Construction Quality Assurance for Recompacted Clay Liners (RCLs)

IOWA DEPARTMENT OF NATURAL RESOURCES

Leading Iowans in Caring For Our Natural Resources

Introductions

- Brian Rath, P.E.
- Mike Smith, P.E.

Purpose of Workshop

- To help ensure proper construction of recompacted clay liner (RCL) using field testing (quality control), validation testing or checks (quality assurance), and documentation.
- Learn how to apply the DNR's expectations for testing, monitoring, and documenting compacted clay liners.
- Provide a refresher on regulatory requirements for daily documentation, construction quality assurance plans, and construction observation reports.

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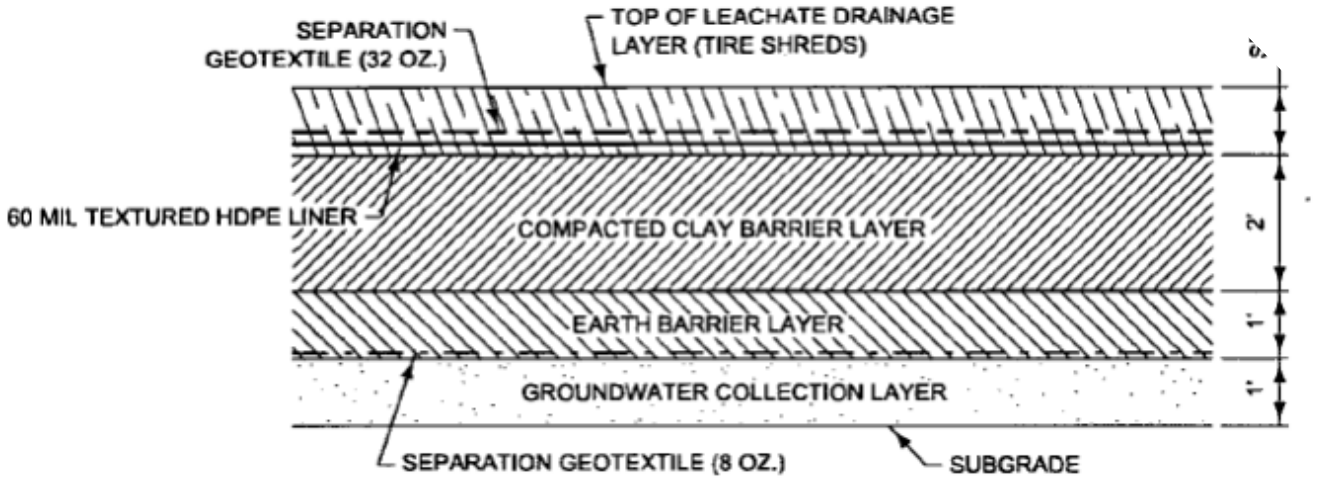
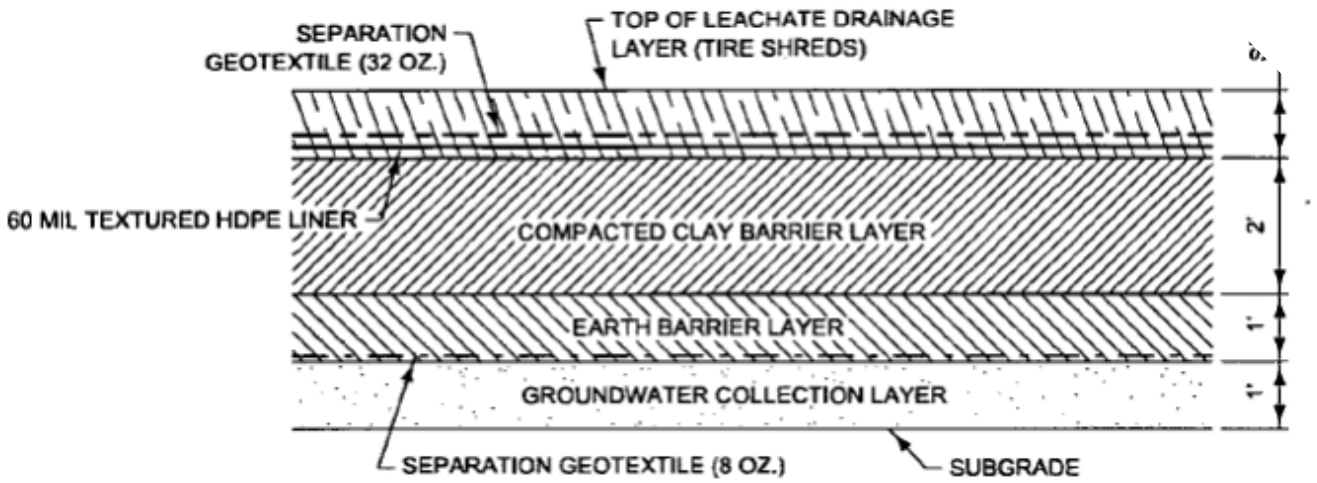
Design Requirements

- Stable Subgrade
- Groundwater Underdrain - 5-foot separation distance from the bottom of the waste
- Recompacted Clay Liner (RCL) - 24 inches of compacted soil with hydraulic conductivity (aka perm) that is less than or equal to 1x10E-7 cm/sec
  - Alternative: Insufficient quantity of low permeability soil, then consider a Geosynthetic Clay Liner (GCL)

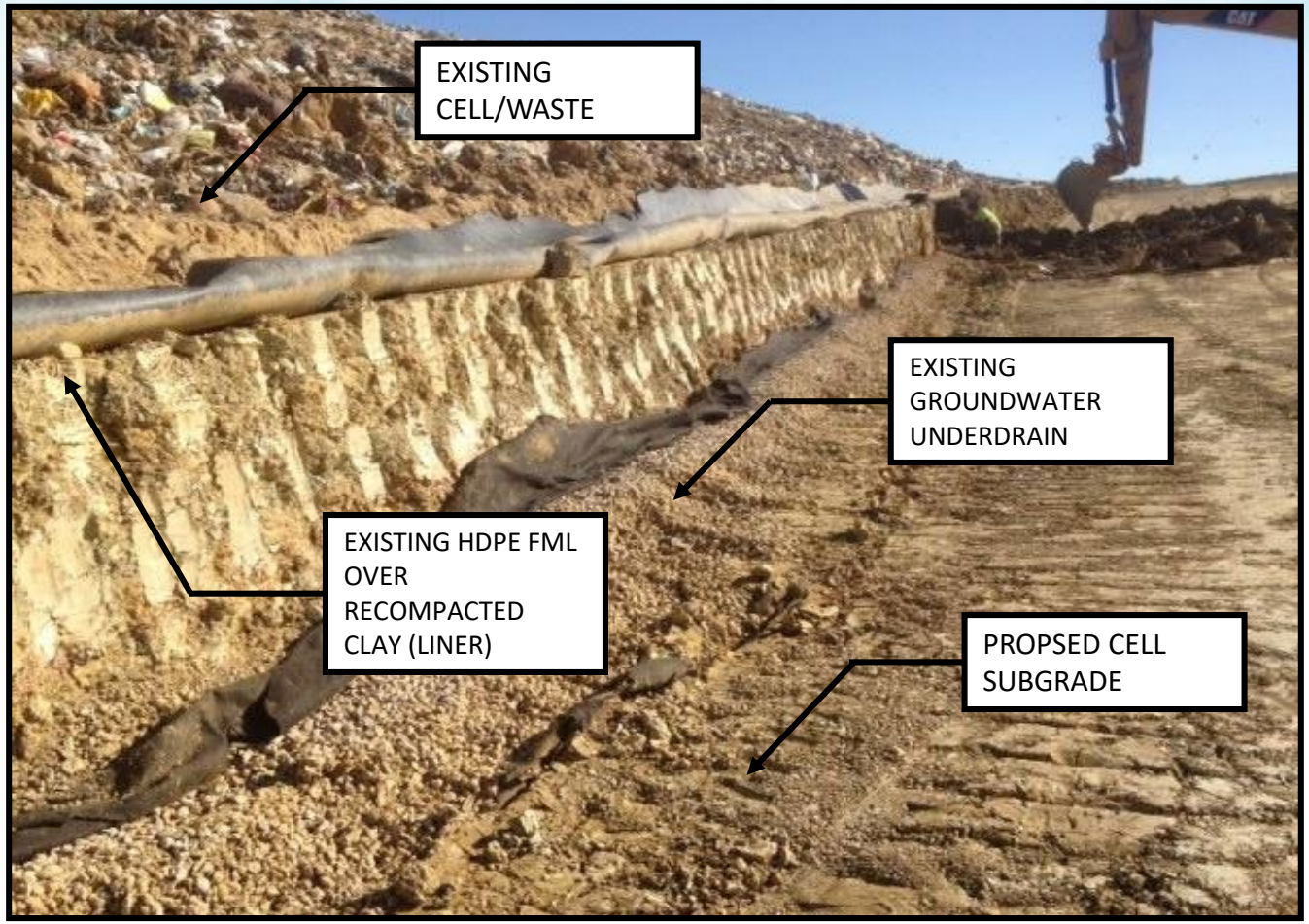


Design Requirements cont.

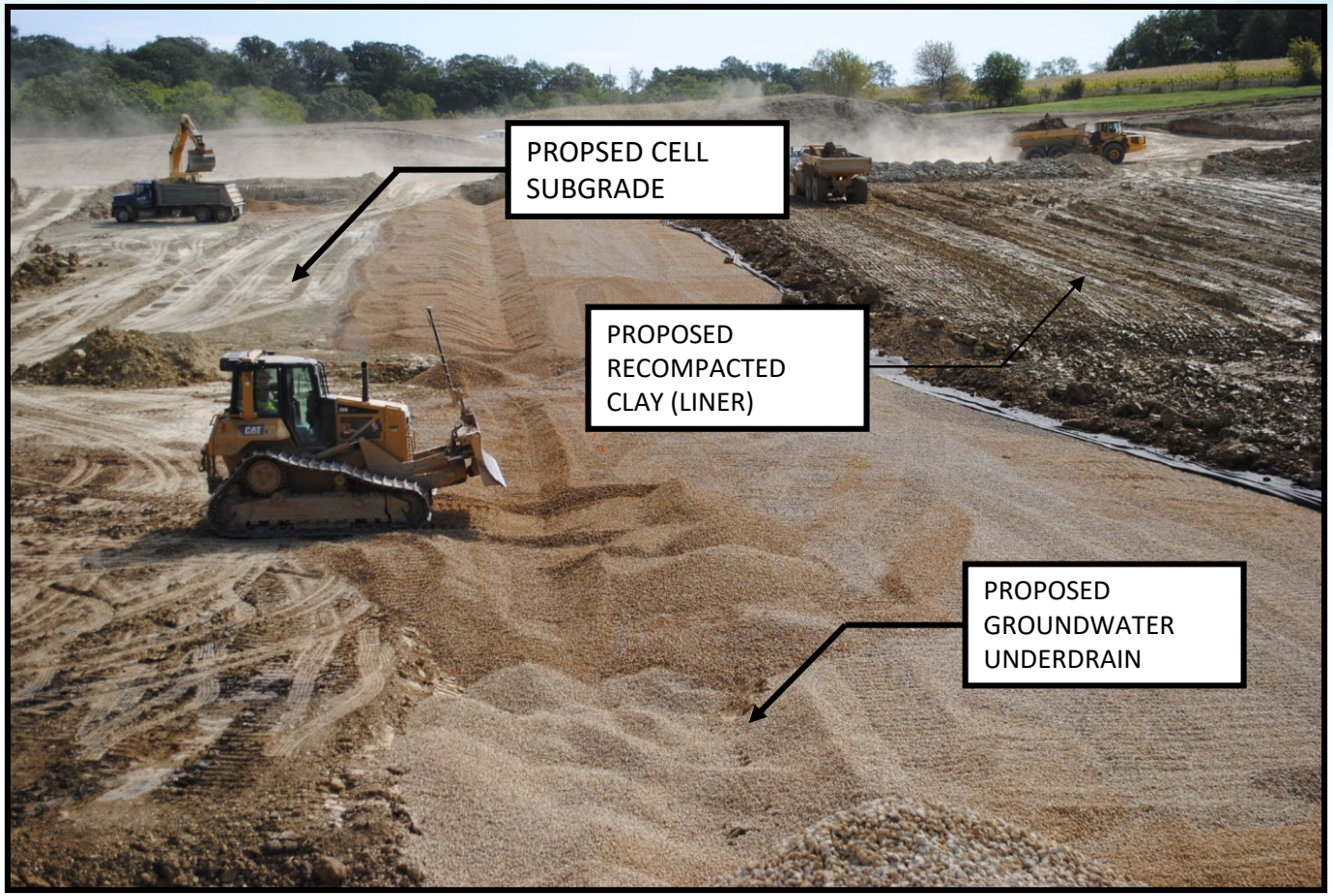
- Leachate Drainage Layer – Aggregate or other approved material that is equal to or greater than 1x10E-2 cm/sec
  - Protective geotextile between FML and drainage layer if not using sand
- Flexible Membrane Liner (FML) - 60-mil high-density polyethylene (HDPE)



Construction



Construction cont.



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Construction cont.

Quality Control and Assurance (QC&A) Programs

- Iowa Administrative Code (IAC) Chapter 567-113.7 – MSWLF unit design and construction standards
  - 113.7(6) Quality control and assurance (QC&A) programs. “to ensure that MSWLF units are constructed in accordance with the requirements of rule 113.7(455B) and the approved plans and specifications. At a minimum, such a QC&A program shall consist of the following. ”
    - Designate a QC&A officer – Professional engineer (P.E.) registered in Iowa.
    - Document compliance with 113.7.
    - Implement a sampling and testing program.
    - Submit a final report that verifies compliance.

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Quality Control and Assurance (QC&A) Programs cont.

- Document compliance with 113.7.
  - Subgrade
  - Liner system
  - Leachate Collection System
  - Any other aspect of construction as required by the department.

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Quality Control and Assurance (QC&A) Programs cont.

- Implement a sampling and testing program
  - Verify compliance
  - Approved by the department
  - Detail how each stage of construction will be verified for compliance
  - Establish criteria for acceptance or rejection based on statistically significant sampling.
  - Actions taken to remedy non-compliance.

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Quality Control and Assurance (QC&A) Programs cont.

- Submit a final report that verifies compliance.
  - Title page and index
  - Facility information
  - Contact information for QC&A officer and delegates, contractors, etc.
  - Daily reports
  - As-built drawings and photographic evidence
  - Statement of compliance, signed and sealed by QC&A officer

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RCL QC&A: Project Soils

- Identify potential borrow soils (one or more) and collect samples. [Field]
- Determine the soil type and develop a Proctor curve for each soil. [Lab]
- Test each soil for hydraulic conductivity (i.e. perm test). [Lab]

RCL QC&A: Project Soils cont.

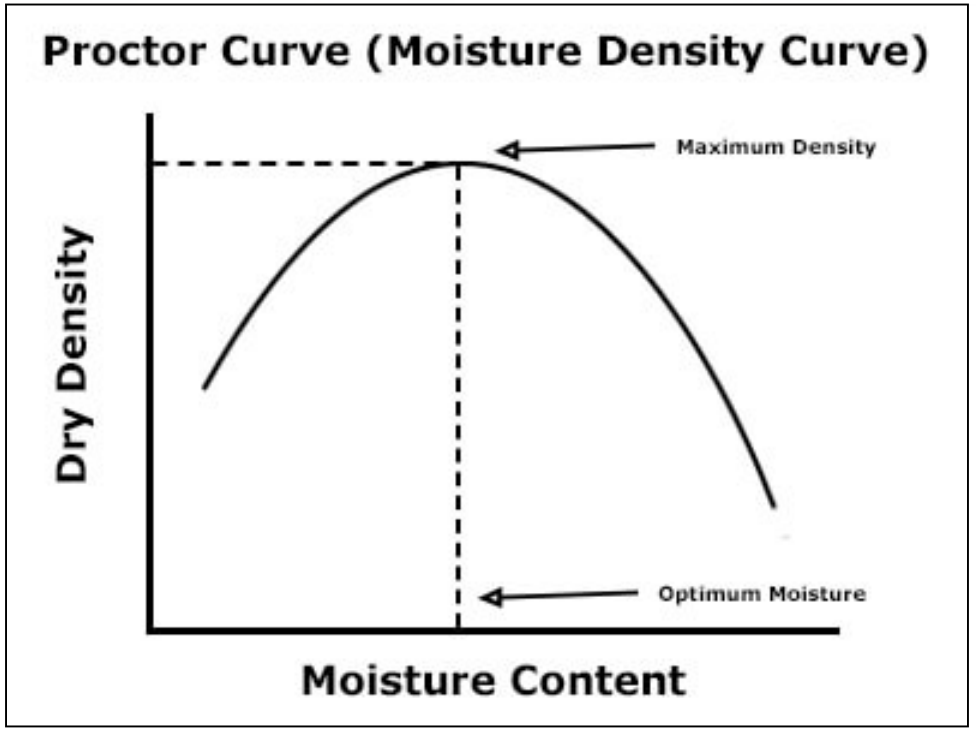
Lab Considerations

- QC&A Officer works with the lab to provide a framework of what is a suitable soil is.
  - Not just based on the required hydraulic conductivity (1xE-7 cm/sec), but also other relevant geotechnical/engineering criteria such as shear strength.
  - These may eliminate a soil from consideration before performing a Proctor or before performing the perm test.

RCL QC&A: Project Soils cont.

Lab Considerations cont.

- Proctor



RCL QC&A: Project Soils cont.

Lab Considerations cont.

- Perm test criteria
  - Generally, engineers specify 95% of the maximum dry density as the minimum field density. Ex. Compact to at least 95% of the maximum standard Proctor density, and…
  - Also, engineers usually start near optimum moisture content and go wetter in their specifications. Ex. ...a moisture of 0% to +3% of optimum Proctor moisture.
  - What moisture and density do you use for the test?

RCL QC&A: Project Soils cont.

Lab Considerations cont.

- Perm test criteria
  - Generally, engineers specify 95% of the maximum dry density as the minimum field density. Ex. Compact to at least 95% of the maximum standard Proctor density, and…
  - Also, engineers usually start near optimum moisture content and go wetter in their specifications. Ex. ...a moisture of 0% to +3% of optimum Proctor moisture.
  - What moisture and density do you use for the test? Run initial perm tests at 95% of maximum density and at 0% moisture.

Example 1

Proctor		Project Specifications	
ASTM D 698-91 A		95% of standard Proctor density	
		0% to +3% of optimum moisture	
Sample	1		
Maximum Dry Density	120.7 pcf	x 95% = Min. Density	114.7 pcf
Optimum Mosture	11.6%	+0% = Min. Moisture	11.6%
Description	Brown	+3% = Max. Moisture	14.6%
Sample	2		
Maximum Dry Density	121.9 pcf	x 95% = Min. Density	115.8 pcf
Optimum Mosture	11.8%	+0% = Min. Moisture	11.8%
Description	Gray, stiff	+3% = Max. Moisture	14.8%

Example 1 cont.

Hydraulic Conductivity		
ASTM D5084-90		
	Sample	1
	Initial Dry Unit Weight	114.7 pcf @ 95%
	Intial Moisture	12.3% @ +0.7%
	Hydraulic Conductivity	1.05E-08 cm/sec
	Sample	2
	Initial Dry Unit Weight	115.8 pcf @ 95%
	Intial Moisture	12.0% @ +0.2%
	Hydraulic Conductivity	5.10E-08 cm/sec

Example 1 cont.

Hydraulic Conductivity		
ASTM D5084-90		
	Sample	1
	Initial Dry Unit Weight	114.7 pcf @ 95%
pass	Intial Moisture	12.3% @ +0.7%
	Hydraulic Conductivity	1.05E-08 cm/sec
	Sample	2
	Initial Dry Unit Weight	115.8 pcf @ 95%
	Intial Moisture	12.0% @ +0.2%
	Hydraulic Conductivity	5.10E-08 cm/sec

RCL Quality Control

Code Requirements

- 5 moisture-density tests/lift/acre.
- 24 inches total thickness.
- Stability.
- Less than 1E-7 cm/sec

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RCL Quality Control cont.

- Prepare
- Communicate
- Document
- Test
- Document and Communicate
- Retest/resolve non-compliance
- Document and Communicate
- Repeat

RCL Quality Control cont.

QC&A Officer Preparations

- Student of QC&A Program, plans and specifications, and IAC 113.
- Gather all forms, tools, documents, supplies, etc.
  - Don’t forget copies of maps to document the test locations.
- Know your Workflow
  - Line of communication.
  - Photo documentation.
    - Location, direction facing, date, time, description.
  - Testing requests, documentation, checks, and communication procedures.
  - Failure/retesting process.
  - Daily Reports

RCL Quality Control cont.

Contractor Inputs

- Equipment choice: Lift thickness is based on equipment capability.
- Construction sequence, including borrow and RCL areas as well as lifts.

RCL Quality Control cont.

Field Testing

- Identify the soil in the field with the appropriate lab reports.
- Determine the number of tests needed per lift in each area contractor will work based on planned lift thickness.
- Utilize a test numbering and documentation system to account for tracking by lift, area, soil type, retest, etc.

RCL Quality Control cont.

Field Testing cont.

- Moisture-Density Testing
  - Pitfall #1

Example 2

Proctor Number	Max. Dry Density (pcf)	Optimum Moisture %
1	120.7	11.6
2	121.9	11.8

Pass?

Date	Test Number	Lift Number	Proctor	Dry Density (pcf)	Moisture Content, %	% Maximu Dry Densit	+/- Optimum Moisture
4/23/2024	100	1	2	122.1	12.4	100.2	0.6
	101	1	2	116.3	14.1	95.4	2.3
	102	1	2	123.9	12.0	101.6	0.2
	103	1	2	119.6	14.2	98.1	2.4
	104	1	1	123.2	11.6	102.1	0.0
	105	1	1	117.9	12.2	97.7	0.6
	106	1	2	124.0	12.6	101.7	0.8
	107	1	2	118.3	11.8	97.0	0.0
	108	1	2	116.3	12.7	95.4	0.9
	109	1	2	121.4	12.6	99.6	0.8
	110	1	2	118.1	14.0	96.9	2.2

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Example 2 cont.

Proctor		Project Specifications	
ASTM D 698-91 A		95% of standard Proctor density	
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Sample	1		
Maximum Dry Density	120.7 pcf	x 95% = Min. Density	114.7 pcf
Optimum Moisture	11.6%	+0% = Min. Moisture	11.6%
Description	Brown	+3% = Max. Moisture	14.6%
Sample	2		
Maximum Dry Density	121.9 pcf	x 95% = Min. Density	115.8 pcf
Optimum Moisture	11.8%	+0% = Min. Moisture	11.8%
Description	Gray, stiff	+3% = Max. Moisture	14.8%

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Example 2 cont.

Proctor Number	Max. Dry Density (pcf)	Optimum Moisture %
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	102	1	2	123.9	12.0	101.6	0.2
	103	1	2	119.6	14.2	98.1	2.4
	104	1	1	123.2	11.6	102.1	0.0
	105	1	1	117.9	12.2	97.7	0.6
	106	1	2	124.0	12.6	101.7	0.8
	107	1	2	118.3	11.8	97.0	0.0
	108	1	2	116.3	12.7	95.4	0.9
	109	1	2	121.4	12.6	99.6	0.8
	110	1	2	118.1	14.0	96.9	2.2

Field dry density > 115.8 or 95%, so it passes on density.

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Example 2 cont.

Proctor Number	Max. Dry Density (pcf)	Optimum Moisture %
1	120.7	11.6
2	121.9	11.8

Date	Test Number	Lift Number	Proctor	Dry Density (pcf)	Moisture Content, %	% Maximu Dry Densit	+/- Optimum Moisture
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	103	1	2	119.6	14.2	98.1	2.4
	104	1	1	123.2	11.6	102.1	0.0
	105	1	1	117.9	12.2	97.7	0.6
	106	1	2	124.0	12.6	101.7	0.8
	107	1	2	118.3	11.8	97.0	0.0
	108	1	2	116.3	12.7	95.4	0.9
	109	1	2	121.4	12.6	99.6	0.8
	110	1	2	118.1	14.0	96.9	2.2

Field moisture is between 11.8 and 14.8, so it passes on moisture.

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Example 2 cont.

Hydraulic Conductivity		
ASTM D5084-90		
	Sample	1
	Initial Dry Unit Weight	114.7 pcf @ 95%
	Initial Moisture	12.3% @ +0.7%
	Hydraulic Conductivity	1.05E-08 cm/sec
	Sample	2
	Initial Dry Unit Weight	115.8 pcf @ 95%
	Initial Moisture	12.0% @ +0.2%
	Hydraulic Conductivity	5.10E-08 cm/sec

Example 2 cont.

Proctor Number	Max. Dry Density (pcf)	Optimum Moisture %
1	120.7	11.6
2	121.9	11.8

Field density is more than perm density, but field moisture is less than perm moisture.

Date	Test Number	Lift Number	Proctor	Dry Density (pcf)	Moisture Content, %	% Maximu Dry Densit	+/- Optimum Moisture
4/23/2024	100	1	2	122.1	12.4	100.2	0.6
	101	1	2	116.3	14.1	95.4	2.3
	102	1	2	123.9	12.0	101.6	0.2
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	104	1	1	123.2	11.6	102.1	0.0
	105	1	1	117.9	12.2	97.7	0.6
	106	1	2	124.0	12.6	101.7	0.8
	107	1	2	118.3	11.8	97.0	0.0
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Example 2 cont.

Proctor Number	Max. Dry Density (pcf)	Optimum Moisture %
1	120.7	11.6
2	121.9	11.8

Field density is more than perm density, but field moisture is less than perm moisture.

Fail!

Date	Test Number	Lift Number	Proctor	Dry Density (pcf)	Moisture Content, %	% Maximu Dry Densit	+/- Optimum Moisture
4/23/2024	100	1	2	122.1	12.4	100.2	0.6
	101	1	2	116.3	14.1	95.4	2.3
	102	1	2	123.9	12.0	101.6	0.2
	103	1	2	119.6	14.2	98.1	2.4
	104	1	1	123.2	11.6	102.1	0.0
	105	1	1	117.9	12.2	97.7	0.6
	106	1	2	124.0	12.6	101.7	0.8
	107	1	2	118.3	11.8	97.0	0.0
	108	1	2	116.3	12.7	95.4	0.9
	109	1	2	121.4	12.6	99.6	0.8
	110	1	2	118.1	14.0	96.9	2.2

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RCL Quality Control cont.

Field Testing cont.

- Moisture-Density Testing
  - Pitfall #1 – Passing a test based on compaction specifications only, and not comparing against the perm test.

RCL Quality Control cont.

Field Testing cont.

- Moisture-Density Testing
  - Pitfall #1 – Passing a test based on compaction specifications only, and not comparing against the perm test.
    - Resolution: Field retest of moisture and density following QC&A program. OR If perm moisture and/or density is too far off the project specifications, have the lab do a perm closer to the specs.

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RCL Quality Control cont.

Field Testing cont.

- Moisture-Density Testing
  - Pitfall #2 – Inadequate acceptability zone.
    - Single perm test result for each soil type forces QC&A officer to use the assumption that soils increase in permeability as moisture content decreases and density remains constant. (i.e. if dryer than the perm test, don't know if meets perm or not)

RCL Quality Control cont.

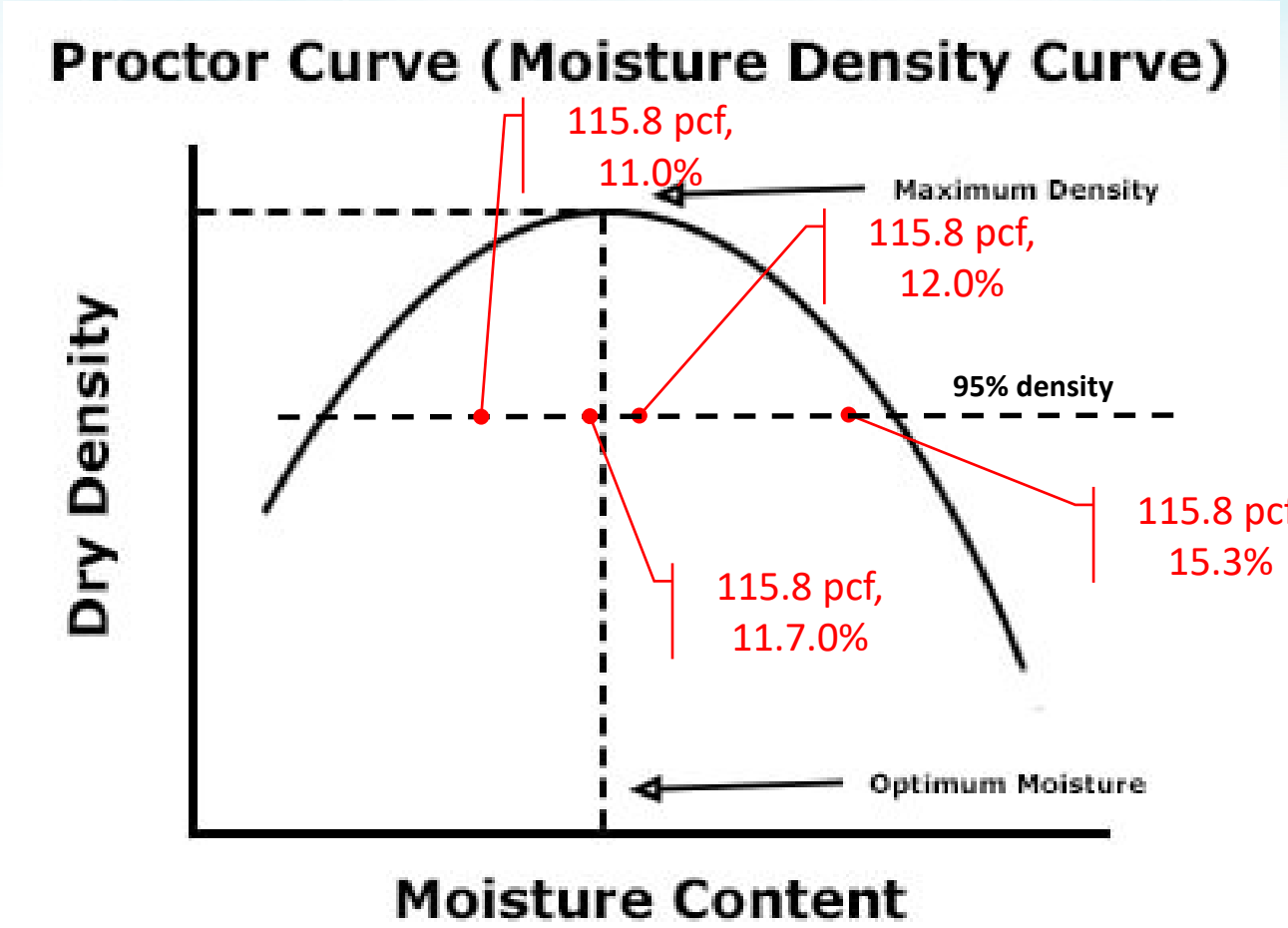
Field Testing cont.

- Moisture-Density Testing
  - Pitfall #2 – Inadequate acceptability zone.
    - Single perm test result for each soil type forces QC&A officer to use the assumption that soils increase in permeability as moisture content decreases and density remains constant (i.e. if dryer than the perm test, don't know if meets per or not).
    - Resolution: Perform perm test at dryer than optimum moisture.

Example 3

Hydraulic Conductivity					
ASTM D5084-90					
Sample	2	Original	Sample	2	Dry
Initial Dry Unit Weight	115.8	pcf @ 95%	Initial Dry Unit Weight	115.8	pcf @ 95%
Initial Moisture	12.0%	@ +0.2%	Initial Moisture	11.0%	@ -0.8%
Hydraulic Conductivity	5.10E-08	cm/sec	Hydraulic Conductivity	4.10E-08	cm/sec
Sample	2	Optimum	Sample	2	Wet
Initial Dry Unit Weight	115.8	pcf @ 95%	Initial Dry Unit Weight	115.8	pcf @ 95%
Initial Moisture	11.7%	@ -0.1%	Initial Moisture	15.3%	@ +3.5%
Hydraulic Conductivity	4.35E-08	cm/sec	Hydraulic Conductivity	7.15E-08	cm/sec

Example 3 cont.



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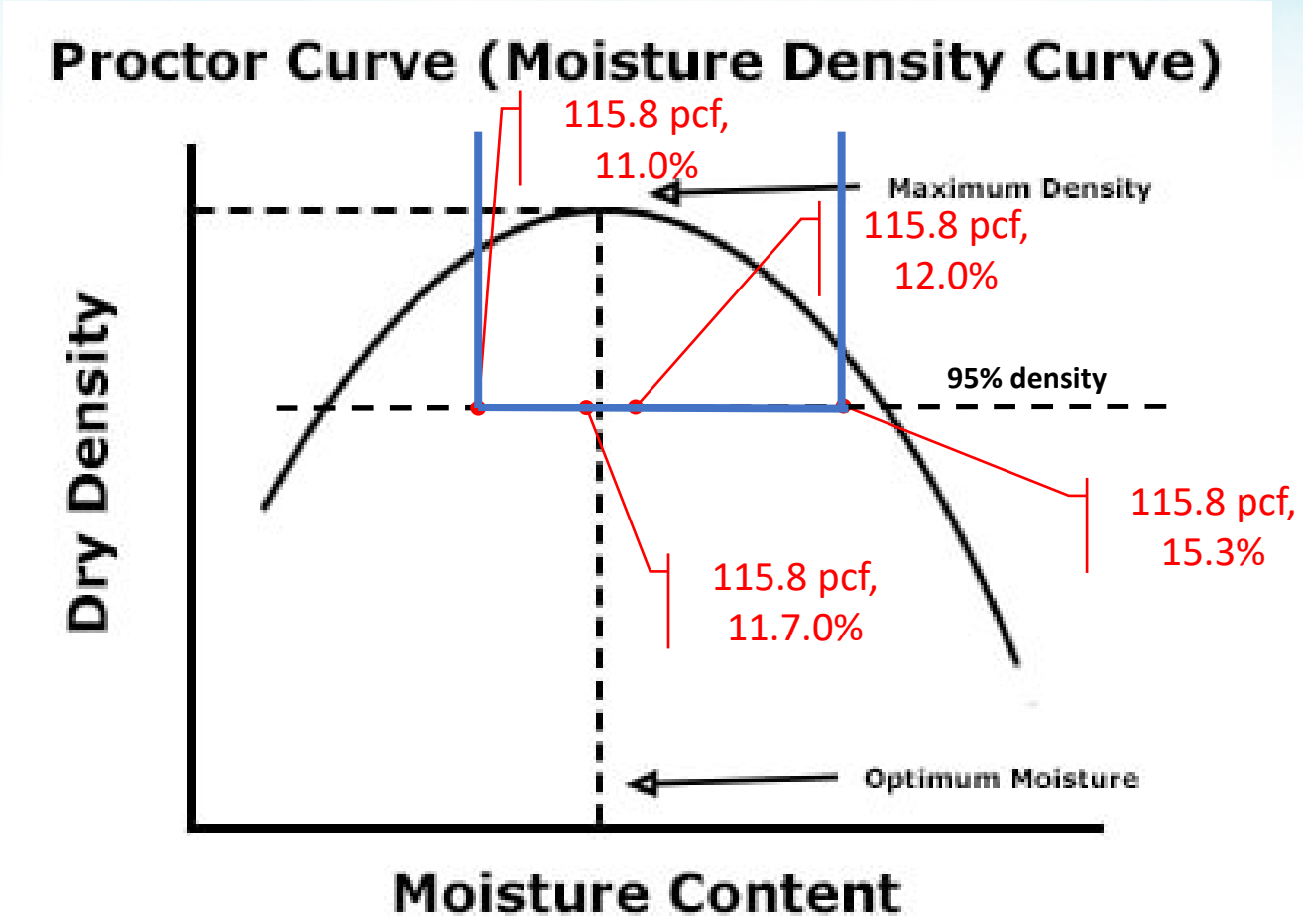
Example 3 cont.



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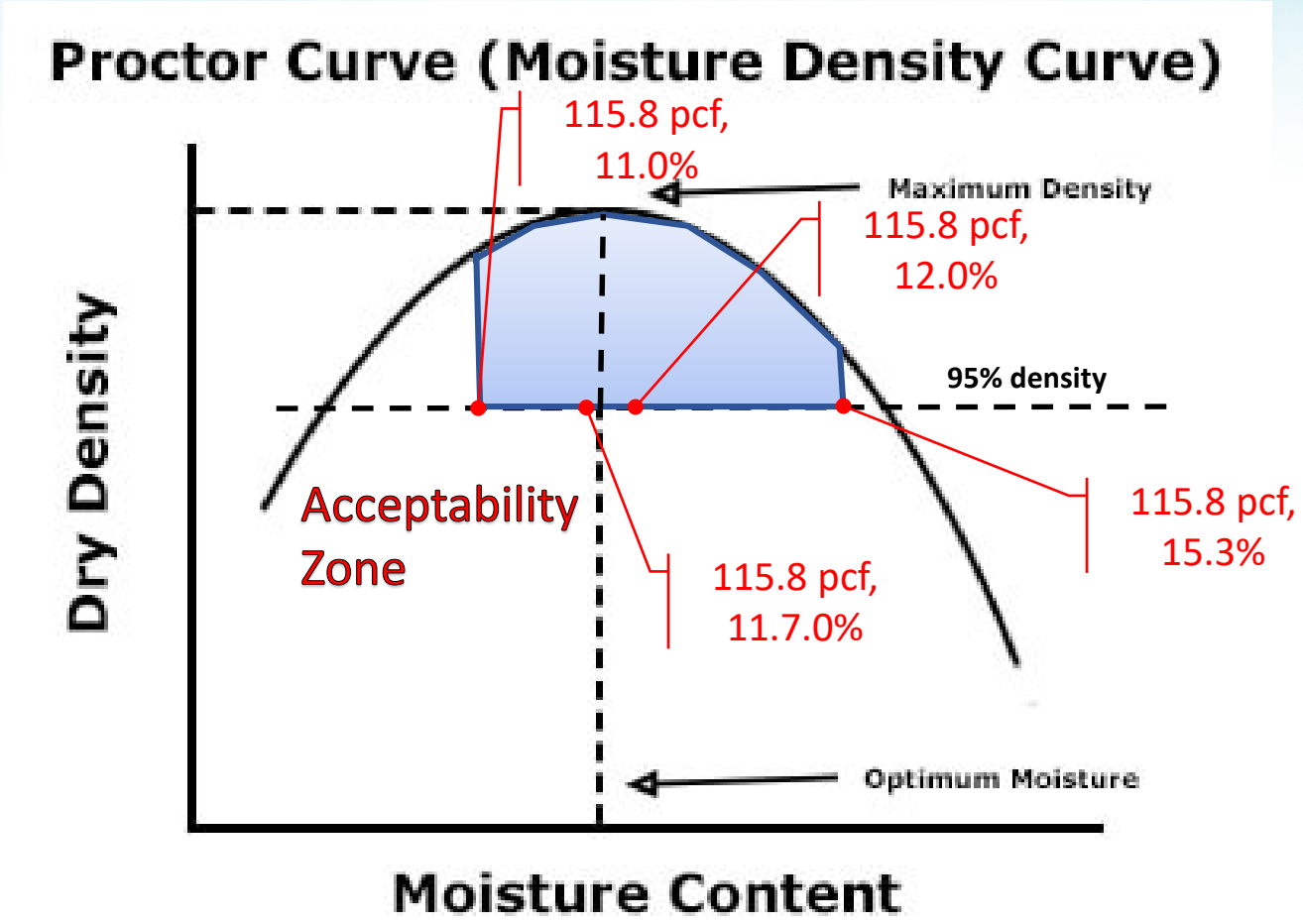
Example 3 cont.



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Example 3 cont.

Proctor Number	Max. Dry Density (pcf)	Optimum Moisture %
1	120.7	11.6
2	121.9	11.8

Test 107 falls within the the acceptability zone.

PASS

Date	Test Number	Lift Number	Proctor	Dry Density (pcf)	Moisture Content, %	% Maximu Dry Densit	+/- Optimum Moisture	Pass
4/23/2024	100	1	2	122.1	12.4	100.2	0.6	Pass
	101	1	2	116.3	14.1	95.4	2.3	Pass
	102	1	2	123.9	12.0	101.6	0.2	Pass
	103	1	2	119.6	14.2	98.1	2.4	Pass
	104	1	1	123.2	11.6	102.1	0.0	Pass
	105	1	1	117.9	12.2	97.7	0.6	Pass
	106	1	2	124.0	12.6	101.7	0.8	Pass
	107	1	2	118.3	11.8	97.0	0.0	Pass
	108	1	2	116.3	12.7	95.4	0.9	Pass
	109	1	2	121.4	12.6	99.6	0.8	Pass
	110	1	2	118.1	14.0	96.9	2.2	Pass

RCL Quality Control cont.

Field Testing cont.

- Other Pitfalls and Considerations
  - Confirm sufficient number of tests per lift
  - Take extra tests
  - Roller/compactor passes
  - Mixing of soils
  - Changing soils
  - Stability
    - Compactor Walkout
    - Proof Roll
    - Pumping
  - Surface desiccation

RCL Quality Assurance

Shelby tube sampling and testing

- Confirmation (i.e. assurance) that required permeability has been achieved.
- Statistical analysis of results is required

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RCL Quality Assurance

Shelby tube sampling and testing

- Confirmation (i.e. assurance) that required permeability has been achieved.
- Statistical analysis of results is required
- Pitfalls and Considerations
  - Start sampling and testing as early as possible
  - Take extra samples
  - Confirm sufficient recovery
  - Check tube and sample ends for damage
  - Document

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Other

- Ensure daily reports have all information required by rule.
- Photos
  - Compliance documentation vs. as-built documentation.
- RCL Thickness Measurement
  - Typically surveyed, except for abutment liners.
- Coordinate with the DNR project officer for timely inspection.

Other cont.

- Double-check
  - Field testing, especially moisture and density pass/fail.
  - Daily reports include failed tests or non-compliance and the resolution.
  - Thickness measurements (early and often).
  - Drainage layer test results: perm and gradation.
  - FML installer documentation.

Discussion

Resources

- Assessment and Recommendations for Improving the Performance of Waste Collection Systems, EPA/600/R-02/099, December 2002.