# Economic valuation of the stormwater management services provided by the Whitetower Park ponds, Gibsons, BC

## Summary

The town of Gibsons, British Columbia is undertaking an assessment of its natural assets to incorporate them in the town's asset management plan. This document presents the assessment of the Whitetower Park ponds. The methods, following the Municipal Natural Assets Initiative guidance document, are as follows: i) characterize the natural asset, ii) develop alternative scenarios around the natural asset, iii) develop and run a hydrologic model (SWMM), iv) conduct an economic valuation (using the replacement cost method), and v) assess beneficiaries. Based on the SWMM model, we found that the ponds have a value of between $3.5 and $4 million. These estimates could be further refined by using a more sophisticated model, or by taking a different economic valuation approach, such as assessing avoided costs related to flood damage. Overall, the approach allows the town to obtain an initial estimate of the value of the Whitetower Park ponds to incorporate their value in an asset management plan.

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## Acknowledgement of funders and supporters

Real Estate Foundation of BC; Bullitt Foundation; Sitka Foundation; Town of Gibsons

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## 1. PURPOSE OF THIS DOCUMENT

The Municipal Natural Assets Initiative (MNAI) is developing resources to incorporate natural capital (i.e. natural or vegetated assets that form part of the urban landscape) into asset management plans. As part of this effort, MNAI developed the Overview Guidance Document for Stormwater Mangement for Canadian Municipalities. This report details the application of the document for one particular asset, a series of ponds in Whitetower Park in the Town of Gibsons. The goal is to illustrate the application of the guidance document and to provide technical details on the modeling approach.

## 2. BACKGROUND AND OBJECTIVES

The Town of Gibsons is located just north of Vancouver, British Columbia on the Sunshine Coast. It has a population of approximately 4,400 and is roughly 1,000 acres in size. With limited resources for infrastructure maintenance and replacement, the town is increasingly focusing on natural capital and the services it provides as a cost-effective alternative. In 2013, Gibsons completed a study seeking to define the physical characteristics of the town's underlying aquifer and better understand the water supply benefits provided by the aquifer. The study concluded that the aquifer provides sufficient water storage to supply the projected population of Gibsons for the foreseeable future at a fraction of the cost of engineered water supply infrastructure (Waterline Resources, 2013). Subsequently, Gibsons increased their investment in maintenance of the aquifer and is now interested in quantifying the value of more of their natural capital, or eco-assets, as defined in their Eco-Asset Strategy report.

For this case study, we look at a series of ponds located within Whitetower Park that provide stormwater retention and flood peak reduction during large storm events[1]. These ponds receive drainage from the upper Charman Creek watershed, an area that is expected to undergo significant urbanization in the coming years (see Figure 1).

[1] In the guidance, this follows Step 1: "Characterize the natural capital assets of interest"

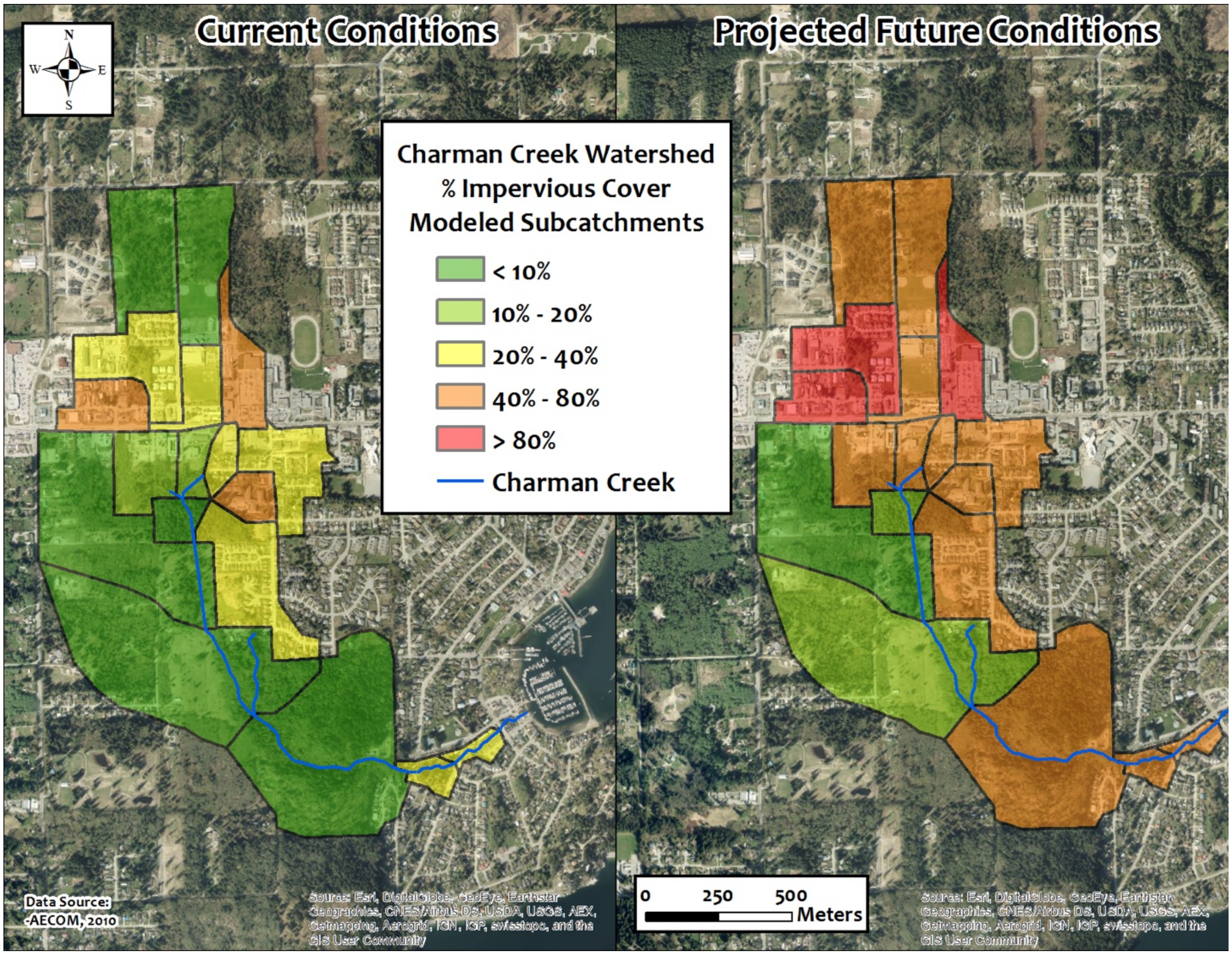


Figure 1 – Current vs. Future land cover within Charman Creek watershed

A key consideration in developing the MNCI guidance document for stormwater management was that the modeling approach have low resource requirements and be reproducible for municipalities with small budgets. Therefore, we use the U.S. EPA's Stormwater Management Model (SWMM) to simulate hydrologic and hydraulic processes, the impact of land use changes on these processes, and the mitigating effects of several management strategies[2]. Hydrological model outputs then inform economic valuation of the stormwater retention and flood peak reduction benefits provided by this system of ponds.

The objectives of this case study are threefold: (1) demonstrate the appropriateness of EPA's SWMM 5.1.010 model for municipalities interested in quantifying the economic value provided by local natural capital; (2) determine the current economic value provided by the Gibsons, B.C. Whitetower Park pond system using a replacement cost methodology; and (3) perform a cost-effectiveness analysis to determine the lowest cost approach to mitigate the stormwater management impacts associated with increased urbanization within the Charman Creek watershed.

[2] A brief literature review on alternative candidate models can be found in the Appendix

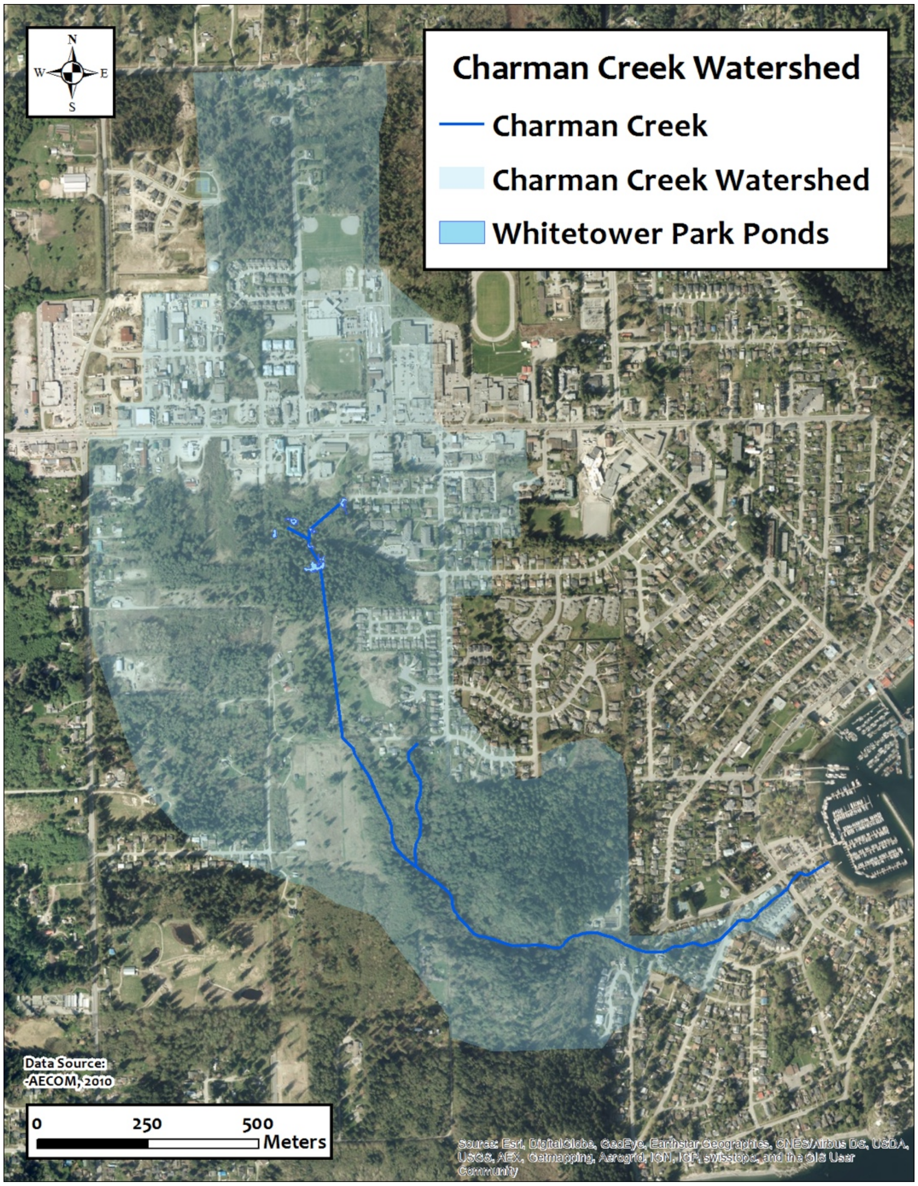

Figure 2 – Charman Creek Watershed within Gibsons, B.C.

## 3. METHODS

To facilitate cross-references, we use the modeling steps laid out in the MNCI guidance document for stormwater management [Molnar et al., 2016].

### 3.1 Characterize the natural capital asset of interest

*Natural capital asset of interest*

The series of ponds in Gibson's Whitetower Park being assessed were highlighted by the Town of Gibsons as natural assets of interest for their ability to manage stormwater and obviate the need for increased investment in engineered stormwater management solutions. A brief site visit confirmed that the location of the ponds is ideal for attenuating peak flows from upstream, and that the depth of the main pond could easily be increased by one to two metres for better service levels.

*Service provided by the eco-asset: preliminary assessment with a simplified SWMM model*

The Whitetower Park ponds are thought to provide flood mitigation through peak flow reduction. To verify this, a simple watershed model was created using SWMM. This 'Simple SWMM' model generalizes the entire drainage area for the Whitetower Park ponds into a single subcatchment with an outlet point directly into a single modeled pond. This has the combined storage capacity of the entire Whitetower Park pond system. Infiltration and runoff calculations for the Charman Creek watershed are performed by using estimated impervious cover for the watershed and applying a curve number approach to pervious areas. Impervious cover percentage was estimated using a land cover GIS dataset. Referencing the NRCS curve number reference tables (USDA, 2009), a curve number of 65 was applied uniformly to all pervious areas within the Charman Creek watershed.

A simplified SWMM model is used in this analysis to allow for municipalities who are unsure if the investment in a 'Full SWMM' model analysis would be worthwhile. While the results from a simple SWMM model should not be viewed as absolute, the comparison of scenarios should yield enough information for a municipality to decide whether or not to invest in creating a more complex model.

In this case, two scenarios were modeled using the simple SWMM approach: 1) current conditions, and 2) current conditions with no Whitetower Park pond system. Each scenario was run for two design storm events, the 10-year, 24-hour storm (69.58 mm of rainfall) and the 100-year, 24-hour storm (88.91 mm of rainfall). Time series data for these design storms was taken from the 'Town of Gibsons Subdivision and Development Bylaw No. 1175, 2012'. By comparing the peak flow outputs from these two scenarios, it is possible to determine whether or not the Whitetower Park ponds should remain an eco-asset of interest.

### 3.2 Run a 'Full SWMM' model to represent the watershed under current conditions

As noted above, the modeling approach relies on the EPA Stormwater Management Model (SWMM). SWMM is a sophisticated, widely-used rainfall runoff model for stormwater management applications. First developed in 1971, SWMM has been refined and improved over the years to reach its current form, SWMM 5. There are several proprietary modeling packages based on the computational routines within SWMM 5 which enhance its graphical user interface (GUI) and integrate it with geographic information system (GIS) applications (PC SWMM, XP SWMM, InfoSWMM). Since these software packages are expensive, we opted to use the EPA's freely available, open source software.

See Appendix 1 for an overview of stormwater models in general and a deeper look into the capabilities of SWMM 5, along with a few examples of common applications for the model.

*Model inputs*

In order to perform an appropriately in-depth analysis, a 'Full SWMM' model was created instead of the Simple SWMM model mentioned in Step 1 above. The goal for the Full SWMM model is to accurately represent all relevant hydrologic and hydraulic components of the Charman Creek watershed. Data inputs for the Full SWMM model were pulled entirely from a previously constructed SWMM model described in AECOM 2010.

The Charman Creek watershed was divided into 18 sub-catchments. Unique properties for each sub-catchment include area, width of overland flow path, per cent of slope, per cent of impervious cover, and per cent of runoff from impervious areas that is routed to pervious areas. Properties that are standardized across all sub-catchments include Manning's N value for impervious and pervious surfaces, depression storage for impervious and pervious surfaces, per cent of impervious area with no depression storage, and soil infiltration parameters for the Green-Ampt method (suction head, conductivity, and initial deficit).

The Charman Creek stream network was divided into 35 separate reaches, many of which represent pipe systems conveying flow to the stream itself. Parameters describing the geometry of each reach include shape, depth, side slopes, length, roughness, inlet and outlet offset, and entry and exit loss coefficients.

Stream reaches connect to one another either at a junction or a storage pond. Properties for the 30 junctions include rainfall derived infiltration and inflow (RDII) (from a local sewer system), invert elevation, maximum depth, and area of ponding when flooded. Storage ponds along the Charman Creek stream network were represented in the model as storage units. Storage curves, maximum depths, and invert elevations for the five ponds were input as in the AECOM 2010 study.

*Rainfall and weather*

The model was run with two design storms and one continuous time series. The design storms that were chosen are the 10-year, 24-hour storm (69.58 mm of rainfall), and the 100-year, 24-hour storm (88.91 mm of rainfall). Time series data for these design storms was taken from the 'Town of Gibsons Subdivision and Development Bylaw No. 1175, 2012'. The continuous time series covers the period from December 11, 2001 to December 23, 2002 and includes 833.2 mm of rainfall over the course of the year. This less-than-average annual rainfall total for Gibsons represents the only continuous rainfall record available for the town. The time series includes both dry periods and brief, intense rainfall events that approach the 100-year, 4-hour storm event.

SWMM requires temperature and weather data to calculate evapotranspiration rates during simulations of continuous time series. Because data were not available for Gibsons, data from West Vancouver, B.C. (about 30 km southwest of Gibsons) were used instead.

### 3.3 Develop the list of alternative scenarios used to compare the eco-asset service

*Scenarios for the economic valuation of the Whitetower Park pond system*

The current economic value provided by the Whitetower Park pond system is quantified using the Full SWMM model for three different scenarios: current conditions, current conditions with detention ponds to replace the Whitetower Park (WTP) pond system, and current conditions with a bypass pipe to replace the WTP pond system.

The ‘current conditions’ scenario is modeled based on the parameter values from the AECOM 2010 study. In the ‘current conditions with detention ponds to replace the WTP pond system’ scenario the WTP pond system is removed and the outlets of the six upper Charman Creek watershed sub-catchments (DC-0800 – DC-0850) are replaced with storage units representing detention ponds. The volume of these six storage units was adjusted until peak flows at the outlet of Whitetower Park roughly matched those in the ‘current conditions’ scenario. In the ‘current conditions with bypass pipe to replace the WTP pond system’ scenario, the WTP pond system is removed and all flow from two sub-catchments (DC-0820 and DC-0840) is routed into a pipe that conveys it from the Charman Creek watershed.

Both of these scenarios reflect management strategies that are being considered by the town as possible alternatives to maintaining the Whitetower Park pond system. Cost estimates are available for each approach.

*Alternative approach: Future build-out stormwater management strategy comparison*

The SWMM model was run for six different scenarios to compare the cost-effectiveness of several management options for dealing with runoff under a future build-out scenario: pre-development, current conditions (same as above), future development, future development with bypass pipe, future development with increased WTP pond storage, and future development with increased WTP pond storage and one acre settling pond.

The ‘pre-development’ scenario is identical to the ‘current conditions’ scenario except that the sub-catchments are modeled as 100 per cent pervious areas. The ‘future development’ scenario is identical to the ‘current conditions’ scenario except that the impervious area has been increased across all sub-catchments. This increase represents a likely development scheme and the percentage increases for each sub-catchment were pulled from the AECOM 2010 study. The ‘future conditions with bypass pipe’ scenario is identical to the ‘future conditions’ scenario except that all flow from two sub-catchments (DC-0820 and DC-0840) is routed into a pipe that conveys it out of the Charman Creek watershed, similar to the corresponding ‘current conditions with bypass pipe’ scenario. The ‘future development with increased pond storage’ scenario is identical to the 'future conditions' scenario except that the depth and storage capacity of the WTP ponds has been increased. Finally, the 'future development with increased WTP pond storage and one-acre settling pond' scenario is identical to the 'future development with increased pond storage' scenario, but also includes an additional 1-acre settling pond directly upstream of the expanded WTP pond.

### 3.4 Economic valuation

After grey infrastructure alternative scenarios have been represented using the Full SWMM model, peak flow rates downstream of the Whitetower Park pond system are compared to determine whether or not the grey infrastructure provides the same level of service as the pond system. Using the replacement cost method for economic valuation, we can assume that the value of the Whitetower Park pond system is equal to the cost of replacing the services it provides. If these two scenarios are able to maintain peak and total flows near the level of current conditions, the value of the stormwater management services provided by the Whitetower Park ponds will be equal to the cost of implementing either scenario.

For each grey infrastructure alternative that provides the same level of service as the Whitetower Park pond system, a cost estimate must be developed to determine an economic value for the ponds. In the case of the distributed detention ponds alternative, a construction cost estimate of $175 per cubic metre of storage was used (Dave Newman, personal communication, 2016). In the case of the bypass pipe, the Town of Gibsons already developed an initial cost estimate of $4,000,000 (Dave Newman, personal communication, 2016).

### 3.5 Incorporate information on beneficiaries

The flood service provided by the ponds benefits two groups of residents: first, tax payers who will bear the cost of stormwater management service that the municipality needs to maintain; second, residents who may be affected by flooding in the absence of the flood mitigation service.

To represent spatially this second group of beneficiaries, we use the sewersheds delineated in the SWMM model and highlight sewersheds downstream of the ponds. Note that this approach to identify potentially flooded areas is approximate, since the actual level and location of flooding depends on the topography and stormwater network (with potential surcharge and backflows, resulting in flooding in areas upstream of the ponds). The sewershed map provides a first screening of areas at risk.

## 4. RESULTS

### 4.1 Hydrologic outputs from the Simplified SWMM model

As shown in Table 1, below, results from the Simple SWMM analysis suggest that the Whitetower Park pond system does provide a peak flow reduction in Charman Creek. Though the predicted peak flow reduction is small, it provides enough justification to proceed with a 'Full SWMM' analysis.

| | Peak Flow at DN-0753 (lps) | | Total Flow at DN-0753 (10^6 liters) | |
|---|---|---|---|---|
| | 10-year 24-hour | 100-year 24-hour | 10-year 24-hour | 100-year 24-hour |
| Current Conditions | 297 | 437 | 18 | 25 |
| Current Conditions w/o WTP Ponds | 314 | 444 | 18 | 25 |

Table 1 – Peak and total flow comparison at DN-0753, just downstream of Whitetower Park (Simple SWMM)

## 4.2 Hydrologic outputs from the Full SWMM model

*Scenarios for the economic valuation of the Whitetower Park pond system*

As shown in Table 2, below, both the detention ponds and bypass pipe replacement scenarios effectively maintained peak and total flow levels at a similar level to current conditions, though the bypass pipe option was less effective during the continuous time series simulation.

| | Peak Flow at DN-0753 (lps) | | | Total Flow at DN-0753 (10^6 liters) | | |
|---|---|---|---|---|---|---|
| | 10-year 24-hour | 100-year 24-hour | 2002 timeseries | 10-year 24-hour | 100-year 24-hour | 2002 timeseries |
| Current Conditions | 338 | 591 | 526 | 24 | 36 | 204 |
| Current Conditions w/ Detention Ponds to Replace WTP Ponds | 306 | 576 | 476 | 17 | 18 | 207 |
| Current Conditions w/ Bypass to Replace WTP Ponds | 311 | 600 | 603 | 22 | 31 | 206 |

Table 2 – Peak and total flow comparison at DN-0753, just downstream of Whitetower Park (Full SWMM)

Given the differences in timing and volume of rainfall between the 10-year, 100-year, and continuous timeseries, the required detention pond storage volume required to replace the loss of the Whitetower Park pond system varied for each. To manage flows from the 10-year 24-hour storm, it was necessary to add 7,750 $m^3$ of upstream detention pond storage. For the 100-year 24-hour storm, it was necessary to add 20,000 $m^3$ of upstream detention pond storage. And for the continuous timeseries, it was necessary to add 2,500 $m^3$ of upstream detention pond storage.

*Alternative approach: Future buildout stormwater management strategy comparison*

As shown in Table 3, below, all three of the alternative future conditions scenarios were effective at reducing peak flows to the current conditions level for the 100-year 24-hour storm event, and both of the 'expanded WTP pond' scenarios were also effective at reducing peak flows to the current conditions level for the 2002 timeseries. The three scenarios were less effective at reducing peak flows during the 10-year storm event, but this may not be significant given that any infrastructure will be designed to handle the higher peak flow levels associated with the 100-year 24-hour storm event.

While the 'bypass pipe' scenario effectively reduces total flow volumes to near 'current conditions' levels for large storm events, neither of the 'expanded WTP pond' scenarios significantly reduces total flow volumes in Charman Creek because the ponds do not provide significant storage.

| | Peak Flow at DN-0753 (lps) | | | Total Flow at DN-0753 (10^6 liters) | | |
|---|---|---|---|---|---|---|
| | 10-year 24-hour | 100-year 24-hour | 2002 timeseries | 10-year 24-hour | 100-year 24-hour | 2002 timeseries |
| Predevelopment | 278 | 472 | 356 | 17 | 29 | 125 |
| Current Conditions | 338 | 591 | 526 | 24 | 36 | 204 |
| Future Development | 566 | 753 | 908 | 36 | 49 | 340 |
| Future Development w/ Bypass Pipe | 413 | 547 | 662 | 29 | 38 | 287 |
| Future Development w/ Expanded WTP Pond | 444 | 525 | 491 | 36 | 49 | 338 |
| Future Development w/ Expanded WTP Pond + Settling Pond | 412 | 503 | 441 | 36 | 48 | 337 |

Table 3 – Peak and total flow comparison at DN-0753, just downstream of Whitetower Park

### 4.3 Valuation of the Whitetower Park pond system

Using the results from the hydrological model, economic measures can be applied to obtain an economic value for the Whitetower Park pond system. The cost-effectiveness of the stormwater management strategies for handling the increased flows resulting from future buildout conditions can be compared.

*Economic valuation of the Whitetower Park pond system*

The cost of constructing detention ponds in Gibsons, B.C. is roughly $175 per cubic-metre of storage (Dave Newman, personal communication, 2016). Applying this cost to the detention pond storage volume estimates listed above, we find that it would cost $1,356,250 to replace the services provided by the Whitetower Park pond system during a 10-year storm event, $3,500,000 to replace the services provided during a 100-year storm event, and $437,500 to replace the services provided over the course of an average year (2002 timeseries). According to the town bylaws, stormwater capture systems should be able to manage flows from the 100-year event so, applying the replacement cost method of economic valuation, we can set the value of the services provided by the Whitetower Park pond system at $3,500,000.

The cost of constructing a bypass pipe to convey flows from Upper Gibsons (subcatchments DC-0820 and DC-0840 in the SWMM model) outside of the Charman Creek watershed has been estimated (preliminarily) at $4,000,000 by Town of Gibsons staff (Dave Newman, personal communication, 2016). Applying the replacement cost method of economic valuation using this estimate, we can set the value of the services provided by the Whitetower Park pond system at $4,000,000.

*Alternative approach: Future buildout stormwater management strategy comparison*

Cost estimates for the expansion of the Whitetower Park pond system and construction of the additional settling pond have yet to be developed by Town of Gibsons staff, but it is assumed that the total cost will be much lower than the estimated $4,000,000 to construct the bypass pipe system. Thus, a stormwater management strategy centered around improving the Whitetower Park pond system will be the most cost-effective option for the Town of Gibsons going forward if peak flow reduction is the main objective.

### 4.4 Mapping of beneficiaries

As noted in 3.5, the two groups of beneficiaries are taxpayers who will contribute to the maintenance of the stormwater management service, and residents downstream of the ponds. Figure 3 estimates the location of these residents, based on the sewersheds in Gibsons. More detailed analyses could be conducted with a map of recently flooded areas (or identified at risk).

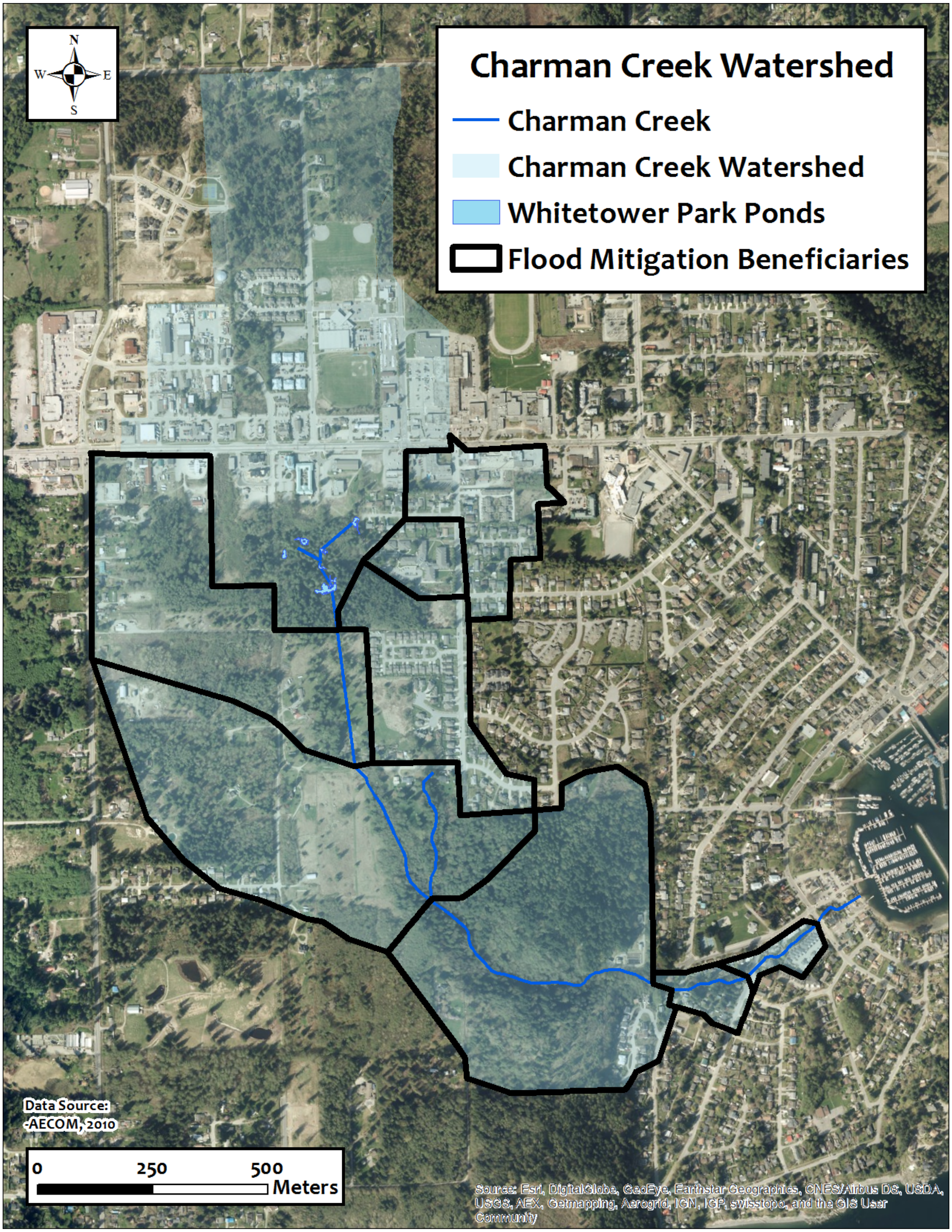


Figure 3 – Map of the beneficiaries of the flood mitigation service provided by the Whitetower Park ponds

# 5. DISCUSSION

The objectives of this case study were threefold: (1) assess the appropriateness of EPA's SWMM 5.1.010 model for municipalities interested in quantifying the economic value provided by local natural capital; (2) determine the current economic value provided by the Gibsons, B.C. Whitetower Park pond system using a replacement cost methodology; and (3) perform a cost-effectiveness analysis to determine the least cost approach for mitigating the stormwater management impacts associated with increased urbanization within the Charman Creek watershed.

## 5.1 Appropriateness of SWMM 5 as the biophysical model

*Simple SWMM model*

The approach described above makes use of a Simple SWMM model as a tool for providing an initial assessment of the biophysical value of the Whitetower Park pond system. The objective for this portion of the analysis is to decide whether further investment of time and resources is worthwhile. The simple SWMM model should be easy to put together while still providing accurate *relative* predictions between modeled scenarios. In this case, the entire drainage area of the Whitetower Park pond system was represented as a single sub-catchment in the Simple SWMM model, using impervious cover percentage and curve number estimates to compute runoff and infiltration. This model took less than a day to put together and provided *relative* flow predictions indicating that a more in-depth analysis would be warranted. These relative flow predictions align with the predictions from the Full SWMM model, indicating that the Simple SWMM model served its purpose, and steered the analysis in the proper direction.

Several different hydrologic/hydraulic models were considered for use as the initial 'simple' model in place of SWMM. WinTR-55 and i-Tree Hydro, in particular, were examined at length. Both of these models have their merits, but it was ultimately decided that SWMM was as simple to use, allowed for more flexibility, and was able to provide all necessary outputs for the initial assessment. An in-depth discussion of both WinTR-55 and i-Tree Hydro can be found in Appendix 1.

*Full SWMM model*

SWMM 5 proved to be a fully capable model for the purposes of this analysis, both in terms of its ability to perform an economic valuation of the Whitetower Park pond system using the replacement cost methodology, and its ability to simulate multiple future land use and stormwater management scenarios.

SWMM 5 is capable of adequately representing natural assets such as ponds and wetlands (in this case the Whitetower Park ponds), and simulating their hydrologic and hydraulic impacts within a watershed. While there is no explicit representation of vegetation within SWMM 5, users interested in quantifying the stormwater management benefits of forests and other natural, pervious areas would be able to do so by adjusting hydrologic parameters such as depression storage, and soil infiltration properties, or by simplifying the model and using a curve number approach to represent the landscape. Distributed detention ponds are a common grey infrastructure replacement for lost natural asset stormwater management services and are easily modeled in SWMM 5. This represents a simple yet valid application of the replacement cost methodology for economic valuation of natural assets.

SWMM 5 is commonly used to simulate and compare multiple stormwater management scenarios, and its appropriateness for this application is well-documented (see Appendix 1 for several examples of similar applications). Once a ‘current conditions’ SWMM model has been created and validated, it is quite simple to adjust hydrologic and hydraulic parameters to represent alternative land use, climate, and stormwater management scenarios.

Ultimately, any hydrologic/hydraulic model is only as good as the input data. This analysis relied on data from a previous study, which was more than adequate for providing sufficiently accurate results to suit the needs of the Town of Gibsons. More time and effort put into the data acquisition and validation phase of the study could have improved the strength of model predictions. SWMM 5 would have been quite capable of taking advantage of more detailed hydrologic and hydraulic data, if it were available.

### 5.2 Economic valuation of the Whitetower Park pond system

Two separate ‘replacement cost’ approaches were taken to determine the economic value provided by the Whitetower Park pond system in terms of stormwater management: 1) using distributed detention ponds as replacement grey infrastructure, and 2) using a bypass pipe system as replacement grey infrastructure. In considering distributed detention ponds as the replacement infrastructure, three different values were derived depending on the duration and intensity of the modeled storm events. Because the Town of Gibsons bylaws state that stormwater infrastructure should be able to manage the 100-year storm event, we chose the value corresponding to the 100-year, 24-hour storm event, putting the economic value provided by the Whitetower Park pond system at $3,500,000. In considering the bypass pipe system as the replacement infrastructure, we take the estimated construction cost of $4,000,000 as the economic value of the Whitetower Park pond system.

These estimates are in fairly close agreement given the level of accuracy desired from this planning-level analysis, according to Town of Gibsons decision-makers. They could be further refined by using a more sophisticated model, or by taking a different economic valuation approach, such as assessing avoided costs related to flood damage. However, using the replacement cost method for economic valuation in conjunction with SWMM has proven to be a practical approach given the objective of limiting resource input requirements.

### 5.3 Future buildout stormwater management strategy comparison

Model results suggest that peak and total streamflow in Charman Creek will increase significantly as the Charman Creek watershed becomes more urbanized (i.e. impervious coverage increases). Expanding the capacity of Whitetower Park pond by increasing the depth is a viable strategy for maintaining peak flow rates at (and even below) the level of current conditions during the 100-year, 24-hour storm event. Adding an additional settling pond directly upstream of the Whitetower Park pond system will further decrease peak flow rates in Charman Creek. Both of these management strategies are expected to be relatively inexpensive compared to the grey infrastructure alternative of constructing a bypass pipe to route flows from a portion of Upper Charman Creek watershed out of the drainage basin. This bypass strategy was also shown to be effective at reducing peak flow rates to a level below that of current conditions during the 100-year storm event, but at an estimated cost of $4,000,000.

Results from the continuous timeseries simulations show that the Whitetower Park pond system expansion is far more effective at reducing peak flows than the bypass pipe alternative. In these simulations, the expanded pond (with or without the additional settling pond) brought peak flows well below the level of current conditions, while the bypass pipe scenario did not.

Note: Further cost-benefits analyses could be conducted with a cost estimate for the Whitetower Park pond expansion.

### 5.4 Assumptions and limitations

It is necessary to acknowledge several assumptions and limitations which have impacted the ultimate economic valuation results for the Whitetower Park pond system.

First and foremost, the SWMM model was never fully calibrated due to a lack of available streamflow data for Charman Creek. Instead, model parameters were adjusted to match predicted streamflows from the InfoSWMM model developed for AECOM 2010. It is likely that the model could be improved if one or more years of streamflow and corresponding weather data were available for Charman Creek. In its current state, we estimate a relative error on the order of 10 per cent for modeled flows.

In modeling the replacement of the Whitetower Park pond system with distributed detention ponds throughout the Upper Charman Creek watershed, no attempt was made to optimize the performance of the detention ponds by adjusting their hydraulic properties. It is likely that the peak flow reduction impacts of this system of detention ponds could be improved by adjusting characteristics such as inlet and outlet control structures. This was beyond the scope of this analysis, but could have a significant impact on the storage volume required to replace the Whitetower Park ponds, and therefore on the ultimate economic value estimate for the ponds. Similarly, no attempt was made to optimize the hydraulic properties of the expanded Whitetower Park pond and additional settling pond in the future conditions scenarios. Again, the peak and total flow impacts provided by these ponds could likely be increased by improving the inlet and outlet control structures.

None of the future conditions scenarios modeled in this analysis included any representation of climate change. This could easily be included in future analyses by increasing or decreasing rainfall volumes by a set percentage. It is likely that the relative performance of natural systems versus grey infrastructure will be impacted by changes in precipitation patterns, and this would be an interesting addition to this analysis.

Lastly, it should be noted that Town of Gibsons staff made it clear at the outset of this analysis that even a ‘rough’ estimate for the value of the Whitetower Park pond system, or the relative flow impacts of future stormwater management strategies would be sufficient for their purposes. As with any analysis, the required accuracy and confidence in model outputs informed the level of effort at each stage of model creation and economic analysis. Any future analyses which follows the steps laid out in this case study should consider their own accuracy/confidence requirements as they build their SWMM model and gather economic data.

## APPENDIX 1 – OVERVIEW OF STORMWATER MODELS

In order for a model to reliably simulate how stormwater moves across a landscape, many different landscape characteristics and hydrologic processes must be represented. Inputs to stormwater models commonly include meteorological (i.e. precipitation, temperature, solar radiation), topographic (i.e. digital elevation models), and land cover data (i.e. soils, land use). Hydrologic models can generally be categorized based on two major sets of characteristics: 1) event versus continuous simulation; and 2) lumped versus spatially distributed parameters (Fletcher et al., 2013).

Event models simulate either single storm events or short time periods, usually 24-hours. Continuous simulation models simulate long time periods, including storm events and inter-storm periods. They are generally more complex than event models because they must simulate evapotranspiration, groundwater flow, and other hydrologic processes that operate during dry periods and over long periods of time (Knapp et al., 1991). Event models are more sensitive to initial conditions, such as antecedent soil moisture, which can be difficult to quantify accurately. Continuous simulation models generally require more input data (e.g. longer time series), though these data can be estimated from nearby areas. An important consideration is that the value associated with natural capital lies not just in the services it provides during storm events, but also in its regulation of hydrologic processes during inter-storm periods. Continuous simulation models are therefore preferable for the purposes of this study, though they require more input data and a more thorough calibration process.

Lumped parameter models use spatially averaged landscape characteristics to simulate hydrologic processes within a catchment. Spatially distributed models simulate individual catchment features and their interactions with adjacent features (Fletcher et al., 2013). Many stormwater models fall somewhere in between lumped and spatially distributed by breaking catchments down into small homogeneous units, or using a hydrologic response unit (HRU) approach which simulates hydrologic processes for a discrete number of land use and soil type combinations (Knapp et al., 1991). The predictive power of spatially distributed models is superior to lumped models, but they also require more detailed data inputs.

### A1.1 EPA SWMM5

SWMM 5 models rainfall-runoff processes and can be used for single event or continuous simulations of stormwater quantity and quality. During setup, users define sub-catchments that have homogeneous landscape characteristics, as well as a network of pipes and channels to which each sub-catchment drains (US EPA, 2015). SWMM 5 is both a hydrologic and hydraulic model, capable of simulating water surface elevations along the conveyance network.

Users may input precipitation data for an extended time period or for a single storm event. Temperature data over the same time period (daily minimums and maximums) allow the model to partition precipitation to rain or snow, and to calculate evapotranspiration rates using the

Hargreaves method (US EPA, 2016). The user may also input wind speed data which will contribute to calculations of snow transport and removal.

After climatic data is entered, the user defines sub-catchment characteristics which determine runoff generation. These characteristics include area, slope, percentage imperviousness, soil properties, and also which other sub-catchment or part of the conveyance system the sub-catchment drains to. There are several options for how to compute infiltration, and required input data will vary based on the user's choice. The user may also input pollutant loading data based on land use type.

It is possible, but not mandatory, to define an aquifer to which some or all sub-catchments drain. If there is an aquifer, SWMM 5 will also model groundwater-surface water interactions. The geometry of pipes, channels, and storage structures within the conveyance network can be set by the user, as well as the flow routing method (several options of varying complexity). Low impact development (LID) controls can also be added to the sub-catchments.

Once all of the relevant parameters have been defined, SWMM 5 computes the runoff response for each sub-catchment and routes flows through the conveyance network. Model output includes peak runoff, total runoff, peak flows at each point of the conveyance network, storage for each LID control, groundwater infiltration rates, groundwater storage, surface water storage, and pollutant build-up and wash-off (US EPA, 2016).

#### *A1.1.1 Previous applications*

EPA SWMM is one of the most widely applied stormwater models, in part because of its ability to simulate both hydrologic and hydraulic processes. Below, we review three applications of SWMM for urban stormwater management.

##### *A1.1.1.1 AECOM, 2010: Town of Gibsons' Integrated Stormwater Management Plan*

In 2010, AECOM completed a stormwater management plan for the Town of Gibsons, British Columbia. They used a SWMM5-based model (InfoSWMM) to simulate the rainfall-runoff processes for the area under pre-development, current, and future development conditions. The SWMM model was used to evaluate the hydrologic and hydraulic impacts for four creeks surrounding Gibsons: Gibsons Creek, Chaster Creek, Charman Creek, and Goosebird Creek. Their model predicted an increase in runoff volume from 34 per cent to 173 per cent over pre-development conditions for the four creeks and they recommended source control best management practices (BMPs) and LID to mitigate this flow increase. AECOM opted to use a separate model (the Water Balance Model) to simulate the impacts of their recommended source control measures, which included expanding and retrofitting a series of detention ponds within a city park. In conjunction with impervious area controls, source controls, and conveyance capacity upgrades, AECOM recommended construction of an 8,000 $m^3$ pond system to maintain flows equivalent to current conditions, and a 15,000 $m^3$ pond system to maintain flows equivalent to pre-development conditions.

#### *A1.1.1.2 Lucas, 2010: Design of Integrated Bioinfiltration-Detention Urban Retrofits with Design Storm and Continuous Simulation Methods*

In this study Lucas used HydroCAD and SWMM to simulate the impacts of bioretention planters and detention trenches on hydrology within an urban catchment. HydroCAD was used to design the green infrastructure retrofits based on a 24-hour rainfall event. The resulting design specifications were added to a SWMM model for an urban catchment, and a design-year distribution of rainfall was simulated. Model results showed that the bioretention planters and detention trenches 47 per cent of storm runoff, reducing combined sewer overflows (CSOs) by 97 per cent.

#### *A1.1.1.3 Borris et al., 2013: Simulating future trends in urban stormwater quality for changing climate, urban land use and environmental controls.*

In this study a SWMM model was used to simulate the water quality impacts of a variety of climate change, increased urbanization, and increased adoption of stormwater controls scenarios within an urban catchment in Sweden. SWMM simulates pollutant buildup during dry periods, and pollutant wash-off during storm events based on user-supplied pollutant data, in this case Event Mean Concentration (EMC) data representative of Swedish urban conditions. Sub-catchment characteristics such as imperviousness, area, and pollutant build-up rate were adjusted to simulate the future scenarios. The model output suggest that imperviousness and urban area have a much stronger impact on stormwater quality and quantity than climate change, but that these impacts could be controlled for by reducing directly connected impervious area.

## A1.2 WinTR-55 (and WinTR-20)

Technical Release 55 (TR-55) was issued by the Soil Conservation Service (SCS) in 1975 as a simplified procedure for calculating storm runoff volume, peak rate of discharge, and storage volumes for storm water management structures (USDA, 2009). Since its initial release, TR-55 has been updated numerous times, eventually becoming WinTR-55, a PC program complete with a graphical user interface. WinTR–55 is a single-event (24-hr storm) rainfall-runoff, small watershed (<25 sq. miles) hydrologic model, that can generate hydrographs for urban and agricultural areas and at points along a stream system. Watersheds can be divided into up to 10 sub-areas, for which the user can define unique landscape characteristics. Hydrographs are generated and routed downstream through channels and/or reservoirs using the Technical Release 20 methodology (TR-20).

TR-20 was originally issued by the SCS in 1965 and is the hydraulic model engine for TR-55. As with TR-55, TR-20 was updated over the years and is now available as a Windows-based computer program called WinTR-20. While the underlying computational routines are the same in both WinTR-55 and WinTR-20, WinTR-20 is capable of simulating larger, more complex systems. Because of the interconnectedness of these two pieces of modeling software, they will be addressed together in this section.

### *A1.2.1 Model overview*

During data entry, WinTR-55 preprocesses time of concentration, land use parameters, channel rating tables, and structure rating tables to be used as input to WinTR-20 computations. Time of concentration (Tc) calculations within WinTR-55 are based on the methods discussed within the National Engineering Handbook, Part 630, chapter 15. Tc is defined as the amount of time required for runoff to travel from the most distant (timewise) point in the watershed to the outlet. Land use details entered by the user are used to calculate weighted curve numbers for each sub-area within the watershed. For each reach designated as a channel, a channel rating table is generated, containing: discharge, cross sectional area, top width, and velocity for depths from 0 to 20 feet. Similarly, a structure rating table is generated for each storage reach, containing: stage, pipe head (only for pipe outlets), pipe or weir flow, and temporary storage.

At a minimum, users must enter the following data to run WinTR-55:

- Project identification data (user, location, project, subtitle)
- Dimensionless unit hydrograph
- Storm data for 24-hour period
- Rainfall distribution identifier
- Sub-area entry and summary (sub-area name, sub-area description, sub-area flows to reach/outlet, area, weighted curve number, time of concentration)

The default dimensionless unit hydrograph is the Natural Resource Conservation Service (NRCS) standard dimensionless unit hydrograph with a peak rate factor of 484 (USDA, 2007), though the user may specify a different dimensionless unit hydrograph. Users may enter storm data manually, or select 24-hour rainfall values from a database which covers most of the United States. The rainfall distribution identifier is included in the rainfall database, or the user may specify a different rainfall distribution. Weighted curve number, and time of concentration may be entered directly by the user or computed using more detailed information. Land cover and hydrologic soil group data may be entered to refine the weighted curve number calculation by sub-area. Curve numbers can be further customized for urban areas by specifying the percentage of connected vs. unconnected impervious area. Length of sheet flow, ‘shallow concentrated flow’, and channel flow may be entered to refine the time of concentration calculation, as well slope and surface roughness (Manning’s N).

Users may include up to 10 reaches within WinTR-55 to simulate the stream network. Reaches can be specified as either channel reaches or storage reaches. For each channel reach, the user may enter data for reach length, Manning’s n, friction slope, bottom width, and side slope, as well as selecting a representative cross section. In WinTR-55, reach cross sections are either rectangular, triangular, or trapezoidal, and the same data will be used to approximate any size flows. In WinTR-20, the user may specify differing channel shapes based on flow volume, which would greatly enhance the predictive power of the model in situations where flows exceed channel capacity, thereby changing the cross sectional structure dramatically. For each storage reach, the user may enter the surface area of the pond and the spillway type and dimensions. Watershed simulations requiring more than 10 reaches or with more complex hydraulics should be run using WinTR-20. Users do not need to include any reach data if all sub-areas flow directly to the watershed outlet.

WinTR-55 output includes hydrographs and flow estimates by stage for the 1-yr, 2-yr, 5-yr, 10-yr, 25-yr, and 100-yr storm events. These can be generated for each channel reach or sub-watershed.

### *A1.2.2 Previous Applications*

In this section, we review two case studies in which WinTR-55 was applied to modeling urban hydrological processes.

#### *A1.2.2.1 Jamaluddin, A.F., Hasan, Z.A., Ghani, A.A., 2011: The impact of campus development on the flash flood potential: A case study at watershed USM Main Campus, Pulau Pinang, Malaysia*

In this study, WinTR-55 was used to estimate the increased flood potential related to urbanization of a university campus in Malaysia. The watershed area was defined using ArcGIS, and subsequently divided into 15 sub-catchments which were each given distinct landscape characteristics in the WinTR-55 model. The post-development scenario was simulated by increasing the curve number and time of concentration for each sub-catchment, reflecting the effects of more impervious surfaces and structures within the watershed area. The model was run for a 24-hour storm with a 2-year return interval, and also a 24-hour storm with a 5-year return interval. Model results show peak flow increases of between 25 per cent and 158 per cent for the 2-year storm, and 15 per cent to 102 per cent for the 5-year storm following urbanization.

#### *A1.2.2.2 Sutjiningsih, D., Soeryantono, H., Anggraheni, E., 2015: Estimation of sediment yield in a small urban ungauged watershed based on the Schaffernak approach at Sugutamu watershed, Ciliwung, West Java*

This study combined WinTR-55 with a sediment model to estimate watershed sediment yield from a storm event. The area of interest was a small, urban watershed in West Java with little available data. WinTR-55 was used to generate a hydrograph which was combined with a 'sediment rating curve' the researchers developed through field surveys. The predicted sediment yield was comparable to results from similar studies in the area.

### *A1.2.3 Pros and Cons of WinTR-55*

Data input requirements for WinTR-55 are minimal, and consist of information that should be readily available to any user. Many of the parameters can be approximated by using look-up tables (e.g. curve number, Manning's N values) if area-specific information is unavailable.

While the model is simple, it is not the most user friendly. The data input process required to run the model is not very intuitive, and might be difficult for inexperienced users. Many of the model parameters are based on empirical relationships rather than physical processes, and thus will be harder to understand for many users.

WinTR-55 is useful for predicting peak streamflow as well as event hydrographs for each channel reach. However, WinTR-55 does not predict total runoff and can only be run for a 24-hour storm, rather than a continuous timeseries. Many of the benefits provided by natural capital are realized over longer periods of time than a single storm event, thus it would be preferable for the model to simulate longer timeseries. However, peak streamflow predictions for a single storm event could be used as proxies for total runoff predictions during the initial assessment.

Event simulation models like WinTR-55 are very sensitive to initial conditions which might be difficult to accurately quantify for municipalities, potentially having a significant impact on the accuracy of model predictions, and raising the bar for input data accuracy. The importance of accurately quantifying initial conditions limits the robustness of WinTR-55.

### A1.3 i-Tree Hydro

The i-Tree software suite was developed by the United States Forest Service (USFS) to assess the benefits and improve management of urban forests. Initially developed in 2008 (Wang et al., 2008), i-Tree Hydro has been updated continuously over the years (Yang et al., 2011; Yang and Endreny, 2013) and is a standalone application within the i-Tree suite that is useful for simulating how land cover and climate changes impact the hydrologic cycle in an area. This model was created for a very similar user-group as the one targeted by this analysis and therefore offers many valuable insights in terms of data input requirements, model structure, computational routines, etc.

#### *A1.3.1 Model Overview*

There are six main computational routines within i-Tree Hydro: interception, impervious, soil, evaporation and transpiration, routing, and pollution. A set of four cold climate hydrology routines were also recently added to the model to allow for simulation of hydrologic processes in watersheds with significant amounts of snow. The interception routine simulates interception of precipitation by vegetation (modified by the cold climate routine to simulate both rain and snow). The impervious routine simulates initial abstraction on the land surface. The soil routine simulates soil surface storage, infiltration and percolation, and discharge from the soil. The evaporation and transpiration routine removes water from the vegetation canopy, impervious surface storage, and soil storage. The routing routine uses either a time-area delay function or a diffusion-based exponential function to create a hydrograph for the outflow point of the watershed. The pollution routine uses the Storm Water Management Model (SWMM) Event Mean Concentration algorithm to estimate loads of various pollutants. Finally, the snow unloading, snowmelt, and snow sublimation routines simulate the removal of snow from the watershed (Yang et al. 2011).

The most unique aspect of i-Tree Hydro is the simplified process for acquiring necessary data inputs for the US. Users can download elevation, streamflow, and meteorological data for their specified area from within the model, which links to an online database of prepared files. Land cover parameters such as 'percentage tree cover' and 'percentage impervious surface' can also be estimated using different applications within the i-Tree suite. This makes the model extremely easy to setup and run, even for users with no previous experience gathering hydrologic data or selecting model parameter values. However, the i-Tree developers have yet to extend their database to include areas outside of the United States.

The first data input requirement is either a digital elevation model (DEM) or topographic index (TI) file for the city or watershed area of interest. Users can select from a list of DEMs covering most cities in the United States or can select from a list of TIs covering most watersheds in the United States. After defining the area of interest, the user must enter basic watershed characteristics such as area, % tree cover, tree leaf area index (LAI), percent evergreen tree cover, percent evergreen shrub cover, and start/end dates and times for the model run. Most of these parameters can be calculated by using other modules within the i-Tree suite if the user does not already have the necessary data. Next, the user has the option to load stream gage and weather station data from the i-Tree database for their specific location or to input their own timeseries. Modeling a city instead of a watershed does not impact model functionality, but does eliminate the option for the user to calibrate the model once data input is complete (USDA, 2010).

On the following screen the user adjusts land cover parameters. Surface cover types are entered as percentages of the total area, and include tree cover, shrub cover, herbaceous cover, water cover, impervious cover, and soil cover. LAI is specified for tree, shrub, and herbaceous cover, and the percentage of directly connected impervious cover is also given. The user can also set the percentages of pervious and impervious cover beneath the tree canopy.

Finally, the user inputs hydrological parameters. The basic hydrological parameters relate to soil and include soil type, wetting front suction, wetted moisture content, surface hydraulic conductivity, depth of root zone, and initial soil saturation. There is also a set of 'advanced parameters' which are initially locked at default values. Advanced users may select to adjust these parameters as well, which include: leaf transition period, leaf on day (1-365), leaf off day (1-365), tree bark area index, shrub bark area index, leaf storage (mm), pervious depression storage (mm), impervious depression storage (mm), scale parameter of power function, scale parameter of soil transmissivity, transmissivity of saturation, unsaturated zone time delay, time constant for surface flow (alpha), time constant for surface flow (beta), and watershed area where rainfall rate can exceed infiltration rate (%) (USDA, 2010).

Once all hydrological parameters have been entered, the user may choose to run through an assisted model calibration process if they are working with a gaged watershed area. However, if the area of interest is a city or if there is no available stream gage data, then it is not possible to calibrate the model.

Model output from i-Tree Hydro includes tables and graphs displaying total streamflow, a hydrograph, total pollutant input, and timeseries of pollutant load. Total streamflow is broken down into impervious flow, pervious flow, and baseflow. The hydrograph can also separate total flow into the impervious, pervious, and baseflow components. The total pollutant input lists pollutant load (kg) for total suspended solids, biochemical oxygen demand, chemical oxygen demand, total phosphorus, soluble phosphorus, total kjeldhal nitrogen, nitrite and nitrate, copper, lead, and zinc. The timeseries of pollutant load lists the kg/hr of the above pollutants. All of these outputs can be viewed as charts with results for the base case displayed next to results for each scenario, making it extremely easy to see the impacts of land use changes.

### *A1.3.2 Previous Applications*

Many studies using i-Tree Hydro have been completed by or for municipalities interested in assessing the impacts of increased tree canopy coverage on urban hydrologic processes. A few of these efforts are summarized below.

#### *A1.3.2.1 Kirnbauer et al., 2013: Estimating the stormwater attenuation benefits derived from planting four monoculture species of deciduous trees on vacant and underutilized urban land parcels*

Kirnbauer et al., 2013 used i-Tree Hydro to investigate the hydrologic impacts of planting trees in vacant and 'underutilized' lots within urban Hamilton, Ontario, Canada. The effects of four different tree species, planted at maximum density on a 1.6-acre lot were compared using i-Tree Hydro. The four tree species differed in their growth rates, leaf area indexes, and the number of trees that could be planted per unit area. i-Tree Hydro was used to determine the amount of interception provided by each tree and by the entire stand of trees over the course of a seven-year simulation period (2002-2008). Researchers found that, depending on the species of tree, individual trees captured between 2.9 $m^3$ and 8.1$m^3$ of rainfall over the course of the year, with the entire stand intercepting and evaporating between 6.5 per cent and 27 per cent of the total rainfall over the simulation period.

#### *A1.3.2.2 Kuehler and Erwin, 2015: Rock Creek Watershed Stormwater Runoff Analysis, i-Tree Hydro Report*

This study looked at the effects of increasing tree canopy cover as well as reducing directly connected impervious area (DCIA) within the increasingly urbanized Rock Creek watershed in Western Little Rock, Arkansas. Land cover classification was performed with the help of i-Tree

Canopy, another application within the i-Tree Suite. i-Tree Hydro was used to simulate 10, 20, and 30 per cent increases in tree canopy coverage, with corresponding decreases in impervious and herbaceous cover. The model was also used to simulate 10, 20, and 30 per cent decreases in DCIA, as well as the combined effects of both increasing tree canopy coverage and decreasing DCIA. Overall, decreasing DCIA was shown to be more effective than increasing tree canopy coverage in terms of reducing overland flow and increasing baseflow. Combining DCIA decreases with tree canopy coverage increases was more effective for reducing overland flow, but less effective for increasing baseflow due to increased interception by the tree canopy.

#### *A1.3.2.3 Plan-It Geo, 2015: Modeling Urban Forest Scenarios and Hydrology in Grand Rapids, Michigan*

In 2009 the city of Grand Rapids, MI set a goal of attaining 40% tree canopy coverage for its urban areas. i-Tree Hydro was used to model the hydrologic impacts of this planned expansion in tree canopy. The study simulated a 24-hour design storm with a 100-year recurrence interval. Using i-Tree Canopy it was determined that canopy coverage would need to be increased by 6% throughout the city to reach the 40 per cent coverage goal. After running i-Tree Hydro for current and future conditions, it was determined that the 6 per cent increase in canopy coverage had the potential to decrease impervious runoff by 5 per cent. Researchers valued this reduction at nearly $100 million using the avoided cost method and an estimate of $1/gal for stormwater mitigation costs.

#### **A1.3.2.4 *Town of Gibsons' Whitetower Park ponds (this study)***

For this analysis, an initial run was performed using i-Tree Hydro in place of the Simple SWMM model described in the main body, above. In the case of Gibsons, B.C. it was not possible to find suitable timeseries containing all of the required weather parameters, so data from nearby weather stations had to be pieced together. Even after locating all of the required data it was difficult to format the timeseries in the manner required by i-Tree Hydro. Ultimately, with help from a few of the i-Tree software developers, a complete input data set was assembled so that the model could be run for Charman Creek. Initial model results conflicted with predictions from the Full SWMM model, so the decision was made to move forward without i-Tree Hydro. i-Tree Hydro would seem to be very well-suited to the goals of this analysis, however further work is needed to work around the issues encountered and assess the full potential of i-Tree for this type of study.

### *A1.3.3 Pros and Cons of i-Tree Hydro*

Overall, i-Tree Hydro is a very user friendly model for watersheds located within the United States. Data input is simple thanks to the user interface which includes informative prompts at each step. The i-Tree software suite contains tools for assisting users in estimating land cover data that would be more difficult to obtain through a GIS. The vast majority of i-Tree Hydro parameters are physically-based, rather than empirical, so even inexperienced users have some sense of the significance of each parameter. One of the more useful features of i-Tree Hydro is the assisted calibration process, which helps guide the user through model calibration and can even make adjustments automatically. Model calibration is an important step in any modeling effort, but is often overlooked when users lacking technical expertise use hydrologic models for decision making. i-Tree Hydro also facilitates scenario comparison by making it easy to define alternative cases. One downside of i-Tree Hydro in terms of user friendliness is that there are no parameters that explicitly model green infrastructure. Instead, users must adjust land cover data to approximate the effects of green infrastructure, and this process may lead to inconsistencies depending on how different users choose to represent green infrastructure. However, there is a guidance document available online (http://www.esf.edu/ere/endreny/GI-iTree/GI-iTreeHydro.htm) to guide users through this process.

For users within the United States, i-Tree data input requirements are minimal. TI files, meteorologic data, and stream gage data can be downloaded for many U.S. cities and watersheds from within the model. i-Tree Hydro requires only easily attainable land cover data and provides default value estimates for all hydrologic parameters.

However, the i-Tree data input process is far more complex for users outside of the United States. In this case, users will need to manually load DEM or TI files as well as weather data, and stream gage data. DEMs are not difficult to obtain or create and the i-Tree Hydro User's Manual (USDA, 2010) provides step-by-step instructions. However, required weather data include wind direction and speed, cloud ceiling, sky cover, temperature, dewpoint, altimeter setting, pressure, and precipitation. Complete datasets containing all of these variables may be difficult to find for many locations. Similarly, hourly stream gage data is not readily available for many streams, which might force users to run the model without calibration, decreasing the strength of model predictions.

After data input and calibration are complete, i-Tree Hydro runs quickly and provides many of the outputs deemed necessary for this analysis: peak flow, total flow, and hydrographs. The model does not include any channel routing routines, but it would be possible to estimate flows at specific points within the channel network by modelling larger watersheds as a number of small catchments. Output graphs facilitate rapid comparison of the base case and alternative scenarios.

The assisted calibration process within i-Tree Hydro makes the model fairly robust, as the model will automatically adjust various hydrologic parameters to accurately reflect the area of interest. However, for ungaged catchments the assisted calibration process is unavailable, so many users will opt to stick with the default values of hydrologic parameters. Model outputs from i-Tree Hydro are very sensitive to adjustments to the set of hydrologic parameters, and while a fairly high level of expertise is required to meaningfully adjust them, not doing so significantly reduces model robustness.

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