Tale of Three Projects
Addressing Dam Safety Concerns within the Muskingum River Basin, OH

AEG Annual Meeting
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TALE OF THREE PROJECTS - OUTLINE

A. MUSKINGUM REGION
   1. Project Locations
   2. Project Descriptions
   3. Local Geology

B. DOVER DAM (foundation anchors)

C. BOLIVAR DAM (seepage barrier & grouting)

D. ZOAR LEVEE (risk assessment)
Located in eastern Ohio, within Muskingum River Watershed

System of 16 USACE dams, mostly built in 1930’s, within Muskingum River Watershed for flood control, recreation and water quality

Dam/Levee Reevaluation
- Changing Criteria
- Poor Performance During High-Water Events
- Portfolio of Dams Prioritization based on Risk Assessments
Three Projects

1. Dover Dam: Concrete gravity dam, founded on bedrock, run-of-river

2. Bolivar Dam: Earthen dam, founded mostly on glacial outwash, run-of-river

GEOLOGY

- Near-horizontal sedimentary rock (bedding)
- Pennsylvanian aged Pottsville Group
- Interbedded sandstone, shale, siltstone, claystone with thin seams of coal and limestone
- Typically joints are high angled with smooth and planar surfaces.
- Solutioned discontinuities are common in thin limestone units.
GLACIAL GEOLOGY

- Unglaciated
- Located near the ice margins of Illinoian and Wisconsin glacial periods
- Site geology influenced by glacial lakes and outwash.
- Typically, +100’ proglacial soil deposits within valley bottom.
REGIONAL DRAINAGE
Flowed North Prior to Continental Glaciers
Local Drainage at Zoar Continues to Flow North

Regional Drainage Diverts South
Antilles advances

Alluvium accumulate
**Wisconsin Stage – Glacial Lake**

- Ice blocks drainage and creates lake
- Fine grained lake deposits accumulate
Lake Spills Through Gap in Drainage Divide

- Downcut Erosion Create Narrow Valley at Dover Dam Site
WISCONSIN ICE ADVANCE – LAKE DRAINS

- Bolivar Dam
- Zoar Levee
- Dover Dam

◆ Lake Drains
WISCONSIN ICE ADVANCE – GLACIAL OUTWASH

- Lake Deposits are Partially Eroded
- Glacial Outwash Sands and Gravel are Deposited
Current Drainage Condition

- Glaciers Retreat
- Regional Drainage Now Flows South, Forming Tuscarawas River

Map showing drainage features and layers:
- Bolivar Dam
- Zoar Levee
- Dover Dam

Layers indicated:
- Recent Alluvium (fines)
- Wisconsin Outwash
- Illinoian Outwash
- Lower Alluvium (fine sand)
- Bedrock
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   1. Potential Bedrock Sliding Failure
   2. Rock Anchor Design
   3. Rock Anchor Installation

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D. Zoar Levee (risk assessment)
CONSTRUCTION COMPLETED - 1938
CONCRETE GRAVITY DAM
FOUNDED ON BEDROCK
- 23 MONOLITHS
- 824 FOOT LENGTH
- 338’ SPILLWAY LENGTH
DOVER DAM

- Non-Overflow 931
- Stream Bed 860
- 71’ HEIGHT FROM STREAM BED
- “RUN OF RIVER”
Prior to spillway flow, the dam fails to provide protection against sliding

PMF overtops dam creating downstream erosion and removal of passive wedge

Dam Safety Action Classification II (urgent)
1. Upper Silty Shale
2. Upper Sandstone
3. Shale
4. Upper Mercer Limestone
5. Bedford Coal
6. Lower Silty Shale
7. Lower Mercer Limestone
8. Carbonaceous Shale
9. Middle Mercer Coal/CLS
10. Interbedded Siltstone and Shale
11. Middle Sandstone
12. Interbedded Shales
13. Lower Sandstone
BEDROCK UNITS

Unit #8 Carbonaceous Shale
- 3’-6’ thick
- Dark gray, soft to mod. hard, carbonaceous

Unit #9 Middle Mercer Coal/Claystone
- <1’ thick
- Black, blocky, occ. shaly

Potential sliding failure plane under valley monoliths
POTENTIAL SLIDING FAILURE PLANES
TYPICAL VALLEY MONOLITH
SLIDING ALONG COAL/CLAYSTONE

COAL/CLAYSTONE
phi=16° c=0psi, near horizontal

FAILURE PLANE ALONG PASSIVE WEDGE
phi angle, cohesion and inclination varies

CONCRETE CUT-OFF (key)
Peak = 40° 11psi
Post-peak = 40° 0psi
POTENTIAL SLIDING FAILURE PLANES
TYPICAL VALLEY MONOLITH
SLIDING AT BASE OF CONCRETE CUT-OFF

SHALE INTERBEDS AT BASE OF CUT-OFF
phi=22° c=0 psi, near horizontal

PASSIVE WEDGE
phi, cohesion and inclination varies

forces

flow

Soil

50 U/S 50 D/S 100 D/S 150 D/S 200 D/S

PASSIVE WEDGE
phi, cohesion and inclination varies
POTENTIAL SLIDING FAILURE PLANES
VALLEY MONOLITHS 12 & 13
SLIDING ALONG THRUST FAULT

THRUST FAULT (base of limestone)
\( \phi = 13^\circ \), \( c = 0 \) psi, near horizontal

Low Angle Thrust Fault

CONCRETE CUT-OFF (key)
Post-peak: \( \phi = 40^\circ \), \( c = 0 \) psi
FOUNDATION ANCHOR SYSTEM
PLAN VIEW

- 117 Anchors Original Design
- 20 Anchors Added During Construction
- 137 Total Anchors Installed

<table>
<thead>
<tr>
<th>Symbol</th>
<th># of Anchors</th>
<th>Anchor Size</th>
<th>Anchor Length</th>
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<tr>
<td>▲</td>
<td>9</td>
<td>54 Strands</td>
<td>124’ – 167’</td>
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<tr>
<td>▲</td>
<td>29</td>
<td>48 Strands</td>
<td>120’ – 163’</td>
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<td>37 Strands</td>
<td>119’ – 138’</td>
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<td>19 Strands</td>
<td>103’ – 110’</td>
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<tr>
<td>▲</td>
<td>60</td>
<td>2.5” Bars</td>
<td>63’ – 108’</td>
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</table>
ANCHOER LENGTH
GEOLOGIC CROSS SECTION

- Middle Mercer Coal
- Lower Silty Shale
- Lowest Failure Plane
- Interbedded Silstone and Shale
- Middle Sandstone
- Interbedded Shales
- Lower Sandstone
- Carbonaceous Shale
- Lower Mercer Limestone
- 5’ Below Failure Plane

Monolith M-9
ANCHOOR LENGTH
GEOLOGIC CROSS SECTION

Monolith M-9

Bedrock Engaged by Anchors

Partial Anchor Depth
ANCHOR LENGTH
GEOLOGIC CROSS SECTION

Monolith M-9
ANCHOR EMBEDMENT DEPTH

- Dam Monolith
- Stilling Basin
- 5' Below Failure Plane
- Rock Mass Engaged by Total Force of Anchor Cluster
- Anchor Cluster
CONSTRUCTION

- Phase I was awarded to Brayman Construction Corp in Sep 2010
- Phase II was awarded to Brayman Construction Corp in Sep 2011
- Phase I completed in Aug 2013
- Phase II nearly all work was completed in Dec 2014
- Construction Cost (Phases I & II): approx. $40 million
- Total Number of Anchors: 137
ANCHOR INSTALLATION – ACCESS (Dam)

Platform for Installation of Most Anchors in Dam

DOVER DAM

STILLING BASIN

SOIL NAIL WALL

TYPICAL DAM MONOLITH CROSS SECTION
ANCHOR INSTALLATION – ACCESS (Stilling Basin)

- Contract included in-the-wet construction and bar anchors.
- Contractor proposed dewatering and strand anchors.
ANCHOR INSTALLATION - DRILLING

- Hole Depth: 72’ – 172’
- Hole Diameter: 6” – 19”
- Down Hole Hammer
- Pilot hole drilled then followed by larger diameter bits.
ANCHOR INSTALLATION – HOLE ALIGNMENT

- Drill Tolerance 1:30 – 1:75
- Directional drilling methods used on select holes. Optical readings on pilot hole.
- Maxibor or Bortrak instruments used for alignment check on final hole.
ANCHOR INSTALLATION - WATERTIGHTNESS

- Hydraulic Pressure Tested
- Tremie and Pressure Grouted.
- Minimize excessive grout penetration.
- Many holes required repeated cycles of redrilling, pressure testing and regrouting.
ANCHOR INSTALLATION – ENCAPSULATION

- Double corrosion protection
- Corrugated Tubing: 100 mil thick if ≥ 10”, 60 mil for smaller tubing.
- Water Tested: <2.75 gal in 10 min.
- Grout annulus between corrugated tubing and drilled hole in multiple lifts.

Corrugation
Grout Annulus
ANCHOR INSTALLATION – INSTALL STRANDS

- Number of Strands: 5 - 54
- Inspect and repair smooth polyethylene extruded strands.
- Greased and extruded strands in stressing length.
- Bare strands in bond length.
- First Stage Grouted
ANCHOR INSTALLATION – STRESSING

- Wedge Plate & Bearing Plate

- Design Load: 60% of MUTS
- Test Load: 133% of Design Load
- Lockoff Load: 70% of Design Load
- Proof, Performance and Creep Tests in accordance with PTI.
- Second stage grouted.
ANCHOR INSTALLATION – COMPLETION

- Anchor capped and filled with corrosion inhibiting compound.
- Concrete filled recess designed to match the appearance of the dam surface.
OTHER ASPECTS OF DOVER PROJECT

PARAPET WALL

DRILLED SHAFT FOUNDATION

BEDROCK TIE-IN GATE STRUCTURE

STONE SLOPE PROTECTION
CHALLENGES DURING CONSTRUCTION

- Multiple cycles of redrilling, pressure testing and regrouting anchor hole.
  - Utilized different grout mixes, varied grouting pressures (safely), isolated zones of high grout takes with packers.

- Some anchors slightly exceeded deformation tolerance during creep tests.
  - Extended creep test from 10 min to 60 min (PTI), additional liftoff tests at extended times (24 hrs, 48 hrs, 1 week), account for steel elongation based on elastic modulus of steel.

- Two anchors (48 & 37 strand), during lockoff/liftoff procedures, had several wedges that failed to properly engage, resulting in broken individual wires and complete 7-wire strand failure.
  - Both anchors were replaced and an investigation was completed. Possible cause: wedge geometry, cleanliness of pockets, rust on teeth

- Stilling basin slab concrete was thinner than original drawings.
  - Increased number of smaller anchors (5 strand) used to better distribute load.
Dover Dam

- Construction completed, ribbon cutting ceremony this past spring
- Post Implementation Evaluation is ongoing to assess the reduced risks resulting from dam safety modifications.
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C. BOLIVAR DAM (seepage barrier & grouting)
   1. Seepage Through Soil Foundation
   2. Seepage Wall Construction
   3. Bedrock Abutment Seepage
   4. Grout Curtain Construction

D. Zoar Levee (risk assessment)
BOLIVAR DAM

- Earthen Dam Founded on Glacial Outwash
- Built in 1938
- 6,400’ Dam Length
- 87’ Dam Height (main)
- “Run of River”

POOL OF RECORD – JAN 2005

Intake Structure

Earthen Dam Founded on Glacial Outwash
Built in 1938
6,400’ Dam Length
87’ Dam Height (main)
“Run of River”
SEEPAGE DURING FLOOD EVENTS

- Downstream Dollen
- Rock Toe Seepage
- Terrace Seepage
- Tail Water
- Terrace Piped Sand
SEEPAGE DURING FLOOD EVENTS

Emergency Filter Placement on Terrace

Terrace Foundation Sand Eroded Out

Overflowing relief well nearing inundation by Dover Dam pool

Artesian flow from piezometer even with extension

Flow through open joints in bedrock in left abutment of dam
Onsite Borrow Area for seepage blanket extension/augmentation work – downstream of right abutment
DAM FOUNDATION CHARACTERISTICS

- Risk assessment resulted in actionable failure modes (internal erosion through foundation sands)
- DSAC II rating (urgent)

Continuity of Sand Layer?

Pervious sands, gravels, & cobbles with open work gravel zones as well as thin silt lenses/layers
SEEPAGE REMEDIATION MEASURES

- Seepage Barrier (Ongoing)
- Slope Filters (Complete)
- Downstream Filter Berms (Complete)
- Rehab Relief Wells (Complete)
- ADAS (Ongoing)
Pre Seepage Remediation: There is a direct path of seepage from Sandy Creek into the pervious foundation of the dam. The 1980’s relief wells and blanket are somewhat effective in reducing head, extending the seepage path, and providing resistance to uplift but are not effective at all pool and tailwater conditions and locations below the dam.
Post Seepage Remediation: Seepage exit gradients are greatly reduced downstream of the dam and the potential piping pathway is cut off reducing the risk of failure of the project to an acceptable level.
SEEPAGE BARRIER & GROUT CURTAIN

BARRIER DIMENSIONS
* 4,519 FEET LONG
* UP TO 144 FEET DEEP
* 2 FEET MIN. THICK

SEEPAGE BARRIER

DRILLING AND GROUTING
* 400 FEET LONG GROUT CURTAIN
* AVG DEPTH 65 FEET

GROUT CURTAIN
CONSTRUCTION

- Contract awarded to Treviicos
- Panel method using hydromill with low strength concrete backfill
- Foundation drilling and grouting subcontracted to TerraFirm
- Construction Award Cost: $44 million
- Notice to Proceed Date: May 2014
- Scheduled Completion Date: Feb 2017

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TERRAFIRM
CONSTRUCTION, LLC
8334 Ruby Avenue - Kansas City - Kansas - 66111

SANDY CREEK OF TUSCARAWAS RIVER
BOLIVAR, OH
BOLIVAR DAM

CONSTRUCTION PLANS
SEEPAGE BARRIER

FEBRUARY 2014

TREVIICOS
SOUTH

BUILDING STRONG®
BARRIER WALL CONSTRUCTION - GUIDE WALL

- Prepare temporary work surface
- Install concrete guide walls
- Survey panel locations

SEEPAGE BARRIER – CONCEPTUAL PROFILE ALONG CENTERLINE
(looking upstream - not to scale)
PANEL EXCAVATION - CLAMSHELL

- 3’ Wide Panels (2’ min. specified)
- Initiate panel excavation with clamshell.
- Maintain bentonite slurry level during excavation.

TOP OF BARRIER 959 (varies)

Bentonite Slurry

BENTONITE MIXING DE-SANDING PLANT

CLAMSHELL
PRIMARY PANEL EXCAVATION - HYDROMILL

- 144’ depth (varies)
- 3 & 5 bite primary panels
- Overlapping excavation to assure no gaps between bites

PLAN VIEW – PRIMARY PANEL

- Bite 1
- Bite 2
- Bite 3

BOTTOM OF BARRIER 815

TOP OF BARRIER 959 (varies)

HYDROMILL

CUTTER HEAD

144’ (varies)
SURVEY PANEL ALIGNMENT

- Koden used to measure verticality and panel thickness
- Multiple measurements determine barrier wall alignment

TOP OF BARRIER 959 (varies)

Bentonite Slurry

EL 815'

25' (3 bites) or 30' (5 bites)

PRIMARY PANEL

KODEN
PANEL BACKFILL

- Continuous and homogenous
- Minimum UCS 750 psi at 28 days (based on 10 point moving average with no test below 500 psi)
- Plastic, high slump concrete mix (not specified)
PRIMARY PANEL EXCAVATION

- Drill Mate System measures verticality.
- Adjustments can be made with the hydromill during excavation.
SECONDARY PANEL EXCAVATION & CLEANING

- Koden measurements taken
- Clean sidewalls of bentonite buildup
- Replace bentonite slurry prior to backfill

PLAN VIEW
PRIMARY & SECONDARY PANELS

CLEANING PANEL SIDEWALLS
SECONDARY PANEL BACKFILL

Tremie Placement

PRIMAR Y PANEL
SECONDARY PANEL
PRIMAR Y PANEL
DEMOnstration SECTION

- Verification Drilling with down-hole-camera.
- In-place permeability $\leq 1 \times 10^{-6}$ cm/s at 28 days.
SEEPAGE BARRIER WALL COMPLETION

EL 815’

4,519’ TOTAL LENGTH
GROUT CURTAIN - LOCATION

- APPROXIMATE LOCATION OF GROUT CURTAIN
- EXISTING SPILLWAY SILL GROUT CURTAIN
- SPILLWAY
- STILLING BASIN
- KEYED INTO BEDROCK
- APPROXIMATE LOCATION OF SEEPAGE BARRIER
- LEFT ABUTMENT

BUILDING STRONG®
LEFT ABUTMENT – BEDROCK SEEPAGE

2005 FLOOD EVENT

LOCATION ABOVE STILLING BASIN

1991 FLOOD EVENT
LEFT ABUTMENT – GEOLOGY

- Soil: (colluvium – fines w/ rock frag.) 16’ thick
- Bedrock: Near horizontal, interbedded, sedimentary bedrock
- Two thin (3’-5’ thick) limestone units (Upper and Lower Mercer Limestone)
UPPER AND LOWER MERCER LIMESTONE

- Limestone Units: thin (3’ to 5’ thick), regionally continuous, very hard, high UCS (as high as 32,000 psi).
- Joints: high angle, solutioned, approx. 5’ spacing, joint set at 90°, interconnected, avenues for groundwater flow.
- Bedding planes: low angle, open, solutioned and continuous.
- Exposed in stilling basin and spillway.

OPEN FRACTURES AT SURFACE

DOWN-THE-HOLE CAMERA IMAGES
GROUT CURTAIN – GENERAL INFORMATION

- Double line grout curtain, 10’ spacing between grout lines.
- Grout curtain is approx. 400’ long, 65’ deep with 3” dia. holes
- 20’ Spacing between Primary holes
- All Primary and Secondary holes will be drilled and pressure tested. Higher order grout holes will be split spaced, if needed.
GROUT CURTAIN – GENERAL INFORMATION

- Double line grout curtain, 10’ spacing between grout lines.
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- Downstream grout line hole are mostly inclined 30° toward the spillway

![Diagram of grout curtain and surrounding geology](image)
- Double line grout curtain, 10’ spacing between grout lines.
- Grout curtain is approx. 400’ long, 65’ deep with 3” dia. holes
- 20’ Spacing between Primary holes
- All Primary and Secondary holes will be drilled and pressure tested. Higher order grout holes will be split spaced, if needed.
- Downstream grout line holes are mostly inclined 30° toward the spillway
- Upstream grout line holes are mostly inclined 30° toward the dam/valley
DRILLING THROUGH SOIL & INSTALL CASING

- Hole location and drill mast orientation is surveyed
- Auger drilling method
- Install temporary casing through soil without use of drilling fluids.
- Place grout seal and grout annulus

TYPICAL GROUT HOLE

- Temporary Casing
- Grout Seal
- Soil
  - Top of Rock
  - Top of Ground
- Claystone
- Upper Limestone
- Interbedded SH/SS/Coal
- Interbedded SH/SS/Coal
- Not to Scale

AUGER DRILL RIG

SURVEY

CASING
DRILLING THROUGH BEDROCK

- Drill 3” diameter hole
- Bottom of grout curtain at elev. 924
- Maximum drill length of 115’
- Vertical to 70° from vertical
- Water actuated down-hole hammer
- Hole sidewalls are cleaned
- Bottom of hole deviation magnitude and orientation is measured
PRESSURE TESTING

- Two Zones to treat upper and lower limestone units separately
- Upstage grouting
- Set packer at top of zone
- Pressure is limited during pressure testing and grouting to prevent hydraulic Jacking

PRESSURE TESTING & GROUT CART
GROUTING

- Six balanced stabilized grout mixes
- Computer monitored grouting and pressure testing
- Typically start with thinner mixes and incrementally increase viscosity
- Upstage grouting
- Grouting refusal set at 0.5 gal/min

GROUT MONITORING

GROUT PLANT
DOWNSTAGE GROUTING

- Downstage grouting if significant drill water loss is encountered (+50%), indicating open foundation conditions.

- Stage is pressure tested and grouted prior to deepening the hole.
GROUT RECORDS – UPSTREAM LINE

GROUT PROFILE
(looking downstream)
GROUT TAKES – UPSTREAM LINE

GROUT PROFILE (looking downstream)

- Downstage Grouting

LEGEND

- Soil (colluvium)
- Shale, Siltstone & Coal
- Sandstone
- Limestone
BOLIVAR DAM: SEEPAGE BARRIER & GROUTING

- ONGOING INDEPENDENT EXTERNAL PEER REVIEW
- UPON COMPLETION: POST IMPLEMENTATION EVALUATION

SEEPAGE BARRIER APPROX. 20% COMPLETE

GROUT CURTAIN APPROX. 30% COMPLETE
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   1. Internal Erosion in Soil Foundation
   2. Seepage Wall Construction
   3. Bedrock Abutment Seepage
   4. Grout Curtain Construction

D. ZOAR LEVEE (risk assessment)
   1. Diversion Dam
   2. Rock Knoll - Levee
   3. Ball Field - Levee
ZOAR LEVEE

- Historic Village (est 1817, German separatist, communal lifestyle)
- Located within Dover Pool
- Earthen Embankment Founded Primarily on Glacial Outwash
- Built in 1938
- Levee Raised 9.5’ in 1951
- Poor Performance During Flood Events – DSAC I (after 2008 event)
ZOAR LEVEE – THREE AREAS OF CONCERN

1. Diversion Dam
2. Rock Knoll Reach (Levee)
3. Ball Field Reach (Levee)

Several additional areas of concern are not addressed in this presentation.
ZOAR DIVERSION DAM – AERIAL VIEW

- Embankment Dam
  - Founded on Bedrock
  - 34’ Dam Height
  - Approx 250’ Length

- Emplacement Site
- Seepage collection system at toe in 1978
- Seepage berm along right abutment in 1993
- Clay blanket in 1947, Geomembrane in 1993
- Sinkhole (repaired)
- Seepage exit 300’ d/s
- Downstream
- Upstream – lake drained
- Seepage collection system at toe in 1978
- Seepage berm along right abutment in 1993
- Clay blanket in 1947, Geomembrane in 1993
- Sinkhole (repaired)
LOWER MERCER LIMESTONE

- Thin, typically 3 to 4 foot thick
- Solutioned high angled joints and low angled bedding planes create avenues for groundwater seepage
- Limestone is missing in portions of dam footprint
ZOAR DIVERSION DAM – RISK ASSESSMENT

- **Seepage exit**: 300’ d/s

- **Hypothetical Ground Water Flow Path**
  - Through interconnected network of open joints

- **Upstream – lake drained**

- **Downstream**

- **Low Risk of Failure**

- **Tolerable Risk Limit**

- **Increasing justification to take action to reduce risk or better define the risk**

- **Total**
  - IPM 101
  - IPM 105
  - IPM 106
  - IPM 108
  - IPM 109

- **Low Probability – High Consequence Events**

- **HISTORIC POOL – EL 916**
  - Pervious
  - Impervious

- **STONE SLOPE PROTECTION**
  - Masonry

- **TOP OF DAM – EL 932**
  - Pervious

- **TOP OF CORE – EL 930**
  - Gravel drain
ZOAR LEVEE – THREE AREAS OF CONCERN

1. Diversion Dam
2. Rock Knoll Reach (Levee)
ROCK KNOLL REACH – ZOAR LEVEE

- Levee Embankment Founded on Glacial Outwash (sands & gravel) and Glacial Lake Deposits (clays & silts)
- Top of Rock 5’ - 25’ Below Levee Foundation.
- 5’ - 20’ Levee Height
- Approx 500’ Length (sta 30+00 – 35+00)

AERIAL VIEW

CROSS SECTIONS
ROCK KNOLL REACH – GEOLOGIC PROFILE

LEGEND
- Levee Embankment (New Impervious Shell)
- Alluvium
- Impervious Core
- Old Silty Sand Shell
- Blanket Drain
- Seepage Berm
- Clay/Silt Alluvial Blanket
- Upper Glacial Outwash
- Lower Glacial Outwash
- Lower Silts and Clays
- Shale
- Sandstone
- Limestone
- Claystone
- Silty Sandstone
- Coal
- Stone Slope Protection / Masonry
- Structural Backfill
- Colluvium - Residual
- Existing Seepage Berm

VERTICAL SCALE: 1" = 20'  VERTICAL EXAGGERATION: 5:1

LOWER MERCER LIMESTONE

BUILDING STRONG®
ROCK KNOLL REACH – FAILURE MODE

SCOUR ALONG LIMESTONE CONTACT

VERTICAL SCALE: 1" = 20'
VERTICAL EXAGGERATION: 5:1

BUILDING STRONG®
ROCK KNOLL REACH – RISK ASSESSMENT

PLAN VIEW

CROSS SECTION

RISK ASSESSMENT (fn chart)
ZOAR LEVEE – THREE AREAS OF CONCERN

1. Diversion Dam
2. Rock Knoll Reach (Levee)
3. Ball Field Reach (Levee)
BALL FIELD REACH – ZOAR LEVEE

- Levee Embankment Founded on Glacial Outwash (sands & gravel)
- 38’ Levee Height (varies)
- Approx 2,500’ Length (ball field reach of levee)

CROSS SECTION
BALL FIELD REACH - SEEPAGE

2005

2008

Seepage within Ball Field Reach of Levee
LEVEE: Original levee constructed in 1937 with crest raised in 1951 to elevation 928.5.

ALLUVIAL BLANKET: Fine grained clays and silt, recent

GLACIAL OUTWASH: Sands and gravels, glacial outwash, Wisconsin ice advance

GLACIAL LAKE - CLAYS AND SILTS: Clays and silts, glacial lake deposits, partially eroded and replaced by overlying Upper Glacial Outwash, Wisconsin ice advance

LOWER ALLUVIUM: Sand and silty sand with lenses of clays and silts, alluvial and possible isolated glacial lake deposits.

BEDROCK: Relatively flat lying sedimentary rock of the Pennsylvanian-aged Pottsville Group
Alluvium (fines)
Outwash (sand, fines & gravel)
Clean Sand (Cu range: 2.7 – 3.9)
Sands & Gravel (potential high-energy braided stream)

Uniform Sand Layer (potential low-energy meander-like stream)

Erosional Surface

Gravel Orientation Indicate Southern Flow Direction

Cross Bedding Indicating Flowing Water in a Southern Direction

Stream Flow Direction

Sample Collected $Cu = 1.7$
BALL FIELD REACH – RISK ASSESSMENT

CROSS SECTION

EXISTING REMEDIAL MEASURES

RISK ASSESSMENT
(fn chart)
BALL FIELD REACH
TENTATIVE SELECTED ALTERNATIVE

Internal Erosion Interception Trench (IEIT)

BUILDING STRONG®
BACKWARD EROSION PIPING - FOUNDATION

- Confining Layer
- Boil
- PREEXISTING DEFECT OR HEAVE
- Weighted Filter Berm
- Uniform Sands
- Backward Erosion Piping Arrested
- ZOOM IN

LEVEE
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QUESTIONS?

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US Army Corps of Engineers
DAM SAFETY MODIFICATION
MANDATORY CENTER OF EXPERTISE

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Marietta OH
1913 Flood
GROUT RECORDS – UPSTREAM LINE

LEGEND

- CASING
- DOWNTIME AND ADDITIONAL DOWNTIMES
- WELL LOCATION AND RUNNING TOTAL
- INJECTED VOLUME
- UPSTAGE TAKE IN GALLONS

PROFILE

EXISTING GROUND

INTERBEDDED SHALE

COAL & MISTONE

EXISTING TUNNELS

PROFILE BASELINE

GROUT BASELINE