Evaluating Potential Effects of Development on Southern Ontario Wetlands

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Wetlands in Ontario serve as an example of environmental degradation due to what Odum (1982) described as the ‘tyranny of small decisions’; not a conscious choice of a preferred solution but rather the outcome of hundreds of small decisions with respect to land use and water management.
The Ontario PPS (2014) specifies:

- **2.1.8 Development and site alteration** shall not be permitted on *adjacent lands* ... unless the *ecological function* of the *adjacent lands* has been evaluated and it has been demonstrated that there will be no *negative impacts* on the natural features or on their *ecological functions*.

- What is involved in demonstrating that an activity will have ‘no negative impact’?
<table>
<thead>
<tr>
<th>Environmental Factors that Control Functions in Wetlands</th>
<th>Scale at which the Control Occurs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical structure of wetlands (e.g., soils, vegetation, rocks)</td>
<td>Site</td>
</tr>
<tr>
<td>Biological structure of wetlands (e.g., physical structure of plants)</td>
<td>Site</td>
</tr>
<tr>
<td>Input of water (amount of water; maximum and minimum water levels)</td>
<td>Landscape and site</td>
</tr>
<tr>
<td>Fluctuations of water levels (frequency, amplitude, direction of flows)</td>
<td>Landscape and site</td>
</tr>
<tr>
<td>Input of sediment</td>
<td>Landscape and site</td>
</tr>
<tr>
<td>Input of nutrients</td>
<td>Landscape and site</td>
</tr>
<tr>
<td>Input of toxic contaminants</td>
<td>Landscape and site</td>
</tr>
<tr>
<td>Temperature</td>
<td>Landscape and site</td>
</tr>
<tr>
<td>Level of acid (pH)</td>
<td>Landscape and site</td>
</tr>
<tr>
<td>Concentration of salts</td>
<td>Mostly site</td>
</tr>
<tr>
<td>Size, connections, and distances of habitat patches in the surrounding landscape</td>
<td>Landscape</td>
</tr>
</tbody>
</table>

The hydrologic regime, characterized by intra- and inter-annual variability, plays a large role in the biotic composition, structure and function of wetland ecosystems.

Changes can result in alteration of wetland processes (e.g. oxidation of organic soils, nutrient dynamics) and species composition

- Hydroperiod (within year variability)
- Frequency and duration of high and low water levels
HYDROLOGIC ALTERATIONS

• Focus here is on hydrologic regimes (both site and landscape scale) as principal controls on wetland functions and

• Hydrologic alterations as important stressors which can lead to negative impacts on wetland functions.

• Demonstrating that there will be no negative impact from hydrologic alterations is essential.
• Need to understand how a wetland works in a hydrological sense and how activities, at both site and landscape scales will affect the wetland water regime.

• A conceptual model is the starting point for the identification of inputs and outputs - the exchanges across the boundaries of the wetland, or “water transfer mechanisms”.

• Hydrologic wetland typology, often based on location within the landscape may be helpful in identifying water transfer mechanisms.
Slope wetlands

Surface water-fed: Wetland underlain by impermeable strata. Input dominated by precipitation, surface runoff and possible spring flow. Output by evaporation and surface outflow.

Slope wetlands

Surface and groundwater-fed: Wetland separated from underlying aquifer by lower permeability layer. Input from groundwater seepage, precipitation and surface runoff. Groundwater input may be restricted by lower permeability layer. Output by evaporation and surface outflow.

Slope wetlands

Groundwater-fed: Wetland in direct contact with underlying aquifer. Input dominated by groundwater seepage, supplemented by precipitation and surface runoff. Output by evaporation and surface outflow.

RCS, 2010
• The conceptualization should include spatial and temporal variability in the presence or dominance of water transfer mechanisms.

• The outcome of this analysis may be diagrams showing water transfer mechanisms, for wetland or different zones of wetland, and for various conditions, such as dry and wet periods.

• Difference between inputs and outputs to a wetland are reflected by changes in the volume of water stored within the wetland boundaries.

• Changes in the amount of water stored in the wetland through the year → hydroperiod
• Balancing inputs, outputs and changes in storage provides a quantitative test of hydrologic understanding. If an approximate balance is not achieved:
  – a potentially significant water transfer may have been omitted, or not estimated accurately, or
  – the cumulative errors in measurement may be too high (although if errors cancel out, this may not be recognized).

Boundaries in space and time need to be clearly defined
THE BALANCE

- An approximate balance does not confirm the hydrologic understanding, but rather confirms that it is plausible.

<table>
<thead>
<tr>
<th>Month</th>
<th>Precipitation + Melt (mm)</th>
<th>ET (mm)</th>
<th>Net GW Inflow (mm)</th>
<th>Change in Storage (mm)</th>
<th>Residual (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>May (from May 8)</td>
<td>25.5</td>
<td>83.1</td>
<td>3.1</td>
<td>-60.6</td>
<td>6.1</td>
</tr>
<tr>
<td>June</td>
<td>96.6</td>
<td>115.6</td>
<td>-0.4</td>
<td>6.2</td>
<td>-25.6</td>
</tr>
<tr>
<td>July</td>
<td>36.2</td>
<td>136.1</td>
<td>15.0</td>
<td>-64.2</td>
<td>-20.7</td>
</tr>
<tr>
<td>August</td>
<td>142.1</td>
<td>120.6</td>
<td>4.4</td>
<td>33.5</td>
<td>-7.6</td>
</tr>
<tr>
<td>September</td>
<td>66.4</td>
<td>90.7</td>
<td>5.0</td>
<td>1.5</td>
<td>-20.8</td>
</tr>
<tr>
<td>October</td>
<td>72.2</td>
<td>56.4</td>
<td>-17.0</td>
<td>29.6</td>
<td>-30.8</td>
</tr>
<tr>
<td>Monitoring Period</td>
<td>439.0</td>
<td>602.5</td>
<td>10.1</td>
<td>-54.0</td>
<td>-99.4</td>
</tr>
</tbody>
</table>

Bradford, 1999
• Requires each term of the water balance equation to be independently estimated. Any term that is estimated as the residual of the water balance will include the accumulated errors (of measurement and omission).

• Although simple in principal, quantifying a wetland water balance is rarely straightforward.

• Estimation may utilize existing data, measurements and/or models

• Some terms will have larger associated uncertainties than other terms
Periods with specific conditions can be used to elucidate the importance of various processes (or constrain magnitudes of contributions).

Bradford, 1999
• With a sound understanding how the wetland works in a hydrological sense, it is possible to examine how a proposed activity will affect the wetland water regime.

• Which water transfer mechanisms are likely to be affected and which may be affected? How will they be affected – magnitude, timing, quality?

• Could the proposed activity change the types of transfers or mechanisms controlling exchanges (e.g. outflow governed by unsaturated flow rather than saturated flow processes)?

• Could the change of land cover on adjacent lands affect the micrometeorological conditions controlling wetland evapotranspiration?
HYDROLOGIC ALTERATIONS

• Wetland water balance (i.e. spreadsheet type analysis) can be expanded to examine development (and mitigation) scenarios. This can reveal how sensitive the wetland water levels may be to changes in various inflows and outflows.

• It may be appropriate to expand the time period and increase the temporal resolution of the analysis.

• Wetland studies have used a broad range of modelling tools.
CHALLENGES OF MODELLING

- It is a challenge for a single model to represent important characteristics at both ‘regional’ and local wetland scales.

- For example, wetland water levels may be influenced by soil structure that cannot be modelled to a sufficient degree of accuracy within a ‘regional’ model.

- Changes in wetland water levels on the order of 0.1 m are expected to result in changes in the vegetation communities of some wetlands; this is well below the accuracy considered to be acceptable in most modeling applications.

- Regardless, models will be effective tools for understanding the types and magnitudes of changes associated with a proposed development.
Fig. 3 Cone of depression around Hardham showing groundwater contours (m OD) and the network of groundwater observation boreholes between the abstraction and Pulborough Brooks (*outlined in red*). The *blue lines* are watercourses.

Fig. 5 Conceptual model of Pulborough Brooks.
Fig. 10  Comparison of water-table predictions for naturalised and fully licensed abstraction scenarios with the UK guideline hydrological regime for MG13 wet grassland (after Environment Agency 2004). The dashed line and the solid line nearly overlie each other. The limited difference between these lines, associated with the fully licensed and naturalised, is indicative of the limited impact that fully licensed abstraction has on water table levels at this location. The green area is the ideal hydrological regime for the MG13 community. The yellow region represents a zone to which water tables may fall during wetter or drier years without an adverse effect on the community (provided they do not occur consistently year on year). Where water levels fall within the red zone there is a high likelihood that the composition of the community will be affected

Gasca and Brooks, 2011
• Where potential hydrologic changes are identified, it must be shown that the wetland feature and its ecological functions are not sensitive to the changes or that the changes can be controlled to prevent a negative impact.

• It is critically important to recognize the full range of hydrologic changes that may have ecological relevance.

• Conceptual ecohydrological models can be valuable to identify links between hydrologic changes and wetland processes (e.g. retention and transformation of nutrients) and biota which may respond.

• Their development also promotes inter-disciplinary knowledge exchange and collaboration
• Ongoing work to answer question “How much hydrologic alteration is acceptable?”

• Meanwhile, let’s shift to looking at hydrologic changes that are occurring and some clear inadequacies in demonstrating no impact
STORMWATER (MIS) MANAGEMENT

- Runoff from urbanizing catchment may be diverted around wetland resulting in too little water OR
- May all be directed to wetland resulting in too much water

- Wet ponds control the rate of outflow but do not control the volume of stormwater runoff reaching downstream wetland

Photo: Bradford
• Rate of inflow to wetland is not the ecologically relevant metric

• Conceptualization is incorrect – increased inflow does not simply translate into increased outflow – it translates into year after year increase in storage, and consequently … rising water levels
• May be groundwater dependent even if “primarily” surface water supplied

• The amount of groundwater may be important to the wetland water balance

• But, even where groundwater contributes a relatively small proportion of water inputs:
  – Timing of contribution may be critical
  – May be a critical source of chemical constituents

Photo: Bradford
Consider vernal pool where hydroperiod (temporal pattern of surface inundation) important to amphibians

- May be flow-through, with little net volumetric contribution from groundwater
- But, difficult to replicate water quality (and timing of drydown) without subsurface exchanges

Absence of visible seepage on wetland surface or piezometric head within aquifer which is below ground surface NOT sufficient evidence for absence of gw fluxes

GD groundwater discharge. Water moving vertically upwards into a wetland from an underlying aquifer. The piezometric head/water level of the aquifer is higher than the water level in the wetland. There may or may not be a lower permeability layer between the wetland and the aquifer that could limit water flow.

GS groundwater seepage. Water moving laterally into a wetland from an adjacent aquifer. There may or may not be a lower permeability layer between the wetland and the aquifer that could limit water flow.
May be exchanges between wetlands and shallow groundwater when the water table is high.

This can also provide subsurface hydraulic connectivity between wetlands at certain times of year.
Wetlands can be located in complex hydrogeological settings and there may be higher hydraulic conductivity pathways.

Sand seams may connect fractured bedrock aquifer to wetland.

Ground Surface (Site Plans)
Bedrock Surface (Geophysical Survey)

Overburden (Halton Till)
Illman, 2011

Bradford, 2011

MW03-05
MW03-04
• Wetlands may be a Type II groundwater dependent ecosystem (Eamus et al. 2006), which include “all ecosystems dependent on the surface expression of groundwater”

• Wetlands may also be a Type III GDE (Eamus et al. 2006), which include “all ecosystems dependent on the subsurface presence of groundwater”
GROUNDWATER DEPENDENCE

• Near surface presence of groundwater can:

  • sustain ET by replenishing soil moisture
  • influence surface runoff processes (saturated overland flow) and upland-wetland linkages
  • influence distribution of inflows throughout a wetland

Photo: Bradford
CONCLUSIONS

• Evaluations of potential effects of development on wetlands are more frequently making use of groundwater and integrated models.

• There are situations where these tools may be essential, such as where the wetland hydroperiod is tied to groundwater table elevation which is controlled by processes outside the wetland boundary.

• Whether or not models are applied, more reliable predictions of the hydrological effects of development on wetlands depend upon sound interpretation of processes affecting wetland hydrology.

• The further step of predicting ecological responses cannot be accomplished without first knowing the types and magnitudes of hydrological changes.