FULL AUTHORITY MEETING
ON-LINE VIDEO CONFERENCE
Friday, November 19, 2021
9:30 A.M.

A G E N D A

CALL TO ORDER – ROLL CALL / STAFF INTRODUCTIONS

The Niagara Peninsula Watershed is located on the traditional territory of Indigenous peoples dating back countless generations. We want to show our respect for their contributions and recognize the role of treaty-making in what is now Ontario.

The Niagara Peninsula Conservation Authority (NPCA) grieves with Indigenous people and communities across the country on the tragic loss of so many children to the Residential School System. We acknowledge that with this difficult history comes the responsibility to honour those who were lost, and to strive to better understand how we can support affected communities. The NPCA stands committed to improving our relationships with Indigenous peoples, and working with them to ensure an equitable and meaningful future for all.

1. APPROVAL OF AGENDA

2. DECLARATIONS OF CONFLICT OF INTEREST

3. APPROVAL OF MINUTES

a) Minutes of the Full Authority Meeting dated October 15, 2021 *(For Approval)*

Page # 1

4. CORRESPONDENCE

a) Correspondence dated October 18, 2021 from Alisa Mahrova, Clerk and Manager, Policy, Toronto and Region Conservation Authority RE: TRCA Wetland Water Balance Modelling Guidance Document *(For Receipt and Referral)*

Page # 8

b) Correspondence dated October 21, 2021 from David Quartermain Director, Real Property Management Air, Marine and Environmental Programs, Transport Canada RE: Establishment of an Eco Park on Transport Canada's Surplus Land Site in Niagara-on-the-Lake *(For Receipt)*

Page # 153

c) Correspondence dated November 5, 2021 from Nicholas Fischer, Policy and Planning Officer RE: Conservation Ontario's Comments on "Minister's Order for Temporary Suspension of Protection Upon the Listing of Black Ash Under the Endangered Species Act" (ERO#019-4278) and "Amendments to Ontario Regulation 242/08 (General Regulation – Endangered Species Act, 2007) Relating to Upcoming Changes to the Species at Risk in Ontario List" (ERO#019-4280) *(For Receipt)*

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5. PRESENTATIONS

a) PowerPoint presentation by Sean-Michael Stephen, Manager, Watson & Associates Economists Ltd. RE: Niagara Peninsula Conservation Authority Parks and Recreation Services Fee Review *(For Receipt - This item is in conjunction with Agenda Item 8. a) Report No. FA-64-2021 RE: 2022 Conservation Area Fees)*

Page # 157

6. DELEGATIONS

7. CONSENT ITEMS

a) Report No. FA-63-2021 RE: Comfort Maple Tree Assessment *(For Receipt)*

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8. DISCUSSION ITEMS

a) Report No. FA-64-2021 RE: 2022 Conservation Area Fees *(For Approval)*

Page # 176

b) Report No. FA-65-2021 RE: Wainfleet Bog Advisory Committee Terms of Reference *(For Approval)*

Page # 185

c) Report No. FA-68-2021 RE: NPCA Transition Plan in Accordance with Section 21.1.4 of the *Conservation Authorities Act (For Approval)*

Page #193

9. COMMITTEE REPORTS

9.1 FINANCE COMMITTEE

a) Minutes of the Finance Committee meeting dated November 4, 2021 *(For Receipt)*

Page # 199

b) Report No. FA-69-21 RE: Financial Report – Q3 – 2021 *(For Receipt)*

Page # 202

c) Report FA-70-2021 RE: 2022 Draft Budgets and Municipal Levies *(For Approval)*

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10. MOTIONS

11. NOTICES OF MOTION

12. NEW BUSINESS

a) C.A.O. Updates - Verbal

b) Niagara Peninsula Conservation Foundation Update – Verbal

13. CLOSED SESSION

a) Litigation or Potential Litigation - Verbal Update on Enforcement and Compliance

14. ADJOURNMENT

FULL AUTHORITY
ONLINE VIDEO CONFERENCE
MEETING MINUTES
Friday October 15, 2021
9:30 A.M.

NOTE:	**The archived recorded meeting is available on the NPCA website. The recorded video of the Full Authority meeting is not considered the official record of that meeting. The official record of the Full Authority meeting shall consist solely of the Minutes approved by the Full Authority Board.** *NPCA Administrative By-law*

MEMBERS PRESENT:
B. Mackenzie (Vice Chair)
S. Beattie
R. Brady
B. Clark
D. Coon-Petersen (arrived at 9:57 a.m.)
D. Cridland
L. Feor
R. Foster (departed 11:15 a.m.)
J. Hellinga
J. Ingrao
K. Kawall
J. Metcalfe
W. Rapley
M. Woodhouse
B. Wright

MEMBERS ABSENT:
D. Huson
B. Johnson
R. Shirton
E. Smith
B. Steele

OTHERS:
K. Baker, Strategy Corp.
T. Insinna, Chair Niagara Peninsula Conservation Foundation
J. Matheson, Strategy Corp.
J. Oblak, Chair of Public Advisory Committee

STAFF PRESENT:
C. Sharma, CAO / Secretary – Treasurer
G. Bivol, Clerk
E. Augustino, Water Quality Technician
A. Christie, Director, Operations
C. Coverdale, Business and Financial Analyst
J. Culp, Manager, Compliance and Enforcement
D. Deluce, Senior Manager, Planning and Regulations
J. Diamond, Water Quality Specialist
M. Ferrusi, Manager, Human Resources
L. Gagnon, Director, Corporate Services

N. Green, Project Manager, Strategic Plan
R. Hull, Manager, Strategic Business Planning and Public Relations
B. Lee, GIS Administrator
L. Lee-Yates, Director, Watershed Management
S. Mastroianni, Manager, Planning and Development
S. Miller, Senior Manager, Water Resources
K. Royer, Community and Volunteer Outreach
G. Shaule, Administrative Assistant
G. Verkade, Senior Manager, Integrated Watershed Planning / Information Management

Vice Chair Mackenzie called the meeting to order at 9:31 a.m..

1. APPROVAL OF AGENDA

Resolution No. FA-167-2021
Moved by Member Clark
Seconded by Member Foster

THAT agenda for the Full Authority Meeting dated October 15, 2021 **BE APPROVED**.

CARRIED

2. DECLARATIONS OF CONFLICT OF INTEREST

None declared.

3. APPROVAL OF MINUTES

a) Minutes of the Full Authority Meeting dated September 17, 2021 – A clerical amendment was requested to denote the absence of Vice Chair Mackenzie from the proceedings.

Resolution No. FA-168-2021
Moved by Member Beattie
Seconded by Member Ingrao

THAT the minutes of the Full Authority Meeting dated September 17, 2021 **BE APPROVED** as amended.

CARRIED

b) Minutes of the Closed Session Meeting dated September 17, 2021 - A clerical amendment was requested to denote the absence of Vice Chair Mackenzie from the proceedings.

Resolution No. FA-169-2021
Moved by Member Rapley
Seconded by Member Wright

THAT the minutes of the Closed Session Meeting dated September 17, 2021 **BE APPROVED** as amended.

CARRIED

4. CORRESPONDENCE

a) Correspondence dated October 5, 2021 to the Honourable David Piccini, Minister of Environment, Conservation and Parks from Andy Mitchell, Chair, Conservation Ontario RE: Update on Conservation Ontario's Client Service and Streamlining Initiative and related bulletin entitled "Conservation Authorities Continue to Demonstrate their Commitment to Improving Client Service and Streamlining"

Resolution No. FA-170-2021
Moved by Member Kawall
Seconded by Member Cridland

THAT the correspondence dated October 5, 2021 to the Honourable David Piccini, Minister of Environment, Conservation and Parks from Andy Mitchell, Chair, Conservation Ontario RE: Update on Conservation Ontario's Client Service and Streamlining Initiative and related bulletin entitled "Conservation Authorities Continue to Demonstrate their Commitment to Improving Client Service and Streamlining" **BE RECEIVED**.

CARRIED

5. PRESENTATIONS

a) Presentation on Strategic Plan by C. Sharma, C.A.O. and N. Green, Project Manager - Agenda Item 8. b) Report No. FA-59-21 RE: NPCA Strategic Plan: 2021-2031 was addressed in conjunction with this presentation. Strategic Planning Committee Chair Ken Kawall provided opening remarks. The Board was introduced to the Strategic Planning Team. CAO Sharma and Project Manager Natalie Green presented with comments thereafter from John Matheson, Strategy Corp. Discussion ensued.

Resolution No. FA-171-2021
Moved by Member Kawall
Seconded by Member Beattie

1. **THAT** Report No. FA-59-21 Draft Strategic Plan: 2021-2031 **BE RECEIVED**.

2. **AND FURTHER THAT** the Draft Strategic Plan 2021-2031 **BE APPROVED**.

CARRIED

b) Presentation by J. Oblak, Chair, NPCA Public Advisory Committee RE: Discussion Paper - Identification of Key Issues and Opportunities within the Niagara Peninsula Conservation Authority (NPCA) Area October 5, 2021

Resolution No. FA-172-2021
Moved by Member Clark
Seconded by Member Cridland

1. **THAT** the presentation by J. Oblak, Chair, NPCA Public Advisory Committee RE: Discussion Paper - Identification of Key Issues and Opportunities within the Niagara Peninsula Conservation Authority (NPCA) Area October 5, 2021 **BE RECEIVED**.

2. **AND THAT** the matter **BE REFERRED** to staff for a report back to the Board.

CARRIED

c) PowerPoint Presentation by Brian Lee, GIS Administrator RE: Watershed Planner / Open Data Hub

Resolution No. FA-173-2021
Moved by Member Feor
Seconded by Member Hellinga

THAT the PowerPoint presentation by Brian Lee, GIS Administrator RE: Watershed Planner/Open Data Hub **BE RECEIVED**.

CARRIED

6. DELEGATIONS

Presentation by Tom Insinna, Chair, Niagara Peninsula Conservation Foundation RE: 2020 Annual Report – Mr. Insinna addressed the Board. Discussion ensued.

Resolution No. FA-174-2021
Moved by Member Wright
Seconded by Member Cridland

THAT the presentation by Tom Insinna, Chair, Niagara Peninsula Conservation Foundation and the 2020 Niagara Peninsula Conservation Foundation Annual Report **BE RECEIVED**.

CARRIED

7. CONSENT ITEMS

a) Report No. FA-58-21 RE: 2021 Memorandum of Understanding between Conservation Ontario and Hydro One Networks Inc.

b) Report No. FA-60-2021 RE: NR Watershed Planning Equivalent Volume 1 and 2 Comments

c) Report No. FA-61-2021 RE: Compliance and Enforcement Q3 Stats

Resolution No. FA-175-2021
Moved by Member Ingrao
Seconded by Member Rapley

THAT the following reports **BE RECEIVED**:

- Report No. FA-58-21 RE: 2021 Memorandum of Understanding between Conservation Ontario and Hydro One Networks Inc.;
- Report No. FA-60-2021 RE: NR Watershed Planning Equivalent Volume 1; and
- Report No. FA-61-2021 RE: Compliance and Enforcement Q3 Stats.

CARRIED

8. DISCUSSION ITEMS

a) Report No. FA-57-2021 RE: NPCA Water Well Decommissioning Grant Program – Steve Miller, Senior Manager, Water Resources spoke to the report.

Resolution No. FA-176-2021
Moved by Member Metcalfe
Seconded by Member Wright

1. **THAT** Report No. FA FA-57-2021 RE: NPCA Water Well Decommissioning Grant Program **BE RECEIVED** for information.

2. **THAT** a copy of this report **BE SENT** to NPCA's Public Advisory Committee for further outreach.

3. **AND FURTHER THAT** staff **CONTINUE** to implement outreach strategies listed in the report**.**

CARRIED

b) Report No. FA-59-21 RE: NPCA Strategic Plan: 2021-2031 - This item was addressed as a part of Agenda Item 5 a) Presentation on Strategic Plan.

c) Report No. FA-62-2021 RE: Update to Niagara Peninsula Conservation Authority (NPCA) Conservation Authorities Act (CA Act) Section 28 Hearing Procedures **-** Leilani Lee-Yates, Director of Watershed Management presented and identified a clerical correction for the staff recommendation to clarify that the administrative By-law would require updates by year's end.

Resolution No. FA-177-2021
Moved by Member Clark
Seconded by Member Brady

1. **THAT** Report No. FA-62-2021 RE: Update to Niagara Peninsula Conservation Authority (NPCA) Conservation Authorities Act (CA Act) Section 28 Hearing Procedures **BE RECEIVED**.

2. **THAT** the NPCA's CA Act Section 28 Hearing Procedures **BE UPDATED** based on the amended CA Act Model Hearing Guidelines, 2021, regarding hearings under s.28.0.1(7), as appended.

3. **THAT** staff **BE DIRECTED** to bring forward the updated NPCA CA Act Section 28 Hearing Procedures as part of the Administrative By-law, to be updated by the end of 2021, as per Provincial requirements resulting from the CA Act regulatory changes.

4. **THAT** until such time as the NPCA's CA Act Section 28 Hearing Procedures are updated, the CA Act Model Hearing Guidelines, 2021, attached as Appendix 1 hereto **BE USED** as required for direction.

5. **AND FURTHER THAT** in collaboration with Conservation Ontario, staff **BE DIRECTED** to develop appropriate training materials for the Board.

CARRIED

9. COMMITTEE ITEMS

9.1 STRATEGIC PLANNING COMMITTEE

9.1.1 Minutes of the Strategic Planning Committee Meeting dated September 17, 2021

Resolution No. FA-178-2021
Moved by Member Feor
Seconded by Member Beattie

THAT the minutes of the Strategic Planning Committee Meeting dated September 17, 2021 **BE RECEIVED**.

CARRIED

9.2 GOVERNANCE COMMITTEE

9.2.1 Minutes of the Governance Committee Meeting dated September 23, 2021

Resolution No. FA-179-2021
Moved by Member Kawall
Seconded by Member Cridland

THAT the minutes of the Finance Committee Meeting dated, September 23, 2021 **BE RECEIVED**.

CARRIED

9.3 PUBLIC ADVISORY COMMITTEE

9.3.1 Minutes of the Public Advisory Committee Meeting dated October 5, 2021

Resolution No. FA-180-2021
Moved by Member Clark
Seconded by Member Ingrao

THAT the minutes of the Public Advisory Committee Meeting dated, October 5, 2021 **BE RECEIVED**.

CARRIED

9.3.2 Minutes of the Watershed Floodplain Subcommittee Meeting dated October 5, 2021

Resolution No. FA-181-2021
Moved by Member Beattie
Seconded by Member Brady

THAT the minutes of the Watershed Floodplain Subcommittee Meeting dated, October 5, 2021 **BE RECEIVED.**

CARRIED

10. MOTIONS

None

11. NOTICES OF MOTION

None

12. NEW BUSINESS

a) C.A.O. Updates – Vice Chair Mackenzie spoke on Conservation Authorities Act Regulations, on behalf of C.A.O. Sharma and Adam Christie, Director of Operations provided an update on the recent Balls' Falls Thanksgiving Festival and the upcoming Holiday Trail.

Resolution No. FA-182-2021
Moved by Member Metcalfe
Seconded by Member Woodhouse

THAT the verbal update from Vice Chair Mackenzie and A. Christie Director, Operations **BE RECEIVED**.

CARRIED

b) Niagara Peninsula Conservation Foundation Update – None

13. CLOSED SESSION

None

14. ADJOURNMENT

Resolution No. FA-183-2021
Moved by Member Clark
Seconded by Member Brady

THAT the Full Authority Meeting **BE ADJOURNED** at 11:38 a.m..

CARRIED

Brenda Johnson, Chair
Niagara Peninsula Conservation Authority

Chandra Sharma, MCIP, RPP
Chief Administrative Officer / Secretary-Treasurer,
Niagara Peninsula Conservation Authority

October 18, 2021

Sent via email

RE: TRCA Wetland Water Balance Modelling Guidance Document

Toronto and Region Conservation Authority (TRCA) Board of Directors, at its meeting, held on September 24, 2021, adopted Resolution #A173/21, as amended, as follows:

WHEREAS wetlands play a crucial role as part of the "green infrastructure" of the Greater Toronto Area region by providing stormwater retention, flood attenuation, filtering of air and water pollutants, wildlife habitat and greenspace for communities to enjoy;

AND WHEREAS Toronto and Region Conservation Authority (TRCA) regulates wetlands and the interference with wetlands under Ontario Regulation 166/06;

AND WHEREAS TRCA staff review and assess submissions for development, infrastructure and site alteration affecting the hydrology of wetlands as part of planning, environmental assessment and permitting applications;

AND WHEREAS the development industry requested a technical guideline to provide guidance to proponents on how to model the hydrology of a wetland when impacts from a proposed development are anticipated to inform mitigation measures. The guidance document provides direction that helps to streamline the application review process by explicitly outlining the procedure for conducting a feature-based water balance modelling exercise for the protection of a wetland's hydrology;

AND WHEREAS in July of 2018, TRCA staff sought input into the development of the draft Modelling Guidance Document from partner municipalities, provincial agencies, the Building Industry and Land Development Association (BILD), consulting firms and neighbouring conservation authorities, and have now finalized the Modelling Guidance Document based on the input received;

THEREFORE, LET IT BE RESOLVED THAT the TRCA Wetland Water Balance Modelling Guidance be approved for use by proponents of development and infrastructure, consultants, and TRCA staff in the planning and development submission, review and approval process;

THAT TRCA staff be directed to continue updating the living document and report back with recommendations in 2022;

AND FURTHER THAT the Ministry of Northern Development, Mines, Natural Resources and Forestry, the Ministry of Transportation, the Ministry of Municipal Affairs and Housing, the Ministry of Environment, Conservation and Parks, the Ministry of the Environment and Climate Change, TRCA's member municipalities, Conservation Ontario and neighbouring conservation authorities be so advised.

The report and referenced resolution are attached to this letter and can also be accessed at the TRCA Board of Directors webpage. If you have any questions or require additional information, please contact Dilnesaw Chekol at 416-661-6600 ext. 5746, dilnesaw.chekol@trca.ca.

Sincerely,

Alisa Mahrova
Clerk and Manager, Policy

cc: John MacKenzie, Chief Executive Officer, TRCA
Sameer Dhalla, Director, Development and Engineering Services, TRCA
Rehana Rajabali, Associate Director, Engineering Services, TRCA
Dilnesaw Chekol, Senior Engineer, Water Resources, TRCA

DISTRIBUTION LIST

Hon. Steve Clark, Minister, Municipal Affairs and Housing
Hon. Caroline Mulroney, Minister, Transportation
Hon. David Piccini, Minister, Environment, Conservation and Parks
Hon. Greg Rickford, Minister, Norther Development, Mines, Natural Resources and Forestry
Hon. Jonathan Wilkinson, Minister, Environment and Climate Change
Gillian Angus-Traill, Clerk, Town of Whitchurch-Stouffville
Susan Cassel, City Clerk, City of Pickering
Todd Coles, City Clerk, City of Vaughan
Nicole Cooper, Director, Legislative and Information Services /Town Clerk, Town of Ajax
Michael de Rond, Town Clerk, Town of Aurora
Mark Early, Chief Administrative Officer and Clerk, Town of Mono
John Elvidge, City Clerk, City of Toronto
Peter Fay, City Clerk, City of Brampton
Kim Gavine, General Manager, Conservation Ontario
Dianne Gould-Brown, Clerk, Township of Adjala-Tosorontio
Laura Hall, Town Clerk, Town of Caledon
Stephen M.A. Huycke, City Clerk, City of Richmond Hill
Kimberley Kitteringham, City Clerk, City of Markham
Debbie Leroux, Clerk, Township of Uxbridge
Kathryn Lockyer, Regional Clerk and Director of Clerks and Legal Services, Regional Municipality of Peel
Kathryn Moyle, Township Clerk, Township of King
Christopher Raynor, Regional Clerk, Regional Municipality of York
Diana Rusnov, City Clerk, City of Mississauga
Ralph Walton, Regional Clerk / Director, Legislative Services, Regional Municipality of Durham
Ontario Conservation Authorities

Section I – Items for Board of Directors Action

<u>RES.#A173/21</u> -	**TRCA WETLAND WATER BALANCE MODELLING GUIDANCE DOCUMENT** Board approval of Toronto and Region Conservation Authority's (TRCA) Wetland Water Balance Modelling Guidance Document, a decision support tool developed to support the *Water Balance for Protection of Natural Features* of TRCA's Stormwater Management Criteria, and The Living City Policies for Planning and Development in the watersheds of TRCA.

Moved by: Jennifer Drake
Seconded by: Linda Jackson

WHEREAS wetlands play a crucial role as part of the "green infrastructure" of the Greater Toronto Area region by providing stormwater retention, flood attenuation, filtering of air and water pollutants, wildlife habitat and greenspace for communities to enjoy;

AND WHEREAS Toronto and Region Conservation Authority (TRCA) regulates wetlands and the interference with wetlands under Ontario Regulation 166/06;

AND WHEREAS TRCA staff review and assess submissions for development, infrastructure and site alteration affecting the hydrology of wetlands as part of planning, environmental assessment and permitting applications;

AND WHEREAS the development industry requested a technical guideline to provide guidance to proponents on how to model the hydrology of a wetland when impacts from a proposed development are anticipated to inform mitigation measures. The guidance document provides direction that helps to streamline the application review process by explicitly outlining the procedure for conducting a feature-based water balance modelling exercise for the protection of a wetland's hydrology;

AND WHEREAS in July of 2018, TRCA staff sought input into the development of the draft Modelling Guidance Document from partner municipalities, provincial agencies, the Building Industry and Land Development Association (BILD), consulting firms and neighbouring conservation authorities, and have now finalized the Modelling Guidance Document based on the input received;

THEREFORE, LET IT BE RESOLVED THAT the TRCA Wetland Water Balance Modelling Guidance be approved for use by proponents of development and infrastructure, consultants, and TRCA staff in the planning and development submission, review and approval process;

AND FURTHER THAT the Ministry of Northern Development, Mines, Natural Resources and Forestry, the Ministry of Transportation, the Ministry of Municipal Affairs, the Ministry of Environment, Conservation and Parks, the Ministry of the Environment and Climate Change, TRCA's member municipalities, Conservation Ontario and neighbouring conservation authorities be so advised.

RES.#A174/21 - AMENDMENT TO THE MAIN MOTION

Moved by: Jack Heath
Seconded by: Jennifer Drake

THAT the following be inserted after the sixth paragraph of the main motion:

> ***THAT TRCA staff be directed to continue updating the living document and report back with recommendations in 2022;***

THE AMENDMENT WAS:

CARRIED

THE RESULTANT MOTION READS AS FOLLOWS:

WHEREAS wetlands play a crucial role as part of the "green infrastructure" of the Greater Toronto Area region by providing stormwater retention, flood attenuation, filtering of air and water pollutants, wildlife habitat and greenspace for communities to enjoy;

AND WHEREAS Toronto and Region Conservation Authority (TRCA) regulates wetlands and the interference with wetlands under Ontario Regulation 166/06;

AND WHEREAS TRCA staff review and assess submissions for development, infrastructure and site alteration affecting the hydrology of wetlands as part of planning, environmental assessment and permitting applications;

AND WHEREAS the development industry requested a technical guideline to provide guidance to proponents on how to model the hydrology of a wetland when impacts from a proposed development are anticipated to inform mitigation measures. The guidance document provides direction that helps to streamline the application review process by explicitly outlining the procedure for conducting a feature-based water balance modelling exercise for the protection of a wetland's hydrology;

AND WHEREAS in July of 2018, TRCA staff sought input into the development of the draft Modelling Guidance Document from partner municipalities, provincial agencies, the Building Industry and Land Development Association (BILD), consulting firms and neighbouring conservation authorities, and have now finalized the Modelling Guidance Document based on the input received;

THEREFORE, LET IT BE RESOLVED THAT the TRCA Wetland Water Balance Modelling Guidance be approved for use by proponents of development and infrastructure, consultants, and TRCA staff in the planning and development submission, review and approval process;

THAT TRCA staff be directed to continue updating the living document and report back with recommendations in 2022;

AND FURTHER THAT the Ministry of Northern Development, Mines, Natural Resources and Forestry, the Ministry of Transportation, the Ministry of Municipal Affairs, the Ministry of Environment, Conservation and Parks, the Ministry of the Environment and Climate Change, TRCA's member municipalities, Conservation Ontario and neighbouring conservation authorities be so advised.

CARRIED

BACKGROUND

At Authority Meeting #7/12, held on September 28, 2012, Resolution #A173/12 was approved, endorsing the TRCA Stormwater Management Criteria document (hereafter referred to as the SWM Criteria document). In accordance with provincial guidance and TRCA's The Living City Policies, applications under TRCA review are required to meet TRCA's criteria for water quantity, water quality, erosion and water balance. For proposals that impact a wetland's hydrology that has been designated for protection through the planning process, a wetland water balance analysis must be undertaken by the proponent. The water balance analysis helps to ensure the protection of wetlands and their ecological functions following development, and to increase the resilience of wetlands to other stressors, such as climate change. Wetland water balance analysis may also reduce municipal risks and liabilities associated with flooding of private property and municipal infrastructure, which are issues that may arise when wetland water balance is not properly considered. A water balance will not generally be required for linear infrastructure, such as roads and railways, where TRCA's regular permitting process would generally be sufficient to address potential impacts to natural features and associated mitigation options.

To help achieve the wetland water balance objectives, TRCA developed a series of technical guidance tools including TRCA's Wetland Water Balance Monitoring Protocol. The protocol was endorsed by Resolution #A143/16 at Authority Meeting #6/16, held on July 22, 2016, TRCA's Wetland Water Balance Risk Evaluation that was endorsed by Resolution #A210/17 at Authority Meeting #9/17, held on November 17, 2017, and TRCA's Wetland Water Balance Modelling Guidance Document (hereafter the Modelling Guidance Document) have been updated as presented in the attached documents.

Wetland Water Balance Modelling Guidance

The Modelling Guidance Document is a technical guideline that was requested by the development industry to outline the approach and procedure for conducting a feature-based water balance modelling exercise for the protection of wetland hydrology, as outlined in the Stormwater Management Criteria Document (SWM Document; TRCA, 2012). The purpose of the modelling exercise is to inform the need for, and the design of, mitigation measures to ensure a minimal difference between the post-development and pre-development water balance of a wetland. This Modelling Guidance Document provides an overview of wetland hydrology modelling, the strengths and weaknesses of various hydrological models, and the information that needs to be included in a feature-based water balance analysis report.

The Modelling Guidance Document is accompanied by a companion document, entitled Wetland Water Balance Modelling Case Studies (hereafter the Modelling Case Studies), that outlines set-up, calibration, and validation of wetland water balance models within five commonly used continuous hydrology models (HEC-HMS, HSPF, SWMM, MIKE-SHE, and VO5). This collection of modelling case studies is not intended to be a definitive guide to application of these models, but rather illustrates potential approaches within each model, and the advantages or drawbacks to application of the models to specific scenarios. The Modelling Guidance Document is intended to be a living document that TRCA staff will update periodically as new information and/or modelling approaches become available.

The Modelling Guidance Document benefits proponents by:

- Providing an overview of wetland hydrology modelling including the strengths and weaknesses of various hydrological models
- Clarifying the information that needs to be included in a feature-based water balance analysis report along with recommended report template and main section headings
- Providing consistency and transparency in decision-making along with a statistical tool that allows selection of acceptable mitigation measures:

- Efficiently using information as it largely requires the use of data and modeling approaches that is already being used as part of the planning process;
- Simplifying the review process by providing step-by-step guidance on risk determination.

RATIONALE

Conservation authorities (CAs) regulate wetlands under section 28 of the *Conservation Authorities Act* due to their importance for the hydrology and the ecology of watersheds. CAs also advocate for the protection of wetlands in their commenting roles under the planning and environmental assessment review processes. Protection of wetlands and their associated hydrological and ecological services is a key objective under provincial policy including the Provincial Policy Statement, the Oak Ridges Moraine Conservation Plan and the Greenbelt Plan.

The protection of wetlands on the landscape helps to fulfill TRCA's key objectives, and those of the Province and municipalities, for watershed resilience to climate change and land use change. Wetlands cover less than five percent of TRCA's jurisdiction yet provide a disproportionately large number of ecosystem services, including water storage, reduction of downstream flooding and erosion, provision of baseflow in streams, and provision of habitat for plants and animals (some of which only occur in wetlands).

The water balance of a wetland is an accounting of the various pathways by which water enters or leaves a wetland, such as rainfall, overland runoff or groundwater seepage. Land use change within the surface water catchment of a wetland may alter the water balance by changing the ratio of surface runoff (water output) to infiltration (water input) within the catchment, the proportion of water lost to evapotranspiration, or the area draining to a wetland through grading and stormwater management activities. Many of the ecosystem services provided by wetlands are dependent on the water balance and altering the water balance can result in loss of ecosystem services.

TRCA has documented several instances in which insufficient consideration of water balance for natural features has resulted in loss of ecosystem services and created nuisance flooding and erosion issues on private lots and back-up of water into municipal stormwater infrastructure. These are issues that are difficult and expensive to mitigate after development has occurred and/or infrastructure has been installed. Proactive mitigation during the planning phase is much more cost-effective but requires that the need for a water balance analysis be identified as early as possible in the planning and development process so that proponents and reviewers can scope the analysis into the application.

The determination of which wetlands will be protected on the landscape is external to any application of this Modelling Guidance Document and will be made as part of a planning or infrastructure review and approval process. The Wetland Water Balance Risk Evaluation (Risk Evaluation; TRCA, 2017) should be completed in advance of any application of this Modeling Document to determine the appropriate scope of analysis and type of model to be used. The Risk Evaluation identifies if a water balance analysis is necessary and, if so, the scope of study (monitoring and modeling) that is appropriate given the features of the application in question. If modelling is determined to be in scope, the Modeling Document and its companion document, the Modelling Case Studies, provides further guidance on suitable approaches and methods in modelling wetland hydrology, the strengths and weaknesses of commonly utilized continuous hydrology models, and the critical information that needs to be included in a feature-based water balance analysis report to identify the need for, and the design of, mitigation measures to ensure a minimal difference between the post-development and pre-development water balance of a wetland.

Stakeholder Consultation
TRCA staff established an External Stakeholder Committee (ESC) with representatives from municipalities, BILD, the consulting industry, Credit Valley Conservation, and other conservation authorities to collaborate on the development of the Modelling Guidance Document. The Modelling Guidance concept and intent to develop the guidance was presented to BILD in September 2016, then the draft document was presented to the ESC in February 2018. Then, drafts of the document were circulated twice for comment (summer 2018 and fall 2019) and revised based on feedback from internal staff, the ESC, and more broadly from external partners, which included all TRCA's partner municipalities, BILD, the consulting industry, relevant provincial agencies, and neighbouring conservation authorities.

External commentators were generally supportive of the intent, structure, and content of the draft version, and some had seen the draft previously through its use by TRCA Engineering staff; preliminary reports from staff are that the draft is helpful as a tool for consultants and staff in scoping water balance modelling exercises.

Furthermore, the Ministry of Northern Development, Mines, Natural Resources and Forestry recently released "Wetland Conservation Strategy for Ontario (2017-2030)" outlines the Province of Ontario's objective of ensuring no net loss of wetlands in southern Ontario by 2025, while the Ontario Flooding Strategy (2020) cites the development of policy tools and approaches to prevent new wetland loss. The Modelling Guidance Document can help achieve the above objectives.

Relationship to Building the Living City, the TRCA 2013-2022 Strategic Plan
This report supports the following strategies set forth in the TRCA 2013-2022 Strategic Plan:
Strategy 2 – Manage our regional water resources for current and future generations
Strategy 4 – Create complete communities that integrate nature and the built environment
Strategy 9 – Measure performance

FINANCIAL DETAILS
The development of the Modelling Guidance Document was supported by capital funding from the regional municipalities of York and Peel. TRCA staff secured external funding in the form of grants from the Great Lakes Protection Initiative (formerly the Great Lakes Sustainability Fund) and the Toronto and Region Remedial Action Plan. These grants, together with funding from the regions of York and Peel, also support continued wetland water balance monitoring in the jurisdiction being led by TRCA and Credit Valley Conservation.

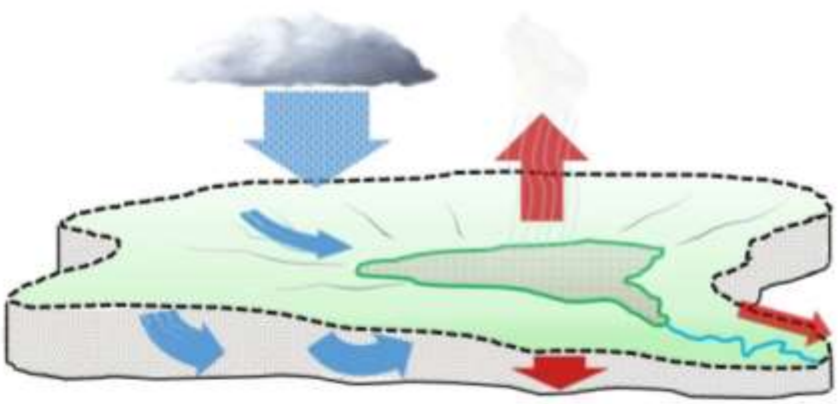
DETAILS OF WORK TO BE DONE
The Modelling Guidance Document will be implemented through the Development and Engineering Services division in review of Planning Act applications, environmental assessments and master planning, and through TRCA's permitting process. TRCA planners, engineers, ecologists and hydrogeologists reviewing applications will continue to work with development proponents and consultants to streamline the review process while striving for the best possible outcome for environmental and growth management objectives. TRCA's Planning and Development Procedural Manual, Environmental Impact Study Guidelines, and Stormwater Management Criteria document will all be updated to reference the Modelling Guidance Document.

The Modelling Guidance Document will be posted on TRCA's website and will be reviewed biennially in conjunction with the Wetland Water Balance Monitoring document and Wetland Water Balance Risk Evaluation to reflect new science and understanding, and any minor updates to the SWM Criteria document. TRCA will communicate the approval of the Modelling

Guidance Document to our municipal and conservation authority partners as well as other stakeholders.

Report prepared by:
Namrata Shrestha, Senior Manager, Watershed Planning and Reporting, ext. 5782; Dilnesaw Chekol, Senior Engineer, Water Resources Engineering Services, ext. 5746
Emails: namrata.shrestha@trca.ca; dilnesaw.chekol@trca.ca
For Information contact: Dilnesaw Chekol, ext. 5746
Emails: dilnesaw.chekol@trca.ca
Date: August 11, 2021
Attachments: 2

Attachment 1: Wetland Water Balance Modelling Guidance Document
Attachment 2: Wetland Water Balance Modelling Case Studies



WETLAND WATER BALANCE MODELLING GUIDANCE DOCUMENT

Toronto and Region Conservation Authority
August 2020

Acknowledgments

This document is made possible by generous funding and contributions provided by:

The Great Lakes Sustainability Fund
The Regional Municipality of Peel
The Regional Municipality of York
Toronto Remedial Action Plan
The Regional Municipality of Durham
The City of Toronto
Credit Valley Conservation

We gratefully acknowledge the contributions of the members of the Wetland Water Balance External Stakeholder Committee throughout the development of this document. The stakeholder committee included technical experts in stormwater engineering, ecology, hydrogeology, and planning with representation from both the public and private sectors.

Special thanks to Neil Taylor for help researching and compiling sections of this document.

For further information about this document, please contact:

Dilnesaw Chekol, Ph.D, P.Eng
Senior Water Resources Engineer, Engineering Services, Development & Engineering Services Division, Toronto and Region Conservation Authority
416-661-6600 ext. 5746
dilnesaw.chekol@trca.ca

Please reference this document as:

Wetland Water Balance Modelling Guidance Document, Toronto and Region Conservation Authority, 2020

Table of Contents

Figures, Tables, and Equations

How to Read This Document

This *Wetland Water Balance Modelling Guidance Document* (hereafter *Modelling Document*) is intended to outline the approach and procedure for conducting a feature-based water balance modelling exercise for the protection of wetland hydrology, as outlined in the Stormwater Management Criteria Document (SWM Document; TRCA, 2012). The purpose of the modelling exercise is to inform the need for, and the design of, mitigation measures to ensure a minimal difference between the post-development and pre-development water balance of a wetland. This *Modelling Document* provides an overview of wetland hydrology modelling, the strengths and weaknesses of various hydrological models, and the information that needs to be included in a wetland feature-based water analysis report.

<u>The sections of this *Modelling Document* correspond to the template format for a feature-based water balance analysis report, which is also outlined in Appendix A of this document.</u> The intent is that the reader should refer to this document section by section to determine the information that is required in each corresponding section of the report (i.e. section 4 of the *Modelling Document*, outlining the development the conceptual model, corresponds to the information that should be included in the same section of the report).

Note that there is also a companion document to this *Modelling Document*, entitled *Wetland Water Balance Modelling Case Studies*, that outlines set-up, calibration, and validation of wetland water balance models within five commonly used continuous hydrology models (HEC-HMS, HSPF, SWMM, MIKE-SHE, and VO5). This collection of modelling case studies is not intended to be a definitive guide to application of these models, but rather illustrates potential approaches within each model, and the advantages or drawbacks to application of the models to specific scenarios. As model codes and modules change rapidly, other continuous hydrology models not listed in this document or the companion document may be acceptable; proponents are asked to verify alternative modelling approaches with TRCA staff prior to any submissions.

Finally, please note that this *Modelling Document* is intended to be a living document that TRCA staff intend to update periodically as new information and/or modelling approaches become available.

1 Introduction

This *Modelling Document* outlines the methods and procedures for conducting a feature-based water balance modelling exercise for the protection of wetland hydrology, as outlined in the Stormwater Management Criteria Document (*SWM Document*; TRCA, 2012) in *Appendix D: Water Balance for Protection of Natural Features.* The purpose of the modelling exercise is to inform the need for, and the design of, mitigation measures to ensure a minimal difference between the post-development and pre-development water balance of a wetland. Figure 1 below depicts an overview of the model development process, including critical steps for consultation with TRCA and/or the municipality.

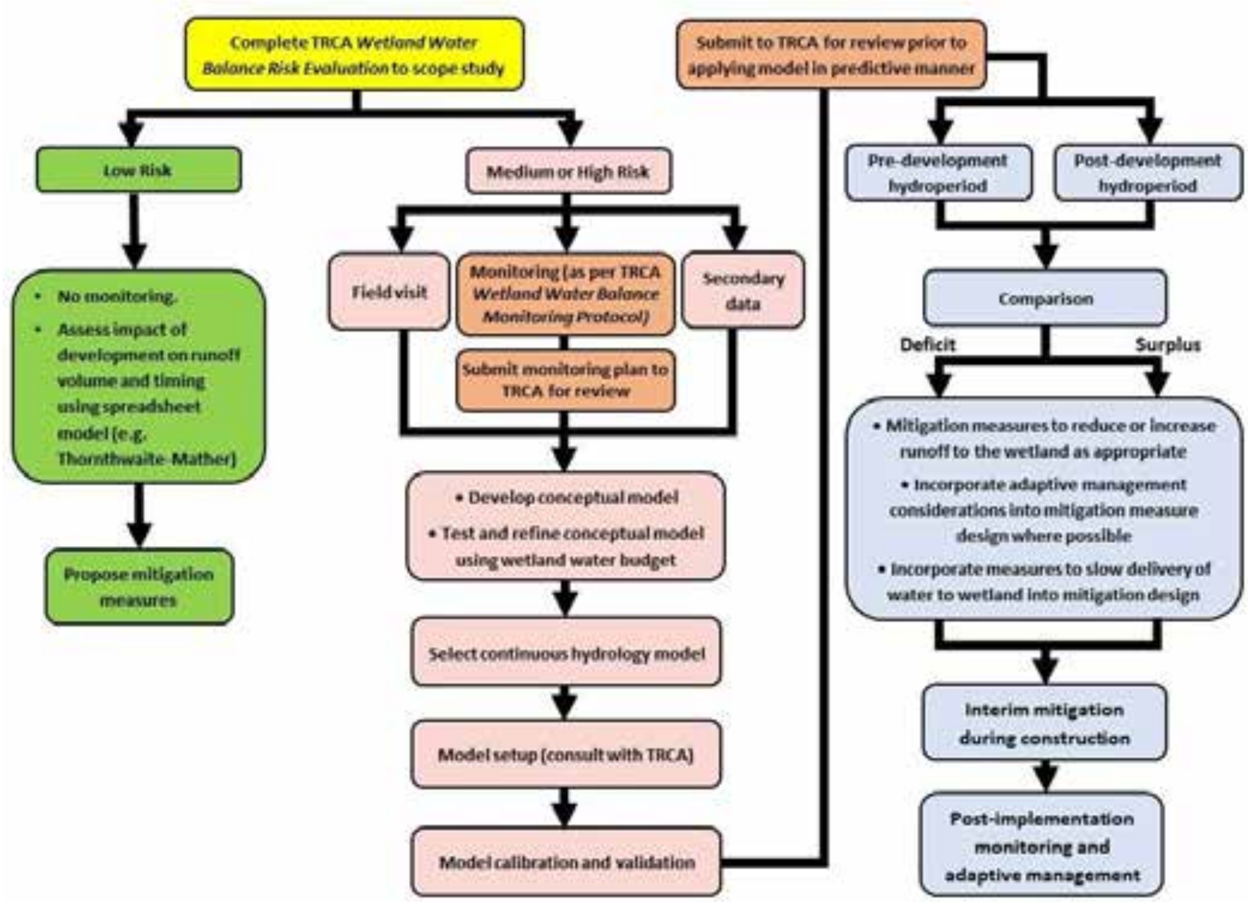


Figure 1: Steps for wetland modelling as part of a Feature-based Water Balance analysis

Proponents of development and infrastructure using this guidance document should refer to the *SWM Document* (TRCA, 2012) for guidance on the overall objectives of feature-based water balance analysis (also referred to as water balance for protection of natural features). The determination of which wetlands will be protected on the landscape is external to any application of this *Modelling Document* and will be made as part of a planning or infrastructure review and approval process. The *Wetland Water Balance Risk Evaluation* (*Risk Evaluation*; TRCA, 2017) should be completed in advance of any application of this guideline to determine the appropriate scope of analysis and type of model to be used. The Risk Evaluation considers the magnitude of potential hydrological change a proposal embodies relative to certain threshold values, as well as the sensitivity of the wetland in question in order to determine an appropriate scope of analysis. The *Modelling Document*, *Risk Evaluation*, and other tools supporting implementation of the *SWM Document* criteria are indicated in relation to the corresponding steps in the *SWM document* in Figure 2.

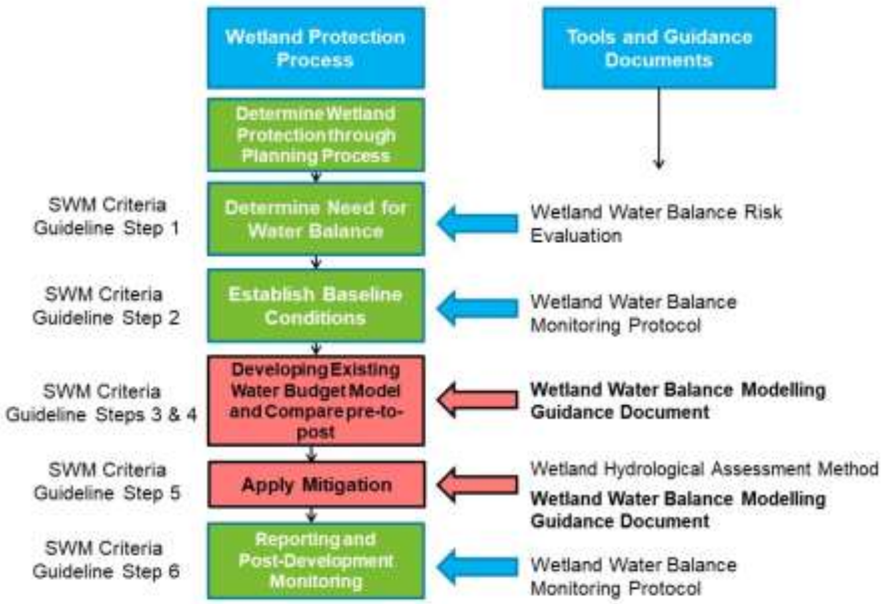


Figure 2: Wetland water balance tools and guidelines and their relation to steps in the SWM Document.

2 Understanding the Hydrological System

This section of the feature-based water balance (FBWB) report must include a discussion of the landscape and hydro(geo)logical contexts of the wetland(s) in question as they relate to the major hydrological processes operating within the wetland under natural (i.e. pre-development) conditions. This discussion should be informed by careful review of existing/secondary information, site surveys, and especially by wetland hydrology monitoring data collected on site.

The hydrology of a wetland directly determines many aspects of its physical, chemical, and ecological characteristics, and as such it is perhaps the most important variable influencing ecological function (Mitsch and Gosselink, 2007). Land development and infrastructure construction can affect the hydrology of a wetland in a number of ways, some of which may have a negative impact on the ecological function of a wetland. For example, water taking directly from a wetland or from an aquifer that discharges directly to a wetland has a clear potential to directly alter the wetland’s water balance. Land use change within the surface water catchment of a wetland may alter the water balance by changing the ratio of surface runoff to infiltration within the catchment as well as the proportion of water lost to evapotranspiration. This is an issue particularly when there is a substantial increase in the proportion of impervious cover such as paved surfaces and roofs (Hicks and Larson, 1997; Reinelt and Taylor, 2001). Alteration to the size of the catchment area draining to a wetland due to land grading activities or stormwater management system design also has the potential to significantly change the water balance.

It is important to note that wetland hydrology encompasses much more than the average annual depth of water in a wetland. Aspects of wetland hydrology such as the proportion of total inflow derived from surface water or groundwater, the timing and duration of inflows, and the timing of water level drawdown over the growing season all contribute to the maintenance of a particular ecological function. For example, amphibian species may require water for breeding during spring but may also require habitat to be seasonally dry to prevent predatory fish from establishing in this habitat. Similarly, some obligate wetland plants will be outcompeted by facultative upland plants if a wetland dries out too early, leading to shifts in the ecological community. Significant differences in wetland ecology and associated ecosystem services can occur between relatively small differences in hydrological regime on the order of tens of centimeters (Baldwin *et al.*, 2001; Mitsch and Gosselink, 2007; Moor *et al.*, 2017).

The term *hydroperiod* is used to refer to the pattern of water level change within a wetland over time, both above and below ground, and is a measure of the net sum of interaction between the different water balance components (i.e. the change in storage). The *hydroperiod* is a key measure by which to track changes in the water balance over time, and is the primary focus of wetland hydrological monitoring, as outlined in the *Wetland Water Balance Monitoring Protocol* (TRCA, 2016).

Under increasing urbanization, ecosystem services provided by wetlands will be affected unless their hydroperiods are protected through implementation of water balance mitigation measures. The design of functioning wetland mitigation measures requires a proper understanding of the wetland hydrological system. A sound conceptual understanding of the wetland hydrological system is a prerequisite to assessment of the impact of any anthropogenic activities on the wetland hydrology. Also, lack of a proper conceptual understanding of how the wetland works will lead to selection of invalid models, which will then result in ineffective mitigation measures.

The hydrology of wetlands can be very complex. Some wetlands discharge to groundwater, while others are recharged by groundwater. Some will retain water year round while others may be dry for part of the year. Depending on the type and condition of vegetation and the amount of open water, evapotranspiration rates will vary greatly. Antecedent conditions of soil moisture and amount of water already stored in the wetland will affect how much storage is available for runoff. Hydrological models are tools that aid in understanding the interaction of the different components of the water balance by providing a simplified representation of these interactions. Provided that this simplified representation is sufficiently complete, good models allow different land use and stormwater management scenarios to be explored in a way that would not be otherwise possible, thereby helping engineers and other professionals come up with designs that minimize the difference between the pre- and post-development wetland hydroperiod.

In evaluating the hydro(geo)logic and landscape context of the wetland, proponents should start by reviewing available studies and datasets that conservation authorities and different levels of government have initiated. For example, regional groundwater studies, watershed and sub-watershed studies, geological and land cover maps, are all helpful in providing the landscape context for the FBWB study.

Following a review of existing/secondary information, the next information sources should be field inspections to verify existing conditions on the ground. Field visits can help confirm if overland drainage patterns inferred from secondary information reflect site conditions, or if features such as culverts or tile drains may cause conditions on the ground to differ from expectations. Field-based hydrology monitoring data on wetland storage dynamics and channelized surface flow is crucial to developing a better understanding of the wetland hydrological system and can reveal a great deal about how the system functions.

In developing a better understanding of the wetland hydrological system through collected monitoring data and secondary sources, it may be helpful to consider the following questions:

1. What are the dominant water transfer mechanisms between the wetland and its surroundings?
2. How long does the wetland contain standing water?
3. Do the maximum depth and areal coverage of surface water change from year to year?
4. How quickly do water levels draw down during extended dry periods?
5. What is the wetland hydroperiod response to precipitation events?
6. Is the amount of surface water flowing into the wetland roughly equal to the amount flowing out?
7. What is the relationship between groundwater head and wetland water levels?
8. Is the hydraulic gradient in the wetland mostly upwards or downwards, and what is the hydraulic conductivity of the soil?
9. How do these observations relate to the observed distribution of wetland habitat?

The first step in attempting to answer these questions should be to construct simple time series plots of the wetland water levels and any data on nearby groundwater levels, surface water flows, etc., with all data displayed on the same plot. Trends should be visually analyzed at different time scales (hourly, daily, weekly, monthly) to identify periodicity and likely water sources and transfer mechanisms. Water sources and transfer mechanisms may vary throughout the year according to season.

3 Developing a Conceptual Model

This section of the FBWB report must include a conceptual diagram of the wetland showing all important hydrological sources, sinks, and transfer mechanisms, and the relationships between them. Any assumptions must be discussed and justified. For some wetlands, it will be necessary to have more than one conceptual diagram to describe its hydrology during different seasons or under different conditions.

After the practitioner has developed a conceptual understanding of the wetland hydrological system, a conceptual model should be developed to represent the important sources, sinks, and transfer mechanisms. A conceptual model should be in the form of a simplified diagram that provides a functional description of the hydrological system under pre-development conditions. The conceptual model needs to represent the main hydrological components and their interrelation and needs to be suitable for implementation in a mathematical model. Figure 3 below illustrates two examples of conceptual diagrams for wetlands with slightly different hydrological components.

Conceptual models should always be written down and using an annotated diagram showing water transfer mechanisms, such as precipitation, evaporation, evapotranspiration, surface flow (overland flow, channelized flow and lateral flow in the unsaturated zone), over-bank flow and groundwater discharge and recharge, along with the structure of the underlying geologic strata. If water transfer mechanisms operate differently at different times (e.g. seasonally, or during dry and wet conditions) then different diagrams should be utilized to show variations of the water transfer mechanisms occurring in the wetland at those different times.

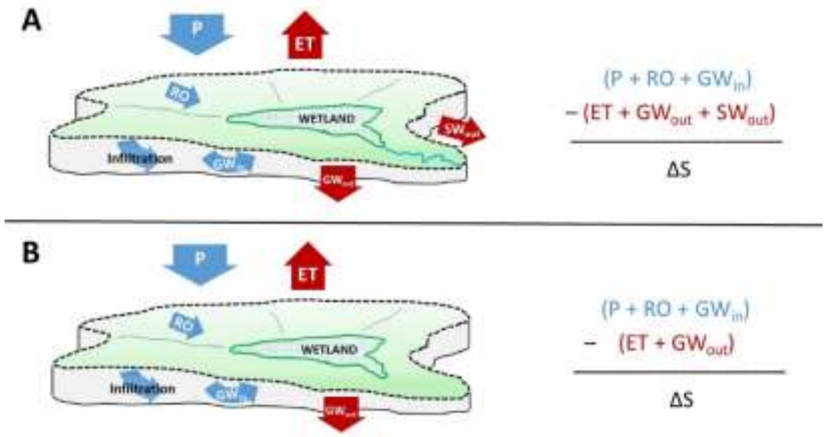


Figure 3: Conceptual diagram of a wetland with channelized surface outflows (A) and a wetland with no channelized surface outflows (B)

The FBWB report must discuss the conceptual model used to characterize the hydrology of the wetland under study. Conceptualization and characterization of the wetland will assist in selection of an appropriate hydrological model as it will help to define the significant water transfer mechanisms of the wetland hydrology and their interrelationships. The spatial boundary of the storage unit in the model representing the wetland and the temporal resolution requirements can be determined from the wetland characterization. Generally, the storage unit and its associated ratings curves (e.g. stage-storage curve) should be determined from the maximum observed water level. As the water transfer mechanisms in the wetland may vary seasonally, selection of the temporal resolution to be used in the computations must take into consideration the seasonal variability of the water transfer mechanisms of the wetlands. Conceptualization will also determine how lumped or detailed the modelled hydrological processes need to be. Any assumptions must be fully discussed and justified.

4 Testing and Refining the Conceptual Model Using a Water Budget Model

This section of the FBWB report must show the refinement of the conceptual model by quantifying rates of water transfer between model components via the transfer mechanisms previously identified in Section 3. A water budget model, as described below, should be used to determine if the components and transfer mechanisms identified in the conceptual model can adequately explain the observed wetland storage dynamics. If missing components or transfer mechanisms are identified, the water budget model should be refined as necessary. At this stage of the FBWB study, the model should be run using a monthly time-step.

The understanding of the wetland hydrological sources, sinks, and transfer mechanisms developed for the conceptual model next need to be tested, validated, and refined using a tool that allows quantification of water transfer rates through each transfer mechanism. A water budget model is a tool for quantifying the transfer of water in and out of the wetland via different pathways.

This model can be a spreadsheet-based tool that uses appropriate equations to calculate the transfer rates and corresponding storage dynamics, or it can be any modelling software that allows quantification of water transfer rates through different transfer pathways over a given time period. The water budget model outputs should be on at least a monthly basis to enable comparison with the observed responses of the wetland hydroperiod, and to test the appropriateness of the conceptual understanding of the wetland water balance.

4.1 Water Budget Model

The approach (i.e. spreadsheet calculations, modelling software) for the water budget model should be selected based on the understanding of the conceptual model. It may be found that the modelling approach may need to be revised as the qualitative understanding of the conceptual modelling is refined based on the difference between observed and simulated wetland storage dynamics.

To assess the transfer of water into and out of the wetland, the wetland should be viewed as a single open system. The system boundary should be drawn around the wetland by projecting the spatial wetland boundary vertically upwards and downwards to horizontal planes at the top and bottom of the system. The establishment of boundaries allows for a balance approach representing the movement of water into and out of the wetland system to be applied. The water balance of any bounded environmental system follows the principle of conservation of mass, and represents a budget of inputs, outputs, and storage of water in the system. The movement of water within the wetland system can be expressed using a water balance, an equation that accounts for water inflows to and outflows from the system. The wetland water balance equation is basically a routing procedure that sums the water inputs into and out of the wetland area, and the storage in the wetland. The wetland water balance can be described in the general form as follows:

$$\text{INFLOWS} - \text{OUTFLOWS} = \Delta\text{STORAGE} \qquad \text{Equation 1}$$

A more specific form of the water balance equation, which decomposes inflows and outflows into their constituent elements, is given in along with a conceptual diagram in Figure 4 below.

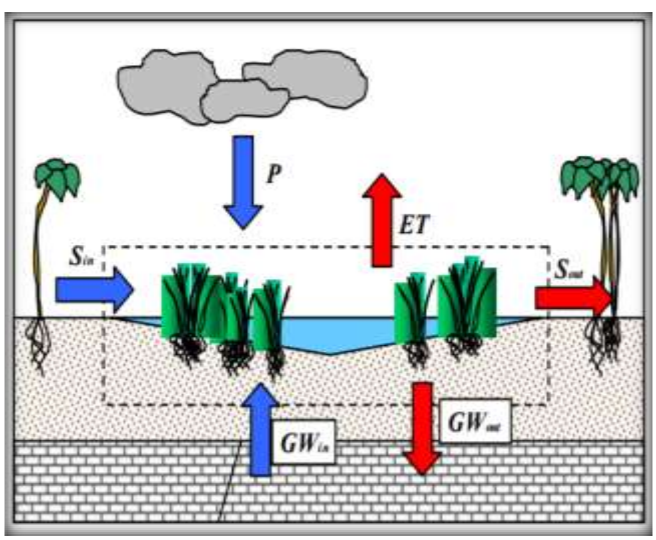


Figure 4: Conceptual representation of a wetland water balance

$$(P + S_{in} + GW_{in}) - (ET + S_{out} + GW_{out}) + \mu = \Delta S \qquad \text{Equation 2}$$

Where:

- P is precipitation in the form of rain or snow on the wetland catchment;
- S_{in} is the surface runoff into the wetland;
- S_{out} is the surface runoff out of the wetland;
- GW_{in} is the groundwater seepage into the wetland;
- GW_{out} is the groundwater seepage out of the wetland;
- ET is evapotranspiration from the wetland;
- μ is the residual; and
- ΔS is the change in water storage of the wetland.

In , the components on the left side represent the inputs (additions) and outputs (losses) to and from the wetland, while the right hand side represents the cumulative change in storage. An error term, μ, is added in order to account for some degree of measurement error. Each of the terms of the water budget can be expressed as depth of water per unit time (L/T) or as volume of water per unit time (L^3/T). The resultant equation quantifies the change in water storage over time as a function of water related inputs and outputs occurring in the wetland over the study period. Water balance analysis allows the conceptual understanding of the wetland hydrology to be refined by identifying gaps in understanding and missing inflows or outflows. A good strategy is to calculate the water balance for a single year representative of long-term average climate conditions, and then to calculate under years representative of relatively wet and relatively dry climatic conditions.

The water balance analysis should be undertaken for the wetland itself as a single hydrological unit. However, there are some complex wetlands which may be impossible to represent as one hydrological unit. For these complex wetlands it is appropriate to subdivide the wetland into two or more hydrologically distinct units, and the water budget should be calculated separately for each of the different hydrological units. Figure 5 below shows a wetland that has two features which are connected when the northern feature is filled and overtops the berm or the divide and flows into the southern feature. It should be noted that during more frequent events these two features may not be hydraulically connected on the surface. However, during major events they are hydraulically connected. In wetland systems such as this, it may be practical to divide the wetland into different hydrological storage units. For such complex wetland systems, calibration will likely be improved if monitoring data is available for each of the wetland hydrological storage units.

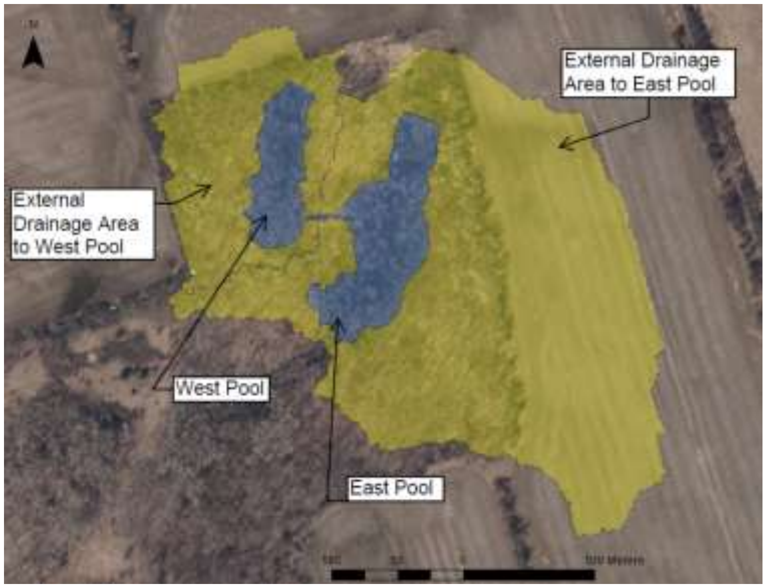


Figure 5: Example of wetland with two distinct hydrological units or pools

In the next sections, each of the water balance components will be discussed in terms of the common methods of estimation available. **For additional information, including governing equations for various water balance components and for potential data sources, the reader should refer to Appendix B**.

4.1.1 Precipitation

Precipitation, in the context of estimating a wetland water balance, refers to the quantity of direct precipitation received by the wetland and surrounding catchment area. Precipitation is most often estimated from the precipitation recorded by a network of gauges, such as those operated by provincial and federal agencies, conservation authorities, and municipalities. Interpolation of precipitation totals, on both an event and an annual basis, is preferable to estimates based on a single point of measurement, as spatial variability associated with precipitation can lead to substantial error and uncertainty. This may be a particular problem in cases where precipitation is a dominant input into the wetland system and a more precise precipitation estimate is needed. There are several methods available for estimating average precipitation from a network. The three most common methods for computing average precipitation within an area are the arithmetic mean, the Thiessen Polygon Method, and the Isohyetal method. There are abundant resources available to assist the proponent in applying each of these methods of calculation, and therefore they are not repeated here.

The steps used to quantify the precipitation component of a wetland water balance are outlined below in Figure 6.

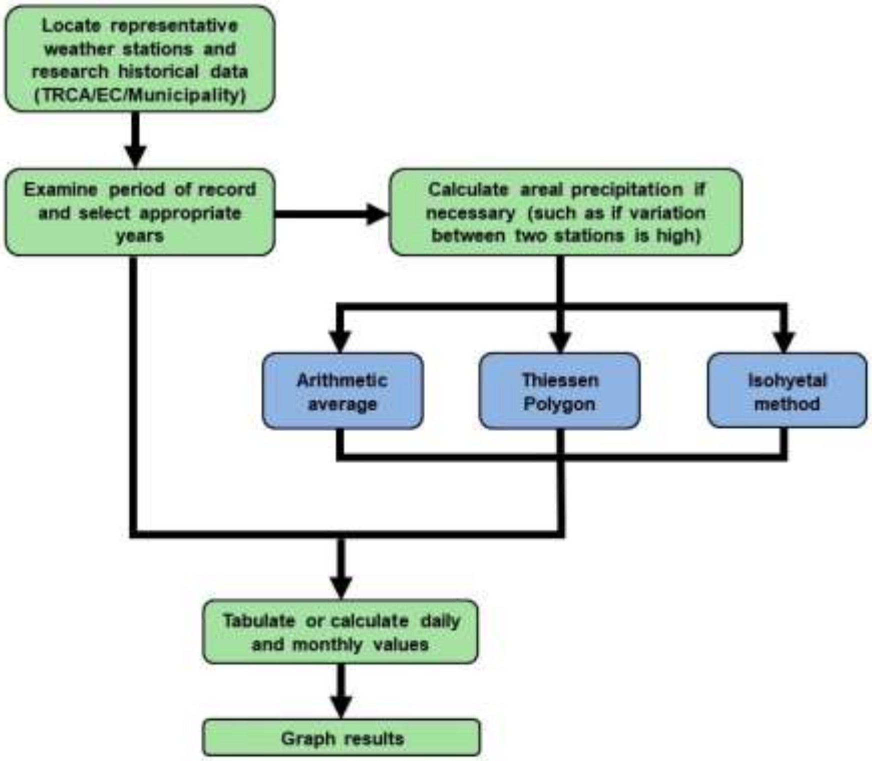


Figure 6: Flow chart for the calculation of the precipitation component of a wetland water budget.

4.1.2 Surface Flow

Surface flow into a wetland can be derived from channelized flow (streamflow), non-channelized flow, and seasonal or periodic inputs from lakes, ponds, and rivers during high water periods. Surface water outflows from wetlands that have precipitation as their dominant input are typically highest during the wet season. However, in wetlands which have major inputs of groundwater, surface water outflows may be more evenly distributed throughout the year. Presence of surface water within a wetland throughout the year depends on the temporal balance of inflows and outflows. Generally, in southern Ontario, runoff rates are highest during the spring due to the combination of abundant rainfall, saturated soils, low evapotranspiration rates, and snowmelt contributions. Runoff rates from May through October tend to be low as evapotranspiration is high and drier soils have greater capacity to infiltrate moderate- and low-intensity rainfall events. Runoff typically increases through fall as plants enter senescence and evapotranspiration decreases. Runoff rates are variable through winter depending on patterns of precipitation and air temperature.

The sections below outline methods that can be used to estimate non-channelized flow from the wetland catchment and channelized flow draining into the wetland.

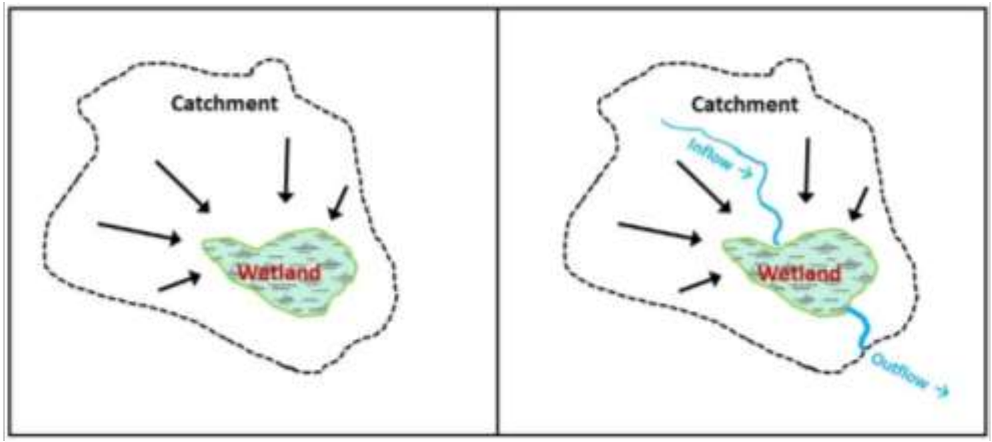


Figure 7: Wetland receiving non-channelized flow only (left) and wetland receiving both non-channelized and channelized flow (right)

Non- channelized Surface Flow

As field measurements of diffuse overland flow are quite challenging, generally a simple modelling approach is used to estimate the volume of overland flow generated by contributing catchment areas. The United States Department of Agriculture's Soil Conservation Service (SCS) developed the curve number (CN) method (SCS, 1972), a simple model to estimate surface runoff volumes generated by a catchment for a given precipitation event. The CN method is widely used and was developed initially for application in small- to medium-sized rural catchments across the United States. To apply the CN method, the contributing catchment area is first divided according to land-use types. An appropriate CN value for each land use type is determined from a lookup table (see Table B1, Appendix B) and a single CN value based on the weighted area of the individual CN values is used to determine the value of potential storage (S) in the CN equation (SCS, 1972).

For more information on the SCS curve number method, relevant equations, and CN lookup values, see section B1 in Appendix B.

Channelized Surface Flow

If the wetland receives surface water in the form of channelized flow, it may be possible to make direct measurements using weirs, flumes, and stage-gauging techniques. Accurate field-based streamflow measurements can provide valuable input data to inform wetland water balance analysis. By establishing the cross-sectional area of flow (A, m^2) associated with each stream or channel stage, the continuity equation can be used to calculate discharge (Q, m^3/s). The velocity component (V, m/s) of the continuity equation can be calculated using Manning's Formula (Manning, 1891). Appropriate values for Manning's roughness factor can be found in Table B2, Appendix B.

In circumstances in which direct discharge measurements using weirs and flumes cannot be made, or in which data is not available, hydrological models may be used to estimate channelized flows. Although models are simplified representations of natural hydrological systems, they are nonetheless valuable tools for quantifying different components of the water balance. Selection of the most appropriate model depends on the ultimate objective of the surface water study and the characteristics of the wetland catchment in question; see section 5.3 and section 5.4 for more information on selection criteria for continuous hydrology models.

The steps used to quantify the surface water portion of a wetland water budget are summarized in Figure 8. All non-channelized surface flow that enters the wetland from the surrounding catchment can be quantified using the runoff curve number or model another hydrological model with the capability to simulate surface runoff from the catchment area. Channelized flow can be estimated using the continuity equation in combination with measured stage-gauge data, or else by using a continuous hydrology model. Quantification of channelized flow using a hydrology model may minimize the need to collect data at a particular site for wetland water balance analysis, but field data may reduce some uncertainty introduced by the simplification of the wetland hydrological system in the model and the selection of model parameters. More information on field monitoring procedures and requirements can be found in the *Wetland Water Balance Monitoring Protocol* (TRCA, 2016).

The sum of channelized and non-channelized flow values constitutes the overall surface water input to the wetland system. An adequate assessment of surface water inputs is important for all wetlands, but for riverine and other surface-water-driven wetlands it is critical. Contributions of non-channelized and channelized flow must be quantified for all sites. Daily and monthly surface water flow values must be calculated for representative wet, dry, and average years. These values should be converted to units of depth per unit time and graphed alongside the other components of the water budget.

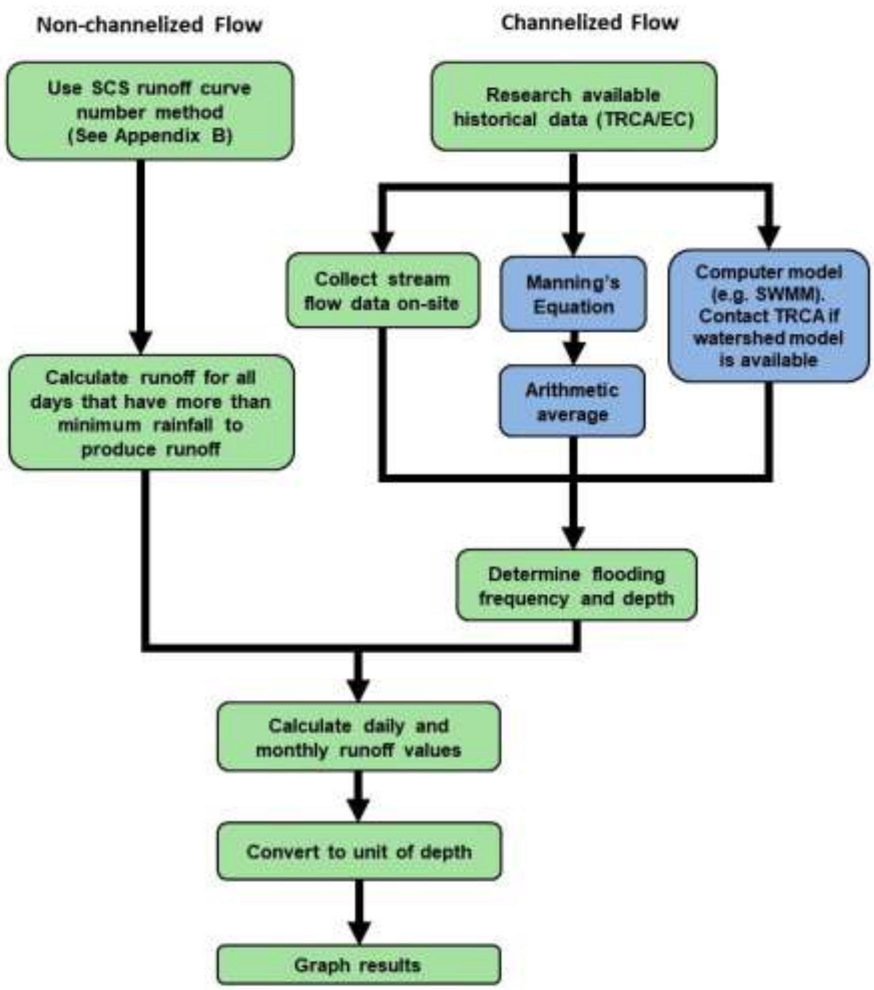


Figure 8: Steps used to quantify surface-flow

4.1.3 Evapotranspiration

Evapotranspiration refers to the loss of water to the atmosphere in the vapour phase from both evaporation (from surface water bodies and soil water) and transpiration (water passing through plants via transpiration). Evapotranspiration (ET) rates from a wetland are affected by several meteorological, physical, and biological variables, including solar radiation, surface temperature, wind speed, relative humidity, available soil moisture, and vegetation type and density. Evapotranspiration varies both seasonally and daily. The evapotranspiration rate is higher during periods when plants are actively growing and transpiring than during periods when they are dormant (Carter, 1996), and tends to be lower at night and on cool, cloudy days and higher on hot, sunny days.

Generally, empirical methods for estimating ET are used to calculate potential evapotranspiration (PET), which is subtracted from the available surface water or soil moisture in the wetland at a given time to calculate actual evapotranspiration (AET). PET rates assume that ET is not limited by water availability; if there is no water left for the atmosphere to extract from the wetland surface and soil, such as during exceptionally dry periods in summer or late fall, then no ET takes place, and AET is lower than PET. As a rule, AET will never exceed PET.

It should be noted that estimating evapotranspiration (ET) is one of the most challenging components of a wetland's water balance to calculate because of the complexity of monitoring this flux and its high variability in time and space. Evapotranspiration rates vary during different growth periods of vegetation communities. A variety of methods are available to estimate ET,

	Method					
Variable	Thorn-thwaite (1948)	Hargreaves *et al.* (1985)	Makkink (1957)	Turc (1961)	Priestley-Taylor (1972)	Penman-Monteith (1965)
Temperature	Required	Required	Required	Required	Required	Required
Humidity				Required		Required
Wind Speed						Required
Radiation		Required*	Required**	Required**	Required***	Required***
No. of daylight hours	Required					
Saturated Vapour pressure						Required
Ground Heat Flux					Required	Required
Resolution	Monthly	Daily	Daily or finer	Daily	Daily or finer	Daily or finer

*Daily radiation at top of atmosphere, as calculated using global solar constants according to latitude and Julian day
**Insolation, or incoming shortwave radiation (only)
***Net radiation, or incoming minus outgoing radiation

Table 1: Comparison of several ET estimation methods in terms of required parameters

including direct-measurement procedures and empirical formulas; however, it has always been a challenge to determine the accuracy and practicability of these methods. Generally, the Penman-Montieth method (Monteith, 1965) is considered the most accurate available empirical method, but requires a number of parameters that may be difficult and/or expensive to measure. For this reason, other estimation methods for ET, requiring a reduced set of input parameters, are more commonly used.

Table 1: Comparison of several ET estimation method below outlines the data requirements for a number of ET methods. More information on a number of empirical equations and their application is provided in Appendix B. The first step should be to establish what meteorological data are available within a reasonable vicinity of the study site, as the parameters available will dictate which methods may be applied. Alternatively, if no suitable data is available, proponents may wish either to collect direct measurement data, or to supplement existing station data with data collected on-site for use with empirical methods. Typically, Environment Canada stations have daily temperature and some have radiation data that can be used as input parameters to estimate ET; some conservation authorities and municipalities may have additional meteorological stations with data for relevant input parameters.

The steps used to quantify the ET portion of a wetland water budget are shown below in Figure 9.

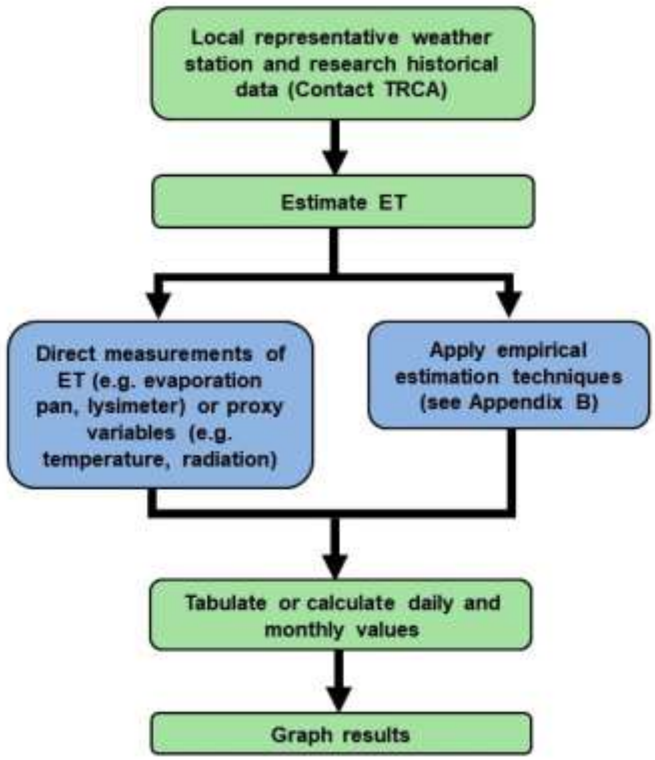


Figure 9: Steps used to quantify the ET component of a wetland water balance

4.1.4 Groundwater flow

Although accurate estimation of the groundwater component of the wetland water balance can be challenging due to the cost of subsurface investigations, estimates of the groundwater flux can be critical to the assessment of water budgets. TRCA advises applicants to begin by researching existing and historical groundwater information in the vicinity of the subject wetland. Regional groundwater datasets, such as that maintained by the Oak Ridges Moraine Groundwater Program, may be useful in this regard. Determining what is known about groundwater and the subsurface environment within the study area will help to determine the amount of data that needs to be collected on-site. Collection of on-site data is often essential to understanding groundwater exchange between the wetland and the surrounding area, as the hydrogeologic environment can vary dramatically over short distances. Collection of hydrological monitoring data, as per the TRCA *Wetland Water Balance Monitoring Protocol* (2016), can help to ascertain local conditions. Drive-point piezometers can be installed by hand within the wetland, including at multiple depth intervals to estimate vertical hydraulic gradients and hydraulic conductivity, and are a much cheaper alternative to drilled wells for investigating the local groundwater environment.

For some wetlands, it may be possible to find an analytical solution to Darcy's Law or various derived forms of Darcy's Law and thereby calculate flow across a series of two-dimensional planes or sections surrounding the wetland. However, for wetlands and aquifers with more complex geometries, or sites dominated by bedrock, an analytical solution using Darcy's Law may not be possible. Under these circumstances, a numerical groundwater flow model can be used to simulate groundwater flow. Numerical groundwater flow models are mathematical representation of an actual groundwater system that can be used to predict water levels as well as the direction and magnitude of flow. Models range from simple to very complex in terms of data-input requirements, calibration requirements, and data output. An internally drained wetland where the outflows from the wetland are only groundwater outflow and evapotranspiration will definitely require a complex numerical ground-water flow model to accurately estimate the groundwater flow exchange between the wetland and the surrounding areas. The applicant should consult with the local conservation authority to determine if there any existing calibrated numerical groundwater flow models.

For both the analytical and modeled solutions to estimating the groundwater component of the water balance, it is critical that wells are installed such that they can adequately characterize water table fluctuations and groundwater movement across the site. The hydraulic conductivity of local aquifers and aquitards must be determined from soil borings, wells, infiltrometers, permeameters, and/or aquifer tests. Daily and monthly groundwater flux rates should be tabulated and graphed for the monitored time period; multi-year data sets may be needed to adequately characterize groundwater interaction, particularly at sites where groundwater head is a dominant control on wetland water levels. Figure 10 outlines the steps used to quantify the groundwater component of a wetland water balance.

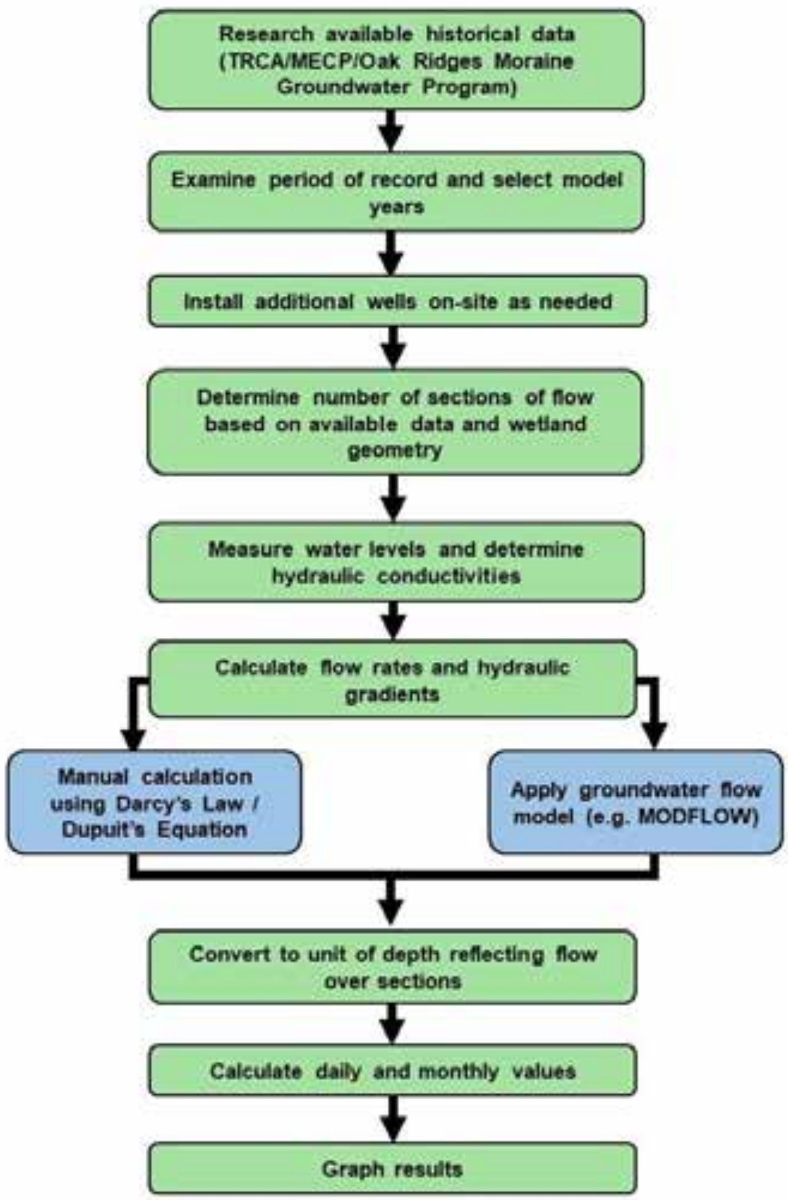


Figure 10: Steps used to quantify the groundwater component of a water balance

4.1.5 Change in Storage

Total storage in a wetland consists of the sum of surface water, soil moisture, and groundwater within the model-defined wetland boundary. The change in storage (ΔS) in a wetland over any period of time represents the difference between the inflows to and outflows from the feature; if the water balance calculation yields a negative ΔS value, more water is flowing out than in, and the opposite is true for a positive ΔS value. The change in storage is essentially equivalent to the *hydroperiod* of the wetland, or the rise and fall of water levels above and below ground within the wetland, as defined in the *Stormwater Management Criteria* (TRCA, 2012). The hydroperiod is the most important variable for monitoring to capture, as outlined in the *Wetland Water Balance Monitoring Protocol* (TRCA, 2016). Monitoring of the hydroperiod is generally most effective when instruments are installed such that the water levels within the lowest points of the wetland, and closest to the center, are captured.

For the standing water portion of a wetland's hydroperiod, ΔS (in units of depth) is equal to the change in water level (stage) multiplied by the area affected; these parameters are related via a stage-storage curve outlining the volume stored in the wetland at each stage. Various techniques with differing levels of accuracy can be used to develop a stage-storage curve, but are beyond the scope of this guideline. A stage gage can be used to help measure change in storage for the standing water portion of the hydroperiod, although important elements of the storage dynamics such as precipitation event response may be lost in the absence of a data logger.

For the below-ground surface portion of a wetland's hydroperiod, ΔS is equal to the change in measured water level multiplied by the specific yield of the sediment. Soils containing a high sand content tend to have a higher specific yield than soils with a higher proportion of silt and clay particles. Some residual storage water remains in the unsaturated zone above the water table when the water table elevation decreases; however, this quantity of storage may be negligible while the water table remains close to the ground surface. Some continuous hydrology models have the capacity to calculate the soil moisture component of ΔS.

Calculating ΔS from monitoring data using one or both of these data-based methods serves as a useful check against the value of ΔS calculated through the water balance approach. The difference between monitored and modeled ΔS can help to quantify the total error/uncertainty in the model, although it is less helpful in distinguishing between sources of error among individual components of the water balance.

4.1.6 Uncertainty/Errors

All water balance calculations have some inherent degree of uncertainty. This uncertainty results from both natural variability within the hydrological cycle and from errors in measurement and estimation. While uncertainty cannot be eliminated, application of appropriate methods can help to both reduce and quantify uncertainty. Calculating the water balance during representative wet, dry, and average climatological years can help to quantify some of the natural variability that may be expected at the site. A sensitivity analysis is a useful tool to help determine how the overall water balance is affected by changes to the magnitude of its individual components. By comparing the change in magnitude of the overall water balance resulting from changes to the magnitude of each individual parameter (e.g. magnitude of groundwater fluxes resulting under different hydraulic conductivity values), the practitioner can quantify the relative sensitivity of each parameter. Additional emphasis should be placed on parameters to which the water balance is especially sensitive in the refinement of the water balance model.

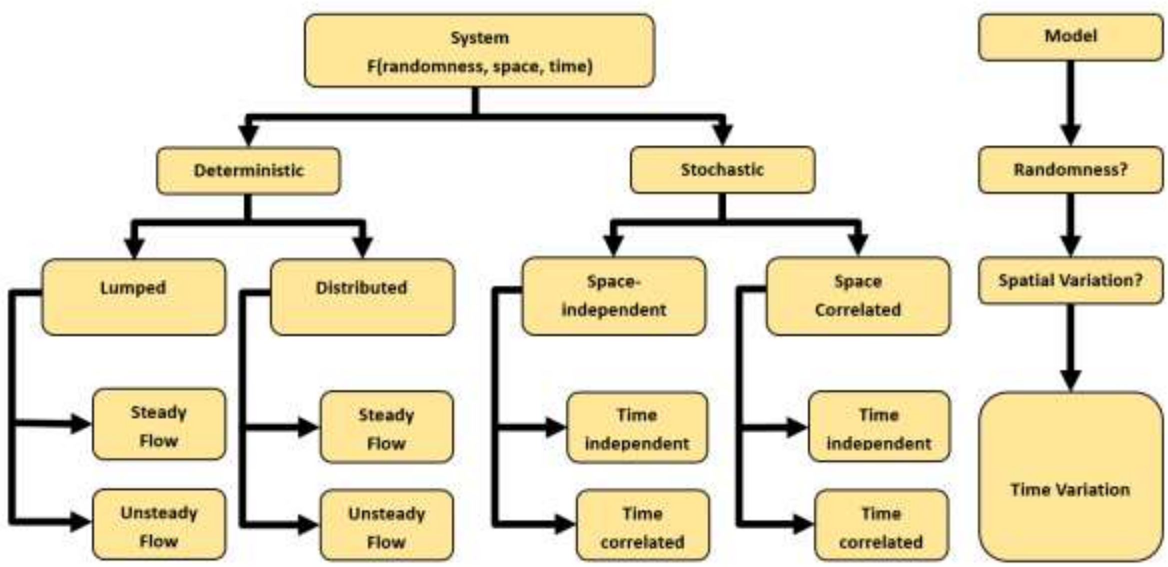
5 Continuous Hydrology Model Selection

This section of the FBWB report must describe the model set-up and the criteria that were used to select a continuous hydrology model as they relate to the objectives of the study. After model setup is complete, TRCA recommends that the applicant submit the model setup to TRCA to discuss before proceeding further to model calibration. This section should describe the procedure that was used to calibrate and validate the model using field monitoring data, including initial and final values of parameters, citing rationale and literature values, as appropriate. TRCA requires that the preliminary model calibration to existing conditions be documented and submitted for review and approval prior to proceeding to the application of the model in a predictive manner.

Continuous hydrology models are simplified representations of hydrological systems, and are the best tool available to practitioners for evaluating the current state of a system against many possible future states (e.g. different land use scenarios or different stormwater management techniques). Models can be broadly understood as a system of equations and logical statements that express relationships between variables and parameters (Clarke, 1973). Whereas parameters are generally assumed to be quantities that are constant in time and represent a fundamental property of the hydrological system (e.g. slope), variables may be measurable and generally assume different values at different times (e.g. storage in a pond) (Clarke, 1973).

Continuous hydrology models can be broadly classified into deterministic versus stochastic models (Chow *et al.* 1988; see Figure 11); deterministic simulation models do not have any random variables, and describe how a mass of water moves through a wetland catchment according to various physically-based hydrological processes. Stochastic models incorporate random variables described by probability distributions. All of the models referred to in this document are deterministic, including HEC-HMS, Hydrological Simulation Program – FORTRAN (HSPF), Precipitation-Runoff Modelling System (PRMS), EPA Storm Water Management Model (SWMM), PCSWMM, VH Otthymo Continuous, MIKE SHE and GSFLOW.

Figure 11: Classification of models, after Chow *et al.* (1988)



Another major distinction within the conceptual framework of Chow *et al.* (1988) is between lumped and distributed hydrological models. Lumped models ignore spatial variability of input variables and catchment parameters, instead subdividing the catchment(s) being represented into hydrologically homogenous units. By contrast, distributed models account for spatial variability of hydrological processes, input data, boundary conditions, and catchment characteristics, representing the catchment as a collection of cells of uniform size. Runoff volumes, determined from hydrological processes occurring within each cell, are routed to adjacent cells based on the direction of slope, down to the catchment outlet.

Hydrological models can be event-based or continuous in their simulation capacity. Event-based simulations represent the catchment hydrological response to an individual rainfall event in terms of runoff quantity, peak, timing, detention etc. In these simulations, which run on timescales of an hour to several days, infiltrating precipitation is omitted from the water balance calculation, "disappearing" into the soil with no further accounting for processes such as interflow or dynamic interaction with groundwater. This is due to the emphasis of these models on characterizing peak flow, to which the contribution of interflow and groundwater is generally believed to be negligible. Event simulation models similarly do not account for evapotranspiration or changes in soil moisture, for the same reason. Continuous models operate over extended periods of time (months to years) and determine fluxes of water via various processes including during periods with no precipitation or runoff. Continuous models also account for infiltrating water, generally routing it into soil moisture storage, groundwater flow, unsaturated flow, and evapotranspiration.

5.1 Why Continuous Simulation for Wetland Hydrology Modelling?

The water input to a wetland catchment reaches and then leaves the wetland on a variety of timescales, producing the seasonal patterns of fluctuations in hydroperiod that are the primary determinant of distinct wetland flora and fauna communities present at a site. Continuous simulation over a longer time period is needed to account for antecedent moisture conditions and the inter-event hydrology of the wetland catchment, and to explore how changes in land use and drainage may affect the hydroperiod of the wetland under the full range of natural conditions that could be expected at a given location. Continuous hydrology models offer a much more detailed representation of the wetland hydrological response under both natural (pre-development) and post-development scenarios, if the model is well conceptualized, calibrated, and validated. Simulation using these types of models therefore provides a more robust basis on which to make decisions about the potential impacts a proposal may have on a wetland and the potential measures to mitigate those impacts.

5.2 Criteria for Selection of Continuous Hydrology Models

Deciding on the right model to simulate wetland hydrology has always been a challenge due to the many factors that must be considered. Hydrological models vary widely in their capabilities, complexity, strengths and weaknesses, making selection of an appropriate model for a specific application difficult (Golmohammadi *et al.*, 2014). Many criteria for model selection will be project-dependent and user-dependent, and therefore somewhat subjective. For example, preferences concerning the graphical user interface (GUI), computer operation system, input-output management and structure, or add-on expansibility, are subject to individual modeler preference and experience.

The following are some of the project-dependent considerations that should be considered in selecting a continuous hydrology model. It might not be possible to be address all concerns in all four areas outlined below, and so selection criteria should be considered iteratively, recognizing that limitations in any of the four areas may restrict choices and thus require re-evaluation of the personnel involved, cost of the exercise, and so on.

A) Objectives of the overall modelling exercise

This consideration is at the very core of a successful modelling exercise. Key questions that need to be answered include:

- Is the broader context of the modelling clear?
- How are the results of the modelling going to be used?
- What specific outputs are needed?
- Where will the model be applied?
- What are the proposed actions that need to be represented in the model?
- Who will be interpreting the results and what decisions will they be making?

Answers to these questions will provide an outline of the basic capabilities required of the models under consideration. Defining the required model outputs defines what the model must be able to represent, and the appropriate scales of time and space for the model exercise. It is very important to consider the main hydrological processes operating in the wetland's pre-development condition, and that may be operating in the post-development condition, based on the best available information about the wetland and the proposed development at the start of the modelling exercise. Generally, the main hydrological processes that need to be considered for inclusion in a continuous wetland hydrology model include precipitation, interception, depression storage, infiltration, overland flow, lateral flow, base (subsurface) flow, stream flow, evapotranspiration, channel routing and reservoir routing.

Other key questions that may help to define model objectives and selection of an appropriate model include:

- Land use: can the model represent existing land use conditions?
- Intended use: is the intended use for planning purposes, engineering/design, or operational performance?
- Model complexity: is a less complex model sufficient?
- Modeler experience: what is the model-specific expertise of current staff? Is there budget to hire an expert?
- Green Infrastructure/LID: does the model has the capability of integrating green infrastructure/LID

When defining the modelling objectives, the modelers and decision-makers should also consider whether the model is required for regulatory compliance, and which models are accepted by the regulatory agency, by consulting with the conservation authority.

B) Availability of input data

The selection of an initial modelling platform based on the identified modelling objectives will define the general data needs. Data limitations are the single biggest constraint to model choice and confidence in results. Without reliable data, there is no reliable way to evaluate the relationship between the simulation results and the conditions in reality.

Some key questions regarding the availability of input data include:

- Are data at the right spatial and temporal resolution available?
- Is there a good understanding of the data accuracy?
- Are the input data collected at the right location, so as to be representative of conditions in the wetland?
- Can all the inputs required by the model be provided within the time and cost constraints of the project?

- How much work is needed to make the data usable in a model?
- If certain data are not available, can they easily be collected?

Failure to consider these questions will likely lead to model results in which there is little confidence.

C) Availability of modelling expertise

Different models require different levels and types of skill to apply and interpret. Important considerations with respect to appropriate expertise include: understanding of the physical processes and catchment behavior involved (e.g. surface water vs. groundwater processes); interpretive and technical understanding concerning models and algorithms; numerical and data manipulation skills; and communication skills (particularly if the modelling is part of a broader development design process). An honest assessment of the capabilities of the team early on will identify major gaps and may limit the type of model the modeler chooses. The overall confidence in a modelling exercise is in general highly dependent on the quality of the modelling team in addition to the model itself.

D) Availability of resources (time and money)

Modelling, data collection, and data manipulation are time consuming. Data are of little use without the expertise for interpretation, and expertise (both technical and non-technical) can be expensive. There will be constraints on total time and money available, possibly limiting the extent to which the original objectives can be met. There will invariably be a trade-off between resources and the extent to which all objectives can be met, and this trade-off needs to be discussed. The modelling team needs to be able to clearly articulate what is reasonable to expect given the available resources, and how an increase or decrease in resources would affect the scope and utility of the modelling exercise.

5.3 Review of Available Continuous Hydrology Models.

Surface hydrology models such as HEC-HMS, HSPF, PRMS, SWMM, Visual OttoHymo, and integrated hydrology models such as MIKE SHE and GSFLOW, have been successfully applied to simulating wetland hydrology and assessing the effect of land use changes on the wetland. A brief description of each of these continuous hydrology models is provided below. As mentioned previously, other continuous hydrology models not listed in this document or the associated case studies companion document may be acceptable, but proponents are asked to verify alternative modelling approaches with TRCA staff prior to any submissions.

HEC-HMS

The US Army Corps of Engineers (US-ACE) Hydrologic Engineering Center HEC-HMS (Hydrologic Modelling System) model is designed to simulate the complete hydrological processes of watershed systems. Hydrological analysis procedures such as event infiltration, unit hydrographs, and hydrological routing are included in HEC-HMS. The model also includes procedures necessary for continuous simulation including evapotranspiration, snowmelt, and soil moisture accounting. Advanced capabilities are also provided for gridded runoff simulation using the linear quasi-distributed runoff transform (ModClark). Supplemental analysis tools are provided for model optimization, forecasting streamflow, depth-area reduction, assessing model uncertainty, erosion and sediment transport, and water quality. HEC-HMS is comprised of a graphical user interface, integrated hydrological analysis components, data storage and management capabilities, and graphics and reporting facilities. Infiltration losses can be simulated for event modelling by initial and constant, SCS curve, gridded SCS curve number, and Green & Ampt methods. The five-layer soil moisture accounting model can be used for continuous modelling of complex infiltration and evapotranspiration environments. Excess precipitation can be transformed into surface runoff by unit hydrograph methods, Clark, ModClark, Snyder, and SCS technique. A variety of hydrological routing methods are included for simulating flow in open channels (lag method, Muskingum method, modified Puls method, kinematic wave or Muskingum-Cunge method). Most parameters for methods included in subbasin and reach elements can be estimated automatically using the optimization manager. Wetland in HEC-HMS can be represented in reservoir routing. HEC-HMS does not simulate groundwater movement explicitly. However, the groundwater recharge and discharge can be calculated externally and the calculated value can be included in the model as point sources.

HSPF

The US Environmental Protection Agency (US-EPA) HSPF (Hydrologic Simulation Program-Fortran) program has its origin in the Stanford Watershed Model developed by Crawford and Linsley (1966). Hydrocomp, Inc. developed its present form. HSPF is a comprehensive, conceptual, continuous watershed simulation model designed to simulate all water quantity and quality processes that occur in a watershed, including sediment transport and movement of contaminants (Bicknell et al., 1997). It can reproduce spatial variability by dividing the basin in hydrologically homogeneous land segments and simulating runoff for each land segment independently. A segment of land can be modeled as pervious or impervious. In pervious land segments HSPF models the movement of water along three paths: overland flow, interflow and groundwater flow. Snow accumulation and melt, evaporation, precipitation and other fluxes are also represented. Routing is done using a modified version of the kinematic wave equation. HSPF includes an internal database management system for input and output.

PRMS

The US Geological Survey (USGS) PRMS (Precipitation-Runoff Modelling System) model is a modular-design, deterministic modelling system developed to evaluate the impacts of various combinations of precipitation, climate, and land use on streamflow, sediment yields, and general basin hydrology (Leavesley et al., 1983). In PRMS a watershed can be divided into subunits based on basin characteristics (slope, aspect, elevation, vegetation type, soil type, land use, and precipitation distribution). Two levels of partitioning are available (USGS, 2000). The first divides the basin into homogeneous response units (HRU) based on the basin characteristics. The sum of the responses of all HRU's, weighted on a unit-area basis, produces the daily system response and streamflow for a basin. A second level of partitioning is available for storm hydrograph simulation. The watershed is conceptualized as a series of interconnected flow planes and channel segments. Surface runoff is routed over the flow planes into the channel segments; channel flow is routed through the watershed channel system. Output options include observed (if available) and predicted mean daily discharge, annual and monthly summaries of precipitation, interception, potential and actual evapotranspiration, and inflows and outflows of the ground water and subsurface reservoirs. Parameter-optimization and sensitivity analysis capabilities are provided to fit selected model parameters and evaluate their individual and joint effects on model output.

SWMM

The US-EPA Storm Water Management Model (SWMM) is a comprehensive dynamic hydrological simulation model for analysis of quantity and quality problems associated with urban runoff (CHI, 2003). Both single-event and continuous simulation can be performed on urban basins. Modeller can simulate all aspects of the urban hydrological and quality cycles, including rainfall, snowmelt, surface and subsurface runoff, flow routing through drainage network, storage and treatment. Flow routing can be performed in the Runoff, Transport and Extran blocks, in increasing order of sophistication. Extran block solves complete dynamic flow routing equations for accurate simulation of backwater, looped connections, surcharging, and pressure flow. The hydrological simulation in the Runoff block uses the Horton or Green & Ampt equations where the data requirements include area, imperviousness, slope, roughness, width (a shape factor), depression storage, and infiltration values for either the Horton or Green & Ampt equations for up to 100 subbasins. The program is driven by precipitation for up to ten gages (distributed spatially), and evaporation. Basic SWMM output consists of hydrographs and pollutographs at any desired location in the drainage system. The model performs best in urbanized areas with impervious drainage. The model lacks GUI, but various vendors have developed user-friendly GUIs (OSU-CE, 2003): (PCSWMM – a menu-driven interface developed by Computational Hydraulics International, XP-SWMM or Visual SWMM by XP Software, the Danish Hydraulic Institute GUI for the Runoff and Extran Blocks, MIKE-SWMM).

Visual OttoHymo

Visual OTTHYMO (VO) is a hydrological modelling software which primarily uses the HYMO model engine developed by J.R. Williams in 1973. This engine was further developed at the University of Ottawa, where it was named OTTHYMO 83. The first graphical interface was developed by the founder of Civica in 1998 (Visual OTTHYMO 1.0). VO is currently being developed by Civica Infrastructure, and additional features and commands continue to be added. The continuous version of VO (5.0) was released in 2017 with the ability to simulate snow melt, infiltration, evapotranspiration and groundwater infiltration. Continuous VO uses the same commands as the single event simulation (with some additional parameters required for continuous modelling). The wetland command is a new feature added to VO 5.0 in 2018. This command is designed to model all the hydrological processes in a wetland including inflow, evaporation, seepage and outflow. The interface for the wetland command is similar to that used in continuous VO, however a groundwater component has been added to the wetland. Groundwater seepage into and out of the wetland are calculated using Darcy's equation and the difference in elevation between the ground water and either the stored water or, if the wetland is dry, the bottom of the wetland.

MIKE SHE

MIKE SHE is a commercial engineering software package developed at the Danish Hydraulic Institute (DHI). MIKESHE, integrated, physically based, fully distributed, modular, dynamic modelling system, the DHI version of the original SHI (Systeme Hydrologique Europeen) program developed through a joint project of CEH Wallingford, Danish Hydraulics Institute and SOGREAH (France). The model is applicable on spatial scales ranging from single soil profiles (for infiltration studies) to regional watershed studies. MIKESHE includes all of the processes in the land phase of the hydrological cycle: precipitation (rain or snow), evapotranspiration, interception, overland sheet flow, channel flow, unsaturated sub-surface flow and saturated groundwater flow. Evapotranspiration is calculated using the Kristensen and Jensen method. MIKESHE's overland-flow component includes a 2D finite difference diffusive wave approach using the same 2D mesh as the groundwater component. MIKESHE includes a traditional 2D or 3D finite-difference groundwater model. There are three options in MIKESHE for calculating vertical flow in the unsaturated zone: the full Richards equation, a simplified gravity flow procedure, and a simple two-layer water balance method for shallow water tables (DHI, 2000b).

GSFLOW

GSFLOW is the USGS modelling system that integrates the surface and groundwater components of the hydrological cycle. GSFLOW is based on two USGS models namely PRMS and MODFLOW. With GSFLOW, the user has the option to run the codes together in a fully fashion or to run each of the models independently. Within GSFLOW, both codes are fully coupled and capable of providing the feedbacks from surface water to groundwater resources vice versa. It is essential to include such feedbacks within GSFLOW for they affect the timing and rates of evapotranspiration, surface runoff, soil-zone flow, and groundwater interactions (Markstrom et al., 2008). GSFLOW is capable modelling system with potential applications to a variety of research questions, such as (i) how surface water processes affect recharge and water table responses, (ii) how climate change is likely to impact groundwater and surface water, and (iii) surface and groundwater effects on the behavior of springs, wetlands, and ecological systems (Markstrom et al., 2008).

Model Features	SWMM	HEC-HMS	HSPF	VH Ottohymo	PRMS
Model Type	Lumped-parameter	Lumped-parameter	Lumped-parameter	Lumped-parameter	Lumped-parameter
Simulation Type	Single-event/continuous	Single-event	Continuous	Single-event/continuous	Continuous
Watershed subdivision unit	Subbasins	Subbasins	subbasins	NasHyds/StandHyds	Hydrologic Response Units
Precipitation	Single/multiple hyetographs	single hyetograph	multiple hyetographs	Multiple hyetographs	Multiple hyetographs
Snow Melt	Snow accumulation Snow redistribution by areal depletion and removal operations Snow melt via heat budget accounting	Yes	Yes	Yes	Yes
Evapotranspiration	Yes (Modified Hargreaves using temperature, or timeseries input)	No	Yes	Yes	Yes
Infiltration	Green-Ampt Infiltration Curve Number infiltration Horton Infiltration	SCS curve number Initial and uniform loss Exponential loss rate Holtan loss rate Green-Ampt loss rate	Empirical equation based on soil type and available storage	SCS curve number	Green-Ampt during storm mode
Rainfall Excess to Runoff	Physically based, nonlinear reservoir model Kinematic Wave	SCS unit hydrograph Clark unit hydrograph Snyder unit hydrograph Kinematic wave	Manning's equation based on the depth of surface detention of excess precipitation	Nash unit hydrograph Standard unit hydrograph	Kinematic wave

Model Features	SWMM	HEC-HMS	HSPF	VH Ottohymo	PRMS
Reservoir storage and routing	Excess volume Under Steady and Kinematic Wave flow routing. In Dynamic Wave routing, the excess volume is assumed to pond over the node with a constant surface area.	Modified-Puls routing Level pool routing	Outflow can be volume or time dependent or user-specified	Modified-Puls routing	Modified-Puls routing Linear-storage routing
Subsurface Soil Water Flow	Computing the water fluxes during given time step using infiltration, evapotranspiration, percolation, seepage, lateral groundwater interflow	Baseflow quantity can be specified	Yes	No	Yes
Channel Routing	Steady flow routing Kinematic wave routing Dynamic wave routing	Muskingum Weighted Inflow Kinematic Wave Muskingum-Cunge Modified Puls Normal Depth Working R and D	Kinematic wave	Variable Storage Coefficient Muskingum-Cunge	Kinematic wave
Reservoir Routing	Steady flow routing Kinematic wave routing Dynamic wave routing	Storage-outflow, Elevation-storage-outflow, elevation area-outflow	Surface area-volume and wind speed	Modified-Puls routing	Puls Linear routing
GIS interface	Interface with GRASS	WMS, Geo-STORM, GISIWAM	no specific interface	Interface with ArcGIS	In development as a component of MMS

Table 2: Comparison of surface hydrological model capabilities

Model Features	MIKE SHE	GSFLOW
Model Type	Lumped-parameter	Lumped-parameter
Simulation Type	Single-event	Continuous
Watershed subdivision unit	Sub-basins	Hydrologic Response Units
Precipitation	Single hyetograph	Multiple hyetographs
Snow Melt	Yes	Yes
Evapotranspiration	Kristensen & Jensen method	Yes
Infiltration	SCS curve number; Initial and uniform loss; Exponential loss rate; Holtan loss rate; Green-Ampt loss rate	Green-Ampt (during storm mode)
Rainfall Excess to Runoff	SCS unit hydrograph Clark unit hydrograph Snyder unit hydrograph Kinematic wave	Kinematic wave
Reservoir storage and routing	Modified-Puls routing Level pool routing	Modified-Puls routing Linear-storage routing
Subsurface Soil Water Flow	Baseflow quantity can be specified	Yes
Channel Routing	Muskingum Weighted Inflow Kinematic Wave Muskingum-Cunge Modified Puls Normal Depth Working R and D	Kinematic wave
GIS interface	WMS, Geo-STORM, GISIWAM	In development as a component of MMS

Table 3: Comparison of integrated hydrological model capabilities

5.4 Model Setup

After going through the steps listed above for scoping the project and selecting an appropriate continuous hydrology model based on the study parameters, model setup can begin. Model setup describes the process of preparing the input data in the correct format, creating the model input files, and undertaking initial simulations. Setup is greatly dependent upon the availability of good quality data and field observations to characterize the study area. Hydrological data must be cleaned from random and systematic errors, otherwise a model may be erroneously rejected, or its calibration otherwise compromised so as to reduce the utility of the model.

In the model setup, there are some differences in the steps required to parameterize hydrological processes in different models. The preparation of inputs for some lumped catchment models is not complex, however data preparation for distributed, physically-based models is typically more complex. That being said, many parameters can be estimated for catchment properties, and therefore during model setup and parameterization, respective model manuals should be consulted and referenced.

Typically, the following input data will be needed for modelling the relevant hydrological processes in most continuous hydrology models:

- High resolution Digital Elevation Model (DEM)
- Land use / land cover
- Soil type and other basin physiographic data (e.g. depression storage coefficients)
- Precipitation and temperature data
- Channel and reservoir hydraulic data
- Stage-storage and stage-discharge data
- Actual or potential evapotranspiration data, or sufficient input data for one of the empirical estimation equations.

The FBWB report must discuss the rationale for model setup, and include a description of the input data preparation and model input files. The report must describe sources of data that are used in the estimation of the parameters for the model and the assumptions that are used in the process. To the greatest extent possible, model parameters should be derived from site-specific observations. The topographic features onsite should be represented at the finest resolution possible and can be derived from digital elevation models or site surveys. Infiltration and recharge parameters, soil zone parameters, and hydraulic conductivities should ideally be obtained from onsite soils analysis or borehole drilling. Land cover mapping should be revised for consistency with the existing site conditions, if required.

As the FBWB methodology outlined in this report requires continuous hydrology modelling, long-term climate data inputs should be prepared for the model simulations. TRCA's *SWM Document* (2012) suggests using climate data from as close as possible to the target site to determine the target (i.e. pre-development baseline) long-term hydroperiod and assessing and mitigating the impact of development. At a minimum, the period from 1991 to 2008, considered to be representative, should be used. This is considered to be a representative period containing wet, average, and dry years. TRCA staff can provide a forcing dataset for the representative period upon request. Model output should be set to daily resolution, which will be used to create weekly, monthly, and annual summaries.

After model setup is complete, TRCA recommends that the applicant submit the model setup to TRCA and discuss with TRCA before proceeding further to model calibration.

5.5 Model Calibration

Watershed models contain many parameters; these parameters are classified into two groups: physical and process parameters. A physical parameter represents physically measurable properties of the catchment (e.g. areas of the catchment, fraction of impervious area and surface area of water bodies, surface slope etc.). Process parameters represents properties of the catchment which are not directly measurable e.g. average or effective depth of surface soil moisture storage, the effective lateral inflow rate, the coefficient of non-linearity controlling the rate of percolation to the groundwater. (Sorooshian, and Gupta 1995). Hence in order to utilize any predictive catchment model for estimating the effectiveness of future potential management practices one needs to select values for the model parameters so that the model closely simulates the behavior of the study site. The process by which the parameters are selected is called model calibration. There are two parts to this process: parameter specification and parameter estimation.

Assigning of initial estimates parameters of the model using prior knowledge about the catchment properties and behaviors is called parameter specification. For "physical" parameters, estimates are made using measurements obtained from maps in the field. The parameters are then typically fixed at these measured values and not adjusted further unless determined to be in error. For "process parameters", estimates of the range (minimum and maximum values) of possible values for these parameters are determined based on judgment and understanding of the hydrology of the catchment. The process of parameter estimation described below then reduces this uncertainty in the parameter estimates.

Parameter estimation is various techniques designed to reduce the uncertainty in the estimates of the process parameters. A typical approach is to first select an initial estimate for the parameters, somewhere inside the ranges previously specified. The parameter values are then adjusted to more closely match the model behavior to that of the catchment. The process of adjustment can be done "manually" or using computer-based "automatic" methods.

As it is mentioned above, the objective of a calibration procedure is the estimation of values for those parameters, which cannot be assessed directly from field data. According to Refsgaard and Storm (1996), three types of calibration procedures can be differentiated:

1. Trial-and-error, manual parameter adjustment;

2. Automatic, numerical parameter optimization;

3. A combination of (1) and (2).

Refsgaard and Storm (1996) argued that the first method is the most common, and especially recommended for the application of more complicated models in which a good graphical representation is a prerequisite. Alternatively, an automatic calibration involves the use of a numerical algorithm, which finds the optimum of a given numerical objective function. This is carried out by applying the model to numerous combinations and permutations of parameter levels, in order to find the best parameter set in terms of satisfying the criterion of accuracy. The combination means that the manual method is placed at the beginning of the procedure in order to delineate rough orders of magnitude, which is followed by the automatic calibration for fine adjustment. The reverse procedure is also possible, whereby the automatic method is used as a kind of sensitivity analysis to find the most important parameters, which are afterwards manually calibrated.

Gan (1988) has recommended that a combination of manual and automatic procedure be adopted for the model calibration. Manual calibration alone is very tedious, time consuming, and requires the experience of the modeler. Because of the time-consuming nature of the manual model calibration, there have been a number of researches towards development of automated calibration methods. Automatic calibration on the other hand relies heavily on the optimization algorithm and the specified objective function.

Model outputs should be calibrated to fall within a percentage of average measured values and then model performance statistics (r^2 and E_{NS}) were evaluated. If measured and simulated means met the calibration criteria and daily, weekly and monthly r^2 and E_{NS} did not, and then additional checking was performed to ensure that rainfall variability and evapotranspiration seasonal variability were properly simulated over time. If all parameters were pushed to the limit of their ranges for a model output (i.e., flow or water level) and the calibration criteria were still not met, then calibration should be stopped for that output and the modeler should do further investigation on the input parameters.

5.6 Validation

In order to utilize any predictive catchment model for estimating the effectiveness of future potential management practices the model must be first calibrated to measured data and should then be tested (without further parameter adjustment) against an independent set of measured data. This testing of a model on an independent data set is commonly referred to as model validation. Model calibration determines the best, or at least a reasonable, parameter set while validation ensures that the calibrated parameters set performs reasonably well under an independent data set. Provided the model predictive capability is demonstrated as being reasonable in both the calibration and validation phase, the model can be used with some confidence for future predictions under somewhat different management scenarios.

5.7 Model Performance Assessment

In order to assess the ability of the calibrated model in mimicking the hydrological processes within the wetland catchment, model performance assessment measures must be applied. Model performance assessment can usually be done by comparing both simulated and observed hydrographs graphically and using statistical measures.

5.7.1 Graphical Comparison of Observed and Calibrated Hydrographs

Graphical display of calibrated and observed flows is very important because the traditional method of evaluating model performance by statistical measures has limitations. Statistical indices are not effective in communicating qualitative information such as trends, types of errors and distribution patterns. In fact, one should not depend on only single statistical measures of model performance. These are sometimes misleading because of the high possibility of compensation of errors from season to season or over years in long-term calibration. In both calibration and validation processes both observed and simulated hydrographs must be compared graphically. Figure 12 and Figure 13 below demonstrate graphical comparisons.

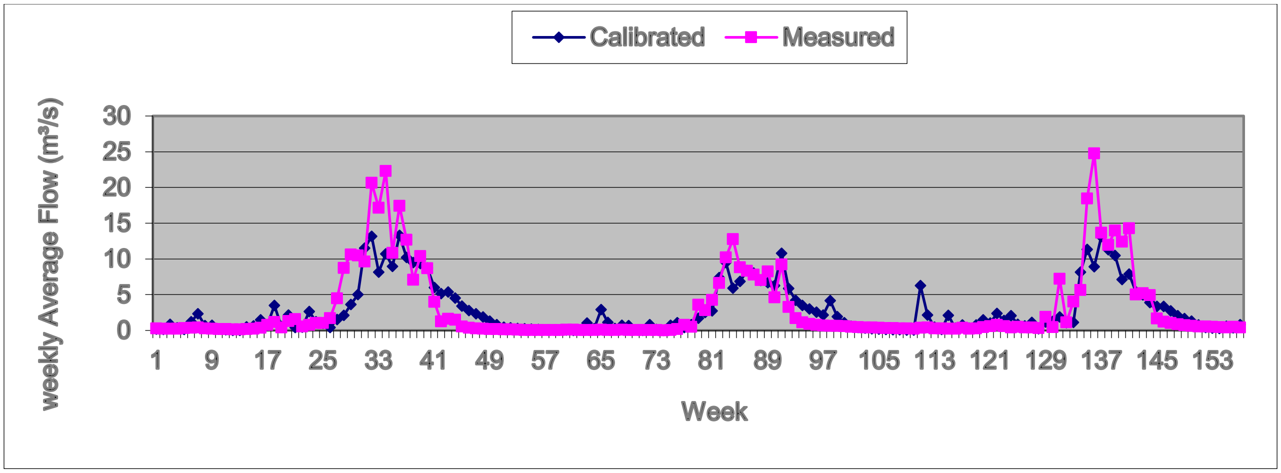


Figure 12: Observed vs. calibrated weekly flow

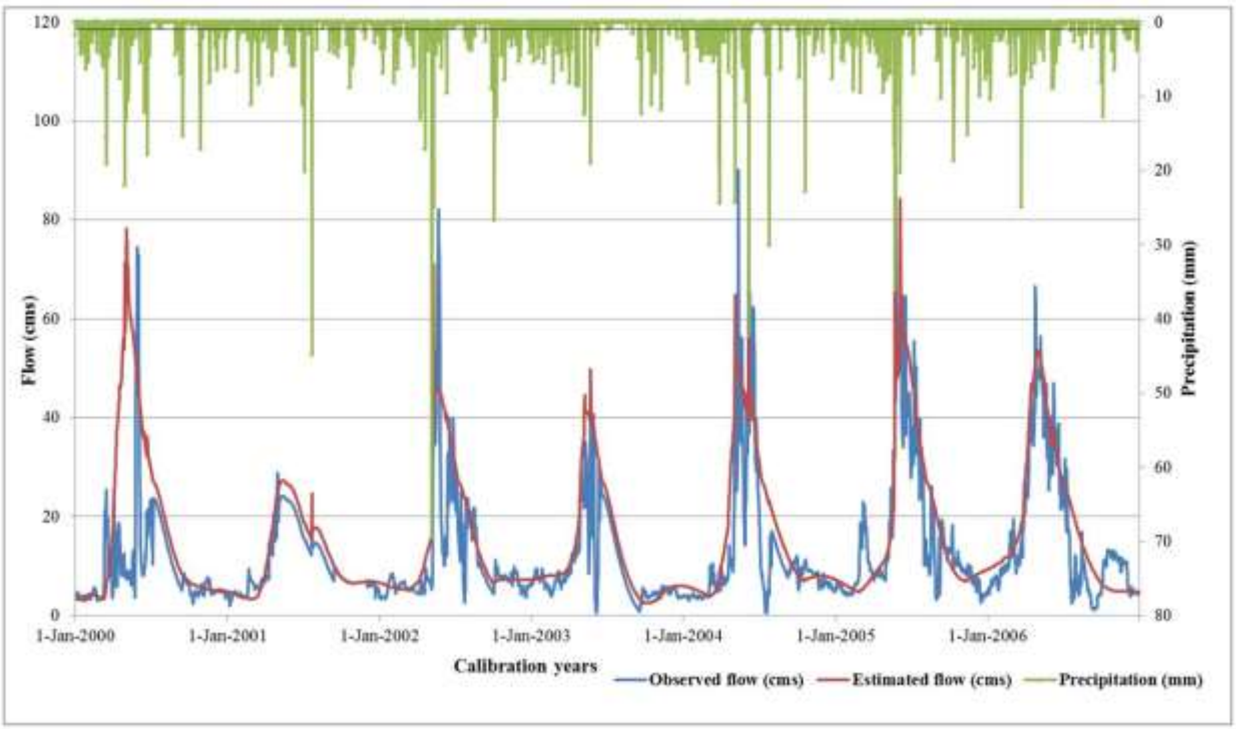


Figure 13: Observed vs calibrated daily flow and rainfall

5.7.2 Statistical Measures

Three methods for goodness-of-fit measures of model predictions can be utilized during the calibration and validation periods, these three numerical model performance measures are the percent difference (D), coefficient of determination (r^2 coefficient) and the Nash-Suttcliffe simulation efficiency (E_{NS}) (Nash and Sutcliffe 1970).

Percent Difference (D)

The percent difference measures the average tendency of the modeled values to be higher or smaller than the measured values for a given quantity over a specified period (usually the entire calibration or validation period in the study). (Gupta et al., 1999). The percent difference for a quantity (D) over a specified period with total days is calculated from measured and simulated values of the quantity in each model time step as:

$$D = 100 \cdot \left[\frac{\left(\sum_{i=1}^{n} q_{si} - \sum_{i=1}^{n} q_{oi} \right)}{\sum_{i=1}^{n} q_{oi}} \right] \quad \text{Equation 3}$$

Where:

- q_{si} *is the simulated values of the quantity in each model time step*
- q_{oi} *is the measured values of the quantity in each model time step*

A value close to 0% is optimal value of D which means the model is simulating accurately. Positive values of D show that the model underestimates whereas negative values show that the model overestimates. . (Legates and McCabe, 1999)

Coefficient of Determination (r^2 coefficient)

The r^2 coefficient is a measure of how well trends in the measured data are reproduced by the simulated results over a specified time period and for a specified time step. The range of values for r^2 is 1.0 (best) to 0.0. The r^2 coefficient measures the fraction of the variation in the measured data that is replicated in the simulated model results. A value of 0.0 for r^2 means that none of the variance in the measured data is replicated by the model predictions. On the other hand, a value of 1.0 indicates that all of the variance in the measured data is replicated by the model predictions.

The r^2 coefficient for n time steps is calculated as:

$$r^2 = \frac{\left[\sum_{i=1}^{n} (q_{si} - \bar{q}_s)(q_{oi} - \bar{q}_o) \right]^2}{\sum_{i=1}^{n} (q_{si} - \bar{q}_s)^2 \sum_{i=1}^{n} (q_{oi} - \bar{q}_o)^2} \quad \text{Equation 4}$$

Where:

- q_{si} *is the simulated values of the quantity in each model time step*
- q_{oi} *is the measured values of the quantity in each model time step*
- $\bar{q}_s$ *is the average simulated value of the quantity in each model time step*
- $\bar{q}_o$ *is the average measured value of the quantity in each model time step*

Nash-Sutcliffe Simulation Efficiency (E_{NS})

The E_{NS} simulation efficiency is a normalized statistic that demonstrates the relative magnitude of the residual variance compared to the variance of the measured data (Nash and Sutcliffe 1970).

The E_{NS} simulation efficiency for n time steps is calculated as:

$$E_{NS} = 1 - \frac{\sum_{i=1}^{n} (q_{oi} - q_{si})^2}{\sum_{i=1}^{n} (q_{oi} - \bar{q}_o)^2} \qquad \text{Equation 5}$$

Where:

- q_{si} *is the simulated values of the quantity in each model time step (in this case, daily, weekly and monthly)*
- q_{oi} is the measured values of the quantity in each model time step (in this case, daily, weekly and monthly)

The statistical index of modelling efficiency (E_{NS}) values range from 1.0(best) to negative infinity. E_{NS} measures how well the simulated results predict the measured data relative to simply predicting the quantity of interest by using the average of the measured data over the period of comparison. E_{NS} is a more stringent test of performance than r^2 and is never larger than r^2. A value of 0.0 for E_{NS} means that the model predictions are just as accurate as using the measured data average to predict the measured data. E_{NS} values range negative infinite and positive 1. When the E_{NS} values are less than 0.0 indicate the measured data average is a better predictor of the measured data than the model predictions while a value greater than 0.0 indicates the model is a better predictor of the measured data than the measured data average. E_{NS} values equalis to 1 is the optimal value. Servat and Dezetter (1991), the ASCE (1993), and by Legates and McCabe (1999) recommended this model performance evaluation technique. The E_{NS} simulation efficiency shows how well a graph of observed versus simulated values fits a 1:1 line

Figure 14 shows an example scatter diagram that demonstrates r^2 coefficient and E_{NS} simulation efficiency measures.

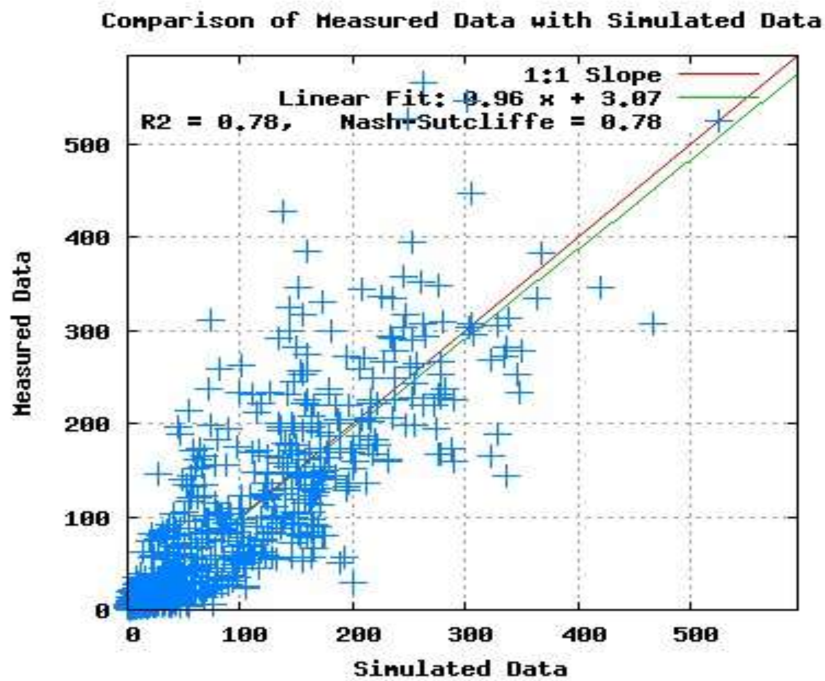


Figure 14: Scatter diagram of simulated vs. measured flow

The established continuous hydrologic model needs to be calibrated with measured data. The parameters in the hydrology model should be adjusted until the model performance statistics fall within D<15%, r^2 >0.75 and ENS >0.65 for daily values. The time step in the continuous hydrologic analysis needs to be daily values and the daily values can be used to generate weekly results.

TRCA requires that the preliminary model calibration to existing conditions be documented and submitted for review and approval prior to proceeding to the application of the model in a predictive manner.

6 Establishing Target Hydroperiod Using Existing Condition

This section of the FBWB report must establish the target hydroperiod by running the calibrated pre-development model using a long-term dataset as described in this section of the guidance document. The calibrated model should be approved by TRCA staff to ensure satisfactory performance prior to being applied in a predictive manner. Results should be presented for each year both graphically and in tabular format as outlined in Section 8.

The *Stormwater Management Criteria Document* (TRCA, 2012) states that the overall objective of FBWB analysis is to “manage the water balance with the intent to maintain the quantity (i.e. volume, timing, and spatial distribution) of surface water and groundwater contributions that ensures the pre-development hydroperiod (seasonal pattern of water level fluctuation) of the wetland is protected" (p.27). The proposed development must not cause significant changes to the hydroperiod that negatively impact the ecological and hydrological functions of the feature, as discussed in Section 8.

To produce the target hydroperiod, the calibrated model (reviewed and approved by TRCA staff) should be run under pre-development baseline conditions using a forcing dataset consisting of precipitation and temperature covering a period of 1991 to 2008. This is considered to be a representative period containing wet, average, and dry years. TRCA staff can provide a forcing dataset for the representative period upon request. Model output should be set to daily resolution, which will be used to create weekly, monthly, and annual summaries.

Following the pre-development model run, the average storage depth for each Julian day (e.g. February 19 = Day 50) during the modelled pre-development period should be calculated and used to create upper and lower boundaries for the 95 percent confidence interval boundaries.

7 Post-development Unmitigated Hydroperiod

This section of the FBWB report must provide the results from running the model using the same forcing data under post-development conditions without stormwater management mitigation practices. The representation of the developed areas of the wetland catchment in the model should be discussed and changes to the parameters of hydrologic response units outlined. The model output should be presented for each year both graphically and in tabular format as outlined in Section 8.

After establishing the target hydroperiod, the calibrated continuous hydrological model needs to be reconfigured to reflect the post-development land use and land cover condition. The configuration and parameterization of sub-catchments should be based on the best available knowledge about the development form and servicing requirements at the time of the analysis. The parameters assigned to the post-development sub-catchments and any changes to the configuration of the model should be reported in this section.

A graphical representation of the pre- to post-development comparison is shown below in Figures 15 and 16. In Figure 15, the proposed development has greatly increased the runoff volume going to the wetland while infiltration is simultaneously reduced, resulting in a significant increase in the wetland storage volume. Figure 16 shows an alternative example where the proposed development diverts most of the runoff volume away from the wetland while also reducing infiltration, resulting in a significant decrease in wetland storage volume.

To produce the post-development unmitigated hydroperiod, the calibrated pre-development model approved by TRCA staff should be run in post-development mode using the same 1991 to 2008 forcing dataset. Model output should be set to daily resolution, which will be used to create weekly, monthly, and annual summaries.

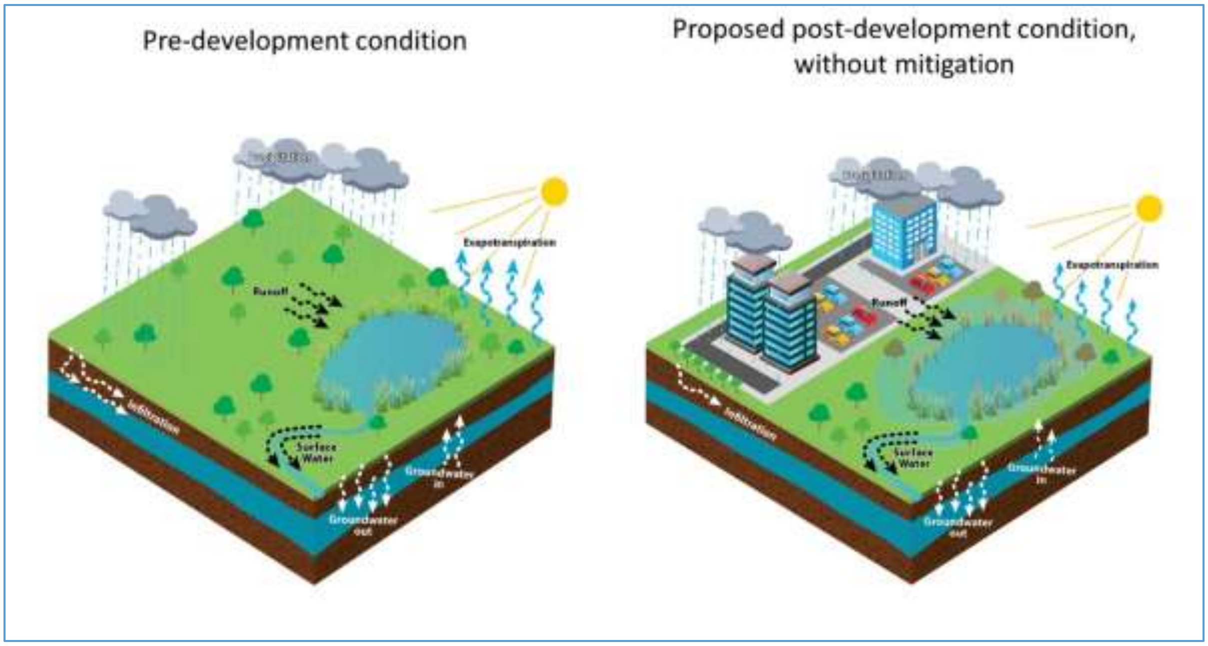


Figure 15: Development increased runoff volume to the wetland and reduced infiltration

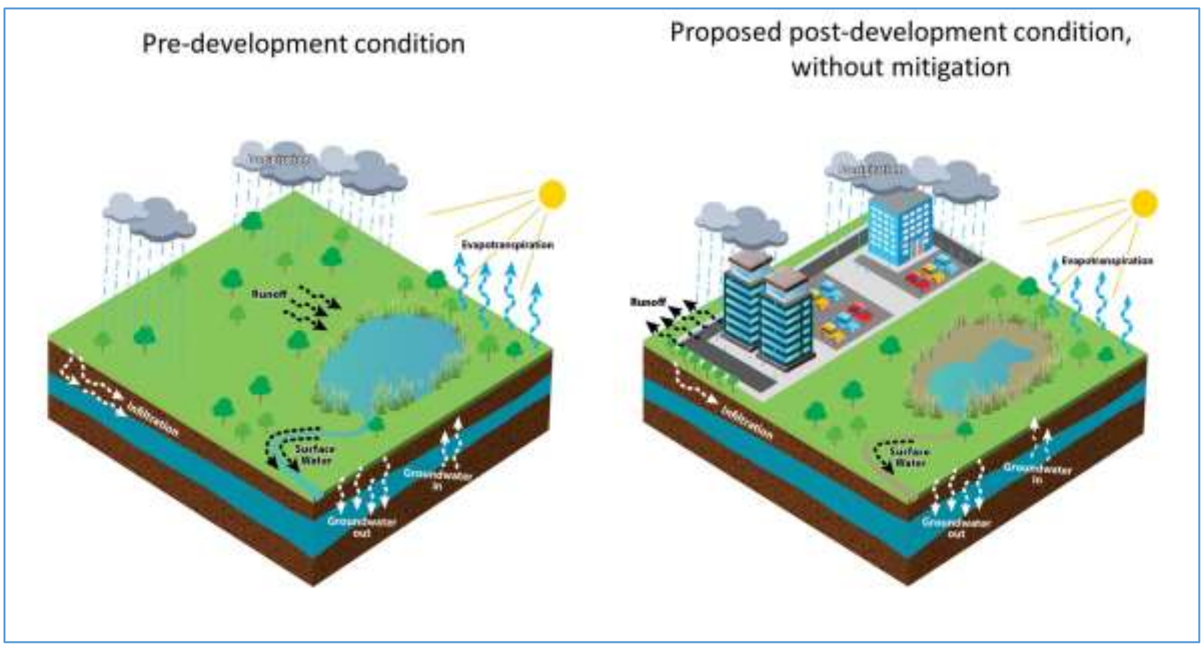


Figure 16: Development decreased runoff volume to the wetland and reduced infiltration

8 Comparison of the Pre-development Target Hydroperiod with the Unmitigated Post-development Hydroperiod

This section of the FBWB report should compare the simulated target hydroperiod with the post-development unmitigated hydroperiod, both graphically and in tabular format, for each model simulation year. A discussion of the potential ecological significance of differences detected between the target and post-development hydroperiod should also be included.

For each simulation year, create a hydrograph showing the modelled pre-development and post-development unmitigated wetland storage levels. The average storage depth for each Julian day (e.g. February 19 = Day 50) during the modelled pre-development period should be calculated and used to create upper- and lower-95 percent confidence interval boundaries, to be plotted on each hydrograph alongside modelled wetland storage. The confidence intervals will be the same for each year. An example of this for one year of data is shown below in Figure 17**.**

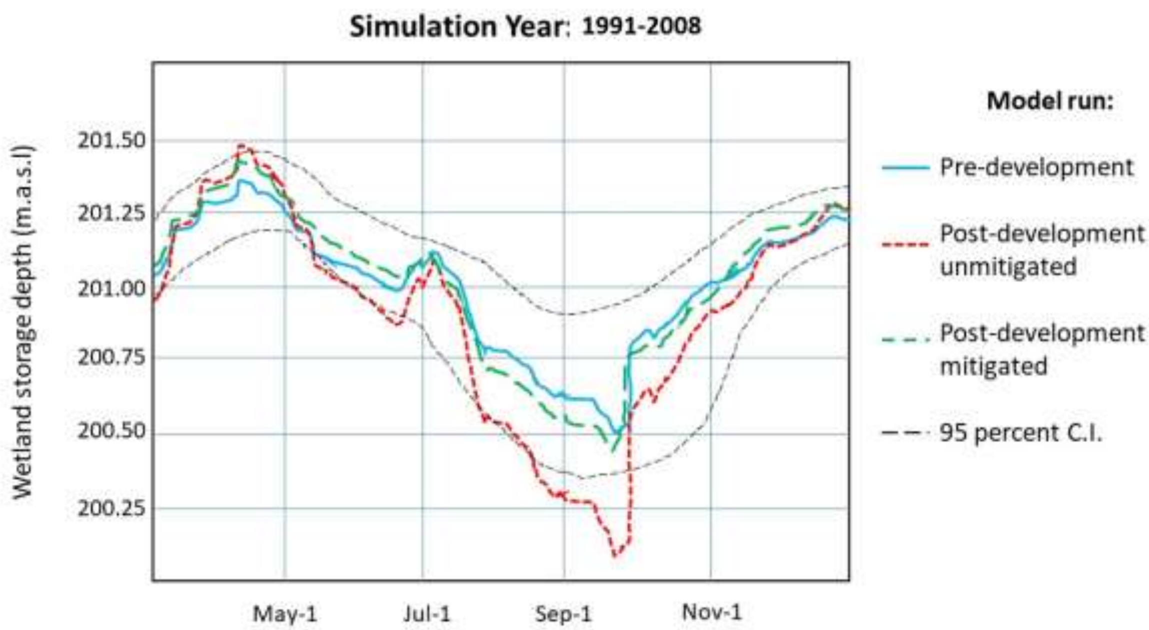


Figure 17: Hypothetical hydrograph for one simulation year comparing pre- and post-development

For tabular presentation of results, the storage depth and the inflow and outflow volumes to and from the wetland storage unit should be reported for each year. Inflow and outflow volumes should be further subdivided into their major constituents (e.g. output broken down into overland flow, ET, and infiltration). Each of these values should be summed over weekly, monthly, and annual intervals within the table, with differences between the pre- and post-development scenario calculated at each time interval as percentage of pre-development volume.

The report should include an assessment of the potential impact of changes on the wetland flora and fauna communities. An ecologist will provide an analysis of the model outputs to determine whether the risk to the wetland's ecological and hydrological functions can be considered acceptable. This assessment should be placed in the context of the model performance and uncertainty under different conditions and times of year.

TRCA staff recognizes that in most cases it will not be possible to achieve a post-development hydroperiod that matches exactly the pre-development hydroperiod. Instead the proponent should focus on minimizing the difference in hydroperiod timing and magnitude in order to minimize negative impacts to the wetland. TRCA is conducting research to support more robust decision making around levels of ecological risk, based on the natural range of observed variation within and among different wetland communities. However, it will continue to be necessary to consult with planning ecologists and other technical review staff to determine the scope of required mitigation.

9 Prepare Mitigation Measures

This section of the FBWB report should outline the design of mitigation measures, where required, and evaluate their performance by running the model using the same forcing data under mitigated post-development conditions. Performance evaluation should be measured against the target hydroperiod using the same graphical and tabular comparison as was used for the previous section. The event-based performance of any proposed stormwater management infrastructure involved in a mitigation solution also needs to be demonstrated.

The modeler should work collaboratively with an ecologist to understand the sensitivity of the wetland and to develop appropriate mitigation measures, where required, to ensure maintenance of the pre-development wetland hydroperiod. Once proposed measures have been identified, the modeler should modify the parameters and structure of the post-development unmitigated model to reflect the proposed changes to the development design, and re-run the model using the same long-term forcing dataset. Note that use of "mitigation measures" does not refer exclusively to stormwater management infrastructure, but rather could include solutions such as increased natural buffer widths or incorporation of more permeable surfaces like parklands within the development area of the wetland catchment.

A detailed description of proposed mitigation measures such as clean roof drainage collector systems directed to bioswales, infiltration galleries, third pipe systems, etc. should be included in the FBWB report. The locations and extents of the proposed mitigation measures and any stormwater management facilities should be clearly indicated in relation to the wetland on a map, including a description of how water will be conveyed to the wetland. Note that clean runoff from greenspace and roof areas is preferred to feed wetlands as necessary, as runoff from roads or paved surfaces as sources of supplemental water should only be considered as a last resort owing to the accumulation of sediment, salt, and hydrocarbons in stormwater runoff from roads and walkways.

Uncertainty in prediction is an issue in hydrological modelling due to uncertainty in input data, errors in measured data used for calibration, model structure uncertainty, and numerical error such as truncation error or roundoff error. There are different methods to estimate uncertainty in hydrological modelling analysis. Assessment of uncertainties of the prediction of the wetland hydrology model can be onerous exercise. However, uncertainty of impact prediction in the design of mitigation measures can be accounted for by expanding proposed mitigation measure by a given factor. In TRCA jurisdiction, it is recommended that a Factor of Safety by implemented for wetland mitigation measures by increasing the catchment area for the measures by 30%.

For development scenarios in which it is necessary to supply additional water to the wetland to maintain the water balance, the mitigation measures should be designed to collect runoff from an area that is 30 percent larger than the calculated area required wherever possible. For example, if a roof drain collector system is being used to supply additional runoff volume to the wetland, and calculations suggest that a total of 1 ha of roof runoff is necessary to replace the volume of water lost, the system should be designed to collect runoff from 1.3 ha of roof area. Additionally, adjustable orifices should be incorporated into the conveyance system, such that the orifice can be reduced or enlarged if monitoring and adaptive management identifies a surplus or a deficit of runoff reaching the wetland, and any excess runoff volume is conveyed via an overflow to the main storm sewer system. The requirement of 30 percent additional contributing area is meant to address the fact that it is much more difficult to add extra contributing roof area to a drain collector system than it is to re-route already connected contributing roof area to a different outlet (e.g. a stormwater management pond). The 30 percent additional contributing area recognizes the inherent uncertainty of modelling input data, output data, and mitigation system performance. The use of an adjustable orifice and overflow system allows for a mitigation system that is both adaptive and that functions in a completely passive manner, once it has been demonstrated to successfully maintain the wetland water balance.

The timing of release of runoff into the wetland resulting from the proposed mitigation design should be evaluated to ensure that there are no concerns around peak flow and localized erosion impacts. To confirm the timing of runoff entering the wetland, provide five (5) hydrograph of distinct storm events of precipitation volumes 15 mm or greater, showing existing and proposed timing of the hydrologic input. A table for each hydrograph should be provided demonstrating the time to the peak inflow rate, the peak inflow rate, and total time of hydrologic input demonstrating the proposed timing matches the existing condition as closely as possible. Further, an additional five (5) hydrographs of distinct storm events should be provided to verify the design, showing the same level of information and comparison. While it will not be possible to precisely match the pre-development timing of inflows to the wetland in the post-development condition, measures to slow the delivery of runoff to the wetland will help reduce the risk of ecological degradation owing to sudden changes in water level and to associated erosion and sediment control impacts.

The model output from the post-development mitigated scenario should be compared for each year against the target hydroperiod and post-development unmitigated hydroperiod using the exact same graphical and tabular presentation formats outlined in Section 8. The difference between the proposed post-development mitigation scenario and the target pre-development should be scenario calculated at each time interval as percentage of pre-development volume, as in Section 8.

Finally, this section should include a discussion about the potential residual negative impacts to the wetland ecological processes resulting from altered hydroperiod, after all mitigation measures have been incorporated. An ecologist should ensure that the mitigated hydroperiod is consistent with the wetland community.

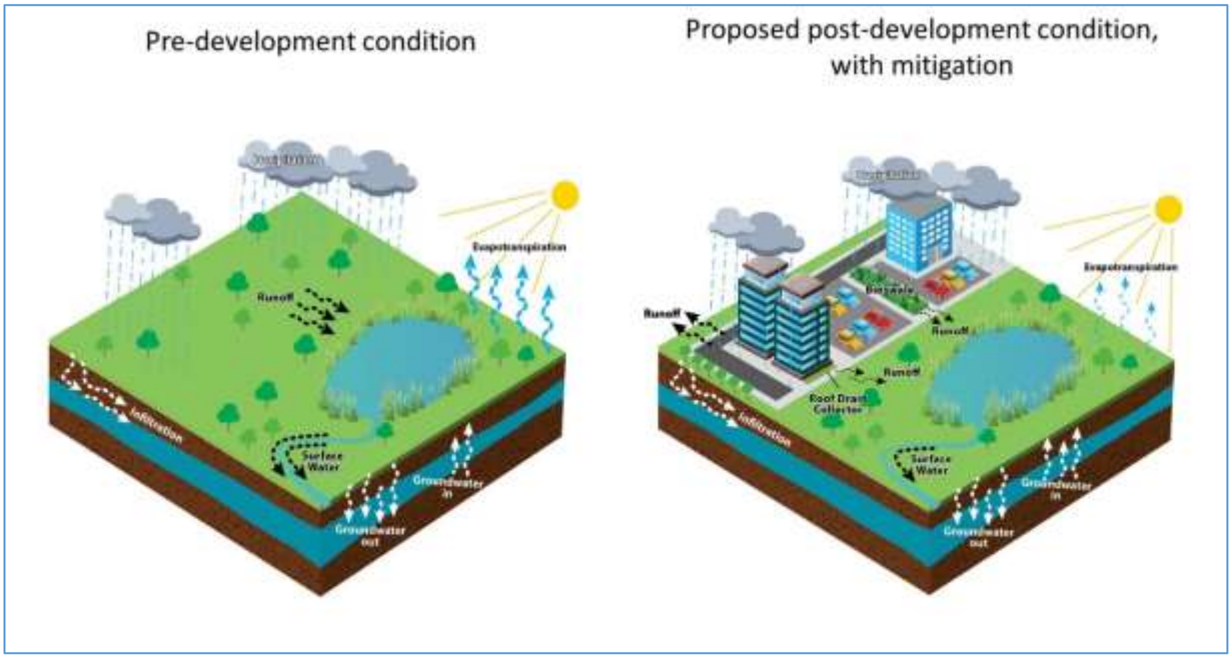


Figure 18: Development incorporated mitigation measures to maintain the pre-development hydroperiod in the post-development condition

10 Interim Mitigation Plan during Construction of the Project

This section of the FBWB report should outline an interim mitigation plan to protect the wetland during the construction phase, where a plan has been deemed necessary through consultation with the conservation authority. The mitigation plan should outline triggers for action and define the corresponding actions to take.

An interim mitigation plan may be required for developments where there is a risk of negative effects to the wetland resulting from the delay between alterations to the wetland catchment (typically during earthworks) and the implementation of mitigation measures (typically during building construction). The need for a mitigation plan will be determined in consultation with TRCA and municipal staff. A mitigation plan should outline active management measures for supplementing the water balance during construction and define triggers for when action is required (e.g. low and high water level thresholds for a specified duration and/or time of year, as deemed appropriate by ecologists). Such measures may be necessary to protect the ecological and hydrological functions of the wetland from multi-year disturbances which degrade the wetland to a point where these functions cannot be restored. In the case where supplemental water is needed to augment the interim water balance, clean sources of water are preferred (e.g. roof runoff, runoff from greenspace, or unchlorinated water from a water truck). Interim mitigation plans may include, for example, phasing soil stripping or grading activities within the wetland catchment, or having an interim grading plan that is designed to compensate for an anticipated surplus or deficit of water during the construction phase.

11 Monitoring and Adaptive Management Plan

This section of the FBWB report should outline the post-implementation monitoring plan where this has been identified as a requirement. The plan should outline the triggers for action and the associated adaptive management options, should post-implementation monitoring identify an excess or deficit in wetland water storage.

For proposals that have been determined to be medium or high risk as per the TRCA *Wetland Water Balance Risk Evaluation* (TRCA, 2017), post-implementation water balance monitoring is required to characterize the new wetland hydrology following construction and to understand any changes to the wetland's ecological function. The TRCA Wetland Water Balance Monitoring Protocol (TRCA, 2016) should be consulted for more detailed guidance. The hydrological monitoring instrumentation should remain in place post-development for a period agreed upon with the agencies, and continuous hydrological data should be collected during these years. The first year of post-development data collection may begin at 80-85% build-out as long as all mitigation measures designed to protect wetland hydrology have been implemented. As the purpose of post-development monitoring is to capture the passive operation of the mitigation system, this phase of the monitoring may not begin until these measures have been fully implemented.

In the FBWB report, the proponent should clearly outline the methods that will be used to evaluate the effectiveness of the mitigation measures in maintaining the pre-development wetland hydroperiod. For example, the modelled long-term hydroperiod can be used as a basis for comparison by plotting the monitored post-development water levels by Julian day-of-year (i.e. day 1-365) against the statistical distribution of long-term annual water levels over the same period. TRCA can provide tools and scripts upon request that can be used to facilitate these analyses and other numerical and graphical comparisons between different scenarios; two such tools are currently available in beta form.

An adaptive management plan should outline potential mitigation actions, should post-implementation monitoring identify an excess or a deficit in wetland water storage. The specifics of the adaptive management plan will necessarily depend strongly on local conditions and constraints, but may include, for example, designs that incorporate adjustable orifices, flow splitters, and similar devices that allow for the post-development area contributing runoff volume to be adjusted to some degree. The benefit of such designs is that they can operate passively without requiring active intervention, once a suitable post-development hydrological regime has been settled on. The feature-based water balance analysis report should identify opportunities to incorporate such designs so that the opportunity to integrate them into servicing and infrastructure is not missed. Consult with the conservation authority regarding appropriate adaptive management plan objectives and hydroperiod targets.

12 Conclusions and Recommendations

This final section of the FBWB report should summarize the original objectives of the modelling exercise and the main outcomes for each objective. The results of the comparison between the pre-development hydroperiod and the post-development hydroperiod should also be summarized. Finally, the design recommendations and supporting rationale with regard to any water balance mitigation measures that have been determined to be necessary through consultation with TRCA staff should be summarized.

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Appendix A: Feature-based Water Balance Analysis Report Template

The following structure is suggested as a standard format for the modelling part of feature based water balance analysis study report. Depending on the characteristics of impacts of the proposed development on the wetland, some sections may not be necessary, while additional sections may be required. The suggested report format and main section headings are listed below.

Suggested Report Format

1. **Introduction**
    a. Determine the scope of analysis applicable to the proposal using TRCA's *Wetland Water Balance Risk Evaluation* and establish the need for a continuous modelling exercise
2. **Understanding the wetland water balance based on monitored and secondary data**
    a. Analyze the monitored hydrological time series data to help answer the following questions:
        i. What are the dominant water transfer mechanisms between the wetland and its surroundings?
        ii. How long does the wetland contain standing water?
        iii. Do the maximum depth and areal coverage of surface water change from year to year?
        iv. How quickly do water levels draw down during extended dry periods?
        v. What is the wetland hydroperiod response to precipitation events?
        vi. Is the amount of surface water flowing into the wetland roughly equal to the amount flowing out?
        vii. What is the relationship between groundwater head and wetland water levels?
        viii. Is the hydraulic gradient in the wetland mostly upwards or downwards, and what is the hydraulic conductivity of the soil?
        ix. How do these observations relate to the observed distribution of wetland habitat?
    b. Identify wetland water sources
    c. Identify water transfer mechanisms
    d. Determine significant hydrological processes
3. **Developing the conceptual model**
4. **Testing and refining the conceptual model**
    a. The conceptual model should be tested using a tool that quantifies the terms of the wetland water balance
5. **Continuous hydrological model**
    a. Describe the selected software for the continuous hydrological model
    b. Provide technical justification for the suitability of the selected model or the criteria applied in selecting the model, referring to list of significant hydrological processes

  c. Model setup
     i. Data requirements (data sources, any shortcomings, any data gap filling techniques employed, etc.)
     ii. Parameterization (limitations)
     iii. Representation of the wetland in the model
  d. Model calibration
     i. Identify all parameters that were changed during calibration
     ii. Develop a table comparing all initial parameter values vs. all calibrated parameter values
     iii. Provide description and justification of calibrated values
  e. Model performance assessment
     i. Graphical
     ii. Statistical – D<15%, r^2 >0.75 and ENS >0.65 for daily values
  f. Model validation

6. **Establishing a pre-development target hydroperiod**
   a. Run a long-term analysis using forcing dataset from nearest available climate station (minimum 1991-2008)
   b. Save model output at daily timestep
7. **Unmitigated post-development scenario hydroperiod**
   a. Modify the parameters of the calibrated model to reflect post-development land use conditions and run the model using the same long-term forcing dataset (minimum 1991-2008)
   b. Save model output at daily timestep
8. **Comparison of the pre-development target hydroperiod with the unmitigated post-development hydroperiod**
   a. Comparisons should be made summarizing daily outputs at weekly, monthly, and annual intervals in a table
   b. Quantify changes in the water budget components at the same intervals
   c. Create a hydrograph for each model year showing the target (pre-development) hydroperiod, post-development hydroperiod, and the 95 percent upper and lower confidence interval boundaries of the target hydroperiod for each Julian day
   d. Assess the impacts of these changes on the wetland flora and fauna communities; an ecologist should analyze model outputs to determine potential ecological impacts
   e. If the pre-to-post development comparison shows that there will be a negative impact to the wetland, mitigation measures will be required to ensure maintenance of the pre-development wetland hydroperiod
9. **Prepare mitigation measures**
   a. Work collaboratively with an ecologist to understand the sensitivity of the wetland and to develop appropriate mitigation measures to ensure maintenance of the pre-development wetland hydroperiod
   b. Modify the parameters of the calibrated model to reflect post-development land use conditions including proposed mitigation measures and run the model using the same long-term forcing dataset (minimum 1991- 2008)

        i. Provide a description of proposed mitigation measures such as clean roof drainage collector directed to bioswales, infiltration galleries, third pipe, etc.
   c. Comparisons between the target (pre-development) hydroperiod and post-development mitigated hydroperiod should be made summarizing daily outputs at weekly, monthly, and annual intervals in a table
   d. Quantify changes in the water budget components at the same intervals
   e. Create a hydrograph for each model year showing the target (pre-development) hydroperiod, post-development hydroperiod, and the 95 percent upper and lower confidence interval boundaries of the target hydroperiod for each Julian day
   f. Discuss the comparison results, deviations from the pre-development condition, and their implications on the ability of the wetland to sustain ecological processes; check with the ecologist to ensure the mitigated hydroperiod is consistent with the wetland community
   g. Describe the design of the proposed mitigation and how it conveys water to the wetland and demonstrate event-based performance

10. **Interim mitigation plan during construction of the project**
    a. Discuss the period of construction and its potential impact on the wetland
    b. Outline interim mitigation measures and triggers for action
11. **Monitoring and adaptive management plan**
    a. Discuss the post-implementation monitoring plan and reporting
    b. Suggest methods to evaluate the effectiveness of the mitigation measures in maintaining the pre-development hydroperiod
    c. Recommend actions for cases where a deficit or excess of water is observed and what adaptive management will be required
    d. Discuss how the design of proposed mitigation measures can be modified to accommodate future adaptive management recommendations
12. **Conclusions and recommendations**
    a. Summarize original objectives of the modelling exercise and the main outcomes for each objective
    b. Summarize the results of the comparison between the pre-development hydroperiod and the post-development unmitigated hydroperiod as determined through the modelling exercise
    c. Summarize the design recommendations and supporting rationale with regard to any water balance mitigation measures that have been determined to be necessary

Appendix B: Hydrological Processes: Governing Equations, Input Data Sources, and References

B1: Precipitation

Environment Canada, conservation authorities, and local municipalities own and operate local weather stations and can provide local precipitation data for these stations. Depending on the instrumentation at a particular station as well as the availability of data summaries, precipitation data can be retrieved at yearly, monthly, daily, or hourly time intervals, and in some cases as real-time data. The proponent should investigate if precipitation values from these weather stations can be utilized for the wetland water balance analysis.

Precipitation events are recorded by gauges at specific locations. If the location of available gauges is not in close proximity with the wetland study area, then the applicant should discuss with the local conservation authority to determine if there is a need for site-specific gauging. Depending the location of the wetland in relation to the gauges' locations, examining data from a nearby representative weather station is the method that is most often used to estimate precipitation input into a wetland system. Precipitation estimates that are based on a single data point, however, may be subject to substantial error and uncertainty because of the spatial variability associated with precipitation. This may cause discrepancies between the estimated total precipitation received by the catchment and the actual amount received, as well as the timing of rainfall at a sub-daily scale. To achieve a more accurate representation of the areal precipitation distribution, data from a network of stations can be used. There are several methods available for estimating average precipitation. The three most common methods for computing average rainfall in a catchment are the arithmetic mean, the Thiessen Polygon Method, and the Isohyetal Method. The steps used to quantify the precipitation amount of the wetland water balance are outlined in Figure 6.

B2: Surface Flow

Surface water inflow to a wetland is derived from channelized streamflow, non-channelized (i.e. overland) flow, and seasonal or periodic flooding of lakes, ponds, and rivers. Surface water outflow results when the storage capacity of a depressional area such as a wetland is exceeded. Outflows from a wetland may be concentrated into a channelized watercourse or may be more diffuse. Surface water inflows and outflows vary seasonally and generally correspond to variations in precipitation and spring thaw. In wetlands where groundwater is a major source to the wetland, surface water outflow may be more evenly distributed throughout the year.

Non-channelized Surface Flows

Non-channelized surface water flows entering a wetland are difficult to quantify using on-site measurements, and so are generally estimated using simple modelling approaches. The runoff curve number (CN) method developed by the United States Department of Agriculture's Soil Conservation Service (SCS) is widely used for estimating runoff from rainfall events in small- to medium-sized watersheds under varying land use and soil types (SCS, 1972). The CN method describes the production of runoff during a rain event, considering the initial depth of rainfall that is "abstracted" as storage in soil moisture in the upper soil horizons and in surface depressions.

Once this initial abstraction depth has been exceeded, all subsequent "excess" rainfall is converted directly to runoff.

The CN value for each combination of land use, land cover, and soil type is determined using a lookup table such as Table B1. The source for all CN values used should be cited. The catchment of the wetland is divided up into as many unique combinations of land use, land cover, and soil type as may be present, and a CN value assigned to each unique combination. A single CN value is then determined based on the areally weighted average for all CN values within the wetland catchment.

The SCS CN equation is (SCS, 1972):

$$Q_{surf} = \frac{(R_{day} - I_a)^2}{(R_{day} - I_a + S)}$$

Equation B-1

$$S = 25.4\left(\frac{1000}{CN} - 10\right)$$

Equation B-2

Where:

- Q_{surf} is rainfall excess (mm),
- R_{day} is daily total rainfall(mm),
- I_a is initial abstraction (sum of surface storage, interception, and infiltration) (mm),
- CN is the curve number determined for the catchment as a whole using lookup tables and the procedure described above (unitless), and
- S is the retention or storage parameter (mm), determined using the *CN* value for the catchment as a whole. The value of S may vary spatially and over time as a function of soil moisture content. The retention parameter varies spatially due to changes in soils, land use, management and slope and temporally due to changes in soil water content.

A common approach is to approximate initial abstraction I_a as 0.2 S, which substituted into Equation B1 then becomes:

$$Q_{surf} = \frac{(R_{day} - 0.2S)^2}{(R_{day} + 0.8S)}$$

Equation B-3

The SCS CN method was originally developed for single rainfall event analysis. To adapt this method for continuous modelling, use Equation B3 to determine the minimum daily total rainfall necessary to produce runoff, then determine runoff for each day where rainfall exceeds this minimum depth.

Landuse (TRCACode)	TIMP	Cover Type	Hydrologic Soil Group			
			A	B	C	D
Cemetery	35	35% Impervious + 65% Lawns	71	81	88	90
Commercial	95	95% Impervious + 5% Lawns	98	99	99	99
Conservation Lands	0	80% Woods + 20% Meadows	38	61	74	80
Estate Residential	40	40% Impervious + 60% Lawns	74	83	89	91
Farm	0	Cultivated	66	74	82	86
Golf Course	0	Lawns	56	71	81	85
Hydro Corridor	10	10% Impervious + 90% Meadows	51	69	79	84
Industrial	95	95% Impervious + 5% Lawns	98	99	99	99
Institutional	80	80% Impervious + 20% Lawns	91	94	96	97
Open Space	0	50% Woods + 50% Meadows	41	63	75	81
Park	10	10% Impervious + 45% Woods + 45% Meadows	47	67	78	82
Recreational	20	20% Impervious + 80% Lawns	65	77	85	88
Residential High	80	80% Impervious + 20% Lawns	91	94	96	97
Residential LowMed	60	60% Impervious + 40% Lawns	82	88	92	94
Road (ROW)	90	90% Impervious + 10% Lawns	96	97	98	99
Rural Residential	20	20% Impervious + 80% Lawns	65	77	85	88
Transportation	60	60% Impervious + 40% Lawns	82	88	92	94
Water	100	Impervious	100	100	100	100
Natural	0	50% Woods + 50% Meadows	41	63	75	81

Table B1: Updated lookup table for Curve Number (CN) based on total imperviousness

Channelized Surface Flows

All wetlands will receive some non-channelized surface water input, but some wetlands may receive equivalent or greater volumes of water from channelized flow as well. To quantify channelized surface water flows, direct on-site measurements made using weirs, flumes, and stage-gauging techniques are the preferred source of data. TRCA's *Wetland Water Balance Monitoring Protocol* (2016) outlines basic procedures for estimate channelized flow at concentrated inflow or outflow locations. Accurate on-site measurements are invaluable as input data for water balance analysis. If the wetland is on a higher order stream, it may be prudent to see if Environment Canada or the local conservation authority operates a stream gauge nearby. Techniques exist for transferring flow data from a watercourse in one basin to another nearby basin with similar characteristics; however, caution should be used before applying these techniques to ensure all underlying assumptions are met.

If direct discharge measurements are not available the next best option is to approximate channelized flows based on the shape of the inflow and/or outflow channel using the continuity equation:

$$Q = VA$$

Equation B-4

Where:

- Q is discharge (m^3/s)
- V is velocity (m/s)

- A is cross-sectional area of flow (m²).

To calculate the velocity term, Manning's equation can be used:

$$V = \left(\frac{1}{n}\right) R^{2/3} S^{1/2}$$

Equation B-5

Where:

- V is velocity (m/s);
- n is Manning's roughness coefficient, based on lookup table;
- R is hydraulic radius(m), equivalent to the cross-sectional area of flow (A) divided by the wetted perimeter (W_p) such that $R = A/W_p$; and
- S is slope (m/m).

Manning's roughness coefficient values based on the type of material lining the channel are listed in Table B2.

The steps used to quantify the surface water portion of a wetland water budget are outlined in Figure 8. An adequate assessment of surface water inputs is important for all wetlands, but for riverine and other surface-water-driven wetlands it is critical. Contribution of non-channelized and channelized flow must be quantified for all sites. The sum of channelized and non-channelized flow values constitutes the overall surface water input to the wetland system. Daily and monthly surface-water flow values should be calculated for representative wet, dry, and average years, expressed in units of depth per unit time and plotted along with the other components of the water budget.

Some continuous hydrological models may have routines that use alternative methods for simulating surface water inputs from the catchment area. All methods and assumptions used in the calculation of the surface water component of the water budget should be listed in the relevant section of the report.

Surface Material	Manning's Roughness Coefficient (*n*)	Surface Material	Manning's Roughness Coefficient (*n*)
Asbestos cement	0.011	Glass	0.010
Asphalt	0.016	Gravel, firm	0.023
Brass	0.011	Lead	0.011
Brick	0.015	Masonry	0.025
Canvas	0.012	Metal, corrugated	0.022
Cast-iron, new	0.012	Natural streams – clean & straight	0.030
Clay tile	0.014	Natural streams – major river	0.035
Concrete – steel forms	0.011	Natural streams – sluggish, deep pools	0.040
Concrete (cement) – finished	0.012	Natural channels – very poor condition	0.060
Concrete – wooden forms	0.015	Plastic	0.009
Concrete – centrifugally spun	0.013	Polyethylene PE – corrugated with smooth inner walls	0.009 - 0.015
Copper	0.011	Polyethylene PE – corrugated inner walls	0.018 - 0.025
Corrugated metal	0.022	PVC – smooth inner walls	0.009 - 0.011
Earth, smooth	0.018	Rubble masonry	0.017
Earth channel – clean	0.022	Steel – Coal-tar enamel	0.010
Earth channel – gravelly	0.025	Steel – smooth	0.012
Earth channel – weedy	0.030	Steel – new, unlined	0.011
Earth channel – stony, cobbles	0.035	Steep – riveted	0.019
Floodplains – pasture, farmland	0.035	Vitrified sewer	0.013 - 0.015
Floodplains – light brush	0.050	Wood – planed	0.012
Floodplains – heavy brush	0.075	Wood – unplaned	0.013
Floodplains – trees	0.150	Wood stove pipe, small diameter	0.011 - 0.012
Galvanized iron	0.016	Wood stove pipe, small diameter	0.012 - 0.013

Table B24: Manning's Roughness Coefficient Values

B3: Evapotranspiration

Evapotranspiration (ET) is one of the most challenging components of a wetland water budget to estimate because of its high variability in time and space and the complexity of monitoring atmospheric water vapour fluxes. ET varies according to both meteorological variables as well as phases of vegetation growth. While the Penman-Montieth method (Monteith, 1965) is often considered the most accurate available empirical method, it requires a number of parameters that may be difficult and/or expensive to measure. For this reason, other estimation methods for ET, requiring a reduced set of input parameters, are more commonly used.

The steps involved in quantifying the ET portion of a wetland water budget are shown in Figure 9. A good first step for any modelling study is to determine the availability of meteorological data in proximity to the study site for the period of interest, and then to determine the necessity of collecting any additional required input data at the study site in order to apply the desired ET estimation method.

Direct Measurement Techniques

An evaporation pan is one example of a direct measurement technique to estimate evapotranspiration. The evaporative water loss from a standard class “A” pan is determined by measuring the decrease in water level or mass over time, or the volume or mass required to maintain a specified water level in the pan. A monthly variable crop coefficient (k) is generally used to convert pan evaporation (E_{pan}) into potential ET (PET) such that PET = $k \cdot E_{pan}$ (Mao *et al.*, 2002). If using a pan evaporation approach, it is important to use local crop coefficients that account for local climate conditions. Conservation authorities and universities can provide appropriate local crop coefficients. The calculated PET is the subtracted from available water held in storage on the surface and in soils at each calculation timestep.

Thornthwaite Method

The Thornthwaite method (Thornthwaite, 1948) calculates PET at monthly resolution using only monthly temperature as an input:

$$PET = 16 * \left(\frac{10 \cdot Ti}{I}\right)^{a} \left(\frac{N}{12}\right)\left(\frac{d}{30}\right)$$

Equation B-6

$$I = \sum_{i=1}^{12} \left(\frac{Ti}{5}\right)^{1.514}$$

Equation B-7

$$a = (492390 + (17920 \cdot I) - (771 \cdot I^2) + (0.675 \cdot I^3)) * 10^{-6}$$

Equation B-8

Where:

- PET is monthly potential evapotranspiration (mm/month)
- T_i is monthly average temperature (°C)
- N is the number of monthly daylight hours for a given latitude, from a lookup table (Thornthwaite, 1948)

- d is the number of days in the given month
- I is the annual heat index for the given year (Equation B6)
- a is a function of I (Equation B7)

While the Thornthwaite method is useful for estimating PET as part of a conceptual water balance model or coarse scale exercise, its monthly output resolution means it may not be appropriate for continuous modelling exercises. Locally calibrated monthly adjustment coefficients to further refine PET estimates from the Thornthwaite method are available (see Metcalfe *et al.,* 2019) and generally show the method to underestimate PET in the spring and fall while slightly overestimating PET in the summer. For any month where T_i is ≤0, estimated PET will be zero.

Hargreaves / Hargreaves-Samani Method

The method of Hargreaves *et al.* (1985), sometimes referred to as the "Hargreaves-Samani 1982" method, is also widely applied because it requires as input only the daily maximum and minimum air temperature. The radiation term does not require site-scale data but rather is calculated for a given latitude and day of year using solar radiation theory (see for example Allen *et al.,* 1998). The equation is given as:

$$\lambda(PET) = 0.0023(T_m + 17.8)\left(\sqrt{T_{max} - T_{min}}\right)R_a$$

Equation B-9

Where:
- λ is the latent heat of vapouration (J/kg)
- PET is daily potential evapotranspiration (mm/day)
- T_m is daily mean air temperature (°C),
- T_{max} is daily maximum air temperature (°C),
- T_{min} is daily minimum air temperature (°C), and
- R_a is extraterrestrial radiation (MJ m^{-2} day^{-1}).

Metcalfe *et al.* (2019) recommend replacing the coefficient of 0.0023 with a monthly variable coefficient calibrated to regional climate conditions. For example, for southwestern Ontario, the locally-calibrated coefficients range from a high of 0.0025 in April to a low of 0.0020 over June through September (Metcalfe *et al.*, 2019).

Makkink Method

The Makkink (1957) method was developed for use in the Netherlands and has been found by TRCA staff to perform well in the Toronto region. The method requires incoming solar radiation at the site or regional scale as well as air temperature as inputs, and can be calculated at variable timesteps:

$$\lambda(PET) = 0.61\, R_s \frac{\Delta}{\Delta + \gamma} - 0.12$$

Equation B-10

Where:
- PET is potential evapotranspiration (mm),
- Δ is the slope of the saturation vapour pressure vs. temperature curve (kPa/K) for the average air temperature over each time interval,

- R_s is incoming solar radiation (W/m^2),
- Υ is the Psychrometric Constant (kPa/K), and
- 0.61 and 0.12 are empirical fitting parameters

Turc Method

The Turc (1961) method was developed for western Europe and requires the same inputs as the Makkink (1957) method, as well as a correction factor for when relative humidity is <50%. TRCA staff have found that this method performs well in the Toronto region.

$$\lambda(PET) = 0.013\, C_{RH} \frac{T}{T + 15} (R_s + 50)$$

Equation B-11

Where:

- PET is daily potential evapotranspiration (mm),
- C_{RH} is an adjustment factor for relative humidity, equal to 1 when RH≥50% and to (1+((50-RH)/70)) when RH<50%, where RH is relative humidity expressed in percent,
- T is daily average air temperature (°C), and
- 0.013 and 50 are empirical fitting parameters

For any day where T is ≤0, estimated PET will be zero.

Priestley Taylor Method

The Priestley-Taylor (1972) method was developed as a simplified form of the Penman-Montieth equation. While it has ben applied in a variety of different settings, it requires site-scale data or appropriate downscaling techniques for the net radiation, ground heat flux, and alpha terms, and as such may be challenging to apply in the absence of site-scale data.

$$\lambda(PET) = \alpha \frac{\Delta}{\Delta + \gamma} (R - G)$$

Equation B-12

Where:

- *PET* is potential evapotranspiration (mm),
- α is an empirical coefficient that varies based on land cover and regional climate, generally set to a default value of 1.26,
- *R* is net radiation (W/m^2), and
- G is ground heat flux, (W/m^2; positive in the downwards direction).

Penman-Monteith Method

The Penman-Monteith (Monteith, 1965) method was developed as a modification of Penman's formula for evaporation from open water surfaces to account for the atmospheric resistance of the vegetation canopy. It considers all major factors contributing to PET, meaning that it is appropriate for use without calibration to local conditions but is also very data intensive.

$$\lambda(PET) = \frac{\Delta(R - G) + \rho_a c_p \frac{(e_s - e)}{r_a}}{\Delta + \gamma\left(1 + \frac{r_s}{r_a}\right)}$$

Equation B-13

Where:

- r_a is aerodynamic resistance (s/m)
- r_s is stomatal or canopy resistance (s/m)
- e is the vapour pressure (kPa)
- e_s is the saturated vapour pressure (kPa)
- ρ_a is the density of air (g/m³)
- c_p is the specific heat capacity of air (≈1.004 J/g/K)

B4: Groundwater Flow

Groundwater is taken to be all subsurface water in the saturated zone below the water table. Although the cost and complexity of subsurface investigations makes accurate quantification challenging, some assessment of the groundwater flux is critical to assessing the water balance of a wetland. TRCA advises applicants to begin with obtaining historical groundwater information in the vicinity of the subject wetland. The Ontario Ministry of Environment, Conservation, and Parks (MECP) well records database and the Oak Ridges Moraine Groundwater Program database are good starting places to help determine the amount and types of data that need to be collected on-site to fully understand groundwater fluctuations and groundwater movement between the wetland and the surrounding area. Because the groundwater environment is hidden from view and can vary dramatically over short distances, it is essential to collect data on-site in order to ascertain local hydrogeologic conditions. Drive point piezometers can be a relatively inexpensive way to assess the subsurface environment of wetlands, for example by determining the presence or absence of vertical hydraulic gradients within the study wetland. Once on-site data have been collected using the *Wetland Water Balance Monitoring Protocol* (TRCA, 2016), the following calculations and models can be used to estimate ground-water inputs to and outputs from the wetland system.

Darcy's Law describes the movement of water through a porous medium from areas of high pressure to low pressure, with the rate of flow being proportional to the difference in hydraulic head between two points and inversely proportional to the length of flow path between two points (Fetter, 2001):

$$Q = KA\left(\frac{\Delta \mathrm{h}}{\mathrm{L}}\right)$$

Equation B-14

Where:

- Q is volumetric discharge (L^3/T; m^3/d),
- K is hydraulic conductivity (L/T; m/d), a proportionality constant,
- A is the cross-sectional area of flow (L^2; m^2),
- L is the flow length (L; m), and
- Δh is the difference in hydraulic head along the flow length L

Using this equation, the rate of flow of ground water into or out of a wetland can be estimated from measurements made on-site, because a number of the above parameters can be measured in the field following installation of wells. The difference in hydraulic head, Δh, can be determined from water-level measurements made in two different wells, where L represents the distance between the wells. The cross-sectional area, A, is calculated as the confined aquifer's saturated thickness, multiplied by the aquifer width. The hydraulic conductivity, K, must be estimated using either on-site tests (e.g. slug tests or bail tests, such as the Hvorslev (1951) method) or existing information about the hydrogeological properties of geological strata. . Note that the hydraulic conductivity is typically greater in the horizontal direction than in the vertical direction as a consequence of bedding planes, laminae, and other sedimentary structures. This information can then be used to estimate the rate and quantity of ground-water inflow to and outflow from a wetland.

A form of Darcy's Law that is used to quantify flow through unconfined aquifers is Dupuit's Equation (Fetter, 2001):

$$q' = \frac{1}{2}K\left(\frac{h_1^2 - h_2^2}{L}\right)$$

Equation B-15

Where:

- q' is flow per unit width (L^2/T; m^2/d)
- K is hydraulic conductivity (L/T; m/d)
- h_1 is head at the origin (L; m)
- h_2 is head at flow length (L; m)
- L is flow length (L; m).

For more complex wetlands, an analytical solution using Darcy's Law may not be practical and not all bedrock-dominated flow systems can be characterized using Darcy's Law. Under these circumstances, a numerical groundwater flow model can be used to simulate groundwater flow. Numerical groundwater flow models are mathematical representation of an actual groundwater system that can be used to predict water levels as well as the direction and magnitude of flow. Models range from simple to very complex in terms of data input requirements, calibration requirements, and data output. An internally drained wetland where the outflows from the wetland are only in the form of groundwater outflow and evapotranspiration will almost certainly require a complex numerical groundwater flow model to accurately estimate the groundwater flow exchange between the wetland and the surrounding areas. The applicant should consult with the local Conservation Authority to determine if there any existing calibrated numerical ground-water flow models in the vicinity of the study site.

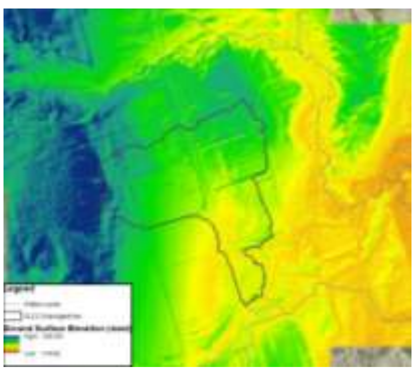
The steps used to quantify the groundwater portion of a wetland water budget are outlined in Figure 10. In summary, historical data should be evaluated to identify data gaps and determine the data needs for feature-based water balance analysis. Historical groundwater data also may be used to generate a long term record from shorter-term measurements and to determine representative wet, dry, and average conditions. Available data on the site's topography, soil type, surficial geology, and hydrography should be examined to determine the number of sections of groundwater flow at a site.

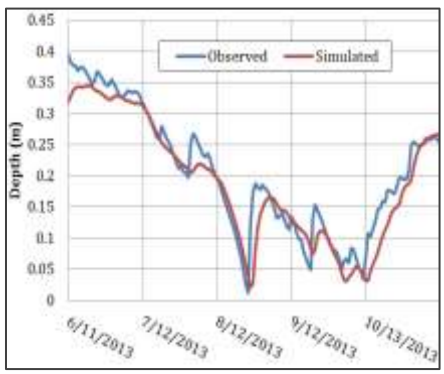
Wells must be installed to adequately characterize water table fluctuations and groundwater movement across the site, both vertically and horizontally. The hydraulic conductivity of both aquifers and aquitards also must be determined from soil borings, wells, infiltrometers, permeameters, and/or aquifer tests. The monitored data should be used to calculate groundwater flow using Darcy's Law and/or outputs from numerical ground-water flow models (e.g. MODFLOW). The results of the analysis can be used to determine groundwater inputs to and outputs from the wetland system. Daily and monthly groundwater flux values can then be tabulated and graphed for the monitoring time period.

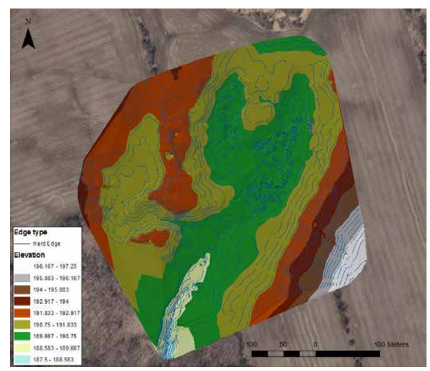
Wetland Water Balance Modelling Case Studies

(Appendix to TRCA Wetland Water Balance Modelling Guidance Document)

July 2018







Toronto and Region Conservation Authority

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1.0 Introduction

1.1 Purpose and Scope

Continuous hydrological models are a key tool for predicting the impact of land development and infrastructure construction on the hydrology of wetlands and other natural features. Models can also be used in the design of stormwater management facilities to offset such impacts, where mitigation is deemed necessary. Determining the appropriate model to simulate wetland hydrology can be challenging, as there are many factors to consider: the hydrological processes operating at a particular wetland, the representation of these processes in the model as they relate to wetland storage dynamics, the representation of stormwater management and low impact development (LID) facilities, and the personal preferences and abilities of the modeler in question, to name just a few. This appendix is intended to be a resource for modelers to help them make more informed decisions in modelling wetland water balance scenarios.

This appendix provides a series of case studies illustrating the set-up, calibration, and validation process for five commonly used continuous hydrology models (HEC-HMS, HSPF, MIKE SHE, Visual Otthymo, and SWMM). The calibrated and validated models are then used to explore the effects of different development scenarios to predict the change in wetland storage relative to the baseline condition, both with and without hypothetical mitigation measures. The modelling case studies shown here were produced by TRCA staff and external contributors from the University of Guelph and Civica Infrastructure. All the examples shown are based on two wetland sites located in central Pickering Township, where monitoring data was collected by TRCA starting in 2013 in anticipation of eventual development of the catchment areas. Additional data on the wetland catchment and basin were compiled for these two sites to inform the modelling exercise. The development scenarios and proposed mitigation measures were hypothetical, as plans for the development of areas surrounding the two wetlands were not sufficiently advanced at the time of writing, but the scenarios are based on realistic assumptions about development form and layout that draw on the experience of professional water resource engineers.

This appendix is intended to be used as a resource for modelers to consult for applications requiring a wetland water balance. It is not intended to definitively outline best practices for modelling, but rather to provide examples of considerations for the application of the five continuous hydrology models shown here, including data requirements, model complexity or simplicity, calibration and validation procedures, representation of different hydrological processes, and so on.

2.0 Common Data Sources

2.1 Aerial Photography

Recent aerial photographs can provide useful information about the land use context in the vicinity of the wetland and can be used to help classify different land cover types for the purposes of subdividing and/or parameterizing the wetland catchment. Some municipalities may be able to provide data free of charge, whereas others may not. TRCA cannot provide aerial photography data to proponents at present. Data can also be purchased from other sources (e.g. First Base Solutions).

2.2 Topography & Bathymetry

Topography data is essential in the delineation of wetland catchments and in understanding how water is stored in and released from the wetland. A minimum vertical resolution of 25 cm is recommended for the area contributing drainage to the wetland. Within the wetland pool itself, a higher vertical resolution is required because wetlands often occur in broad, flat areas, where there can be dramatic differences in the area of ponded water with relatively small changes in stage. Similarly, where surficial outflow channels are poorly defined, the stage-discharge curves must be very precise in order to define the elevation at which a wetland begins to discharge. For these reasons, a vertical resolution of 5 cm is recommended for the area of the wetland that might contain standing water at any point during the year. Where there is standing water at the time of topographic data collection, it may be necessary to collect bathymetry data to better constrain wetland storage volumes. High resolution (e.g. LiDAR-derived) topographic data exists for the entire TRCA jurisdiction and can be purchased from private vendors.

2.3 Wetland Pool Rating Curves

For the reasons cited above, realistic and accurate simulation of wetland storage dynamics requires precise topography and bathymetry data within the wetland pool. The elevation at which wetland pools begin to discharge is a key variable to inform development of wetland pool rating curves. As these rating curves can change dramatically over a small elevation range where outlets are less well defined, a vertical resolution of 5 cm is recommended. Some hydrodynamic models (e.g. MIKE-11) also have hydrodynamic routines to determine inflow and outflow condition dynamics and the inundation process of the wetland; these may be accepted in lieu of rating curves where model capabilities allow.

Some wetlands may consist of multiple pool areas that may be connected by overland flow or channelized flow, particularly for larger wetlands. Representation of these wetlands as a single storage unit with one associated rating curve or as separate units is a decision that will depend on expert opinion and the capabilities of the model(s) under consideration.

2.4 Catchment Delineation

Delineation of the wetland catchment should be completed using the highest resolution digital elevation model available. In most cases, software packages (e.g. ArcHydro) will offer the highest degree of precision in delineating the wetland catchment. However, it may be appropriate in some cases to manually correct delineated catchments to reflect the influence of subsurface or concealed drainage features (e.g. culverts, tile drains) on the wetland's contributing drainage area.

2.5 Land Use

Land use data is important for catchment parameterization, and is available from a variety of sources. Land Information Ontario offers a wide variety of classified land use layers for purchase. Municipalities and conservation authorities may also offer land use datasets free of charge or for a nominal data service fee. Aerial photographs may also be used to manually classify land use.

2.6 Soils

The surficial soils within the catchment, in combination with the topography, control to a large extent the catchment's hydrological response, and are often used in combination with land use data to determine catchment parameters and/or delineate hydrologic response units. As regional-scale datasets (e.g. Ontario Ministry of Agriculture and Rural Affairs soil atlas) generally offer little detail at the site scale, local geotechnical investigations or the finest resolution surficial sediment mapping data available are always preferred.

2.7 Monitored Well Data

Monitoring well data can be used to estimate the potential degree of groundwater interaction at the wetland in question. Some models require groundwater timeseries data to calibrate an aquifer component or the groundwater component of an integrated groundwater-surface water model. The Ontario Ministry of the Environment collects data through the Provincial Groundwater Monitoring Network. The Oak Ridges Moraine Groundwater Program (https://oakridgeswater.ca/) provides groundwater data on a subscription basis, with data coverage across south central Ontario. Municipalities and conservation authorities often have groundwater monitoring networks and may be able to provide data.

2.8 Meteorological Data

Environment Canada maintains a data portal with current and historical meteorological records varying in temporal resolution from daily to 5-minute intervals. Conservation authorities and municipalities may also have precipitation gauges and meteorological stations. It is always preferable to use multiple meteorological stations to interpolate precipitation and other forcing variables between stations, rather than simply using the closest station available, to increase model accuracy.

3.0 Continuous Hydrologic Models

3.1 Hydrologic Modelling System (HEC-HMS)

3.1.1 HEC-HMS: Background

The US Army Corps of Engineers (USACE) Hydrologic Engineering Centre Hydrologic Modelling System (HEC-HMS) model is designed to simulate the complete hydrologic processes of watershed systems. HEC-HMS is comprised of a graphical user interface, integrated hydrologic analysis components, data storage and management capabilities, and graphics and reporting facilities. HEC-HMS is flexible in that there are many different methods available to calculate the losses, runoff transform, baseflow, routing, and reservoirs, each of which can be selected separately. The soil moisture accounting (SMA) loss method in conjunction with potential evapotranspiration data and snowmelt routines is ideal for conducting continuous simulations. The SMA model is patterned after Leavesley's Precipitation-Runoff Modelling System (1983) and is described in detail in Bennett (1998). **Figure 1** presents a conceptual model schematic for the continuous soil moisture accounting algorithm.

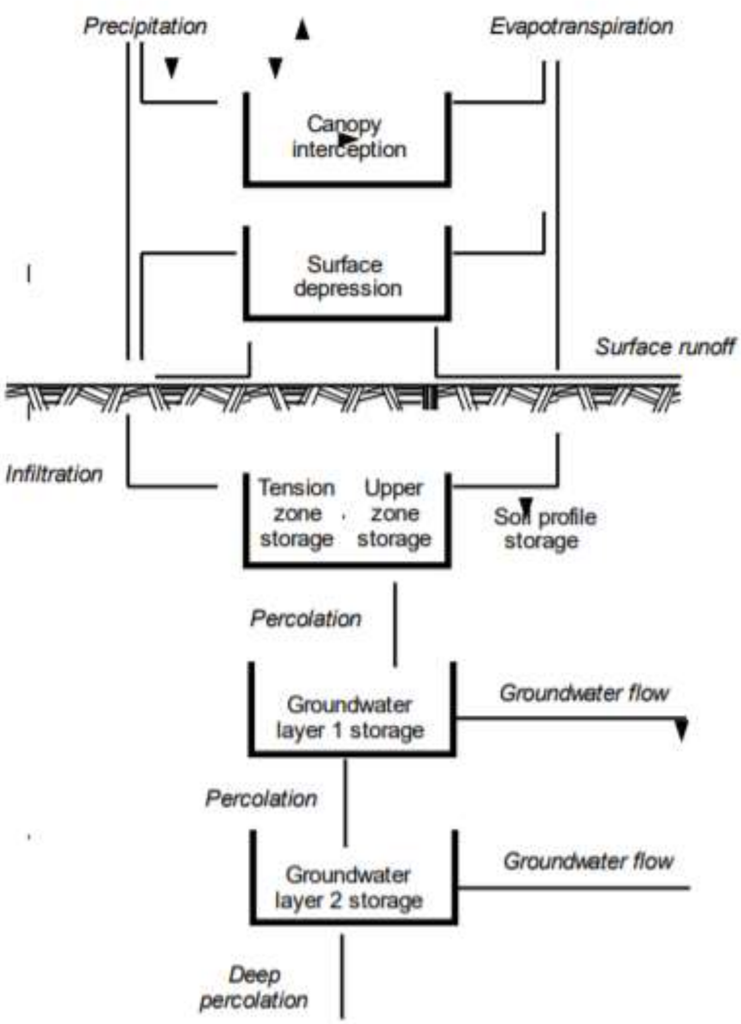

Figure 1: Conceptual schematic of the continuous soil moisture accounting algorithm (Bennett, 1998)

3.1.2 HEC-HMS: Model Setup, Existing Conditions

The case study area used for evaluation is a wetland at Seaton Sideline 26, which is located in the City of Pickering within the Duffins Creek Watershed. **Figure 2** shows the wetland and drainage areas, which were delineated using a 1m by 1m bare earth grid that was generated using LiDAR data from 2014. The wetland is divided into two pools. 2.05 hectares drain to the west pool of the wetland. The west pool drains overland to the east pool. The east pool receives runoff from an additional 7.31 hectares of land, for a total drainage area of 9.36 hectares.

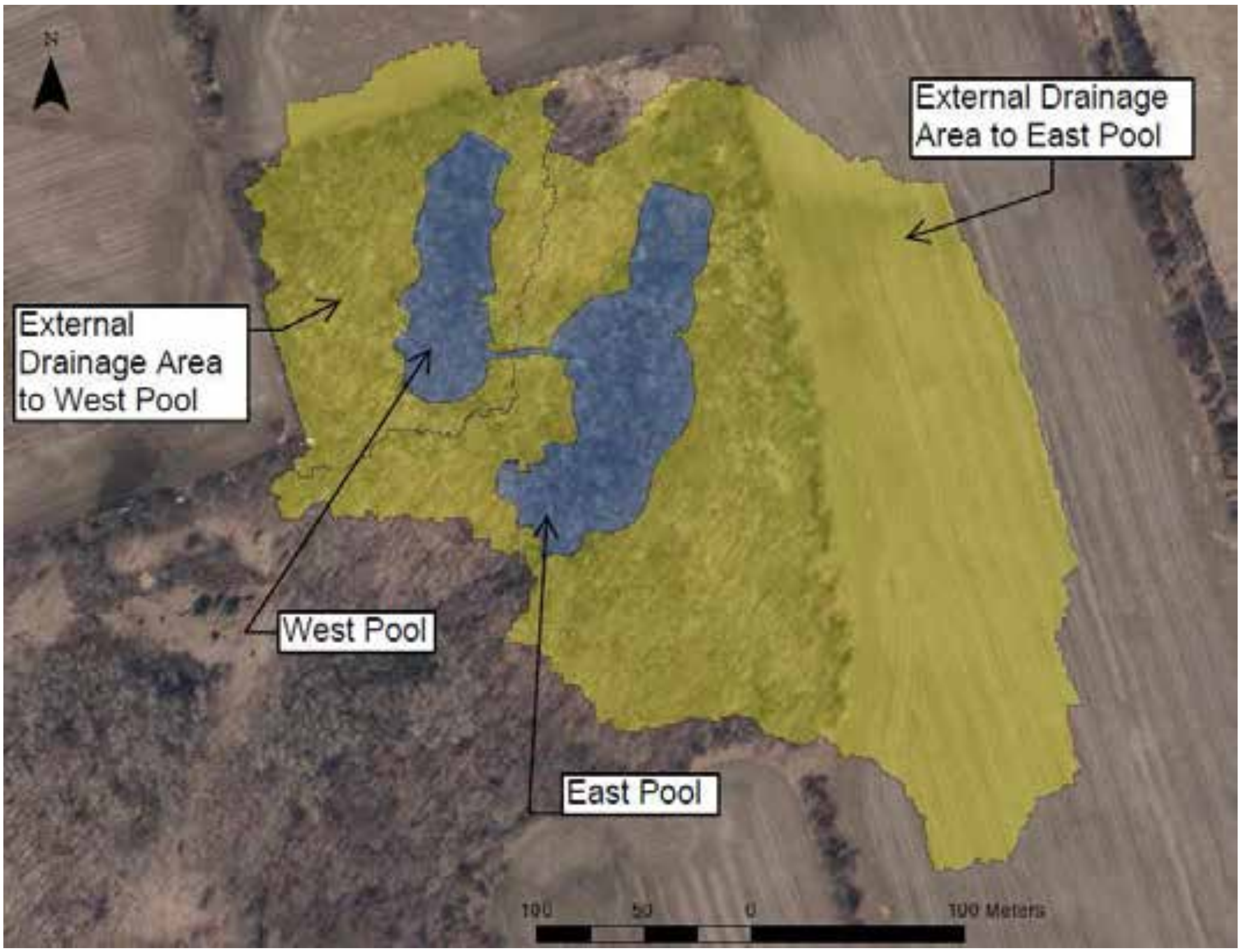

Figure 2: Sideline 26 Wetland Drainage Areas

Figure 3 shows the land use within the wetland drainage area, which includes farmland, forest, successional, and wetland. The parameters for each subbasin were lumped based on the area-weighted parameters of each of the four land use categories.

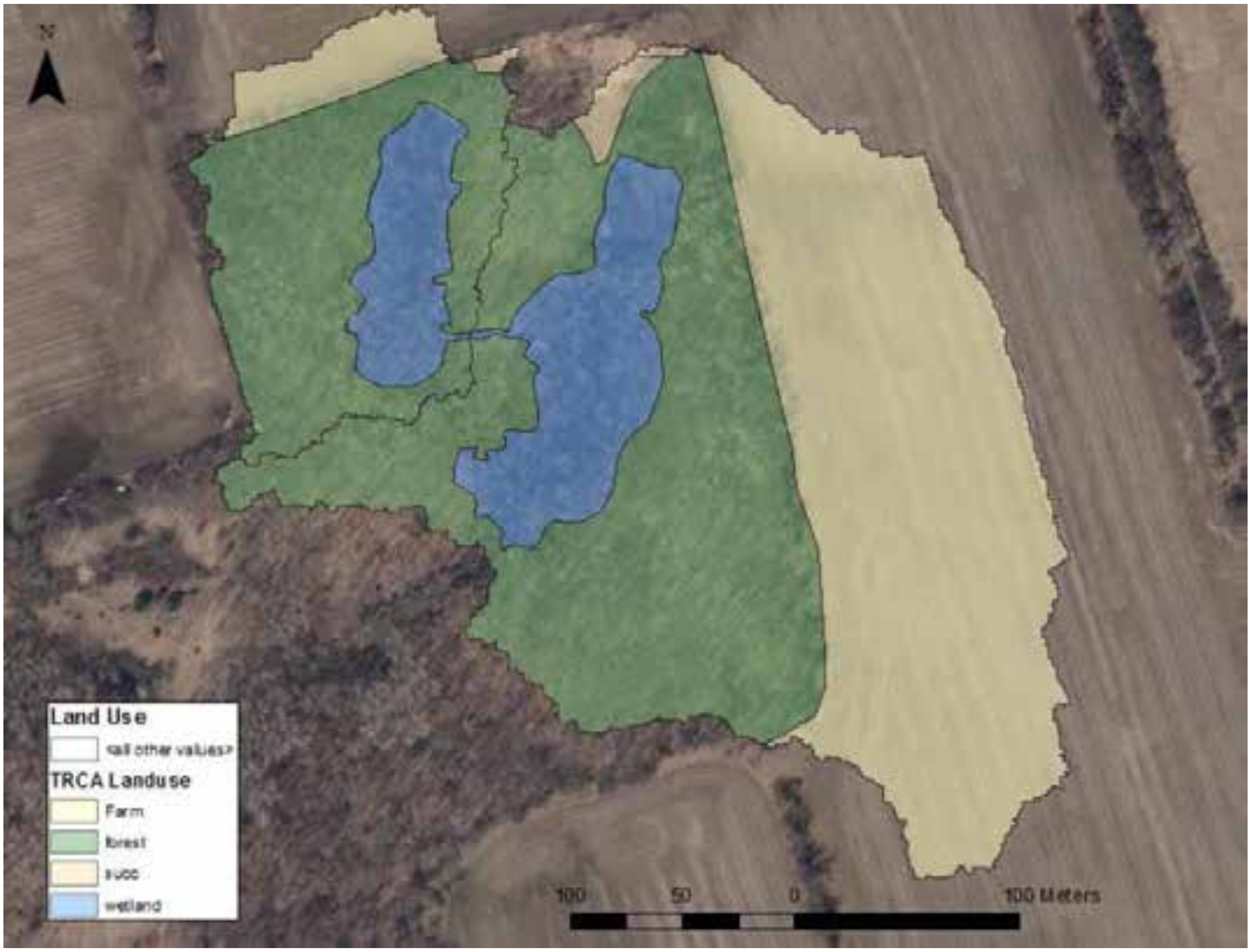

Figure 3: Sideline 26 Wetland Land Use

The soil classification for the entire drainage area to the wetland is a Gleyed Gray Brown Luvisol. A soil description from Agriculture and Agri-Food Canada was used to generate initial parameters for the maximum infiltration, soil storage, tension storage, soil percolation, groundwater percolation, and groundwater storage parameters.

Figure 4 shows the topography and bathymetry of the wetland, which was generated from a site survey. The elevation information was used to create detailed stage-storage relationships for each of the two major wetland pools. In order to estimate the discharge at each stage, the wetland was modeled in HEC-RAS as two storage areas connected by a broad-crested weir, and discharging over a second broad-crested weir to the downstream channel. Cross-sections were cut at the outlet of each pool using the elevation information, and the cross-section information was used for the weir geometry. An unsteady simulation was performed, with flow rates gradually ramped up from a low flow to a high flow, in order to ensure that the results would have a good spread of stage-discharge information. Equations were fit to the resulting rating curves, so that discharge values could be calculated at each known elevation and storage for each pool. The resulting stage-storage-discharge information was used in two separate reservoir commands which represent the surface storage at the west pool and the east pool of the wetland. The exact elevation at which each pool begins to discharge, as well as the discharge estimates closest to these elevations were treated as a calibration parameters. The outflow structures reservoir method was used in order to account for percolation from the wetland. A depth-surface area relationship for each pool was also required in order to account for the monthly evaporation from the wetland.

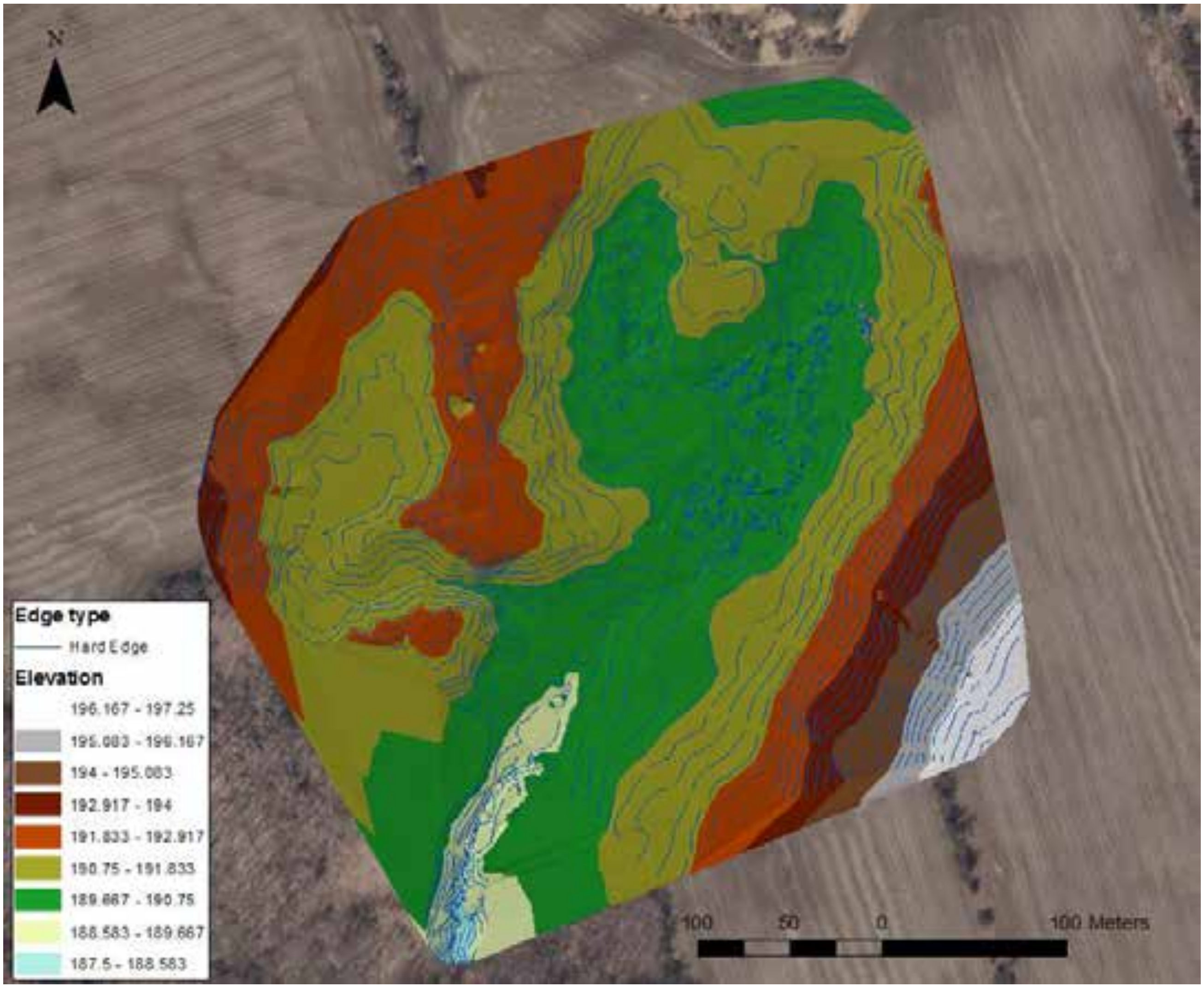

Figure 4: Sideline 26 Wetland Topography and Bathymetry

3.1.3 HEC-HMS: Calibration, Existing Conditions

Figure 5 shows the location of monitoring stations at Sideline 26. There were a set of three wells at four main locations in the wetland, each with a 30cm long screen. One well (SW well) had a screen from +0.05 to -0.25m relative to the surface, another well (1m well) had a screen from -0.7m to -1m relative to the surface, and the third well (2m well) had a screen from -1.7m to -2.0m relative to the surface. The SW well at *Transect 1 - 40m* was used to calibrate the west pool, and the SW well at *Transect 2 – 40* was used to calibrate the east pool. The water levels in the wetland were used for calibration instead of discharge for two main reasons. Firstly, the flume downstream of the wetland became blocked and was circumvented by flow, so there was not enough confidence in the monitored data to use it for calibration. Secondly, the water level in each pool is a variable that can be directly and easily used to assess impact on the ecological functioning of the wetland. Differences in observed water levels between the SW, 1m, and 2m wells were used to gain an understanding of the vertical hydraulic gradients for the monitored periods, and differences in observed water levels at the 1m wells between stations were used to gain an understanding of the horizontal hydraulic gradients for the monitored periods. These values were used to calculate time-series of percolation values from the reservoir commands that represent the wetland pools.

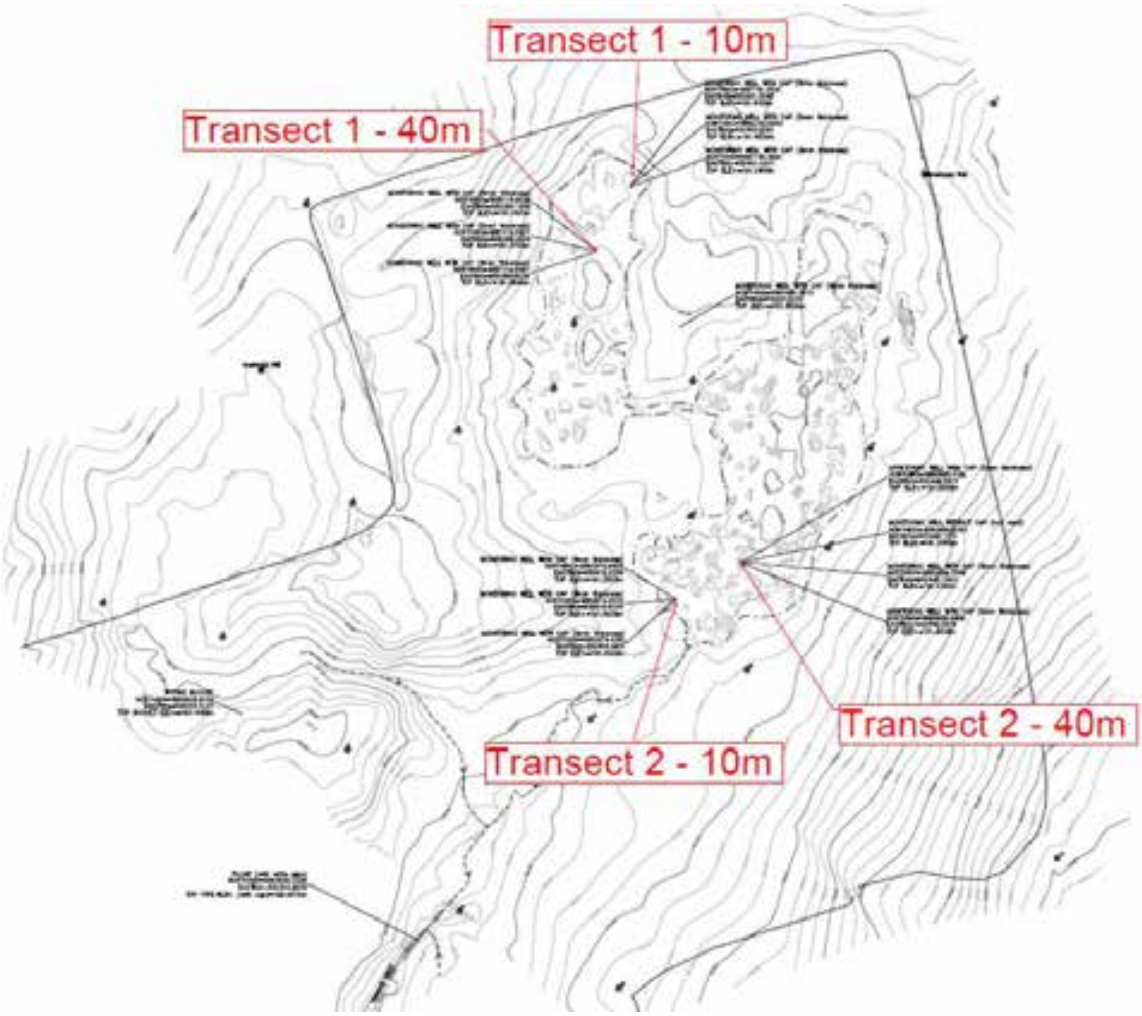

Figure 5: Sideline 26 Monitoring Stations

Observed data for 2013 was used to calibrate the model. The water level observations were recorded hourly, and converted to a daily average for the purpose of calibration. The model was run with an hourly time step, and daily average output was used for comparison with observed data.

After achieving a reasonable visual match, the procedure was repeated twice using data from 2014 and 2015 in order to validate the calibration. The initial model calibrations did not produce simulation results that closely matched observed data for the validation years, so the calibration process was iterated until all three years showed reasonable results.

Table 1 shows the main parameters that were modified from initial parameters during the calibration and validation process.

3.1.4 HEC-HMS: Validation, Existing Conditions

Table 1: HEC-HMS calibration parameters

Parameter	Units	Initial Value	Calibrated Value
Canopy: Max Storage	mm	1 to 2.7	1.03 to 1.2
SMA Loss: Max Infiltration	mm/hr	3 to 15	7
SMA Loss: Soil Storage	mm	121.75	153.2
Tension Storage	mm	39	39
Modeled stage-discharge curve for west pool	n/a	as modeled	elevation of first discharge and low flow discharge values were modified during calibration
Modeled stage-discharge curve for east pool			
Additional outlet for west pool percolation	m^3/s	0	1E-05 to 3E-05
Additional outlet for east pool percolation		0	1E-05 to 1.2E-04

After a reasonable visual match with all three years of data was achieved, three statistical measures were used to compare the goodness of fit between observed and simulated water level: Percent Difference (%D), coefficient of determination (R^2), and Nash-Sutcliffe simulation efficiency (E_{NS}).

Figures 6 through 11 show the calibration and validation results for the two wetland pools.

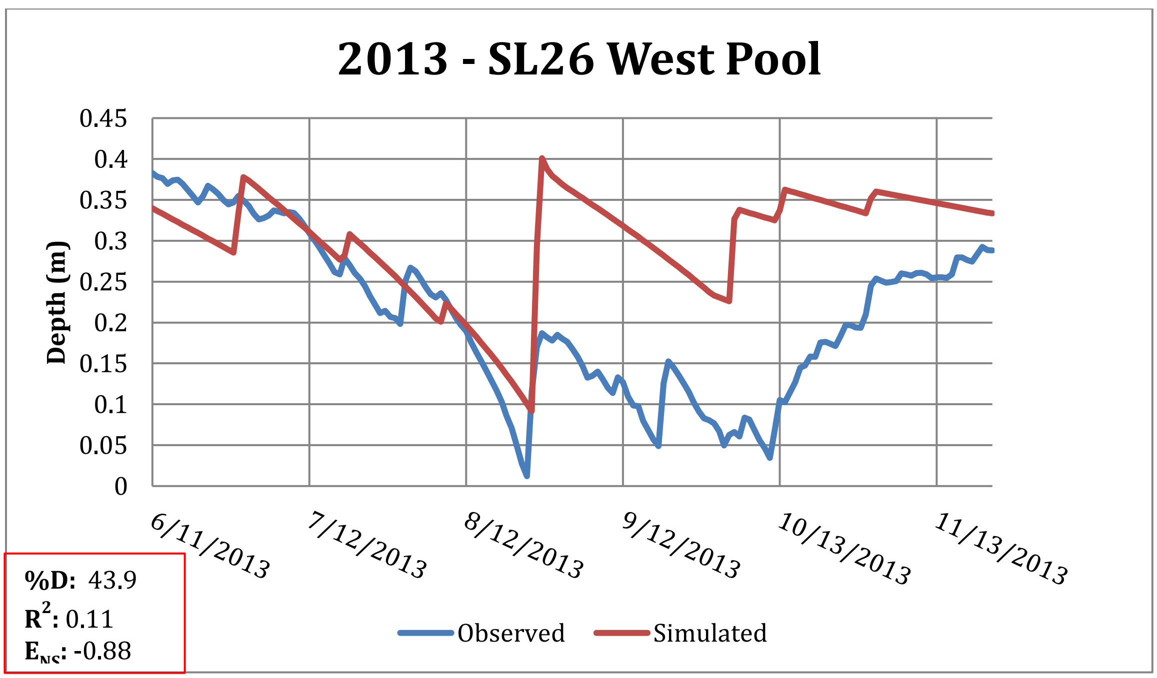

Figure 6: Sideline 26 West Pool Calibration with 2013 data

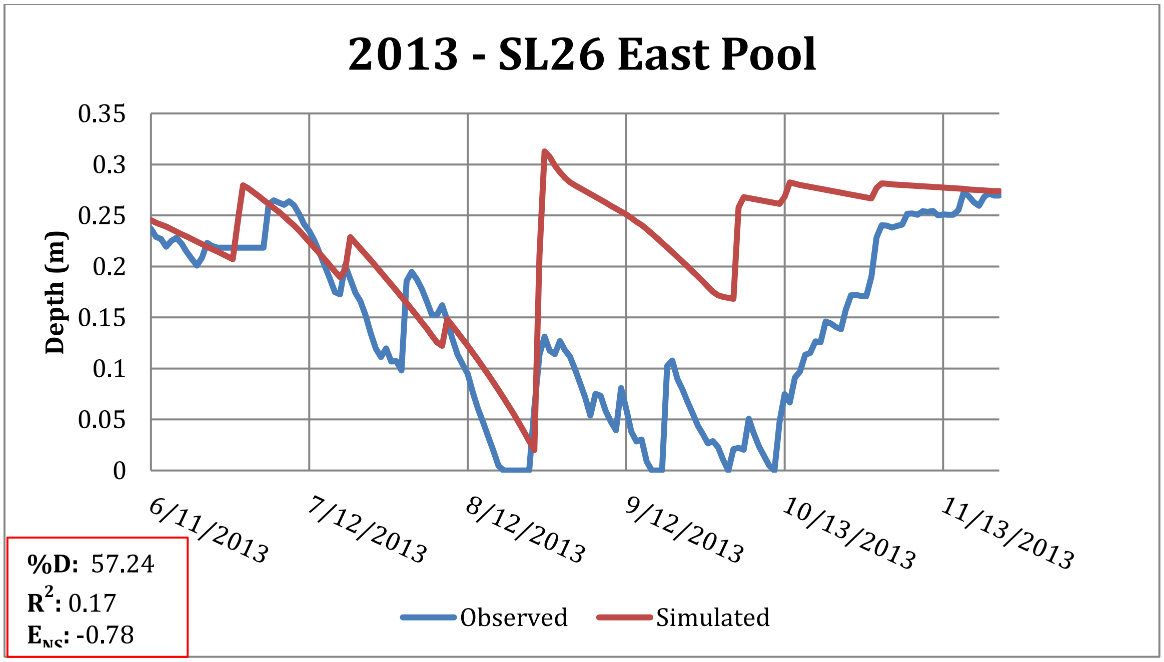

Figure 7: Sideline 26 East Pool Calibration with 2013 data

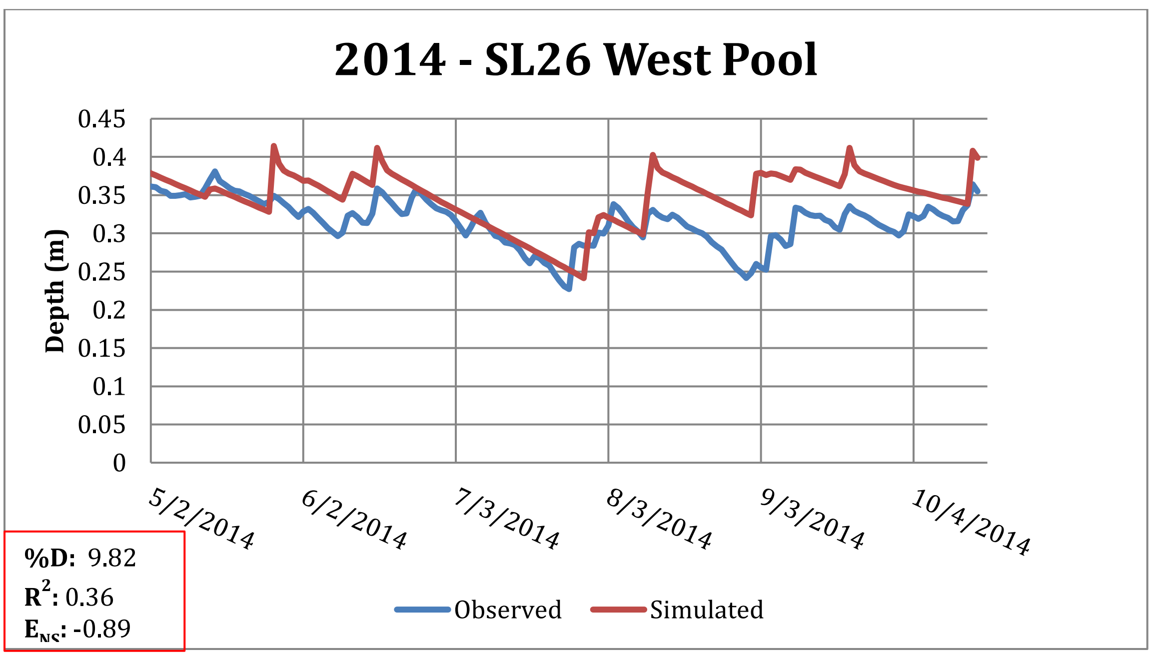

Figure 8: Sideline 26 West Pool Validation with 2014 data

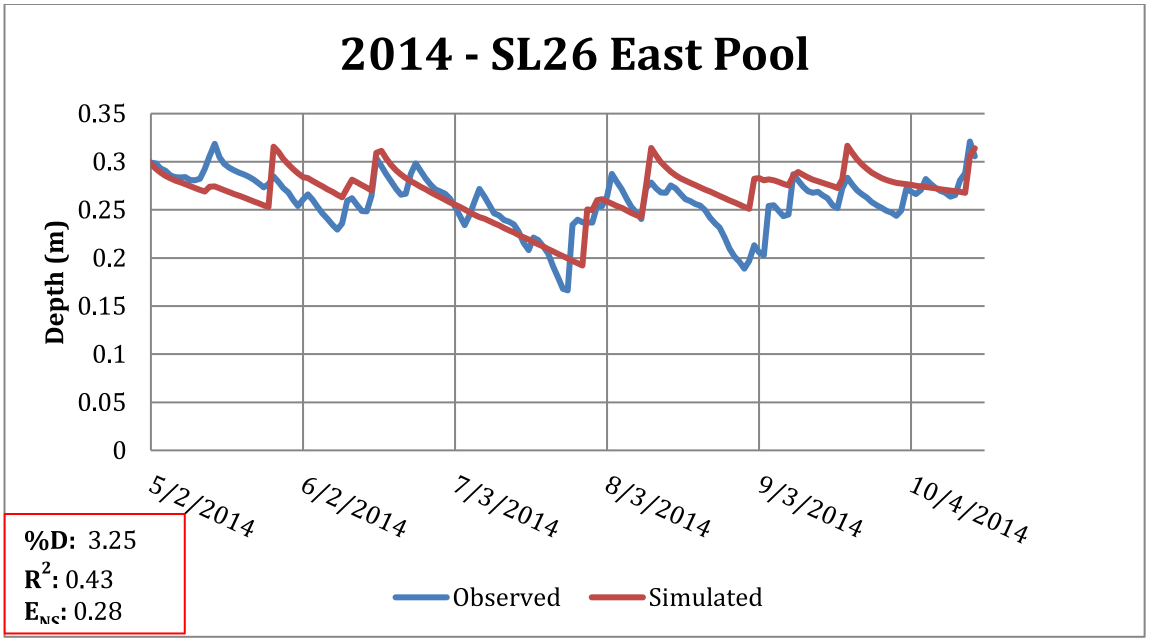

Figure 9: Sideline 26 East Pool Validation with 2014 data

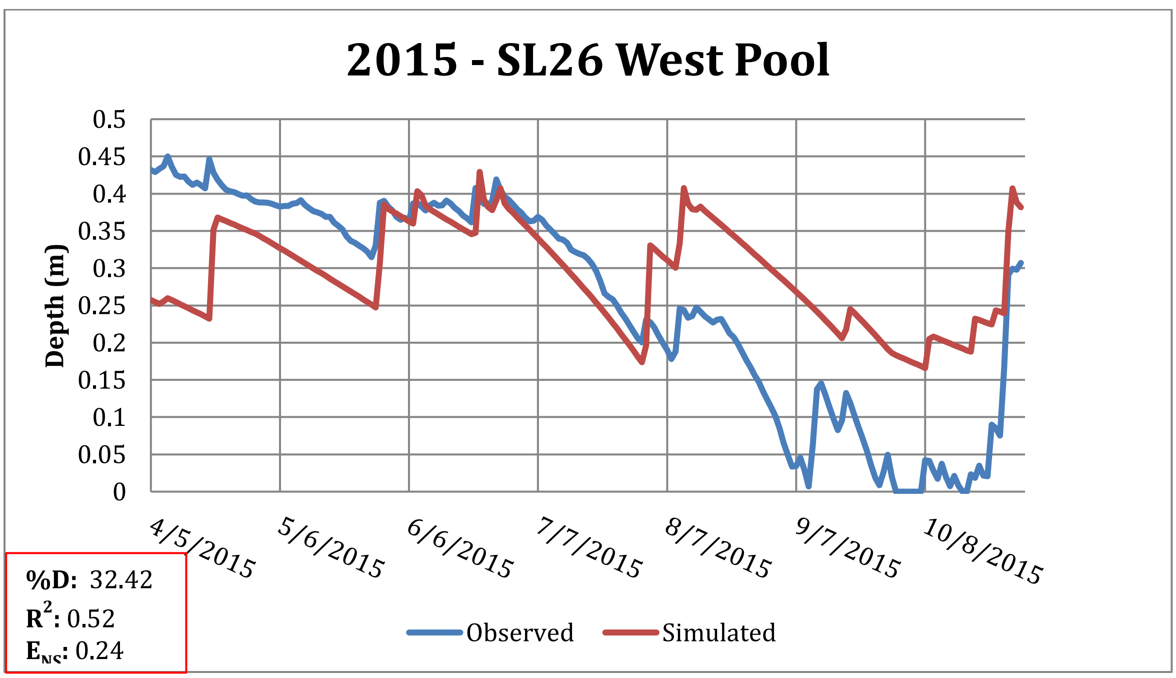

Figure 10: Sideline 26 West Pool Validation with 2015 data

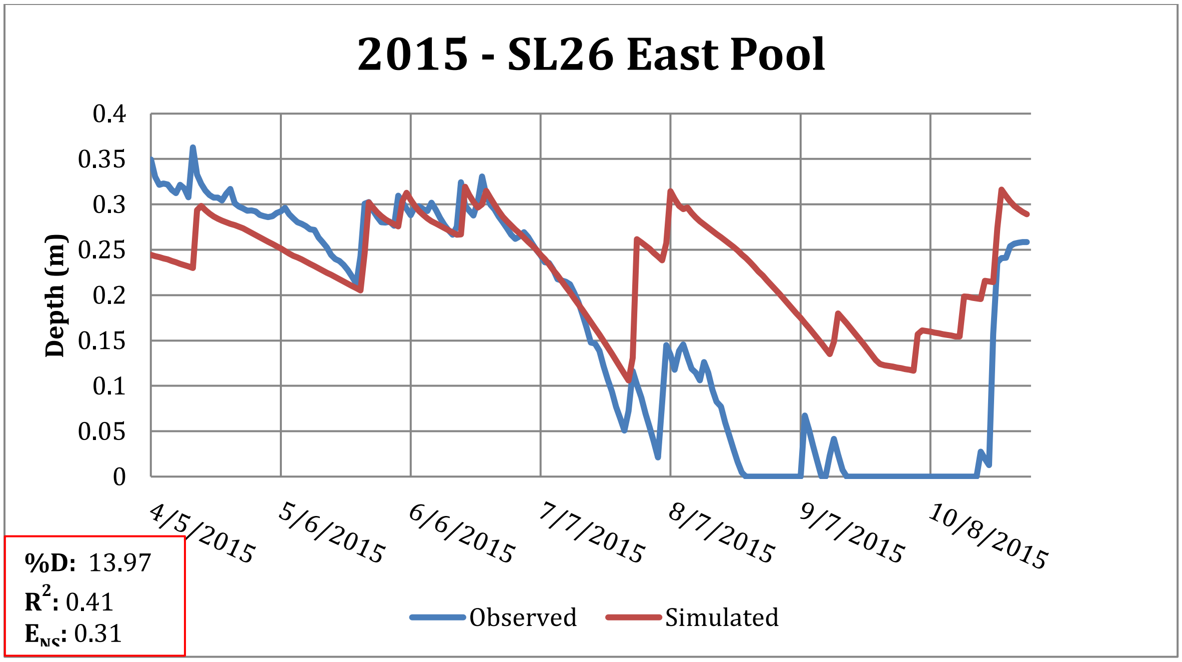

Figure 11: Sideline 26 East Pool Validation with 2015 data

3.1.5 HEC-HMS: Long-term Simulation, Proposed Conditions without Mitigation

Once the model was calibrated and validated, a post-development model was created. 3 hectares of farmland draining to the East Pool of the wetland was urbanized and diverted away from the wetland. A long-term simulation was conducted with the pre-development and post-development models in which 20 years of historical meteorological were used. These simulations used a daily time-step. Since the evaporation from the wetland is represented by fixed monthly values, the discharge to the wetland from the affected drainage area was compared instead of the wetland water level. Figure 12shows a comparison of pre and post development cumulative discharge volume from the disturbed drainage area.

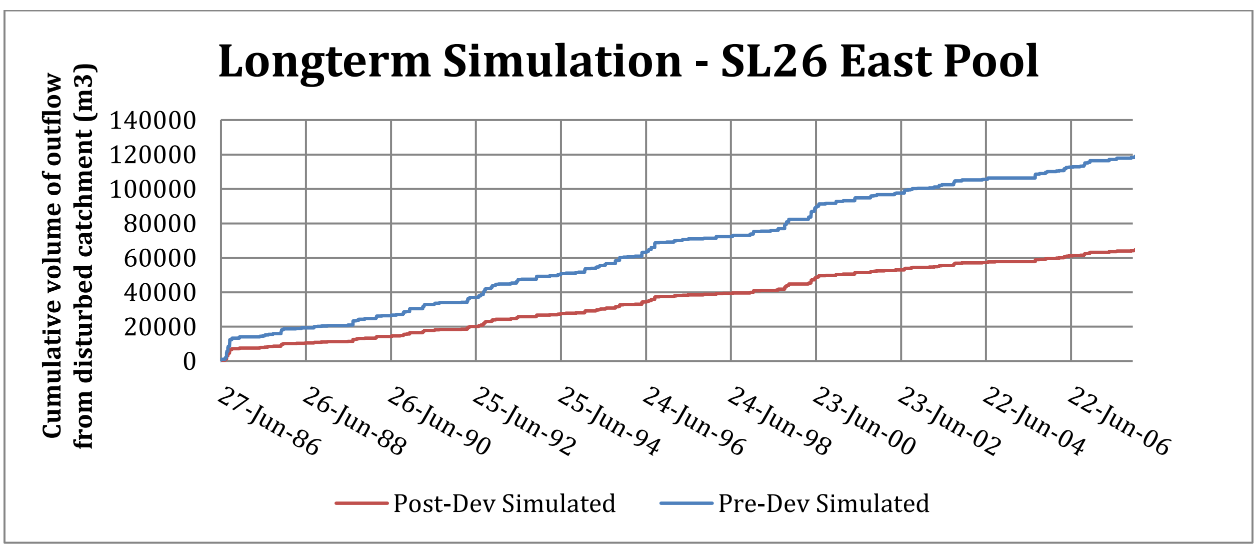

Figure 12: Long-term simulation for Pre-development and Post-development land use condition

3.1.6 HEC-HMS: Long-term Simulation, Proposed Conditions with Mitigation

A third model was created to inform the mitigation measures that would be required to ensure minimal changes to the wetland hydrology as a result of the land-use change. A percentage of the impervious area diverted away from the wetland was re-introduced to the wetland in order to maintain the existing-condition wetland hydro period. It was found that the discharge to the wetland was maintained when 11% of the 3 hectare urbanized catchment was allowed to drain to the wetland. A portion of clean runoff from the roof area of the new development equal to 11% of the 3 hectare urbanized catchment could be directed to the wetland's East Pool to maintain the wetland hydroperiod. Figure 13shows a comparison of the long-term simulations for the pre-development and mitigated post-development cumulative discharge volume from the disturbed drainage area.

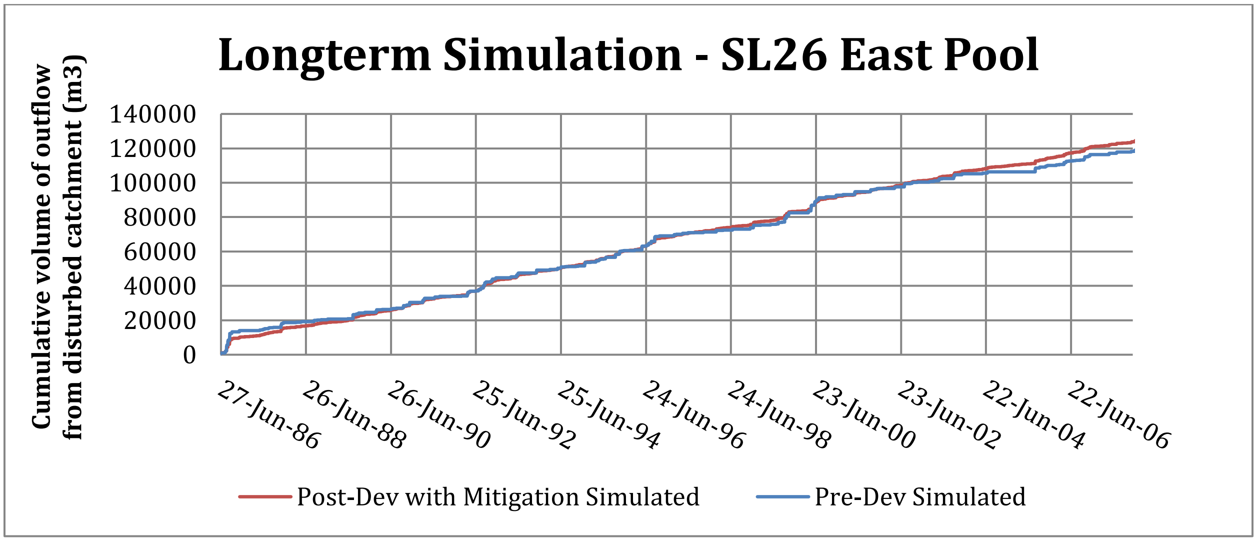

Figure 13: Long-term simulation for Pre-development and Mitigated Post-development land use condition

3.1.7 HEC-HMS: Benefits, Challenges, Recommendations and References

In conducting this case study, a number of benefits, challenges, and recommendations for using HEC-HMS for feature based water balance analysis were identified and summarized below.

Benefits

- User friendly interface, and very intuitive for new users
- Interception storage and crop coefficients can be variable based on time of year
- *Outflow Structures* reservoir method allows for multiple outlets, so percolation losses from the surface storage in the reservoir command can be accounted for separately from the stage-storage-discharge relationship
- The reservoir command allows for monthly evaporation to be accounted for
- Time-series simulation results for all model variables can be easily viewed and compared, which speeds up manual calibration and validation process.
- Quick model run-time
- Many low impact development measures could be easily represented through a combination of subbasin and reservoir commands

Challenges

- When modelling the wetland as a combination of a subbasin (to account for interception storage, underlying soil storage, and to generate runoff from the catchment area) and a downstream reservoir command (to accept flow from external drainage areas, and to account for the stage-storage-discharge relationship of the wetland surface) evapotranspiration must be partitioned between the subbasin and the reservoir commands.
- Evaporation from the reservoir command is represented by fixed monthly values. This introduces a source of error into the simulation, and it also greatly decreases the feasibility of conducting long-term simulations for the wetland water level. To avoid this drawback, long-term simulations could be conducted on the inflows to the wetland; the limitation being that if there are differences in the pre-development and mitigated post-development scenarios, the severity of those differences cannot be assessed with as much certainty as with a comparison of wetland water levels.
- When modelling the wetland as a combination of a subbasin and a downstream reservoir command, a calculation outside of the program is required to represent percolation from the reservoir command. This can become problematic during long-term simulations where monitored groundwater data is not available, especially if the percolation values are highly influenced by down-gradient soil and groundwater storage
- Dynamic interaction with groundwater that is outside of the surface drainage area of the wetland is not possible

Recommendations

- HEC-HMS may be suitable for conducting feature-based water balance analyses on low-medium risk wetlands that are surface-water driven
- Fixed monthly evaporation from the reservoir command is a major limitation when attempting to simulate and compare wetland water levels

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Scharffenberg, W (2016). Hy drologic Modelling System HEC-HMS User's Manual. U.S. Army Corps of Engineers Institute for Water Resources Hydrologic Engineering Center, August 2016.

US Army Corps of Engineers, Hydrologic Engineering Center. *HEC-HMS.* Retrieved from http://www.hec.usace.army.mil/software/hec-hms/

3.2 Hydrologic Simulation Program – Fortran (HSPF)

3.2.1 HSPF: Background

The US Environmental Protection Agency (US-EPA) HSPF (Hydrologic Simulation Program-Fortran) program has its origin in the Stanford Watershed Model developed by Crawford and Linsley (1966). It can reproduce spatial variability by dividing the basin in hydrologically homogeneous land segments and simulating runoff for each land segment independently. A segment of land can be modeled as pervious or impervious. In pervious land segments HSPF models the movement of water along three paths: overland flow, interflow and groundwater flow. Snow accumulation and melt, evaporation, precipitation and other fluxes are also represented. HSPF uses a continuous simulation approach, and is a highly flexible model that aims to be comprehensive in its representation of watershed hydrology and water quality processes. The potential applications and uses of the model are comparatively large, and include flood control planning and operations, hydropower studies, river basin and watershed planning, storm drainage analyses, water quality planning and management, point and nonpoint source pollution analyses, soil erosion and sediment transport studies, evaluation of urban and agricultural best management practices, fate, transport, exposure assessment, and control of pesticides, nutrients, and toxic substances, and time-series data storage, analysis, and display (AQUA TERRA Consultants, 2011).

Figure 14 presents a conceptual model schematic for HSPF.

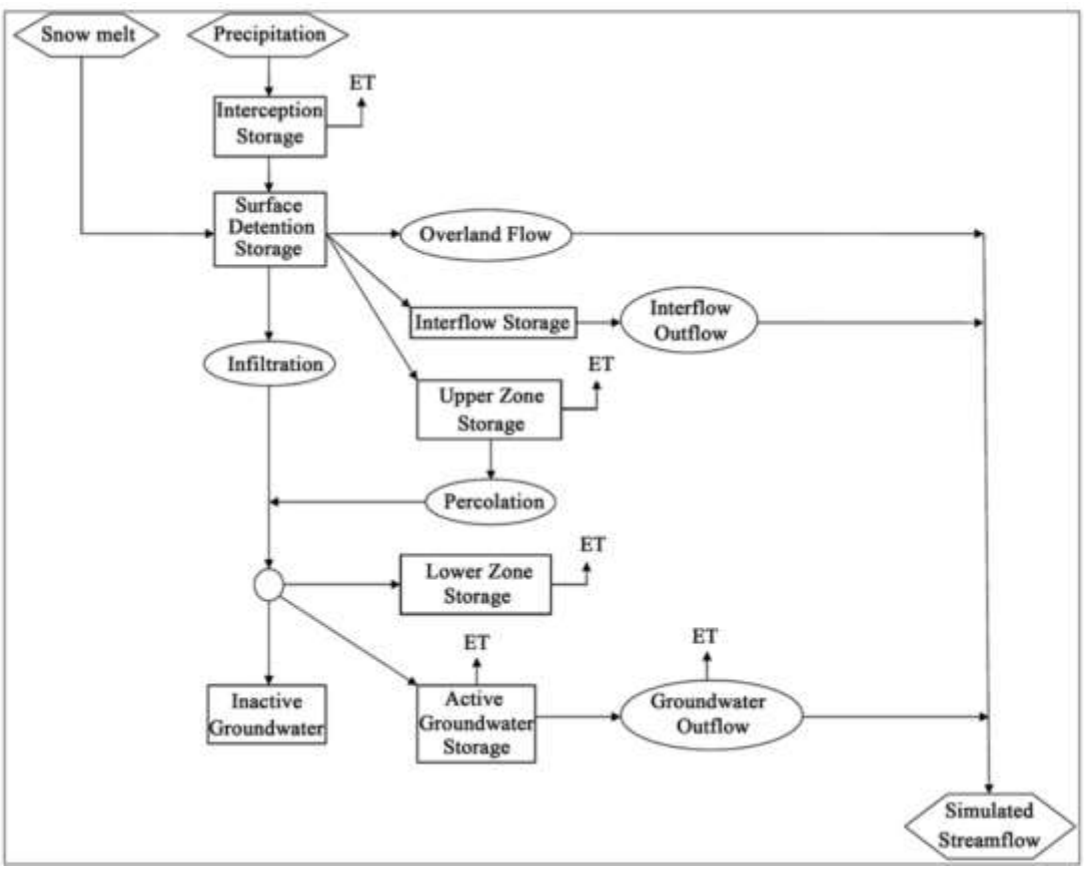

Figure 14: Conceptual Model Schematic for HSPF (Source: Amirhossien et al., 2015)

3.2.2 HSPF: Model Setup, Existing Conditions

The case study area used for evaluation is a wetland at Seaton Sideline 26, which is located in the City of Pickering within the Duffins Creek Watershed. Figure 2 shows the wetland and drainage areas, which were delineated using a 1m by 1m bare earth grid that was generated using LiDAR data from 2014. The wetland is divided into two pools. 2.05 hectares drain to the west pool of the wetland. The west pool drains overland to the east pool. The east pool receives runoff from an additional 7.31 hectares of land, for a total drainage area of 9.36 hectares.

Figure 3 shows the land use within the wetland drainage area, which includes farmland, forest, successional, and wetland. The drainage areas were further separated into these four land use categories, in order to use different parameters for each land use within the model. In particular, the difference in land use was reflected in different values for the interception storage capacity (CEPSC) and the lower zone evapotranspiration (LZETP) parameters.

The soil classification for the entire drainage area to the wetland is a Gleyed Gray Brown Luvisol. A soil description from Agriculture and Agri-Food Canada was used to generate initial parameters for Lower Zone Nominal Storage (LZSN) Infiltration (INFILT) and Upper Zone Nominal Storage (UZSN). In particular, the values for the volume of air in the soil at various pore pressures and the saturated hydraulic conductivity at the various soil horizons in the soil description were used to estimate the LZSN, INFILT, and UZSN parameters in the model.

Initial values for the groundwater recession rate (AGWRC) parameter were first estimated by observing the rate of decline of flow at a flume downstream of the wetland. Initial values for the initial active groundwater storage (AGWS) parameter were first estimated by observing the starting water level at the 2m deep well relative to the 1m deep soil column that was represented by the UZSN and LZSN parameters. Both of these parameters were used as calibration parameters. The initial values for the DEEPFR parameter (fraction of groundwater inflow which will enter deep inactive groundwater and thus be lost from the system as defined in HSPF) were initially set to zero, with the knowledge that they would be one of the main calibration parameters that determine how much moisture is lost from the system.

Figure 4 shows the topography and bathymetry of the wetland, which was generated from a site survey. The elevation information was used to create detailed stage-storage relationships for each of the two major wetland pools. In order to estimate the discharge at each stage, the wetland was modeled in HEC-RAS as two storage areas connected by a broad-crested weir, and discharging over a second broad-crested weir to the downstream channel. Cross-sections were cut at the outlet of each pool using the elevation information, and the cross-section information was used for the weir geometry. An unsteady simulation was performed, with flow rates gradually ramped up from a low flow to a high flow, in order to ensure that the results would have a good spread of stage-discharge information. Equations were fit to the resulting rating curves, so that discharge values could be calculated at each known elevation and storage for each pool. The resulting stage-storage-discharge information was used in two separate FTABLES in HSPF which represent the surface storage at the west pool and the east pool of the wetland. The exact elevation at which each pool begins to discharge, as well as the discharge estimates closest to these elevations were treated as a calibration parameters.

3.2.3 HSPF: Calibration and Validation, Existing Conditions

Figure 5 shows the location of monitoring stations at Sideline 26. There were a set of three wells at four main locations in the wetland, each with a 30cm long screen. One well (SW well) had a screen from +0.05 to -0.25m relative to the surface, another well (1m well) had a screen from -0.7m to -1m relative to the surface, and the third well (2m well) had a screen from -1.7m to -2.0m relative to the surface. The SW well at *Transect 1 - 40m* was used to calibrate the west pool, and the SW well at *Transect 2 – 40* was used to calibrate the east pool. The water levels in the wetland were used for calibration instead of discharge for two main reasons. Firstly, the flume downstream of the wetland became blocked and was circumvented by flow, so there was not enough confidence in the monitored data to use it for calibration. Secondly, the water level in each pool is a variable that can be directly and easily used to assess impact on the ecological functioning of the wetland.

In order to make the calibration process more intuitive, the observed water levels were converted into 'observed' surface storage volumes, so that differences between observed and simulated inputs, outputs, and storages could be more easily conceptualized during calibration. Observed water levels in the 2m wells were used to approximate initial groundwater storage values. Differences in observed water levels between the SW, 1m, and 2m wells were used to gain an understanding of the vertical hydraulic gradients for the monitored periods, and differences in observed water levels at the 1m wells between stations were used to gain an understanding of the horizontal hydraulic gradients for the monitored periods.

Observed data for 2013 was used to calibrate the model. The water level observations were recorded hourly, and converted to a daily average for the purpose of calibration. The model was run with an hourly time step, and daily average output was used for comparison with observed data.

Daily average observed water level was converted to daily average 'observed' storage, and visually compared with simulated daily average storage within the wetland. After achieving a good visual match, the procedure was repeated twice using data from 2014 and 2015 in order to validate the calibration. The initial model calibrations did not produce simulation results that closely matched observed data for the validation years, so the calibration process was iterated until all three years showed good results. All model parameters remained the same between simulations with two exceptions: AGWS (used to specify the initial active groundwater storage at the start of the simulation) and VOL (initial volume of water in the reach/reservoir) were different for each of the three years to account for the different observed water levels at the start of the simulation period for each of the three years.

Table 2 and Table 3 show the main parameters that were modified from initial parameters during the calibration and validation process.

Table 2: HSPF calibration parameters related to Pervious Land Segments

Parameter	Parameter Description	Units	Initial Value	Calibrated Value	Comments
PWAT-PARM2					
LZSN	Lower zone nominal storage	mm	128.2	319	Initially calculated as volume of voids in soil column (minus voids taken up by hygroscopic water) in A and B soil horizon minus 25.4mm for UZSN. Modified during calibration to include voids in C soil horizon (minus voids taken up by hygroscopic water), and to account for calibrated UZSN value
INFILT	Index to infiltration capacity of soil	mm/hr	7	3.3	Modified during calibration to allow for more surface runoff and interflow during higher intensity rainfall events
PWAT-PARM3					
DEEPFR	Fraction of groundwater that becomes inactive	fraction	0	0.73 to 0.8	Last parameter to be modified during calibration, once the other losses (PET fraction and percolation from RCHRES had been selected)
PWAT-PARM4					
UZSN	Upper zone nominal storage	mm	25.4	5	Modified during calibration to allow for more surface runoff and interflow during higher intensity rainfall events
PWAT-STATE1					
AGWS	Initial active groundwater storage	mm	1	1 to 12	Modified during calibration to reflect initial groundwater conditions and allow for difference in simulation between years that had different groundwater conditions

Table 3: HPSF calibration parameters related to Reach-Reservoir commands

Parameter	Parameter Description	Units	Initial Value	Calibrated Value	Comments
HYDR-INIT					
VOL	Initial volume of water in RCHRES	1.0E-6 m^3	n/a	n/a	Modified during calibration in conjunction with AGWS to ensure that initial volume in wetland matches with observed initial volume in wetland
FTABLES					
FTABLE for West Pool RCHRES	Stage-storage-discharge relationship	n/a	n/a	n/a	Because stage-discharge relationships were estimated using hydraulic models rather than measured, the elevation where discharge first occurs needed to be modified to match observed water levels.
FTABLE for East Pool RCHRES					
Additional outlet for West Pool RCHRES	To account for percolation from RCHRES	m^3/s	0	1.04E-05	A harmonic mean of saturated hydraulic conductivity estimates from Agriculture and Agri-food Canada's soil description, as well as a range of saturated hydraulic conductivity estimates from pumping tests conducted in the field were used in conjunction with observed lateral hydraulic gradients to provide estimates of percolation from the wetland pools.
Additional outlet for East Pool RCHRES			0	1.40E-04	
EXT SOURCES					
MultFact of POTEV for West Pool RCHRES	Fraction of PET applied to RCHRES	fraction	0	0.33	In order to calibrate using water level in a RCHRES, a fraction of the evapotranspiration needs to be deducted after the water enters the RCHRES
MultFact of POTEV for East Pool RCHRES	Fraction of PET applied to RCHRES	fraction	0	0.33	

After a good visual match with all three years of data was achieved, three statistical measures were used to compare the goodness of fit between observed and simulated water level: Percent Difference (%D), coefficient of determination (R^2), and Nash-Sutcliffe simulation efficiency (E_{NS}).

Figures 15 through 20 show the calibration and validation results for the two wetland pools.

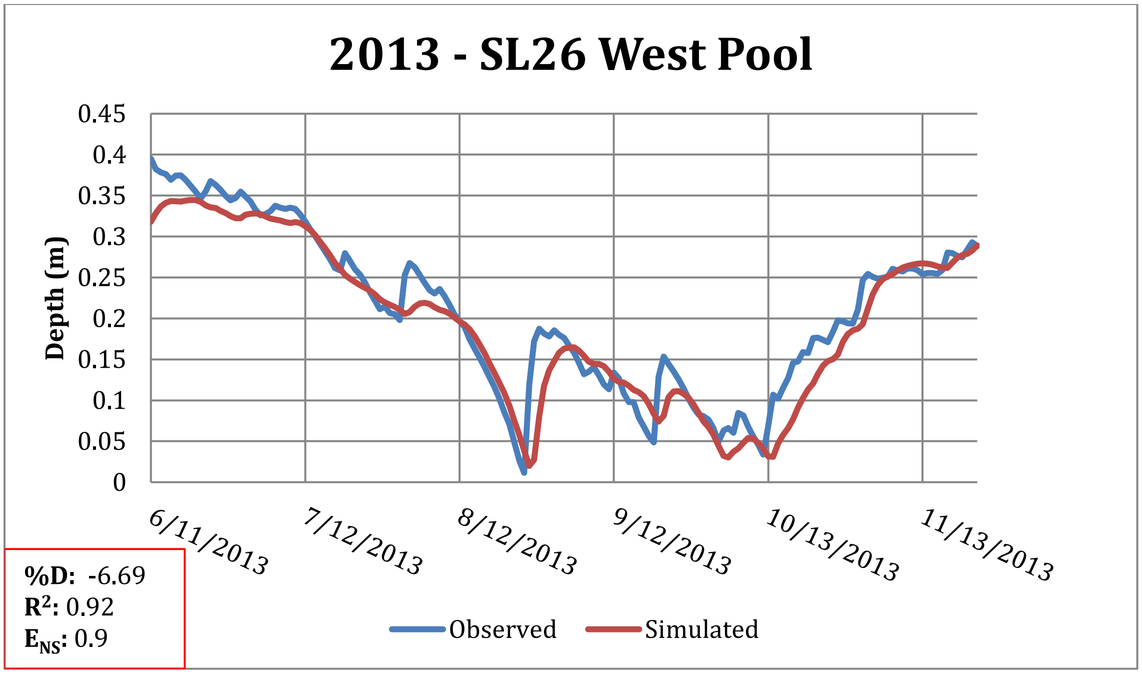

Figure 15: Sideline 26 West Pool Calibration with 2013 data

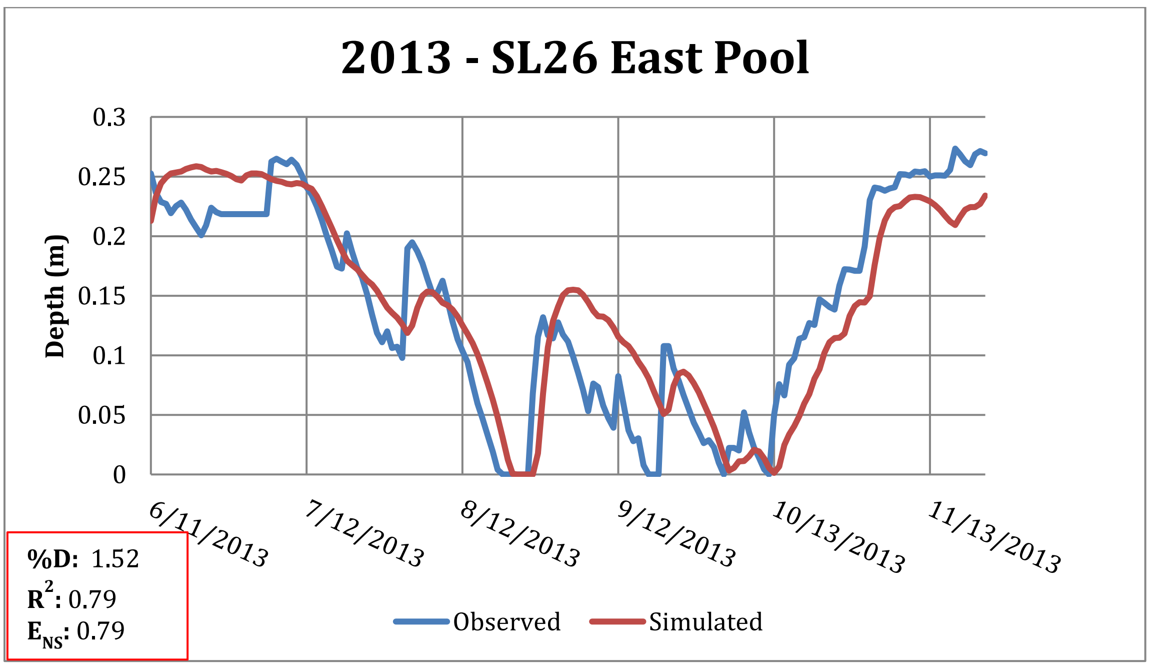

Figure 16: Sideline 26 East Pool Calibration with 2013 data

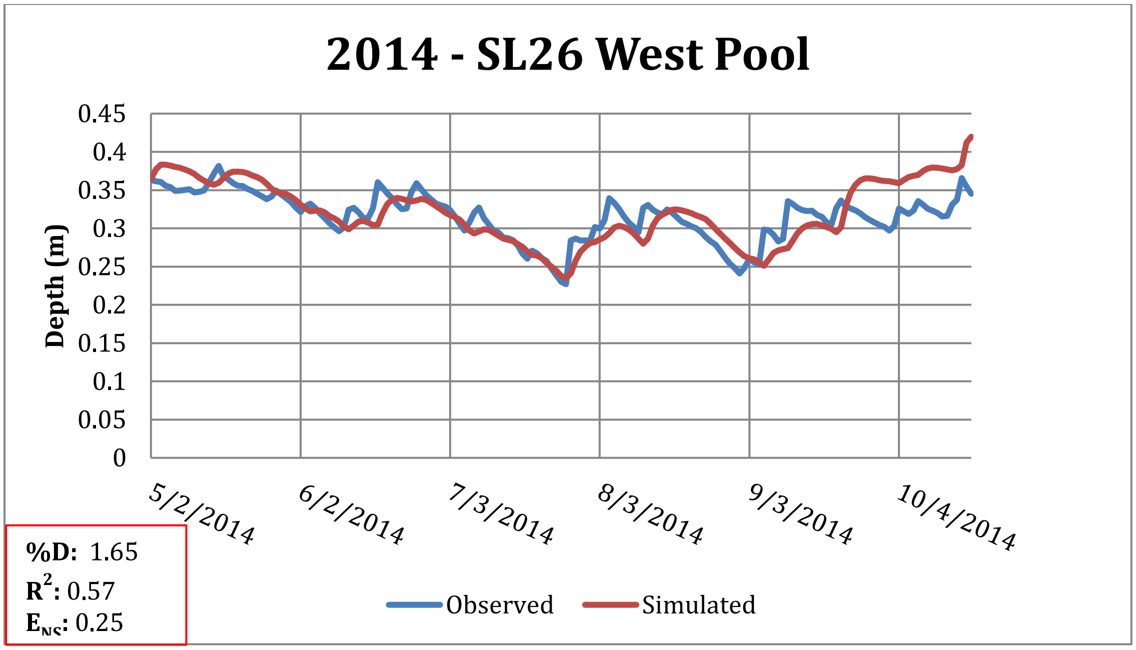

Figure 17: Sideline 26 West Pool Validation with 2014 data

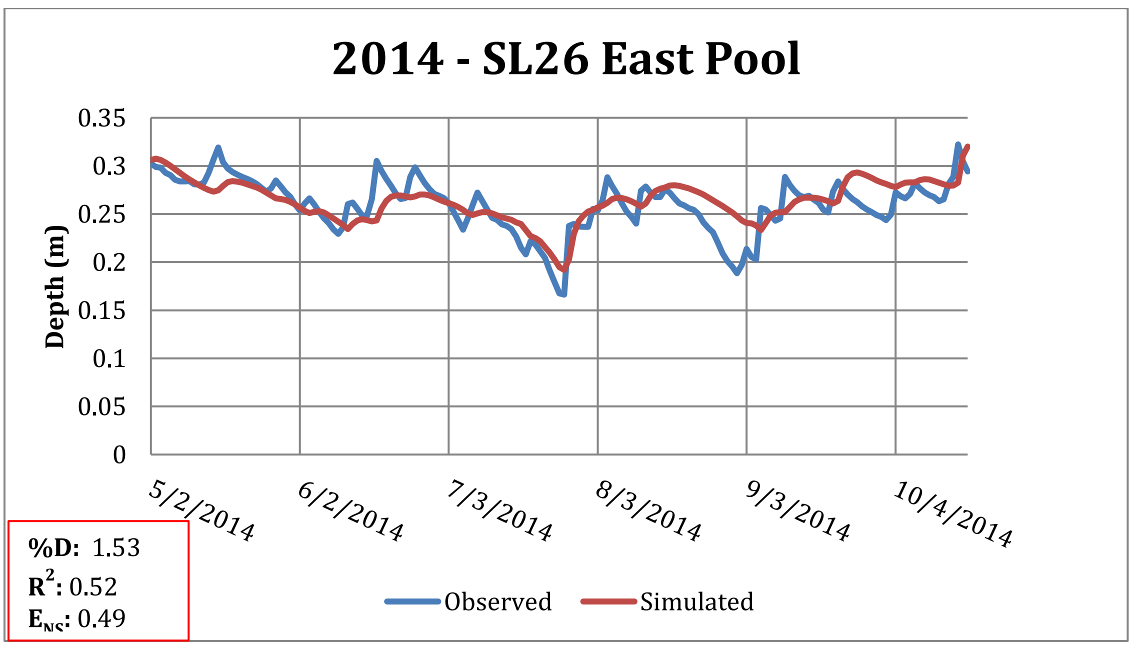

Figure 18: Sideline 26 East Pool Validation with 2014 data

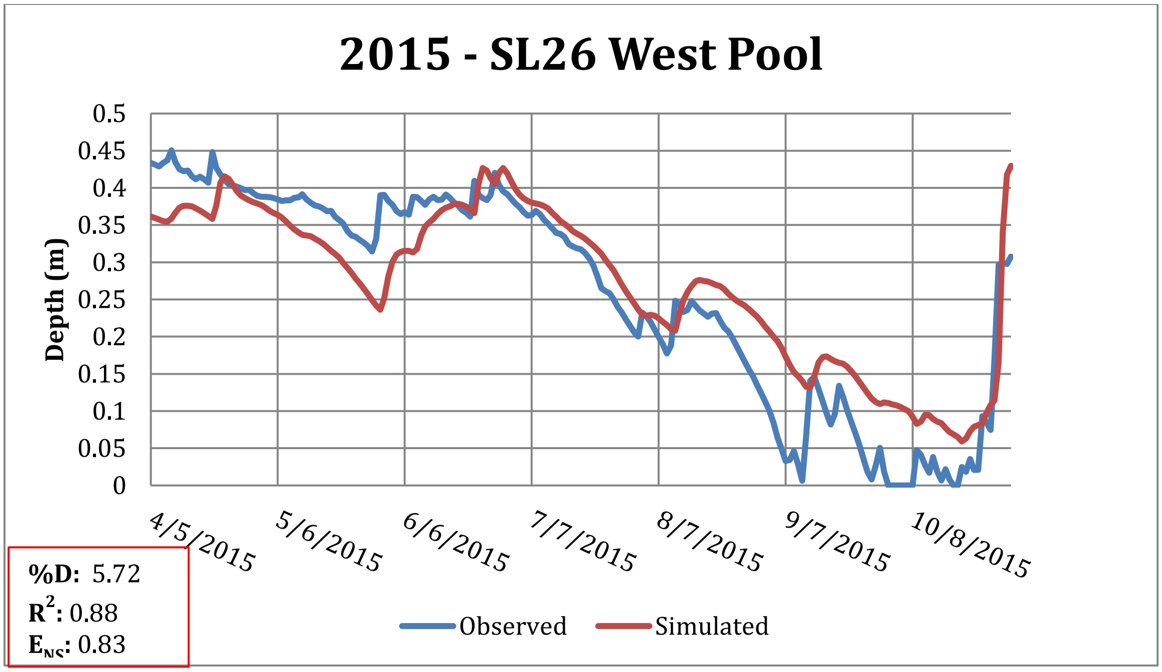

Figure 19: Sideline 26 West Pool Validation with 2015 data

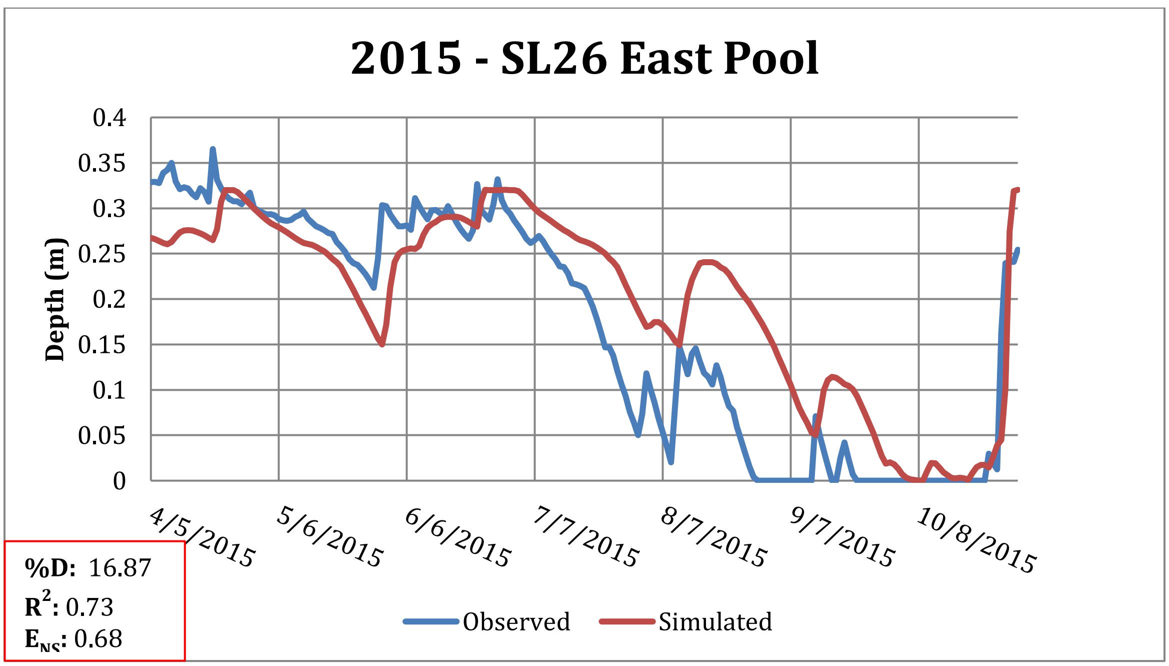

Figure 20: Sideline 26 East Pool Validation with 2015 data

3.2.4 HSPF: Long-term Simulation, Proposed Conditions without Mitigation

Once the model was calibrated and validated, a post-development model was created. 3 hectares of farmland draining to the East Pool of the wetland was urbanized and diverted away from the wetland. A long-term simulation was conducted with the pre-development and post-development models in which

20 years of historical meteorological were used. These simulations used a daily time-step, and the results were compared visually using a running monthly-average, as shown in Figure 21: Long-term simulation for Pre-development and Post-development land use condition.

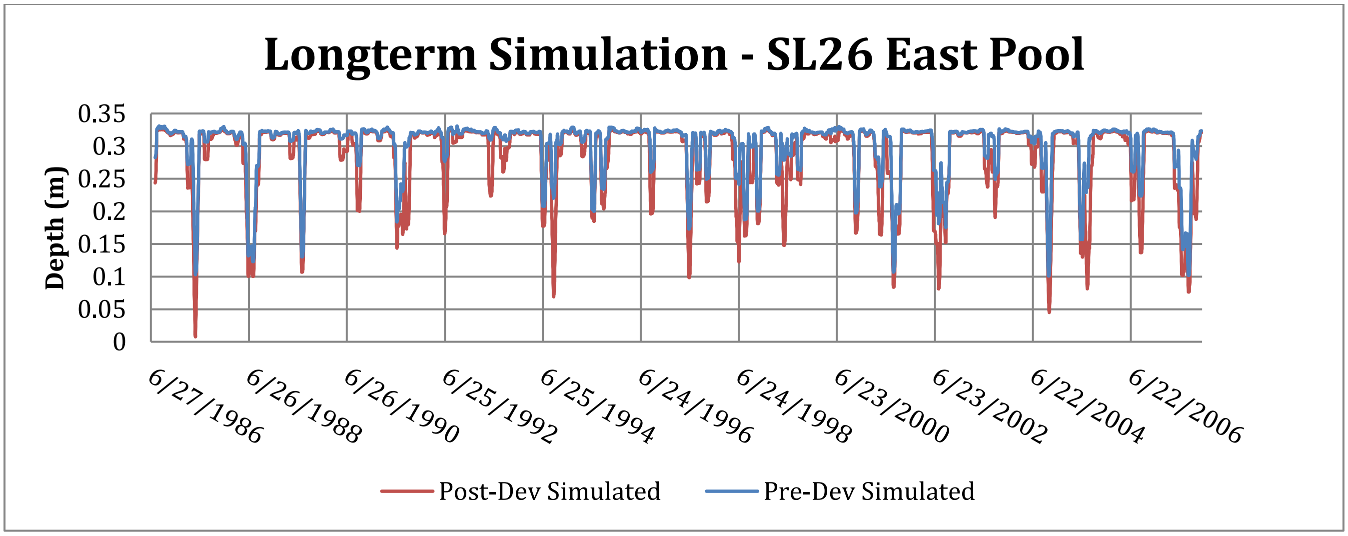

Figure 21: Long-term simulation for Pre-development and Post-development land use condition

3.2.5 HSPF: Long-term Simulation, Proposed Conditions with Mitigation

A third model was created to inform the mitigation measures that would be required to ensure minimal changes to the wetland hydrology as a result of the land-use change. A percentage of the impervious area diverted away from the wetland was re-introduced to the wetland in order to maintain the existing-condition wetland hydro period. It was found that the hydroperiod was maintained when 25.9% of the 3 hectare urbanized catchment was allowed to drain to the wetland. A portion of clean runoff from the roof area of the new development equal to 25.9% of the 3 hectare urbanized catchment could be directed to the wetland's East Pool to maintain the wetland hydroperiod. Figure 22 shows a comparison of the long-term simulations for the pre-development and mitigated post-development scenarios.

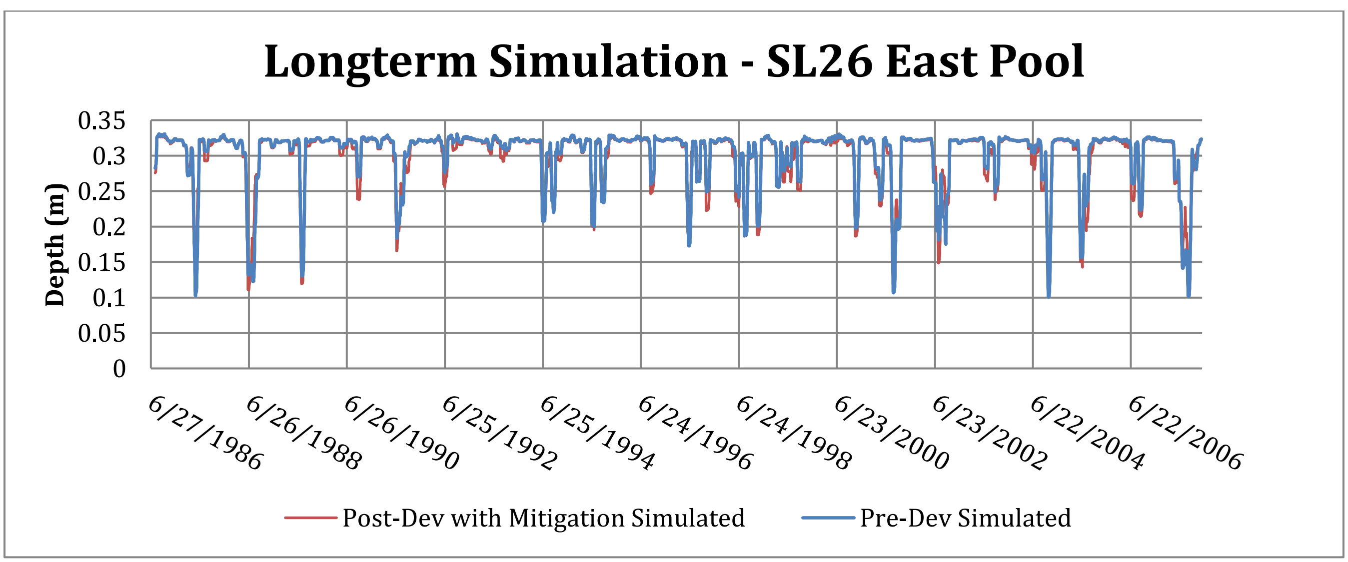

Figure 22: Long-term simulation for Pre-development and Mitigated Post-development land use condition

3.2.6 HSPF: Benefits, Challenges, Recommendations and References

In conducting this case study, a number of benefits, challenges, and recommendations for using HSPF for feature based water balance analysis were identified and summarized below.

Benefits

- The WinHSPF 3.0 interface is helpful for new users to parameterize the model after the User Control Input (UCI) file has been created.
- Many key parameters can be varied monthly
- Time-series simulation results for all model variables can be viewed and compared using Basins, which speeds up manual calibration and validation process.
- Potential Evapotranspiration time-series can be used for both land segments and the reach/reservoir storage-discharge relationships. For modelling of wetlands, it is critical that evapotranspiration can be accounted for after the runoff and/or groundwater discharge enters the reach/reservoir command.
- Shallow water table conditions can be simulated by including the PWAT-PARM6 and PWAT-PARM7 tables, which allow for the water table to rise above groundwater storage and fill upper and lower zone soil storages.
- Reach/Reservoir command allows for multiple outlets, so percolation losses from the surface storage in the reach/reservoir command can be accounted for separately from the stage-storage-discharge relationship
- Quick model run-time
- Many low impact development measures could be easily represented through a combination of land segment and reach/reservoir commands
- BMP Reach Toolkit in Win HSPF 3.0 helps with parameterization of BMP's for infiltration-based stormwater control practices

Challenges

- Creating an initial UCI file can be time-consuming for new users
- WDMUtil tool for managing the time-series WDM files is not currently available for download on the Aqua Terra Website
- When modelling the wetland as a combination of a pervious land segment (to account for interception storage, underlying soil storage, and to generate runoff from the catchment area) and a downstream reach/reservoir command (to accept flow from external drainage areas, and to account for the stage-storage-discharge relationship of the wetland surface) evapotranspiration must be partitioned between the pervious land segment and the reach/reservoir commands.
- When modelling the wetland as a combination of a pervious land segment and a downstream reach/reservoir command, a calculation outside of the program is required to represent percolation from the reach/reservoir command. This can become problematic during long-term simulations where monitored groundwater data is not available, especially if the percolation values are highly influenced by down-gradient soil and groundwater storage
- Dynamic interaction with groundwater that is outside of the surface drainage area of the wetland must be calculated outside of the program.
- Calibration process can be challenging and time-consuming. In particular, the DEEPFR (fraction of groundwater inflow which enters deep inactive groundwater) has a large influence on

simulation results, and appropriate values of this parameter are highly dependent on the spatial scale of the model and the particular feature of interest.

Recommendations

- HSPF is generally well-suited for conducting feature-based water balance analysis
- Calibration in HSPF using wetland water level is possible, but can be time-consuming
- For wetlands with significant groundwater contribution from outside of the surface-water drainage areas, many calculations external to the model would be required

References

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3.3 MIKE SHE

3.3.1 MIKE SHE: Background

MIKE SHE is a physically-based distributed model that represents an extension of the Systéme Hydrologique Européen (SHE) model, and is maintained and distributed by DHI. MIKE SHE is flexible in terms of the level of detail in which each hydrologic process is simulated. The choice of the appropriate methodology to use for each of the simulated components is a function of a) the specific questions that need to be addressed by the model, and b) the availability of input data with which to construct and calibrate the model. The model has a long history (relative to other integrated flow models) and is used worldwide.

Figure 23 presents the process schematic for MIKE SHE. With the exception of channel routing, all calculations, including precipitation, unsaturated flow, overland flow, and saturated flow are calculated on the same (uniform) grid basis. MIKE SHE links to MIKE-11, DHI's 1D hydraulic model, for channel routing. Table 4 summarizes the major model features in MIKE SHE

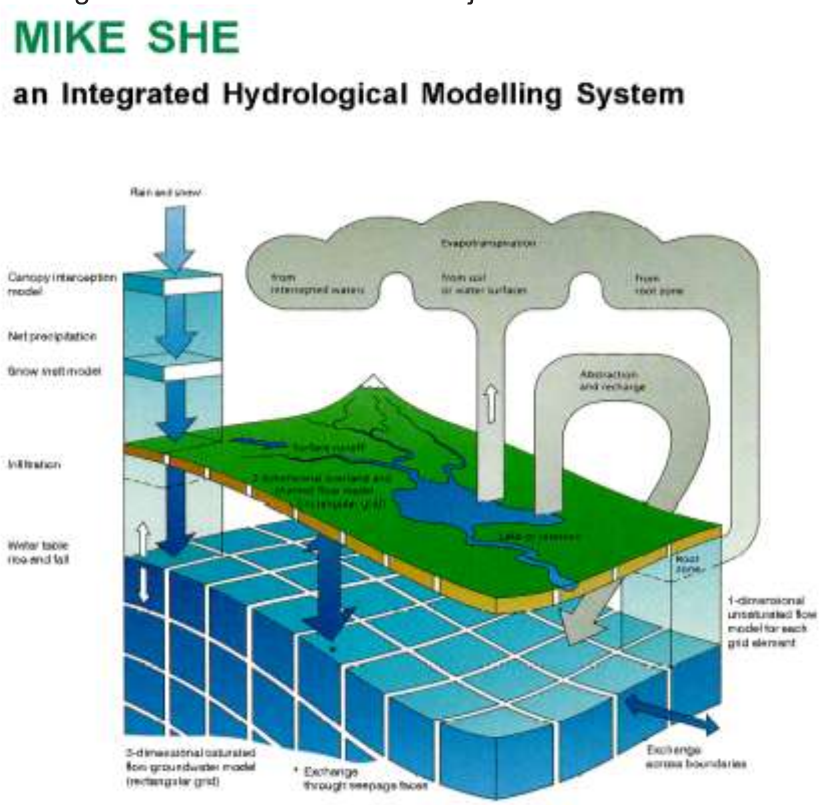


Figure 23: MIKE SHE Process Schematic (Source: DHI, 2009a)

Table 4: MIKE SHE Model Features

Model Features	MIKE SHE
Model Type	Physically-based distributed parameter/lumped parameter
Simulation Type	Continuous/ single-event
Precipitation	Multiple/single hyetograph

Snow Melt	Modified Degree-day approach
Evapotranspiration	Vegetation-based ET (LAI/Rooting Depth)
Infiltration	Fully Richards equation
	Gravity Flow equation
	Two-Layer Water Balance plus Green-Ampt for dry soil condition
Overland Flow	2D diffusive wave approximation/lumped sub-catchment-based
Subsurface Soil Water Flow	1D unsaturated flow
Channel/Reservoir	1D fully dynamic wave approximation
	1D diffusive wave approximation
	1D kinematic wave flow
	Muskingum /Muskingum-Cunge Routing
Groundwater Flow	3D groundwater flow/Linear Reservoir Approach
GIS interface	Accept GIS format data including point/contour/polygon/polyline/ASCII

Applications of the MIKE SHE model have a very long publication record including the recent work of Vazquez et al. (2008), Hansen et al. (2007) and Thompson et al. (2004). Additionally, MIKE SHE has consistently ranked high in a number of model comparison studies including Gordon et al. (2005), Weber et al. (2004) and Camp Dresser & McKee (2001). Because the model is proprietary, the source code is not available. The model is well-documented and actively being maintained and updated. DHI, the developers of MIKE SHE, also provide numerous training courses on their software at locations around the world. MIKE SHE can be purchased online at: www.mikepoweredbydhi.com. The cost of the code varies depending on the options the user wishes to include. Prices range from approximately CAD $14,160 for government agencies to CAD $17,700 for standard commercial use for a perpetual license that includes the first year of technical support and upgrades. While the perpetual license does not time-out, an annual service and maintenance fee is required after the first year in order to continue receiving technical support and software updates. The annual cost of the service agreement is approximately CAD $5,000.

3.3.2 MIKE SHE: Model Setup, Existing Conditions

The case study area used for evaluation is Seaton Sideline22 Wetland area, which is located in City of Pickering within Duffins Creek watershed. Total drainage area is 17.34ha, and wetland pool area is 0.58ha. A1-m LiDAR map (Figure 24) shows the topography of the area. In the study area land cover is dominated by agricultural fields and wood areas (see Figure 25), and soil is dominated by sandy loam/loam. An existing regional groundwater model (MODFLOW) was available covering most of TRCA’s jurisdiction. Table 5: MIKE SHE data sourcesTable 5 summarizes the available data collected for this study.

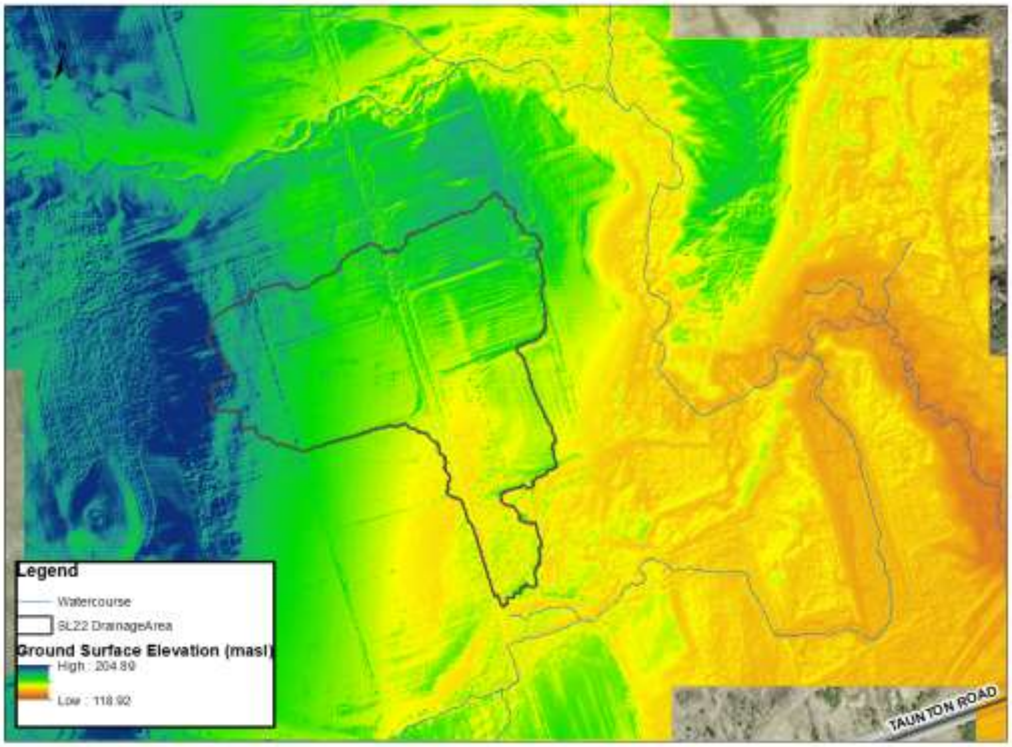


Figure 24: 1-m LiDAR Data in Seaton Sideline 22

Figure 25: Land use map of Seaton Sideline 22

Table 5: MIKE SHE data sources

Data Type	Data Sources
Topography	10-m DEM, 1-m LiDAR, wetland bathymetry
Climate data	5-min precipitation, temperature, and daily Potential ET (2013 – 2015) estimated using Hargreaves Equation
Land use	TRCA Existing Land use, and Land use for Post Development
Soil data	Detailed Soil Database from Agriculture and Agri-Food Canada
Channel	TRCA water-course layer and cross-sections cut from 1-m LiDAR data
Groundwater Model	Import from broader regional groundwater model provided by Oak Ridges Moraine Groundwater Program
Water Level Monitoring	1-hr water level data at 0m, -1m and -2m (reference to ground surface) within/near wetland area (2013 – 2015)

Model Domain

In order to have proper groundwater boundary conditions, a regional MIKE SHE model was first built and initially calibrated against observed water levels and then a local-scale MIKE SHE model was built using extracted groundwater boundaries from the regional model. shows the regional model domain and local-scale model domain. Regional model has 100m by 100 grid cell size, and local-scale model has 10m by 10m grid cell size. Table 6 summarizes the processes included in the model and approaches associated to each process.

Table 6: MIKE SHE model process approaches

Model Process	Approach
Precipitation	5-min hyetograph
Snow Melt	Modified Degree-day approach
Evapotranspiration	Kristensen and Jensen, Vegetation-based ET (time varying LAI/Rooting Depth)
Unsaturated flow	1D Fully Richards equation
Overland Flow	2D diffusive wave approximation of the St. Venant equations of flow.
Channel/Reservoir	1D fully dynamic wave approximation of the St. Venant equations of flow.
Groundwater Flow	3D Finite Difference implementation of Darcy's equation.

Climate

For calibration and validation of the model, simulation period was used for this study is year of 2013 – 2015, and year of 2013 was used as calibration period and years of 2014 and 2015 were used for validation/verification periods. As with any hydrologic model, climate data is a critical input. Climate data from the TRCA climate station (HY009) was used to represent the climate for the study area. Available data fields are maximum/minimum 5-min temperature, 5-min precipitation. Daily potential evapotranspiration rates were generated by Hargreaves potential evapotranspiration method (Hargreaves et al, 1985). This method considers daily temperature maximum and minimum as well as daily solar radiation to compute an estimate of potential evapotranspiration.

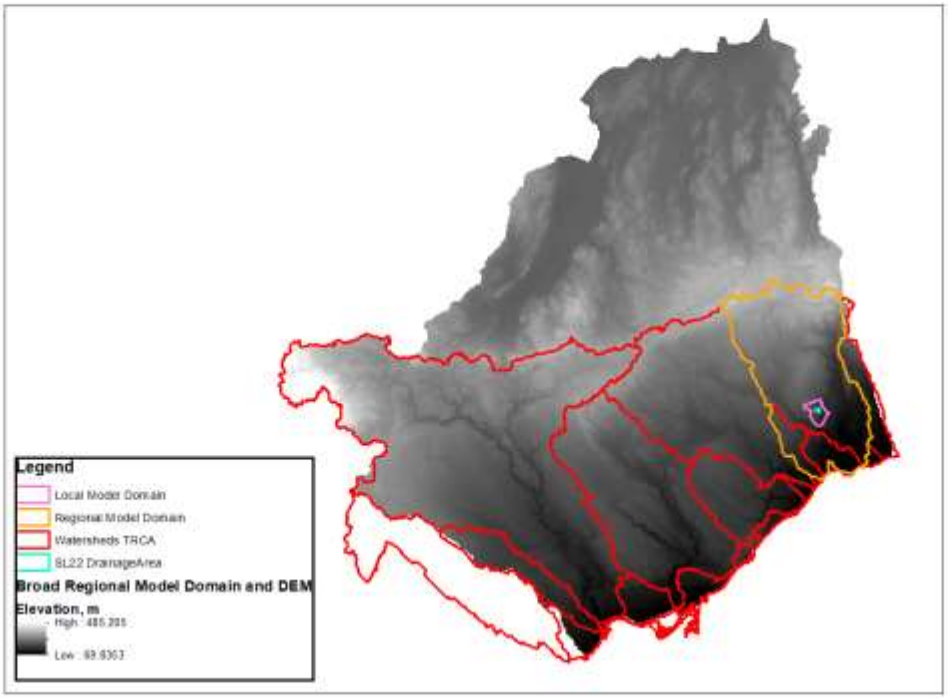


Figure 26: MIKE SHE Regional Model Domain and Local-scale Model Domain

Land use

Land use is used within hydrologic models to consider the effects of the land surface on hydrologic processes such as overland flow, infiltration, evapotranspiration and unsaturated soil zone processes. Based on the land use categories and TRCA standard Manning's n values shown in Table 7, a spatial distribution of overland roughness was generated. These coefficients were then adjusted during the calibration process. Land use data are also used to generate vegetation-specific datasets, specifically the leaf area index (LAI) and the rooting depth. LAI has significant seasonal variation, and it normally reaches a lower limit during winter time and an upper limit during summer time with full leaf cover. No specific information is available for LAI in the study area, thus values from scientific literature (Scurlock et al., 2001) and professional judgement were used in the model. MIKE SHE utilizes a rooting depth parameter to represent the maximum depth of vegetation roots. Significant seasonal variations in the rooting depth are typical for annual and deciduous plants, whereas for many perennial and evergreen plants, rooting depth values remain relatively constant throughout the year. The primary function of the rooting depth specification in MIKE SHE is in establishing the depth to which plants can remove water from the subsurface for transpiration. Specific rooting depth values were not available for the study area, therefore the values used in the model represent literature values for similar vegetation, climate, and soil conditions (Schenk and Jackson, 2003).

Table 7: MIKE SHE catchment parameters by land use type

Land Use Type	Manning's n Value
Farm	0.08
Meadow	0.05
Road	0.025
Wetand	0.035
Forest	0.08

Soil
The materials present at the ground surface play a critical role in partitioning precipitation into runoff and infiltration. To represent these materials, either soils or surficial geology mapping is used in hydrologic investigations. For this study, soil data is from detailed Soil Database from Agriculture and Agri-Food Canada, and it includes soil horizon, soil texture, saturated conductivity, water contents at different pressure levels.

Stream Network
MIKE SHE relies on the MIKE 11 1D hydraulic model to represent the stream network. The MIKE SHE/ MIKE 11 linkage uses a two-way exchange to collect overland flow, calculate exchange flux between the surface and groundwater systems, and route streamflow downstream. The stream network included in the model included the major rivers and tributaries in the local-scale model. In total, 14 branches are included, and are shown in Figure 27: MIKE 11 1D River network. Cross sections were extracted from the 1 m LiDAR with 30m spacing in order to capture the conveyance of those complexes. In total, 372 cross sections were used in the model.

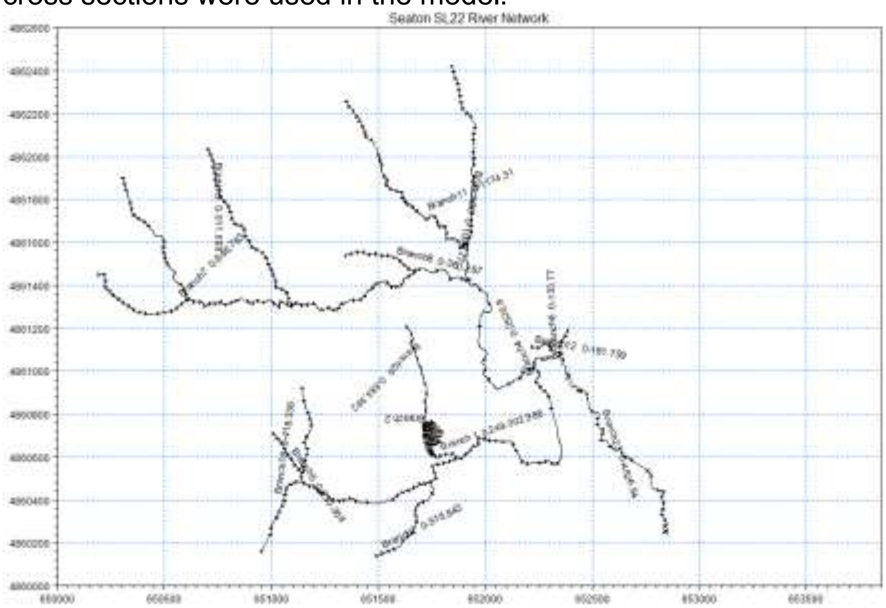


Figure 27: MIKE 11 1D River network

Groundwater
To simulate the groundwater flow system, the properties of the subsurface materials (e.g., hydrostratigraphic layer elevations, hydraulic conductivity distributions) must be specified. All saturated zone properties for the MIKE SHE model were directly taken from existing regional MODFLOW model provided by Oak Ridges Moraine Groundwater Program. This includes layer elevations, hydraulic conductivities, specific storage and specific yield values. As mentioned in Model Domain section, a regional MIKE SHE model was first developed and initially calibrated. For local-scale model, the initial groundwater heads and external boundary conditions were extracted from regional MIKE SHE model.

3.3.3 MIKE SHE: Calibration, Existing Conditions

There are nine water level monitoring wells installed within/near wetland pool area (see **Figure 28**), and water levels were collected at 0m, 1m and 2m below ground surface with 5-min interval for 2013, 2014 and 2015. The year of 2013 was used as calibration period, and the years of 2014 and 2015 were used as validation period.

Figure 28: Location of water level monitoring wells at Sideline 22

When working with a highly parameterized model like MIKE SHE, it is critical to identify which parameters are most sensitive so that the calibration effort can be focused on a subset of the available model parameters. An additional consideration is the degree to which a given parameter is known. For those parameters that are well-constrained by measurements or detailed studies there is less justification for making adjustment. On the other hand, some parameters are based on limited or no site-specific information or are known to have a wide range of reasonable values. For the latter group of parameters, there is significantly more leeway with which to make adjustments. For all parameters, however, it is important to consider the upper and lower bounds of reasonable values to ensure that all model parameter values remain realistic. Table 8summarizes the major calibration parameters in MIKE SHE model.

Table 8: List of parameters adjusted during MIKE SHE calibration process

Model Parameter	Description
Detention Storage	This parameter is used to limit the amount of runoff that the model produces as well as control the timing of runoff relative to precipitation. The parameter also has an indirect effect on infiltration and ET

Riverbed Leakage Coefficient	This parameter regulates the exchange of water between the groundwater and channel flow components of the model.
Soil Moisture Contents	This set of parameters influences the amount of ET, infiltration, and groundwater recharge and indirectly affects the timing and magnitude of runoff.
Saturated Hydraulic Conductivity	This parameter controls the infiltration rate and indirectly affects the rate of groundwater recharge, ET, and runoff.
Manning's Roughness	This parameter controls the timing and magnitude of runoff.
Horizontal/Vertical Hydraulic Conductivity	This set of parameters controls the groundwater flow rate and direction, and interactions with rivers, soils and overland flow.

During simulation, MIKE SHE generates calibration plots at each selected calibration locations, and also produces calibration statistics for each plot with available observation data. Table 9 lists available statistics generated in MIKE SHE calibration plot, and Figures 29 through 32 show calibration plots.

Table 9: MIKE SHE statistical performance metrics

Statistics	Description
ME	Mean Error
MAE	Mean Absolute Error
RMSE	Root Mean Square of Error
STDres	Standard Deviation of Residual (Error)
R(Correlation)	Correlation Coefficient
R2(Nash_Sutcliffe)	Nash Sutcliffe Correlation Coefficient

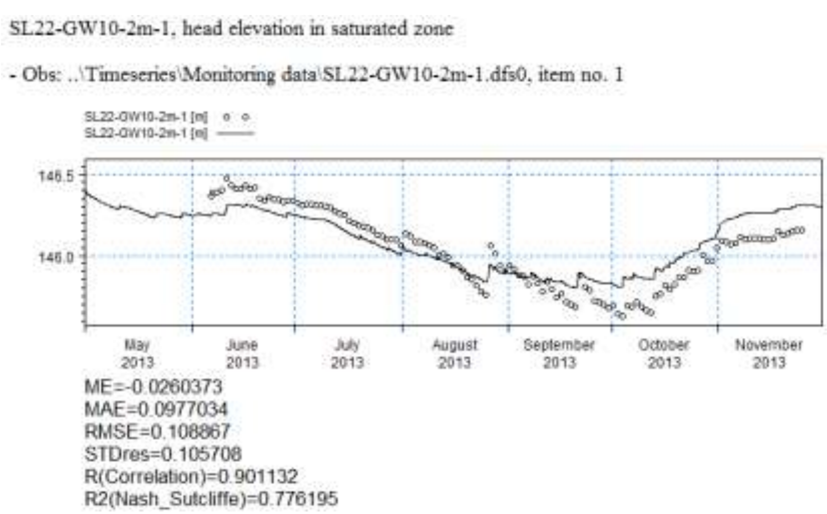
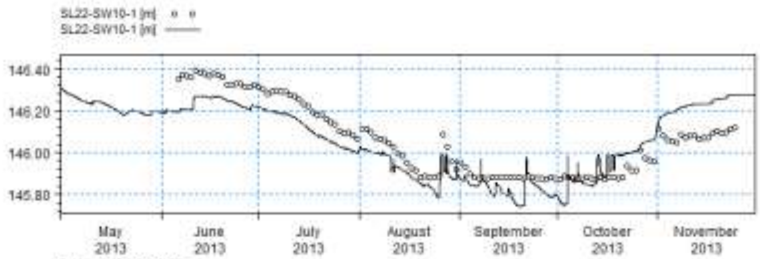


Figure 29: Sideline 22 calibration with 2013 data (1)

SL22-SW10-1, head elevation in saturated zone

- Obs: ..\Timeseries\Monitoring data\SL22-SW10-1.dfs0, item no. 1

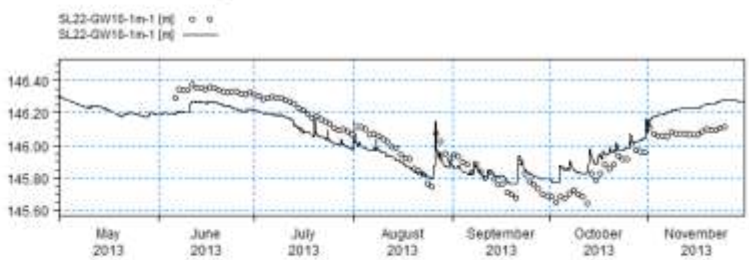


ME=0.0280615
MAE=0.0866865
RMSE=0.0955888
STDres=0.0913771
R(Correlation)=0.854547
R2(Nash_Sutcliffe)=0.688697

Figure 30: Sideline 22 calibration with 2013 data (2)

SL22-GW10-1m-1, head elevation in saturated zone

- Obs: ..\Timeseries\Monitoring data\SL22-GW10-1m-1.dfs0, item no. 1

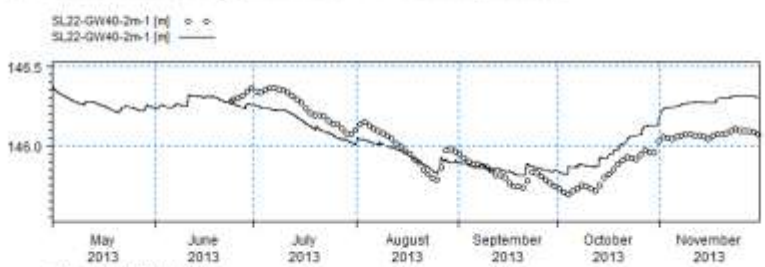


ME=-0.00248879
MAE=0.092044
RMSE=0.101217
STDres=0.101187
R(Correlation)=0.883944
R2(Nash_Sutcliffe)=0.772946

Figure 31: Sideline 22 calibration with 2013 data (3)

SL22-GW40-2m-1, head elevation in saturated zone

- Obs: ..\Timeseries\Monitoring data\SL22-GW40-2m-1.dfs0, item no. 1



ME=-0.0441166
MAE=0.10505
RMSE=0.122955
STDres=0.114767
R(Correlation)=0.797729
R2(Nash_Sutcliffe)=0.570157

Figure 32: Sideline 22 calibration with 2013 data (4)

3.3.4 MIKE SHE: Validation, Existing Conditions

After calibration, next step is to validate the model against different set of monitoring data with calibrated parameters. The years of 2014 and 2015 were used as validation period. Figure 33 through Figure 36 show the validation plots.

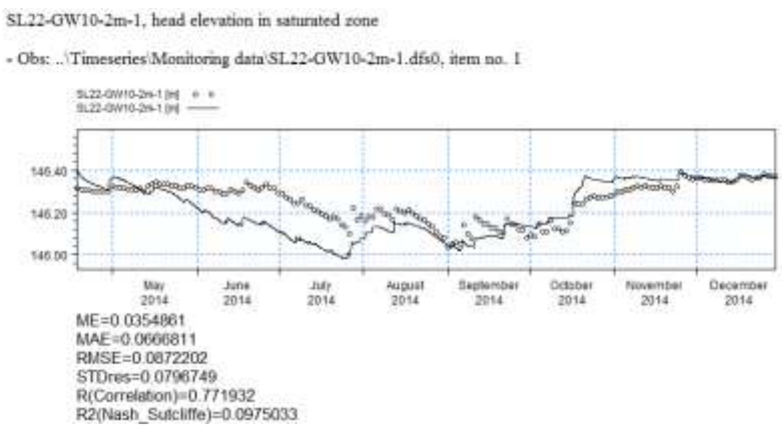


Figure 33: Sideline 22 validation with 2014 data (1)

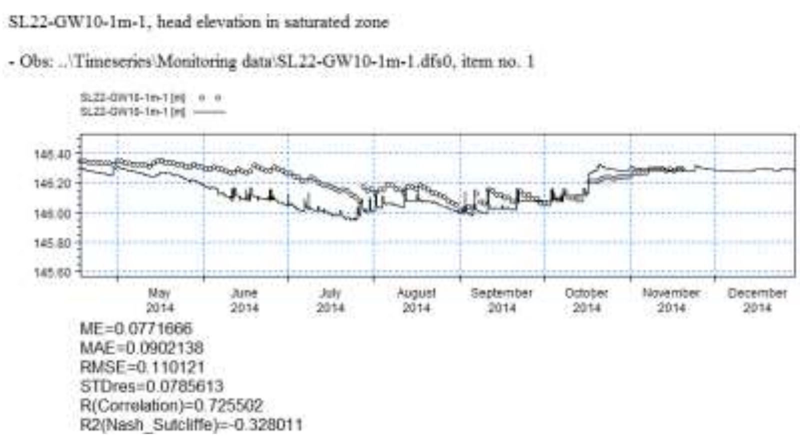


Figure 34: Sideline 22 validation with 2014 data (2)

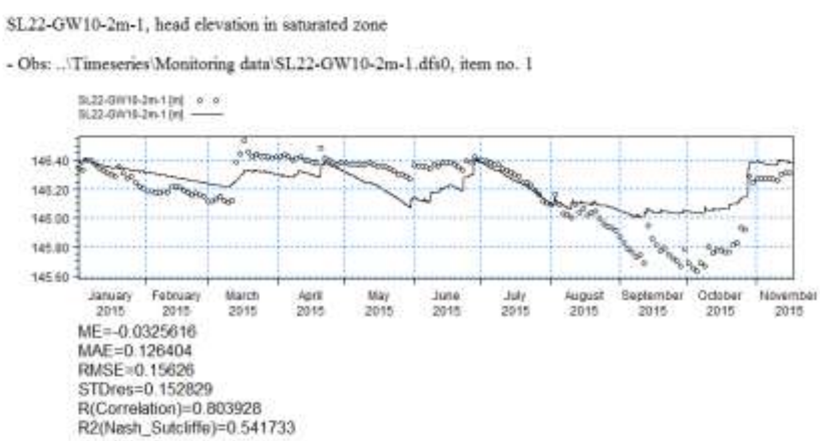


Figure 35: Sideline 22 validation with 2014 data (3)

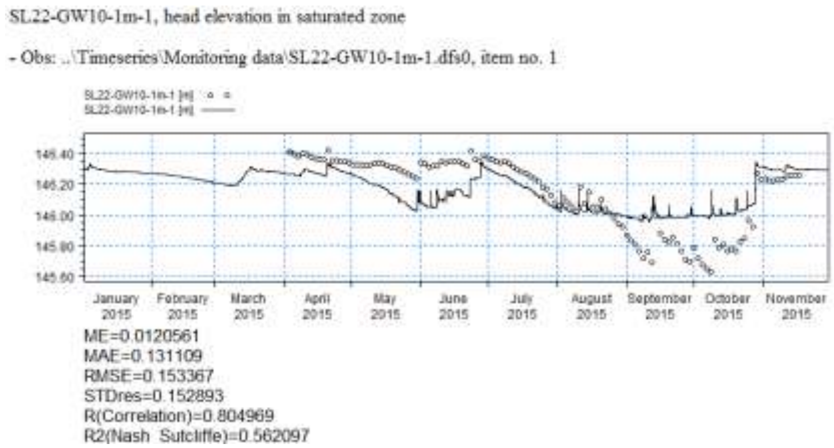


Figure 36: Sideline 22 validation with 2014 data (4)

3.3.5 MIKE SHE: Long-term Simulation, Proposed Conditions without Mitigation

The proposed development area in SL22 is North Division which is shown in Figure 37: Location of Proposed Development Area - North Division. The assumption is 60% of North Division is paved surface but there is no grading change, i.e. ground surface in North Division remained unchanged.

Figure 37: Location of Proposed Development Area - North Division

MIKE SHE's Ponded Drainage Feature was used to implement development area, and this feature was developed to support green infrastructure such Low Impact Developments (LIDs) and Sustainable Urban Drainage (SUDs). MIKE SHE's Ponded Drainage Feature allows directly drain storm water to internal depressions, boundaries and streams and paved surface areas was integrated into reduced surface-subsurface leakage function.

A long term simulation was carried out for period of 6/1/1996 – 12/30/2009 (13 years) without mitigation measure for post condition.

3.3.6 MIKE SHE: Long-term Simulation, Proposed Conditions with Mitigation

A long term simulation was carried out for period of 6/1/1996 – 12/30/2009 (13 years) with mitigation measure for post condition by diverting surface runoff from paved surface directly to wetland using MIKE SHE Ponded Drainage Feature. Figure 38 shows the diverted flow from paved surface in North Division to wetland, Figure 39 shows the comparison of water levels between No Mitigation and With Mitigation and Figure 40 shows the comparison of wetland depth and extent between No Mitigation and With Mitigation.

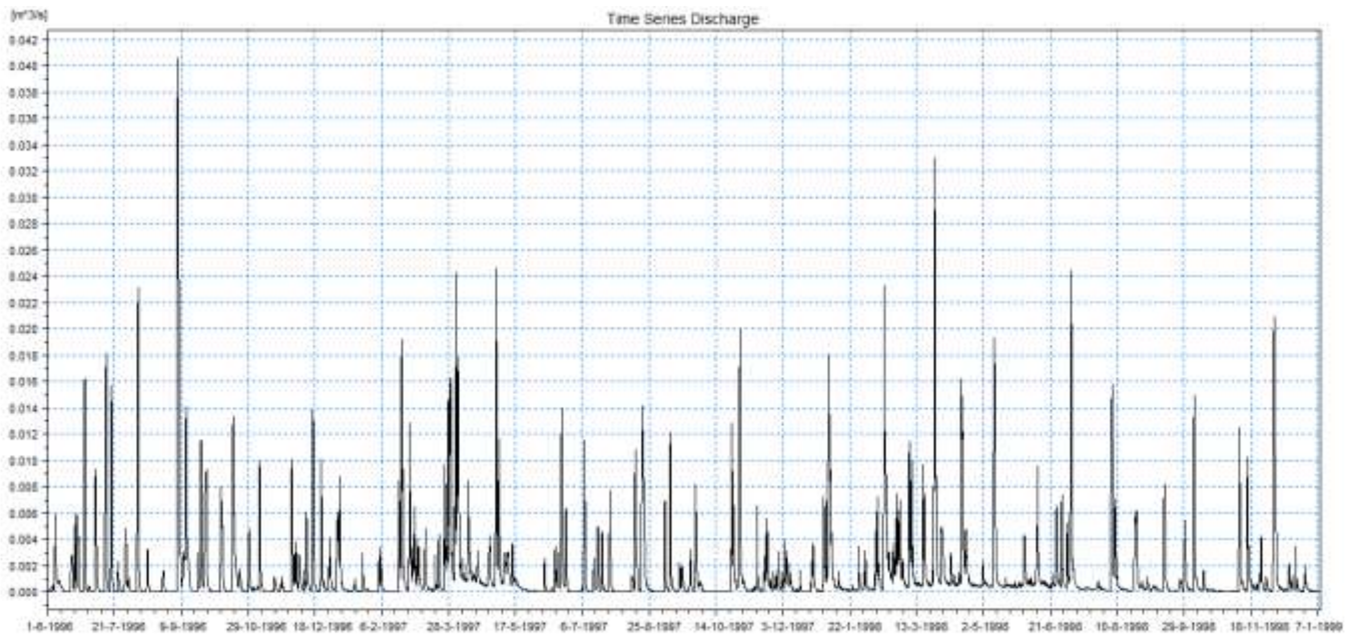


Figure 38: Diverted flow from North Division to Wetland

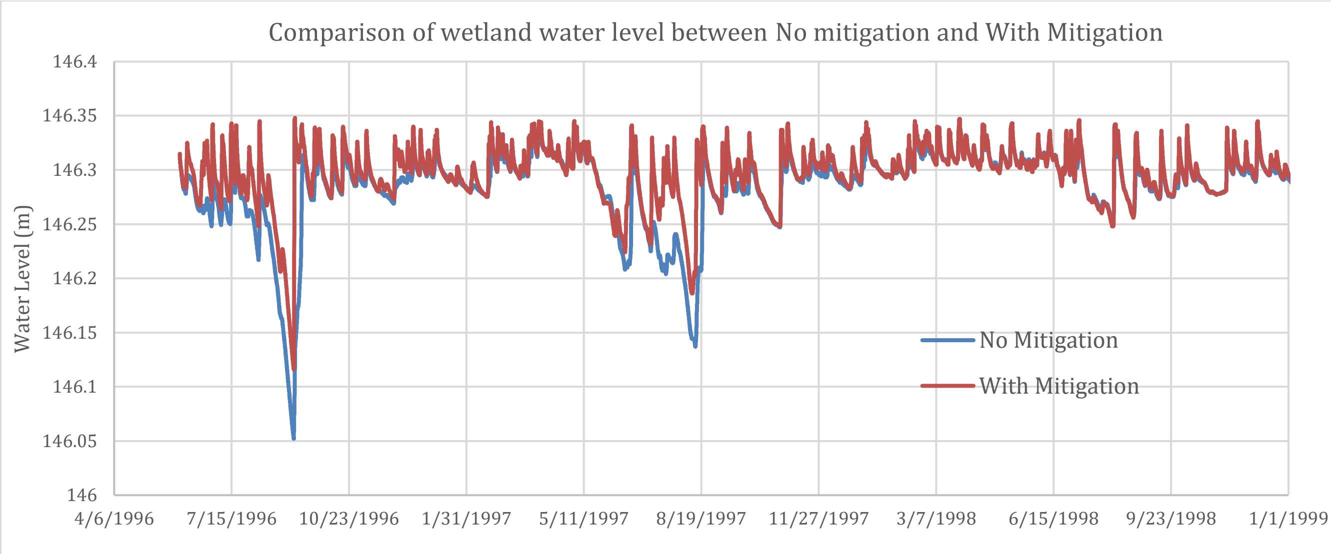


Figure 39: Comparison of wetland water levels between No Mitigation and With Mitigation scenarios

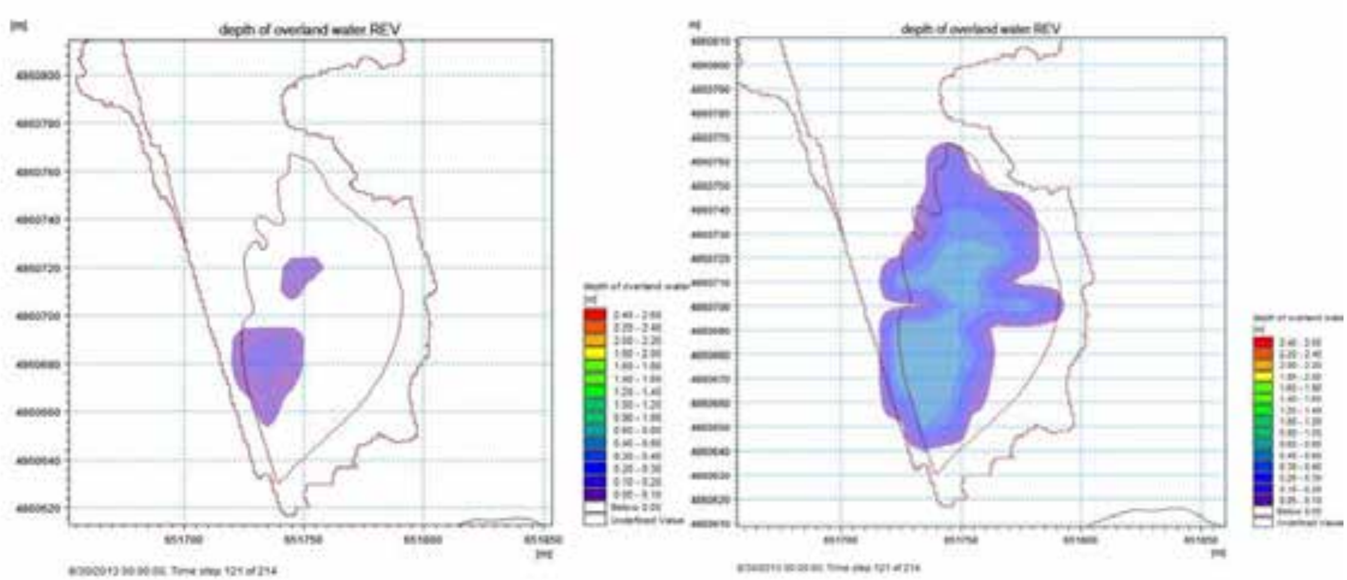


Figure 40: Comparison of wetland water depth and extent between No Mitigation (left) and With Mitigation (right)

3.3.7 MIKE SHE: Benefits, Challenges, Recommendations and References

Benefits

- A well-developed graphical user interface that strongly aids in model construction, debugging and calibration phases as well as ongoing pre and post processing of model data during these phases.
- The ability to import input data as GIS surfaces or shape files directly into the model greatly expedites the model construction phase and reduces the possibility of data conversion errors.
- Input dataset can have different spatial resolution (e.g. finer grid than model grid) and time interval (e.g. shorter time interval than model time steps) as model used.
- Scalable modular structure and multiple algorithms allow certain processes to be simplified, and allow to focus on properly representing other processes.

- MIKE SHE generates calibration plots with common used statistics during simulation that helps speed up the calibration process.
- MIKE SHE includes Ponded Drainage feature that supports LIDs and SUDs green infrastructure and makes implementation of proposed development much easier.
- MIKE SHE includes water budget calculation tool that can calculates water balance on both model domain basis and sub-catchment/area basis, and produces water balance items such as precipitation, actual evapotranspiration, infiltration/recharge, surface runoff, exchange flow between river/wetland and aquifer etc.
- MIKE SHE generates variety of output (timeseries, 2D time varying outputs and 3D groundwater outputs), especially 2D time varying depth of overland output that can be used to analyze wetland hydroperiod.

Challenges

- MIKE SHE uses uniform grid. By not being able to increase the spatial resolution locally within areas of interest, the modeler needs to increase the resolution globally or create a regional model prior to build a local scale model focusing on area of interest. This increases the level of complexity throughout the model, and adds considerably to the computational requirements or effort of model construction.
- MIKE SHE is physical-based, highly parameterized model, and therefore requires extensive model data and physical parameters. Calibration of model can be challenge sometime.
- Model use requires a great deal of technical expertise and the learning curve is steep for new modelers.
- Source code is not available to the public. The proprietary source code of MIKE SHE is also a limitation in that users cannot examine or modify the source code of the model.
- MIKE SHE is not free software. Prices range from approximately CAD $14,160 for government agencies to CAD $17,700 for standard commercial use, and the annual cost of the service agreement is approximately CAD $5,000.

Recommendations

- MIKE SHE is well suitable for wetland study for both short-term and long-term simulations.
- MIKE SHE has capability to model impact of development due to land use change and model mitigation measure using Ponded Drainage feature.

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3.4 Visual Otthymo 5 (VO5)

3.4.1 VO5: Background

Visual OTTHYMO (VO) is a hydrologic modelling software which primarily uses the HYMO model engine developed by J.R. Williams in 1973. This engine was further developed at the University of Ottawa, where it was named OTTHYMO 83. The first graphical interface was developed by the founder of Civica in 1998 (Visual OTTHYMO 1.0). VO is currently being developed by Civica Infrastructure, and additional features and commands continue to be added.

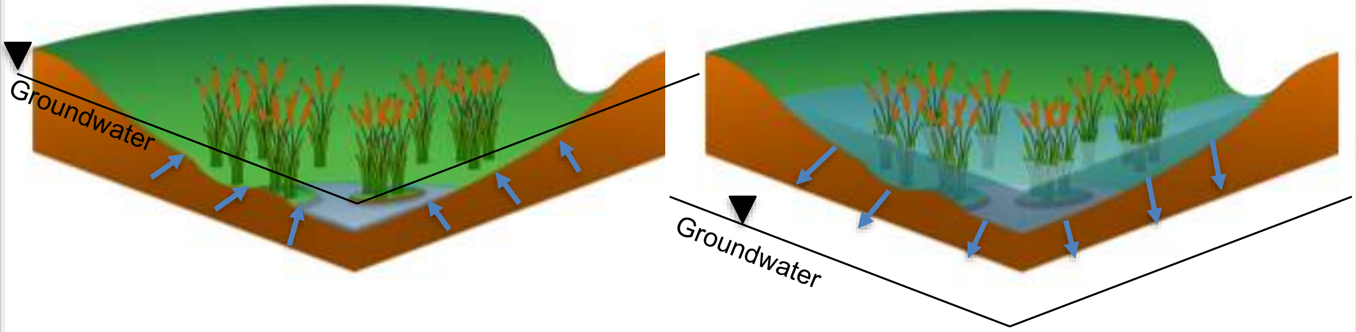
The continuous version of VO (5.0) was released in 2017 with the ability to simulate snow melt, infiltration, evapotranspiration and groundwater infiltration. Continuous VO uses the same commands as the single event simulation (with some additional parameters required for continuous modelling). The approach used for the continuous engine is as follows:

- Snow accumulation, compaction, refreezing and melt is modelled using the approach in GASWER model;
- Infiltration is modeled using the SCS equation to account for soil moisture and unit hydrographs are used to transform the excess rainfall to runoff;
- Flow is routed through channels and reservoirs using the variable storage coefficient method;
- Routing through reservoirs is modeled using the storage indication method.
- Evapotranspiration can be entered as Potential evapotranspiration,

The wetland command is a new feature added to VO 5.0 in 2018. This command is designed to model all the hydrologic processes in a wetland including inflow, evaporation, seepage and outflow. The interface for the wetland command is similar to that used in continuous VO, however a groundwater component has been added to the wetland. Groundwater seepage into and out of the wetland are calculated using Darcy's equation and the difference in elevation between the ground water and either the stored water or, if the wetland is dry, the bottom of the wetland.

Features specific to the VO5 water balance are as follows:

Ground water elevations are treated as model parameters and are entered as a time series similar to the way precipitation is added to a model. This means you do not have to calibrate an aquifer component in your model to represent the ground water interactions with a wetland.

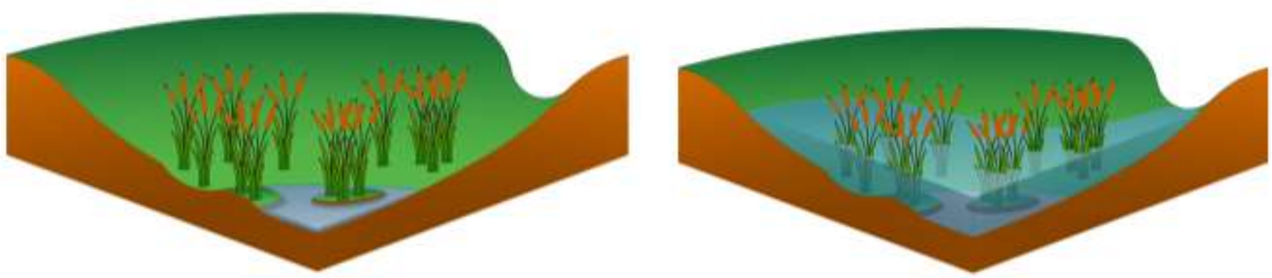


If the groundwater is higher than the surface water, ground water seeps into the wetland.

If the groundwater is lower than the surface water, then surface water seeps into the ground.

Figure 41: Groundwater Impacts on Wetland

The wetland command combines a rural runoff command (NasHYD) and a Route Reservoir command to model dry and wet areas of the wetland. These areas change size as the wetland storage area fills and drains. This allows users to more accurately model the runoff generated by the dry area of a wetland.



Dry Area = 9.0 ha
Storage Area = 1.0 ha
Wetland Area = 10 ha

Dry Area = 3.0 ha
Storage Area = 7.0 ha
Wetland Area = 10 ha

Figure 42: Dynamic wet and dry areas in wetland

The user interface for this model is simple to use and guidance on parameter selection is provided through direct links to the user manual. The model also provides tools for model calibration and produces easy to follow result summaries and scenario comparison reports.

3.4.2 VO5: Model Setup, Existing Conditions

The VO5 model was simple to set up; only an upstream drainage area and the wetland were included in our model. The data required to complete the wetland water balance in VO5 is summarized in Table 10.

Table 10: Data required for VO5 Wetland Water Balance model

	Upstream catchment	Wetland
Command Used	NasHYD	RouteWetland
Topography	10-m DEM, 1-m LiDAR, wetland bathymetry Provided by TRCA	Depth/area and depth/outflow curves provided by TRCA
Land Cover	Air photo and TRCA land use classification (Refer to **Figure 43**)	
Soil data	Data from existing geotechnical reports	
Ground water levels	1-hr groundwater level data from piezometers at multiple depths within wetland; data Provided by TRCA	
Water Levels	1-hr surface water level data from piezometers at multiple depths within wetland; data Provided by TRCA	
Precipitation (Rain / Snow)	5-min precipitation from nearby Brock West Landfill station (provide by TRCA)	
Evapotranspiration	Daily PET calculated by TRCA using Hargreaves Equation	
Temperature	Daily min / max temperature provided by TRCA	

The data summarized in Table 10 was used to assign parameters to the upstream drainage area and wetland. Model parameters for the wetland are summarized in **Figure 43: Land Use for Sideline** 26 **Wetland**

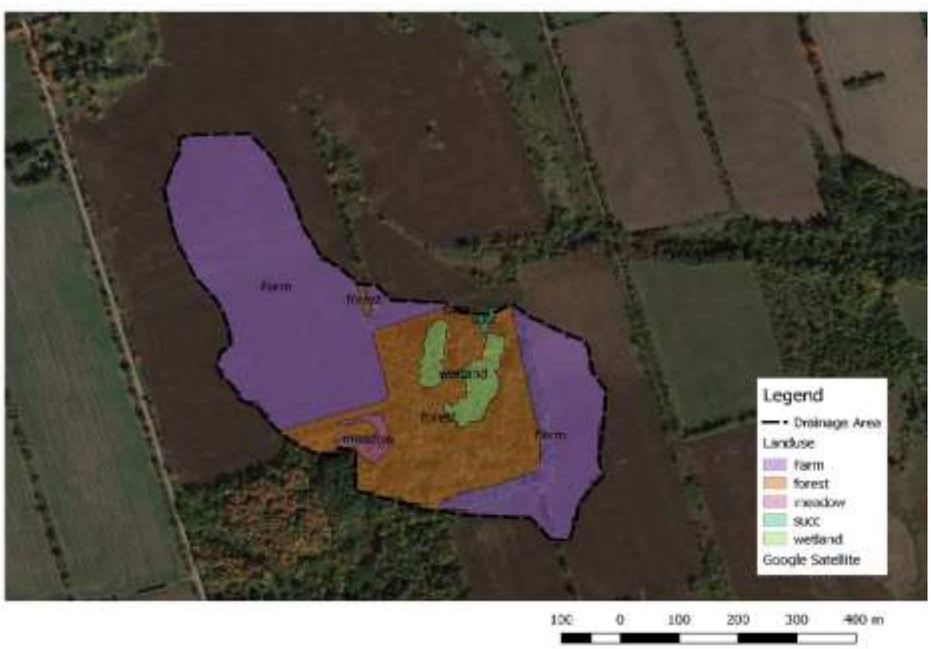


Table 11 and Table 12**.**

Figure 43: Land Use for Sideline 26 Wetland

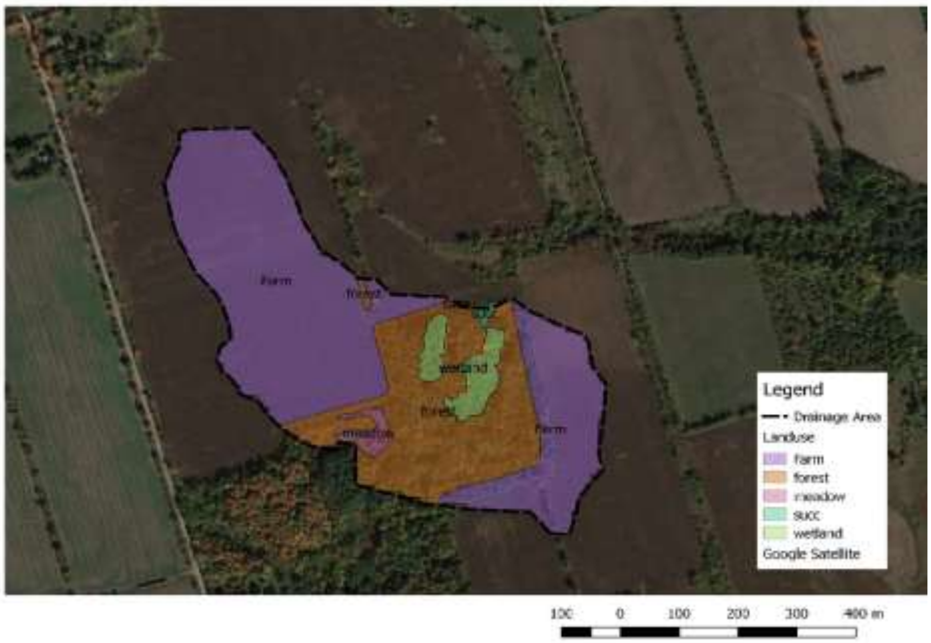


Table 11: Continuous NasHyd Parameter Table (Sideline 26)

Parameter	Description	Upstream Drainage Area
Command		NasHyd
Area (ha)	Drainage area calculated using topography and watercourse layers	28 ha
CN	Curve number used for SCS	68
IA (mm)	Pervious Area Depression Storage	8 mm
Inter event time	Minimum amount of time without precipitation required to define a new event	4 hr
N	Number of linear reservoirs	3.0
TP (hr)	Time to peak	0.66 hrs
Land Cover	General description of vegetation	Crops to shoulder height
K	K = GI /Pan Evaporation - Growth index of a crop / Pan Evaporation. Used to estimate potential evapotranspiration.	1.4
VEGK3	ET opportunity coefficient, used to calculate ET from soil	6.0
Soil Texture	Description of soil base on relative content of sand, silt, clay particles	Clay Loam
Total Porosity	Fraction of soil that is made up of spaces (pores) between particles	0.464

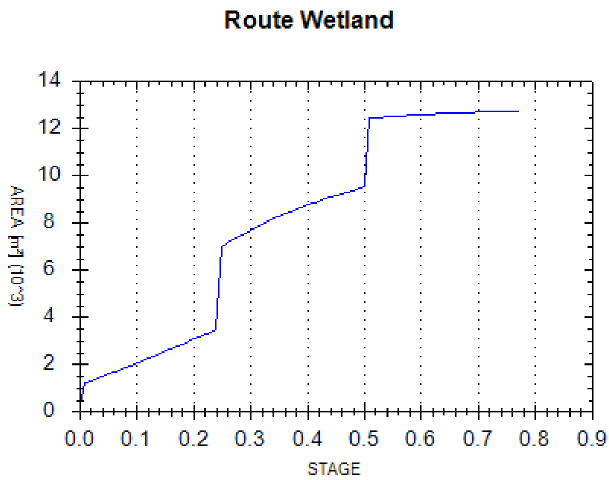
Field Capacity	Soil moisture held in soil after excess water has drained away	0.310
Wilting Point	Moisture left in dry soil that is not accessible to plants, causing them to wilt	0.187
Saturated K (mm/day)	Hydraulic conductivity of the soil when saturated, represent the ease at which moisture can move through a soil in which all easily drained pore spec is filled with liquid.	24.38 mm/day

Table 12: Wetland Parameter Table (Sideline 26)

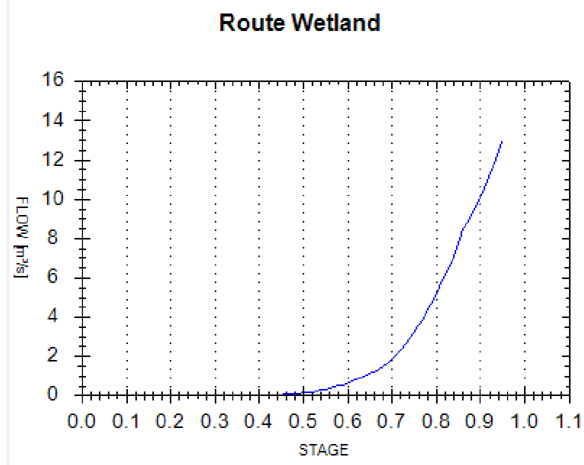
Parameter	Description	Wetland
Command		RouteWetland
Storage Area Geometry		
Initial water Depth (m)	Depth of water in the wetland at the start of a model run	0.40m
Bottom Elevation (m)	Elevation at the lowest point in the wetland	189.96m
Depth Area Curve	Depth area curve for the entire wetland (Dry and wet areas), Starts at the bottom elevation of the wetland	See Error! R eference source not found.
Storage Area - Soil		
Soil Thickness (m)	Thickness of the soil layer constraining movement between surface and ground water	1.5m
Hydraulic Conductivity (mm/day)	Saturated hydraulic conductivity for soils in areas with ponded water, represent the ease at which moisture can move through a soil in which all easily drained pore space is filled with liquid	1800 mm/day
Fringe Area		
Soil Texture	Description of soil base on relative content of sand, silt, clay particles	Clay Loam
Total Porosity	Fraction of soil that is made up of spaces (pores) between particles	0.464
Field Capacity	Soil moisture held in soil after excess water has drained away	0.310
Wilting Point	Moisture left in dry soil that is not accessible to plants, causing them to wilt	0.187
Saturated K (mm/day)	Hydraulic conductivity of the soil in dry areas when saturated, represent the ease at which moisture can move through a soil in which all easily drained pore spec is filled with liquid	24.38 mm/day
CN	Curve number used for SCS	68
IA (mm)	Pervious Area Depression Storage	10 mm
Evapotranspiration		
Land Cover	General description of vegetation	Crops to shoulder height
k	K = GI /Pan Evaporation - Growth index of a crop / Pan Evaporation	1.4
VEGK3	ET opportunity coefficient, used to calculate ET from soil	6.0
Outlet		
Type	Choice of method for defining outlet (Currently only Stage Discharge is available)	Stage Discharge

Discharge Curve	Depth discharge curve for the wetland, depth is defined from the bottom elevation of the wetland	Refer to Error! Reference source not found.

Figure 44: Depth Area and Depth Discharge Curves for the Sideline 26 Wetland



Stage vs Area Curve



Stage vs Discharge Curve

Although there are two distinct pool in this wetland only one stage area curve was used, this being the total area in the wetland for each depth starting with the lowest elevation in the wetland. Figure 45 shows the user interface once the upstream area and wetland were linked together in the model.

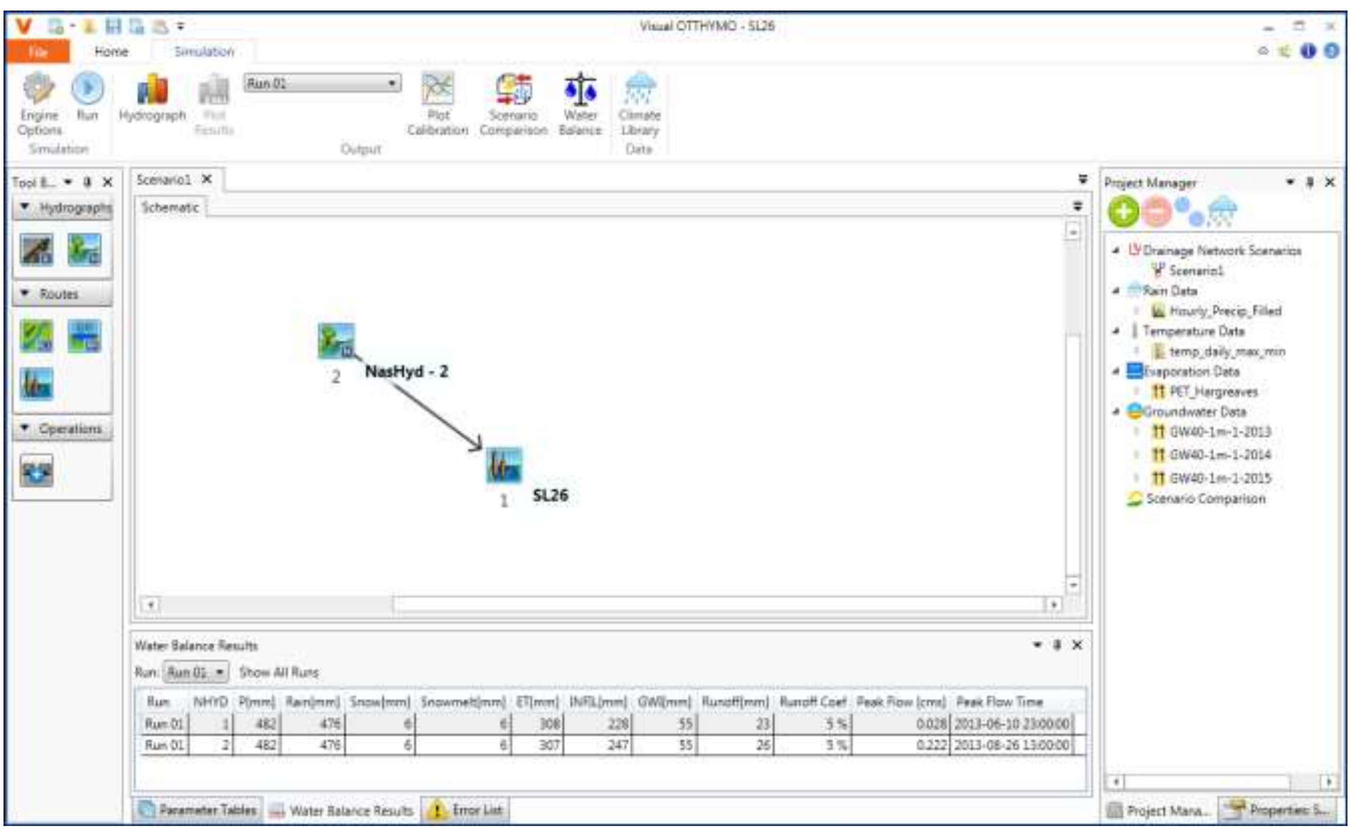


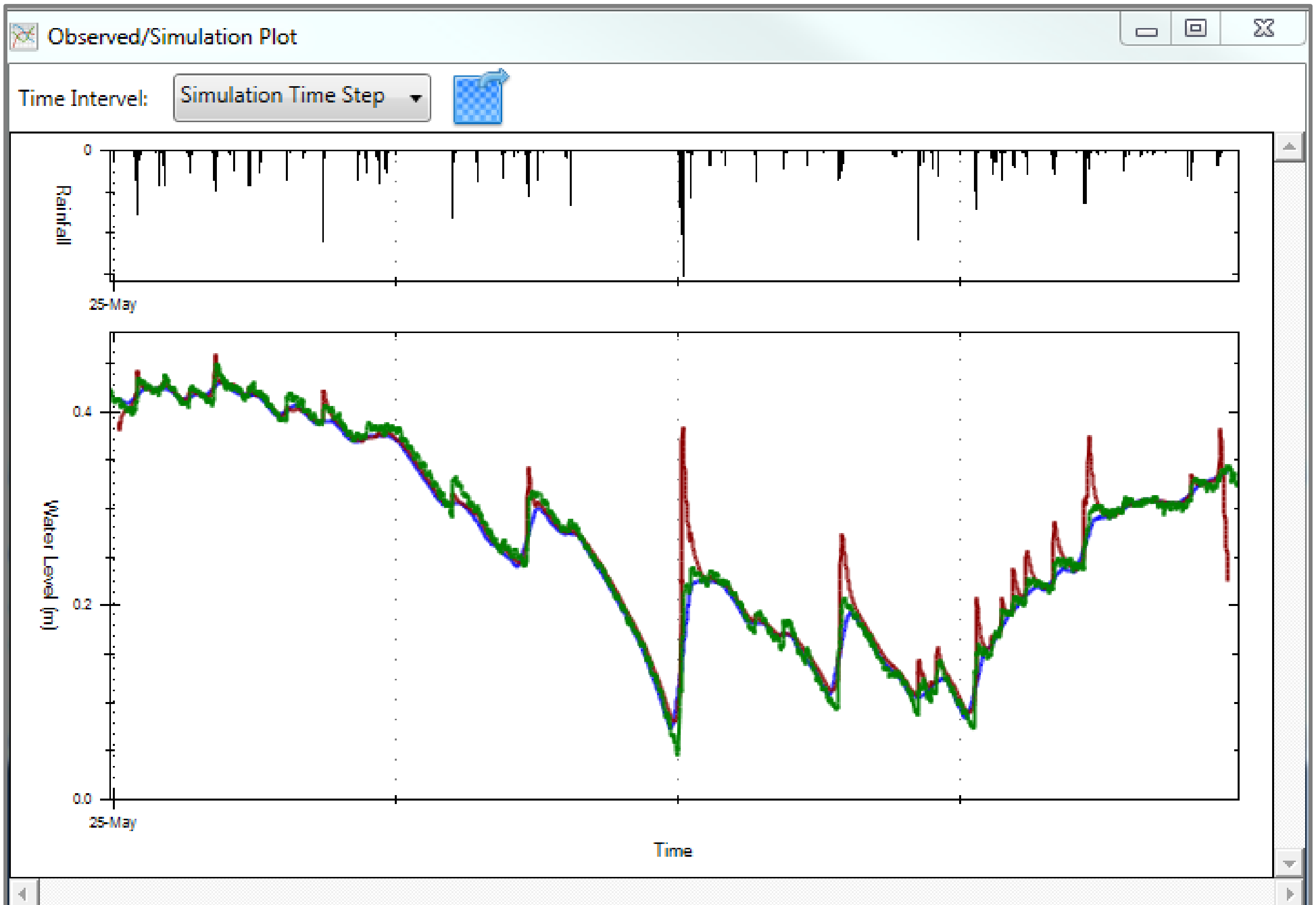
Figure 45: VO5 model schematic

For more complex wetland systems multiple wetland and drainage areas can be added to the model and either diretly linked or linked through route channel and route pipe commands. For a simple wetland such as this one the model build time is approximately 2 days to review and convert data to the appropriate file formats and 2 hours to build the model. Climate data and groundwater time series are .csv files formated as follows:

- Precipitation
  - Column 1 – Date / Time (year/month/day hour:minutes:seconds)
  - Column 2 – Value (mm)
- Temperature
  - Column 1 – Date (year/month/day)
  - Column 2 – Minimum Value (^{0}C)
  - Column 3 – Maximum Value (^{0}C)
- Evapotranspiration
  - Column 1 – Date (year/month/day)
  - Column 2 – Value (mm)
- Groundwater Elevations (at the lowest point in the wetland)
  - Column 1 – Date / Time (year/month/day hour:minutes:seconds)
  - Column 2 – Value (masl)

3.4.3 VO5: Calibration, Existing Conditions

Once the wetland was built, the model was calibrated using the monitoring data for 2013. The VO5 calibration interface allows users to graph modeled and monitored water levels providing users with a visual representation of the calibration after each run. Statistics (percent difference in water level, Coefficient of determination (R^2) and Nash Sutcliffe (NSE)) are shown at the bottom of the graph to quantify the calibration results.



Interval	Percent Difference (%)	R2	NSE
Daily	1.219	0.985	0.983
Weekly	1.006	0.995	0.992
Monthly	0.843	0.999	0.997

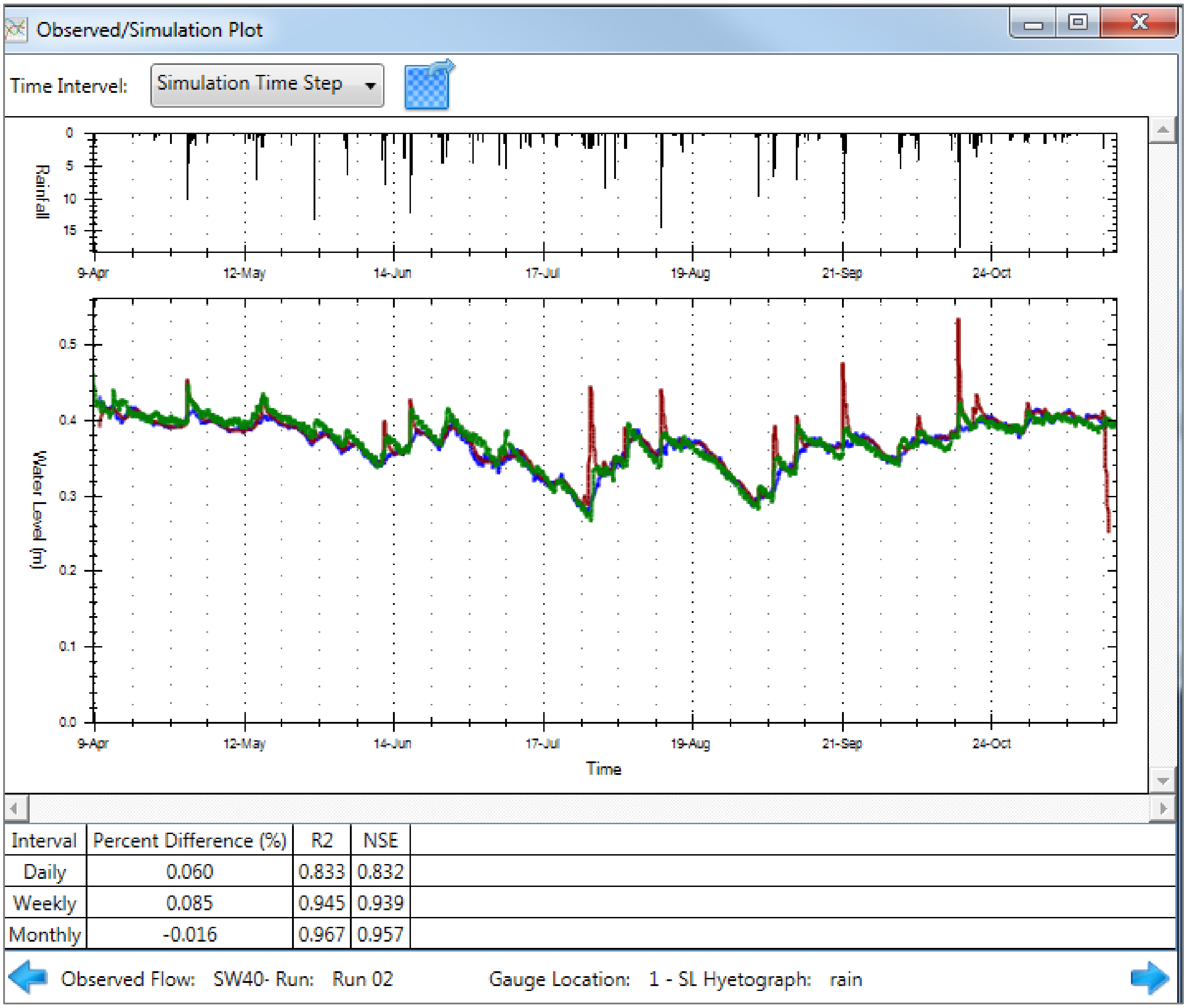
Observed Flow: SW40- Run: Run 01 Gauge Location: 1 - SL Hyetograph: rain

Figure 46: Sideline 26 Wetland Calibration Results (2013)

As can be seen in Figure 46 the modeled data (shown in red) matches closely with the monitored data (shown in green). The blue line shows the ground water elevations used in the model. The statistics provided at the bottom of the graph also support a strong correlation between modeled and monitored data.

3.4.4 VO5: Validation, Existing Conditions

The model was then validated using monitored data from 2014 and 2015. Model validation results are provided in Figure 47 and **Figure 48** respectively. As with the model calibration the validation runs show a close match to the monitored data.



Interval	Percent Difference (%)	R2	NSE
Daily	0.060	0.833	0.832
Weekly	0.085	0.945	0.939
Monthly	-0.016	0.967	0.957

Figure 47: Sideline 26 Wetland Validation Results (2014)

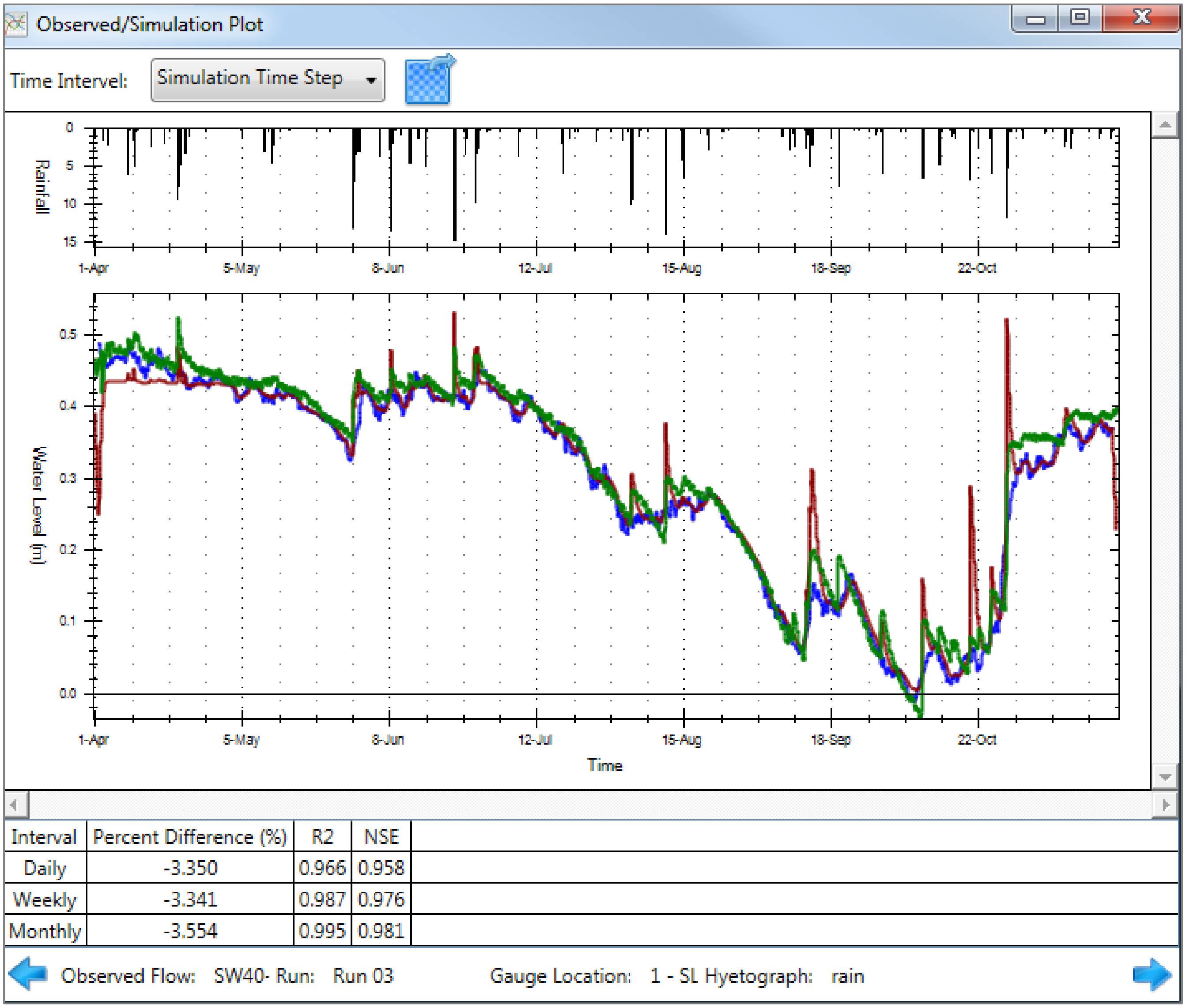


Figure 48: Sideline 26 Wetland Validation Results (2015)

3.4.5 VO5: Long-term Simulation, Proposed Conditions without Mitigation

Once the model provided a satisfactory representation of the wetland water levels for three years of monitoring data, set up was completed for the long-term simulation. This included inputting precipitation, temperature and evapotranspiration data provided by TRCA for 1991 – 2007 into the model. As groundwater levels were not available for this time period, the average values from the three years of data available were used, these groundwater patterns were repeated for each year.

A development scenario was then created in which 50% of the catchment area was diverted away from the wetland to simulate runoff being routed to a different outlet location. Given the current regulations protecting wetlands, this is often done in order to prevent large volumes of water from drowning the wetlands. The results of this flow diversion are shown on Figure 49 - Figure 51. Comparing the maximum water levels over the long-term scenario shows that the max water depth in the wetland drops from 0.553m to 0.520m while the average water level drops from 0.330m to 0.327m.

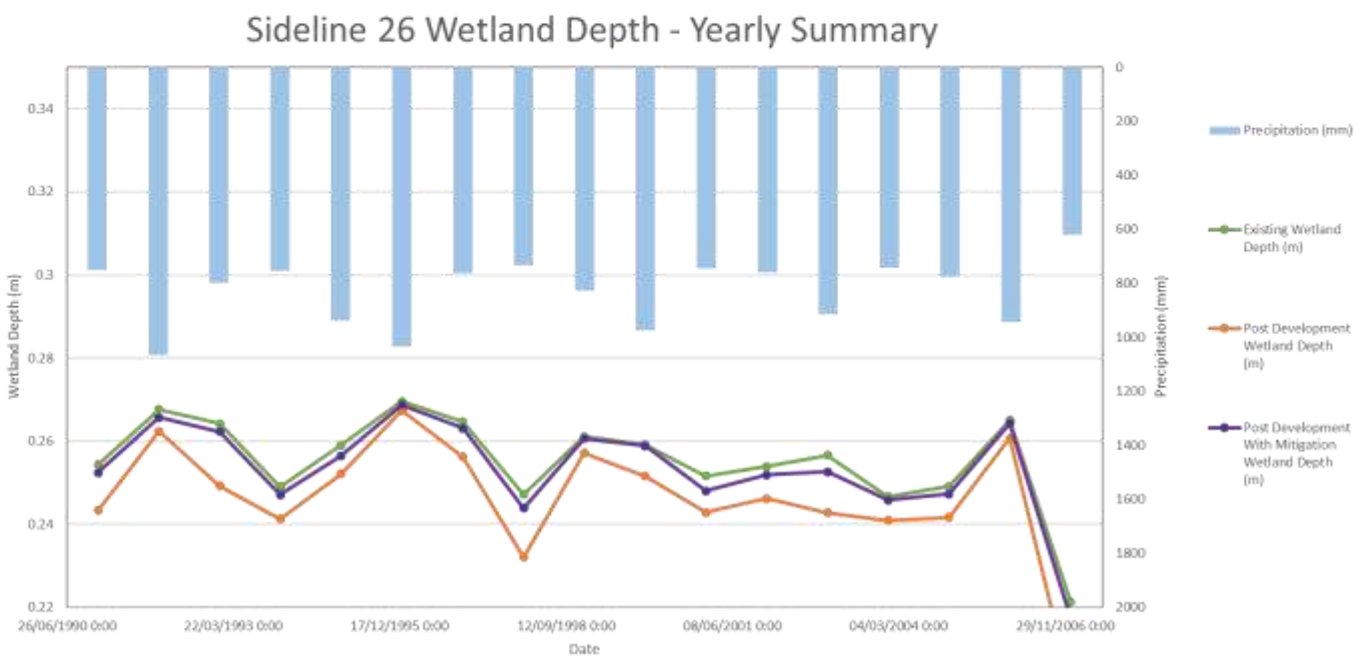


Figure 49: Average Annual Depth in Sideline 26 Wetland

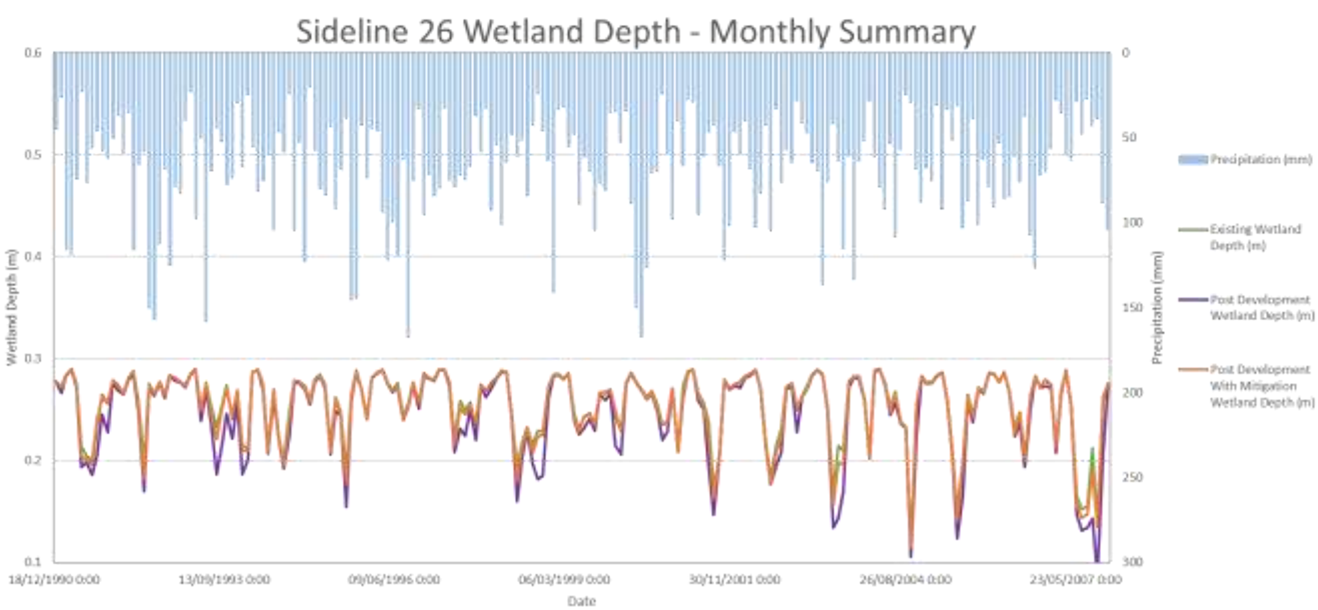


Figure 50: Average Monthly Depth in Sideline 26 Wetland

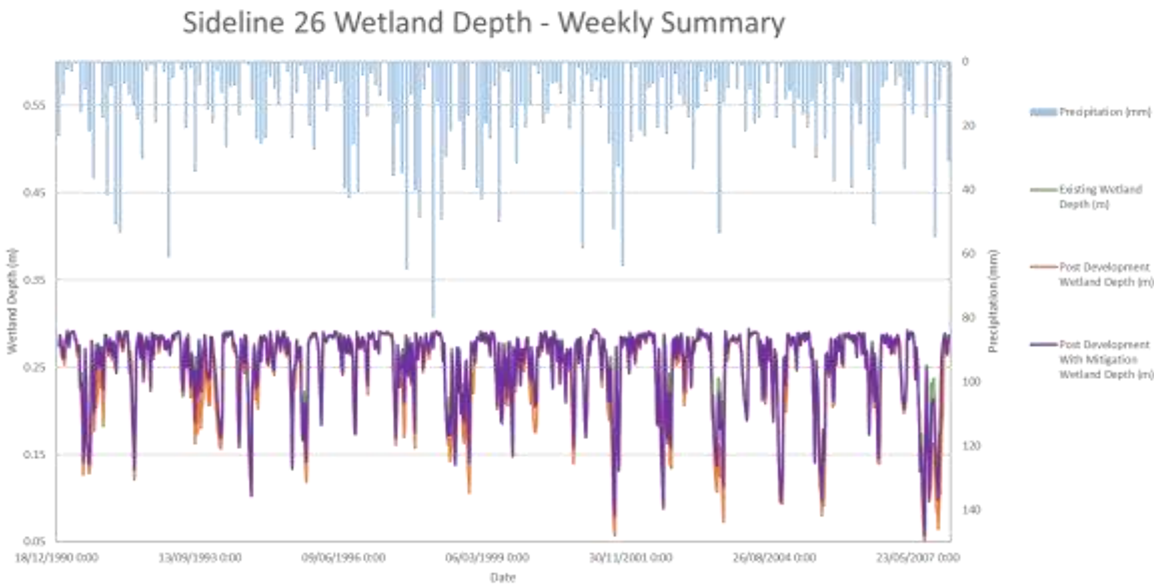


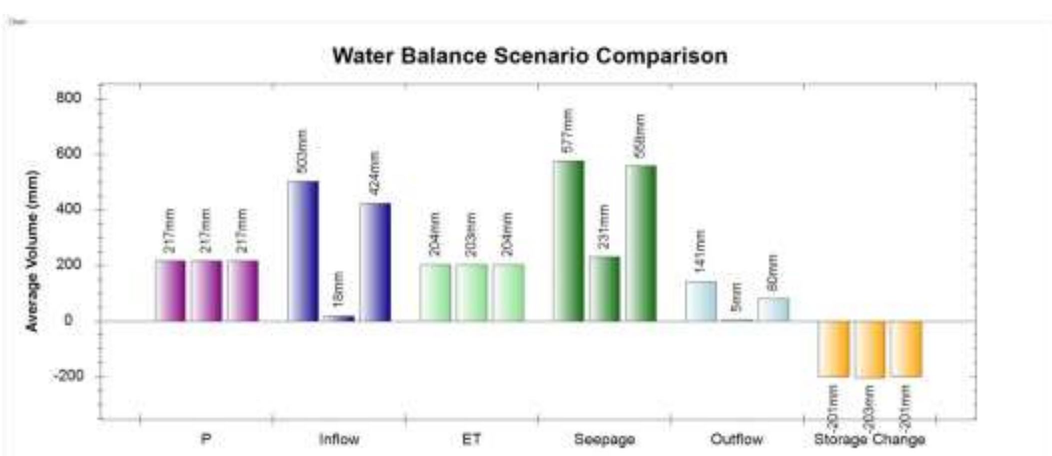
Figure 51: Average Weekly Depth in Sideline 26 Wetland

3.4.6 VO5: Long-term Simulation, Proposed Conditions with Mitigation

In order to simulate the mitigation scenario, a catchment was added to represent roof tops being directed to the wetland. A depression storage value of 10mm was used on the roof to catchment to mimic retention in a rain garden or bioretention cell upstream of the wetland, and a route reservoir was added to mimic the detention component of an LID. Using this methodology, the area of roofs and size of an upstream LID could be estimated in order to mitigate the impacts of the upstream development. The results of this mitigation are shown on Figure 49 - Figure 51. Comparing the maximum water levels over the long-term scenario shows that the maximum water depth in the wetland, which drop from 0.553m to 0.520m with development and no mitigation increase to 0.525m with mitigation. The average water level, which dropped from 0.330m to 0.327m in the scenario with no mitigation, is restored to 0.330m with mitigation.

Figure 52 summarizes the components of the wetland water balance on an annual, seasonal and monthly basis.

Figure 52: Sample water balance graph



3.4.7 VO5: Benefits, Challenges, Recommendations and References

Benefits

- Simple to use, generates defendable results. Having a command designed to represent a wetland makes modelling and calibration simpler than some other models, where different components are modeled separately (and potentially in multiple models).
- Having groundwater elevations as a model input simplifies building and calibrating the model. Although the impact of the wetland on the groundwater is not modeled, this model does use groundwater elevations to calculate soil saturation levels, changes in infiltration rates and groundwater seepage into the wetland.

Challenges

- As this is a hydrology model and does not model impact of the wetland on the local aquifer, it is only suitable for wetlands which do not have a large impact on the ground water. The model does not predict groundwater elevations and shows a water level of zero once the water level is below ground.
- Not having LIDs in the model made modelling mitigation a bit more challenging; however, VO developers intend to add LIDs functions to VO5 by the end of 2018.

Recommendations

- Discuss the use of this model with your local conservation authority prior to starting a water balance project as it is not suitable for use in wetlands which are primarily groundwater fed or for wetlands which may impact groundwater elevations. In most cases small wetlands will not have a noticeable impact on groundwater elevations as aquifers tend to have large catchments of which the wetland is only a small component.
- It is important when setting up a wetland model in VO that the groundwater, depth area curve and stage discharge curve are all generated relative to the lowest point in the wetland. If ground water elevations are not measured at the lowest point in the wetland, it may be necessary to adjust these elevations, in consultation with a hydrogeologist or geotechnical engineer, to represent groundwater levels at the lowest point in the wetland.

References

Visual OTTHYMO User Manual, Civica infrastructure Inc, August 2017 -
http://visualotthymo.com/downloads/v5.0_usermanual.pdf

Visual OTTHYMO Reference Manual, Civica infrastructure Inc, March 2017
http://visualotthymo.com/downloads/Reference%20Manual%20-%20VO5.pdf

3.5 Storm Water Management Model (SWMM)

3.5.1 SWMM: Background

First developed in 1971 by the United States Environmental Protection Agency (EPA), the Storm Water Management Model (SWMM) is a dynamic rainfall-runoff simulation model that allows for both single event and continuous (long-term) simulation of runoff quantity and quality. It is geared towards analysis of urban and urbanizing catchments. The current version (SWMM 5) provides an integrated modelling environment for editing the properties of subcatchments and flow routing networks, running hydrologic, hydraulic, and water quality simulations, and viewing simulation results. The runoff component of SWMM simulates generation of runoff and pollutant loads from various subcatchment areas, while the routing component simulates the transport of runoff and pollutants through both natural and engineered flow networks. Model capabilities are summarized below in Table 13.

Table 13: SWMM model features summary

Model Features	SWMM
Model Type	Physically-based lumped parameter
Simulation Type	Single-event/continuous
Precipitation	Multiple/single hyetograph
Snow Melt	Heat budget equation, areal depletion curves, and modified degree-day
Evapotranspiration	Evaporation from water stored at surface and in soil; PET input as timeseries or computed from temperature using Hargreaves method
Infiltration	Horton infiltration
	Modified Horton infiltration
	Green-Ampt infiltration
	Modified Green-Ampt infiltration
	Curve Number infiltration
Overland Flow	Nonlinear reservoir routing
Subsurface Soil Water Flow	Vertical exchanges within 2-zone groundwater layer (saturated/unsaturated)
Channel/Reservoir	1D dynamic wave approximation
	1D kinematic wave flow
Groundwater Flow	Vertical exchange within 2-zone groundwater layer; lateral exchange with drainage network nodes (but not between subcatchments)
GIS interface	Accept GIS format data including point/contour/polygon /polyline/ASCII

EPA-SWMM is provided free of charge and is available for download at https://www.epa.gov. Various proprietary graphical user interfaces have been developed using the SWMM 5 engine (e.g. PC-SWMM, XP-SWMM), and can facilitate the editing of subcatchment and flow network properties and the viewing and exporting of data, but the underlying fundamental representation of hydrologic processes remains the same. See Rossman (2015) for a detailed description of model representation of hydrologic processes.

3.5.2 SWMM: Model Setup, Existing Conditions

The SWMM engine (using the PC-SWMM graphical user interface) was used to model two different wetland catchments, both of which are to the north of Taunton Road in Pickering, Ontario. The sites are referred to as Sideline 22 and Sideline 26; detailed descriptions and of both sites are provided in sections 3.1.2, 3.2.2, 3.3.2, and 3.4.2, with accompanying figures.

The data used to determine the conceptual water balance and in model set-up is outlined in Table 14 below, along with the data source.

Table 14: SWMM data types and sources

Data Type	Data Sources
Topography	10-m DEM; sub-centimeter resolution field topographic/bathymetric survey of wetland basins used to derive stage-storage curves
Climate data	5-min precipitation and temperature from nearby Brock West Landfill station (~3.0 km from study sites)
Land use	TRCA land use data; hypothetical post-development land use and catchment parameters
Soil data	Data from existing geotechnical reports and hand-augured soil samples; slug test-derived hydraulic conductivity estimates
Channel	TRCA DEM-derived drainage lines
Groundwater	Static groundwater level measurements from consultant hydrogeological reports ; slug test-derived hydraulic conductivity estimates
Water Level Monitoring	1-hr surface water and groundwater level data from piezometers at multiple depths within wetland; data covers growing season of 2013 and 2014; 2013 data used to calibrate models and 2014 to validate

Prior to calibration and validation of the models, a conceptual water balance model for each site was created based on the water transfer mechanisms known to exist or suspected of being present at each site. Conceptual models considered data on wetland hydrogeomorphic and hydrogeological setting, known spillway elevations, and ecological indicators of hydrological conditions. The conceptual water balance models for the two sites consisted of the following terms:

a. Sideline 22: $P + RO + GW_{in} - ET - GW_{out,L} = \Delta S + residual$

b. Sideline 26:

i. Basin 1: $P + RO + GW_{in,L} - ET - GW/SW_{out\ (to\ Basin\ 2)} = \Delta S + residual$

ii. Basin 2: $P + RO + GW/SW_{in\ (from\ Basin\ 1)} - ET - GW_{out,V} - GW/SW_{out,L} - SW_{out} = \Delta S + residual$

where P is precipitation, RO is overland runoff, GW_{in} is groundwater inflow (both vertical and lateral components, unless specified by subscript), ET is evapotranspiration, GW_{out} is groundwater outflow (both vertical and lateral components, unless specified by subscript), SW_{out} is channelized surface water outflow, ΔS is the change in volumetric storage, and *residual* is the residual error term. Where surface water and groundwater terms are showed together in combination, it indicates that subsurface volumetric storage above the water table (i.e. interflow) was included together with overland flow.

After determining the terms of the wetland water balance equations for each, the following general approach was used in the calibration and validation process for the models under existing conditions:

1. Where possible, independently estimate known inputs, outputs, and storage changes along with their corresponding uncertainties;
2. Determine the terms of the water balance associated with the greatest amount of error based on analysis of wetland storage response monthly water balance analysis;
3. Evaluate the relative contribution of water transfer mechanisms and the temporal variability of these contributions to the water balance.

3.5.3 SWMM: Calibration, Existing Conditions

The simulation settings used for both the calibration and validation of the model are summarized in Table 15.

Table 15: SWMM simulation settings for calibration and validation

Climatology and simulation options	1-hr dry weather time step, 5-min wet-weather time step, 30-s routing time step; *ET* calculated using Hargreaves method and inputs of daily precipitation totals, maximum and minimum temperatures
Wetland parameterization	Wetland represented as dynamic storage feature; detailed stage-storage curve was defined to account for open water, bank storage, and subsurface storage; calibration focused on wetland storage response to precipitation events
Catchment and aquifer parameterization	Multiple upstream catchments defined for both wetlands based on shared land use and soil drainage properties; one aquifer unit defined for all upstream catchments for both wetlands; aquifer properties defined using combination of local and regional geological data
Groundwater interaction	Wetlands received groundwater flow from upstream aquifer units; for Sideline 26, observed vertical losses simulated using seepage parameters; for Sideline 22, wetland lateral losses to groundwater were simulated using a downstream catchment and aquifer unit
Sensitivity, calibration and validation	Parameter sensitivity analysis performed; calibration and validation assessed using both visual and statistical (e.g. Nash-Sutcliffe efficiency) measures

Monitored surface water and groundwater level data collected at both Sideline 22 and Sideline 26 in the growing seasons of 2013 and 2014 was used to calibrate the model. An iterative process was followed to simulate wetland storage dynamics, whereby water transfer mechanisms were added one at a time to an initial simple water balance equation to try and mimic wetland storage dynamics under both wet and dry conditions. The following summarizes the general process that was followed to calibrate the wetland hydrology models for a) Sideline 22 and b) Sideline 26:

a. Sideline 22
   i. Parameterize catchment and perform sensitivity analysis
   ii. Incorporate wetland and stage-storage curve
   iii. Compare simulation results to observed surface water levels (monitoring data)
   iv. Refine stage-storage curve to include subsurface (extend curve to reflect depth-dependent specific yield of soils)
   v. Compare simulation results to observed groundwater levels (monitoring data)
   vi. Incorporate groundwater inflow
   vii. Compare simulation results to observed groundwater levels (monitoring data)
   viii. Investigate options for simulating groundwater outflow (orifice loss versus DS catchment)
   ix. Calibrate and validate model for both groundwater outflow scenarios

b. Sideline 26
   i. Parameterize catchment and perform sensitivity analysis
   ii. Incorporate two wetland basins and stage-storage curve
   iii. Compare simulation results to observed surface water levels (monitoring data)
   iv. Refine stage-storage curve to include subsurface (extend curve to reflect depth-dependent specific yield of soils)
   v. Compare simulation results to observed groundwater levels (monitoring data)
   vi. Incorporate estimated groundwater inflow
   vii. Compare simulation results to observed groundwater levels (monitoring data)
   viii. Add spillover overland flow connection from Basin 1 to Basin 2
   ix. Compare simulation results to observed groundwater levels (monitoring data)
   x. Add subsurface outflow pathways from Basins 1 and 2
   xi. Calibrate and validate model

The stage storage curves for both wetlands were defined using a combination of high resolution topographic/bathymetric survey data and estimates of soil specific yield (S_y) to account for changes in volumetric storage occurring in the subsurface zone. Different specific yield values were used for Areas 1 and 2; initial estimates of the specific yield terms were derived from Gasca and Ross (2009). Figure 53 depicts the process that was used to determine ΔS (volumetric storage, i.e. the wetland hydroperiod) for the model calibration and validation.

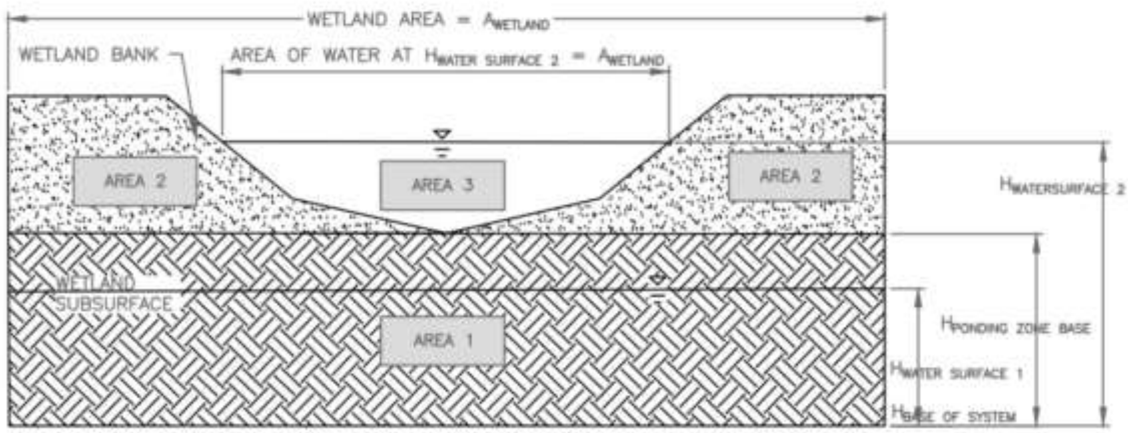


Figure 53: Calculation of total volumetric storage, incorporating specific yield (from Charbonneau, 2016)

The volumes for the respective reservoirs outlined in Figure 53 were calculated as follows:

$$V_{Area\ 1} = A_{wetland} \times (h_{water\ surface} - h_{base\ of\ system}) \times S_{y,subsurface}$$

$$V_{Area\ 2} = (A_{wetland} - A_{water\ surface}) \times (h_{water\ surface} - h_{base\ of\ ponding\ zone}) \times S_{y,banks}$$

$$V_{Area\ 3} = Surveyed\ wetland\ basin\ volume$$

$$\Delta S \begin{cases} \text{If water level < ponding zone base} = V_{Area\ 1} \\ \text{If water level > ponding zone base} = V_{Area\ 1} + V_{Area\ 2} + V_{Area\ 3} \end{cases}$$

An analysis of diurnal water level variations during several dry periods (periods with minimal 7-day antecedent rainfall during which no events >2 mm occurred) was used to isolate ET and vertical groundwater inflow fluxes following the method of McLaughlin and Cohen (2014). This method allowed the magnitude of these two terms to be estimated independently. For Sideline 26, owing to the relatively low conductivity soils within the catchment, it was assumed that there was no groundwater entering the wetland, and a small vertical outflow of groundwater from Basin 2 was identified through the monitored vertical hydraulic gradients. For Sideline 22, only vertical groundwater inflow was considered, while lateral groundwater outflow was identified as an important water transfer mechanism. Two methods were explored to replicate this water transfer mechanism in SWMM: 1) groundwater interactions within a downstream subcatchment aquifer unit, and; 2) outflow from the storage unit via an orifice. For the first method, an additional subcatchment with an aquifer unit associated with it was added to the model, and negative groundwater coefficients were added to the model to simulate groundwater outflow. For the second method, a circular orifice was added to the base of the wetland storage unit, and the coefficient and area were adjusted to attempt to replicate the lateral groundwater outflow.

The results of the model calibration are shown visually in Figure 54 and Figure 54 below; numerical results of the calibration as well as the validation of both models are shown in the subsequent section.

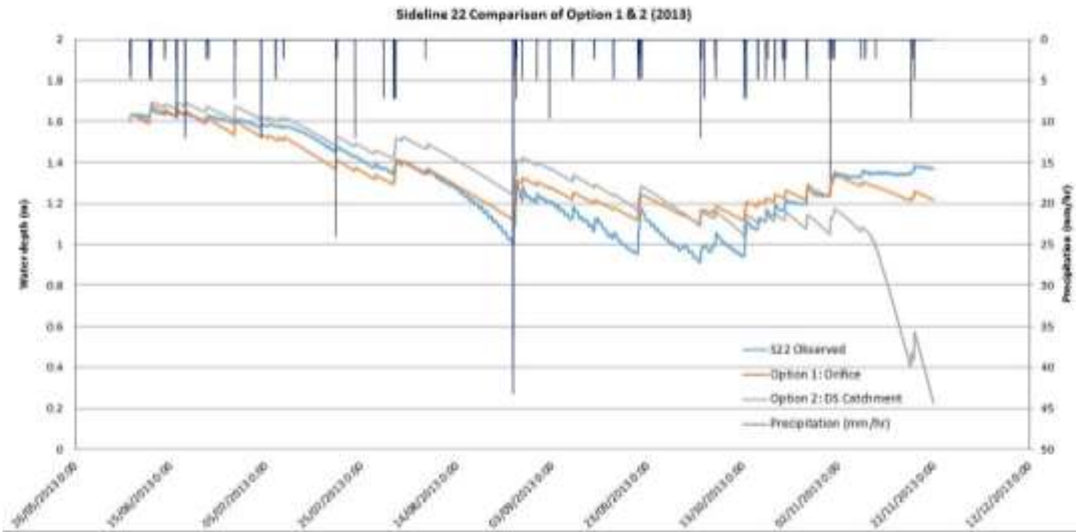


Figure 54: Results of calibration for Sideline 22, showing the representation of lateral groundwater outflow using both option 1 (orifice) and option 2 (catchment-aquifer unit), as described in text (from Charbonneau, 2016)

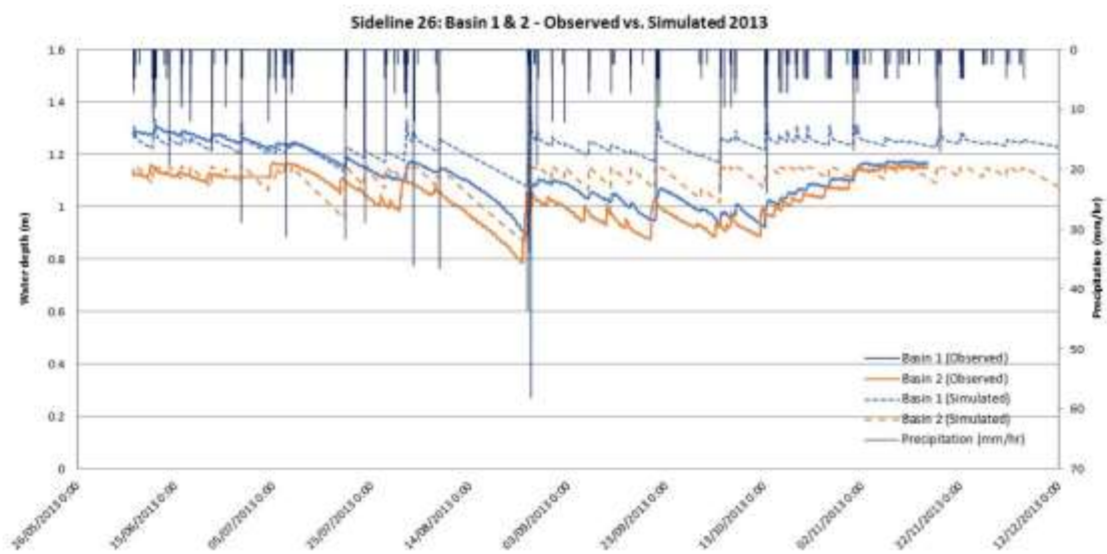


Figure 55: Results of calibration for Sideline 26, showing monitored and calibrated water levels for both Basin 1 and Basin 2 (from Charbonneau, 2016)

3.5.4 SWMM: Validation, Existing Conditions

Following calibration of the water balance models for Sideline 22 and Sideline 26 using monitoring data from the growing season of 2013, monitoring data for the year 2014 was used to validate the models. The results of the model performance for both the calibration and validation are shown in Table 16 and Table 17.

Table 16: Statistical performance measures for model calibration and validation for Sideline 22 (from Charbonneau, 2016)

Evaluation Functions	Value of Perfect Measure	Option 1: Orifice			Option 2: Downstream Catchment		
		2013 (189 days)	2013 (144 days)	2014 (246 days)	2013 (189 days)	2013 (110 days)	2014 (246 days)
Nash-Sutcliffe efficiency (NSE)	1	-0.037	0.862	-1.04	0.794	0.694	-1.01
Coefficient of determination	1	0.306	0.908	0.110	0.91	0.857	0.147
Standard error of estimate (SEE)	0	0.215	0.0804	0.418	0.127	0.126	0.142
Simple least squares (LSE)	0	190	17.8	940	53.3	55.4	109
Root mean square error (RMSE)	1	6.22	3.16	21.9	6.03	6.19	5.19

Table 17: Statistical performance measures for calibration and validation for Sideline 26 (from Charbonneau, 2016)

Evaluation Functions	Value of Perfect Measure	Basin 1		Basin 2	
		2013	2014	2013	2014
Nash-Sutcliffe efficiency (NSE)	1	0.502	-82.3	-11.2	-3.79
Coefficient of determination (R2)	1	0.12	0.01	0.03	0.06
Standard error of estimate (SEE)	0	0.362	0.291	0.312	0.231
Simple least squares (LSE)	0	538	461	398	291
Root mean square error (RMSE)	1	12.7	10.5	10.1	10

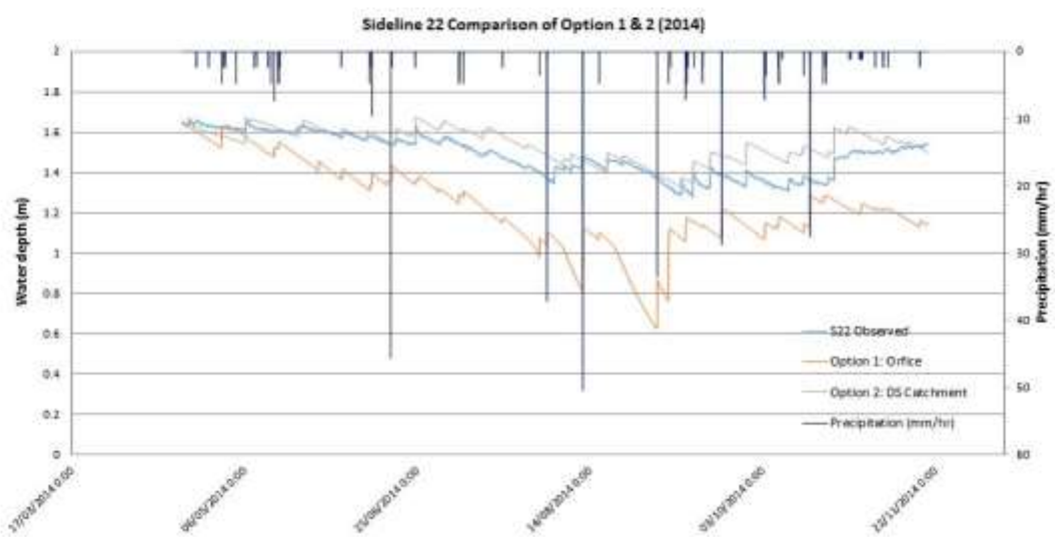


Figure 56: Results of validation for Sideline 22, showing difference between showing the representation of lateral groundwater outflow using both option 1 (orifice) and option 2 (catchment-aquifer unit) (from Charbonneau, 2016)

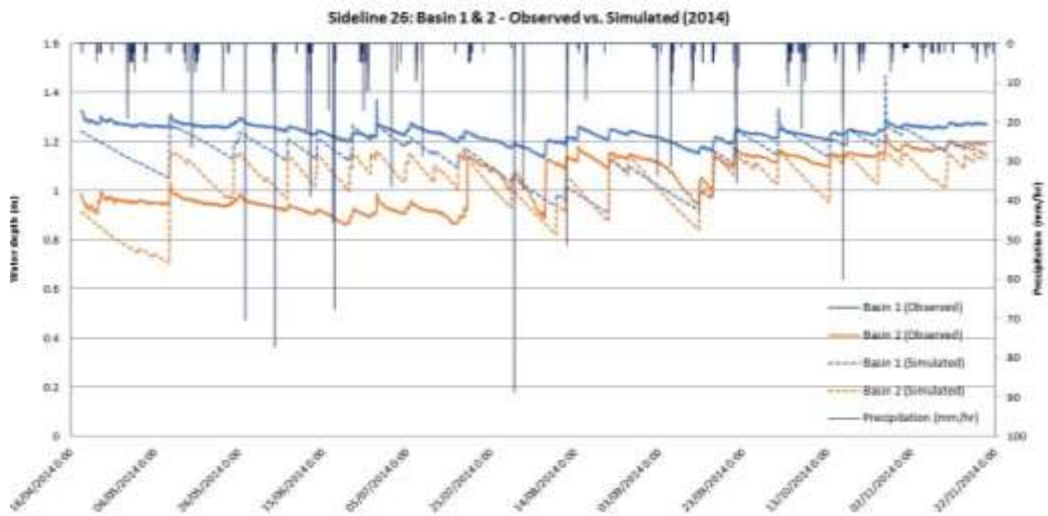


Figure 57: Results of validation for Sideline 26, showing monitored and calibrated water levels for both Basin 1 and Basin 2 (from Charbonneau, 2016)

For Sideline 26, the model showed a reasonable agreement between monitored and simulated wetland storage dynamics in both Basin 1 and Basin 2. The increase in storage in response to precipitation was occasionally overestimated in Basin 1, and a hypothesized subsurface flow path from Basin 1 to Basin 2 was not replicated but nonetheless the model represents wetland storage dynamics reasonably well.

At Sideline 22, there was a greater discrepancy between the modeled and monitored water levels, particularly in the late fall period. Lateral groundwater loss from the catchment needed to be simulated to account for the fact that no channelized surface water outflow existed at the site. Neither of the two methods used to simulate this water transfer mechanism (i.e., the downstream catchment-aquifer unit and circular orifice approaches, as described in Section 3.5.3) were fully satisfactory in replicating wetland storage dynamics, with the downstream catchment approach underestimating wetland water storage in 2013 while the orifice method underestimated storage in 2014. This shortcoming of the model speaks to the importance of using models that are capable of more explicitly representing groundwater-surface water interactions in settings characterized by a high degree of groundwater interaction such as the Sideline 22 wetland.

3.5.5 SWMM: Proposed Conditions without Mitigation

A post-development scenario was developed for Sideline 22 (only) by consulting preliminary draft subdivision plans for the area of the wetland catchment, which is zoned for residential development with some small commercial lots. The hypothetical development scenario was created based on the preliminary extent of development in the catchment and the proposed lot layout. To simulate the development, the degree of imperviousness in the upstream catchment area was increased from 3.5% to 50% and changing maximum flow path length to 30 m.

Table 18 shows the effect of development on each of the major terms in the water balance equation for Sideline 22. As would be expected for a large increase in the degree of catchment imperviousness, the proportion of water leaving the system as groundwater recharge decreases by nearly 50% (from 192.9 mm to 100.8 mm) while the proportion of precipitation entering the wetland as runoff increases from 12.9

mm to 187.0 mm. A relatively large decrease in total catchment evapotranspiration can also be observed (from 229.7 mm to 144.6 mm). Alterations to the wetland water balance of this magnitude clearly have the potential to lead to degradation or loss of wetland ecological functions as well as potential erosion issues, in the absence of a well-designed water balance mitigation strategy.

Table 18: Comparison of pre- to post-development water balance terms at Sideline 22 (from Charbonneau, 2016)

Sideline 22 Subcatchment 1	Pre-development	Post-Development (No Mitigation)
Surface		
Percent Impervious	3.5%	50%
Area (ha)	13.03	13.03
Surface Evaporation, E (mm)	2.5	40.8
Infiltration, I (mm)	420.1	204.6
Runoff, RO (mm)	12.9	187.0
Subsurface		
Evapotranspiration, ET (mm)	227.2	103.8
Groundwater Outflow, GW (mm)	11.5	9.0
Catchment Water Balance		
Rainfall (mm)	435.4	435.4
Groundwater recharge, GWR (mm)	192.9	100.8
Groundwater Outflow, GW (mm)	11.5	9.54
Total Evapotranspiration, E + ET (mm)	229.7	144.62
Runoff, RO (mm)	12.9	187.0

3.5.6 SWMM: Proposed Conditions with Mitigation

A number of scenarios were explored to determine the effect of different mitigation strategies. For the purposes of this review, the two scenarios that best demonstrated the capacity of SWMM to represent LID practices are reported here. These scenarios, referred to as Scenario 6 and Scenario 7, are described below. Both scenarios utilized bioretention cells to detain and infiltrate excess runoff from impervious surfaces. These cells are represented in SWMM as a three layer system (surface vegetated area, engineered soil, and storage layer), with an option to include an underdrain that was not used in this evaluation. The bioretention cells were sized to a 1-hr, 25 mm event. The parameters used to represent the bioretention cells are shown below in Table 19. An analysis of the sensitivity of total catchment infiltration, evapotranspiration, and runoff volume to the bioretention cell design parameters (soil depth, storage layer thickness, vegetation volume, berm height, cell area, and soil hydraulic conductivity) showed that only cell area had a significant effect on the volume of water infiltrated by the cells. As ponded water was rarely present on the cells across a wide range of settings, infiltration volume was seldom limiting, but rather it was the volume of runoff reaching the cells that controlled total infiltration volume.

Table 19: Parameters used in representation of LID practices (bioretention cells) (from Charbonneau, 2016)

Surface Layer	Value
Berm height (mm)	300
Vegetative volume (fraction)	0.10
Surface roughness (-)	0.0
Surface slope (%)	0.0
Soil Layer	**Value**
Thickness (mm)	200
Porosity (-)	0.40
Field capacity (-)	0.105
Wilting point (-)	0.047
Conductivity (mm/hr)	60
Conductivity slope (%)	5.0
Suction head (mm)	60
Storage Layer	**Value**
Thickness (mm)	200
Void ratio (voids/solids)	0.7
Seepage rate (mm/hr)	5.5
Clogging factor	0.0

For Scenario 6, 88% of the impervious area in the catchment (driveways, roofs, and portion of right-of-way) was treated by bioretention cells. From this treated runoff volume, 40% of the roof area runoff was diverted from the bioretention cells to a rainwater harvesting system, represented as a “rain barrel” in SWMM. This scenario represented the maximum extent of infiltration practices that could be used without exceeding the pre-development groundwater recharge volume. The bioretention cells were insufficient to mitigate the full excess runoff volume generated, and additional stormwater LIDs in the form of rainwater harvesting were thus required. However, it was noted that SWMM underestimates the volume lost to ET from bioretention cells, as ET cannot occur from the subsurface storage layers. This is a shortcoming of SWMM in long term continuous simulations of LID performance.

For Scenario 7, additional bioretention cell area was added such that 95% of impervious areas were treated. As in Scenario 6, 40% of the roof area runoff was diverted to a rainwater harvesting practice. Scenario 7 represented an “enhanced” recharge scenario, with groundwater recharge exceeding pre-development levels. The authors of this review note that such an option should only be considered in the context of an integrated urban water management plan where enhanced recharge is needed to mitigate factors such as water table drawdown due to external water takings or diversion. As SWMM is not capable of simulating dynamic interaction with groundwater, it would not be an appropriate tool to assess the potential consequences of an enhanced recharge program such as that in Scenario 7. Nonetheless, catchment runoff was reduced by >50% relative to Scenario 6, which reduced total catchment runoff to levels approaching but not matching pre-development conditions; the rainwater harvesting system mitigated the remaining unmitigated runoff.

The differences in the surface, subsurface, and total catchment water balance terms between the pre-development condition and Scenarios 6 and 7 are summarized in Table 20 below.

Table 20: Comparison of mitigation scenarios with pre-development water balance terms (from Charbonneau, 2016)

Sideline 22 Subcatchment 1	Pre-development	Scenario 6	Scenario 7
Surface			
Percent Impervious	3.5%	50%	50%
Area (ha)	13.03	13.03	13.03
Surface Evaporation, E (mm)	2.5	47.09	48.00
Surface Infiltration, I (mm)	420.1	328.0	365.0
Runoff, RO (mm)	12.9	65.5	65.5
Subsurface			
Subsurface Evaporation, ET (mm)	227.2	119.48	119.0
Groundwater Outflow, GW (mm)	11.5	10.0	11.6
Catchment Water Balance			
Rainfall (mm)	435.4	435.4	435.4
Groundwater Recharge, GWR (mm)	192.9	198.8	241.2
Total Evaporation, E + ET (mm)	229.7	166.6	167.0
Groundwater Outflow, GW (mm)	11.5	10.0	11.5
Runoff, RO (mm)	12.9	65.5	31.5

3.5.7 SWMM: Benefits, Challenges, Recommendations and References

Benefits:

- The SWMM model is capable of representing many important hydrological processes without requiring excessive input data or highly specialized expertise to operate.
- Representing wetlands as storage units allows for stage-storage and stage-discharge relationships to be defined, and for subsurface flow from the catchment to be transferred to the wetland; storage relationships can also be extended to include shallow subsurface storage.
- The representation in SWMM of LID practices as discrete features within the flow network with variable properties allows for a more realistic simulation of LIDs than simply changing the lumped parameters of the wetland catchment.

Challenges:

- Limitations in the representation of certain groundwater exchange pathways (e.g. lateral outflows from catchment outlet, groundwater mounding beneath LIDs) limit the validity of simulations of wetland storage dynamics where these processes constitute a large proportion of the overall water balance.
- The inability of SWMM to simulate ET from the soil layer of LIDs means that the ability of LIDs such as bioretention cells to mitigate excess runoff via evapotranspiration is likely underestimated in long-term simulations.

Recommendations:

- Wetland water balance modelling is an iterative process, and additional water transfer mechanisms should be added to an initial simplified water balance equation as the monitoring data and calibration process reveal their existence.

- It is critical to have multiple years of monitoring data to be able to isolate hydrological processes that are associated with wet or dry conditions or that vary seasonally; data should always be analyzed at multiple timescales (annual, seasonal, monthly, weekly, diurnal) to help isolate these processes.
- Independent estimates of certain water balance terms (e.g. ET, vertical groundwater inflow) can help to isolate other processes occurring simultaneously, and methods exist that can be applied to monitoring data for this purpose.
- Detailed topographic information can reduce the uncertainty in the above ground stage-storage relationship for wetland; site-specific information is needed reduce the error associated with the specific yield estimates below ground.

References:

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Transport Canada | Transports Canada

330 Sparks Street, Tower C
Ottawa ON K1A 0N5

October 21, 2021

Ms. Chandra Sharma
Chief Administrative Officer/Secretary-Treasurer
Ms. Brenda Johnson
Chair
Niagara Peninsula Conservation Authority
c/o Mr. Grant Bivol
gbivol@npca.ca

Dear Ms. Sharma and Ms. Johnson:

Thank you for your correspondence of June 17, 2021, in which you expressed your support for the establishment of an Eco Park on Transport Canada's surplus land site (NN-026-C) in Niagara-on-the-Lake.

Transport Canada is currently reviewing the status of this parcel of land to determine if it will be divested or remain part of the department's land holdings in support of Seaway operations.

TC officials have connected the Region's staff with the St. Lawrence Seaway Management Corporation to initiate discussions regarding the establishment of an Eco Park on the lands.

Should you have additional questions, please contact Transport Canada directly at seawaydisposition-alienationdelavoiemaritime@tc.gc.ca.

Sincerely,

David Quartermain

David Quartermain
Director, Real Property Management
Air, Marine and Environmental Programs

Canada

November 5th, 2021

Public Input Coordinator
Ministry of Environment, Conservation and Parks
Species at Risk Branch
300 Water Street
5th Floor, North Tower
Peterborough ON
K9J 8M5

Re: Conservation Ontario's comments on "Minister's Order for temporary suspension of protection upon the listing of Black Ash under the Endangered Species Act" (ERO#019-4278) and "Amendments to Ontario Regulation 242/08 (General Regulation – Endangered Species Act, 2007) relating to upcoming changes to the Species at Risk in Ontario List" (ERO#019-4280)

Dear Public Input Coordinator:

Thank you for the opportunity to provide comments on the two above referenced proposals. Conservation Ontario is the network of Ontario's 36 conservation authorities (CAs). These comments are not intended to limit consideration of comments shared individually by CAs through this review and consultation process.

Conservation authorities are local watershed management agencies that deliver programs and services that protect and manage water and other natural resources in partnership with government, landowners and other organizations. Through these partnerships, CAs deliver a number of programs and services that help protect species at risk (SAR) and their habitats within CA watershed jurisdictions. Programs and services offered through agreement with municipalities include natural heritage system planning (e.g., restoration, enhancement and protection), climate change mitigation and adaptation, and, stewardship and outreach programs. As the Province's second-largest landowners, CAs protect and manage a considerable amount of habitat that supports SAR. In addition to these owned and managed lands, CAs' watershed science and monitoring programs collect up-to-date information which supports the integrity of these landholdings which also benefit SAR protection and recovery.

Within the context referenced above, Conservation Ontario offers the following general comments on the proposal to temporarily suspend protection of the Black Ash as well as proposed amendments made to the general regulation under the *Endangered Species Act.*

<u>Minister's Order for temporary suspension of protection upon the listing of Black Ash under the Endangered Species Act</u>

It is understood that a Minister's regulation is proposed which would temporarily pause the protections for Black Ash under the *Endangered Species Act* for two years from the time it is added to the Species at

Risk in Ontario List. This temporary pause would allow the Ministry time to gather relevant information to better understand the threats to Black Ash trees and the best way to recover the species.

Conservation Ontario has no objections to the proposed temporary suspension for Black Ash, however, additional clarity is requested as to why this suspension is required, given that the Ministry will be completing the recovery strategy for this species by January 27, 2023. Under the *Endangered Species Act*, recovery strategies are prepared for each species that is listed to the Species at Risk in Ontario List as an endangered or threatened species. Recovery strategies must include: an identification of the habitat needs of the species, **a description of the threats to the survival and recovery of the species**, **and advice and recommendations to the Minister with respect to the protection and recovery of the species**. As such, the analysis of threats and recommendations for recovery would be completed through the recovery planning process by January 27, 2023, so it is unclear at this time why the suspension period would need to extend to January 27, 2024.

While it is acknowledged that the Ministry is proposing that "proponents will not need to seek authorizations for activities that impact Black Ash and its habitat" it should be acknowledged that other authorizations may still apply. Black Ash is predominantly a wetland species, found in swamps, floodplains and fens. Activities in these areas may be regulated under Section 28 of the *Conservation Authorities Act*, and as such, proponents should contact the local Conservation Authority (if applicable) to inquire about any permissions which may be required prior to undertaking works.

Lastly, Conservation Ontario notes that a potentially helpful outcome of the temporary suspension period would be the development of supplemental guidance and/or protocols for assessing the health of Black Ash, similar to that which exists for Butternut in Ontario. This supplemental guidance could include protocols for assessing the health of Black Ash, particularly with regard to the severe threat posed by the Emerald Ash Borer.

Amendments to Ontario Regulation 242/08 (General Regulation – Endangered Species Act, 2007) relating to upcoming changes to the Species at Risk in Ontario List

It is understood that, under the current framework, the Committee on the Status of Species at Risk in Ontario (COSSARO) provides an annual report to the Minister, which includes the assessment and, if necessary, reclassification of species at risk in Ontario (e.g., classified as extirpated, endangered, threatened or special concern). With the receipt of this report, the Species at Risk in Ontario (SARO) List must be updated within one year's time to reflect any new classifications. Once a species is listed to the SARO List, the *Endangered Species Act*, including prohibitions against harming species and their habitats, come into effect. The Ministry is proposing to amend section 0.1 of O. Reg. 242/08 (General) under the *Endangered Species Act*, so that the regulation would apply to all species listed to the SARO List as of January 2022. As a result, all conditional exemptions under the General Regulation would be available to proponents, with select exclusions as noted in the Environmental Registry proposal. It is understood that conditional exemptions are used to streamline approvals for routine activities that have common mitigation actions which protect the species.

Conservation Ontario has no objections to the Ministry's proposed amendments to the general regulation, including the proposed exclusions from select conditional exemptions for some newly-listed species. It is understood that despite the conditional exemptions, activities undertaken through sections 23.4 – 23.20 of O. Reg. 242/08 (General) would require a person or entity to register the activity with the Ministry by submitting a notice of activity form through the online registry, and that all activities will be planned to minimize the adverse effects of the activity on the species and its habitat.

Thank you for the opportunity to review and provide comments on the "Minister's Order for temporary suspension of protection upon the listing of Black Ash under the Endangered Species Act" (ERO#019-4278) and "Amendments to Ontario Regulation 242/08 (General Regulation – Endangered Species Act, 2007) relating to upcoming changes to the Species at Risk in Ontario List" (ERO#019-4280). Should you have any questions about this letter please feel free to contact myself at extension 229.

Sincerely,

Nicholas Fischer

Nicholas Fischer
Policy and Planning Officer

c.c. All CA CAOs/GMs

Conservation Ontario
120 Bayview Parkway, Newmarket ON L3Y 3W3
Tel: 905.895.0716 Email: info@conservationontario.ca
www.conservationontario.ca

Watson & Associates ECONOMISTS LTD.

Niagara Peninsula Conservation Authority Parks and Recreation Services Fee Review

Board of Directors

November 19, 2021

Introduction
Background

- Watson & Associates Economists Ltd. (Watson) was retained by NPCA to undertake a review of the full costs of providing parks and recreation services and make fee recommendations to achieve full cost recovery
- Fee review is being undertaken in response to recent changes to the *Conservation Authorities Act (CAA)* and the release of Ontario Regulations 686/21 and 687/21
- NPCA has not previously undertaken a comprehensive full cost assessment and fee review study for parks and recreation services

Introduction

Objectives/Deliverables

- Full cost assessment
  - Identify mandatory (land care for passive conservation parks or "passive recreation") and non mandatory ("active recreation") programs and services at each of the 41 NPCA conservation parks; and
  - Assess full cost of each program or service.
- Fee recommendations
  - Recover the full cost of active recreation programs and services by January 1, 2024 (i.e. regulatory transition date);
  - Conform with legislation and be defensible;
  - Balance NPCA's need to achieve full cost recovery with stakeholder interests, affordability and competitiveness; and
  - Reflect industry best practices.

Legislative Context and Trends

Conservation Authorities Act

- Changes to the CAA made through the *Building Better Communities and Conserving Watershed Act, 2017* (Bill 139) and the *More Homes, More Choice Act, 2019* (Bill 108) define the programs and services provided by conservation authorities to include:
  - **Mandatory programs and services** (s. 21.1) that can be funded through the municipal levy
  - **Non-Mandatory programs and services** (s. 21.1.1) provided on behalf of a municipality through a MOU or agreement and funded through the municipal levy
  - **Other programs and services** (s. 21.1.2) funded through self generated revenues

Legislative Context and Trends

Conservation Authorities Act

- The Province of Ontario has recently released Ontario Regulation 686/21 (Mandatory Programs and Services) and 687/21 (Transition Plans and Agreements for Programs and Services Under Section 21.1.2 of the Act)
- Mandatory programs and services include Conservation and Management of Lands, including passive recreation, i.e.:
  - “programs and services to maintain any facilities, trails or other amenities that support public access and recreational activities in conservation areas and that can be provided without the direct support or supervision of staff employed by the authority or by another person or body. s.9. (1) 2. ii
- Therefore, programs and services that are not a mandatory program or service will need to be funded through self generated revenues, or through an MOUR and service level agreement with a Municipal partner by January 1, 2024

Legislative Context and Trends

Conservation Authorities Act

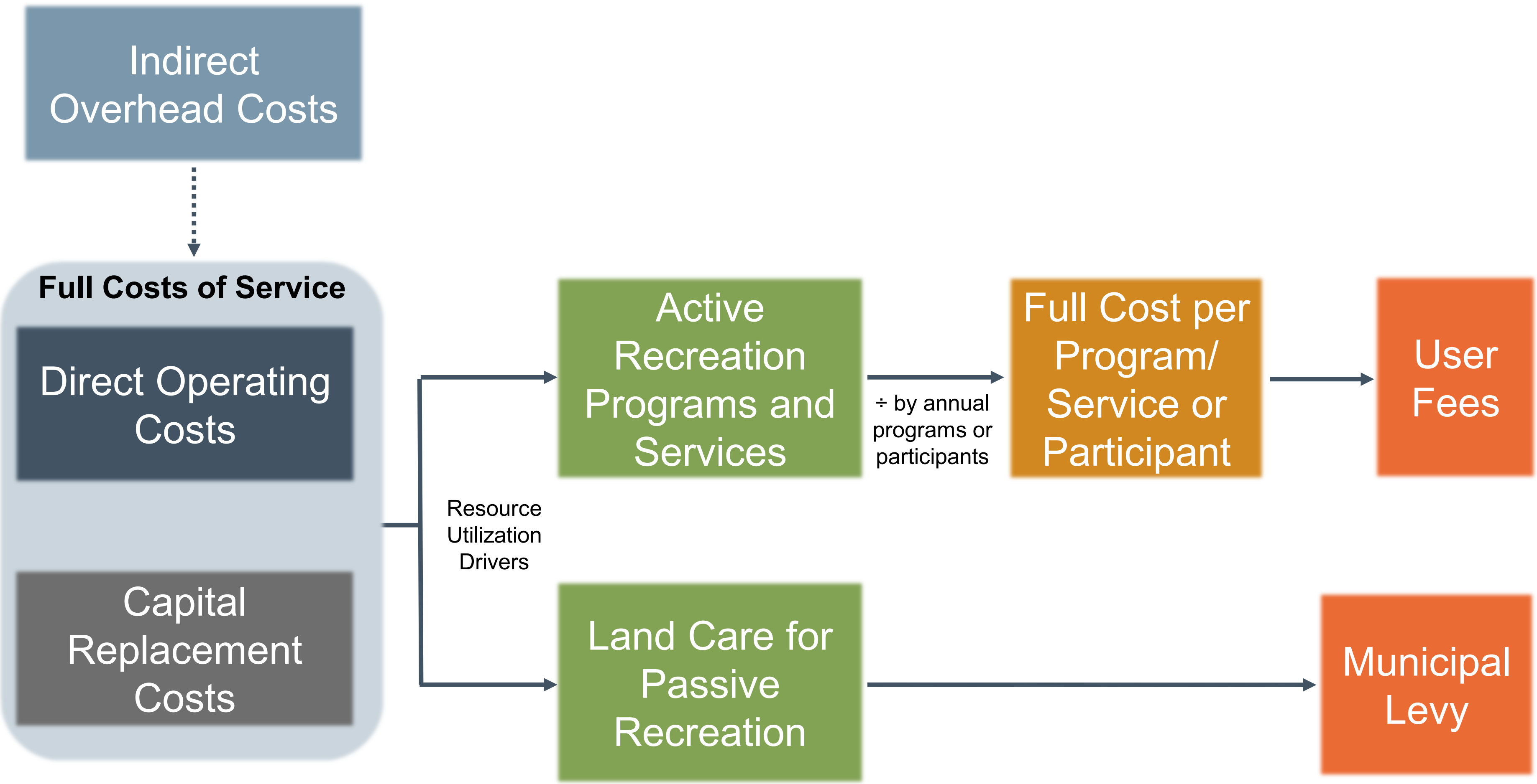
- Authorities will be required to:
  - Prepare detailed inventories of programs and services by February 28, 2022;
  - Identify the classification of service as well as the average annual historical and/or anticipated costs of each program and service; and
  - Identify the sources of funding.

Legislative Context and Trends

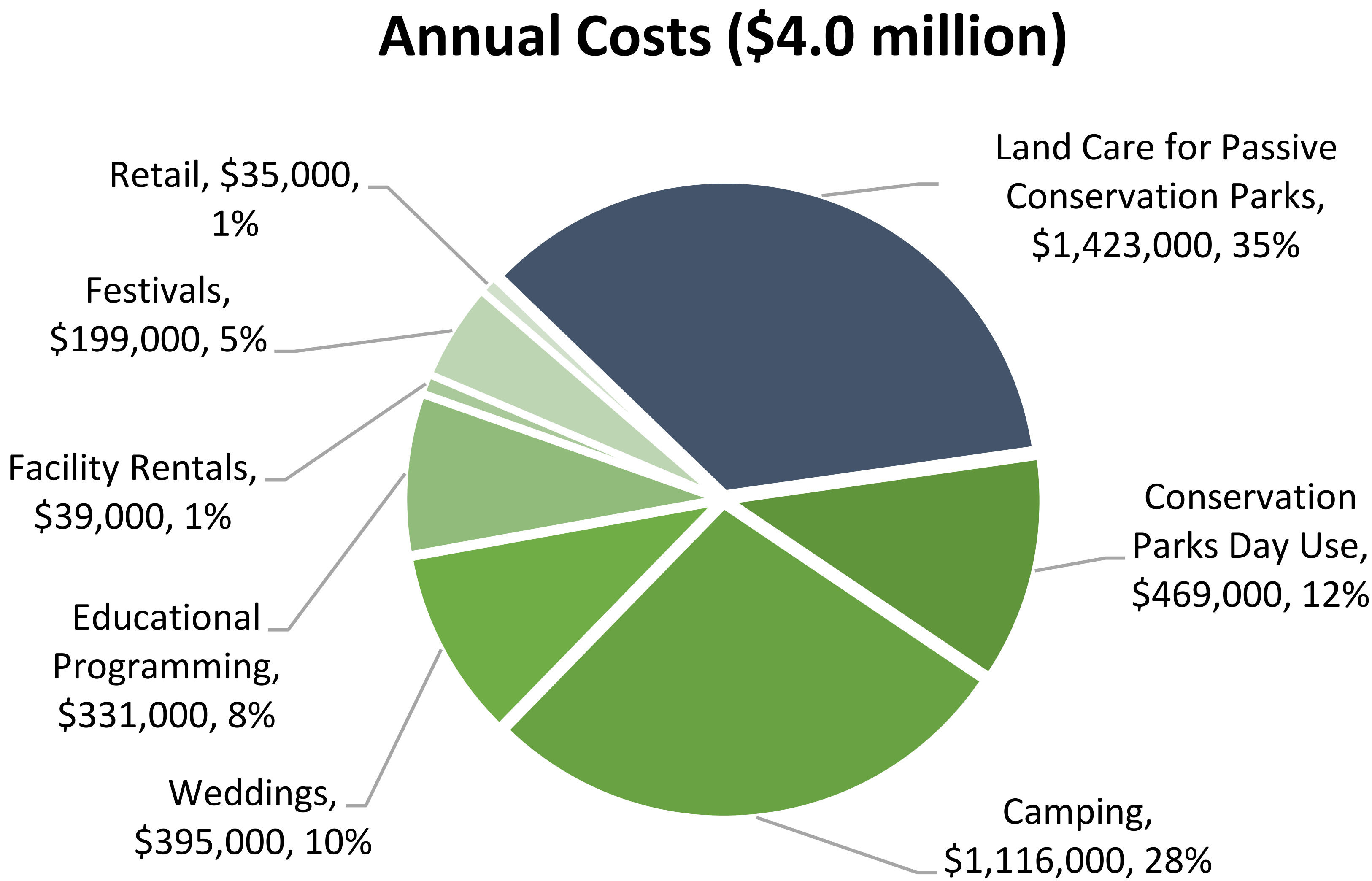
Conservation Authorities Act

- Outstanding Legislation:
  - The abilities of conservation authorities to fund overhead and support costs through the municipal levy is anticipated to be clarified in the forthcoming second phase of the CAA regulations (i.e. municipal levy regulation)
  - In the absence of this further regulation, the full cost assessment has included a preliminary assessment of indirect support costs (e.g. CAO/Board and Corporate Services). These costs will be adjusted during phase 2 of the study and aligned with the cost assessment of NPCA passive properties and land care

Full Cost Assessment Methodology
Parks and Recreation User Fees



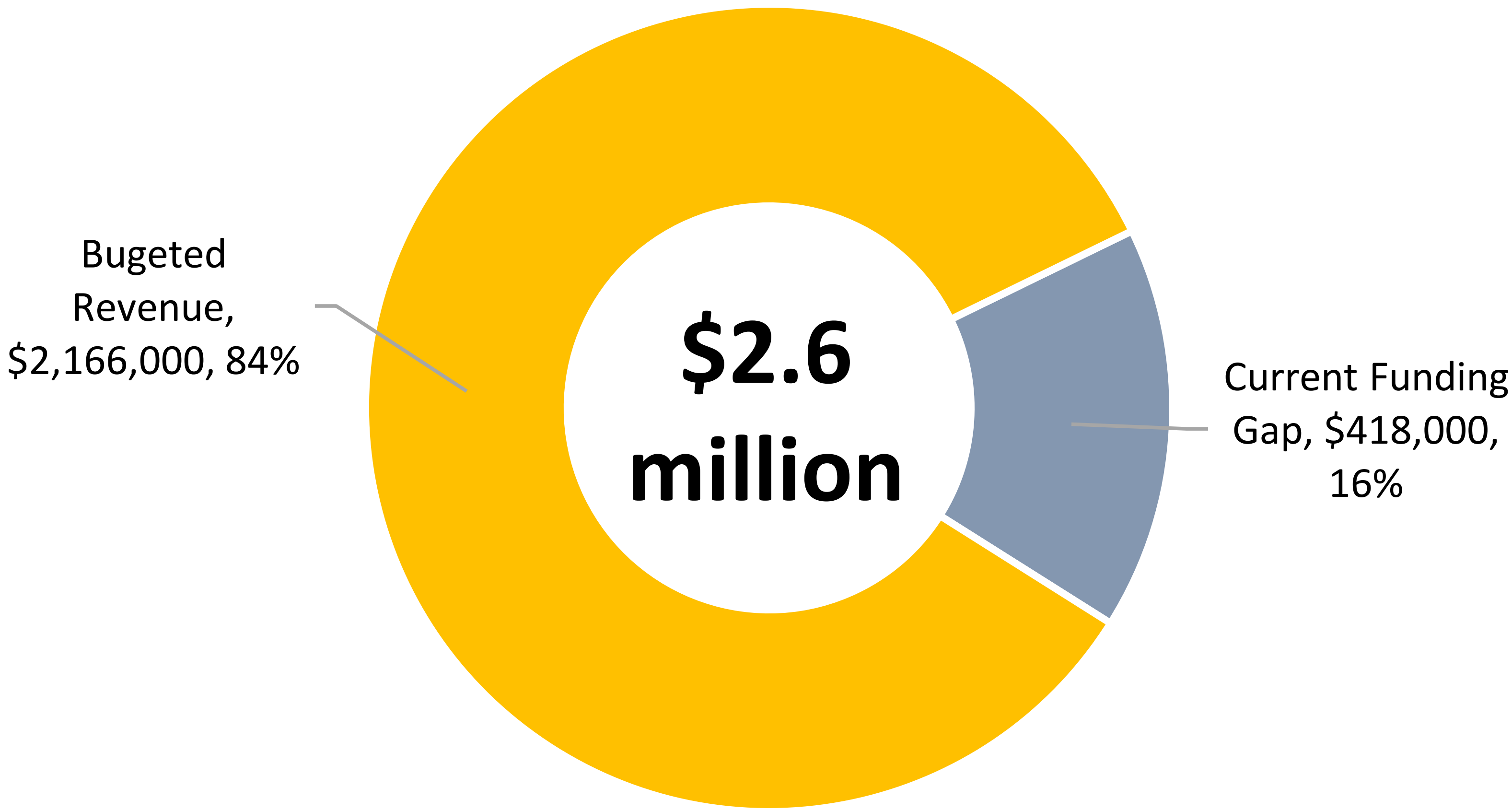
Annual Costs of Service



- Total active recreation costs of $2.5 million (excluding indirect overhead costs)

Active Recreation
Annual Cost/Revenue Summary

Budgeted Revenue From Fees for Active Recreation Programs and Services



Fee Recommendations
Considerations

- Recovery of full cost of service (i.e. 19% increase in fees)
- Market sensitivity to fee increases to avoid decreased service utilization and NPCA fee revenue
- Competitiveness of fees with comparative service providers (i.e. conservation authorities and private service providers)

Fee Recommendations

- Recommended fees increases of 19.1% are to be phased in over three years (i.e. 6.1% per year between 2022 and 2024), to:
  - Recover the full cost of service in 2024 (Regulatory transition date);
  - Mitigate significant one-time fee increases; and
  - Remain within the range of fees imposed by comparative service providers.
- Inflationary cost increases within NPCA budgets would need to be included in fees in addition to the above recommendations

Fee Recommendations

- Current fee structures proposed to remain unchanged except for day use park fees
- Day Use Fees
  - **Current Fee:** Per visitor with a max vehicle fee (maximum fee equivalent to fee for three adult visitors)
  - **Proposed Fee:** Per vehicle and driver fee plus fee per additional passenger. Maintain maximum vehicle charge.
  - Proposed fee has considered visitor profile of groups (e.g. families vs. couples vs. individuals)
- Considerations
  - Minimal impact of fee structure change to families vs. individuals/ couples
  - Promotion of value offered through annual membership compared to day use fees

Fee Recommendations
Future Considerations

- Further fee adjustments may be required to:
  - Fund share of indirect overhead costs, dependent on future municipal levy regulation; and
  - To provide annual capital lifecycle funding obligations identified in future asset management plans
    - Asset management plans will be required for water control and erosion control infrastructure and could be extended to all conservation authority managed infrastructure.
    - To be further developed in phase 2 of the study

Regulatory Compliance
Next Steps

- The recent regulations provide timelines for compliance with required components of the mandatory programs and services and transition plans
- This fee review provides a starting point towards meeting many of the requirements, including:
    - Conservation Area Strategy
        - Identification of the mandatory and non-mandatory programs and services provided on conservation authority land financing sources
        - Preparation of a Land Inventory that, amongst other requirements identifies where active recreation programs and services are provided
    - Programs and Services Determination and Budgeting
        - Classification of services into mandatory, non-mandatory, and other programs and services and estimate costs and funding sources

Next Steps

- Receive feedback on proposed fee increases from Board of Directors
- Implement phased fee recommendations – January 1, 2022
- Review forthcoming regulations and complete phase 2 of conservation parks and land care costs, including indirect overhead costs
- Report to Board of Directors on phase 2 of conservation parks and land care costs for final approval in 2023

Report To: **Board of Directors**

Subject: **Comfort Maple Tree Preservation**

Report No: **FA-63-21**

Date: **November 19, 2021**

Recommendation:

THAT Report No. FA-63-21 RE: Comfort Maple Tree Assessment **BE RECEIVED**.

Purpose:

The purpose of this report is to update the Board of Directors of the health status and maintenance required for preservation of the Comfort Maple Tree.

Background:

The Comfort Maple Conservation Area conserves what is widely believed to be the oldest and finest sugar maple tree in Canada and was designated a heritage tree in June 2000 under the Ontario Heritage Act. The tree is estimated to be over 500 years old and towers about 24.4 metres at its crown with a trunk circumference of 6 metres. The tree was entrusted to the Niagara Peninsula Conservation Authority in 1961 by Edna and Eleanor Comfort for the purpose to preserve the tree for its scenic, biological, and historical significance. The Comfort Maple Tree is recorded in the Honour Role of Ontario Trees by the Ontario Forestry Association and was recognized in 1975 by the International Shade Tree Conference Canada. It is a landmark which is part of social history, a living museum that has been experienced and admired for decades. The NPCA entered into a lease agreement with Edna and Eleanor Comfort on April 17, 1961, for the duration of 999 years, or until the death of the Comfort Maple Tree, whichever date shall fist occur.

The Niagara Peninsula Conservation Authority and Niagara Parks Commission (Botanical Gardens/School of Horticulture) entered a partnership in 2019 to propagate the Comfort Maple Tree to preserve the genetic legacy for future generations. There is currently fifteen cuttings that are dormant in the NPC's secure greenhouse. Depending on the growth rate, it could be another two years before they can be planted out in the natural environment.

Discussion:

The NPCA uses specialists in preservation, enhancement, and management of all aspects of the urban forest to provide an assessment and maintenance recommendations to guide the management of the Comfort Maple Tree.

The NPCA obtained Urban Forest Innovations to assess the tree in August 2021. Based upon the results of the assessment, it was determined that the tree is in fair structural condition and health. Although the tree is in a state of slow decline, the decline is consistent with the tree's advanced age and is manageable for continued retention. Urban Forest Innovations Inc. provided recommendations for the long-term management of the tree which includes tree support, root zone enhancement and ongoing monitoring. NPCA will be implementing the following initiatives in 2021-22 to support the long-term health of the Comfort Maple Tree.

Maintenance and Supplementation of Tree Support

An intricate network of static and dynamic cables currently exists throughout the crown of the tree and between most major limbs. Although many components of the hardware and attachments are in generally good condition, several of the cables are now slacking and are no longer functioning as originally intended. All cables will be tightened, and additional supplemental tree support components will be installed in the tree.

Root Zone Enhancement and Fencing

A critical component of retaining the subject tree is to improve rooting zone conditions and support root development and functioning. The rooting area needs to be enhanced by the complete removal of turf beneath the dripline and a reapplication of a mulch bed to at least the dripline and to a depth of 10-15cm uniformly. Soil decompaction using Airspace or Air Knife technologies will also be used to apply the mulch to help aerate the rooting area and incorporate wood chips into the upper soil. Permanent fencing will also be added to exclude the public from under the dripline of the tree to restrict foot traffic and soil compaction of the rooting area.

Removal of Lightning Protection System Hardware

A lightning protection system is presently installed with air terminals and ground connections running from the tips of both the north and south stems, meeting at the crown base, and terminating at the ground level. The system is showing signs of significant disrepair and the ground terminal has become disconnected from the underground portion of the conducting cable. The hardware components throughout the tree are not serving their intended purpose and will be completely removed.

Cavity Filling Stabilization

The cavity filling on the north stem is continuing to degrade with the most significant area being the base of the concrete. Action will be put in place to stabilize this area, so that that the whole concrete pillar does not disintegrate and collapse.

Maintenance Oversight and Reassessment

To ensure the cabling recommendations in the assessment report are implemented correctly, NPCA staff will obtain Urban Forest Innovations to attend site visits to provide specific instructions to contractors. NPCA staff will have the tree assessed again in 2023 where an additional tomographic investigation is recommended.

Financial Implications:

There are no financial implications resulting from this report as all costs in maintaining the Comfort Maple Tree are included in NPCA's annual operating budget. The annual budget to maintain the Comfort Maple Tree is an estimated $10,000.

Links to Policy/Strategic Plan:

The health of the Comfort Maple Tree affiliates with managing NPCA lands to increase biodiversity, habitat connectivity, and natural cover under the Healthy Climate Resilient Watersheds as well as creating equitable access to greenspace for the heath and wellbeing of people. The Comfort Maple Tree is also a heritage landmark that is used to improve cultural connections and heritage appreciation.

Related Reports and Appendices:

None

Authored by:

Original Signed by:

Adam Christie
Director, Land Operations

Submitted by:

Original Signed by:

Chandra Sharma, MCIP, RPP
Chief Administrative Officer/Secretary-Treasurer

Report To: **Board of Directors**

Subject: **2022 Conservation Area Rates**

Report No: **Report No. FA-64-21**

Date: **November 19, 2021**

Recommendation:

1. **THAT** Report No. FA-64-21 regarding the 2022 Conservation Area Rates **BE RECEIVED**.

2. **AND THAT** the 2022 Conservation Area Rates outlined in Appendix 1 of Report No. FA-64-21 **BE APPROVED**.

Purpose:

The purpose of this report is for the NPCA Board to consider and approve the proposed 2022 Conservation Area Rates.

Background:

The Niagara Peninsula Conservation Authority (NPCA) administers a fee schedule for a wide variety of services offered at its conservation areas. The fee schedule is reviewed and analyzed annually considering three central factors, which include: balancing inflation pressures, user demand for services, and comparable services and facilities at other Conservation Authorities, provincial parks and within the local private sector. This schedule has not been formally reviewed in several years.

In 2021, the NPCA commissioned a comprehensive, phased rate review for services offered within NPCA conservation areas. This review was deemed necessary in 2021 to proactively address service level gaps and associated costs, prepare the organization for regulatory changes resulting from Conservation Authority Act updates, as well as prepare the organization to provide the best standard of service to the growing number of visitors to conservation parks.

The 2021 Conservation Area Rate Review was undertaken by Watson and Associates Economists Ltd, a highly respected, arms-length third party firm with experience in the review of public-sector operations. This comprehensive review has been divided into two phases:

a) Phase 1: An initial review of the direct and capital costs of conservation area operations within active recreation areas where admission rates are applied, and an analysis of the current level of cost recovery addressed by the NPCA's current rates for programs and services.

Phase 2: The second, forthcoming phase of the review will analyze and make recommendations on the cost of maintaining passive recreation areas where admission rates are not applied, and land care. The complete phase two review will be brought forward to the NPCA Board of Directors in 2022 after a full analysis of pending CA Levy Regulations to be released by the province in the coming months

Key Considerations: The first phase of the review was completed in early November 2021. After determining the cost associated with the operation of active conservation areas, Watson and Associates made analytically supported recommendations for conservation areas rates to ensure full cost recovery of services delivered. Considering the recommendations, NPCA staff continue to strive towards balancing the value of services and facilities within conservation areas and associated fees, regard stakeholder interests, affordability, and equitable access to conservation areas for watershed residents and ensure NPCA rates are comparable to those at neighbouring conservation authorities and provincial parks.

Discussion:

The Building Better Communities and Conserving Watershed Act, 2017 and the 2019, More Choice, More Homes Act, precipitated revisions to the Conservation Authorities Act (CAA). The results of these changes are observed in Ontario Regulations 686/21 and 687/21. These changes have implications for the delivery of programs and services delivered by Conservation Authorities, as well as the available funding sources for the delivery of such programs and services. These changes have further promoted the need for the NPCA to undertake a fulsome review of cost accounting and rates for services delivered to be prepared in advance of the future transition.

The CAA and Ontario Regulations 686/21 and 687/21 define the mandatory programs and services that conservation authorities are required to provide and the funding structures that conservation authorities may utilize to deliver on these mandatory services. O. Reg. 686/21 states that Conservation and Management of Lands is a mandatory service that can be funded through the municipal levy and further that passive recreation (those programs and services undertaken to maintain facilities, trails and amenities that can be provided to the public without staff supervision) is a mandatory service. These activities on conservation area lands are considered Category 1 programs and services. The phase two review will address the costs associated with these deliverables and will make recommendations towards the municipal levy amounts associated with these mandatory services.

Conversely, active recreation programs and services delivered within conservation areas, or those services requiring direct staff support or supervision to be provided, would not be included within the required components of the mandatory program or service. As such, these programs and services would be classified as Category 3 programs, where conservation authorities may determine that these programs and services support the CA's mandate and are advisable to deliver to the community. Category 3 programs must be funded either through self-generated revenue, grants, or other agreements including cost apportion agreements with municipalities. Based on these changes, the NPCA will need to ensure that costs for active conservation area programs and services are fully recovered.

The phase one comprehensive rates review conducted by Watson and Associates provides evidence-based support for an NPCA active conservation area fee structure which will recover the full cost of services, while conforming with O. Reg. 686/21 ensuring the costs of all non-mandatory programs and services are fully funded through self-generated revenue, balancing stakeholder interests, affordability and competitiveness, follow industry best practices, and administrative capacities.

NPCA staff have reviewed and analyzed the phase one Parks and Recreation Services Fee Review and recommended rates for the 2022 season by Watson and Associates Economists Ltd. as attached in Appendix 1. An activity -based costing methodology has been utilized by Watson and Associates with a recommendation that the NPCA fees adjustment be spread out over a course of three years to cover the gap by 2024 CAA regulatory transition period. This amounts to a total or 6.1% (or an increase of $1 to a max of $ 6 approximately depending on the type of service, visitor and or transportation) per year so that the anticipated admission and service fee revenues would fully recover the costs to deliver active recreation programs and services, including the operation of day use conservation areas, campgrounds, facilities rentals, and educational programming. Following this rate structure, the NPCA would ensure that anticipated revenue for non-mandatory programs and services would be fully recovered by the regulatory transition deadline of January 1, 2024. This increase does not include annual inflationary increases, which would need to be applied to program and services rates above the recommendations as appropriate and approved by the Board.

Of note, in the process of reviewing conservation area service rates at neighbouring Conservation Authorities including Hamilton Conservation Authority, Watson and Associates and NPCA staff recommend a revised fee structure for conservation area admissions. This revised day-use admission rate structure is demonstrated in Appendix 1. The primary changes to day use admission account for primary visitor attendance in motorized vehicles by promoting carpooling as a sustainable and cost-effective method of transportation, and promoting NPCA NaturePlus Pass membership, while also providing rates that accommodate seniors (65+ years), students (with valid student ID), and people with accessible parking permits. A breakdown of group visitation rates is provided by Watson and Associates in Table 1 below, demonstrating the rate changes associated with group transportation and carpooling, and comparing the current and recommended rates as applied to groups attending in the same vehicle. Notably, under the new rate structure the cost of the one-year NaturePlus Pass membership is equivalent to eight visits by an individual or the cost of four visits by a family of four (two adults, two students). The value of the NPCA NaturePlus Pass will be promoted to the watershed community.

Table 1: Group Day Use Admission Fee Comparison

Group	Current Fee	2022	Change ($)
1 Adult	**8.00**	**13.00**	**+$5.00**
2 Adults	**16.00**	**17.50**	**+$1.50**
3 Adults	**24.00**	**22.00**	**-$2.00**
1 Senior/Student	**6.00**	**9.75**	**+$3.75**
2 Senior/Students	**12.00**	**13.25**	**+$1.25**
2 Adults and 1 Senior/Student	**22.00**	**21.00**	**-$1.00**
2 Adults and 2 Senior/Student	**24.00**	**24.50**	**+$0.50**
2 Adults and 3 Senior/Student	**24.00**	**26.50**	**+$2.50**

As a result of the rate review and Watson and Associates' recommendations, NPCA staff recommend a 6.1% rate increase to conservation area programs and services for 2022, and no further increases applied in 2022 to account for annual inflation. This recommendation recognizes the importance of ensuring equitable access to conservation areas across the watershed alongside cost recovery, while reducing the economic burden of COVID-19 on families and remaining within a competitive bracket when compared alongside neighbouring conservation authorities including Hamilton Conservation Authority and the Grand River Conservation Authority.

Links to Policy/Strategic Plan:

The NPCA 2021-2031 Strategic Plan includes the objective "Connecting People to Nature" which seeks to improve "access to and connections with nature for the health and wellbeing of all people." Through this Strategic Plan, the NPCA will prioritize opportunities to improve the accessibility of NPCA conservation areas, promote active and sustainable transportation, promote active recreation including camping, and promote equitable access to the natural and cultural heritage uniquely located within NPCA conservation areas. A second goal within "Connecting People to Nature" includes leading nature education and environmental stewardship, which the NPCA will achieve this through the delivery of educational programs and day camps.

Lastly, the Strategic Plan also includes the objective to be a Partner of Choice within the watershed, with the goal to improve engagement with local Indigenous peoples and communities and implement actions that support Truth and Reconciliation. One significant opportunity to work towards reconciliation includes recognition the National Day of Truth and Reconciliation on September 30th annually within NPCA conservation areas. Recognition of this day will honour Indigenous histories, knowledges and peoples within conservation areas and will be delivered in collaboration with Indigenous communities.

Financial Implications:

The estimated financial implications of the recommended conservation area fee changes results in a 6.1% increase as recommended by Watson and Associates, with no additional increase associated with annual inflation in 2022. This increase in active conservation area programs and services revenue will be approximately $254,864 and is reflected in the 2022 operating budget.

Related Reports and Appendices:

Appendix 1: Proposed 2022 Conservation Area Rates

Authored by:

Original Signed by:

Adam Christie
Director, Operations and Strategic Initiatives

Authored by:

Original Signed by:

Alicia Powell, BSc, MA, PhD
Manager, Conservation Area Services

Submitted by:

Original Signed by:

Chandra Sharma, MCIP RPP
CAO/Secretary-Treasurer

Report No. FA-64-21 Appendix 1 **Proposed 2022 Conservation Area Rates**

All fees include HST

Ball's Falls CA	2021	**2022**	Change ($)
Day Use			
Vehicle and Driver	-	$ 13.00	N/A
Vehicle and Senior/Accessible/Student Driver	-	$ 9.75	N/A
Additional Passenger - Adult	-	$ 4.50	N/A
Additional Passenger - Senior/Student	-	$ 3.50	N/A
Max Car	$ 24.00	$ 26.50	$ 2.50
Bus (Over 20/ vehicle)	$ 135.00	$ 143.00	$ 8.00
Shoulder Season Admission (Fall-Winter) (No attendant)	-	$ 8.00	N/A
Auto Gate Peak Season (No Attendant)	-	$ 13.00	N/A
Fall Festival			
General Admission	$ 8.00	$ 8.50	$ 0.50
Seniors (65+ years)	$ 6.00	$ 6.50	$ 0.50
Children (3 to 11 years)	$ 6.00	$ 6.50	$ 0.50
Holiday Trail			
General Admission	$ 12.00	$ 12.00	$ -
Seniors (65+ years)	$ 10.00	$ 10.00	$ -
Children (3 to 11 years)	$ 10.00	$ 10.00	$ -
Binbrook CA			
Day Use			
Vehicle and Driver	-	$ 13.00	N/A
Vehicle and Senior/Accessible/Student Driver	-	$ 9.75	N/A
Additional Passenger - Adult	-	$ 4.50	N/A
Additional Passenger - Senior/Student	-	$ 3.50	N/A
Max Car	$ 24.00	$ 26.50	$ 2.50

Bus (Over 20/ vehicle)	$	135.00	$	143.00	$	8.00
Shoulder Season Admission (Fall-Winter) (No attendant)	-		$	8.00	N/A	
Auto Gate Peak Season (No Attendant)	-		$	13.00	N/A	
Chippawa Creek CA						
Day Use						
Vehicle and Driver	-		$	13.00	N/A	
Vehicle and Senior/Accessible/Student Driver	-		$	9.75	N/A	
Additional Passenger - Adult	-		$	4.50	N/A	
Additional Passenger - Senior/Student	-		$	3.50	N/A	
Max Car	$	24.00	$	26.50	$	2.50
Bus (Over 20/ vehicle)	$	135.00	$	143.00	$	8.00
Auto Gate Peak Season (No Attendant)	-		$	13.00	N/A	
Camping						
Non Serviced One Night	$	48.03	$	50.94	$	2.91
15 Amp One Night	$	52.55	$	55.73	$	3.18
15 Amp Seasonal	$	2,650.16	$	2,810.86	$	160.70
15 Amp One Night Premium	$	57.07	$	60.52	$	3.45
15 Amp Seasonal Premium	$	2,901.96	$	3,077.94	$	175.98
30 Amp One Night	$	59.33	$	62.92	$	3.59
30 Amp Seasonal	$	3,028.00	$	3,211.61	$	183.61
30 Amp One Night Premium	$	61.59	$	65.31	$	3.72
30 Amp Seasonal Premium	$	3,273.73	$	3,472.25	$	198.52
Reservation Fee	$	12.00	$	12.00	$	-
Change / Cancellation Fee	$	8.00	$	8.00	$	-
Long Beach CA						
Day Use						
Vehicle and Driver	-		$	13.00	N/A	
Vehicle and Senior/Accessible/Student Driver	-		$	9.75	N/A	

Additional Passenger - Adult	-	$ 4.50	N/A
Additional Passenger - Senior/Student	-	$ 3.50	N/A
Max Car	$ 24.00	$ 26.50	$ 2.50
Bus (Over 20/ vehicle)	$ 135.00	$ 143.19	$ 8.00
Auto Gate Peak Season (No Attendant)	-	$ 13.00	N/A
Camping			
Non Serviced One Night	$ 48.03	$ 50.94	$ 2.91
15 Amp One Night	$ 52.55	$ 55.73	$ 3.18
15 Amp Seasonal	$ 2,650.16	$ 2,810.86	$ 160.70
15 Amp One Night Premium	$ 57.07	$ 60.52	$ 3.45
15 Amp Seasonal Premium	$ 2,901.96	$ 3,077.94	$ 175.98
30 Amp One Night	$ 59.33	$ 62.92	$ 3.59
30 Amp Seasonal	$ 3,028.00	$ 3,211.61	$ 183.61
30 Amp One Night Premium	$ 61.59	$ 65.31	$ 3.72
30 Amp Seasonal Premium	$ 3,273.73	$ 3,472.25	$ 198.52
30 Amp Seasonal Premium / Ridge	$ 3,619.51	$ 3,838.99	$ 219.48
Reservation Fee	$ 12.00	$ 12.00	$ -
Change / Cancellation Fee	$ 8.00	$ 8.00	$ -
Passes and Permits			
NPCA NaturePlus Membership Pass	$ 113.00	$ 120.00	$ 8.00
NPCA NaturePlus Membership Pass Replacement Fee	$ 24.00	$ 28.25	$ 4.25
Photography Permit (per day)	$ 113.00	$ 120.00	$ 7.00
Filming Permit (per hour)	$ 141.25	$ 150.00	$ 8.75
NPCA Hunting Permit (tax inc)	$ 40.00	$ 42.50	$ 2.50
Educational Programs (HST not applied)			
Half-Day School Visit (per student)	$ 7.00	$ 7.50	$ 0.50
Full-Day School Visit	$ 12.00	$ 12.75	$ 0.75
Single Day Camp (PD, March Break, Summer)	$ 40.00	$ 42.50	$ 42.50

Full Week Day Camp (March Break, Summer)	$ 150.00	$ 160.00	$ 10.00
Additional Child Full Week Day Camp	$ 135.00	$ 145.00	$ 10.00

Report To: **Board of Directors**

Subject: **NPCA Wainfleet Bog Advisory Committee Terms of Reference**

Report No: **FA-65-21**

Date: **November 19, 2021**

Recommendation:

1. **THAT** Report No. FA-65-21 RE: NPCA Wainfleet Bog Advisory Committee Terms of Reference **BE RECEIVED**.

2. **THAT** the Board **APPROVE** the NPCA Wainfleet Bog Advisory Committee Terms of Reference attached as Appendix 1.

3. **AND THAT** this report **BE CIRCULATED** to the City of Port Colborne and the Township of Wainfleet.

Purpose:

The purpose of this report is to receive board approval of the NPCA Wainfleet Bog Advisory Committee Terms of Reference.

Background:

The Wainfleet Bog is located approximately eight km northwest of the urban area of Port Colborne, within the Township of Wainfleet and the City of Port Colborne. The Wainfleet Bog was historically mined for peat, which resulted in significant adverse impacts to this rare and unique ecosystem. The two largest landowners of the Wainfleet Bog natural area are the NPCA and the Ministry of Natural Resources and Forestry (MNRF), with NPCA retaining the largest land holding. The Wainfleet Bog Conservation Area was acquired in 1995 by NPCA and is the largest of NPCA's Conservation Areas, at approximately 2,000 acres (800 hectares) in size. The Wainfleet Bog is a provincially significant wetland and is the largest least disturbed bog remaining within the Carolinian region of Ontario. This rare ecosystem provides habitat to a variety of unique plants and animals, as well as a suite of recreational uses.

At the June 18, 2021, NPCA Board approved resolution FA-126-2021 endorsing staff recommended approach for the future management of drainage in the Wainfleet Bog. That recommended approach also included creation of a stakeholder and community advisory committee. Staff were directed to expedite the development of a terms of reference for the advisory committee by the third quarter of 2021.

Discussion:

The NPCA Wainfleet Bog Advisory Committee is being established with an aim to provide collaborative perspective, guidance, and expert advice in the review, revision and implementation of the Wainfleet Bog Management Plan and other site strategies for the Wainfleet Bog Conservation Area. Staff consulted with First Nations and various relevant stakeholders during the development of the Wainfleet Bog Advisory Committee Terms of Reference (Appendix1). This consultation has ensured that there is accurate representation of relevant stakeholders included within the Terms of Reference.

Additionally, as per June 2021 Board direction, staff have also completed a draft design for the control structure for consideration of the Advisory Committee at their inaugural meeting. Implementation of proposed restoration project and post project monitoring will be initiated in 2022.

Over the past few months staff have met with various community partners and stakeholders including staff representatives from Six Nations of the Grand River Elected Council to keep them engaged in the project.

Following approval of the Terms of Reference, staff will initiate the recruitment process to establish the Wainfleet Bog Advisory Committee.

Financial Implications:

There are no financial implications associated with this Report. The NPCA Wainfleet Bog Advisory Committee has an in-kind budget of $2,500.00 for NPCA staff time, which is included in the 2022 operating budget.

Links to Policy/Strategic Plan:

The creation of the NPCA Wainfleet Bog Advisory Committee affiliates with developing management plans for each NPCA property as mandated by the Conservation Authorities Act. The development of the control structures on two separate canals on NPCA owned properties supports managing invasive species and enhancing biodiversity at NPCA properties.

Related Reports and Appendices:

Appendix 1: NPCA Wainfleet Bog Advisory Committee Terms of Reference

Authored by:

Original Signed by:

Adam Christie, BA
Director, Land Operations

Submitted by:

Original Signed by:

Chandra Sharma, MCIP RPP
Chief Administrative Officer/Secretary-Treasurer

NIAGARA PENINSULA CONSERVATION AUTHORITY

NPCA Wainfleet Bog Advisory Committee

Terms of Reference – DRAFT

Committee Name:	NPCA WAINFLEET BOG ADVISORY COMMITTEE
Type:	Advisory Committee
Date of Formation:	October 2021
Staff Support:	Secretariat including Senior staff (Director/Manager) and administrative support
Enabling Legislation:	June 16, 2021 – FA-39-21 Report
Amended Version:	N/A
Total No. of Members:	10
Meeting Frequency:	Quarterly – or as required
Annually:	
Budget:	$ 2500 (NPCA staff in kind)
Reporting Method:	Draft Minutes provided to CAO, reporting to the Board once per year, or as needed related to specific project approvals.

1. TITLE:

The name of the Advisory Committee shall be "**NPCA Wainfleet Bog Advisory Committee**".

2. ACCOUNTABILITY AND MANDATE:

To provide collaborative perspective, guidance and expert advice in the review, revision, and implementation of the NPCA management plan and other site strategies of the Wainfleet Bog Conservation Area. Members will serve in a non-governance capacity with a focus on providing advice and recommendations for consideration by NPCA staff.

3. TERMS OF APPOINTMENT AND VACANCIES:

Upon establishment of the Committee, members will be appointed to serve for a term of FOUR (4) years beginning in January of that year. Positions vacated will be filled through a "Call for Expression of Interest" to be conducted as required. In the event of a vacancy during a regular term, the vacancy may be filled for the remainder of that term.

4. RESOURCES & BUDGET:

Staff secretariat including one senior staff and one committee administrative coordinator will be provided by NPCA in kind. Facility or other supports will also be provided in kind. Members of Committee will be subject to NPCA volunteer policies, code of conduct, and media protocols. Provision of mileage or other reimbursement is not applicable for volunteer members. Small meeting expense may be covered as part of NPCA's regular budgets as appropriate at the discretion of senior staff.

Other subject matter experts (NPCA staff) may attend as necessary. Committee will be coordinated by NPCA staff.

5. REPORTING:

Meeting Agendas will be prepared by the NPCA's staff in consultation with the Advisory Committee.

Minutes shall be recorded and circulated to members. DRAFT of unapproved minutes may be submitted to the NPCA CAO following a COMMITTEE meeting as long as Committee members are given 2 weeks to review the draft minutes. Staff reports to the Board will be presented as needed for information and /or approvals.

6. RESPONSIBILITIES:

- Act as Champions/Ambassadors for the Wainfleet Bog ecosystem.
- Advise on potential partnership opportunity and fundraising.
- Provide a conduit to the local community within their sector.
- Provide input based on their expertise and experience.

7. MEMBERSHIP:

The NPCA WAINFLEET BOG ADVISORY COMMITTEE shall consist of up to Eleven (11) members comprising multi-stakeholder representation including: residing area municipalities, business sector, agriculture, conservation/naturalist clubs, science/academia, hunting, Indigenous representatives, adjacent partners/landowners and NPCA staff. The NPCA recognizes diversity as a source of strength and works to champion inclusive attitudes and encourage adoption of inclusive approaches that lead to full and meaningful participation of all.

7.1 REPRESENTATIVE SEAT STRUCTURE:

The Public Advisory Committee shall consist of the following representation:

- TWO (2) members representing local municipal government (Wainfleet and Port Colborne)
- TWO (2) members representing stakeholders
- TWO (2) members representing conservation/naturalist clubs or ENGO's
- ONE (1) member representing the science/academia sector

- TWO (2) members representing First Nations
- TWO (2) for the NPCA (NPCA Board and senior staff member).

7.2 Internal or external persons (experts) may be invited to attend the meetings at the request of staff, on behalf of the NPCA Wainfleet Bog Advisory COMMITTEE, to provide advice and assistance where necessary.

7.3 NPCA WAINFLEET BOG ADVISORY COMMITTEE members may cease to be a member of the Committee if they:

- Resign from the Committee
- No longer objectively represent their respective sector
- Fail to adhere to NPCA Administrative By-law Code of Conduct and Media protocols.
- Fail to meet their responsibilities, prompting the Committee to recommend their removal to the NPCA CAO.

7.4 DECISION MAKING AND RULES OF ENGAGEMENT:

Decisions of the NPCA WAINFLEET BOG ADVISORY COMMITTEE are by consensus and advisory and no formal voting process is required. Should a consensus not be reached by the Advisory Committee on a any major topic the topic will be taken to the NPCA Board of Directors for consideration.

7.5 A meeting quorum will be 50% + 1 of current filled positions.

8. COMMITTEE ADMINISTRATION:

To provide leadership, NPCA staff will serve as the Facilitator of NPCA WAINFLEET BOG ADVISORY COMMITTEE. NPCA staff will provide administrative services for the Advisory Committee, including preparation and distribution of agendas, recording of meeting minutes/notes, reports, and general information as required.

The responsibilities include:

- Building consensus
- Providing leadership and ensuring the fair and effective functioning of the Committee
- Scheduling meetings and notifying WAINFLEET BOG ADVISORY COMMITTEE members
- Inviting special guests to attend meetings when required
- Guiding the meeting according to the agenda and time available
- Ensuring all discussion items end with a decision, action, or definite outcome
- Review and approval of draft minutes before distribution
- Approving agenda items and correspondence

- Approving delegations for Advisory Committee meetings
- Act as a conduit between the NPCA Wainfleet Bog Advisory Committee and the NPCA CAO.

9. ROLES AND EXPECTATIONS OF MEMBERS:

- Review meeting materials in advance of the meetings and arrive prepared to provide a broad perspective on the issues under consideration.
- Submit agenda items to staff at a minimum of two (2) weeks prior to the meeting date for approval.
- Make every effort to attend regularly scheduled meetings. If not available, notify the Chair and staff contact on inability to attend at least one day prior to the meeting date.
- Agree to describe, process, and resolve issues in a professional and respectful manner.
- Provide constructive input to help identify future projects or strategic priorities for consideration, respective of their sector representation.
- Members are encouraged to go back to their respective sectors with information received at Advisory Committee meetings to notify of opportunities to give feedback.

10. DURATION OF MEETINGS:

Meetings will be approx. one and a half (1.5) hours in duration. Exceptions may occur from time to time to deal with significant items.

11. APPLICATION PROCESS – CALLS FOR EXPRESSIONS OF INTEREST:

- Potential applicants will be assessed and recommended for appointment based not only on if there is an available seat but also on their ability to meet the roles and expectations of a member (Section 9). Seats may remain vacant until candidates with the requisite background and skills can be identified.
- The Call of Expressions of Interest will be fully transparent and made public and published via NPCA website, social media venues and local print media.
- Applicants shall be required to submit the following information:
    - Contact information
    - Area of expertise, general availability, why they want to serve on NPCA WAINFLEET BOG ADVISORY COMMITTEE
    - Highest level of education
    - Professional/employment background and professional memberships.
- Applications will be evaluated by staff and recommended to the Board based on the following criteria:
    - Knowledge and experience related to the sector representation
    - Knowledge of the Niagara Peninsula Conservation Authority
    - Experience working on multi-sector committees

  - Relevant volunteer/community service work related to the seat they are applying for.

- Final recommendation of candidates will be presented to the NPCA Board for appointment. NPCA maintains a strong policy of equal opportunity. The NPCA recognizes that diversity is a source of strength and works to champion inclusive attitudes and approaches to recruitment that lead to full and meaningful participation of all.

NOTE: Personal member information, other than name and resident municipality, will be kept confidential in accordance with Provincial legislation.

12. AMENDMENTS:

The Terms of Reference and the role of the NPCA WAINFLEET BOG ADVISORY COMMITTEE shall be reviewed and assessed every 4 years by NPCA CAO and presented to the Board for approval.

Report To: **Board of Directors**

Subject: **NPCA Transition Plan in Accordance with Section 21.1.4 *of the Conservation Authorities Act***

Report No: **FA-68-21**

Date: **November 19, 2021**

Recommendation:

1. **THAT** Report No. FA-68-21 RE: NPCA Transition Plan in Accordance with Section 21.1.4 of the Conservation Authorities Act **BE RECEIVED**.

2. **AND FURTHER THAT** the NPCA Transition Plan, as appended, **BE APPROVED** and **SUBMITTED** to the Ministry of Environment and Parks (MECP) with a copy to NPCA funding municipalities and posting on the NPCA website.

Purpose:

The purpose of this report is to seek NPCA Board of Directors approval of NPCA Transition Plan in accordance with Section 21.1.4 of the updated Conservation Authorities Act and prior to submission to the MECP by the December, 2021 deadline.

Background:

With the recently proclaimed provisions in the *Conservation Authorities Act* (CA Act) and accompanying Regulation 687/21, there is a requirement to deliver a Transition Plan to the Province and participating municipalities on how conservation authorities propose to meet the requirements of the CA Act. The Transition Plan must include timelines for developing required inventories of program and services and development and execution of MOU's/Agreements.

The Transition Plan is to be submitted to the Ministry of the Environment, Conservation and Parks (MECP) and shared with participating municipalities along with posting on the Conservation Authority website.

The CA Act includes the following requirements and deadlines:

a) Completion of a Transition Plan on or before December 31, 2021
b) Completion of an Inventory of Conservation Authority Programs and Services by February 28, 2022
c) Submission of six quarterly progress reports to MECP throughout July 2022 – October 2023.
d) Completion of MOU/Agreements between CA's/Municipal Government(s) by January 1, 2024

The attached Transition Plan sets out the process and timelines through which NPCA will be developing and executing MOUs/Agreements with NPCA's participating municipalities, and other lower tier municipal partners in order to fund any program and services. The plan also includes progress reporting to municipalities and communication activities through this transition process.

Financial Implications:

Staff resourcing needs are addressed through internal reallocations of resources and new budget requests as appropriate.

Links to Policy/Strategic Plan:

The NPCA approved a new 10-year Strategic Plan in 2021 strategically aligned with the CA Act transition.

Related Reports and Appendices:

Appendix 1: NPCA Transition Plan in accordance with Section 21.1.4 of the *Conservation Authorities Act*

Authored and Submitted by:

Original Signed by:

Chandra Sharma, MCIP RPP
Chief Administrative Officer / Secretary-Treasurer

Niagara Peninsula Conservation Authority Transition Plan

In accordance with Section 21.1.4 of the Conservation Authorities Act

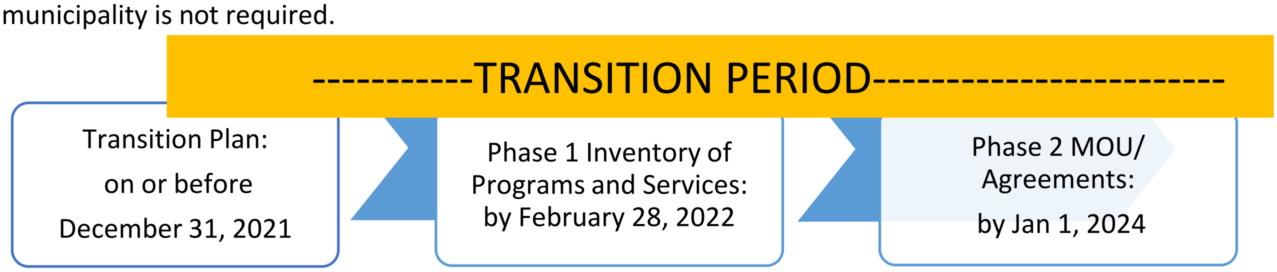
BACKGROUND & TRANSITION PERIOD

The recently proclaimed provisions within the *Conservation Authorities Act* and accompanying regulations establish a requirement for Transition Plans and Agreements for Programs and Services (see Section 21.1.2 of the Act and Regulation 687/21). The purpose of the transition period is to provide Conservation Authorities (CA) and municipalities with the time to address changes to the budgeting and levy process based on:

Category 1: Mandatory programs and services where municipal levy could be used without any agreement;

Category 2: Non-mandatory programs and services at the request of a municipality with municipal funding through a MOU or agreement; and

Category 3: This category includes other non-mandatory programs and services that a CA determines are advisable. These may use the municipal levy through a MOU/agreement. Programs and services in Category 3 may also be funded through other means. In the latter situation, a MOU/agreement with the municipality is not required.



PART 1 **PART 2** **PART 3**

Figure 1. Key Components and deadlines for *Transition Plan and Agreements* Regulation (O.Reg. 687/21)

WORK PLAN, TIMELINE AND CONSULTATIONS

The process will support 2024 budget discussions including the new categorization of Conservation Authority (CA) programs and services. Although each Conservation Authority has its own budget processes and timelines, the NPCA and neighbouring Conservation Authorities that share a municipality are coordinating for consistency.

PHASE 1: TRANSITION PLAN AND INVENTORY OF CURRENT PROGRAMS AND SERVICES

Task	Date
Phase 1: October 2021 - February 2022	
Transition Plan	
Present Draft Transition Plan to Board of Directors	Nov. 19, 2021
Provide Transition Plan to municipalities and initiate work plaining	Dec. 2021
Provide Transition Plan to MECP	Dec. 2021
Transition Plan on Website	Dec. 2021
Inventory of Programs and Services	
Develop inventory of current programs & services draft in consultation with Conservation Ontario and Municipalities	Dec.-Jan. 2022
Present draft inventory to BOD	Jan. 2022
Provide Inventory to Municipalities	Jan. 2022
Provide Inventory to MECP	Feb. 2022
Inventory on Website	Feb. 2022

DRAFT

PHASE 2: MOU'S/AGREEMENTS

Task	Date
Phase 2: February 2022 -December 2023	
Draft inventory with categories 1, 2 and 3	Feb. 2022
Consult with municipalities on inventory Consult with other Ministries as necessary	July – Sept. 2022
Financial Forecast (Programs & Services approved and aligned with Strategic Plan and Core Watershed RM Strategy) 2024-2030	Sept. – Dec. 2022
Create draft MOU/agreements for "other programs and services" requiring levy	Sept. 2022 – Jan. 2023
Apportion levy for 2024 budgets onwards	Sept. 2022 – Jan. 2023
Bring draft MOU/agreements with cost apportionment scenario to BOD	Feb.-Mar. 2023
Consult with municipal staff on draft MOU/agreements	Mar.- June 2023
Formal Resolution from BOD re: MOU/agreements to municipalities	June 2023
Circulate MOU/agreements to municipalities	June – Aug. 2023
Execute MOU/agreements	Aug. – Sept. 2023
Develop draft 2024 budget	Sept. 2023
BOD approves draft 2024 budget to circulate to municipalities	Oct. 2023
Presentations to Municipal Councils	Nov. 2023-Jan. 2024
Submit copies of signed MOU/agreements to MECP	Dec. 2023
Transition period ends	Jan. 1, 2024
Submit final version of inventory to MECP	Jan. 31, 2024
Post final MOUs/agreements on CA website	Jan. 31, 2024

DRAFT

PROGRESS REPORTS TO MINISTRY OF ENVIRONMENT, CONSERVATION AND PARKS

Progress Reports	Date
Progress report to MECP	July 1, 2022
Progress report to MECP	Oct. 1, 2022
Progress report to MECP	Jan. 1, 2023
Progress report to MECP	April 1, 2023
Progress report to MECP	July 1, 2023
Progress report to MECP	Oct. 1, 2023
Final Report to MECP	Jan. 1, 2024

COMMUNICATIONS PLAN

The NPCA has a culture of good internal and external communication. This transition will follow effective and timely communications.

Audience	Method of Communications
NPCA Staff	In person/online meetings, email updates
NPCA Board of Directors	Board meeting reports, email updates
Municipal staff	Regular meetings and correspondence
Municipal Councils	Delegations to council/ reports (joint reports by all CA's where possible)
General public	Website, statements, social media

DRAFT

FINANCE COMMITTEE
ON-LINE VIDEO CONFERENCE
MEETING MINUTES
Thursday, November 4, 2021
9:30 a.m.

MEMBERS PRESENT: J. Metcalfe, Chair
S. Beattie
R. Brady
R. Foster
B. Mackenzie
M. Woodhouse

MEMBERS ABSENT: B. Steele

STAFF PRESENT: C. Sharma, Chief Administrative Officer/Secretary–Treasurer
G. Bivol, Clerk
A. Christie, Director, Operations
C. Coverdale, Business and Financial Analyst
L. Gagnon, Director, Corporate Services
E. Gervais, Procurement Officer
G. Shaule, Administrative Assistant
S. Shah, Administrative Assistant, Corporate Services
G. Verkade, Senior Manager, Integrated Watershed Planning / Information Management

Chair Metcalfe called the meeting to order at 9:30 a.m.

1. APPROVAL OF AGENDA

Recommendation No. FC-25-2021
Moved by Member Brady
Seconded by Member Woodhouse

THAT the Finance Committee meeting agenda dated November 4, 2021 **BE ADOPTED**.

CARRIED

2. DECLARATIONS OF CONFLICT OF INTEREST

None

3. APPROVAL OF THE MINUTES

a) Minutes of the Finance Committee meeting dated July 28, 2021 – A clerical amendment was noted to reflect the designation of Member Brady as Vice Chair of the Finance Committee.

DRAFT

Recommendation No. FC-26-2021
Moved by Member Beattie
Seconded by Member Brady

THAT the minutes of the Finance Committee meeting dated July 28, 2021, **BE APPROVED** as amended.

CARRIED

4. CORRESPONDENCE

None

5. DELEGATIONS

None

6. PRESENTATIONS

None

7. CONSENT ITEMS

None

8. DISCUSSION ITEMS

a) Report No. FC-16-21 RE: 2022 Draft Budgets and Municipal Levies – Lise Gagnon, Director of Corporate Services presented via PowerPoint. Members posed questions. Lengthy discussion ensued.

Recommendation No. FC-27-2021
Moved by Member Woodhouse
Seconded by Member Foster

THAT the PowerPoint presentation entitled "2022 Draft Budgets and Municipal Levies" from Lise Gagnon, Director of Corporate Services **BE RECEIVED**.

CARRIED

Recommendation No. FC-28-2021
Moved by Member Woodhouse
Seconded by Member Foster

1. **THAT** Report No. FC-16-21 RE: 2022 Draft Budgets and Municipal Levies **BE RECEIVED** for Committee review.

2. **THAT** the Finance Committee is recommending that the Board of Directors **CONSIDER** and **APPROVE** the following recommendations:

a. **THAT** the 2022 Draft Budgets and Municipal Levies **BE APPROVED** at the Board of Directors meeting on November 19th, 2021 for discussion with participating municipal staff, in accordance with Board approved Budget Assumptions.

b. **THAT** Staff **CONTINUE** to discuss the possibility of reinstating the Land Acquisition Reserve contributions with municipal funding partners.

c. **THAT** the list of 2022 unfunded pressures **BE PROVIDED** to partner municipalities for any future opportunities outside the 2022 budget through collaborative projects or external funding.

d. **THAT** NPCA staff **REPORT** the results of discussions with participating municipal staff to the 2022 Q2 Finance Committee and Board of Directors meetings.

e. **AND FURTHER THAT** a copy of the 2022 Draft Budgets and Municipal Levies **BE FORWARDED** to partner municipalities in advance of the November 19th, 2021 NPCA Board of Directors meeting.

CARRIED

b) Report No. FC-17-21 RE: Financial Report – Q3 – 2021 – Lise Gagnon, Director of Corporate Services, Adam Christie, Director of Operations and C.A.O. Chandra Sharma presented. Members posed questions. Discussion ensued.

Recommendation No. FC-29-2021
Moved by Member Woodhouse
Seconded by Member Foster

THAT Report No. FC-17-21 RE: Financial Report – Q3 - 2021 **BE RECEIVED**.

CARRIED

9. NEW BUSINESS

None

10. ADJOURNMENT

By consensus, the meeting adjourned at 11:03 a.m..

John Metcalfe, Committee Chair	Chandra Sharma, MCIP, RPP Chief Administrative Officer / Secretary - Treasurer

Report To: **Board of Directors**

Subject: **Financial Report – Q3 - 2021**

Report No: **FA-69-21**

Date: **November 19, 2021**

Recommendation:

THAT Report No. FA-69-21 RE: Financial Report – Q3 - 2021 **BE RECEIVED**.

Purpose:

The purpose of this report is to provide the Board of Directors with a summary of operating and capital expenditures and to provide a comparison of actual results to the budget as approved by the Board.

Background:

On November 4, 2021, the Finance Committee received Report No. FC-17-21 RE: Financial Report – Q3 – 2021 (Recommendation No. FC-29-2021).

Discussion:

The report confirms the general financial oversight and compliance with Public Sector Accounting Board Standards.

Financial Implications:

The Revenue and Expenditure lines are within budget allocations identified during the budget preparation and approval cycle.

Related Reports and Appendices:

Appendix 1: 2021 Operating Statement – Q3

Appendix 2: Capital Projects 2021 – Q3

Prepared by:

Original Signed by:

Lise Gagnon, CPA, CGA
Director, Corporate Services

Submitted by:

Original Signed by:

Chandra Sharma, MCIP, RPP
Chief Administrative Officer/
Secretary-Treasurer

Niagara Peninsula Conservation Authority

2021 CONSOLIDATED OPERATING STATEMENT - Q3 - January 1 to September 30, 2021

Appendix 1 - Report No. FA-69-21	Year to date				Annual	
	Actual	Budget	Variance	Var %	Budget	Comments
Source of Funds						
Municipal Funding	4,657,639	4,660,109	- 2,470	-0.1%	6,213,479	Variance not material
Provincial Funding	308,628	324,771	- 16,143	-5.0%	383,594	Timing only - cash flow from MECP
Federal Funding	71,031	15,800	55,231	0.0%	70,000	Unbudgeted ECCC for Riparian Buffers and Student Wage Subsidy
Park Operations	2,157,105	1,777,288	379,817	21.4%	2,183,045	Better than expected revenue generation
Permits and Regulatory Fees	424,540	373,500	51,040	13.7%	498,000	Permit fees exceeding targets
Other Revenue	211,796	306,375	- 94,579	-30.9%	517,000	Timing - will self correct
Total Revenues/Source of Funds	**7,830,739**	**7,457,843**	**372,896**	**5.00%**	**9,865,118**	
Use of Funds						
Salaries and Benefits	4,675,851	4,892,537	- 216,686	-4.4%	6,625,056	Delay in filling operating operations + savings due to the pandemic
Other Employee Related Expenses	136,082	174,620	- 38,538	-22.1%	236,649	Covid-19 - mileage/staff exp, training offset by incr health/safety
Board and Volunteer	19,879	47,700	- 27,821	-58.3%	63,600	Covid-19 impact
Professional Fees	298,750	531,378	- 232,628	-43.8%	759,843	Timing of contractor serv, consulting & lab analysis
Occupancy Costs	424,440	405,187	19,253	4.8%	543,250	Insurance premium increase - 22%
Vehicles and Equipment	173,938	206,689	- 32,751	-15.8%	275,240	Delivery delay - rental vehicles
Park Maintenance	481,861	410,651	71,210	17.3%	514,890	Tree removal; building and grounds maintenance
Cost and Expenses	217,070	221,096	- 4,026	-1.8%	347,400	Variance not material
Materials and Supplies	153,214	162,645	- 9,431	-5.8%	216,690	Variance not material
Marketing and Promotion	172,031	227,372	- 55,341	-24.3%	282,500	Covid-19 impact - special events
Total Expenses/Use of Funds	**6,753,116**	**7,279,875**	**- 526,759**	**-7.2%**	**9,865,118**	
Net Surplus as at September 30, 2021	**1,077,623**	**177,968**	**899,655**		**-**	

Niagara Peninsula Conservation Authority - 2021 CAPITAL PROJECTS

Appendix 2 - Report No. FA-69-21

Project Name	Location	Funding Source	Munic.	Funding: External	Funding: 2021	Funding: Total Project	Budget Carried Forward	YTD Spend at 31-DEC-2020	YTD Spend at 30-SEPT-2021	Total Project Spend at 30-SEPT-2021
Corporate Services										
Annual PC replacements	Various	Special Levy - ALL	All		**45,000**	**45,000**	-	-	30,981	30,981
Data Centre Network Upgrades	HQ - Welland	Special Levy - ALL	All	-	**37,000**	**37,000**	-	-	4,686	4,686
Digital Terrain Model Update	Various	Special Levy - ALL	All	-	**150,000**	**150,000**	-	-	-	-
Natural Areas ELC Mapping Update	Various	Other	All	-	**150,000**	**150,000**	-	-	-	-
Records Management - phased	HQ - Welland	Special Levy - ALL	All	-	**40,000**	**40,000**	-	-	-	-
2020 Restoration & Watershed Plan Data Update	Various			-	-	-	**150,000**	-	35,359	35,359
2020 Restoration Site Design - Lakewood	Lakewood			-	-	-	**50,000**	-	-	-
2020 Financial Reporting & Budgeting Module	HQ - Welland			-	-	-	**42,100**	-	27,628	27,628
TOTAL - Corporate Services				$ -	**$ 422,000**	**$ 422,000**	**$ 242,100**	**$ -**	**$ 98,654**	**$ 98,654**
Land Operations										
Deferred Projects - BF Septic System:										
- 2020 Flood Plain Mapping - Beaver Creek	Beaver Creek	Other	Niagara	150,000	-	**150,000**	-	-	16,327	16,327
- 2020 CFC Gallery Upgrades	Balls Falls	Other	Niagara	49,870	**15,130**	**65,000**	-	(27,180)	12,720	(14,460)
- 2020 Equipment Sustainment	Various	Other	All	-	**54,586**	**54,586**	-	-	54,586	54,586
- 2020 Balls Falls Internet Upgrade	Balls Falls	Other	Niagara	-	**40,000**	**40,000**	-	2,035	6,615	8,650
- 2020 Asset Management Program	Various	Other	All	-	**30,000**	**30,000**	-	33,010	22,072	55,082
Field Centre Restoration - Phase 2	Balls Falls	Special Levy - Niagara	Niagara	-	**47,500**	**47,500**	-	-	49,832	49,832
Roadway Improv - Phase 1 - Chippawa	Chippawa Creek	Special Levy - Niagara	Niagara	-	**100,000**	**100,000**	-	-	10,532	10,532
St John's - Heritage Building Restoration	Central Workshop	Special Levy - Niagara	Niagara	-	**130,000**	**130,000**	-	-	119,003	119,003
Mowers (Chippawa and Binbrook)	Central Workshop	Special Levy - ALL	All	-	**35,000**	**35,000**	-	-	42,606	42,606
RTV (CW)	Vaious - Niagara	Special Levy - Niagara	Niagara	-	**20,000**	**20,000**	-	-	15,005	15,005
Skid Steer (Central Workshop)	Central Workshop	Special Levy - ALL	All	-	**26,000**	**26,000**	-	-	24,787	24,787
Mini Excavator	Central Workshop	Special Levy - ALL	All	-	**70,000**	**70,000**	-	-	62,475	62,475
Cave Springs Parking Lot	Central Workshop	Special Levy - Niagara	Niagara	-	**105,000**	**105,000**	-	-	26,452	26,452
Rollon/rolloff - dual axle 7600 Int'l Truck	Central Workshop	Special Levy - ALL	All	-	**140,000**	**140,000**	-	-	-	-
Wainfleet Quarry	Wainfleet			-	-	**60,000**	-	-	37,724	37,724
Restoration Project - Binbrook	Binbrook			85,000	-	**85,000**	-	-	5,882	5,882
Automated Gates - Binbrook & Ball's Falls	Binbrook/ Ball's Falls			-	-	**TBD**	-	-	32,198	32,198
Land Purchase - Morgan's Point	Morgan's Point			-	-	**772,900**	-	-	772,894	772,894
2020 - North Side Comfort Station	Long Beach			-	-	-	**397,100**	76,933	320,351	397,284
2020 - Water Treatment System Upgrades	Binbrook			-	-	-	**155,000**	37,582	12,395	49,977
2020 - Treetop Trekking Building & Amenities	Binbrook			-	-	-	**203,000**	73,517	122,646	196,163
2020 - Septic System - Binbrook	Binbrook			-	-	-	**852,000**	27,775	52,573	80,348
2020 - Field Centre Restoration	Balls Falls			-	-	-	**35,000**	6,754	23,277	30,031
TOTAL - Land Operations				$ 199,870	**$ 813,216**	**$ 1,013,086**	**$ 1,642,100**	**$ 230,426**	**$ 1,842,951**	**$ 2,073,377**
Watershed										
Floodplain Mapping - Big Forks Creek	Niagara	Special Levy - Niagara	Niagara	150,000	-	**150,000**	-	-	15,086	15,086
Water Quality Equipment	Pelham	Special Levy - Niagara	Niagara	-	**20,000**	**20,000**	-	-	-	-
Stream Gauge Equipment	Various	Special Levy - ALL	All	-	**10,000**	**10,000**	-	-	-	-
Virgil Dam - Remedial Measures	Niagara	Special Levy - Niagara	Niagara	-	**200,000**	**200,000**	-	-	6,034	6,034
TOTAL - Watershed				$ 150,000	**$ 230,000**	**$ 380,000**	**$ -**	**$ -**	**$ 21,120**	**$ 21,120**
GRAND TOTAL				**$ 349,870**	**$ 1,465,216**	**$ 1,815,086**	**$ 1,884,200**	**$ 230,426**	**$ 1,962,725**	**$ 2,193,151**

Report To: **Board of Directors**

Subject: **2022 Draft Budgets and Municipal Levies**

Report No: **FA-70-21**

Date: **November 19, 2021**

Recommendation:

1. **THAT** Report No. FA-70-21 RE: 2022 Draft Budgets and Municipal Levies **BE RECEIVED**.

2. **THAT** the 2022 Draft Budgets and Municipal Levies **BE APPROVED** for discussion with participating municipal staff, in accordance with Board approved Budget Assumptions.

3. **THAT** Staff **CONTINUE** to discuss the possibility of reinstating the Land Acquisition Reserve contributions with municipal funding partners.

4. **THAT** the list of 2022 unfunded pressures **BE APPROVED** and **PROVIDED** to partner municipalities for any future opportunities outside the 2022 budget through collaborative projects or external funding.

5. **AND FURTHER THAT** the final 2022 Budget **BE BROUGHT** back to the Finance Committee and Board of Directors meetings for approval.

Purpose:

The purpose of this report is to provide the Board of Directors with:

2022 General Levy Apportionment
2022 Draft Budgets & Municipal Levies (General and Special)
2022 Unfunded Pressures

Background:

In September 2021, the Board of Directors approved the Budget Assumptions for 2022 (Resolution No. FA-158-2021). In the development of the recommended budget assumptions for the 2022 budget process, Staff has reviewed and considered the following:

- Cost of living adjustments (COLA) and grid step increases
- Inflation (Consumer price index – CPI)
- Multi-year contractual obligations, including OPSEU collective agreement provisions
- Operating and capital unfunded pressures
- Operational impact of the Covid-19 pandemic
- Budget guidelines from municipal partners
- General economic outlook and political climate
- Future service delivery capacity and standard
- Conservation Act Regulations
- Asset management, state of good repair for asset base, capital funding gaps, deferred capital projects and building a sustainable capital plan
- New programs and growth initiatives/pressures
- Board approved Strategic Plan 2021 -2031

The NPCA has received 2022 budget guidance from both Niagara Region and the City of Hamilton, which includes a provision for a 2% increase over 2021. Budget guidelines from Haldimand County have not been received yet. As such, NPCA Staff have applied a 2% consolidated strategy for all partner municipalities in the preparation of the 2022 municipal General Levy.

Please note that, as previously reported in 2021, expenses budgeted in 2022 specific to the Covid-19 Pandemic have been presented as a separate line item, in accordance with budget guidelines from Niagara Region.

On November 4, 2021, the Finance Committee approved the 2022 Draft Budgets & Municipal Levies Report No. FC-16-21 (Resolution No. FC-27-2021).

Discussion:

2022 Draft Operating Budgets

Summary of Operating Budget Revenues and Expenses:

Operating Budget - Revenues	2022 Budget	2021 Budget	Variance
Municipal Funding	6,337,748	6,213,479	124,269
Provincial Funding	391,978	383,594	8,384
Federal Funding	120,000	70,000	50,000
Program Revenue	3,443,838	2,681,045	762,793
Other	564,485	517,000	47,485
Total - Operating Revenues	10,858,049	9,865,118	992,931
Operating Budget - Expenses	**2022 Budget**	**2021 Budget**	**Variance**
Salaries and benefits, Employee Related	7,475,602	6,861,705	613,897
Governance	57,600	63,600	- 6,000
Professional Fees, Contractor Services	514,500	555,343	- 40,843
Materials & Supplies, Vehicles & Equipment	575,250	491,930	83,320
Occupancy Costs	540,460	493,250	47,210
Park Maintenance	580,300	514,890	65,410
Information Management/GIS	418,037	340,500	77,537
Marketing, Advertising, Printing, Signs	111,000	160,500	- 49,500
Special Events (Festival, Holiday Trail)	315,600	161,100	154,500
Flood Forecasting	127,000	127,000	-
Miscellaneous	142,700	95,300	47,400
Total - Operating Expenses	10,858,049	9,865,118	992,931

Overall, the operating volume in this zero-based budget is projected to increase by 10.2% ($993K) attributed to a 2% increased to the Municipal General Levy, and 8.2% resulting from increases in Authority Generated Funds. As noted in the “Summary – 2022 Draft Municipal Levy” section on page 4, the Municipal General Levy increase is in compliance with municipal guidelines at 2% over the 2021 fiscal year and represents a consolidated increase of $123,311.

Salaries and Benefits: the variance of $614K over 2021 is due to an anticipated COLA increase to existing salary complement, augmented by an addition to FTE complement of 4 permanent positions to address the growing pressures in Planning and Development as well as CA Act requirements for Land Management Planning.

Special Events: 2022 includes a provision for the Holiday Trail initiative (unbudgeted for 2021). Increase in expenses is offset by event revenues.

Full details of the 2022 Draft Operating Budget are outlined in Appendix 1.

2022 Draft Capital and Special Projects Budget

Summary of Capital and Special Projects:

Capital and Special Projects	2022 Budget	2021 Budget	Variance
Corporate Services	218,469	452,000	- 233,531
Land Operations - Balls Falls	174,564	152,500	22,064
Land Operations - Binbrook	52,898	1,210,000	- 1,157,102
Land Operations - Chippawa Creek	195,723	100,000	95,723
Land Operations - Long Beach	105,796	-	105,796
Land Operations - Passive Parks	457,040	580,586	- 123,546
Watershed	550,140	530,000	20,140
Total - Capital & Special Projects	1,754,630	3,025,086	- 1,270,456

The 2022 Draft Capital and Special Projects budget represents past backlog and current critical priorities. Further to discussion with Niagara Region municipal staff, and in consideration of current pressures on municipal budgets, Staff is recommending a very conservative budget increase over 2021 for Capital and Special Projects of $289,415 (excluding $1.21M from the City of Hamilton for Binbrook projects).

Full details of the 2022 Draft Capital and Special Projects Budget are outlined in Appendix 1.

Summary - 2022 Draft Municipal Levy

The General Levy Apportionment for 2022 breaks down as follows:

2022 Levy Apportionment			
	2022	2021	Variance
Niagara	76.9681%	76.9811%	-0.0130%
Hamilton	21.1634%	21.1565%	0.0069%
Haldimand	1.8685%	1.8624%	0.0061%
Total	100.0000%	100.0000%	0.0000%

In keeping with prior years, the levy apportionment ratios are calculated from assessment data provided by MPAC, and further revised based on the Conservation Authority Levies Regulation.

General Levy

	General Levy - 2021	Pandemic Funding	Total 2021	General Levy - 2022	Pandemic Funding	Total 2022	Levy Variance Amount	Levy Variance %
Niagara	4,684,681	109,464	4,794,145	4,767,623	110,422	4,878,044	82,942	1.8%
Hamilton	1,307,257	-	1,307,257	1,341,283	-	1,341,283	34,026	2.6%
Haldimand	112,077	-	112,077	118,421	-	118,421	6,344	5.7%
TOTAL	**6,104,015**	**109,464**	**6,213,479**	**6,227,326**	**110,422**	**6,337,748**	**123,311**	**2.0%**

Municipal Levy Summary - 2022

LEVY SUMMARY - 2022				
			Variance	
	2022	2021	Amount	%
NIAGARA				
General Levy	4,767,623	4,684,681	82,942	
Special Levy	1,505,490	1,241,073	264,417	
TOTAL	**6,273,113**	**5,925,754**	**347,359**	**5.86%**
Pandemic Funding	110,422	109,464	958	
Total	6,383,535	6,035,218	348,317	
HAMILTON				
General Levy	1,341,283	1,307,251	34,032	
Special Levy	232,986	199,503	33,483	
TOTAL	**1,574,269**	**1,506,754**	**67,515**	**4.48%**
HALDIMAND				
General Levy	118,420	112,077	6,343	
Special Levy	12,697	24,640	- 11,943	
TOTAL	**131,117**	**136,717**	**- 5,600**	**-4.10%**
CONSOLIDATED				
General Levy	6,227,326	6,104,009	123,317	
Special Levy	1,751,173	1,465,216	285,957	
TOTAL	**7,978,499**	**7,569,225**	**409,274**	**5.41%**
Pandemic Funding	110,422	109,464	958	
Total	8,088,921	7,678,689	410,232	

Land Acquisition Reserve Contributions

Niagara

From 2016 to 2018, Niagara Region contributed $500,000 annually to a Land Acquisition Reserve, adding $1.5M to an opening balance of $298,176. The reserve balance as of December 31, 2020, is $1.798M. This reserve balance will be reduced by the acquisition cost of a parcel of land on Morgan's Point Road in Wainfleet in the amount of $750K plus closing and legal fees.

Staff would like to continue discussions with Niagara Region Staff on the feasibility of a Land Acquisition Reserve contribution in the amount of $500,000.

Hamilton

From 2016 to 2020, the City of Hamilton contributed $100,000 annually to a Land Acquisition Reserve. The reserve balance as of December 31, 2020, is $994,152.

Staff would like to continue discussions with Hamilton Staff on the feasibility of a Land Acquisition Reserve contribution in the amount of $100,000.

2022 Unfunded Budget Priorities

In the last several years, NPCA's ability to undertake both operating special projects and capital investments have been significantly impacted by a lack of financial resources. The following issues contributed in part:

a) The COVID 19 Pandemic has exerted a great deal of pressure on NPCA's Greenspace and Parks. NPCA needs to make significant investments in infrastructure upgrades and staffing resources to safely serve our communities.
b) Staff anticipates significant planning and growth pressures in the coming years in the NPCA's jurisdiction requiring NPCA to proactively invest in science and information to support decision making.
c) NPCA's assets and infrastructure have a significant state-of good repair backlog and gaps that needs to be addressed.
d) Completion of NPCA 10 Year Strategic Plan has identified several gaps and priorities that NPCA must address in the coming years.
e) Conservation Authority Act update and associated regulations requires several transition priorities to be completed in 2022 and beyond.

An assessment of current unfunded pressures was prioritized by Staff, summarized below. These initiatives ($7.723M), classified in 4 categories outlined below, are detailed in Appendix 1.

2022 Unfunded Budget Priorities					
Classification	**Niagara**	**Hamilton**	**Haldimand**	**External**	**TOTAL**
Restoration & Shoreline Resiliency	324,182	72,640	6,413	0	403,236
Planning and Growth Pressures	620,176	82,537	7,287	0	710,000
Conservation Authority Act Transition	115,452	31,745	2,803	0	150,000
State of Good Repair/Health and Safety	4,955,836	1,353,528	50,636	100,000	6,460,000
	6,015,645	**1,540,451**	**67,140**	**100,000**	**7,723,236**

Financial Implications:

The NPCA's 2022 Budgets and Municipal Levies have been developed in accordance with the existing levy guidelines of *The Conservation Authorities Act (CAA).*

Updated Levy Regulations are anticipated to be released by the Province of Ontario later in 2021 and may impact future budgets (2024) to meet the requirements of the CA Act updates.

Unfunded pressures are currently not included in the 2022 Budget. A diverse range of strategies will be deployed to address these gaps. Staff will investigate external funding sources and liaise with external stakeholders and all levels of governments to look for collaborative opportunities outside the existing budget processes.

Related Reports and Appendices:

Appendix 1: NPCA 2022 Draft Budgets & Municipal Levies

Authored by:

Original Signed by:

Lise Gagnon, CPA, CGA
Director, Corporate Services

Submitted by:

Original Signed by:

Chandra Sharma, MCIP, RPP
Chief Administrative Officer/Secretary-Treasurer

Niagara Peninsula Conservation Authority

2022 DRAFT BUDGETS & MUNICIPAL LEVIES

November 2021

NIAGARA PENINSULA CONSERVATION AUTHORITY

Appendix 1 - Report No. FA-70-21

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2022 DRAFT BUDGET SUMMARY

Operating Budget - Revenues	2022 Budget	2021 Budget
Municipal Funding	6,337,748	6,213,479
Provincial Funding	391,978	383,594
Federal Funding	120,000	70,000
Program Revenue	3,443,838	2,681,045
Other	564,485	517,000
Total - Operating Revenues	10,858,049	9,865,118

Operating Budget - Expenses	2022 Budget	2021 Budget
Salaries and benefits, Employee Related	7,475,602	6,861,705
Governance	57,600	63,600
Professional Fees, Contractor Services	514,500	555,343
Materials & Supplies, Vehicles & Equipment	575,250	491,930
Occupancy Costs	540,460	493,250
Park Maintenance	580,300	514,890
Information Management/GIS	418,037	340,500
Marketing, Advertising, Printing, Signs	111,000	160,500
Special Events (Festival, Holiday Trail)	315,600	161,100
Flood Forecasting	127,000	127,000
Miscellaneous	142,700	95,300
Total - Operating Expenses	10,858,049	9,865,118

Capital and Special Projects	2022 Budget	2021 Budget
Corporate Services	218,469	452,000
Land Operations - Balls Falls	174,564	152,500
Land Operations - Binbrook	52,898	1,210,000
Land Operations - Chippawa Creek	195,723	100,000
Land Operations - Long Beach	105,796	-
Land Operations - Passive Parks	457,040	580,586
Watershed	550,140	530,000
Total - Capital & Special Projects	1,754,630	3,025,086
Total Operating, Capital & Special Projects	**12,612,679**	**12,890,204**

2022 DRAFT OPERATING BUDGET

Description	2021 Approved Budget	2022 Draft Budget	Program Revenue	Provincial Funding	Federal Funding	Municipal Funding	Other
			2022 Draft Operating Budget Funding Sources				
CAO and Governance							
- CAO and Office Expenses, Governance	496,944	546,039		32,377		513,662	
- Human Resources / Health and Safety	444,314	427,906				427,906	
- Strategic Planning, Innovation & Community Relations	622,290	546,958				546,958	
Total - CAO and Governance	**1,563,548**	**1,520,903**	**-**	**32,377**	**-**	**1,488,526**	**-**
Corporate Services							
- Management, General Corporate Services and Administration	395,821	374,006		11,265		286,356	76,385
- Occupancy Costs	493,250	540,460				540,460	
- Financial Services and Procurement	438,594	471,380				471,380	
- Information Management and GIS	587,847	721,179				721,179	
- Niagara River Remedial Action Plan	173,823	173,964		103,964	70,000		
- Riparian Buffers	-	50,000			50,000		
- Restoration and Integrated Watershed Management	640,305	627,448				396,348	231,100
- Fleet and Equipment Management	234,240	253,000				253,000	
Total - Corporate Services	**2,963,880**	**3,211,437**	**-**	**115,229**	**120,000**	**2,668,723**	**307,485**
Land Operations							
- Management and Land Care Passive Parks	349,351	369,781					51,500
- Balls Falls Conservation Area	390,090	395,489	435,500				
- Binbrook Conservation Area	409,417	487,420	621,900				
- Chippawa Creek Conservation Area	339,120	345,661	420,404				
- Long Beach Conservation Area	394,876	446,669	588,500				
- Special Events	149,106	314,202	515,000				
- Land Care - Passive Parks	575,440	445,819				172,237	
- Educational Programming	131,491	313,534	313,534				
Total - Land Operations	**2,738,891**	**3,118,575**	**2,894,838**	**-**	**-**	**172,237**	**51,500**
Watershed							
- Management - Watershed	964,676	966,154		64,206		886,948	15,000
- Source Water Protection	120,082	128,466		128,466			
- Water Resources Engineering	543,519	758,066		36,200		531,366	190,500
- Planning and Permitting / Compliance and Enforcement	655,726	861,436	549,000	15,500		296,936	
- Planning Ecology	314,796	293,012				293,012	
Total - Watershed	**2,598,799**	**3,007,134**	**549,000**	**244,372**	**-**	**2,008,262**	**205,500**
TOTAL OPERATING PROGRAMS	**9,865,118**	**10,858,049**	**3,443,838**	**391,978**	**120,000**	**6,337,748**	**564,485**

2022 DRAFT CAPITAL AND SPECIAL PROJECTS

Description	2021 Approved Budget	2022 Draft Budget	2022 Draft Capital and Special Projects Budget Funding Sources: Provincial Funding	Federal Funding	Municipal Funding: Niagara	Hamilton	Haldimand	Other
Corporate Services								
- Annual PC Replacements	45,000	69,102			52,615	15,072	1,415	
- Information Technology Infrastructure	37,000	21,262			16,189	4,638	435	
- Digital Terrain Model Update	150,000	-						
- Natural Areas ELC Mapping Update	150,000	-						
- Large Scale Surface Water Inventory Mapping Update	-	106,311			80,946	23,188	2,176	
- Asset Management and Capital Planning	30,000	22,857			17,403	4,985	468	
- Electronic Content Management/Records Management	40,000	-						
- Internet Upgrade - Balls Falls	40,000	-						
Total - Corporate Services	**492,000**	**219,532**	**-**	**-**	**167,153**	**47,883**	**4,494**	**-**
Land Operations								
- Balls Falls - Centre for Conservation Gallery Upgrades	65,000							
- Balls Falls - Heritage Building Restoration	47,500	147,236			147,236			
- Balls Falls - Pedestrian Path Upgrades (Accessibility)	-	26,292			26,292			
- Binbrook - Parking Infrastructure Pavilion 2	-	54,784				54,784		
- Binbrook - Septic, Water System, TTT Building	1,210,000	-						
- Chippawa Creek - Roads Infrastructure	100,000	157,753			157,753			
- Chippawa Creek - Comfort Station Tanks	-	36,809			36,809			
- St. John's Conservation Area - Heritage Building Restoration	130,000	-						
- Cave Springs Conservation Area - Exterior Infrastructure	105,000	131,461			131,461			
- Long Beach - Electrical & Water Services - Ridge (Phase 3)	-	105,169			105,169			
- Equipment Sustainment	345,586	220,063			167,561	48,000	4,506	
- Hazard Tree Removal and Reforestation	-	106,003			80,946	23,189	-	1,868
Total - Land Operations	**2,003,086**	**985,570**	**-**	**-**	**853,227**	**125,973**	**4,506**	**1,868**
Watershed								
- Floodplain Mapping - Beaver Creek	150,000							
- Floodplain Mapping - Big Forks Creek	150,000							
- Floodplain Mapping - Coyle and Drapers Creek		120,944			120,944			
- Virgil Dam - Remedial Measures	200,000							
- Dam Safety Review (Binbrook and Welland River)		132,889			101,183	28,985	2,720	
- Shoreline Mapping Update - Lake Erie		157,753			157,753			
- Karst Void Mapping		90,102			68,804	19,710		1,587
- Sustainment - Stream Gauge Equipment	10,000	21,262			16,189	4,638	435	
- Sustainment - Water Quality Monitoring Equipment	20,000	26,578			20,237	5,797	544	
Total - Watershed	**530,000**	**549,528**	**-**	**-**	**485,110**	**59,130**	**3,699**	**1,587**
TOTAL CAPITAL AND SPECIAL PROJECTS - 2022	**3,025,086**	**1,754,630**	**-**	**-**	**1,505,490**	**232,986**	**12,699**	**3,455**

2022 MUNICIPAL LEVY SUMMARY

Levy Apportionment - 2022

The levy apportionment ratios are calculated from assessment data provided by MPAC, and further revised based on the Conservation Authority Levies Regulation.

Municipality	% in CA	Municipal Population	Municipal Population in CA	Prior Year CVA in CA	2022 Levy Apportionment	2021 Levy Apportionment	Variance
Haldimand	25%	40,523	10,009	$1.778B	1.8685%	1.8624%	0.0061%
Hamilton	21%	449,877	94,924	$20.141B	21.1634%	21.1565%	0.0069%
Niagara	100%	369,284	369,284	$73.251B	76.9681%	76.9811%	-0.0130%
Total		859,684	474,217	$95.170B	100.0000%	100.0000%	0.0000%

LEVY SUMMARY - 2022

	2022	2021	Variance Amount	Variance %
NIAGARA				
General Levy	4,767,623	4,684,681	82,942	
Special Levy	1,505,490	1,241,073	264,417	
TOTAL	**6,273,113**	**5,925,754**	**347,359**	**5.86%**
Pandemic Funding	110,422	109,464	958	
Total	6,383,535	6,035,218	348,317	
HAMILTON				
General Levy	1,341,283	1,307,251	34,032	
Special Levy	232,986	199,503	33,483	
TOTAL	**1,574,269**	**1,506,754**	**67,515**	**4.48%**
HALDIMAND				
General Levy	118,420	112,077	6,343	
Special Levy	12,697	24,640	- 11,943	
TOTAL	**131,117**	**136,717**	**- 5,600**	**-4.10%**
CONSOLIDATED				
General Levy	6,227,326	6,104,009	123,317	
Special Levy	1,751,173	1,465,216	285,957	
TOTAL	**7,978,499**	**7,569,225**	**409,274**	**5.41%**
Pandemic Funding	110,422	109,464	958	
Total	8,088,921	7,678,689	410,232	

2022 UNFUNDED BUDGET PRIORITIES

Description	2022 Unfunded Priority	2022 Unfunded Budget Priorities - Proposed Funding Sources			
		Municipal Funding			
		Niagara	Hamilton	Haldimand	Other
RESTORATION					
Water Quality Non-Point Source Modelling	80,000	61,574	16,931	1,495	
Conservation Authority Lands Restoration Inventory	173,236	133,336	36,663	3,237	
Welland River SWAT Decision Support Model	60,000	60,000			
Natural Asset Management - Phase 1 (carbon sequestration)	60,000	46,181	12,698	1,121	
Restoration Warranty Provision - plant material	30,000	23,090	6,349	561	
Total - Restoration and Shoreline Resiliency	**403,236**	**324,182**	**72,640**	**6,413**	**-**
PLANNING AND GROWTH PRESSURES					
Watershed/sub-watershed Data Update - growth/intensification	100,000	76,968	21,163	1,869	
Shoreline Management & Resiliency Update (Lake Ontario)	220,000	220,000			
Sustainable Technologies and Green Infrastructure	90,000	69,271	19,047	1,682	
Climate Risk and Vulnerable Action Plan	50,000	38,484	10,582	934	
Terrestial and Aquatic monitoring	100,000	76,968	21,163	1,869	
City View Reconfiguration	50,000	38,484	10,582	934	
Upper Virgil Dam Erosion Protection	100,000	100,000			
Total - Planning and Growth Pressures	**710,000**	**620,176**	**82,537**	**7,287**	**-**
CONSERVATION AUTHORITY ACT TRANSITION					
Watershed Based Resource Management Strategy	25,000	19,242	5,291	467	
Land Management Plan Updates	125,000	96,210	26,454	2,336	
Total - Conservation Authority Act Transition	**150,000**	**115,452**	**31,745**	**2,803**	**-**

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2022 UNFUNDED BUDGET PRIORITIES

Description	2022 Unfunded Priority	2022 Unfunded Budget Priorities - Proposed Funding Sources			
		Municipal Funding			
		Niagara	Hamilton	Haldimand	Other
STATE OF GOOD REPAIR / HEALTH AND SAFETY					
Internet Upgrade	50,000	38,484	10,582	934	
Asset replacement and sustainment (amortization)	875,000	673,471	185,180	16,349	
Speed Bumps - All Parks (Phase 2)	100,000	76,968	21,163	1,869	
Barn Storage Facility	50,000	50,000			
Argo (Bog & Wainfleet Wetlands)	20,000	20,000			
Passive Parks Gates	330,000	330,000			
Centre for Conservation Upgrades (gift Shop)	50,000	50,000			
Furniture	25,000	19,242	5,291	467	
Lime Restoration	40,000	40,000			
New Metal Stairs for Bruce Trail	100,000				100,000
Info Signs / Kiosk	300,000	230,904	63,490	5,606	
Pavilion 1 Demolition	50,000		50,000		
Playground Upgrade	300,000		300,000		
New Washroom Facility	300,000		300,000		
Main Boat Launch Upgrade	100,000		100,000		
Northside Playground	125,000	125,000			
Drainage South Side	100,000	100,000			
Rebuild Comfort station #2 South Side	400,000	400,000			
Beach Washroom Renovations	15,000	15,000			
Electrical Upgrades	1,000,000	1,000,000			
New Pavilion	125,000	125,000			
New Playground Equipment	150,000	150,000			
Tile Drain in Day Use	125,000	125,000			
Roadway Improvements	965,000	742,742	204,227	18,031	
St. Johns Valley Centre Septic System	225,000	225,000			
St. Johns Valley Centre Post Office & House Restoration	115,000	115,000			
Fencing for All Parks	170,000	130,846	35,978	3,176	
Waste bins for All Parks	30,000	23,090	6,349	561	
Picnic tables for passive parks	15,000	11,545	3,175	280	
Work Vehicles	150,000	115,452	31,745	2,803	
New AED Units (H&S)	30,000	23,090	6,349	561	
Equipment for Glanbrook Conservation Committee	30,000		30,000		
Total - State of Good Repair / Health and Safety	**6,460,000**	**4,955,836**	**1,353,528**	**50,636**	**100,000**
TOTAL 2022 UNFUNDED BUDGET PRIORITIES	**7,723,236**	**6,015,645**	**1,540,451**	**67,140**	**100,000**