle the peak flow or routed peak flow from the 25-year, 24 hour precipitation event, as defined in the Design Storage Volume section of this standard. The crest of the spillway shall be sited above the design storage volume elevation.

Excavations. Design embankments and excavated side slopes to meet the requirements of WI NRCS CPS 313, 520, 521 and 522, as applicable.

Table 1. In-Place Earth Criteria for Waste Storage Facility Impoundments 20 Feet Deep or Less Note 1, 2

Size		
Design Storage Volume	≤ 300,000 cu. feet	> 300,000 cu. feet
Manure Produced at Farm per Year	≤ 600,000 cu. feet	> 600,000 cu. feet
Waste Characteristics	≥ 4% manure solids in stored waste, ruminant animals only	All
Soils (In Place)		
% Fines	≥ 40%	≥ 40%
Plasticity Index (PI)	≥ 7	≥ 12
Total Thickness (measured perpendicular to storage surface, includes thickness of recompacted layer)	≥ 5 feet Note 3	≥ 5 feet Note 3
Thickness of Recompacted Surface Layer	≥ 1 foot	≥ 1 foot
WI FOTG Construction Specification for Recompacted Layer	204, Earthfill for Waste Storage Facilities	300, Clay Liner
Sub-Soil Note 4		
% Fines	≥ 20%	≥ 20%
Plasticity Index (PI)	—	—
Thickness (bottom and sides)	≥ 3 feet	≥ 3 feet
Separation Distances		
Well Distance Note 5	≥ 250 feet	≥ 250 feet
Sinkholes or Other Karst Features	≥ 800 feet	≥ 400 feet
Subsurface Saturation	≥ 8 feet	≥ 8 feet
Bedrock	≥ 8 feet	≥ 8 feet
Impoundment		
Inside Slope	2.5:1 or flatter	
Other		
Scour Protection	Agitation and Pumping Locations	Minimum 20 feet wide x 30 feet long x 4 inches thick concrete pad or sump in bottom and 20 feet wide ramp or a 16-foot wide ramp with 12-inch high curbs to the top of the facility.
	Scraping and Other Mechanical Means of Removing Solids and Sand	Protect with hard surfacing designed for the expected conditions and loads, a minimum of 4 inches thick.
Existing Field Drain Tile	Additional site investigation shall be completed to determine the presence of existing subsurface drain or underground outlet within 100 feet of the footprint of the facility. Any tile found must be abandoned or removed.	

Note 1 The depth is measured from the bottom of the impoundment to the maximum operating level.

Note 2 Facilities in this table do not meet the requirements of NR 213.

Note 3 Thickness is calculated based on a maximum permeability of 1×10^{-7} cm/sec

Note 4 Sub-soils are located beneath the required in place soils and above subsurface saturation or bedrock. Sub-soils must be in situ materials.

Note 5 Community water system wells may require larger separation distances (see Wisconsin Administrative Code, Chapter NR 811 (NR 811)).

Table 2. Minimum Embankment Top Widths

Effective Height (feet)	Top width (feet)
< 15	8
15–19.9	10
20–25	12

Additional Criteria for Fabricated Structures

The following criteria establish additional design parameters, acceptable installation processes, or performance requirements for waste storage structures.

Foundation. Based on subsurface investigation, provide a foundation for fabricated waste storage structures to safely support all superimposed loads without excessive movement or settlement.

Total and Differential Settlement. Where a non-uniform foundation cannot be avoided or where applied loads may create highly variable foundation loads, calculate both total and differential settlement based upon site-specific soil test data. Index tests (such as Atterberg limits, moisture content, etc.) of site soils may allow correlation with similar soils for which test data is available.

Bearing Capacity. If no site specific test data are available, presumptive bearing strength values for assessing actual bearing pressures obtained from Table 3 or another nationally recognized building code may be used. In using presumptive bearing values, provide adequate detailing and articulation to avoid distressing movements in the structure (i.e., settlement).

Structural Loadings. Design the waste storage structure to withstand all anticipated loads in accordance with the requirements in NRCS NEM, Part 536, Structural Design. Such loads should include internal and external loads, hydrostatic uplift pressure, concentrated surface and impact loads, and water pressure due to subsurface saturation, frost or ice. If a dense ice cover can be expected, account for the additional point load associated with an ice sheet against a vertical wall.

Calculate loading from lateral earth pressures using soil strength values determined from the results of appropriate soil tests and procedures described in NRCS Technical Release 210-74, Lateral Earth Pressures. Table 4 provides minimum lateral earth pressure values when soil strength tests are not available. If heavy equipment will operate near the wall, use an additional soil surcharge as indicated in footnote 4 in Table 4 in the wall analysis.

For the lateral load from stored waste not protected from precipitation, use a minimum 65 pounds/square foot/foot of depth as the design internal lateral pressure. Use a minimum value of 60 pounds/square foot/foot of depth for the lateral load from stored waste protected from precipitation and not likely to become saturated. Use a minimum internal lateral pressure of 72 pounds/square foot/foot of depth for sand-laden manure storage if the percentage of sand exceeds 20 percent. Designers may use lesser values if supported by measurement of actual pressures of the waste to be stored.

Design structure covers to withstand both dead and live loads. Use the minimum live load values for covers contained in ASABE EP378, Floor and Suspended Loads on Agricultural Structure Due to Use, and in ASABE EP393, Manure Storages. Use the actual axle load for tank wagons having more than a 2,000 gallon capacity.

If the structure is to have a roof, use WI NRCS CPS Roofs and Covers (Code 367) for design of waste storage facility covers or roofs, as needed. Use snow and wind loads specified in American Society of Civil Engineers (ASCE) SEI/ASCE 7-10 or newer version, Minimum Design Loads for Buildings and Other Structures. If the facility is to serve as part of a foundation or support for a building, consider the total load in the structural design.

Concrete Joints. Wall control joints with embedded waterstop – Cast-in-place cantilevered vertical walls shall have a control joint spacing less than or equal to 100 feet of running wall length, including around corners and bends. This criterion does not apply to hoop strength design or tanks with pin connections at both the top and bottom of the wall or to liquid-tight concrete walls designed in compliance with ACI-350.

Table 3. Presumptive Allowable Foundation and Lateral Pressure Note 1

Class of materials	Allowable foundation pressure (pounds per square foot)	Lateral bearing	Coefficient of friction	Cohesion (pounds per square foot)
Crystalline bedrock	12,000	1,200	0.70	-
Sedimentary and foliated rock	4,000	400	0.35	-
Sandy gravel or gravel (GW and GP)	3,000	200	0.35	-
Sand, silty sand, clayey sand, silty gravel, clayey gravel (SW, SP, SM, SC, GM and GC)	2,000	150	0.25	-
Clay, sandy clay, silty clay, clayey silt, silt and sandy silt (CL, ML, MH and CH)	1,500	100	-	130

Note 1 International Building Code (IBC), 2015, International Code Council (ICC)

Waterstop. Use embedded or expansive waterstop in accordance with WI Construction Specification 004-WS Embedded or Expansive Waterstop. The type of waterstop is based on the joint movement criterion indicated below.

Install an embedded waterstop at the wall to footing intersection if the joint is designed for movement. Install either an expansive or embedded waterstop at this joint if it is not designed for movement (fixed).

If there is no embedded waterstop at the wall base, cast the wall joint waterstop a minimum of 4 inches into the footing. If there is an embedded waterstop between the footing and the bottom of the wall, weld the wall joint waterstop to a factory fabricated intersection at the base of the wall.

Floor joints in vertical walled structures, if used, should be extended through the footing and continue to the top of the vertical wall. Joints and liner shall meet the criteria listed in WI NRCS CPS Pond Sealing or Lining – Concrete (Code 522).

Joints for pre-cast walls shall demonstrate evidence of equivalent performance to waterstop joints as determined by the NRCS State Conservation Engineer.

Make transitions from concrete wall footings to concrete slabs at a ratio of one inch of thickness change to one inch of run (1:1) or flatter.

Table 4. Lateral Earth Pressure Values Note 1

Description of Backfill Material Note 2	Unified Soil Classification Note 3	Design lateral soil load (pounds/square foot/foot of depth) Note 4
Well-graded, clean gravels; gravel-sand mixes Note 5	GW	60
Poorly graded clean gravels; gravel-sand mixes	GP	60
Silty gravels, poorly graded gravel-sand mixes	GM	60
Clayey gravels, poorly graded gravel-sand mixes	GC	60
Well-graded, clean sands; gravely sand mixes	SW	60
Poorly graded, clean sands; gravely sand mixes	SP	60
Silty sands, poorly graded sand-silt mixes	SM	60
Sand-silt clay mix with plastic fines	SM-SC	100
Clayey sands, poorly graded sand-clay mixes	SC	100
Inorganic silts and clayey silts	ML	100
Mixture of inorganic silt and clay	CL-ML	100
Inorganic clays of low to medium plasticity	CL	100
Inorganic clayey silts, elastic silts	MH	Note 6
Inorganic clays of high plasticity	CH	Note 6

Note 1 Table 1610.1, Lateral Soil Load, International Building Code (IBC), 2015, International Code Council (ICC). For lightly compacted soils (85% to 95% maximum standard density). Includes compaction by use of typical farm equipment.

Note 2 Base the definition and classification of soil in accordance with ASTM D2487 and D2488.

Note 3 All definitions and procedures in accordance with ASTM D2488 and D653.

Note 4 Design loads based on moist conditions for the specified soils at optimum density. Include the weight of the buoyant soil plus hydrostatic pressure for submerged or saturated soil. Pressures are calculated for level backfill for a distance equal to the wall height. If backfill exceeds wall height at a distance equal to or less than the wall height, increase pressures accordingly. If equipment loads are expected or are possible to operate within a distance equal to the wall height behind the wall, use an additional live load soil surcharge equal to 2 feet of backfill for 5,000 pound wheel loads and more or less for other wheel loads, as appropriate.

Note 5 Generally, only washed materials are in this category.

Note 6 Not recommended. Requires special design if used.

Structural Design. Design structures with reinforced concrete, steel, wood, or masonry materials in accordance with NRCS-NEM, Part 536, Structural Engineering. Account for all items that will influence the performance of the structure, including loading assumptions, durability, serviceability, material properties, construction quality, waterstops, pipe penetration, channel penetrations, anchor plates, or other attachments to walls such as fence posts. Ensure that the material used for a fabricated structure is compatible with the waste product to be stored.

Indicate design assumptions and construction requirements on the construction plans. Construct any penetration of the structure to maintain the performance and integrity of the structure.

Tanks may be designed with or without a cover. Design covers, beams, or braces that are integral to structural performance accordingly and indicate their location and design requirements on the construction drawings. Design openings in a covered tank to accommodate equipment for loading, agitating, and emptying. Equip these openings with fencing, grills or secure covers for safety, and for odor and vector control as necessary.

Fabricated structures shall be designed according to the following criteria:

- Steel: Manual of Steel Construction, American Institute of Steel Construction.
- Timber: National Design Specifications for Wood Construction, American Forest and Paper Association.
- Concrete:
  - » Building Code Requirements for Reinforced Concrete, American Concrete Institute (ACI) 318. Concrete design calculations shall use a minimum design compressive strength of 3,500 psi.
  - » Code Requirements of Environmental Engineering Concrete Structures, ACI 350.
  - » Concrete used as part of a structure: WI Construction Specification 4, Concrete.

Separation Distance. Fabricated structures must meet the separation distances listed in the liner standard(s) used; see WI NRCS CPS 520, 521 and 522, as applicable.

Additional Criteria - Stacking Facilities

This criteria applies to stacking the following materials at the animal production area:

- Separated manure solids
- Compost
- Dewatered, recycled sand storage
- Poultry litter (turkey or broiler operations)
- Dry poultry layer manure
- Bedded manure (> 50% solids)
- Waste feed

Criteria for stacking facilities are shown in Table 5. Solids stacking within the animal production area may be done in an impoundment, fabricated structure or stacking slab, when provisions are made to capture seepage and runoff.

A stacking facility may be open, covered, or roofed and is used for wastes which behave primarily as solid. Determine the wall height using the anticipated stacking angle of the waste material. Construct a stacking facility of durable materials such as reinforced concrete, reinforced concrete block, or treated lumber. Design the stacking facility with adequate safety factors to prevent failure due to internal or external pressures, including hydrostatic uplift pressure and imposed surface loads such as equipment which may be used within, on, or adjacent to the structure.

Reduced seepage concrete with waterstop is allowed as a liner in place of the soil requirements of Table 5.

Seepage. All facilities lacking permanent, engineered roofs are considered not roofed for the purposes of this standard. Tarps, plastic coverings, or other temporary measures are considered not roofed. Facilities that are not roofed must have floors sloped to control surface drainage and all leachate and runoff (up to the 25-year, 24-hour storm) must be managed. Prevent influent seepage in amounts that would infringe on designed storage capacity. Seepage control may not be necessary on sites that have a roof or waste material with little seepage potential.

Internal Drainage. Make provisions for drainage of leachate, and rainfall from the stacking areas without a roof. Collect leachate and runoff in a facility suitable for liquid containment (as defined within this standard) or transfer receptacle meeting WI NRCS CPS Waste Transfer (Code 634), until land applied in accordance with WI NRCS CPS Nutrient Management (Code 590), or provide other acceptable treatment.

Poultry Litter Stacking Facility. To reduce the potential for spontaneous combustion damage to wood walled facilities, design the height of the litter stack not to exceed 7 feet, with litter to wood contact limited to 5 feet. Compost facilities should be designed and operated to meet the requirements of WI NRCS CPS Composting Facility (Code 317).

Design facilities to prevent run-on and runoff, and operate them to prevent ponding and significant hydrostatic head. Facilities may commonly be located near the ground surface, but may be above or below ground. Determine the wall height using the anticipated stacking angle of the waste material.

Table 5. Liner Criteria for Permanent Solids Stacking Facilities at the Animal Production Area Note 1

	Roofed		Not Roofed	
	Work Surface Note 2	**No Surface** Note 3	**Work Surface** Note 2	**No Surface** Note 3
Soils In-Place Liner Note 3				
% Fines	≥ 30%	≥ 30%	≥ 40%	≥ 40%
Plasticity Index (PI)	-	≥ 7	-	≥ 7
Thickness	≥ 2 feet	≥ 2.5 feet	≥ 3 feet	≥ 5 feet
Soils Compacted Liner Note 3				
% Fines	≥ 30%	≥ 40%	≥ 40%	≥ 40%
Plasticity Index (PI)	≥ 5	≥ 7	≥ 7	≥ 7
Thickness	≥ 1.5 feet	≥ 2 feet	≥ 2 feet	≥ 3 feet
Compaction	WI Spec 204	WI Spec 204	WI Spec 204	WI Spec 204
Separation Distances				
Sinkholes	≥ 400 feet	≥ 400 feet	≥ 400 feet	≥ 400 feet
Well Distance Note 4	≥ 100 feet	≥ 100 feet	≥ 100 feet	≥ 100 feet
Subsurface Saturation	≥ 3 feet	≥ 3 feet	≥ 5 feet	≥ 5 feet
Bedrock	≥ 3 feet	≥ 3 feet	≥ 5 feet	≥ 5 feet
Stacking Area	Stacking area not to exceed 7 acres for unroofed managed compost, 2 acres for sand, 2 acres for roofed facilities, or 1 acre for all other materials.			

Note 1 Solids and sand stacking facilities, treatment areas and other production area structures and systems may be subject to surface water setbacks and other requirements under state and local rules. MOL requirements do not apply to this Table.

Note 2 The work surface may be constructed of any of the following: minimum 3 in. for asphalt; minimum 4 in. for concrete; or minimum 8 in. for macadam, and designed for anticipated equipment 0p5loads. Refer to industry standard design criteria for each work surface material. The purpose of the work surface is to protect the liner material.

Note 3 Facilities without a work surface must be operated to minimize rutting and removal of the soil liner. Ruts must be repaired and the soil liner thickness maintained after material handling. Stacking height is not to exceed 10 feet.

Note 4 Additional separation distances to wells may be necessary on WDNR regulated farms.

CONSIDERATIONS

Additional recommendations relating to design which may enhance the use of, or avoid problems with, this practice, but are not required to ensure its basic conservation function are as follows:

Consider using the companion documents located in Chapter 10 of the NRCS, Agriculture Waste Management Field Handbook (AWMFH).

Consider using the Waste Storage Design spreadsheet located in Chapter 10 of the NRCS AWMFH for design storage volume, liner thicknesses, and other calculations described in this standard.

This standard does not preclude the addition of other off farm organic materials not specifically prohibited by standard, pending approval by the appropriate regulatory authority. During planning, consider discussing the potential for off farm organic material storage with the landowner. Encourage the landowner to investigate the impact of accepting off farm organic material to waste consistency, toxic gas generation, nutrient management, and remaining volume prior to accepting any off farm waste. Incorporate any additional operation or maintenance requirements resulting from these discussions.

Consider implementing erosion control methods on the top half of the inside slopes of earthen impoundments.

Consider adding agitation locations on different sides of the storage facility, or different cardinal directions, allowing the location of agitation to be adjusted if wind direction changes.

Consider adding curbs, structural or visual components to all agitation and pumping locations, which may reduce the risk of accidental entry and damage to the liner during agitation.

When designing impoundment embankments, consider using flatter slopes on the outside embankment slope for better operation access and easier maintenance.

Consider adding an auxiliary spillway, additional embankment height, or both as needed to help protect the embankment, particularly for systems that store large volumes of runoff. Factors such as downstream hazards and receiving waters should be evaluated in this consideration.

Consider adding or including steel reinforcement in slabs that will be scraped; this may prevent vertical displacement at crack locations.

Consider placing a permanent marker to designate the empty level. This consideration is particularly important for operations considering future herd expansion to WPDES permit size (see Figure 1).

Monitoring and leakage collection systems should be considered for larger waste storage facilities, especially where the site assessment indicates the area is sensitive for groundwater impacts. This is particularly important for operations considering future expansion to WPDES permit size. Components of a designed system may include secondary containment (soil or synthetic), leachate collection, leachate recirculation, monitoring sumps, and/or monitoring wells. See Wisconsin Administrative Code, Chapter NR 141 (NR 141) for regulations concerning monitoring wells.

For exposed liners utilizing HDPE or similar materials that are slippery when wet, consider the use of textured liners or addition of features such as tire ladders that would allow for escape from the waste storage facility.

Consider solid/liquid separation of runoff or wastewater entering impoundments to minimize the frequency of accumulated solids removal and to facilitate pumping and application of the stored waste.

Due consideration should be given to environmental concerns, economics, the overall waste management system plan, and safety and health factors.

Since the economics and risks associated with waste storage facilities are quite high, consider providing the operator with the cost to close the facility. Cost should include removal of the planned sludge accumulation volume and the waste stored at the maximum operating volume.

Consider using well construction logs within ½ mile of the proposed facility, available from the Wisconsin Geologic and Natural History Survey and/or the Wisconsin Department of Natural Resources, which promote understanding of water supply aquifers in the area along with area hydrogeology.

Considerations for Improving Air Quality

Liquid manure storage may result in emissions of volatile organic compounds, ammonia, hydrogen sulfide, methane, nitrous oxide, and carbon dioxide. Solid manure storage may result in emissions of particulate matter, volatile organic compounds, ammonia, carbon dioxide, and nitrous oxide.

To reduce emissions of greenhouse gases, ammonia, volatile organic compounds, particulate matter and odor, other WI NRCS CPSs such as Anaerobic Digester (Code 366), Roofs and Covers (Code 367), Waste Treatment (Code 629), Amendments for Treatment of Agricultural Waste (Code 591), and Composting Facility (Code 317) can be added to the waste management system. Additionally, consider adding the following components: siting of livestock housing or feedlots, manure storage, and land application; biofilters; feed ration additives and adjustments; manure additives, disinfectants, or aeration; incorporation of manure when land-applied; moisture and dust control within livestock housing areas; and dead animal disposal plans.

For additional information on odor abatement, see ASABE EP379.54 April 2012, Management of Manure Odors.

Adjusting pH below 7 may reduce ammonia emissions from the waste storage facility but may increase odor when waste is surface applied, see WI NRCS CPS Nutrient Management (Code 590).

Some fabric and organic covers have been shown to be effective in reducing odors.

Maintain appropriate manure moisture content for solid manure storage facilities. Excessive moisture will increase the potential for air emissions of volatile organic compounds, ammonia, and nitrous oxide, and may lead to anaerobic conditions, which will increase the potential for emissions of methane and hydrogen sulfide. Too little moisture will increase the potential for particulate matter emissions.

PLANS AND SPECIFICATIONS

Prepare plans and specifications that describe the requirements for applying the practice to achieve its intended use. As a minimum, include the following in the engineering plans and specifications:

- Plan view of system layout.
- Minimum of two cross sections, perpendicular to each other, for each waste storage facility.
- Structural details of all components, including reinforcing steel, type of materials, thickness, anchorage requirements, and lift thickness, sufficient to clearly show the construction requirements.
- Locations, sizes, and type of pipelines and appurtenances including a profile of the waste transfer system.
- Requirements for foundation and preparation and treatment, including bedrock treatment.
- Surface Drainage/Grading plan.
- Subsurface drainage details.

- Location of soil test pits within 100 feet of the facility footprint on the plan view, and a summary of soil logs plotted on the cross sections or profile, with subsurface saturation and bedrock elevations marked, if encountered.
- Safety features, roof covers, fencing, ladders, and safety signs.
- Construction site erosion control practices.
- Specifications for materials and installation.
- Vegetative requirements.
- Quantity of materials.
- Approximate location of utilities and notification requirements.
- Other site-specific information necessary to construct the waste storage facility.
- Applicable Wisconsin Construction Specifications.
- Signature of the person responsible for the design, their engineering stamp, NRCS Job Approval or WDATCP Agricultural Engineering Practitioner Certification level, the date, and a statement attesting the plans meet the requirements of this standard and appropriate liner standard(s).

The following information should be included only if applicable to the project:

- Details for joining different liner types or new liners to existing liners.
- Waterstop joint layout for slabs and walls.
- References to components supplied by others (pumps, etc.).
- Identification of borrow source location(s).
- Reclamation plans for borrow area.

Engineering Design Documentation. Prepare engineering design documentation in compliance with the Design Deliverables in the WI NRCS Statement of Work for the WI NRCS CPS Waste Storage Facility (Code 313), and demonstrate that the criteria in the NRCS practice standard have been met. Include all substantiating data, assumptions, computations and analyses in design documentation. The design documentation shall include:

- Management assessment,
- Site assessment,
- Operation and maintenance plan,
- Construction plan,
- Construction Quality Assurance Plan,
- Engineering computations, such as runoff, structural (unless using NRCS Standard Drawings), earthwork quantities, and volumetric computations for sizing of waste storage facility.

Construction Quality Assurance Plan

A construction quality assurance plan is required that describes the type and frequency of testing, items requiring observation, and the documentation required. The plan shall be approved by a person with NRCS Job Approval, WDATCP Agricultural Engineering Practitioner Certification, a Wisconsin registered professional engineer, or staff under the direction and control of the person holding the aforementioned credentials. The construction quality assurance plan shall address all the following items:

- Contact information and responsibilities of key parties (including owner, designer, construction observer, and contractor).
- Pre-construction meeting agenda items (including quality assurance plan, construction plans and specifications, design change procedures, and critical project-specific items).
- Observation and construction verification (including items to be verified, sequencing, layout/staking, notification requirements, and on-site materials testing documentation).
- Items to be noted on as-built plans, job diary, and other certification (attesting) documentation.

OPERATION AND MAINTENANCE

Develop an operation and maintenance plan that is consistent with the purposes of the practice, its intended life, safety requirements, and the criteria for its design. At a minimum, the plan will contain where appropriate:

Include a narrative describing the purpose of the system or structure and how it is intended to operate. This narrative should include design criteria such as number and type of animals, type of waste, type of bedding, days of storage, method for emptying, vehicle sizes intended to operate within or near the system and other pertinent operational information. Include the operational requirements for emptying the storage facility, including the expected storage period. Also include the requirement that waste be removed from storage and utilized at locations, times, rates, and volume in accordance with the overall waste management system plan and WI NRCS CPS Nutrient Management (Code 590).

Manage the stored waste such that it remains below the maximum operating level during normal operating conditions. Include a contingency plan, which shall be implemented when the maximum operating level is reached. The contingency plan shall include how to handle unexpected volumes of wastewater and/or runoff that could cause the system to overflow or negatively impact the liner before scheduled emptying can occur. The contingency plan shall provide for the safe disposition of waste. Include requirements for location and methods of waste removal and emergency disposal.

For impoundments and other liquid storages include an explanation of the staff gauge or other permanent marker to indicate the maximum operating level. For storages where the contents are not visible and a staff gauge would not be visible, such as below a slatted floor, identify the method for the operator to measure the depth of accumulated waste. Include requirements for monitoring the waste level relative to the permanent maximum operating level markers or indicators.

Include a provision for emergency removal and disposition of liquid waste in the event of an unusual storm event that may cause the waste storage facility to fill to capacity prematurely.

If an observation and pumping port is installed, monitor the discharge in the port for flow depth and pollutants. If pollutants are identified, block the gravity outlet and utilize a pump to remove the polluted liquids until the source is identified and repairs can be completed. Pump pollutants to an appropriate location (e.g. pumped back to the structure or spread per a nutrient management plan).

Describe safety issues and procedures/requirements connected with waste storage facilities, including confined spaces. Include additional measures needed to address the fatal or serious inhalation hazards of gases including, but not limited to, hydrogen sulfide (H_2S), carbon dioxide (CO_2), methane (CH_4), and ammonia (NH_3), which may or may not exist where manure gases are generated through the handling of liquid or semi-solid manure through activities such as pumping, mixing, agitating, spreading, or cleaning-out. Agitating open-air manure storage facilities can be especially hazardous when high humidity and low winds may cause hydrogen sulfide gas to reside near the storage.

Include instructions as needed for ventilating confined spaces according to ASABE Standard S607, Venting Manure Storages to Reduce Entry Risk.

Develop an emergency action plan for waste storage facilities where there is a potential for significant impact from breach or accidental release. Include site-specific provisions for emergency actions that will minimize these impacts.

Include a requirement to contact the appropriate regulatory authority for approval prior to storing any off-farm waste material in a waste storage facility that has been constructed using the criteria in this standard.

Include a description of the routine maintenance needed for each component of the facility. Also include provisions for maintenance that may be needed as a result of waste removal or material deterioration and requirements for inspecting and maintaining the structural components and mechanical systems.

Maintain appropriate manure moisture content for solid manure storage facilities. Excessive moisture will increase the potential for air emissions of volatile organic compounds, ammonia, and nitrous oxide, and may lead to anaerobic conditions, which will increase the potential for emissions of methane and hydrogen sulfide. Too little moisture will increase the potential for particulate matter emissions.

REFERENCES

American Society for Testing and Materials. Annual Book of ASTM Standards. Standards D 653, D 698, D 1140, D 1760, D 2487, D 2488, D5084. ASTM, Philadelphia, PA.

American Society of Civil Engineers (ASCE), Minimum Design Loads for Buildings and Other Structures, SEI/ASCE 7-10 or newer version.

American Society of Agricultural and Biological Engineers (ASABE), Standards EP378, EP393, EP379, and EP470.

Manual of Steel Construction, American Institute of Steel Construction.

National Design Specifications for Wood Construction, American Forest and Paper Association.

USDA NRCS. 1992. Agricultural Waste Management Field Handbook. USDA-NRCS, Washington, DC.

USDA NRCS. General Manual. USDA-NRCS, Washington, DC.

USDA NRCS. National Engineering Manual. USDA-NRCS, Washington, DC.

USDA NRCS. National Handbook of Conservation Practices.

USDA NRCS Wisconsin Field Office Technical Guide (FOTG), Section IV, Practice Standards and Specifications.

USDA Soil Conservation Service. 1989. Technical Release Number 74, Lateral Earth Pressures, USDA-SCS, Washington, DC.

Wisconsin Administrative Code, Department of Natural Resources, Chapters NR 141, NR 213, NR 243 and NR 811.

DEFINITIONS

Animal Production Area – Means any part of the livestock operation that is used for the feeding and housing of livestock. This includes the entire animal confinement and feeding area, and any adjacent manure storage areas, raw materials storage areas, and waste containment areas. This does not include pasture and cropland.

Bedrock – The solid or consolidated rock formation typically underlying loose surficial material such as soil, alluvium or glacial drift. Bedrock includes but is not limited to limestone, dolomite, sandstone, shale and igneous and metamorphic rock.

> *Note: Although solid or consolidated bedrock can sometimes be removed with typical excavation equipment, these materials are included in the above definition.*

Clean Water – Water that has not been mixed with manure, wastewater or other contaminants

Conduits to Groundwater – Sinkholes, swallets, fractured bedrock at the surface, mine shafts, non-metallic mines, tile inlets discharging to groundwater, quarries, or depressional groundwater recharge areas over shallow fractured bedrock. Wells were intentionally left out of this NR 151 list.

Confined Space – Confined Space is a space that 1) contains or has the potential to contain a hazardous atmosphere; 2) is large enough and so configured that a person can bodily enter; 3) has limited or restricted means for entry or exit; and 4) is not designed for continuous human occupancy.

Contaminated Runoff – Runoff that has come through or across a barnyard or animal lot or feed storage area. It generally includes the runoff and any manure, sediment, feed, or other material carried in the runoff. It contains lower concentrations of contaminants than leachate from feed or manure.

Control Joints – Control joints, often called contraction joints, are used to control the location of cracks caused by concrete shrinkage during setting and thermal changes. Steel reinforcement is interrupted in control joints with embedded waterstop.

Cultural Resources – Cultural resources are the traces of any past activities and accomplishments of people. They include tangible traces such as historic districts, sites, buildings, structures, historical documents and cemeteries. They also include traces of less tangible objects such as dance forms, aspects of folk-life, cultural or religious practices, and some landscapes and vistas.

Drainage System – Water conveyance measures of specified capacity, location, and material that insure the removal of water to a free outlet.

Effective Height – The difference in elevation between the auxiliary (emergency) spillway crest or the settled top of the embankment if there is no auxiliary spillway and the lowest point in the cross section taken along the centerline of the embankment at existing ground surface.

Flood Prone Areas – These include areas delineated as floodplains on Federal Emergency Management Agency (FEMA) maps, or local floodplain maps as well as areas along perennial streams (blue lines) shown on the United States Geologic Survey quadrangle sheets that may be subject to out of bank flows.

Footprint – This is the horizontal area within the perimeter of a facility liner, or the perimeter of a work surface that may cover a liner. For a liquid or solids containment facility, the footprint is the maximum horizontal extent of containment. For a liquid impoundment facility or pond, the footprint is normally defined by the inside top of the embankment. For a solids storage facility, the footprint is normally defined by the edge of the pad, the curb on a pad, or the inside surface of bunker walls.

Gleyed Soil – A soil condition resulting from prolonged soil saturation, which is manifested by the presence of grayish, bluish or greenish colors through the soil matrix. Gleying occurs under reducing conditions, by which iron is reduced predominantly to the ferrous state.

Impoundment – A waste storage facility constructed of an earthen embankment(s) (which is lined) and/or excavations for the purpose of storing waste. The impoundment, below the existing ground, may be lined or unlined if meeting CPS 313, Table 1 Soils (In Place).

Impoundment depth – Depth is the distance from the bottom of the impoundment up to the maximum operating level (M.O.L.).

In-Place Earth – A waste storage facility impoundment where the entire bottom surface is sited where in-situ soils have sufficiently low hydraulic conductivity to provide waste storage without a constructed liner. The bottom is excavated a minimum depth of one foot into the in-situ soils as measured from the planned floor elevation.

Karst features – Refers to areas of land underlain by carbonate bedrock (limestone or dolomite). Typical land features in karst areas include sinkholes, network of interconnected fissures, fractures, disappearing streams, closed depressions, blind valleys, caves, and springs. See the companion document in Chapter 10 of the AWMFH for additional discussion of karst features.

Leachate – Concentrated liquid waste which has percolated through or drained by gravity from a pile of manure, manure processing derivative, or animal feed. It contains much higher concentrations of contaminants than Contaminated Runoff.

Liquid Waste Storage Impoundment – A facility where the stored material does not consistently stack and is either a manmade excavation, or diked area formed primarily of earthen materials, such as soil (although the unit may be lined with earthen or manmade materials) .

Manure Processing Derivatives – The by-products and waste components that are produced as a result of treatment and processing practices. These include, but are not limited to, the following waste components: separated sand, separated manure solids, precipitated manure sludges, supernatants, digested liquids, composted biosolids, process waters.

Nutrient Management Plans – A planning document that outlines the requirements for managing the amount, form, placement, and timing of applications of plant nutrients to cropland.

Perched Conditions – A soil moisture condition consisting of limited area including 1) saturated soil 2) depleted, gleyed or reduced matrices or, 3) reduced redoximorphic features, located above or part of a barrier to downward flow. Directly below the barrier to downward flow and above the normal free water elevation a soil moisture condition exists in a soil layer(s) which does not display 1) saturation; 2) depleted, gleyed or reduced matrices; or 3) reduced redoximorphic features.

Percent Fines (% Fines) – Percentage of given sample of soil which passes through a #200 sieve.

Permeability – The coefficient of permeability (K) is a measure of the ability of soil to transmit liquids. It is used to compute the flow rate of liquid through a soil liner for specific conditions of soil thickness and fluid head (e.g., 1x10-7 cm/s).

Plasticity Index (PI) – A soil property indicating moldability. Measured by ASTM D4318.

Sinkholes – Closed, usually circular depressions which form in karst areas. Sinkholes are formed by the downward migration of unconsolidated deposits into solutionally enlarged openings in the top of bedrock.

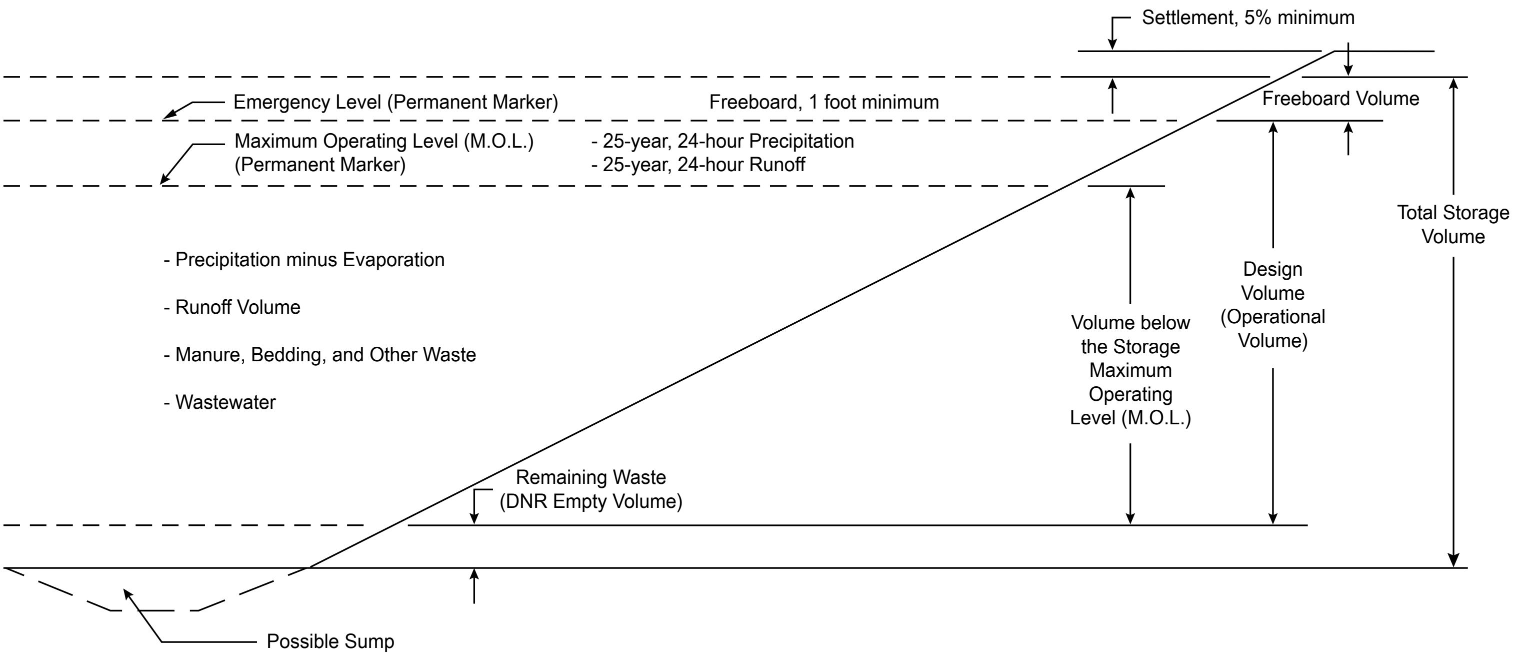
Structure – A waste storage facility consisting of constructed surfaces, tanks, or walls for the purpose of storing waste above or below the ground surface. Structures may be constructed of concrete, steel, wood or other construction materials.

Sub-Liner Soil – The soil directly below the bottom of the liner. This may be placed or in-situ material.

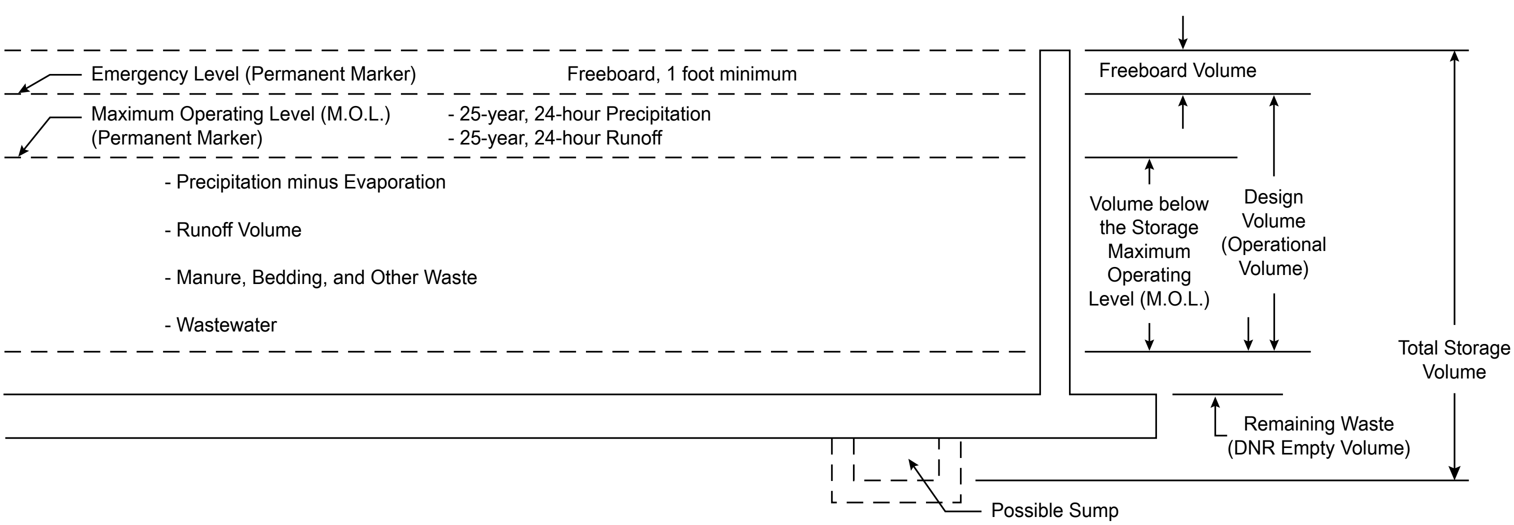
Sub-Soil – The soil directly below the bottom of the liner. This must be in-situ material.

Wastewater – Milking center waste, flush water, leachate from feed holding areas, and similar waste materials generated at the animal production area.

FIGURE 1
Design Storage Volume



IMPOUNDMENT



STRUCTURE

WISCONSIN CONSTRUCTION SPECIFICATION

300. CLAY LINER

1. SCOPE

The work shall consist of:

1. Construction of a clay liner as shown on the construction plans.
   or
2. Re-compaction of the upper one foot of clay material specific to WI NRCS Conservation Practice Standard (WI CPS) 313 Table 1.

2. CLAY LINER MATERIAL

Clay liner material shall have a minimum plasticity index of 12 ($PI \geq 12$) and a minimum percentage passing the No. 200 sieve (P_{200}) as specified in the construction plans. The clay liner material shall be capable of providing a liner with a maximum hydraulic conductivity (permeability) of 1×10^{-7} centimeters per second.

Proposed liner material properties shall be determined in the lab prior to placement for each different borrow area and material, at the specified minimum frequency shown in Table 1. These tests are typically done in the design phase with additional tests required when unpredicted changes in borrow material are observed.

A standard or modified proctor test density curve, and optimum moisture, shall be developed from the borrow materials. A hydraulic conductivity (permeability) shall be determined on a re-compacted sample. The sample shall be re-compacted to the minimum density and moisture content specified in Section 6, Compaction.

Table 1 Borrow Material Testing

Test Reference	**Minimum Frequency**
Standard Proctor (ASTM D 698) or Modified Proctor (ASTM D 1557)	1 per 5,000 cubic yards of estimated in-place liner quantity
Atterberg Limit (ASTM D 4318) and Percent Fines (ASTM D 1140)	1 per 5,000 cubic yards of estimated in-place liner quantity
Permeability (ASTM D 5084)	1 per 5,000 cubic yards of estimated in-place liner quantity

3. FOUNDATION PREPARATION

Foundation surfaces shall be graded to remove surface irregularities and shall be scarified or otherwise acceptably scored or loosened to a minimum depth of 2 inches. The moisture content of the loosened material shall be controlled as specified for the clay liner. The surface materials of the foundation shall be compacted and bonded with the first layer of the clay liner as specified for subsequent layers of clay liner.

4. PLACEMENT

The clay liner shall not be placed until the required foundation preparation has been completed and the foundation has been inspected and approved by the Technician or Engineer. The clay liner shall not be placed upon a frozen surface, nor shall snow, ice, or frozen material be incorporated in the clay liner.

Clay materials shall contain no sod, brush, roots, frozen soil, or other perishable materials. Rock particles larger than 3 inches shall be removed prior to compaction of the clay.

The clay liner shall be placed in lifts. The thickness of each lift before compaction shall not exceed the smaller of 6 inches or the length of the teeth of the footed compactor used.

The distribution of materials throughout the clay liner shall be essentially uniform, and the clay liner shall be free from lenses, pockets, streaks, or layers of material differing substantially in texture, moisture content, or gradation from the surrounding material.

If the surface of any layer becomes too hard and smooth for proper bond with the succeeding layer, it shall be scarified to a depth of not less than 2 inches before the next layer is placed.

5. CONTROL OF MOISTURE CONTENT

During placement and compaction of the clay liner, the moisture content of the clay being placed shall be maintained above the optimum moisture as determined by the standard proctor test or modified proctor test.

The application of water to the clay shall be accomplished at the borrow areas in-so-far as practicable. Water may be applied by sprinkling the clay after placement and before compaction of the liner, if necessary. Uniform moisture distribution shall be obtained by disking.

6. COMPACTION

The clay liner shall be compacted to a minimum of 95% of standard proctor dry density or to a minimum of 90% of modified proctor dry density.

The clay liner shall be compacted with a footed compactor weighing at least 25,000 pounds, operated continuously over the clay material.

7. REWORKING OR REMOVAL AND REPLACEMENT OF DEFECTIVE LINER

Clay liner placed at densities lower than the specified minimum density or at moisture contents lower than the optimum moisture content or otherwise not conforming to the requirements of the specifications shall be reworked to meet the specifications or removed and replaced. The replacement clay material and the fill surfaces upon which it is placed shall conform to all requirements of this specification for foundation preparation, approval, placement, moisture control, and compaction.

8. TESTING METHOD SPECIFICATIONS

- ASTM D 698 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3 (600 kN-m/m^3))
- ASTM D 1557 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3 (2,700 kN-m/m^3))
- ASTM D 4318 Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
- ASTM D 1140 Standard Test Methods for Amount of Material in Soils Finer than No. 200 (75 μm) Sieve
- ASTM D6938 Standard Test Methods for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)

- ASTM D7698 Standard Test Method for In-Place Estimation of Density and Water Content of Soil and Aggregate by Correlation with Complex Impedance Method
- ASTM D 2937 Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method
- ASTM D 2167 Standard Test Method for Density and Unit Weight of Soil in Place by the Rubber Balloon Method
- ASTM D 1556 Standard Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method
- ASTM D 5084 Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter

9. TESTING FREQUENCY

Clay liner construction shall be tested and documented by a third party engineering or testing firm at the specified minimum frequency shown in Table 2.

Field density tests shall be completed on the compacted in-place clay liner, as the liner is being placed. Atterberg limit and percent fines shall be completed on samples obtained next to the field density test. After the completion of the liner, undisturbed samples shall be taken from the constructed clay liner for permeability verification.

Copies of the test locations and test results (documentation report) shall be provided to the owner to document compliance with this specification.

Table 2 Liner Testing

Test Reference	**Minimum Frequency** (Standard mathematical rounding rules apply)
Field Density (ASTM D 2922, or D 6938, or D 2167, or D 1556 or ASTM D 7698)	1 test per 500 cubic yards of in-place liner, distributed throughout the structure (Horizontally and Vertically)
Atterberg Limit (ASTM D 4318) and Percent Fines (ASTM D 1140)	1 test per 2000 cubic yards of in-place liner
Permeability (ASTM D 5084)	1 per 5,000 cubic yards of in-place liner (2 minimum per facility)[1]

1. At least one of these tests should be obtained from the side slope of the facility

All undisturbed sample test holes in the constructed clay liner shall be backfilled using powdered bentonite mixed with clay soil used in liner construction and compacted by hand tamping. The clay shall be broken down into clods less than ½ inch in diameter. A minimum of 25% of each backfilled test hole volume shall be occupied by powdered bentonite after backfilling.

WISCONSIN CONSTRUCTION SPECIFICATION 300 CLAY LINER

Addendum A

This addendum clarifies the specification's scope #2. (The re-compacted layer (Upper 1' of soil) required by WI NRCS Conservation Practice Standard (WI CPS) 313, Table 1. All other parts of the Wisconsin Construction Specification 300 Clay Liner apply.

1. RE-COMPACTED CLAY MATERIAL

   Re-compacted clay material shall have the same properties and tested for Standard or Modified Proctor, Atterberg Limits, and Percent Fines as specified above in 2. CLAY LINER MATERIAL.

   The clay material may be obtained from any location within the footprint to the proposed waste storage facility.

2. FOUNDATION PREPARATION

   The facility shall be excavated 12 inches below the designed bottom elevation. The surface shall be scarified or otherwise acceptably scored or loosened to a minimum depth of 2 inches. The moisture content of the loosened material shall be controlled as specified above in 5. CONTROL OF MOISTURE CONTENT. The foundation materials shall be compacted and bonded with the first clay material lift.

3. PLACEMENT

   The first clay material lift shall not be placed until the required foundation preparation has been completed and the foundation has been inspected and approved by the Technician or Engineer.

   The re-compacted layer shall be placed in lifts. The thickness of each lift before compaction shall not exceed the smaller of 6 inches or the length of the teeth of the footed compactor used. The placement and compaction process continues until the specified elevation has been achieved.

   The re-compacted layer shall then be tested and documented by a third party engineering or testing firm at the specified minimum frequency shown in Table 2 for Field Density, Atterberg Limits, and Percent Fines.