HydroGeoSphere Model Development and Wetland Sensitivity Testing for the Washington Creek Watershed in Southern Ontario

Final Report

April 15, 2026

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1.0 INTRODUCTION AND OBJECTIVES

The Washington Creek watershed in southern Ontario, encompassing approximately 19.5 km², is a predominantly agricultural landscape. Wetlands within the watershed are thought to play a critical role in its hydrologic behavior; however, questions remain regarding their current and potential future effectiveness. Accordingly, the present study develops and applies a fully integrated surface water–groundwater model to quantify watershed-scale hydrologic behavior and the sensitivity of stream flow to wetland extent. The model employed is HydroGeoSphere (HGS), a physics-based, fully integrated groundwater–surface water model that captures the dynamic exchange of water between surface and subsurface domains, as well as overland flow and channel flow. HGS is particularly well suited to evaluating the hydrologic influence of wetlands.

The primary objectives of the study are to:

1. Develop a high resolution HGS model of the Washington Creek watershed that accurately reproduces transient streamflow rates and wetland water levels.
2. Assess the influence of wetland expansion on transient hydrologic behavior over an annual cycle, including baseflow and event-scale peak flow.
3. Quantify the hydrologic sensitivity to wetland areal extent under design storm conditions.
4. Provide science-based evidence to guide watershed management and flood-risk mitigation through wetland utilization.

2.0 STUDY AREA

Washington Creek is a sub-watershed within Southern Ontario (Figure 1) with an area of 19.5 km^2. Situated to the west of Kitchener, it flows into the Nith River, then the Grand River, and ultimately Lake Erie. Agriculture dominates the land use in Washington Creek, with approximately 80% of its area dedicated to agricultural production. The remaining land is primarily composed of forests and wetlands, some of which are strategically designed and maintained for flood attenuation. The wetlands are thought to play a crucial role in managing water flow, reducing the flood risk associated with heavy rainfall and snowmelt, and providing a natural buffer against drought risk.

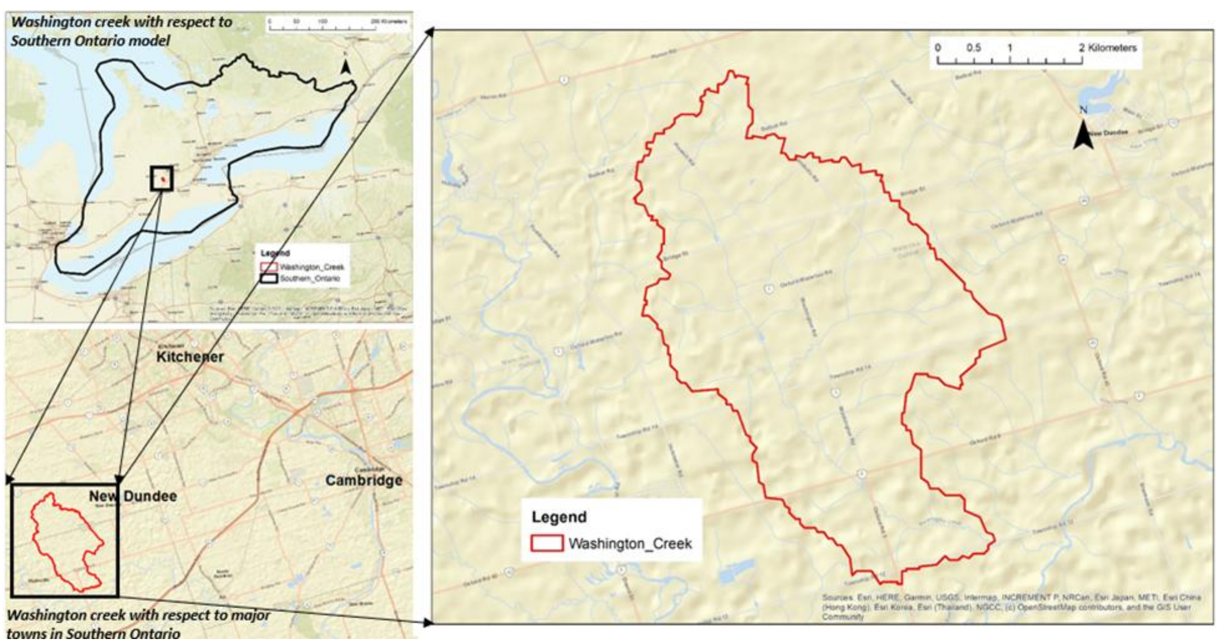

Figure 1. *Washington Creek watershed within Southern Ontario, and Washington Creek watershed with respect to neighboring cities.*

3.0 MODEL DEVELOPMENT

3.1 HydroGeoSphere

The HydroGeoSphere (HGS) fully integrated surface water-groundwater model was employed for the study herein. For a detailed technical description of HGS, interested readers are referred to Aquanty (2024), while only a brief overview of the HGS features relevant to this study is provided here. For water flow, HGS utilizes a globally implicit control volume finite difference approach with adaptive time stepping and OpenMP parallelization (Hwang et al., 2015) to solve a coupled set of equations based on the three-dimensional Richards' equation for variably saturated subsurface flow, the two-dimensional diffusion wave equation for surface flow, and the Manning's one-dimensional open channel flow equation for channel flow. The exchange of water between the surface and subsurface domains occurs seamlessly in response to pressure gradients that vary in response to climate and hydrologic conditions. Evapotranspiration processes in HGS consider climate conditions, time-varying plant root growth and leaf area index, spatially varying land cover, and surface and subsurface moisture availability (Kristensen & Jensen, 1975). For the representation of sub-mesh scale topographic detail, such as small wetlands and prairie potholes, HGS utilizes an element-based spatially varying rill storage formulation to equate wetland storage into an equivalent element-based surface water depth, which acts as an exceedance threshold required for the initiation of overland flow. Readers are referred to (Frey et al., 2021) for a detailed description of the HGS formulation used in this study.

3.2 Finite Element Mesh

AlgoMesh (HydroAlgorithmics, 2016) was used to generate the unstructured finite element mesh (FEM). The unstructured mesh allows scaling of detail to focus model resolution on areas of importance or hydrologic significance. The model was designed with 30 m spatial resolution along the surface water channels and roadways, and up to 50 m spatial resolution in areas distal to channels (Figure 2). There are 46,625 total nodes per mesh sheet (a total of 466,250 nodes spanning across the 10 vertical sheets) and 91,929 total triangular elements per layer (a total of 827,361 triangular elements across the 9-layer subsurface model domain).

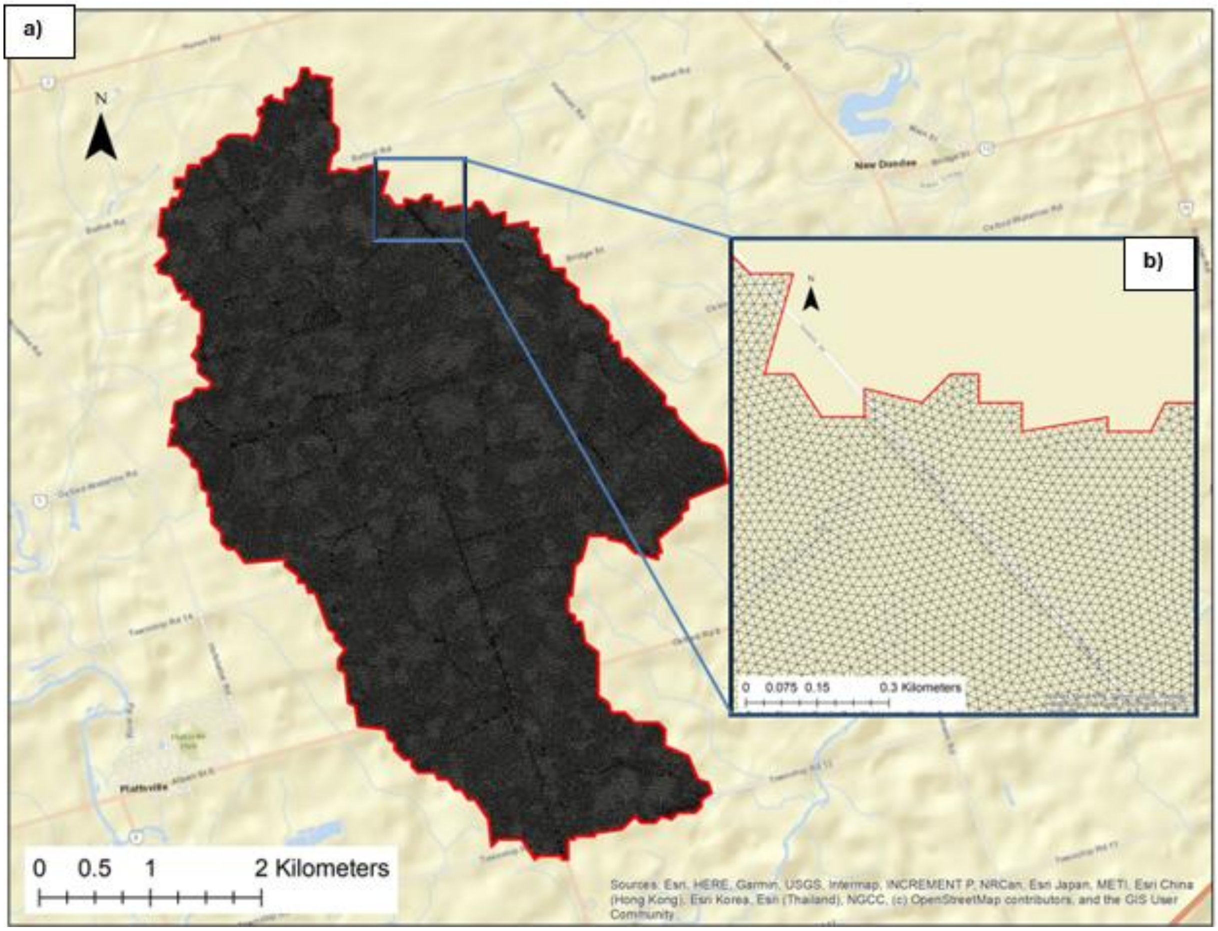

Figure 2*. a) The Washington Creek sub-watershed with complete finite element mesh, b) A magnified portion of the finite element mesh.*

3.3 Digital Elevation Model

A Digital Terrain model (DTM) derived from the Ontario Digital Terrain Model (Lidar-Derived) raster dataset, representing the bare-earth terrain derived from classified lidar point cloud, was used. This DTM has a resolution of 0.5 m and was used to define the surface topography of the model (Figure 3). The DTM was not subjected to a stream burning procedure, as all elevation adjustments were made directly to the nodal coordinates.

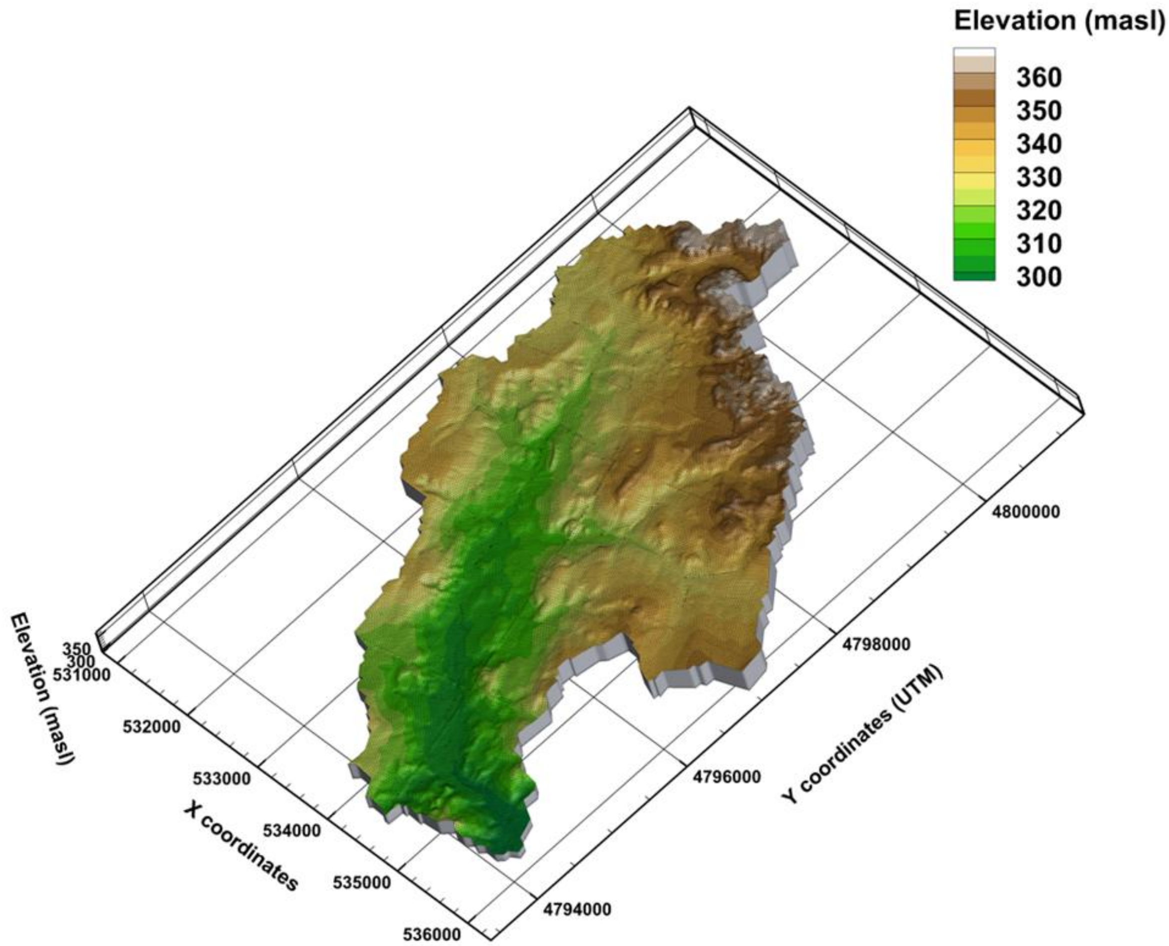

Figure 3. *Three-dimensional representation of the Washington Creek sub-watershed HydroGeoSphere model, with the digital terrain model rendered onto the top surface.*

3.4 Surface Water and Road Network

Within the mesh there are approximately 33.5 km of one-dimensional surface water channels (Figure 4) derived from multiple sources, namely Ontario Integrated Hydrology (OIH) (Figure 4a), Natural Resources Canada ("Natural Resources Canada," 2016), (Figure 4b), and Grand River Conservation Authority (GRCA) (Figure 4c). Figure 4d shows the final combination of the stream networks along with manual additions based on aerial imagery. For each segment, the Manning's *n* friction coefficient for all channels was initially set to a default value of 0.04, and then adjusted during the model calibration stage. Down-gradient flow was enforced along the channels using elevation controls on FEM nodes coincident with channel locations. The Road network for the watershed was derived from the Ontario Road Network (ORN) and overlain with the final stream network (Figure 4e).

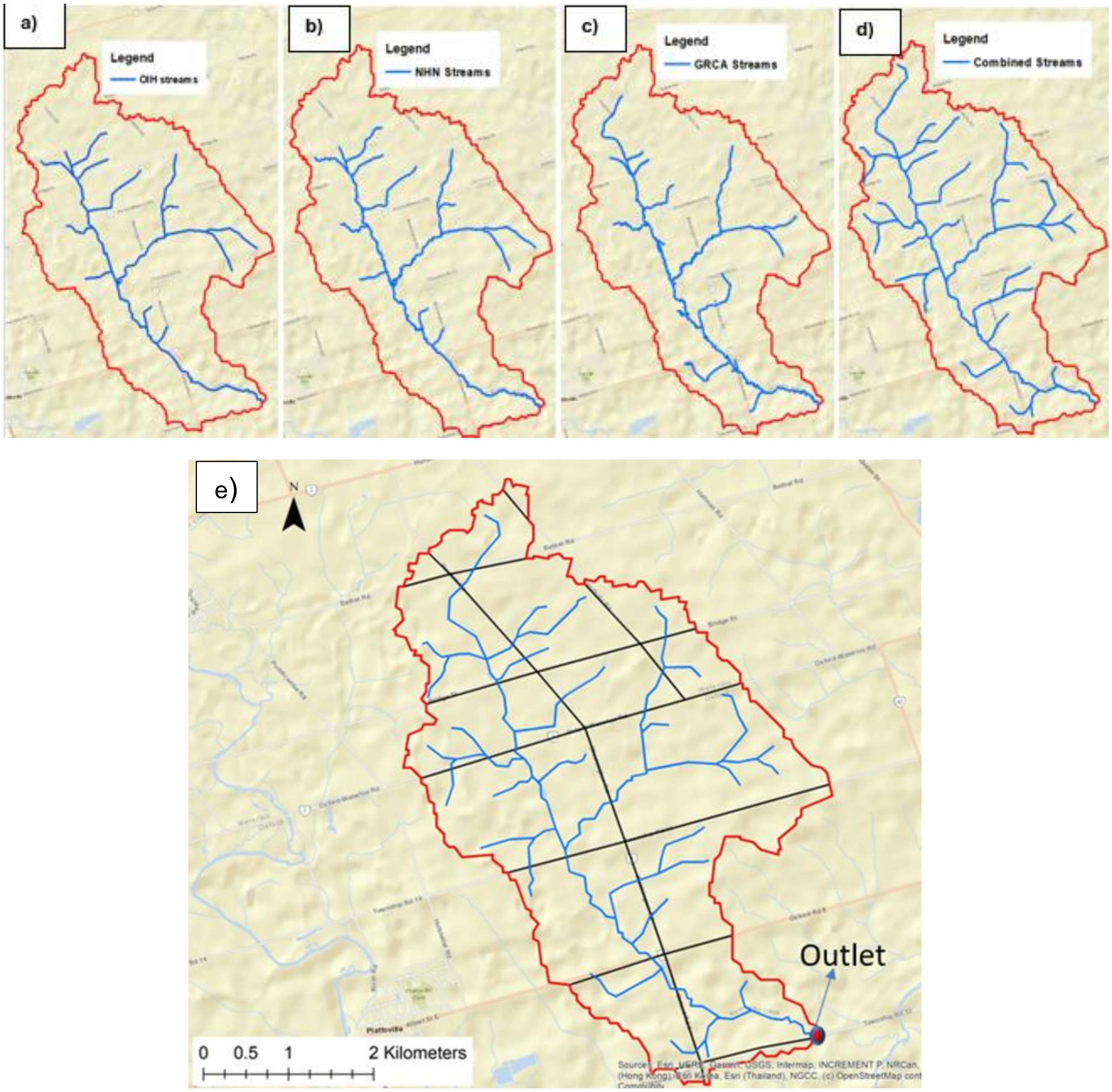

Figure 4. *Stream network from (a) Ontario Integrated Hydrology, (b) Natural Resource Canada, (c) Grand River Conservation Authority, (d) Combination of all streams (left to right), and (e) final stream and road network used in the HGS model.*

3.5 Landcover

The base-case spatially distributed land cover was used as provided by Ducks Unlimited Canada (DUC) from the Southern Ontario Land Resource Information System (SOLARIS) (Figure 5). The SOLARIS v1.0 landcover that was mapped into HGS carried 15 m resolution, and was originally developed in three phases: 1) Provincial base data compilation/updating, where all the relevant base data layers (water, wetlands, woodlands, Ontario Road Network are evaluated, 2) modelling analysis, and 3) accuracy assessment (Landry, 2019). The HGS simulations conducted with the base-case landcover served as the benchmark to which the scenarios were compared.

3.5.1 Landcover and Wetland Representation

When ingesting landcover, HGS reads the value of pixels from the raster file and assigns overland flow and evapotranspiration parameters based on the associated land cover class. These parameters include transpiration limiting pressure heads (wilting point, field capacity, oxic limit, and anoxic limit), Leaf Area Index (LAI), a time-varying root density function (RDF), and evaporation limiting factors (evaporation depth, canopy evaporation). Root depth was derived from (Canadell et al., 1996), while LAI was derived from MODIS imagery (Myneni et al., 2015). For all landcover classes, evaporation depth was set to 0.2 m, meaning that water in the top 0.2 m of the soil profile would be able to evaporate.

Wetland representation in the model was controlled with evapotranspiration, flow resistance (friction) parameterization, as well as surface water holding capacity. When finite elements within the model grid were assigned as a wetland land class, as part of the scenario testing, the parameters associated with that element were changed accordingly. Specifically for wetlands, the Manning's friction coefficient was set to 0.15 (for reference, the value for crops is 0.04) and the surface water holding capacity was set to 0.40 m, which effectively means that a water depth of 0.40 m must be reached before downstream or downgradient flows can occur.

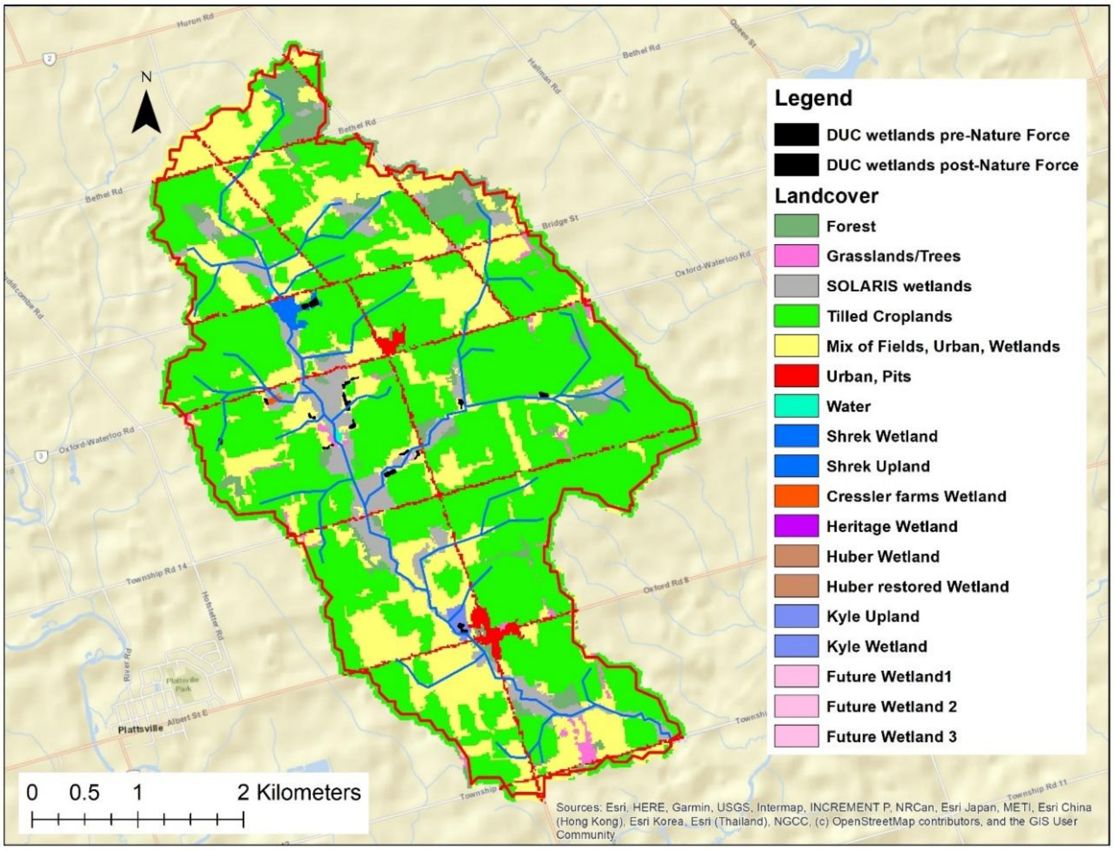

Figure 5. *SOLARIS landcover for the Washington Creek watershed with additional Ducks Unlimited Canada wetlands burned in.*

3.6 Soil

Spatially distributed soil property information was derived from the Agriculture and Agri-Food Canada – Agriculture Canada (AAFC) Detailed Soil Survey of Canada (DSS) (Agriculture and Agri-Food Canada, 2010), which defines 16 different soil types across the watershed (Figure 6). In the model, soil layers were defined at 0.25, 0.5, and 1 m depths. Hydraulic properties for each DSS polygon were unique for each of the three soil layers, and were estimated by inputting sand, silt, and clay percentages, bulk density, and moisture retention information for KP33 and KP1500 tensions to the Rosetta pedotransfer function model (Schaap et al., 2001). The Rosetta function then generated estimates for residual and saturated water content (θr, θs), the van Genuchten α and n parameters, and saturated hydraulic conductivity (Ks), hydraulic parameters required by HGS.

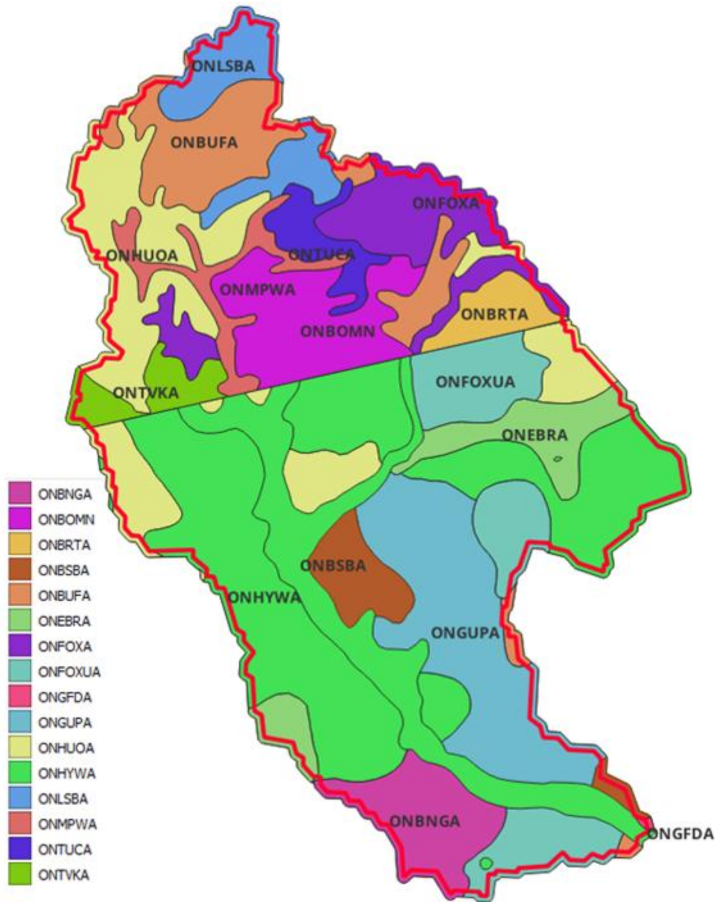

Figure 6. Soil mapping based on the Detailed Soil Survey (DSS), with soil polygons representing a soil type from the DSS database.

3.7 Hydrostratigraphy

The hydrostratigraphy in the Washington Creek model follows the configuration used in the Southern Ontario regional HGS model (Frey et al., 2019) that was based off regional three-dimensional Paleozoic and Quaternary geological models. However, for Washington Creek the hydrostratigraphy is simplified to include only the nine uppermost hydrostratigraphic layers as compared the Southern Ontario model's 21 layers. This simplification was made because the deep regional groundwater flow system will have minimal impact on local wetland, stream, and shallow groundwater conditions in Washington Creek. It is the shallow hydrostratigraphy that controls hydrologic behavior relevant to this study.

The model subsurface can be effectively divided into 3 components that represent soil, surficial, and bedrock hydrostratigraphy. Surficial hydrostratigraphy in the Southern Ontario model was derived from a 9-layer surficial geology model (Logan et al., 2020; Frey et al., 2019) that was modified at the top and bottom to conform to the respective topographic surface and the top of the bedrock surface. The surficial hydrostratigraphy was reduced to five layers that can be broadly characterized from top to bottom as upper sediment/aquifer, upper aquitard, upper aquifer, mid aquifer, and lower deposits. Hydraulic properties for the surficial hydrostratigraphy were derived from textural information associated with the borehole data used to construct the surficial geology model, such that each hydrostratigraphic layer has unique lithology distribution within it. The bedrock layers are derived from Carter et al., 2019, and effectively act as a basal aquitard at bottom of the models hydrostratigraphic sequence. The arrangement of the zones and layers between each sheet in the model is presented graphically in Figure 7.

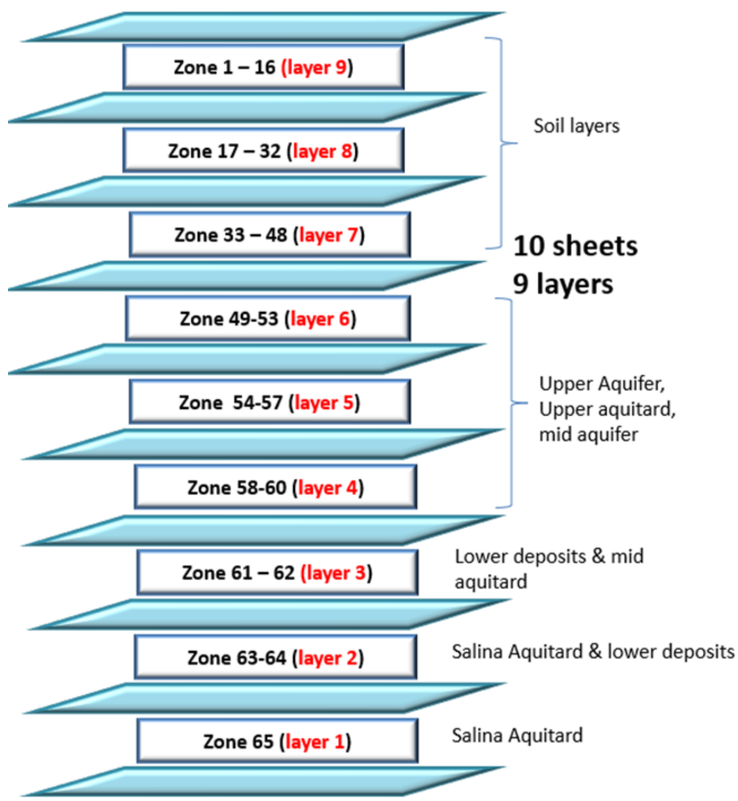

Figure 7. *Diagrammatic representation of the zonation and vertical arrangement of soil, surficial, and bedrock layers in the Washington Creek HydroGeoSphere model.*

3.8 Boundary Conditions

A specified flux (Neumann) boundary condition was used on the top surface of the model to represent liquid water flux (rainfall and snowmelt), and potential evapotranspiration. Groundwater recharge and discharge is computed internally by HGS, and unlike common groundwater flow models, does not get prescribed as a boundary condition. A critical depth boundary condition was applied to the surface nodes around the model perimeter to allow surface water outflow from the domain.

The perimeter of the subsurface porous media domain and the base of the model were considered no-flow boundary conditions.

3.9 Hydrometric Stations

Four stream flow monitoring stations and four wetland water level observation points were provided by DUC and included in the model, the locations of which are shown in Figure 8. Additional hydrometric stations were also added in reaches downstream of future proposed wetlands in order to help understand the influence of proposed wetlands on hydrologic behavior.

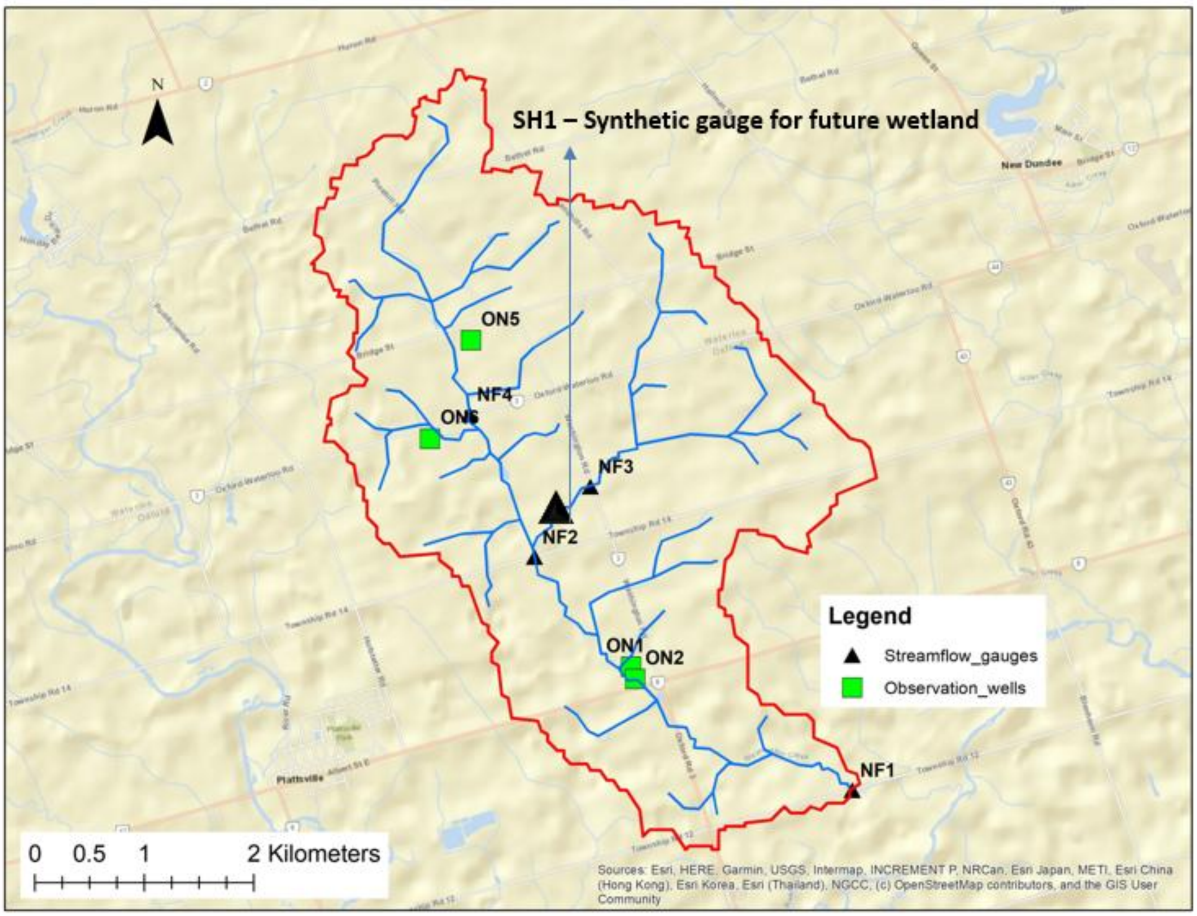

Figure 8. *Streamflow and groundwater observation stations added in the model. NF stations represent surface water flow monitoring and ON stations represent wetland water level monitoring. NF1 is located at the watershed outlet and was the only flow monitoring location with continuous data collection.*

3.10 Climate Forcing Data

The daily transient liquid water flux (LWF) required as forcing data for HGS was calculated using total precipitation data from the nearest Grand River Conservation

Authority (GRCA) meteorological stations located at Laurel Creek and Baden (12.7 km and 6.3 km from Washington Creek, respectively), with missing periods backfilled with Canadian Precipitation Analysis (CaPA). Snow Data Assimilation System (SnoDAS) data was used for snowpack snow water equivalent estimation and was validated against GRCA snow pillow data collected outside the Washington Creek watershed. To calculate the daily potential evapotranspiration (PET) forcing data for HGS, climate variables available from the GRCA meteorological stations were used as input to the Hargreaves PET calculation method. To further improve PET estimates, meteorological data from the University of Waterloo meteorological station (located 13 km from Washington Creek), which includes all the climate variables required to compute PET according to Penman Monteith (FAO 56), was used to calculate both Penman Monteith and Hargreaves PET. A bias analysis was then performed to test for differences between Penman Monteith PET and Hargreaves PET. Scaling, based on the bias analysis, was then used on the GRCA station-based Hargreaves PET data to bring it in line with what would be expected from a Penman Monteith calculation. This bias corrected Hargreaves PET was then used as HGS forcing.

3.11 Model Spin-Up

In order to initialize the model for daily transient simulations, a steady state simulation with an average precipitation value of 45 mm/y was run for a period of 1000 years at which point the model reached steady state. The steady state condition was then used as the initial condition for subsequent monthly normal simulations. Monthly normal simulations were conducted for sequential 10-year cycles until year-over-year stability was achieved and the model reached a quasi-equilibrium state. Using the quasi-equilibrium as an initial condition, daily transient simulations for the 2019 - 2024 time interval were conducted.

3.12 Model Calibration

Model calibration was performed by adjusting hydrological parameters to improve simulation performance. Specifically, the Manning’s roughness coefficient, rill storage capacity, and soil hydraulic conductivity values were systematically refined to optimize the model’s ability to reproduce observed hydrological conditions. Streamflow observations and wetland water level records provided by DUC, available from mid-2023 to mid-2024, were used as calibration targets.

Figure 9 shows comparisons of simulated streamflow (solid line) against observed data (red symbols) at four monitoring sites (NF1–NF4), while the dashed lines represent observed flows modelled using a rating curve derived from discrete field measurements in order to provide a continuous reference to compare the model against. Station NF1 was the only location where continuous data was logged, and hence was the focus of model calibration. At NF1 the model was able to reproduce stream flow with good accuracy, with a root mean square error of 0.08 m^3/s; a total bias of 9.2 %; and a Kling-Gupta model efficiency coefficient of 0.63, where a value of 1 indicates a perfect match and a value of -0.41 indicates a model with predictive capability equal to the mean of the observed data (Knoben et al., 2019). The continuous observation time series at NF2, NF3, and NF4 are all rating curve outputs and are presented here for visual comparison purposes. Overall, the results indicate the model can capture the general temporal variability and magnitude of streamflow conditions at all four sites, and at the location with continuous flow logging, the statistical performance of the model is satisfactory.

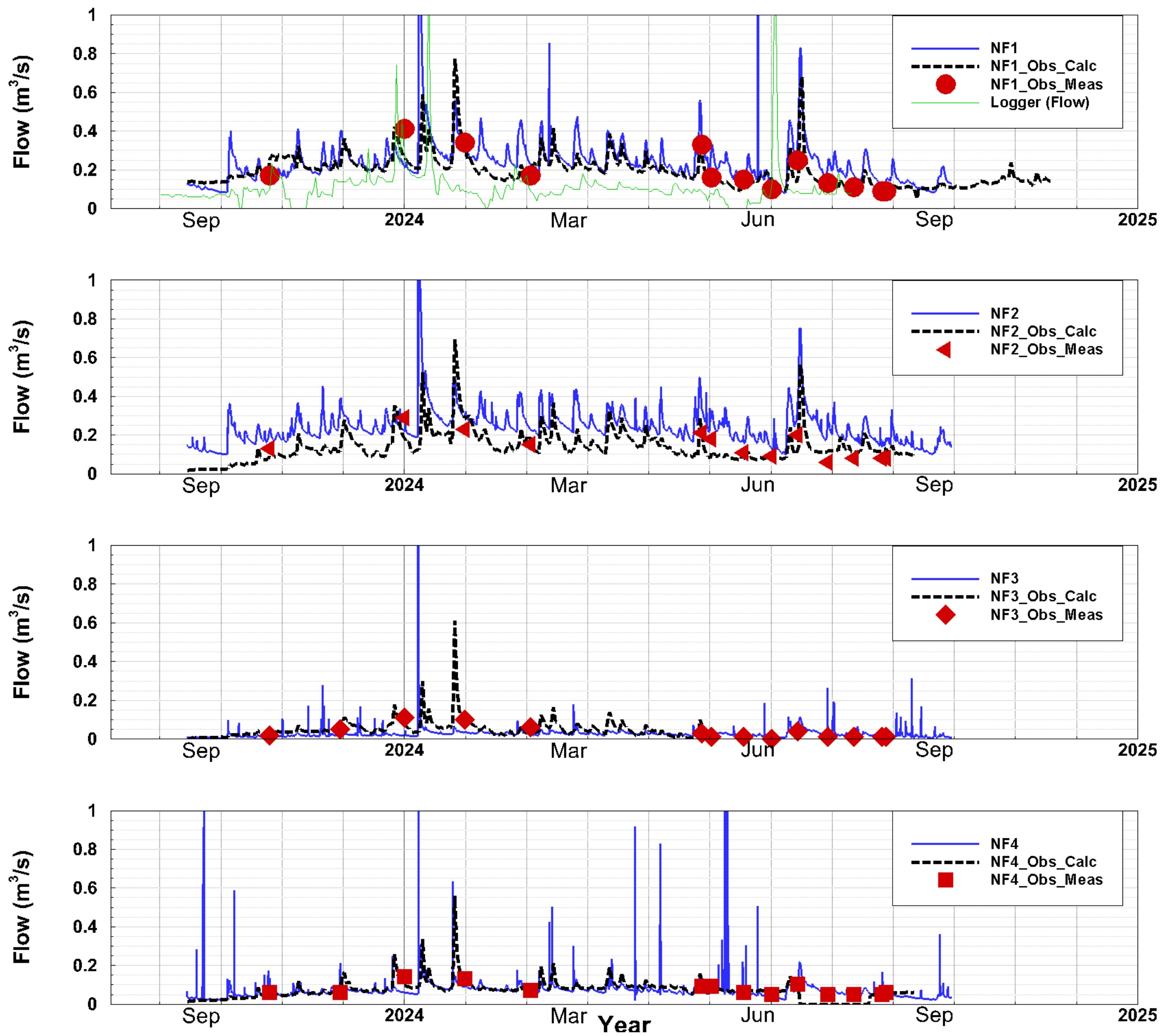

Figure 9. *Comparison of simulated (solid blue line) and observed (or rating curve based) streamflow at monitoring stations NF1–NF4. Red markers represent discrete observed measurements, while dashed lines show interpolated observed flows derived from field data.*

Comparison between simulated and observed wetland water levels are presented in Figure 10 for the four monitored wetlands, ON1, ON2, ON5, and ON6 (Figure 8). These results demonstrate the model is able to reproduce the long-term average water levels at each monitored wetland very well, with simulated values remaining within a few centimeters of the corresponding observed records.

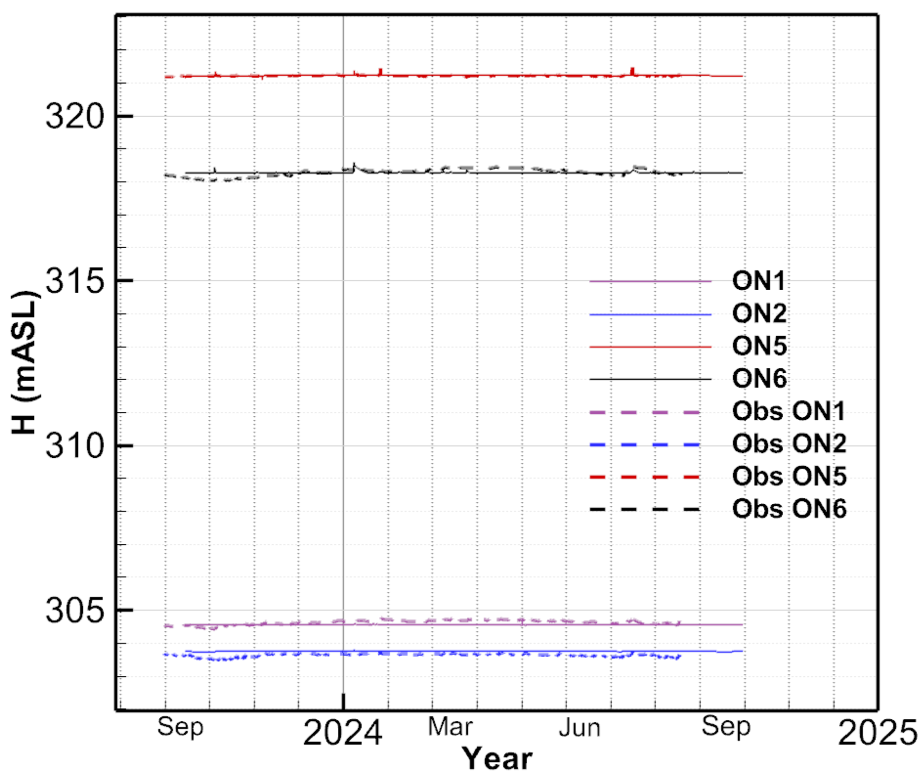

Figure 10. *Comparison of simulated (solid line) and observed (dashed line) water levels (total head, H, meters above sea level) at wetland monitoring stations ON1, ON2, ON5, and ON6.*

A scatter plot comparison between simulated and observed average water levels at stations ON1, ON2, ON5, and ON6 is presented in Figure 11, and further demonstrates excellent model performance. The points align closely with the 1:1 line, indicating that simulated values are nearly identical to observed measurements across the monitoring sites. The coefficient of determination ($R^2 = 0.99$) further confirms the strong agreement, highlighting the model's ability to reliably reproduce wetland water levels. Because wetland water levels are an expression of the groundwater levels, these results also infer good groundwater simulation performance across the watershed.

Water level simulation results indicate the model captures both the magnitude and variability of water levels with minimal bias, providing confidence in its application for wetland hydrological assessment.

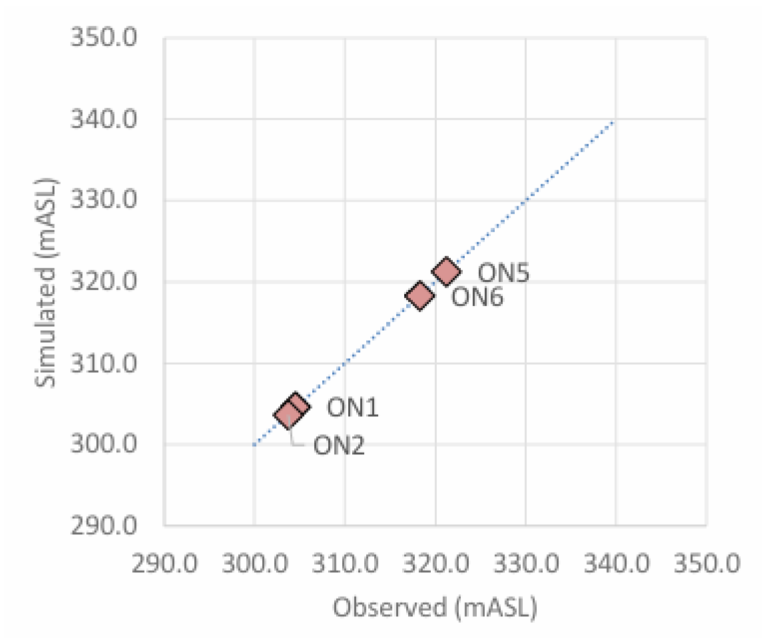

Figure 11. *Simulated vs observed average water levels at wetland monitoring stations ON1, ON2, ON5, and ON6.*

4.0 SCENARIO SIMULATION RESULTS

4.1 Wetland Scenario 1 – Continuous Simulation

The first scenario that DUC provided to Aquanty focused on three wetland complexes on a tributary to Washington Creek that were slated for potential expansion (Figure 12). The total area of these three areas, as added into the model, was 0.070 km^2. Continuous simulations for the 2023 – 2024 time interval were run for the base case (existing conditions) and for the scenario with the three additional wetlands. Using simulated flow conditions at the synthetic gauge SH1 (Figure 8), the hydrologic impact can be assessed at a point immediately downstream from the three added wetlands, as well as for their overall impact on watershed hydrology by looking at flows at NF1, the watershed outlet point.

Flow sensitivity results at SH1 are presented in Figure 13. While actual flow rates are relatively low (ranging from 0.01 to 0.15 m^3/s), the simulated hydrographs show that peak flow rates immediately downstream from the subject wetlands, during large flow events, can decline by approximately 30 – 40 %, however, based on the event which occurred in late July this reduction is not consistently observed because event response is also highly dependent on antecedent conditions. The additional wetlands can also act to increase baseflow conditions, where for example the lowest summer flow at SH1 is approximately 30 % higher in the proposed wetland scenario compared to the base-case (Figure 13).

The impact of these three additional wetlands was not noticeable in the simulated flows at station NF1 located at the watershed outlet. It is important to note that these three wetlands comprise only 0.36 % of the total Washington Creek watershed area.

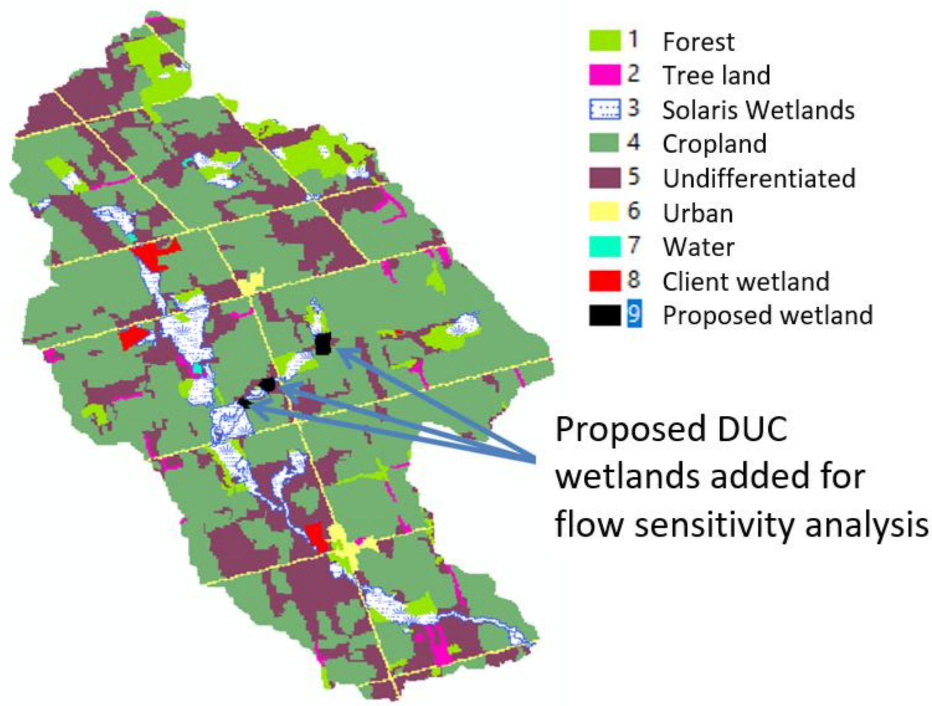

Figure 12. *Wetland scenario considered in the Sc. 1 continuous flow evaluation.*

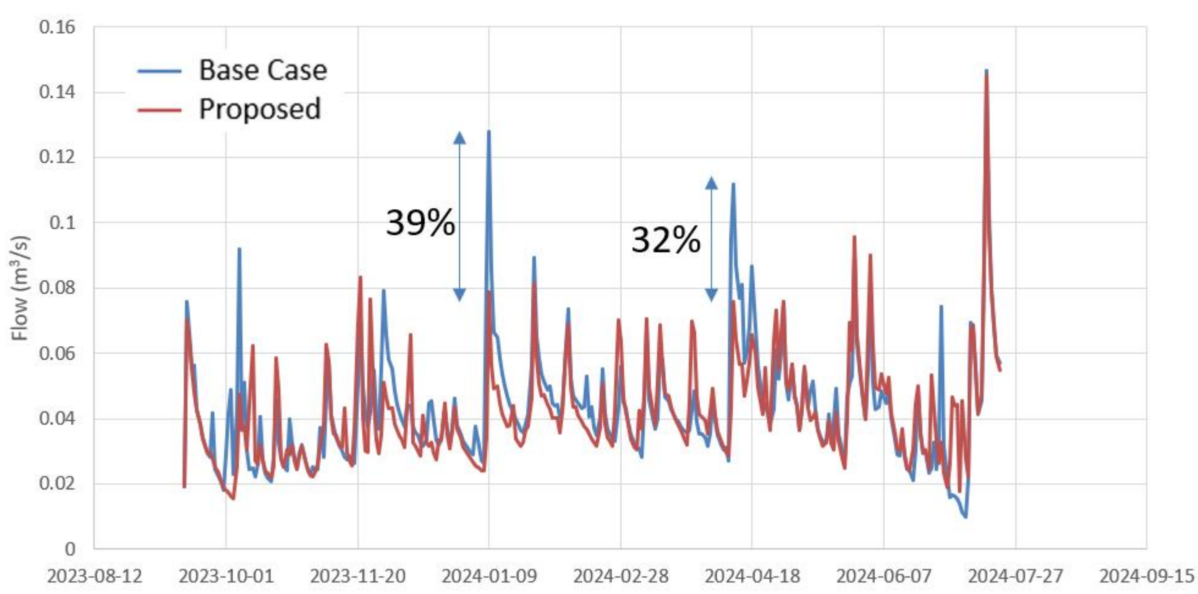

Figure 13. *Simulated stream flow at the SH1 synthetic hydrograph (located immediately downstream of the proposed wetlands) under the base case, and the Sc.1 wetland scenario.*

4.2 Wetland Scenario 2 – Continuous Simulation

For this scenario, continuous simulations covering the 2019–2024 period were conducted for both the base case and the scenario 2 (Sc. 2) wetland modification scenario identified Table 1. This scenario involved systematic adjustments to the wetland water storage capacity within the DUC Pre- and Post-Nature Force wetlands, with incremental increases and decreases of ±10%, ±25%, ±50%, ±75%, and ±100% relative to the base case.

The Nature Force wetlands are in general smaller and more distributed across the watershed as compared to the wetlands in Scenario 1. The total wetland area being tested in this scenario is 0.044 km2 or 0.22 % of the total watershed area (Table 1).

The simulated hydrographs presented in Figure 14 compare the base case with all wetland scenarios at model outlet (Station NF1). Variations in flow among the scenarios are minimal, as the wetland areas represent only a small fraction of the watershed, rendering their hydrological influence negligible within the model's resolution. Correspondingly, Figure 15 illustrates the relative changes in peak flow and base flow compared to the base case. The mean variation is approximately ±0.25%, with no significant trend observed across the wetland storage capacity scenarios.

To adequately capture the potential hydrological effects of these very small wetlands, future work should employ nested models with higher spatial resolution and smaller catchment extents, where the influence of localized wetland dynamics can be more effectively represented.

Table 1. *Land area associated with the different land cover classes and wetland complexes within the Washington Creek watershed. Note that Sc.2 and Sc. 3 represent the two wetland scenarios evaluated, where Sc. 3 represents the assemblage of existing DUC site projects and Sc. 2 represents the Nature Force wetland configuration.*

Landcover	**Area (km^2)**	**Percentage (%)**	**DUC Feature**	**Area (km^2)**	**Percentage (%)**
Forest	0.950	4.87			
Grasslands/Trees	0.186	0.95			
SOLARIS Wetlands	1.204	6.18			
Croplands	11.557	59.27			
Mix	4.785	24.54			
Urban	0.660	3.39			
Water	0.013	0.07			
Shrek wetland	0.006	0.03	Sc.3	0.14	0.74
Shrek Upland	0.066	0.34			
Cressler farms Wetland	0.009	0.04			
Heritage Wetland	0.003	0.01			
Huber Wetland	0.001	0.00			
Huber R Wetland	0.001	0.01			
Kyle Upland	0.044	0.22			
Kyle Wetland	0.004	0.02			
Future Wetland 1	0.003	0.02			
Future Wetland 2	0.005	0.03			
Future Wetland 3	0.003	0.01			
Pre-Nature	0.021	0.1	Sc.2	0.044	0.22
Post-Nature	0.044	0.22			

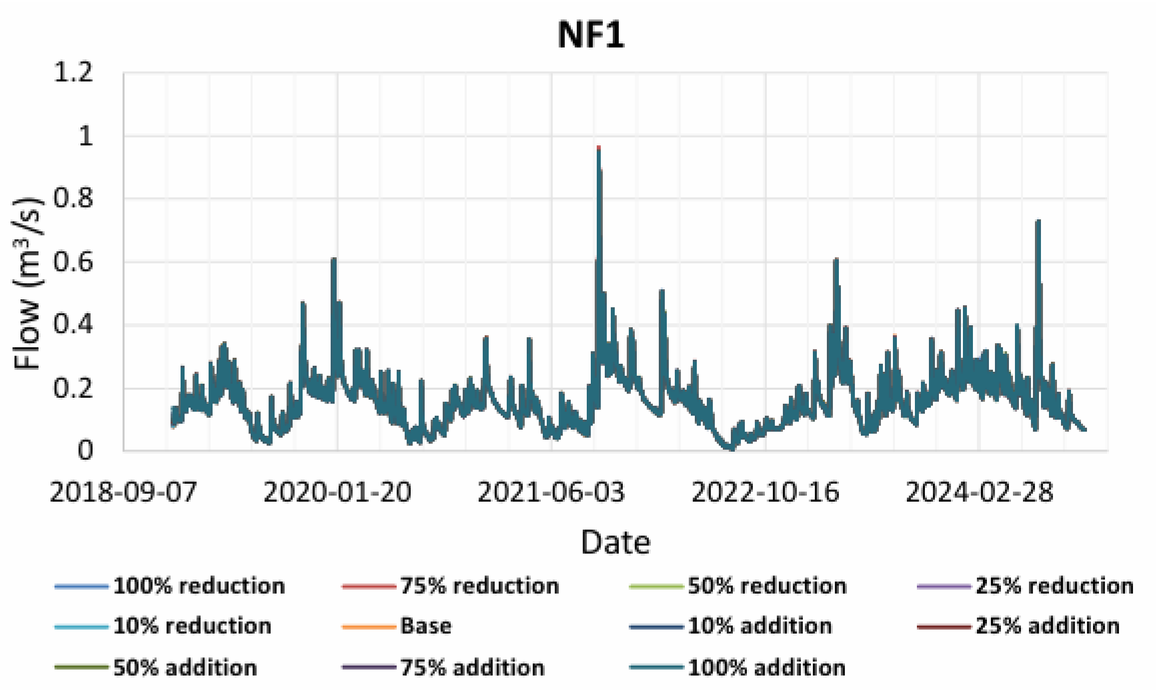

Figure 14. *Simulated stream flow at the NF1 hydrograph (located at model outlet) under the base case, and proposed Nature Force Sc. 2 wetland scenario..*

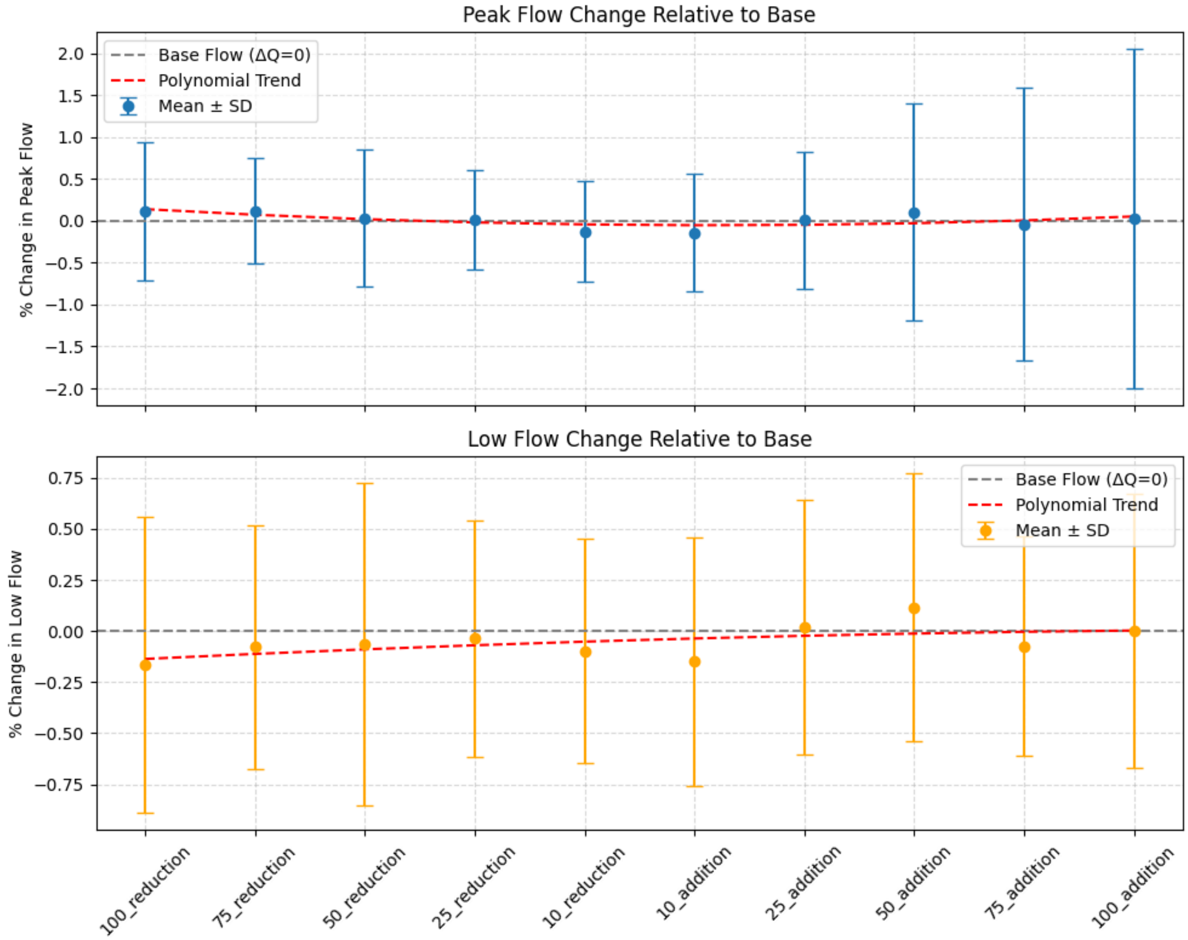

***Figure 15**. Effect of wetland area extent within the Washington Creek watershed on peak flow rates at the watershed outlet NF1 for the Nature Force Sc. 2 proposed wetland scenarios.*

5.0 DESIGN STORM SIMULATIONS

To assess the hydrologic influence of the DUC wetlands on flood resiliency within the Washington Creek watershed, a series of simulations were conducted under design storm conditions. Using the design storm as model forcing, a set of wetland storage scenarios was evaluated, and the resulting hydrographs at the NF1 location were compared. The scenarios involved systematic adjustments to wetland water storage capacity within the DUC wetlands by ±10%, ±25%, ±50%, ±75%, and ±100% relative to the base case.

The storm event applied in the model was derived from intensity–duration–frequency (IDF) relationships developed for the Cambridge Galt MOE climate station located approximately 24 km from Washington Creek watershed. A 24-hour rainfall intensity with a 100-year return period was selected as the event, following the estimates reported by Soulis et al. (2017). Figure 16 illustrates rainfall intensity estimates as a function of return period based on the Meteorological Service of Canada (MSC) Gumbel method. Accordingly, a 24-hour rainfall intensity of 5 mm h^{-1} was applied as the model input for design storm simulation.

The design storm simulations extended over a 30-day period, beginning at the onset of the storm.

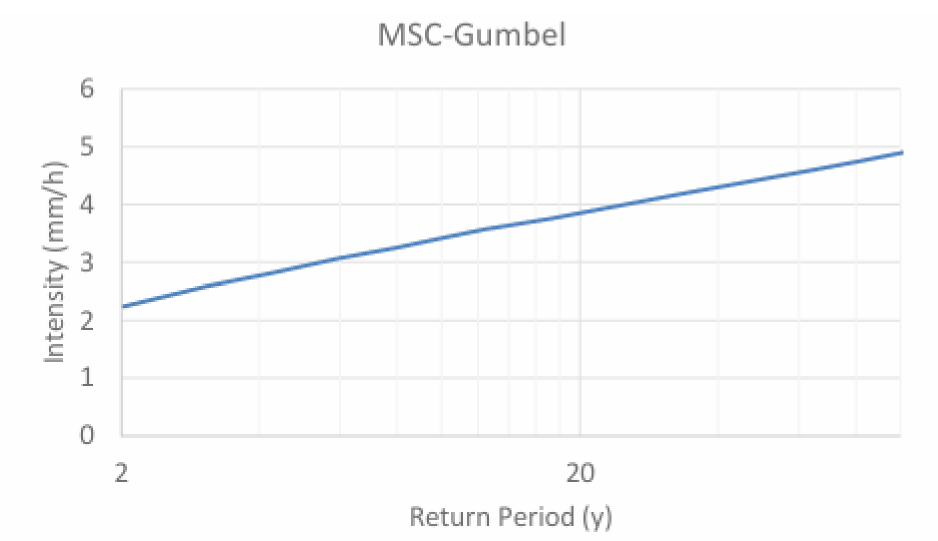

Figure 16. *Twenty four hour rainfall intensity for return periods ranging from 2 to 100 years for Washington Creek watershed (based on the Galt MOE climate station) for 1960-2010 (derived from Soulis et.al., 2017).*

5.1 Wetland Scenario 2 – Design Storm Simulation

Figure 17 illustrates the simulated hydrographs at NF1 for the base case and wetland scenario 2. The results show negligible differences in both flow magnitude and timing among the scenarios. Given the relatively small wetland extent compared to the overall watershed area, the influence on peak discharge is limited and falls below the detection sensitivity of the current model configuration.

Figure 18 depicts the percent change in peak and low flows relative to the base case for wetland scenario 2, and for a +/- 100 % range of wetland water storage capacities scaled off scenario 2. Results show that variations in peak flow are minor, remaining within ±2% for all scenarios. Overall, the responses and magnitude of variability are nonlinear and remain within the model's uncertainty range.

These results indicate that the hydrologic impact of the DUC Nature Force wetlands on flood attenuation during a 100 year rainfall event is insignificant at the current model scale and spatial resolution, when evaluating peak flows at the outlet of the Washington Creek watershed. To capture such localized effects more accurately, future studies should employ nested or higher-resolution hydrologic models applied to smaller catchments, where the interactions between wetland storage dynamics and surface runoff can be more accurately resolved.

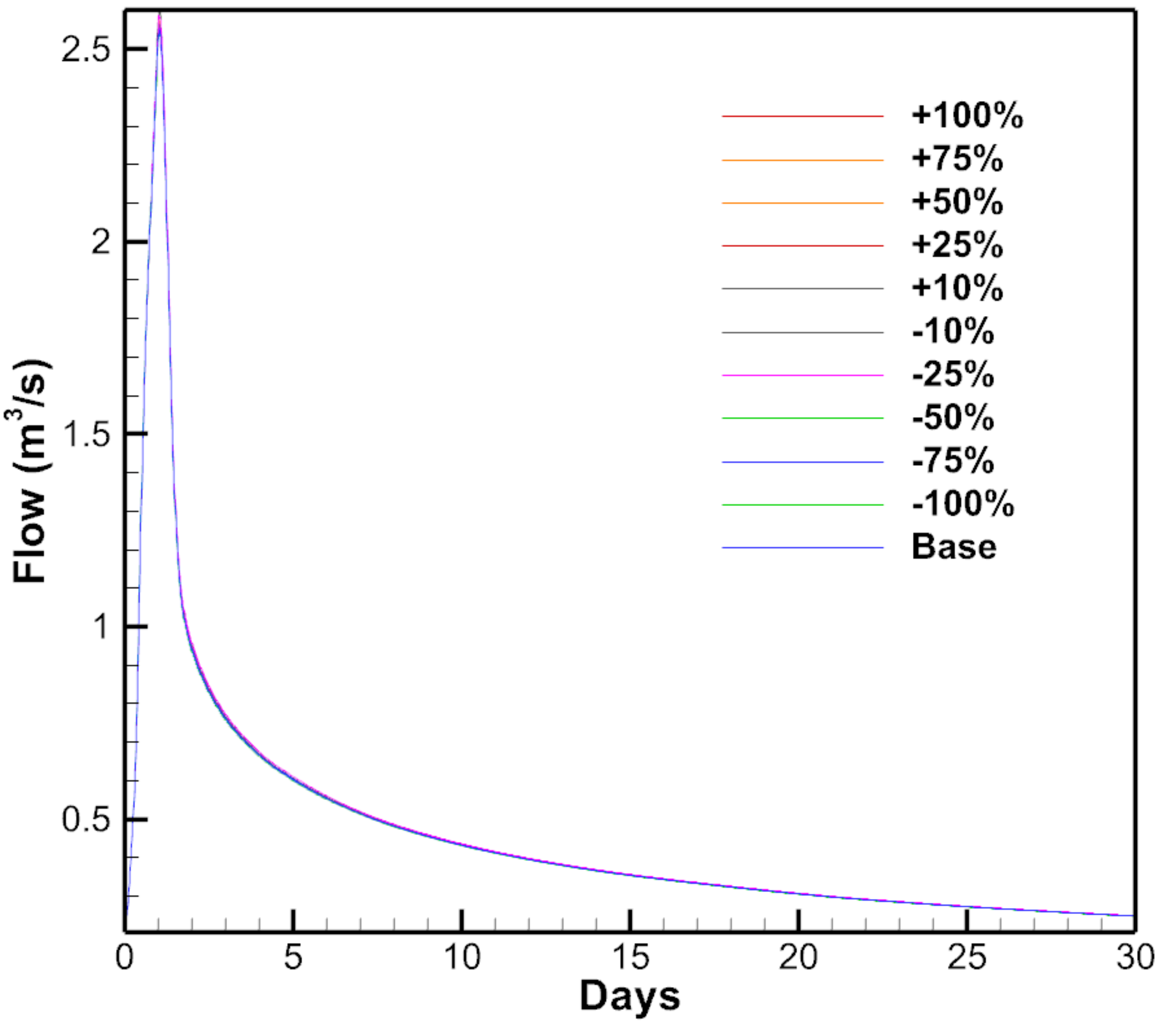

***Figure 17**. Effect of wetland area changes on streamflow hydrographs at the watershed outlet*

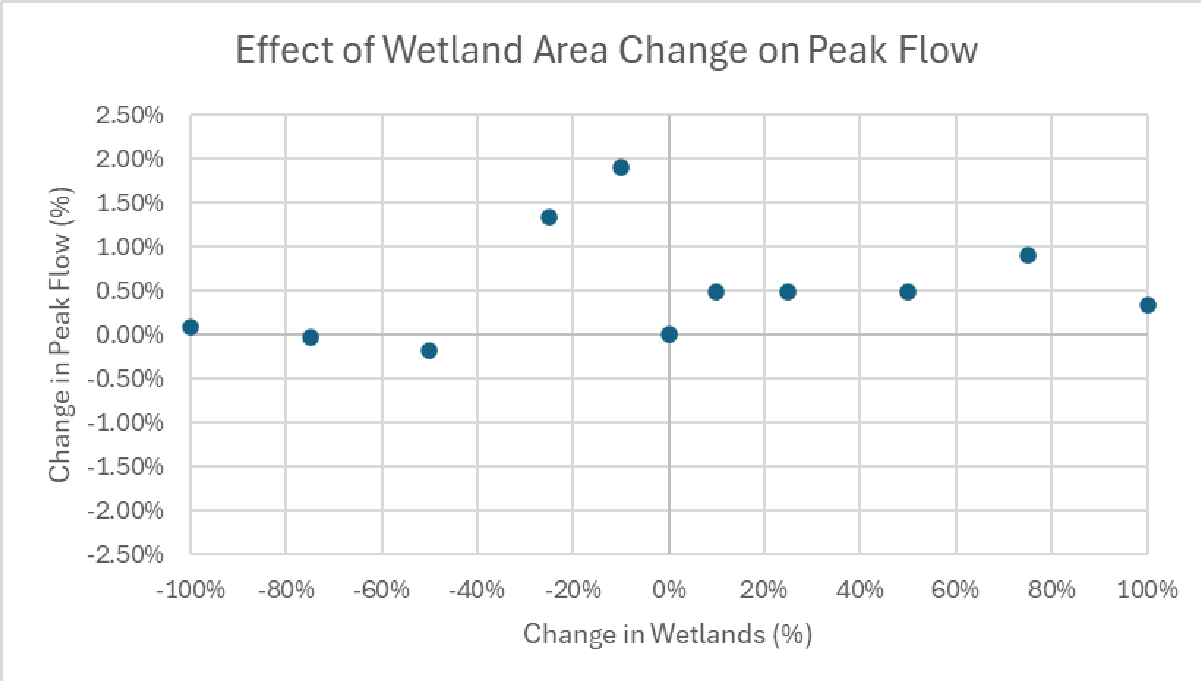

Figure 18. *Effect of wetland area extent within the Washington Creek watershed on peak flow rates at the watershed outlet following a 100-year, 24-hour rainfall design storm (Sc.2).*

5.2 Wetland Scenario 3 – Design Storm Simulation

The wetlands included in this analysis, identified in Figure 5, encompass an area of approximately 0.14 km² (0.74% of the watershed) and correspond to the DUC wetland scenario 3 (Sc.3) described in Table 1.

The hydrographs show that in this scenario, changes in wetland area do influence simulated peak flow during the hydrologic response to the event (Figure 19). Increasing wetland area results in a reduction of peak flow, while decreasing wetland area produces higher peak flows compared to the base-case. On the trailing limb of the event hydrograph the flow recession patterns converge, indicating that wetland size predominantly affects short-term flood attenuation rather than long-term baseflow in design storm scenarios. The Figure 19 inset provides a focused look at the sensitivity of peak flow to wetland area changes, with larger wetland areas providing greater peak flow reduction.

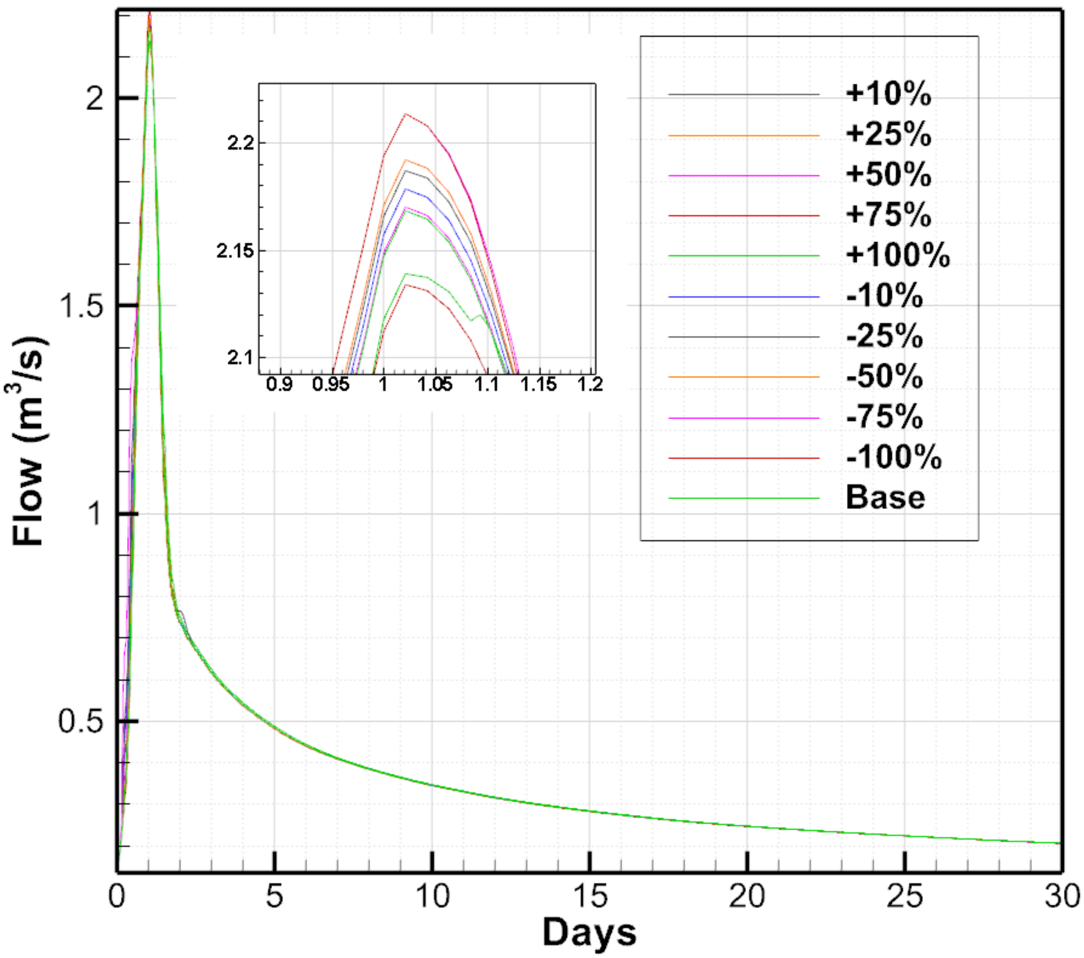

Figure 19*. Effect of wetland area changes (Sc.1) on streamflow hydrographs at the watershed outlet.*

Figure 20 shows the relationship between changes in wetland area and changes in peak flow, expressed as percentages. The x-axis represents the change in wetlands (% of base case), ranging from -100% (complete DUC scenario 3 wetland loss) to +100% (DUC scenario 3 wetland area doubled), while the y-axis shows the corresponding change in peak flow (%), from about -2.5% to +2.5%. The scatterplot data points demonstrate a clear negative trend: as wetland area increases, peak flow decreases, and vice versa. A linear regression line is fitted to the data, with the equation (presented in Figure 20) indicating that every 100% increase in wetlands reduces peak flow by approximately 2%. The coefficient of determination (R^2 = 0.9598) suggests that the linear model explains about 96% of the variance, showing a very strong correlation between wetland area change and peak flow response. Because of the strong correlation, the relationship presented in Figure 20 provides a robust scale for quantifying the flood risk reduction efficacy of additional wetlands in the Washington Creek watershed. However, it also needs to be recognized that these results are generalized, and based on scaling the size of existing DUC scenario 3 wetlands. If wetlands were to be added in parts of the watershed not represented with existing (or planned) DUC wetland coverage, their individual impacts may differ from the relationship presented in Figure 20. Furthermore, there is likely a lower threshold, below which the simulated effects on flow on not detectable with the scale and resolution of the model used here.

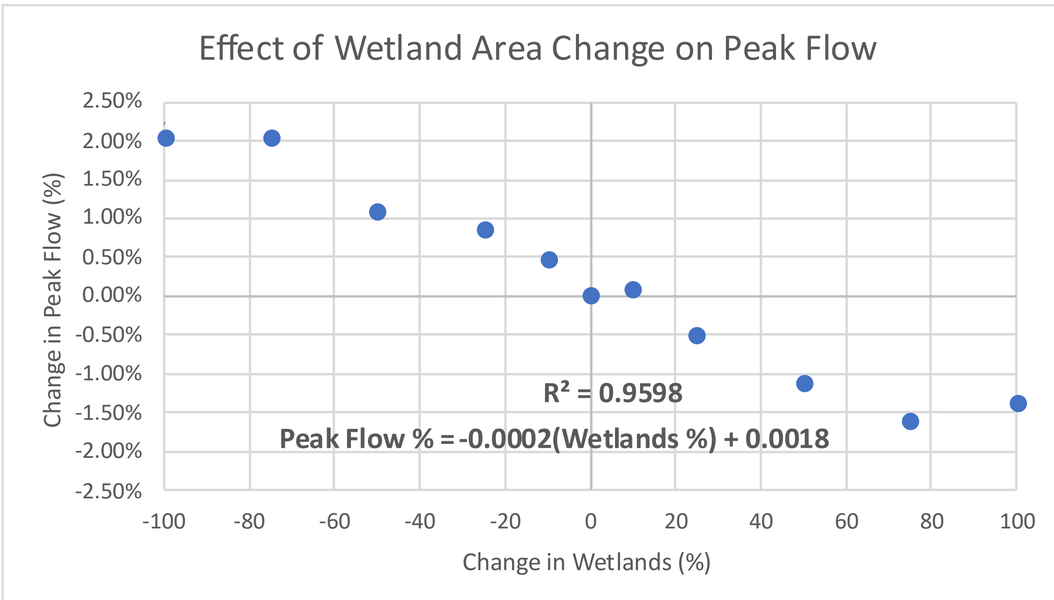

***Figure 20**. Effect of wetland area extent (Sc.1) within the Washington Creek watershed on peak flow rates at the watershed outlet following a 100-year, 24-hour rainfall design storm.*

6.0 CONCLUSIONS

- A HydroGeoSphere fully-integrated groundwater – surface water model was developed for the 19.5 km^2 Washington Creek watershed in Southern Ontario.
- The model successfully recreated surface water flow rates and wetland water levels over the 2023 – 2024 simulation interval.
- For wetland landcover scenarios with a low overall areal footprint within the watershed (i.e. the Nature Force wetlands with 0.22 % watershed coverage) the hydrologic sensitivity at the watershed outlet is very low, to the point of being non detectable with the full watershed scale model.

For the wetland scenarios with larger areal footprints than the Nature Force scenario, the following conclusions can be made:

  - Clustered addition of wetlands according to DUC design plans had the effect of lowering localized peak flow rates by up to almost 40%, however, this effect was inconsistent between events.
  - In the 1-year continuous simulations, localized summer low flows were increased by up to 30%.
  - For 100-year, 24 hour rainfall design storm conditions, a linear regression relationship was developed to describe the effect of incremental increases and decreases in wetland areal extent on peak flow rates during the simulated hydrologic response to the event.
  - Doubling or removing the DUC wetland coverage in the watershed (which under the base case is ~0.74% of the Washington Creek watershed area) had the respective effect of increasing and decreasing peak watershed outflow rates, in response to the design storm, by approximately 2%.
  - Largely due to the relatively low wetland coverage in the Washington Creek watershed, simulation results indicate a muted response at the watershed scale to wetland additions and removals scaled from 0x to 2x existing wetland coverage; however, localized (sub-watershed) scale effects are more notable.

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