VILLANOVA UNIVERSITY
COLLEGE OF ENGINEERING

CENTER FOR RESILIENT WATER SYSTEMS

SUBSURFACE HYDROLOGY USING SOIL MOISTURE CONCEPTUAL FRAMEWORK

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OVERVIEW

Goal: Use soil moisture profile conceptual framework to understand the larger picture of soil moisture at subsurface layer in a GSI system which dictates the system's response and recovery to a storm event.

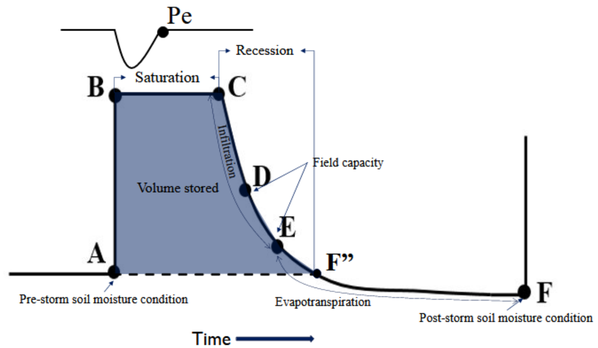

Figure 1: Soil moisture profile conceptual framework

Framework Application (figure 1)
- Monitor subsurface hydrology
- Determine longevity of a subsurface system to hold water
- Understand system recovery process
- Provide site specific soil conditions

METHODS

1. Rainfall event selection based on ideal soil moisture profile (figure 2)
2. Identify specific soil moisture points (ABCDEFF") based on the change in slope (figure 2)
3. Categorize soil moisture profile based on pre- and post-storm soil moisture (figure 3)
4. Analyze subsurface parameters
   a. Average soil moisture (figure 1)
   b. Duration of saturation (figure 1)
   c. Soil moisture recession (figure 1)
   d. Time of desaturation (figure 4),
   e. Infiltration and evapotranspiration rates

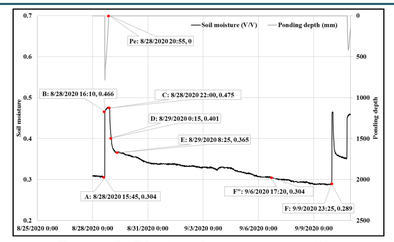

Figure 2: Ideal soil moisture profile

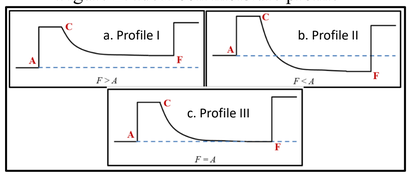

Figure 3: Ideal soil moisture profile

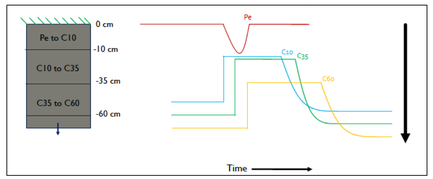

Figure 4: Desaturation estimation

STUDY SITE

Figure 5. (a) Linear bioswale in northeast Philadelphia at the cross section of Marlborough street and Shackamaxon street, (b) soil moisture sensor installed at 10cm, 35cm and 60cm

RESULTS

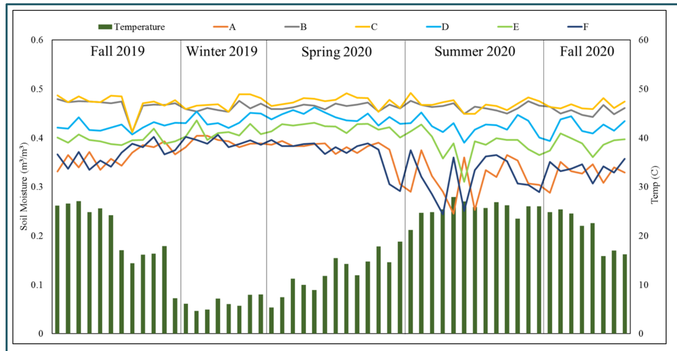

Figure 6: Average soil moisture dynamics over one year at 10 cm depths

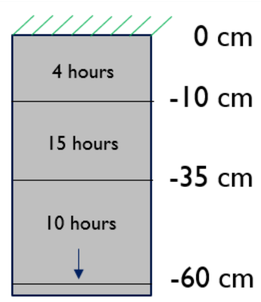

Figure 7: Duration of water to move along soil depth after saturation is reached

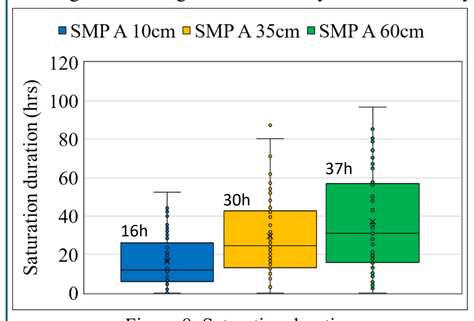

Figure 8: Saturation duration

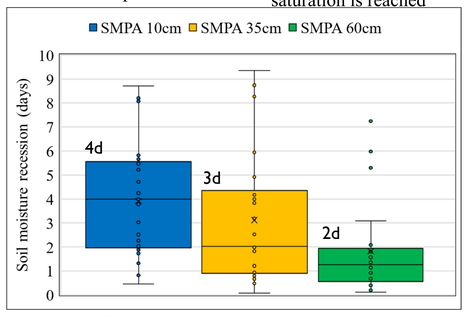

Figure 9: Soil moisture recession

Infiltration rate (cm/hr): $\frac{Soil\ Layer}{Duration\ of\ desaturation}$ = 5 cm/hr at 10 cm, 3 cm/hr at 35 cm, and 4 cm/hr at 60 cm

$$Evapotranspiration\ rate = \frac{\Delta\, SM_{10}\ (E-F)}{\Delta\, T_{10}\ (E-F)} * 20.33 + \frac{\Delta\, SM\ 35\ (E-F)}{\Delta\, T\ 35\ (E-F)} * 20.33 + \frac{\Delta\, SM\ 60\ (E-F)}{\Delta\, T\ 60\ (E-F)} * 20.33 \ = 0.48\ \text{cm/day}$$

SUMMARY

- Established system response and recovery
- Framework provides consistency with which system response to storm events is analyzed
- Knowledge is transferable to other GSI sites with different soil type
- Improved understanding of subsurface hydrology

Benefit of using conceptual framework
- Improvements in designs (soil type, depth)
- Track the system's maintenance requirement
- Modelling effort
- Provide realistic expectations of subsurface (especially GSI units) performance in managing storm
- Dictates the efficacy of GSI designs

FUTURE WORK

- Automated Identification of points ABCDEFF" (figure 10)

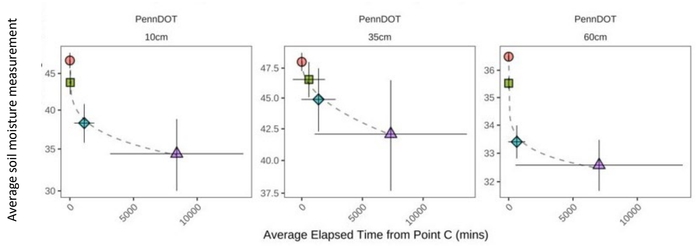

Figure 10: Automated average soil moisture at point C, D, E and F

- Exploration to volume storage analysis
- Subsurface modelling tool (figure 11)

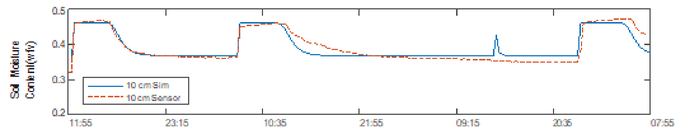

Figure 11: Comparing soil moisture measurements with HYDRUS simulations

- Framework validation

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