Advances in the Use of Passive Wetland Systems for Selenium Treatment of Mine-Impacted Water




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Selenium is Present in Surface Coal Mine Drainage

- Geology of selenium
  - Low sulfur, fresh water coal deposits of Southern WV
  - Selenium concentrated in the coal & associated black shales
    - pit scrapings, bone coal, organic-rich material
    - low detection in overburden sandstone (present, but minor)
  - Results in neutral to alkaline drainage, but with elevated Se
- Sources in post-mining landscapes
  - Valley fills, waste rock piles, “pavement” at base of backstack; anywhere black (organic-rich) material located

Water Quality Control Technology Selection Choice: Passive or Active Treatment?

Natural Systems

- Land Intensive
- Capital construction cost
- Natural processes
- Low O&M (not zero O&M)

Conventional Systems

- Energy/chemical dependent
- Capital construction cost
- Engineered processes
- Higher O&M

Natural systems can be augmented (semi-passive treatment)
Conventional systems can be designed for low energy/chemical input

Post-mining landscape: the reality of long term treatment

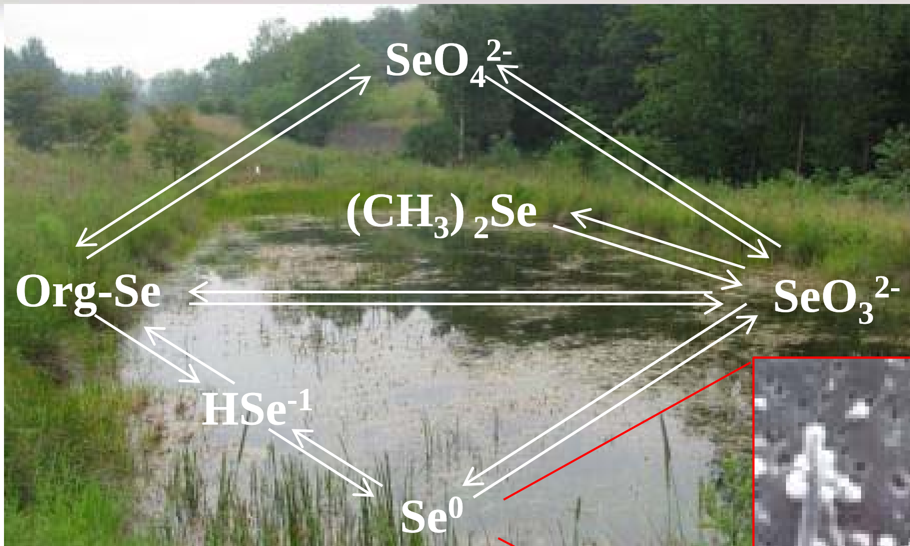
Existing Se Passive Treatment Systems are Free Water Surface Wetlands

Chevron's Water Enhancement Wetland, Richmond CA

Hansen et al, 1998

- Area: 36 ha
- Flow: ~6,540 m^3/d
- Date: since 1991
- HRT: 7-10 days
- Se reduction: 89%
- Se in: 20-30 µg/L
- Se out: <5 µg/L
- Volatilization: 10-30%

Wetland Processing and Storage of Selenium



Dissimilatory Reduction

$SeO_4^{2-} \rightarrow SeO_3^{2-} \rightarrow Se^0 \rightarrow Se^{2-}$

- Distribution in wetland sediments:
  - 0:13:41:46
- 89-92% reduction from selenate to elemental Se in 10 - 16 days

Volatilization

- Organic + $SeO_3^{2-} \rightarrow (CH_3)_2Se$
- Volatilized from plant tissues
- 5-30% cumulative loss from sediments and plants

Sorption

- Selenite sorbs to sediments and soil constituents: Fe^-, Mn^- or Al^- oxyhydroxides and organic matter

Plant Uptake

- Rapid uptake
- Tissue concentrations increase but not detrimental
- No long term storage in plants; Se transferred to sediments

Anaerobic “Bioreactor” Wetland Demonstration Showed High Efficiency in Minimal Area

- Volume: 124 m^3
- Flow: 11-131 m^3/d
- Date: 9/08-10/09
- HRT: 2.4 d
- Se reduction: (90% winter) 98%
- Se removal rate: 73 $mg/d/m^3$
- Se out: 0.5 ug/L

US Bureau of Reclamation 2010

Functional Role of Aerobic Wetlands in Anaerobic + Aerobic Combination

Surface Flow Wetlands

Functions

- Treat BCR by-products
  - Oxidize BOD, COD
  - Trap particulates
  - Assimilate excess nutrients
  - Odor reduction
  - Reduce color
- Se polishing to trace levels
  - Biological vegetation uptake, transformation and burial
  - Hydrologic attenuation to equalize possible variation in flows and concentrations

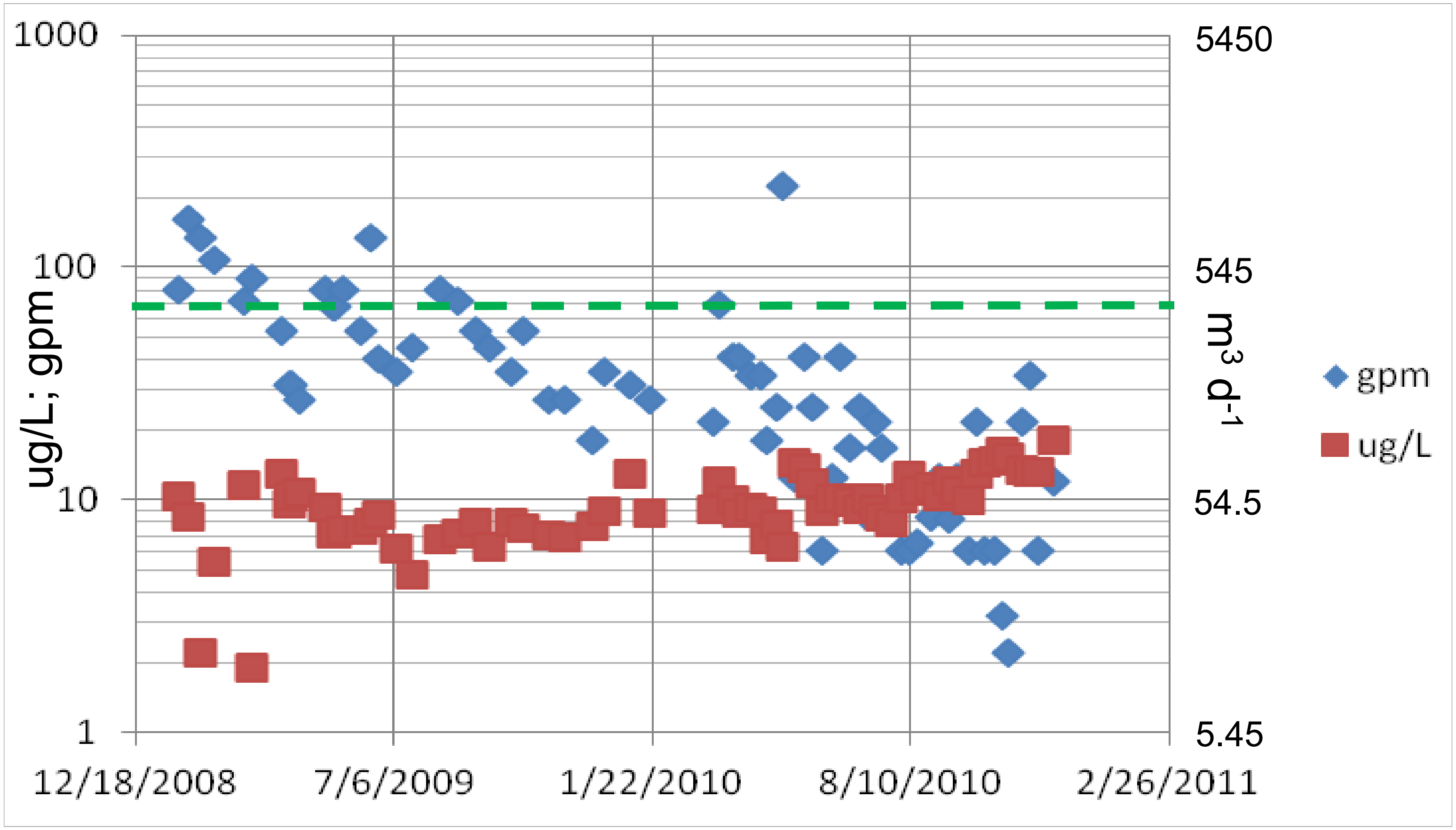
Passive Se Treatment in WV: Case History

Overview

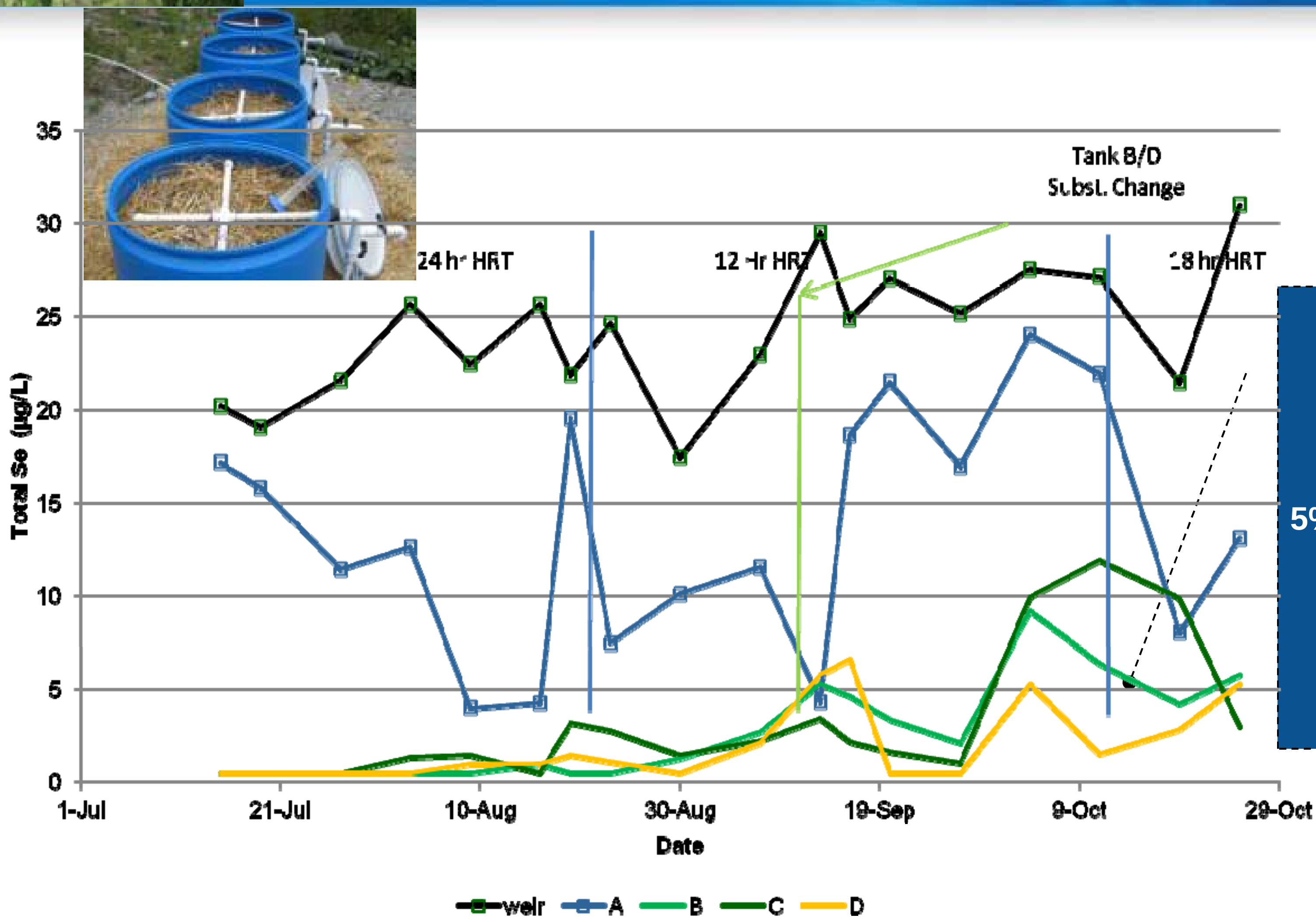
- Two outlets assigned stringent selenium discharge standard:
  - **4.7** ug/L monthly mean
  - **8.2** ug/L daily max
- Conducted barrel studies to formulate ideal substrate, calibrate model
- Designed two distinct systems based on landscape, space, treatment
- First system July 2011
- Second system November 2011

Location

System A: Design Flow Set to Capture Load and Account for Inter-annual Variation



Barrel Treatability Study Showed Highest Se Removal with High HRT & Organic Media

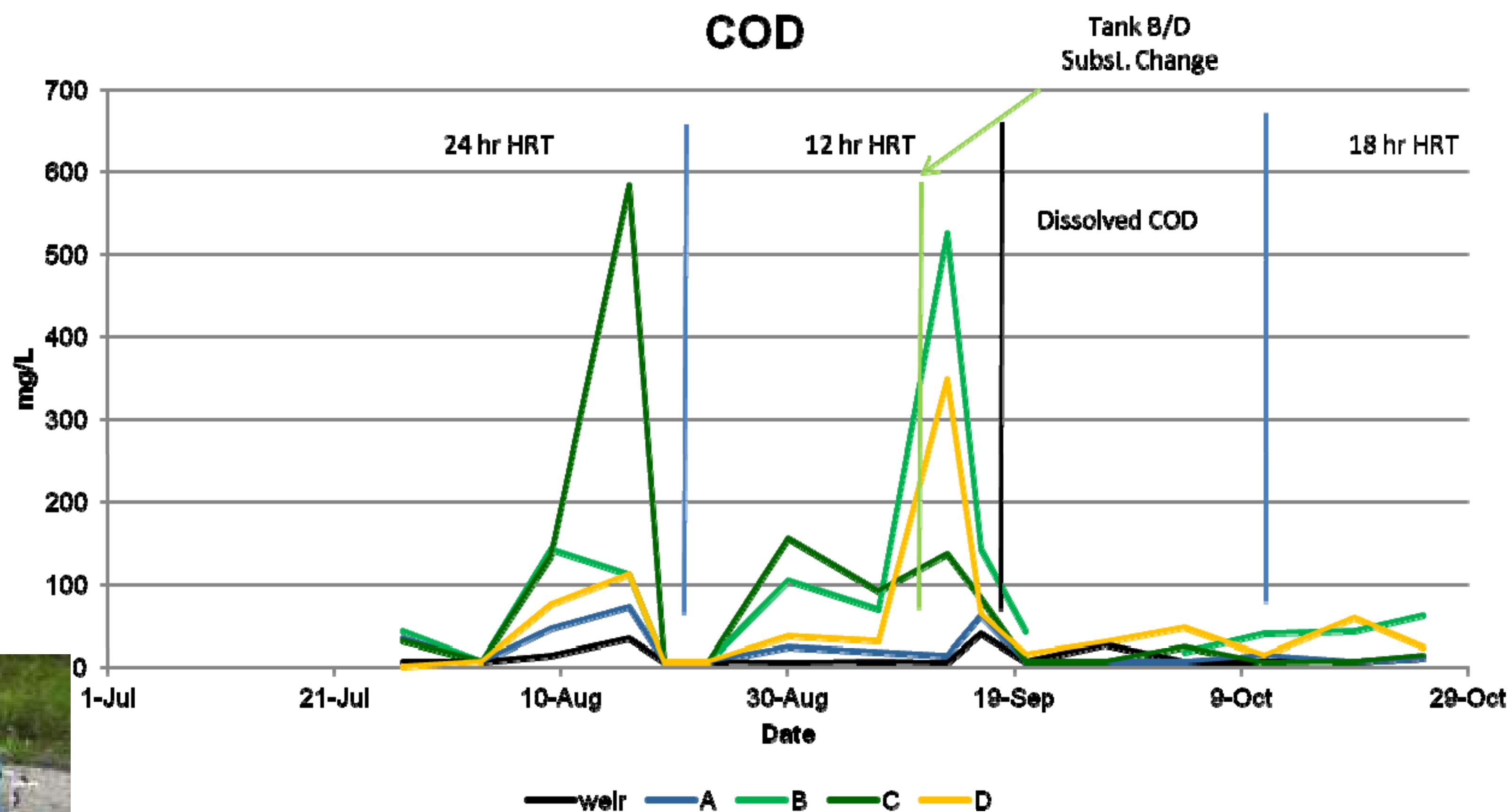


20% woodchips
35% sawdust
10% peat moss
5% limestone sand
25% hay,
5% composted manure

24 hr HRT
~ 17 mg/d/m³ media

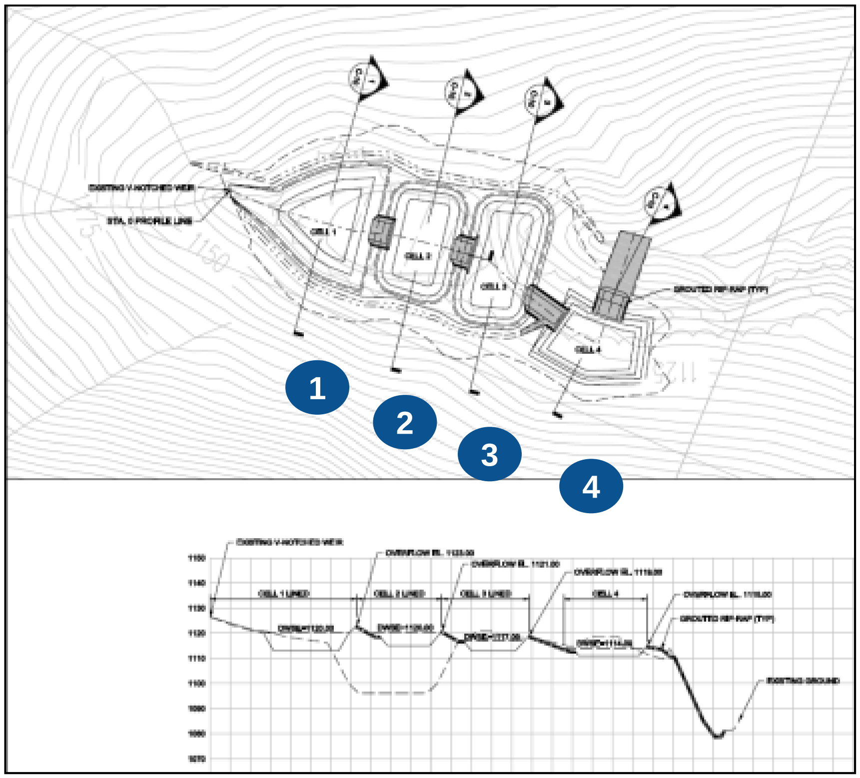
k_{20} ~1700 m/yr

Barrel Study Confirmed Significant Post-Startup "Byproduct" Discharges



Gravity Flow and Sequential Process Concept Balanced Area and Compliance Challenge

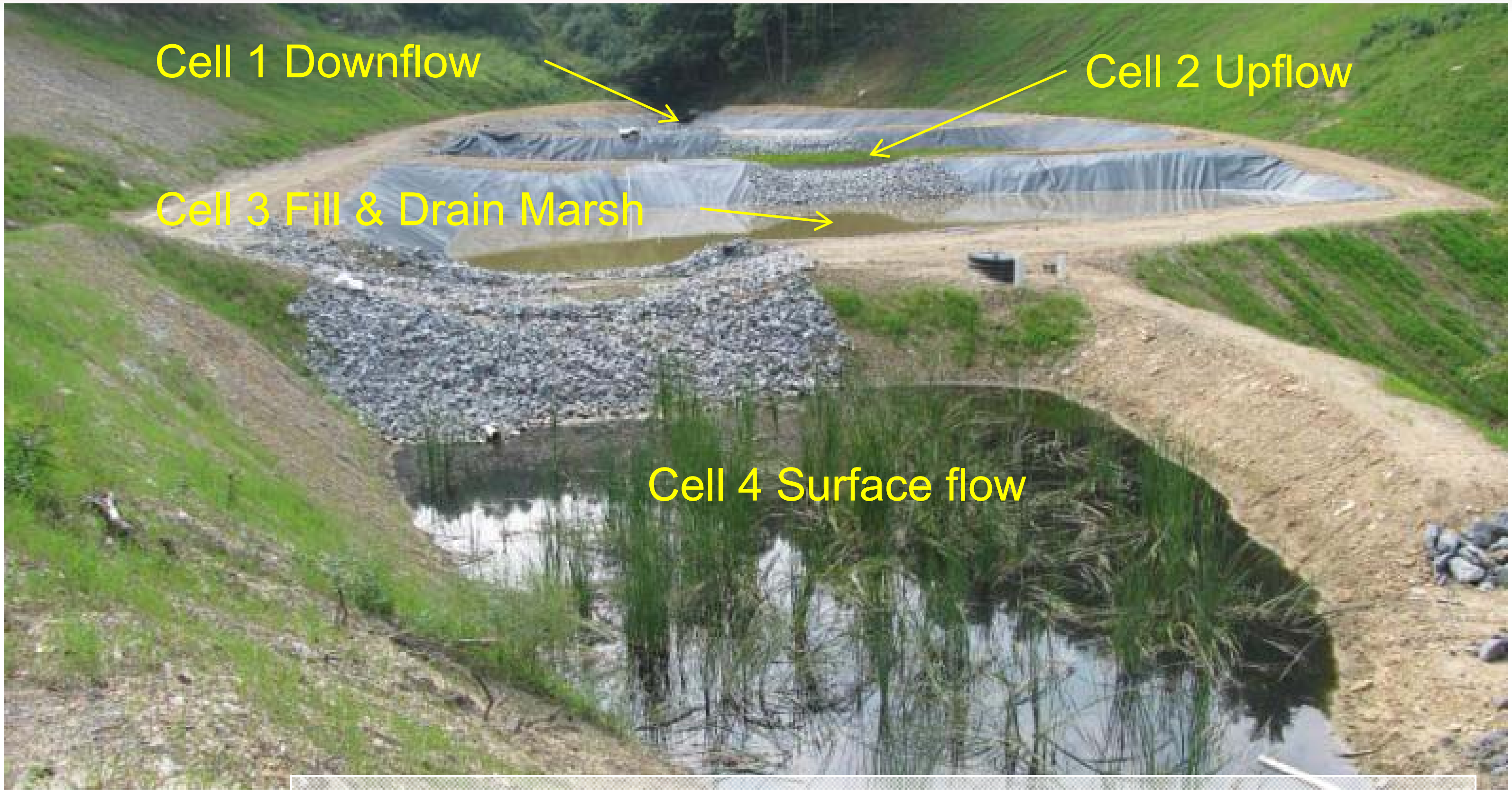
System Plan and Profile



Design Concepts

- Replace existing sediment pond
  - ➢ 409 m^3/d base flow
- Four cells-in-series:
  1. Downflow biochemical reactor
  2. Anaerobic upflow wetland
  3. Fill-and-drain wetland
  4. Aerobic surface flow marsh

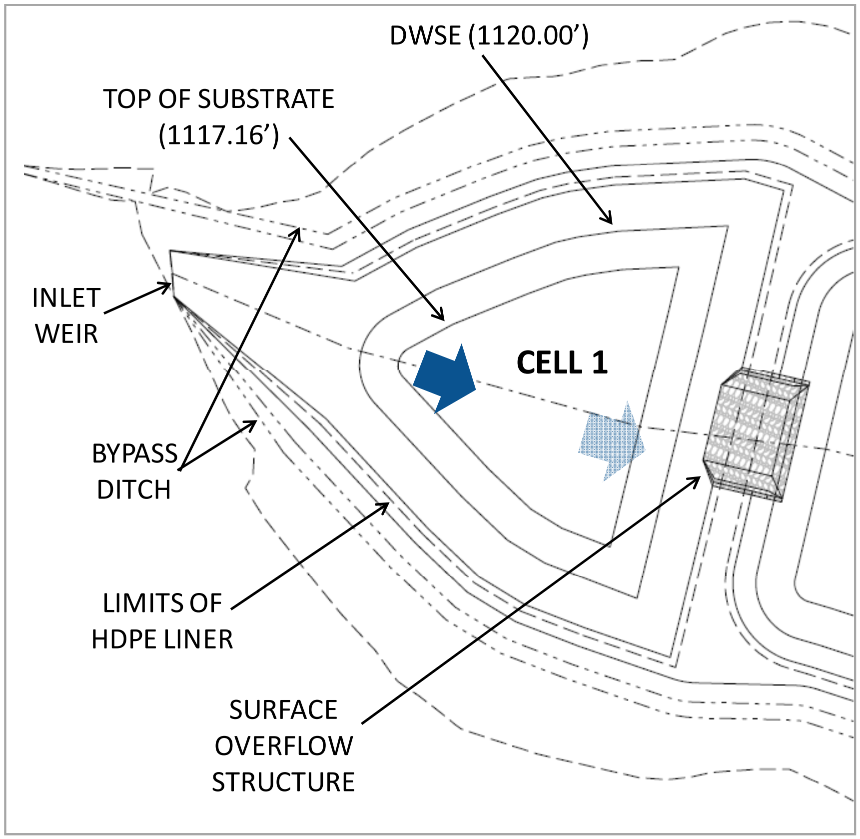
Passive Se Treatment in WV: Completed 2011



- Weekly samples (6/29/11 – 12/28/11)
- Flow rate 11-381 m^3/d
- In: 5.7 – 16.8 µg/L total Se; Out BDL (<0.1 ug/L)
- 88% - 99% removal efficiency

Cell 1: Downflow Biochemical Reactor (BCR)

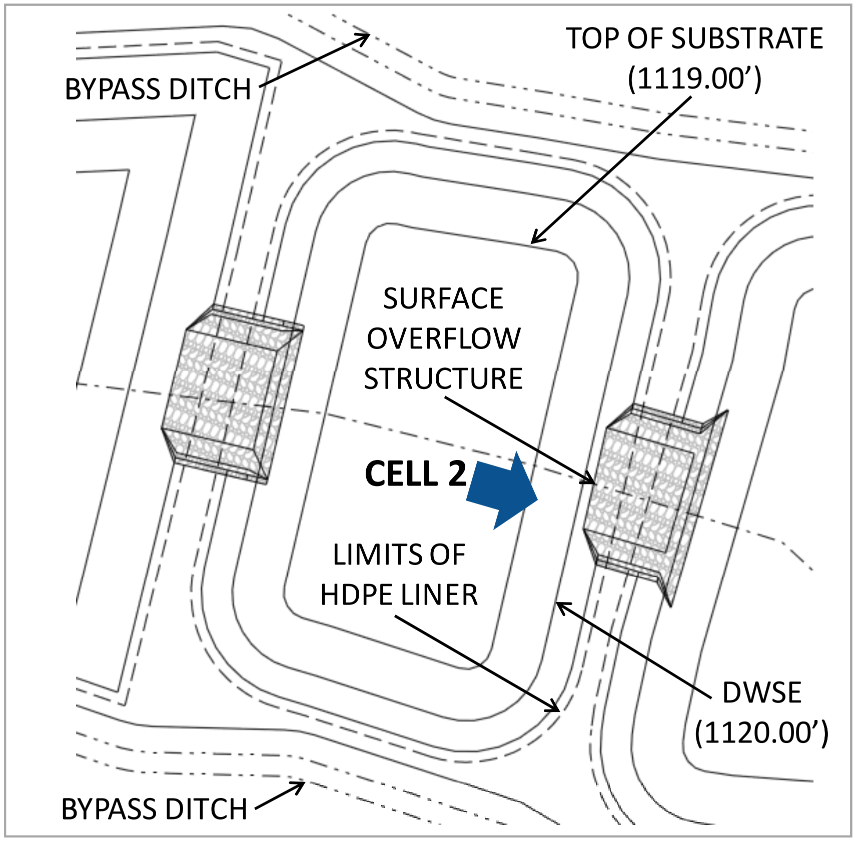
Plan



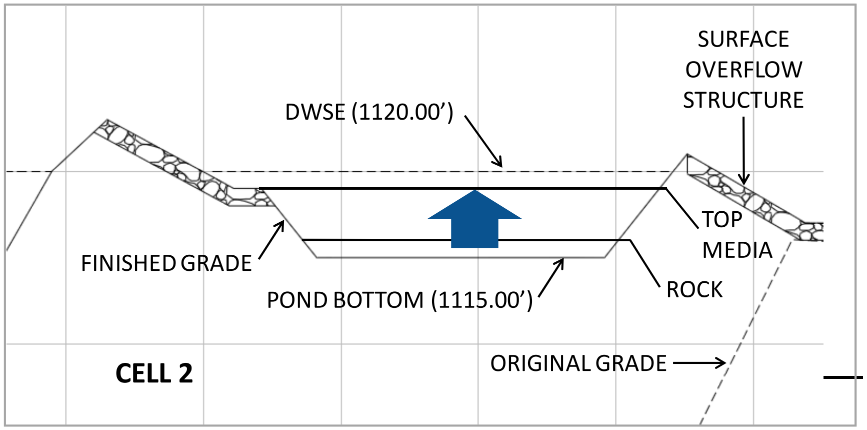
m²	Type	Media	Plants	Function
526	Downflow biochemical reactor	Mixed organic	None	Selenium reduction

Cell 2: Upflow Anaerobic Wetland

Plan



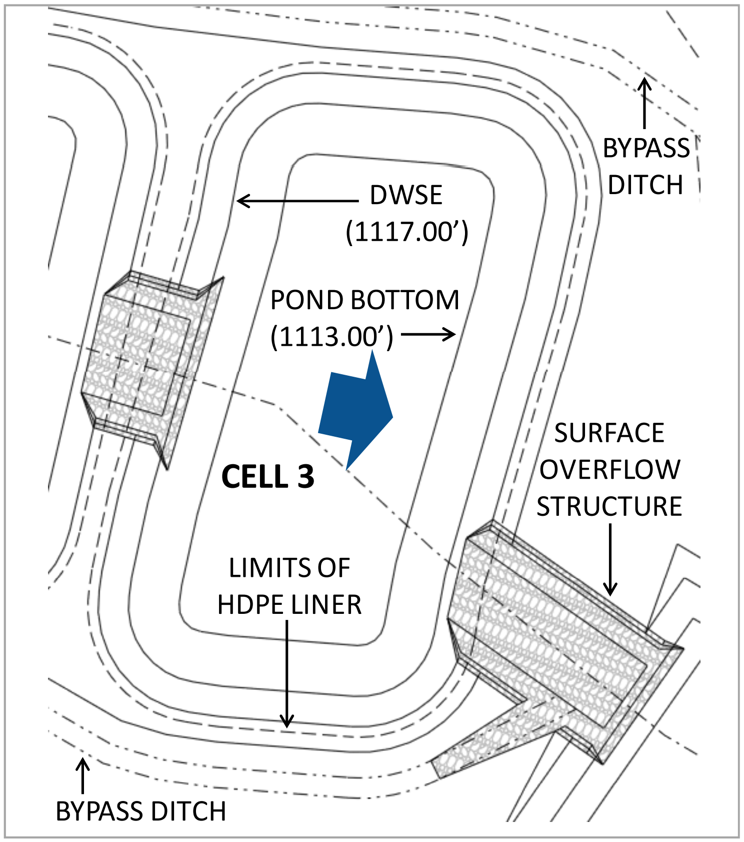
Profile



m^2	Type	Media	Plants	Function
567	Upflow anaerobic	Peat	Sedges, rush	Selenium reduction, Byproduct polishing

Cell 3: Fill-and-Drain Polishing Wetland

Plan



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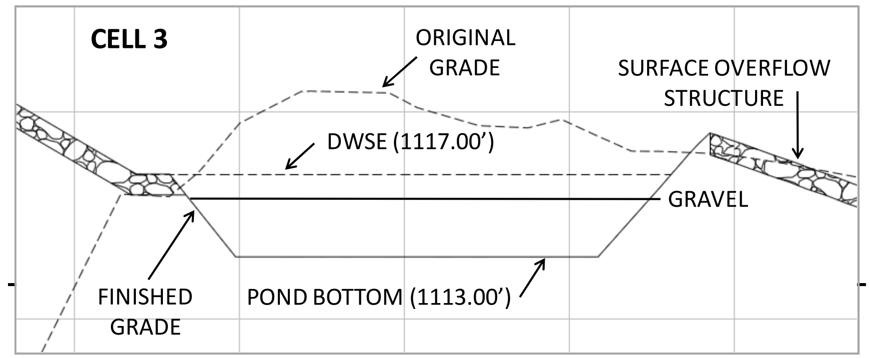
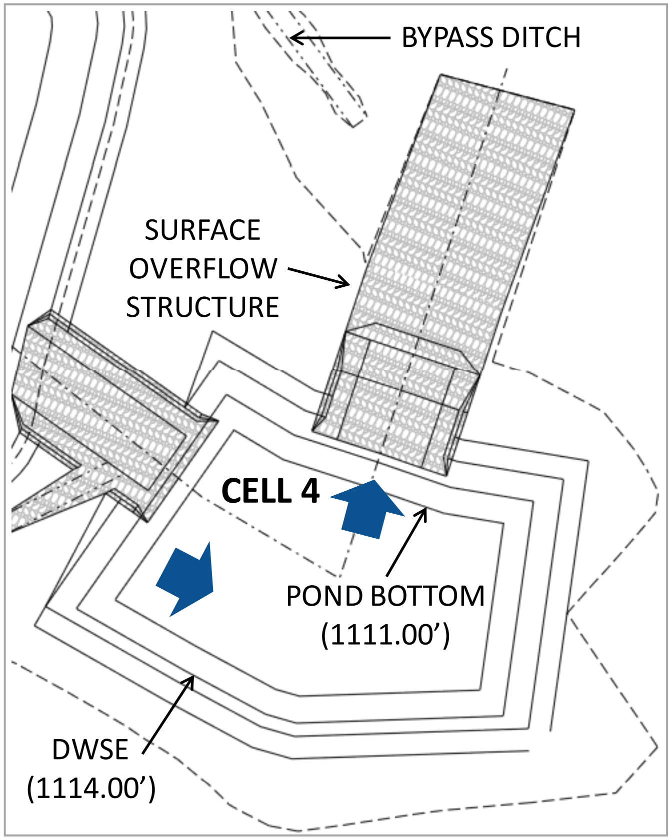


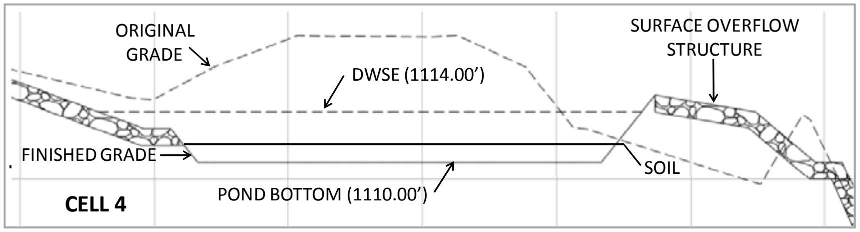
m^2	Type	Media	Plants	Function
648	Subsurface fill and drain	Limestone gravel	Cattails	Byproduct polishing

Cell 4: Free Water Surface Polishing Wetland

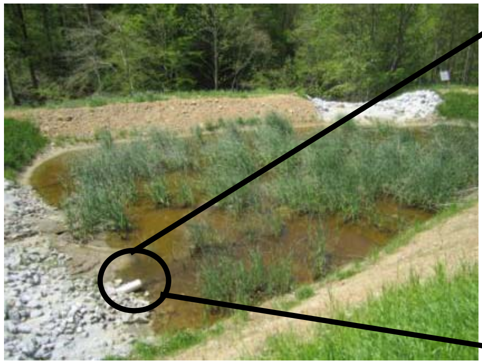
Plan



Profile



m^2	Type	Media	Plants	Function
445	Free water surface	Topsoil and ponded water	Cattails	Byproduct polishing



On Balance, Natural Systems Favored (System A example)

Natural Systems

- BCR+wetland footprint fits (just)
- Construction $534K
- Natural processes
- O&M $15K/yr

Conventional Systems

- Can be made to fit
- Construction $MMs
- Engineered processes
- O&M $500K

Conclusions

- Critical water quality management issue
- Can combine lessons learned from treating ag drainage, mine-water, municipal, & stormwater
- Pilot studies are necessary to establish removal rates
  - Consistent removals at 24 hr HRT
- Selenium reduced and sequestered year-round
- Small footprint, lower cost of wetland reactor systems
- Integrate by-product control into design

Acknowledgements

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