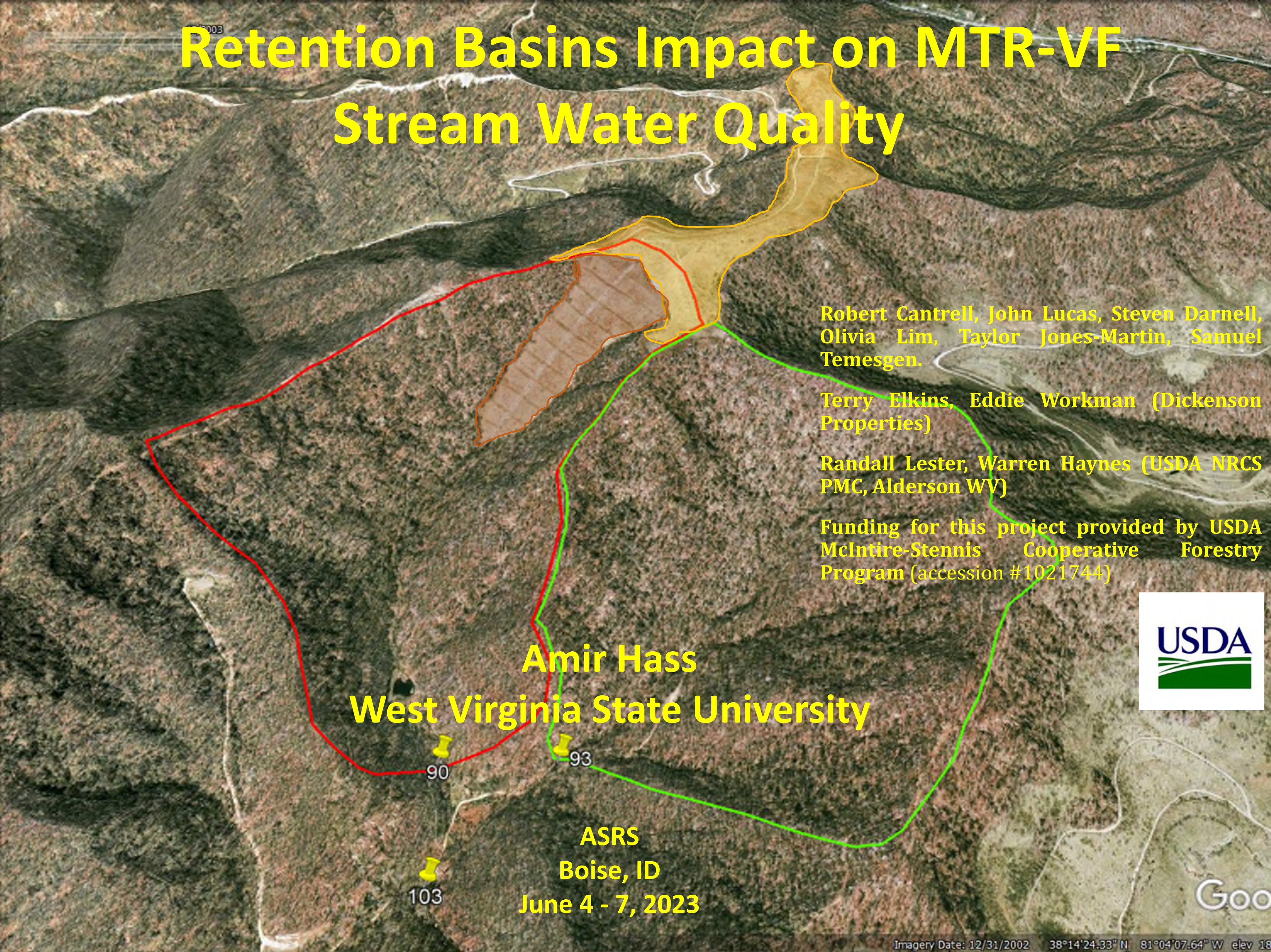
Retention Basins Impact on MTR-VF Stream Water Quality



Robert Cantrell, John Lucas, Steven Darnell, Olivia Lim, Taylor Jones-Martin, Samuel Temesgen.

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Funding for this project provided by USDA McIntire-Stennis Cooperative Forestry Program (accession #1021744)

USDA

Amir Hass

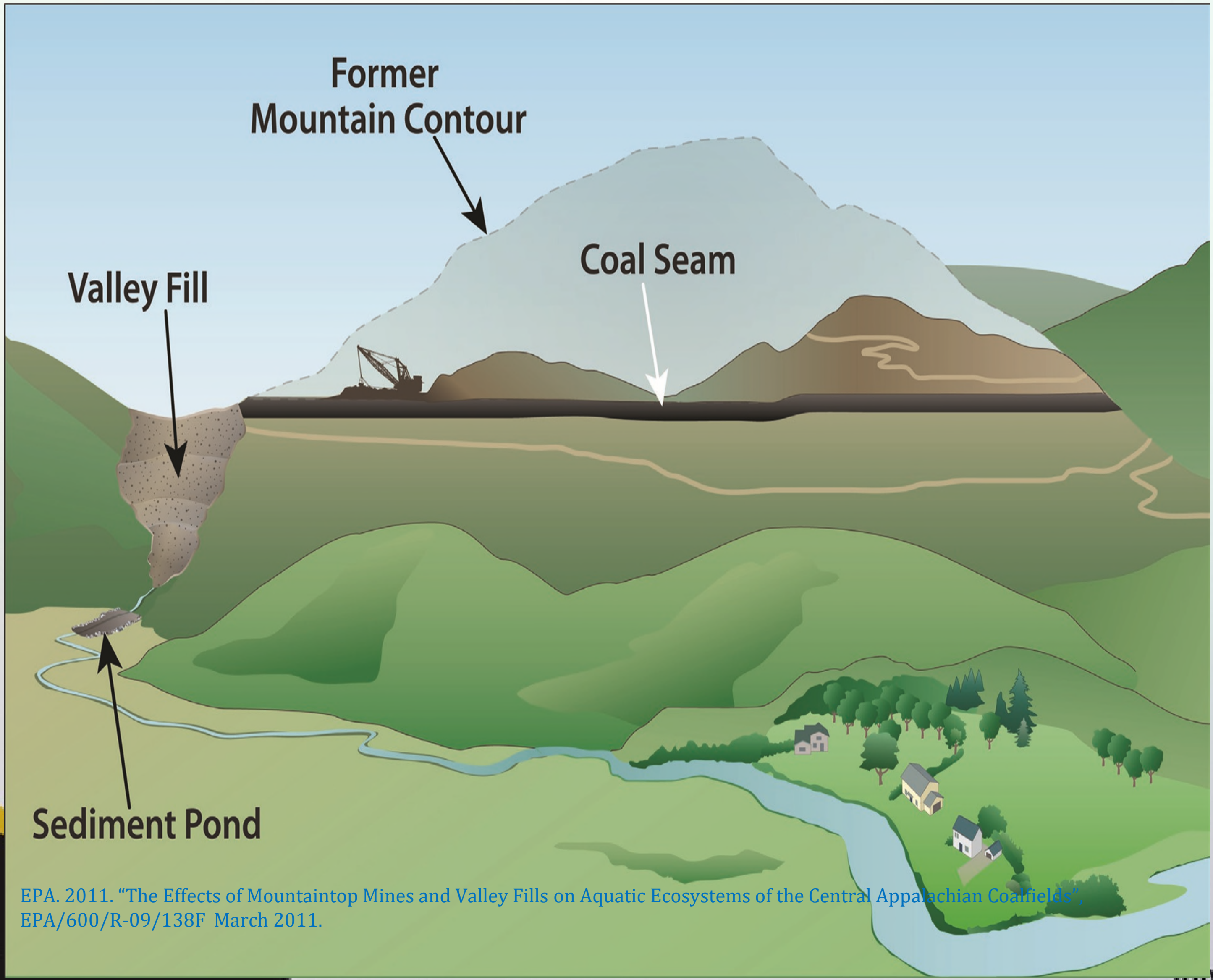
West Virginia State University

ASRS

Boise, ID

June 4 - 7, 2023

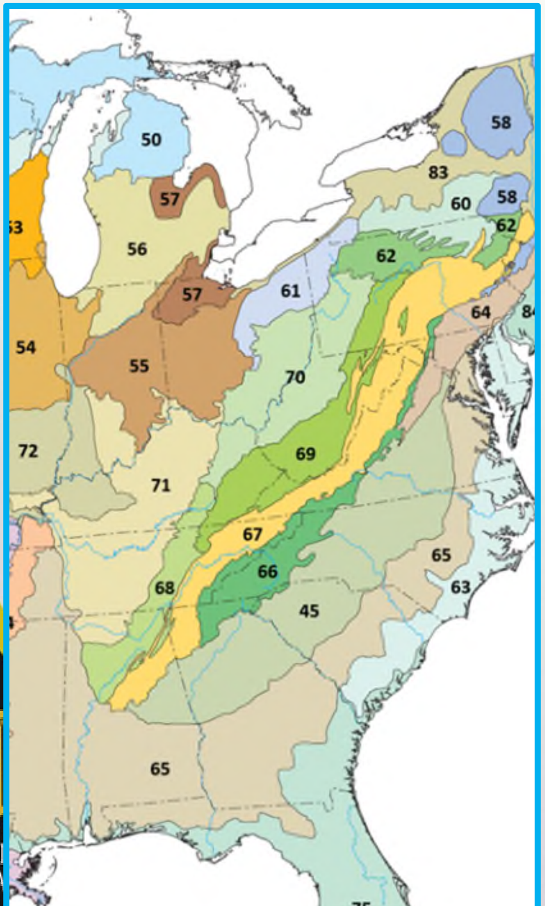
Mountaintop Removal Valley-Fill Coal Mining Operation

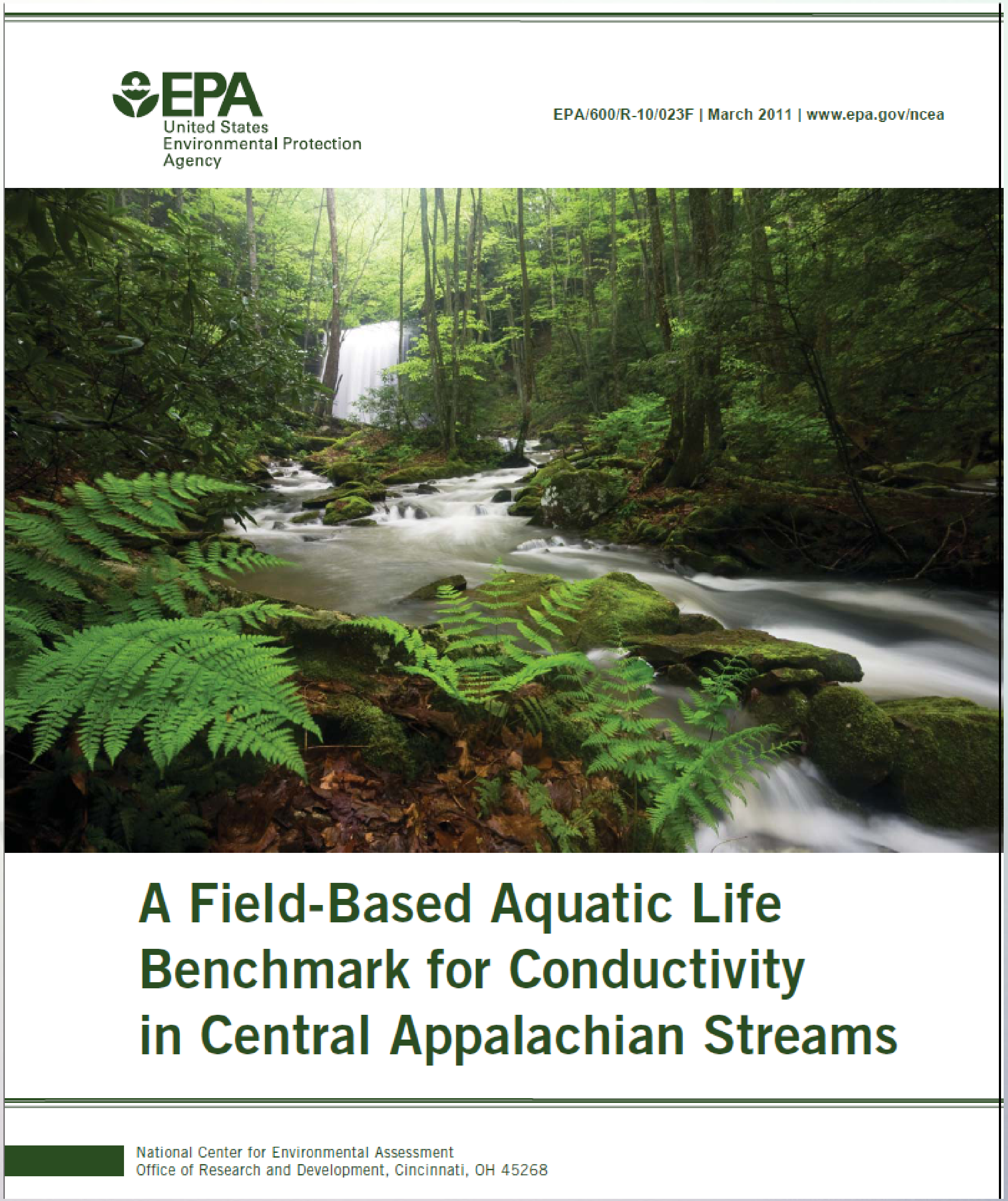


EPA. 2011. "The Effects of Mountaintop Mines and Valley Fills on Aquatic Ecosystems of the Central Appalachian Coalfields", EPA/600/R-09/138F March 2011.

The chronic aquatic life benchmark value… is 300 µS/cm.

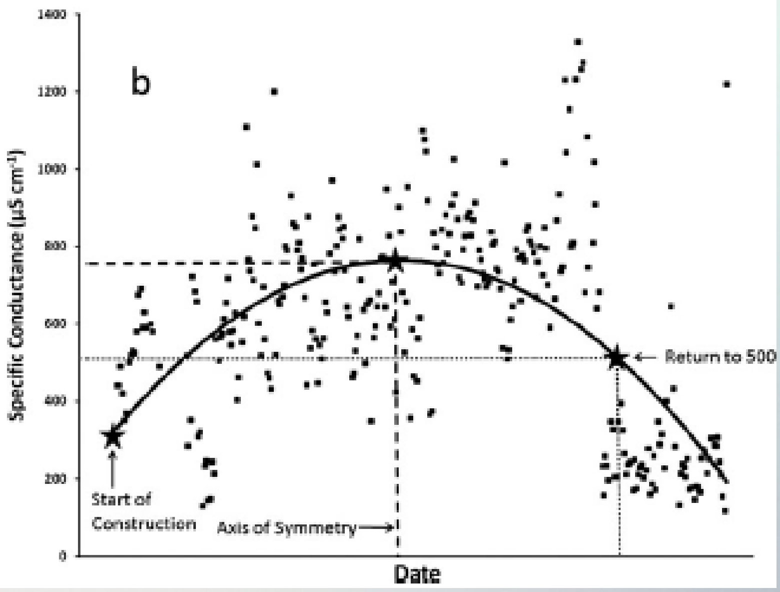
“the conductivity value below which 95% of the observations of the genus occur and above which only 5% occur.”





"… lysimeter studies … clearly indicate that TDS release potential from non-acid forming spoils should **drop quickly** once they are exposed to leaching. However, … actual long-term TDS discharge response of a large number (n> 100) of valley fills … indicates that the time for discharge SC to decline below 500 us/cm was **10–15 years**, on average, beyond final revegetation." (Daniels et al., 2014. Int. J. Coal Sci. Technol. 1(2):152–162)

Recovery of water quality back to pre-mining baseline levels within **two decades** (137 VF's, 1 – 33 y; Evans et al., 2014. J. Am. Wat. Res. Ass. 50:1449-1460)

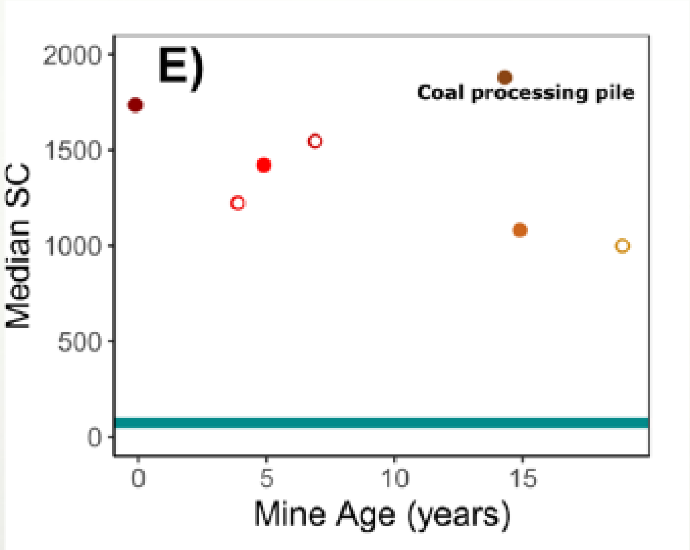


"…**no age effect** on SC was apparent…" (5 VF's, 2.5 – 20 y; Clark et. al., 2016. Environ. Earth Sci. 75:1222. – commented on Evans et. al., 2014 – "Number of years since initial disturbance was not a predictor for mean discharge SC")

"Temporal trend analysis demonstrated **limited recovery** … to natural background conditions." (18 VF's; Cianciolo et al., 2020, Sci. Tot. Environ. 717:137216)

Selected 5 of 18 VF's showed "… decline from 1.9% to 3.7% of mean annual SC, suggesting long time periods … ca. 40 years". (Cianciolo et al., 2020)

"…three streams …no active mining since 1985 and still contain annual mean SC levels greater than the 300 µS cm^{-1} conductivity benchmark, with **no declining SC trends**" (Cianciolo et al., 2020)



"…elevated ion and pollutant concentrations for at least decades (Ross *et al* 2016), but **likely longer**…" (7 VF's, 0 – 19 y; Ross et. al., 2021. Environ. Res. Lett. 16 075004)

"The ecologic, hydrologic, and biogeochemical processes active in these new places … may be on new trajectories … keep them different from unmined landscapes **forever**." (Ross et. al., 2021)

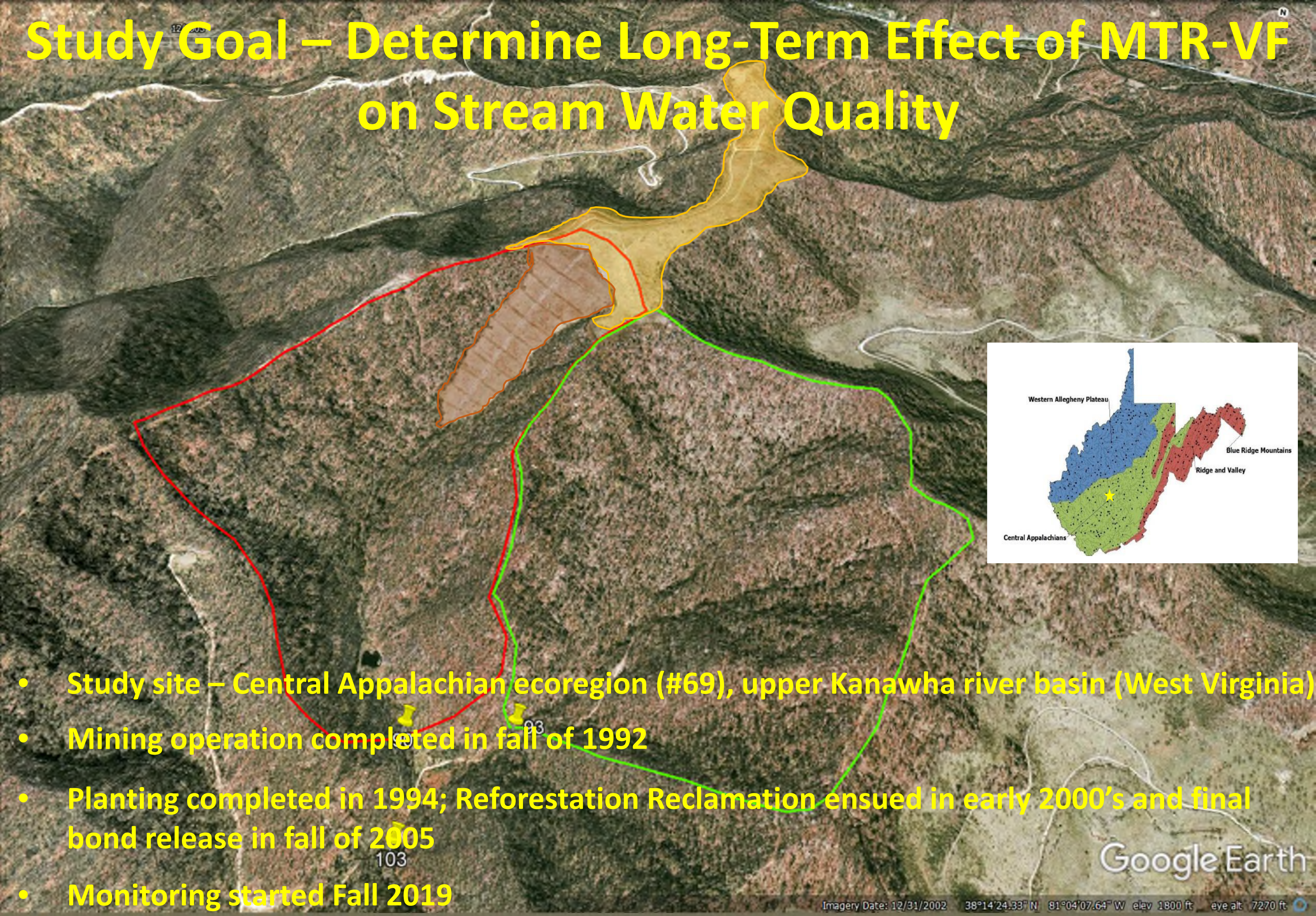
Damage from MTR-VF activities - irreparable (Palmer et al., 2010. Science. 327: 148-149)

~~Mitigation Approach~~

Prevention (Evans et. al., 2014, Daniels et al., 2014):

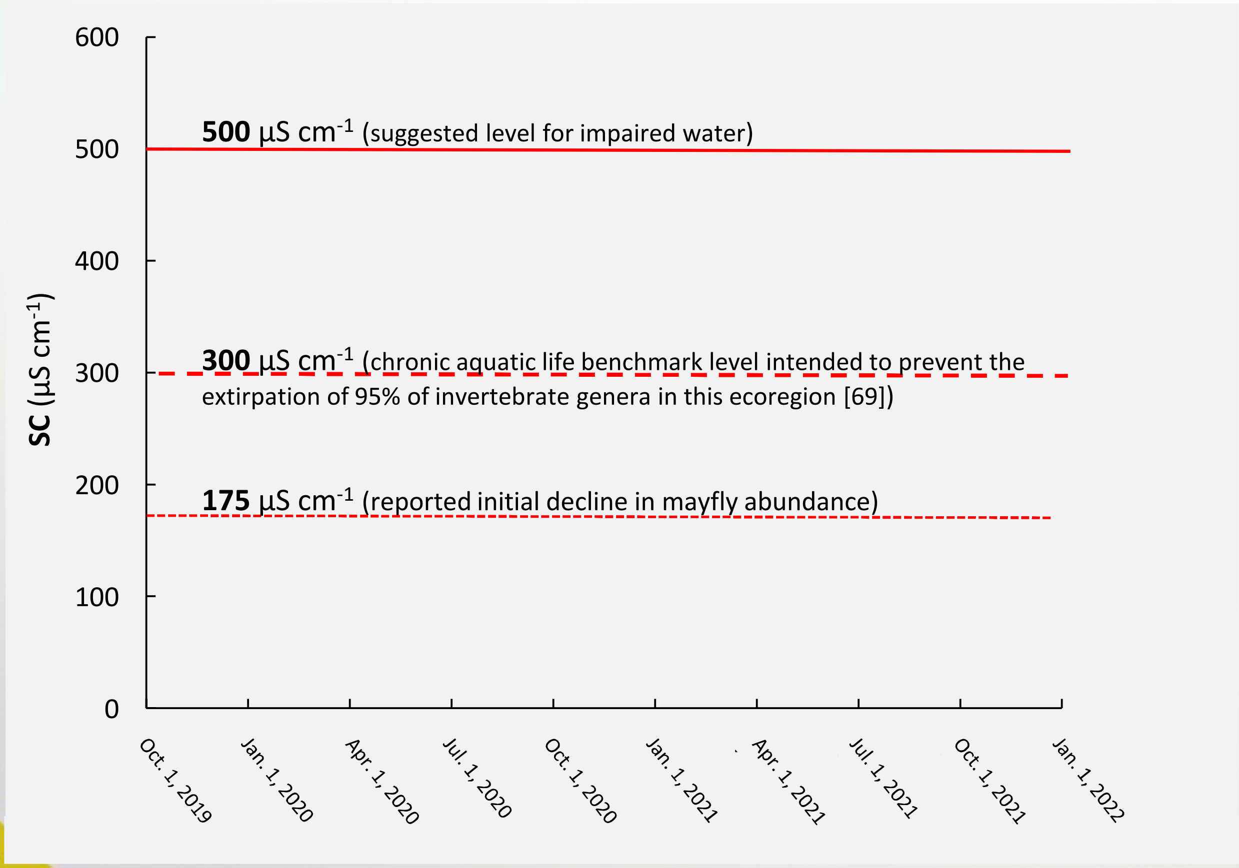
- Placement of high TDS producing strata/material away from hydrological pathways.
- Use weathered strata of low TDS-producing potential as topsoil substitute.
- Compact fill lifts to reduce deep infiltration and water storage.
- Reforestation reclamation and promotion of evapotranspiration loss and near surface flow.

Study Goal – Determine Long-Term Effect of MTR-VF on Stream Water Quality



- Study site – Central Appalachian ecoregion (#69), upper Kanawha river basin (West Virginia)
- Mining operation completed in fall of 1992
- Planting completed in 1994; Reforestation Reclamation ensued in early 2000's and final bond release in fall of 2005
- Monitoring started Fall 2019

Conductivity – Spatial & Temporal Variation



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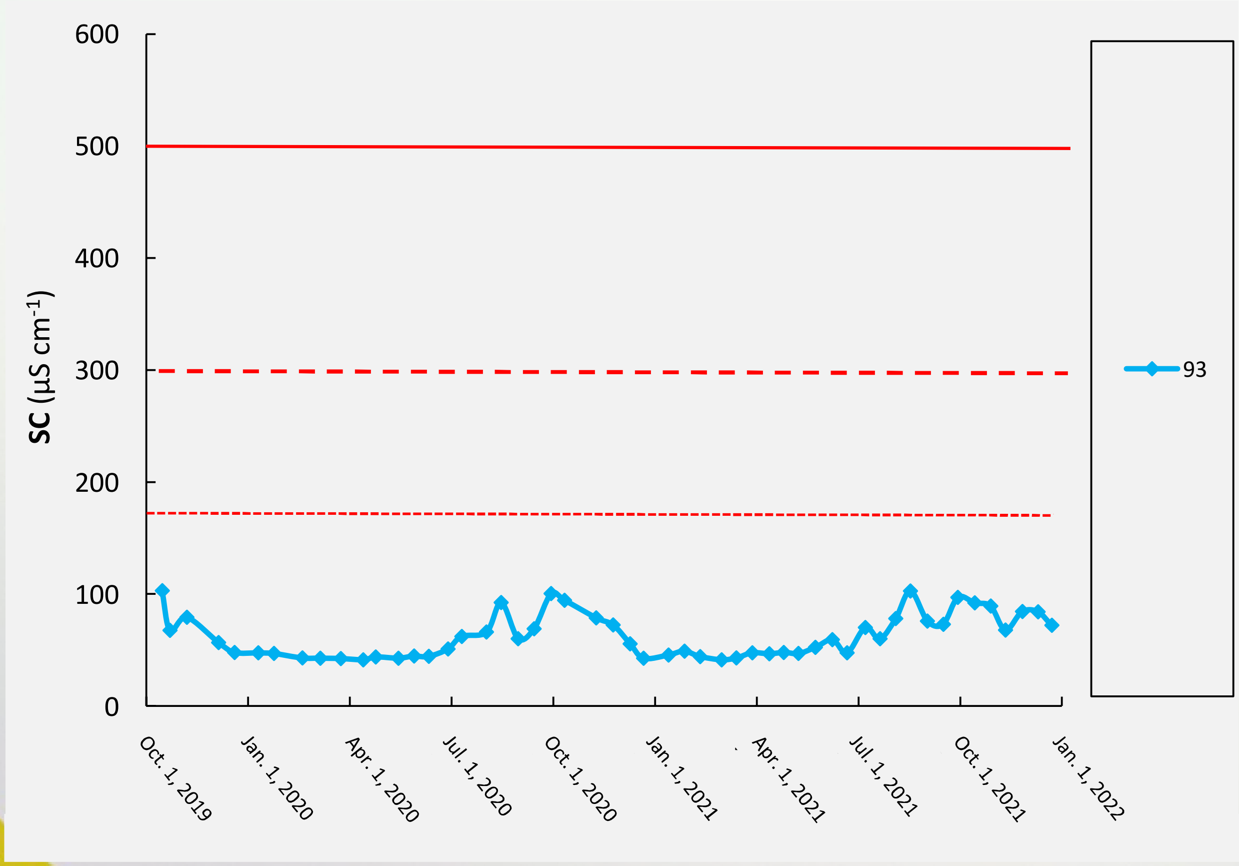
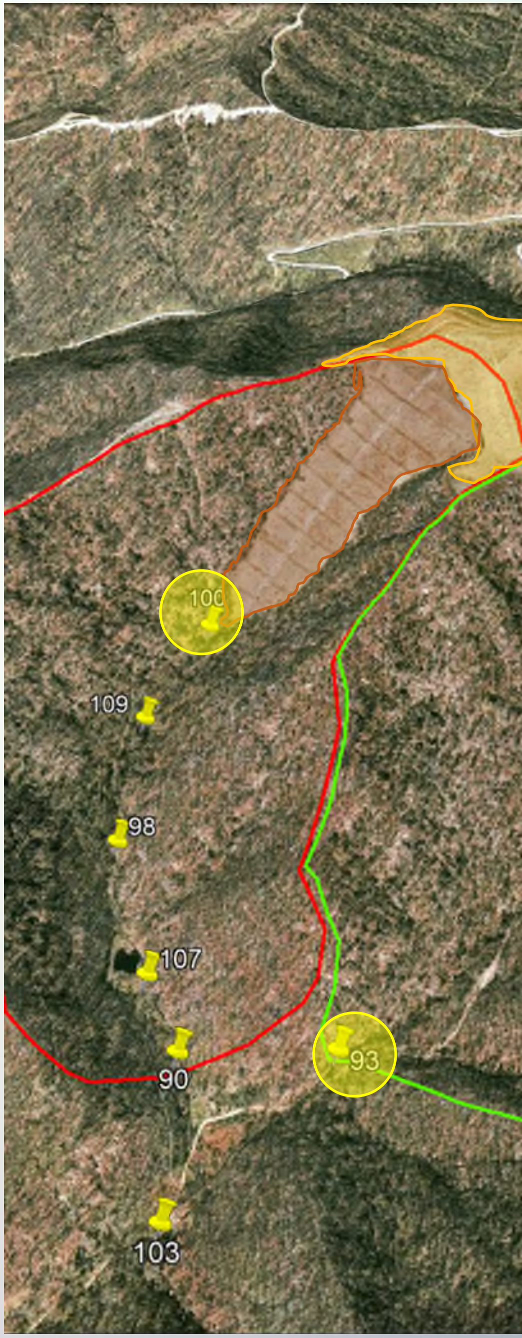
Conductivity – Spatial & Temporal Variation





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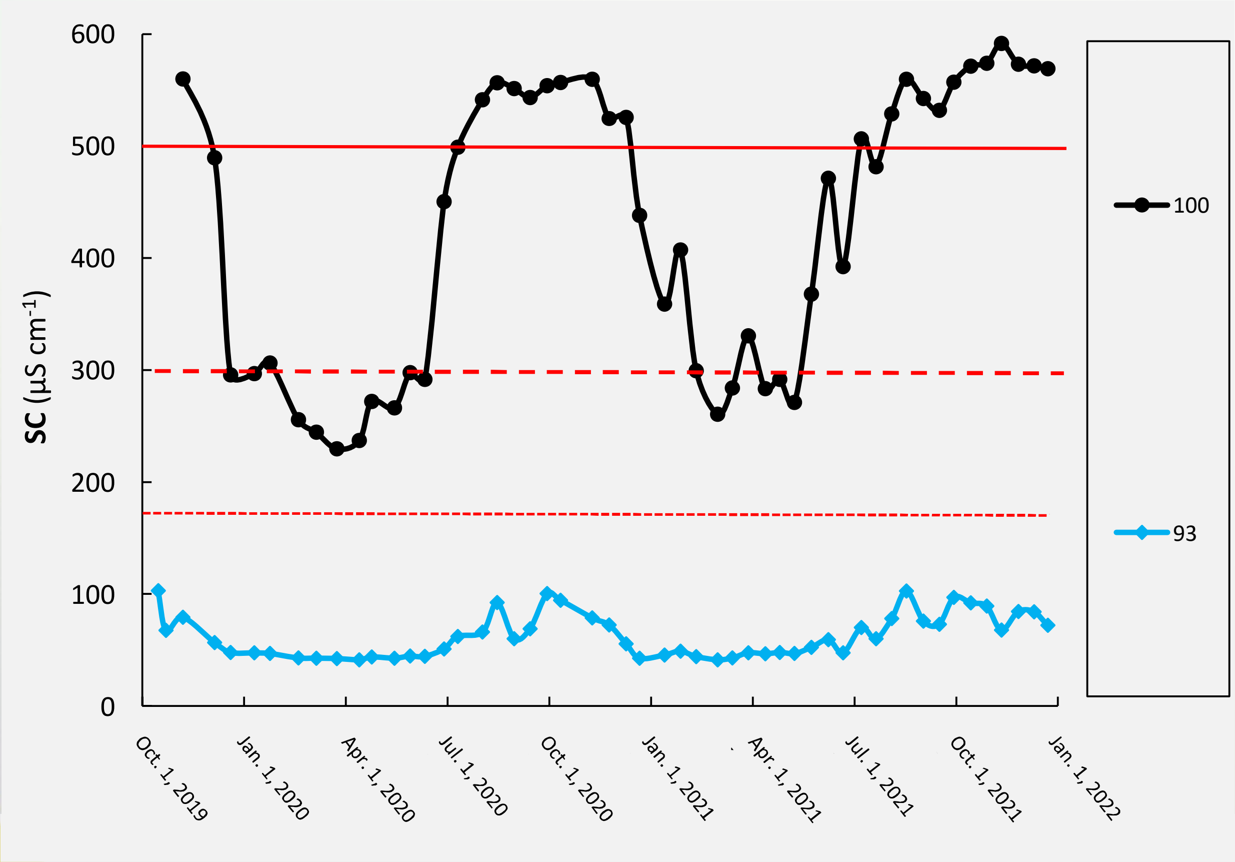
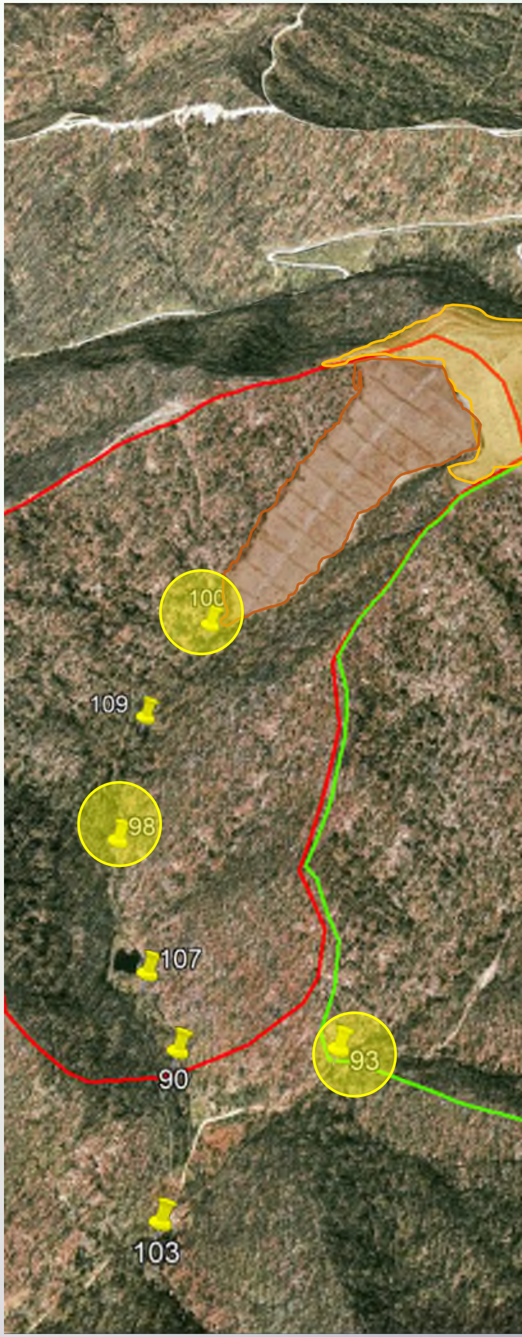
Conductivity – Spatial & Temporal Variation





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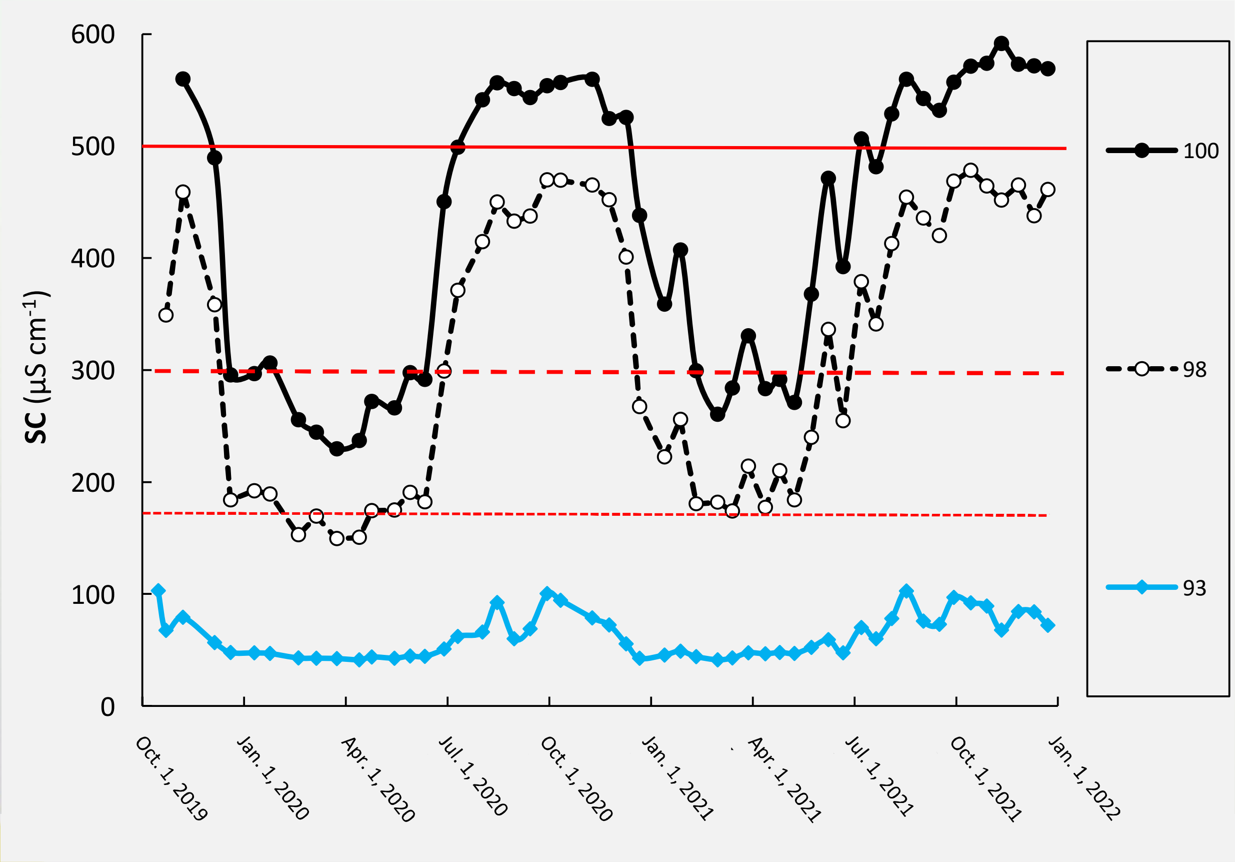

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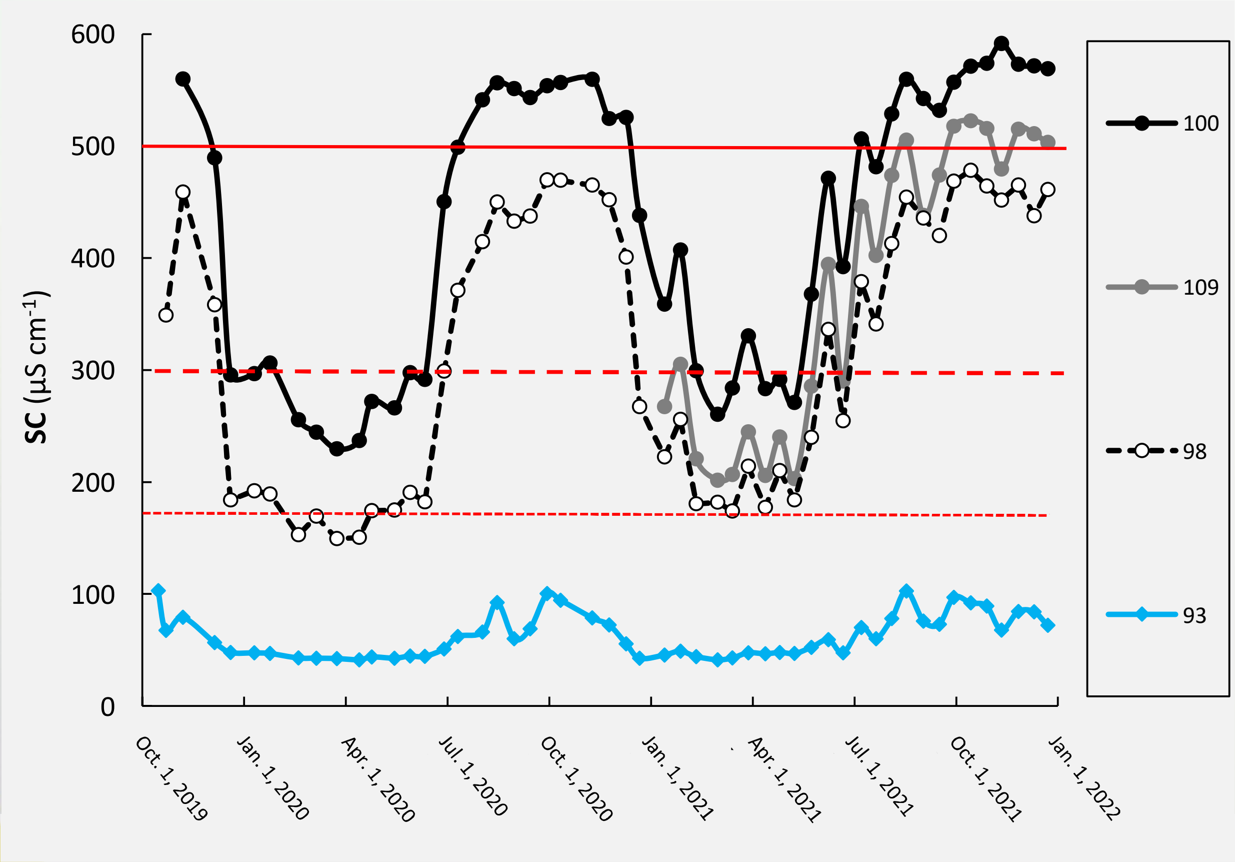

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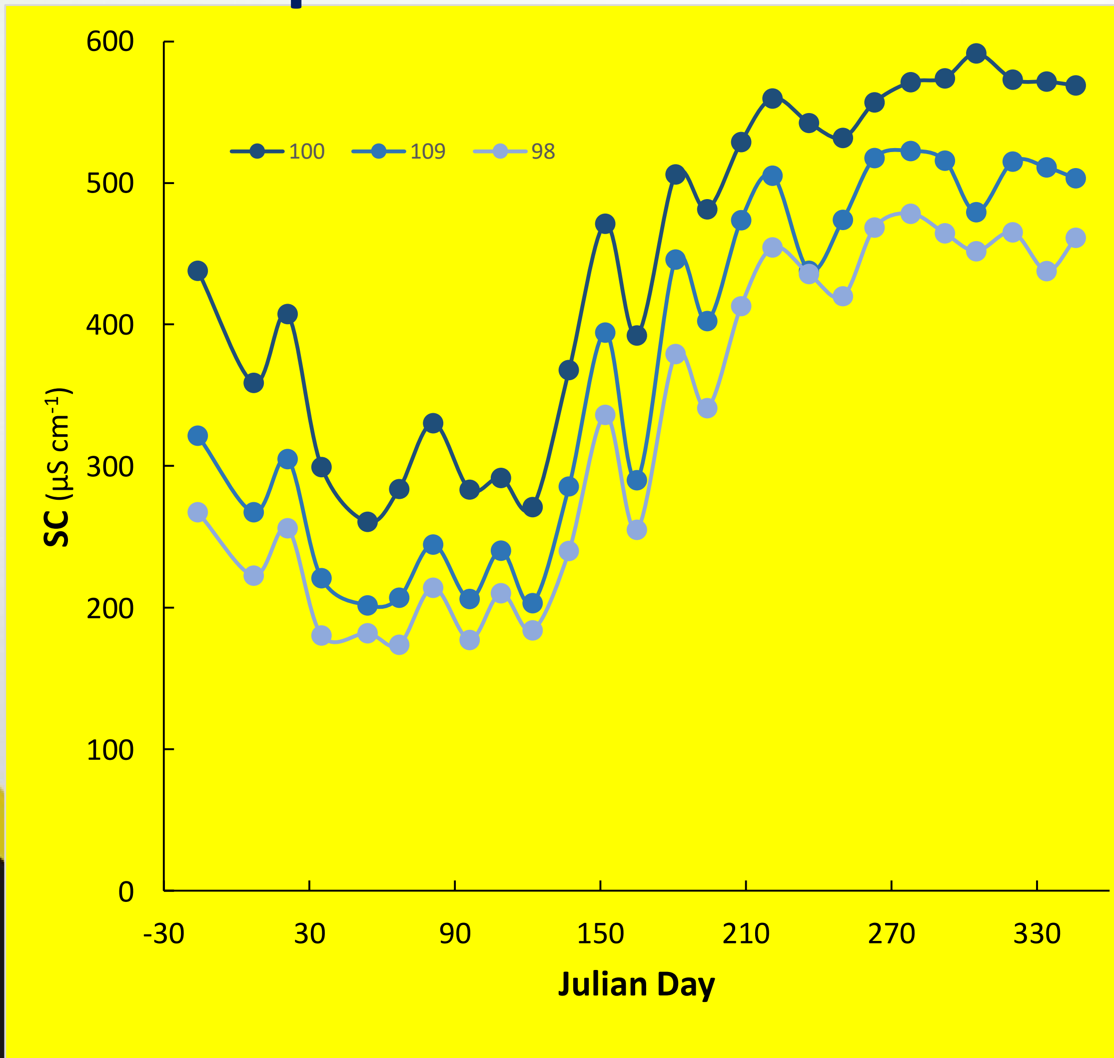
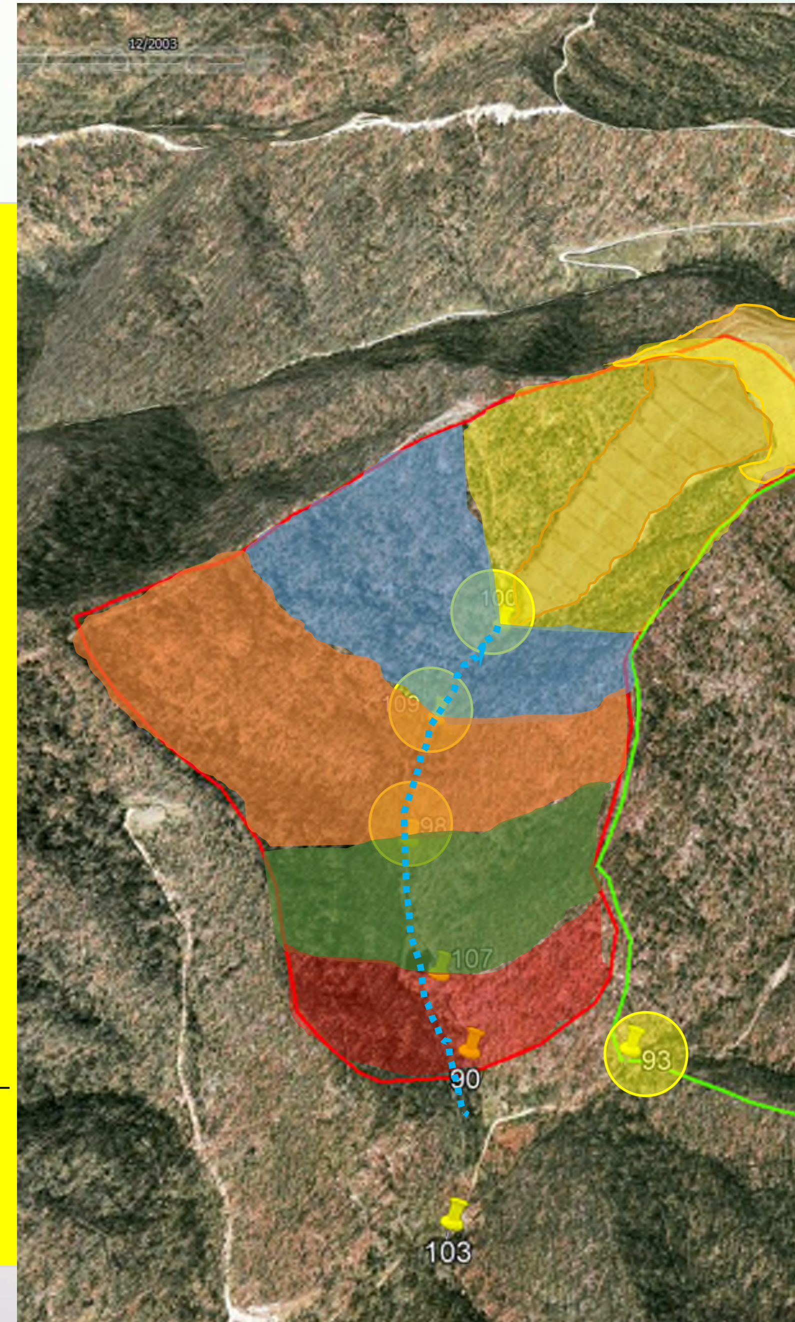
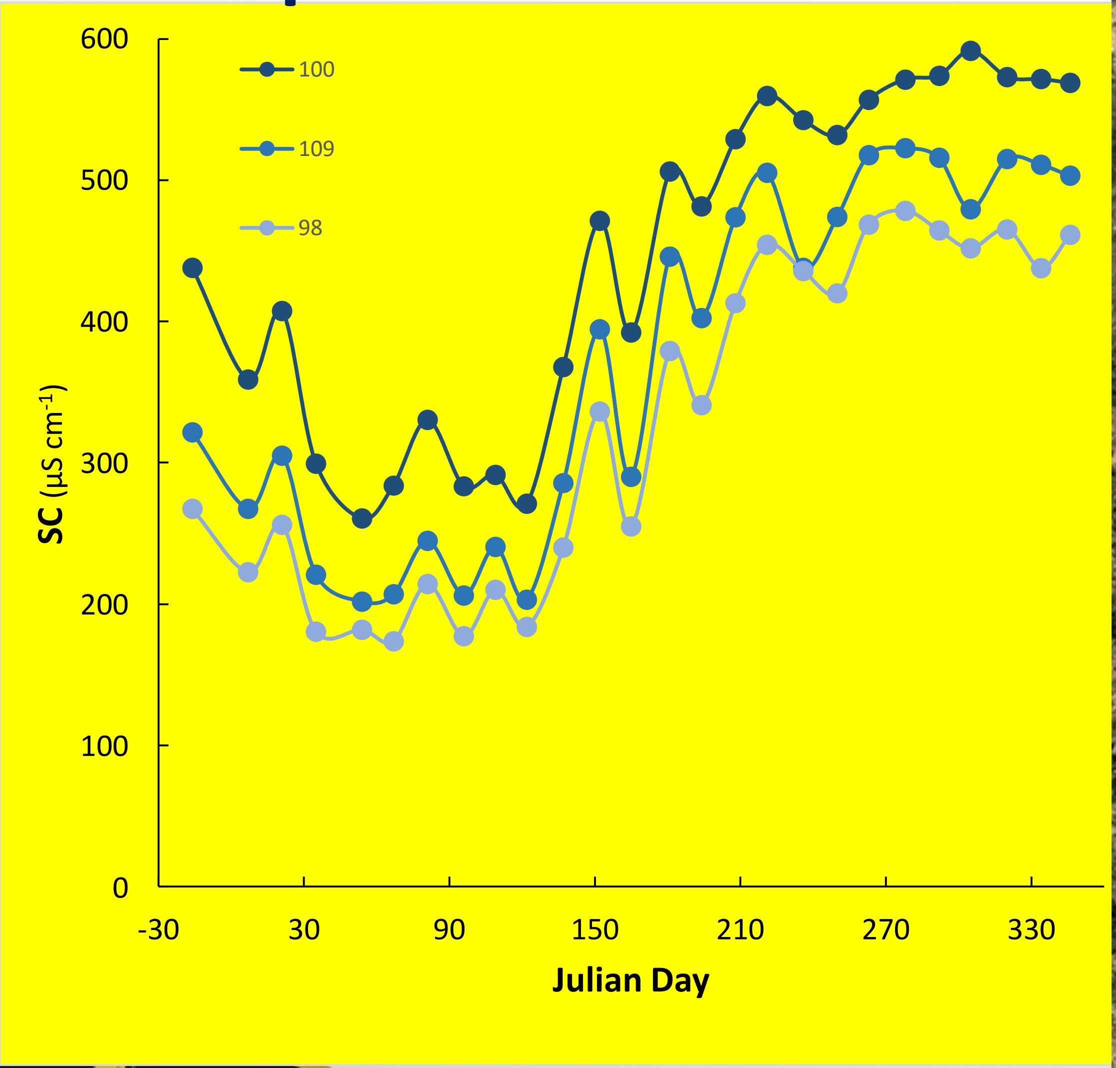
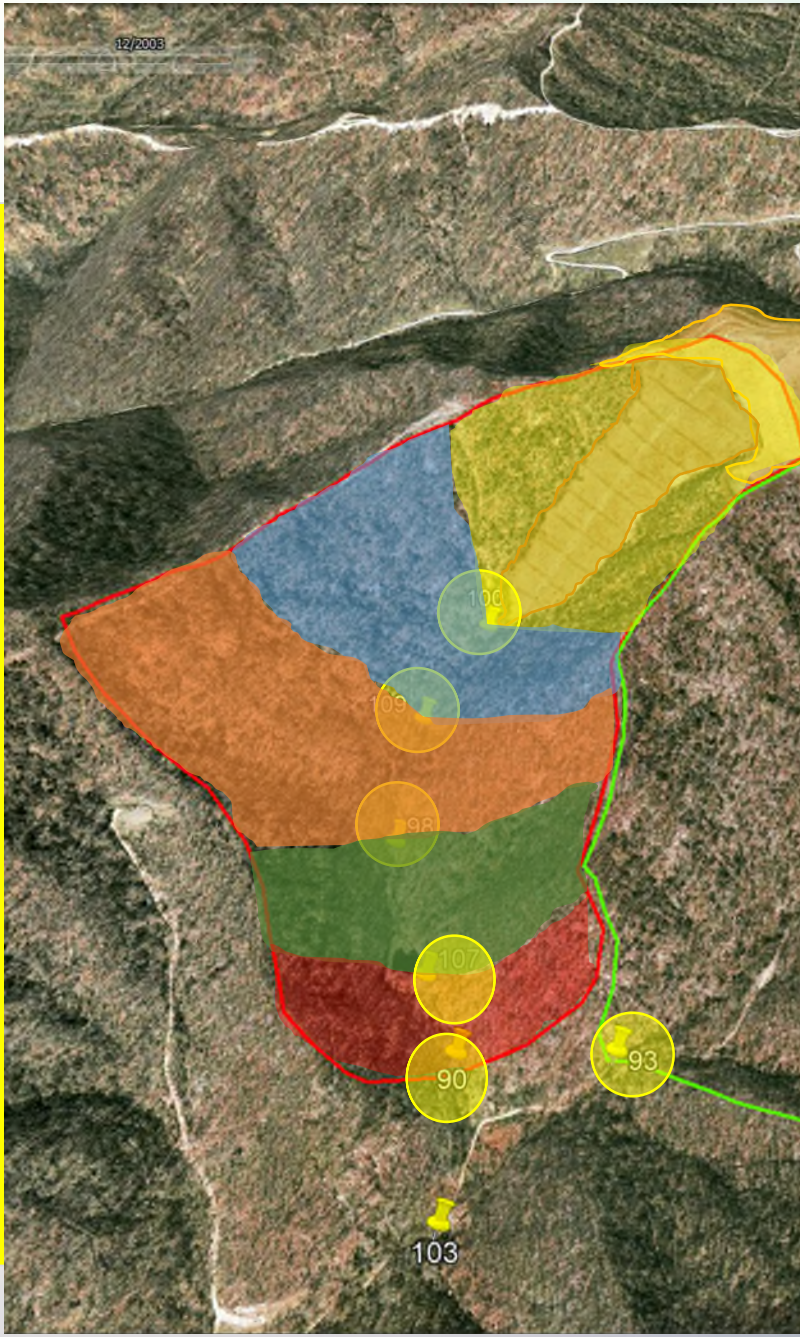
Conductivity – Spatial & Temporal Variation 2021





Conductivity – Spatial & Temporal Variation 2021





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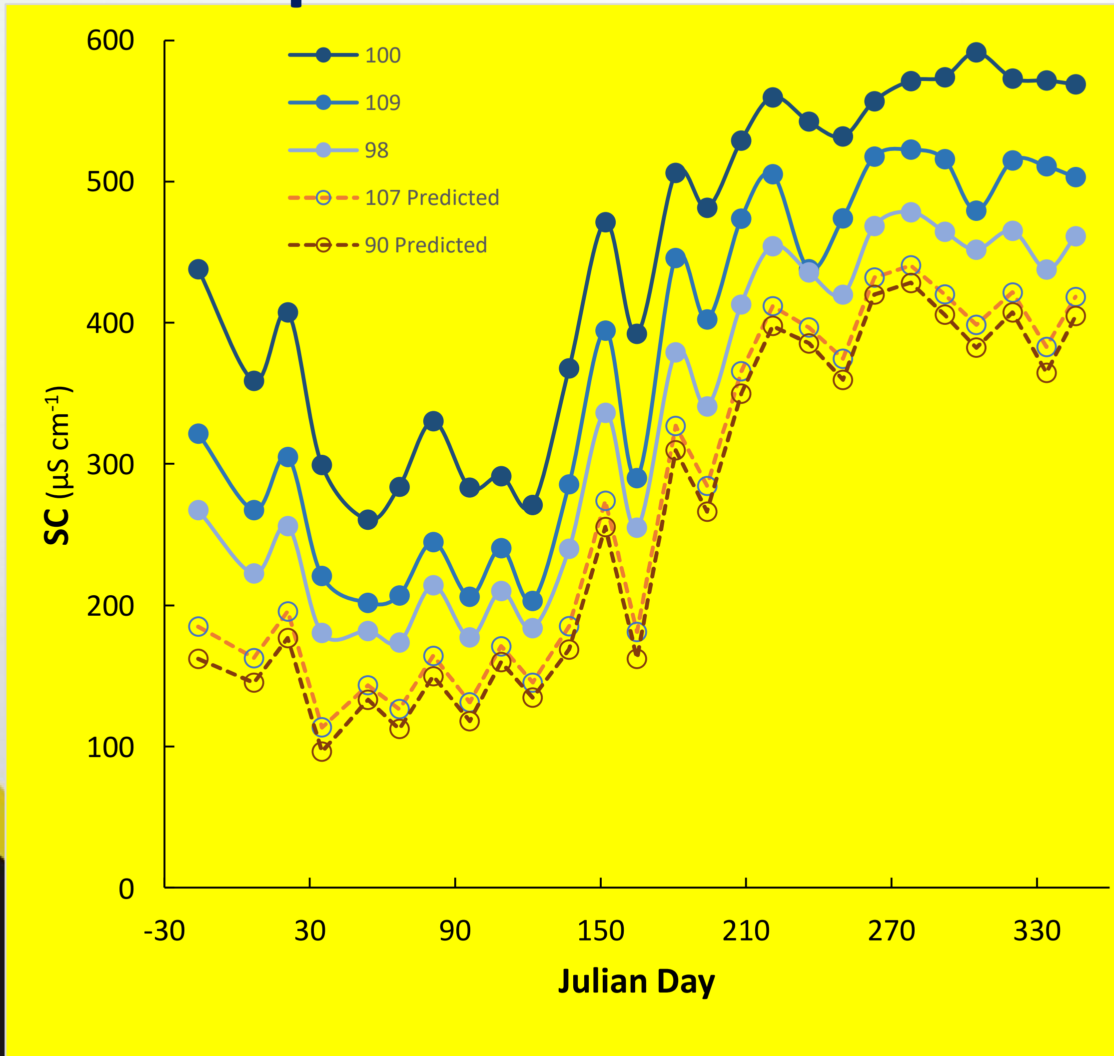

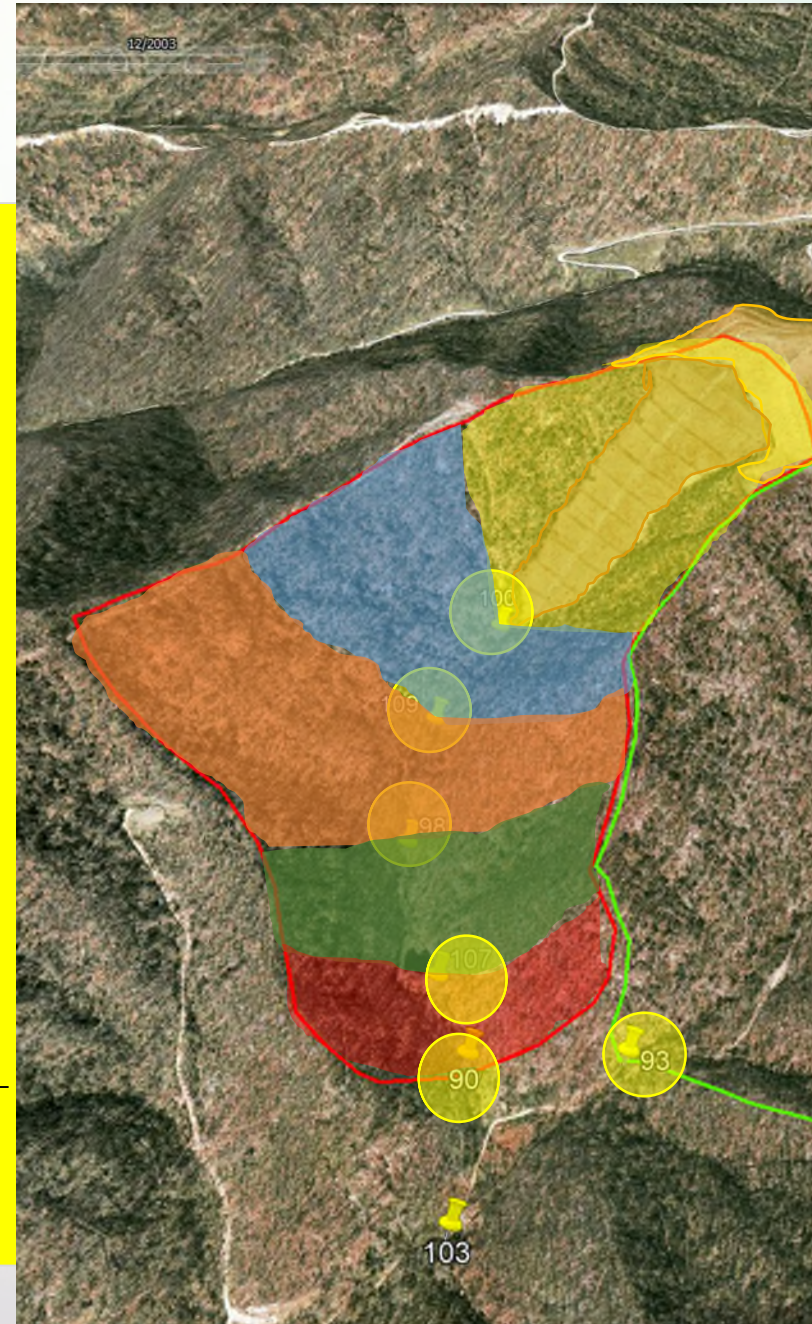

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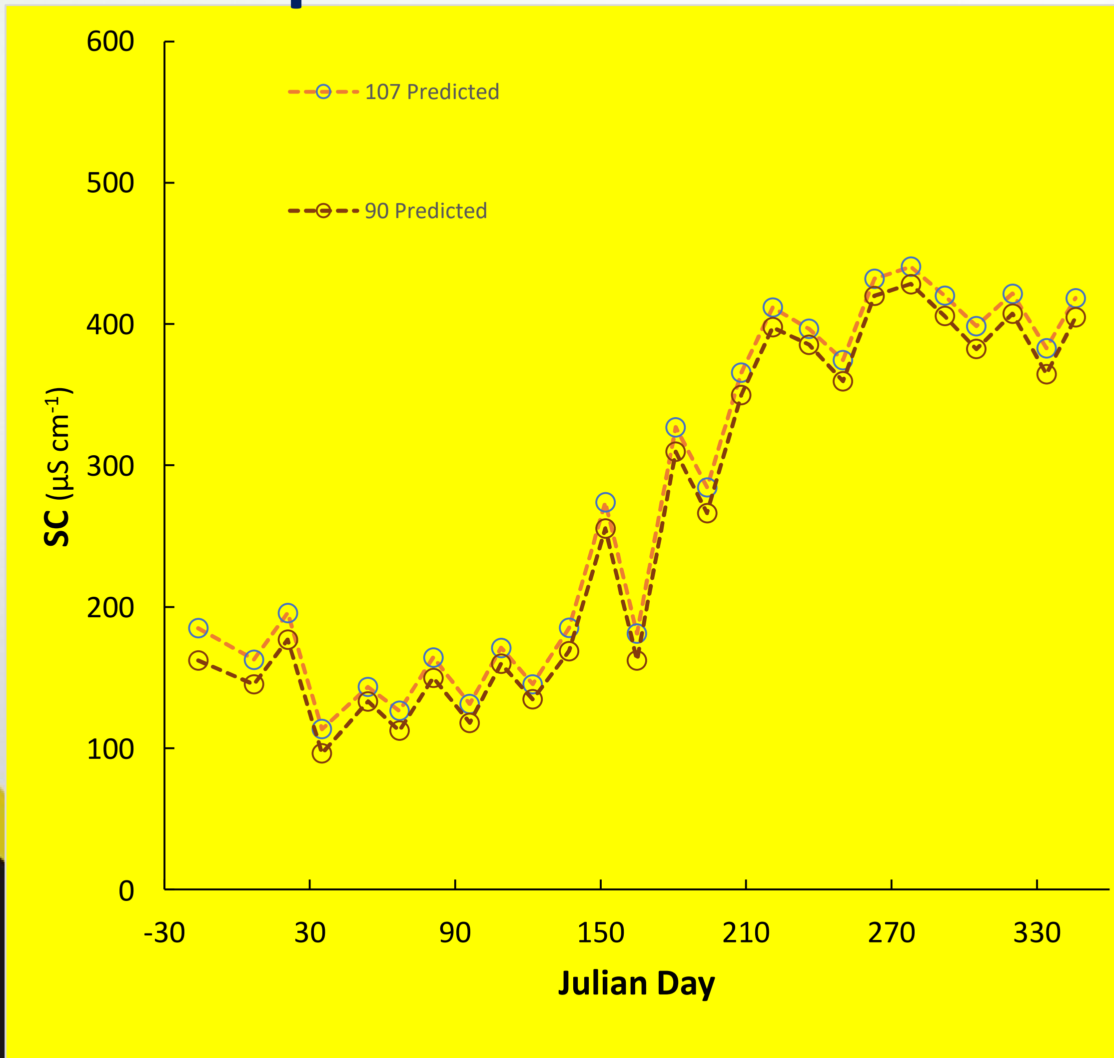
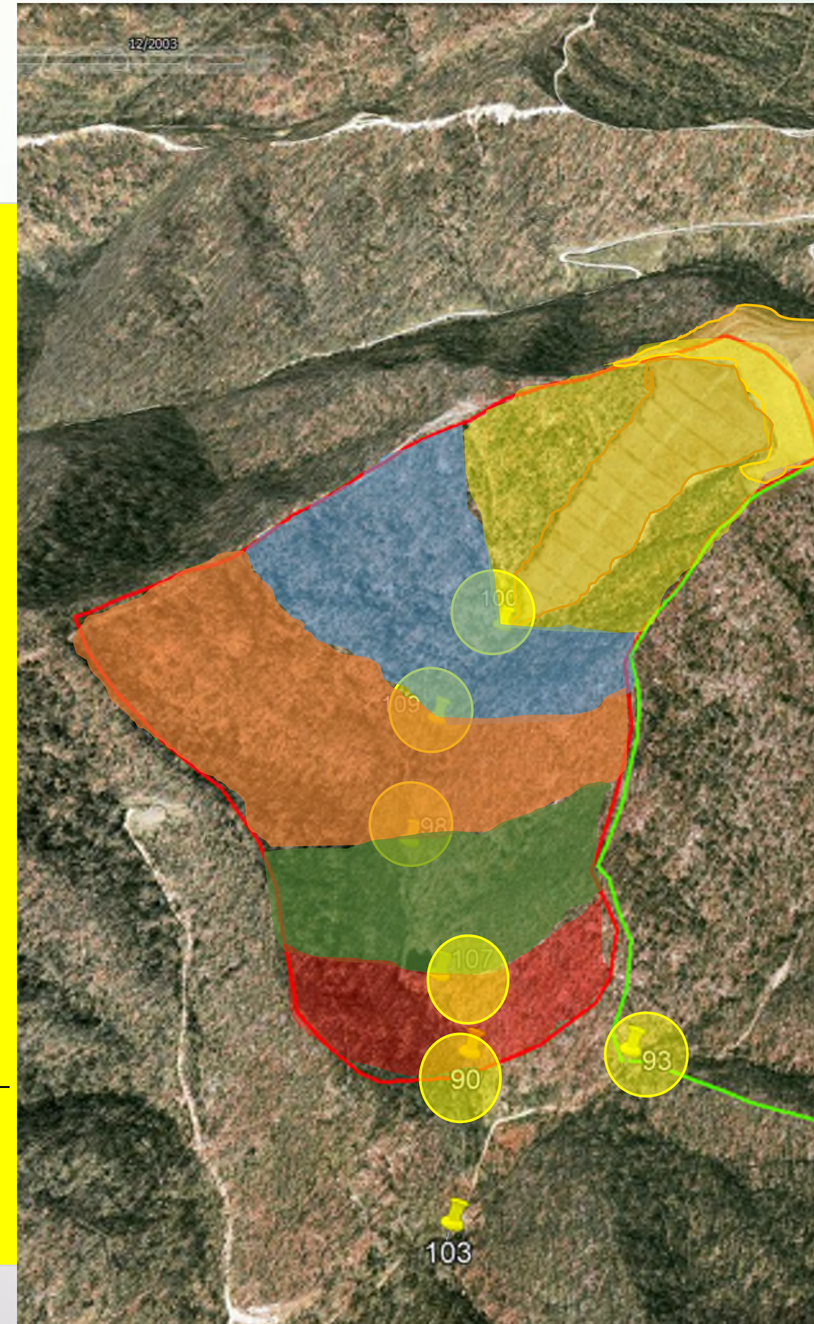
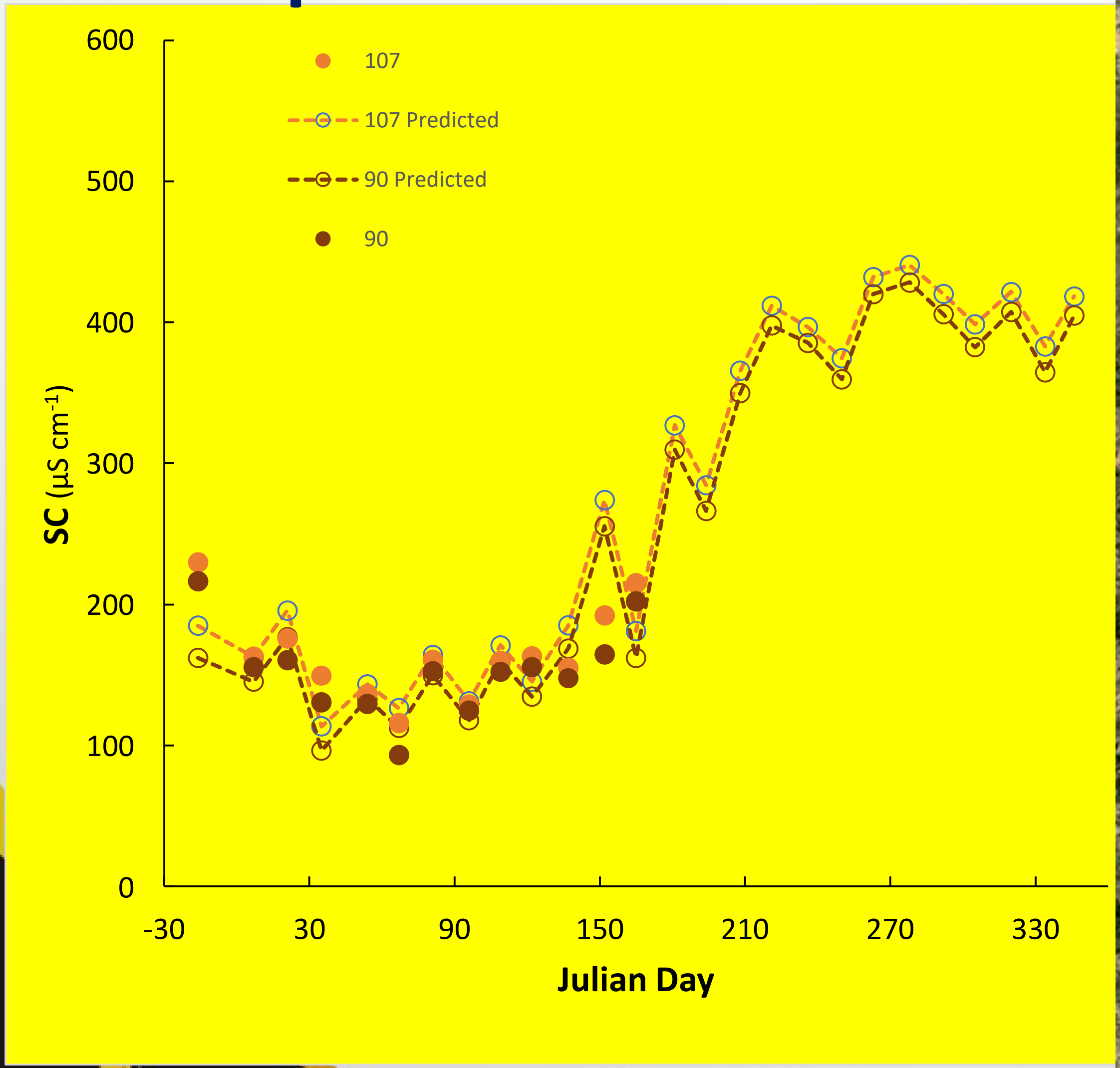
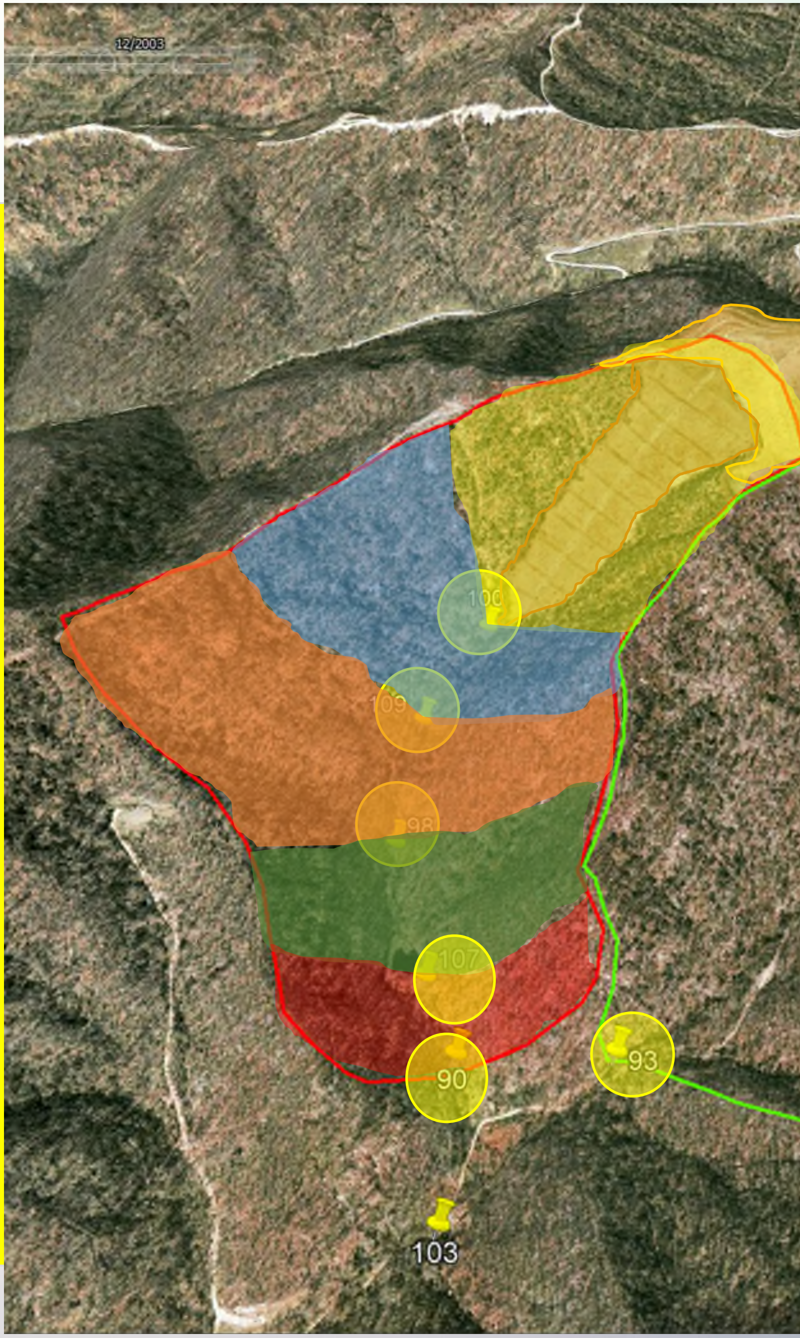




Conductivity – Spatial & Temporal Variation 2021





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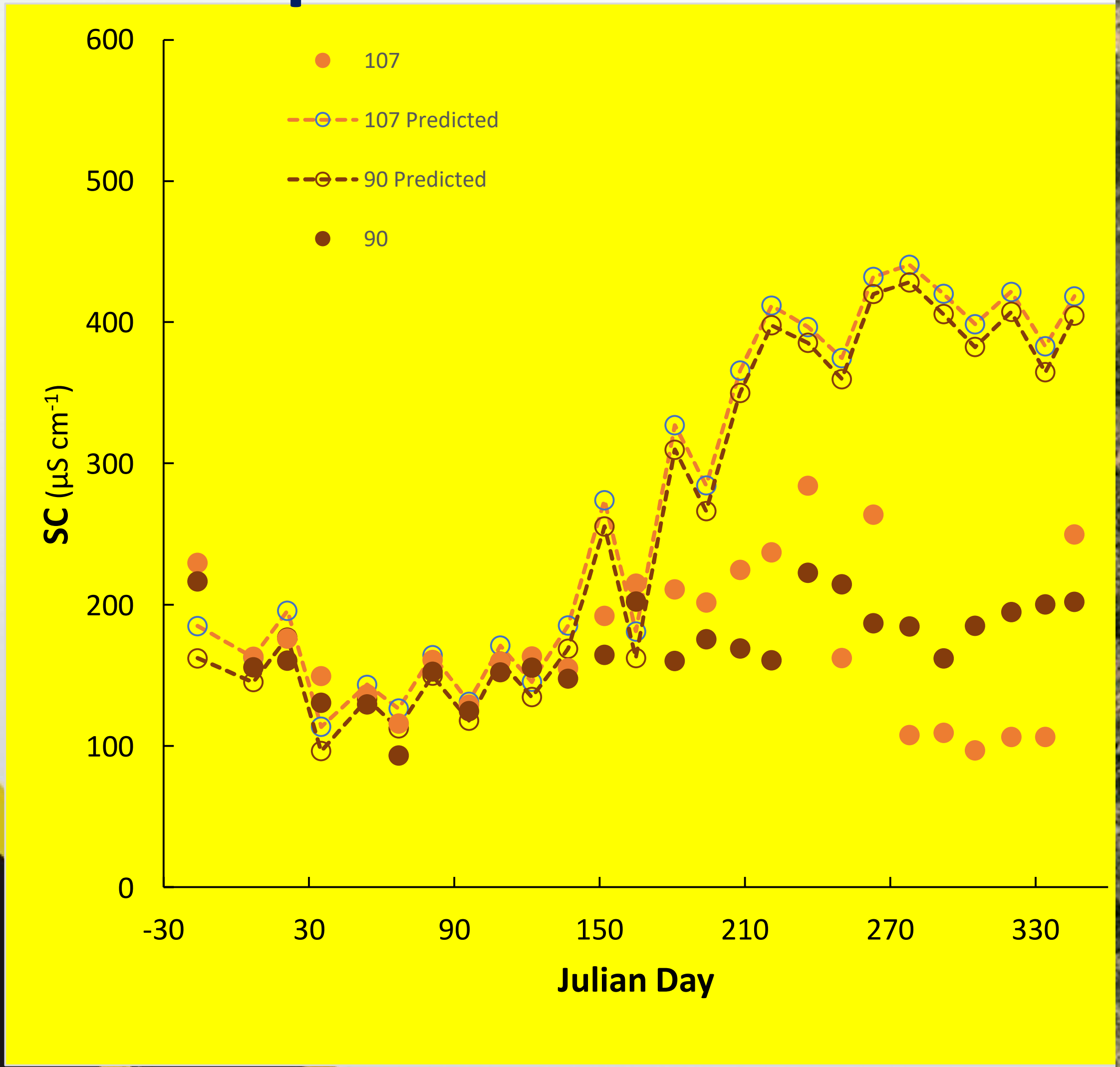

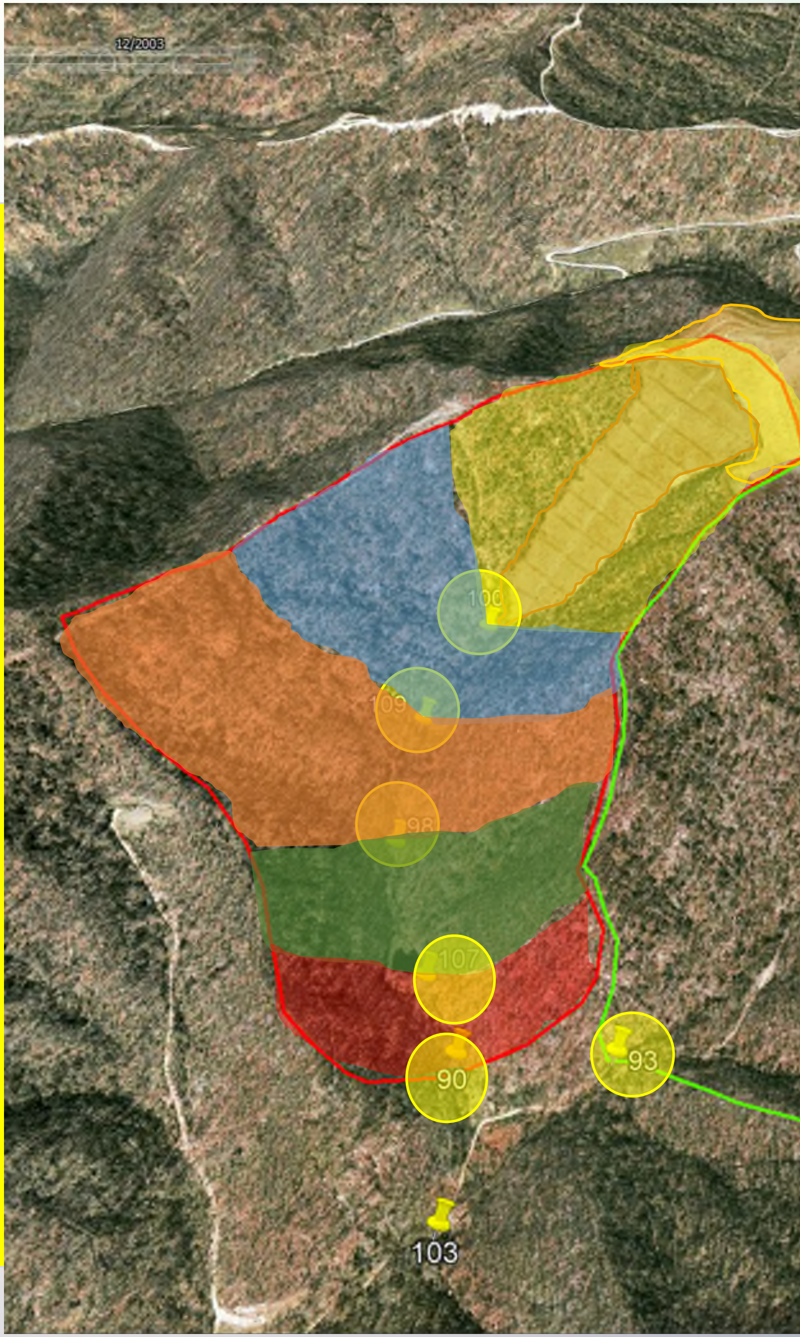

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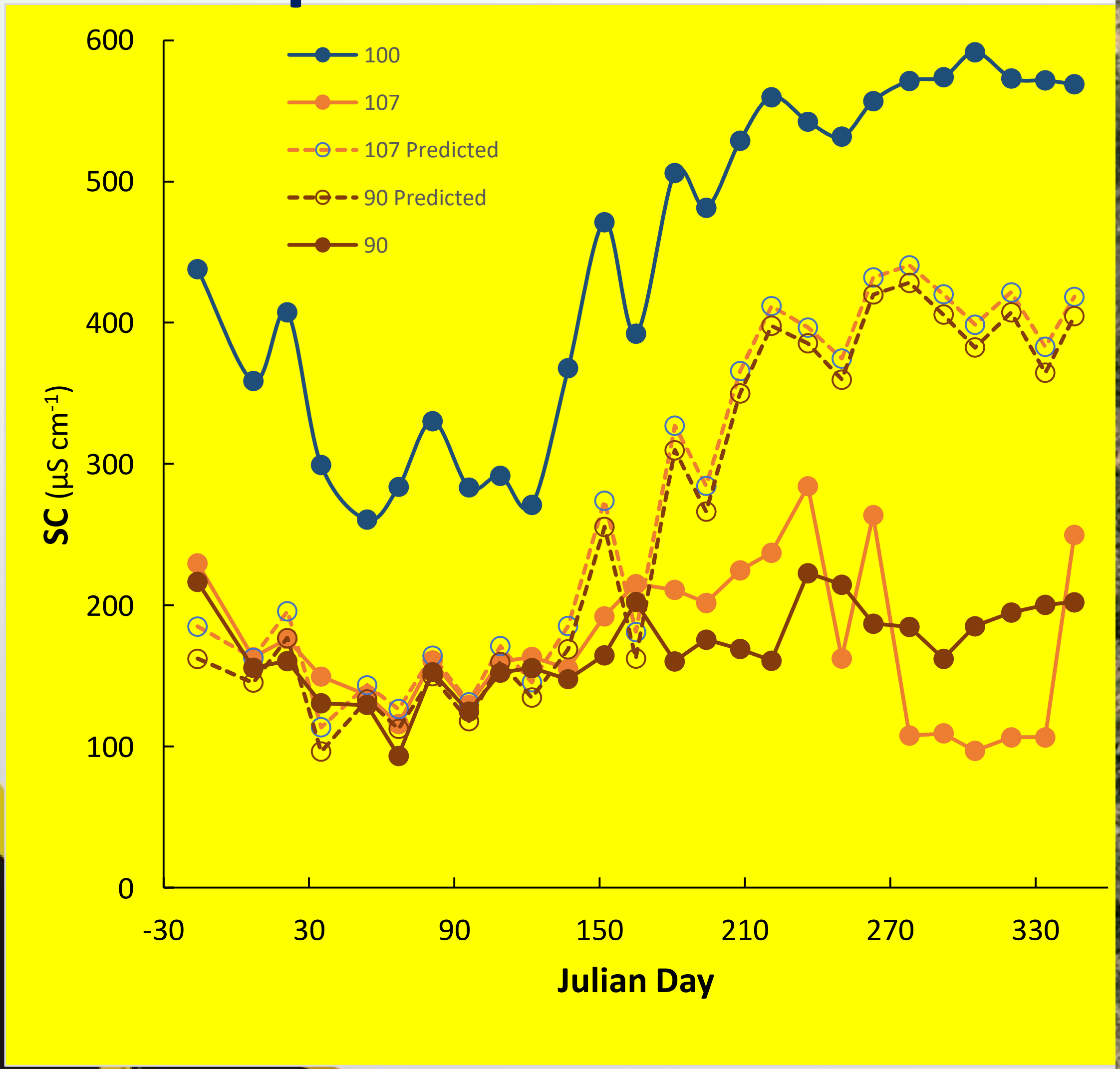
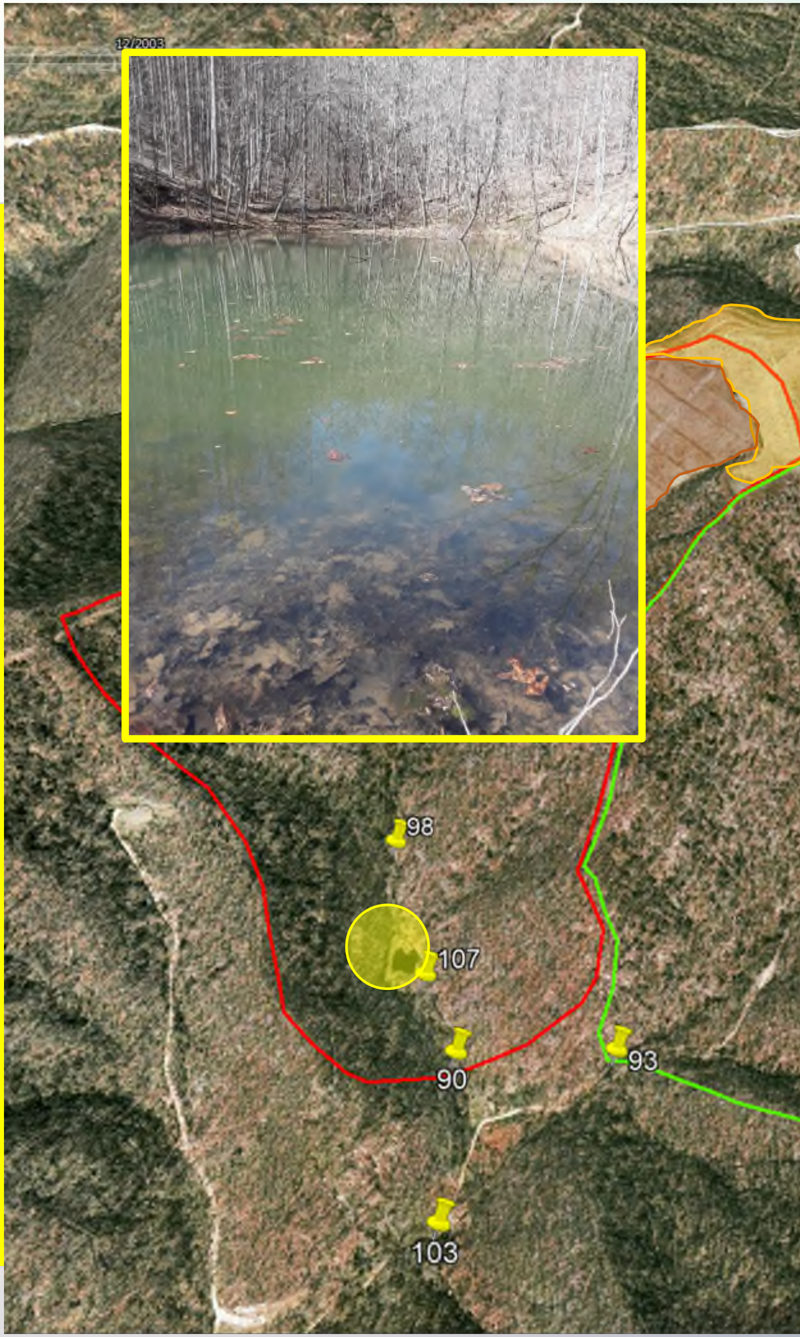


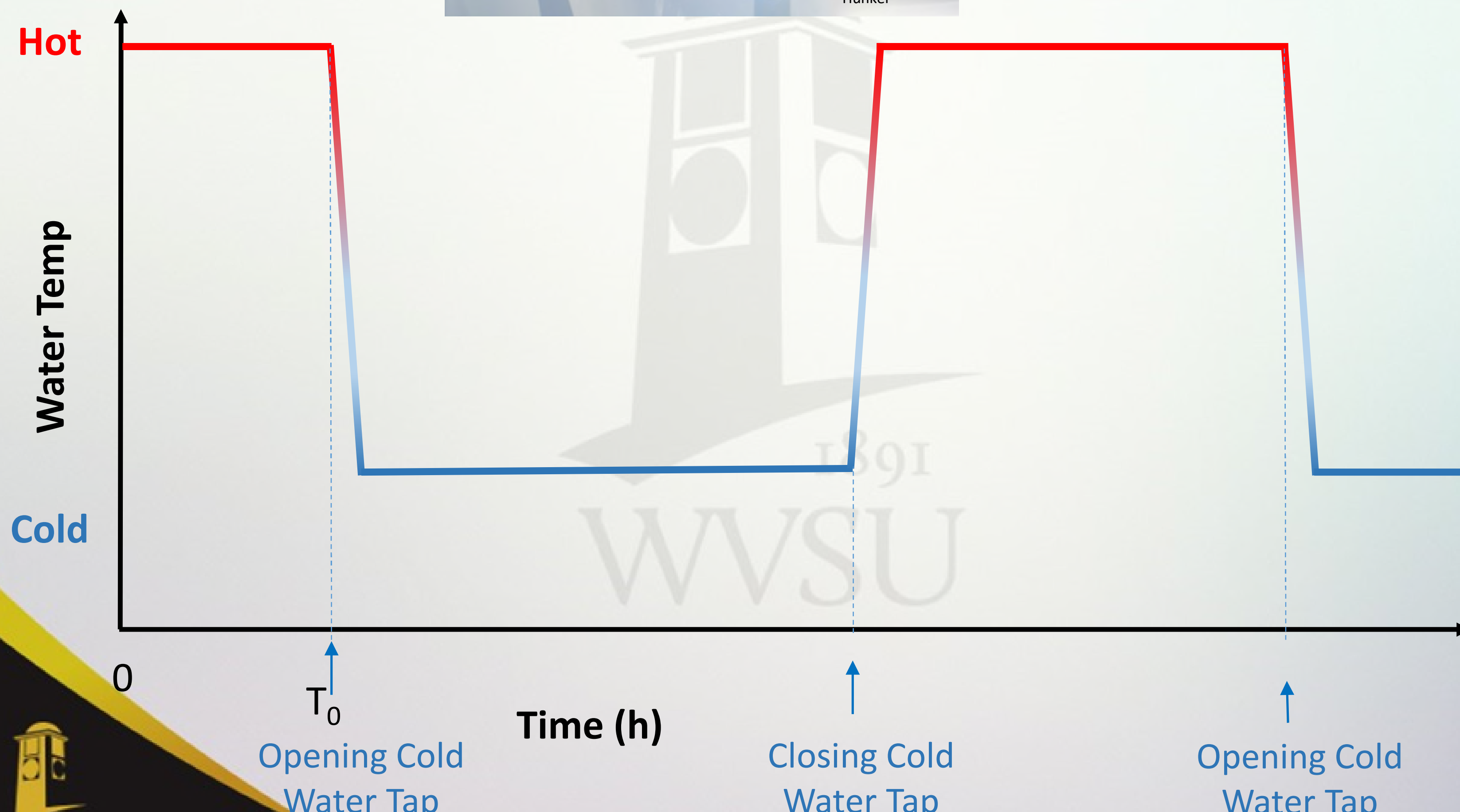


The Bathtub Phenomenon


Hunker

Hot water: 1 gal/hour

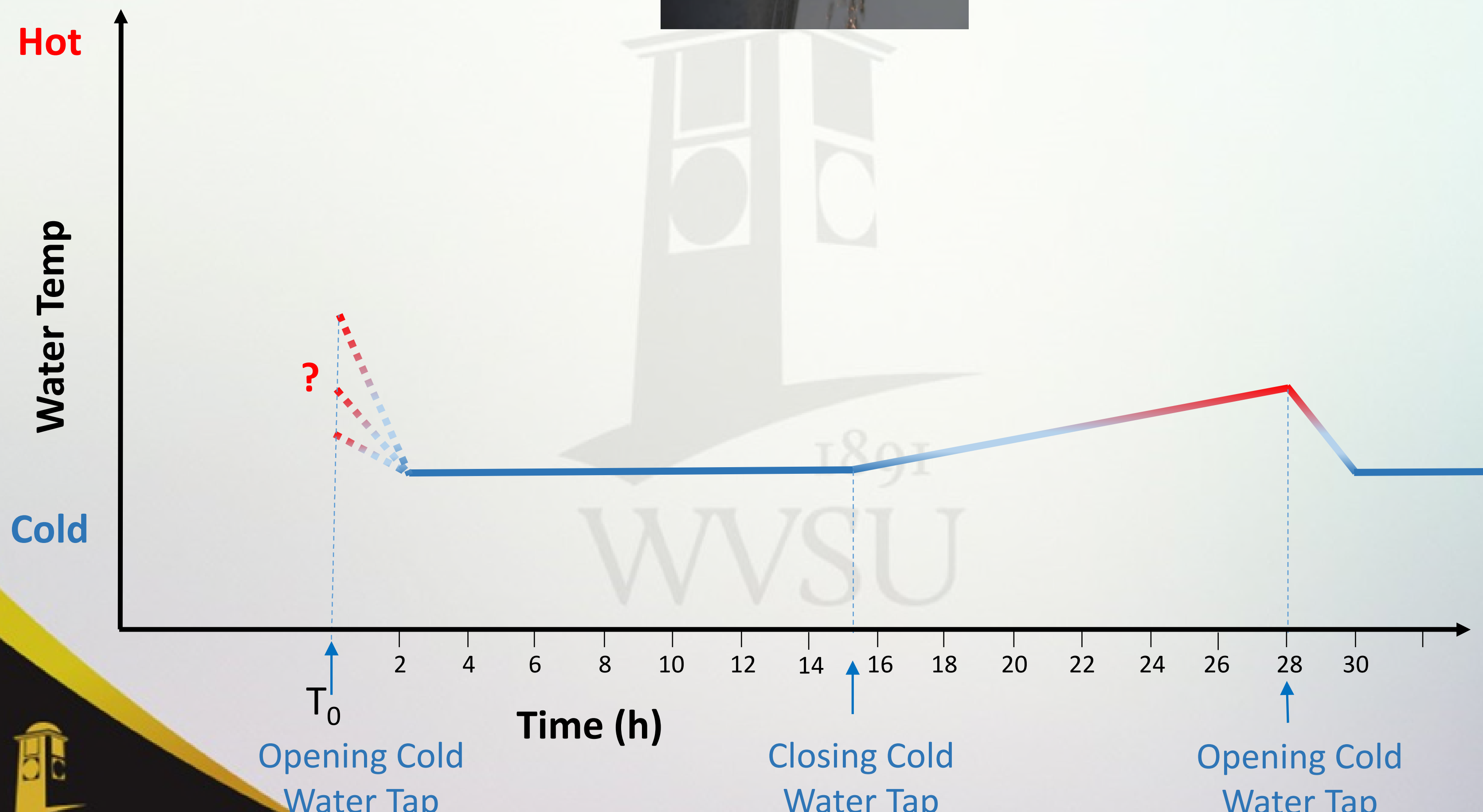
Cold water: 100 gal/hour



Hot water: 1 gal/hour

Cold water: 100 gal/hour

Bathtub Capacity: 100 gal



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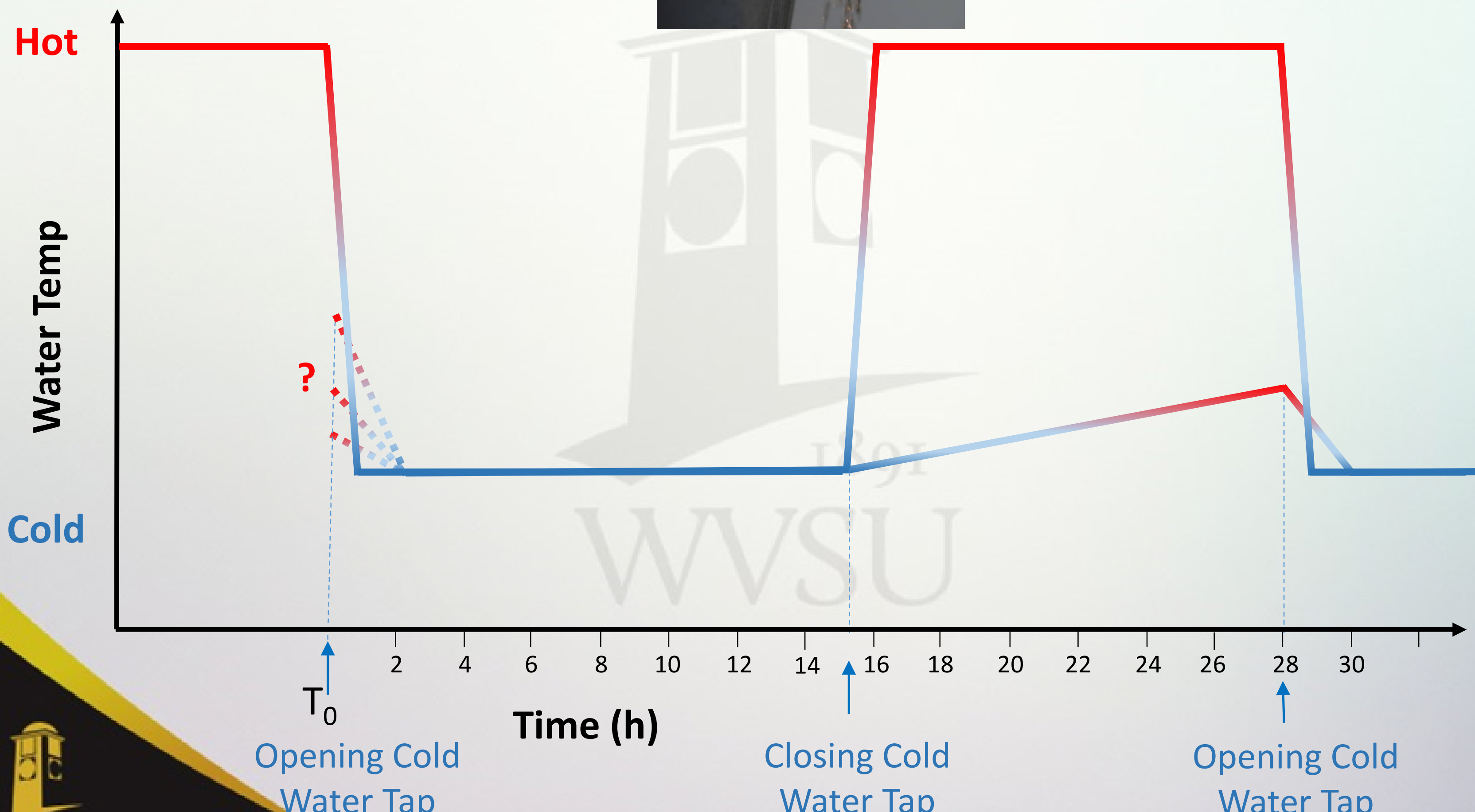
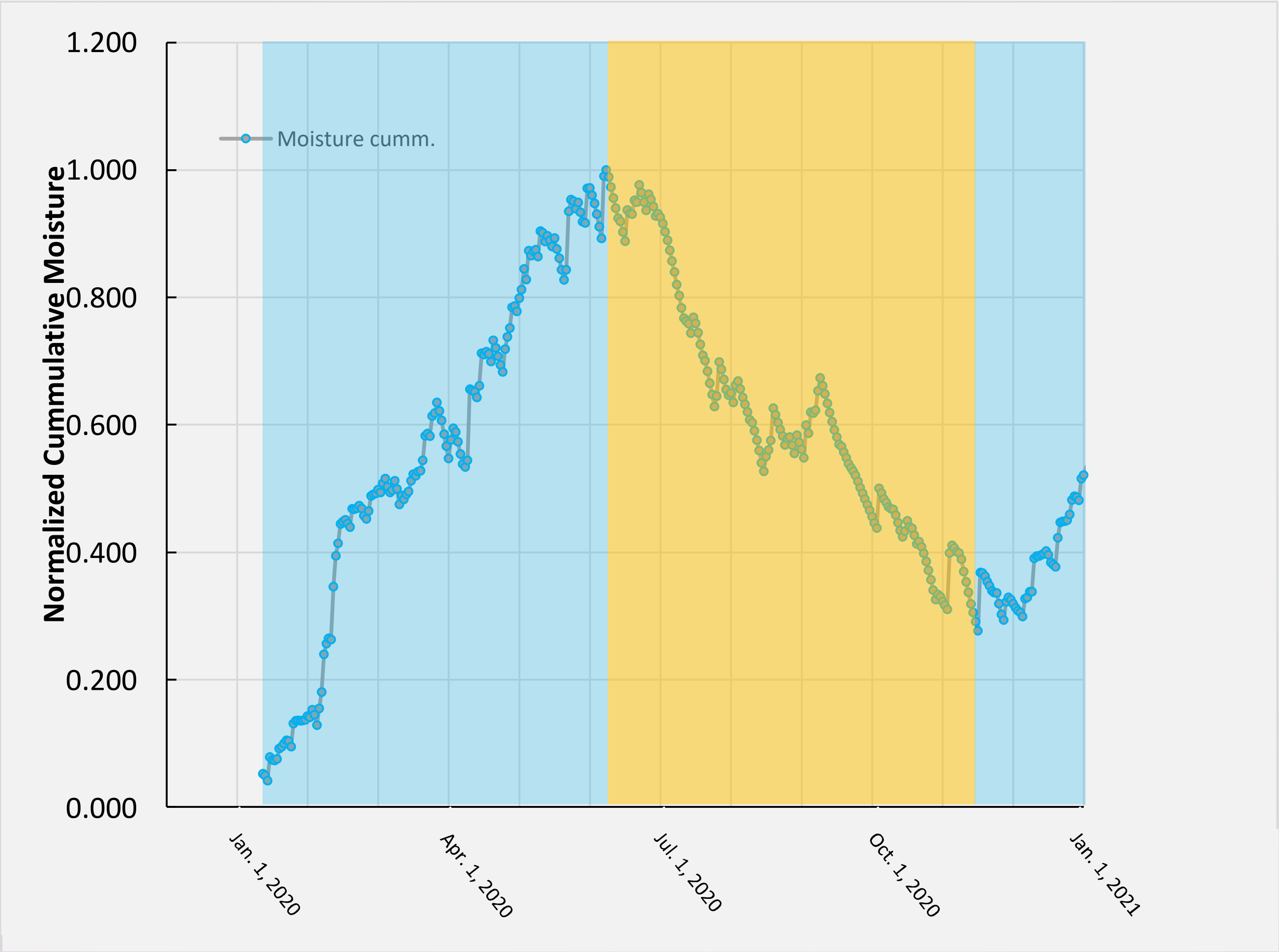


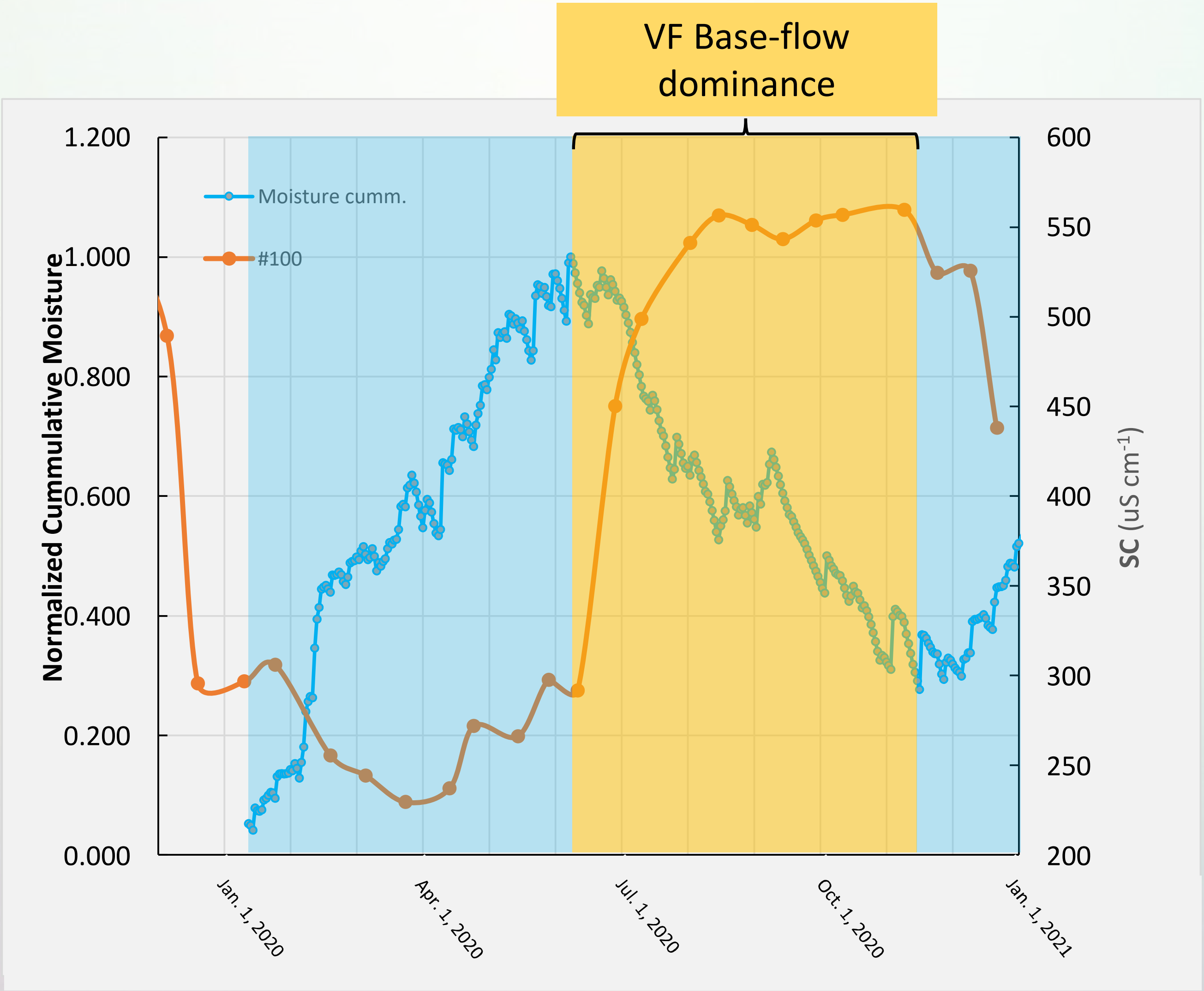
Moisture Budget Balance



$$MB_{cumm.i} = \sum_{i=x}^{x-1}(P_i - ET_i)$$

P, daily precipitation, mm; ET, daily evapotranspiration, mm; i, calendar Julian day

Moisture Budget Balance



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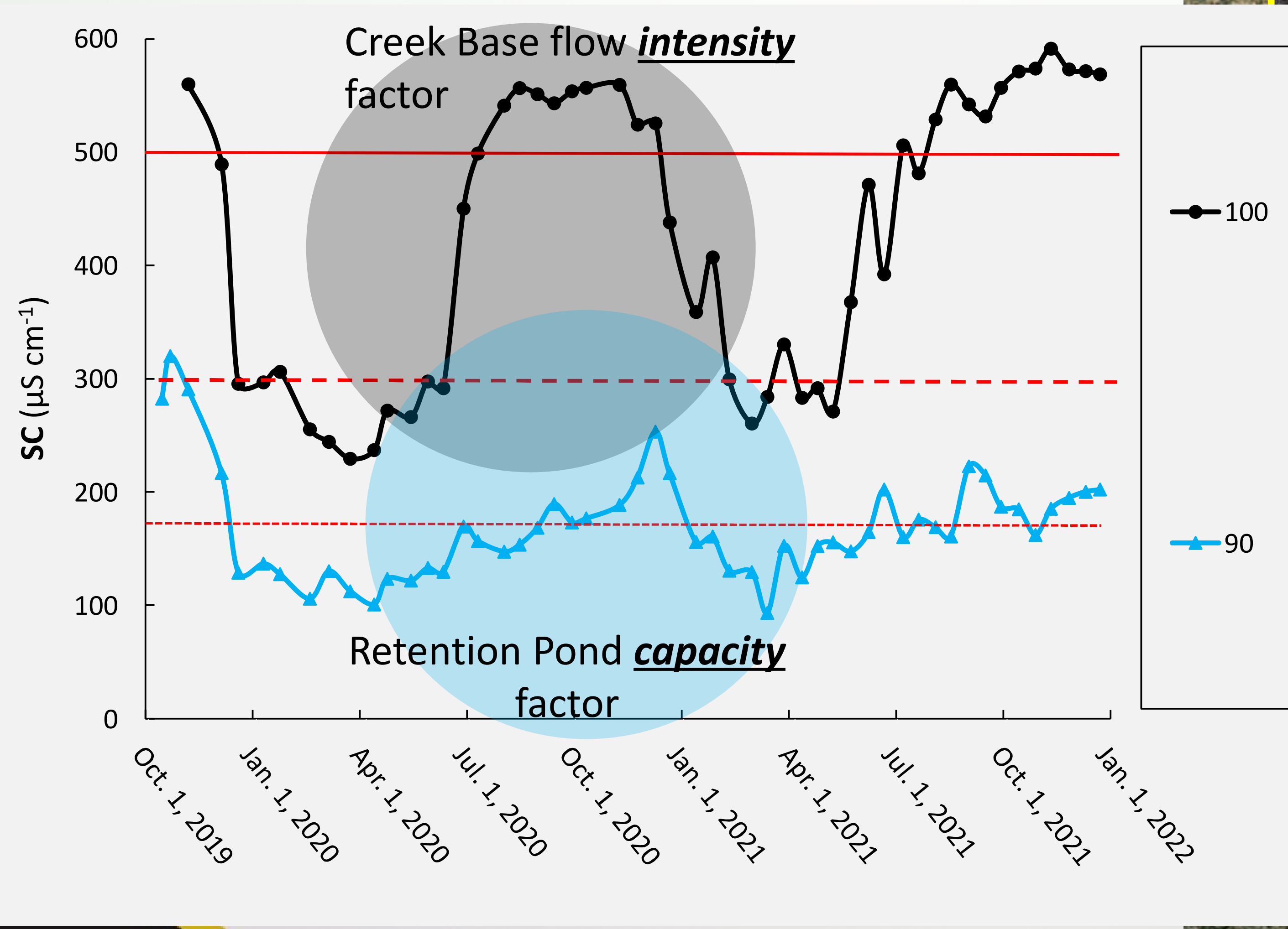
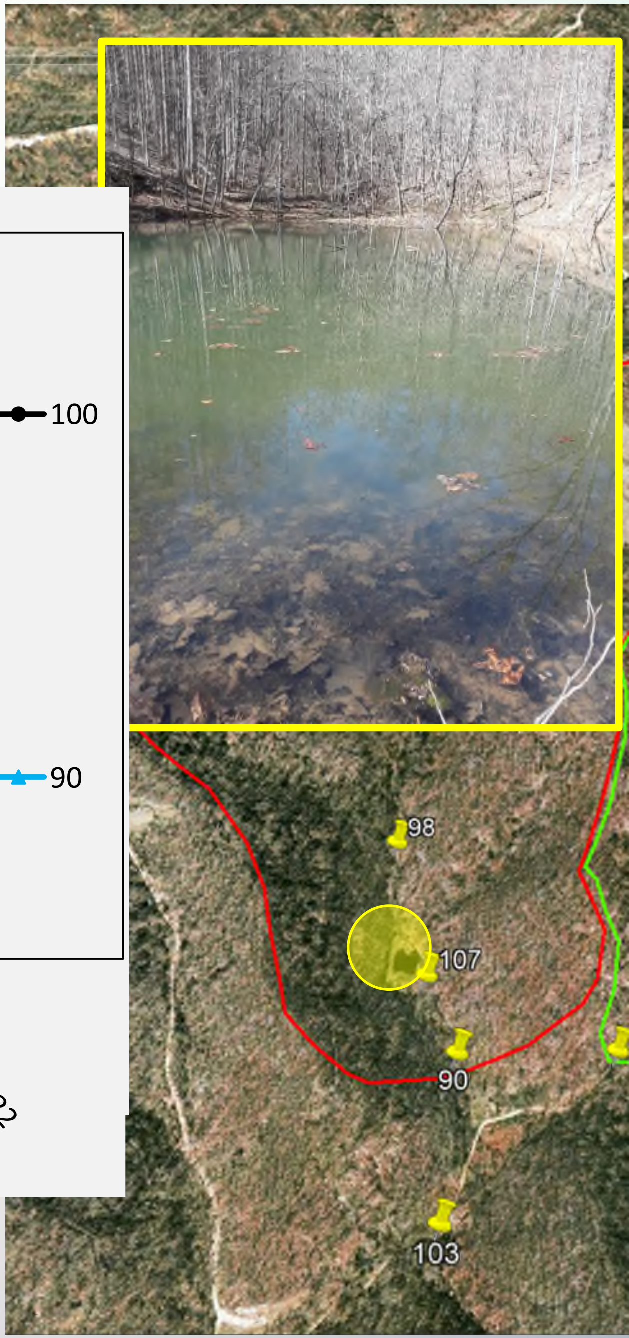
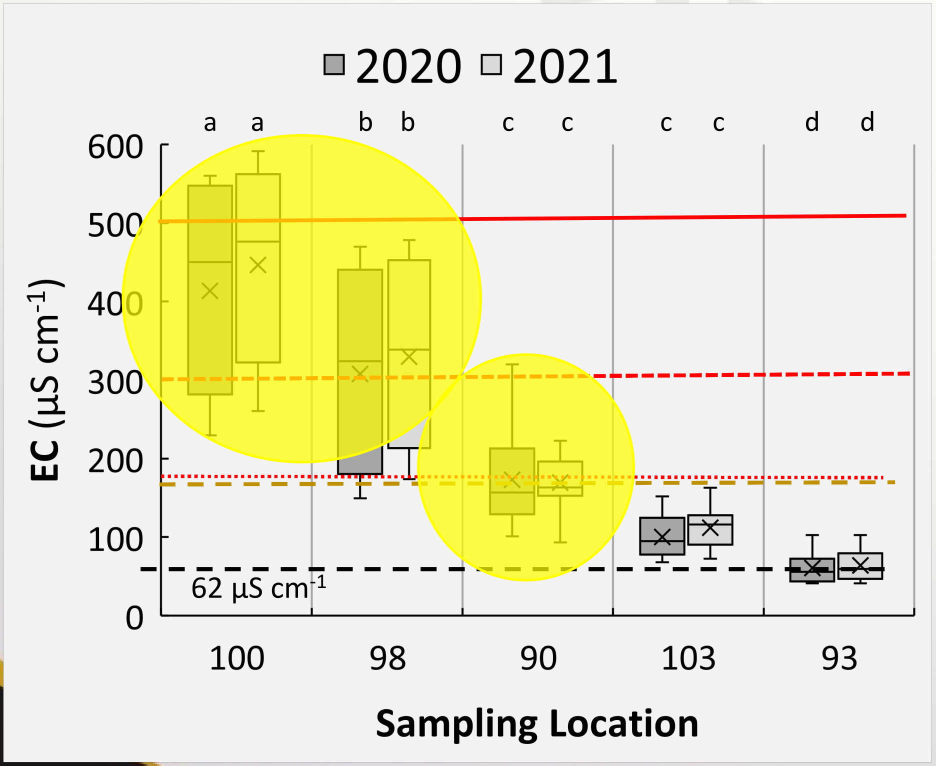
Retention Basin Impact





Conductivity (2019 – 2022)

- < 2% of the time did MTR-VF headwater creek water SC exceeded the recommended 300 µS cm^{-1} Benchmark.
- Average MTR-VF headwater creek water SC was below 175 µS cm^{-1}.



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Retention Basin Impact - Simulation

VF Base-Flow		Pond
Flow	TDS	TDS
m^3/min	uS/cm	uS/cm
0.012	500	50
m^3/day		
17.28		

Swiss site - Estimated Pond Dimention

surface area: about 1,080 m^2 (based on deliniated pond area in google earth using 2003 sattelite image)

Assuming and average of 0.8 meter deep, total pond volume: 864 m^3

Swiss site conditions falls somwhere between scenario E and F

(pond volume = 32 to 64 times the daily estimated VF Base-Flow [0.2 l/s])

Calculation:

$$Pond\ TDS_{day\ i} = \frac{\left[(BF_{Daily\ volume} \times BF_{TDS}) + \left((Pond_{volume} - BF_{Daily\ volume}) \times Pond\ TDS_{day\ i-1}\right)\right]}{Pond_{volume}}$$

$$BF_{Daily\ volume} = Constant\ (17.28_{m^3 d^{-1}})$$

$$BF_{TDS} = constant\ (500_{uS\ x\ cm^{-1}})$$

$Pond_{volume}$= Constant, depending on scenario

For Example - Scenario E:

$$Pond\ TDS_{day\ i} = 15.62 + 0.96926\ x\ Pond\ TDS_{day\ i-1}$$

Runoff

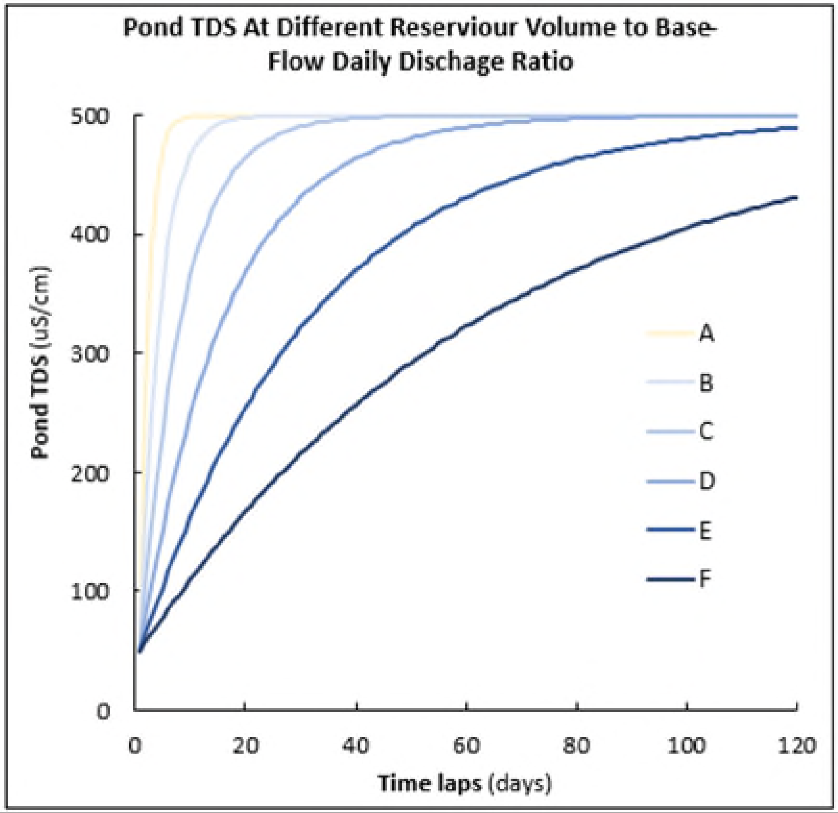
Estimated drainage area: 37.18 ha

CN for forest in good hydrologic conditions
and SHG B = 55

For Rain event of 2 inches

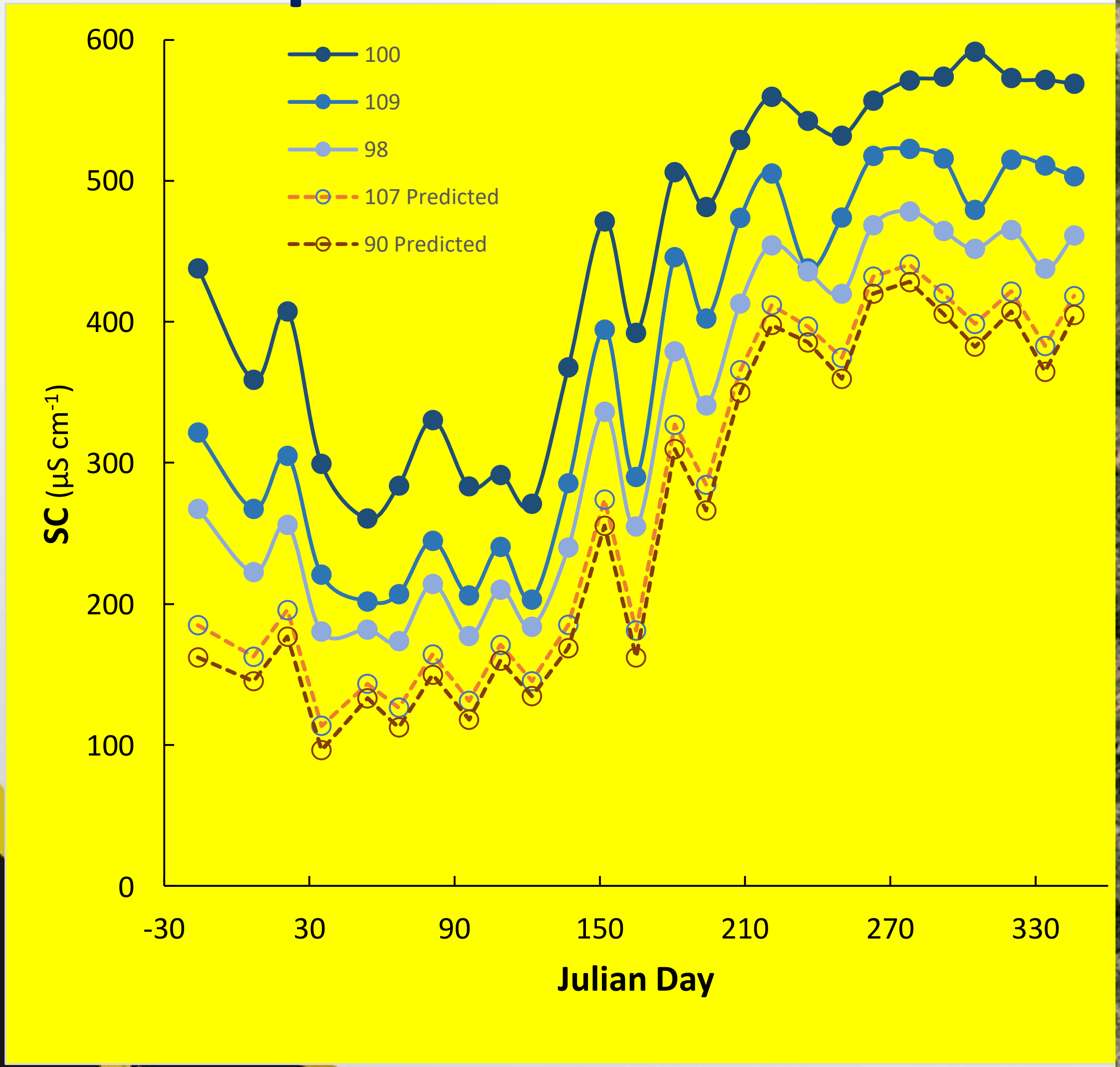
runoff = 0.39mm x 37.18 x 10000/1000= 145m3

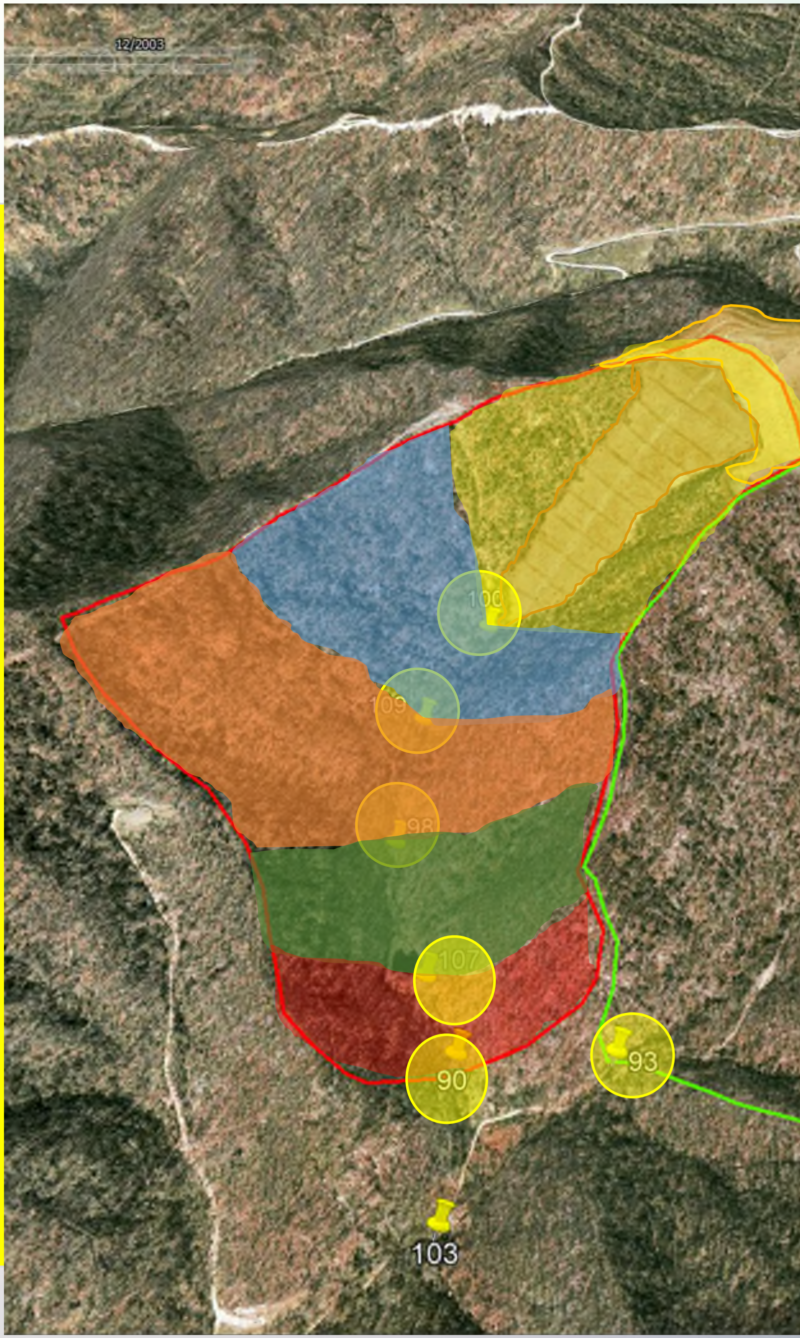
Scenario	ratio
D	0.52
E	0.26
F	0.13



Retention Basin Impact

Conductivity – Spatial & Temporal Variation 2021





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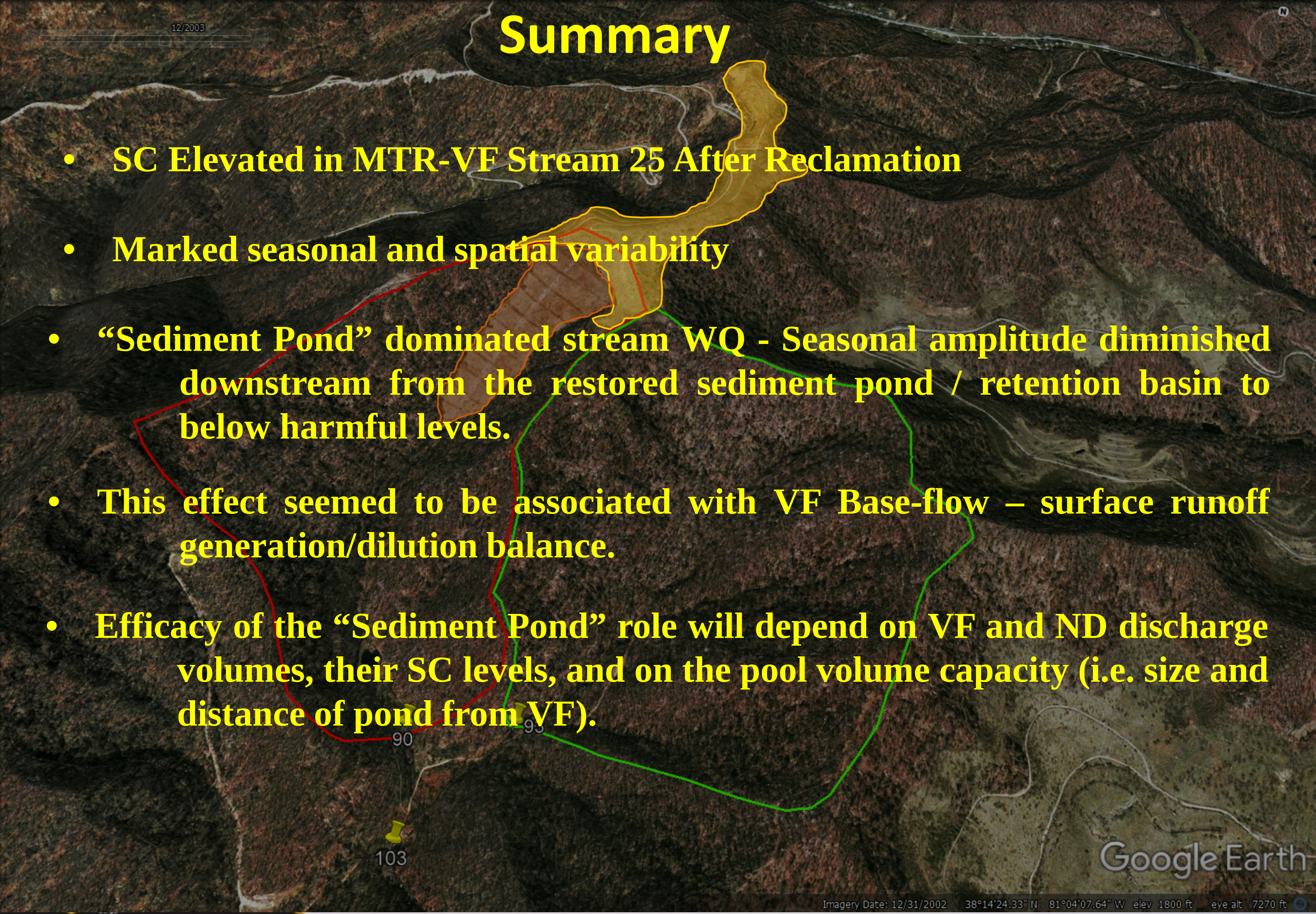
Summary

- SC Elevated in MTR-VF Stream 25 After Reclamation
- Marked seasonal and spatial variability
- "Sediment Pond" dominated stream WQ - Seasonal amplitude diminished downstream from the restored sediment pond / retention basin to below harmful levels.
- This effect seemed to be associated with VF Base-flow – surface runoff generation/dilution balance.
- Efficacy of the "Sediment Pond" role will depend on VF and ND discharge volumes, their SC levels, and on the pool volume capacity (i.e. size and distance of pond from VF).



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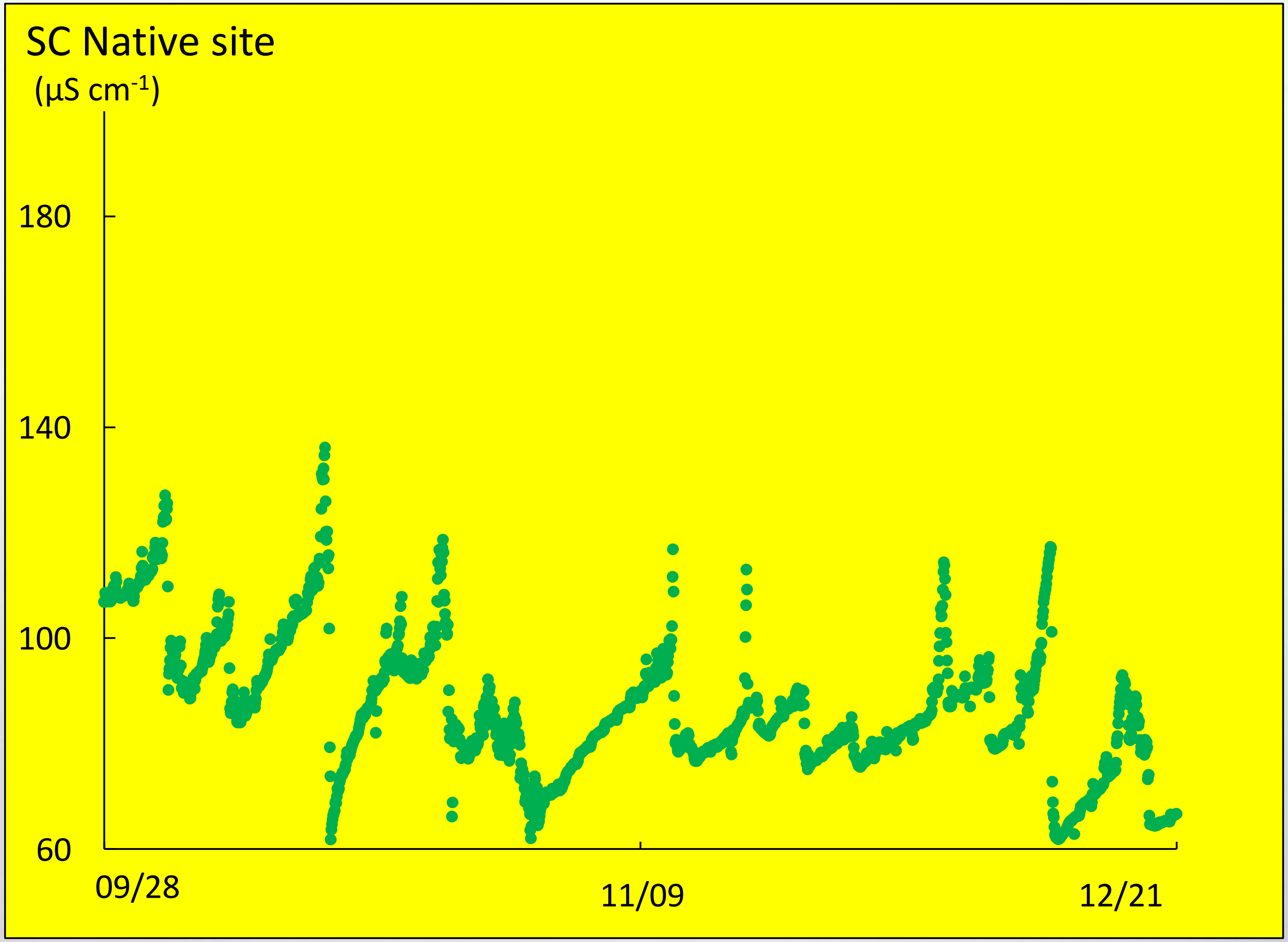
Contact: amirhass@wvstatu.edu

SC in VF and NAT sites

(Fall 2021)



SC in VF and NAT sites

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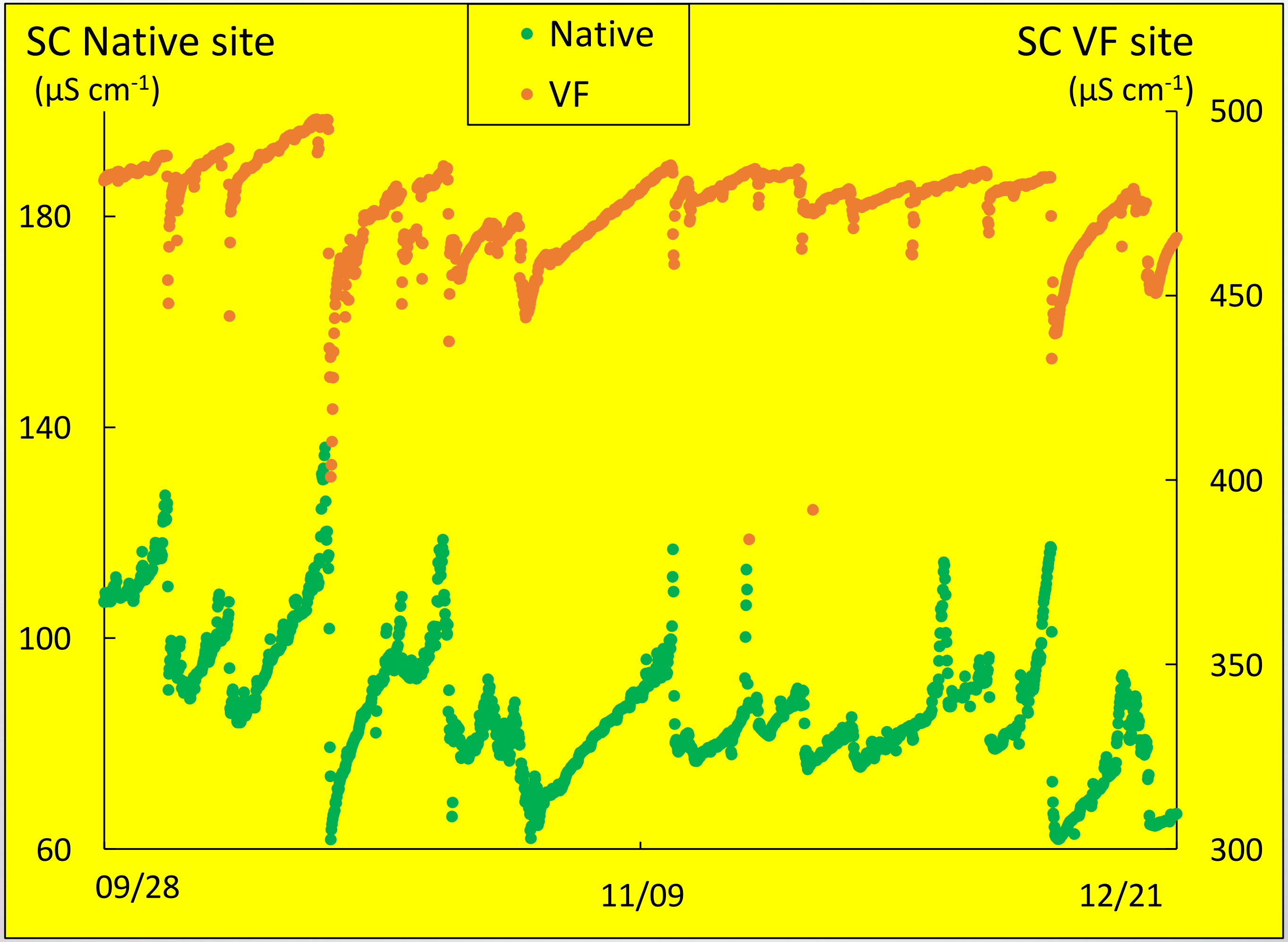

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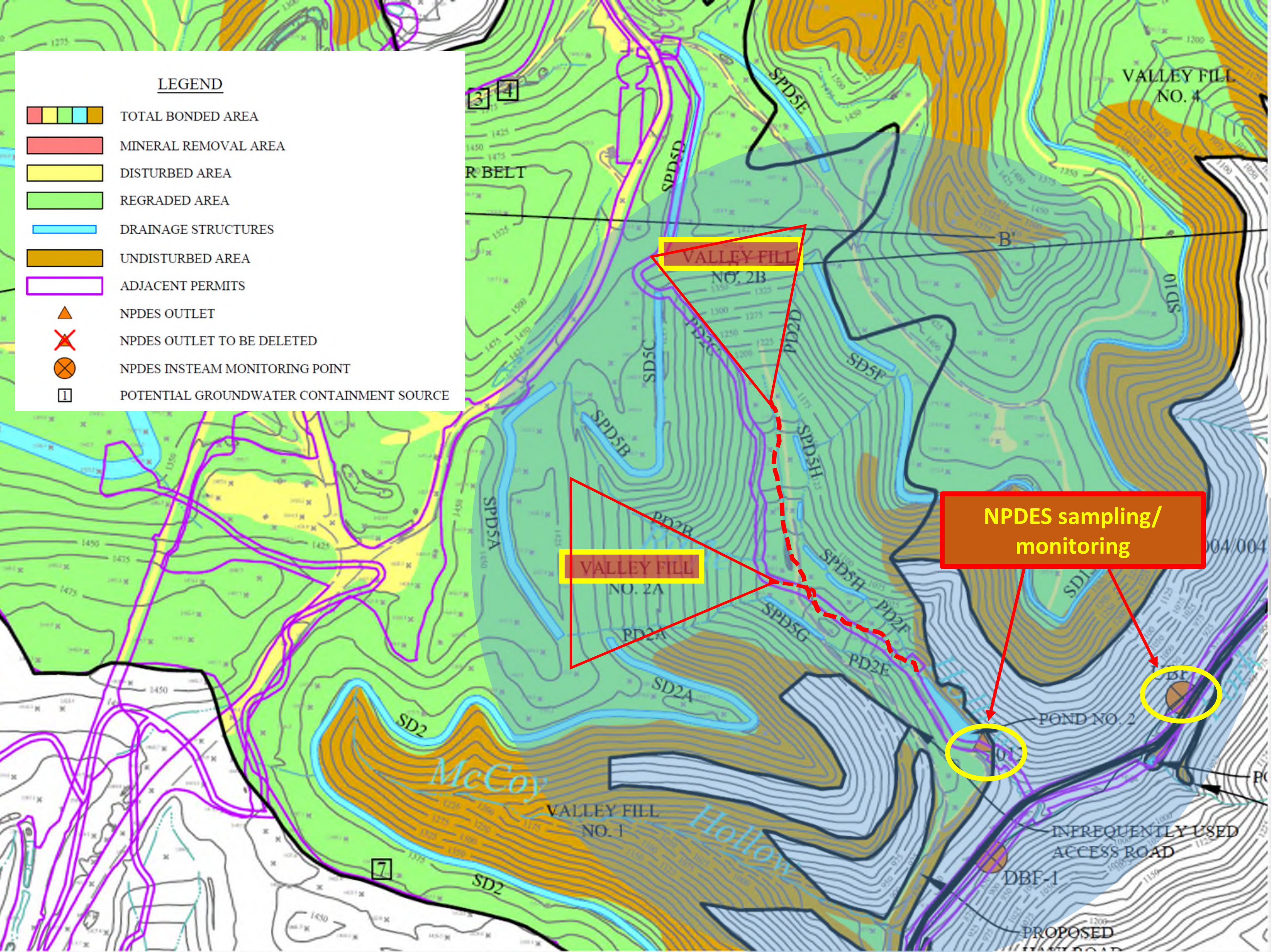

LEGEND
TOTAL BONDED AREA
MINERAL REMOVAL AREA
DISTURBED AREA
REGRADED AREA
DRAINAGE STRUCTURES
UNDISTURBED AREA
ADJACENT PERMITS
NPDES OUTLET
NPDES OUTLET TO BE DELETED
NPDES INSTEAM MONITORING POINT
POTENTIAL GROUNDWATER CONTAINMENT SOURCE
VALLEY FILL NO. 4
VALLEY FILL NO. 2B
VALLEY FILL NO. 2A
VALLEY FILL NO. 1
NPDES sampling/ monitoring
POND NO. 2
INFREQUENTLY USED ACCESS ROAD
DBF-1
PROPOSED
McCoy
Hollow
SPD5E
SPD5D
SPD5F
SPD5B
SPD5A
SPD5H
SPD5G
SD5C
PD2C
PD2D
PD2B
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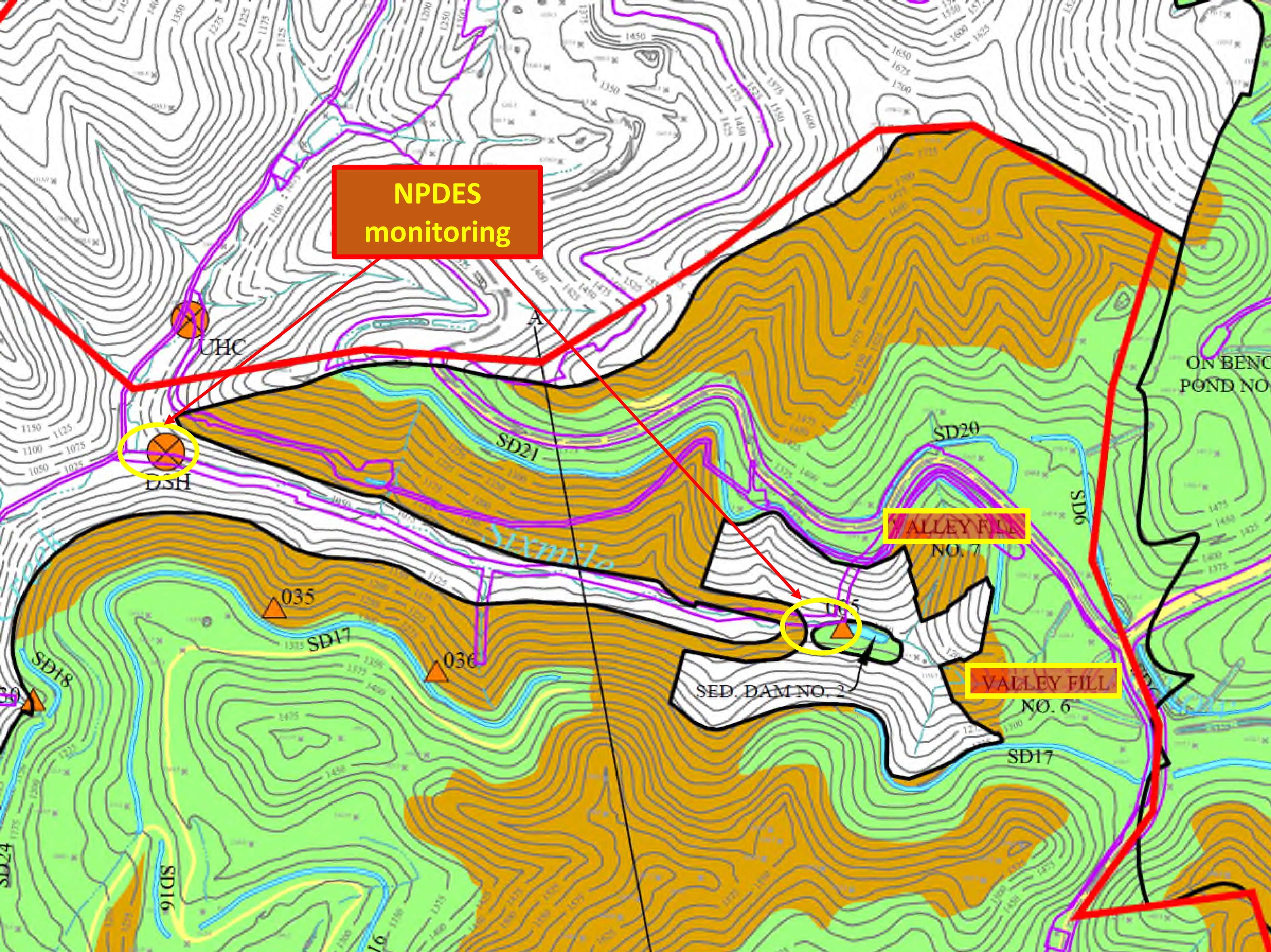
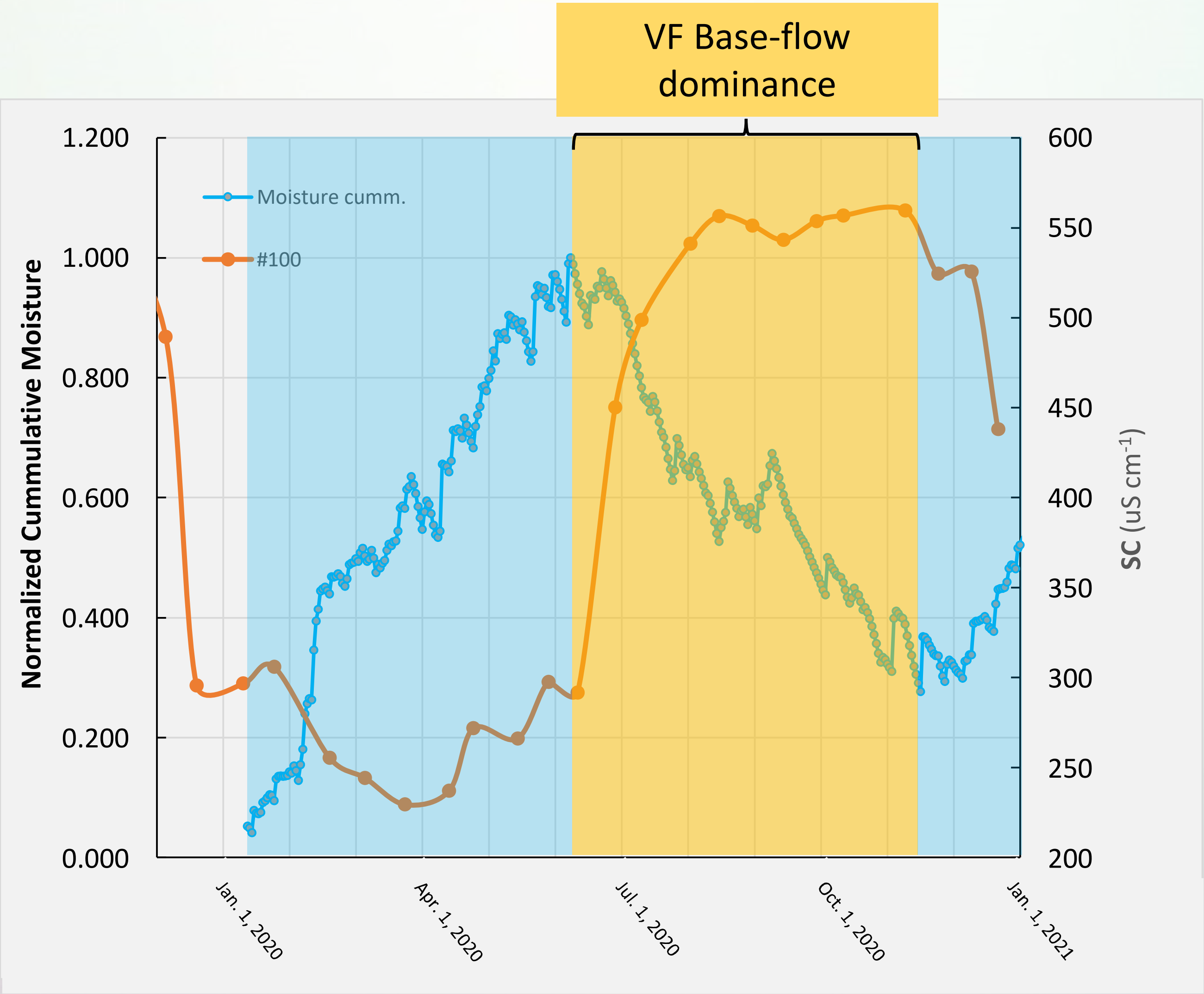
PD2E
SD2A
SD2
SD10


NPDES
monitoring
UHC
DSH
SD21
SD20
SD6
VALLEY FILL
NO. 7
VALLEY FILL
NO. 6
SED. DAM NO. 2
SD17
035
036
SD18
SD16
SD24
Sixmile
ON BENC
POND NO

Moisture Budget Balance



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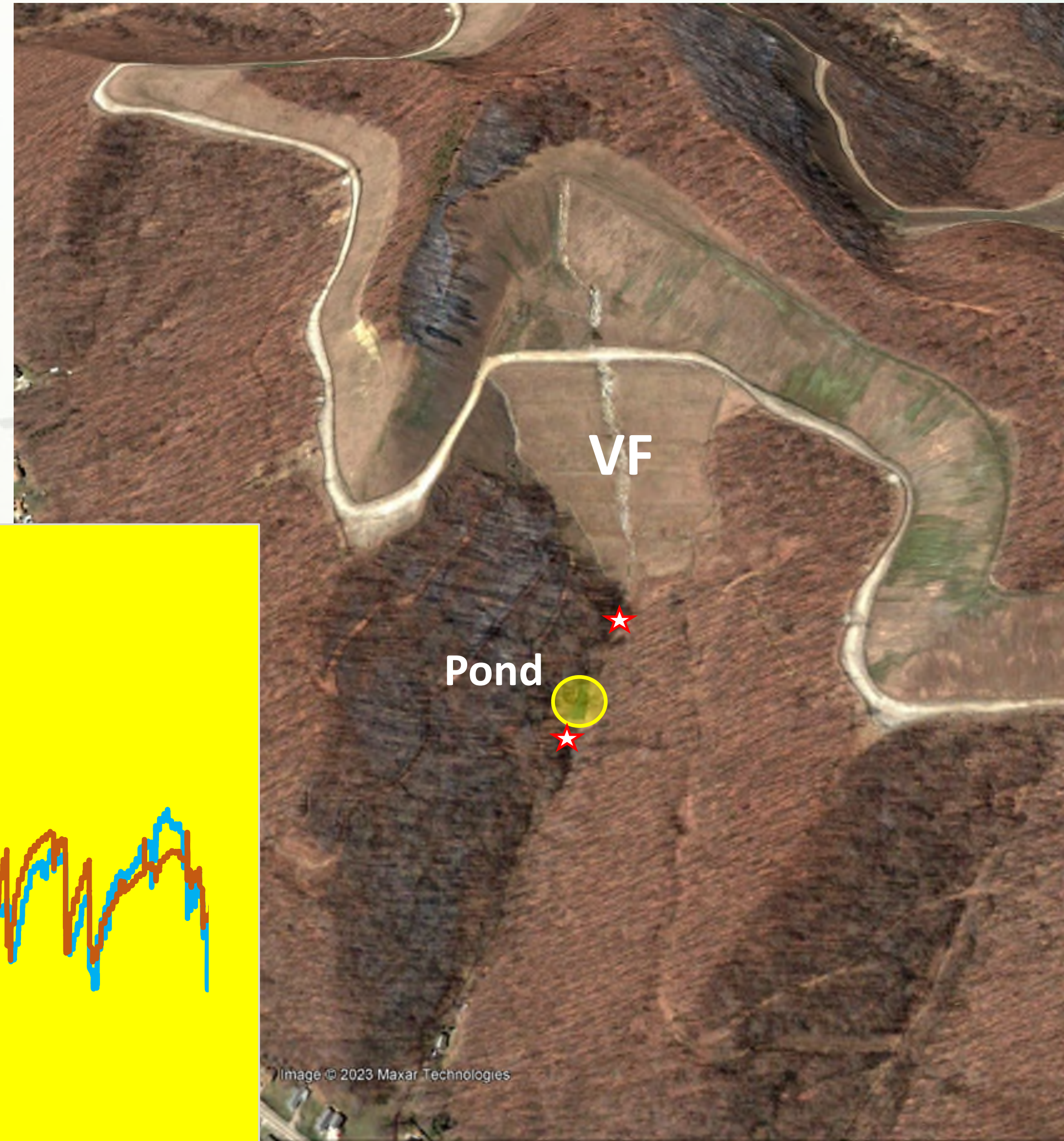
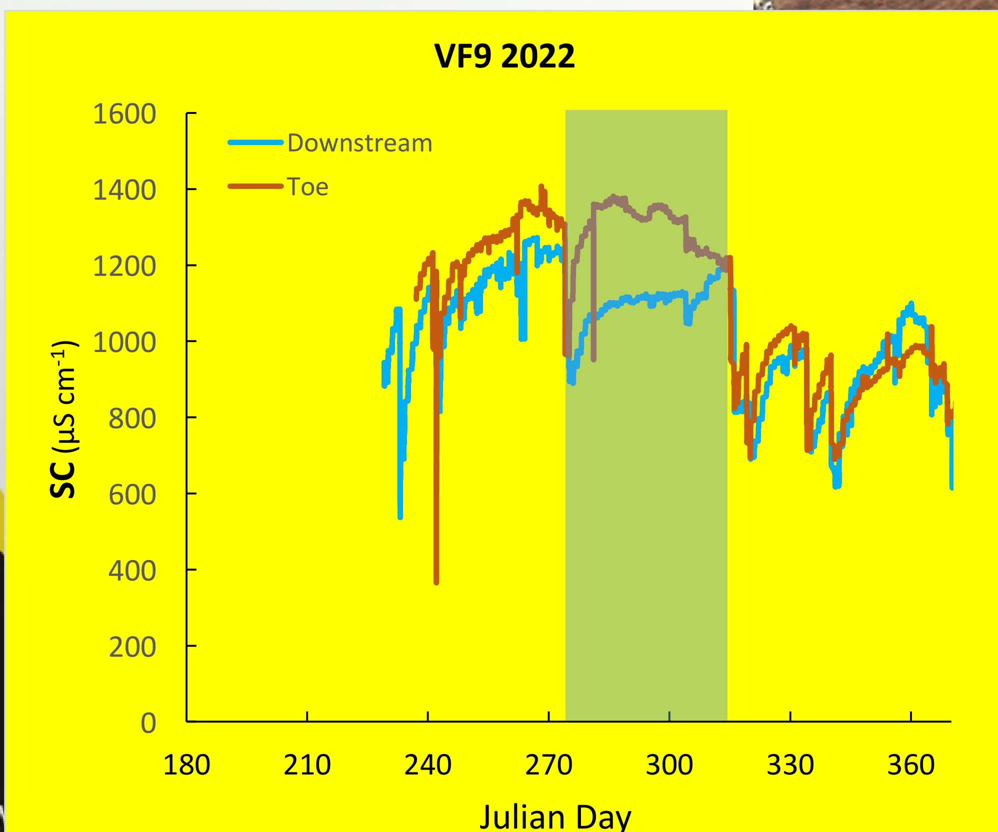

VF
Pond
Image © 2023 Maxar Technologies


VF9 2022
Downstream
Toe
SC (µS cm-1)
1600
1400
1200
1000
800
600
400
200
0
180
210
240
270
300
330
360
Julian Day

Conductivity (2019 – 2022)

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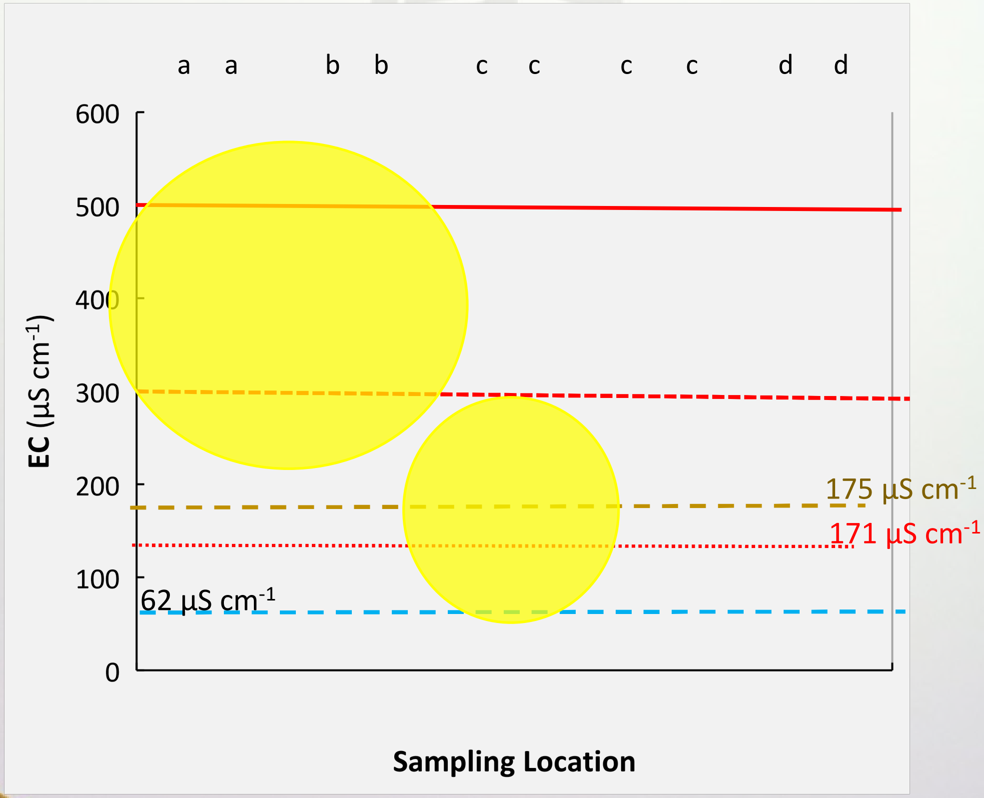
- Average MTR-VF headwater creek water SC was below 175 µS cm-1.



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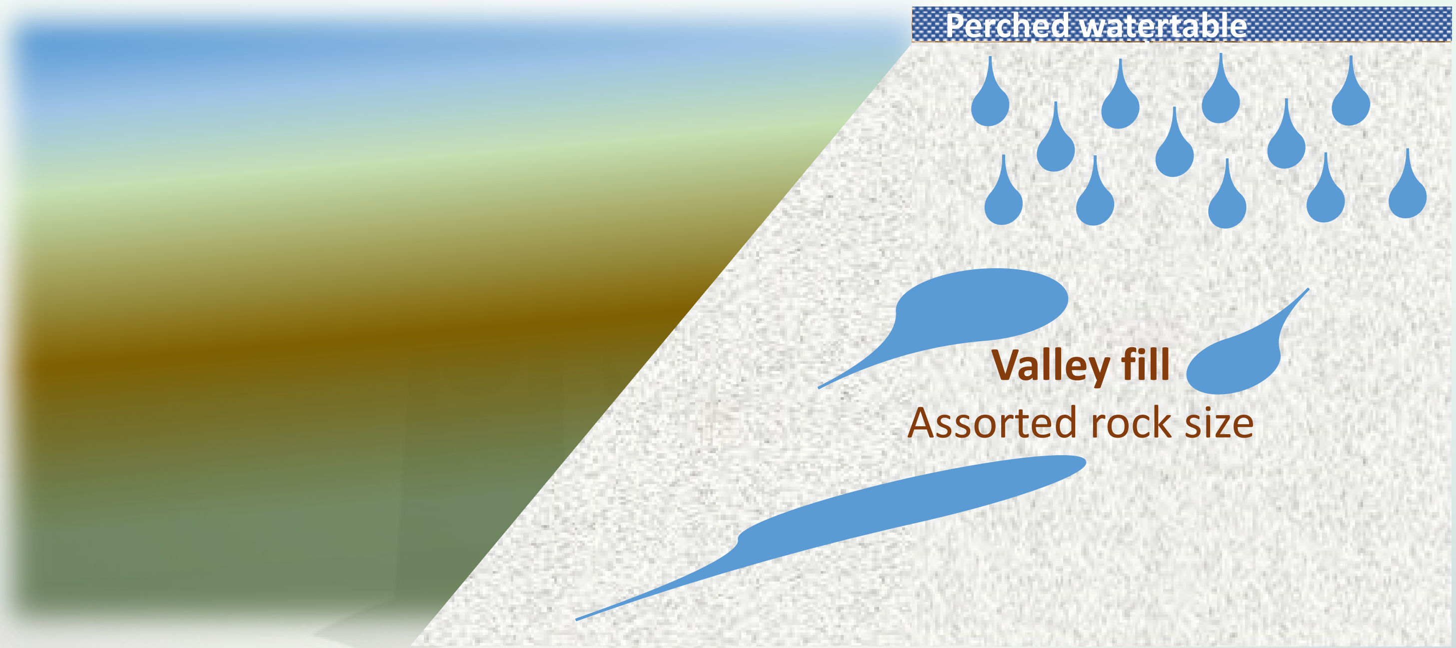
VF Hydrology and Creek Base-Flow



VF Hydrology and Creek Base-Flow