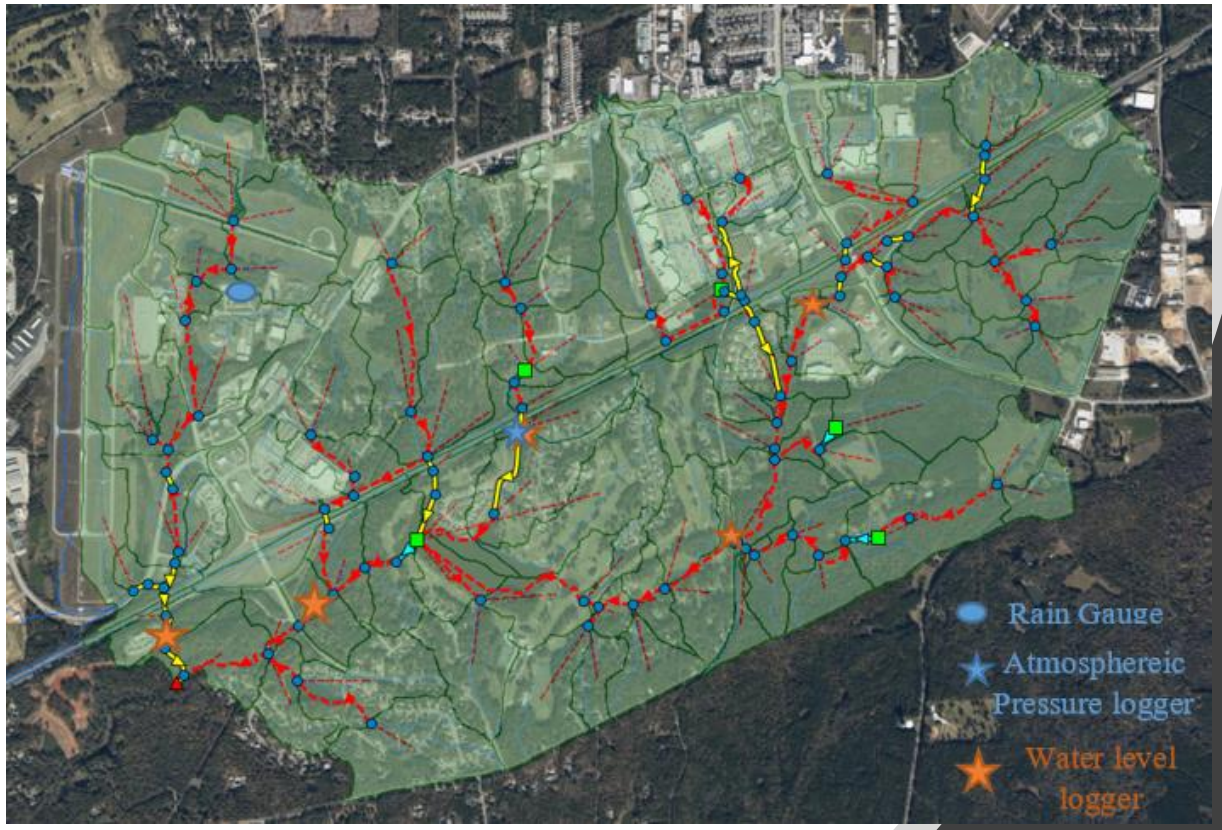

Alternative approaches to setup CN and imperviousness in SWMM models

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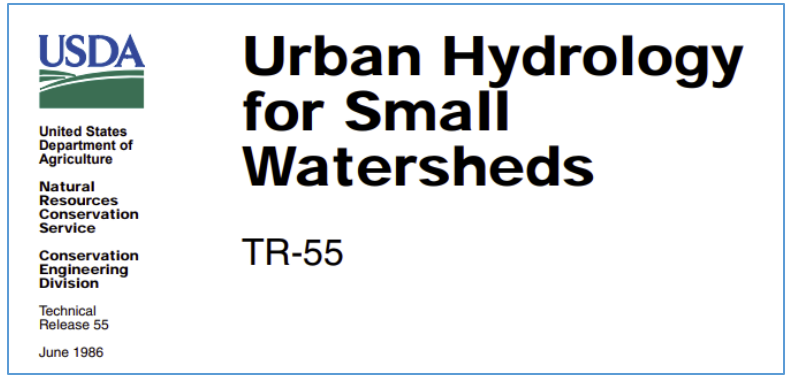
Presentation outline

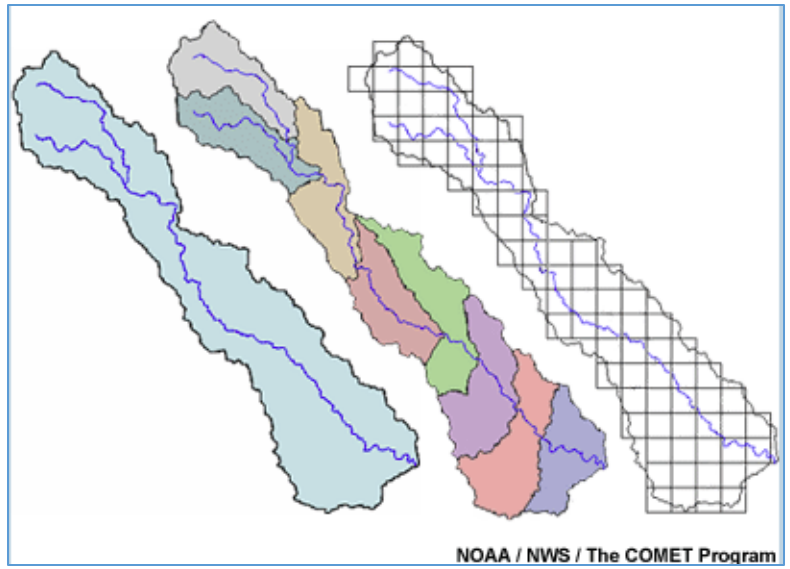
- Hydrological modeling of urban watersheds
  - Strategies for rainfall abstraction computation
- Using CN in hydrological models
  - Approaches for implementing CN within SWMM
- Application: Moore's Mill Creek in Lee County, AL
  - Results and discussion
  - Comparison SWMM 5 vs. WinTR-55
- Discussion and Final Remarks

Hydrological modeling of urban watersheds

$$Q = ciA$$

- Approaches have included:
  - Peak flow determination for hydraulic design
  - NRCS-based methods to determine peak flows and hydrographs
  - Semi and fully-distributed hydrological models
- Current stormwater management practices involve (semi)distributed models
  - Models undergoing calibration and validation
  - Hydrological and water quality management
- A commonly adopted model is EPA's SWMM





Infiltration in hydrological models

- Methods include
  - Horton/Modified Horton Equation
  - Green-Ampt Equation
  - Richards Equation
  - NRCS Curve Number (CN)
- Curve Number is a popularly adopted approach
  - Presented in the NRCS TR-55
  - Computed effective runoff depth (R) from rainfall depth (P), maximum moisture storage capacity (S), and initial abstraction (Ia)
  - Meant for an event-based calculations
  - GIS databases facilitate assigning CN in hydrological models

$$R = \frac{(P - Ia)^2}{P - Ia + S}$$

$$S = \frac{1000}{CN} - 10$$

SWMM 5 general characteristics

- Hydrological, hydraulic, water quality model
- Event-based or continuous simulation
- Semi-distributed model
  - Subcatchments define hydrological properties, including rainfall abstractions
- Different alternatives for infiltration and rainfall losses
- Incorporation of sustainable stormwater practices in its formulation
- Broad user base, open-source, commercial implementations that improve model usability

Implementation of CN within SWMM

- CN implementation to SWMM models have a few changes from the original NRCS approach
  - No need to consider the initial abstraction with the depression storage property in subcatchments
  - Infiltration is implemented in an incremental fashion to enable continuous hydrological modeling
  - Ability to recover the storage capacity during dry periods
- Effects of CN are only on the pervious fraction of subcatchments.

Assigning CN values to SWMM subcatchments

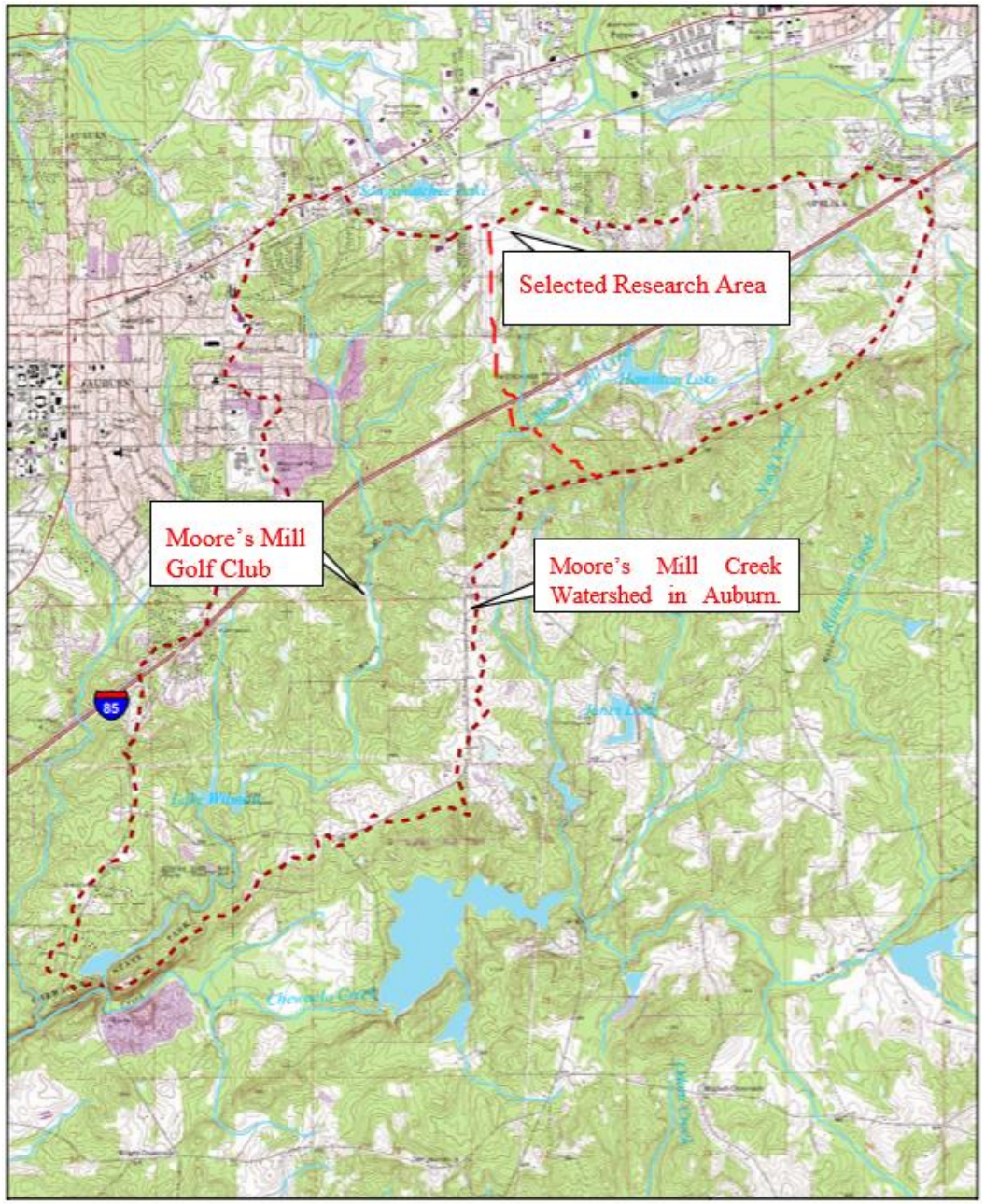
- Tables with CN included impervious land uses with large values (~98)
  - Large CN values in a subcatchment minimizes infiltration
  - Could an average of CN from pervious and impervious areas be representative for an entire subcatchment?
- Yet, within SWMM, pervious areas can be separated from impervious
  - Then CN values would be computed considering only pervious areas
  - Rainfall in impervious areas (except depression storage) becomes runoff.
- Which approach would be more adequate for a hydrological model?

Objectives

- To compare the results of a SWMM model considering different approaches to assign CN values in subcatchments
  - **Fully-composite**: All areas in subcatchments are pervious, and CN values are averaged among land uses that are impervious and pervious.
  - **Cut-off approaches**: Areas with CN values above a threshold are considered impervious. The CN values are averaged only using subcatchments below the cut-off value
- Results are compared with data collected in the field with a peri-urbanized watershed in Lee County, Alabama

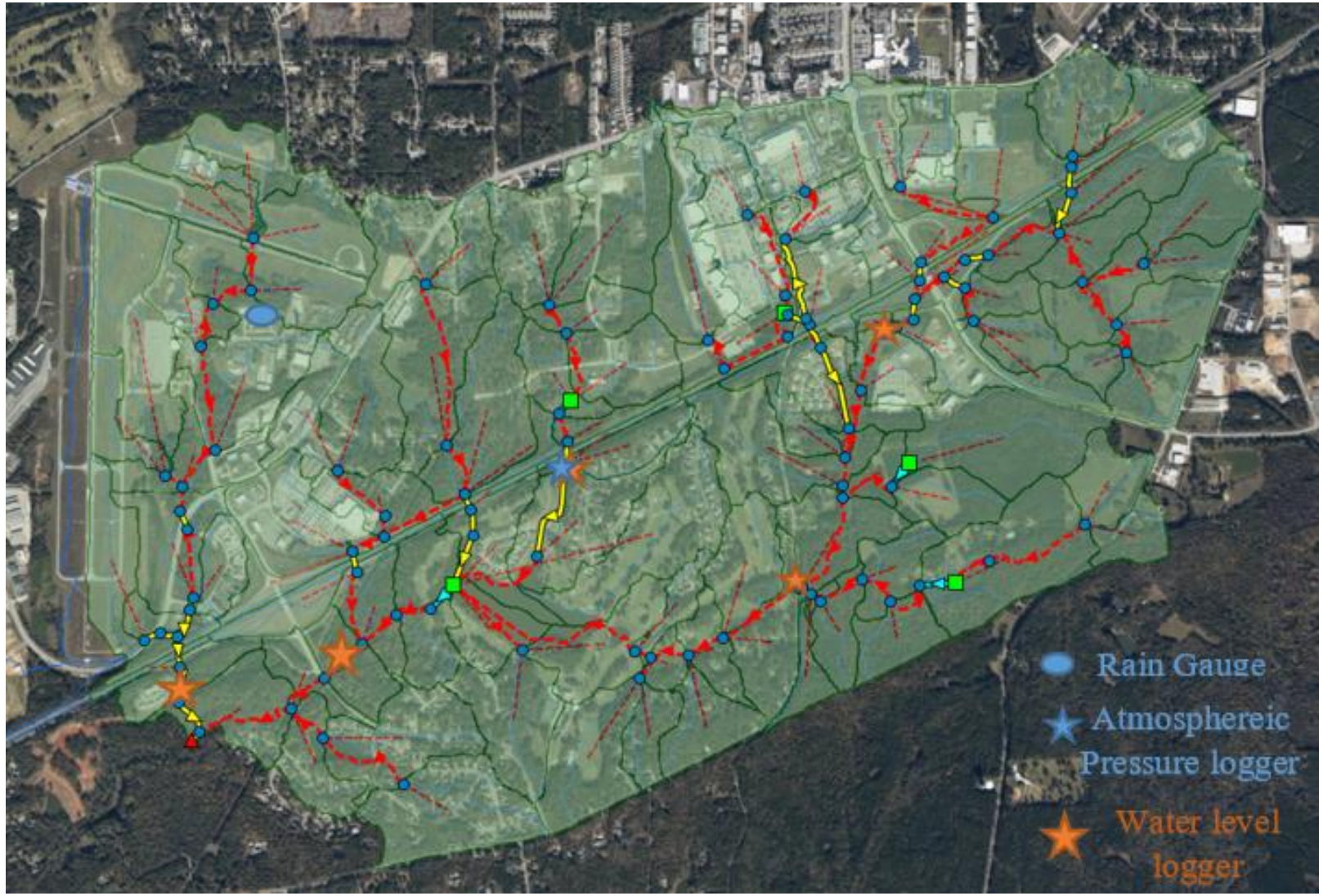
Moore's Mill Creek Watershed

- Spans over the Cities of Opelika and Auburn, AL
- Area 30 km^2
- Mixed land use: undeveloped, commercial, residential areas
- Selected area is located mostly in Opelika (~10 km^2)



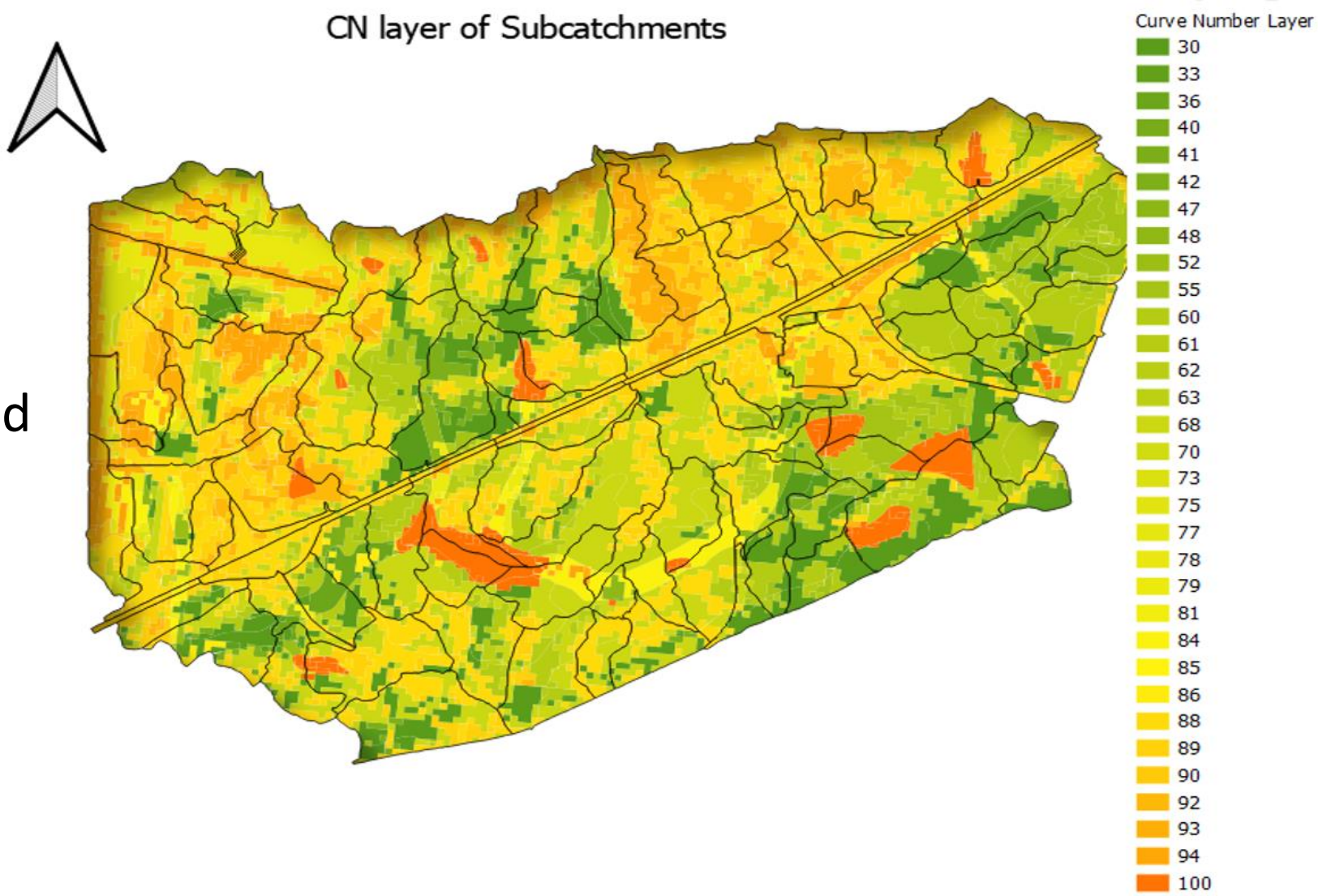
Field monitoring program

- Used HOBO U20L-04 for stream gage depth and atmospheric pressure
- HOBO RG3 rain gauge
- Other rain gauges in the area
- Global Water current meter
- Field surveys

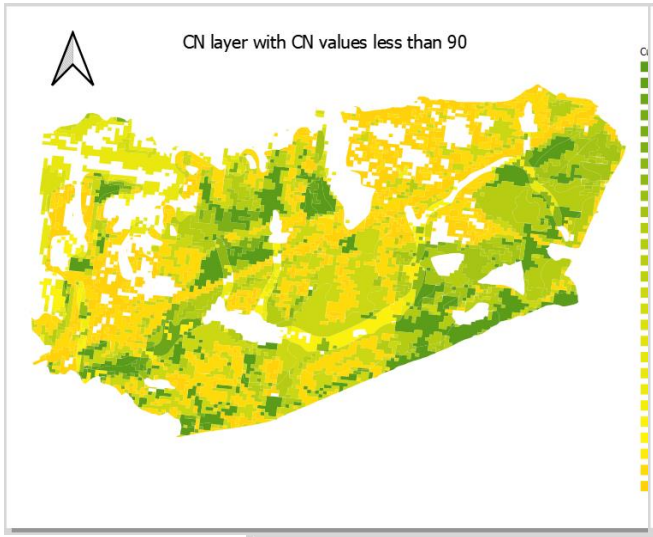


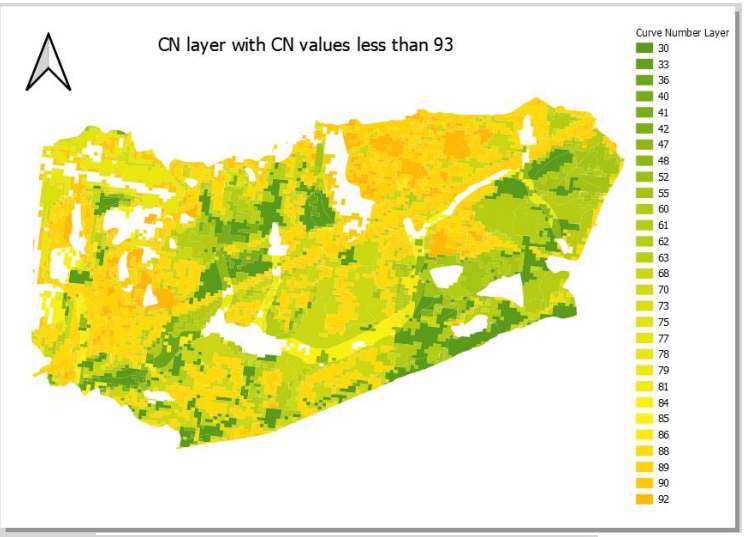
SWMM model characteristics

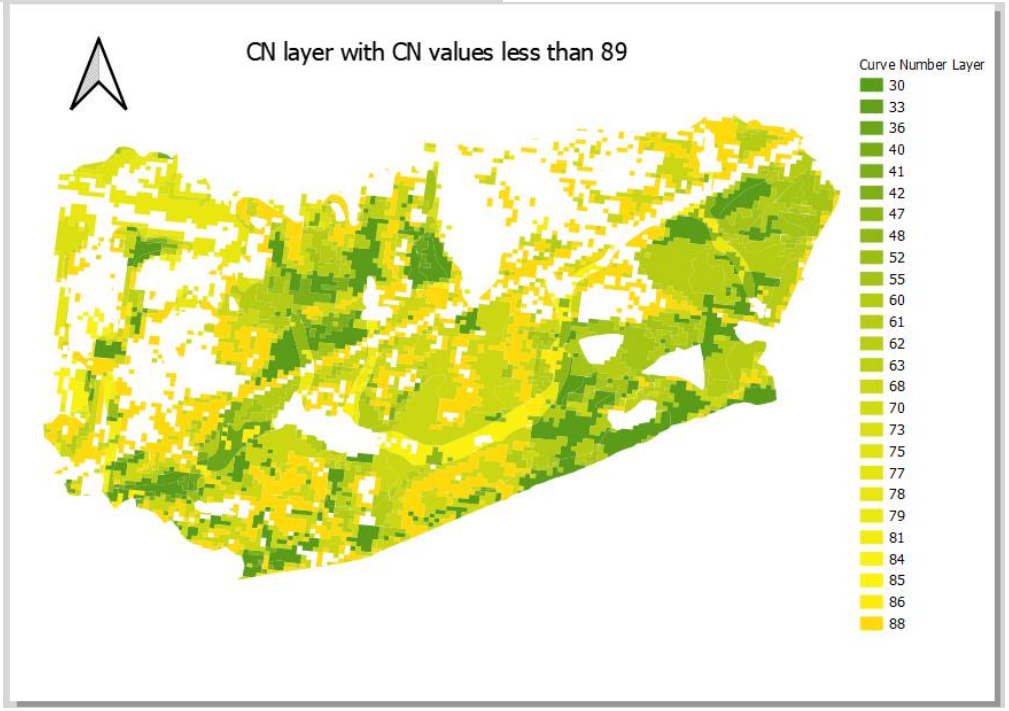
- Used automatic delineation with CHI's PCSWMM
- Total 109 subcatchments (average 10 ha in size)
- Used DEM (5 m x 5 m) to delineate subcatchments and determine slopes
- Used the QGIS plugin by Siddiqui (2020) to compute gridded CN values
  - 100' x 100' grid size
- Average CN values assigned to subcatchments



Fully-composite vs. Cut-off approaches for CN distribution







- CN values in subcatchments are averaged from gridded CN values.
- “White” patches are considered impervious.
- Fully composite: higher average CN number for subcatchments, 100% pervious
- Cut-off: Non-zero impervious fraction, lower CN assigned to subcatchments

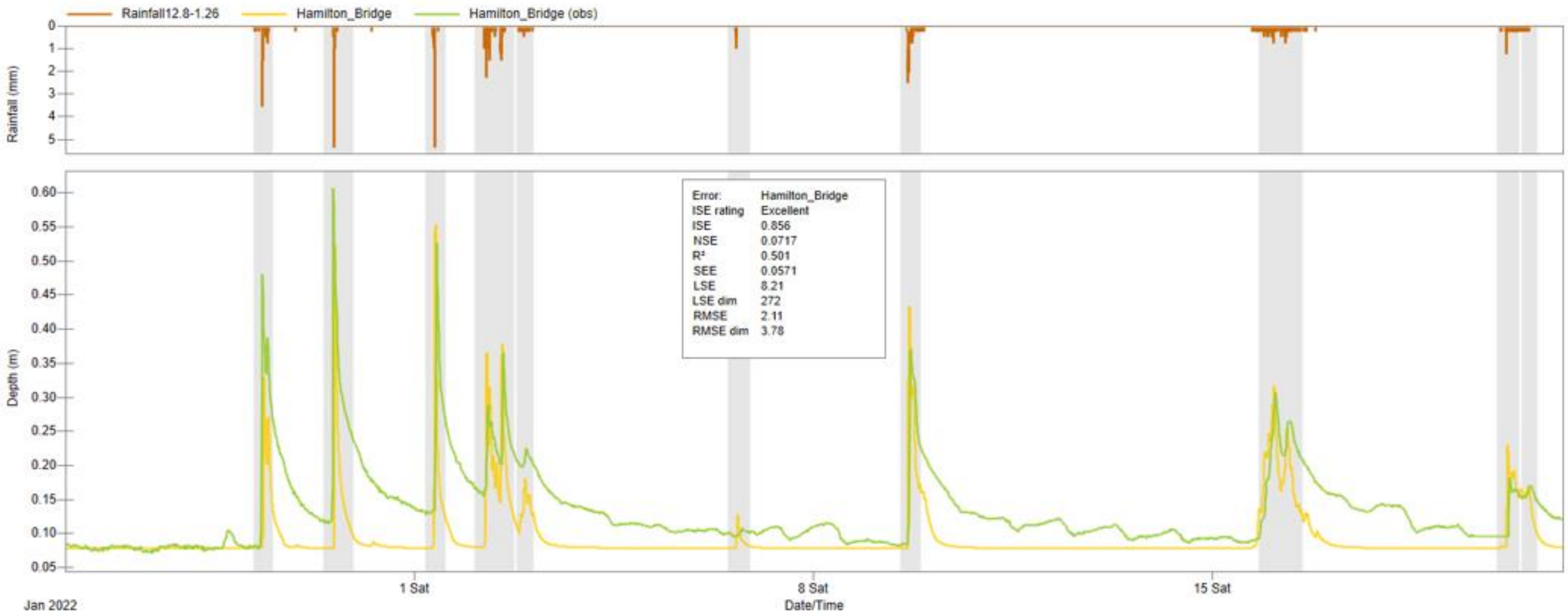
Model setup and calibration

- DEM and survey used to characterize channel conveyance
  - Existing SW collection system was not explicitly included
  - Aquifer components not added in SWMM – no explicit GW interactions!
- Calibration goal: To represent peak flow depths
- Small number of parameters were considered
  - Subcatchment slope (+/- 20% from DEM value)
  - Subcatchment drying time
- Adopted tabulated values for
  - Manning Roughness (impervious/pervious)
  - Depression storage

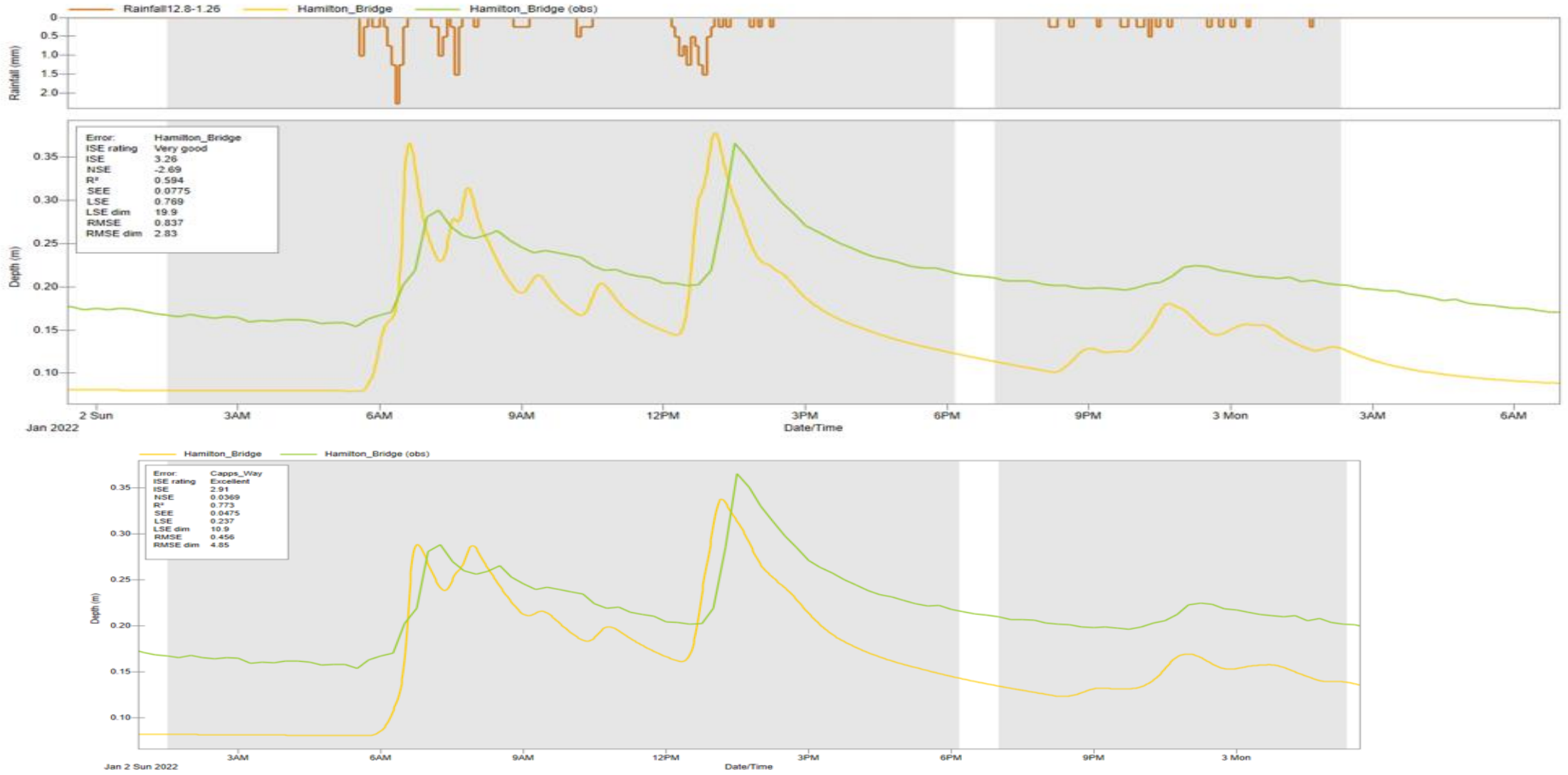
Moore's Mill Creek: Monitored Locations

- Capps Way – Most upstream, low-density residential, forested areas, and some ponds. Average CN = 70
- Hamilton Rd – Mid-point, includes a commercial area (TigerTown), add some more ponds and forested areas. Average CN = 68
- Bent Creek Rd – Downstream, add some low-intensity residential areas, more ponds. Average CN = 69
- Lakeshore Dr. – Tributary to Moores Mill Creek, drains mostly forested, residential area with a pond. Average CN = 66
- Champions Blvd. – Tributary to Moores Mill Creek. Poorly drained soils, airport, no pond. Higher average CN = 76

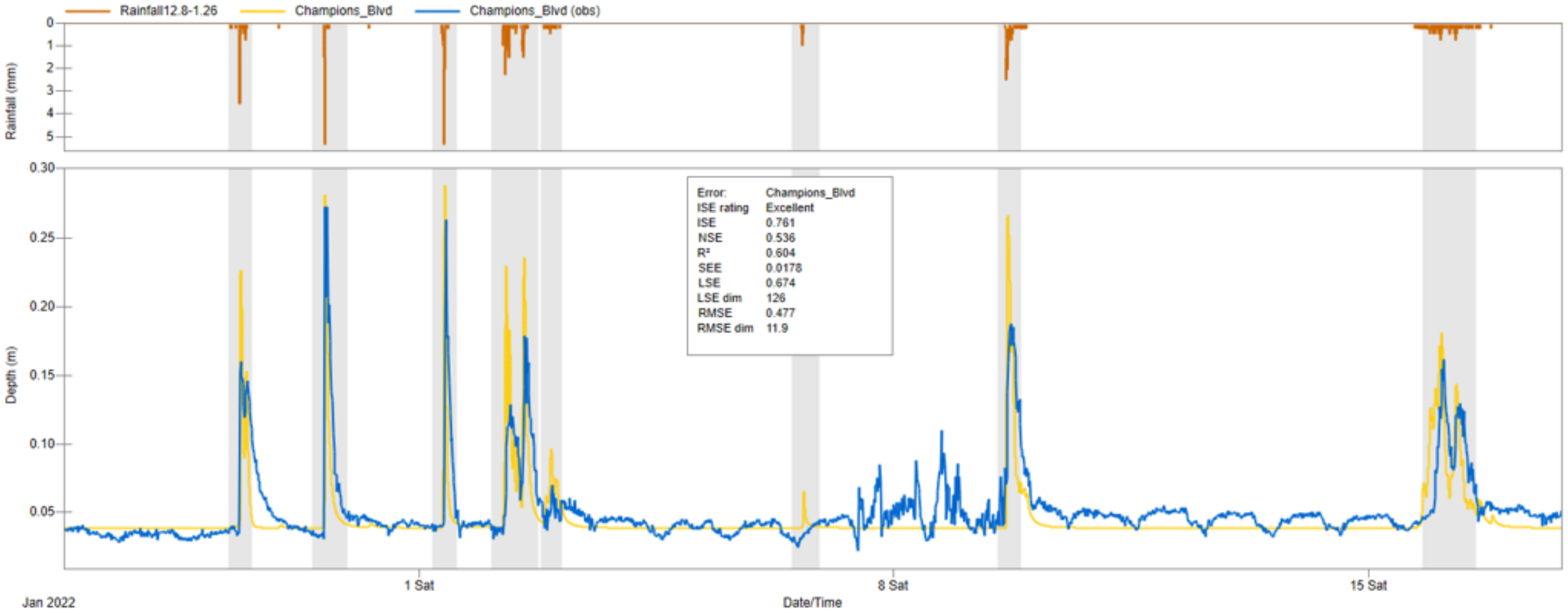
Results – Hamilton Rd. Hydrographs, Cut-off at CN=90



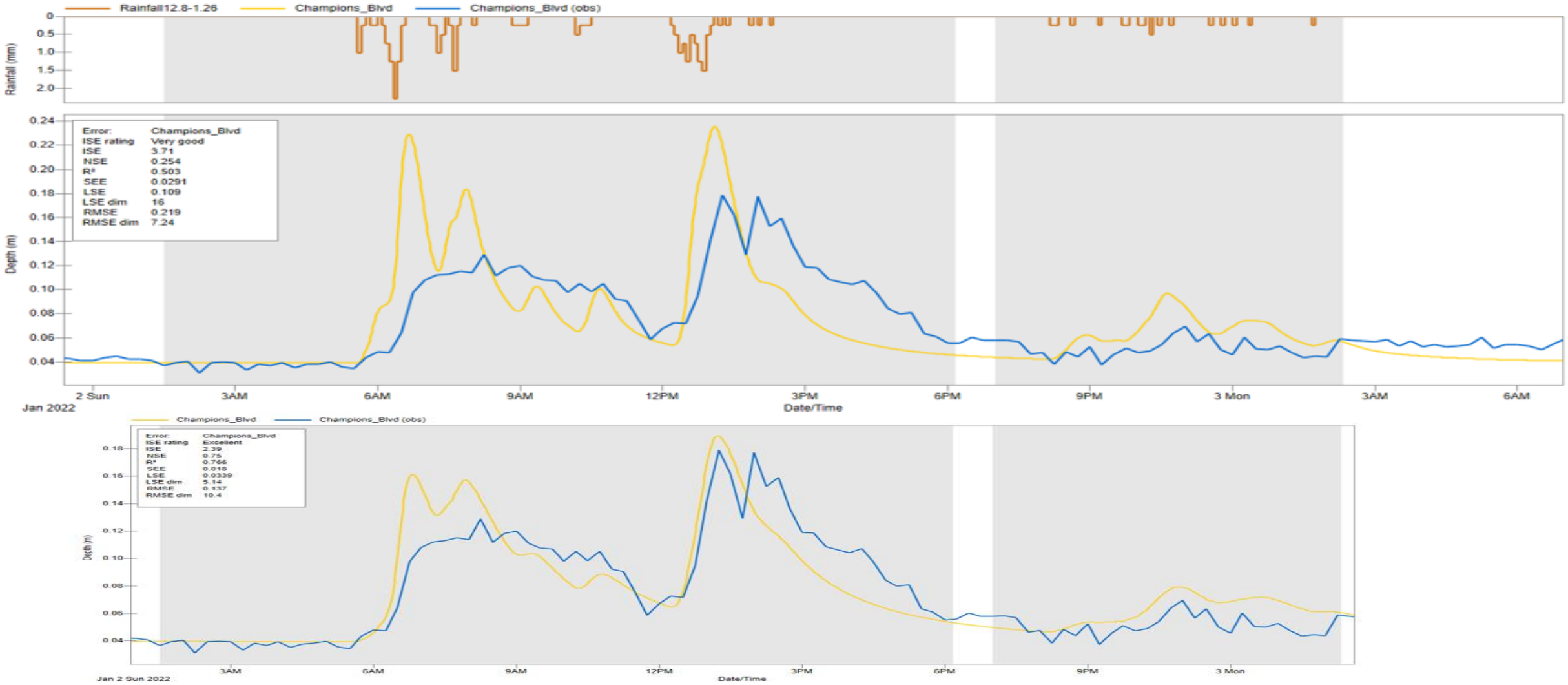
Results – Hamilton Rd. Hydrographs, Cut-off at CN=90 (top) vs. Fully Composite



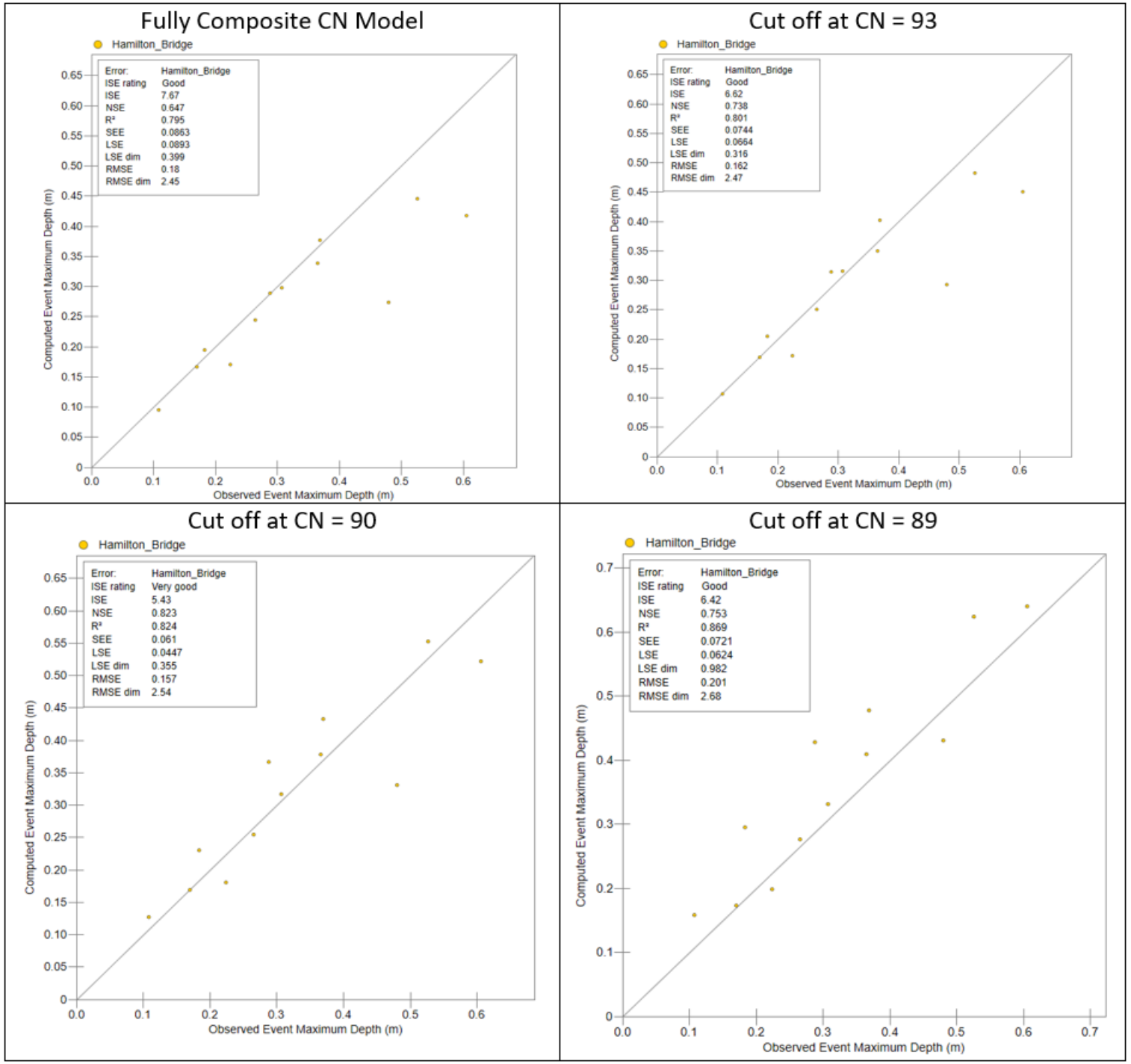
Results – Champions Blvd. Hydrographs, Cut-off at CN=90



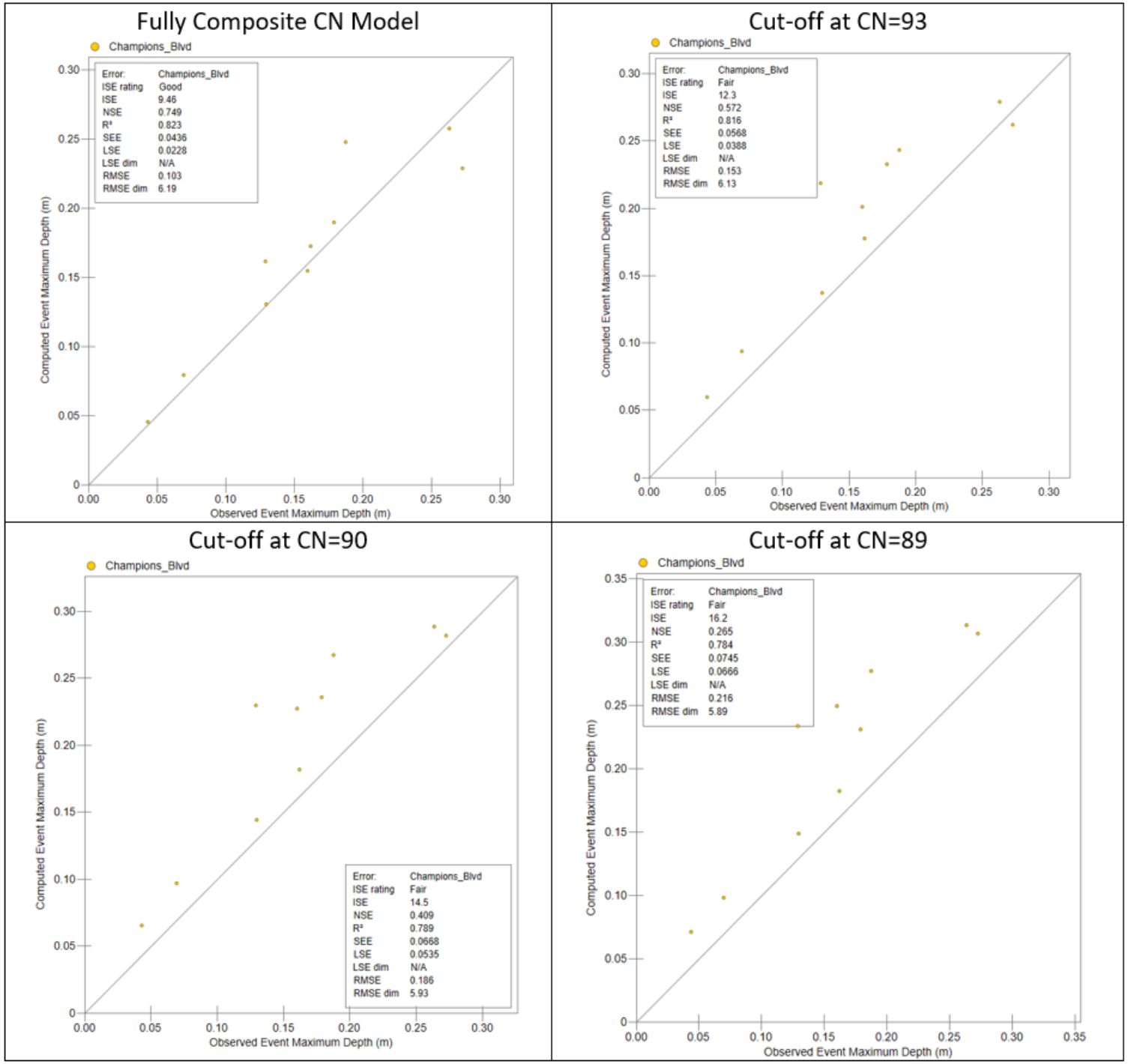
Results – Champions Blvd. Hydrographs, Cut-off at CN=90 (top) vs. Fully Composite



Modeling results: Peak flow depths at Hamilton Rd.



Modeling results: Peak flow depths at Champions Blvd.



Comparing SWMM 5 results with WinTR-55

WinTR-55 Small Watershed Hydrology

Project Identification Data

User: HX | State: Alabama

Project: Moore's Mill | County: Lee

Subtitle: test | Execution Date: 9/16/2022

Sub-areas are expressed in:
- ○ Hectares
- ◉ Square Kilometers

Dimensionless Unit Hydrograph: <standard>

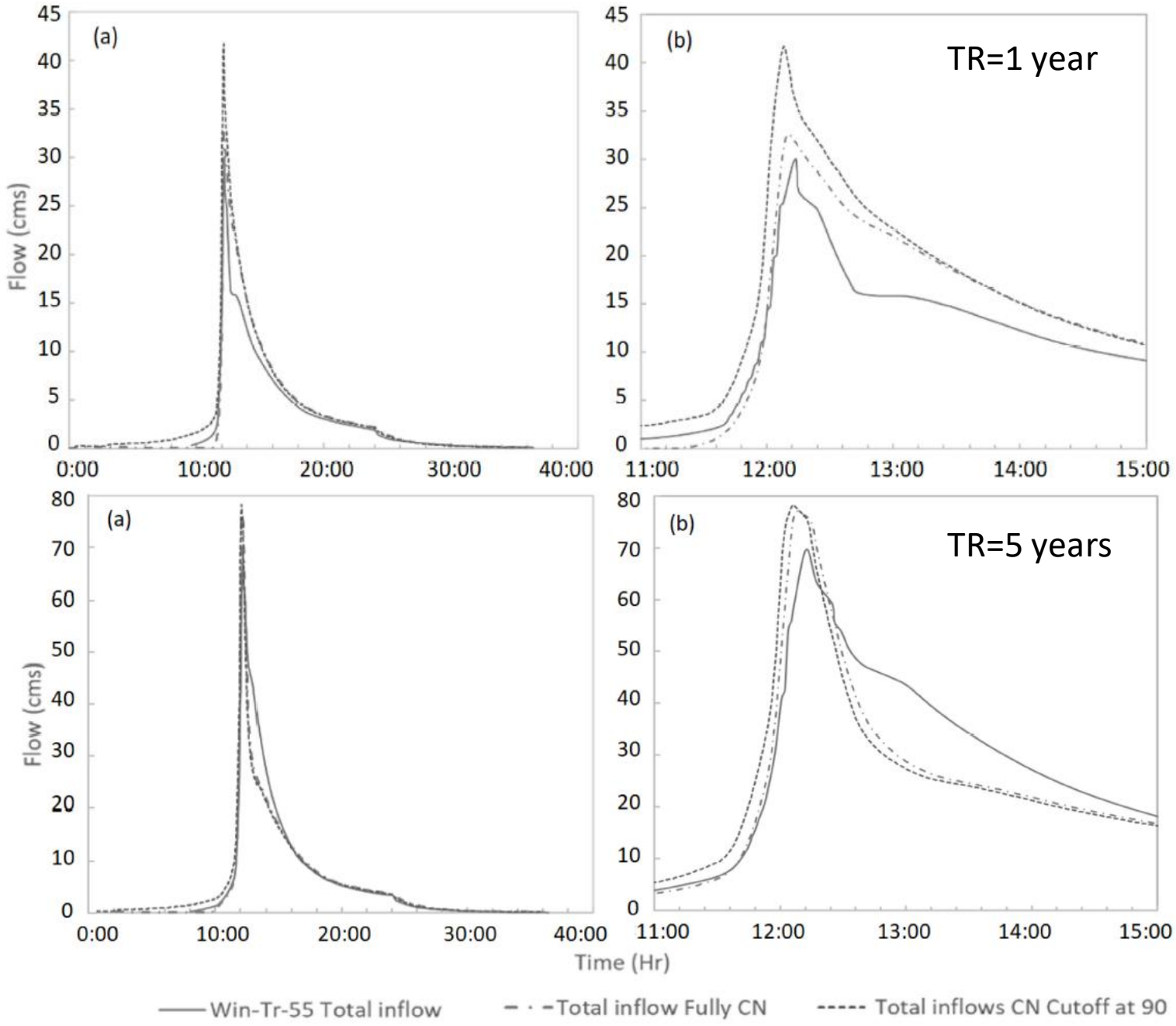
Storm Data Source: Lee County, AL (NRCS)

Rainfall Distribution Identifier: Type III

Sub-area Entry and Summary

Sub-area Name	Sub-area Description	Sub-area Flows to Reach/Outlet	Area (km²)	Weighted CN	Tc (hr)
S1	Capps Way	Reach 1	1.57	71	0.172
S2	Tigertown	Reach6	0.79	87	0.100
S3	Hamilton Road	Reach 2	1.62	63	0.166
S4	Hamiton Lake	Reach3	1.47	75	0.167
S5	Bent Creek Road	Reach4	0.59	70	0.162
S6	Champions Blvd & Outlet	Outlet	1.07	59	0.151
S7	Lakeshore Drive	Reach7	0.61	70	0.159
S8	Creek Nation Dr	Reach8	0.75	65	0.159
S9	Sam's Club	Reach9	0.35	87	0.100
S10	Auburn Airport	Reach10	1.92	83	0.178

Project Area: 10.74 (km²)



Discussion and Final Remarks

- Fully-composite model peak depth results are smaller than cut-off, and this increases with the level of cut-off
  - CN averaging with larger CN does not make-up for the impervious fraction for extended-period simulations
- Cut-off performed better with subcatchments with lower average CN
- WinTR-55 yield lower peaks flows than SWMM5 for comparable conditions, but difference decreases for larger TR.
- Fully composite approach worked better in the tributary with largest average CN, flashier and short drawdown period.

Acknowledgement

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Thank you!

Questions?

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