TDS Mitigation in Mining Affected Streams using In-Stream Retention Ponds

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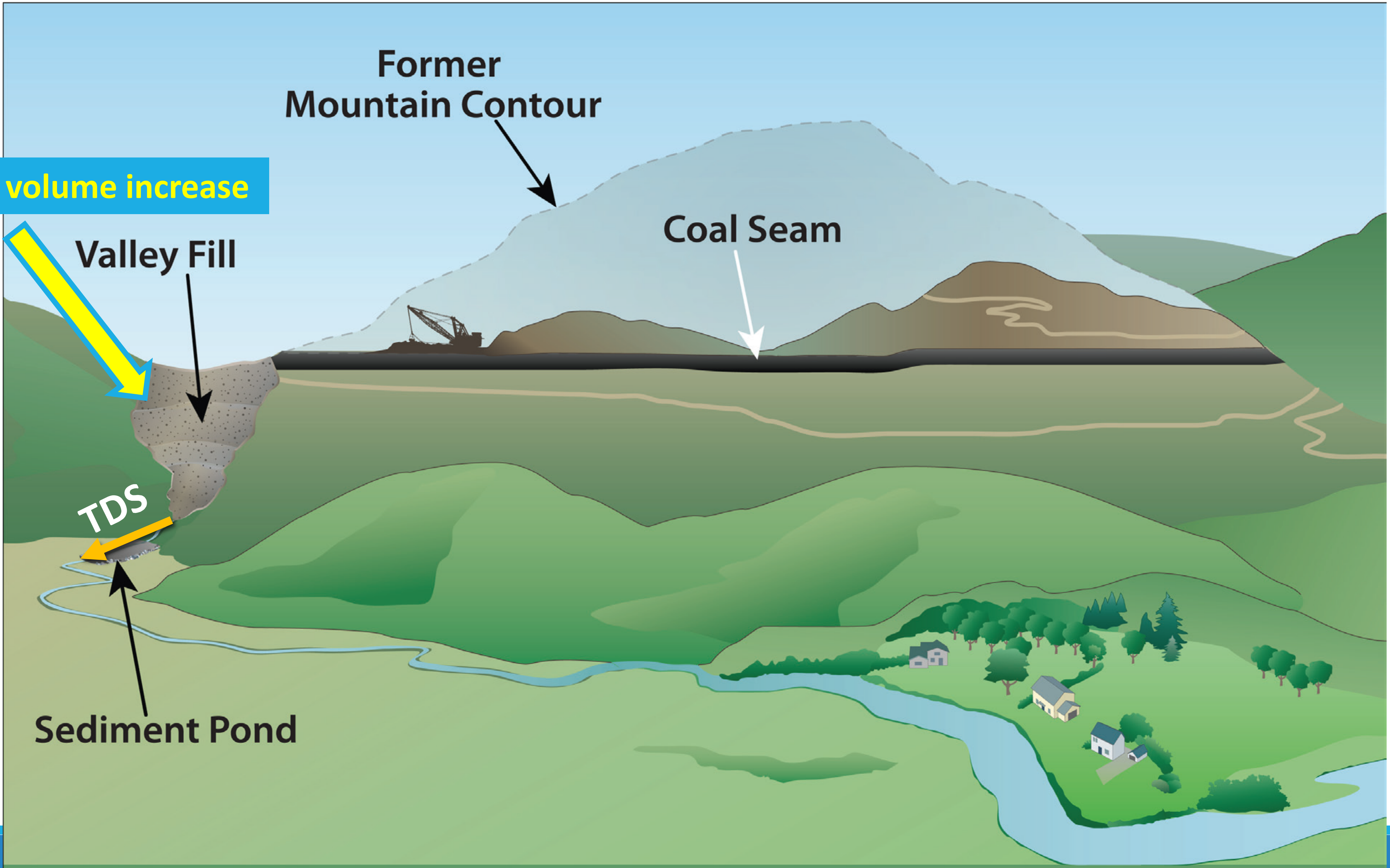
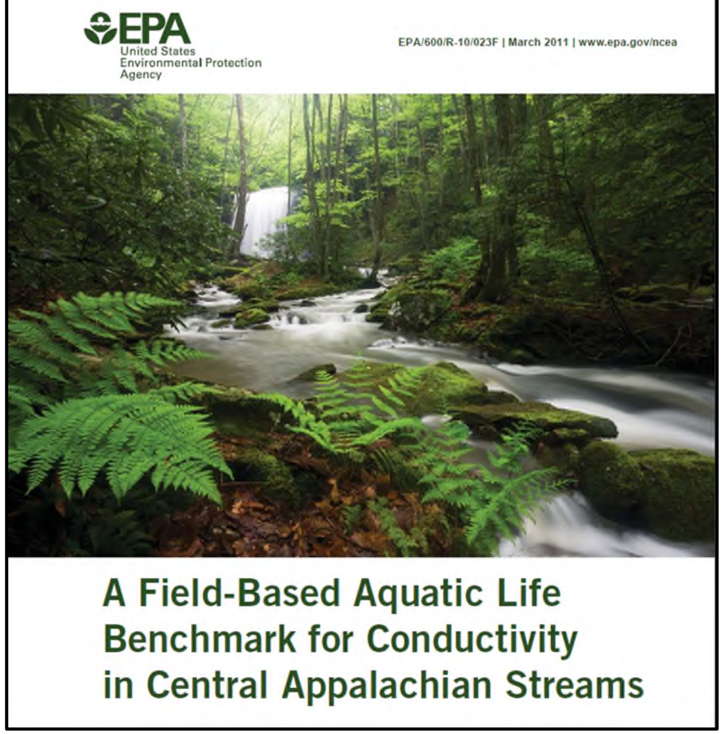
Mountaintop Removal Valley Fill (MTR-VF)



30 – 40% volume increase

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



EPA
United States
Environmental Protection
Agency

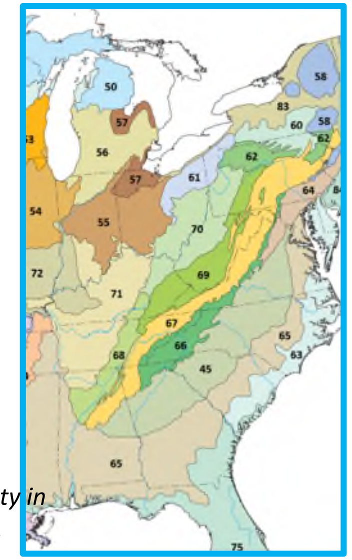
EPA/600/R-10/023F | March 2011 | www.epa.gov/ncea

A Field-Based Aquatic Life
Benchmark for Conductivity
in Central Appalachian Streams

U.S. EPA. 2011. A Field-Based Aquatic Life Benchmark for Conductivity in Central Appalachian Streams. Washington, DC. EPA/600/R-10/023F.

The chronic aquatic life benchmark:

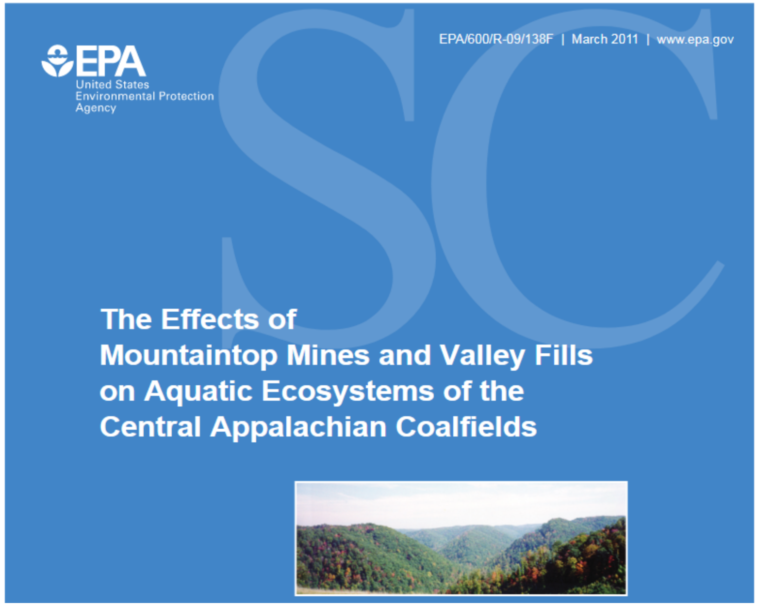
300 µS/cm



"…developed for year-round application. **This level is intended to prevent the extirpation of 95% of invertebrate genera in this region**"

Mean conductivity of Valley Fills:

1,020 µS/cm



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The Effects of
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Long-term Effects of Elevated TDS

"… **TDS release potential** from non-acid forming spoils **should drop quickly**" once they are exposed to leaching
- (Daniels et al., 2014)

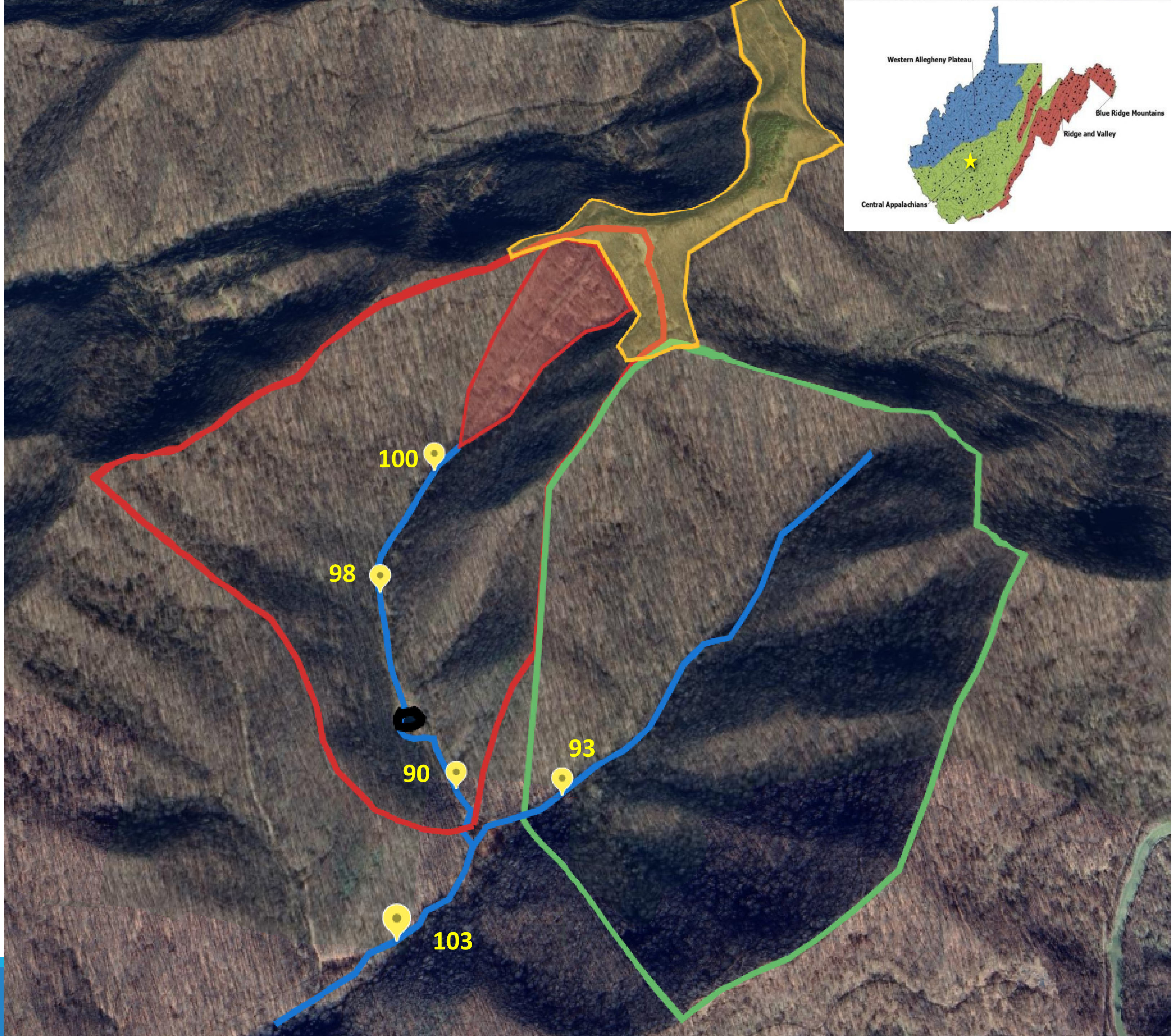
"… the time for **discharge SC to decline … was 10–15 years**, on average, "
- (Daniels et al., 2014)

"… approximately **25 years for decline** of annual mean SC **to reach 300 µS/cm** [EPA conductivity benchmark]…"
- **(Cianciolo et al., 2020)**

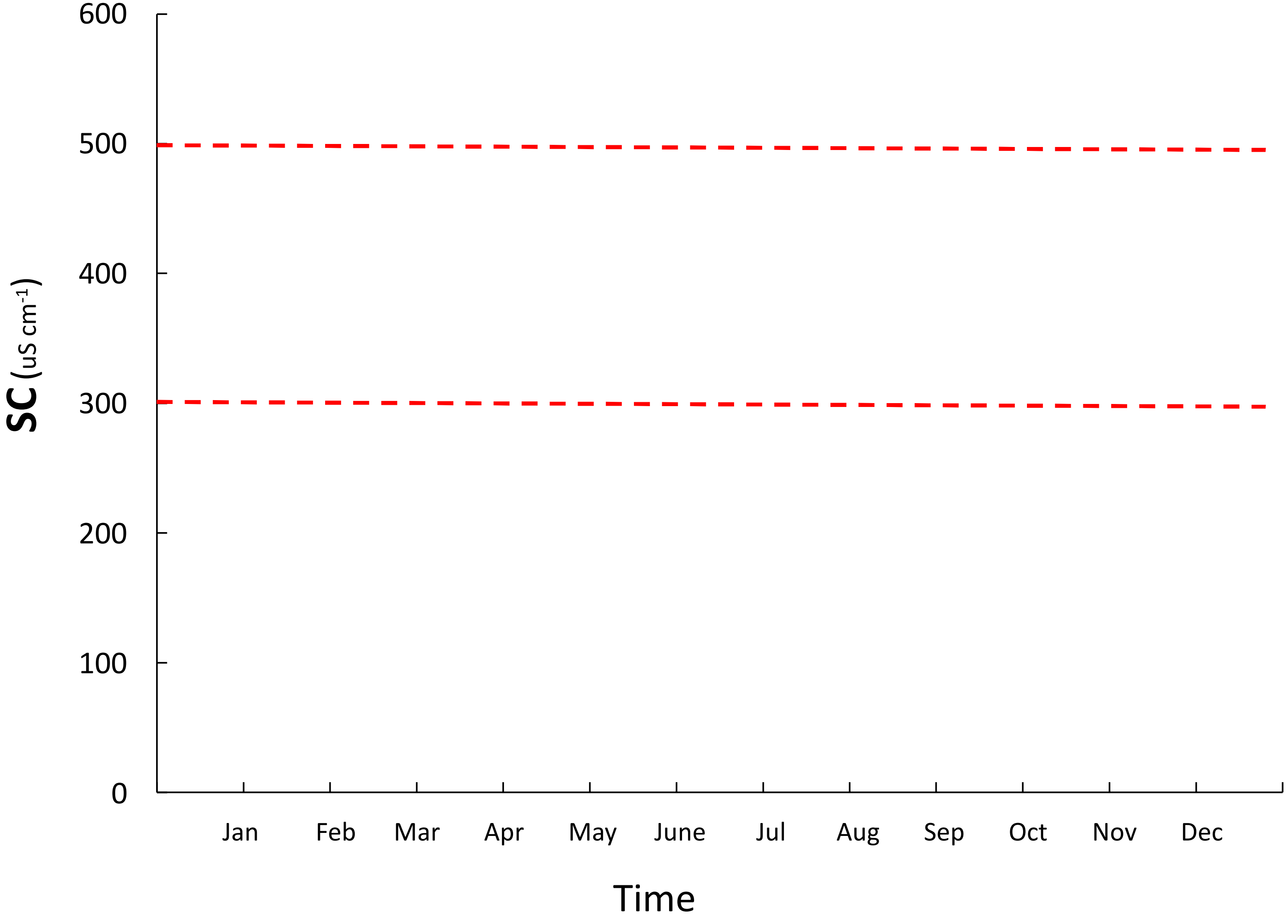
"…may be on **new trajectories of evolution** that will keep them **different from unmined landscapes forever**."
- **(Ross et al., 2021)**

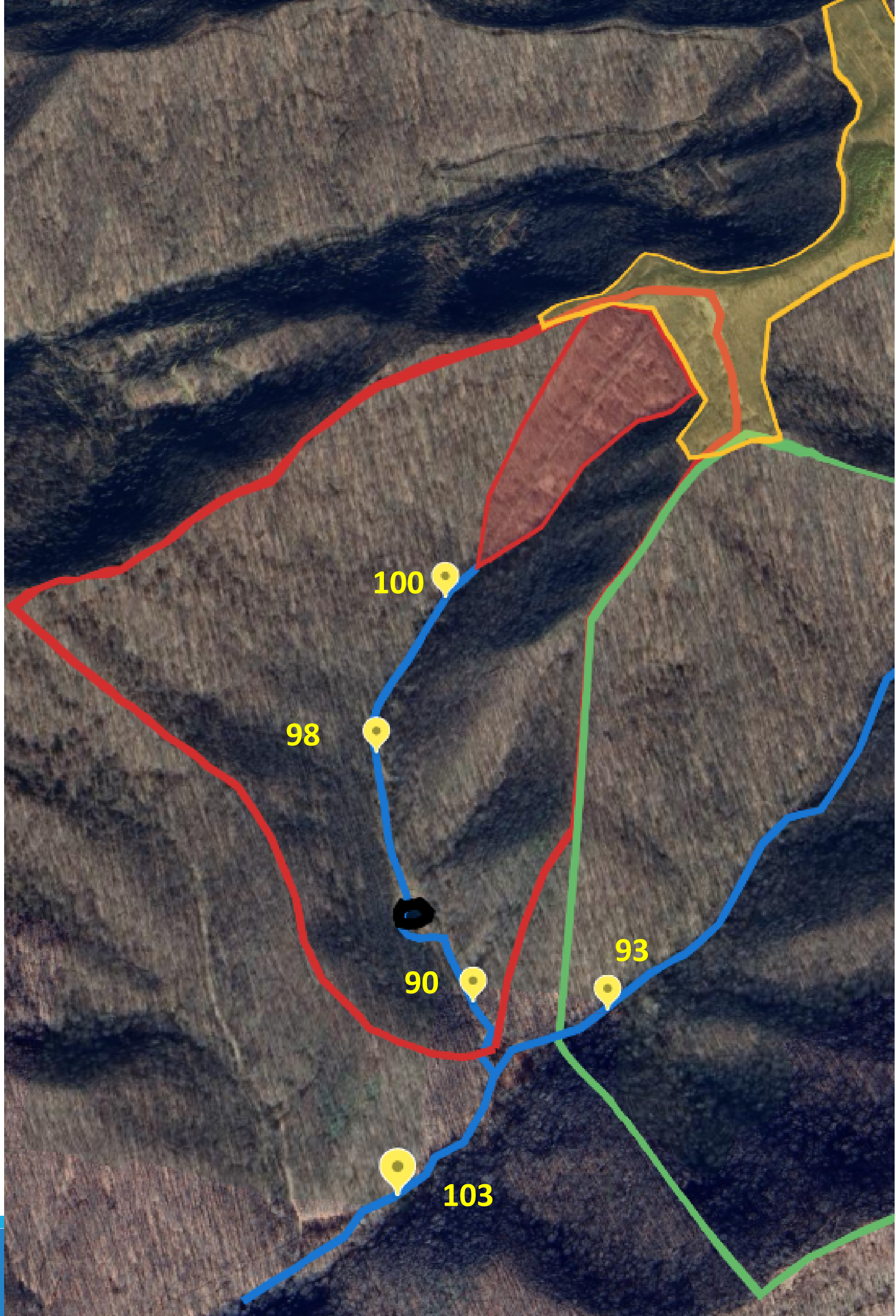
The role of restored sediment pond on stream water TDS

- Central Appalachian ecoregion (#69), upper Kanawha river basin (West Virginia)
- Mining operation completed in Fall of 1992
- Planting completed in 1994
- Final bond release in Fall of 2005
- Monitoring started Fall 2019



Temporal and Longitudinal Changes in Specific Conductance





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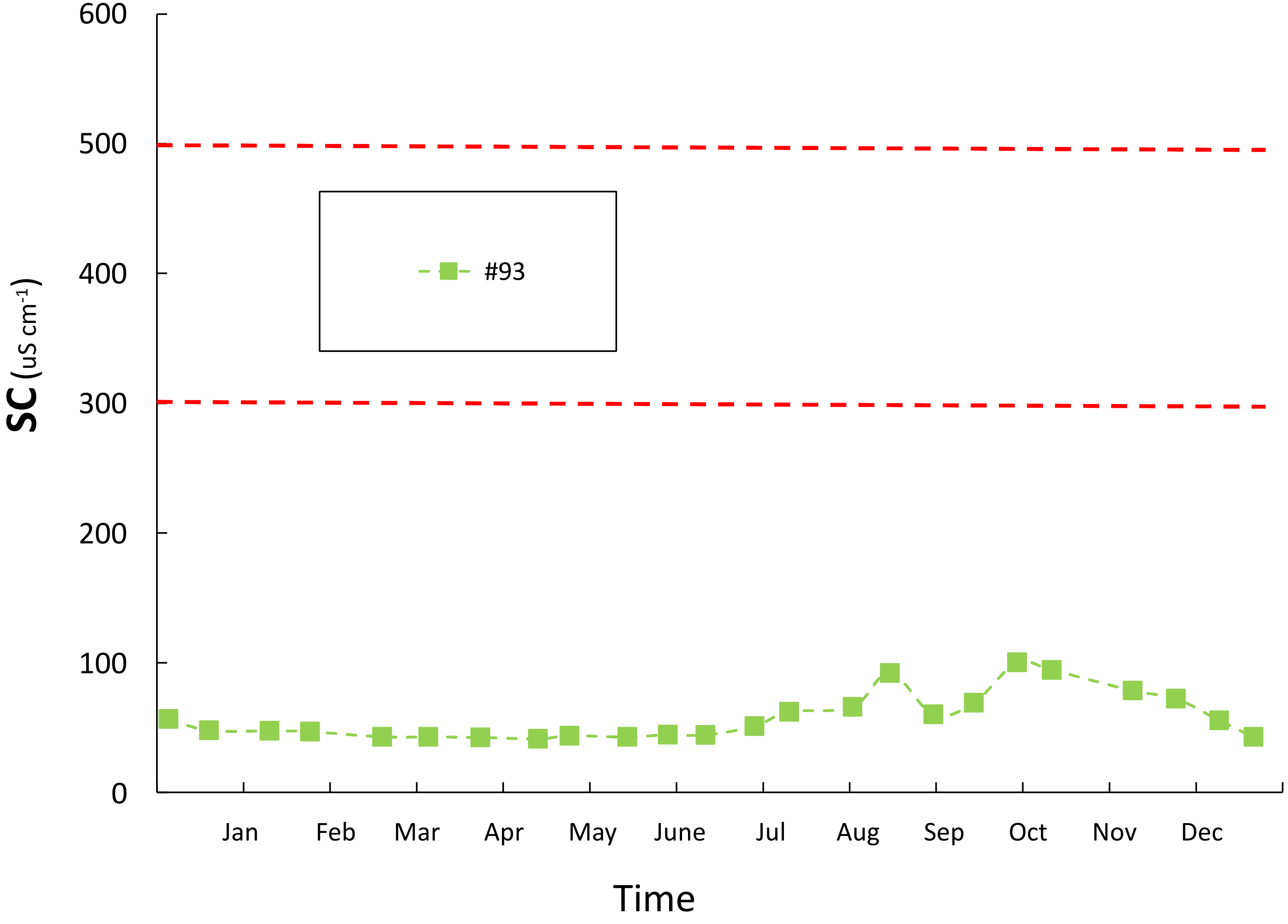

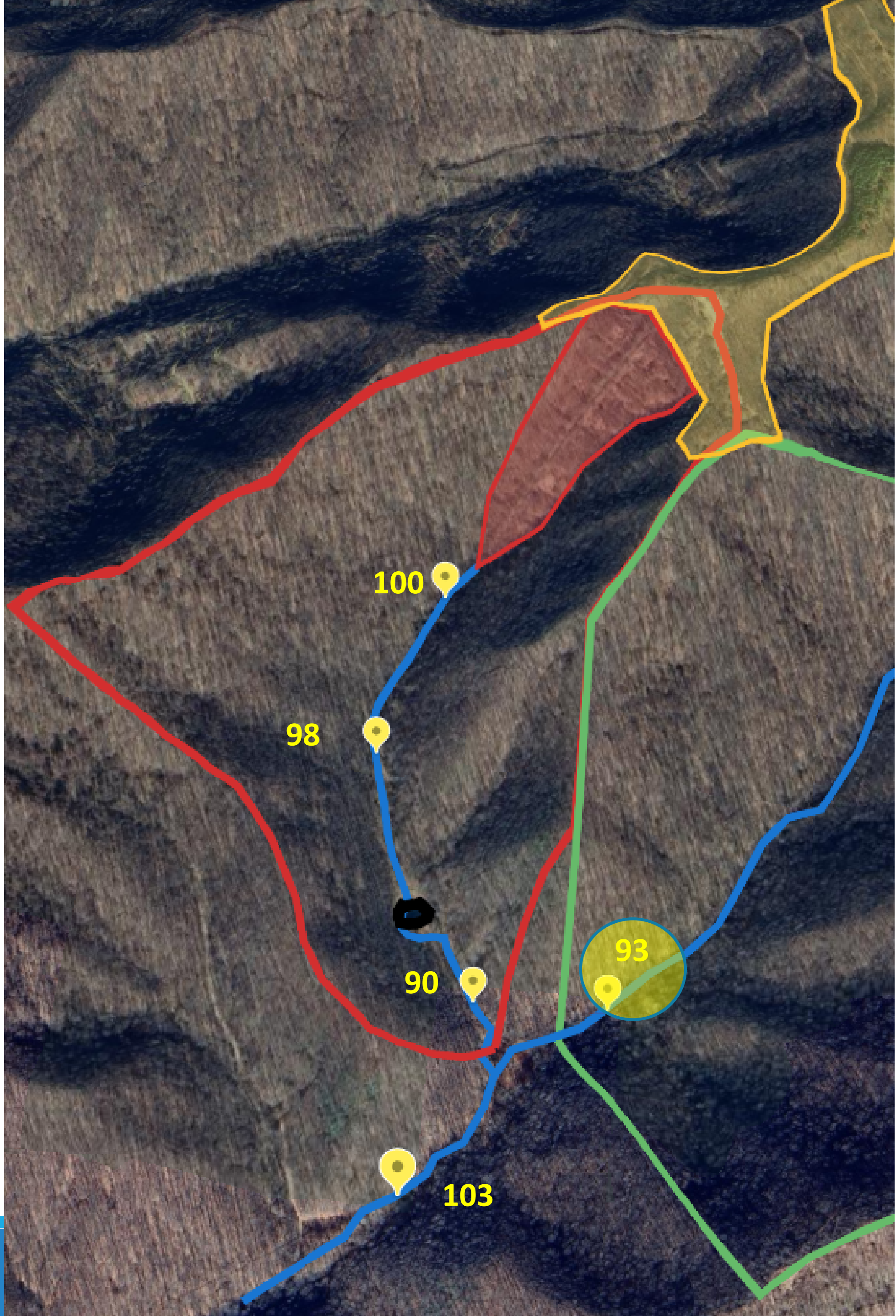

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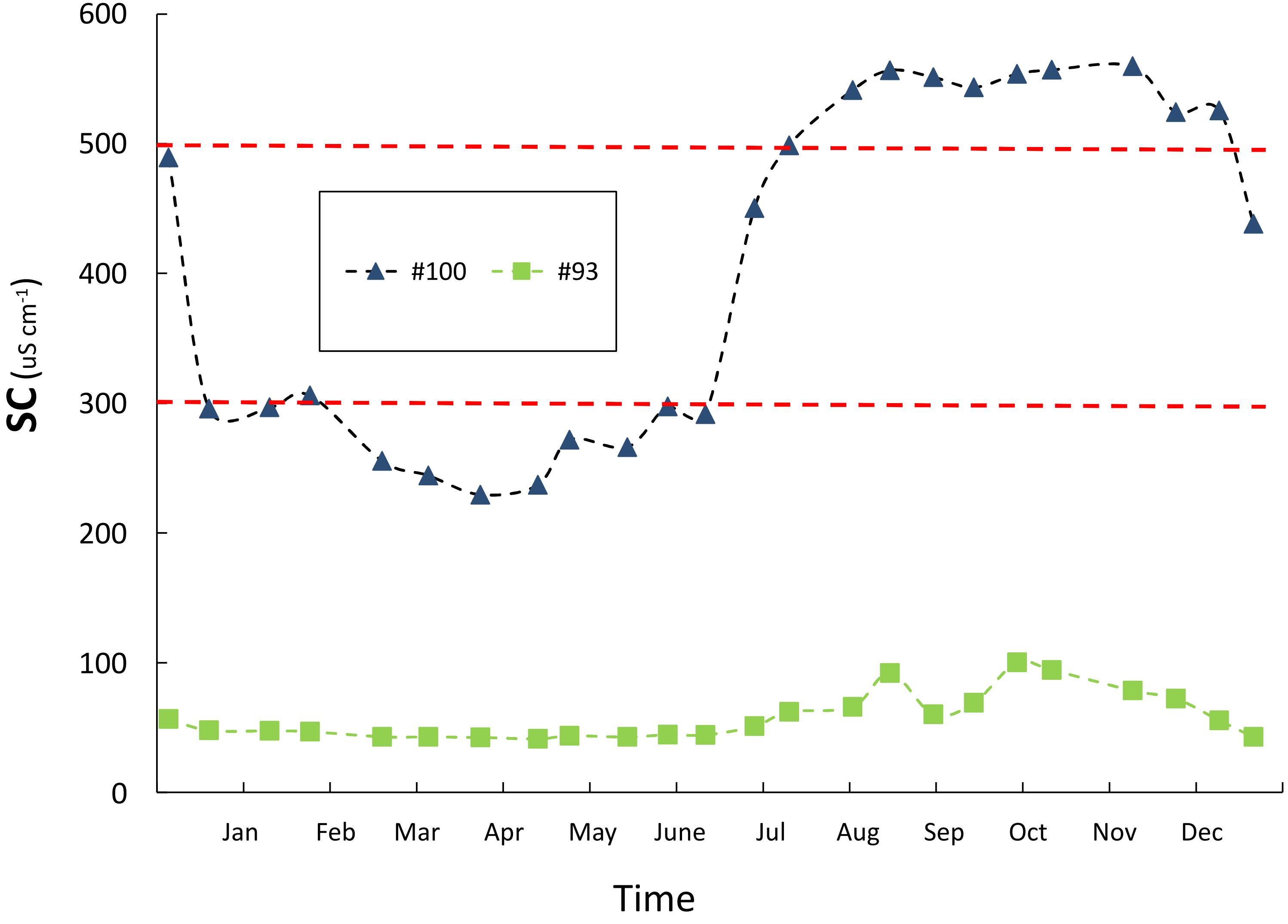

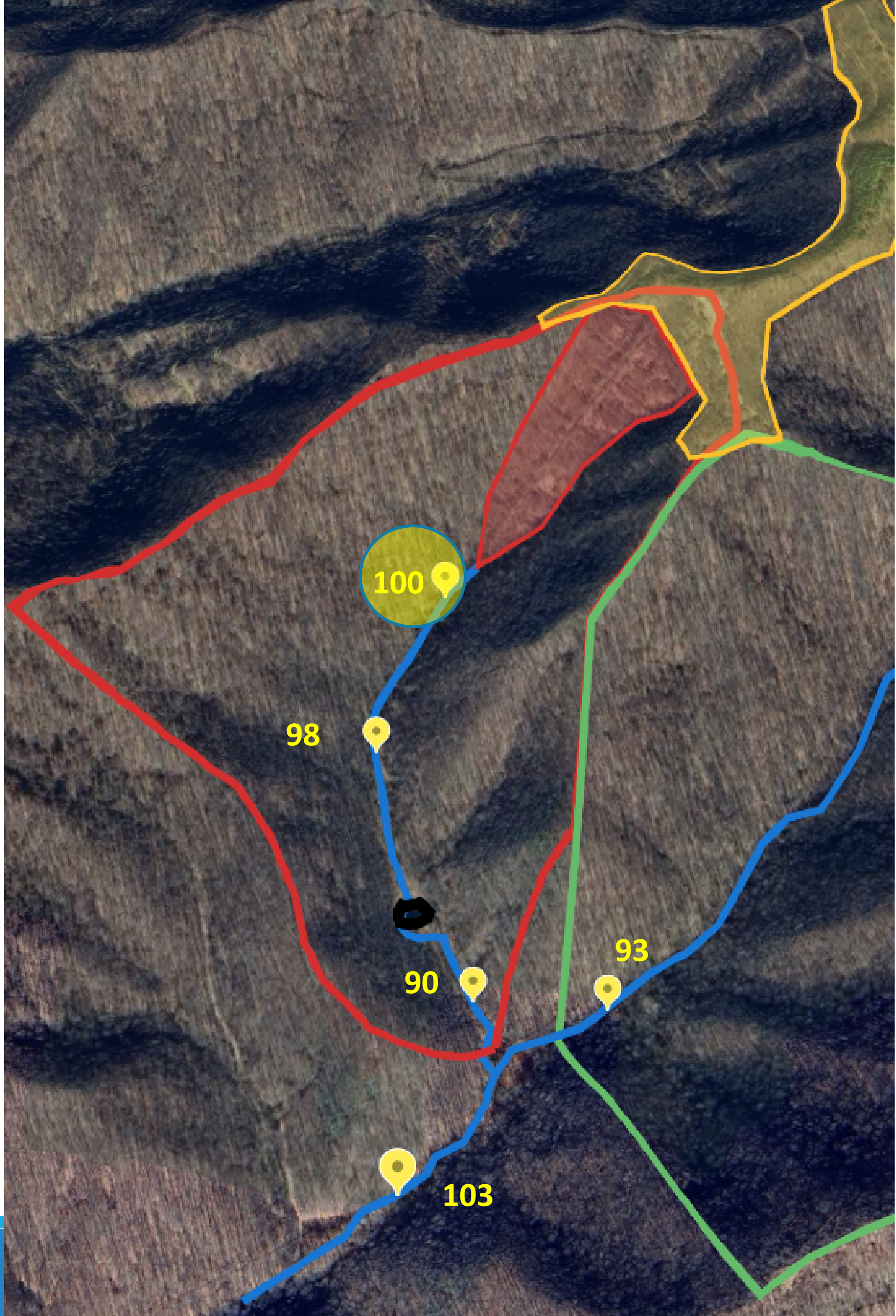

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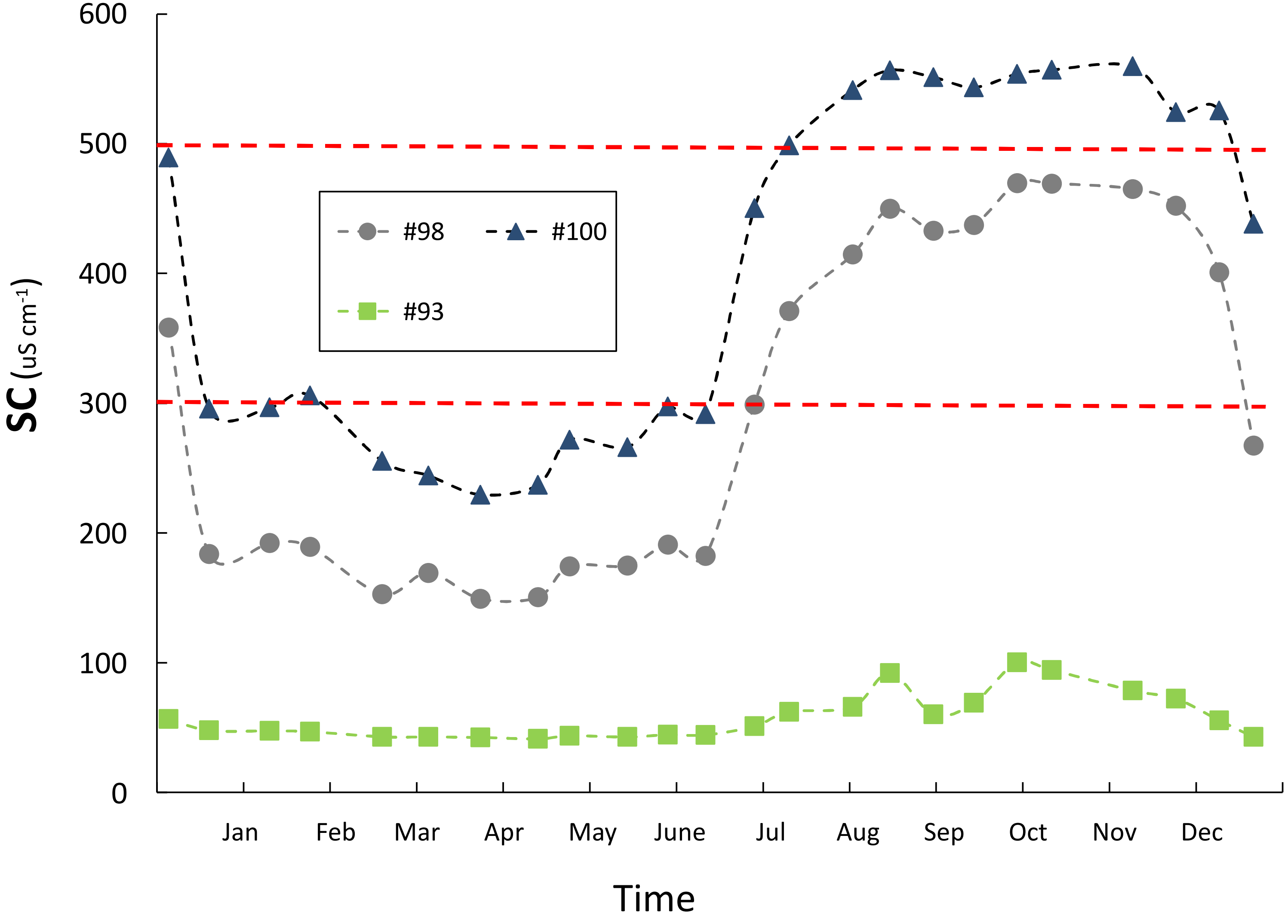

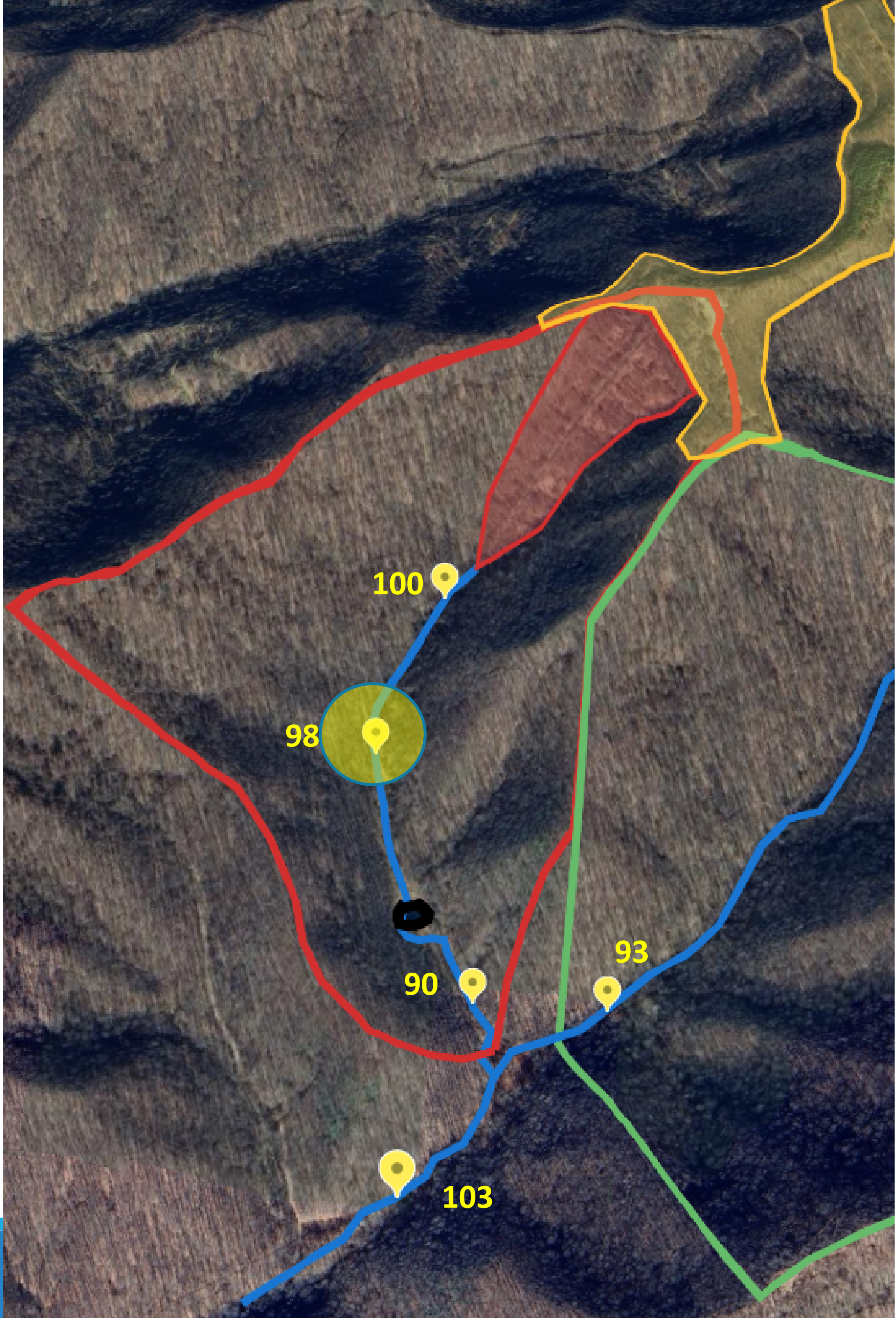

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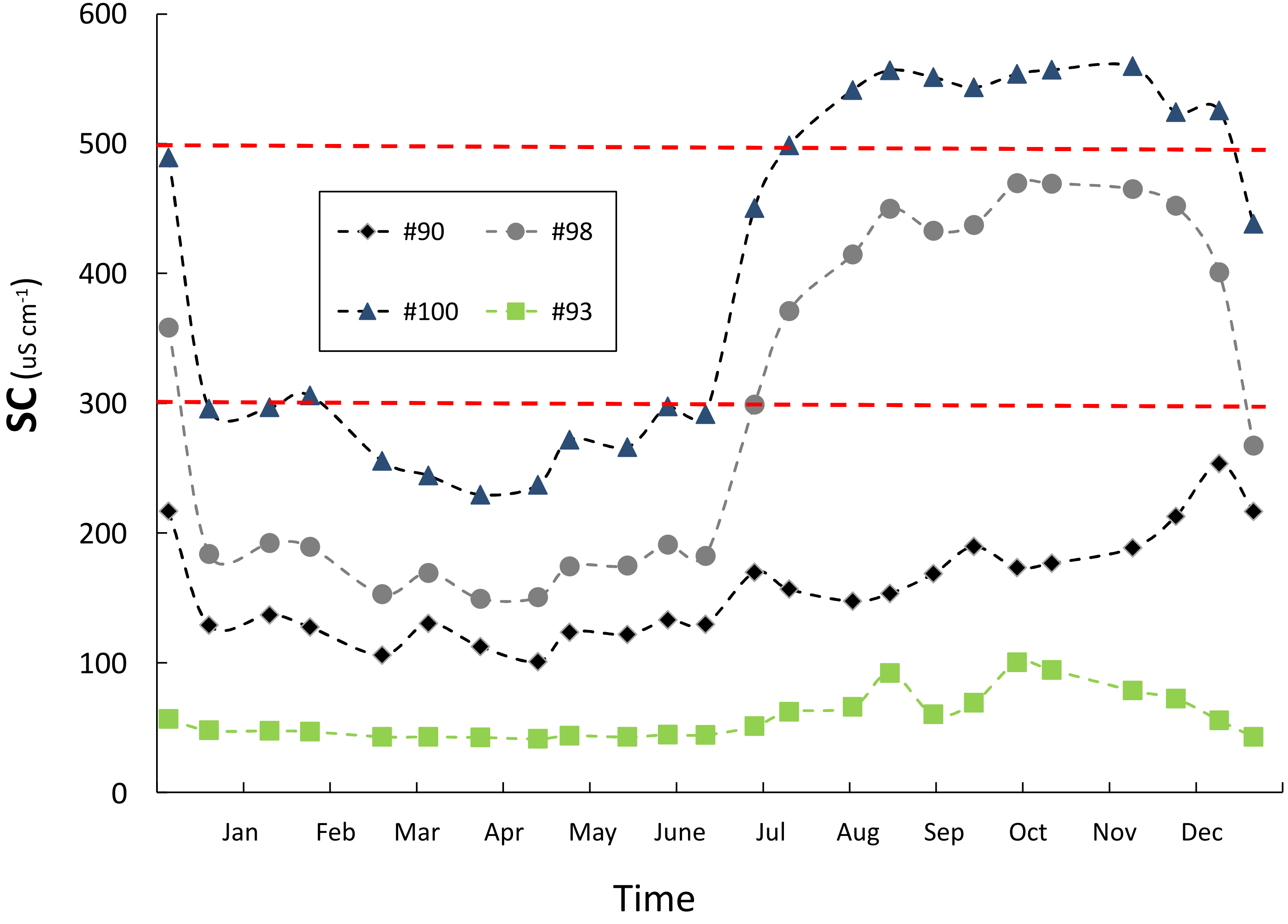

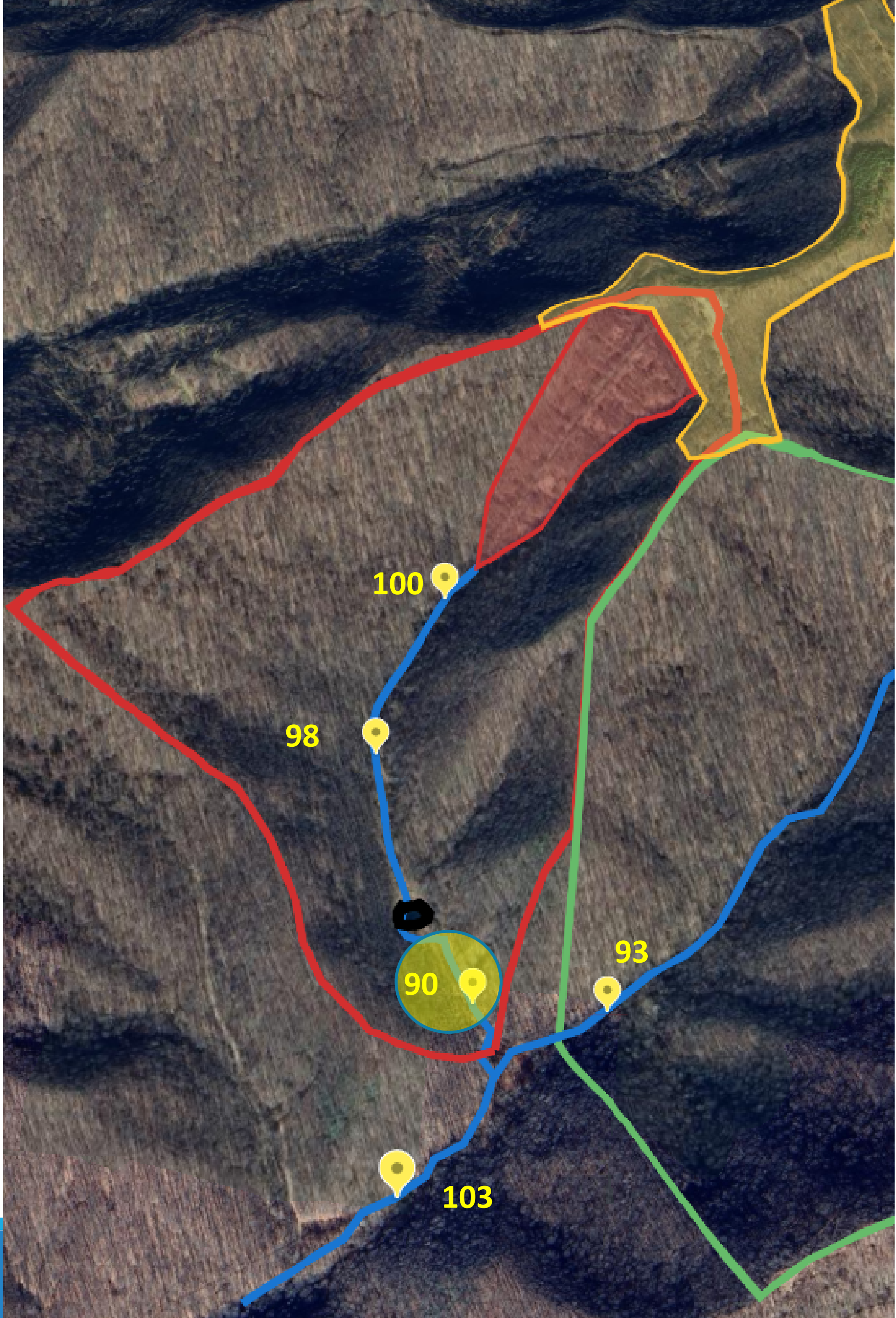

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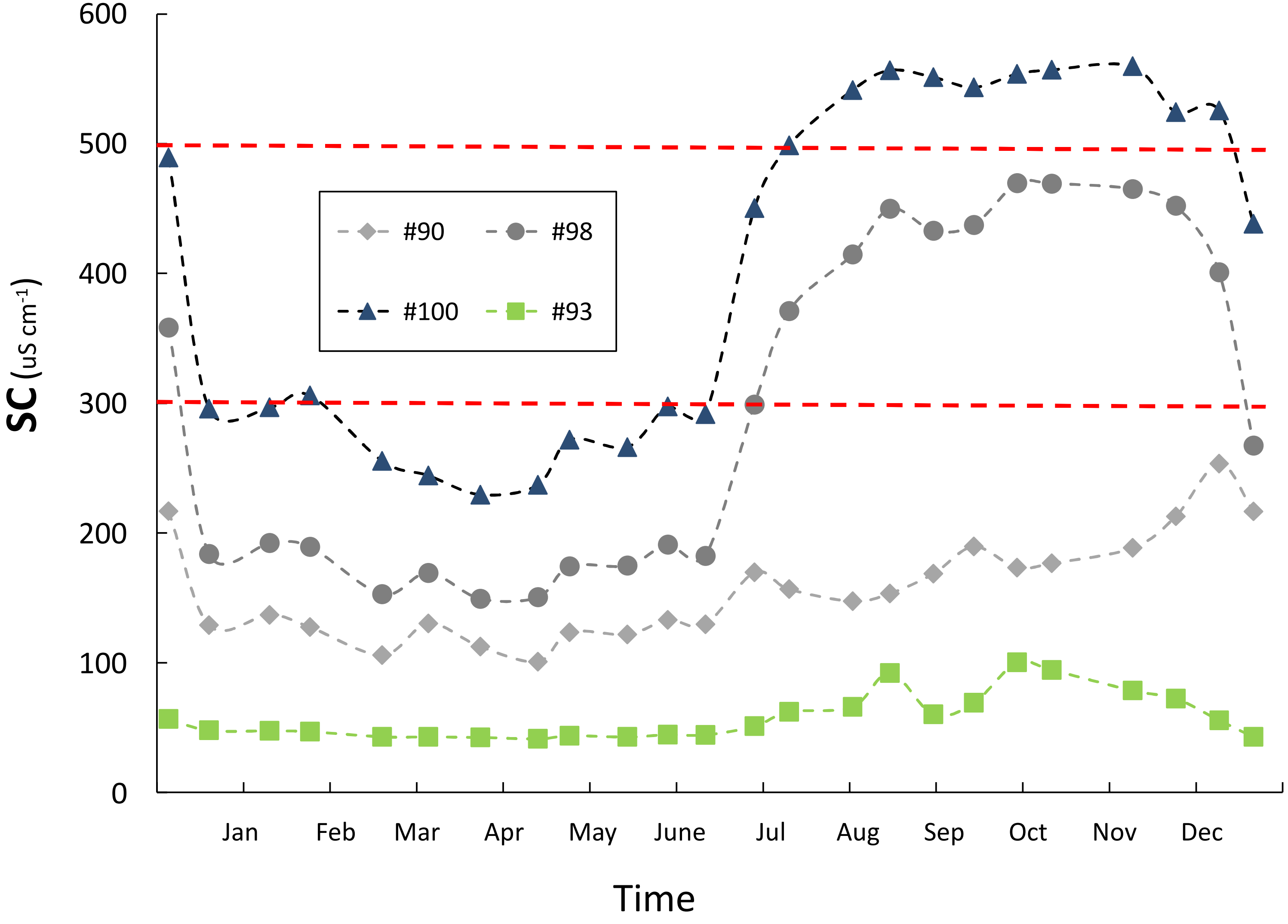

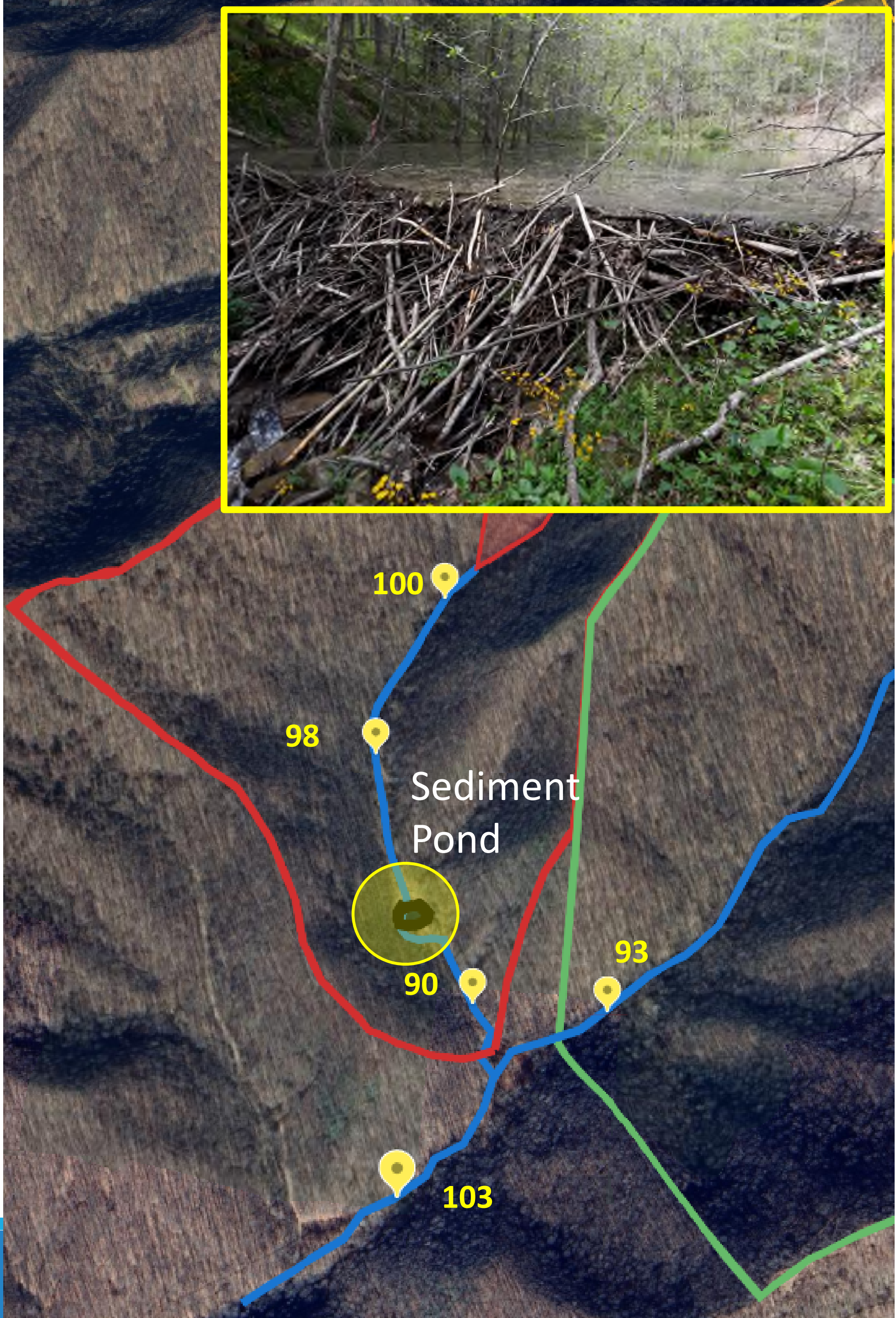

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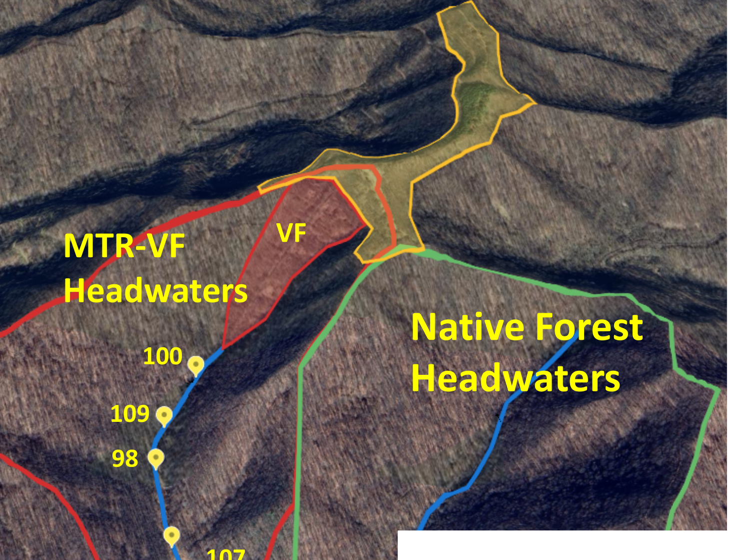
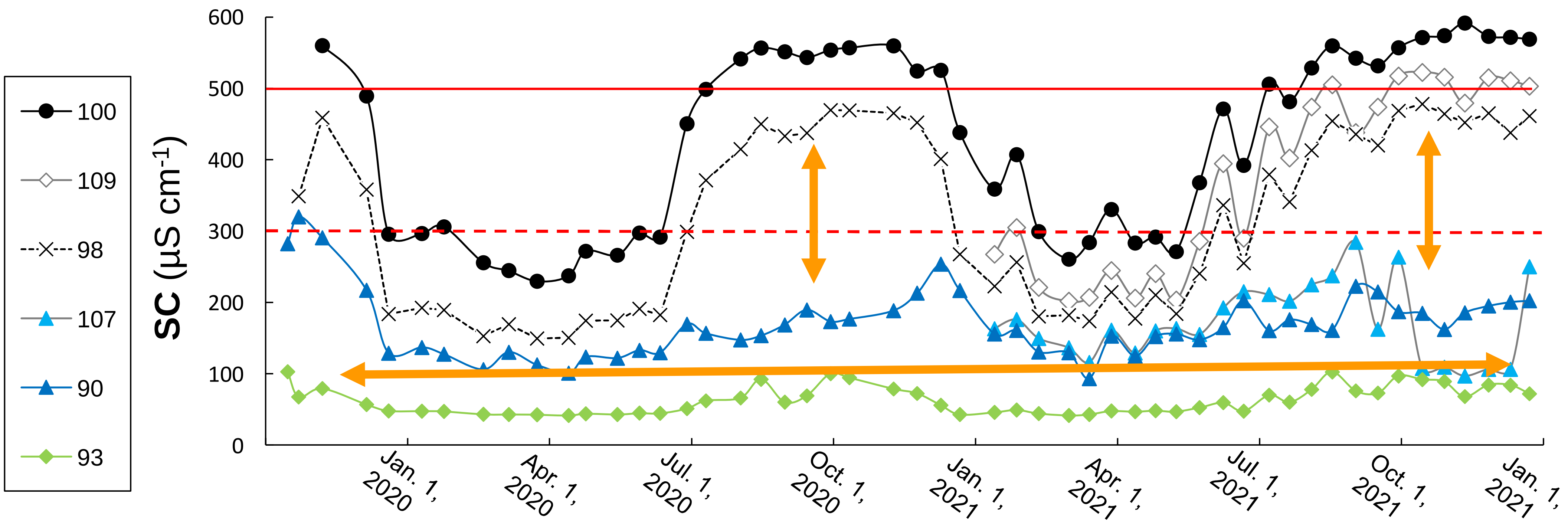
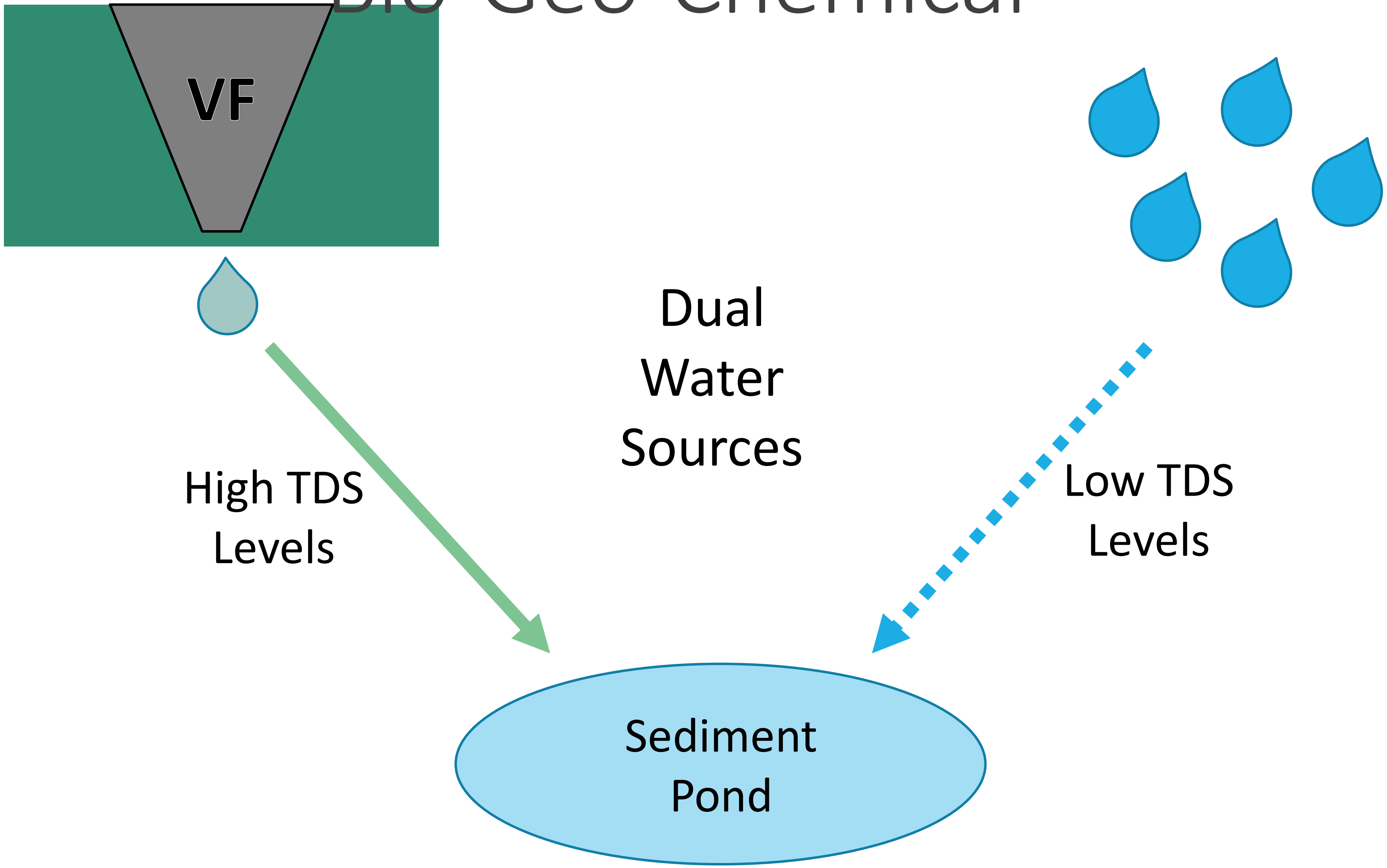


Two-Years ('20-'21)



Hydrologic
Bio-Geo-Chemical



Dual
Water
Sources

High TDS
Levels

Low TDS
Levels

Sediment
Pond

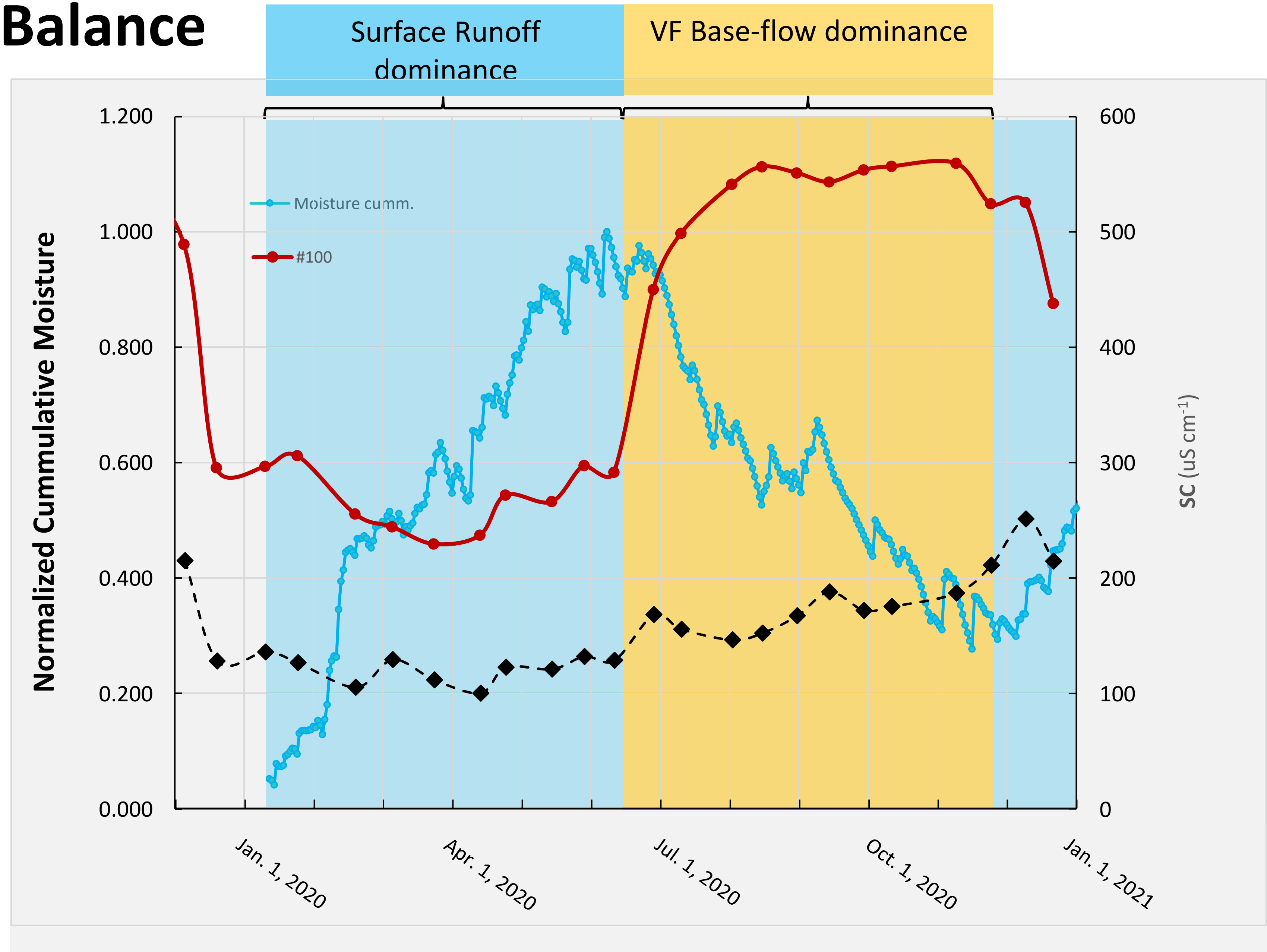
Moisture Budget Balance

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

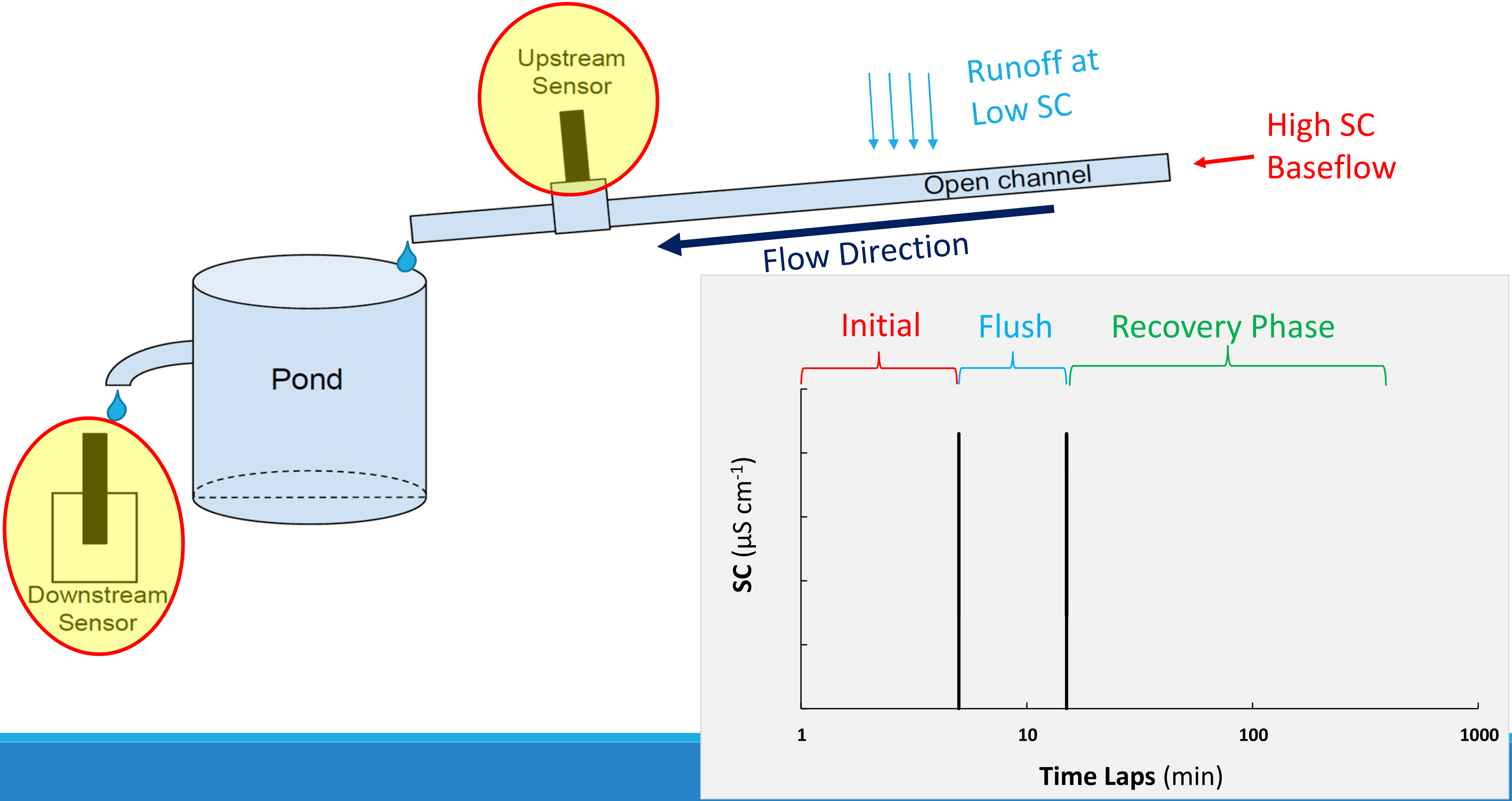
P, daily precipitation, mm;

ET, daily evapotranspiration, mm;

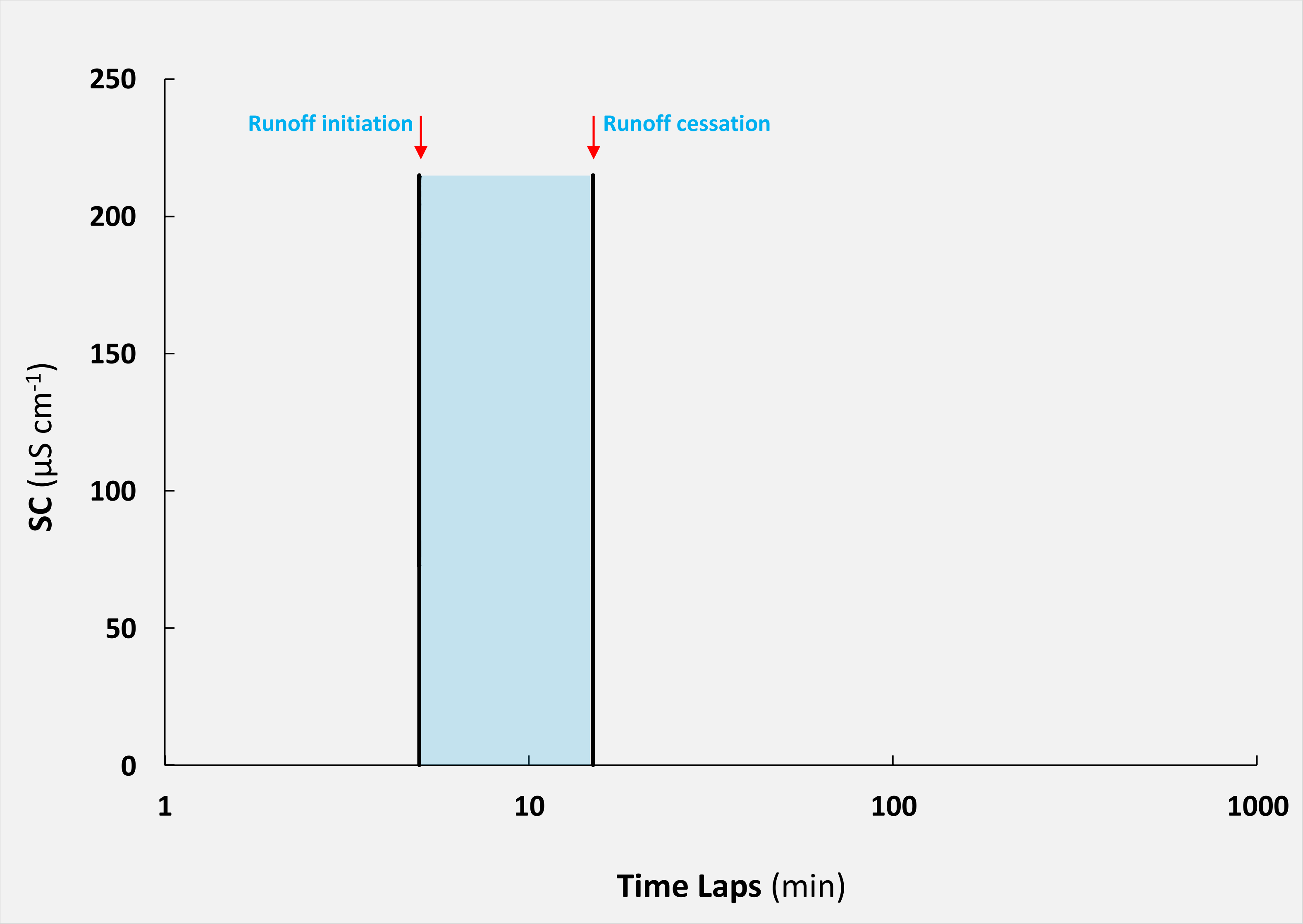
i, calendar Julian day

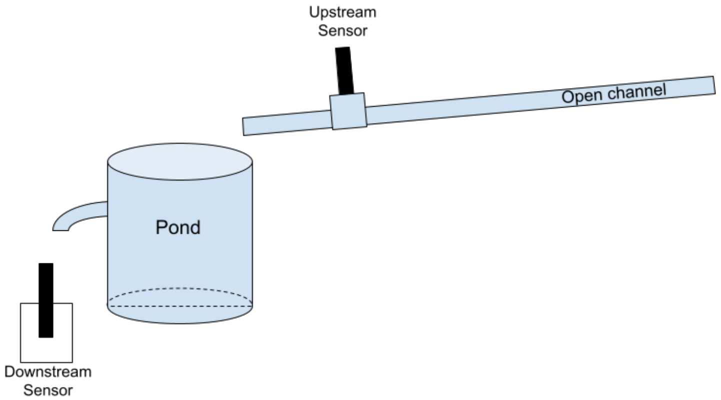


In-Lab Simulation Setup



Initial Data - Pond effect on creek SC





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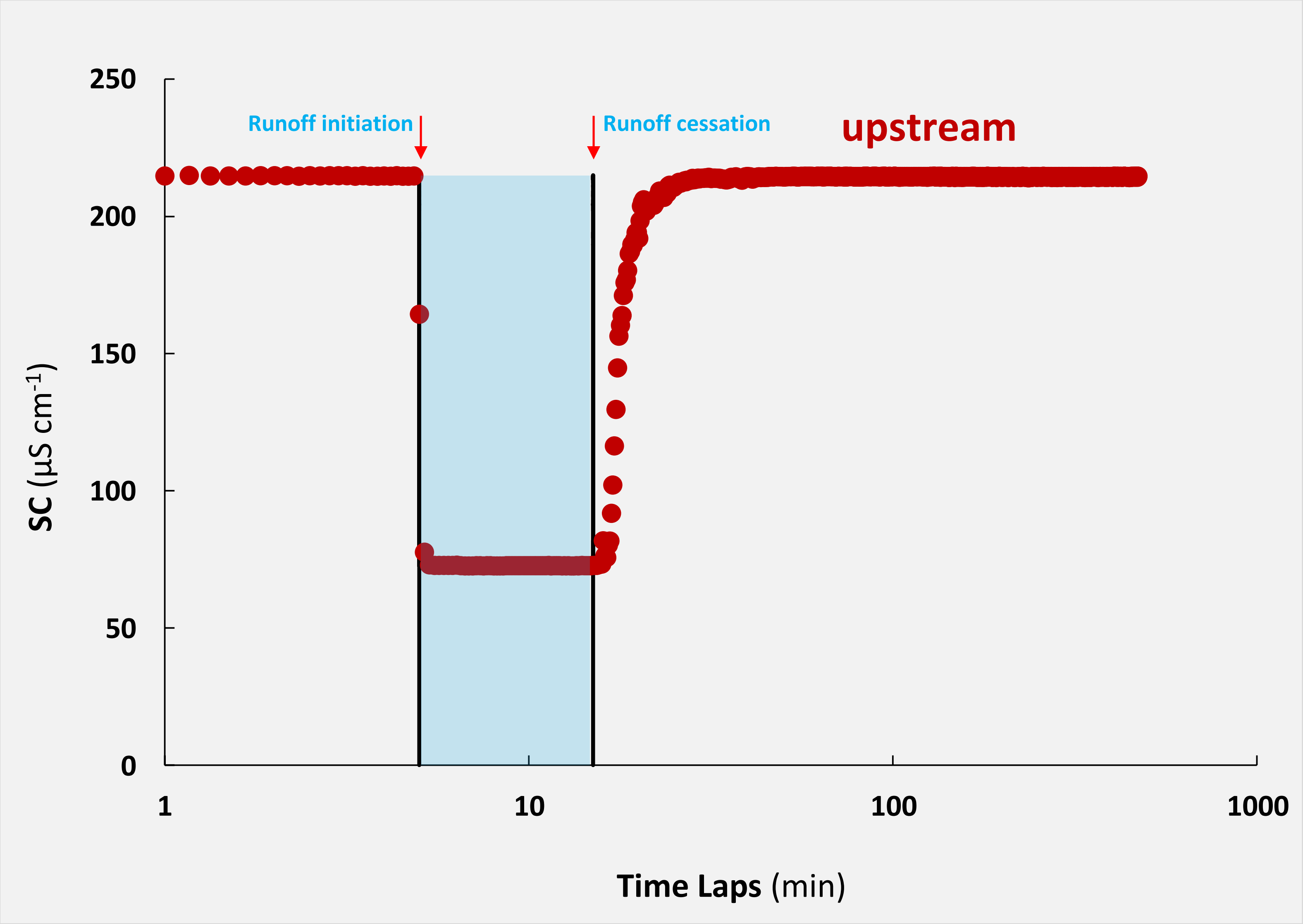

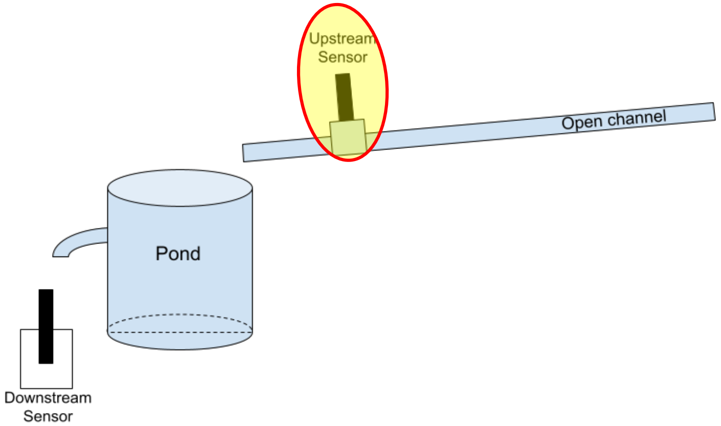

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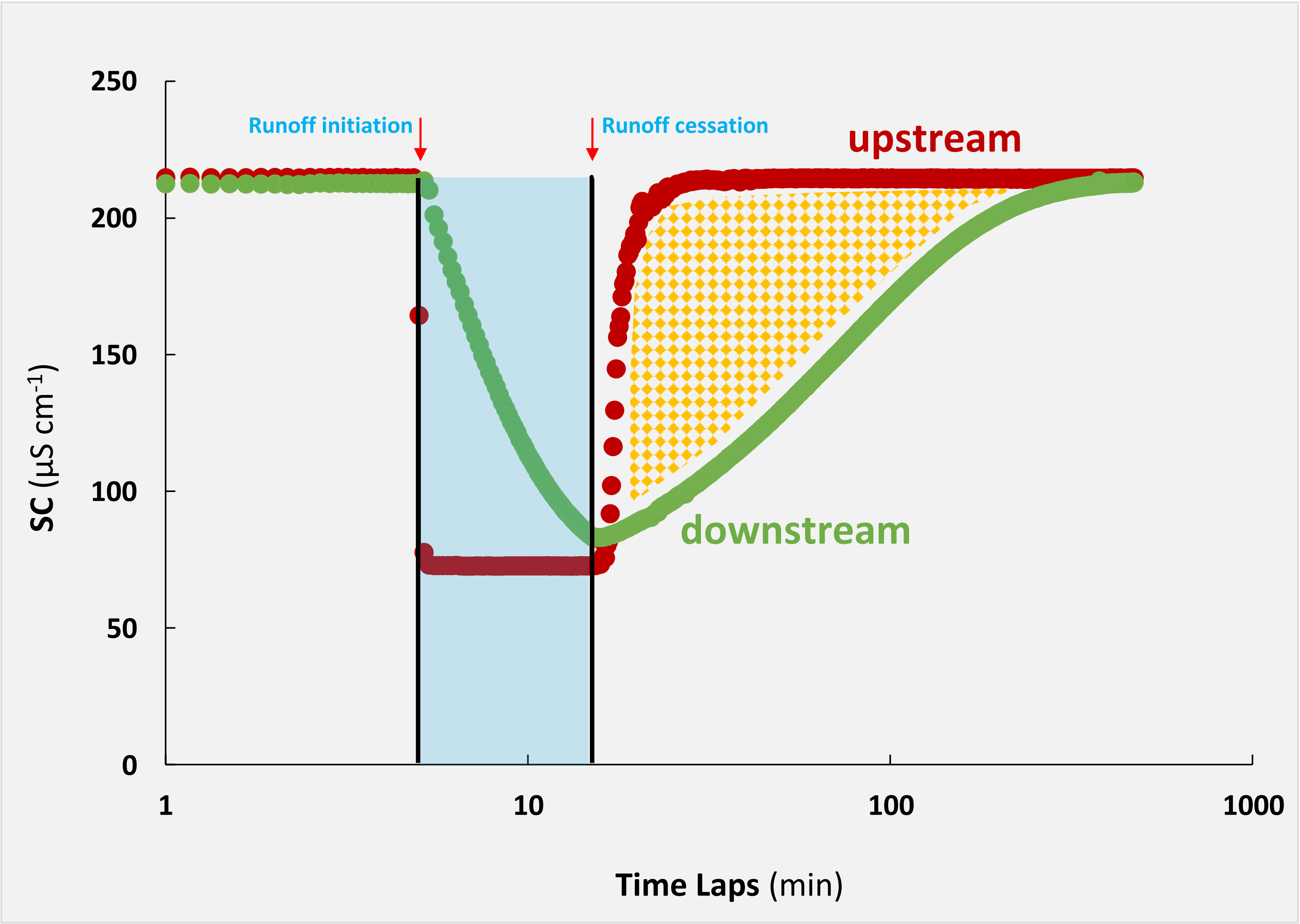
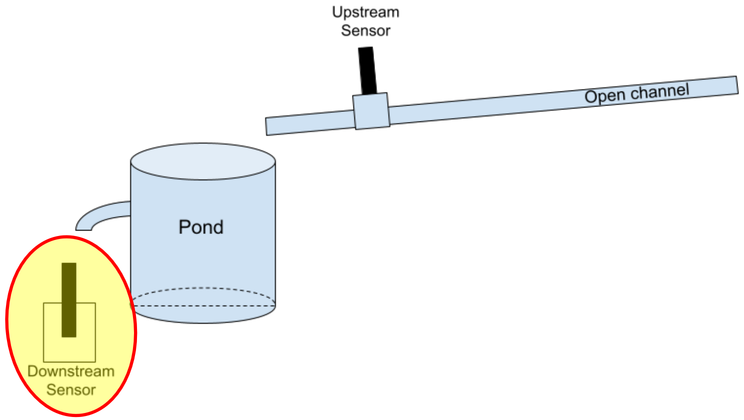




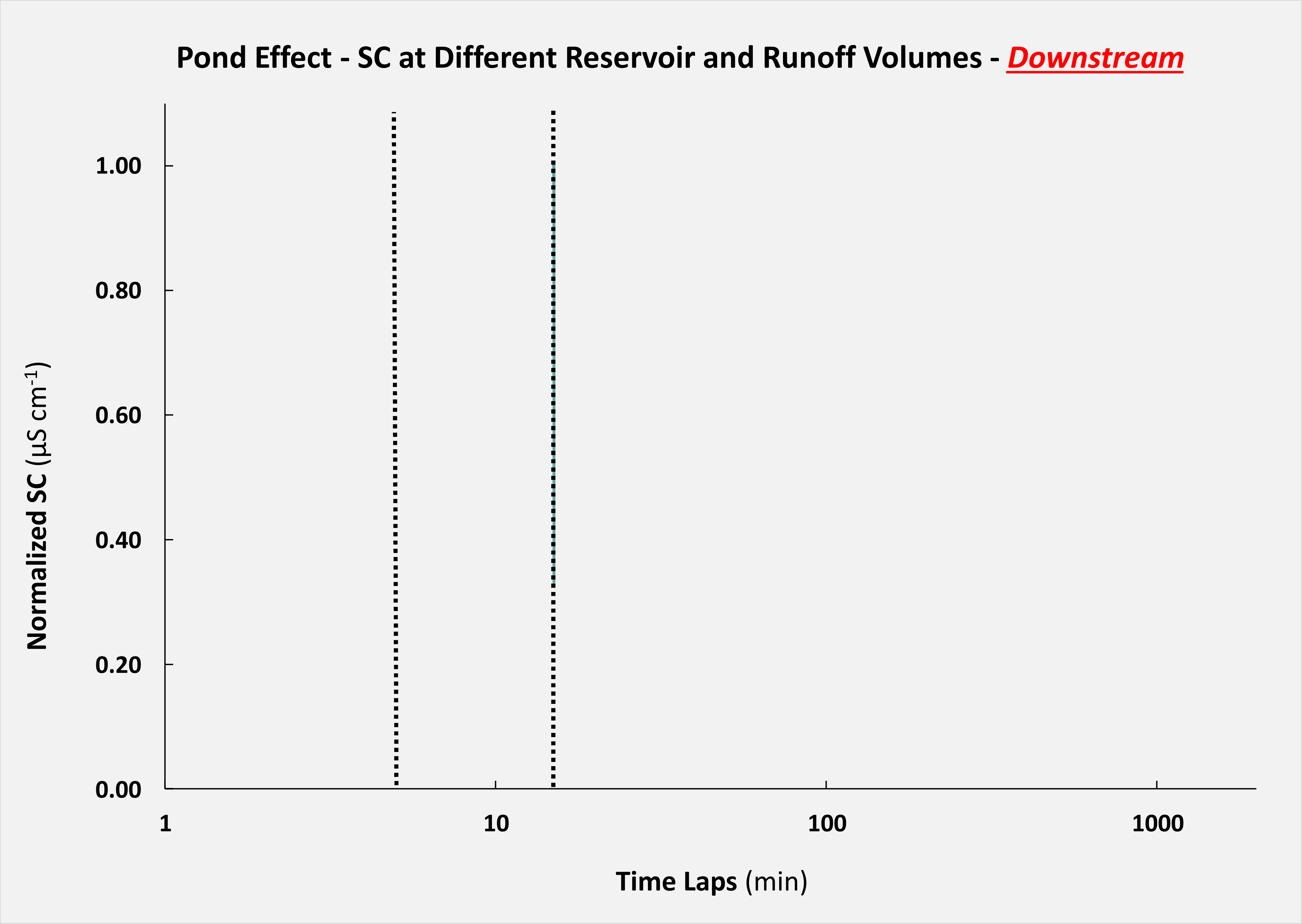
Variables - Pond effect on creek SC

Runoff Volume

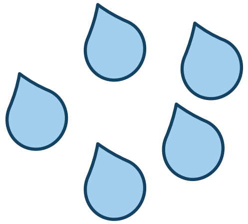
Pond Volume

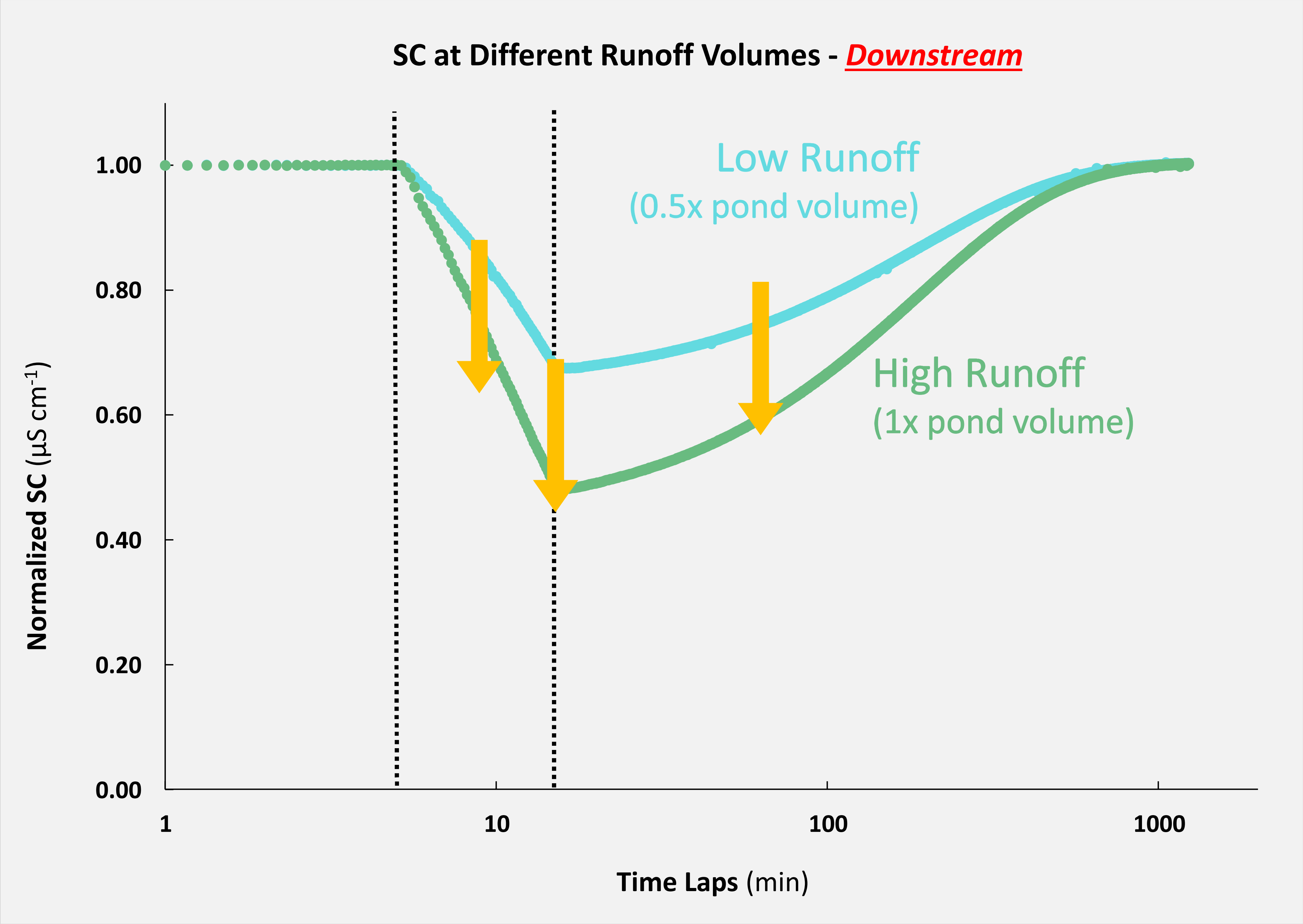
SC

Baseflow (TDS, ***flow rate***)


Pond Effect - SC at Different Reservoir and Runoff Volumes - *Downstream*
Normalized SC (µS cm-1)
1.00
0.80
0.60
0.40
0.20
0.00
1
10
100
1000
Time Laps (min)

Runoff Volume Effect

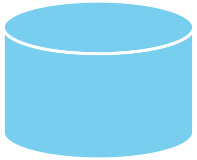


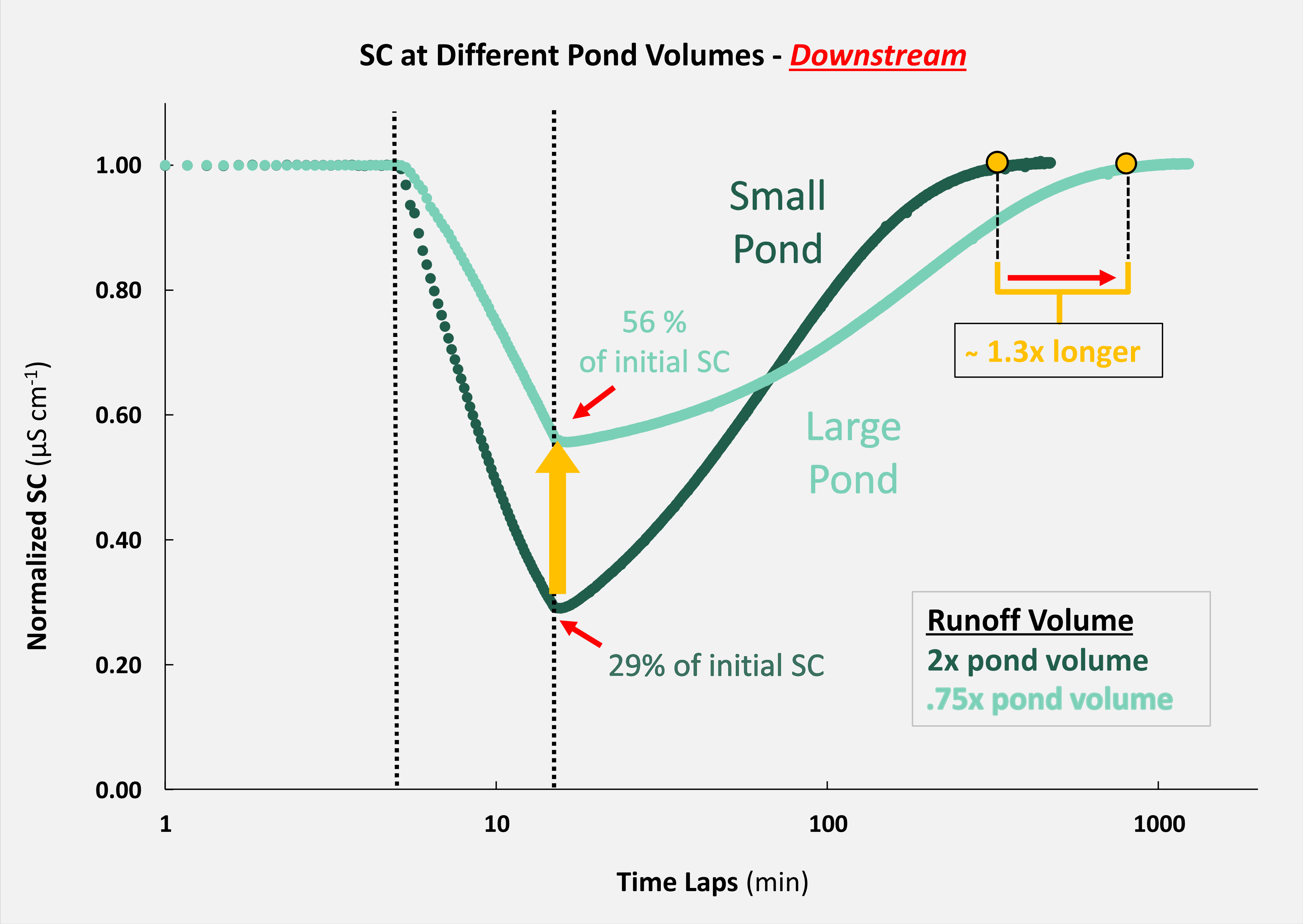


Runoff Volume

Distance from VF	Drainage Area	Runoff Volume	Efficacy on reducing SC
Close	Small	Small	Least Effective
Far	Large	Large	Most Effective

Pond Volume Effect





Pond Volume Effect

Trends in resistance to change

Pond Volume	Reducing Specific Conductance	Recovery Time
Small	More Effective	Faster
Large	Less Effective	Slower

Mass-Balance Based Theoretical Model

Input = Output

$$M_{in}V_{in} = M_{out}V_{out}$$

$$SC_{in}V_{in} = SC_{out}V_{out}$$

M: Mass
V: Volume
SC: Specific Conductance
t: Time

Upstream:

$$SC_{up_t} = \frac{\sum_{i=1}^{2} SC_i V_i}{\sum_{i=1}^{2} V_i}$$

Input (i): Baseflow, *Runoff*

Mass-Balance Based Theoretical Model

Input = Output

$$SC_{in}V_{in} = SC_{out}V_{out}$$

V: Volume
SC: Specific Conductance
t: Time

Upstream:

$$SC_{up_t} = \frac{\sum_{i=1}^{2} SC_i V_i}{\sum_{i=1}^{2} V_i}$$

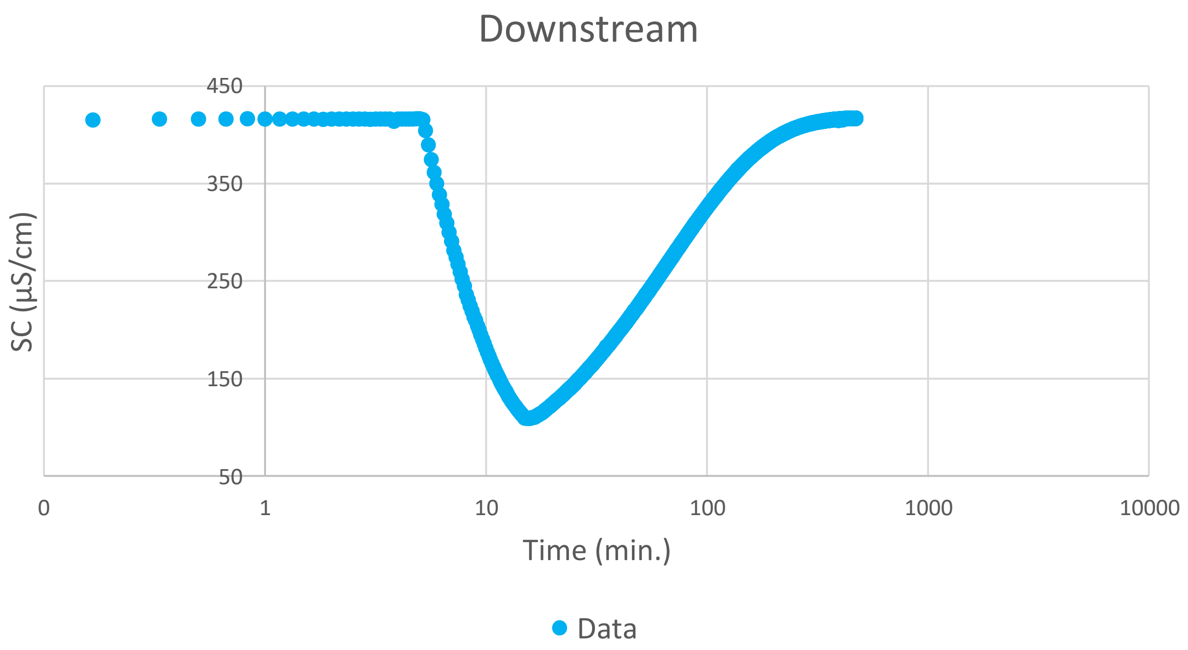
Input (i): Baseflow, *Runoff*

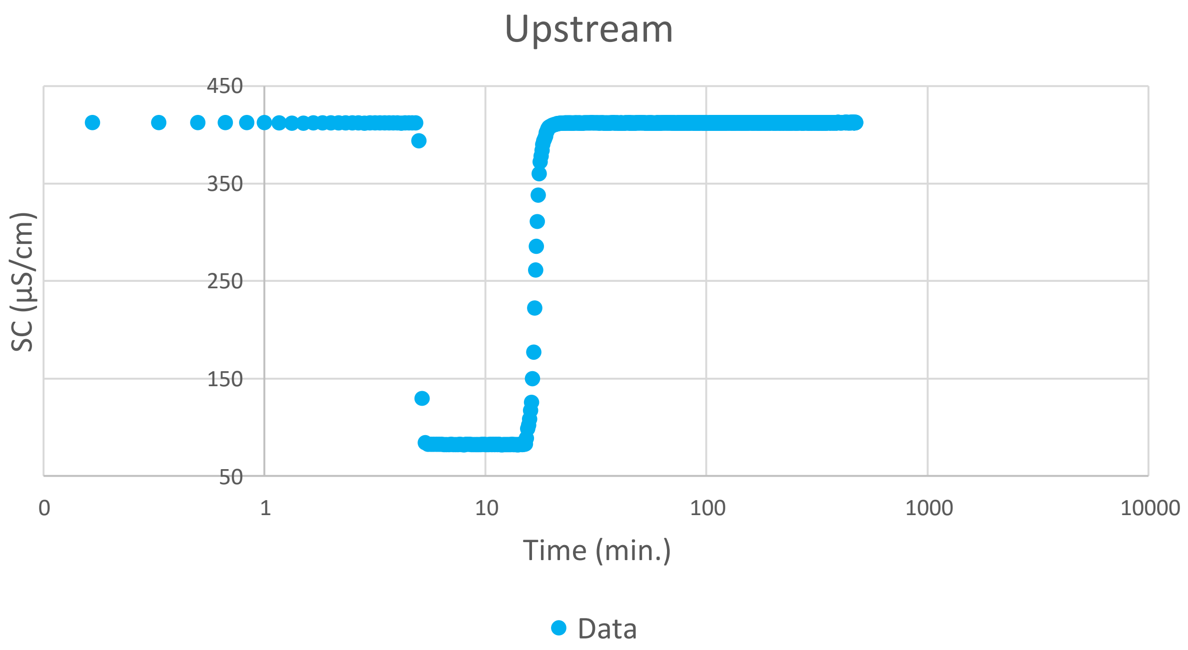
Downstream:

Pond:

$$SC_{pond_t} = \frac{\sum_{i=1}^{2} SC_i V_i + \left(SC_{pond_{t-1}} V_{pond}\right)}{\sum_{i=1}^{2} V_i + V_{pond}}$$

Comparing Theoretical to Simulation





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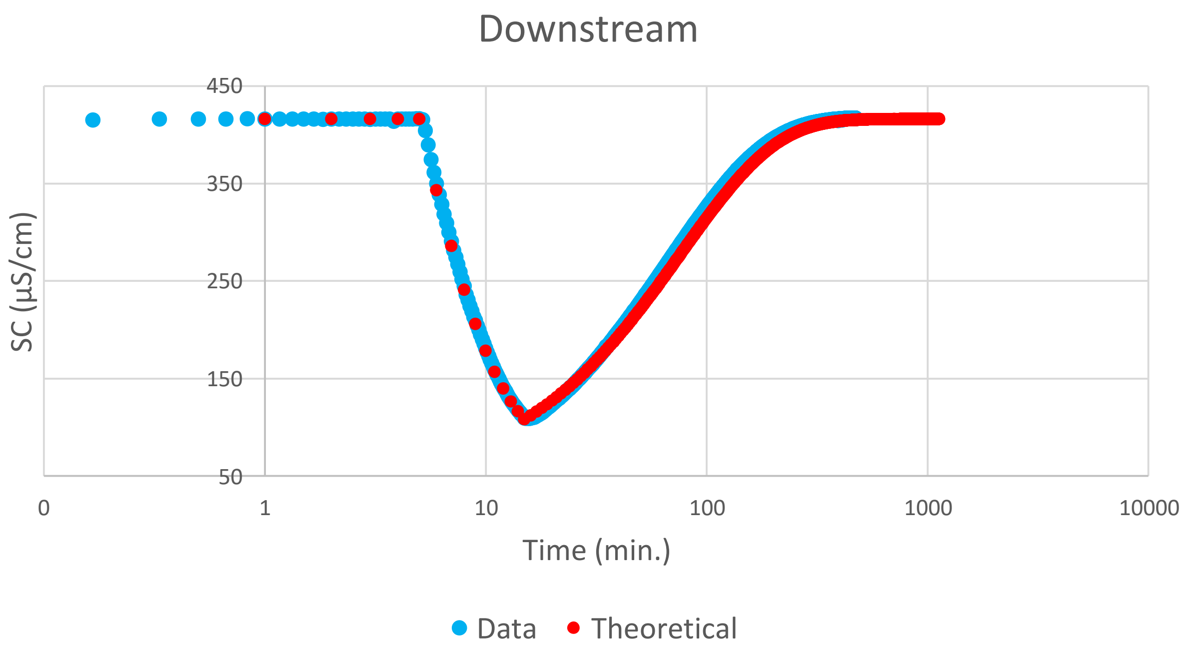
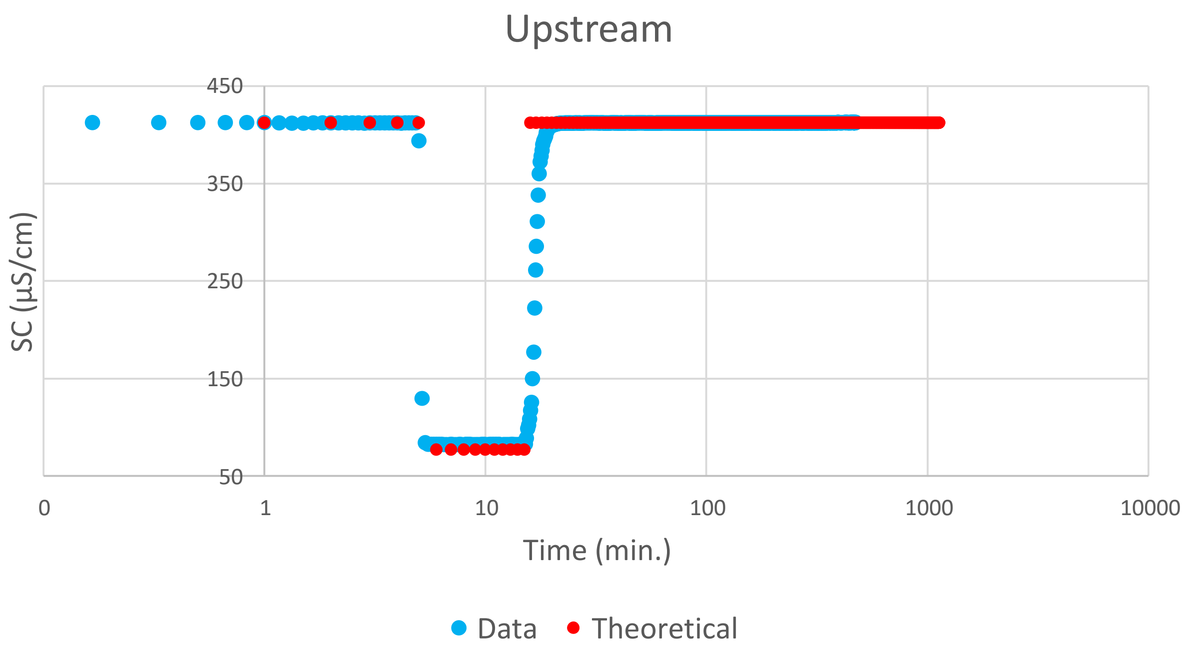




Correlation Coefficient: 0.998972

ANOVA: No statistical difference

p= 0.29971; F stat < F crit (1.0766 < 3.8513)

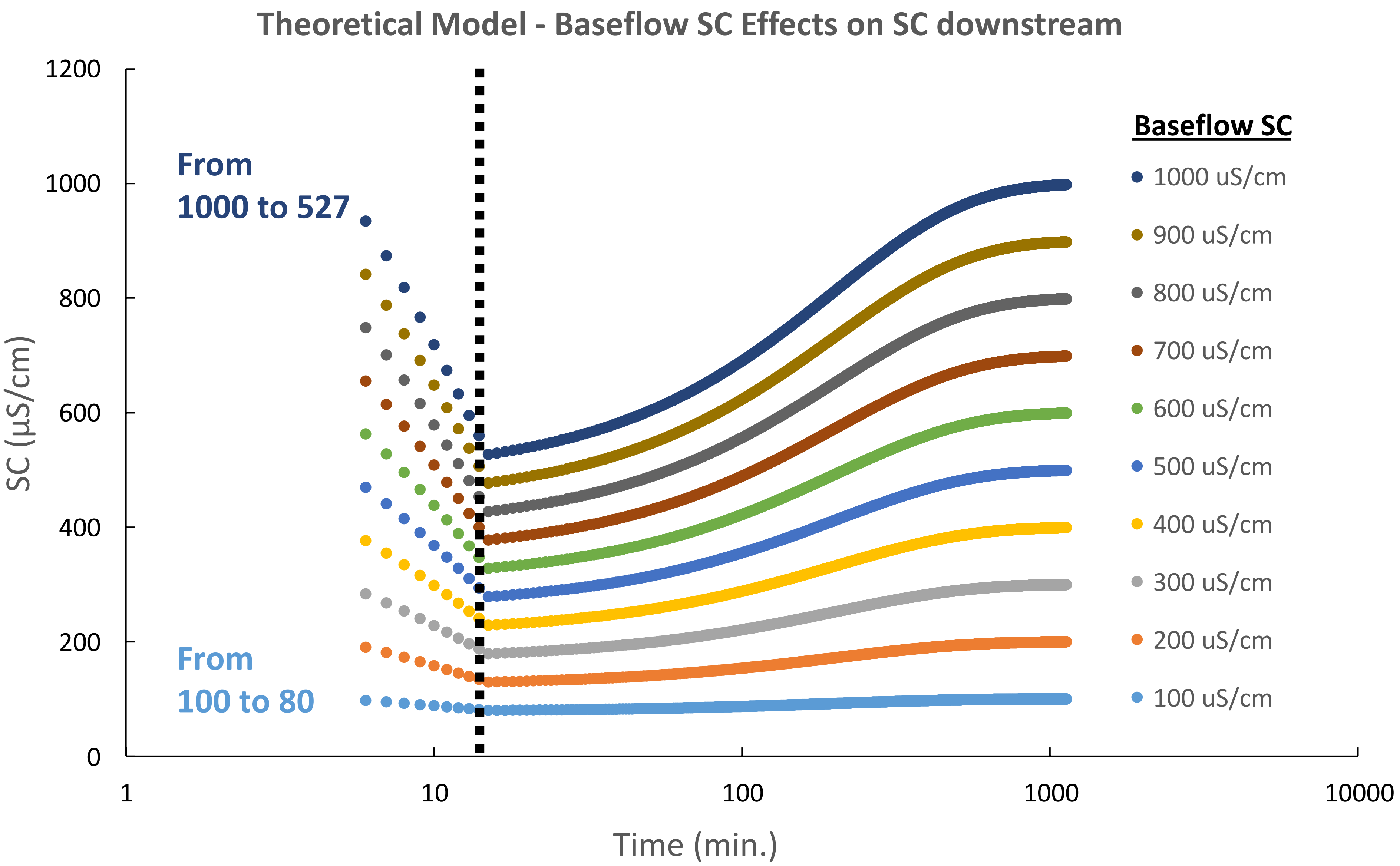
Correlation Coefficient: 0.954331

ANOVA: No statistical difference

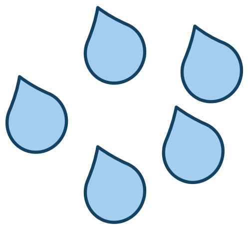
p= 0.79230; F stat < F crit (0.0694 < 3.8513)

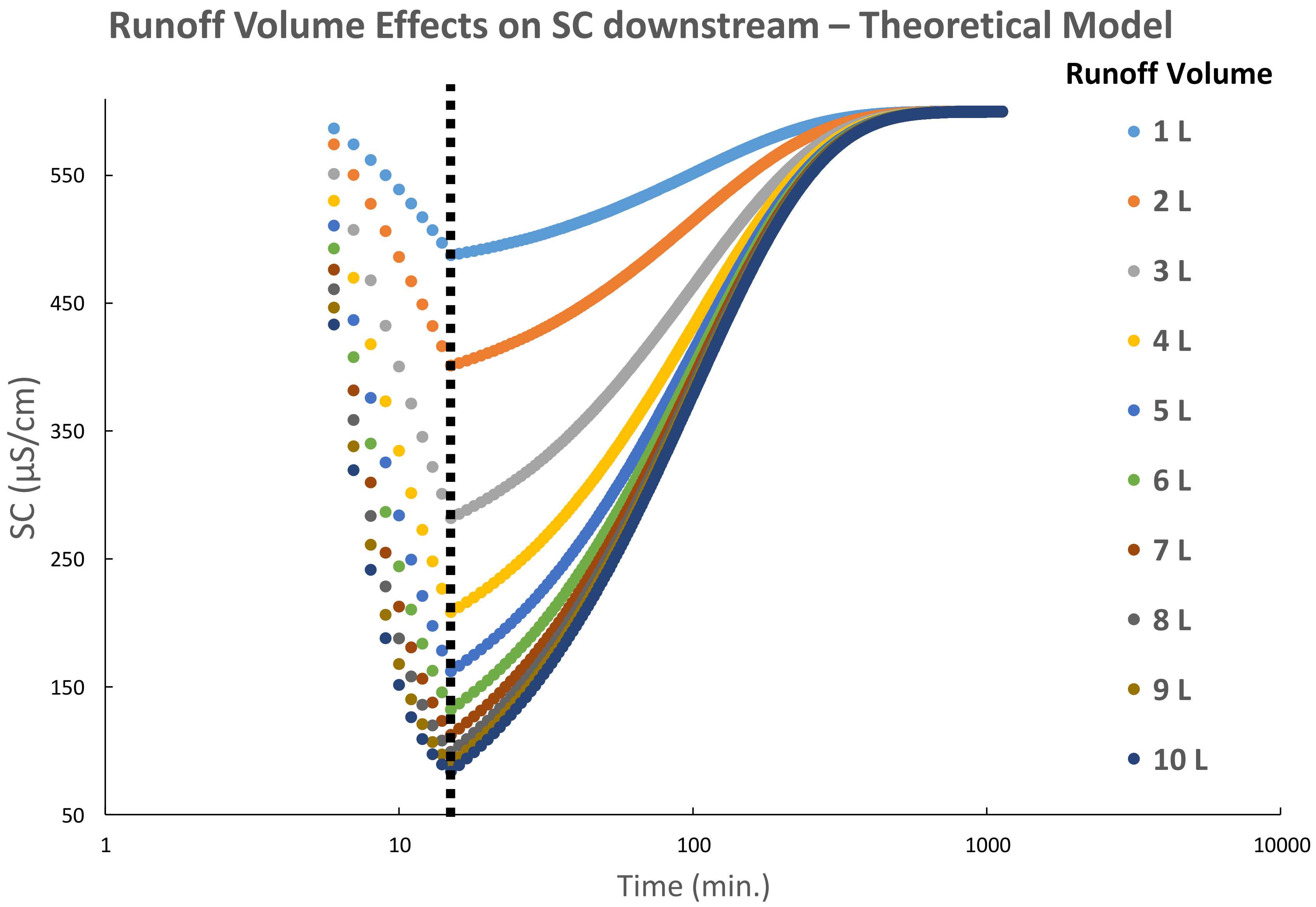
Baseflow SC Effect

SC



Runoff Volume Effect





Summary, conclusion, and future work

- High levels of TDS contribute to degraded water quality in the Appalachian region decades after reclamation
- There are no effective mitigation practices available to reduce elevated TDS levels
- Field observations suggest in-stream retention ponds can positively affect downstream TDS levels
- Implementation/conservation of existent sediment ponds could provide an avenue for tackling this issue
- Monitoring of other Valley Fill affected streams with in-stream ponds is ongoing for further field evidence of this phenomenon
- There is potential for the development of a mathematical model with which to implement at other high TDS afflicted streams

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