



Saskatchewan  
Watershed  
Authority

**Methodology to Assess the  
Water Volume Impact  
of Wetland Drainage  
in the Waldsea, Deadmoose,  
Houghton, and Fishing Lake  
Watersheds**

Saskatchewan Watershed Authority

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## 1.0 Introduction

In the spring of 2007 numerous lakes and streams across central and eastern Saskatchewan experienced high levels and flows. For terminal lakes such as Waldsea, and near-terminal lakes such as Deadmoose, Houghton, and Fishing lakes, this marked the second consecutive year of high inflows that had begun with above normal rainfalls in the fall of 2005. Other lakes that have been affected by this same weather pattern include Duck, Quill, Humboldt, and Wolverine lakes.

At Waldsea and Fishing lakes, a large number of seasonal and permanent homes were affected by the high lake levels in 2007, either flooded or at risk of flooding. Levels of Deadmoose Lake rose sufficiently over 2006 and 2007 to spill over to and then equalize with Houghton Lake. In turn Houghton Lake in 2007 reached its overflow level to begin passing water to Lenore Lake. Deadmoose and Houghton lakes have high salt concentrations. Lenore Lake also has elevated salt concentrations but is able to support a sport fishery. A significant concern is that the water from Houghton Lake would impact the fishery in Lenore Lake.

In response to the 2007 flooding on these lakes, the province committed to providing short-term flood dyking on Waldsea and Fishing lakes, long-term flood-proofing of affected cottage areas on those two lakes, and a review of the impact of drainage on all four lakes. This report documents the development of a methodology to assess the change in runoff volumes into these lakes. The methodology takes advantage of new technologies to detect and map wetland drainage. For each of the four lakes, sample calculations are made using the methodology to demonstrate both the extent of drainage in each watershed, and the order of magnitude of the change in runoff volume into each lake.

## 2.0 Drainage Impact Methodology

### 2.1 Aerial Photography – Acquisition and Processing

Two sets of aerial photography were acquired for each of the four watersheds of interest: Current epoch photography was collected on May 17, 2007 at a scale of 1:30,000; and historical epoch photography collected in 1958 and 1959 at a scale of 1:50,000. See Appendix A for specifications and processing details. The initial datasets were delivered in November 2007 and were used in this analysis. The final product was delivered in October 2008 and was found to be not significantly different from the initial dataset.

### 2.2 Wetland and Watercourse Capture/Delineation

Hydrographic features, including waterbodies and watercourses (linear drainage features) were captured (digitized) from both the historical and current photography. Waterbody and watercourse features were captured by the Orthoshop’s professional photogrammetrists while viewing the imagery in 3-D, enabled by the stereo pairs; the exception being a small part of the Deadmoose Lake watershed that did not have photo coverage. SPOT 2.5m satellite imagery was used for this area; therefore, there was no stereo viewing capability and interpretation had to be done in 2-D.

The minimum polygon size captured for area features was 200 square metres. The photogrammetrists classified the features into the following categories based on their visual assessment of the photos:

Waterbodies:

- Wetland (Emergent Vegetation) – Hydrophytic vegetation occupying wetland basin.
- Wetland (Open Water) – Open water within an intact wetland basin.
- Wetland (Altered) – Hydrophytic vegetation occupying a topographic depression with evidence of agricultural disturbance (i.e. haying, grazing).

Note that, due to the extremely high water levels at the time of the acquisition of the 2007 photography, it was extremely difficult to distinguish between true “wetland” (i.e. permanent or semi-permanent waterbody with hydrophytic vegetation present) versus “sloughs” (temporary water occupying a depression in a field). Therefore, the dataset is not sufficient to assess “wetland loss” *per se* by simple subtraction of wetland areas in the current epoch from those in the historic epoch.

#### Watercourses:

- Drainage – Linear, man-made drainage features. These features are usually 0.5 m or deeper. The flow direction and elevation of the start and end points was also included.
- Drainage (Worked) – Linear, man-made drainage features that are actively cultivated. Cultivated drainage features are approximately 0.25 to 0.5 m deep. This class shall include “V-ditching.” The flow direction and elevation of the start and end points was also included.
- Connecting Stream – Natural or minimally altered linear feature, with evidence of recent flow activity, which would serve to connect two or more wetlands or lakes together. The flow direction and elevation of the start and endpoints was also included.

### 2.3 Area and Volume of Impacted Wetlands

In ArcMap, all three waterbody type classes were merged together and their boundaries dissolved, in order to create one polygon for each waterbody. These waterbody polygons and the drainage feature polylines were overlaid on top of the orthorectified photo mosaics. Each waterbody was visually assessed on the photo as to whether or not it could potentially drain into the lake of interest (Fishing, Waldsea, Deadmoose, or Houghton Lake). In other words, could it be contributing water into one of these major lakes, based on visual evidence of drainage works or natural watercourses.

The areas of all the waterbody polygons were calculated using the “XTools” extension in ArcMap. These areas were then converted to volume estimates using the equation  $\text{Volume} = 2.85 * \text{Area}$ , and for comparison,  $\text{Volume} = 2.85 A^{1.22}$ . These equations were taken from the “Upper Assiniboine River Basin Study – Appendix A: Drainage and Flood Control Committee Report, August, 2000.” The equations were referred to as “(1) PFRA Project Data – wetlands under 4 ha,” and “(9) DU and PFRA Data – Log-Log analysis – wetlands under 10 ha” respectively.

Note that the historical epoch data did not end up being required for the drainage impact methodology ultimately decided on, and was therefore not included in the calculations.

### 2.4 Standard Contributing Drainage Area Method

Prairie hydrologists have long recognized that not all of a watershed contributes to flow in the outlet stream or lake in all years, and that the area that does contribute will vary from year to year depending a number of factors including the carryover storage in wetlands from the previous year, soil moisture at freeze-up, and snow water equivalent at onset of the melt in spring. To deal with this complexity, often with incomplete information on the watershed, a simple but robust methodology was developed.

The Contributing Drainage Area Method is based on a number of assumptions and definitions:

- Contributing Drainage Area (CDA): The portion of the watershed area that contributes to flow at the outlet (or into the terminal lake) in any given year.
- Effective Drainage Area (EDA): That portion of the watershed expected to contribute to streamflow at the outlet in a median runoff year.
- Gross Drainage Area (GDA): The entire watershed defined by topographic height of land.
- Land-Locked Area (LLA): In some watersheds, there is a portion of the area that is not expected to contribute to streamflow under even the most extreme conditions.

In the Standard CDA method, used for at least the past 30 years, the contributing drainage area was assumed to vary from the EDA in median or less runoff years to either the LLA or GDA in a very high runoff year.

For determining the impact of wetland drainage in a watershed, the standard approach has been to compare the estimated runoff calculated using the original (or natural) EDA with the runoff calculated using an increased EDA, which includes the area tributary to the drained wetlands. This involves two additional assumptions:

- The drained wetlands were all originally outside of the natural EDA and drainage moves them into the EDA.
- The drained wetland area has the same hydrologic characteristics as the rest of the watershed landscape.

This methodology was developed in a series of drainage impact studies through the 1970's and has been used essentially unchanged to the present for both large impact studies such as in the Upper Assiniboine River Basin Study (August, 2000) and numerous smaller studies. It can be expressed in the following formula:

$$\text{Incremental Volume} = \text{Yield} * (\text{CDA}_{\text{Current}} - \text{CDA}_{\text{Natural}}).$$

## 2.5 Modified CDA Method

A recent refinement to the standard CDA method was used by R. Pentland of Water Resource Consultants (WRC) in his assessment of the impact of drainage of Parker Slough on lakes in the Lenore Lake Basin (draft April 2008). The key innovation in the WRC study is the recognition of a “backflood” loss of a fully drained wetland. It is often observed during runoff that drained wetlands retain water, often up to their natural Full Supply Level (FSL). This temporarily retained water is released as channel hydraulic conditions allow. During the period that water is retained in the former wetland, the key assumption is that some of that water replenished the soil moisture reserve that was used during the growing season of the previous year. In a sense, the drained wetland is behaving as a Backflood Drainage project. Thus the outflow from the drained wetland is not equal to the inflow, but to the inflow less the backflood loss.

In the case of Parker Slough, WRC calculates the outflow from the slough under both drained and undrained conditions. In the undrained condition, the outflow is equal to the inflow minus the volume stored in the wetland to replace evaporation lost during the previous year. Under the drained condition, the outflow equals the inflow minus the backflood loss. Thus, the incremental impact of drainage of Parker Slough can be found simply by multiplying the surface area of the slough by the difference between the net evaporation rate and the backflood infiltration rate.

$$\text{Incremental Volume} = \text{Surface Area} * (\text{Net Evaporation Rate} - \text{Backflood Loss Rate}).$$

This modification can be applied to all wetlands within the original EDA either to individual wetlands, or to using the summed surface areas available from the GIS product to all the impacted wetlands.

Similar logic can be applied to a completed drained wetland originally located outside of the EDA. Under natural conditions, the inflow to that wetland in a median runoff year would be entirely stored in that wetland and subjected to evaporation over the summer. When that wetland is drained, the Standard CDA method assumes all the inflow to that wetland is passed on downstream. However, this outflow should be reduced for the backflood loss over the surface area of the wetland. This can be done for individual wetlands, or applied to all drained wetland outside of the EDA by summing up their areas. Thus for wetlands outside the original EDA, the following formula applies:

$$\text{Incremental Volume} = \text{Yield} * (\text{CDA}_{\text{Current}} - \text{CDA}_{\text{Natural}}) - (\text{Surface Area} * \text{Backflood Loss Rate}).$$

## 2.6 Application of Modified CDA Method

- Determine natural EDA, Current EDA, Land-locked area, and GDA.
- Determine surface areas of drained wetlands within the natural EDA ( $SA_{\text{eda}}$ ) and drained wetlands outside of the natural EDA ( $SA_{\text{neda}}$ ).
- Determine the average annual Net Evaporation for the watershed (NE).

Net evaporation for the Waldsea, Deadmoose, and Houghton watersheds over the normal period 1971-2000 is 436 mm based on average annual Wynyard gross evaporation of 828 mm from PFRA and Environment Canada annual average precipitation of 392 mm from Humboldt, filled with missing values from Muenster and Pilger.

Net evaporation for the Fishing Lake watershed over the normal period 1971-2000 is 375 mm based on adjusted average annual Wynyard gross evaporation of 796 mm from PFRA and Environment Canada annual average precipitation of 421 mm from Margo.

- Assume a reasonable backflood loss rate for a median year and for a 1:500 year runoff (BF). Estimate the unit runoff for the frequencies desired (Y).
- Determine the CDA for both conditions for the desired frequency using the Standard CDA methodology.
- Calculate the incremental volume due to wetland drainage:

$$V = (NE-BF)*SA_{eda} + [Y*(CDA_{cur}-CDA_{nat}) - (BF)*SA_{neda}].$$

Assumptions:

- BF and NE are assumed to decrease with higher runoff events and increase in drier years.
- The difference between NE and BF remains constant.

## 2.7 Further Possible Refinements and Research Needs

- Research into backflood loss rates under various hydrologic conditions and for various soils and landscape regions.
- Determine whether there is a relationship between hydrology return period and the previous year's NE.

## 2.8 One-Time Impact of Wetland Drainage or Restoration

There is a one-time downstream volume increase when a wetland is first drained. Assuming the drainage work is done in the fall and that the wetland was full that spring, the volume increase is the wetland storage at its full level, minus the volume lost to that summer's net evaporation.

Conversely, when a drained wetland is first restored, the downstream volume is reduced by the lesser of the following year's inflow, or the wetland storage volume plus the backflood loss.

## **3.0 Application of Methodology**

### **3.1 Waldsea Lake**

#### **3.1.1 Watershed and Lake Characteristics**

Waldsea Lake is a terminal lake with no instances of recorded or anecdotal outflow. Recorded water levels on the lake have varied from a low of 529.2 m in the fall of 1964 to a high of 534.8 m in 2007. Between 1974 and 1995, lake levels remained in a 1.6 m range from 531.6 m to 533.2 m. At elevation 532.5 m, the lake is about 16 m deep, has a surface area of about 500 ha and holds about 35,000 cubic decametres of water. With an elevation of 534.78 m on May 17, 2007, the surface area of the lake had expanded to 578 ha.

The natural outlet is to Deadmoose Lake with the lowest height of land between the two lakes at elevation 540.95 m, over 6.0 m above the 2007 peak water level.

PFRA lists the gross drainage area to Waldsea Lake as 208.6 km<sup>2</sup> and the effective area as 42.9 km<sup>2</sup>. The current effective drainage area is 67.1 km<sup>2</sup> due to projects and drainage works in the watershed. For this assessment, 92.2 km<sup>2</sup> of the gross drainage area was considered land-locked. That is, it was still within the topographic height of land for the Waldsea Lake watershed, but would not contribute to the lake in any reasonable hydrologic scenario. Thus, of the total gross area of 208.6 km<sup>2</sup>, only 116.4 km<sup>2</sup> is considered to be hydrologically connected to Waldsea Lake under very high runoff conditions.

Between 1967 and 1997, an additional 25.9 km<sup>2</sup> were contributing to Waldsea Lake through the Brockman Slough diversion ditch constructed by the Waldsea Lake Regional Park. That ditch had been constructed in response to perceived low water levels through the early and mid 1960's. Under natural conditions, Brockman Slough overflows to Deadmoose Lake.

The Waldsea Lake watershed lies mainly to the south and west of the lake. Most of the watershed area and all of the effective area is within the Quill Lake Plain landscape area of the Aspen Parkland ecoregion. The western fringe of the watershed is within the Elstow Plain of the Moist Mixed Grassland ecoregion. The far northwest corner is in the Cudworth Plain of the Aspen Parkland.

#### **3.1.2 Previous Studies**

In 1999, a hydrology study of Waldsea Lake was completed by SaskWater, which investigated probable causes of high water levels experienced in 1996-97. While above normal precipitation from 1991 through 1997 was the most direct cause, the report also found that three identifiable projects increased the water levels by 2.5 m. The diversion of Brockman Slough outflow from the Deadmoose Lake watershed into Waldsea Lake starting in 1967 was found to have a cumulative effect of 2.0 m by 1997. The permanent closure of the Brockman Slough diversion will, over a long period of time (decadal scale), result in water levels being 2.0 m lower.

Waldsea Lake has been studied by limnologists and is the subject of a number of articles published in scientific journals on its atypical chemistry, and biology.

### **3.1.3 Sample Drainage Impact Calculations for Waldsea Lake**

Analysis of the imagery identified 363 wetlands potentially impacted by drainage works with a cumulative surface area of 129.5 ha and estimated volume of 370 cubic decametres ( $\text{dam}^3$ ). Using the methodology outlined above, the additional inflow to Waldsea Lake is 650  $\text{dam}^3$  in a median runoff year. This represents about 15 cm over the surface of the lake at elevation 532.5 m. One-time restoration of all the wetlands would store about 695  $\text{dam}^3$ , or about 16 cm over the lake area.

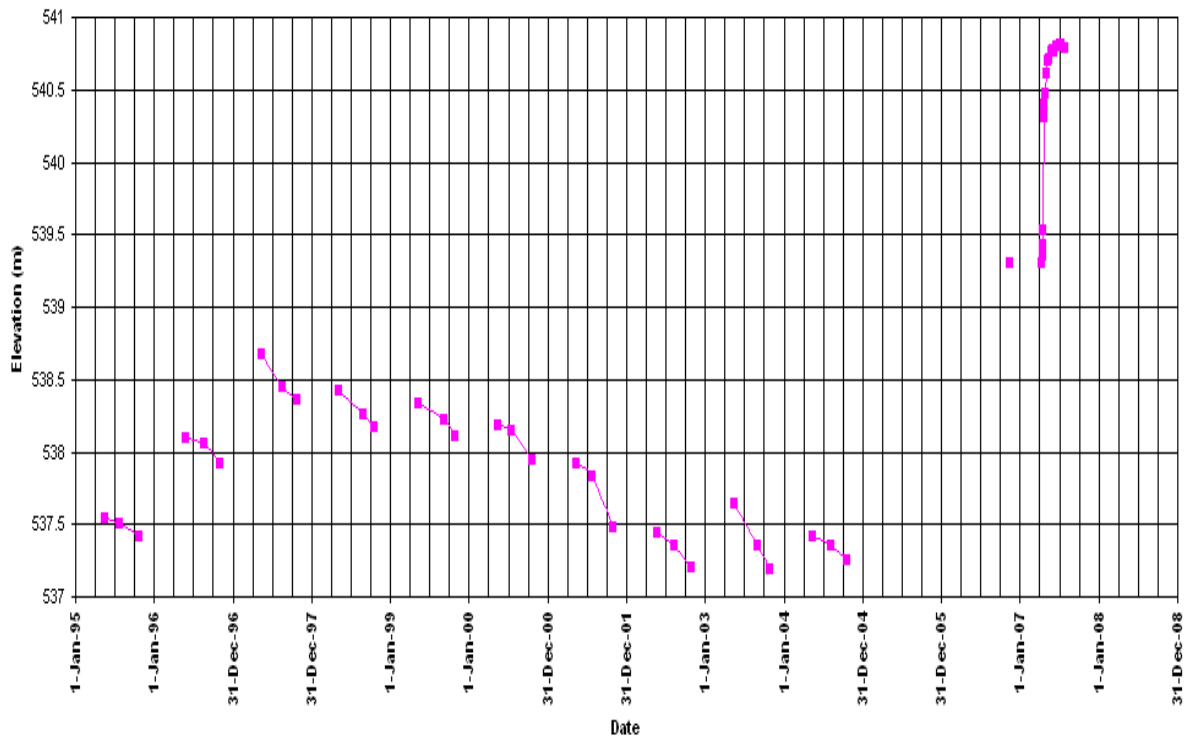
## **3.2 Deadmoose Lake**

### **3.2.1 Watershed and Lake Characteristics**

Deadmoose Lake is a semi-terminal lake with rare instances of observed outflow to Houghton Lake, the most recent being 2007. The Saskatchewan Watershed Authority's (Authority) Northeast Region has monitored lake levels thrice annually since 1968. Levels since 1995 are plotted below. From 1995 through 2004, levels varied between 537.2 m and 538.6 m. At elevation 540.1 m, Deadmoose overflows and eventually equalizes with Houghton Lake. Together the two lakes then overflow to Lenore Lake at elevation 540.66 m. If for any reason outflow is blocked from Deadmoose or Houghton lakes, there is the risk that Deadmoose could overflow to Waldsea Lake at elevation 540.95 m.

At elevation 538 m, the lake is about 33 m deep, has a surface area of about 1,190 ha and holds about 102,000  $\text{dam}^3$  of water. With an elevation of 540.72 m on May 17, 2007, the surface area of the lake had expanded to 1,465 ha.

## Deadmoose



**Figure 1: Deadmoose Lake**

For this study the gross drainage area to Deadmoose Lake was found to be 236.3 km<sup>2</sup> and the original effective area to be 205.1 km<sup>2</sup>. Parker Slough, Burton Lake, and Brockman Slough are all considered to be within the effective drainage area of Deadmoose Lake. The current effective drainage area is 214.5 km<sup>2</sup> due to projects and drainage works in the watershed.

Alteration of natural flows into Deadmoose Lake began as early as 1907 when the Canadian National Railway (CNR) began pumping water from Burton Lake to Humboldt for use in steam engines. Sometime before 1932, ditching was constructed to drain water from Parker Slough into Burton Lake to augment the CNR water supply. In 1960, the Town of Humboldt officially took over the CNR works taking water from Burton Lake. In 1987 the City applied to construct a weir to raise Burton Lake and thus increase the allowable water use from the lake. In December 1996, Humboldt began using water from the SaskWater Wakaw-Humboldt supply line and ceased using water out of Burton Lake. In 1999, the Humboldt Golf Club received approval to use the former CNR/City works to take water from Burton Lake to supplement their use from Mile Slough in the Humboldt Lake watershed. Between 1967 and 1997, the drainage area was reduced by 25.9 km<sup>2</sup> with the diversion of Brockman Slough to Waldsea Lake.

One part of the Deadmoose Lake watershed lies to the east and south of the lake, while the second part lies to the west. Waldsea Lake is to the south west and Houghton Lake is to the north. The entire eastern and southern portion and the eastern half of the western portion of the watershed area is within the Quill Lake Plain landscape area of the Aspen Parkland ecoregion. The west half of the western portion is within the Cudworth Plain of the Aspen Parkland.

### **3.2.2 Previous Studies**

Four hydrology studies were completed between 1966 and 1974 focused on Burton Lake as a water supply for Humboldt, various levels of drainage from Parker Slough, and the impacts of these projects on Deadmoose Lake. A 1981 study considered further options for improving the Humboldt water supply including the raising of Burton Lake. A 1996 study examined the impact on Deadmoose Lake levels of discontinuing water use from Burton Lake. It found that over a 52-year period from 1944 to 1995, Deadmoose Lake would be 0.95 m higher without the water use than with the water use.

In early 2008, the Authority commissioned a brief study of the potential impact of closure of the Parker Slough ditch on downstream lake levels. That study found that there would be a one-time reduction in flow as Parker slough re-filled to its natural overflow level. If Deadmoose Lake is not overflowing to Houghton Lake, this one-time volume represents about 25 cm less water in Deadmoose Lake. Following the one-time fill, the long-term net impact would be about 300 dam<sup>3</sup> per year due to increased evaporation from the surface area of Parker Slough. This represents a reduction of about 3 cm per year in Deadmoose water levels, assuming it is not overflowing. If Deadmoose and Houghton lakes are overflowing, the closure of Parker Slough ditch makes no difference on the level of the two lakes as the incremental water from Parker Slough passes through the lakes and on downstream.

Deadmoose Lake has been studied by limnologists and is the subject of a number of articles published in scientific journals on its atypical chemistry, and biology.

### **3.2.3 Sample Drainage Impact Calculations for Deadmoose Lake**

Analysis of the imagery identified 1016 wetlands potentially impacted by drainage works with a cumulative surface area of 738.9 ha and estimated volume of 3910 dam<sup>3</sup>. Using the methodology outlined above, the additional inflow to Deadmoose Lake is 1340 dam<sup>3</sup> in a median runoff year. This represents about 11 centimeters over the surface of the lake at elevation 538 m. One-time restoration of all the wetlands would store about 5750 dam<sup>3</sup>, or about 48 cm over the lake area.

### 3.3 Houghton Lake

#### 3.3.1 Watershed and Lake Characteristics

Houghton Lake is a shallow lake which occasionally spills into Lenore Lake, most recently in 2007. The Authority's Northeast Region has monitored lake levels thrice annually since 1968. Levels since 1995 are plotted below. From 1995 through 2004, levels varied between 538.4 m and 539.6 m. At elevation 540.1 m, Deadmoose overflows to and eventually equalizes with Houghton Lake. Together the two lakes then overflow to Lenore Lake at elevation 540.66 m. If for any reason outflow is blocked from Houghton Lake, Deadmoose and Houghton would rise together until they overflow into Waldsea Lake at elevation 540.95 m.

At elevation 539 m, the lake is only about 1.3 m deep, has a surface area of about 1,470 ha and holds about 11,100 dam<sup>3</sup> of water. With an elevation of 540.72 m on May 17, 2007, the surface area of the lake had expanded to 2,050 ha.

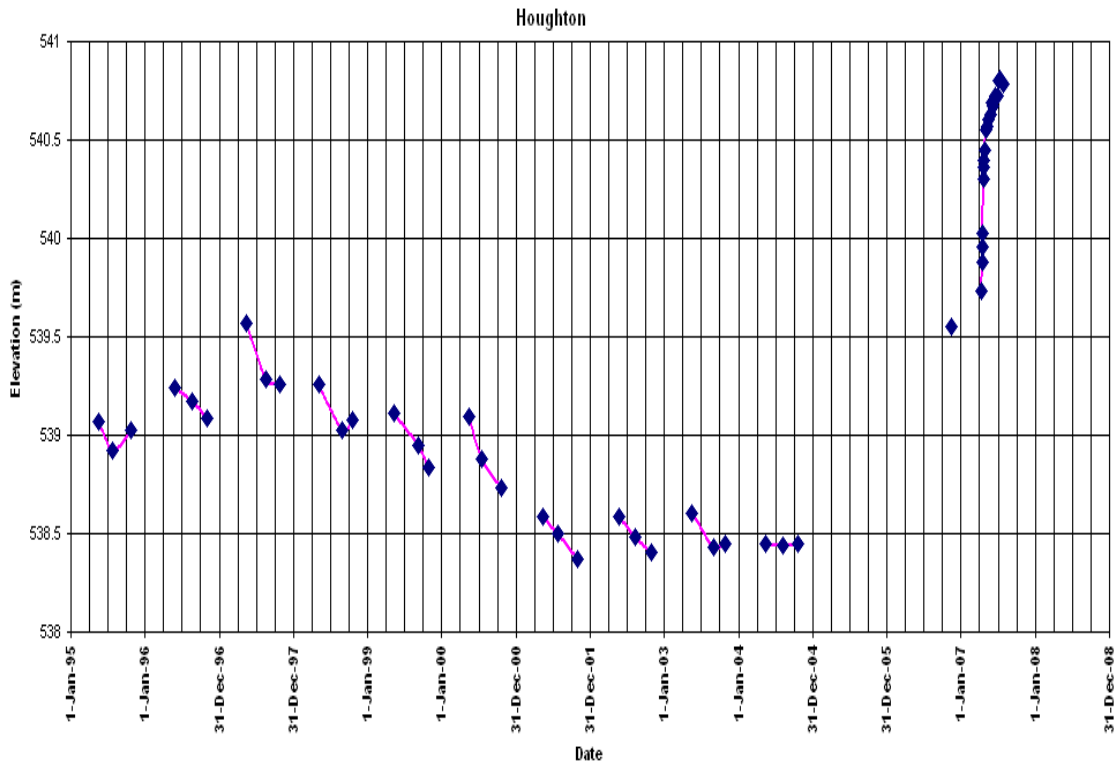


Figure 2: Houghton Lake

For this study the gross drainage area to Houghton Lake was found to be 229.2 km<sup>2</sup>, not including the Deadmoose Lake drainage area. The original effective area was 125.3 km<sup>2</sup>. Flat, Mantrap, and Murphy lakes are all considered to be outside of the original effective drainage

area of Houghton Lake. The current effective drainage area is 198.1 km<sup>2</sup> and includes Flat, Mantrap and Murphy lakes.

The only sizable water project in the Houghton Lake drainage area is the Ducks Unlimited Flat Lake project. This project was authorized in January 2000. The project has a surface area of 140 ha and stores 564 dam<sup>3</sup> of water.

A small portion of the Houghton Lake watershed lies to the east of the lake, while most of the watershed lies to the west. The Deadmoose Lake watershed is to the south and Lenore Lake watershed is to the north. All of the eastern and the western portion within one to six kilometres of the lake is within the Quill Lake Plain landscape area of the Aspen Parkland ecoregion. The Cudworth Plain of the Aspen Parkland makes up the portion of the watershed further west. A small area just north of the north end of the lake is within the Tiger Hills Upland landscape of the Boreal Transition ecoregion.

### **3.3.2 Previous Studies**

No hydrology study has been done specifically for Houghton Lake. In 1984, a study of Lenore Lake was done to examine the effect of drainage and of the then proposed Ranch Lake Control structure. A series of simulations were done in which each sub-basin had increasing levels of agricultural drainage ranging from none to 100 percent drainage. In that study, the Houghton Lake watershed was simulated as a separate sub-basin to Lenore Lake. Survey information available at the time suggested that Deadmoose Lake spilled to Waldsea, not to Houghton. The study period covered 60 years from 1921 to 1980. In the pre-development simulation, Houghton Lake spilled to Lenore Lake in nine years (15 percent of the total of 60 years). The lowest simulated fall elevation was 537.58 m. Maximum elevations were limited by the overflow level to Lenore Lake. As increasing levels of drainage were simulated, the number of years of spill increased to a maximum of 20 (out of 60) and the minimum elevation simulated over the study period increased to 538.97 m.

### **3.3.3 Sample Drainage Impact Calculations for Houghton Lake**

Analysis of the imagery identified 1116 wetlands potentially impacted by drainage works with a cumulative surface area of 567.7 ha and estimated volume of 2430 dam<sup>3</sup>. Flat, Mantrap, and Murphy were excluded from the area and volume totals and they are not completely drained. Using the methodology outlined above, the additional inflow to Houghton Lake is 1600 dam<sup>3</sup> in a median runoff year. This represents about eleven centimetres over the surface of the lake at elevation 539 m. One-time restoration of all the wetlands would store about 3850 dam<sup>3</sup>, or about 26 cm over the lake area.

It should be noted that there are two conditions under which the impact of drainage on Houghton Lake water levels collapses to zero. The first condition is after a series of high flow years during which Houghton Lake would have filled and spilled even under conditions of no drainage. The second condition is during droughts in which Houghton Lake goes dry even with the current level of agricultural drainage.

### 3.4 Fishing Lake

#### 3.4.1 Watershed and Lake Characteristics

Fishing Lake is a semi-terminal lake with several instances of observed and anecdotal outflow to Stoney Lake and the Whitesand River system. At elevation 529.2 m, Fishing Lake overflows into and eventually equalizes with Hazel Lake. If Fishing Lake continues to rise, the two lakes then overflow to Stoney Lake and the Whitesand River at elevation 529.74 m. Fishing Lake water levels have been monitored since 1964 and have been simulated back to 1912 (see figure below).

When Fishing Lake becomes extremely low, a land bridge emerges which separates the lake into two basins. The western basin is referred to as Indian Lake on some topographic maps.

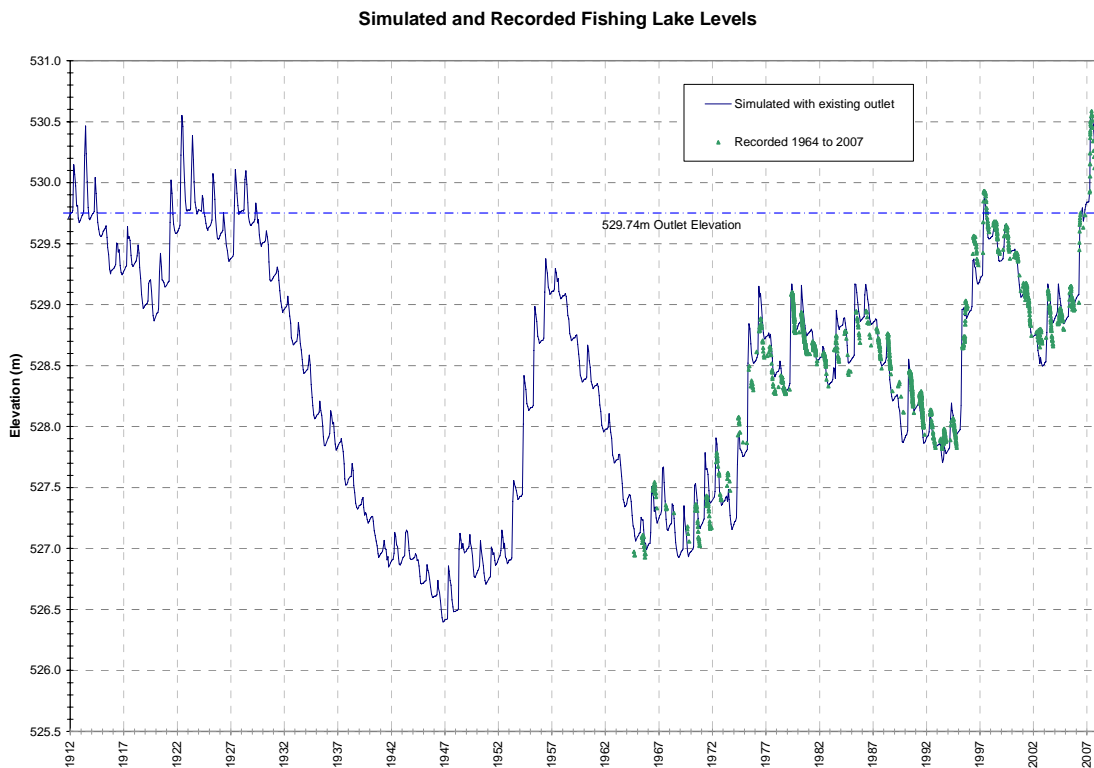


Figure 3: Fishing Lake

At elevation 528.5 m, the lake is about 21 m deep, has a surface area of 3,310 ha and holds almost 216,000 cubic decametres of water. With an elevation of 530.5 m on May 10, 2007, the surface area of the lake had expanded to 4,330 ha.

For this study the gross drainage area to Fishing Lake was found to be 620.5 km<sup>2</sup> and the original effective area to be 304.7 km<sup>2</sup>. Hazel Lake was considered to be within the effective drainage area of Fishing Lake based on simulations of Hazel Lake inflows and elevations in previous studies. The PFRA effective drainage area for Fishing Lake of 170.8 km<sup>2</sup> had excluded Hazel Lake. The current effective drainage area is 430.6 km<sup>2</sup> due to drainage works in the watershed.

Most of the Fishing Lake watershed area is within the Quill Lake Plain landscape area of the Aspen Parkland ecoregion. A small portion to the south and east of the lake is within the Whitesand Plain of the Aspen Parkland. The north-eastern quarter of the watershed is within the Barrier River Upland of the Boreal Transition ecoregion.

There are seven authorized surface water projects in the Fishing Lake watershed having a combined water allocation of 125 dam<sup>3</sup>; six are authorized to operate and one has authorization for construction. Pertinent information on the projects is tabulated below.

**Table 1: Surface Water Projects**

<b>Water Right #</b>	<b>Purpose</b>	<b>Owner</b>	<b>Allocation</b>	<b>Status</b>
4588	Domestic	Private	2	To operate
6215	Wildlife	Ducks Unlimited	0	To operate
7972	Wildlife	Ducks Unlimited	17	To operate
7973	Wildlife	Ducks Unlimited	5	To construct
12367	Municipal	RM of Sasman	31	To operate
14978	Fisheries	Sask Wildlife Federation	25	To operate
15506	Irrigation	Foam Lake Golf Club	45	To operate

There are five recognized drainage projects in the Fishing Lake watershed. Three of the projects have not received Authorization to Construct (ATC) from SaskWater. Of the two which have received ATC, one has also received Approval to Operate. Each project is discussed briefly below in order of project number:

- DR #645 This is the ditch from Silver Lake immediately south of the Village of Kuroki to Fishing Lake. This project does not have SaskWater ATC as it was built in 1920. The project pre-dates provincial jurisdiction over natural resources.

- E5-31 This project in SW 7-34-11 W2 was to consist of 1.54 km of 200 mm tile drain. The project was only partially constructed and is to be cancelled as the proponent has sold this land. The project never received ATC.
- E5-53 This project is located in sections 2, 3, 4 and 10-35-12 W2, involving the ditching of a number of sloughs in the 1970s. A dam was to be constructed at the outlet and operated so as to minimize impacts on downstream lands. This project has not received ATC and is currently subject to a formal complaint.
- E5-75 This project involves approximately 100 m of channelization of Van Patten's Creek in SW 36-33-12 W2. It received ATC and was constructed in the fall of 1987. The project has not received Approval to Operate.
- E5-116 This drainage project is located directly behind Saskin Beach in NW 21-33-11 W2. It has received both ATC and Approval to Operate. The project has a gated control and a condition was included in the Approval to Operate that releases only be made when they will not affect cottage lands on Saskin Beach.

### **3.4.2 Previous Studies**

#### ***Milligan Creek Diversion Project***

Low water levels on Fishing Lake in the early 1960s led to investigations by the Conservation and Development Branch of the Saskatchewan Department of Agriculture into the possibility of diverting water from Milligan Creek into Fishing Lake. Associated with the diversion was a recognition that an outlet from Fishing Lake would also be needed to control excess water in high flow years. Survey plans drawn up in 1963 proposed an outlet ditch along much the same course as the current proposal. From those plans, it was established that the natural outlet elevation of Fishing Lake was 1738.0 feet (529.74 m) and that the drainage divide was located east of Hazel Lake.

No hydrology studies related to the proposed diversion of Milligan Creek have been located.

#### ***1983 Preliminary Water Balance Study***

In 1983, an attempt was made to develop a computer simulation of water balance for Fishing Lake based on recorded water levels and flows from 1964 through 1980. Unfortunately, the period of record then available was not long enough to provide sufficient data for a proper statistical analysis of the lake levels. Initial results could not match recorded water levels. The preliminary simulated levels rose much higher than the recorded levels.

### ***1997 Fishing Lake Environmental Project Proposal***

In response to the high water levels in 1997, a hydrology study was prepared in support of a proposal to construct an outlet ditch with control structures from Fishing Lake, through Hazel and into Stoney Lake. Inflow series for Fishing and Hazel lakes were constructed for the period 1912 through 1997 and calibrated to observed water levels starting in 1964. The proposal would essentially have lowered the outlet level of the lake by 0.9 m. Over the simulated period, water levels would have been 0.5 m to 1.0 m lower than without the proposed works. Due to immitigable issues around the quality of the outflow from Fishing Lake, the project did not proceed.

### ***2001 Hazel Lake Control Structure Hydrology Study***

In 2001, the Fishing Lake Watershed Association proposed a project to construct a control structure between Hazel and Fishing lakes. The structure would be operated to allow normal Hazel Lake outflow into Fishing Lake in years when Fishing Lake was low, however, in years in which Fishing Lake was higher than desired, the structure would be operated to store Hazel Lake water in Hazel Lake above its normal level. If inflows to Hazel Lake were sufficiently large, excess water would spill over the natural overflow into Stoney Lake and the Whitesand River system. Simulations showed that a reasonable measure of flood protection could be achieved with this project if operated consistently over time; however, the project did not proceed.

### **3.4.3 Sample Drainage Impact Calculations for Fishing Lake**

Analysis of the imagery identified 2640 wetlands potentially impacted by drainage works with a cumulative surface area of 1525.7 hectares and estimated volume of 5860 dam<sup>3</sup>. Using the methodology outlined above, the additional inflow to Fishing Lake is 2720 dam<sup>3</sup> in a median runoff year. This represents about eight centimetres over the surface of the lake at elevation 528.5 m. One-time restoration of all the wetlands would store about 9670 dam<sup>3</sup>, or about 29 cm over the lake area.

## 4.0 Summary and Conclusions

- An improved method for calculating the impact of drained wetlands has been developed. This new method acknowledges that complete drainage of wetlands within the natural effective area has a downstream effect on flow volumes. The method also makes allowance for the soil moisture storage available in completed drained wetlands outside of the original effective drainage area. This method can be applied for any desired return period event, and can be applied either on a watershed scale or to individual wetlands.
- Detection of wetland drainage works from aerial photography is now possible.
- Together with the aerial photograph interpretation, the use of GIS to map wetlands and drainage works now makes it possible to map and assess the level of artificial drainage on a watershed scale.
- The magnitude of the impact of artificial drainage in the Waldsea, Deadmoose, Houghton, and Fishing lake watersheds on these lakes in a median year has been assessed.

## **Appendix A     Details of Aerial Photography Processing**

## Appendix A – Details of Aerial Photography Processing

### Current Epoch (2007):

Aerial photography was flown on May 17, 2007 by Foto Flight Surveys Ltd, with the following specifications:

- Scale: 1:30,000;
- Camera: RC 30 with UAG-S15 13332 lens;
- Film: AGFA 80 (panchromatic/black-and-white);
- Forward overlap: 60 percent; and
- Flying Altitude: 4590 metres.

Additional processing of the photography was then undertaken by Atlis Geomatics Inc. Film was scanned at 12.5 microns to generate digital imagery at 50 cm/pixel resolution. Aerial triangulation of the photography was also completed by Atlis, as was an orthophoto mosaic for use in GIS software.

Capture/delineation of wetland and drainage features was done by The Orthoshop Geomatics Ltd. They used the exterior orientation of the images (“models”), supplied by Atlis, to position the photos. Leica Photogrammetry Suite (LPS) digital workstation was used by the photogrammetrists to delineate the hydrological features using 3D stereo viewing. The DGN vector files were then converted to Shapefiles using ESRI ArcCatalog.

### Historical Epoch (1958/59):

The National Air Photo Library (NAPL) and Information Services Corporation aerial photography archives were searched in order to find the oldest photography for the area of interest that was of sufficient quality and at an appropriate scale for the project. 1:50,000 scale photo diapositives were purchased from the NAPL as follows:

- Deadmoose/Houghton/Waldsea – 1959; and
- Fishing Lake – May 15 and May 19, 1958.

Processing of the diapositives was completed by Orthoshop. as follows:

- 1958 and 1959 diapositives were scanned at 12.5 microns resolution to create 50cm/pixel resolution digital images.
- Digital images were adjusted with the software package ORIMA, a component of the Leica Photogrammetry Suite (LPS). To determine the interior orientation of the images, the camera calibration protocols provided by the NAPL, dated January 8, 1958 and August 18, 1958 were used. On each image four fiducial marks were read. The exterior orientation was determined using ground control information from the 2007 imagery and tie points measured by the operators.

Hydrological features were then mapped within LPS. The DGN files were converted to Shapefiles using ESRI ArcCatalog.