Integrated Modeling and Drainage Design of a Post-development Ravine Catchment in Lake Park, MKE

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Project Objectives

A catchment, defined as a site where water is collected to one outlet, can be time-intensive to study and design adequate drainage infrastructure for, due to the complexity of its water-conveying response to storm events. Conventional drainage infrastructure such as manholes, grates and pipes, and unconventional drainage infrastructure such as natural conveyance pools and bioswales require inputs within the catchment to be adequately designed, with a sum of outputs that meet certain water quality and peak outlet flow criteria for storm events with varying intensities.

An integrated modeling approach helps to connect the many inputs and outputs for greater accuracy. As a result, this design project set out to study and apply this modeling approach to:

i. Quantify the peak hydraulic response of a developed, urban catchment
ii. Understand the effects of manmade and natural structures, topography, and surface characteristics on this response
iii. Design drainage infrastructure to reduce this peak hydraulic response, or runoff rate (assuming the site is redeveloped), to at least 10% less than pre-development peak runoff rates for the 2-year and 100-year storm events (City of Milwaukee, 2021)

Modeling Methodology

Topographic Modeling

(1) defining a catchment and (2) subcatchments respective to existing drainage structures, and (3) integrating a digital elevation model (DEM) as an independent variable for catchment and drainage structure response

Existing/Design Conveyance and Drainage Modeling

Representing as model entities for analysis and design:
- Road surface conveyance
- Ravine natural channel conveyance
- Surface-subsurface exchange
- Land use overland flow
- Existing subsurface infrastructure

Design Modelling

Using the connected flow outputs from existing topography and structures as inputs to proposed design object entities, with the ability to quantify the effect of designs on the overall output of the catchment as a peak discharge for the storm events studied

Design Response

- Minimum discharges were obtained for pre-settlement, maximum discharges for post-development, and a greater than 10% reduction was obtained for the post-development with the green infrastructure (GI) model
- Green infrastructure consisted of nine cascading swale sections of 10'-by-100' and a 4% slope along the road that naturally conveyed and infiltrated run-off to reduce peak discharges. Peak Discharge Results can be seen below in Figure 1.
- Instability in the tail-end of the GI model requires further investigation

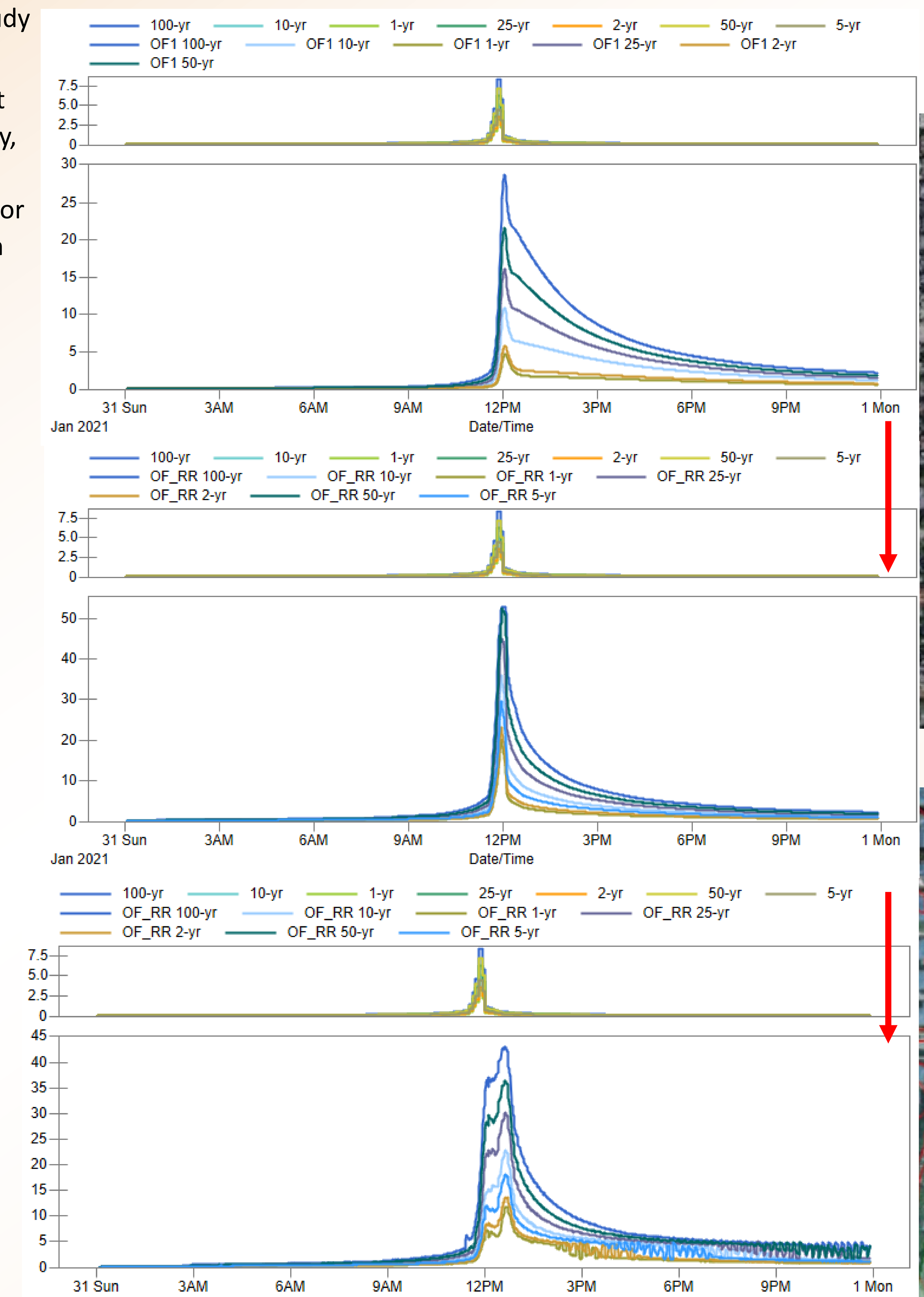

Figure 1: Discharge-time curves (Hydrographs) for the catchment outfall pre-settlement (top), post-development (middle), and post-development after GI Infrastructure (bottom) during various 24-hr design storms

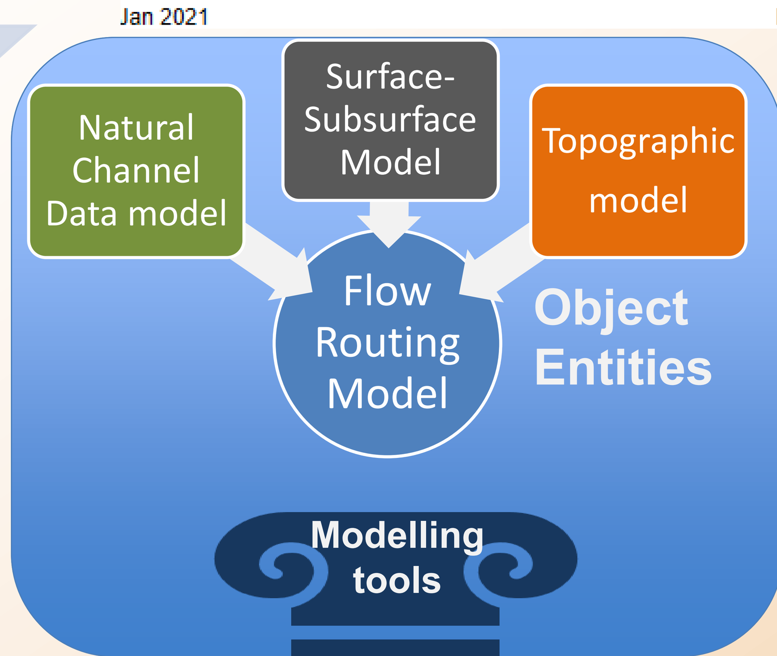

Figure 2: Integrated modelling method

Broader Implications

- The integrative modelling methodology employed in this project can serve as a general framework for catchment drainage design. Bringing topographic and infrastructure elements to interact together
- Parameter calibration can make or break a model and the extent of its effectiveness
- More accurate entity responses which refine existing storage and rating curves reflecting friction loss and field conditions would make the model more accurate and robust to changes

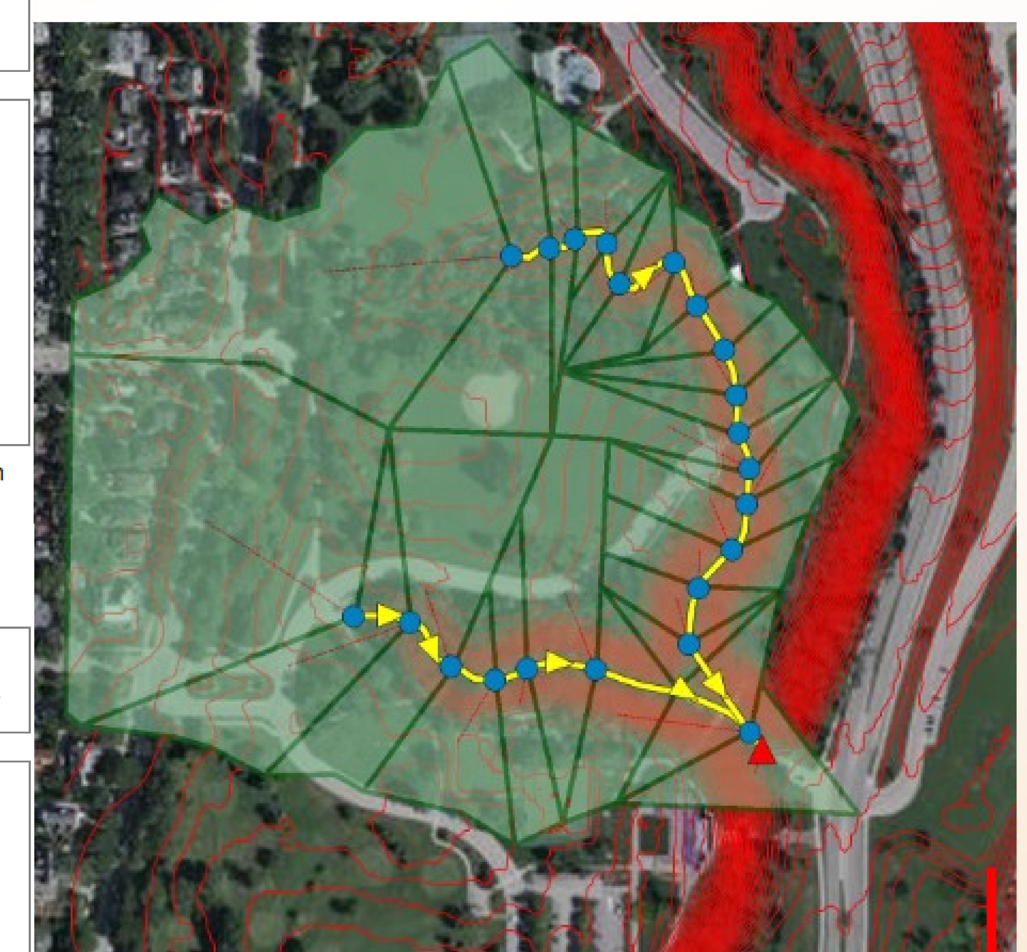

Figure 3: Pre-development Model

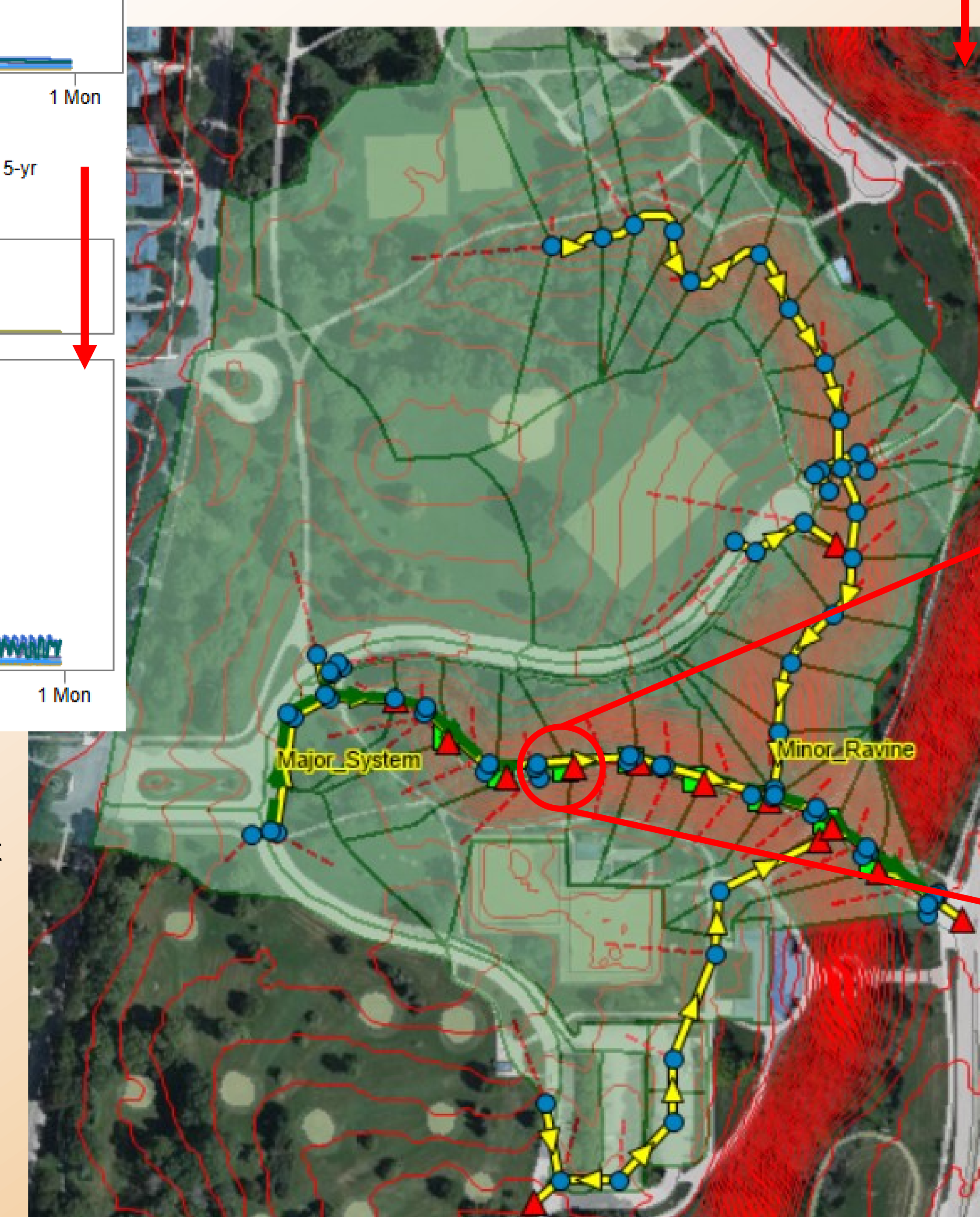

Figure 4: Post-development model with green infrastructure

References

City of Milwaukee. (2021). SWMP FAQs. https://city.milwaukee.gov/SWMP/Management-Plans/FAQ

Acknowledgements

Special thanks to Computational Hydraulics International (CHI) for generously providing their powerful modelling software, PCSWMM for educational use, to Randy Videkovich, Project Mentor Jake Brunoehler, Michael Brill of MKE County, and the CEE faculty and Industry mentors for their helpful advice and support

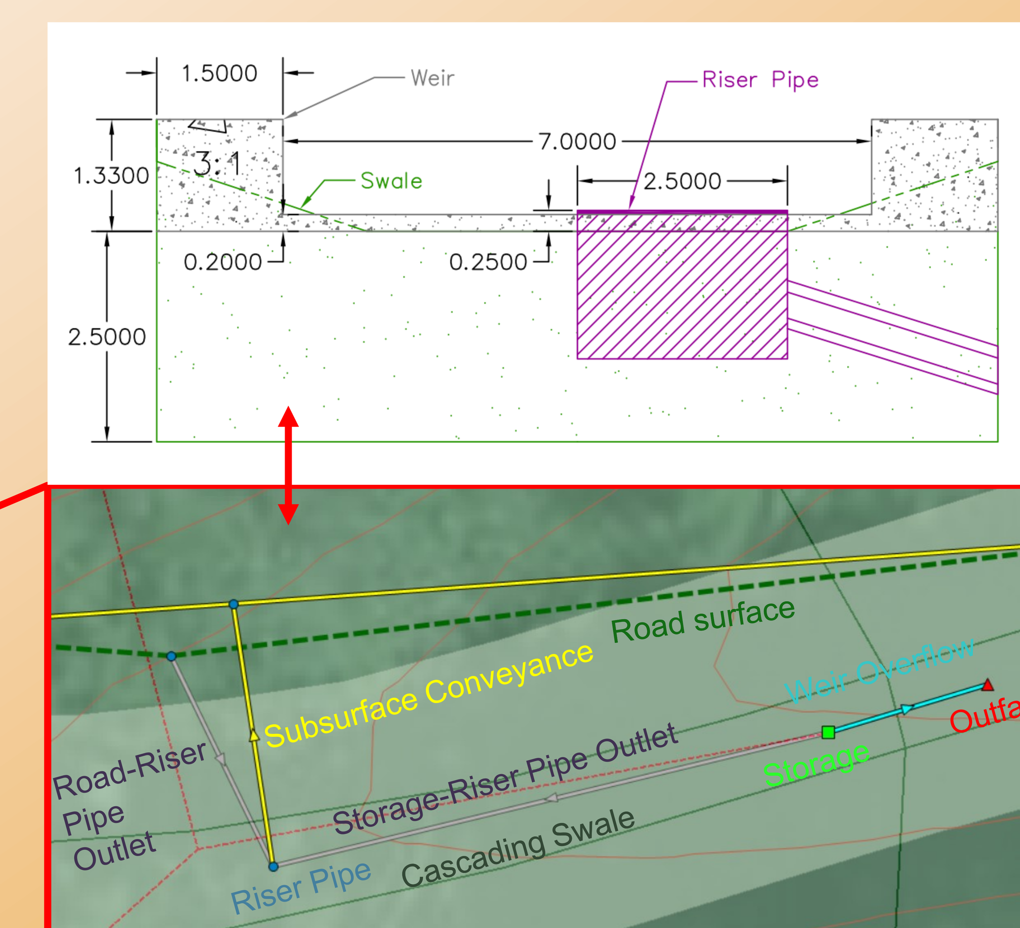

Figure 5: Green infrastructure (cascading swale) object entities to reduce peak discharge

Run-off first gathers in the storage node. When the storage node is filled to the weir depth, run-off cascades through the weir to the next swale using an outfall. If the node is filled to the greater depth of the riser-pipe, it enters the sub-surface drainage system. If the sub-surface drainage system is full, it will flood to the roadway through the road-riser pipe outlet.