Assessment of Stream Resources at Regulated Coal Mining and Remining Sites in Ohio

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Advances In Geomorphic Reclamation at Coal Mines

Albuquerque, New Mexico, May 21, 2014

Research Objective

- Evaluate physical, biological and chemical characteristics of reconstructed streams and impacts to buffer zones, and compare with similar natural system standards (unmined streams*)*

- Evaluate and characterize the long–term effects that mining and reclamation practices have had on stream resources 5 to 30 years following reclamation

Expected Outcomes

- Results and data will be useful to Ohio's mining program

- Evaluate effectiveness of reclamation practices over a long period of time

- Make recommendations for improvements to mining and reclamation program areas

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Scope of Study

Assess:

- Current fluvial-geomorphic conditions of streams at reclaimed coal mine sites
- Post-mining stream recovery (e.g. stream habitat, stability, channel or flow patterns, and vegetation) in comparison to target values
- Biological resources in comparison to target values
- Chemical water quality in comparison to target values

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Specific Tasks

- Review reconstructed streams representative of extraction activities of various coal seams and dissimilar lithology
- Mixture of stream gradients
- Most streams will be Primary Headwater Habitat (PHWH) streams, i.e. watershed area < 1 square mile
- For reconstructed floodplain soils on low gradient streams, perform laboratory testing of soil quality compared to control sites (soil profiles at unmined biological sample sites)
- Compare with control streams where possible

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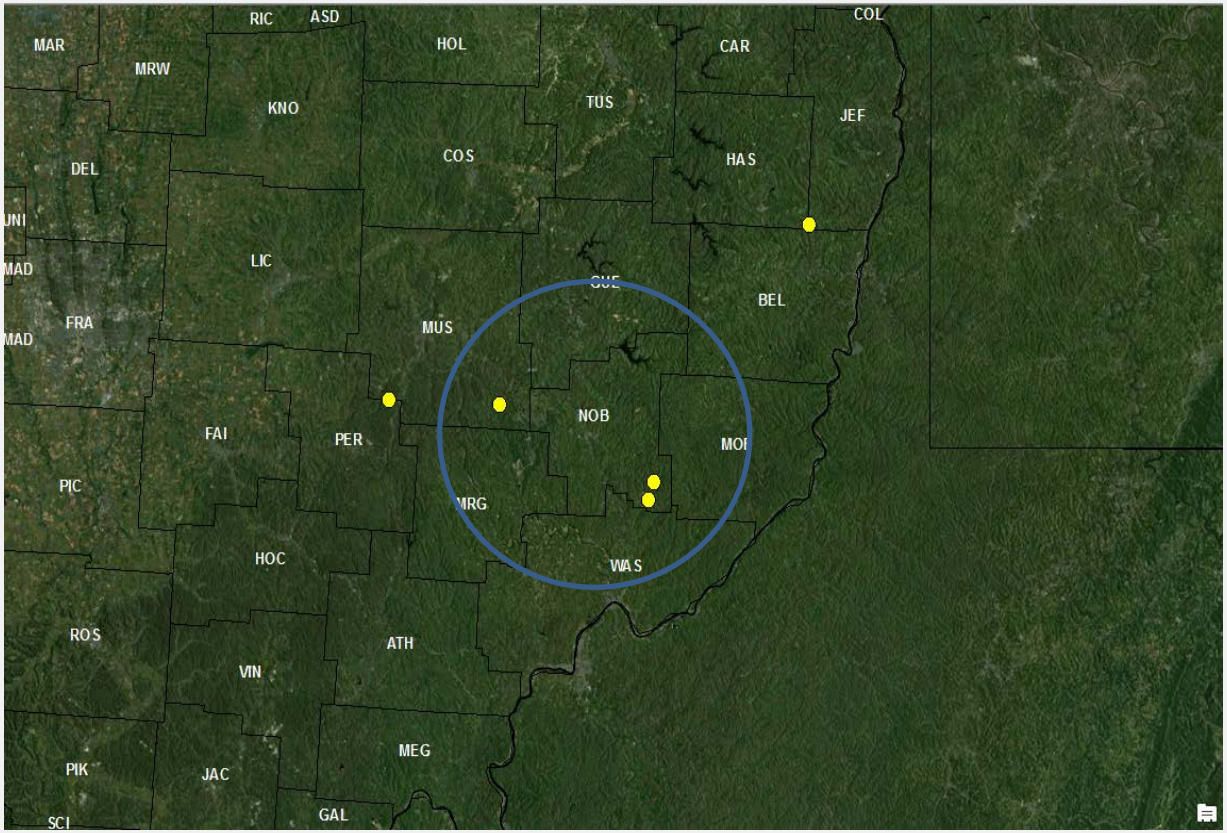
Approach

- Selected 5 reclaimed mine sites in Eastern Ohio containing reconstructed headwater streams for scoring Headwater Habitat Evaluation Index(HHEI) on 200 foot reaches

- In drainage area of reconstructed channels selected 5 biological sites in unmined streams to conduct a biological Headwater Macroinvertebrate Field Evaluation Index (HMFEI) score and Headwater Habitat Evaluation Index(HHEI) score on 200 foot reaches



Trapezoidal Rock Channel & Natural Channel Design (NCD)

- Central Ohio Coal Company's C-0209 was reconstructed using the trapezoidal rock channel practice current at the time (1973-1998)

- Modern day mining permits (post 2000) - B&N Coal's D-0958 and D-0807 were designed and constructed using NCD approach

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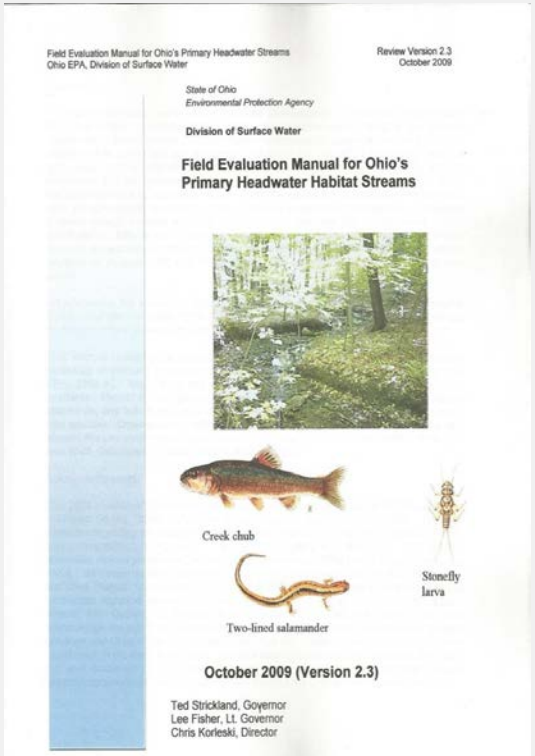
OhioEPA: Field Evaluation Manual for Ohio's Primary Headwater Habitat Streams, 2009


Field Evaluation Manual for Ohio's Primary Headwater Streams
Ohio EPA, Division of Surface Water

Review Version 2.3
October 2009

State of Ohio
Environmental Protection Agency

Division of Surface Water

Field Evaluation Manual for Ohio's Primary Headwater Habitat Streams

Creek chub

Stonefly larva

Two-lined salamander

October 2009 (Version 2.3)

Ted Strickland, Governor
Lee Fisher, Lt. Governor
Chris Korleski, Director

- Developed as a tool to provide standardized assessment for primary habitat streams in Ohio.
- Focus on PHWH streams with either continuous or periodical flowing water, watershed area < 1.0 square mile, and maximum pool depth < 15.7 inches.
- Uses biological indicators to assess overall stream ecological integrity
- Established indices of habitat quality such as Qualitative Habitat Evaluation Index (QHEI), Headwater Habitat Evaluation Index(HHEI), etc.
- Manual describes methods that Ohio EPA has developed to better assess actual and expected biological conditions in streams and to classify primary headwater habitat streams.
- OSU researchers relied upon the tools in this manual to complete the assessment of streams evaluated in this study.

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Summary steps to use to assign designation of PHWH stream

- The Headwater Habitat Evaluation Index (HHEI) is a rapid field assessment to determine potential of
  - aquatic life use
  - based entirely on physical measurements
  - assists in stream classification
- Sum of metrics (substrate, maximum pool depth, bank full width)
- Other data (riparian width, floodplain quality, flow regime, stream gradient, stream channel category: natural, recovered, recovering, or recent or no recovery)
- Increased confidence when the HHEI is accompanied with a biological evaluation of the stream

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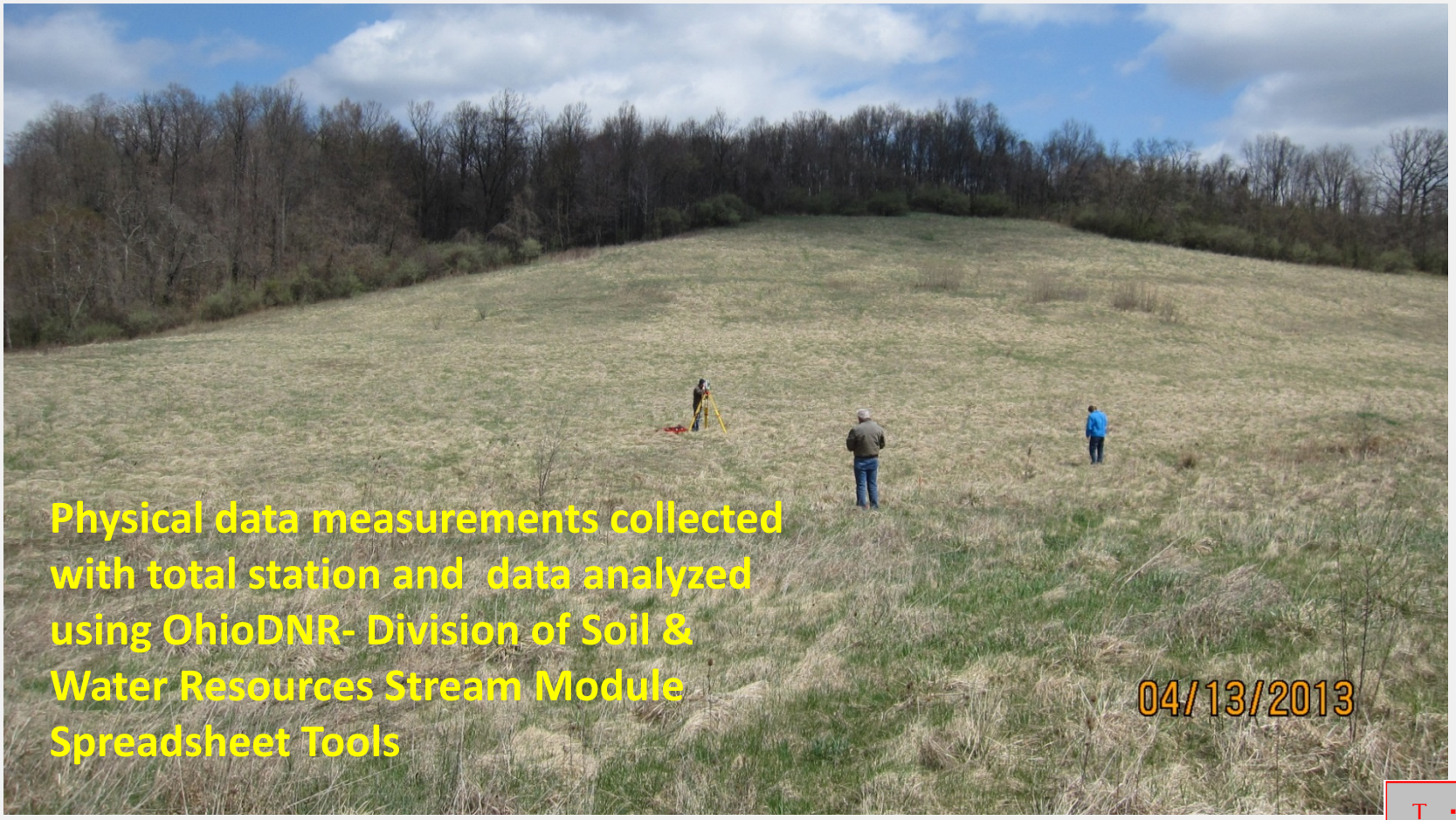
Physical measurements at reconstructed streams



Physical data measurements collected with total station and data analyzed using OhioDNR- Division of Soil & Water Resources Stream Module Spreadsheet Tools

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Biological Sampling and Evaluation

- Macroinvertebrate Aggregate Index for Streams (MAIS) approach
- Level I and II Biological sampling methods
- D-frame net and kick seine technique
- OhioEPA Headwater Macroinvertebrate Field Evaluation index (HMFEI) scoring
- Headwater Habitat Evaluation Index (HHEI) physical measurements obtained with steel tape

HMFEI scoring categories

Table 7. Headwater Macroinvertebrate Field Evaluation Index (HMFEI) scoring categories for use in assessing primary headwater habitat streams in Ohio.

Group 1 Taxa (Scoring Value = 1)	Group 2 Taxa (Scoring Value = 2)	Group 3 Taxa (Scoring Value = 3)
Sessile Animals (Porifera, Cnidaria, Bryozoa)	Crayfish (Decapoda)	Mayfly Nymphs[1] (Ephemeroptera)
Aquatic Worms (Turbellaria, Oligochaeta, Hirudinea)	Dragonfly Nymphs (Anisoptera)	Stonefly Nymphs[1] (Plecoptera)
Sow Bugs (Isopoda)	Riffle Beetles (Dryopidae, Elmidae, Ptilodactylidae)	Caddisfly Larvae[1] (Trichoptera)
Scuds (Amphipoda)		Fishfly Larvae (Corydalidae)
Water Mites (Hydracarina)		Water Penny Beetles (Psephenidae)
Damselfly Nymphs (Zygoptera)		Cranefly Larvae (Tipulidae)
Alderfly Larvae (Sialidae)		
Other Beetles (Coleoptera)		
Midges (Chironomidae)		
Larvae of Other Flies (Diptera)		
Snails (Gastropoda)		
Clams (Bivalvia)		

Note: Hemiptera (True Bugs) do not receive any points in the HMFEI.

[1] Note: each identified taxon of the Ephemoptera, Plecoptera, and Trichoptera (EPT taxa) receives three points under the HMFEI scoring system.

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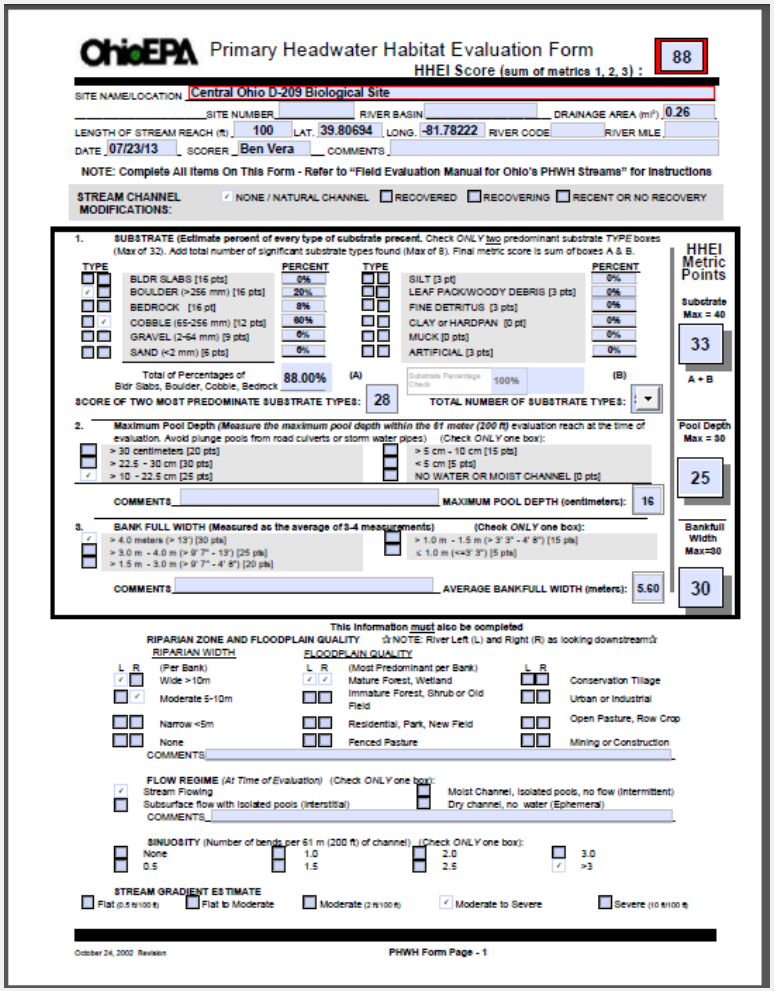
Headwater Habitat Evaluation Index (HHEI)

Features of Evaluation Form

- HHEI can be used to score physical habitat features that have been found to be statistically important determinants of biological community structure in PHWH streams

- Substrate metric was calibrated based upon the use of the visual estimation method



OhioEPA Primary Headwater Habitat Evaluation Form

HHEI Score (sum of metrics 1, 2, 3) : 88

SITE NAME/LOCATION Central Ohio D-209 Biological Site

SITE NUMBER ____ RIVER BASIN ____ DRAINAGE AREA (mi²) 0.26

LENGTH OF STREAM REACH (ft) 100 LAT. 39.80694 LONG. -81.78222 RIVER CODE ____ RIVER MILE ____

DATE 07/23/13 SCORER Ben Vera COMMENTS ____

NOTE: Complete All Items On This Form - Refer to "Field Evaluation Manual for Ohio's PHWH Streams" for Instructions

STREAM CHANNEL MODIFICATIONS: ✓ NONE / NATURAL CHANNEL ☐ RECOVERED ☐ RECOVERING ☐ RECENT OR NO RECOVERY

1. SUBSTRATE (Estimate percent of every type of substrate present. Check ONLY two predominant substrate TYPE boxes (Max of 32). Add total number of significant substrate types found (Max of 8). Final metric score is sum of boxes A & B.

TYPE	PERCENT	TYPE	PERCENT
☐ BLDR SLABS [16 pts]	0%	☐ SILT [3 pt]	0%
✓ BOULDER (>256 mm) [16 pts]	20%	☐ LEAF PACK/WOODY DEBRIS [3 pts]	0%
☐ BEDROCK [16 pt]	8%	☐ FINE DETRITUS [3 pts]	0%
✓ COBBLE (65-256 mm) [12 pts]	60%	☐ CLAY or HARDPAN [0 pt]	0%
☐ GRAVEL (2-64 mm) [9 pts]	0%	☐ MUCK [0 pts]	0%
☐ SAND (<2 mm) [6 pts]	0%	☐ ARTIFICIAL [3 pts]	0%

Total of Percentages of Bldr Slabs, Boulder, Cobble, Bedrock 88.00% (A) Substrate Percentage Check 100% (B)

SCORE OF TWO MOST PREDOMINATE SUBSTRATE TYPES: 28 TOTAL NUMBER OF SUBSTRATE TYPES: ____

HHEI Metric Points — Substrate Max = 40: 33 (A + B)

2. Maximum Pool Depth (Measure the maximum pool depth within the 61 meter (200 ft) evaluation reach at the time of evaluation. Avoid plunge pools from road culverts or storm water pipes) (Check ONLY one box):

☐ > 30 centimeters [20 pts] ☐ > 5 cm - 10 cm [15 pts]
☐ > 22.5 - 30 cm [30 pts] ☐ < 5 cm [5 pts]
✓ > 10 - 22.5 cm [25 pts] ☐ NO WATER OR MOIST CHANNEL [0 pts]

COMMENTS ____ MAXIMUM POOL DEPTH (centimeters): 16

Pool Depth Max = 30: 25

3. BANK FULL WIDTH (Measured as the average of 3-4 measurements) (Check ONLY one box):

✓ > 4.0 meters (> 13') [30 pts] ☐ > 1.0 m - 1.5 m (> 3' 3" - 4' 8") [15 pts]
☐ > 3.0 m - 4.0 m (> 9' 7" - 13') [25 pts] ☐ ≤ 1.0 m (<=3' 3") [5 pts]
☐ > 1.5 m - 3.0 m (> 9' 7" - 4' 8") [20 pts]

COMMENTS ____ AVERAGE BANKFULL WIDTH (meters): 5.60

Bankfull Width Max=30: 30

This information must also be completed

RIPARIAN ZONE AND FLOODPLAIN QUALITY ☆NOTE: River Left (L) and Right (R) as looking downstream☆

RIPARIAN WIDTH (Per Bank) L R	FLOODPLAIN QUALITY (Most Predominant per Bank) L R	L R
✓ ☐ Wide >10m	✓ ✓ Mature Forest, Wetland	☐ ☐ Conservation Tillage
☐ ✓ Moderate 5-10m	☐ ☐ Immature Forest, Shrub or Old Field	☐ ☐ Urban or Industrial
☐ ☐ Narrow <5m	☐ ☐ Residential, Park, New Field	☐ ☐ Open Pasture, Row Crop
☐ ☐ None	☐ ☐ Fenced Pasture	☐ ☐ Mining or Construction

COMMENTS ____

FLOW REGIME (At Time of Evaluation) (Check ONLY one box):

✓ Stream Flowing ☐ Moist Channel, Isolated pools, no flow (Intermittent)
☐ Subsurface flow with Isolated pools (Interstitial) ☐ Dry channel, no water (Ephemeral)

COMMENTS ____

SINUOSITY (Number of bends per 61 m (200 ft) of channel) (Check ONLY one box):

☐ None ☐ 1.0 ☐ 2.0 ☐ 3.0
☐ 0.5 ☐ 1.5 ☐ 2.5 ✓ >3

STREAM GRADIENT ESTIMATE

☐ Flat (0.5 ft/100 ft) ☐ Flat to Moderate ☐ Moderate (2 ft/100 ft) ✓ Moderate to Severe ☐ Severe (10 ft/100 ft)

October 24, 2002 Revision PHWH Form Page - 1

Ohio's Primary Headwater Habitat (PHWH) Stream Classification

- **Class III** PHWH Stream: Cool-cold water adapted native fauna
- **Class II** PHWH Stream: Warm water adapted native fauna
- **Class I** PHWH Stream: Ephemeral stream, normally dry channel

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Water Quality Data

- Capturing seasonal flows
- OhioDNR-DMRM lab analysis for typical mining parameters and compared to Coal Mining NPDES Technology based limits:
  - pH: 6.0-9.0
  - Fe: max daily 6 mg/L
  - Manganese: max daily 4 mg/L
  - Total Suspended Solids (TSS): max daily 70 mg/L

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Central Ohio Coal Company C-0209 reconstructed stream segment #1

Area mining with Big Muskie dragline, spoil graded to AOC, 8 inches of resoiling material, trapezoidal rock channel design

Mining completed in 1979

683 acres affected

Drainage Area: 76.8 Acres (.12 square miles)

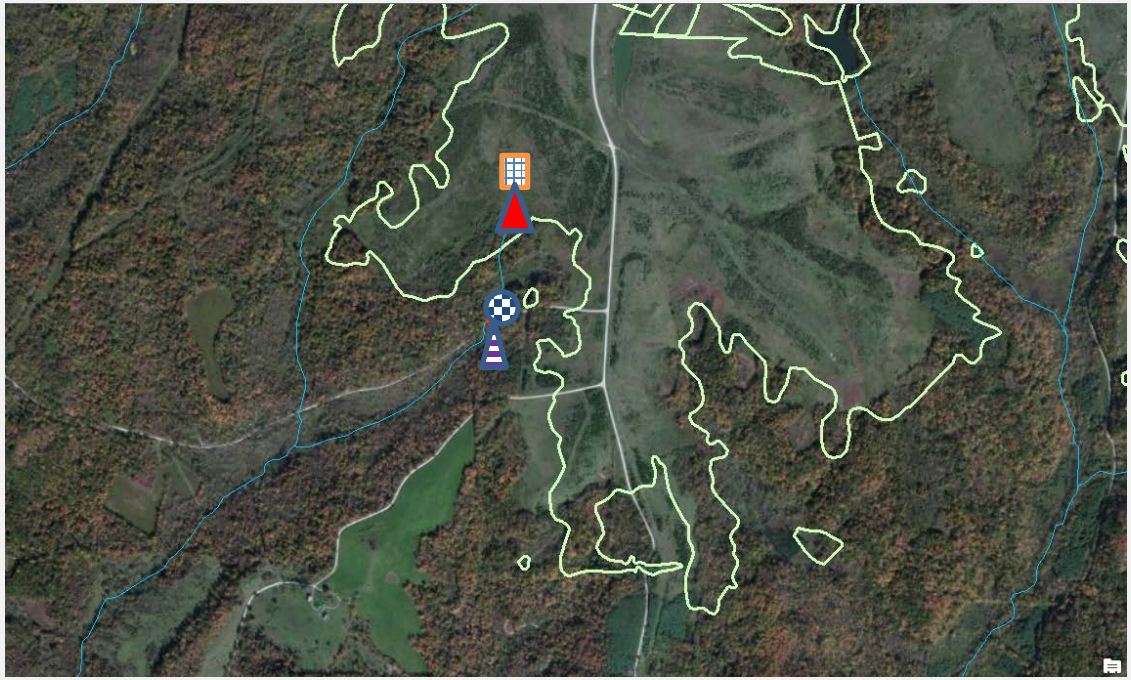
Slope: 13% (steep)

- Muskingum County, watershed - Meigs Creek
- Reconstructed Stream

Biological Site

Water quality C-0209 downstream

Water quality C-0209 Bio



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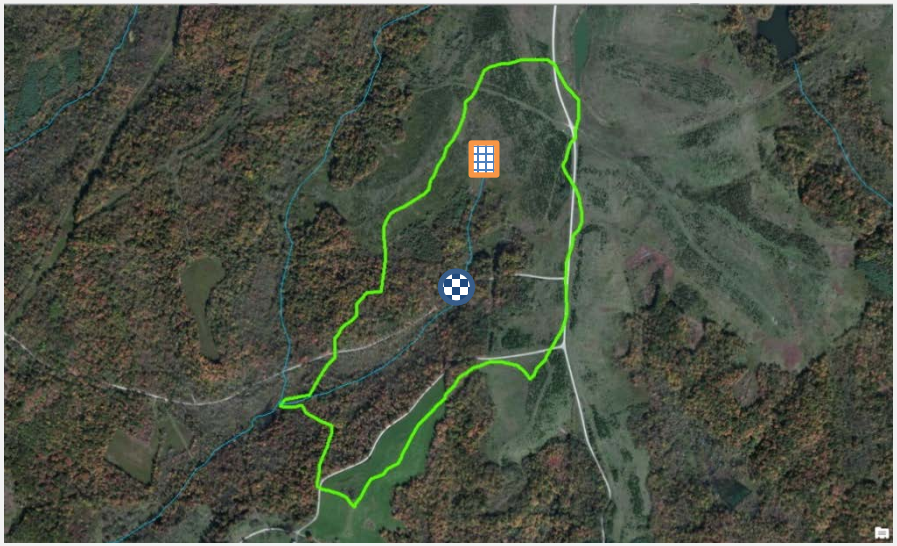
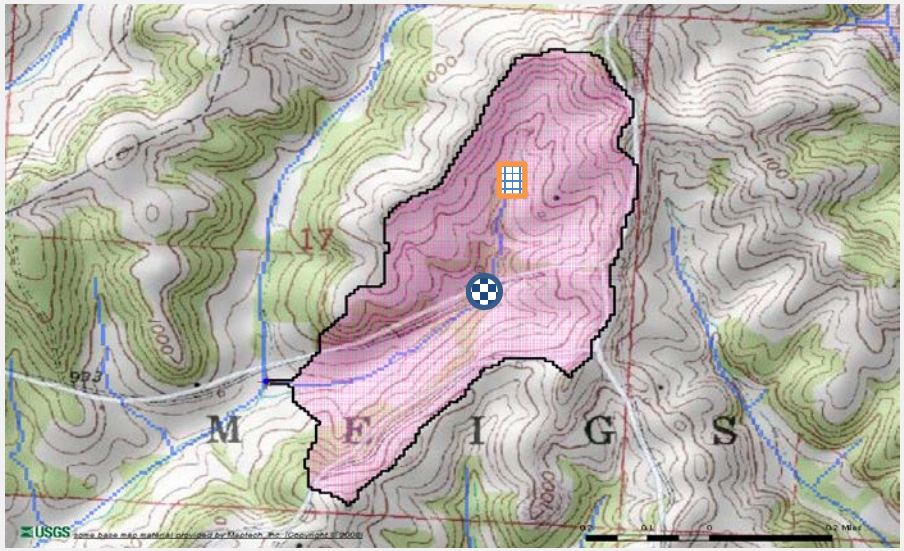
USGS Streamstats for C-0209

- Drainage area is 0.26 square miles
- Mean annual precipitation is 37.4 inches

Streamstats in Ohio

- One of the better developed sites in the Nation (Greg Colton USGS developer for Streamstats, Ohio)
- 30-40% error factor
- Based on rural method of Ohio





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C-0209 Reconstructed Stream Channel Riparian Zone

- Riparian corridor after 35 years (6 inch up to 32 inch diameter tree growth throughout the riparian zone)

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C-0209 Summary

Bank Full Width (bkf): 5.3 ft

HHEI Score: 42

Class I PHWH ephemeral stream, normally dry channel

Status: Recovered

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C-0209 Biological site- weight of evidence

- HHEI score: 88
- Biological community
  - **Species present- crayfish, salamanders, creek chubs, and black nosed dace**

- HMFEI Score 25 = **Class III perennial stream (cool and cold water adapted aquatic species)**

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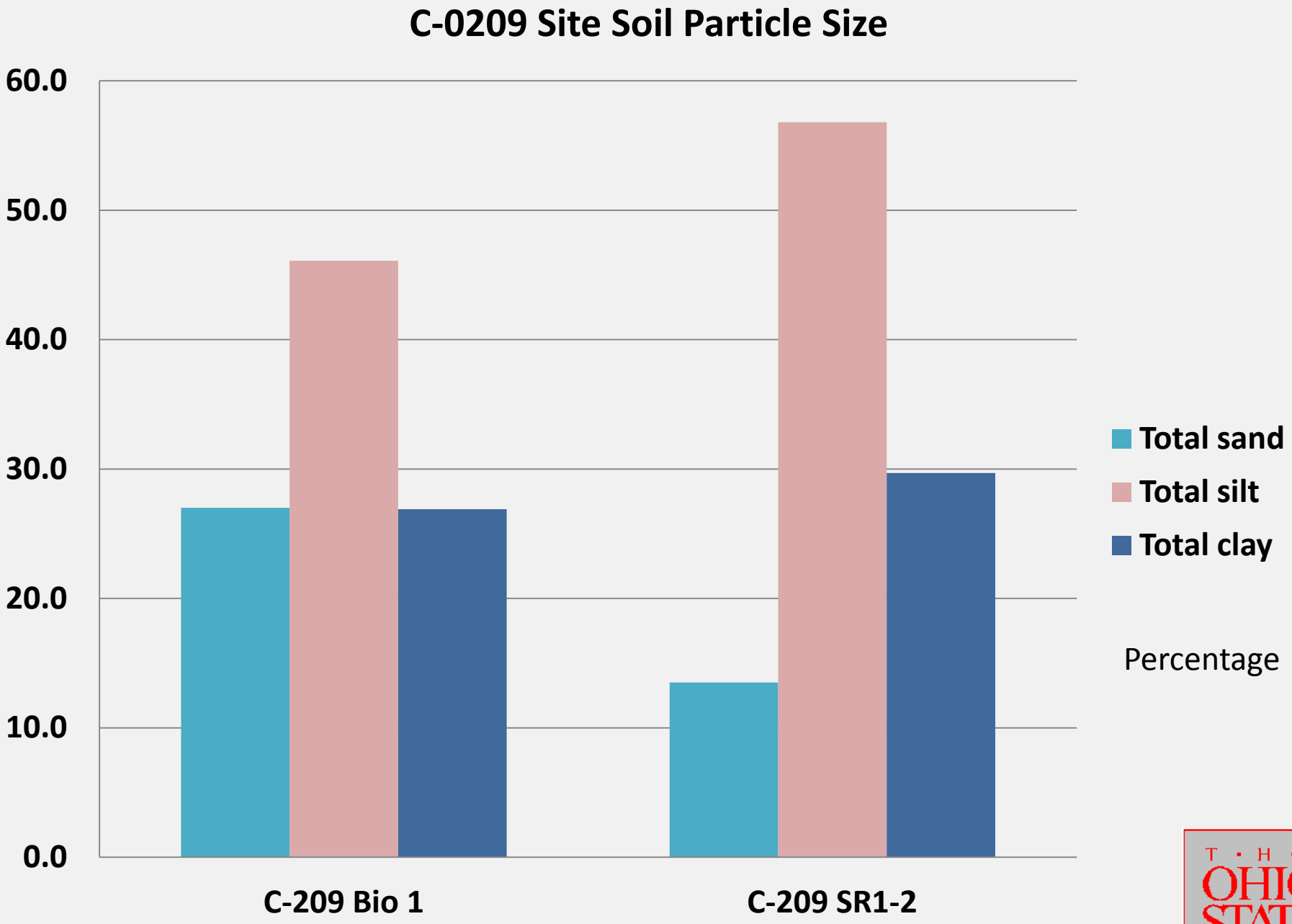
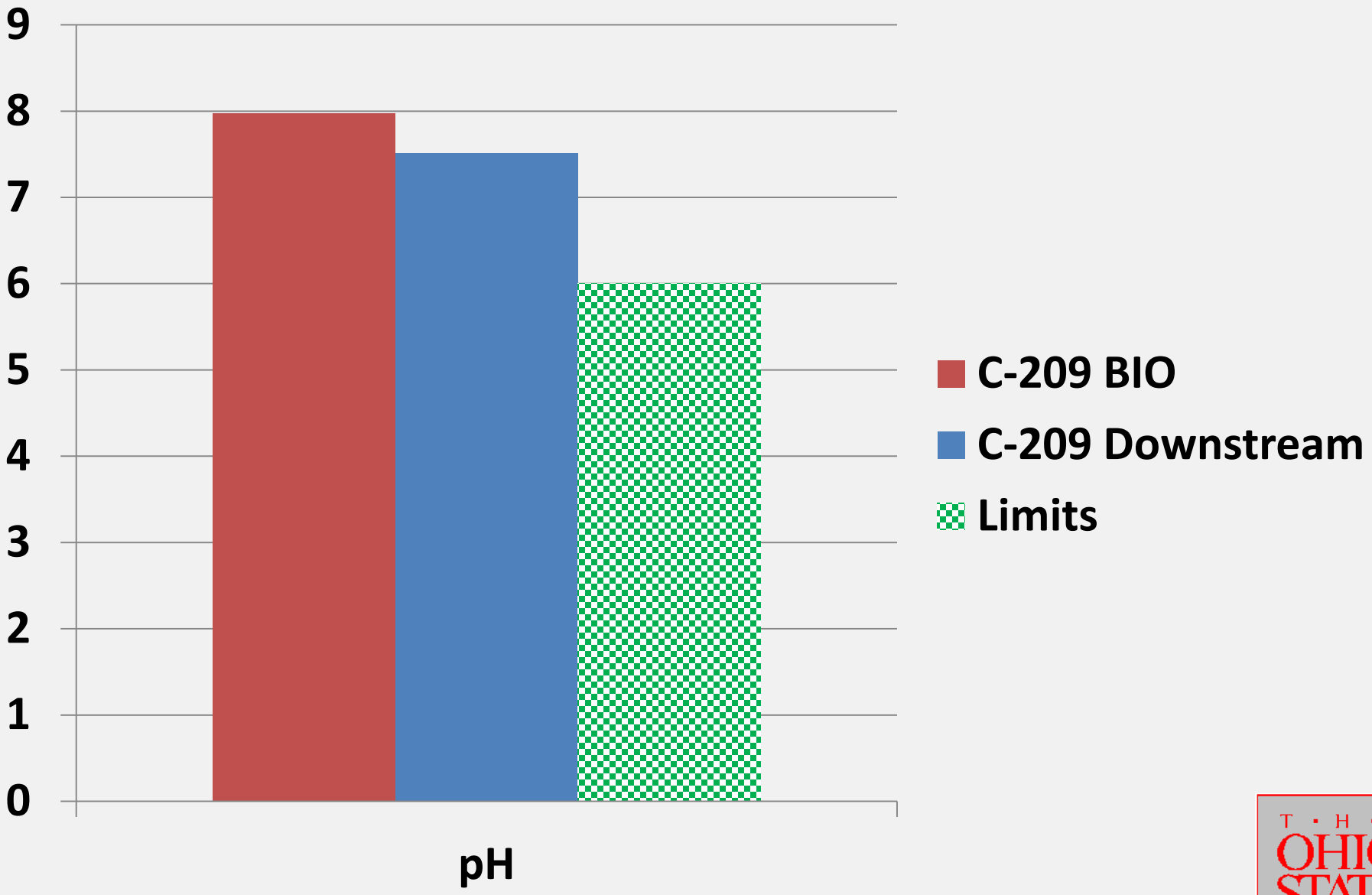
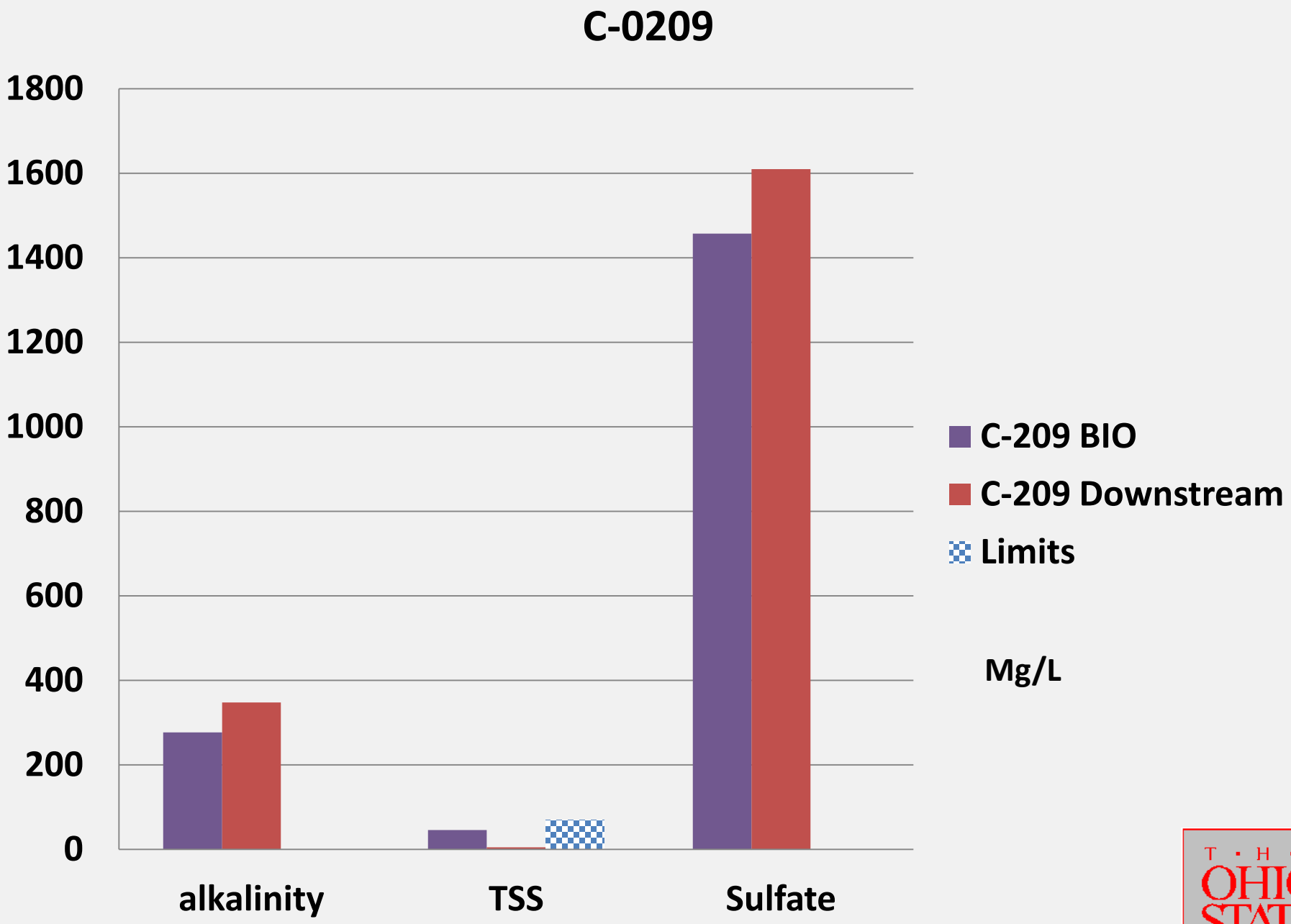
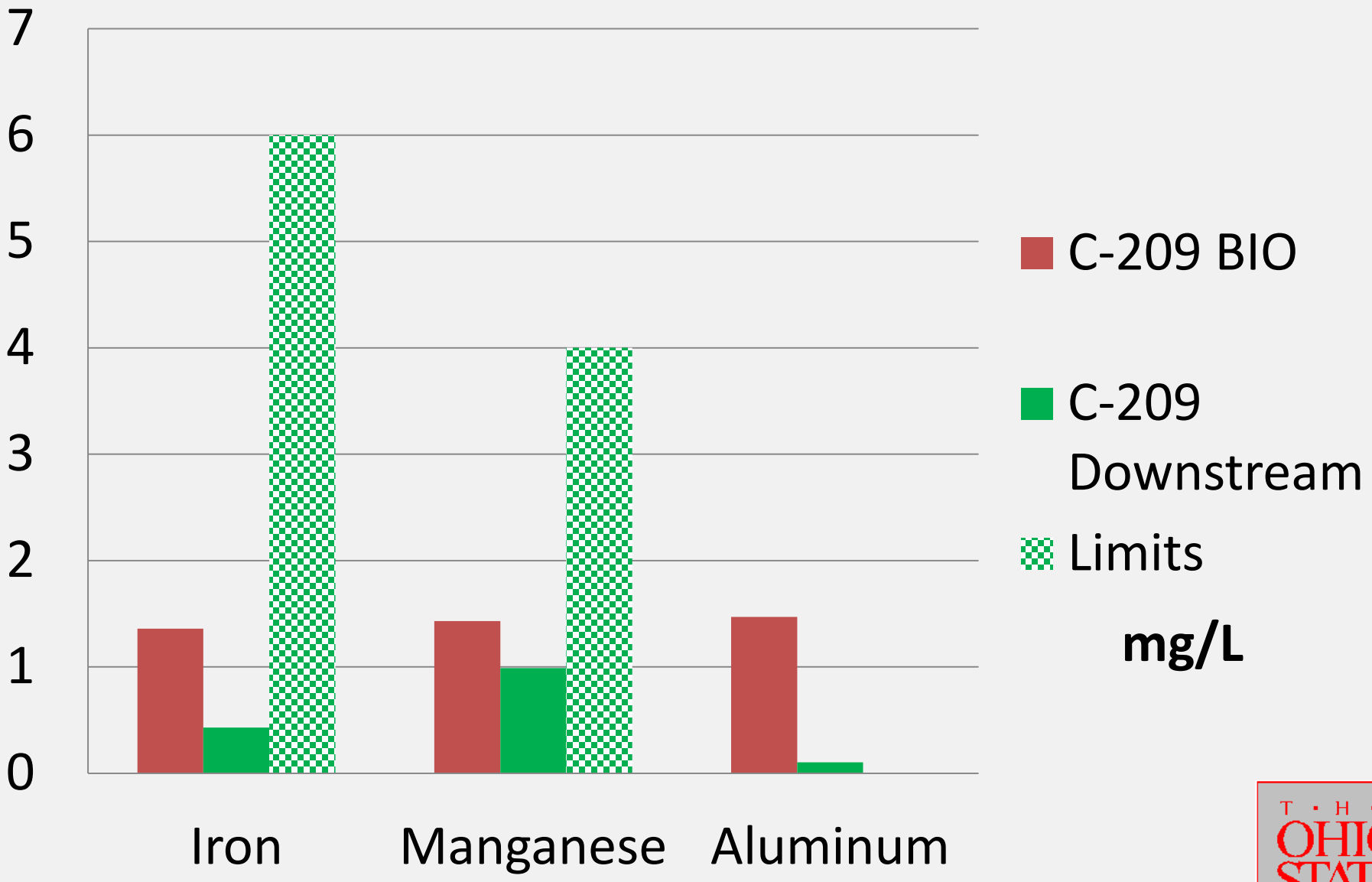

C-0209 Site Soil Particle Size
60.0
50.0
40.0
30.0
20.0
10.0
0.0
C-209 Bio 1
C-209 SR1-2
Total sand
Total silt
Total clay
Percentage

C-0209 pH




C-0209
1800
1600
1400
1200
1000
800
600
400
200
0
alkalinity
TSS
Sulfate
C-209 BIO
C-209 Downstream
Limits
Mg/L

C-0209


7
6
5
4
3
2
1
0
Iron
Manganese
Aluminum
C-209 BIO
C-209 Downstream
Limits
mg/L

D-0958 Reconstructed Stream

Contour remining operation with pan & dozers, resoiled with 8 inches of suitable material

Year 6 planted in 1998, Released in 2003

Natural Channel Design Approach

Drainage Area: 89.6 acres (.14 square miles)

Slope: 1.5%

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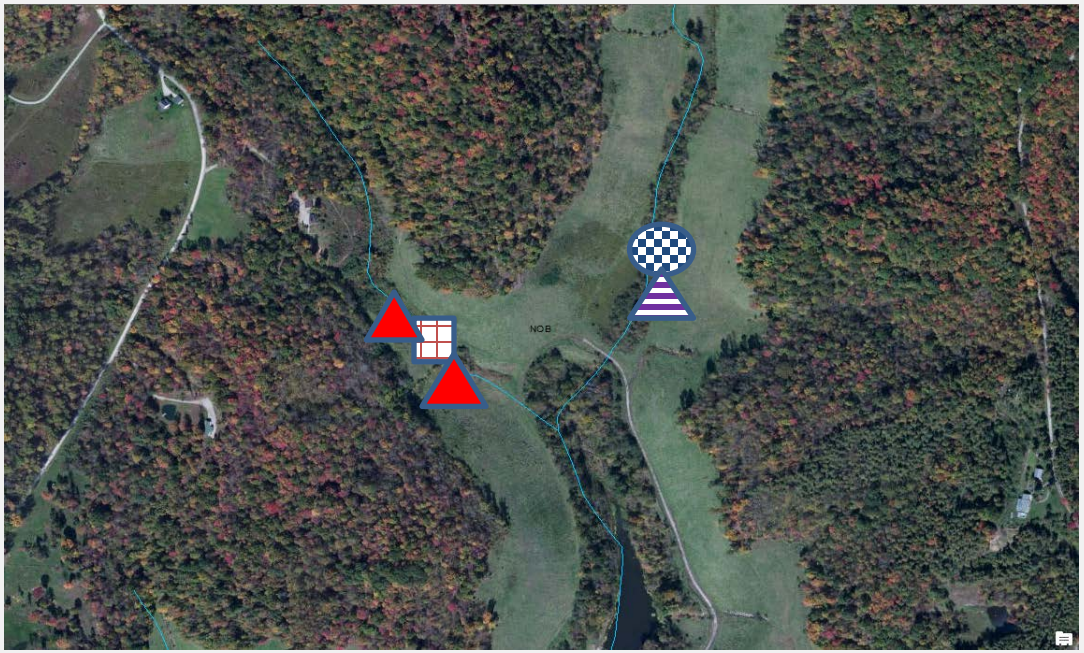
B&N Coal D-0958

Noble County, East Fork Duck Creek watershed



Reconstructed Stream

Biological site

D-0958 upstream and downstream water quality sites

D-0958 Bio water quality site

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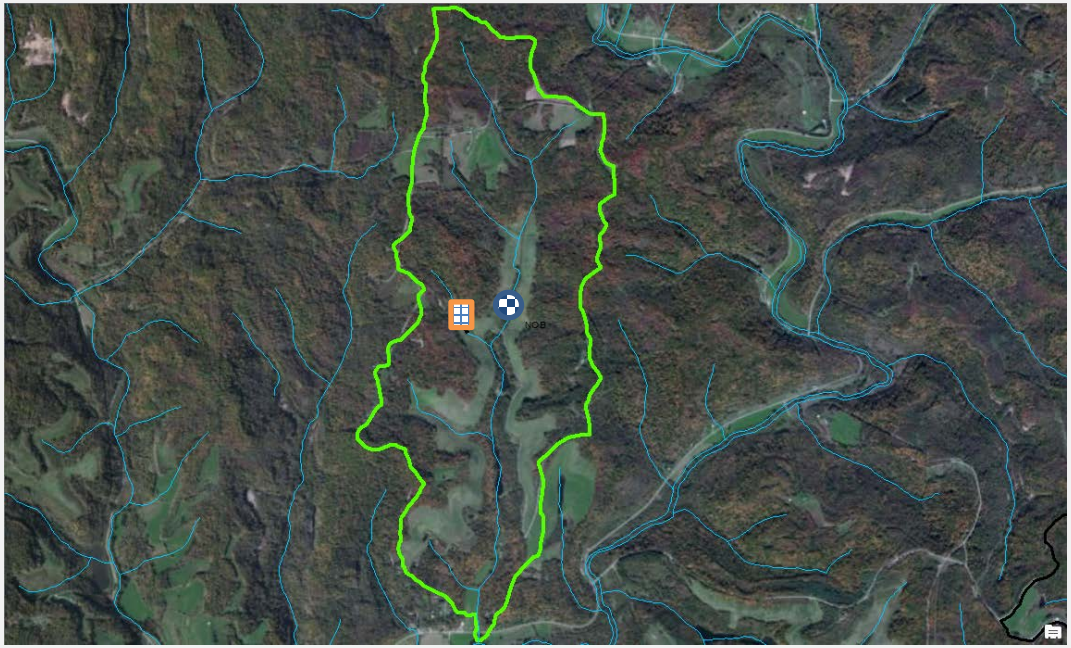
B&N Coal Co. D-0958

- D-958 Streamstats Ohio
  - **Drainage area is 0.7 square miles**
  - **Annual mean precipitation is 39.8 inches**



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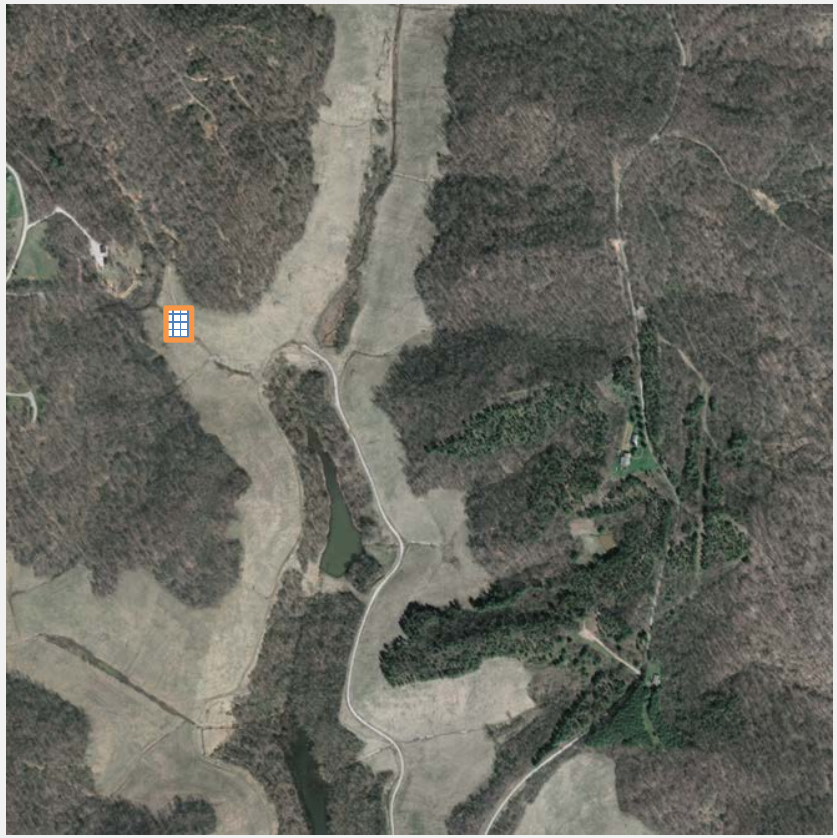
B&N Coal- D-0958 Stream Reach 1

Total Acreage – approx. 235.7

reconstructed stream reach 1

1951 Imagery

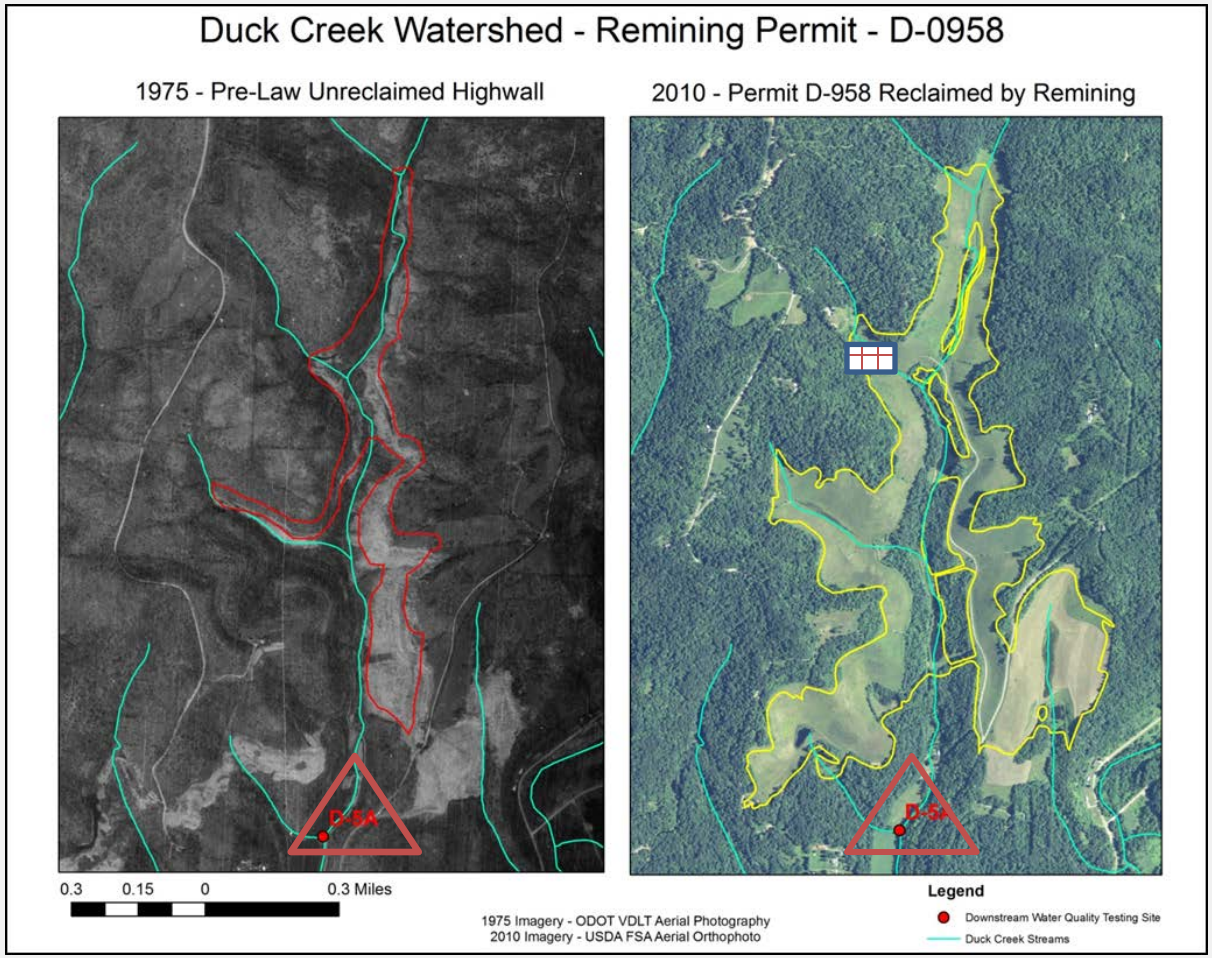
2010 Imagery



Remined Acreage – approx. 81 acres
Highwall length eliminated – approx. 3 miles

Reconstructed stream reach 1

DMRM water quality site D-5a



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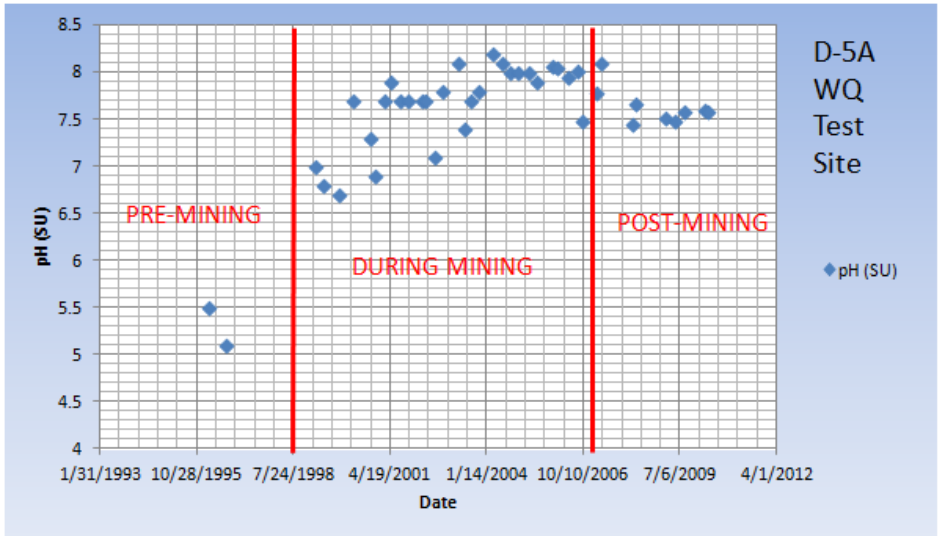
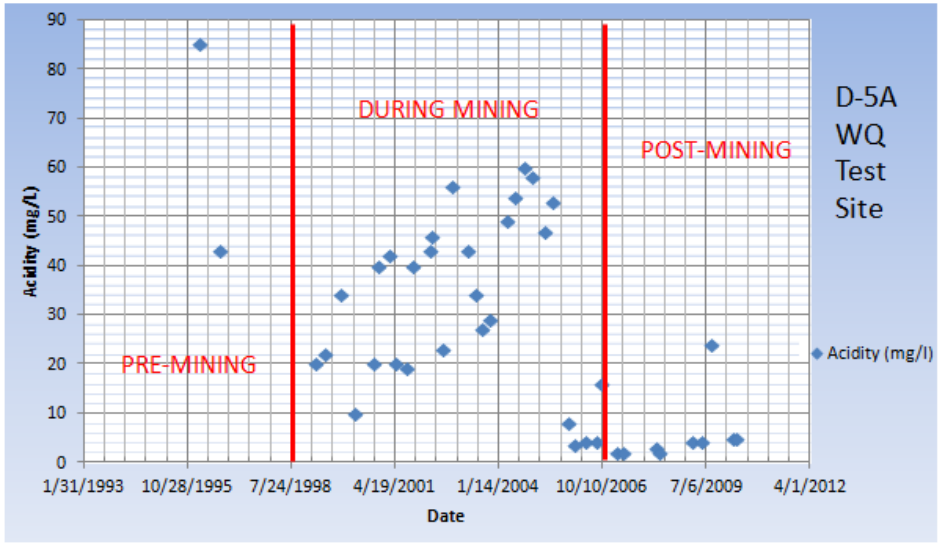
Remining at B&N Coal's Permit D-0958

The D-5A sampling point captures the water quality in the main stem of Rocky Run, below drainage of D-0958.

Water quality data extracted from ODNR-DMRM permitting shows broad improvements in pH (S.U) and acidity (mg/L).





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D-0958

Stream Reach # 1

- Design and construction based on DMRM's 1999 *Natural Channel Design Procedure for Reconstructed Small Headwater Streams*

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D-0958 Reconstructed Stream Summary

Bank Full Width (bkf): 11.9 ft

HHEI Score: 47

Modified Class II PHWH intermittent stream

Recovering

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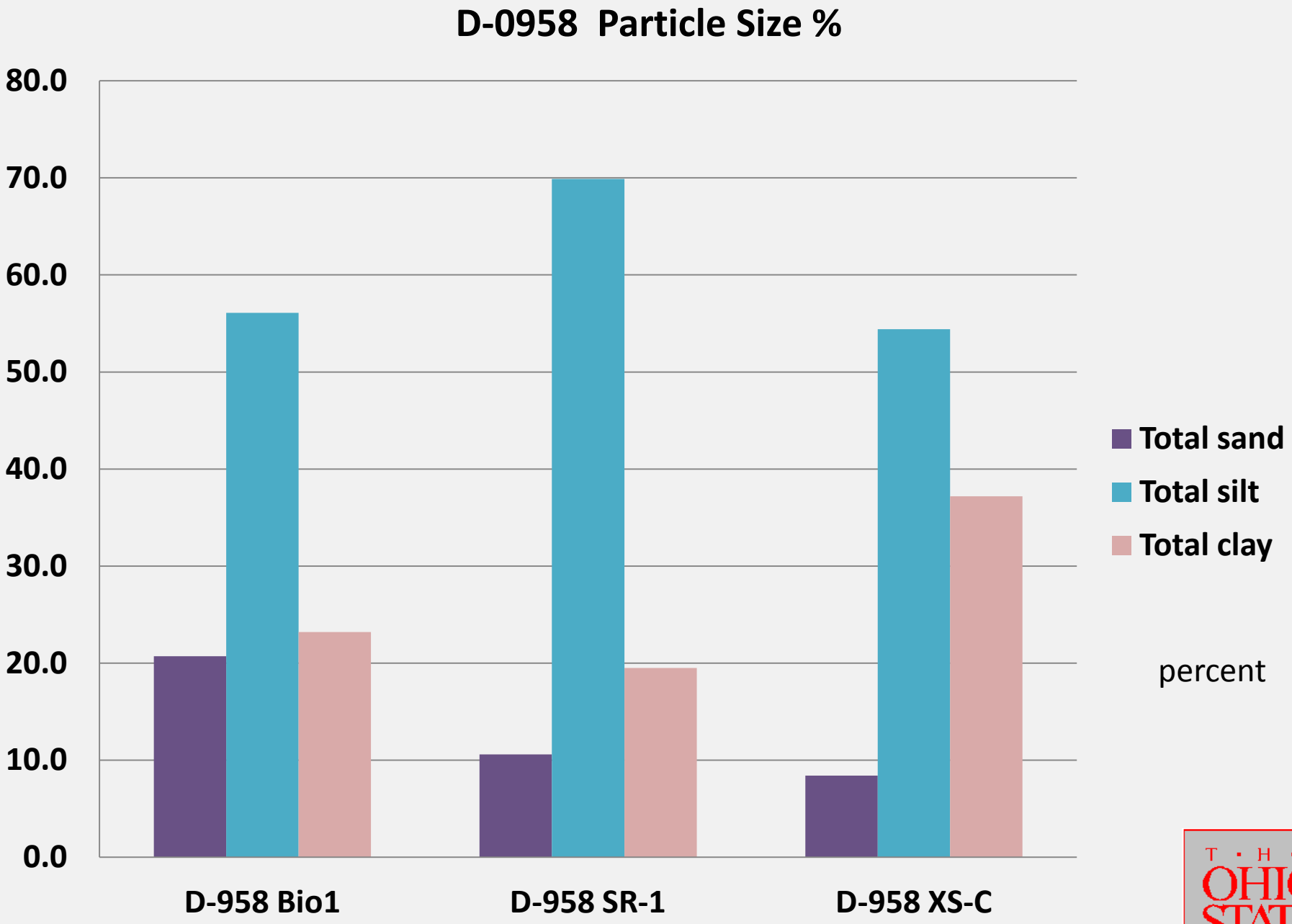
D-0958 Biological site- weight of evidence

- HHEI score 64
- Some unmined areas upstream of site
- Biological Community
  Species present: **3 mayfly families with 4 different taxa, Crayfish, larval Northern 2 lined salamanders**
- HMFEI Score 25 = **Class III stream (cool and cold water adapted aquatic species)**



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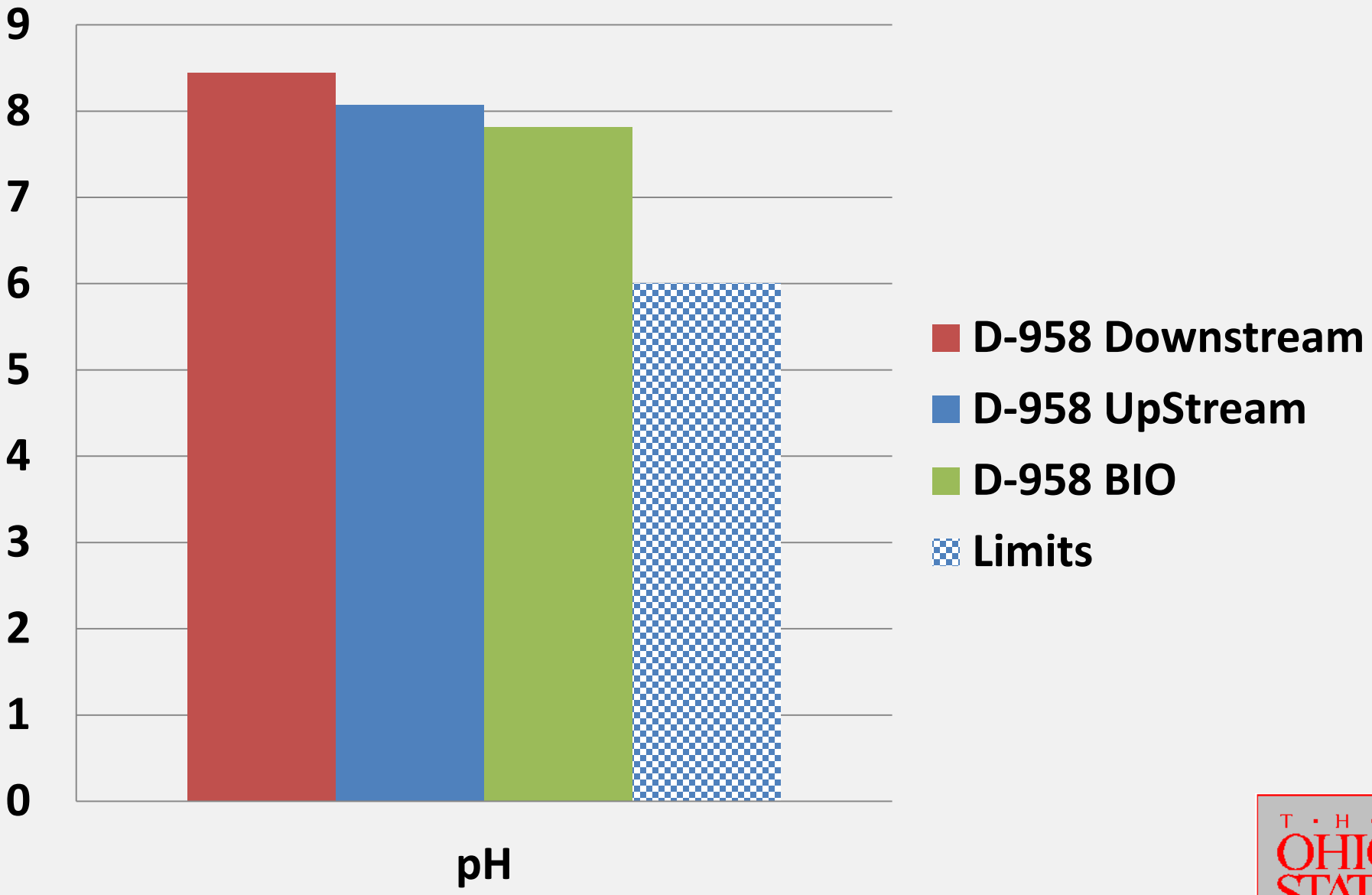
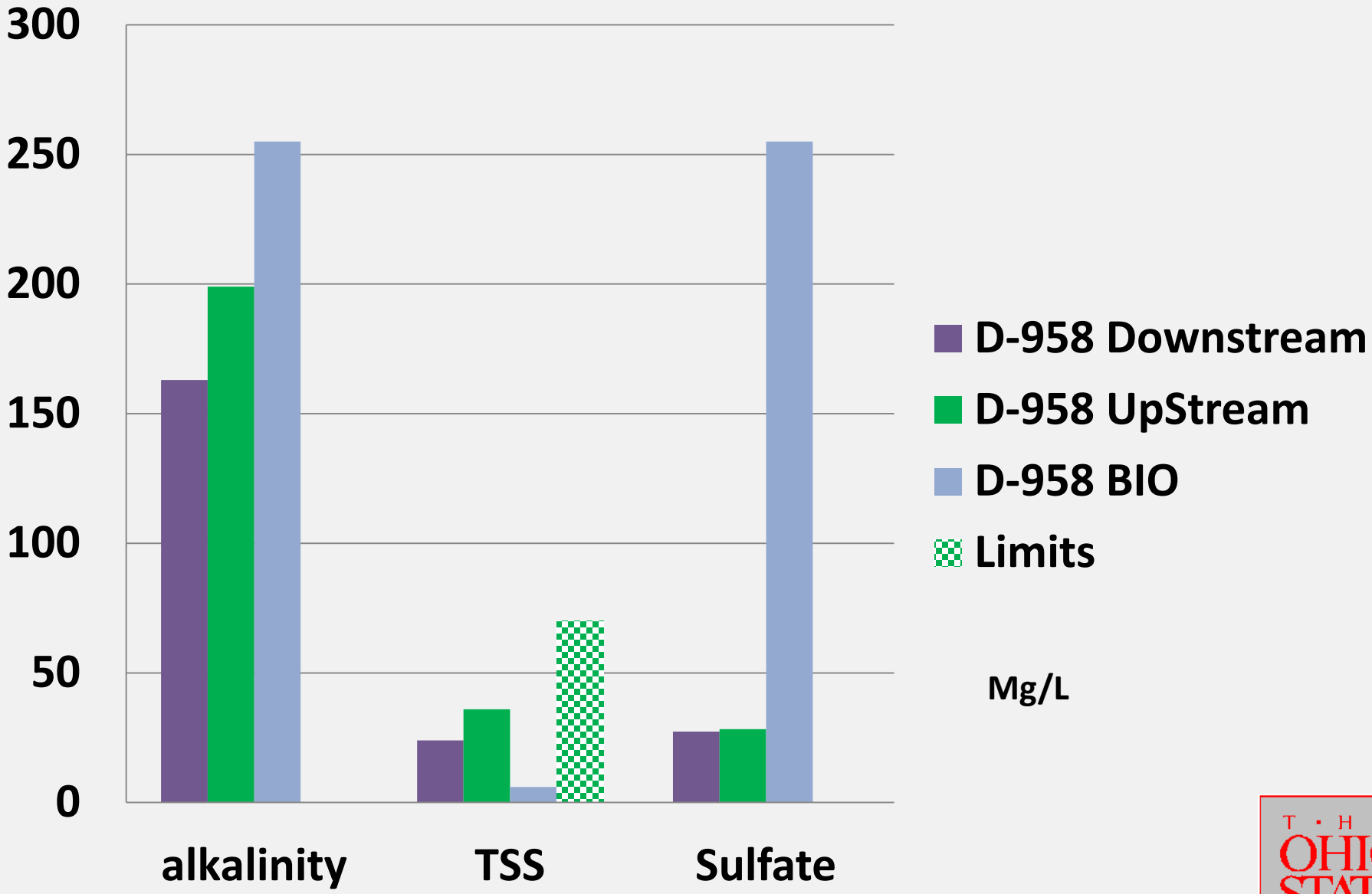
D-0958 pH


9
8
7
6
5
4
3
2
1
0
pH
D-958 Downstream
D-958 UpStream
D-958 BIO
Limits

D-0958



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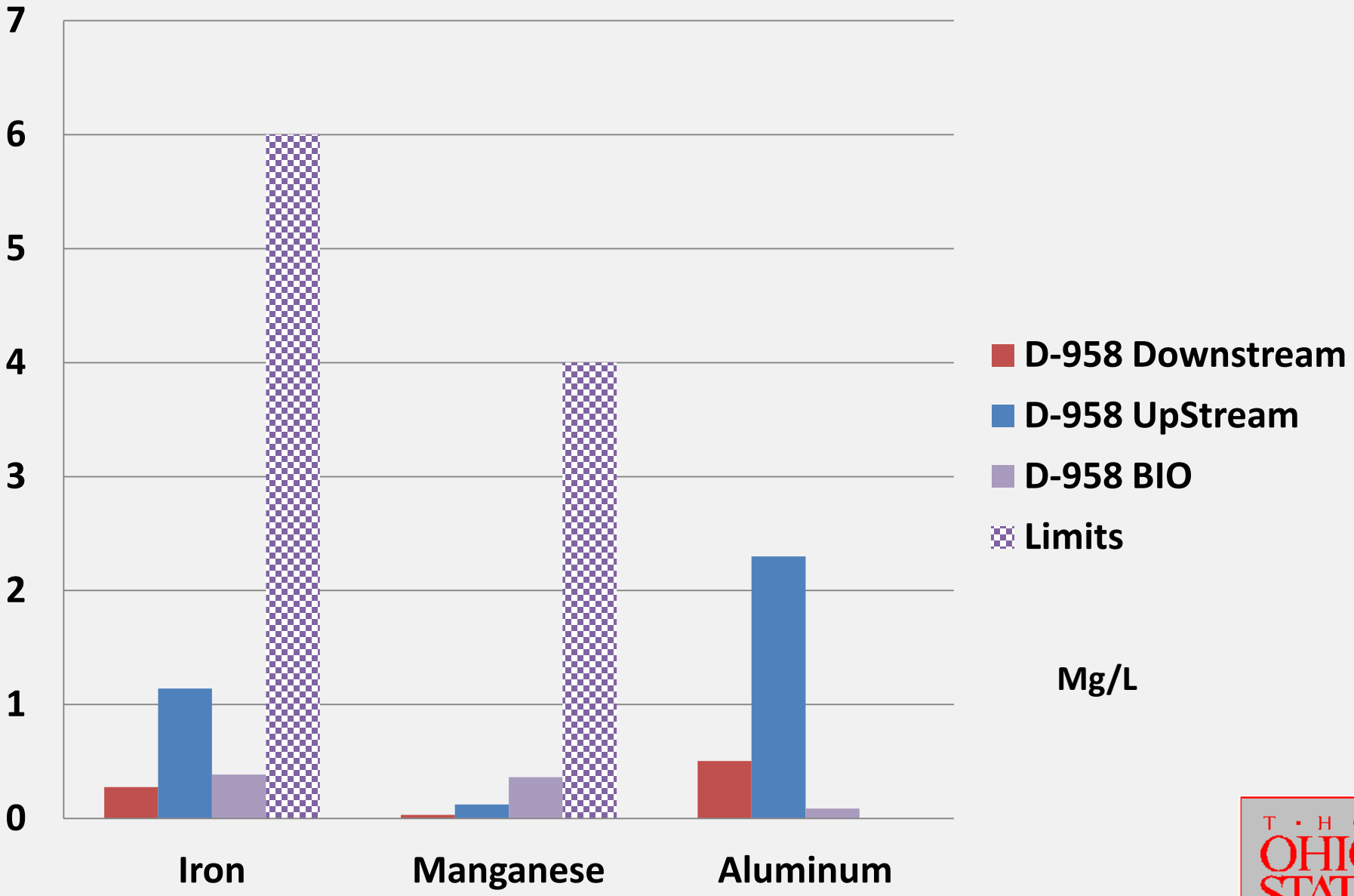
D-0958



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B&N D-0807 Stream Reach 1

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Noble County- East Fork Duck Creek Watershed

Contour mining , 8 inches of resoiling material

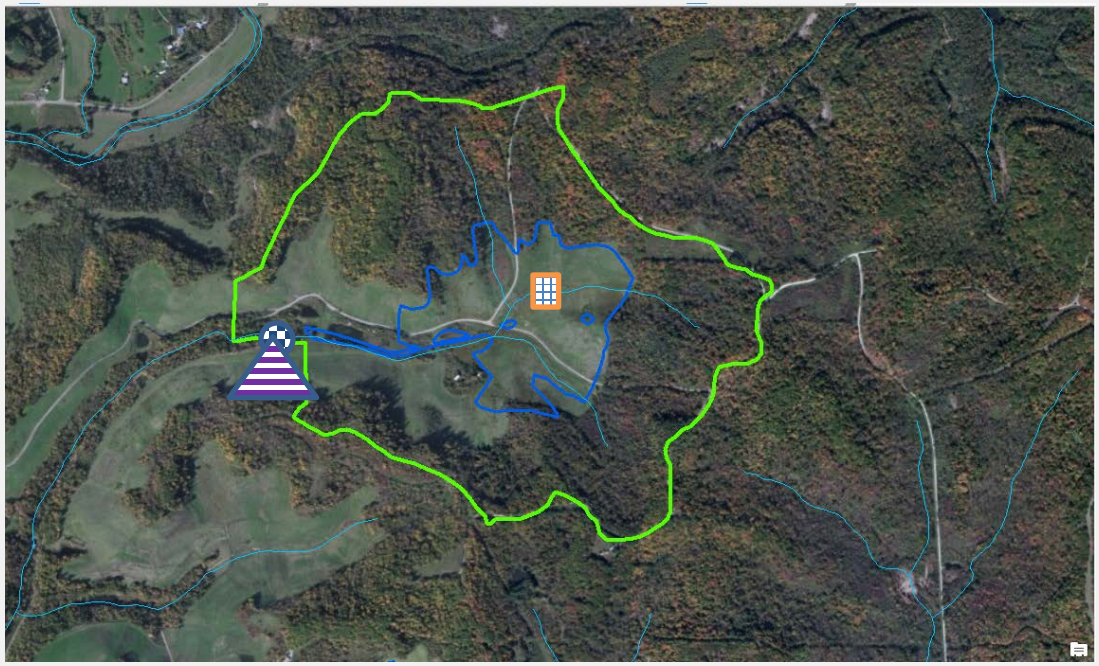
Year 12 was planted in 2001 and was released in 2007

Drainage Area: 96 Acres (.15 square miles)

Slope: 1 %

D-0807 Stream Reach and data collection sites

- affected area of 68 acres
- Drainage area(.58 sq. miles)



Reconstructed stream

Biological site

D-0807 Bio water quality site

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D-0807 Reconstructed Stream Reach # 1 - Natural Channel Design Approach

B&N Coal Co. D-0807 reconstructed stream summary

Bank Full Width (bkf):3.5 ft

HHEI Score: 35

Modified Class II PHWH intermittent stream

Recovering

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D-0807 Biological site- weight of evidence

- HHEI score = 73
- Biological Community
  - Species present- **abundance of all taxa low with the exception of tricoptera and caddis flies;**
  - **Other taxa included, creek chubs, Crayfish, larval Northern 2 lined salamanders**
- HMFEI Score 21 = **Class III stream (cool and cold water adapted aquatic species)**

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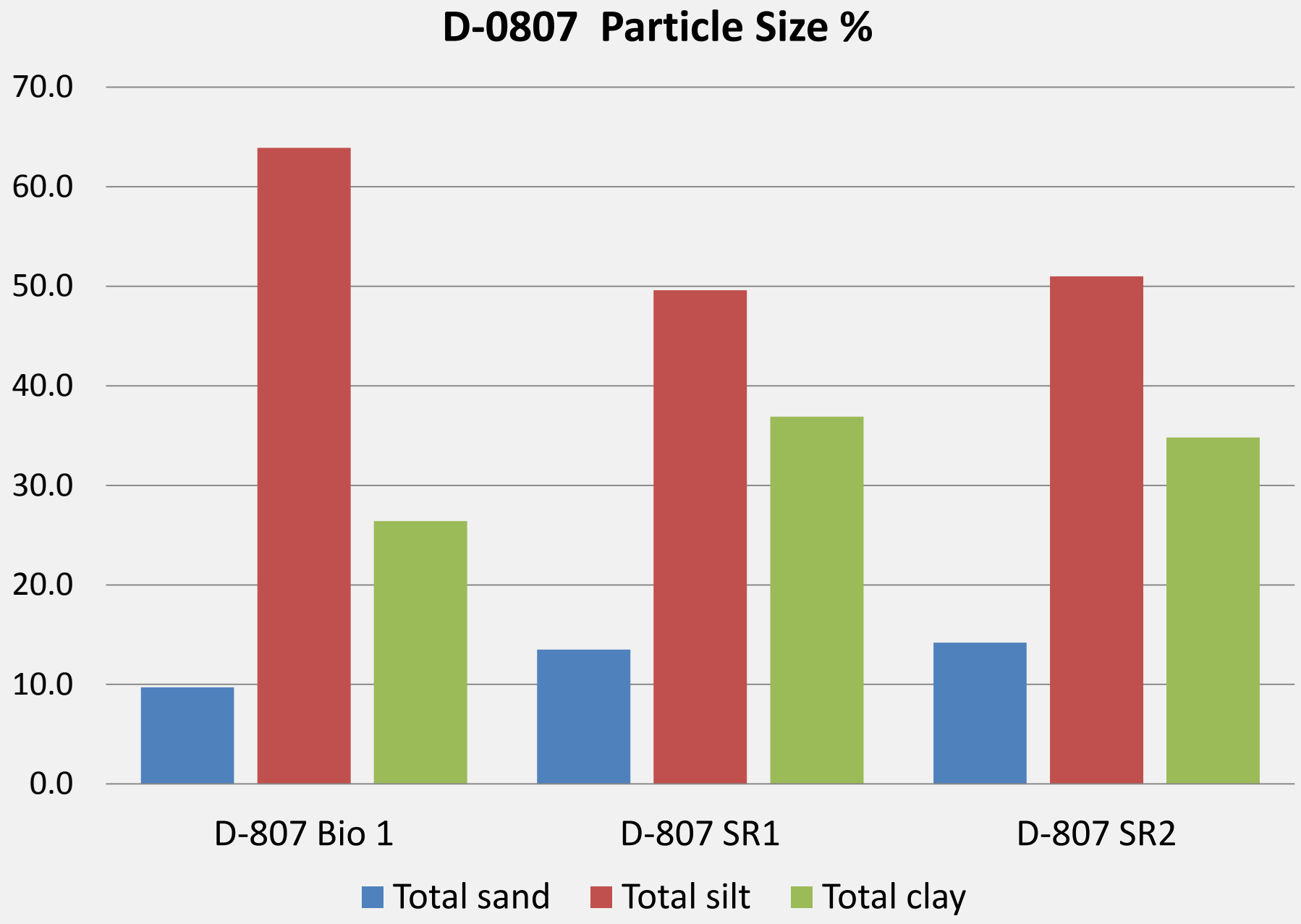
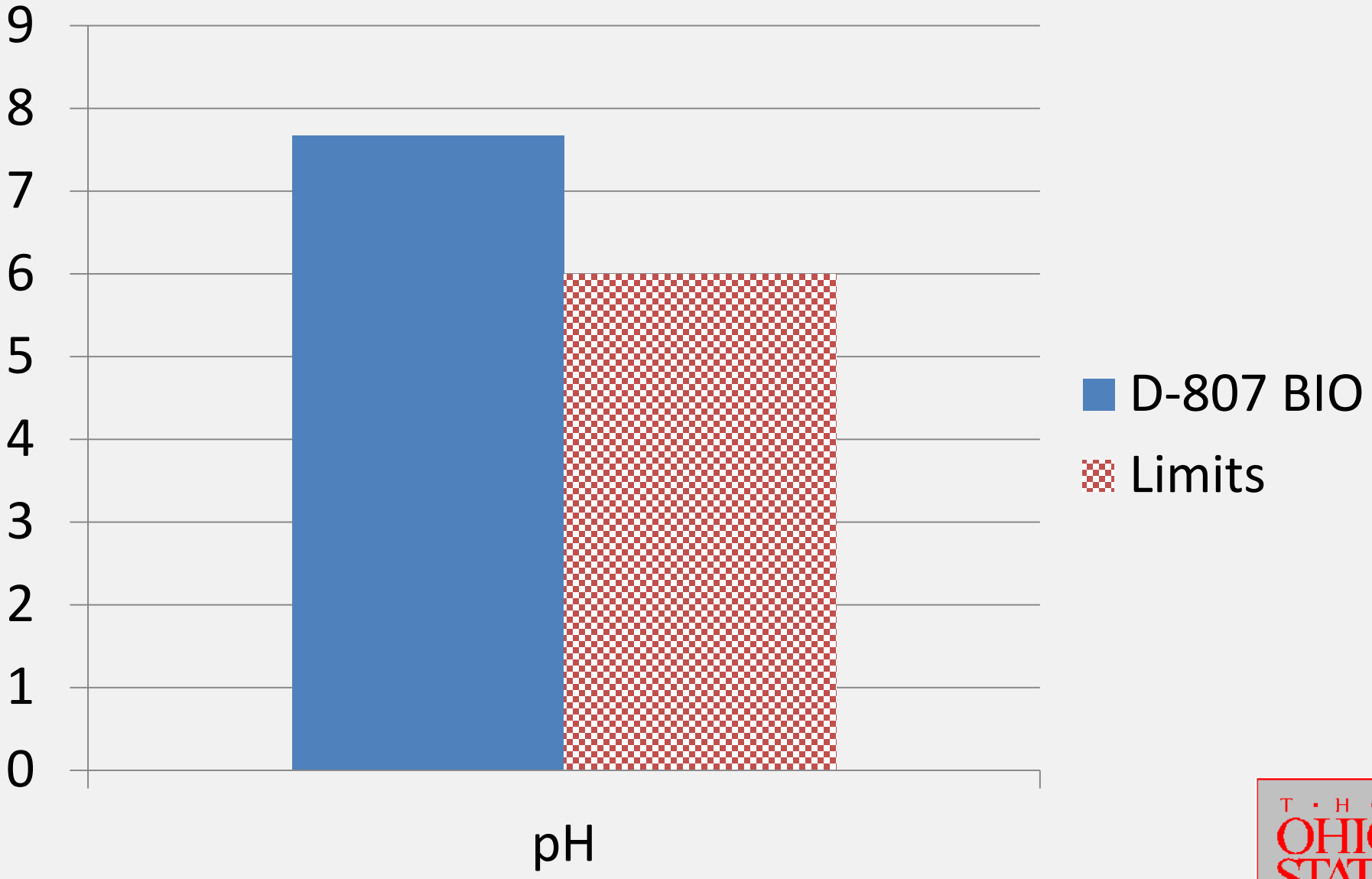
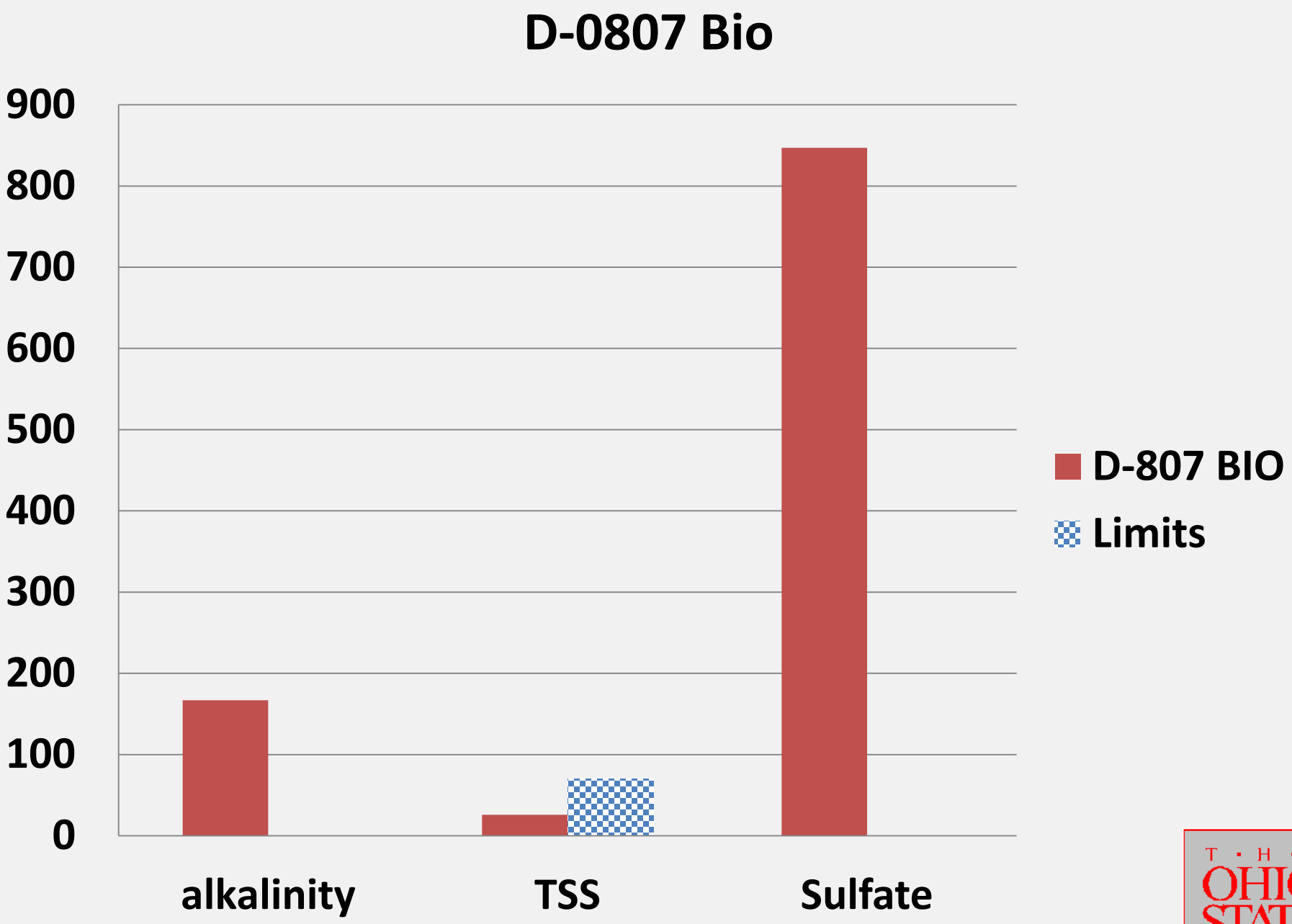
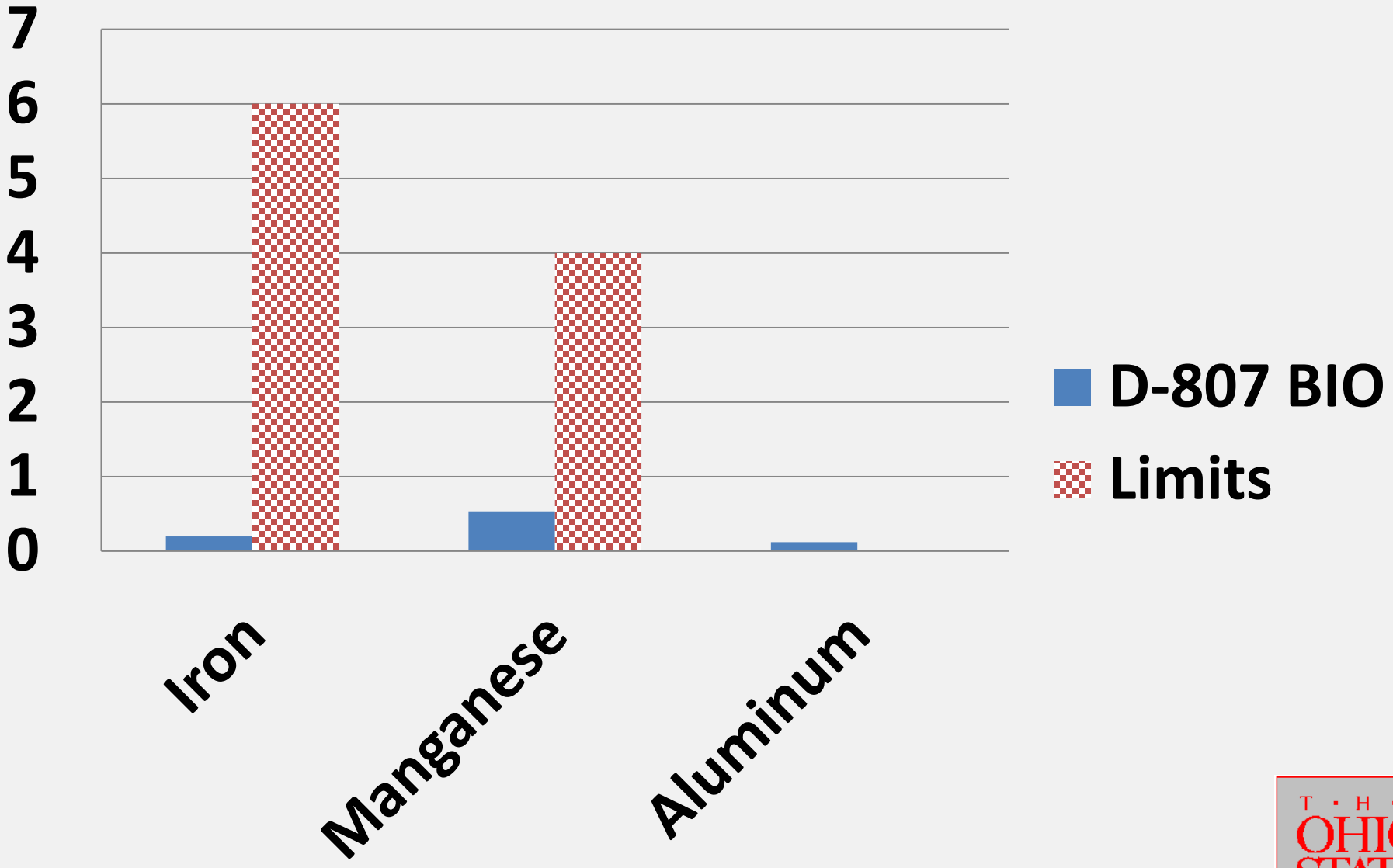

D-0807 Particle Size %
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
D-807 Bio 1
D-807 SR1
D-807 SR2
Total sand
Total silt
Total clay

D-0807 pH




D-0807 Bio
900
800
700
600
500
400
300
200
100
0
alkalinity
TSS
Sulfate
D-807 BIO
Limits

D-0807 Bio



Stream Summary

Permit	Site type	HHEI score	HMFEI score	Stream type	Stream Classification
C-0209	reconstructed	42*	n/a	ephemeral	Class I
C-0209	biological	88	25	perennial	Class III
D-0958	reconstructed	47	n/a*	intermittent	Class II
D-0958	biological	64	25	perennial	Class III
D-0807	reconstructed	35*	n/a*	intermittent	Class II
D-0807	biological	73	21	perennial	Class III

* To be re-evaluated or new evaluation to be conducted

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Preliminary Conclusions

- Downstream and adjacent biological sites of reconstructed stream segments exhibit Class III bio diversity characteristics
- Water quality standards are met at all sites
- Stream segments D-0958 and D-0807 are in a state of quasi equilibrium while C-0209 is in equilibrium
- Reconstructed streams (including steeper slopes) should include trees plantings in the riparian zone

Work Under Progress

- Seasonal water quality sampling for all sites
- At least one additional HMFEI biological evaluation at reconstructed stream sites
- One physical profile at biological site
- Further analysis of data
- Conclusions and recommendations
- Drafting of Final Report

Coal Combustion Products Program

Ohio State's Coal Combustion Products Program focuses on sustainable, high-volume beneficial uses of coal combustion products (CCPs), primarily from sulfur dioxide scrubbing processes, in construction, reclamation, infrastructure rehabilitation, manufacturing and agricultural applications. This program advances the beneficial uses of CCPs from sulfur dioxide scrubbing processes as well as more traditional byproducts, including fly ash, bottom ash, boiler slag and fluidized-bed combustor ash. Re-use of CCPs provides a low-cost raw construction material; extends the life of landfills, and lessens the need for new ones; and helps keep energy production costs in check.

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Funded by the Ohio Coal Development Office, Ohio State University, Ohio coal-fired utilities, ash marketers, private businesses and trade and farming organizations, the Coal Combustion Products Program improves and discovers technically sound, environmentally friendly and commercially competitive uses of CCPs in many interdisciplinary sustainable applications.

The program aids the CCP industry through research, education, technology transfer and outreach in its efforts to:

- expand uses in proven areas, such as highway and agricultural applications;
- remove or reduce regulatory and perceptual barriers to use;
- develop new or under-used large-volume market applications, such as mine land reclamation; and
- place greater emphasis on sulfate and sulfite flue gas desulfurization byproducts utilization.

More than 500 animal feeding pads in more than 12 Ohio counties are made from coal combustion products, including feeding pads at The Wilds in Muskingum County.

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To learn more, visit ccp.osu.edu.

Resources Available to You

Our online library collection has been subdivided into the following categories:

Material Characterization

Applications

Economics of Beneficial Use

Our library listing of journal articles, conference papers and published information sources is related to Coal Combustion Products research. Many of our documents can be downloaded (typ. as pdf files). For references not available online and not subject to copyright restrictions, a paper copy can be provided by contacting Carol Scott at scott.30@osu.edu.

You are welcome to submit articles for inclusion in our reference library. Contact Dr. Tarunjit S. Butalia at butalia.1@osu.edu.

Graduate Student Research

M.S. Thesis

Dorothy Adams, Swelling characteristics of dry sulfur dioxide removal waste products
Jeffreys Chapman, Stress Model Verification with Reclaimed Asphalt Pavement
Malcolm Hargraves, The effect of freeze-thaw cycles on the strength of stabilized flue gas desulfurization sludge
James Howdyshell, Strain compatibility analysis in slope stability modeling
Jun Huang, Degradation of resilient modulus of saturated clay due to pore water pressure buildup under cyclic loading
Na Jin, Fly Ash Applicability in Pervious Concrete
James Kirch, Potential Use of Flue Gas Desulfurization Gypsum (FGD) in a Flowable Grout for Re-mining of Abandoned Coal Mines
Jangguen Lee, The Behavior of Pore Water Pressure in Cohesive Subgrade Soils
Jung Woo Lee, Beneficial reuse of FGD by-products as flowable fill
Yong-Woong Lee, Measurement and Prediction of Resilient Modulus of Lime-Fly Ash Stabilized Cohesive Subgrade Soils
Aleia Long, Evaluating material properties of fly ash modified concrete plates under low velocity impact
Ryan Mackos, Environmental Analysis of Full Depth Reclamation Using Coal Combustion By-Products
Deepa Modi, Potential Utilization of FGD Gypsum for Reclamation of Abandoned Highwalls
Jennifer Myers, Stabilization of sludge using spray dryer absorber ash
Salman Nodjomian, Clean-coal technology by-products used in a highway embankment stabilization demonstration project
Xueling Pan, The Effect of Freeze Thaw Cycling on the Permeability of Stabilized Flue Gas Desulfurization (FGD) Materials
Rachel Pasini, An Evaluation Of FGD Gypsum For Abandoned Mine Land Reclamation
Renee Payette, Landslide Remediation Using Clean Burning Coal Technology By- Products
Gloria Rodgers, Resilient modulus predictions using engineering properties and neural networks
Alexis Semach, Geotextiles for Use in Drainage Systems in Coal Combustion Product Landfills
Sharon Studer, Seepage analysis of a highway embankment constructed from the Flue Gas Desulfurization by-product
Wei Tu, Evaluation of Full-Scale CCP Pavement Performance Using Accelerated Loading Facility
Michael Nuhfer, Use of flue gas desulfurization by-product as a lake-bed liner

Ph.D. Dissertations

Dong-Gyou Kim, Development of a Constitutive Model for Resilient Modulus of Cohesive Soils
Sung Hwan Kim, A decision support system for highway embankment design using FGD by-products
J.W. Lee, Real-Time Monitoring of Landslide Using Wireless Sensor Network
Panuwat Taerakul, Characterization of trace elements in dry flue gas desulfurization (FGD) by-products
Wei Tu, Response Modeling of Pavement Subjected to Dynamic Surface Loading Based on Stress-Based Multi-layered Plate Theory
Chin-Min Cheng, Leaching of coal combustion products: field and laboratory studies

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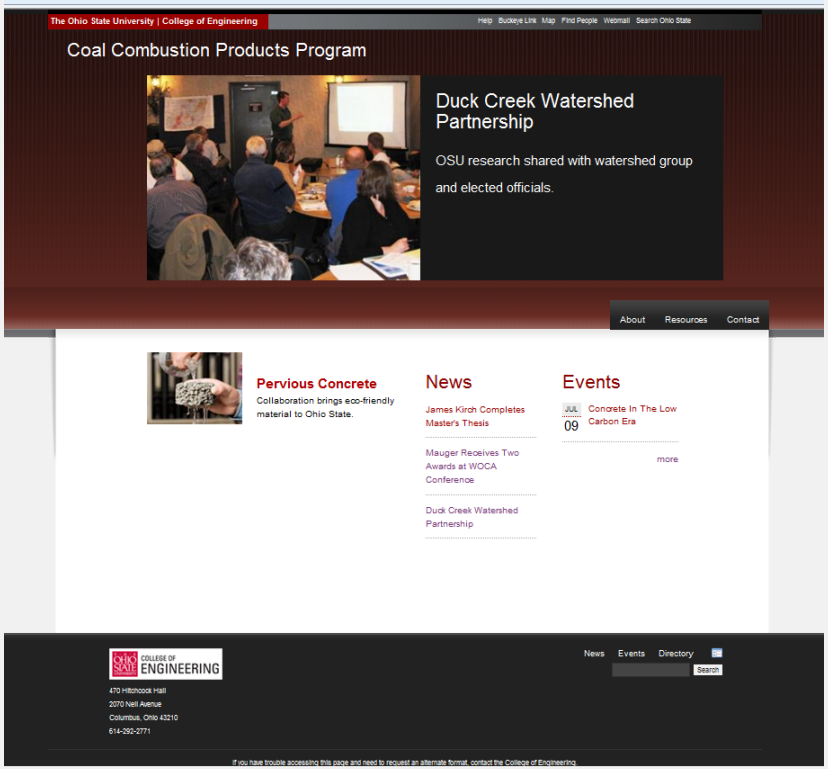

The OSU CCP program addresses the needs of the industry and helps advance the technically sound, environmentally friendly, and commercially competitive uses of CCPs in many interdisciplinary sustainable applications.

You are invited to have a link from your website to the OSU CCP Program website. We will be glad to reciprocate this, in mutual appreciation.

References

- DMRM- Natural Channel Design Procedures for Reconstructed Small Headwater Streams within Coal Mine Operations in the Western Allegheny Plateau Ecoregion of Ohio- 1999
- DMRM- Reconstructed Stream Design Guidelines- 2014
- Environmental Hydrology 2nd Edition- A. Ward- 2004
- OEPA-Field Evaluation Manual for Ohio's Primary Headwater Habitat Streams- 2009
- ODNR, Division of Soil & Water Resources/ Stream Modules Spreadsheet Tools

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Glossary of terms

- HHEI- Headwater Habitat Evaluation Index
- PHWH- Primary Headwater Habitat
- HMFEI- Headwater macroinvertebrate Field Evaluation Index
- Weight of evidence- HHEI and HMFEI scores, and BFW compared to streamstats

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Two Stage Channel

Consider two stage channels in the reconstruction design process where appropriate

Benefits:

- Stable Banks
- Greater Flood Control
- Sediment Removal
  a) Allows for heterogeneous sedimentation which increases biodiversity
- Nutrient Removal
  a) Increased de-nitrification as a result of a higher surface area
  b) Greater Bio-assimilation, or plant growth, allowing for peak attenuation