# Investigation Acidic Discharges at the Monahan Abandoned Mine Lands Site, Kansas*

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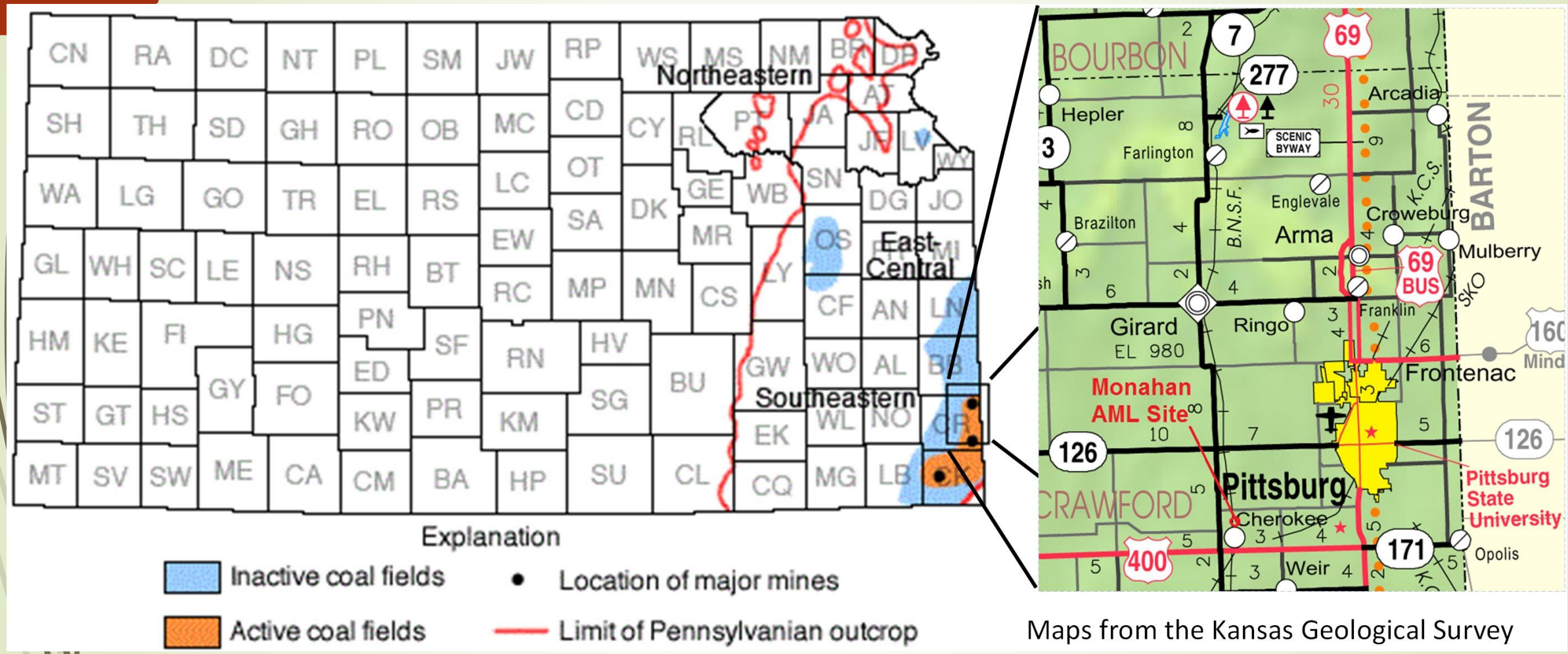
# Investigation Acidic Discharges at the Monahan Abandoned Mine Lands Site, Kansas - **What will we be Covering?**

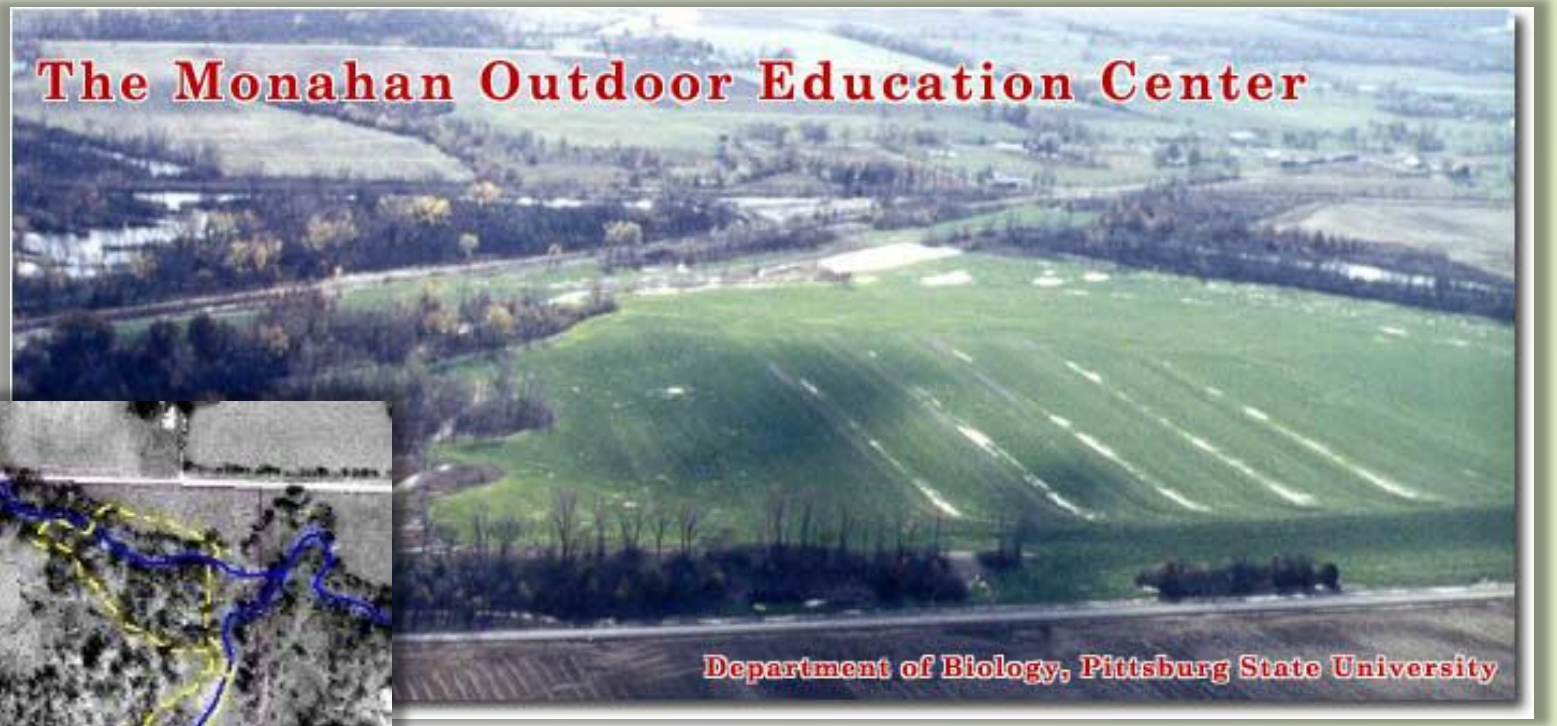
- Location and history of coal mining at the Monahan AML site.
- Occurrence of acid mine drainage (AMD) at Monahan.
- Previous Investigations.
- KDH&E/OSMRE/PSU Baseline Hydrologic Investigation.
  - Updated water quality of AMD and freshwater resources.
  - Weir installation and flow measurements.
  - Jar testing.
- Topographic Mapping.
- Conceptual design of the Monahan Passive Treatment System (PTS).
- Final Engineering design and construction of the Monahan PTS.
- Preliminary PTS Performance.

# Location of the Monahan AML Site




Maps from the Kansas Geological Survey

# Location of the Monahan AML Site





Pittsburg State University

# History of Coal Mining at the Monahan Site

| Date | Project Description (extracted in part from Arruda, 2003) |
|---|---|
| 1899-1918 | The 3-ft. thick Weir-Pittsburg coal interval was underground mined beneath the Monahan site by the Western Coal Mining Co.; 100-ft. deep shafts were located onsite. |
| 1930-1940's | From the mid-30s to early-40's the 1.5 ft. thick Mineral coal seam extracted by area-type surface mining (Commercial Fuels Co. Mine #10); the 25 ft. overburden removed by a stripping shovel. |
| 1930-1940's | Coal from several Commercial Fuels Co. surface mines were processed onsite by wet-type shaker screens. A 30-acre slurry pond contains ~ 15-ft. thick of coal refuse fines contains about composed of about 50% of the high sulfur coal. An adjacent coarse refuse "gob" pile was partially burned after abandonment (red slope areas; Imhoff, 1994). |
| 1930-1940's | A 17-acre gob pile has a 20-30 ft. height (USDA-SCS, 1983); in sum,~80 acres were covered with acid-forming coal waste materials. |
| 1940-1980's | The 80-acre Monahan AML site formed a more-or-less barren wasteland. AMD seepage developed along the north end of the re-graded gob pile (Fig. 4) and several shallow acidic impoundments formed in the slurry area with a pH 2.2-2.6. |

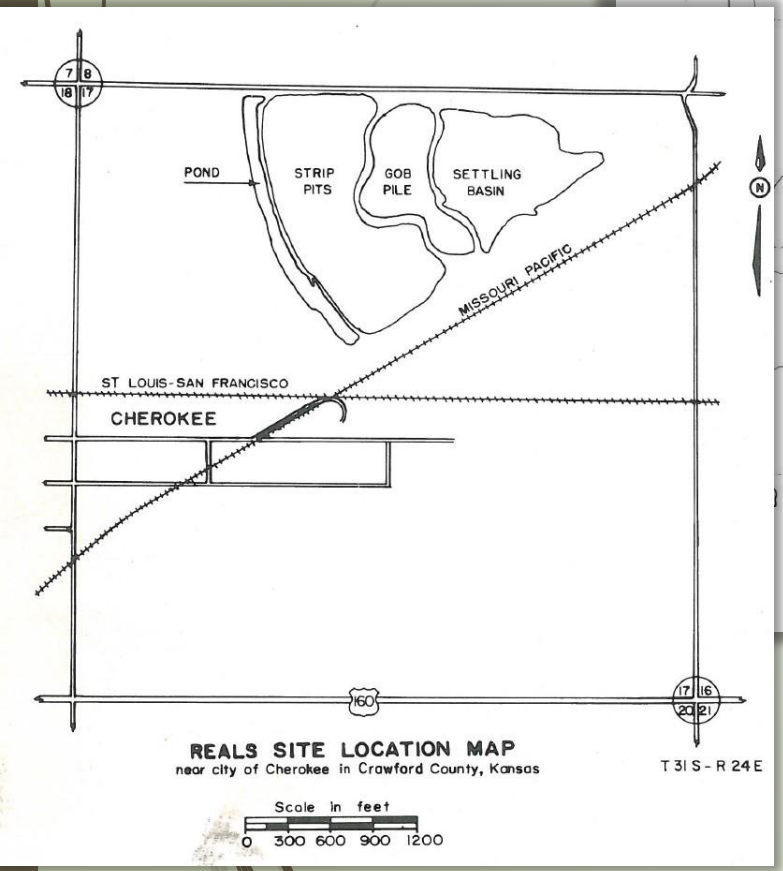
# 1983 RAMP Program Land Reclamation

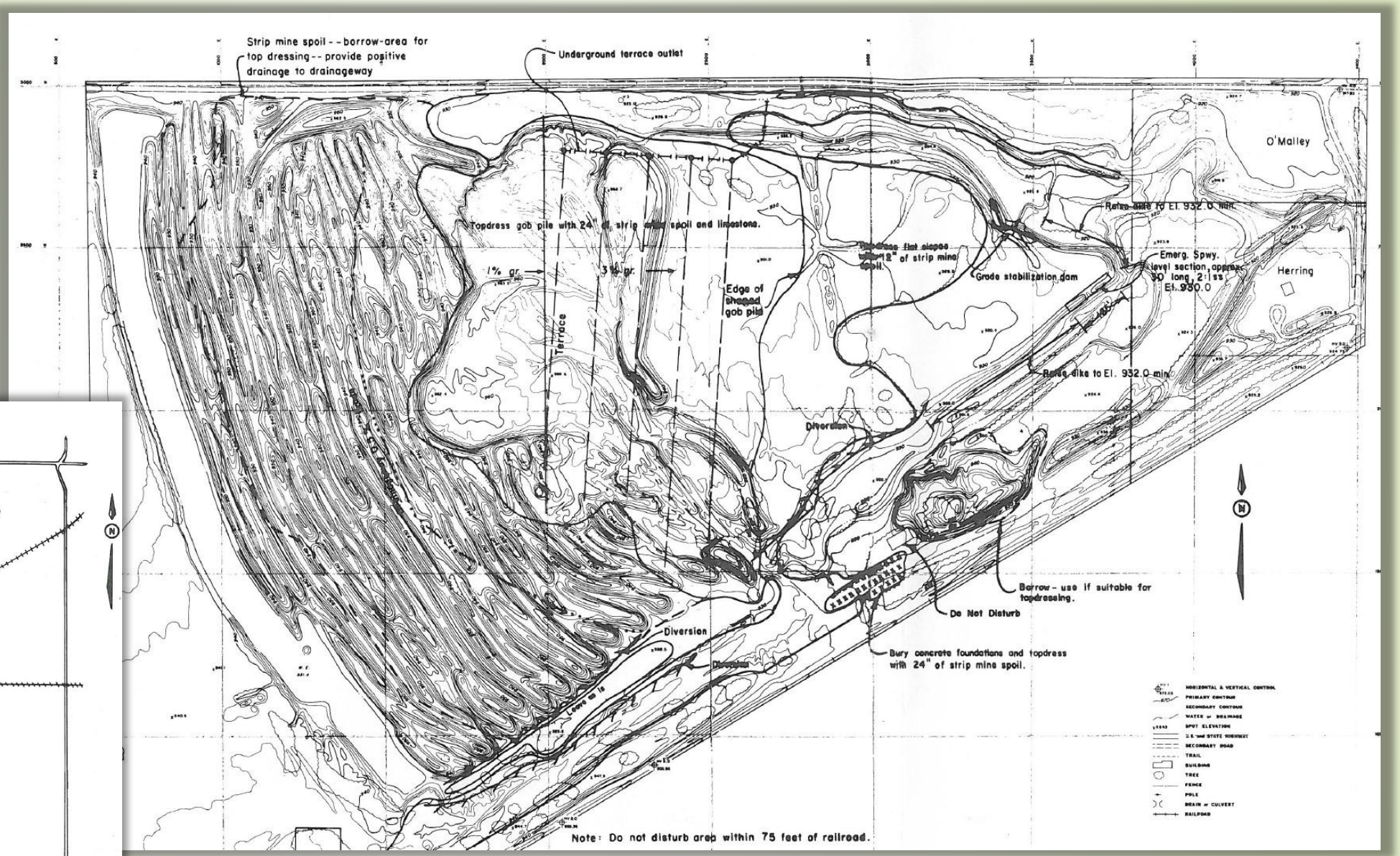
TABLE OF QUANTITIES

| ITEM | UNIT | QUANTITY |
|---|---|---|
| GRADE STABILIZATION DAM | JOB | |
| RAISE DIKE TO El. 932.0 | Cu. Yd. | 122 |
| DIVERSIONS | Lin. Ft. | 1,550 |
| BURY CONCRETE FOUNDATIONS | JOB | |
| RESHAPE GOB PILE (Exc.) | Cu. Yds. | 136,000 |
| CRUSHED LIMESTONE | Tons | 17,000 |
| TOP DRESSING | Cu. Yds. | 121,000 |
| TERRACES | Cu. Yds. | 9,520 |
| UNDERGROUND TERRACE OUTLET | JOB | |
| GATES | Each | 4 |
| FENCE | Lin. Ft. | 8,200 |
| LIME | Tons | 560 |
| SEEDING, MULCHING & FERTILIZING | Acres | 80 |
| WOODY PLANTS | JOB | |
| IDENTIFICATION SIGN | Each | 1 |

| Date | Project Description (extracted in part from Arruda, 2003) |
|---|---|
| 1984-1985 | Reclamation was conducted by the Natural Resources Conservation Service (NRCS) using Rural Abandoned Mine Program (RAMP) funds, which reclaimed an old "gob" pile and established prairie vegetation (Reals reconstruction; USDA-SCS,1983). This project re-graded the mine spoil and filled acid pits with gob, placed 1-foot layer of agricultural ground limestone over 34 acres underlain with gob, covered most of the site with 1-ft. of weathered mine spoil, and constructed five terraces on the western slope of the re-shaped gob pile with a subsurface terrace drain outlet to a road ditch that extends along the northern boundary. |

# Land Reclamation




- Source: Reals Reconstruction; USDA-SCS,1983

# Previous AMD Investigations

AMD along road ditch (U1 to U4).


PSU well data and sample location map (Arruda, 2003)

| Parameter | Mean East | West | North |
|---|---|---|---|
| pH (su) | 5.7 | 5.9 | 5.5 |
| conductivity (mS/cm) | 3.56 | 4.72 | 4.87 |
| dissolved oxygen (mg/L | 1.5 | 1.1 | 1.2 |

| Well | Total Iron (mg/L) | Sulfates (mg/L) |
|---|---|---|
| East | 1140 | 390 |
| West | 1130 | 340 |
| North | 2760 | 620 |

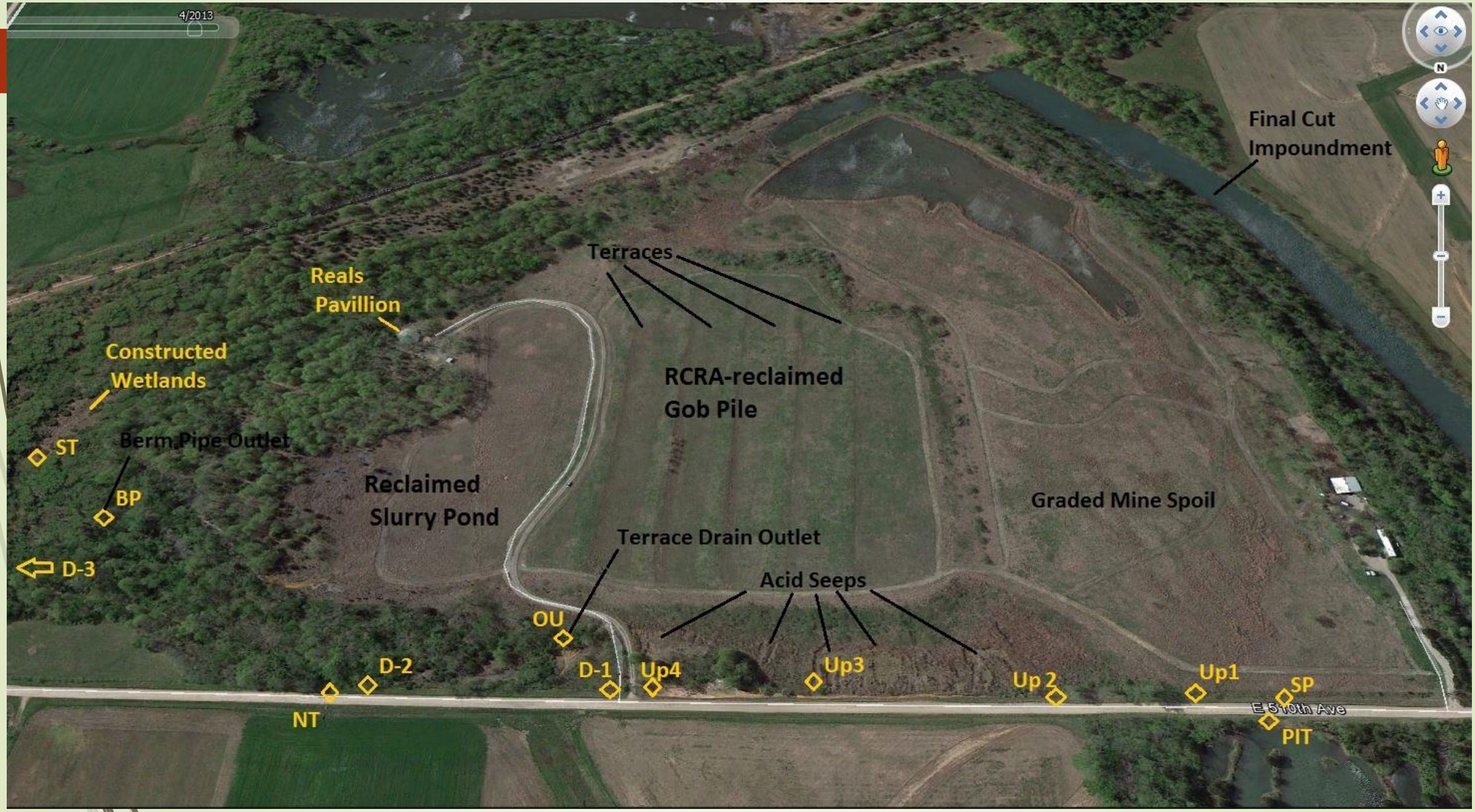
| Date | Project Description (extracted in part from Arruda, 2003) |
|---|---|
| 1987, 1993 | Vegetation surveys by PSU Dept. of Biology staff and graduate students (Vickers, 1989; Yates, 1996) which found sparse vegetation being replaced in time by a diverse range of species that covered most of the site. |
| 1990-1991 | Reconnaissance investigation of AMD at the Monahan site by PSU Dept. of Biology graduate student (Imhoff, 1994). |
| 2000 | KDHE's Bureau of Environmental Remediation installed a set of 3 monitoring wells to evaluate the movement of water beneath the refuse cap and further understand the processes occurring near the north slope AMD seeps. |
| 2000-2003 | Two initial baseline water quality investigations were conducted by Pittsburg State University (Arruda, 2003) which systematically identified water quality across at the site. |
| 2012 | KDHE Bureau of Environmental Remediation conducted a Pre-CERCLIS* survey of the Monahan site; Cd and Zn were found to exceed surface water quality standards at several locations. |

*CERCLIS (SEMS) is a repository for site and non-site-specific Superfund data from1983 to the present.

## **Baseline Hydrologic Investigation:** 2015-2018 Updated water quality of AMD and freshwater resources

- KDHE/OSM/PSU hydrogeological study:
  - Two continuously monitored weirs.
  - Bimonthly surface water sampling.
  - Geochemical modeling using OSM TIPS *Geochemists Workbench* software.
  - Increased flow data allowed calculation of contaminant loading and development of an AMD/dilution water mixing model.

# Baseline Hydrologic Investigation: Sample Site Locations



# KDHE/OSMRE/PSU Baseline Hydrologic Investigation: Baseline Water Data

| | Discharge (GPM)* | Field pH | SpecC. (mS/cm) | D. Fe (mg/L) | D. Al (mg/L) | D. Mn (mg/L) | D. Ni (mg/L) | D. Zn (mg/L) | Sulfate (mg/L) | $Acidity_{calc}$ (mg/L CCE) | Alkalinity (mg/L CCE) | Net Acid. (mg/L CCE) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **AMD** | | | | | | | | | | | | |
| D-1 | 8.85 | 2.84 | 3.065 | 193.38 | 12.423 | 22.75 | 0.460 | 1.110 | 2,000.0 | 639.75 | 0.00 | 639.75 |
| D-2 | 22.92 | 2.80 | 3.360 | 109.15 | 20.467 | 18.50 | 0.214 | 1.810 | 1,992.5 | 428.59 | 0.00 | 428.59 |
| D-3 | 18.35 | 2.87 | 2.140 | 37.90 | 8.900 | 9.10 | 0.182 | 1.090 | 1,500.0 | 223.14 | 0.00 | 223.14 |
| D-4 | 111.08 | 3.67 | 1.575 | 4.44 | 5.045 | 7.56 | 0.120 | 0.019 | 1,150.0 | 66.83 | 0.00 | 66.83 |
| **Dilution Water** | | | | | | | | | | | | |
| PIT | 0.00 | 7.70 | 1.065 | 0.07 | 0.022 | 0.53 | 0.005 | 0.050 | 344.2 | 1.33 | 104.00 | -102.67 |
| BP | 6.38 | 6.59 | 2.175 | 0.65 | 0.026 | 4.40 | 0.048 | 0.050 | 1,049.3 | 2.02 | 88.00 | -85.98 |
| SP | 0.00 | 7.76 | 1.028 | 0.04 | 0.026 | 1.00 | NT | NT | 400.0 | 2.02 | 104.00 | -101.98 |
| ST | 25.40 | 6.82 | 1.523 | 0.35 | 0.031 | 2.07 | 0.024 | 1.190 | 845.0 | 5.87 | 64.40 | -58.53 |
| **1:1 Blend** | | | | | | | | | | | | |
| SP/D-1 Blend | | 3.15 | 2.080 | 82.00 | 5.920 | 13.00 | NT | NT | 1,100.0 | 441.55 | 0.00 | 441.55 |

1) Source AMD (D1 and D2) had a high concentration of metals (Fe > 100 mg/L, Mn >18, Al >14 mg/L and Zn > 1.1 mg/L).
2) Weir at Site D-2 used to estimate AMD discharge ~ 23 GPM; dilution water weir at Site ST ~25 GPM.
3) A blend of AMD (Site D-1) and dilution water (Site SP) was modelled with *Geochemist Workbench*: Blend is net acidic (441 mg/L CCE) with a pH = 3.15 and moderate Al (~6 mg/L).
4) Added dilution by slurry cell (BP) and pit impoundment (ST) (compare D3 and D4 to D1 and D2).

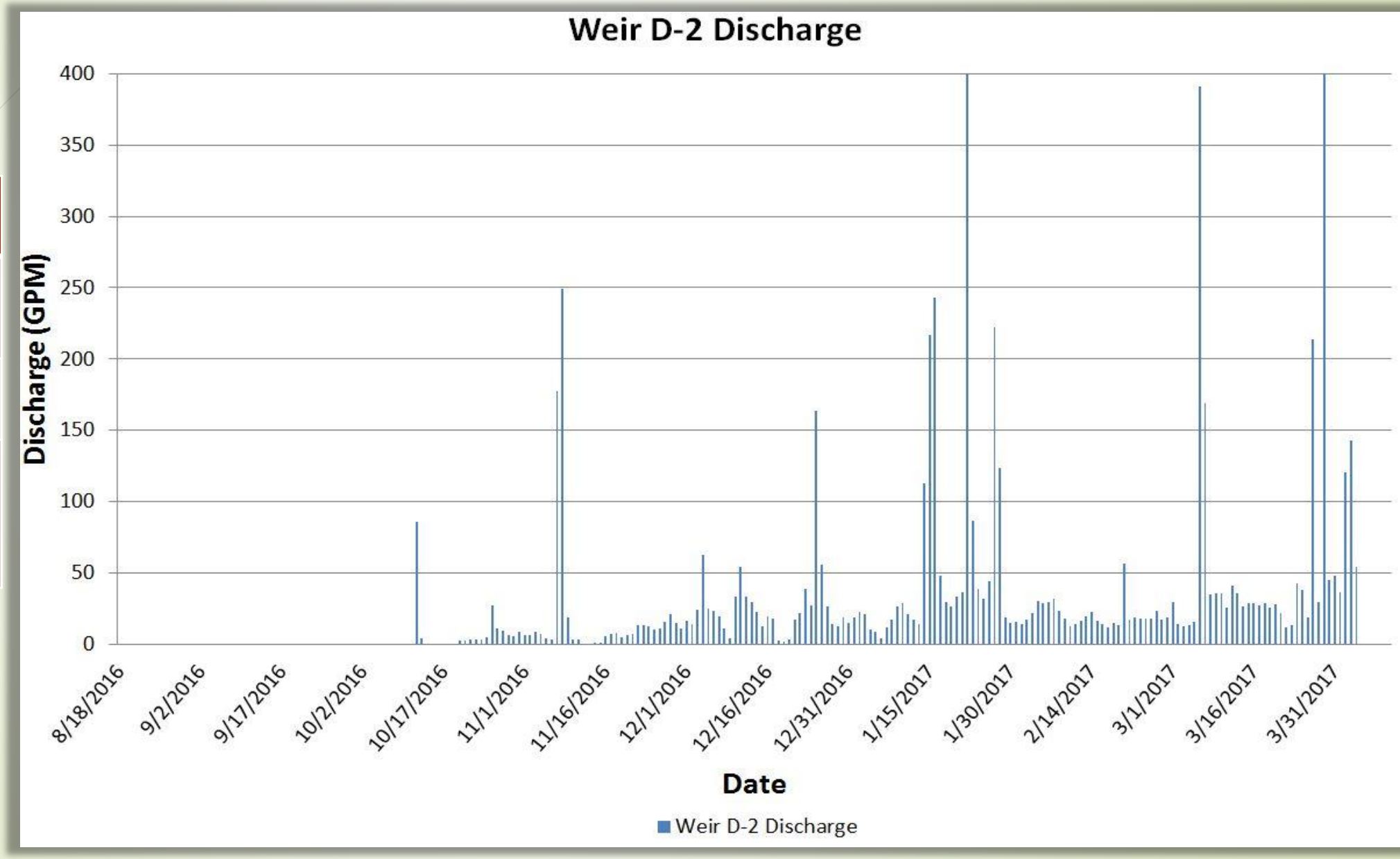
# KDHE/OSMRE/PSU Baseline Hydrologic Investigation: Weir Installation and Discharge Measurements

Team weir construction in the Reals Pavilion

Wier installed at AMD site D-2

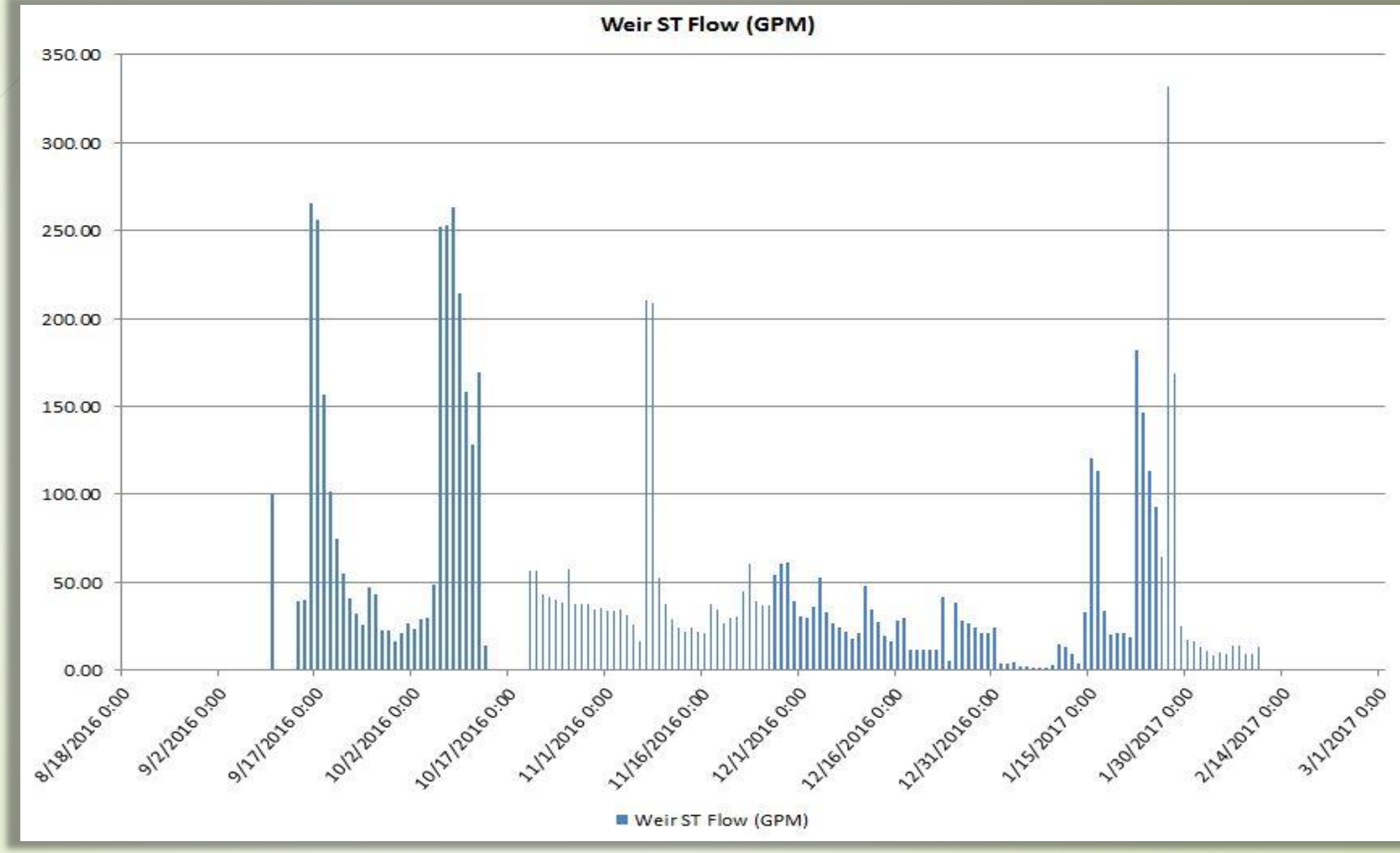
# KDHE/OSMRE/PSU Baseline Hydrologic Investigation:
## Site D-2 Raw AMD Hydrograph

| Site D-2 AMD | |
|---|---|
| Flow | 22.9 GPM |
| pH | 2.80 |
| Net Acidity | 428.6 mg/L CCE |

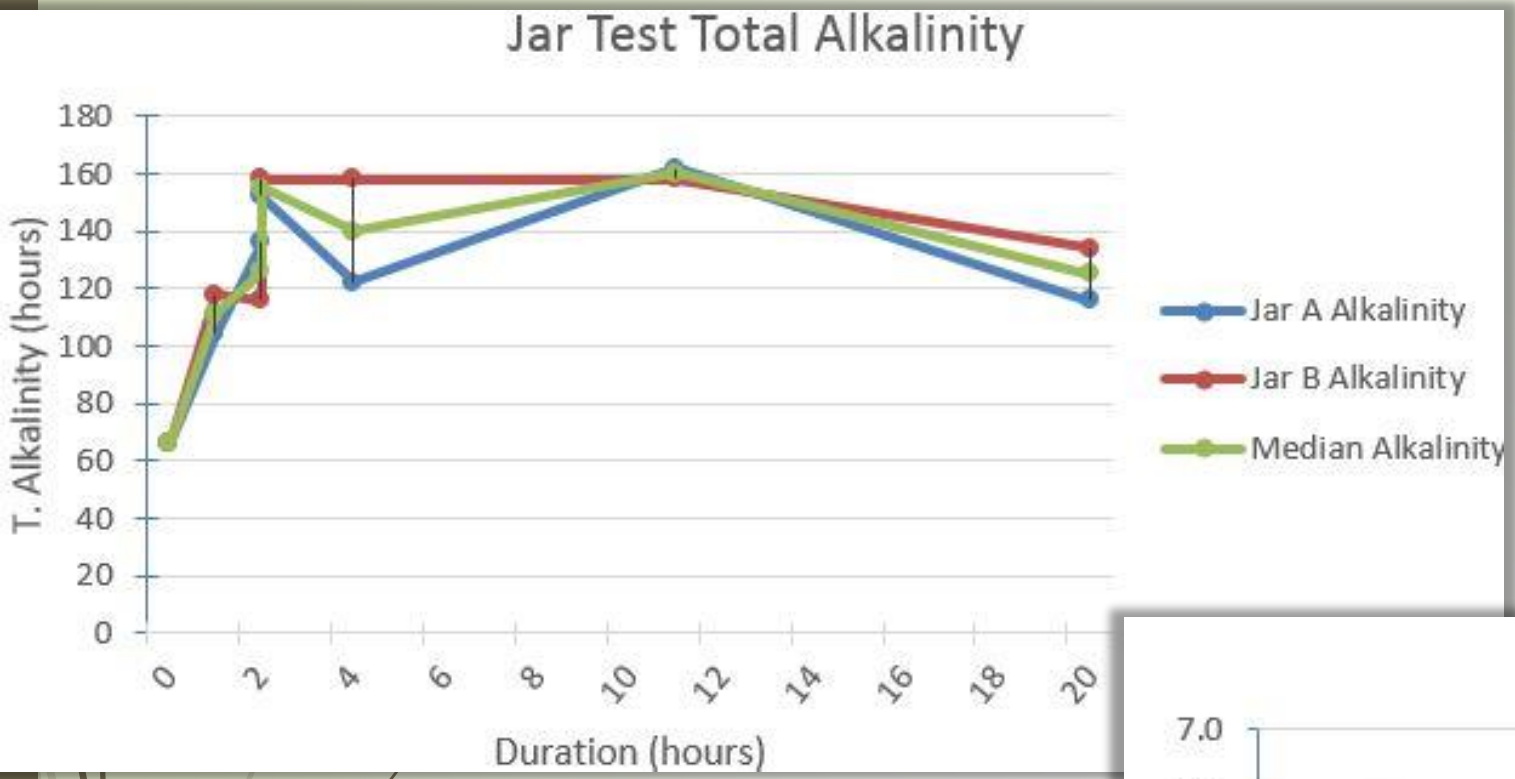


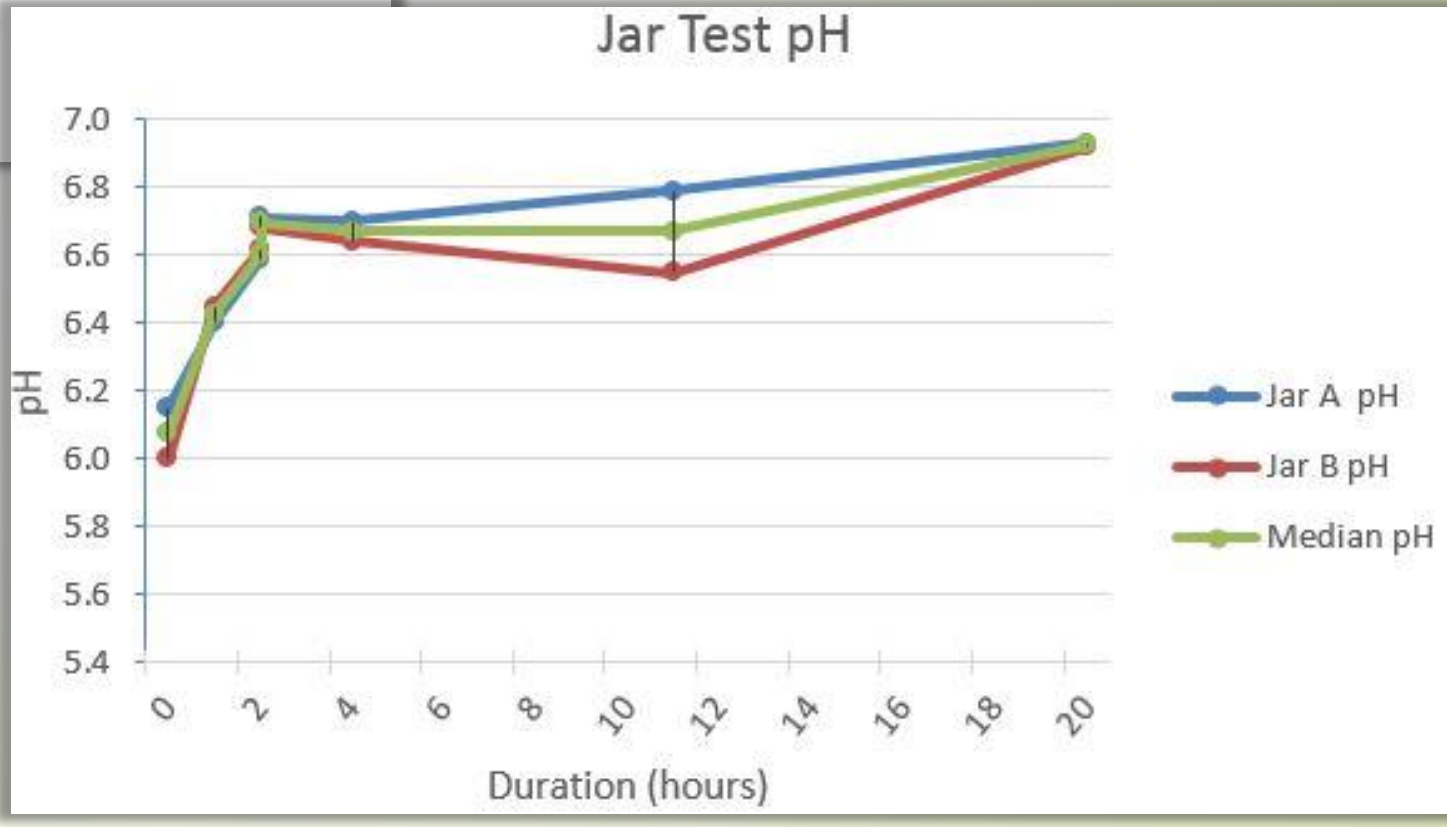
# KDHE/OSMRE/PSU Baseline Hydrologic Investigation: Site ST Dilution Water Hydrograph

| Site ST Dilution | |
|---|---|
| Flow | 25.4 GPM |
| pH | 6.82 |
| Net Acidity | (-)58.5 mg/L CCE |



# KDHE/OSMRE/PSU Baseline Hydrologic Investigation: Jar Test (blended D-1AMD/Site SP dilution water)



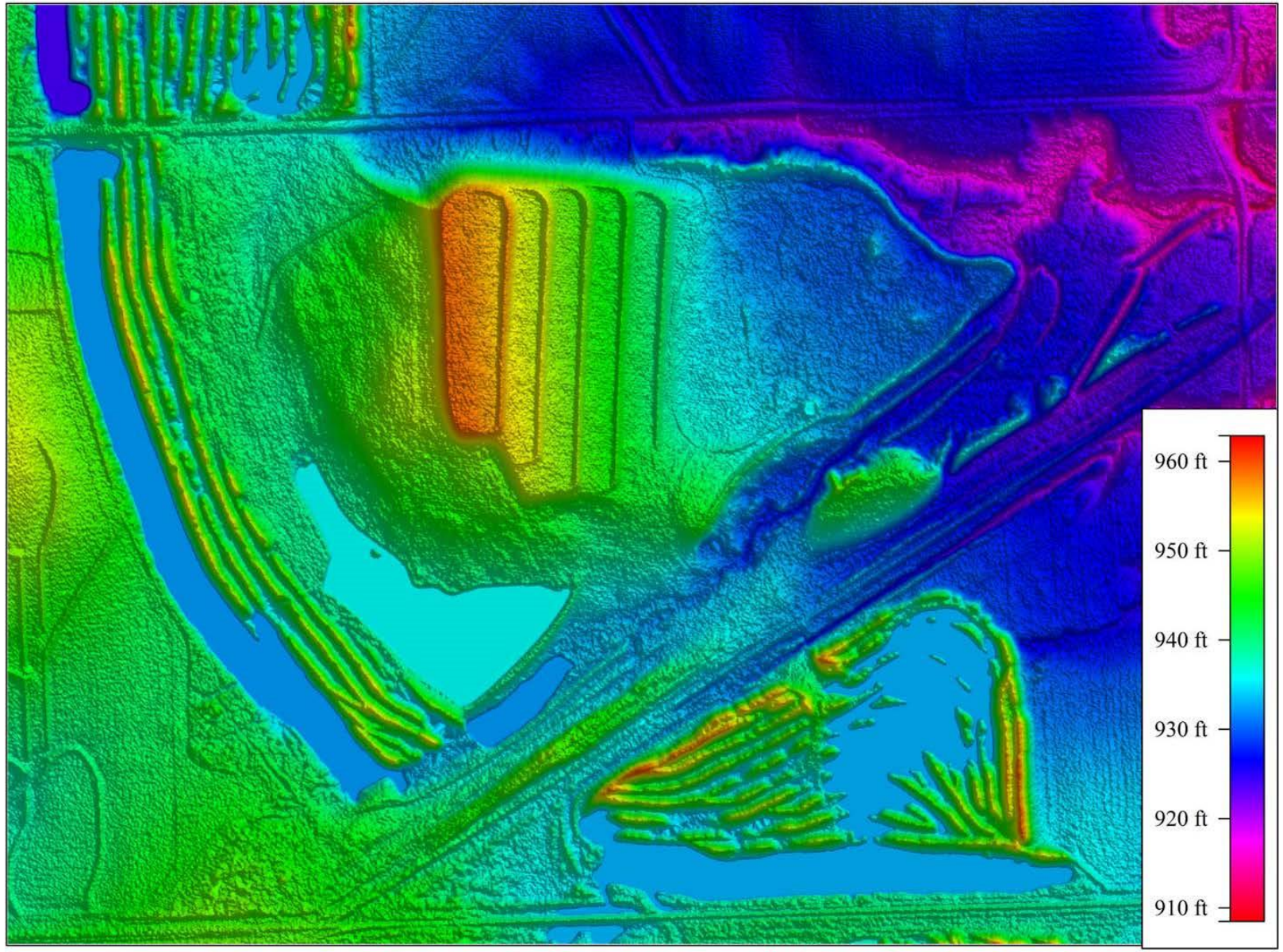




<u>At 12 hours Detention Time</u>:

1) T. Alkalinity ~160 mg/L.
2) pH ~ 6.7

# Topographic Mapping: Lidar-derived Data

Imagery generated by Chis Kiser, P.E.

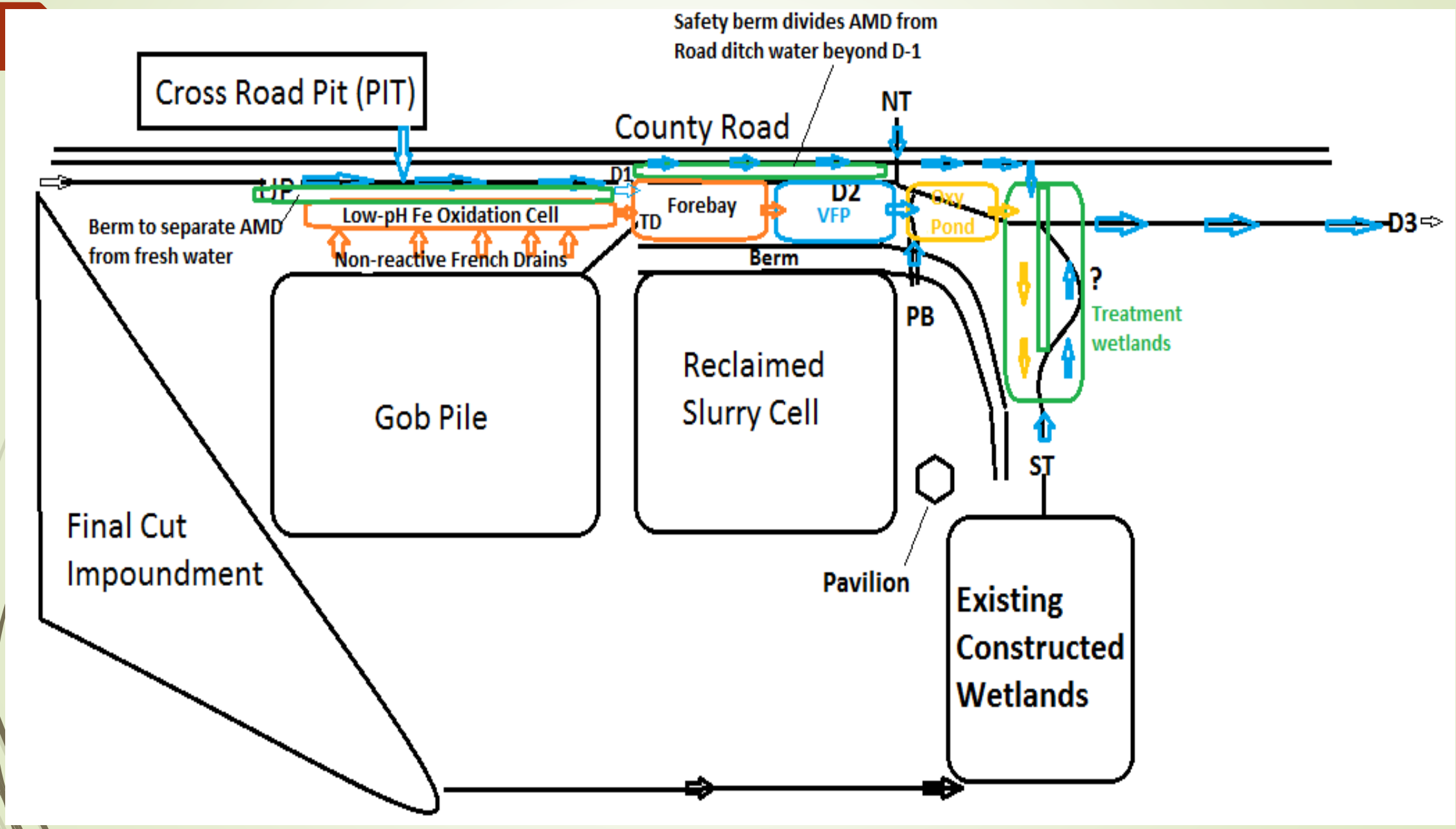


# Conceptual Design: AMD remediation at Monahan.

Site BP – Berm pipe discharge (runoff accumulating in the former slurry cell.

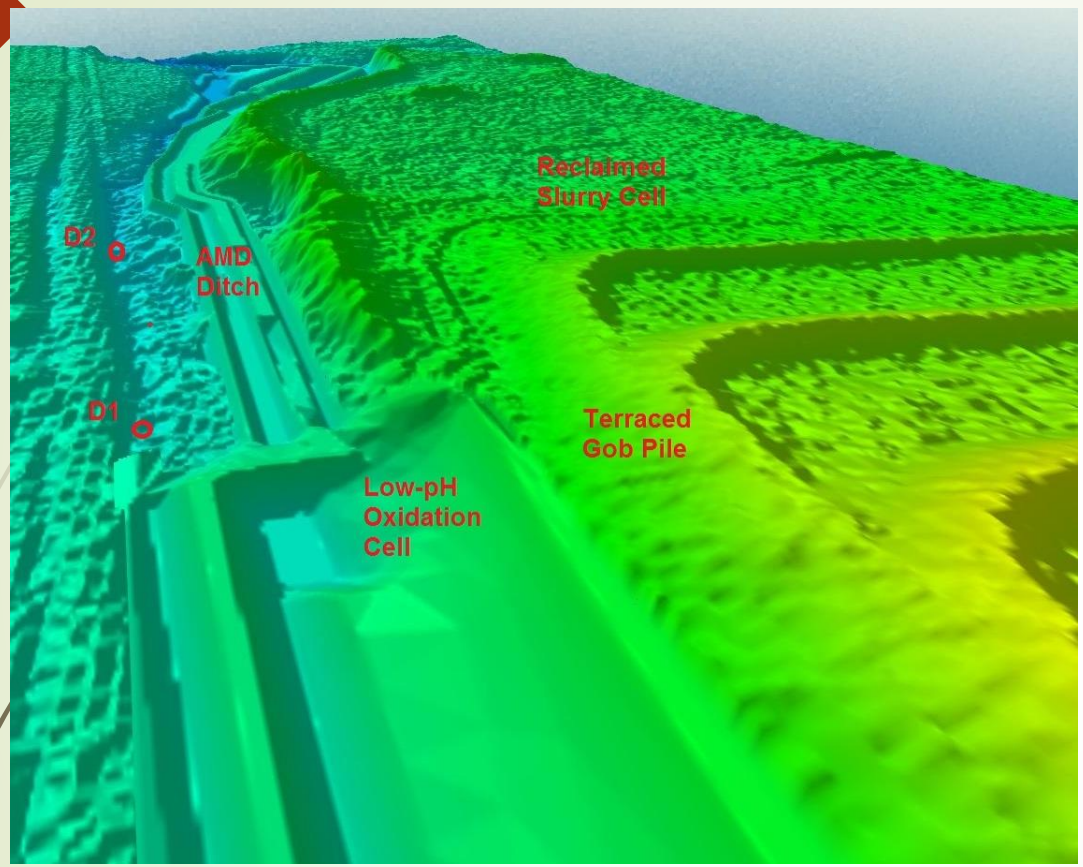
- Removal of acid-forming materials, burial within mine spoil fill, and replace with weathered spoil.
- Collection of AMD by a French drain using non-reactive stone plus a collection ditch.
- Dilute AMD with final impoundment water (Site SP @1:1 to 2:1).
- Promote low pH iron oxidation in 2 shallow water cells and an AMD conveyance ditch.
- Passively add alkalinity with a vertical flow pond (VFP).
- Promote Fe and Mn precipitation in a follow-up 2-cell oxidation pond & aerobic wetland.
- Dilute treated water with discharges ST and BP.

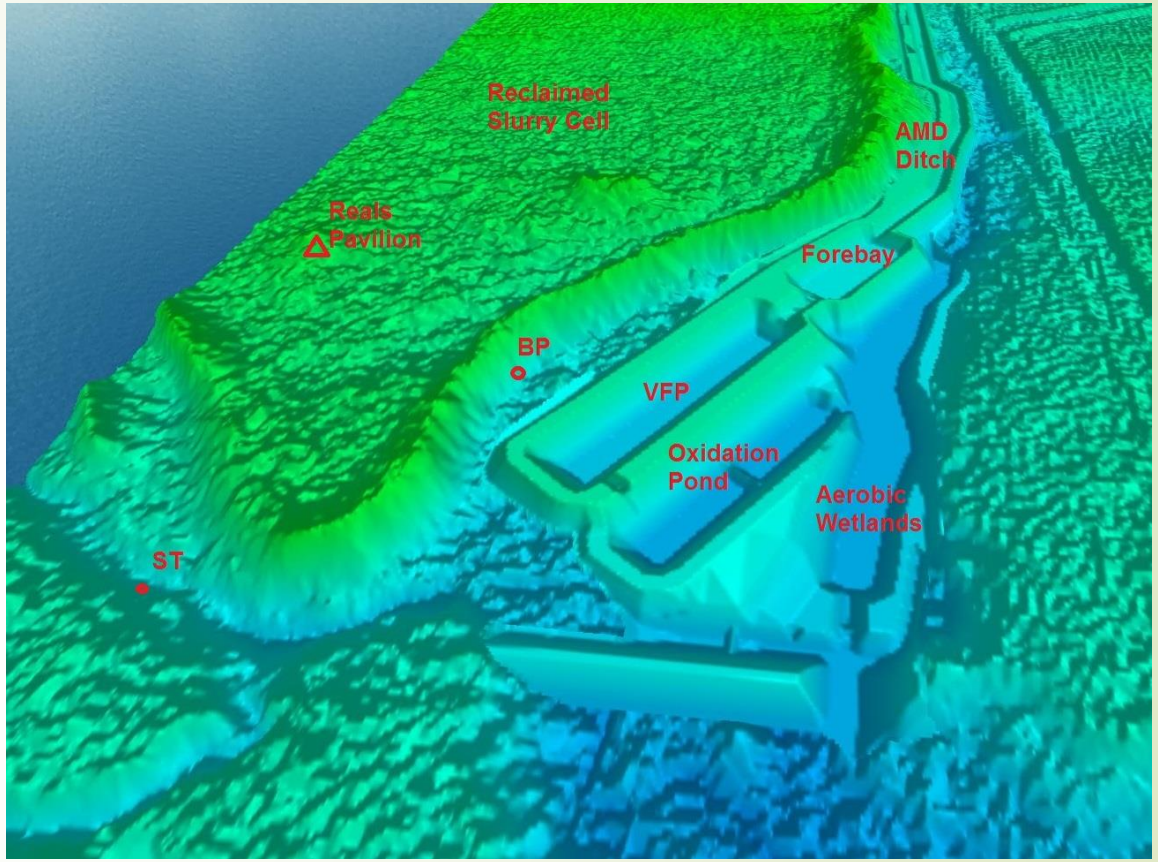
# Flowchart: Original Monahan PTS Design



# Revised Conceptual Design of the Monahan PTS

Imagery generated by Chis Kiser, P.E.



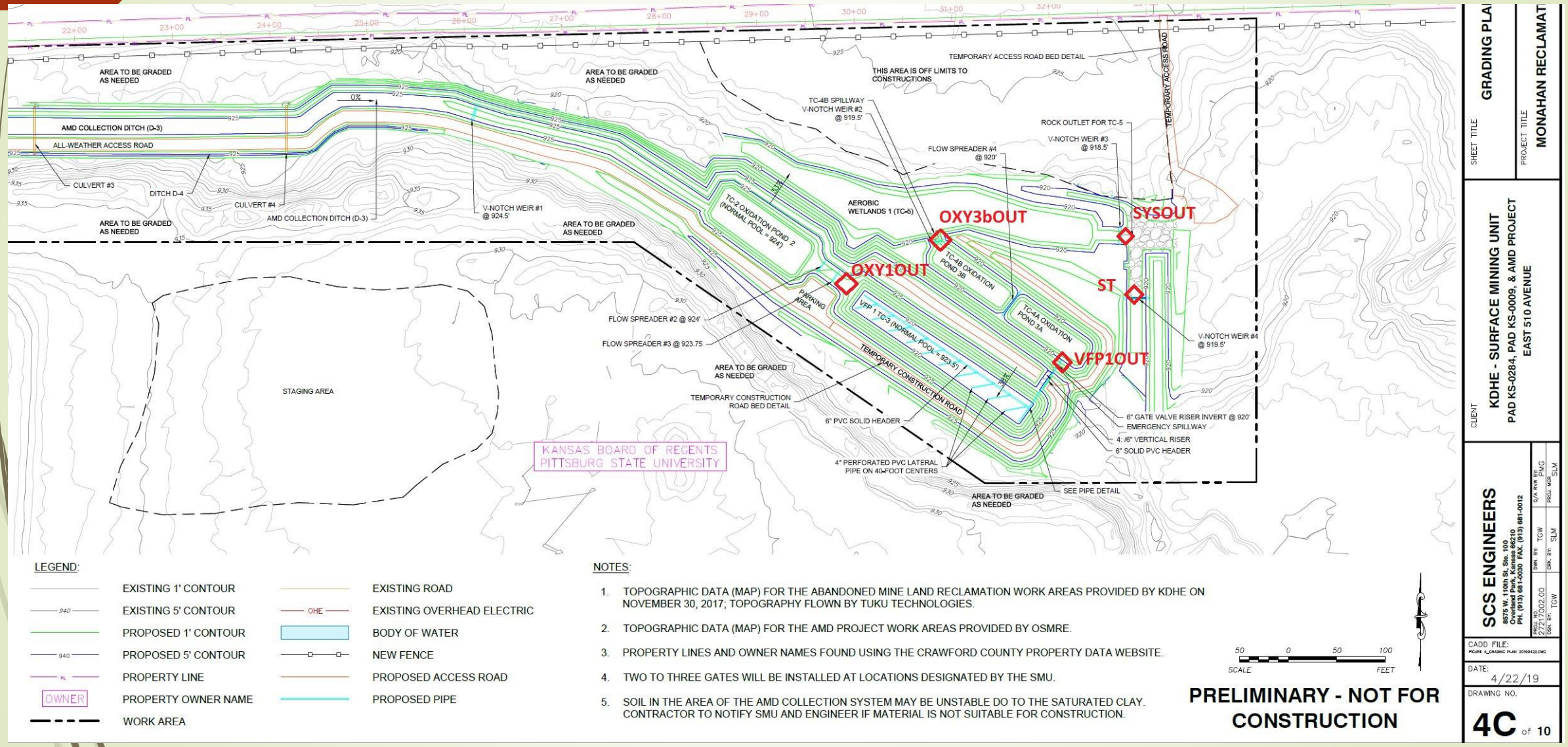




| Date | Project Description |
|---|---|
| 2017-2018 | KDHE/OSM passive treatment design employing OSMRE-TIPS *AMDtreat* and various CAD and mapping software. |
| 2019-2020 | Final engineering design completed by SCS Engineers, Overland Park, Kansas |
| 2022-2023 | Construction of the Monahan Passive Treatment System. |

Topographic model of OSM's conceptual PTS design.

# Final Engineering Design: The Monahan PTS

SCS Engineers of Overland Park, Kansas lead by Susan L. McCart, P.E., P.G. Senior Project Manager completed the engineering design and bid documents.




LEGEND:

- EXISTING 1' CONTOUR
- EXISTING 5' CONTOUR
- PROPOSED 1' CONTOUR
- PROPOSED 5' CONTOUR
- PROPERTY LINE
- PROPERTY OWNER NAME
- WORK AREA
- EXISTING ROAD
- EXISTING OVERHEAD ELECTRIC
- BODY OF WATER
- NEW FENCE
- PROPOSED ACCESS ROAD
- PROPOSED PIPE

NOTES:

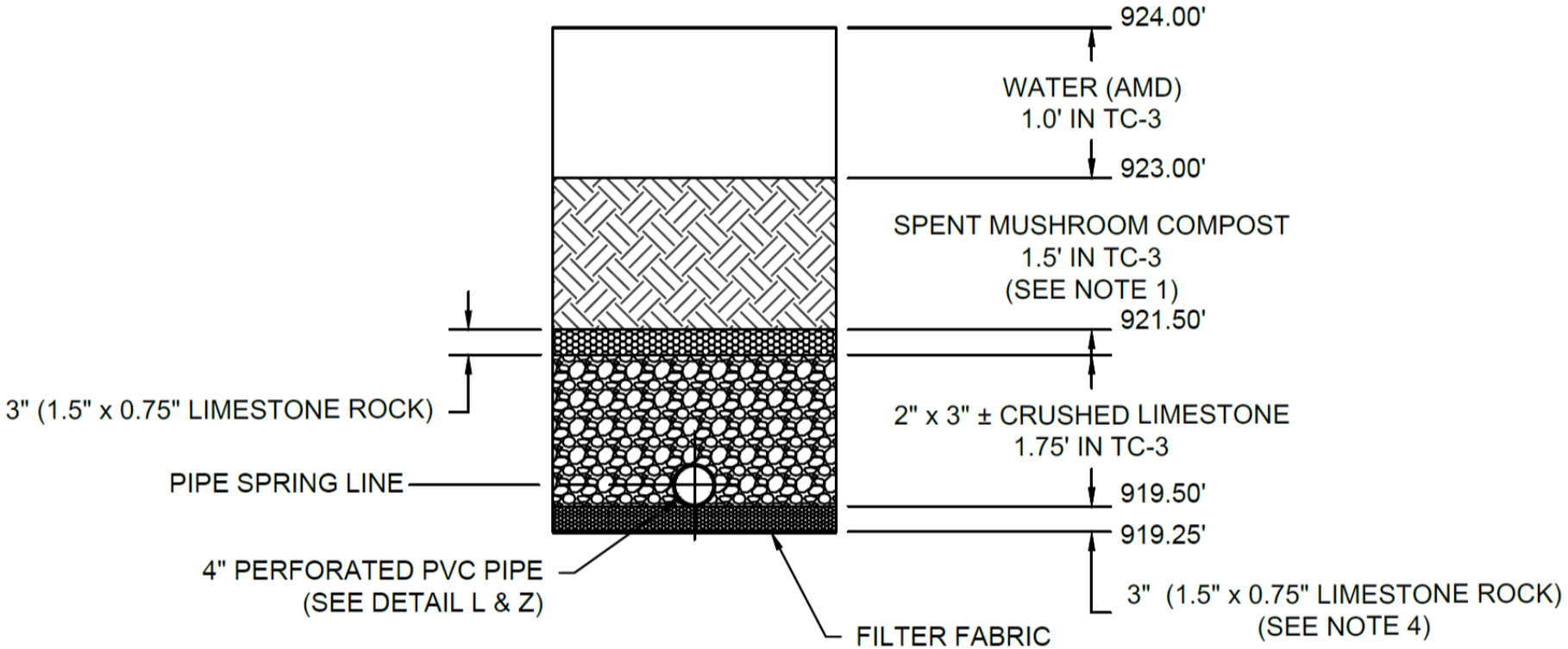
1. TOPOGRAPHIC DATA (MAP) FOR THE ABANDONED MINE LAND RECLAMATION WORK AREAS PROVIDED BY KDHE ON NOVEMBER 30, 2017; TOPOGRAPHY FLOWN BY TUKU TECHNOLOGIES.
2. TOPOGRAPHIC DATA (MAP) FOR THE AMD PROJECT WORK AREAS PROVIDED BY OSMRE.
3. PROPERTY LINES AND OWNER NAMES FOUND USING THE CRAWFORD COUNTY PROPERTY DATA WEBSITE.
4. TWO TO THREE GATES WILL BE INSTALLED AT LOCATIONS DESIGNATED BY THE SMU.
5. SOIL IN THE AREA OF THE AMD COLLECTION SYSTEM MAY BE UNSTABLE DO TO THE SATURATED CLAY. CONTRACTOR TO NOTIFY SMU AND ENGINEER IF MATERIAL IS NOT SUITABLE FOR CONSTRUCTION.

SCALE 50 0 50 100 FEET

**PRELIMINARY - NOT FOR CONSTRUCTION**

Draft engineering drawing of the eastern part of the Monahan PTS _Modified from SCS Engineers.

# Monahan VFP Design




NOTES:

1. ORGANIC SUBSTRATE BLEND SHALL BE SPENT MUSHROOM COMPOST AND AGRICULTURAL GROUND LIMESTONE (>10% BY VOLUME). THE COMPOST SHALL BE WELL BLENDED AND SHALL BE PLACED EVENLY WITH LIMITED EQUIPMENT COMPACTION.
2. COMPACT MATERIAL BELOW SPRING LINE.
3. FABRIC (GEOTEXTILE) OR FILTER LAYER SHALL BE THRACE-LINQ® 250EX OR KDHE-SMU APPROVED EQUIVALENT.
4. THE THICKNESS OF THE FINE AGGREGATE BELOW THE PIPE MAY BE ADJUSTED AS PER SITE SOIL CONDITIONS. IF SITE SOIL CONDITIONS ARE UNSUITABLE, CONTRACTOR TO NOTIFY SMU AND ENGINEER.

Vertical flow pond cross-section - Monahan PTS by SCS Engineers.

# Monahan PTS Construction

Monahan VFP excavation

Precast Weir Installation 2023


AMD collection ditch 2022

VFP May 2024

# Monahan PTS Construction As-Built

Oxidation Pond 3

Wetland 1
May 2024

# Monahan PTS – Preliminary Performance

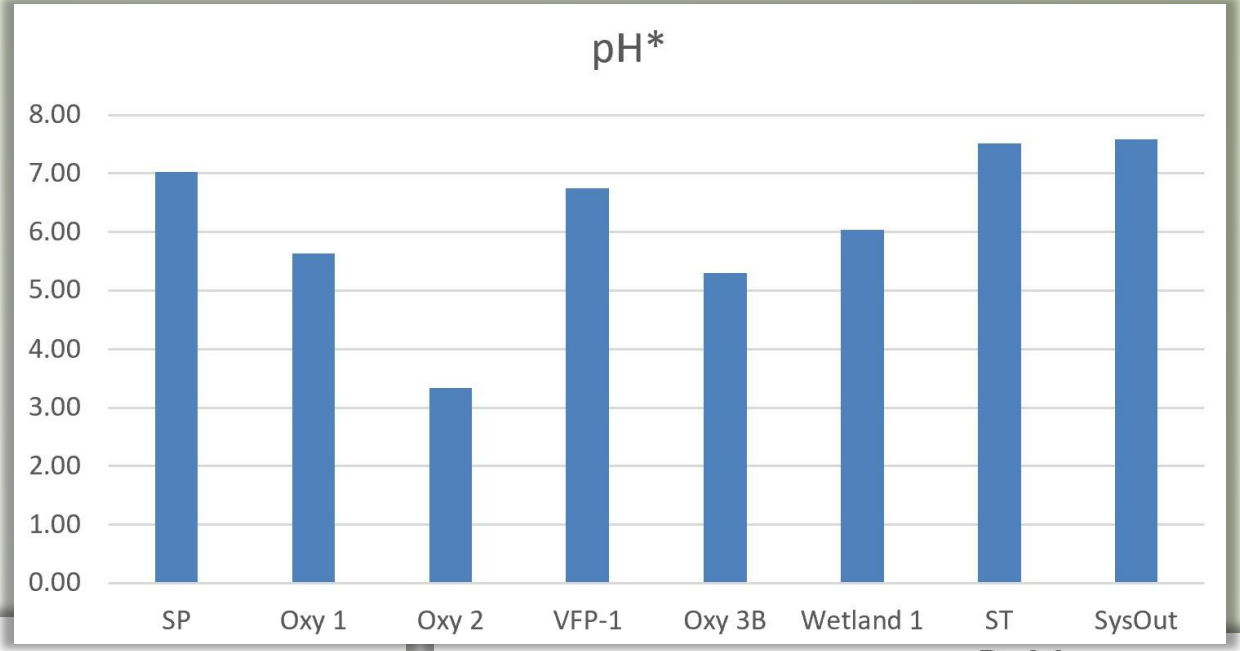
| Sample Location | pH | SpecC (mS/cm) | D. Fe (mg/L) | D. Al (mg/L) | D. Mn (mg/L) | D. Ni (mg/L) | D. Zn (mg/L) | Sulfate (mg/L) | $Acidity_{calc}$ (mg/L CCE) | Alkalinity (mg/L CCE) | Net Acidity (mg/L CCE) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SP (DW*) | 7.03 | 2.112 | 0.221 | 0.130 | 0.953 | 0.023 | 0.012 | 1,192 | 2.70 | 310.00 | -307.30 |
| Oxy 1 | 5.63 | 3.600 | 588.19 | 0.676 | 13.18 | 0.018 | 0.381 | 2,824 | 1,245.56 | 13.33 | 1,232.23 |
| Oxy 2 | 3.34 | 3.365 | 363.67 | 0.466 | 10.00 | 0.023 | 0.309 | 2,751 | 755.97 | 0.00 | 755.97 |
| VFP-1 | 6.75 | 2.562 | 38.90 | 0.097 | 6.61 | 0.048 | 0.023 | 1,886 | 89.50 | 97.30 | -7.80 |
| Oxy 3B | 5.29 | 1.685 | 0.470 | 0.046 | 18.14 | 0.023 | 0.017 | 1,482 | 34.31 | 85.45 | -51.14 |
| Wetland 1** | 6.03 | 2.530 | 0.195 | 0.026 | 14.00 | | | 1,705 | 25.95 | 10.00 | 15.95 |
| ST (DW*) | 7.52 | 1.581 | 0.195 | 0.077 | 2.23 | 0.014 | 0.067 | 964 | 4.94 | 71.61 | -66.67 |
| System Out | **7.58** | 1.685 | 0.093 | 0.028 | **6.84** | 0.010 | 0.036 | 1,002 | 7.37 | 69.15 | **-61.78** |

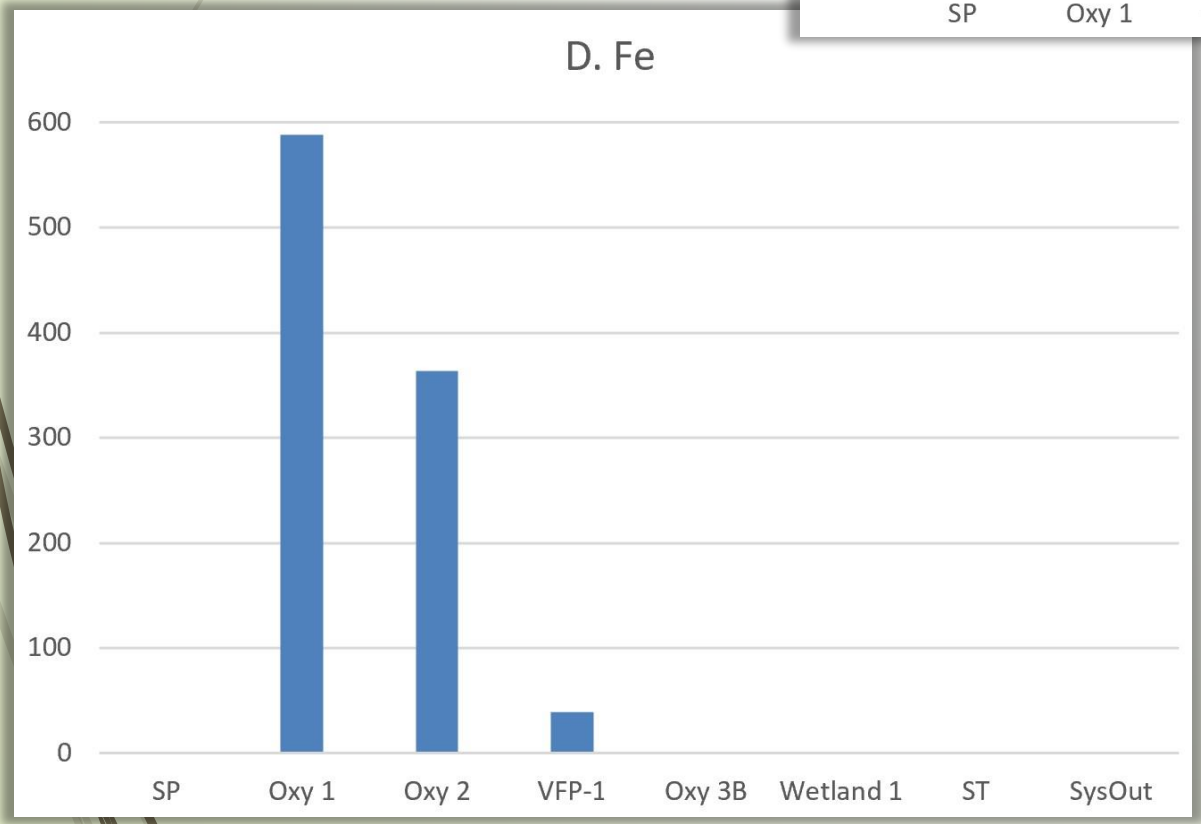
**Compare Oxy 2 (VFP 1 Inlet) to SP/D1 Blended AMD from Baseline Study**

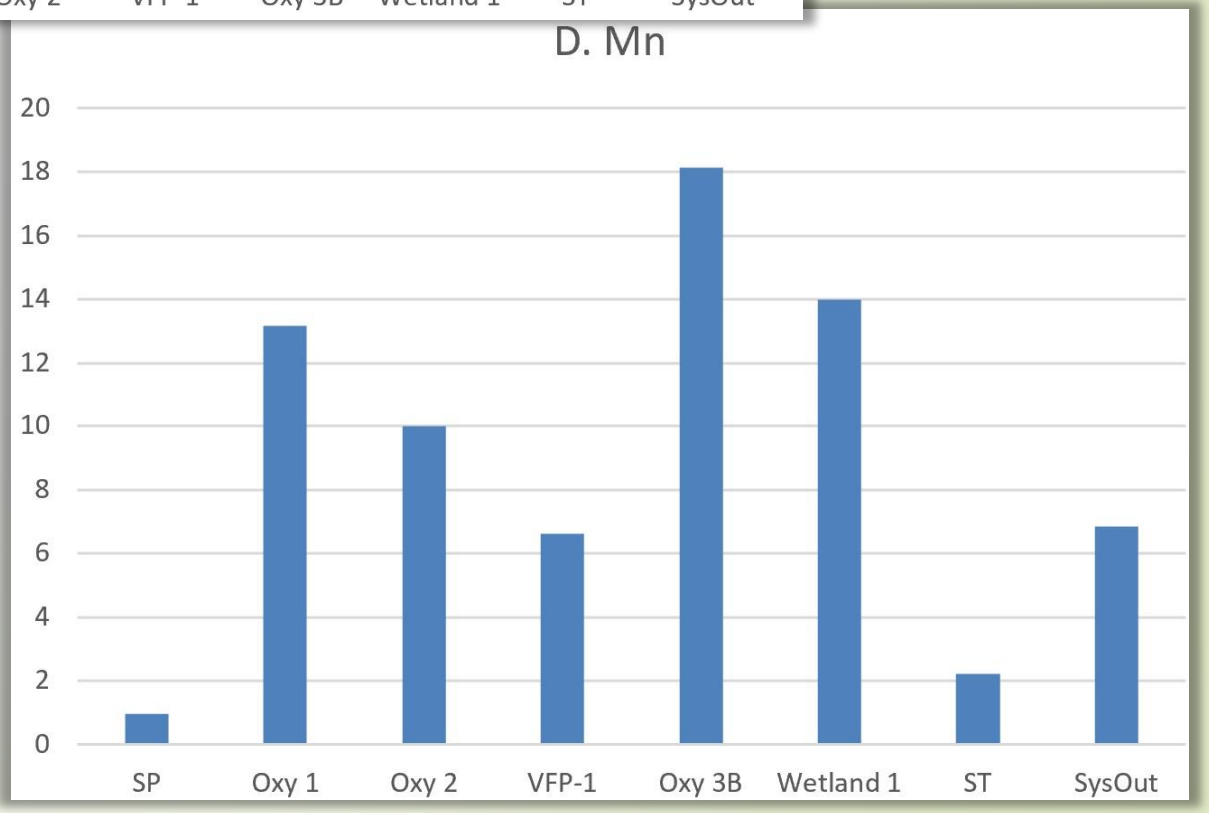
| | Discharge (GPM)* | Field pH | SpecC. (mS/cm) | D. Fe (mg/L) | D. Al (mg/L) | D. Mn (mg/L) | D. Ni (mg/L) | D. Zn (mg/L) | Sulfate (mg/L) | $Acidity_{calc}$ (mg/L CCE) | Alkalinity (mg/L CCE) | Net Acid. (mg/L CCE) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SP/D-1 Blend | | 3.15 | 2.080 | 82.00 | 5.920 | 13.00 | NT | NT | 1,100.0 | 441.55 | 0.00 | 441.55 |

*DW = Dilution water source; **Wetland 1 is under repair.

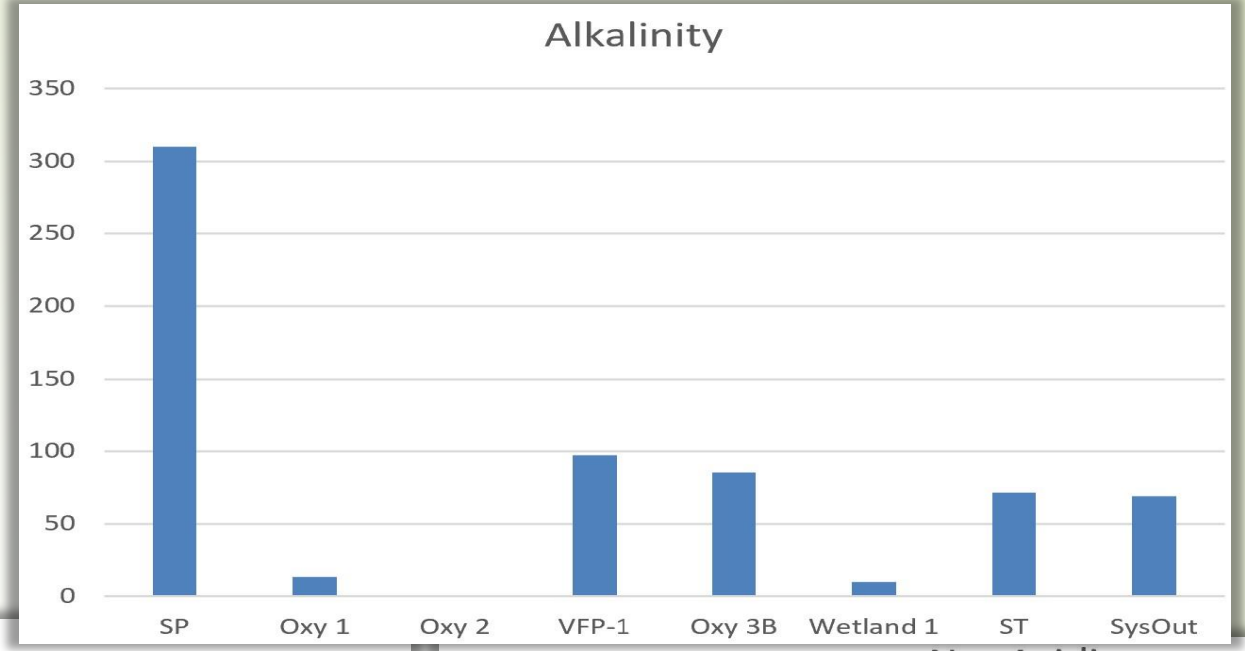
# Monahan PTS – Preliminary Performance

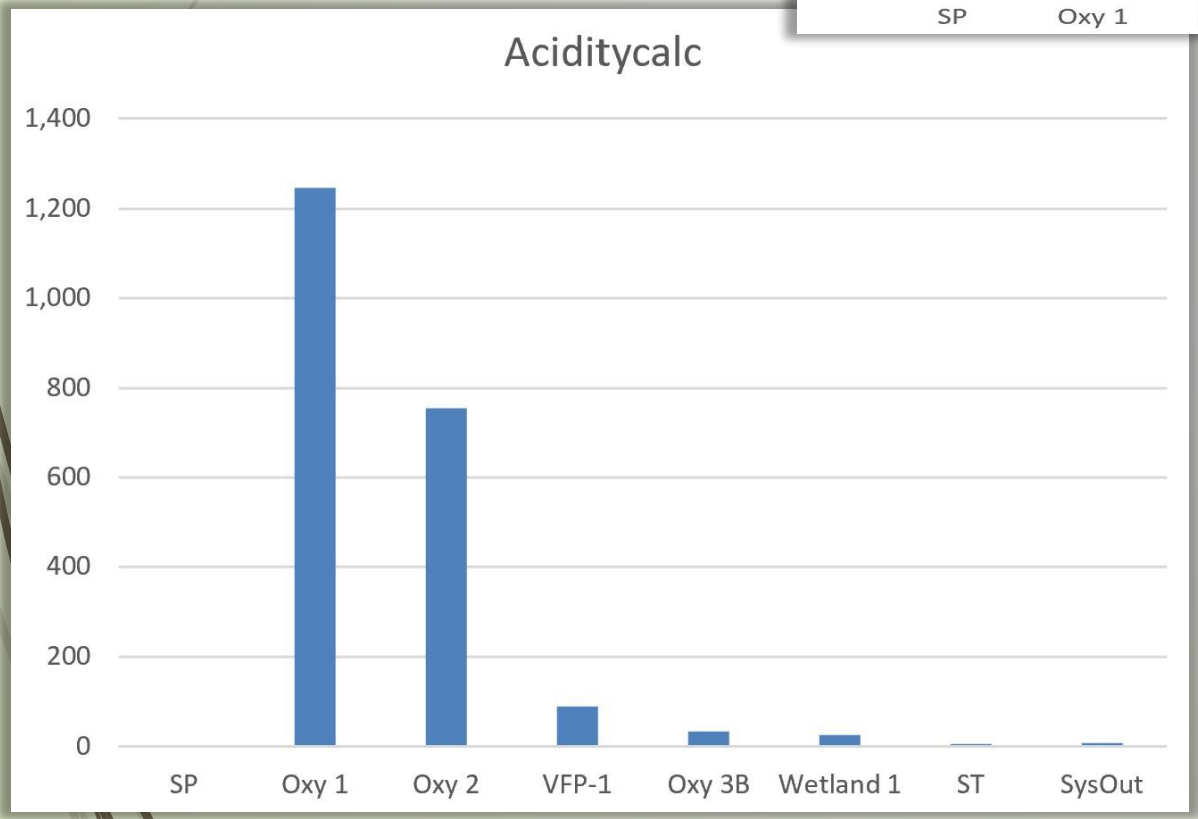


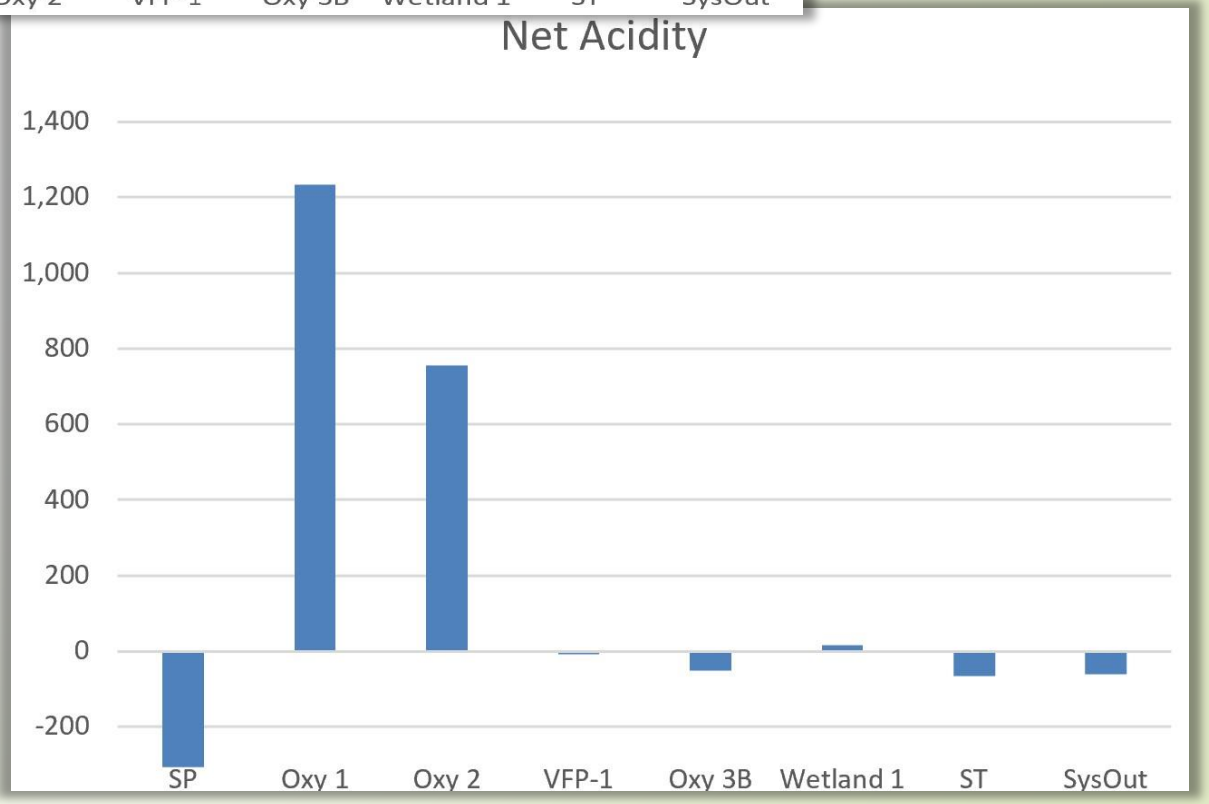



# Monahan PTS – Preliminary Performance



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- McCart, S. 2019, Draft design drawings, KDHE PAD-0284, PAD KS-0009 and AMD Project, SCS Engineers, Overland Park, Kansas.

# Acknowledgements


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- Toni Anderson, Environmental Spec.
- Daniel Evilsizor, Environmental Spec.
- Sydney Hulvey (Intern)

Office of Surface Mining Reclamation and Enforcement, Interior Regions 3, 4 and 6.

- Karly Ellis, AmeriCorps Member
- Riley Hickey, AmeriCorps Member.
- LaChelle Harris, AML & REG Program Specialist.
- Ethan Schuth, Hydrologist.
- Chike Etumudor, AML & REG Program Specialist.
- Kwang (Min) Kim, Chief - Technical Services Branch.

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Pat Goeke, Senior Remedial Engineer.
Dillon Baird, Design Engineer.
Shane Latimer, Toxicology Spec.

# Investigation Acidic Discharges at the Monahan Abandoned Mine Lands Site, Kansas - The End

**Questions?**

Kansas Department of Health and Environment | Division of Environment