Groundwater surface water interactions in a wetland rich, low relief Boreal environment

by

Kevin Tattrie
B.Sc., University of Victoria, 2005

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Supervisory Committee

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Abstract

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This study investigates surface water and groundwater interactions in a wetland/peatland region surrounding Fort McMurray, Alberta. This work measured local meteorology, water table variation, and isotope and geochemistry concentrations over a two year period. Results from vertical water budget calculations showed episodic runoff events ranging between 0 and 38 mm/yr. Groundwater evaluations showed limited groundwater gradients with mean hydraulic conductivities of $1.01*10^{-5}$ cms^{-1} (NE7) and $1.78 * 10^{-5}$ cms^{-1} (SM8). Overall, groundwater flux estimates were variable and heterogeneous across the catchments areas. Isotopic composition showed mixing between winter precipitation, groundwater and surface water, with groundwater representing the average input signature. This study showed that runoff events were largely associated with spring freshet and significant summer storm events.

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Without the support of friends and family, I would never have completed this degree. I would like to thank my parents, my son Garnet, and friend Sarah Cook for helping me get through the process. Finally, the staff in the Geography department was both helpful and supportive.

Dedication

This is dedicated to Alvin and Evelyn Simpson, my Grandparents. Thanks for always believing in me, I wish you were around to see this.

1. Background

Acid sensitivity of aquatic and terrestrial ecosystems continues to be an important area of research throughout Canada (Environment Canada, 2004). Research into the effects of industry related acid emissions in northern Alberta is ongoing and has prompted investigation of a range of biogeochemical processes to better understand the response of the Boreal ecosystem to increased acid inputs (Alberta Environment, 1999; RAMP, 2004). The Alberta oil sands region (AOSR), centred on Fort McMurray and situated approximately 400 kilometres north of Edmonton, is located on the boreal plain. The region is characterized by very low topographic relief, small ponds, shallow lakes, and extensive wetlands (Figure 1.1). Assessing the critical loadings of this environment is fundamental in decision making concerning oil sands mining, upgrading, refining and eventual reclamation. The Alberta government classifies this region as highly sensitive to acid deposition, based on levels of emissions, soil types and geologic substrate (Alberta Environment, 1999).

For this reason, the Cumulative Environmental Management Association (CEMA) formed the NOx-SOx Management Working (NSMWG) group to monitor the levels of nitrogen and sulphur species in the environment surrounding the AOSR. Ongoing work has focused on a subset of 50 lakes from the Regional Aquatic Monitoring Program (RAMP) lake database of over 400 lakes (Bennett *et al.*, 2009). For this study, two lake basins from the subset were selected for intensive instrumentation and detailed analysis of the surface and shallow ground water hydrology. Acid sensitivity is typically evaluated through the application of a critical loads model such as the Steady State Water Chemistry (SSWC) Model. The output from the SSWC model is a critical load of acidity which relies on estimates of base cation concentration, catchment water yield values and a defined acid neutralizing capacity (ANC) limit designed to protect specific ecosystem organisms or communities (Henriksen, 1992).

The NSMWG has the task of improving the critical loads estimates in this region. One strategy for accomplishing this task is to sponsor research using the Model of Acidification of Groundwater in Catchments (MAGIC), a lumped-parameter model, to test the long term effects of acid deposition on surface water and soils. Typical inputs are monthly or annual averages for variables such as climate, biological production, atmospheric deposition of ions, and runoff volume and routing within the catchments. This type of dynamic model is extremely useful in poorly monitored areas such as the study region, because greater levels of complexity can be incorporated in the model and therefore it can be finely tuned to a particular environment (Aherne *et al*., 2006).

The study described here has focused on evaluating runoff volume and routing of surface and shallow groundwater in two detailed basins in order to describe the flow paths and connections within each catchment. This input is required to fine-tune the dynamic model. Typically, previous studies investigating critical loads have relied on gauged data from major river systems and models of groundwater flow to estimate runoff and flow routing. Because of the detailed nature of this study and the unique hydrological conditions of these lakes, new approaches were explored providing hydrologic inputs. As part of the NSMWG program, several parallel studies were undertaken concurrently. Studies investigating acidification of forest soils, nutrient cycling, fen chemistry and carbon fluxes were also undertaken. For the hydrological component a number of important research questions emerged and are presented here.

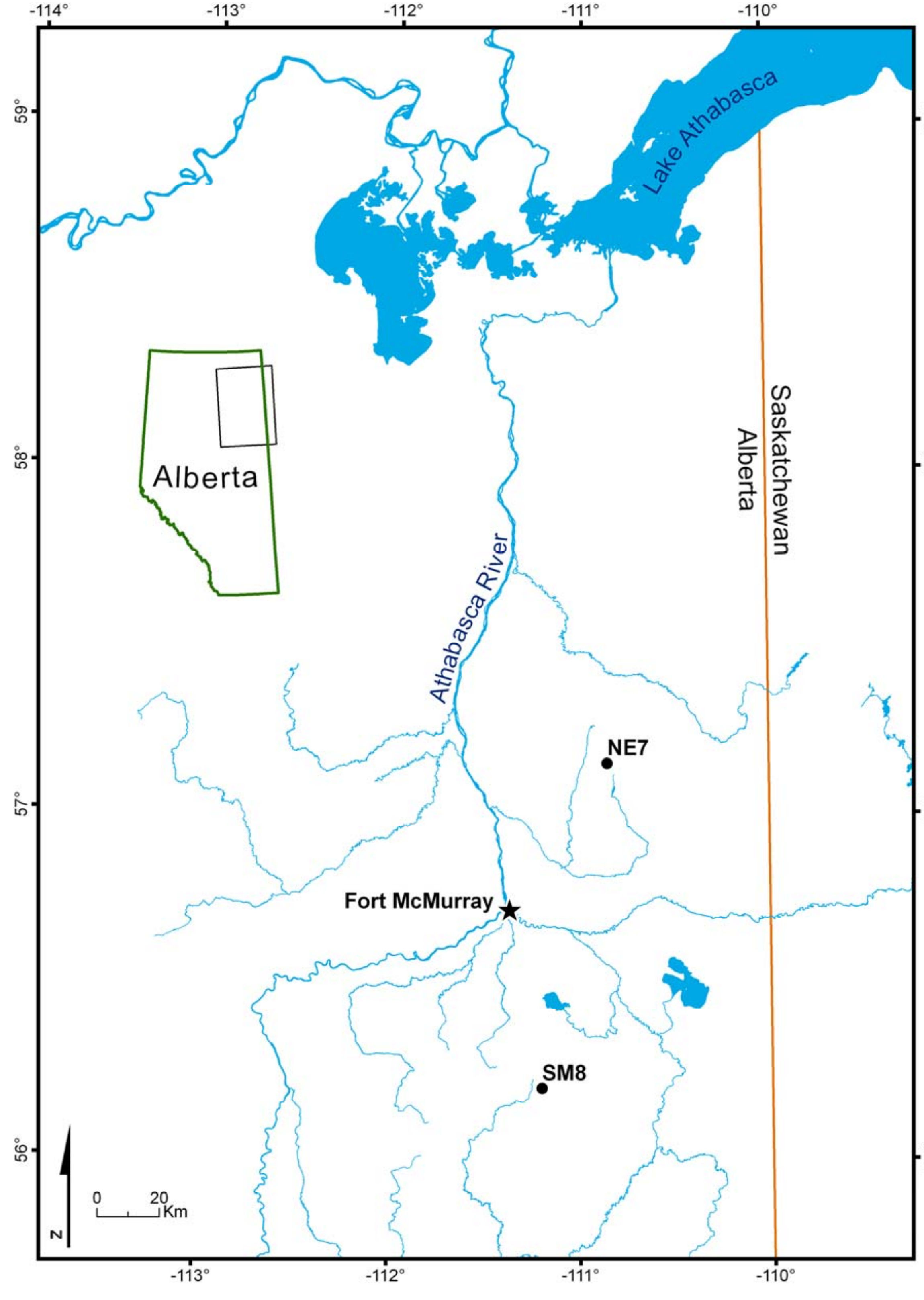


Figure 1.1 Study area map
Fort McMurray at the confluence of the Athabasca and Clearwater rivers with study sites situated north (NE 7) and south (SM 8) of the city.

1.1. Research Question

How is the landscape in this low relief, wetland dominated region, connected to local lakes?

On the Boreal Plains, in areas of extremely low relief, channelized connections between the landscape and the lake are rare and ephemeral and make it difficult to measure or quantify the local hydrological runoff response. The research question is necessarily straight forward and will be answered iteratively through the following chapters, with findings assembled in the concluding chapter. It is expected that lake levels will fluctuate in relation to seasonal precipitation inputs and in response to variation in amount of precipitation input from year to year. Seasonal inputs such as snow melt and storm generated runoff makeup a significant hydrologic input in spring and summer respectively. In summer, precipitation/evaporation is the main control on lake water levels and will vary from year to year.

1.2. Objectives

To answer the above research question a series of field investigations were initiated in two watersheds near Fort McMurray which provided key opportunities to better understand runoff regime in typical lake-wetland watersheds. The following study objectives were considered to be of primary importance to this task:

Objective 1: *To classify the basin landscape into hydrological response terrain units given the hypothesis that these terrain units will have unique hydrological responses.*

Objective 2: *To evaluate the role runoff plays in the overall water budget of these catchments by generating a vertical water balance for selected terrain units.*

Objective 3: *To determine the dominant flowpaths for movement of water from these landscape units into the lake (i.e. is it a shallow flow system dominated by saturated overland flow or is there a component of deeper ground water?), by using high resolution DEM in the ARCGis environment, calculating vertical water budget for individual terrain units, investigating potential groundwater fluxes (hydraulic gradients/hydraulic conductivity)*

Objective 4**:** *To apply isotopic and geochemical tracers to identify potential gradients and connectivity between surface and subsurface waters.*

1.3. Introduction

This study is based upon data collected during two field seasons and is primarily concerned with determining the interactions of groundwater and surface water and dominant flow pathways in two low relief, wetland dominated headwater lake basins near Fort McMurray, Alberta (Figure 1.1). Due to the paucity of historical hydrometric information and the lack of research studies on these systems, the research design applied in this study was intentionally broad, incorporating aspects of physical hydrology coupled with hydrogeochemical and environmental isotope methods. Other studies have shown that the later methods are very useful in regions where the hydrometric monitoring network is sparse. In these settings, isotope tracers have been demonstrated to provide reliable site specific hydrologic information where previous measurements do not exist (Gibson *et al*., 2002; Bennett *et al*., 2008; Gibson *et al*., 2010 a, b).

1.4. Study Area

Fort McMurray, Alberta is located at the confluence of the Athabasca and Clearwater rivers at the southern extent of the Wood Buffalo region approximately 400 km northeast of Edmonton (Figure 1.1). Situated on the Mixed-Wood Boreal Plain, the region is typified by moist cool summers and long cold winters (Turchenek and Pigot, 1988). The 30-year climate normals at the Fort McMurray airport (56° 39’ N 111° 13’ W) show a mean air temperature of 16.8 ° C, -18.8 ° C for July and January respectively, with an annual mean of 0.7 °C. Annual precipitation is 456 mm with 25 % falling as snow between November and April (MSC, 2008). Evaporation is estimated between 480 mm as yearly average for the region (Hamon, 1961; New *et al*., 1999), and as high as 578 mm for open water evaporation (Bothe, 1987; Abraham, 1993). The landscape is composed of regions of extremely low relief and extensive wetland cover. As noted in Johnson *et al*., 1995, peatlands dominate large areas of the region and are populated by an array of sphagnum and other moss species. Common shrub and grass species include: *Carex, Eriophorum, Ledum, Salix, Rubus, Vaccinium* sp. Black spruce (*Picea mariana*) is the dominant tree species in the peatland, with tamarack (*Larix laricina*) also present in mineral rich fens. In the well drained upland soils, jack pine (*Pinus banksiana*), reindeer lichen (*Cladina* sp.) and *Vaccinium* sp. are most common. Aspen (*Populus tremuloides*) and birch (*Betula* sp.) are most common in upland areas with sufficient moisture and create a very different under story containing non-sphagnum moss species, bunchberry (*Cornus canadensis)* and cloudberry (*Rubus chamaemorus*) (Johnson *et al*., 1995). Elevation and saturation level strongly influence plant communities. At lower elevation, where the terrain is flat and the ground is saturated throughout the open water season, peat is able to develop and sphagnum will become the dominate species. Yet in both catchments, the presence of as little as a one metre rise in elevation is sufficient to alter the microclimate in such a way as to create isolated uplands in the middle of a wetland.

1.5. Geologic and Hydrologic Setting

The hydrology of the Fort McMurray region is dominated by the Athabasca River, flowing in from the west and draining toward the north, Fort McMurray sits at confluence of the Clearwater River, which originates in the shield terrain to the east. The Horse, the House, the Hangingstone and the Christina rivers are important tributaries draining the region south of Fort McMurray, and the Firebag, Muskeg and Steepbank rivers are important tributaries draining the region north of Fort McMurray. Mean annual runoff from the Athabasca River is 151 $mmyr^{-1}$, draining an area 131 000 km^2 (RAMP, 2006). Peak discharge in the Athabasca River occurs in July (1390 m^3s^{-1}) and low flow occurs under ice cover in February (160 m^3s^{-1}) (WSC, 2008).

The Athabasca and Clearwater rivers (and to some degree their tributaries), have large and deeply incised river channels. In sharp contrast to these two main channels, there is very little organized overland flow on the Boreal Plain, where the landscape is covered with >50 % peatland (Turchenek and Pigot, 1988). Because of the generally level and undulating topography typical of large areas of this region, small landforms and micro topography influence drainage and create conditions perfect for peatland development (Vitt, 1990). Peat frequently develops to depths of two to three metres with depth generally increasing northward. Large fen complexes are frequent across the landscape and more common than bogs generally. Dome or Plateau bogs occur within large fens and may occur as or basin bogs or string bogs elsewhere in the landscape (Johnson *et al.*, 1995; Turchenek and Pigot, 1988; Vitt, 1990). For these reasons, open water channels are seldom observed upstream of lakes where any surface flow is generally ephemeral.

The surficial mineral material is comprised of glacial drift and fluvial sediments of varying thickness. The topography is generally flat to undulating at present day. Uplands, such as the Stony Mountain region south of Fort McMurray, consist of remnant bedrock outcrops overlain by a thin mantle of glacial till. There are buried paleo-river channels, in the regions both north and south of Fort McMurray, which are filled with deep, coarse deposits of glacial-fluvial material, and represent a very significant portion of the regional groundwater storage potential (Bayrock and Reimchen, 1973; Andriashek and Meeks, 2000).

North of Fort McMurray the surficial geology is uniform with large units of till. The northern study site, NE 7, is located close to the margin between a ground moraine and outwash sands and gravels with drift thickness between 30 and 60 metres. Also, noted locally in the Muskeg Mountain area is a fine grained, silty-clay, lacustrine deposit 10 to 20 metres in depth which constitutes much of the catchment area of Lake NE 7. The underlying bedrock in the area is the Grand Rapids formation; a fine grained sandstone, with siltstone and silty shale present (Bayrock, 1970). There is a significant buried channel located west of the study site which may be important regionally (Andriashek and Meeks, 2000).

To the south of Fort McMurray the topography has greater relief at the Stony Mountains. The surficial material here is much thinner and the composition of those materials more diverse. The study site SM 8 is located upon the Kinosis till, but the bulk of the catchment area is classified as organic soil, indicating extensive peatlands north, west and south of the lake itself. There is an isolated aeolian deposit in the northwest section of the catchment and a significant upland composed of the local till in the east. The Kinosis till is a ground moraine composed of loam, with some pebbles and boulders. The topography is undulating and this thin mantle of till overlays the La Biche formation of shale and silty shale bedrock (Bayrock and Reimchen, 1973). The bedrock topography at this location slopes westerly and becomes part of the Conklin channel, another significant buried river channel (Andriashek and Meeks, 2000).

1.6. Previous Work in the Region

Recent work has been published evaluating water balance variation and runoff amounts in the 50 RAMP lakes using environmental isotopes in comparison with a physically based water budget calculated using gridded climate and hydrometric from the national monitoring network stations in the region (Bennett *et al*., 2008; Gibson *et al*., 2010 a, b). It is difficult to predict runoff based on climate data alone primarily because of the significant control variable landscape units exert on the runoff response from watersheds in this region. In concurrent studies, Whitfield *et al*., (2009) examined the intra-seasonal variation in water quality across several fens at the same detailed research sites used in this study. This work included application of major ion and nutrient chemistry, stable isotopes, and physical water level variations to understand seasonal patterns in fen chemistry and hydrology. Strong evaporation signals were noted through stable isotope analysis, but local areas of cold, nutrient-rich water suggested that the hydrologic behaviour is not homogeneous. Other wetland hydrology studies have applied these techniques in similar environments (Gibson *et al*., 2002; Hayashi *et al*., 1998).

Surface water and groundwater interactions have been investigated in the region west of Fort McMurray in a shallow pond environment. While less dominated by wetlands than the study sites presented here the area was monitored to evaluate hydraulic conductivity and to assess vertical and lateral groundwater gradients using piezometers (Smerdon *et al*., 2005; Ferone and Devito, 2004). By identifying areas in the catchment with higher rates of hydraulic conductivity, points of groundwater discharge into the lake were isolated and more closely examined for chemical make-up and quantified for groundwater fluxes through the use of seepage meters.

Other work has pursued detailed answers to the diurnal and seasonal variation in groundwater flow direction. Devito *et al*., (1997) identified reversals in flow direction where geologic substrate limited groundwater movement to shallow ephemeral flow systems. Specifically in the wetland environments which dominate the mixed-wood Boreal forest, there is a paucity of research dealing with these complex hydrologic interactions. Smerdon *et al*., (2005), investigated shallow groundwater in a wetland/lake system situated on coarse grained outwash sediments in this region. Similarly, the authors identified groundwater flow reversals and connected these to the sensitivity of shallow hydrologic/hydrogeologic systems to seasonal changes in evapotranspiration rates and precipitation inputs. The importance of understanding evapotranspiration losses in the Boreal forest have been noted in other studies (Petrone *et al*., 2007).

In addition to the most recent publications applying stable isotopes in this region mentioned above (Bennett *et al*., 2009; Gibson *et al*., 2010 a, b), isotopes were used to clarify hydrological issues in the region in the past including studies relating to lake through flow and residency time (Gibson *et al*., 2002), controls on nutrient loading (Prepas *et al*., 2001) and the effects of landscape alteration through forest fire and timber harvesting (McEachern *et al*., 2000).

2. Methods

2.1. Field Methods

2.1.1. Landscape Classification

Using the system outlined by Halsey *et al*., 2003, (Table 2.1) surficial mapping was conducted and used in conjunction with wetland classifications derived from aerial photograph interpretation to characterize individual and hydrologically important landscape units (R. Bloise, pers com, 2008). The degree of and texture of vegetation cover and specific physical characteristics (e.g. permafrost collapse scars) on the landscape are important features that are visible on aerial photographs that assist in wetland classification. During the 2005 field season, work was conducted primarily on a reconnaissance level, to establish sample networks in each catchment. During the second field season (2006), more areas of the catchment were described to capture details from areas not visited routinely. Subsurface investigation through soil coring was conducted as part of shallow well installation and soil samples analysed for grain size. Vegetation, surface morphology, water level and water quality parameters (pH, T °C, and electrical conductivity μScm^{-1}) were noted at each site as required for application of the Alberta Wetland Classification Standards 2.0 (Halsey *et al*., 2003) (Table 2.2).

In this environment, small changes in elevation can have a significant effect on hydrologic conditions. Achieving reliable topographic data by traditional land surveying techniques is difficult in this saturated environment. A LiDAR survey was sub-contracted in the fall of 2006 to provide fine resolution ground elevation data otherwise unobtainable. Gridded data sets were used to create topographic maps and to acquire point data for all elevation calculations related to this study. Depression storage and runoff flow routing were determined for both catchments using common algorithms (Fassenacht, 2008 pers com) and incorporated into discussion of the surface hydrology at the study sites. The data derived from this technique, when combined with field data and observations, provides an extensive dataset for terrain analysis.

Figures 2.1 and 2.2 are produced from the application of the AWI standards to the study area. Wetland polygons were digitized from air photos for all fifty lakes in the CEMA database (R. Bloise, pers com, 2008). This classification is used to compartmentalize runoff values generated from the vertical water balance and assist in understanding which terrain units are most significantly contributing to the lake hydrology.

2.1.2. Micro-Meteorological Data

Detailed climate data at the sub-basin scale for both aquatic and terrestrial components of the catchment area were collected at micro-meteorological stations established in the lake and on the land (Figure 2.3). Measurements taken every 30 seconds were downloaded as 30-minute averaged data to Campbell Scientific CR 23X data loggers. Recorded variables include air, water and soil temperature, relative humidity, wind speed and direction, and net radiation. Stations were established during the first week of June and disassembled the first week of October in each of the two study years (2005-2006). In conjunction with these stations, the lake based stations were also equipped with standard class A evaporation pans.

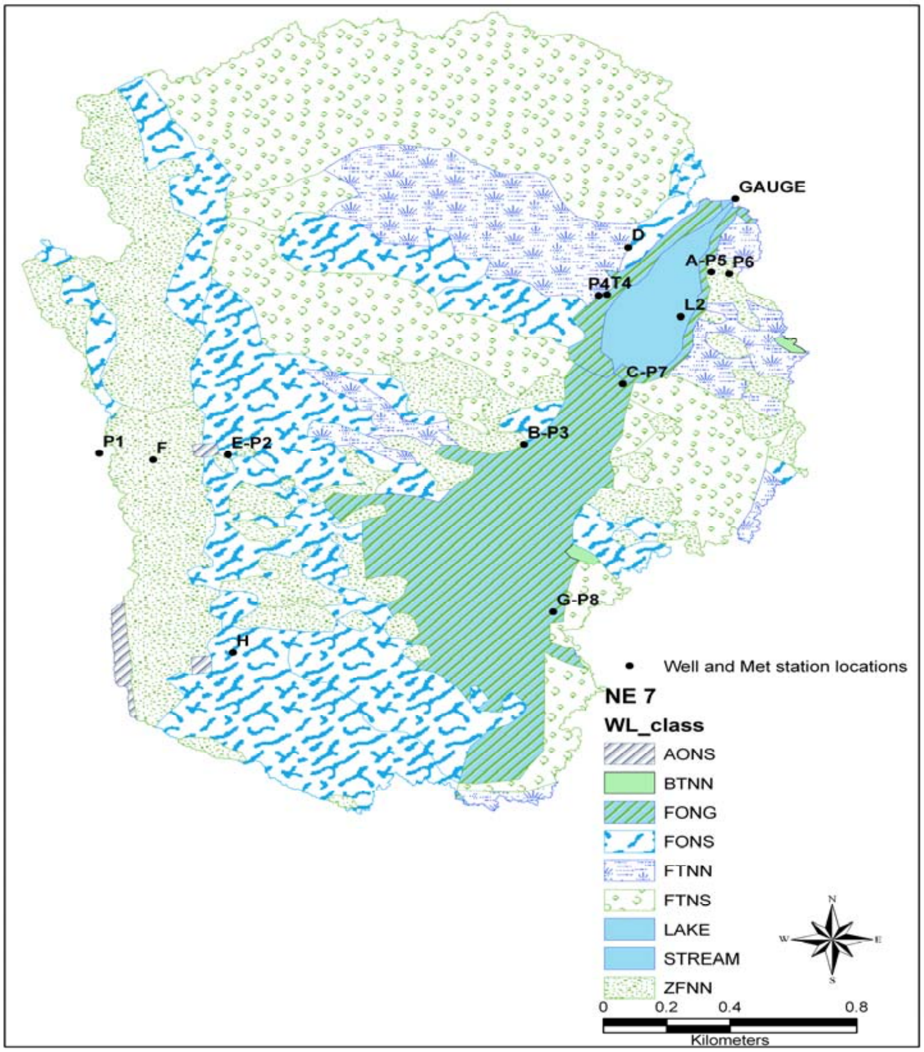


Figure 2.1 Landscape classifications NE 7
Sample network locations are shown and classifications defined in Table 2.1.

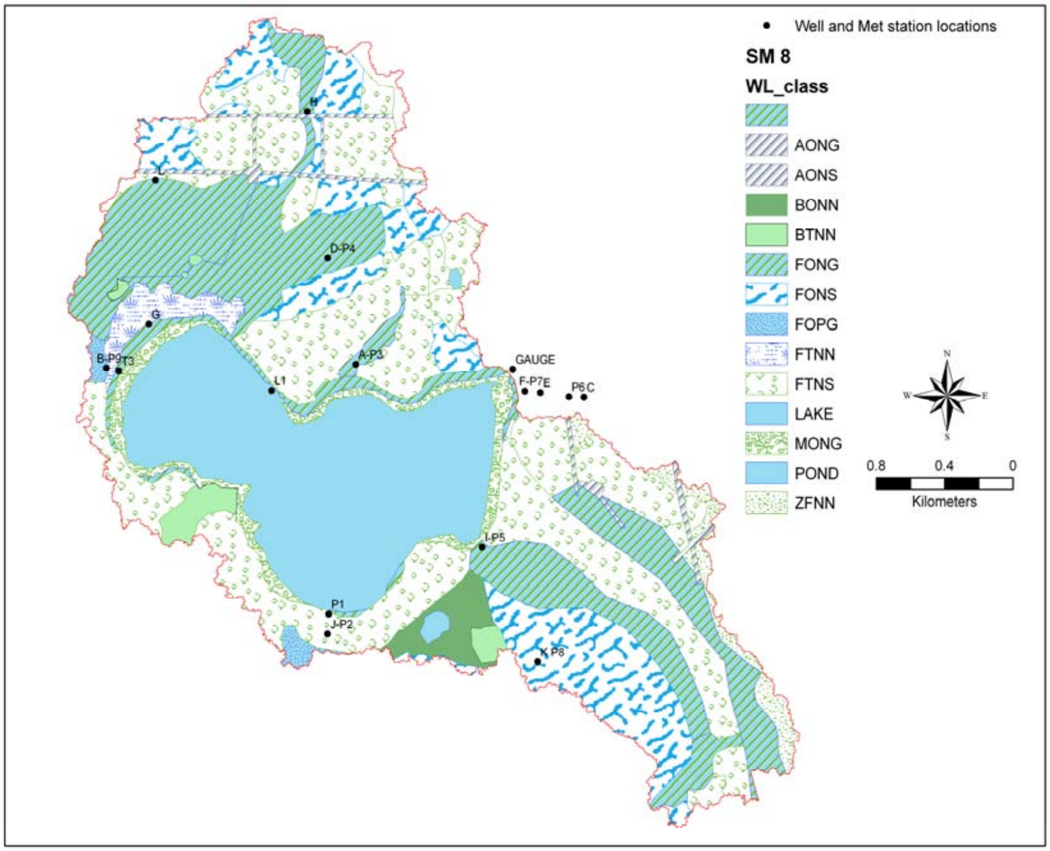


Figure 2.2 Landscape classifications SM 8
Sample network locations are shown and classifications defined in Table 2.1.

Table 2.1 Landscape classification based on Halsey et al. (2003)
Each of the four letters in each code represents an element of the landscape.

Classification Code	Description
AONG	Man made, Open, No permafrost/patterning, Graminoid dominated
AONS	Man made, Open, No permafrost/patterning, Shrub dominated
BONN	Bog, Open, No permafrost/patterning, No internal lawns
BTNN	Bog, Treed, No permafrost/patterning, No internal lawns
FONG	Fen, Open, No permafrost/patterning, Graminoid dominated
FONS	Fen, Open, No permafrost/patterning, Shrub dominated
FOPG	Fen, Open, Permafrost/patterning present, Graminoid dominated
FTNN	Fen, Treed, No permafrost/patterning, No internal lawns
FTNS	Fen, Treed, No permafrost/patterning, Sedge dominated.
MONG	Marsh, Open, No permafrost/patterning, Graminoid dominated.
ZFNN	Upland, Forested, No permafrost/patterning, No internal lawns

Table 2.2 Wetland types and area as % cover

NE 7		SM 8	
WL Class	**% cover**	**WL Class**	**% cover**
Fen	77.5	Fen	70
Bog	0.1	Bog	3.2
Upland	19.8	Upland	1.8
Open water	2.1	Open water	21.7
other	0.5	other	3.3

Figure 2.3 Micro meteorological stations
These stations are set up both in the lake (left) on a standard construction scaffold platform and in a terrestrial setting (right) on a tripod. Equipment configuration is listed in Table 2.3.

Table 2.3 Meteorological station configuration
Both the land and lake based stations have the same configuration with the exception that the lake stations have the addition of pressure transducers for monitoring water level.

Parameter	Instrument	Height/Position Above soil/water
Air Temperature	Vaisala HMP	1.8 metres
Relative Humidity	Vaisala HMP	1.8 metres
Net Radiation	Zipp and Konen NR lite	1 to 1.2 metres
Precipitation	Texas Instruments TE 525 Tipping bucket	1.8 metres
Ground and Water Temperature	Campbell Scientific 107 B thermistors	Depth profiles in soils and lake
Wind Speed and Direction	Gill and Young Anemometer and Vane	2 metres
Air Pressure	Young barometric air pressure sensor	Within logger enclosure
Water level in Lake and in Pan	Keller Pressure Transducer SDX Pressure Transducer	In lake and in Evaporation Pan

2.2. Energy Balance

Two methods for estimating evaporation from basic meteorological data were selected. Both the Penman combination (Chow *et al*., 1988) and the Priestley-Taylor (1972), methods for calculating energy balance are frequently used in Northern Canada (Boudreau 1995; Gibson

1996; Reid, 1993, 1996) and are shown to work well in this environment especially on small water bodies where total heat fluxes remain small on a daily scale (Chow *et al.*, 1988). Both these techniques are based on data collected at a single elevation above the surface (Table 2.3), at two stations situated in different environments (over both the lake and the land). The Priestley Taylor (1972) method has been applied repeatedly in northern tundra and wetland environments with great success because of its simplicity and flexibility. The inclusion of the term α in (equation 3), replaces the aerodynamic component in the Penman combination method and is intended to account for moisture limitation. Typically, α = 1.26, is used to represent open water evaporation (lakes and ponds) and lower α values are applied for evaporation from land surfaces with varying levels of saturation with α = 0.96 being a common value applied to terrestrial sites (Munro, 1986; Boudreau and Rouse, 1995).

$$E_{PT} = \alpha \frac{\Delta}{(\Delta - \gamma)} E_r \qquad \text{(Priestley-Taylor, 1972)} \qquad (1)$$

E_{PT} = predicted evaporation,
α = Priestley-Taylor coefficient-empirically derived, generally assumed as 1.26 for open water
Δ = slope of the saturation vapour curve at air temperature of interest
γ = psychrometric constant ($kPa°C^{-1}$)
G = heat flux transfer into soil and water
E_r = Energy balance given below

$$E_r = \frac{(R_n - G)}{l_v \rho_w} \qquad (2)$$

Rn = net radiation
l_v = latent heat of vaporization
ρ_w = density of water

The Penman combination method incorporates a term for aerodynamics E_a :

$$E_p = \frac{\Delta}{\Delta + \gamma} E_r + \frac{\gamma}{\Delta + \gamma} E_a \qquad (3)$$

The Energy Balance component E_r,

$$E_r = \frac{R_n - H - G}{l_v \rho_w} \qquad (4a)$$

Or without convective loss as:

$$E_r = 0.395\ \mathrm{R_n} \qquad (4a)$$

The Aerodynamic component E_a:

$$E_a = B(e_{as} - e_a) \qquad (5)$$

Where B is controlled by wind speed and $(e_{as}-e_{a})$ is the difference between saturated and actual vapour pressure (Chow *et al.*, 1988).

Er for the two methods varies by the exclusion of sensible heat (H) and an aerodynamic component e_a from the Priestley-Taylor (PT) version. In this way, PT assumes no advection through the sample location.

Both methods require simple meteorological data that were collected at each of the two stations in each catchment.

2.3. Piezometer and Water Table Monitoring

Over the two years of this study, 20 shallow water level monitoring points and a total of 17 piezometer nests were established, many at the same location as the shallow water monitoring network (Figures 2.1 and 2.2). In both detailed basins, wells and piezometers were established in each of the major terrain units of interest and in a transect from the upland to wetland. The shallow wells are a maximum depth of 1.5 m screened along the entire length and are equipped with an Odyssey™ water level capacitance probe to log continuous water level fluctuations in the saturated zone (active layer). This device is a Teflon coated cable calibrated to record water level fluctuation of less than a millimetre (Figure 2.4). A second well was established to collect water samples for routine monitoring of physical parameters (pH, T °C, and electrical conductivity µScm^{-1}), and sample collection for analysis of stable water isotopes (SWI) and major ions.

The piezometer nests, established to study surface water and groundwater interactions in this low relief, wetland environment, were installed at depths ranging between three and ten metres, and were located with existing shallow water table wells where possible. In this way, piezometric head at three depths were used to determine vertical fluxes of shallow groundwater (< 1.5 m, 3-5m, 6-10m). Installation of this type of piezometer was accomplished using a *Pionjar*™ rock hammer to drive lengths of steel pipe to the desired depth. The piezometers themselves consist of a stainless steel *Solinst*™ model 615 drive-point piezometer tip which is internally screened to prevent sediment build up. The piezometer tip threads onto 1.5 metre lengths of high carbon steel pipe (Figure 2.5). In order to ensure that water is not contaminated by the steel pipe, polyethylene tubing (PET) is fixed to the drive-point at a barbed nipple and lines the entire length of the steel pipe. Water level measurements are obtained manually using a *Heron 'little dipper'* electronic measuring tape which is deployed down the well bore inside the PET. Water level is manually read off the tape when the sensor indicates the water level has been reached. Piezometers are developed by repeatedly pumping the piezometer using a *Waterra* foot-valve attached to ¼ inch diameter PET inserted inside the larger ½ inch PET. Once the piezometers are established, water samples for SWI and geochemical analysis are collected using the same *waterra* foot-valve and tubing.

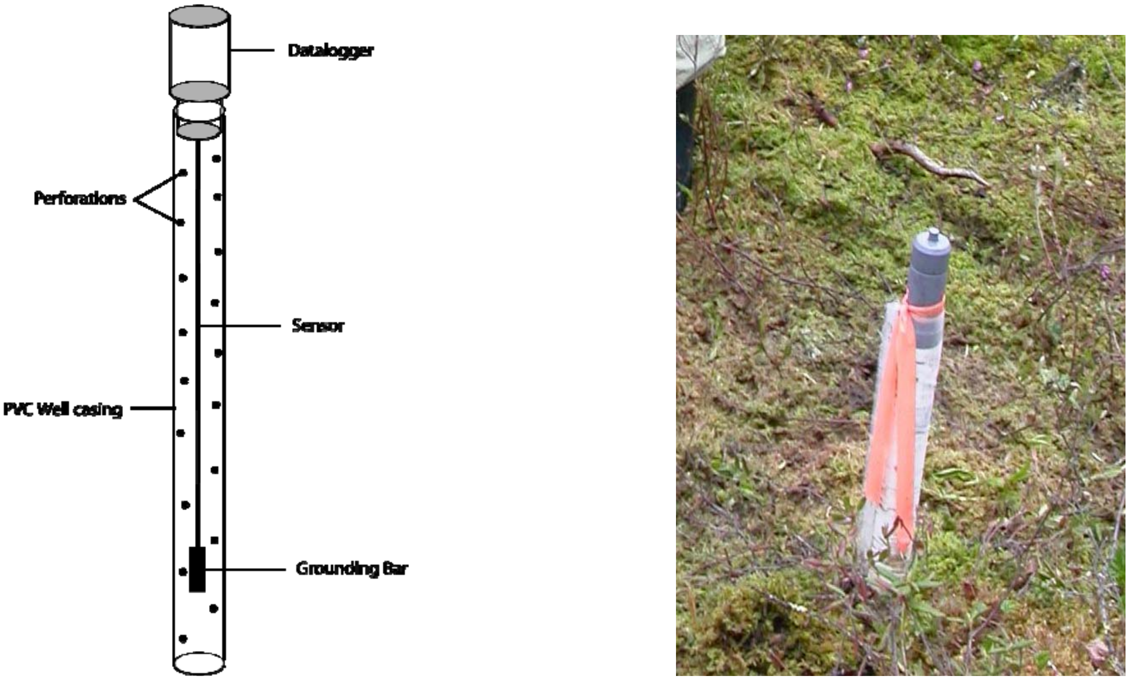


Figure 2.4 Shallow water level monitoring
Odyssey water level capacitance probes measuring continuous water level throughout the year. Schematic on left shows configuration of PVC well with probe installed and field installation in photo on right. Note the length of PVC casing is screened with Nitex™ (not shown in figure on left but visible on photo on right) to prevent sediment build up (not shown in diagram to left).

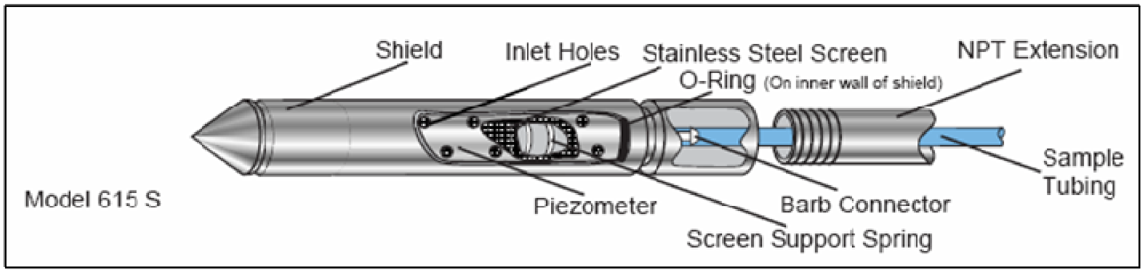


Figure 2.5 Schematic of Solinst™ model 615 stainless steel piezometer tip

Figure 2.6 Remote piezometer installation
Many sites were accessed by helicopter only as foot travel was much too difficult. The gas powered Pionjar™ is capable of driving piezometer tips to depths of >10 metres.

2.4. Hydraulic Properties

2.4.1. Soils

Soil samples were collected as part of the shallow well installation and as part of landscape classification exercises. Samples were collected using a 5 cm soil auger from discrete depths or through extracting and intact core. A selection of samples was sent to Pacific Soil Analysis in Vancouver, BC. All results were reported as % weight and particle size was determined by the pipette method for clay and silt and by wet sieving for the sand fraction, according to McKeague (1978) (Pacific Soil Analysis Inc, 2007). Soils were described and classed based on the system of Folk and Ward (1957).

These data were applied in the Hazen method for calculating intrinsic permeability which may be used as proxy for hydraulic conductivity.

2.4.2. Shallow Conductivity

Drainage from both lakes during the summer is sluggish to the extent that it was insufficient to allow the use of even the price micro current meters. For the period of the open water season, outflow is considered negligible. Subsurface hydraulic properties are measured or estimated using multiple methods. Hydraulic conductivity for both the surface and subsurface was estimated by using sediment grain size as an indicator of intrinsic permeability (Hazen method) and calculated using head recovery tests (Hvorslev method) respectively (Fetter, 1980).

One method of assessing hydraulic conductivity at the surface of the soil/peat interface is to use grain size to estimate intrinsic permeability. The relationship between grain size and permeability is well documented and discussed at length by Shepherd, 1989. Intrinsic permeability is expressed as:

$$K = C(d_{10})^2 \qquad \text{(Fetter, 1988 p. 81)} \qquad (6)$$

K = hydraulic conductivity cms^{-1}
C = dimensionless constant
d_{10} = the effective grain size (defined as the grain size where 10% of sample is finer)

Known as the Hazen Method and based on empirical studies, it incorporates a dimensionless constant, which is as function of the sediment sorting, particle size and induration. Sheppard (1989) showed that in fact C and the exponent in equation (6) decrease when sediments are poorly sorted and with increased lithification of sediments and therefore decreased permeability. For the purposes of this study, equation (6) will be used as an approximation for hydraulic conductivity and will be accepted in this form, recognizing that there are limitations to this technique for fine grained silty soils. The technique was originally design for estimating conductivity in sand aquifers with uniform grain-size distribution. Therefore estimates for the silt soils are should be used cautiously. For peat-rich soils, estimates of hydraulic conductivity were taken from the literature and no attempt was made to measure in the field (Holden, 2005).

2.4.3. Piezometer Conductivity

For the piezometers, hydraulic conductivity is calculated according to the Hvorslev method using the following equation:

$$K = \frac{r^2 \ln(L/R)}{2LT_0} \qquad \text{(Fetter, 1988: p. 198)} \qquad (7)$$

r = radius of standpipe
L = length of well screen
R = radius of well screen
T_0 = time for water level to recover to 37 percent of the initial change

The technique for collecting the necessary data for this calculation involves removing a volume of water from the well to create a change in hydraulic head, and monitor the recovery rate to a known point based on the initial water level position. The advantage of this method is that it is useful in situations where a piezometer is completed in an unconfined aquifer or in a situation where the piezometer does not fully penetrate the aquifer (Freeze and Cherry, 1979). In this study a volume of water was removed from the piezometer using a *waterra* foot-valve and hand pumped. Recovery was monitored over time using an electric measuring tape lowered into the piezometer and measurements taken every 30 seconds to one minute for the first ten minutes depending on the rate of recovery and then every ten minutes for one hour. If insufficient recovery was achieved in the one hour period and sufficient time was available on a given field trip then the piezometer was visited again in 24 hrs. Keep in mind this was a remote area, where travel by foot through wetland terrain made it difficult to visit the same site more than once during a given field trip.

2.4.4 Hydraulic Gradients and Groundwater Fluxes

Hydraulic gradients and groundwater fluxes were also calculated to determine areas of potential groundwater exchange. Hydraulic gradients are calculated using equation 8, where the dh is the difference between pressure head in a set of piezometers and dl the distance between piezometer screens. If the interest is in knowing the vertical flux as in between the surface and shallow subsurface, the dL is the vertical distance between piezometer screens (Freeze and Cherry, 1979, p. 24).

$$i = dh/dl \qquad (8)$$

i = hydraulic gradient
dh = change in pressure head
dL = distance between piezometer screens

In order to determine the potential flux between the subsurface we can apply Darcy's law as given in equation 9,

$$Q = -KiA \qquad (9)$$

Q = groundwater flux
K = hydraulic conductivity
A = unit area

2.5. Isotopic and Geochemical Monitoring

2.5.1. Water Sampling Methods

Water samples were collected from surface water (lakes, ponds, standing water, rill flow, and subsurface melt flow and from shallow and deep piezometers) on a biweekly to monthly interval during the open water season of both 2005 and 2006. Source sites were routinely monitored for pH, T °C, and electrical conductivity μScm^{-1}. Samples were collected for analysis of Stable Water Isotopes (oxygen-18, deuterium) and enriched tritium (^3H) as well as major ions, trace elements and DOC. All samples were collected in high density polyethylene (HDPE) bottles and sealed tightly. Samples for oxygen-18 and deuterium (30 ml) were left unfiltered and stored at room temperature until shipped for analysis. The samples for enriched tritium (1 l) were double bagged with heavy duty Ziploc bags and stored as above. All other samples were collected in HDPE bottles (60 ml for cations and anions, 120 ml for DOC).

Samples for geochemical analysis were returned to the field laboratory for filtering immediately after sampling where possible. All samples were filtered to 0.45 μm to remove suspended solids. Samples for cation analysis were acidified with 16N nitric acid. Samples for DOC were collected in opaque bottles and kept dark to avoid photo-degradation.

Where sufficient sample volumes were obtained, alkalinity was measured by way of colorimetric titrations using a *HACH*™ alkalinity kit and expressed as HCO_3-.

2.5.2. Stable Isotopes

Stable isotope analyses of waters were performed at the Environmental Isotope Laboratory (EIL), University of Waterloo (UW). Standard methods were applied to measure the ratios of $^{18}O/^{16}O$ and $^{2}H/^{1}H$ using isotope ratio mass spectrometry. These ratios are expressed as per mil (‰) deviations from the standard VSMOW (Vienna Standard Mean Ocean Water). Quality assurance and quality control analysis are performed by technical staff in the EIL at UW and the data is rechecked upon receiving it at UVic. Analytical uncertainty for is 0.01 ‰ and 1 ‰ for ^{18}O and ^{2}H respectively. Standard delta "δ" notation is used to denote variations according to:

$$\delta^{18}O \text{ or } \delta^{2}H = [R_{sample}/R_{standard} - 1] * 10^{3} ‰, \qquad (10)$$

where R is the ratio of the sample and standard in permil ‰.

Stable isotopes of water have multiple uses in a study where water balance or flow path mechanisms are important. The conservative nature of the water molecule makes it excellent environmental tracer by allowing for labelling and partitioning of discrete water parcels. In depth reviews of stable isotope theory are available from Gat (1996) and Kendall and Caldwell (1998). In brief, natural labelling of water as it is processed through the hydrologic cycle and the systematic enrichment of surface water may be expressed as the ratio of heavy ($^{1}H^{2}H^{16}O$ and $^{1}H^{1}H^{18}O$) and light ($^{1}H^{1}H^{16}O$) isotopes as compared against an international standard of Vienna Standard Mean Ocean Water (VSMOW) (Gat, 1996). The benefit of this technique is the ability to compare various water sources and position them along a local meteoric water line (precipitation) or evaporation line (surface water) (LMWL or LEL respectively), typically displayed in a cross-plot in ^{18}O and ^{2}H space).

2.5.3. Major Ions

The major ions and trace element samples were submitted to the Aqueous Geochemistry Lab, School of Earth and Ocean Sciences, University of Victoria. This laboratory uses both ICP-MS and Ion Chromatograph technology to analyse water for major cations, anions, trace elements and Dissolved Organic Carbon. Quality assurance and quality control analysis are performed by technical staff in the AGL at UVic and the data is rechecked upon receiving it at our lab.

2.6. Vertical Water Balance

For very flat surfaces, the vertical water budget (VWB) is a means to estimate runoff as the sum of vertical fluxes and the resultant change in storage in the ground (i.e. $P\text{-}ET \approx \Delta S$). To calculate a VWB it is necessary to have measurements or estimates for precipitation and evaporation and for physical characteristics of the various terrain units such as soil or peat porosity and water level variation. Based on available data, VWB's are generated for the two seasons of this study. The vertical balance is a means of balancing meteorological fluxes with physical changes in the environment (water level) while considering physical properties of the site (porosity and shallow groundwater storage) to estimate runoff potential.

Boudreau and Rouse (1995) give the water balance for a wetland as:

$$P - ET - RO = \Delta S \qquad (11)$$

P = Precipitation (mm)
ET = Evapotranspiration (mm)
RO =surface runoff out of the catchment (mm)
ΔS = change in storage (mm)

Rearranging the equation to solve for Runoff results in:

$$RO = P - ET - \Delta S \qquad (12)$$

In this study precipitation is measured directly at both met stations and evaporation is estimated based on the energy balance methods discussed above. The change in storage is calculated as follows:

$$\Delta S = \Delta WL\,(Ys) \qquad (13)$$

ΔWL = change in water level from one time-step to the next (mm)
Ys = specific yield %

Water level is measured at each well site on a continuous basis. Specific yield (*Ys*) of a soil is defined as the amount of water that can freely drain under the force of gravity and in expressed as a % (Ward and Robinson, 2000). Specific yield has been defined for numerous soil types by Johnson (1967) (Table 2.4) and these values are adopted for calculations here.

Previous studies in similar low relief environments have applied the vertical water balance approach to studying wetland hydrology (e.g. Hayashi *et al*., 1998; Kranostein and Oldham, 2004; LaBaugh *et al*., 1997). Saturated land surfaces have been show to play an important role in catchment water balance through variation of evaporation and transpiration rates from wetland dominated catchments (Woo, 1976). Monitoring saturated zone storage will provide insight into the hydrologic behaviour of distinct landscape types such as bogs and fens and allow for the improvement of the conceptual hydrologic model of these detailed study basins through calculating a vertical water budget (Heliotis and Dewitt, 1987; Kranostein and Oldham, 2004).

This is the first study applying VWB to wetland dominated basins in the Fort McMurray area.

Table 2.4 Specific yield values for various soil types (Johnson 1967)

Material	**Specific Yield (%)**		
	min	**avg**	**max**
Clay	0	2	5
Sandy clay (mud)	3	7	12
Silt	3	18	19
Fine sand	10	21	28
Medium sand	15	26	32
Coarse sand	20	27	35
Gravely sand	20	25	35
Fine gravel	21	25	35
Medium gravel	13	23	26
Coarse gravel	12	22	26
Peat		44	

3. Physical and Chemical Hydrology

3.1. Introduction

In the Wood Buffalo region near Fort McMurray, the Athabasca and Clearwater Rivers constitute the major rivers. These two large rivers and several tributaries are the focus of the Water Survey of Canada (WSC) gauging network in the region. By focusing monitoring primarily on large rivers, this gauging network leaves extensive areas of peatland terrain disconnected from the major rivers and poorly represented in the existing datasets (Bennett *et al*., 2009). Other monitoring strategies include regional and seasonal lake surveys, in concert with nutrient, geochemical and isotopic sampling (RAMP, CEMA). Lakes and wetlands located on the plateau areas are disconnected from the hydrology of the major rivers and are poorly understood. These lakes and wetlands however, comprise a significant spatial component of the regional landscape. Given the saturated condition of the low relief, undulating terrain, and the apparent lack of connected channelized drainage, quantitatively characterizing the hydrology of the region is difficult. This chapter will discuss the landscape characteristics, microclimate, surface water and shallow groundwater hydrology, and water balance for two detailed study basins situated in the Fort McMurray region.

Lakes NE 7 and SM 8 are similarly situated within 50 km of Fort McMurray (Figure 1.1). These lakes, part of a larger network of lakes monitored by the Cumulative Environmental Management Association (CEMA), were selected based on their position along a hydrologic continuum representing a range of hydrologic states from high through flow to high evaporation systems (Bennett *et al*., 2009). Using stable water isotope techniques, a through flow index (x = E/I) expresses the flow dynamics of a lake system where a lower x ratio indicates a higher through flow system (Gibson *et al*., 2002). NE 7 is classified as a through flow system (E/I =

18.3) and SM 8 is considered an evaporative system (E/I = 43.6) (Bennett *et al*., 2008). These classifications represent a broad regional hydrologic approach. During the open water period of 2005 and 2006, detailed studies were conducted in the two selected basins and the findings of these two field seasons are reported here.

3.2. Conceptual Model

Figure 3.1 outlines the conceptual model designed to guide this work. The hypothesis of a snowmelt dominated, shallow groundwater system with ephemeral flow was assumed, a monitoring network designed, and equipment installed to provide data to capture variability in water balance parameters. Using micro-meteorological stations, site specific detailed measurements of meteorological fluxes are possible, thus improving results over the use of interpolated regional climate datasets. The conceptual model indicates potential for surface runoff between landscape units and, based on the typical micro-topography of hummocks and depressions, the depressions may retain hydrologic input and attenuate runoff. There is also potential for shallow water movement (laterally and vertically) through peat or at the peat/mineral soil interface (Holden, 2005). There may also be intermediate groundwater flow within the catchment or between adjoining catchments, and this may be an important component of the water balance as well as a potential source for major ions to the lake (important for acid neutralization in aquatic ecosystems) (Anderson and Bowser, 1986; Heneriksen *et al*., 1992). Regional groundwater fluxes are difficult to account for in this scenario because there is no observation well network in the region and the piezometer nests within the study basins are limited to 10 metres in depth. This model is designed to explain the hydrologic behaviour during the open water season and must make assumptions related to snow pack and spring melt hydrology.

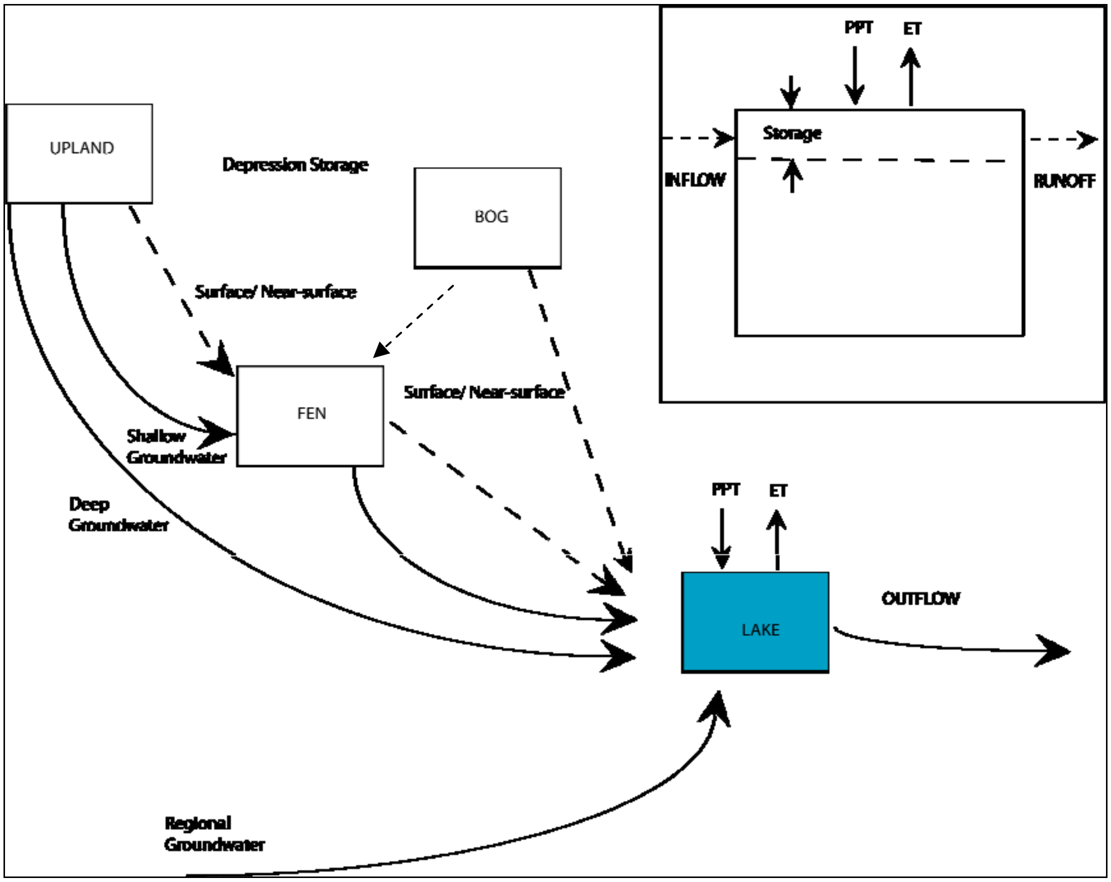


Figure 3.1 Conceptual model of groundwater/surface water interactions
Solid lines denote subsurface flow and dashed lines denote overland flow. Runoff is limited to spring freshet and ephemeral flow in rills and depressions related to storm events and seasonal ice melt. Significant surface roughness encourages depression storage and fill and spill type run off where the depressions must first fill before runoff occurs.

3.3. Local Climate

Local climate variables were measured during the open water seasons in each of the two field seasons at two locations in each basin. Basic station configuration is given in Table 2.1, and Figure 3.2 shows an example of the seasonal data collected at each station (see Appendix 1 for full dataset).

3.4. Energy Balance-Potential Evaporation

In order to calculate evaporation, two methods of the energy balance were applied to the dataset. The results from the application of the Penman combination (PC) method and the Priestley-Taylor (PT) methods as described above are presented below.

The relationship between the estimates of the two methods at the same station (Figure 3.3) shows that very strong agreement. The Penman method consistently estimates higher total E except at the NE 7 lake station where it estimates lower total E for both study years (Table 3.2).

Table 3.1 Mean annual evaporation calculated by two methods
Evaporation as calculated using the Penman combination method (PC) and the Priestley-Taylor method (PT) for each year at each lake for both the land and lake based meteorological stations.

		SM 8				NE 7			
		Lake		Land		Lake		Land	
		2005	**2006**	**2005**	**2006**	**2005**	**2006**	**2005**	**2006**
days in record		*109*	*119*	*108*	*119*	*104*	*121*	*104*	*120*
E(PC)	**total**	272.91	309.30	270.55	338.29	241.23	318.59	194.48	300.63
	min	-0.18	-0.31	0.00	-0.07	-0.23	-0.43	0.09	0.02
	max	6.45	7.33	5.81	7.65	6.37	6.74	4.31	6.44
	mean	2.48	2.58	2.42	2.86	2.30	2.61	1.85	2.59
E(PT)	**total**	267.00	300.00	231.35	257.38	247.44	320.48	171.00	246.84
	min	-0.33	-1.54	0.00	-0.23	-0.46	-0.73	0.03	-0.07
	max	6.21	7.21	4.60	5.63	5.92	6.63	4.11	4.45
	mean	2.43	2.50	2.07	2.17	2.36	2.63	1.63	2.11

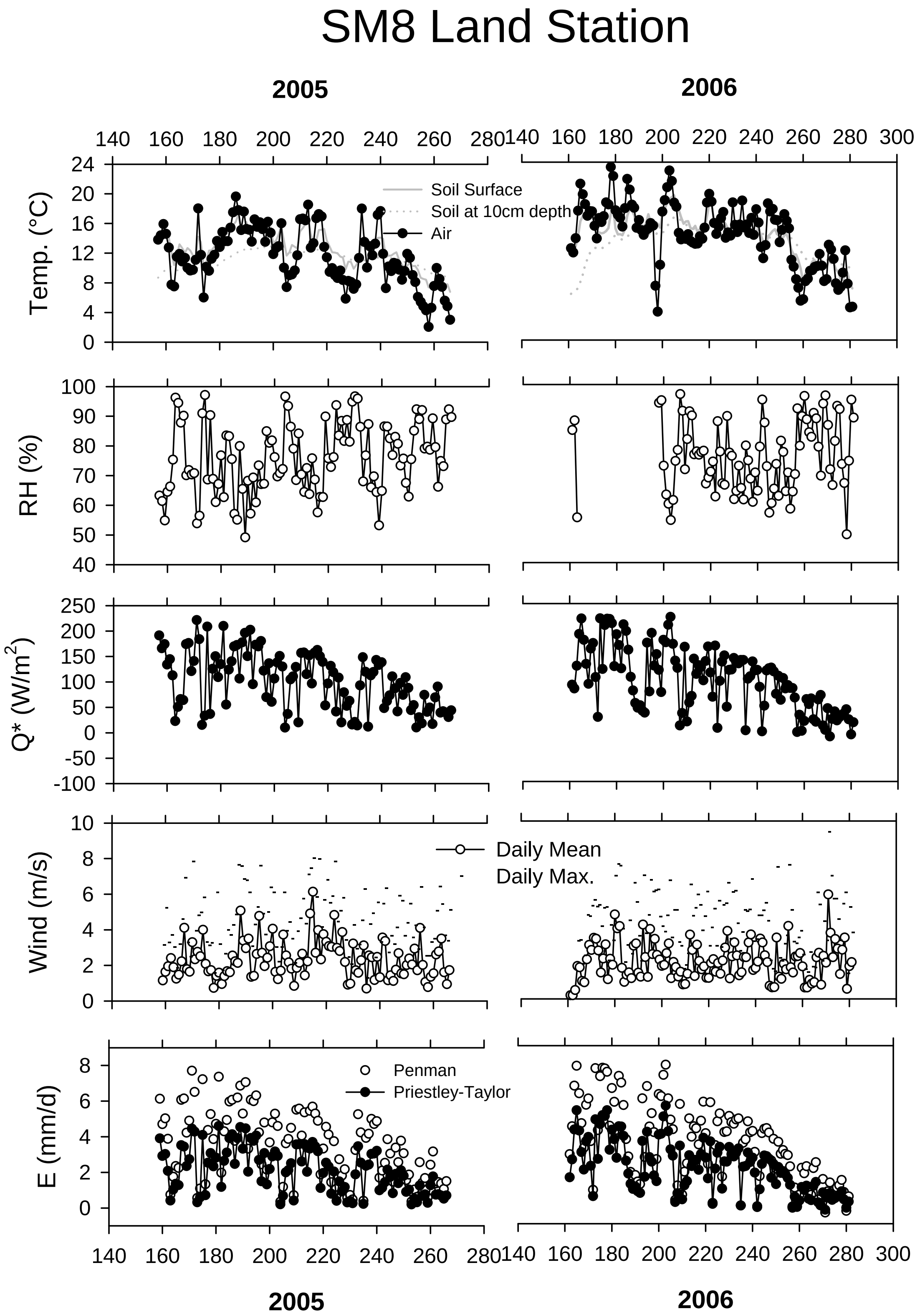


Figure 3.2 Basic meteorological data for two seasons from one station at SM8
Inter seasonal trends are stable for the two years presented here with air temperature being slightly higher in 2006 than 2005.For the remainder of data see appendix 1.

3.5. Water Level Variation

During the 2005 field season, shallow water table wells, equipped with continuous water level monitoring probes were established throughout the two study basins and are denoted by a capital letter (e.g. NE 7 A, B etc). These water level data are presented as a hydrograph and are important in storage calculations for vertical water balance calculations (see Figures 3.4 and 3.5 for water level variability in each landscape type in the each catchment).

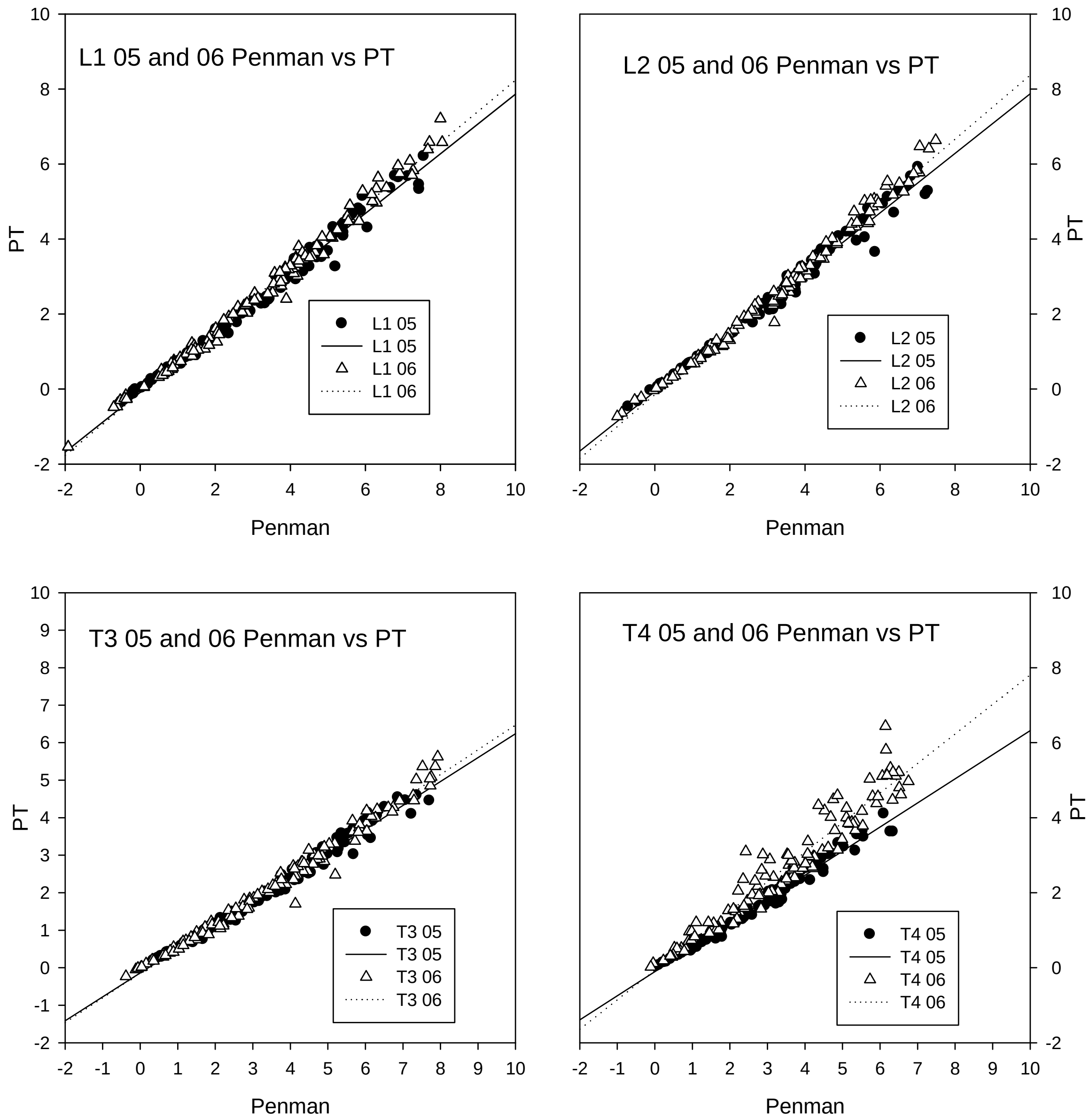


Figure 3.3 Cross plot of energy balance

Cross plot of energy balance estimates using two methods. Plots show data from the same station for two years as a comparison of how well the two methods agree in terms of estimating evaporation. Stations L1 and L2 represent lake based stations and T3and T4 represent the terrestrial based stations.

3.5.1. NE 7

At NE 7, water level is lowest during the March, approximately day 70 in 2006; the exception is the upland site F, where the minimum water level was reached approx DOY 355 2005. In all cases the spring melt period is marked by a sharp increase in water level especially at upland type locations such as NE 7 A and F. Wells located in fen, with thick peat deposits and a near ground surface water table, exhibit muted water level fluctuations, in comparison with wells in upland or forest sites with mineral soil substrate. In locations with shallow peat or those elevated above the surrounding saturated zone (e.g. NE 7 A, E), large fluctuations in water level commonly occur in response to significant rain events (Figure 3.4). Fen sites show the least variation during the open water season (e.g. NE 7 B, C, and G). These sites are essentially saturated all season and because of their locations lower in the catchment do not drain water the same as higher locations.

3.5.2. SM 8

The monitoring wells in the SM 8 catchment show a very similar behaviour to those in NE 7. Wells reached minimum water level between DOY 50 and 100 2006 with the exception of location E, a well completed in mineral soil, which reached its lowest water level late in 2005 (DOY 355) and maintained that water level until DOY 125 2006.

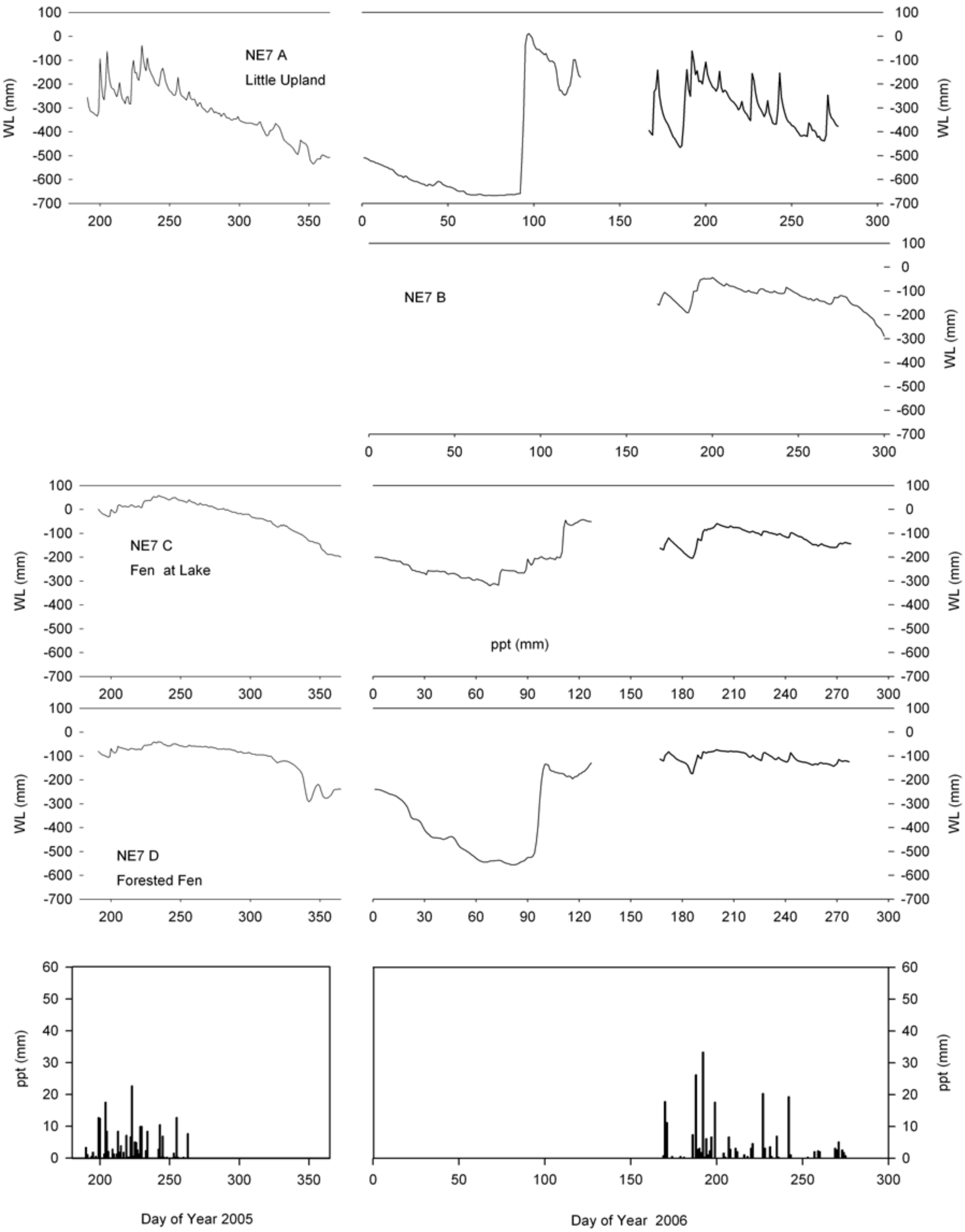


Figure 3.4 Landscape unit hydrographs NE 7
Hydrographs show the rapid rise and fall of water levels in the upland mineral soil unit and the more attenuated water level variation in the fen units. The peat dominated fen locations in contrast have a great capacity to store water and overall show very little water level variation. Ground surface is set at zero along the y-axis in the water level panels in above figure.

During the same time period in 2006 discharge was observed along the southern shore of the lake through macro-pores easily observed in the scarped edge of the 1.5 m to 2.0 m be consistent if you are going to spell out metre or meter or just use m. thick peat deposit. In both situations topography causes ponding of water to cover a large expanse landward of the lake shore. Drainage is either through the macro-pores or overland when significant saturation occurs. While periods of runoff are noted at various locations around the catchments, stream outflow is difficult to quantify.

One point of interest within this catchment is the observation of overland runoff occurring more frequently than in NE 7. At well location SM 8 A, runoff was observed in the field repeatedly during the dates 2005 from DOY 205-244 and in 2006 DOY 128-32 (the water level was above the ground surface Figure 3.5), as part of the freshet period. Runoff was observed again in relation to large precipitation events DOY194-5 and 200-01, 2006. The topography at this location channels any runoff from two small Jack pine and lichen upland mounds adjacent to the shoreline into a depression which focuses runoff. SM 8 D also had periods where the water level was above the ground surface in 2005 in response to a significant precipitation between DOY 205-12 and 230-36.

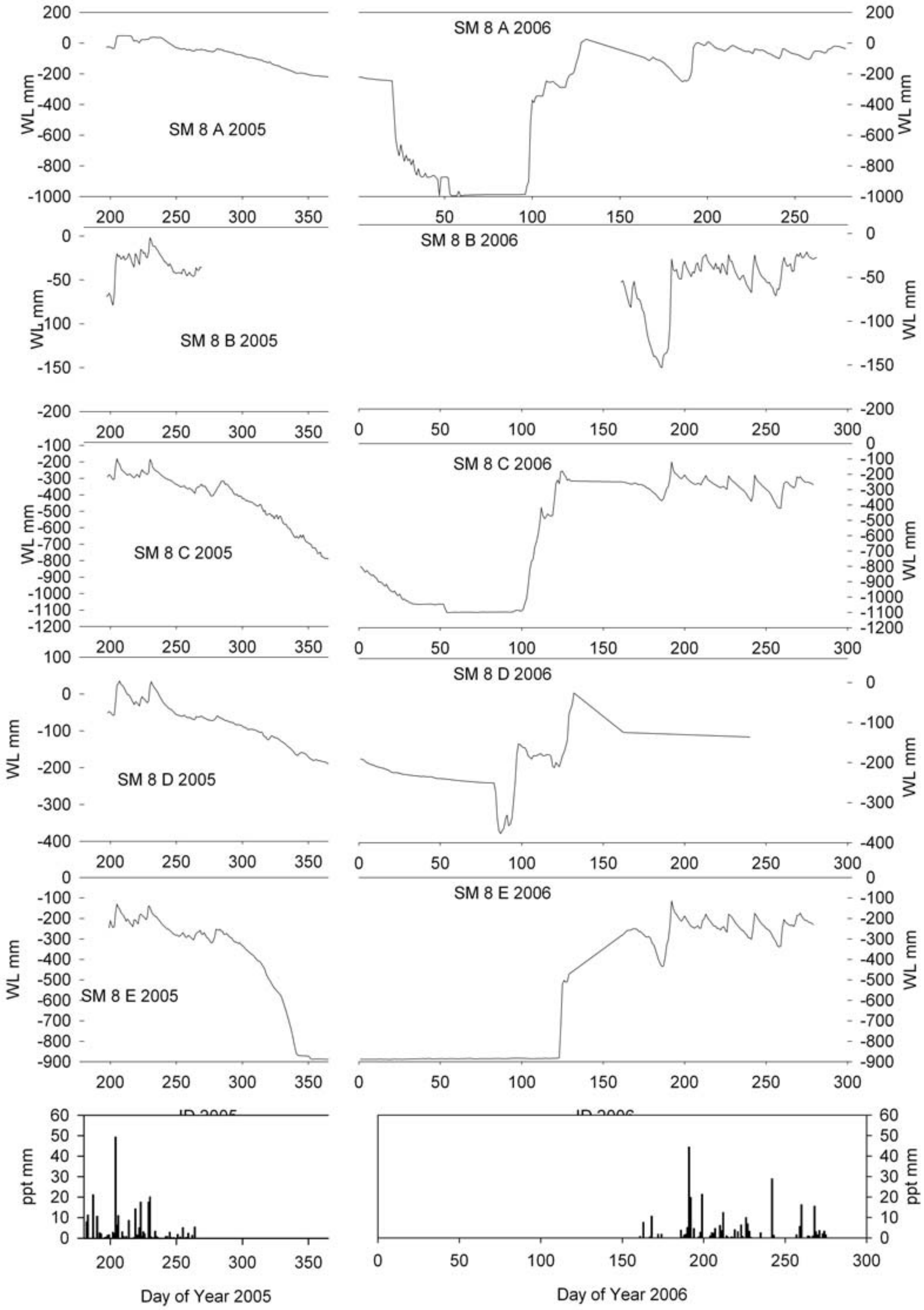


Figure 3.5 Landscape unit hydrographs SM 8

Landscape Unit hydrographs show the rapid rise and fall of water levels in the upland mineral soil unit and the more attenuated water level variation in the fen units. The peat dominate fen locations have a great capacity to store water and overall show very little water level variation. Ground surface is set at zero along the y-axis in the water level panels in above figure.

3.6. Vertical Water Balance

As displayed in the conceptual model (Figure 3.1), the degree of saturation and detention storage is an important consideration when attempting to determine potential fluxes from individual terrain units. In an environment with little channelized runoff, where low relief and well developed peat dominated wetlands cover the majority of the landscape, gauging stream flow is very difficult to conduct as a means to describe the surface hydrology. Water fluxes on the landscape become vertical rather than typical lateral fluxes associated with river dominated catchments where traditional stream gauging or weirs are able to quantify discharge. Calculating the vertical water balance presents an alternative way to calculate water fluxes.

Examining the VWB for 2005 and 2006 shows that the variable precipitation inputs are reflected in the VWB for each basin where runoff is strongly related to significant precipitation events. While the timing of some events is similar between the two catchments, the magnitude is often very different (Figures 3.6 and 3.7, Appendix 2). It is difficult to compare the runoff estimates for both years, because some instrumentation was not installed until after DOY 182 in 2005 where the record for 2006 is longer starting on DOY 165. Peak runoff in 2005 was around DOY 200 at both lakes with several events coming close to runoff later in the season, but not breeching the 15 mm depression storage threshold until DOY 260 2005 in NE7 at site A and E. SM8 has runoff potential between approximately DOY 200 and 230, but shows a marked decrease following DOY 230 as a result of no major precipitation events.

The data record for 2006 is longer starting on approximately DOY 165. The total precipitation values for each catchment are much closer than in 2005 (within 8%), and most of the runoff occurred between DOY 190 and 245. NE 7 shows runoff prior to DOY 180 at site A and SM8 shows no runoff prior to DOY 195. Lowland and fen sites show more rapid response to precipitation events with the upland trough and the mineral upland at site F show a slightly delayed response at NE 7.

SM8 shows a large runoff event on DOY 196 for all sites in response to a precipitation event of over 30 mm (Figure 3.7). Obvious overland runoff was observed in the field during this event and supports the results of the VWB estimates for potential runoff. Another significant precipitation event around DOY 240 resulted in runoff at several locations at SM8 and at all locations in NE 7 (Appendix 2).

Table 3.2 Vertical water balance
VWB estimates for runoff (mm/yr) at five sites for two years in each of the study basins SM 8 and NE 7.

	NE 7					**SM 8**				
Site WL Class	**A Upland Min**	**C Fen**	**D Treed Fen**	**E Fen**	**F Upland Peat**	**A Fen**	**B Fen**	**C Upland Peat**	**D Fen**	**E Upland Min**
2005	22.1	37.6	0	0.3	0	22.4	18.5	5.9	18.4	12.1
2006	10.3	6.2	22.9	14.9	11.6	5.7	11.8	4.1	31.1	10.4

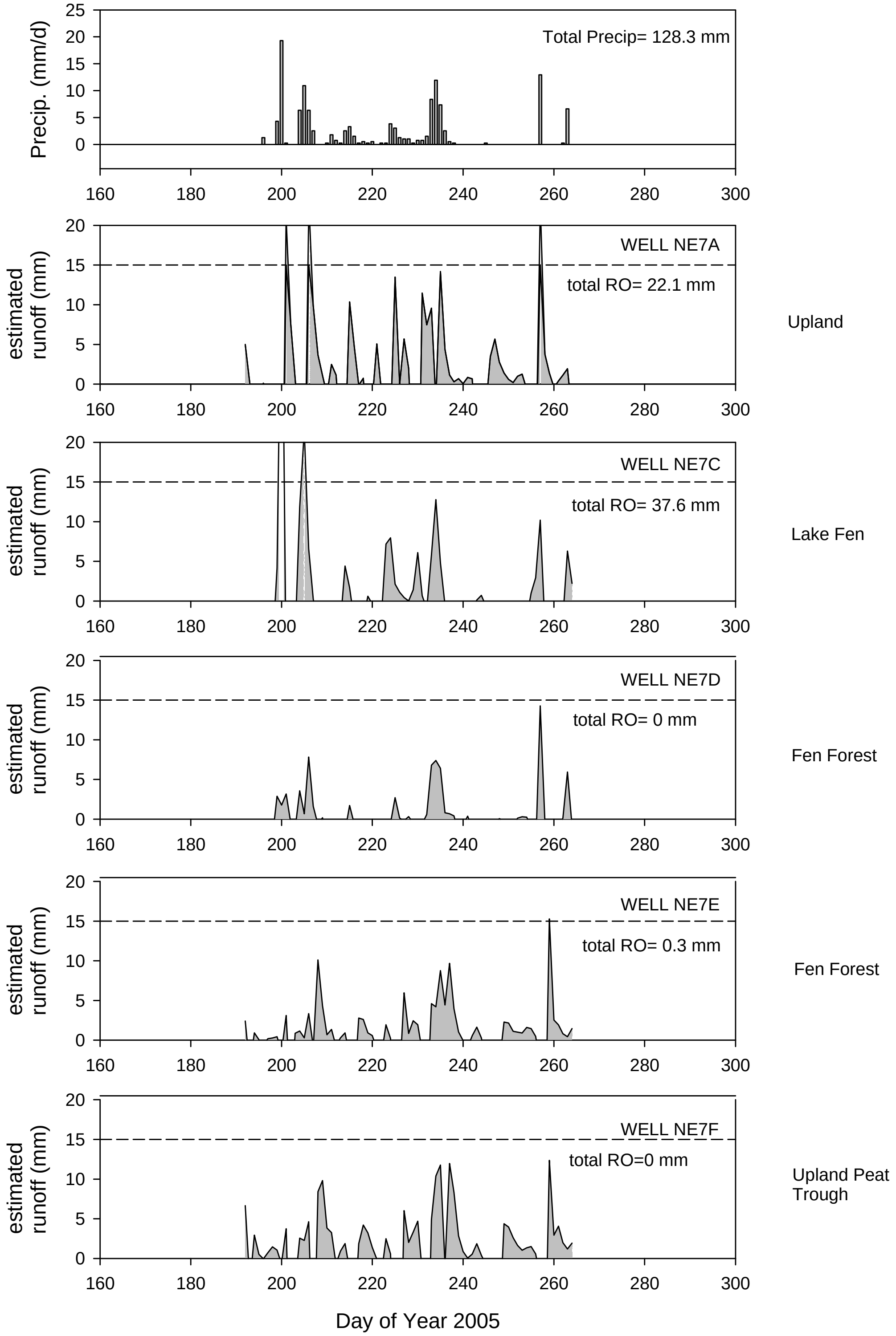


Figure 3.6 Vertical water balance for select sites NE 7 2005
Local precipitation is presented in top panel with VWB results for selected sites shown in the following panels. The dotted line represents the 15 mm depression storage potential that must be filled before runoff will occur. Sites variable to precipitation, with upland sites showing the most immediate response.

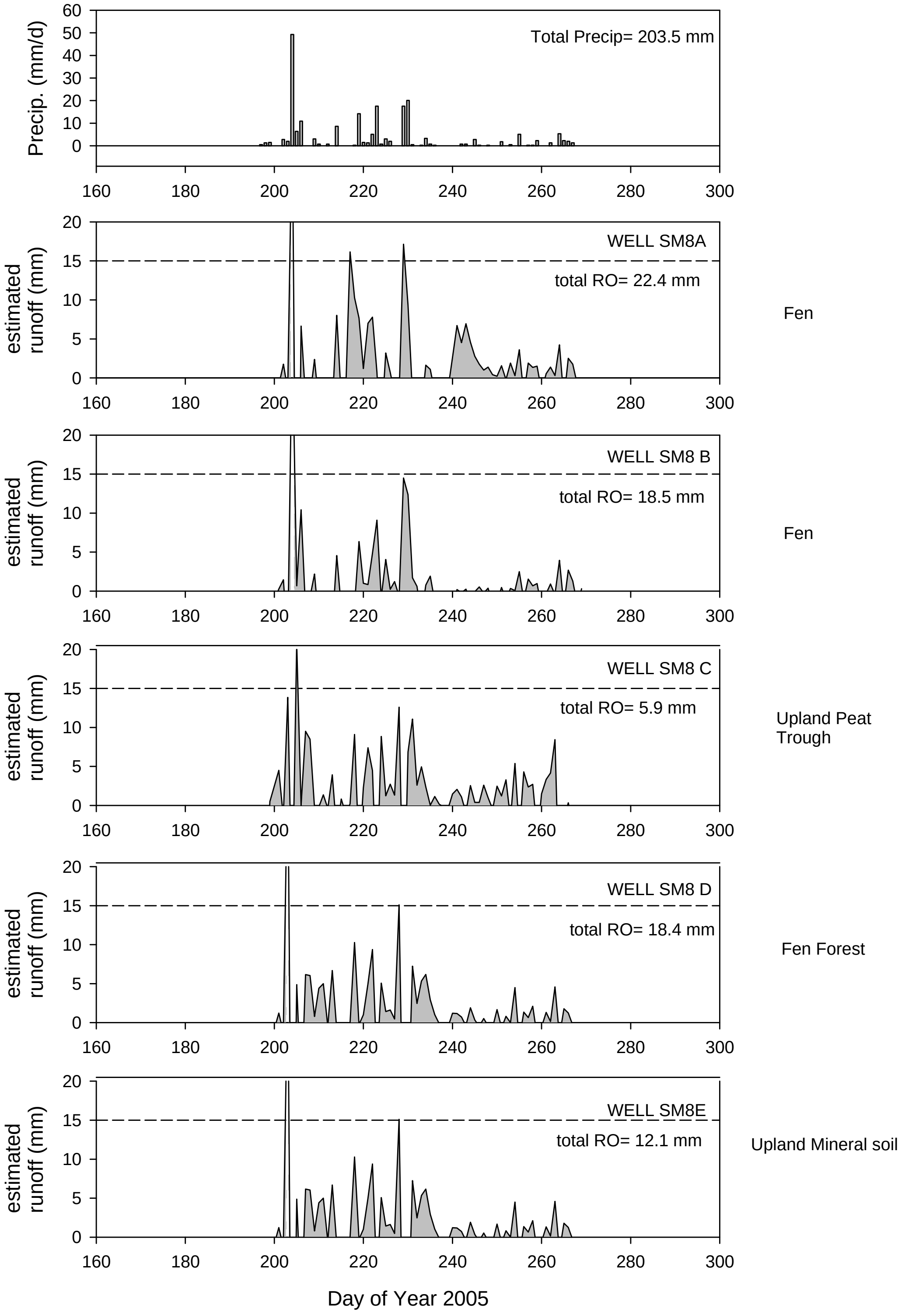


Figure 3.7 Vertical water balance for select sites SM 8 2005.
Local precipitation is presented in top panel with VWB results for selected sites shown in the following panels. The dotted line represents the 15 mm depression storage potential that must be filled before runoff will occur. Sites variable to precipitation, with upland sites showing the most immediate response.

3.7. DEM Derived Flow Path

Flow paths were generated by using standard algorithms in the ArcGIS environment based on DEM data. This is a multi-step process in which the DEM is first filled or smoothed to remove pits which may interfere with flow routing and then flow accumulation and flow direction are calculated based on the v Jensen and Dominique (1998). Using this technique, flow direction is determined for an individual grid cell by the hydrologic behaviour of the eight neighbouring cells. First, in this landscape with no significant channel flow within the catchments (except the outlet), human disturbance in the landscape in the form of trails and cut-lines, has a noticeable influence on the flow network in both catchments where strong flow paths are associated with the well established cut-lines. Even though no visible surface flow was observed along the cut-lines, the disturbance associated with these roads/trails, creates a sufficient alteration to the landscape that they act as a drainage point for local surface flow as is visible in the drainage pattern displayed in Figures 3.8 and 3.9. Secondly, the flow path maps show that locations where overland runoff is observed in the field indeed are located at points showing significant flow routing was calculated from the elevation data. In this wetland environment where physical studies such as this one are difficult, fine or high resolution remotely sensed data are a useful tool for unravelling the surface hydrology for a large number of lake catchments in a single survey.

3.8. Groundwater/Surface Water Interactions

A difficult component of the water balance to quantify is the groundwater flux. Groundwater surface water interaction is controlled by the ability of the substrate to transmit water from the surface to the subsurface or vice versa in the form of recharge to an aquifer or as discharge to the surface either in a water body or a terrestrial landscape unit. Hydraulic conductivity through peat has been discussed by other workers, who have noted that the porosity and density of peat changes with depth and the variability in conductivity ranges from 10^0 to 10^{-4} cms^{-1} in the upper 25 cm (acrotelm) of the peat column to 10^{-6} to 10^{-8} at depths > 25 cm (catotelm) (Holden, 2005).

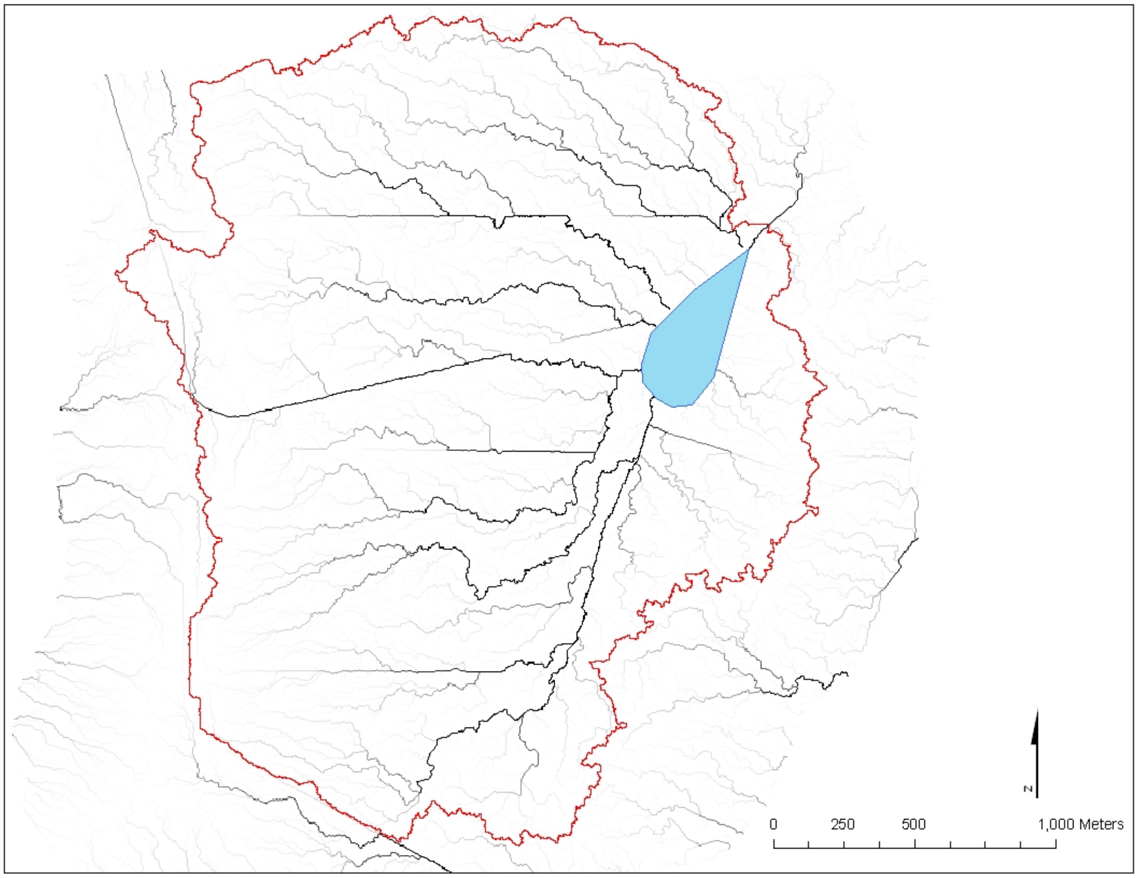


Figure 3.8 Flow networks as determined using DEM at NE7

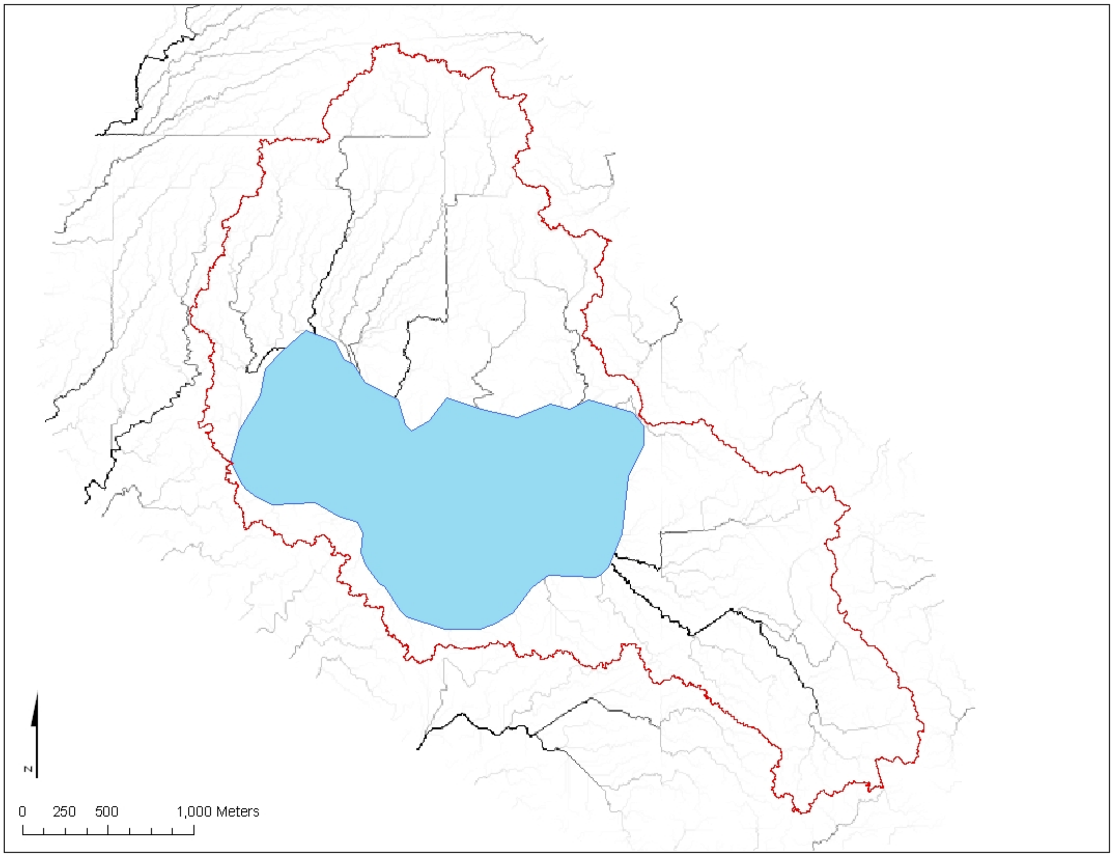


Figure 3.9 Flow networks as determined using DEM at SM8

3.8.1. Hydraulic Conductivity NE 7

For the purposes of this study, two methods are used to assess the conductivity of the mineral soils present. The Hazen method is applied to sediment samples collected from the shallow subsurface throughout the two catchments. The Hazen method produced a range of conductivity estimates for NE 7 ($2.67 * 10^{-4}$ cms^{-1} to $3.56 * 10^{-4}$ cms^{-1}) with a mean of $3.18 * 10^{-4}$ cms^{-1} (see Table 3.4, Appendix 3). While this method was intended for use with sand size sediments, the sediments from the study area are primarily coarse silt. However, the above results are in good agreement with expected values for hydraulic conductivity through similar silt sediments (Freeze and Cherry, 1979).

Piezometers are not necessarily completed in a known confined aquifer and in some cases do not fully penetrate an aquifer, but are installed for the purpose of monitoring water levels in the unsaturated zone and collecting water samples for isotopic and geochemical analysis. The piezometers installed throughout the catchments produced variable water level responses and not all the piezometers in each catchment had a suitable volume of water to conduct the necessary tests to properly assess the hydraulic conductivity. For those wells which did not recover within the monitoring time frame, recovery times (T_0) were estimated based on the level of recovery during the monitoring period. These data are shown in Table 3.5. The mean K value as calculated using the Hvorslev method is $1.01*10^{-5}$ cms^{-1} with a range of $1.05 * 10^{-4}$ to $2.02 * 10^{-8}$.

Table 3.3 Hydraulic conductivity estimates (Hazen Method**)**
Hydraulic conductivity estimated using the Hazen Method (Fetter, 1988. p 82).

Site	K cm/s	Site	K cm/s
NE 7 F1	2.67E-04	**SM 8 Q3**	3.09E-04
NE 7 F2	2.95E-04	**SM 8 H**	2.38E-04
NE 7 Q5A	3.21E-04	**SM 8 Q2**	2.41E-04
NE 7 Q6	3.32E-04	**SM 8 Q1**	2.43E-04
NE 7 G P8	2.94E-04	**SM 8 Lake**	3.79E-04
NE 7 Q3	3.38E-04	**SM 8 Q5**	2.54E-04
NE 7 Q2A	3.45E-04	**SM 8 L**	2.57E-04
NE 7 Q4	3.04E-04	**SM 8 D**	2.39E-04
NE 7 Camp	3.56E-04	**SM 8 Camp**	2.70E-04
NE 7 A	3.30E-04	**SM 8 C1**	2.47E-04
		SM 8 C2	3.34E-04
Min	**2.67E-04**	**Min**	**2.38E-04**
Max	**3.56E-04**	**Max**	**3.79E-04**
Mean	**3.18E-04**	**Mean**	**2.74E-04**

Table 3.4 Hydraulic conductivity estimates (Hvorslev Method**)**
Calculated hydraulic conductivity based on bail test results (Fetter, 1989. p 198).

Site	NE 7	SM 8
	K cm/s	K cm/s
1A	1.05E-04	3.53E-06
1B	NA	5.54E-09
2A	7.86E-07	3.78E-07
2B	NA	NA
3A	2.43E-07	1.12E-08
3B	NA	6.04E-09
4A	NA	NA
4B	1.54E-07	NA
5A	2.02E-08	9.89E-07
5B	3.23E-08	so fast
6A	4.04E-07	NA
6B	4.04E-07	NA
7A	4.53E-08	NA
7B	8.54E-07	1.05E-07
8A	3.71E-06	7.72E-07
8B	NA	1.31E-06
8C	NA	NA
9A	NA	NA
9B	NA	2.15E-07
10A	NA	1.12E-04
10B	NA	1.12E-04
10C	NA	NA
11A	NA	2.21E-07
11B	NA	NA
11C	NA	NA
min	**2.02E-08**	**5.54E-09**
max	**1.05E-04**	**1.12E-04**
mean	**1.01E-05**	**1.78E-05**

3.8.2. Hydraulic Conductivity SM 8

The Hazen method for SM 8 also has a wide range of permeability (2.38 $*10^{-4}$ cms^{-1} to 3.79 $*10^{-4}$ cms^{-1}) the mean value is lower at 2.74$*10^{-4}$ cms^{-1}. This is noticeably lower permeability estimate than at NE 7. The range of hydraulic conductivity within SM 8 reflects the heterogeneous nature of the catchment. The highest K was calculated for P10A and B (1.12 x 10^{-4} cms^{-1}), located at the lake shore adjacent to station L2. While the recharge was very quick at this location, the hydraulic gradients do not support groundwater discharge into the lake. The lowest K value was calculated for P3B and P1B (6.04 x 10^{-9} and 5.54 x 10^{-9} cms^{-1}) with a mean K for all the piezometers tested of 1.78 x 10^{-5} cms^{-1}.

3.8.3. Hydraulic Gradients

The potential for groundwater to discharge to the surface or for surface water to recharge an aquifer is evaluated through calculating a hydraulic gradient, (given as dh/dl (Freeze and Cherry, 1979)). It is a useful way to determine important areas to monitor for surface water/groundwater interaction. Using piezometer 'nests', it is possible to investigate exchange between the surface and shallow subsurface. Hydraulic gradients calculated at individual 'nests' or between 'nests' over longer distances in the catchment give an indication where groundwater flow my have sufficient pressure head to discharge from the subsurface (Figure 3.10).

Table 3.5 Groundwater flux estimates Calculations for groundwater flux estimates between Piezometers and surface water based on the Darcy equation.

Site	NE 7 Q mm/yr		SM 8 Q mm/yr	
	Upper	Lower	Upper	Lower
P1	-1.9E+03	1.8E+04	-1.4E+03	-5.1E+02
P2	-1.2E+03	1.3E+02	-1.4E+03	NA
P3	-1.9E+03	-6.5E+01	-9.3E+02	-3.4E+00
P4	-3.2E+02	-6.1E+01	NA	NA
P5	-1.6E+03	-9.9E+00	-7.3E+02	1.5E+00
P6	-1.8E+03	-1.2E+02	NA	NA
P7	-3.1E+02	-3.3E+02	-1.0E+03	-4.4E+01
P8	-1.1E+03	1.9E+01	-6.7E+02	-3.7E+02

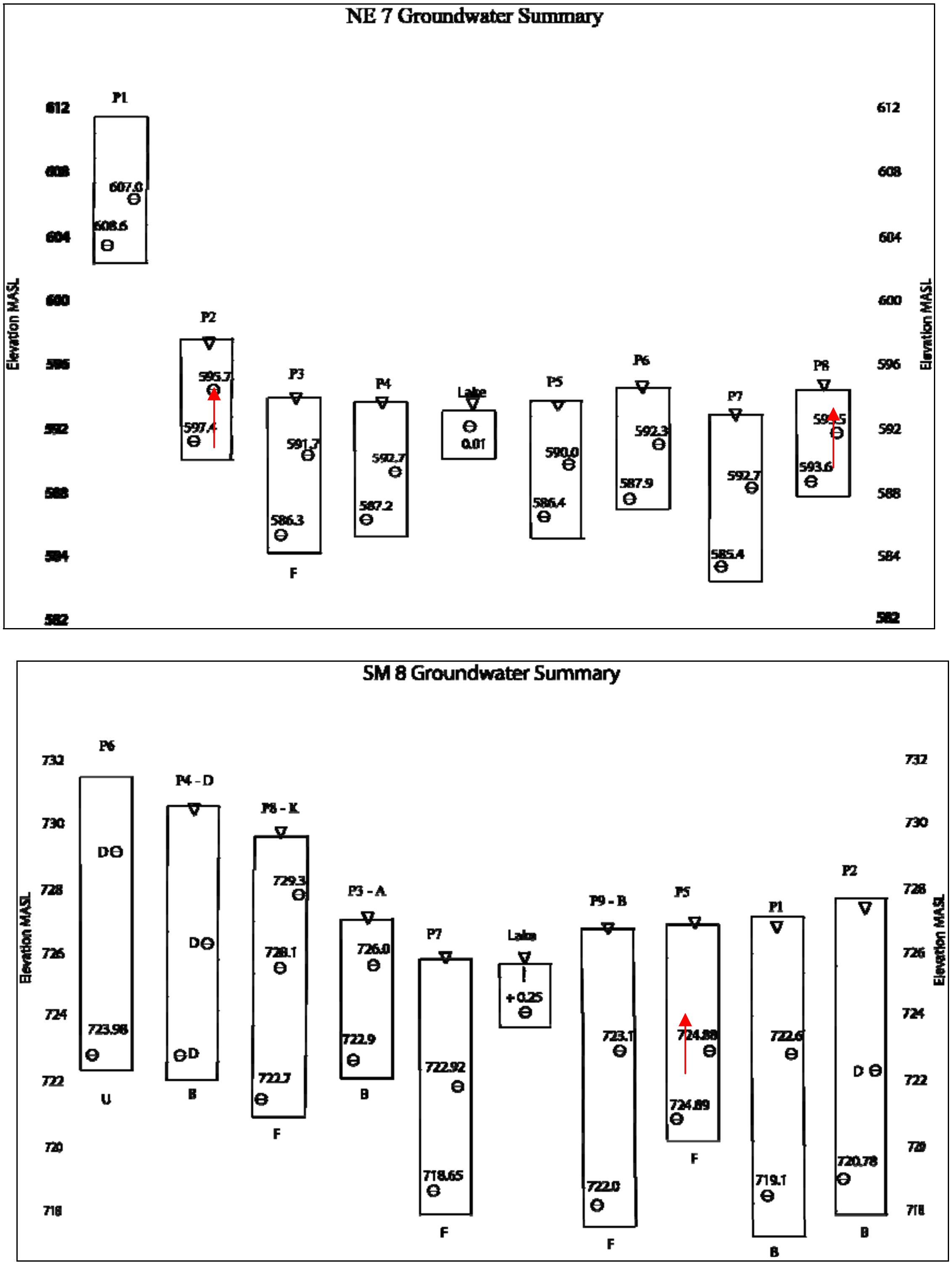
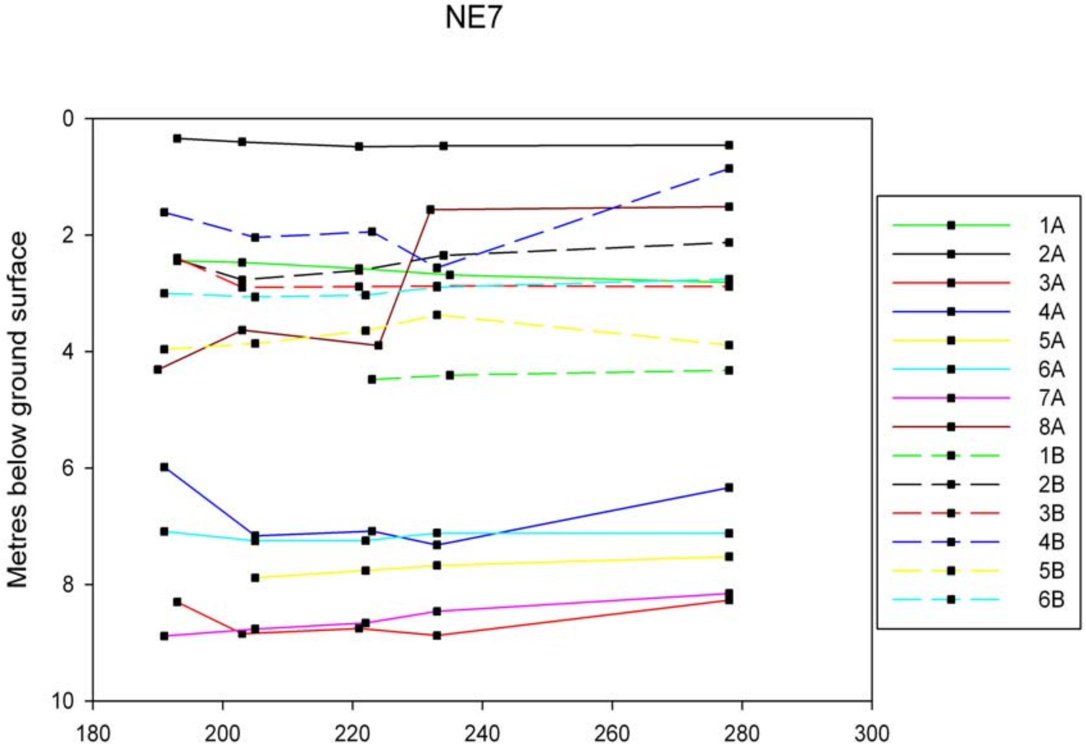


Figure 3.10 Piezometer elevation and hydraulic gradients at NE7 and SM8

Circle represents the well screen depth with water elevation (head) (MASL) in text above. Piezometers are arranged by elevation. Red arrow indicates locations with upward gradient. See Table 3.5 for flux estimates.

At NE 7 (Figure 3.8) there were three piezometer nests with upward gradients (P1, P2, P8). Starting with P1, located near the highest point in the catchment, the hydraulic gradient was positive. The upward gradient at this particular site is difficult to explain as it is near to the highest point in the catchment area and is not a location typically indicative of a discharge zone. The mineral soil at this location is sand dominated and there are saturated zones locally which may be the cause of recharge laterally to this perched aquifer through the sandy moraine deposit. Site P2, at the bottom of the hill slope, displays a strong upward gradient. The third location displaying an upward gradient was P8. This site is located toward the southern end of the large fen draining north into NE 7 (Figure 3.8).

At SM8 (Figure 3.9) there was only one well nest that displayed an upward gradient (P5). This location is close to the lake and a site where overland flow occasionally occurs. It is important to note that at no other location was there an upward gradient and this may be related to the position of this catchment on a regional upland, as this location is more likely to be a source of regional recharge rather than discharge. The position of site P5 relative to the local uplands associated with the eastern end of the catchment area may be an important factor controlling the local hydraulic gradient. Several other wells were completely dry, or the shallow well was dry while the deeper well had a small volume of water or wells at both depths had water, but in very small quantity.



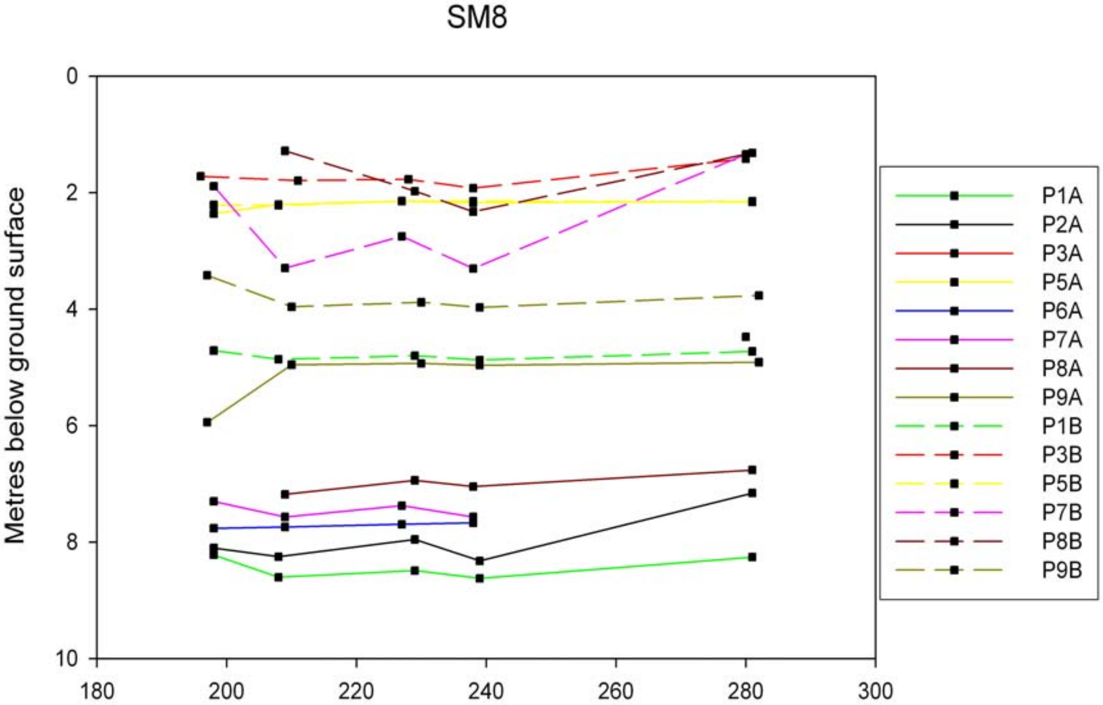


Figure 3.11 Piezometer levels during 2006 field season at NE7 and SM8
Water levels are measured in metres below ground surface (y axis) at days of year 2006 (x axis). Piezometers with no measurable water level (dry) are left out of this plot.

Investigation into the gradients between the shallow sub surface and surface show that the potential groundwater fluxes are highly variable but are all downward gradients (i.e. recharge conditions). At NE 7 the range is from -314.88 to -1892.64 mm/yr. At SM 8 the range is -665.95 to -1436.20 mm/yr (Table 3.5). Clearly, there is greater potential for exchange between the surface and subsurface at the peat/mineral soil interface than at depth where hydraulic conductivities are apparently very low.

Figure 3.11 shows that over the course of the 2006 field season some wells show little water level variation while others show significant water level changes. At NE7 the most significant change is at P8A, where over the season the water level rises greater than two metres. Other locations at NE 7 (P4), piezometers at both depths show a similar decline and rise in water level through the season. P8 is also associated with a potential point of discharge. P4 on the other hand is very close to the lake and while the hydraulic gradients do not suggest a discharge point, it is possible that this location is reflecting some connectivity to the lake. SM 8, however, shows little in the way of total water level variation, although P7B and P8B show similar trend to P4 at NE 7. P7 at SM 8 is also situated very close to the lake. The fact that the majority of groundwater levels remain fairly stable suggests that deep subsurface connections between mineral soil and surface are steady and respond slowly to seasonal changes in surface conditions.

3.9. Stable Water Isotopes

Previous isotope studies have shown that lakes in this region have maintained very stable positions isotopically over time and therefore lend themselves to detailed study (Bennett *et al.*, 2009). Figure 3.12 and 3.13 show cross-plots of $\delta^{18}O$ versus $\delta^{2}H$ for various water balance components at the two study sites for the two years of interest (all data in Appendix 4). These plots show the Global Meteoric Water Line (G MWL), a local evaporation line (LEL) and the position of each water balance component relative to these lines. The LEL shows the degree of evaporation surface waters are undergoing and is usually described in terms of the slope and offset from the GMWL. SM 8 has a very stable slope for the two years of the study at 4.58. NE 7 has a very similar slope to SM 8 in 2005, though in 2006 the slope of the LEL at NE 7 is noticeably steeper (slope 6.14).Along with the slope, the surface waters do not show the same degree of offset (between -18 and -16 ^{18}O while SM 8 is as low as -11 ^{18}O) from the GMWL at NE 7 as they do at SM 8.

3.9.1. Snow and Precipitation

Snow from the region plots at the most depleted end of the GMWL, while summer rain plots over a wide range and in fact shows some enrichment during the summer period. Summer precipitation at both lakes showed significant enrichment during 2006 (Figure 3.13). This enrichment took place during the month of July, although not during the same storm event. The wide range of isotope values for precipitation represents the range of potential recharge to groundwater and is reflected in the range of groundwater isotope signatures.

3.9.2. Groundwater

Groundwater is representative of a mixture of slow recharge snow melt/summer precipitation and in some cases evaporated surface water recharge based on the range of groundwater values. The samples that show the most enriched signal are from open fen sites which have both upward and downward gradients exhibited through monitoring the hydraulic head at these locations. The enrichment at these locations suggests that there is a component of surface water in the recharge to these shallow flow systems and this in consistent with other data from quaternary aquifers where recharge occurs from some combination of precipitation and surface waters through shallow flow systems associated with fens.

3.9.3. Wetlands

Isotope ratios for different wetland classes are shown in Figure 3.12 and 3.13 for the two years of the study. The effect of evaporation is visible on samples collected from open fen with decreasing evaporative enrichment at treed fen and upland locations. The uplands sites, in particular from 2006, plot parallel to the GWML and may represent a LMWL or in the least suggest a strong precipitation recharge signal in the uplands.

Variable isotopic composition reflects the nature of each of the hydrologic entities sampled as part of this research program. While this study has been primarily concerned with the open water season and using the evaporative enrichment signal to describe the surface hydrology in each of the two detailed study basins, it is important to understand the fluctuations in isotopic composition in relation to the yearly hydrologic cycle.

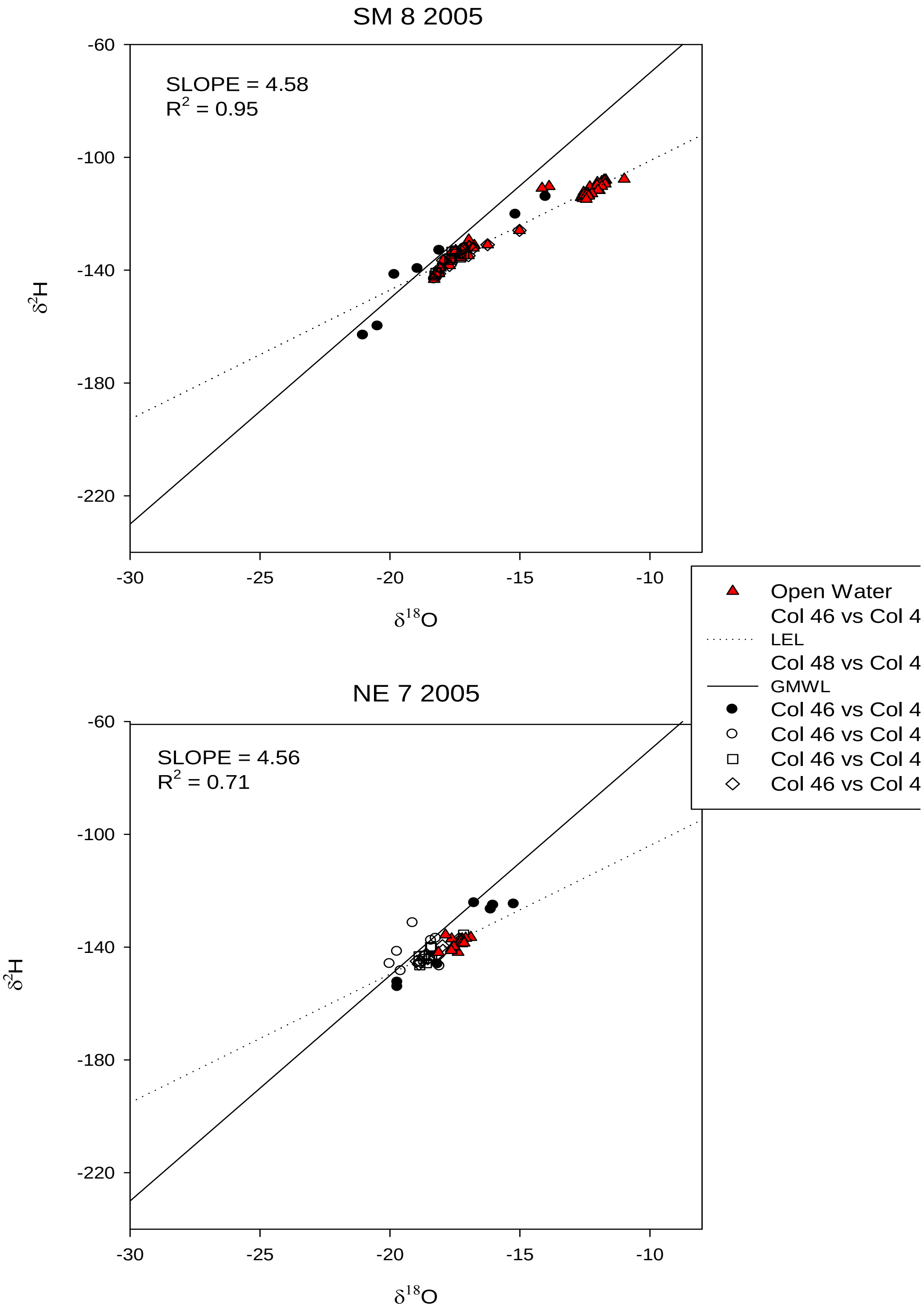


Figure 3.12 Stable isotope cross-plot 2005 at NE7 and SM8

Figure 3.12 shows isotope results for samples collected from open water, precipitation, and from shallow groundwater from various landscape units for both catchments during 2005. The effect of evaporation is seen at SM8 for the is year as late season samples are of set from the meteoric water line along a local evaporation line.

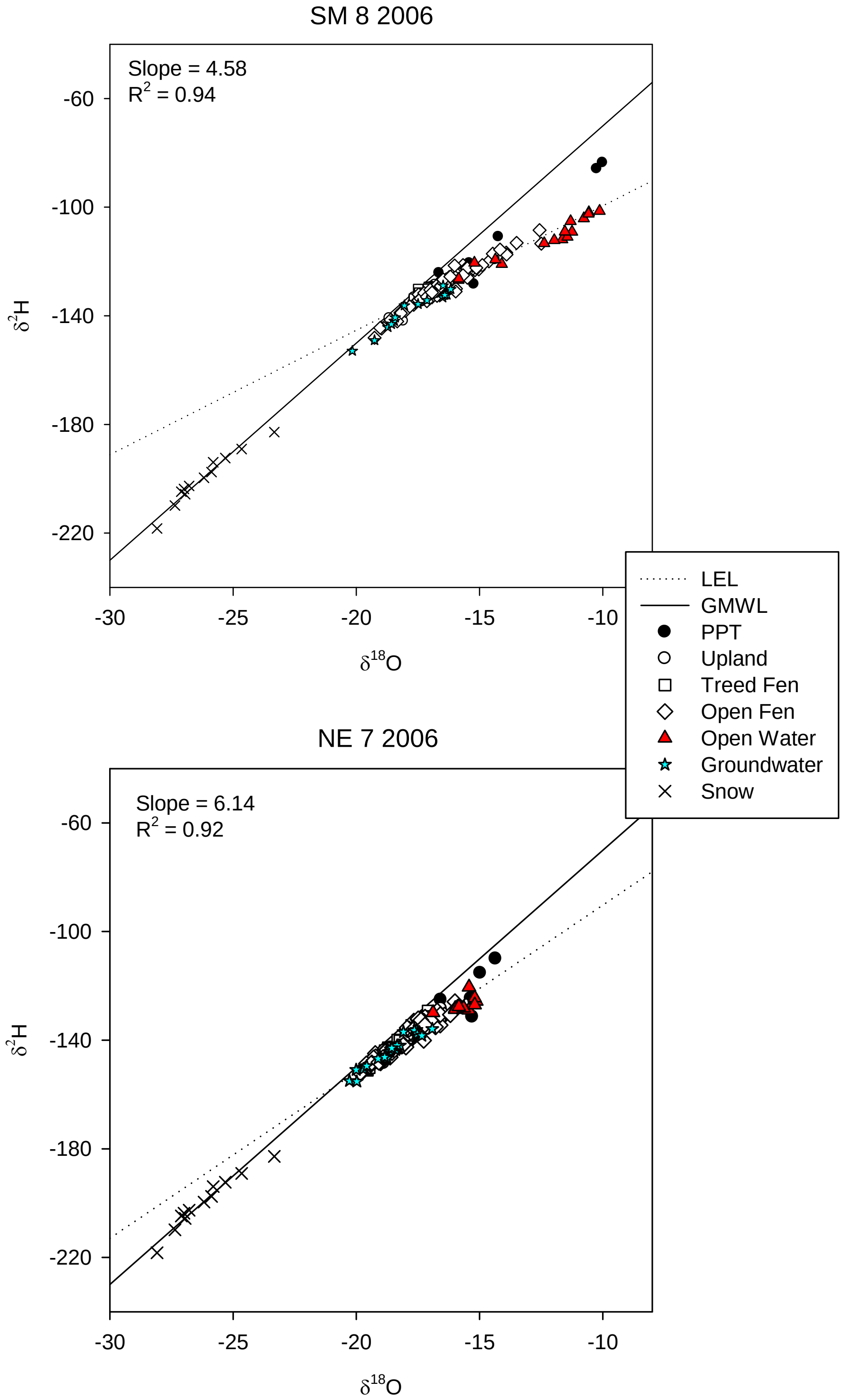


Figure 3.13 Stable isotope cross-plot 2006 at NE7 and SM8

Figure 3.13 shows isotope results for samples collected from open water, precipitation, snow, shallow groundwater from various landscape units, and from groundwater sampled at intermediate piezometers during 2006. Similar to 2005, SM 8 surface water plots further off set along an LEL than NE 7. Groundwater in both catchments plots close to the junction of the LMWL and LEL and shows a mixture of recharge.

Overall, the most significant difference in the two lakes is the isotopic position relative to the meteoric water line. Both lakes display an enrichment trend over the two years of the study, with the average lake isotope composition enriching by 1.32‰ (SM 8) and 1.64‰ (NE 7) for $\delta^{18}O$ over the study period. In absolute terms SM 8 is more enriched than is NE 7 and this is consistent with enriched isotope values throughout a longer term study (Bennett *et al*., 2008).

The labelling of water balance components is evident in the cross-lots displayed in Figures 3.12 and 3.13 where the effects of evaporation can be clearly seen. Samples from 2006 in Figure 3.13 show clearly distinguishable groups of water samples ranging from snow with the lowest values (most negative) to surface water having undergone evaporation at the most enriched end of the plot (the most positive) (Figure 3.13). Snow, as the most depleted form or precipitation plots along the Meteoric Water Line and shows a significant amount of variation, but is clearly set apart from other waters that have undergone evaporation or are a result of mixing. The effects of evaporation are the most clearly evident for SM 8 in 2006 where samples migrate along a Local Evaporation Line with a significant offset from the MWL. In this way two lakes can be compared with regards the degree of evaporation taking place with SM 8 clearly undergoing more evaporative enrichment than NE 7. Most samples fall somewhere between the depleted snow samples and the highly evaporatively enriched surface water samples. Samples such as groundwater and many of the wetland samples, plotting at the junction of the evaporation line and meteoric water line are indicative of a mixture of other components where depleted snow can be a source of recharge to the shallow groundwater system which in turn can feed the wetlands where it is mixed with more evaporated surface water stored in wetland depressions or simply is evaporated.

3.10. Major Ion Chemistry

Interpretation of the major ion geochemistry in this study is largely descriptive and qualitative because of the small sample size. A single sample was collected in the summer of 2006 from the lakes, precipitation, shallow wells and piezometers that produced enough water for sample collection (20 samples in total, see Appendix 5).

There is a strong distinction between precipitation, surface water and groundwater based on pH, EC and alkalinity and major ion chemistry. Surface water is very dilute and lakes are less acidic than surface water from wetlands in many cases and with very low to zero alkalinity. Groundwater has a higher pH and conductivity in general and overall SM 8 has lower pH than NE 7.

The relationship between anion and cation concentrations is presented in Figures 3.14 and 3.15. At both lakes there is a distinct separation between surface water samples with very low alkalinity and groundwater samples with higher alkalinity. Generally, groundwater has higher concentrations of cations, while anions seem to show less separation between surface water and groundwater samples. In both catchments there are exceptions with high levels of SO_4 (NE 7 P6A, SM 8 P2A, P5B, P7A). The chloride concentrations at NE 7 are also generally higher.

Shallow samples from peatland sites are elevated in DOC, and generally deeper piezometers or shallow wells situated in mineral soil have lower DOC values. At two locations there are piezometers which show levels of DOC similar to that typical for peatland water suggesting there may be some interaction between the surface water and the shallow groundwater. The lakes have variable DOC levels as well, with NE 7 having almost three times the DOC concentration of SM 8 potentially reflecting surface runoff from peatlands to the lake.

Almost exclusively the water samples collected from SM8 are dominated by magnesium and at NE7 by calcium, with the lake in both catchments and a single precipitation sample at SM8 being the most notable exception. These results may be affected by incorrect measurement technique used for alkalinity/bicarbonate. In some cases, zero alkalinity was measured because of the use of an acid of too high a concentration for the extremely low bicarbonate values. While the bicarbonate is low it is not likely zero as reported.

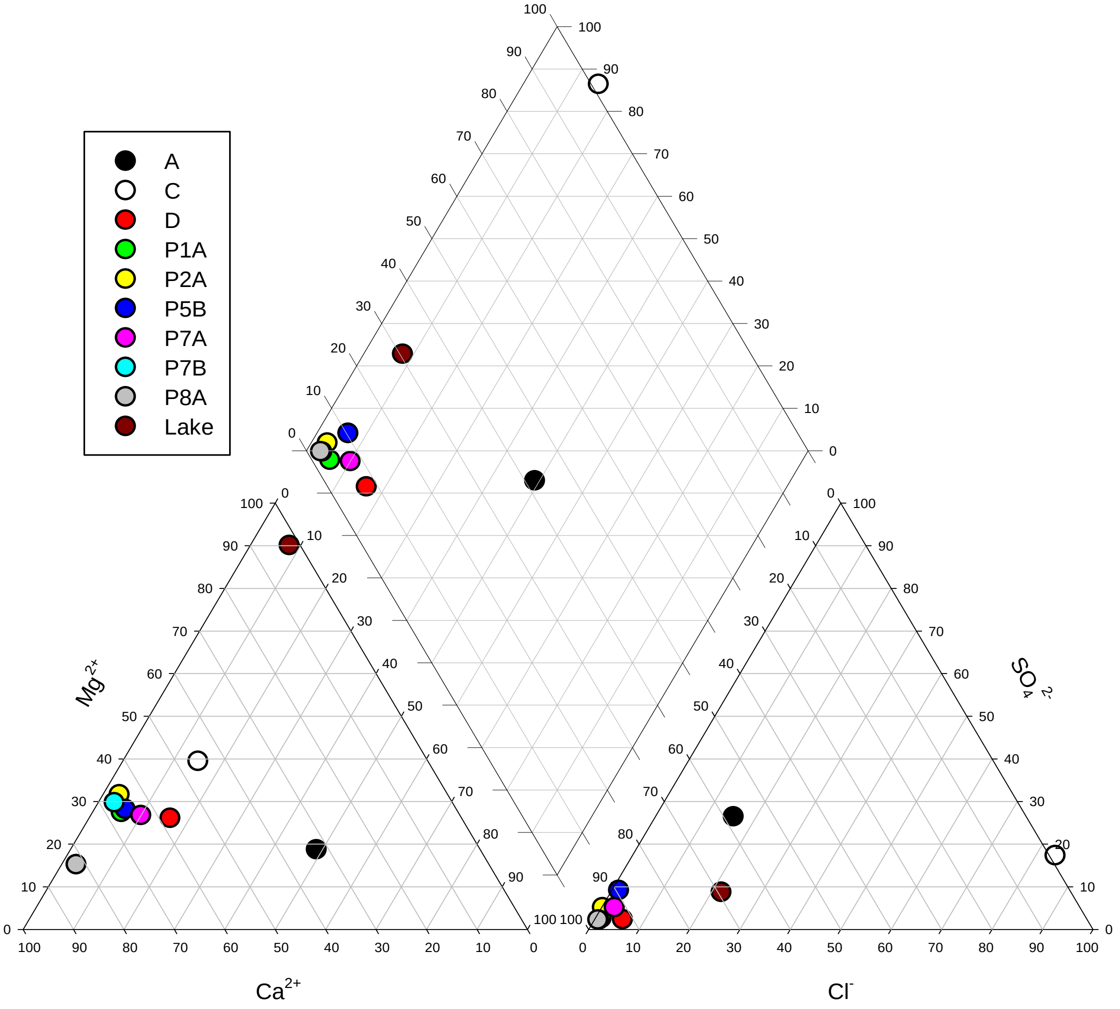


Figure 3.14 Major ion chemistry results for NE 7
The piper plot above shows the relative proportions of major ions. The piper plot reveals strong groupings based on sample type. The groundwater samples, generally higher in cations Ca and NA+K and bicarbonate. Surface water plots to the right of the groundwater samples, more dilute in Ca, higher in Mg and Cl.

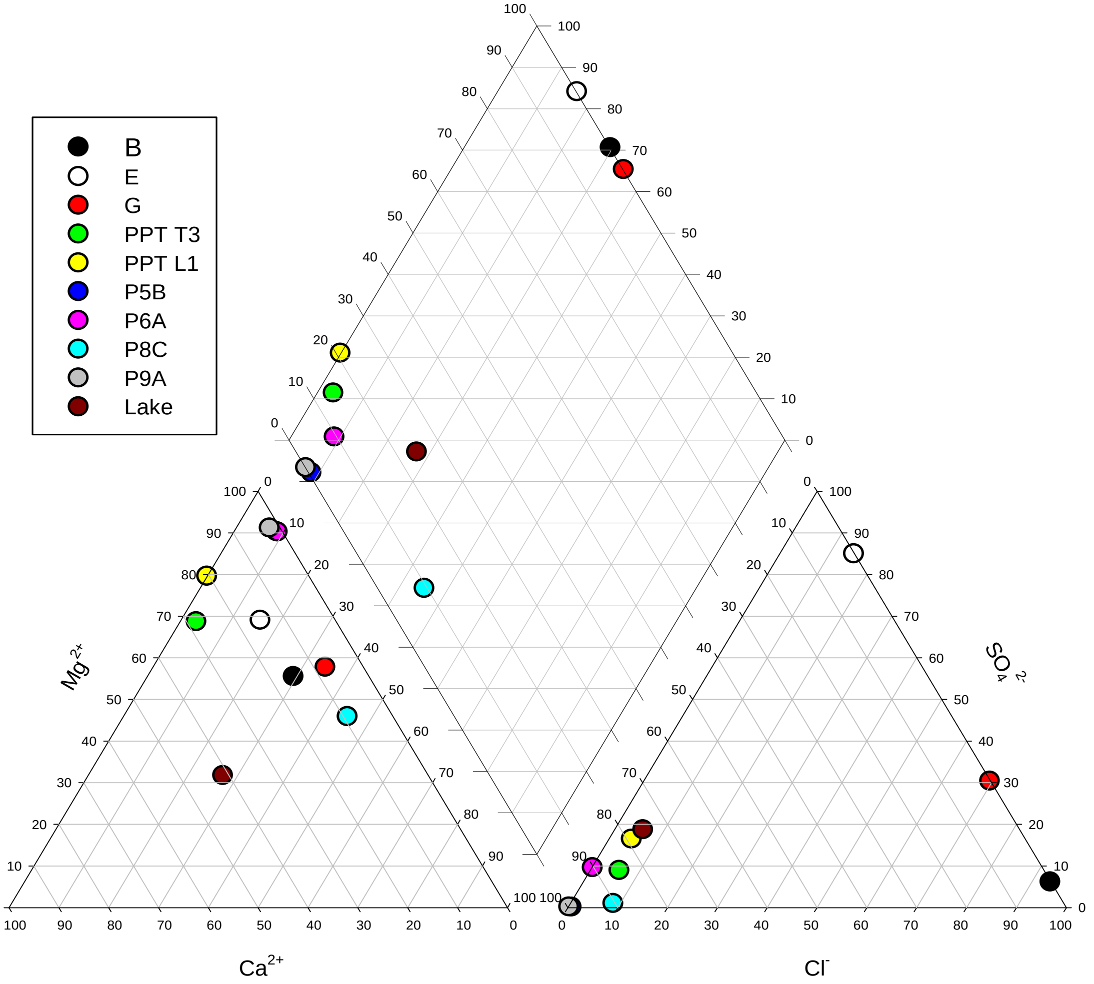


Figure 3.15 Major ion chemistry results for SM 8

The piper plot for SM 8 shows distinctly grouped samples as well. In Figure 3.15 all water types are noticeably more dilute in Ca and higher in Mg while the anions show a distinct division between surface water and groundwater controlled by bicarbonate where the surface water plots with a value of zero.

4. Discussion

4.1. Introduction

This study combined field measurements and laboratory results to describe the surface water groundwater interactions in two basins. Often, it is not possible to quantify each of the components of the water balance and it is necessary to estimate some hydrologic fluxes. In this study, difficulties related to inflow are addressed by applying a vertical water balance to estimate the runoff from the catchment. These calculations are derived from locally collected data for both climate variables and water level measurements. This study shows that runoff is highly variable across the landscape, with a few locations producing the most significant runoff values. Because the large storage capacity of the landscape, precipitation events in excess of 10 mm are required to produce runoff events. Where there is a significant level of depression storage, runoff will occur when the depressions fill. Therefore, antecedent moisture conditions are very important when discussing runoff in wetland environments (Helliotis and Dewitt, 1987).

4.2. Landscape Characteristics

The most significant difference between the two lake systems is the catchment area/lake area ratios (CA/LA). The ratio for NE 7 is 10 times greater (46.09) than that of SM 8 (4.63). While the total drainage area at NE 7 is only 58% of the total drainage area at SM 8 there is proportionally more terrestrial ecosystem contributing to the lake in this system. It is also worth noting that less of the drainage area is classified as open water and 10 times as much is classed as upland. These differences are also apparent in the land cover type percentages also with a much more significant proportion of the NE 7 catchment area comprised of uplands than in SM 8 (19.8 % and 1.8 % respectively) (Table 2.1).

4.3. Vertical Water Balance/Runoff

The sites with the greatest runoff were not consistent at each of the lakes for each of the two seasons monitored. In 2005, fen sites at both lakes showed the greatest calculated runoff, though not all fen sites. In contrast in 2006 the sites that had the highest runoff in 2005 showed a marked decrease and other sites showed an increase of 100%. Timing of runoff events was similar between the catchments with significant runoff produced early in 2005 (~ DOY 200). SM 8 produced another runoff event up until DOY 230 and then showed a significant decline. NE 7 on the other hand had runoff at two locations early in the season and then little until approx DOY 260.

In 2006 the timing of the runoff was similar in that there were significant runoff events early in the season at both lakes and then a significant decline in runoff potential until late in the summer (~DOY 240). All runoff events are in response to a precipitation event of greater then 20 mm and where a complete record exists, all sites produced runoff except at an upland peat location where it is likely that sufficient drainage was possible to offset even a precipitation event of 20 mm.

What is contributing to runoff is worth considering. Presumably there is significant runoff proceeding the observation period of our instrumentation associated with the spring freshet and the potential for significant input of antecedent moisture. Importantly, calculated depression storage of 15 mm means that a large amount of the incoming summer precipitation is stored as depression storage before reaching a volume sufficient to cause runoff. For much of the summer evaporation exceeds the precipitation amounts for the same period of time returning a portion of the incoming precipitation back to the environment as direct evaporation from a saturated landscape or as transpiration through plants.

4.4. Groundwater

Groundwater in this study was monitored both within the peat layers which make up the majority of the landscape and within the mineral soils underlying the peatlands and comprising the uplands. Several studies of groundwater behaviour in peatland areas have shown flow reversals which are strongly related to evapotranspiration regimes (Ferone and Devito, 2004; Fraser et al., 2001). While the groundwater was monitored throughout the catchment area in this study, it was not possible to detect any significant flow reversal patterns. Few locations displayed upward gradients, but the locations which did, did so consistently. These locations were situated in positions, relative to local uplands, which would be typical of groundwater discharge.

Groundwater levels were also very stable over the course of 2006, the second field season of this study. There are few sites that showed any significant water level fluctuations and unlike the study of Ferone and Devito (2004) there is no discernible flow reversal from the wetland into the upland. At several locations, the shallower piezometer displayed some variability which may be associated with an increase in evapo-transpiration during the middle of the monitoring period but following the water level decline, these piezometers returned to previous levels as evapo-transpiration decreased toward the end of the summer.

The largest and most persistent water level alteration occurred at NE 7 P8A, which has previously been identified as a potential point of groundwater discharge. The water level at this location increased by greater than two metres and remained at that level. The general lack of variability is likely related to the low hydraulic conductivity which inhibits significant interaction between surface water and groundwater and therefore also isolates the groundwater to a large extent from the effects of climatic fluctuations at the surface. Variation is evident at depth between piezometers and between the shallowest piezometer and the surface water table with the flux between the surface and shallow piezometer being exclusively recharge and in some cases an order of magnitude greater. Overall, calculated groundwater fluxes are lower at depth than near the mineral soil/peat interface.

4.5. Isotopes and Geochemistry

Several studies have utilized a variety of geochemical tracers to determine flow paths and groundwater/surface water interactions (Gibson *et al.,* 1996; Hayashi *et al*., 1998, Ferone and Devito, 2004) and have shown degrees of connection between surface and subsurface waters. In this study there is a distinct difference between the geochemistry from shallow groundwater wells completed within the peat layer and groundwater from piezometers completed in the mineral soil. Generally, surface water and shallow groundwater display much more dilute conditions than that of the groundwater which have higher concentrations of major ions. The opposite is true of DOC which higher at locations in contact with peat or other mineral soils.

There have been several regional studies into the hydrology of the lakes on the Boreal Plain (Gibson et al, 2002; Bennett et al., 2008). Both these studies applied stable isotopes techniques to quantify hydrologic fluxes and to understand variation in surface water hydrology on a regional scale. Bennett *et al* (2008) in particular relates to the study here in that these lakes were selected for detailed study from the dataset used in that study.

There have been few similar studies into wetland hydrology in this region. The studies that have been conducted are focussed primarily on comparing two ponds in different topographic positions adjacent to one another (Ferone and Devito, 2004). This work found similarly low hydraulic conductivity from the subsurface based on fine grained sediments and identified the depression storage capability of peatlands, specifically in the riparian environment. Unlike the study presented here, Ferone and Devito focussed on a small region and were able to install instrumentation and monitoring equipment in great detail, allowing groundwater fluxes to be calculated and flow direction and reversal to be determined. Because of the scale and proximity of the study sites presented here, results are necessarily quantitative, but are still able to show only moderate groundwater surface water interaction. In other words, the lakes may be substantially disconnected from the landscape except during significant precipitation events where surface saturation exceeds the depression storage capacity, and wetlands flow to the lakes.

5. Regional Upscaling

5.1. Introduction

A description of the hydrologic regime at two lakes on the low relief, wetland dominated peatlands of northeastern Alberta is presented in the preceding chapters. In the case of lakes NE 7 and SM 8, visible runoff from the landscape during the summer months is limited to a few areas where the topography is sufficient to channel runoff into rills and/or when the surface becomes sufficiently saturated, as sheet flow over the land surface. It is well known that thick peat deposits will attenuate runoff as the void space in the peat column can store a significant volume of water (Holden, 2005). Since the results presented above show that there is little runoff occurring in the summer and in fact the water balance of these lakes is often in a deficit ($P < E$), a crude water balance was constructed to attempt to explain the timing and magnitude of hydrologic fluxes off the landscape and investigate how closely the physically derived estimates match isotope mass balance techniques for a larger number of lakes in the region and is explained in the following.

From the work presented in the preceding chapter, it is shown that generally low runoff in summer is seen in the two basins investigated in this study. There is clearly insufficient data to explain the hydrologic behaviour for the remainder of the calendar year. The existence of a regional dataset of hydrology based the isotope mass balance suggests an excellent means of evaluating what the source of runoff may be that is going undetected in the study presented in the preceding. To this end, a model which accounted for snow melt and estimated the proportion of summer precipitation that might reach the lake is constructed in order to define an evaporation/inflow ratio (E/I) for comparison with E/I based on isotope mass balance (see

Gibson et al. (2010a). This is an important development in understanding wetland hydrology in this region.

In order for this work to be useful in a broader regional application it is compared against pre-existing and long-term stable isotope data as applied through an Isotope Mass Balance model (IMB). Guided by a conceptual model where snow melt run off and open water season run off values are generalized based on physically measured values, it is shown that these estimates hold well for a number of regions, but certainly require more refinement in others. It clearly shows that even within regions different lakes behave differently with regards to runoff.

There are 50 lakes in the region monitored by CEMA annually for a number of geochemical and isotopic characteristics. These lakes are separated into six geographic regions. Variables such as wetland assemblage, slope, elevation, soils etc are all important factors affecting the hydrologic regime. To consider each of these variables would require an extremely complex model, therefore, this model remains simple and is intended only to consider how well a generalized physical model will predict inflow to lakes when compared to isotopically calculated inflow.

The working hypothesis is that most of the lakes in this peatland region are dominated by snowmelt runoff prior to the melting of the underlying peat, and therefore allowing a significant amount of the snowmelt to runoff directly to the lake with out infiltration into the surrounding catchment landscape. Working through the vertical water balance in Chapter 4 provided guidelines for the amount of runoff that might be expected from this type of environment during the summer months. Snow runoff was set at 50 % based on the assumption described above that when melting of the snow occurs prior to the thawing of the underlying peat, infiltration is limited. Runoff from summer rain was set at 10% based on areal weighted runoff values from the VWB presented earlier.

The desired outcome of this model is to generate a physically based E/I ratio that can be compared to the isotopically derived E/I ratio and can be expressed as:

Inflow to the catchment is calculated as:

$$\begin{aligned} I = ((PPTLa\ (m) * LA\ (m^2)) + (rainCa\ (m) * CA\ (m^2) \\ * 0.1) + (SWECa\ (m) * CA\ (m^2) * 0.5)) \end{aligned} \qquad (14)$$

I = Inflow
PPT = total annual precipitation
Ca = portion rain/SWE on catchment
La = portion rain/SWE on on lake
CA = spatial quantification of Catchment Area (not including lake)
LA = spatial quantification of Lake Area
SWE = snow water equivalent

Precipitation is divided into to snow water equivalent and rain based on climate normal proportions (snow = 25 % yearly precipitation, rain = 75 % yearly precipitation (Env Can, 2009). Evaporation is calculated from a gridded dataset and the same value is used in both the physically and isotopically generated E/I (J. Birks pers com, 2009).

5.2. Results

A complete summary of results is presented in Appendix 6. A simple linear regression was calculated for each of the regions where the E/I calculated using the isotope derived inflow was compared with an E/I estimate using the physically based estimate incorporating hypothesized run off values from the landscape (50% snow, 10% rain). Of the six regions, only two produce show strong agreement between the two estimates. The lakes in the northeast (NE) and Caribou Mountains (CM regions) produce regression results with R^2 of 0.855 and 0.722 respectively (Table 5.1). The other regions showed very poor agreement between the two estimates for E/I.

Table 5.1 **Regional water yield estimate comparison**
Relationship between isotopically and physically estimates of E/I for 50 lakes in 6 regions surrounding Fort McMurray

Region	# of Lakes	R sq
NE	11	0.855
SM	10	0.0304
WF	8	0.0306
BM	11	0.112
CM	5	0.722
S	5	0.356

5.3. Conclusion

While the two methods of calculating E/I do not work perfectly for all lakes in the dataset, the fact there is good correlation between the two methods for some of the regions suggests that there is a relationship that may be worth investigating further between particular lakes, the type of landscape they are situated in and the nature of runoff generation. As a means of evaluating the similarity between lakes and run off, this crude, back of the envelope estimate of runoff has shown that there are patterns detectable and certainly in a region as poorly monitored as the wetlands in northeastern Alberta, this may be a very useful addition to understanding the hydrology of the region.

6. Conclusion and Recommendations

6.1. Conclusions

Hydrology in the low relief, wetland rich Boreal Plain region is complicated by the lack of connection with larger drainage network in the region. The ability of peatlands to store significant hydrologic inputs results in periods of episodic runoff only when this storage potential is exceeded. Both the lakes in this study have a single outlet and no permanent, gaugeable inflow. Because of these characteristics, several methods were used in conjunction to ascertain the dominant flow paths for water from the landscape to the lake and to identify locations for potential groundwater exchange.

The application of the vertical water balance revealed periodic surface runoff from the landscape, but these events were brief and very localized. During some of these runoff events, physical flow was observed in the landscape at both study sites. Drainage from thick peat deposits was also observed through macro-pores at the lake edge. This drainage was likely a result of precipitation and melting seasonal ground frost flowing through the subsurface.

Groundwater monitoring showed that the underlying mineral substrate was fine grained coarse silt sediment that allowed only very slow groundwater surface water exchange. While there were some locations with upward gradients, given the very tight nature of the mineral soil, groundwater exchange as indicated in table 3.5 is slow.

Isotope and geochemical analysis confirmed that precipitation, surface water and groundwater, in most cases, have distinct labels with groundwater plotting along a mixing line between winter precipitation (most depleted) and surface water (most enriched). Surface waters plot along a distinct evaporation line unique to each lake catchment. Snow and summer precipitation plot along the global meteoric water line and to some degree the summer precipitation diverges to form a local meteoric water line.

Similar division between groundwater, surface water and precipitation is visible when examining the major ion geochemistry at the study sites. While some sites indicate that there may be moderate mixing between shallow wells and surface water, the majority of locations show a strong distinction between the various sample sources.

Surface hydrology can be generalized in some regions based on physically based estimates of runoff, but these estimates do not match well with other methods of estimating runoff for the majority of the regions. More physical data is necessary to refine estimates of runoff if a more accurate depiction of runoff in this region is to be achieved.

6.2. Recommendations

1. In order to create a more complete picture of the water balance of small lakes in the Boreal region, groundwater fluxes and lake discharge should be better quantified. Given the difficulty of working in this environment, significant effort is required to gather the data necessary to accomplish this task. Seepage meters installed in the lake bed and the construction of a weir in the outflow of each lake would provide necessary data regarding these fluxes.

2. In the absence of a more complete physical dataset, the existing isotopic dataset should be evaluated using the isotope mass balance model previously applied in this region by Gibson *et al* (2002) and Bennett *et al* (2008). Isotope data exists to look at the mass balance at a monthly

time step for the two years of this study and this may provide more insight into the site specific hydrologic regime.

3. Another significant improvement to the understanding of the hydrology of these wetland dominated catchments would be better quantification of the spring freshet runoff contribution. At this time our understanding of wetland/lake hydrology is based on the open water period. Setting monitoring stations and visiting the study site prior to and during the spring melt period, would prove very useful for completing our understanding of the hydrology in these remote wetland catchments.

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Appendix 1 Meteorological data

SM8 Lake Station 2005

L105						
Day	Wind Speed	Wind Direction	Tair	RH	PPT	Q*
	Mean		Mean	Mean		Mean
	(m/s)	degrees	(C)	(%)	mm/day	(W/m2)
158.00	2.19	149.35	15.81	59.18	0.00	161.83
159.00	2.01	175.85	16.84	51.21	0.00	145.80
160.00	1.76	211.27	16.10	60.65	0.00	126.77
161.00	1.53	179.34	12.81	67.32	0.00	123.62
162.00	1.86	168.22	8.07	74.97	0.00	97.19
163.00	1.75	118.45	7.60	95.97	6.60	-2.48
164.00	2.92	125.87	11.42	93.05	10.92	40.83
165.00	2.26	226.71	11.99	87.52	13.46	65.90
166.00	3.52	204.39	11.22	88.79	5.84	61.23
167.00	5.06	255.37	11.60	70.70	0.00	143.22
168.00	1.53	196.85	10.25	71.43	0.00	173.22
169.00	1.43	136.38	9.85	69.99	0.00	118.77
170.00	4.24	256.09	11.08	70.04	0.00	128.82
171.00	3.09	267.18	11.40	53.76	0.00	213.30
172.00	4.40	198.20	17.80	59.09	0.00	212.03
173.00	2.39	224.53	12.25	89.89	6.86	-4.91
174.00	3.88	311.75	6.24	97.22	3.30	11.76
175.00	2.83	226.49	10.33	70.04	0.00	214.19
176.00	1.93	231.20	10.20	89.46	8.64	21.42
177.00	1.51	224.66	11.22	69.72	0.25	139.83
178.00	1.08	115.56	12.47	59.62	0.00	133.76
179.00	2.28	175.29	14.37	62.55	0.76	106.95
180.00	1.83	241.43	12.97	77.14	0.25	138.38
181.00	1.40	137.79	15.61	62.33	0.00	202.04
182.00	2.08	248.08	14.78	80.16	7.62	46.23
183.00	2.16	267.68	14.53	82.84	15.49	113.42
184.00	2.05	239.94	15.60	75.52	0.00	135.12
185.00	3.41	231.17	18.00	57.32	0.00	160.54
186.00	3.03	218.74	20.42	54.60	0.00	167.77
187.00	2.67	199.44	18.04	79.16	17.02	102.75
188.00	6.24	252.40	15.62	67.33	0.00	169.36
189.00	4.34	227.73	17.69	51.16	0.00	194.44
190.00	3.92	233.08	15.93	67.10	9.40	146.23
191.00	4.45	241.38	15.67	57.85	0.00	190.81
192.00	2.02	183.79	15.16	67.02	1.78	73.05
193.00	2.21	211.63	17.28	58.92	1.78	165.90
194.00	3.34	228.45	16.20	73.95	0.00	152.24
195.00	6.29	282.93	16.70	68.26	0.00	196.63

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SM8 Lake Station 2005

L105					
Day	Mean Water Temp			Air Press	Water Level
	upper 10cm	Mid depth	Bed		
	degrees C	degrees C	degrees C	Kpa	m
158.00	19.22	18.16	16.42	92.55	0.98
159.00	19.37	18.51	17.09	92.29	0.98
160.00	19.47	18.68	17.17	92.36	0.97
161.00	18.96	18.32	17.19	92.53	0.96
162.00	17.30	17.18	16.76	92.86	0.95
163.00	15.11	15.30	15.55	92.88	0.95
164.00	13.79	13.91	14.30	92.57	0.95
165.00	14.30	14.11	13.95	92.19	0.97
166.00	14.50	14.36	14.02	92.70	0.97
167.00	14.48	14.34	13.93	92.96	0.97
168.00	15.25	14.69	14.21	92.68	0.97
169.00	15.34	14.89	14.34	92.23	0.96
170.00	15.43	15.16	14.44	93.35	0.96
171.00	15.58	14.80	14.25	92.94	0.95
172.00	17.43	16.88	15.32	92.16	0.95
173.00	16.99	16.77	15.96	92.26	0.94
174.00	14.35	14.53	14.88	93.01	0.94
175.00	14.43	13.79	13.71	92.91	0.94
176.00	14.85	14.64	14.27	93.07	0.94
177.00	14.50	14.02	13.86	93.38	0.95
178.00	15.89	14.76	13.98	93.29	0.94
179.00	17.13	16.27	14.95	93.11	0.94
180.00	17.17	16.24	15.31	92.79	0.94
181.00	18.71	17.21	15.67	92.24	0.93
182.00	19.54	18.54	16.89	92.02	0.93
183.00	19.35	18.15	16.88	92.46	0.94
184.00	19.91	18.33	17.21	92.79	0.95
185.00	19.53	18.80	17.46	92.50	0.94
186.00	20.14	19.38	17.95	91.81	0.94
187.00	20.49	19.59	18.37	91.87	0.94
188.00	18.59	18.79	18.08	92.03	0.95
189.00	18.17	17.94	17.49	91.88	0.94
190.00	18.79	18.78	17.79	92.37	0.94
191.00	17.92	18.25	17.66	92.93	0.94
192.00	19.23	18.43	17.69	93.19	0.94
193.00	20.15	18.27	17.59	92.84	0.94
194.00	20.34	19.57	18.11	92.59	0.93
195.00	19.32	19.21	18.51	92.69	0.93
196.00	18.56	18.37	17.95	92.53	0.92

SM8 Lake Station 2005

L105						
Day	Wind Speed	Wind Direction	Tair	RH	PPT	Q*
	Mean		Mean	Mean		Mean
	(m/s)	degrees	(C)	(%)	mm/day	(W/m2)
197.00	2.04	276.10	14.22	84.58	0.76	65.80
198.00	2.96	280.87	16.14	81.39	2.03	133.68
199.00	4.39	227.02	15.45	80.82	0.76	57.03
200.00	4.85	296.11	12.62	75.47	0.00	90.15
201.00	2.06	238.57	13.57	68.08	0.00	137.01
202.00	1.23	161.73	12.80	71.26	1.52	154.56
203.00	2.22	153.66	16.03	72.17	1.52	125.76
204.00	3.51	224.82	10.27	96.57	48.77	-13.20
205.00	2.90	313.12	7.63	93.03	5.59	24.91
206.00	2.68	269.42	9.72	86.02	12.45	92.73
207.00	2.04	260.43	9.19	79.43	0.00	98.27
208.00	1.46	154.88	10.69	67.27	0.00	124.74
209.00	4.24	168.63	12.57	81.92	2.29	14.60
210.00	2.55	231.38	16.49	71.69	0.25	152.93
211.00	3.29	246.01	17.26	63.88	0.00	152.64
212.00	1.88	203.47	17.01	70.14	0.76	108.41
213.00	4.50	158.42	18.92	63.82	0.00	116.08
214.00	6.12	256.44	13.38	76.07	7.87	155.85
215.00	7.80	298.12	13.84	69.03	0.00	-0.33
216.00	3.21	243.61	17.27	56.73	0.00	160.93
217.00	5.09	269.26	17.92	62.12	0.00	115.42
218.00	3.02	257.49	17.49	62.03	0.25	129.24
219.00	5.03	279.76	13.36	89.47	11.94	63.40
220.00	4.30	302.95	11.87	75.96	1.27	92.77
221.00	3.52	293.74	9.95	71.92	1.27	109.08
222.00	3.93	244.04	10.96	74.89	4.06	138.98
223.00	5.39	315.36	9.28	93.63	14.48	39.80
224.00	3.25	301.84	8.90	82.81	0.51	100.42
225.00	3.65	281.94	10.15	87.40	2.54	13.68
226.00	4.56	310.93	8.62	81.37	1.78	74.69
227.00	2.66	280.53	6.24	88.10	0.00	39.62
228.00	1.88	123.77	8.63	80.93	0.00	51.80
229.00	1.21	116.69	8.17	94.29	17.78	6.32
230.00	2.57	202.23	7.30	96.62	20.83	10.23
231.00	1.79	254.13	7.98	95.73	0.25	15.91
232.00	3.65	155.37	11.33	87.62	0.00	94.82
233.00	2.98	218.11	17.45	69.09	0.00	156.30
234.00	3.89	249.60	13.54	77.34	5.59	110.69
235.00	0.95	146.37	10.87	88.01	0.51	1.25
236.00	2.00	238.61	13.29	65.32	0.00	114.39

SM8 Lake Station 2005

L105					
Day	Mean Water Temp			Air Press	Water Level
	upper 10cm	Mid depth	Bed		
	degrees C	degrees C	degrees C	Kpa	m
197.00	18.38	18.00	17.68	92.89	0.92
198.00	18.84	18.14	17.48	92.05	0.91
199.00	18.70	18.52	17.84	92.04	0.91
200.00	16.63	16.60	16.92	93.02	0.91
201.00	16.84	16.14	16.23	93.66	0.91
202.00	17.64	16.38	16.14	93.19	0.90
203.00	18.41	17.37	16.56	92.40	0.90
204.00	16.70	16.71	16.68	93.26	0.93
205.00	13.93	14.06	14.99	93.51	0.96
206.00	14.11	14.03	14.36	93.60	0.98
207.00	14.44	14.08	14.31	93.43	0.99
208.00	15.06	14.03	14.15	93.01	1.00
209.00	14.64	14.46	14.28	92.66	1.00
210.00	16.11	14.99	14.45	92.91	1.01
211.00	17.35	16.60	15.46	92.94	1.01
212.00	18.15	17.25	16.19	92.66	1.01
213.00	18.90	18.27	16.88	92.47	1.01
214.00	17.79	17.74	17.25	92.60	1.01
215.00	15.27	15.35	15.81	93.23	1.00
216.00	16.29	15.86	15.48	92.80	1.00
217.00	17.48	17.20	16.30	93.00	0.99
218.00	17.88	17.22	16.56	92.81	0.99
219.00	17.58	17.43	16.83	93.25	1.00
220.00	16.25	16.23	16.24	93.61	1.00
221.00	15.47	15.46	15.64	93.68	0.99
222.00	15.21	15.17	15.25	92.96	0.99
223.00	14.20	14.33	14.82	93.80	1.01
224.00	13.32	13.20	13.84	93.04	1.02
225.00	13.04	13.13	13.57	93.05	1.02
226.00	12.57	12.67	13.17	93.69	1.02
227.00	11.58	11.64	12.50	93.65	1.02
228.00	11.96	11.78	12.19	93.03	1.02
229.00	11.76	11.82	12.22	92.59	1.02
230.00	10.96	11.10	11.79	92.86	1.05
231.00	10.48	10.51	11.22	93.08	1.07
232.00	11.32	11.02	11.19	92.86	1.08
233.00	13.53	12.39	11.87	92.80	1.08
234.00	15.05	14.33	13.19	93.06	1.07
235.00	14.76	14.31	13.71	93.16	1.08
236.00	14.51	14.09	13.68	92.90	1.07

SM8 Lake Station 2005

L105						
Day	Wind Speed	Wind Direction	T air	RH	PPT	Q*
	Mean		Mean	Mean		Mean
	(m/s)	degrees	(C)	(%)	mm/day	(W/m2)
237.00	2.21	269.66	12.35	67.98	0.00	111.28
238.00	1.22	191.98	14.65	64.33	0.00	127.68
239.00	3.00	238.14	17.57	54.17	0.00	128.58
240.00	4.23	130.91	18.47	62.08	0.00	145.56
241.00	3.27	279.53	12.44	85.69	0.00	37.00
242.00	4.08	259.26	7.68	86.63	0.25	54.21
243.00	2.39	148.30	10.51	82.15	0.51	62.20
244.00	2.06	228.77	11.22	75.40	0.00	96.65
245.00	1.95	150.76	11.90	80.85	2.79	77.45
246.00	2.36	246.14	12.06	79.51	0.00	28.61
247.00	3.81	262.59	10.98	71.56	0.00	61.10
248.00	2.15	256.99	10.49	71.35	0.25	56.82
249.00	1.91	223.71	11.55	64.31	0.00	79.31
250.00	2.85	220.53	13.30	60.70	0.00	73.28
251.00	3.34	245.58	12.60	72.46	2.29	36.11
252.00	2.24	279.23	9.90	83.66	0.00	42.75
253.00	2.35	252.94	8.26	92.78	0.76	2.02
254.00	1.66	250.24	6.75	87.86	0.00	18.13
255.00	5.48	295.75	6.29	90.09	3.81	-3.84
256.00	2.39	244.50	5.04	77.68	0.25	69.21
257.00	1.59	113.62	4.52	76.87	0.00	31.94
258.00	0.88	170.73	3.48	77.35	0.00	44.05
259.00	2.23	194.99	5.68	84.45	2.79	5.67
260.00	2.17	236.22	8.26	77.58	0.00	66.02
261.00	3.39	239.74	10.54	65.25	0.00	82.85
262.00	3.58	250.94	9.53	72.26	0.76	42.23
263.00	4.37	268.97	8.10	72.45	0.25	36.03
264.00	2.24	262.15	6.46	86.54	5.08	29.38
265.00	1.46	238.23	5.71	89.79	1.02	12.69
266.00	2.60	254.31	4.52	87.95	1.52	32.67
267.00	2.58	223.64	5.99	78.44	0.00	42.92
268.00	4.52	254.33	7.95	81.01	4.32	48.09

SM8 Lake Station 2005

L105					
Day	Mean Water Temp			Air Press	Water Level
	upper 10cm	Mid depth	Bed		
	degrees C	degrees C	degrees C	Kpa	m
237.00	14.60	14.04	13.69	92.61	1.07
238.00	15.80	14.41	13.88	92.73	1.06
239.00	15.89	15.14	14.29	92.74	1.06
240.00	16.72	16.11	14.91	92.28	1.05
241.00	17.04	16.70	15.79	92.59	1.04
242.00	14.40	14.38	14.78	92.89	1.04
243.00	14.02	13.70	13.94	93.03	1.03
244.00	14.63	13.99	13.81	92.79	1.03
245.00	14.80	14.26	14.00	92.53	1.03
246.00	15.04	14.60	14.18	92.79	1.02
247.00	14.03	13.96	13.98	93.09	1.01
248.00	14.05	13.73	13.73	93.38	1.01
249.00	14.01	13.58	13.55	92.99	1.01
250.00	14.21	13.88	13.67	92.32	1.00
251.00	14.05	13.96	13.77	92.57	1.00
252.00	13.26	13.10	13.40	93.35	0.99
253.00	12.70	12.74	13.02	92.81	0.99
254.00	11.67	11.78	12.41	92.36	0.99
255.00	10.42	10.63	11.58	92.67	0.98
256.00	9.91	9.77	10.74	92.79	0.98
257.00	9.44	9.57	10.38	93.26	0.98
258.00	9.15	8.89	9.82	93.17	0.97
259.00	9.00	9.14	9.73	92.70	0.97
260.00	9.35	9.06	9.55	92.32	0.97
261.00	10.21	10.09	9.99	92.01	0.97
262.00	10.59	10.56	10.51	92.55	0.96
263.00	9.68	9.78	10.24	93.22	0.95
264.00	9.57	9.55	9.94	93.26	0.95
265.00	9.62	9.56	9.88	92.96	0.95
266.00	9.06	9.14	9.63	92.74	0.95
267.00	8.80	8.85	9.36	92.06	0.95
268.00	9.16	9.20	9.43	92.53	0.95

SM8 Lake Station 2006

L106						
Day	Wind Speed	Wind Direction	Tair	RH	PPT	Q*
	Mean		Mean	Mean		Mean
	(m/s)	degrees	(C)	(%)	mm/day	(W/m2)
162	1.90	NA	9.75	86.18	0.00	82.91
163	2.04	NA	11.68	72.41	7.62	117.22
164	4.43	66.75	16.07	62.48	0.00	175.37
165	4.71	154.29	19.86	58.68	0.00	216.73
166	2.40	147.25	19.50	61.28	0.00	177.07
167	1.90	131.90	17.81	76.00	0.51	124.10
168	2.71	117.88	15.81	91.30	10.67	80.19
169	3.91	206.09	16.22	86.53	0.00	159.90
170	3.61	273.50	16.45	74.96	0.00	148.83
171	4.78	268.43	14.80	78.42	0.00	125.24
172	4.40	287.43	12.20	86.90	1.78	19.81
173	3.53	299.14	15.83	59.81	0.00	206.93
174	1.86	258.92	15.22	58.22	1.78	116.87
175	2.77	203.67	17.03	52.53	0.00	186.09
176	3.79	239.89	18.15	41.97	0.00	216.83
177	1.50	274.96	18.71	50.32	0.00	204.34
178	4.65	159.47	23.23	52.44	0.00	176.03
179	3.49	163.43	22.06	59.09	0.00	120.74
180	6.09	212.90	17.05	44.39	0.00	88.62
181	5.19	275.60	16.22	49.99	0.00	231.69
182	5.16	269.00	15.39	60.63	0.00	69.02
183	1.88	290.80	14.82	60.64	0.00	206.70
184	1.77	231.29	18.23	58.12	0.00	194.69
185	1.81	131.22	22.28	54.15	0.00	155.13
186	1.59	162.15	21.29	68.46	3.81	99.66
187	1.13	179.38	17.43	83.60	0.25	75.39
188	4.01	175.02	17.49	78.46	1.27	26.03
189	4.09	214.34	14.06	81.04	1.78	45.06
190	2.23	258.89	15.44	82.85	5.08	41.40
191	2.01	202.08	13.88	93.48	44.45	26.13
192	5.38	126.63	12.69	90.86	19.81	31.96
193	3.01	226.88	13.11	77.30	0.00	168.45
194	1.61	258.02	14.28	82.25	4.57	75.33
195	5.09	207.97	14.78	66.32	0.00	132.23
196	3.44	261.89	15.01	61.49	0.00	120.30
197	4.54	255.11	14.65	73.06	0.51	146.45
198	3.42	268.70	15.78	70.29	2.79	104.77
199	3.07	245.96	13.61	84.35	21.34	68.00

SM8 Lake Station 2006

L106					
Day	Mean Water Temp			Air Press	Water Level
	upper 10cm	Mid depth	Bed		
	degrees C	degrees C	degrees C	Kpa	m
162	10.01	10.46	9.98	93.17	NA
163	12.97	12.59	11.83	93.33	NA
164	16.64	15.90	14.72	93.82	0.74
165	18.60	17.50	15.97	93.61	0.74
166	20.25	18.72	17.14	92.79	0.74
167	21.12	19.46	17.89	92.32	0.73
168	20.91	19.72	18.32	92.01	0.73
169	20.47	19.27	18.05	91.92	0.72
170	20.70	19.89	18.67	92.70	0.72
171	19.50	19.34	18.63	92.81	0.71
172	16.48	16.85	17.08	92.54	0.71
173	17.73	17.14	16.03	93.02	0.70
174	18.48	17.87	17.18	93.44	0.71
175	19.43	18.43	17.36	93.66	0.70
176	19.80	19.24	18.21	94.06	0.70
177	21.39	19.20	18.33	94.11	0.69
178	22.76	21.43	19.53	93.91	0.69
179	21.75	20.73	19.97	92.98	0.68
180	19.42	19.61	19.16	92.55	0.67
181	17.66	18.15	18.05	92.89	0.66
182	16.70	17.14	17.26	93.11	0.65
183	18.01	17.15	16.86	92.91	0.64
184	20.16	18.31	17.44	93.33	0.64
185	22.49	20.17	18.66	93.64	0.64
186	22.61	21.33	19.90	93.44	0.63
187	20.97	20.62	19.83	93.05	0.63
188	20.00	20.33	19.67	92.95	0.63
189	17.11	17.33	17.91	92.67	0.62
190	17.23	17.21	17.16	93.23	0.63
191	16.83	17.23	17.06	93.03	0.64
192	15.84	16.21	16.03	92.35	0.70
193	16.05	15.14	15.29	91.59	0.70
194	9.40	16.69	16.14	92.47	0.71
195	0.00	17.17	16.58	92.40	0.71
196	1.78	17.30	16.85	92.44	0.71
197	1.78	17.12	16.76	92.71	0.71
198	0.00	17.74	17.10	92.98	0.71
199	0.00	17.38	17.09	93.15	0.72

SM8 Lake Station 2006

L106						
Day	Wind Speed	Wind Direction	Tair	RH	PPT	Q*
	Mean		Mean	Mean		Mean
	(m/s)	degrees	(C)	(%)	mm/day	(W/m2)
200	2.22	274.54	16.10	71.69	0.00	176.64
201	2.64	273.20	19.00	59.43	0.00	173.50
202	3.47	256.85	20.83	57.22	0.00	192.95
203	3.85	271.07	23.49	51.26	0.00	224.37
204	1.54	259.06	22.06	55.27	1.02	167.73
205	2.31	207.32	18.34	71.29	2.54	123.28
206	2.36	259.49	18.29	74.03	2.29	109.65
207	1.61	216.40	12.87	94.79	4.57	-17.32
208	1.62	142.09	12.11	89.95	0.00	26.28
209	1.20	207.15	13.29	69.25	0.00	167.71
210	0.98	110.86	13.29	77.13	6.10	1.89
211	1.34	112.99	12.49	89.66	3.56	55.06
212	4.46	143.52	11.63	87.88	12.45	53.60
213	3.25	295.30	11.13	75.79	0.00	141.37
214	1.48	286.08	11.38	75.09	1.02	100.62
215	4.05	215.06	11.59	75.44	0.25	107.21
216	3.08	244.39	12.46	76.30	0.00	117.64
217	2.09	235.47	12.51	75.43	0.51	88.93
218	2.31	238.18	15.14	64.66	0.25	115.69
219	1.43	191.25	18.02	65.57	40.60	156.67
220	2.56	203.71	18.97	66.15	0.00	117.42
221	3.11	123.07	18.28	71.48	3.05	62.40
222	3.00	246.31	15.80	58.39	0.00	144.40
223	1.63	251.50	13.20	84.34	6.35	-9.42
224	2.71	263.23	14.27	74.69	0.76	81.97
225	1.83	285.43	16.01	63.58	0.00	125.55
226	2.74	245.97	16.89	63.29	9.91	132.94
227	3.90	252.73	12.47	87.63	6.86	35.81
228	4.97	256.69	13.10	76.06	3.30	132.80
229	1.63	265.96	13.54	74.37	0.25	108.57
230	3.21	188.80	18.66	58.63	0.00	136.36
231	4.15	230.98	15.26	62.15	0.00	100.92
232	2.92	283.01	13.53	70.29	0.00	130.51
233	2.43	252.81	16.10	63.10	0.00	112.48
234	3.93	158.16	18.71	59.22	0.00	116.56
235	2.57	150.93	14.08	77.26	2.54	-17.10
236	3.00	271.26	14.82	71.76	0.00	80.52
237	4.05	298.48	13.57	67.03	0.00	87.34
238	4.96	269.47	16.05	58.69	0.00	157.93
239	2.40	241.92	12.88	67.24	0.00	107.72

SM8 Lake Station 2006

L106					
Day	Mean Water Temp			Air Press	Water Level
	upper 10cm	Mid depth	Bed		
	degrees C	degrees C	degrees C	Kpa	m
200	0.00	17.13	16.77	90.92	0.74
201	0.76	18.51	17.50	93.28	0.74
202	2.03	19.99	18.62	93.55	0.74
203	0.76	21.45	19.85	93.63	0.73
204	0.00	21.57	20.51	93.27	0.73
205	0.00	21.36	20.40	92.94	0.73
206	1.52	21.45	20.48	92.57	0.73
207	1.52	20.47	20.20	92.57	0.73
208	48.77	18.55	18.75	92.58	0.73
209	5.59	17.79	17.83	92.75	0.73
210	12.45	18.41	18.10	93.24	0.73
211	0.00	17.40	17.52	92.95	0.73
212	0.00	16.66	16.89	92.17	0.74
213	2.29	15.65	15.99	91.83	0.75
214	0.25	16.01	15.98	92.35	0.75
215	0.00	16.26	16.11	92.98	0.75
216	0.76	15.97	15.95	93.11	0.75
217	0.00	16.09	16.00	92.93	0.75
218	7.87	16.39	16.00	92.90	0.75
219	0.00	16.85	16.51	93.08	0.76
220	0.00	17.39	16.71	93.04	0.76
221	0.00	18.45	17.56	93.03	0.76
222	0.25	18.65	17.87	93.01	0.75
223	11.94	18.20	17.92	93.17	0.76
224	1.27	17.37	17.21	92.88	0.76
225	1.27	17.25	17.03	92.72	0.76
226	4.06	18.12	17.46	92.89	0.76
227	14.48	17.63	17.46	92.81	0.77
228	0.51	16.12	16.37	92.62	0.77
229	2.54	16.32	16.22	92.89	0.77
230	1.78	17.50	16.76	93.32	0.78
231	0.00	18.05	17.46	93.17	0.77
232	0.00	17.00	16.99	93.05	0.77
233	17.78	17.17	16.78	93.46	0.76
234	20.83	18.10	17.36	93.44	0.76
235	0.25	17.78	17.55	92.96	0.76
236	0.00	16.48	16.54	92.73	0.76
237	0.00	16.33	16.33	92.66	0.75
238	5.59	16.39	16.19	93.01	0.75
239	0.51	15.94	16.02	92.68	0.74

SM8 Lake Station 2006

L106						
Day	Wind Speed	Wind direction	Tair	RH	ppt	Q*
	Mean		Mean	Mean		Mean
	(m/s)	degrees	(C)	(%)	mm/day	(W/m2)
240	4.35	220.76	16.61	63.81	0.00	69.85
241	2.69	146.63	15.94	73.08	0.00	79.25
242	4.20	215.42	10.88	92.94	28.96	-19.09
243	4.03	306.39	9.37	85.27	1.27	44.66
244	3.23	287.43	12.07	69.19	0.00	97.78
245	2.81	234.93	17.62	56.63	0.00	112.76
246	0.99	197.85	17.87	55.91	0.00	109.33
247	1.00	119.12	18.45	61.26	0.00	105.15
248	2.16	101.41	16.91	67.79	0.00	56.36
249	4.80	114.42	16.09	60.07	0.00	120.60
250	1.48	282.49	11.85	77.90	0.00	40.67
251	4.08	211.70	13.39	77.16	0.00	90.44
252	6.20	141.53	15.79	64.46	0.00	-54.70
253	2.73	146.59	15.76	66.08	0.00	81.23
254	5.13	222.32	14.36	58.04	0.00	86.84
255	2.48	260.93	10.70	60.10	0.00	60.44
256	1.26	225.31	9.12	68.82	0.00	51.97
257	1.79	152.15	5.50	90.48	1.52	-13.77
258	1.89	184.61	4.10	78.34	0.00	24.17
259	1.96	127.25	2.01	88.99	5.59	-8.68
260	1.64	185.04	2.28	96.16	16.26	27.17
261	1.68	263.05	5.46	84.59	0.00	58.25
262	1.59	117.77	5.92	81.64	0.00	48.82
263	2.08	116.40	6.79	81.21	0.00	51.92
264	0.99	169.65	6.95	88.38	1.02	21.01
265	0.89	136.76	7.55	87.83	0.76	17.97
266	3.15	206.85	8.44	77.34	0.00	44.02
267	3.23	226.20	9.83	67.45	1.03	59.38
268	1.43	266.23	7.69	90.88	15.49	2.85
269	2.81	167.94	5.32	94.38	3.05	-11.45
270	2.84	304.86	5.41	86.06	1.52	40.79
271	7.35	231.81	10.90	70.38	3.56	-10.74
272	4.46	282.20	10.16	66.12	0.00	26.28
275	3.75	276.11	4.03	90.23	1.52	17.97
276	2.17	281.66	5.20	71.63	0.00	20.98
277	3.79	218.48	6.91	66.28	0.00	25.29
278	4.25	213.34	9.83	50.75	0.00	41.29
279	0.78	266.64	5.72	70.46	0.00	13.53
280	2.41	164.43	1.97	92.65	2.54	-20.72
281	2.84	231.46	1.70	87.10	0.00	7.84

SM8 Lake Station 2006

L106					
Day	Mean Water Temp			Air Press	Water Level
	upper 10cm	Mid depth	Bed		
	degrees C	degrees C	degrees C	Kpa	m
240	0.00	16.48	16.10	93.44	0.74
241	0.00	17.03	16.54	92.98	0.74
242	0.00	16.23	16.42	91.92	0.74
243	0.00	14.28	14.89	92.01	0.76
244	0.00	14.00	14.31	92.90	0.76
245	0.00	14.93	14.69	93.38	0.77
246	0.25	15.82	15.36	93.29	0.77
247	0.51	16.57	15.95	93.24	0.77
248	0.00	17.40	16.56	93.60	0.77
249	2.79	17.41	16.89	93.86	0.77
250	0.00	16.08	16.22	93.40	0.77
251	0.00	15.48	15.50	93.51	0.76
252	0.25	15.47	15.45	93.21	0.76
253	0.00	15.38	15.30	92.76	0.75
254	0.00	15.45	15.37	92.60	0.75
255	2.29	14.41	14.70	93.07	0.75
256	0.00	13.81	14.21	93.24	0.74
257	0.76	12.69	13.46	92.92	0.74
258	0.00	10.59	11.94	93.44	0.74
259	3.81	8.82	10.44	93.76	0.74
260	0.25	6.63	8.51	93.60	0.75
261	0.00	7.12	8.13	93.71	0.76
262	0.00	7.64	8.35	93.59	0.76
263	2.79	8.36	8.72	93.44	0.76
264	0.00	8.83	9.13	92.67	0.76
265	0.00	8.84	9.18	92.35	0.76
266	0.76	9.04	9.22	93.46	0.76
267	0.25	9.80	9.74	93.02	0.77
268	5.08	9.96	10.04	92.92	0.77
269	1.02	9.51	9.82	92.75	0.78
270	1.52	8.87	9.30	93.39	0.79
271	0.00	9.21	9.40	93.65	0.79
272	4.32	9.04	9.30	92.08	0.79
275	7.95	8.36	8.87	92.07	0.80
276	7.55	7.92	8.43	93.20	0.80
277	7.15	7.63	8.15	93.89	0.80
278	6.97	7.29	7.80	93.49	0.80
279	7.64	7.75	8.02	92.33	0.79
280	6.71	7.28	7.82	92.77	0.79
281	5.59	6.23	7.02	93.25	0.79

NE7 Lake Station 2005

L205						
Day	Wind Speed	Wind Direction	Tair	RH	PPT	Q*
	Mean		Mean	Mean		Mean
	(m/s)	degrees	degrees C	%		(W/m2)
159	2.515	185.0526	17.934	51.753	0.000	170.316
160	3.100	125.469	16.019	65.521	0.000	126.324
161	4.415	51.96925	11.019	74.530	0.000	144.276
162	3.357	48.0839	7.088	75.817	0.000	98.959
163	2.256	53.16379	8.252	91.762	5.330	-1.396
164	2.156	117.2784	13.201	77.277	1.270	87.256
165	2.097	186.5856	12.162	93.591	12.450	24.152
166	1.985	180.7757	11.723	94.262	23.620	26.222
167	4.461	267.6975	10.565	75.489	0.250	122.662
168	2.600	126.0997	7.906	79.676	0.000	90.912
169	2.074	58.89621	10.807	64.497	0.000	160.606
170	3.147	241.3473	8.759	78.767	2.030	107.351
171	2.662	248.5321	10.663	56.974	0.000	206.838
172	2.791	196.6596	16.088	63.221	2.030	147.778
173	3.293	127.8051	10.413	98.084	11.430	-13.301
174	4.589	46.54748	6.433	96.678	4.060	5.991
175	2.961	216.1429	10.913	67.179	0.000	209.135
176	3.277	80.77554	9.865	87.746	1.780	39.141
177	2.663	97.04296	11.717	59.210	0.000	182.543
178	1.189	179.2163	11.853	59.462	0.000	97.111
179	1.726	176.6754	13.228	69.758	0.760	32.268
180	1.740	166.7602	13.111	81.613	2.030	113.307
181	1.043	164.2385	15.808	59.806	0.000	191.586
182	1.537	204.9699	15.640	68.553	4.320	107.356
183	2.107	214.7881	15.933	72.373	0.250	105.809
184	2.136	230.8154	16.929	69.673	2.540	157.176
185	3.604	210.8594	17.561	62.566	0.000	175.718
186	3.207	206.4215	19.414	56.436	0.000	162.807
187	1.767	185.6545	19.003	74.925	5.590	100.562
188	5.986	231.1654	15.979	69.736	0.250	160.143
189	4.513	228.9075	18.269	50.686	0.000	200.371
190	2.819	199.4826	15.648	69.700	8.640	86.340
191	3.929	232.8323	14.912	63.919	0.000	128.256
192	2.445	212.4521	16.380	58.344	0.000	173.323
193	1.907	202.5859	17.716	53.340	0.000	193.870
194	2.996	211.6835	17.634	66.769	0.000	162.001
195	3.304	235.5494	16.053	77.300	0.000	111.169
196	2.954	235.2758	17.620	62.326	1.270	139.578
197	2.567	110.5348	15.303	84.043	0.000	78.851
198	2.463	226.0946	17.016	79.299	0.000	145.316

NE7 Lake Station 2005

L205					
Day	Mean Water Temp			Air Press	Water Level
	upper 10cm	Mid depth	Bed		
	degrees C	degrees C	degrees C	Kpa	m
159	19.520	17.304	16.181	93.95919	1.558
160	19.506	17.837	16.700	93.77419	1.548
161	18.430	17.518	16.798	93.94092	1.536
162	16.791	16.393	16.118	94.15238	1.523
163	14.801	14.921	15.041	94.52448	1.516
164	14.229	14.087	14.169	94.46358	1.513
165	14.873	14.380	14.189	94.03877	1.514
166	14.555	14.164	14.036	93.69196	1.526
167	14.244	13.931	13.817	94.1145	1.552
168	14.110	13.777	13.676	94.54956	1.561
169	14.112	13.582	13.460	94.25477	1.564
170	14.927	14.176	13.798	93.8246	1.564
171	15.037	14.095	13.785	94.8044	1.562
172	16.335	14.879	14.240	94.28896	1.559
173	16.109	15.295	14.778	93.69123	1.564
174	13.805	13.905	14.029	93.82754	1.581
175	13.602	13.236	13.235	94.45421	1.588
176	14.386	13.878	13.637	94.45858	1.593
177	14.446	13.827	13.580	94.6031	1.594
178	15.178	13.975	13.717	94.8905	1.589
179	15.503	14.174	13.783	94.82073	1.586
180	15.698	14.507	14.082	94.60975	1.587
181	16.763	14.530	14.126	94.25933	1.582
182	17.664	14.828	14.301	93.6689	1.577
183	18.274	15.544	14.688	93.43777	1.577
184	18.403	16.423	15.489	93.87625	1.571
185	18.915	17.189	16.134	94.15921	1.564
186	19.415	17.848	16.827	93.86431	1.555
187	20.441	18.005	17.042	93.25475	1.551
188	19.587	18.463	17.549	93.15235	1.545
189	18.890	17.974	17.392	93.33608	1.534
190	19.038	18.044	17.414	93.26638	1.534
191	18.427	17.723	17.284	93.14071	1.531
192	18.832	17.692	17.159	94.3374	1.523
193	19.841	17.949	17.356	94.6205	1.515
194	20.596	18.653	17.693	94.22827	1.507
195	20.115	18.933	18.189	93.9405	1.499
196	20.122	18.872	18.206	94.03283	1.495
197	19.876	18.791	18.186	94.02419	1.488
198	20.235	18.873	18.247	94.31831	1.482

NE7 Lake Station 2005

L205						
Day	Wind Speed	Wind Direction	Tair	RH	PPT	Q*
	Mean		Mean	Mean		Mean
	(m/s)	degrees	degrees C	%		(W/m2)
199	2.680	208.276	14.886	88.351	4.320	41.721
200	4.510	244.3953	12.800	81.099	19.300	120.215
201	2.524	217.5825	13.931	67.508	0.250	123.634
202	2.191	113.8506	11.510	68.663	0.000	154.408
203	2.776	145.5035	15.281	74.378	0.000	114.769
204	5.263	100.9606	9.615	94.474	6.350	-19.022
205	2.651	250.7995	8.341	93.078	10.920	22.965
206	3.161	233.9231	9.559	89.285	6.350	28.862
207	2.172	265.2696	8.770	76.614	2.540	88.137
208	1.395	201.2513	9.782	69.065	0.000	107.847
209	3.016	174.2652	12.204	79.257	0.000	26.609
210	2.478	208.0596	15.250	77.015	0.250	133.349
211	3.307	226.9215	16.879	63.649	1.780	183.722
212	1.641	201.1113	15.568	73.662	0.760	102.665
213	2.503	163.2525	19.198	65.275	0.250	160.452
214	4.855	233.9092	13.886	73.649	2.540	69.176
215	5.357	288.1317	13.427	72.231	3.300	84.914
216	3.173	217.4144	17.046	58.708	1.520	124.825
217	3.972	249.3802	18.056	67.611	0.250	110.881
218	1.975	225.2802	16.825	63.845	0.510	119.085
219	2.913	257.2258	13.504	88.591	0.250	44.634
220	3.244	288.4935	11.933	74.479	0.510	86.661
221	3.391	295.6417	9.427	75.995	0.000	61.930
222	2.974	228.31	9.859	79.657	0.250	98.862
223	5.057	278.0889	9.596	94.907	0.250	15.694
224	2.943	251.744	9.435	83.315	3.810	81.292
225	3.138	263.9271	10.767	85.369	3.050	39.740
226	4.059	288.5384	7.951	82.890	1.270	75.645
227	2.496	247.6104	7.482	89.870	1.020	41.394
228	1.181	111.2215	8.739	85.032	1.020	45.458
229	1.415	64.45535	8.692	94.765	0.250	2.458
230	4.012	32.17427	8.180	95.736	0.760	6.295
231	1.869	111.7611	9.260	94.240	0.760	37.703
232	2.977	172.8606	12.010	84.055	1.520	102.436
233	3.266	212.81	16.936	74.215	8.380	135.713
234	3.491	229.5267	13.931	78.183	11.940	121.165
235	1.567	175.5388	12.824	72.463	7.370	74.370
236	3.252	33.89843	13.294	66.548	2.540	113.227
237	1.952	106.627	11.830	69.506	0.510	107.558
238	1.674	189.4213	13.996	62.359	0.250	123.128

NE7 Lake Station 2005

L205					
Day	Mean Water Temp			Air Press	Water Level
	upper 10cm	Mid depth	Bed		
	degrees C	degrees C	degrees C	Kpa	m
199	19.982	18.997	18.393	93.41006	1.477
200	18.386	18.075	17.906	93.42958	1.496
201	18.335	17.725	17.504	94.49235	1.501
202	18.114	17.480	17.295	95.20173	1.498
203	18.520	17.600	17.248	94.72027	1.495
204	16.549	16.750	16.917	94.0619	1.499
205	14.353	14.898	15.418	94.75129	1.528
206	14.034	14.377	14.773	94.96177	1.544
207	13.993	14.122	14.404	95.08919	1.555
208	14.253	14.003	14.215	94.91677	1.559
209	14.350	14.184	14.253	94.4476	1.562
210	14.913	14.203	14.162	94.09404	1.566
211	16.274	15.245	14.805	94.28775	1.566
212	17.340	15.875	15.363	94.36369	1.564
213	18.274	16.749	15.966	93.98881	1.564
214	18.127	17.274	16.664	93.76442	1.567
215	16.357	16.145	16.077	94.32565	1.566
216	16.589	15.997	15.797	94.56229	1.561
217	17.380	16.578	16.139	94.10288	1.556
218	18.037	16.860	16.400	94.38915	1.552
219	18.098	17.153	16.625	94.21069	1.552
220	17.348	16.863	16.596	94.63985	1.552
221	16.003	15.969	16.047	95.09177	1.545
222	15.472	15.395	15.493	94.96998	1.539
223	14.532	14.734	15.014	94.43625	1.553
224	13.885	14.022	14.326	95.292	1.584
225	13.885	13.956	14.163	94.4445	1.598
226	13.431	13.591	13.860	94.52481	1.615
227	13.007	13.144	13.445	95.19054	1.624
228	13.047	13.044	13.285	95.20871	1.631
229	12.757	12.903	13.141	94.66421	1.641
230	11.717	12.140	12.588	94.29213	1.673
231	11.435	11.664	12.078	94.3846	1.693
232	12.122	11.911	12.069	94.54396	1.700
233	13.869	12.892	12.659	94.27819	1.702
234	15.255	14.015	13.504	94.1856	1.715
235	15.668	14.217	13.837	94.53863	1.720
236	15.621	14.612	14.174	94.73865	1.717
237	15.581	14.646	14.348	94.42994	1.710
238	15.981	14.649	14.387	94.02627	1.701

NE7 Lake Station 2005

L205						
Day	Wind Speed	Wind Direction	Tair	RH	PPT	Q*
	Mean		Mean	Mean		Mean
	(m/s)	degrees	degrees C	%		(W/m2)
239	2.715	211.1751	17.355	58.418	0.000	122.681
240	2.341	142.4303	18.309	60.547	0.000	126.015
241	5.657	54.83983	11.684	87.391	0.000	14.984
242	3.498	241.3039	6.464	89.510	0.000	22.309
243	1.695	165.5126	8.946	82.182	0.000	64.344
244	1.654	196.5022	10.134	80.116	0.000	100.740
245	1.338	150.86	10.347	85.904	0.250	37.284
246	2.014	206.8135	11.723	80.903	0.000	59.700
247	3.221	238.6173	11.061	72.705	0.000	75.260
248	1.660	216.3173	9.654	69.601	0.000	67.656
249	1.480	217.5269	9.885	67.190	0.000	78.374
250	2.826	200.8006	11.671	66.814	0.000	72.369
251	2.585	216.9213	11.703	78.430	0.000	50.100
252	2.889	224.3969	10.255	89.110	0.000	31.098
253	4.282	116.7319	8.585	94.918	0.000	3.346
254	1.462	119.7726	6.808	90.487	0.000	6.238
255	3.937	276.2004	6.153	94.578	0.000	8.105
256	2.387	201.9751	3.486	87.459	0.000	53.016
257	1.290	63.88867	2.448	82.008	12.950	23.746
258	0.933	137.2009	2.616	70.975	0.000	56.218
259	1.863	179.2442	4.819	78.289	0.000	26.955
260	2.160	202.5598	7.518	79.151	0.000	58.979
261	2.821	212.8831	10.749	65.260	0.000	75.908
262	3.516	220.6775	9.582	70.404	0.000	30.877
263	2.764	215.5539	7.611	80.063	0.000	30.005
264	1.241	136.1482	4.641	84.816	0.000	24.841

NE7 Lake Station 2005

L205					
Day	Mean Water Temp			Air Press	Water Level
	upper 10cm	Mid depth	Bed		
	degrees C	degrees C	degrees C	Kpa	m
239	16.887	15.253	14.684	94.12979	1.689
240	17.315	15.749	15.128	94.16563	1.680
241	16.571	16.019	15.651	93.86354	1.667
242	13.885	14.205	14.531	94.07796	1.658
243	13.183	13.321	13.660	94.39115	1.652
244	13.831	13.395	13.480	94.48785	1.656
245	13.671	13.434	13.522	94.32942	1.656
246	14.051	13.520	13.479	93.93863	1.657
247	13.659	13.451	13.470	94.17371	1.650
248	14.007	13.543	13.489	94.53079	1.644
249	13.944	13.474	13.478	94.80848	1.636
250	13.926	13.528	13.471	94.37515	1.626
251	13.919	13.574	13.523	93.66096	1.617
252	13.697	13.501	13.496	94.04581	1.608
253	12.894	12.982	13.186	94.91475	1.600
254	12.079	12.315	12.649	94.34154	1.593
255	11.244	11.643	12.093	93.8864	1.590
256	10.502	10.920	11.450	94.20256	1.598
257	9.874	10.433	11.012	94.40869	1.595
258	9.612	9.852	10.436	94.80408	1.589
259	9.310	9.745	10.259	94.64723	1.582
260	9.423	9.637	10.033	94.12569	1.576
261	10.243	10.129	10.287	93.67675	1.570
262	10.337	10.340	10.511	93.34883	1.563
263	10.035	10.136	10.397	93.94113	1.558
264	9.795	9.914	10.214	94.75854	1.557

NE7 Lake Station 2006

L206						
Day	Wind Speed	Wind Direction	Tair	RH	PPT	Q*
	Mean		Mean	Mean		Mean
	(m/s)	degrees	degrees C	%		(W/m2)
156	3.33	231.13	14.62	53.26	0.00	157.12
157	3.87	262.32	7.27	78.08	0.00	102.37
158	1.40	165.65	9.67	62.83	0.00	145.48
159	2.57	143.91	14.64	49.89	0.00	170.48
160	2.21	153.25	11.78	64.91	0.00	59.09
161	2.17	161.59	10.52	78.84	0.00	71.08
162	3.48	49.23	10.61	77.59	0.00	103.21
163	1.64	171.93	13.13	67.60	0.00	111.78
164	3.15	174.20	17.29	55.02	0.00	198.85
165	3.08	162.96	21.44	51.30	0.00	205.73
166	2.03	162.59	22.14	51.16	0.00	210.49
167	1.72	155.04	20.70	57.22	0.00	164.60
168	2.00	110.61	19.36	69.01	0.00	167.08
169	2.59	242.68	18.68	79.69	1.27	163.59
170	1.64	207.25	15.91	89.96	16.76	41.54
171	2.66	257.55	15.97	78.96	11.18	122.68
172	2.77	265.97	14.36	85.33	0.25	97.12
173	2.13	184.76	16.85	55.27	0.25	200.83
174	2.57	234.47	16.33	58.73	0.51	152.06
175	2.66	225.69	17.69	48.76	0.00	169.38
176	3.41	246.24	18.10	48.47	0.00	198.37
177	1.47	201.61	17.86	51.58	0.00	195.99
178	3.31	167.36	24.29	43.72	0.00	199.08
179	2.91	188.83	22.54	57.57	0.25	149.38
180	4.59	230.75	17.35	46.63	0.00	162.81
181	5.03	257.14	16.65	50.92	0.25	149.65
182	4.48	273.55	14.76	66.15	0.00	190.80
183	2.88	205.11	14.10	67.60	0.00	162.52
184	1.48	197.68	16.44	57.16	0.00	193.08
185	2.44	170.27	22.74	48.82	0.00	157.88
186	3.48	72.99	19.77	65.06	7.37	99.63
187	2.18	88.56	18.25	74.61	0.25	119.58
188	2.44	142.06	15.75	93.32	27.69	0.20
189	2.98	148.76	14.81	84.91	2.29	72.72
190	2.97	173.91	16.50	78.84	0.25	106.82
191	2.37	73.85	14.57	85.27	1.52	115.73
192	3.23	191.33	11.76	96.32	2.79	5.70
193	2.56	241.13	12.61	79.38	5.84	105.16
194	1.16	159.06	14.29	77.74	0.76	98.64
195	3.49	230.98	14.44	79.20	0.25	163.18

NE7 Lake Station 2006

L206					
Day	Mean Water Temp			Air Press	Water Level
	upper 10cm	Mid depth	Bed		
	degrees C	degrees C	degrees C	Kpa	m
156	15.98	16.23	14.29	93.62	1.21
157	15.40	15.54	14.40	94.80	1.20
158	14.99	15.13	13.92	95.43	1.19
159	15.66	15.86	13.96	95.47	1.18
160	15.78	15.99	14.42	95.33	1.18
161	15.11	15.25	14.23	94.70	1.17
162	14.61	14.75	13.97	94.93	1.17
163	15.13	15.39	13.89	95.33	1.16
164	16.17	16.44	14.28	95.00	1.15
165	17.81	18.15	15.16	94.19	1.14
166	19.63	20.19	16.16	93.74	1.13
167	20.96	21.76	16.96	93.45	1.12
168	21.39	22.02	17.60	93.41	1.12
169	22.20	22.83	18.43	94.08	1.11
170	21.63	22.11	18.82	94.22	1.12
171	21.04	21.45	18.68	93.93	1.12
172	20.53	20.80	18.72	94.50	1.13
173	20.52	20.82	18.58	94.85	1.13
174	20.93	21.26	18.81	95.09	1.13
175	20.60	20.86	18.90	95.44	1.12
176	20.54	20.80	18.84	95.54	1.11
177	21.11	21.49	18.90	95.35	1.11
178	21.87	22.34	19.09	94.32	1.10
179	22.36	22.81	19.69	93.98	1.09
180	21.42	21.66	19.82	94.38	1.08
181	19.13	19.19	19.01	94.36	1.07
182	18.55	18.66	18.21	94.32	1.07
183	18.70	18.86	18.01	94.84	1.06
184	19.60	19.93	17.91	95.12	1.06
185	20.67	21.21	18.10	94.85	1.05
186	20.95	21.30	18.85	94.56	1.05
187	20.63	20.93	18.98	94.44	1.05
188	20.32	20.59	19.01	94.15	1.07
189	18.59	18.67	18.37	94.66	1.09
190	18.63	18.79	17.93	94.39	1.10
191	18.94	19.09	17.96	93.93	1.10
192	17.42	17.43	17.69	93.22	1.14
193	16.63	16.71	16.79	93.91	1.18
194	17.08	17.09	16.47	93.86	1.20
195	17.56	17.81	16.48	93.83	1.23

NE7 Lake Station 2006

L206						
Day	Wind Speed	Wind Direction	Tair	RH	PPT	Q*
	Mean		Mean	Mean		Mean
	(m/s)	degrees	degrees C	%		(W/m2)
196	2.29	207.90	14.68	71.08	0.25	107.38
197	3.03	246.80	15.38	76.84	1.02	125.80
198	3.74	220.65	18.52	60.37	0.00	184.88
199	1.65	181.84	14.08	84.26	0.25	32.88
200	2.18	265.55	16.52	68.10	5.08	181.14
201	2.01	186.02	18.35	62.24	2.79	148.88
202	2.91	233.96	21.40	54.82	0.51	173.82
203	2.72	240.32	22.45	53.92	0.25	174.90
204	1.48	213.33	21.09	57.78	0.25	162.57
205	2.21	231.57	18.26	70.32	0.00	77.94
206	2.76	160.29	16.30	75.25	0.00	97.86
207	1.82	57.59	11.21	93.80	0.25	-24.95
208	1.53	95.67	12.63	77.82	0.00	103.35
209	1.19	173.17	13.58	66.21	0.00	128.95
210	1.74	58.60	14.86	67.55	0.25	47.12
211	1.99	107.10	12.63	89.72	0.00	2.05
212	3.87	277.31	11.50	86.81	0.25	40.26
213	3.43	246.82	9.83	85.82	0.00	91.26
214	1.63	222.73	11.97	73.12	0.25	116.80
215	2.80	203.19	10.85	78.00	0.00	91.36
216	1.99	201.75	11.73	80.34	0.00	77.45
217	1.51	121.26	12.20	78.46	0.00	90.11
218	1.81	182.99	14.32	70.94	0.00	115.53
219	1.77	211.32	17.45	59.89	0.51	152.79
220	1.38	148.55	18.54	71.30	0.76	78.19
221	2.45	197.92	18.53	70.68	1.27	75.62
222	2.64	217.91	15.58	59.26	0.51	137.73
223	1.27	127.73	14.12	74.33	0.51	-1.24
224	2.32	226.24	15.41	66.76	0.51	118.10
225	1.72	217.16	15.32	65.92	0.25	125.70
226	2.76	214.73	15.98	65.09	0.00	138.23
227	2.99	227.32	13.49	88.30	5.84	29.56
228	3.62	266.20	12.25	87.58	2.54	60.55
229	1.63	201.31	12.73	71.26	1.78	111.58
230	3.45	214.34	18.97	58.87	0.76	134.33
231	3.18	255.04	14.42	71.52	0.25	93.18
232	2.73	255.73	13.37	75.66	0.25	97.55
233	2.10	182.74	15.66	61.28	0.00	130.10
234	3.21	167.01	19.76	53.40	0.25	129.26
235	2.63	159.13	15.71	73.68	0.00	17.27

NE7 Lake Station 2006

L206					
Day	Mean Water Temp			Air Press	Water Level
	upper 10cm	Mid depth	Bed		
	degrees C	degrees C	degrees C	Kpa	m
196	18.25	18.56	16.88	94.11	1.24
197	18.10	18.32	17.01	94.36	1.26
198	18.75	19.05	17.26	94.47	1.28
199	18.63	18.91	17.51	94.22	1.30
200	18.75	19.26	17.15	94.72	1.35
201	19.52	20.10	17.24	94.94	1.36
202	20.28	20.84	17.79	94.97	1.37
203	21.25	21.86	18.39	94.54	1.36
204	22.03	22.64	18.98	94.34	1.36
205	21.96	22.65	19.10	94.01	1.35
206	21.26	21.65	19.31	93.99	1.34
207	19.43	19.50	19.08	94.14	1.33
208	17.91	18.00	18.02	94.27	1.34
209	18.24	18.08	17.52	94.72	1.34
210	18.19	18.34	17.28	94.45	1.33
211	17.53	17.62	17.27	93.73	1.32
212	16.46	16.47	16.81	93.21	1.32
213	15.62	15.63	16.14	93.85	1.31
214	15.92	15.85	15.76	94.46	1.30
215	15.88	15.92	15.60	94.50	1.28
216	15.90	16.03	15.63	94.39	1.28
217	16.05	16.16	15.63	94.39	1.27
218	16.67	16.93	15.71	94.51	1.26
219	17.74	18.15	16.01	94.48	1.25
220	18.37	18.85	16.20	94.54	1.24
221	18.55	19.09	16.43	94.42	1.24
222	18.50	18.76	16.92	94.56	1.23
223	18.10	18.30	17.10	94.38	1.22
224	18.07	18.30	16.95	94.15	1.21
225	18.59	18.90	17.04	94.32	1.20
226	18.74	19.07	17.17	94.20	1.19
227	18.48	18.64	17.49	94.00	1.19
228	17.21	17.26	17.08	94.25	1.20
229	17.19	17.29	16.63	94.79	1.20
230	17.82	18.08	16.54	94.50	1.19
231	17.91	18.06	17.00	94.41	1.18
232	17.68	17.81	16.97	94.91	1.18
233	17.80	17.99	16.91	94.87	1.17
234	18.37	18.60	17.09	94.36	1.17
235	18.10	18.22	17.34	94.22	1.16

NE7 Lake Station 2006

L206						
Day	Wind Speed	Wind Direction	Tair	RH	PPT	Q*
	Mean		Mean	Mean		Mean
	(m/s)	degrees	degrees C	%	mm/day	(W/m2)
236	2.02	254.32	14.87	73.00	0.00	103.83
237	2.38	270.91	13.27	70.88	0.00	63.83
238	3.89	230.23	15.16	62.11	0.00	101.30
239	2.10	220.83	12.34	71.42	0.00	95.09
240	3.04	165.22	16.60	59.69	0.00	90.85
241	2.79	166.10	15.27	79.26	0.00	74.10
242	3.88	291.02	11.42	93.35	0.00	-28.52
243	3.17	292.93	8.59	84.65	0.00	36.09
244	3.04	196.66	11.67	69.01	0.00	97.96
245	2.90	198.56	17.12	61.31	0.00	111.33
246	1.16	182.21	17.83	55.97	0.00	111.18
247	1.57	101.21	18.30	59.99	0.00	108.71
248	1.74	129.80	17.36	67.95	0.00	61.41
249	3.82	251.49	16.43	62.15	0.00	99.46
250	1.97	154.02	12.50	78.29	0.00	56.10
251	2.90	158.64	13.50	73.84	0.00	76.68
252	4.23	159.63	16.32	61.02	0.00	73.83
253	3.17	194.13	16.23	63.02	0.00	68.07
254	4.26	235.37	14.24	57.47	0.00	71.28
255	2.47	233.41	10.33	59.14	0.00	54.80
256	2.24	99.73	7.97	78.10	0.25	9.61
257	4.03	32.72	5.91	86.27	1.78	10.91
258	3.00	39.50	4.72	71.42	0.00	53.71
259	3.23	33.50	4.10	71.15	2.79	17.42
260	2.85	123.75	4.10	87.32	1.27	15.59
261	1.13	122.43	6.41	74.28	0.00	58.44
262	1.22	161.73	6.21	77.51	0.00	52.88
263	1.43	170.61	7.52	80.75	0.00	45.15
264	1.33	84.59	8.95	78.71	0.00	32.03
265	0.95	168.50	8.25	76.63	0.00	42.34
266	3.43	215.29	8.35	74.00	0.00	34.82
267	2.52	258.20	9.20	62.16	0.00	55.85
268	1.77	180.17	9.56	65.35	0.00	27.71
269	2.47	252.42	5.60	88.19	2.54	-10.21
270	2.78	225.00	5.87	83.96	2.03	30.95
271	4.06	251.67	10.39	76.71	6.60	40.64
272	2.46	240.06	7.71	74.82	0.00	1.42
273	1.38	206.16	7.29	85.39	2.29	4.29
274	2.30	274.82	5.25	89.64	1.52	6.20
275	2.26	273.74	4.54	89.09	0.51	1.39

NE7 Lake Station 2006

L206					
Day	Mean Water Temp			Air Press	Water Level
	upper 10cm	Mid depth	Bed		
	degrees C	degrees C	degrees C	Kpa	m
236	17.80	17.95	17.05	94.08	1.16
237	17.57	17.67	17.04	94.42	1.16
238	17.02	17.08	16.79	94.02	1.15
239	16.83	16.86	16.50	94.93	1.14
240	16.50	16.59	16.25	94.33	1.14
241	16.92	17.06	16.28	93.39	1.13
242	16.09	16.08	16.27	93.44	1.13
243	14.37	14.27	15.39	94.38	1.15
244	14.06	14.04	14.70	94.75	1.15
245	14.98	15.06	14.73	94.63	1.15
246	16.18	16.33	15.09	94.69	1.14
247	17.28	17.64	15.42	95.07	1.14
248	17.69	18.02	16.01	95.33	1.14
249	17.44	17.64	16.26	94.74	1.13
250	16.97	17.06	16.28	95.00	1.13
251	16.20	16.24	15.97	94.69	1.12
252	15.72	15.74	15.71	94.10	1.12
253	15.66	15.71	15.48	94.01	1.11
254	15.33	15.34	15.35	94.41	1.11
255	14.71	14.70	15.04	94.63	1.10
256	13.70	13.60	14.51	94.48	1.10
257	12.20	12.05	13.71	95.16	1.10
258	10.45	10.25	12.55	95.51	1.10
259	8.98	8.73	11.46	95.33	1.09
260	7.91	7.64	10.42	95.34	1.09
261	8.12	7.93	9.87	95.16	1.09
262	8.69	8.60	9.79	94.98	1.09
263	9.39	9.36	9.99	94.15	1.08
264	9.58	9.53	10.19	93.93	1.08
265	10.26	10.31	10.26	94.97	1.08
266	10.10	10.09	10.46	94.38	1.08
267	10.06	10.06	10.43	94.37	1.07
268	10.33	10.33	10.53	94.25	1.07
269	9.78	9.72	10.44	94.93	1.07
270	9.30	9.23	10.10	95.08	1.08
271	9.62	9.61	10.01	93.42	1.08
272	9.37	9.32	9.99	93.46	1.08
273	9.11	9.05	9.80	93.17	1.08
274	8.78	8.71	9.59	93.55	1.08
275	8.45	8.36	9.37	94.69	1.08

SM8 Land Station 2005

T305						
Day	Wind Speed	Wind Direction	Tair	RH	PPT	Q*
	Mean		Mean	Mean		Mean
	(m/s)	degrees	degrees C	%	mm/day	W/m2
157	1.22	152.40	13.81	63.24	0.00	191.17
158	0.94	177.05	14.38	61.39	0.00	166.06
159	1.15	183.82	15.93	54.87	0.00	174.15
160	1.63	215.09	14.60	64.50	0.00	133.95
161	1.94	114.83	12.74	66.28	0.00	144.36
162	2.41	74.88	7.73	75.34	0.00	112.83
163	1.89	80.51	7.50	96.22	6.60	22.95
164	1.25	131.70	11.50	94.49	11.43	50.65
165	1.48	233.18	11.88	87.79	9.40	65.93
166	2.23	206.76	10.88	90.17	6.86	63.95
167	4.11	257.38	11.33	70.12	0.00	174.14
168	1.78	158.22	10.00	71.86	0.00	176.17
169	1.64	88.07	9.64	70.37	0.00	121.19
170	3.30	273.60	9.75	70.83	0.25	140.72
171	2.34	262.22	11.10	53.89	0.00	221.31
172	2.76	199.50	18.02	56.43	0.00	183.58
173	2.51	195.70	11.75	90.97	8.13	15.20
174	4.00	297.32	6.00	97.13	4.06	33.39
175	2.08	227.92	10.14	68.69	0.00	208.60
176	1.67	186.35	9.61	90.31	8.64	36.72
177	1.73	154.92	11.24	68.88	0.25	125.59
178	0.73	177.43	11.74	61.02	0.00	150.29
179	1.41	184.54	13.62	67.18	1.02	109.07
180	1.59	250.61	12.82	76.79	0.51	134.47
181	0.95	192.68	14.84	62.72	0.00	209.83
182	1.39	267.15	13.60	83.48	7.87	55.12
183	1.67	264.02	13.59	83.31	11.18	123.84
184	1.61	236.95	15.42	75.55	0.00	140.35
185	2.55	231.91	17.50	57.05	0.00	169.49
186	2.23	221.01	19.61	55.12	0.00	172.25
187	2.14	186.94	17.79	79.95	21.08	106.35
188	5.08	248.06	15.11	65.47	0.00	177.42
189	3.39	225.31	17.58	49.17	0.00	196.19
190	2.97	238.88	15.24	68.28	10.67	150.56
191	3.50	247.75	15.13	57.19	0.00	202.22
192	1.36	227.16	13.53	69.31	2.54	95.35
193	1.41	213.15	16.54	60.95	2.03	172.94
194	2.64	248.97	15.54	73.46	0.00	169.62
195	4.78	277.33	16.16	67.11	0.00	180.13

SM8 Land Station 2005

T305				
Day	Mean Ground Temp			Air Press
	10 cm	20 cm	40cm	
	degrees C	degrees C	degrees C	Kpa
157	14.05	12.17	8.69	92.87
158	14.75	13.19	9.05	92.91
159	15.15	13.87	9.46	92.54
160	14.97	14.17	9.88	92.28
161	14.13	13.79	10.12	92.35
162	12.09	12.80	10.19	92.53
163	10.38	11.56	10.00	92.86
164	11.67	11.07	9.69	92.88
165	13.18	12.02	9.67	92.56
166	12.69	12.27	9.82	92.21
167	12.05	11.97	9.88	92.70
168	12.70	12.12	9.90	92.96
169	12.34	12.14	9.98	92.69
170	11.71	12.02	9.99	92.38
171	11.25	11.56	9.93	93.36
172	14.22	12.84	10.02	92.87
173	13.48	13.33	10.35	92.15
174	10.38	11.83	10.37	92.27
175	10.75	10.71	10.01	93.01
176	12.34	11.91	9.99	92.92
177	12.37	11.73	10.01	93.07
178	12.88	12.08	10.09	93.38
179	14.13	13.13	10.30	93.30
180	14.33	13.48	10.58	93.11
181	15.13	13.89	10.81	92.79
182	15.44	14.81	11.18	92.24
183	14.63	14.03	11.36	92.02
184	15.76	14.51	11.50	92.46
185	15.75	15.01	11.76	92.79
186	16.25	15.11	11.95	92.50
187	17.31	15.89	12.19	91.82
188	14.79	15.44	12.45	91.89
189	14.85	14.90	12.46	92.03
190	16.22	15.34	12.51	91.90
191	14.81	14.86	12.56	92.38
192	14.77	14.66	12.52	92.93
193	15.40	14.63	12.46	93.19
194	16.47	15.67	12.61	92.81
195	15.25	15.56	12.81	92.62

SM8 Land Station 2005

T305						
Day	Wind Speed	Wind Direction	Tair	RH	PPT	Q*
	Mean		Mean	Mean		Mean
	(m/s)	degrees	degrees C	%	mm/day	W/m2
196	2.71	256.08	15.22	67.23	0.25	121.66
197	1.95	246.94	13.52	84.96	0.51	70.03
198	2.42	281.07	16.22	81.03	1.27	136.40
199	3.08	232.87	14.75	81.87	1.52	60.51
200	4.06	282.56	11.86	76.22	0.00	106.58
201	1.63	234.12	12.68	69.69	0.00	138.13
202	1.22	117.41	12.92	70.83	2.79	150.88
203	1.70	139.37	16.02	72.20	2.03	130.14
204	3.72	191.87	10.04	96.64	49.28	10.13
205	2.55	305.07	7.42	93.43	6.35	36.66
206	2.17	265.11	9.02	86.45	10.92	104.58
207	1.81	254.05	9.12	79.03	0.00	110.74
208	0.85	225.06	9.65	68.48	0.00	129.06
209	1.86	170.43	11.68	84.17	3.05	20.22
210	2.14	232.97	16.57	70.37	0.76	156.82
211	2.65	251.91	16.66	64.47	0.00	157.51
212	1.44	211.64	16.41	72.51	0.76	115.27
213	2.22	212.04	18.52	63.73	0.00	152.00
214	4.91	252.53	12.72	75.78	8.64	96.69
215	6.13	292.24	13.30	68.68	0.00	157.37
216	2.71	236.67	16.69	57.58	0.00	162.48
217	3.98	263.68	17.25	62.83	0.00	150.01
218	2.33	259.69	16.96	62.74	0.25	139.13
219	3.75	275.28	12.85	89.93	14.22	53.36
220	3.32	296.57	11.44	75.81	1.52	96.46
221	3.08	301.98	9.47	72.89	1.27	131.31
222	3.03	256.74	9.97	76.19	5.08	118.88
223	4.83	304.42	9.02	93.70	17.53	41.53
224	2.98	284.52	8.64	83.52	0.76	108.20
225	2.80	274.38	9.63	88.42	3.05	20.36
226	3.87	303.84	8.36	81.66	2.03	79.06
227	2.19	277.81	5.84	88.73	0.00	52.98
228	0.91	170.40	8.25	81.40	0.00	62.36
229	0.97	107.80	8.09	94.91	17.53	16.15
230	3.22	117.11	7.17	96.68	20.07	21.16
231	1.73	252.04	7.77	95.90	0.51	14.09
232	1.58	170.26	11.35	86.42	0.00	93.01
233	2.29	224.47	17.99	67.98	0.25	148.27
234	3.12	248.44	13.51	76.77	3.30	119.65

SM8 Land Station 2005

T305				
Day	Mean Ground Temp			Air Press
	10 cm	20 cm	40cm	
	degrees C	degrees C	degrees C	Kpa
196	14.81	15.05	12.82	92.69
197	14.92	14.91	12.78	92.53
198	15.89	15.14	12.77	92.89
199	15.52	15.63	12.93	92.05
200	13.35	14.62	12.92	92.06
201	13.71	14.00	12.71	93.02
202	14.51	14.33	12.61	93.66
203	15.58	15.02	12.69	93.19
204	13.71	15.03	12.87	92.45
205	11.67	12.88	12.59	93.27
206	12.12	12.43	12.17	93.51
207	13.10	12.77	11.98	93.60
208	12.86	12.70	11.91	93.43
209	12.65	12.85	11.88	92.98
210	14.94	13.05	11.79	92.66
211	15.38	14.05	12.02	92.91
212	15.93	14.42	12.24	92.93
213	16.73	14.85	12.46	92.55
214	14.66	15.06	12.72	92.46
215	13.34	13.93	12.66	93.02
216	13.67	13.50	12.47	93.21
217	15.13	14.18	12.46	92.78
218	15.16	14.32	12.54	92.99
219	15.26	14.71	12.67	92.83
220	13.66	14.01	12.69	93.23
221	12.90	13.49	12.55	93.62
222	12.13	12.95	12.36	93.58
223	12.08	12.83	12.19	93.00
224	11.97	12.32	11.97	93.80
225	11.54	12.28	11.85	93.04
226	11.40	11.96	11.67	93.07
227	9.82	11.26	11.46	93.69
228	10.85	11.20	11.20	93.65
229	10.83	11.35	11.11	93.03
230	9.90	11.01	10.99	92.58
231	10.38	10.73	10.81	92.86
232	11.09	10.70	10.67	93.08
233	13.77	11.59	10.70	92.86
234	14.24	12.79	11.02	92.82

SM8 Land Station 2005

T305						
Day	Wind Speed	Wind Direction	Tair	RH	PPT	Q*
	Mean		Mean	Mean		Mean
	(m/s)	degrees	degrees C	%	mm/day	W/m2
235	0.70	197.95	10.04	87.37	0.76	11.77
236	2.55	181.17	12.93	66.06	0.25	112.64
237	2.45	234.69	11.68	69.73	0.00	119.24
238	1.18	247.92	13.28	64.40	0.00	143.08
239	2.47	252.95	17.16	53.20	0.00	133.00
240	1.33	165.20	17.66	64.83	0.00	138.42
241	3.56	249.34	11.91	86.57	0.00	48.24
242	3.37	257.62	7.27	86.51	0.76	61.87
243	1.16	159.60	10.19	82.51	0.76	73.20
244	1.44	251.47	9.59	76.87	0.00	110.55
245	1.13	210.96	10.66	83.05	2.79	87.37
246	1.75	268.61	10.56	80.71	0.25	41.82
247	2.68	261.03	9.75	73.39	0.00	97.78
248	1.54	265.67	8.41	75.69	0.25	74.26
249	1.50	233.51	9.57	67.51	0.00	108.97
250	2.01	222.25	11.90	62.85	0.00	87.85
251	2.38	243.32	11.37	75.47	1.78	44.47
252	2.05	237.36	9.04	85.16	0.00	53.99
253	2.94	156.20	8.11	92.35	0.51	10.28
254	1.72	224.10	6.09	88.98	0.00	30.17
255	4.10	292.39	5.41	92.08	5.08	18.35
256	2.02	234.74	4.83	79.07	0.00	74.30
257	1.07	142.07	4.28	79.72	0.25	40.77
258	0.77	249.36	2.05	78.69	0.25	49.15
259	1.36	209.96	4.62	89.27	2.29	16.93
260	1.55	238.66	7.57	79.59	0.00	69.43
261	2.60	234.97	9.98	66.18	0.00	90.46
262	2.78	247.15	8.50	74.91	1.27	39.38
263	3.50	260.20	7.45	73.14	0.00	42.00
264	1.61	261.33	5.58	88.89	5.33	39.82
265	0.94	241.26	4.84	92.34	2.29	30.59
266	1.73	248.96	3.00	89.71	2.03	43.79

SM8 Land Station 2005

T305				
Day	Mean Ground Temp			Air Press
	10 cm	20 cm	40cm	
	degrees C	degrees C	degrees C	Kpa
235	12.48	12.54	11.25	93.05
236	13.03	12.39	11.25	93.16
237	12.54	12.38	11.30	92.89
238	12.68	12.24	11.29	92.60
239	14.06	12.96	11.38	92.73
240	14.09	13.16	11.54	92.69
241	13.94	13.52	11.72	92.28
242	11.44	12.37	11.70	92.60
243	11.69	11.82	11.46	92.88
244	11.68	11.88	11.33	93.03
245	11.95	11.85	11.25	92.78
246	12.11	12.05	11.23	92.52
247	11.04	11.58	11.17	92.79
248	10.46	11.12	11.01	93.09
249	10.08	10.71	10.82	93.38
250	10.34	10.68	10.66	92.98
251	10.70	10.84	10.57	92.28
252	10.26	10.67	10.52	92.56
253	10.28	10.59	10.44	93.34
254	9.74	10.26	10.33	92.80
255	8.68	9.67	10.16	92.50
256	8.53	9.24	9.90	92.66
257	8.44	9.16	9.72	92.78
258	7.38	8.60	9.52	93.26
259	7.49	8.26	9.26	93.16
260	8.08	8.35	9.07	92.69
261	8.33	8.63	9.01	92.31
262	8.44	8.80	9.00	92.01
263	8.03	8.58	8.96	92.56
264	7.76	8.31	8.85	93.22
265	7.81	8.28	8.74	93.26
266	6.80	7.91	8.64	92.94

SM8 Land Station 2006

T306						
Day	Wind Speed	Wind Direction	Tair	RH	PPT	Q*
	Mean		Mean	Mean		Mean
	(m/s)	degrees	degrees C	%	mm/day	W/m2
161	0.20	NA	10.20	84.64	1.52	89.98
162	0.20	NA	9.51	87.85	0.25	82.75
163	0.50	28.29	11.79	NA	0.00	127.41
164	1.85	161.10	16.18	NA	0.00	189.99
165	1.77	161.93	20.52	NA	0.00	220.34
166	1.00	158.04	18.83	NA	0.00	178.34
167	0.93	157.53	17.25	NA	0.25	131.12
168	2.22	193.32	15.37	NA	11.68	91.74
169	3.03	271.63	16.14	NA	0.00	161.09
170	2.74	263.56	16.09	NA	0.00	171.91
171	3.43	282.83	13.77	NA	0.00	105.01
172	3.38	299.85	11.76	NA	1.27	26.76
173	2.71	264.87	15.02	NA	0.00	220.56
174	1.47	207.57	14.38	NA	0.76	121.21
175	2.26	263.16	15.32	NA	0.00	207.33
176	3.06	270.59	17.53	NA	0.00	219.98
177	1.10	191.85	17.22	NA	0.00	219.42
178	2.25	165.52	23.19	NA	0.00	211.28
179	1.91	206.09	21.74	NA	0.00	126.43
180	4.74	272.23	16.25	NA	0.00	189.38
181	3.96	263.97	15.52	NA	0.00	168.13
182	4.09	270.45	15.06	NA	0.00	122.16
183	1.74	205.99	13.66	NA	0.00	208.70
184	0.95	147.91	16.59	NA	0.00	196.06
185	1.35	201.58	21.28	NA	0.00	158.95
186	1.48	144.78	19.58	NA	3.81	105.54
187	1.16	128.27	17.15	NA	0.00	78.96
188	2.98	243.19	16.67	NA	1.52	54.11
189	3.11	249.87	13.46	NA	2.54	44.62
190	1.46	203.54	14.71	NA	5.33	49.66
191	1.24	146.44	13.07	NA	37.08	38.70
192	4.17	225.56	12.33	NA	17.53	35.10
193	2.35	264.69	13.06	NA	0.00	172.87
194	1.23	231.64	13.36	NA	5.84	76.81
195	3.92	258.53	14.21	NA	0.00	192.15
196	2.51	257.16	13.80	NA	0.00	127.70
197	3.36	265.13	NA	NA	0.25	150.01
198	2.47	242.25	NA	NA	3.30	119.45
199	2.20	271.01	NA	NA	15.49	75.59

SM8 Land Station 2006

T306				
Day	Mean Ground Temp			Air Press
	10 cm	20 cm	40cm	
	degrees C	degrees C	degrees C	Kpa
161	10.25	7.44	2.91	93.16
162	9.55	7.69	3.13	93.35
163	10.54	8.02	3.27	93.83
164	12.10	9.77	3.88	93.56
165	14.51	11.86	4.75	92.76
166	15.36	12.78	5.91	92.31
167	15.61	13.55	7.31	92.00
168	15.78	14.21	8.53	91.97
169	16.11	14.67	9.34	92.72
170	15.88	14.66	9.98	92.80
171	13.83	13.65	10.28	92.55
172	12.32	12.75	10.20	93.09
173	12.72	12.73	10.03	93.46
174	12.57	12.80	10.17	93.67
175	12.68	12.94	10.33	94.06
176	12.93	13.53	10.62	94.12
177	13.42	13.76	10.83	93.90
178	15.74	15.00	11.36	92.94
179	16.79	15.73	11.96	92.55
180	13.37	15.00	12.27	93.06
181	12.40	13.71	11.98	93.04
182	12.46	13.35	11.74	92.94
183	12.30	13.17	11.50	93.34
184	13.24	13.80	11.57	93.64
185	15.38	14.91	11.99	93.44
186	16.47	15.51	12.49	93.04
187	16.25	15.45	12.81	92.96
188	15.51	15.32	12.97	92.74
189	13.47	14.09	12.74	93.26
190	13.72	13.81	12.48	93.02
191	13.90	13.83	12.38	92.34
192	13.69	13.65	12.35	91.83
193	14.10	13.49	12.11	92.49
194	15.65	14.53	12.43	92.41
195	14.27	14.31	12.55	92.48
196	13.54	13.90	12.53	92.73
197	14.41	13.86	12.48	92.69
198	14.13	14.10	12.58	93.14
199	13.51	13.83	12.60	92.81

SM8 Land Station 2006

T306						
Day	Wind Speed	Wind Direction	Tair	RH	PPT	Q*
	Mean		Mean	Mean		Mean
	(m/s)	degrees	degrees C	%	mm/day	W/m2
200	1.86	277.07	16.03	72.62	0.25	178.21
201	1.90	255.93	17.90	62.89	0.00	173.56
202	2.56	269.37	19.96	59.79	0.00	207.83
203	3.11	254.82	22.62	54.30	0.00	223.48
204	1.16	209.18	20.93	61.01	0.51	170.61
205	2.07	253.74	17.48	74.20	2.54	137.37
206	1.78	213.60	16.85	77.89	2.29	123.16
207	1.25	112.68	12.64	96.73	3.81	10.12
208	1.52	198.45	11.60	91.09	0.25	34.14
209	0.81	171.09	11.91	71.39	0.25	164.58
210	0.84	133.76	11.67	81.57	4.83	17.78
211	1.41	87.72	12.43	90.93	3.30	55.28
212	3.61	282.89	11.35	89.55	13.21	68.21
213	2.74	263.26	11.10	76.40	0.00	141.10
214	1.28	214.50	10.89	77.43	1.02	111.15
215	3.04	244.77	10.95	76.31	0.25	128.17
216	2.13	241.43	12.10	77.18	0.00	124.67
217	1.66	231.05	11.70	77.63	0.25	98.54
218	1.82	232.94	13.48	66.56	0.25	136.69
219	1.18	186.42	17.51	68.63	4.06	165.24
220	1.18	119.35	18.89	70.59	0.00	114.28
221	2.01	251.18	17.66	73.99	1.78	66.21
222	2.23	254.81	14.24	62.19	0.00	167.00
223	1.52	220.56	12.47	87.59	6.86	5.32
224	2.00	280.50	13.61	77.41	0.76	97.78
225	1.41	239.81	15.00	66.69	0.00	135.46
226	2.16	233.51	16.00	66.17	10.16	147.38
227	2.88	256.40	11.86	89.32	6.86	47.00
228	3.82	268.52	12.70	77.04	3.81	119.44
229	1.14	250.23	12.18	75.94	0.25	119.80
230	2.39	222.83	17.52	61.33	0.00	142.69
231	3.17	279.42	13.91	64.11	0.00	134.71
232	2.44	258.71	12.76	72.63	0.00	132.10
233	1.32	204.02	13.97	65.06	0.00	138.67
234	1.49	162.69	17.82	61.24	0.00	138.69
235	2.35	251.12	13.50	79.41	2.03	0.50
236	2.34	290.96	13.99	74.42	0.25	102.09
237	3.16	279.72	12.63	68.28	0.00	106.68
238	3.62	242.67	15.04	60.42	0.00	135.83

SM8 Land Station 2006

T306				
Day	Mean Ground Temp			Air Press
	10 cm	20 cm	40cm	
	degrees C	degrees C	degrees C	Kpa
200	15.64	14.20	12.57	93.29
201	16.55	15.47	13.10	93.56
202	17.39	16.21	13.65	93.63
203	18.08	17.00	14.22	93.19
204	18.40	17.49	14.71	92.93
205	18.68	17.77	15.17	92.59
206	17.18	17.19	15.18	92.56
207	16.33	16.53	15.07	92.58
208	15.16	15.46	14.57	92.76
209	14.12	14.81	14.08	93.25
210	14.48	14.79	14.00	92.94
211	14.52	14.43	13.71	92.17
212	13.42	14.39	13.58	91.83
213	13.29	13.94	13.32	92.39
214	13.76	13.99	13.23	92.99
215	12.83	13.80	13.15	93.09
216	13.26	13.55	12.97	92.93
217	13.45	13.64	12.94	92.91
218	13.29	13.52	12.86	93.08
219	15.31	14.34	13.01	93.04
220	17.39	15.60	13.56	93.03
221	17.24	16.20	14.10	93.01
222	14.64	15.42	14.16	93.17
223	14.44	14.79	13.98	92.88
224	14.19	14.45	13.71	92.72
225	14.10	14.43	13.59	92.89
226	14.56	14.73	13.70	92.81
227	14.08	14.75	13.78	92.62
228	13.12	14.00	13.54	92.90
229	13.16	13.77	13.30	93.33
230	14.32	14.27	13.35	93.15
231	13.42	14.08	13.42	93.04
232	13.28	13.81	13.30	93.47
233	13.05	13.55	13.17	93.43
234	14.11	14.17	13.26	92.93
235	13.87	14.22	13.43	92.73
236	12.80	13.38	13.13	92.67
237	12.63	13.30	12.98	93.02
238	12.52	12.85	12.75	92.68

SM8 Land Station 2006

T306						
Day	Wind Speed	Wind Direction	Tair	RH	PPT	Q*
	Mean		Mean	Mean		Mean
	(m/s)	degrees	degrees C	%	mm/day	W/m2
239	1.62	209.66	12.33	70.29	0.00	118.20
240	1.73	168.94	16.42	64.21	0.00	119.42
241	2.09	257.43	14.29	79.06	0.00	85.92
242	3.38	299.06	10.39	94.89	28.45	-1.57
243	3.16	303.25	8.57	87.15	1.27	49.00
244	2.44	234.04	10.69	72.39	0.00	118.08
245	2.06	206.60	17.38	56.76	0.00	122.44
246	0.73	180.89	16.06	59.98	0.00	123.80
247	0.64	174.52	16.48	64.86	0.00	116.39
248	0.65	181.75	14.74	73.20	0.00	72.33
249	3.44	285.47	14.68	62.47	0.00	107.65
250	1.24	191.45	11.13	81.02	0.00	60.42
251	1.13	163.20	13.11	77.24	0.00	103.25
252	1.97	164.75	15.66	64.02	0.00	82.78
253	1.65	227.73	14.58	70.33	0.00	89.24
254	4.10	257.05	13.39	58.07	0.00	83.56
255	1.78	248.67	8.33	63.90	0.00	83.30
256	1.47	159.10	7.24	69.77	0.00	64.72
257	2.38	86.22	5.23	91.92	1.52	-2.80
258	2.40	71.02	3.86	79.34	0.00	31.00
259	2.57	76.19	1.77	89.30	4.83	-0.56
260	1.81	212.86	2.03	96.12	15.49	19.06
261	0.64	118.40	4.91	88.23	0.00	61.96
262	0.63	165.00	5.30	83.87	0.00	51.92
263	1.07	170.37	6.59	82.34	0.00	63.09
264	0.85	132.33	6.67	90.39	0.51	22.06
265	0.93	164.48	7.19	88.55	0.51	17.31
266	2.33	240.81	7.30	79.00	0.25	61.23
267	2.59	275.10	9.26	69.20	1.02	69.90
268	0.79	159.41	7.38	93.57	14.22	9.95
269	2.42	301.36	4.92	96.25	3.56	1.29
270	2.03	232.14	5.21	86.34	1.78	43.92
271	5.86	215.55	10.76	71.38	3.56	-11.48
272	3.71	96.77	9.96	66.10	0.00	23.03
273	2.34	183.48	8.48	80.95	2.29	37.61
274	3.35	64.13	4.56	92.78	3.81	19.81
275	2.82	58.59	3.51	91.69	2.03	26.01
276	1.39	203.62	3.98	73.18	0.00	30.55
277	2.76	300.58	6.28	66.78	0.00	33.80
278	3.45	164.69	9.86	49.49	0.00	41.67

SM8 Land Station 2006

T306				
Day	Mean Ground Temp			Air Press
	10 cm	20 cm	40cm	
	degrees C	degrees C	degrees C	Kpa
239	12.16	12.85	12.64	93.45
240	12.88	13.11	12.63	92.86
241	13.54	13.48	12.77	91.92
242	12.22	13.18	12.82	92.03
243	11.26	12.31	12.46	92.95
244	10.23	11.54	12.02	93.39
245	12.11	11.92	11.82	93.28
246	12.46	12.38	11.94	93.25
247	12.98	12.92	12.18	93.61
248	13.24	13.24	12.43	93.85
249	12.49	13.05	12.52	93.38
250	11.99	12.51	12.34	93.51
251	11.61	12.14	12.11	93.18
252	12.33	12.47	12.08	92.64
253	12.43	12.54	12.11	92.61
254	11.44	12.31	12.10	93.09
255	9.96	11.24	11.77	93.24
256	9.17	10.44	11.30	92.92
257	9.22	10.05	10.93	93.47
258	8.26	8.98	10.40	93.76
259	6.98	8.07	9.82	93.60
260	4.86	7.08	9.15	93.72
261	6.17	6.72	8.52	93.59
262	6.22	7.16	8.35	93.44
263	7.27	7.71	8.38	92.65
264	8.06	8.12	8.50	92.37
265	8.26	8.26	8.56	93.47
266	7.51	8.00	8.54	93.00
267	7.83	8.04	8.47	92.99
268	8.23	8.26	8.51	92.75
269	7.40	8.18	8.54	93.41
270	7.01	7.72	8.34	93.62
271	8.34	8.16	8.33	92.09
272	7.82	8.07	8.35	92.09
273	7.96	8.04	8.30	91.76
274	6.79	7.81	8.25	92.14
275	6.40	7.45	8.06	93.23
276	5.37	6.86	7.80	93.91
277	5.11	6.32	7.45	93.45
278	5.90	6.29	7.20	92.31

NE7 Land Station 2005

T405						
Day	Wind Speed	Wind Direction	Tair	RH	PPT	Q*
	Mean		Mean	Mean		Mean
	(m/s)	degrees	degrees C	%	mm/day	W/m2
159	NA	NA	17.72	52.30	0.00	146.79
160	NA	NA	15.87	63.02	0.00	117.57
161	NA	NA	10.92	71.16	0.00	138.30
162	NA	NA	6.90	73.16	0.00	96.75
163	NA	NA	8.14	92.30	0.00	7.31
164	NA	NA	13.04	77.89	0.00	68.16
165	NA	NA	12.23	94.06	0.00	21.50
166	NA	NA	11.67	94.66	0.00	24.42
167	NA	NA	10.38	75.22	0.00	118.08
168	NA	NA	7.57	77.96	0.00	92.93
169	NA	NA	10.23	65.99	0.00	128.99
170	NA	NA	8.26	78.45	0.00	97.14
171	NA	NA	10.72	56.86	0.00	181.93
172	NA	NA	16.04	64.21	0.00	121.01
173	NA	NA	9.78	98.67	0.00	7.89
174	NA	NA	5.90	97.31	0.00	22.28
175	NA	NA	10.95	66.55	0.00	180.98
176	NA	NA	9.58	87.94	0.00	38.01
177	NA	NA	11.60	57.16	0.00	152.96
178	NA	NA	11.48	58.33	0.00	87.72
179	NA	NA	12.83	70.24	0.00	35.32
180	NA	NA	13.09	81.37	0.00	99.46
181	NA	NA	15.36	60.53	0.00	157.42
182	NA	NA	14.78	70.27	0.00	92.87
183	NA	NA	15.55	73.61	0.00	93.24
184	NA	NA	16.97	69.92	0.00	133.32
185	NA	NA	17.85	61.16	0.00	152.55
186	NA	NA	19.54	55.86	0.00	138.69
187	NA	NA	18.73	75.97	0.00	85.62
188	NA	NA	16.12	67.38	0.00	143.28
189	NA	NA	18.62	47.96	0.00	174.13
190	NA	12.87	15.48	69.46	3.30	89.78
191	2.84	241.79	14.83	61.74	1.02	124.30
192	2.13	222.33	16.26	59.20	0.00	141.70
193	1.90	201.84	17.89	53.67	0.00	157.19
194	2.47	214.00	17.55	66.40	0.51	130.65
195	2.10	236.62	15.70	77.34	1.78	85.52
196	2.07	235.51	17.42	61.70	0.00	114.82
197	1.80	159.14	15.19	83.88	0.51	70.92

NE7 Land Station 2005

T405				
Day	Mean Ground Temp			Air Press
	10 cm	20 cm	40cm	
	degrees C	degrees C	degrees C	Kpa
159	12.72	7.91	1.46	93.97
160	12.96	8.37	1.69	93.79
161	11.85	8.22	1.88	93.95
162	9.60	7.40	1.91	94.16
163	8.45	6.53	1.81	94.53
164	8.88	5.96	1.68	94.47
165	10.30	6.68	1.73	94.04
166	10.03	6.98	1.94	93.69
167	10.49	7.45	2.16	94.11
168	9.89	7.45	2.33	94.54
169	10.15	7.45	2.42	94.25
170	10.68	7.81	2.56	93.82
171	10.72	7.69	2.68	94.80
172	12.84	8.66	2.85	94.28
173	12.11	9.28	3.25	93.69
174	9.37	8.18	3.43	93.82
175	9.79	7.16	3.20	94.45
176	11.23	8.31	3.19	94.45
177	11.37	8.26	3.39	94.60
178	11.53	8.74	3.58	94.88
179	11.98	8.98	3.76	94.82
180	12.43	9.09	3.92	94.61
181	14.17	9.91	4.12	94.26
182	14.74	10.84	4.51	93.67
183	14.68	11.12	4.88	93.44
184	15.57	11.47	5.14	93.88
185	16.09	12.05	5.41	94.16
186	15.91	12.14	5.65	93.86
187	17.27	12.70	5.87	93.26
188	16.41	12.88	6.14	93.15
189	15.58	12.35	6.22	93.33
190	15.45	12.44	6.28	93.27
191	14.26	11.73	6.24	93.75
192	14.56	11.47	6.09	94.34
193	15.41	11.81	6.06	94.62
194	16.40	12.44	6.19	94.23
195	15.61	12.40	6.41	93.94
196	15.60	12.32	6.52	94.03
197	15.31	12.32	6.61	94.03

NE7 Land Station 2005

T405						
Day	Wind Speed	Wind Direction	Tair	RH	PPT	Q*
	Mean		Mean	Mean		Mean
	(m/s)	degrees	degrees C	%	mm/day	W/m2
198	1.72	230.95	17.21	77.83	0.00	126.72
199	2.19	212.66	14.78	88.87	12.70	44.71
200	2.70	237.31	12.35	81.48	12.45	95.27
201	1.63	216.47	13.66	67.03	0.00	104.21
202	1.82	123.25	11.69	66.86	0.00	129.07
203	2.92	145.59	15.58	73.95	1.27	92.62
204	3.64	117.17	9.12	95.37	17.53	7.32
205	1.65	245.02	8.04	94.48	8.38	31.64
206	2.08	235.84	9.39	89.95	2.03	25.50
207	1.34	261.47	8.28	76.51	0.00	74.79
208	1.33	220.02	9.82	68.86	0.00	93.06
209	3.95	174.36	12.28	79.90	2.79	21.63
210	2.30	214.30	15.66	76.48	1.27	96.18
211	2.42	244.87	17.05	62.80	0.00	140.77
212	1.51	215.29	15.60	73.77	1.27	90.18
213	3.25	182.79	18.10	68.28	8.38	110.52
214	3.33	237.36	13.46	74.31	1.78	63.44
215	3.35	280.60	13.04	72.14	3.81	93.33
216	2.36	232.93	16.89	59.17	0.00	100.55
217	2.70	248.99	18.06	67.22	1.78	88.47
218	1.47	228.71	16.21	65.92	0.00	99.73
219	1.94	251.28	13.27	89.50	7.11	43.04
220	1.98	272.94	11.61	73.68	0.25	81.05
221	2.03	277.76	8.70	76.00	0.25	63.56
222	2.12	247.51	9.59	79.45	6.60	85.50
223	3.03	264.07	9.19	96.70	22.61	22.97
224	1.83	242.42	9.22	84.39	0.51	67.38
225	2.08	255.65	10.56	85.84	5.08	32.66
226	2.42	266.97	7.58	83.62	4.83	50.51
227	1.64	254.91	7.21	90.81	2.54	37.01
228	1.49	130.17	8.68	85.75	1.27	38.49
229	2.66	72.83	8.69	94.98	9.91	3.41
230	4.02	46.31	8.01	96.46	9.91	13.04
231	1.37	141.01	9.14	95.09	0.00	33.70
232	3.88	182.96	11.74	85.51	0.00	79.33
233	3.11	212.29	17.15	74.29	2.29	105.57
234	2.56	245.21	14.01	78.11	8.38	109.43
235	1.42	208.51	12.78	72.52	0.00	67.73
236	2.60	75.00	13.16	64.72	0.00	99.32

NE7 Land Station 2005

T405				
Day	Mean Ground Temp			Air Press
	10 cm	20 cm	40cm	
	degrees C	degrees C	degrees C	Kpa
198	15.46	12.17	6.64	94.32
199	15.52	12.45	6.73	93.41
200	14.19	12.02	6.88	93.44
201	14.11	11.69	6.76	94.49
202	13.82	11.53	6.66	95.20
203	14.93	11.82	6.63	94.72
204	13.03	11.74	6.76	94.10
205	11.04	10.29	6.69	94.75
206	11.18	9.76	6.34	94.96
207	11.23	9.64	6.12	95.09
208	11.39	9.59	5.99	94.92
209	11.97	10.04	5.98	94.45
210	13.26	10.26	6.06	94.10
211	14.89	11.48	6.33	94.29
212	15.08	12.15	6.78	94.36
213	15.65	12.53	7.14	93.99
214	15.48	13.17	7.53	93.77
215	13.86	12.38	7.77	94.33
216	13.65	11.77	7.67	94.56
217	15.44	12.35	7.60	94.10
218	15.27	12.63	7.75	94.39
219	15.43	12.97	7.93	94.21
220	14.28	12.52	8.03	94.64
221	12.63	11.74	7.94	95.09
222	11.87	10.82	7.65	94.97
223	12.12	10.90	7.42	94.44
224	11.87	10.73	7.34	95.29
225	12.40	11.05	7.36	94.44
226	12.29	11.32	7.40	94.52
227	11.38	10.69	7.40	95.19
228	11.44	10.48	7.28	95.21
229	10.85	10.13	7.17	94.66
230	10.01	9.32	6.97	94.29
231	9.73	8.81	6.68	94.38
232	10.23	8.76	6.45	94.54
233	11.65	9.27	6.39	94.28
234	13.11	10.25	6.58	94.19
235	12.90	10.75	6.92	94.54
236	12.56	10.67	7.15	94.74

NE7 Land Station 2005

T405						
Day	Wind Speed	Wind Direction	Tair	RH	PPT	Q*
	Mean		Mean	Mean		Mean
	(m/s)	degrees	degrees C	%	mm/day	W/m2
237	1.64	166.77	11.41	67.83	0.00	96.94
238	1.69	223.30	13.74	62.77	0.00	106.74
239	1.95	227.93	17.43	56.30	0.00	103.76
240	3.53	138.93	17.57	60.91	0.00	98.94
241	3.59	93.24	11.36	86.43	0.00	21.99
242	2.23	250.77	6.04	89.50	2.79	33.75
243	2.20	178.32	9.11	82.56	10.41	52.49
244	1.42	221.33	10.44	78.82	0.25	89.22
245	2.22	173.60	9.89	86.44	6.86	38.51
246	1.59	234.96	11.50	80.72	0.25	51.94
247	2.29	245.28	10.94	71.14	0.00	66.85
248	1.33	248.42	9.70	69.01	0.25	58.75
249	1.25	246.25	9.69	66.92	0.00	69.05
250	2.45	214.08	12.04	65.61	0.00	58.22
251	2.17	229.71	11.53	78.65	0.00	41.86
252	1.70	229.35	9.88	88.82	0.00	36.12
253	2.42	147.35	8.23	96.19	1.52	12.12
254	1.24	136.43	6.56	91.41	0.25	1.87
255	2.52	266.52	5.81	95.83	12.70	19.28
256	1.85	187.41	3.32	86.42	0.25	47.86
257	1.89	95.66	2.45	81.65	0.00	28.69
258	1.01	194.66	2.12	71.84	0.00	53.15
259	2.04	197.63	4.48	81.01	0.00	29.38
260	1.92	216.30	7.91	78.08	0.25	44.33
261	2.19	223.79	10.74	65.65	0.00	60.00
262	2.48	230.83	9.37	70.84	0.00	25.56
263	1.88	227.84	7.42	80.01	7.62	27.98
264	1.05	162.90	4.37	85.35	0.00	33.20

NE7 Land Station 2005

T405				
Day	Mean Ground Temp			Air Press
	10 cm	20 cm	40cm	
	degrees C	degrees C	degrees C	Kpa
237	12.49	10.67	7.27	94.43
238	12.40	10.64	7.35	94.03
239	13.53	10.98	7.43	94.13
240	13.90	11.50	7.63	94.17
241	13.79	11.79	7.86	93.87
242	11.69	11.04	7.96	94.08
243	10.66	10.00	7.72	94.40
244	11.07	9.87	7.41	94.49
245	11.17	10.03	7.29	94.33
246	11.31	9.85	7.18	93.94
247	12.05	10.35	7.14	94.17
248	11.89	10.49	7.19	94.53
249	11.20	10.12	7.19	94.81
250	11.19	9.94	7.08	94.38
251	11.78	10.16	7.02	93.66
252	11.22	9.95	7.00	94.05
253	10.70	9.72	6.93	94.92
254	9.83	9.15	6.78	94.34
255	8.50	8.45	6.56	93.89
256	8.16	7.86	6.25	94.20
257	6.68	7.18	5.97	94.41
258	5.73	6.24	5.55	94.80
259	5.87	5.88	5.12	94.65
260	6.90	6.00	4.83	94.13
261	8.08	6.57	4.74	93.68
262	8.10	7.01	4.82	93.35
263	7.65	6.95	4.88	93.94
264	6.70	6.43	4.84	94.76

NE7 Land Station 2006

T406						
Day	Wind Speed	Wind Direction	Tair	RH	PPT	Q*
	Mean		Mean	Mean		Mean
	(m/s)	degrees	degrees C	%	mm/day	W/m2
157	2.42	270.66	7.17	73.92	0.00	103.88
158	1.41	175.24	9.29	62.23	0.00	138.65
159	3.96	123.34	14.55	50.93	0.00	150.26
160	3.01	147.03	11.74	65.38	0.00	60.62
161	2.01	163.84	10.57	77.87	0.00	66.79
162	2.57	128.18	10.62	75.09	0.00	96.87
163	1.91	168.37	12.97	67.69	0.00	104.94
164	3.74	162.07	17.06	56.03	0.00	171.82
165	4.04	145.80	21.16	52.71	0.00	173.53
166	2.44	152.38	21.66	52.40	0.00	176.48
167	2.32	161.89	20.31	57.71	0.00	143.65
168	2.55	107.41	19.00	70.04	0.00	144.57
169	1.81	248.72	18.91	76.94	0.76	151.03
170	1.19	209.94	15.37	90.33	17.78	63.81
171	1.81	241.85	15.79	77.49	11.18	120.81
172	1.80	262.22	14.20	84.03	0.00	104.21
173	1.77	209.24	16.94	53.62	0.00	192.23
174	1.77	250.46	15.96	56.35	0.51	147.73
175	2.00	225.95	17.24	46.39	0.00	165.49
176	2.15	262.17	18.06	45.26	0.00	182.43
177	1.40	199.01	17.79	49.90	0.00	185.33
178	4.19	151.37	24.05	45.34	0.00	173.15
179	3.05	188.85	22.70	56.71	0.51	134.16
180	3.21	234.53	16.90	42.54	0.00	162.87
181	3.39	240.98	16.41	47.63	0.25	130.06
182	2.81	266.55	14.81	62.93	0.00	169.01
183	1.86	231.06	13.58	64.88	0.00	153.07
184	1.42	198.91	16.02	55.77	0.00	180.82
185	2.60	160.48	23.06	48.70	0.00	136.86
186	2.88	121.28	19.74	63.77	7.37	86.56
187	1.88	134.49	18.24	73.67	0.00	101.59
188	2.34	149.77	15.41	93.52	26.16	15.41
189	2.47	166.15	14.51	85.07	2.79	71.07
190	2.59	185.71	16.44	78.27	3.05	105.31
191	4.29	93.82	14.09	86.33	1.78	142.12
192	3.44	175.71	11.62	96.43	33.27	23.38
193	1.84	241.40	12.53	78.21	0.25	100.09
194	1.21	182.49	13.98	77.09	6.10	95.49
195	2.47	222.63	14.57	77.21	1.02	157.34

NE7 Land Station 2006

T406				
Day	Mean Ground Temp			Air Press
	10 cm	20 cm	40cm	
	degrees C	degrees C	degrees C	Kpa
157	12.46	10.87	3.91	94.81
158	12.33	10.32	4.22	95.44
159	12.85	10.69	4.56	95.47
160	12.62	11.07	4.99	95.33
161	12.18	10.80	5.41	94.70
162	12.01	10.77	5.80	94.94
163	12.79	10.92	6.14	95.33
164	13.60	11.42	6.44	95.00
165	15.14	12.28	6.78	94.20
166	16.55	13.37	7.22	93.75
167	17.17	14.33	7.77	93.45
168	17.21	14.67	8.30	93.42
169	17.89	15.17	8.74	94.09
170	17.37	15.52	9.28	94.23
171	16.71	15.20	9.60	93.93
172	16.90	15.34	9.87	94.51
173	17.53	15.47	10.04	94.86
174	17.68	15.96	10.25	95.10
175	17.01	15.74	10.45	95.44
176	17.82	15.88	10.55	95.55
177	17.65	15.88	10.66	95.35
178	18.34	16.29	10.79	94.33
179	18.93	16.67	10.99	93.98
180	18.07	16.83	11.22	94.39
181	16.46	15.97	11.32	94.35
182	16.69	15.58	11.26	94.33
183	16.04	15.24	11.18	94.84
184	16.27	14.98	11.07	95.12
185	17.62	15.61	11.04	94.85
186	17.53	16.05	11.20	94.57
187	17.50	15.97	11.35	94.44
188	17.05	16.15	11.56	94.15
189	16.17	15.56	11.66	94.67
190	16.52	15.48	11.62	94.39
191	16.57	15.69	11.63	93.94
192	15.09	15.26	11.79	93.22
193	15.76	14.83	11.74	93.92
194	16.67	15.35	11.64	93.86
195	17.72	15.95	11.69	93.83

NE7 Land Station 2006

T406						
Day	Wind Speed	Wind Direction	Tair	RH	PPT	Q*
	Mean		Mean	Mean		Mean
	(m/s)	degrees	degrees C	%	mm/day	W/m2
196	1.80	210.12	14.52	70.30	2.29	104.18
197	2.05	242.80	15.16	75.90	6.60	127.63
198	2.82	216.40	18.49	58.31	0.00	184.63
199	1.34	191.14	13.85	83.72	17.53	43.15
200	1.52	255.78	16.69	65.50	0.00	187.52
201	1.69	208.08	18.57	60.09	0.00	156.17
202	2.07	233.52	21.24	52.50	0.00	179.41
203	1.94	242.69	22.22	52.55	0.00	174.67
204	1.22	221.54	20.89	54.78	1.52	168.32
205	1.47	255.65	17.92	68.84	0.25	89.55
206	1.97	195.87	16.32	72.19	0.00	107.15
207	3.15	55.30	11.09	93.62	6.60	-0.29
208	2.18	98.22	12.47	77.65	2.79	111.20
209	0.95	206.80	13.23	64.65	0.00	139.59
210	1.47	141.02	14.37	66.11	0.00	55.57
211	1.64	166.98	12.19	89.71	3.05	20.41
212	2.37	270.20	11.20	85.83	2.03	50.91
213	2.16	267.63	9.69	83.71	0.00	94.54
214	1.23	226.92	11.58	71.89	0.00	121.15
215	2.10	211.35	10.87	76.43	0.00	106.62
216	1.80	197.43	11.67	79.54	1.02	89.58
217	1.80	134.06	11.95	78.74	0.00	86.71
218	1.86	189.72	14.15	71.11	0.51	121.35
219	1.51	218.66	17.54	58.51	0.00	148.83
220	1.72	143.61	18.52	71.31	3.05	76.97
221	2.33	186.74	18.68	68.94	4.57	75.19
222	1.89	232.42	15.21	58.60	0.00	150.46
223	1.20	156.95	13.79	73.58	0.00	15.08
224	1.54	258.25	15.42	64.75	0.00	117.73
225	1.32	223.11	15.15	64.98	0.00	131.72
226	2.23	217.82	16.07	63.00	0.00	146.57
227	2.10	217.64	13.16	88.10	20.32	42.48
228	2.34	248.81	11.89	87.30	3.05	69.19
229	1.18	240.04	12.31	70.63	0.00	120.55
230	2.71	208.78	18.98	57.99	0.00	132.95
231	2.10	248.79	14.00	70.81	3.56	105.55
232	1.80	257.48	13.27	74.24	0.51	100.02
233	2.26	181.85	15.73	60.38	0.00	136.97
234	3.99	154.48	19.47	55.14	0.00	123.63

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T406				
Day	Mean Ground Temp			Air Press
	10 cm	20 cm	40cm	
	degrees C	degrees C	degrees C	Kpa
196	17.50	16.16	11.78	94.11
197	17.14	15.88	11.82	94.36
198	17.68	16.02	11.82	94.47
199	16.85	15.95	11.89	94.23
200	16.54	15.33	11.93	94.73
201	17.67	15.94	11.94	94.94
202	18.43	16.41	12.06	94.97
203	18.90	16.84	12.25	94.54
204	19.21	17.15	12.46	94.34
205	19.37	17.52	12.66	94.01
206	18.08	16.89	12.83	93.99
207	16.68	16.20	12.82	94.14
208	15.59	15.04	12.65	94.28
209	15.81	14.83	12.40	94.72
210	16.00	15.04	12.24	94.45
211	15.35	14.81	12.18	93.73
212	14.76	14.36	12.06	93.22
213	14.40	13.96	11.89	93.86
214	14.24	13.71	11.69	94.46
215	14.26	13.74	11.53	94.50
216	13.86	13.47	11.41	94.40
217	14.01	13.40	11.28	94.40
218	14.41	13.46	11.18	94.52
219	15.38	13.80	11.15	94.48
220	16.31	14.48	11.26	94.54
221	16.79	14.98	11.46	94.43
222	16.37	15.13	11.67	94.57
223	15.43	14.94	11.80	94.38
224	15.52	14.57	11.82	94.15
225	15.74	14.62	11.79	94.32
226	15.81	14.76	11.80	94.21
227	15.73	14.94	11.91	94.00
228	14.88	14.50	11.99	94.25
229	14.55	14.11	11.95	94.79
230	15.46	14.25	11.87	94.51
231	15.58	14.66	11.90	94.42
232	15.57	14.67	11.98	94.92
233	14.98	14.43	12.00	94.88
234	15.51	14.55	11.98	94.37

NE7 Land Station 2006

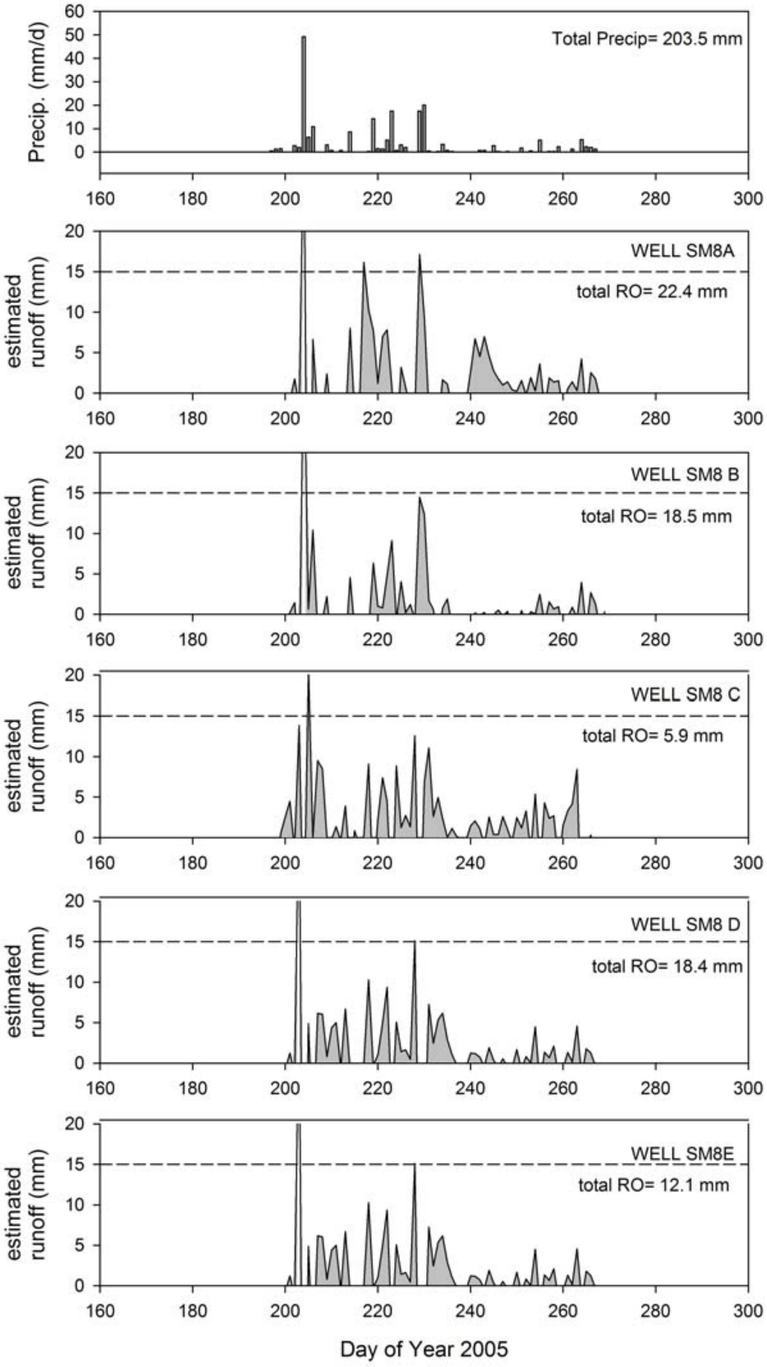
T406						
Day	Wind Speed	Wind Direction	Tair	RH	PPT	Q*
	Mean		Mean	Mean		Mean
	(m/s)	degrees	degrees C	%	mm/day	W/m2
235	2.15	196.45	15.48	73.52	6.86	25.85
236	1.31	263.87	14.06	72.07	0.25	112.86
237	1.50	264.11	12.79	70.00	0.00	80.49
238	3.02	220.16	15.13	60.89	0.00	100.97
239	1.56	204.84	12.58	69.66	0.00	100.36
240	4.21	154.40	16.45	61.09	0.00	82.17
241	2.14	186.65	15.21	78.09	0.00	73.96
242	2.36	276.13	10.94	93.91	19.30	-3.28
243	1.98	283.39	8.04	84.92	1.02	49.63
244	2.38	204.76	11.41	69.00	0.00	115.88
245	2.41	202.40	17.27	59.78	0.00	116.20
246	1.15	198.68	17.59	55.66	0.00	115.27
247	1.50	145.27	17.94	58.74	0.00	102.98
248	2.56	118.30	17.67	67.84	0.00	62.57
249	2.59	249.82	16.43	60.36	0.00	100.90
250	1.69	158.69	12.43	77.95	0.00	61.66
251	4.07	139.29	13.51	74.97	0.00	84.58
252	5.86	141.76	16.15	62.56	0.00	69.32
253	3.21	183.14	16.41	62.74	0.25	67.16
254	2.96	229.34	13.85	54.88	0.00	81.25
255	1.69	246.27	9.51	58.75	0.00	80.26
256	1.81	159.08	7.53	76.55	0.00	26.83
257	3.73	78.08	5.62	85.10	2.03	29.65
258	4.33	38.38	4.42	72.51	0.00	61.46
259	3.76	47.66	3.86	71.13	2.29	29.15
260	1.92	184.65	3.83	87.35	2.03	20.43
261	1.69	126.99	6.09	75.18	0.00	63.11
262	1.25	216.40	5.71	76.99	0.00	60.56
263	1.44	171.92	7.49	80.66	0.00	46.21
264	1.89	95.47	8.76	79.47	0.00	27.74
265	0.90	214.49	8.27	76.20	0.00	48.63
266	2.48	212.88	7.99	73.41	0.00	45.29
267	1.67	255.50	8.91	61.31	0.00	68.31
268	1.23	206.97	9.38	64.13	0.00	30.45
269	1.44	263.59	5.16	88.91	3.05	6.66
270	2.51	216.47	5.78	83.94	2.54	42.28
271	2.94	235.70	10.36	75.97	5.08	40.59
272	1.59	239.32	7.04	74.92	0.00	17.01
273	1.20	209.47	6.70	86.75	2.54	14.58
274	1.47	262.02	4.66	90.37	1.78	22.85

NE7 Land Station 2006

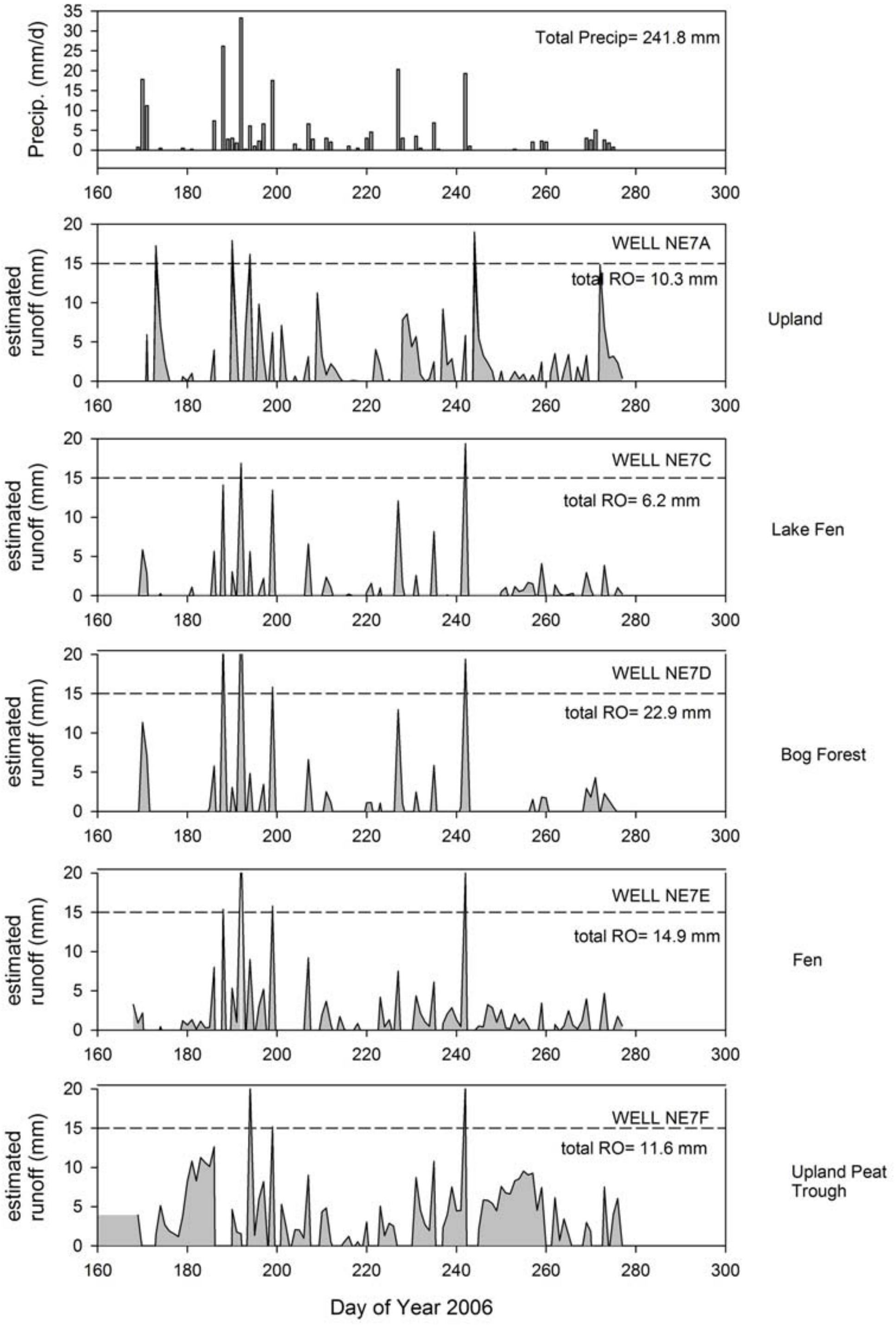
T406				
Day	Mean Ground Temp			Air Press
	10 cm	20 cm	40cm	
	degrees C	degrees C	degrees C	Kpa
235	15.52	14.82	12.02	94.23
236	15.12	14.59	12.11	94.09
237	14.66	14.33	12.09	94.42
238	14.27	14.01	12.01	94.02
239	14.36	13.90	11.92	94.93
240	14.05	13.75	11.83	94.34
241	14.45	13.79	11.76	93.40
242	14.00	13.93	11.77	93.45
243	13.02	13.31	11.81	94.39
244	12.15	12.55	11.65	94.75
245	12.81	12.39	11.42	94.63
246	13.63	12.81	11.30	94.70
247	14.21	13.25	11.30	95.08
248	14.74	13.73	11.39	95.34
249	14.78	13.99	11.52	94.74
250	14.53	13.97	11.64	95.01
251	13.76	13.62	11.68	94.70
252	13.64	13.40	11.63	94.11
253	13.89	13.34	11.58	94.02
254	13.72	13.41	11.55	94.41
255	12.41	12.82	11.51	94.64
256	11.26	12.02	11.34	94.48
257	10.75	11.42	11.09	95.16
258	9.49	10.60	10.80	95.51
259	8.75	9.93	10.45	95.33
260	8.27	9.36	10.10	95.35
261	8.78	9.24	9.77	95.16
262	8.28	9.01	9.54	94.99
263	8.93	9.10	9.33	94.16
264	9.28	9.29	9.21	93.94
265	9.56	9.45	9.15	94.97
266	8.81	9.29	9.11	94.38
267	8.97	9.14	9.02	94.37
268	9.02	9.14	8.94	94.25
269	8.74	9.08	8.87	94.93
270	8.40	8.78	8.79	95.08
271	9.09	8.93	8.69	93.42
272	8.49	8.88	8.66	93.46
273	7.90	8.46	8.58	93.17
274	7.65	8.22	8.45	93.55

Appendix 2 Vertical Water Balance

SM 8 2005


Precip. (mm/d)
60
50
40
30
20
10
0
Total Precip= 203.5 mm
estimated runoff (mm)
20
15
10
5
0
WELL SM8A
total RO= 22.4 mm
WELL SM8 B
total RO= 18.5 mm
WELL SM8 C
total RO= 5.9 mm
WELL SM8 D
total RO= 18.4 mm
WELL SM8E
total RO= 12.1 mm
160
180
200
220
240
260
280
300
Day of Year 2005

NE 7 2005


Precip. (mm/d)
35
30
25
20
15
10
5
0
Total Precip= 241.8 mm
160
180
200
220
240
260
280
300
estimated runoff (mm)
WELL NE7A
total RO= 10.3 mm
Upland
WELL NE7C
total RO= 6.2 mm
Lake Fen
WELL NE7D
total RO= 22.9 mm
Bog Forest
WELL NE7E
total RO= 14.9 mm
Fen
WELL NE7F
total RO= 11.6 mm
Upland Peat Trough
Day of Year 2006

Appendix 3 Sediments - Grain size

Mean grain size and d10 for application Hazen method.

SM 8			NE 7		
	mean µm	d10 µm		mean µm	d10 µm
Q3	44.3	2.78	F1	32.58	2.59
H	17.83	2.44	F2	40.87	2.71
Q2	19.56	2.46	Q5	48.15	2.83
B	16.73	2.47	Q6	50.93	2.88
Lake edge	65.62	3.08	G	42.99	2.71
M (Q5)	32.84	2.52	Q3(E)	50.84	2.91
L	29.45	2.54	H	54.32	2.94
D	20.43	2.45	Q4	45.66	2.76
A	40.68	2.6	P1 (camp)	62.17	2.98
C1	24.29	2.49	A	50.67	2.87
C2	60.19	2.89			

Appendix 4 Isotope data

NE7 2005

sample id	date	location	$\delta^{18}O$	$\delta^{2}H$
NE7				
KT05_04	07/06/2005	NE7 Lake	-17.38	-141.82
KT05_05	07/06/2005	NE7 Rill at tower	-18.17	-143.06
KT05_06	07/06/2005	NE7 evap pan	-17.85	-142.33
KT05_15	02/07/2005	NE7 lake	-17.42	-138.76
KT05_16	02/07/2005	NE7-evap pan	-8.58	-101.21
KT05_17	08/07/2005	NE7-mini-piezo	-20.68	-150.05
KT05_18	08/07/2005	NE7F	-18.6	-145.75
KT05_19	08/07/2005	NE7E	-18.4	-143.19
KT05_20	08/07/2005	NE7B	-18.88	-146.05
KT05_21	09/07/2005	NE7D	-17.17	-135.56
KT05_22	09/07/2005	NE7A	-17.52	-137.72
KT05_23	09/07/2005	NE7C	-17.34	-137.05
KT05_24	09/07/2005	NE7-ppt west	-16.03	-125.2
KT05_25	09/07/2005	NE7-ppt east	-16.12	-126.64
KT05_45	25/07/2005	NE7A	-19.5	-141.62
KT05_46	25/07/2005	NE7D	-18.71	-144.17
KT05_47	25/07/2005	NE7C	-17.96	-141.17
KT05_48	26/07/2005	NE7B	-18.84	-145.1
KT05_49	26/07/2005	NE7E	-18.44	-139.96
KT05_50	26/07/2005	NE7F	-18.88	-143.25
KT05_51	27/07/2005	NE7-evap pan	-11.81	-113.97
KT05_52	27/07/2005	NE7-Lake	-17.63	-137.02
KT05_53	27/07/2005	NE7 rill at tower	-18.2	-142.63
KT05_54	28/07/2005	NE7-ppt west	-19.71	-152.5
KT05_55	28/07/2005	NE7-ppt east	-19.71	-154.13
KT05_59	30/07/2005	upland soil sample	-18.44	-148.45
KT05_69	01/08/2005	upland soil sample	-17.32	-136.93
KT05_70	05/08/2005	NE7E	-18.41	-140.26
KT05_71	05/08/2005	NE7F	-18.88	-144.94
KT05_72	07/08/2005	NE7C	-17.98	-139.53
KT05_73	07/08/2005	NE7D	-18.66	-143.01
KT05_74	07/08/2005	NE7B	-18.97	-144.99
KT05_75	07/08/2005	NE7A	-19.25	-146.8
KT05_76	07/08/2005	NE7-evap pan	-10.45	-103.24
KT05_77	07/08/2005	NE7 Lake	-17.86	-135.69
KT05_78	07/08/2005	NE7-ppt east	-16.76	-124.35
KT05_79	06/08/2005	upland soil sample	-17.16	-131.45
KT05_112	09/08/2005	NE7 Lake	-16.89	-136.55
KT05_113	10/08/2005	NE7 Lake	-17.09	-136.82
KT05_114	11/08/2005	NE7 Lake	-17.22	-137.05
KT05_115	12/08/2005	NE7 Lake	-17.25	-137.62
KT05_116	13/08/2005	NE7 Lake	-17.26	-137.82
KT05_117	14/08/2005	NE7 Lake	-17.25	-138.82

NE7 and SM8 2005

sample id	date	location	$\delta^{18}O$	$\delta^{2}H$
NE7				
KT05_118	15/08/2005	NE7 Lake	-17.15	-138.57
KT05_119	22/09/2005	NE7B-well	-18.54	-144.12
KT05_120	22/09/2005	NE7E-well	-18.48	-142.96
KT05_121	22/09/2005	NE7F-well	-18.85	-146.43
KT05_122	22/09/2005	NE7D-well	-18.5	-143.96
KT05_123	22/09/2005	NE7A-well	-18.86	-145.96
KT05_124	22/09/2005	NE7C-well	-17.27	-137.26
KT05_125	24/08/2005	NE7-lake	-18.13	-141.85
KT05_126	23/08/2005	NE7-ppt west	-18.16	-146.11
KT05_127	22/08/2005	NE7 Lake	-17.64	-140.62
KT05_128	29/08/2005	NE7 Lake	-17.56	-139.96
KT05_129	05/09/2005	NE7 Lake	-17.54	-139.86
KT05_130	12/09/2005	NE7 Lake	-17.64	-141.2
KT05_161	07/08/2005	NE7 ppt west	-15.23	-124.83
KT05_162	07/08/2005	NE7rill at tower	-18.6	-142.55
sample id	date	location	$\delta^{18}O$	$\delta^{2}H$
SM 8				
KT05_01	04/06/2005	SM8 Lake	-11.95	-111.76
KT05_02	04/06/2005	SM8 evap pan	-12.04	-112.35
KT05_03	06/06/2005	SM8 Fen at tower	-15.02	-125.92
KT05_26	15/07/2005	SM8 ppt west	-15.17	-120.28
KT05_27	15/07/2005	SM8 B	-16.24	-131.02
KT05_28	15/07/2005	SM8 G	-17.28	-135.53
KT05_29	15/07/2005	SM8 A	-16.8	-132.15
KT05_30	16/07/2005	SM8 D	-17.7	-135.7
KT05_31	16/07/2005	small pond northside	-16.76	-131.18
KT05_32	16/07/2005	SM8 C	-17.63	-136.35
KT05_33	16/07/2005	SM8 F	-18.07	-139.23
KT05_34	17/07/2005	SM8 eap pan	-6.44	-88.58
KT05_35	17/07/2005	SM8 Lake	-10.99	-107.74
KT05_56	30/07/2005	SM8 C	-17.48	-133.04
KT05_57	30/07/2005	SM8 E	-17.15	-132.24
KT05_58	30/07/2005	SM8 F	-17.95	-136.56
KT05_60	31/07/2005	SM8 ppt west	-16.95	-131.57
KT05_61	31/07/2005	SM8 ppt west	-14.01	-113.99
KT05_62	31/07/2005	SM8 G	-17.17	-134.38
KT05_63	31/07/2005	SM8 evap pan	-10.33	-103.37
KT05_64	31/07/2005	SM8 Lake	-12.31	-110.49
KT05_65	31/07/2005	SM8 ppt east	-18.1	-133.01
KT05_66	31/07/2005	SM8 D	-17.5	-134.13
KT05_67	01/08/2005	SM8 A	-17.18	-132.3
KT05_68	01/08/2005	small pond southeast	-16.97	-129.29
KT05_89	12/08/2005	SM8 A	-18.69	-132.97
KT05_90	12/08/2005	SM8 C	-19.58	-135.

SM8 2005

sample id	date	location	$\delta^{18}O$	$\delta^{2}H$
SM8				
KT05_91	12/08/2005	SM8 E	-19.38	-134.24
KT05_92	12/08/2005	SM8 F	-19.69	-136.51
KT05_93	13/08/2005	SM8 B	-18.71	-131.13
KT05_94	13/08/2005	SM8 ppt west	-19.82	-141.62
KT05_95	13/08/2005	SM8 Lake	-14.15	-110.92
KT05_96	13/08/2005	SM8 evap pan	-12.81	-109.14
KT05_97	13/08/2005	SM8 ppt east	-18.93	-139.55
KT05_98	13/08/2005	SM8 G	-19.28	-135.79
KT05_100	01/08/2005	SM8 Lake	-13.88	-110.34
KT05_101	02/08/2005	SM8 Lake	-11.85	-108.55
KT05_102	03/08/2005	SM8 Lake	-12.02	-108.9
KT05_103	04/08/2005	SM8 Lake	-11.83	-108.65
KT05_104	05/08/2005	SM8 Lake	-11.7	-108.05
KT05_105	06/08/2005	SM8 Lake	-11.76	-108.04
KT05_106	07/08/2005	SM8 Lake	-11.81	-108.6
KT05_107	08/08/2005	SM8 Lake	-11.75	-108.44
KT05_108	09/08/2005	SM8 Lake	-11.72	-109.48
KT05_109	10/08/2005	SM8 Lake	-11.91	-109.55
KT05_110	11/08/2005	SM8 Lake	-12.04	-109.92
KT05_111	13/08/2005	SM8 D	-17.62	-133.42
KT05_131	26/09/2005	SM8 ppt east	-20.47	-159.92
KT05_132	26/09/2005	SM8 evap pan	-10.33	-106.99
KT05_133	26/09/2005	SM8 C	-18.27	-141.9
KT05_134	26/09/2005	SM8 A	-17.71	-138.38
KT05_135	26/09/2005	SM8 F	-18.12	-141.19
KT05_136	26/09/2005	SM8 E	-18.3	-143.22
KT05_137	26/09/2005	SM8 Lake	-12.45	-114.88
KT05_138	27/09/2005	SM8 ppt west	-21.03	-163.11
KT05_139	27/09/2005	SM8 B	-16.98	-134.84
KT05_140	27/09/2005	SM8 G	-18.23	-140.89
KT05_141	28/09/2005	SM8 D	-18.13	-140.72
KT05_142	15/08/2005	SM8 Lake	-11.85	-110.29
KT05_143	17/08/2005	SM8 Lake	-12	-111.64
KT05_144	19/08/2005	SM8 Lake	-12.46	-113.89
KT05_145	21/08/2005	SM8 Lake	-12.58	-114.07
KT05_146	23/08/2005	SM8 Lake	-12.65	-114.22
KT05_147	25/08/2005	SM8 Lake	-12.57	-114.6
KT05_148	27/08/2005	SM8 Lake	-12.55	-112.39
KT05_149	29/08/2005	SM8 Lake	-12.37	-113.41
KT05_150	31/08/2005	SM8 Lake	-12.59	-113.88
KT05_151	02/09/2005	SM8 Lake	-12.46	-113.7
KT05_152	06/09/2005	SM8 Lake	-12.39	-112.91
KT05_153	08/09/2005	SM8 Lake	-12.51	-113.37
KT05_154	10/09/2005	SM8 Lake	-12.23	-112.87

SM8 2005

sample id	date	location	$\delta^{18}O$	$\delta\,^{2}H$
SM8				
KT05_155	12/09/2005	SM8 Lake	-12.4	-112.97
KT05_156	14/09/2005	SM8 Lake	-12.43	-112.66
KT05_157	16/09/2005	SM8 Lake	-12.53	-113.23
KT05_158	18/09/2005	SM8 Lake	-12.45	-113.38
KT05_159	20/09/2005	SM8 Lake	-12.35	-113.5
KT05_160	22/09/2005	SM8 Lake	-12.36	-113.71

sample id	date	location	$\delta^{18}O$	$\delta^{2}H$
NE7				
KT06 01	04/06/2006	NE 7 Lake	-17.45	-137.51
KT06 02	05/06/2006	NE 7 D	-18.59	-143.04
KT06 03	05/06/2006	NE 7 A	-18.89	-148.5
KT06 04	05/06/2006	NE 7 C	-17.99	-142.54
KT06 05	05/06/2006	NE 7 B	-19.11	-146.35
KT06 06	05/06/2006	NE 7 E	-18.8	-145.45
KT06 07	05/06/2006	NE 7 F	-19.55	-150.53
KT06 08	05/06/2006	rill at tower	-18.53	-143.84
KT06 18	15/06/2006	NE 7 D	-18.83	-143.92
KT06 19	15/06/2006	NE 7 A	-18.84	-147.02
KT06 20	15/06/2006	NE 7 C	-18.3	-142.44
KT06 21	16/06/2006	NE 7 B	-19.02	-148.41
KT06 22	16/06/2006	NE 7 E	-18.88	-144.96
KT06 23	16/06/2006	NE 7 F	-19.48	-150.12
KT06 29	15/06/2006	NEFT1	-19.23	-145.77
KT06 30	15/06/2006	NEFT2	-19.24	-147.26
KT06 31	15/06/2006	NEFT3	-19.44	-148.74
KT06 32	15/06/2006	NEFT4	-19.41	-149
KT06 33	15/06/2006	NEFT5	-19.25	-147.92
KT06 34	15/06/2006	NEFT6	-18.79	-145.36
KT06 35	15/06/2006	NEFT7	-18.13	-142.1
KT06 36	15/06/2006	NEFT8	-18.65	-145.77
KT06 37	15/06/2006	NEFT9	-18.98	-145.89
KT06 38	15/06/2006	NEFT10	-19.8	-152.07
KT06 39	14/06/2006	NEF1	-18.7	-145.79
KT06 40	14/06/2006	NEF2	-18.82	-143.6
KT06 41	14/06/2006	NEF3	-18.75	-144.01
KT06 42	14/06/2006	NEF4	-18.97	-144.87
KT06 43	14/06/2006	NEF5	-19.05	-145.01
KT06 44	14/06/2006	NEF6	-18.88	-147.06
KT06 45	14/06/2006	NEF7	-19.04	-147.98
KT06 46	14/06/2006	NEF8	-19.01	-146.92
KT06 47	14/06/2006	NEF9	-19.09	-146.93
KT06 48	14/06/2006	NEF10	-19.14	-147.74

NE7 2006

sample id	date	location	$\delta^{18}O$	$\delta^{2}H$
NE7				
KT06 51	10/07/2006	NE 7 evap pan	-7.5	-81.73
KT06 52	10/07/2006	NE 7 Lake	-15.44	-128.96
KT06 59	11/07/2006	NE 7 D	-17.23	-132.56
KT06 60	11/07/2006	NE 7 A	-16.56	-128.48
KT06 61	11/07/2006	NE 7 C	-16.72	-129.2
KT06 62	11/07/2006	NE 7ppt west	-14.35	-110.02
KT06 65	12/07/2006	NE7 B	-17.35	-132.32
KT06 68	12/07/2006	NE 7 E	-17.92	-136.56
KT06 69	12/07/2006	NE 7 ppt upland	-14.97	-115.32
KT06 70	12/07/2006	NE 7 F	-17.09	-129.3
KT06 71	12/07/2006	Ponding water upland	-16.89	-129.87
KT06 99	22/07/2006	NE 7 P3A	-20.01	-150.93
KT06 106	23/07/2006	NE 7 G	-16.87	-134
KT06 107	24/07/2006	NE 7 P6A	-18.76	-146.69
KT06 108	24/07/2006	NE 7 P6B	-18.85	-146.29
KT06 109	24/07/2006	NE 7 P5B	-18.35	-141.95
KT06 110	24/07/2006	NE 7 A	-17.69	-135.77
KT06 111	24/07/2006	NE 7 D	-17.65	-135.09
KT06 112	24/07/2006	NE 7 evap pan	-9.64	-103.82
KT06 113	24/07/2006	NE 7 Lake	-15.99	-128.31
KT06 114	24/07/2006	NE 7 P7B	-18.56	-142.93
KT06 115	24/07/2006	NE 7 P7A	-18.6	-143.45
KT06 116	24/07/2006	NE 7 C	-17.11	-132.66
KT06 117	24/07/2006	NE 7 ppt west	-18.71	-146.35
KT06 118	24/07/2006	NE 7 rill at tower	-17.21	-131.51
KT06 119	25/07/2006	NE7 P4A	-19.58	-149.52
KT06 120	25/07/2006	NE7 P4B	-19.12	-146.85
KT06 121	25/07/2006	NE 7 Q2	-19.55	-151.08
KT06 122	25/07/2006	NE7 H	-17.96	-138.5
KT06 143	09/08/2006	NE 7 E	-18.7	-142.83
KT06 144	09/08/2006	NE 7 B	-17.91	-137.5
KT06 145	09/08/2006	NE 7 F	-17.92	-138.17
KT06 146	10/08/2006	NE 7 D	-17.06	-131.29
KT06 147	10/08/2006	NE 7 C	-16.42	-130.73
KT06 148	10/08/2006	NE 7 A	-17.81	-137.07
KT06 149	11/08/2006	NE 7 evap pan	-7.87	-99.06
KT06 150	11/08/2006	NE 7 Lake	-15.99	-128.7
KT06 151	11/08/2006	NE 7 ppt west	-15.35	-124.62
KT06 152	12/08/2006	NE 7 P8B	-17.34	-138.38
KT06 153	12/08/2006	NE 7 G	-16.6	-134.46
KT06 154	12/08/2006	NE 7 Q2	-19.15	-147.42
KT06 155	12/08/2006	NE 7 H	-17.95	-139.23

NE7 2006

sample id	date	location	$\delta^{18}O$	$\delta^{2}H$
NE7				
KT06 156	12/08/2006	NE 7 rill at tower	-17.51	-134.74
KT06 180	20/08/2006	NE 7 G	-16.79	-135.17
KT06 181	20/08/2006	NE 7 Q2	-18.71	-143.38
KT06 182	20/08/2006	NE 7 H	-17.83	-137.61
KT06 183	21/08/2006	NE 7 B	-17.61	-135.01
KT06 184	21/08/2006	NE 7 D	-17.57	-136.32
KT06 185	21/08/2006	NE 7 P5A	-18.23	-141.99
KT06 186	21/08/2006	NE 7 A	-18.02	-140.65
KT06 187	21/08/2006	NE 7 evap pan	-8.49	-101.64
KT06 188	21/08/2006	NE 7 Lake	-15.64	-128.19
KT06 189	21/08/2006	NE 7 ppt east	-17.73	-139.77
KT06 190	21/08/2006	NE 7 C	-16.67	-132.52
KT06 191	22/08/2006	NE 7ppt west	-17.85	-140.86
KT06 192	22/08/2006	NE 7 rill at tower	-17.4	-136.05
KT06 193	22/08/2006	NE 7 MP 1	-18.82	-146.63
KT06 194	22/08/2006	NE 7 MP 2	-18.77	-146.02
KT06 195	22/08/2006	NE 7 inflow at TS 3	-17.65	-136.45
KT06 196	22/08/2006	NE 7 LP 1	-16.92	-135.85
KT06 197	22/08/2006	KB S4	-18.81	-145.53
KT06 198	22/08/2006	KB S5	-18.63	-144.32
KT06 199	22/08/2006	NE 7 E	-18.61	-143.69
KT06 200	22/08/2006	NE 7 F	-18.23	-140.22
KT06 201	23/08/2006	NE 7 P1A	-19.98	-155.21
KT06 202	23/08/2006	NE 7 P1B	-18.41	-143.59
KT06 262	23/08/2006	NEF T1A	-17.64	-133.91
KT06 263	23/08/2006	NEF T2A	-17.82	-135.59
KT06 264	23/08/2006	NEF T3A	-17.45	-133.12
KT06 265	23/08/2006	NEF T4A	-17.67	-132.98
KT06 266	23/08/2006	NEF T5A	-17.49	-132.39
KT06 267	23/08/2006	NEF T6A	-17.26	-133.05
KT06 268	23/08/2006	NEF T7A	-16.59	-130.55
KT06 269	23/08/2006	NEF T8A	-17.86	-135.9
KT06 270	23/08/2006	NEF T9A	-17.62	-134.95
KT06 271	23/08/2006	NEF T10A	-17.94	-135.51
KT06 272	22/08/2006	NEF 1A	-17.41	-132.1
KT06 273	22/08/2006	NEF 2A	-17.29	-133.38
KT06 274	22/08/2006	NEF 3A	-17.49	-132.14
KT06 275	22/08/2006	NEF 4A	-17.36	-133.55
KT06 276	22/08/2006	NEF 5A	-17.46	-134.85
KT06 277	22/08/2006	NEF 6A	-17.38	-132.94
KT06 278	22/08/2006	NEF 7A	-17.46	-133.66
KT06 279	22/08/2006	NEF 8A	-17.68	-135.93
KT06 280	22/08/2006	NEF 9A	-17.38	-134.75

NE7 2006

sample id	date	location	δ^{18}O	δ^{2}H
NE7				
KT06 281	22/08/2006	NEF 10A	-17.36	-133.96
KT06 282	22/08/2006	NEF 11A	-16.99	-132.71
KT06 283	22/08/2006	NEF 12A	-17.38	-132.62
KT06 284	23/08/2006	NEF 1B	-15.55	-127.44
KT06 285	23/08/2006	NEF 2B	-16.19	-130.6
KT06 286	23/08/2006	NEF 3B	-15.88	-127.81
KT06 287	23/08/2006	NEF 4B	-17.22	-134.44
KT06 288	23/08/2006	NE 08	-15.2	-127.04
KT06 289	05/06/2006	NE 7 ppt west winter	-15.29	-131.41
KT06 292	23/07/2006	NE 7 P1A	-20.28	-155.01
KT06 293	23/07/2006	NE 7 Q1	-16	-125.82
kt06 300	05/10/2006	NE 7 G	-15.56	-127.33
kt06 301	05/10/2006	NE 7 Q2	-17.79	-137.15
kt06 302	05/10/2006	NE 7 H	-17.85	-137.67
kt06 303	05/10/2006	NE 7 F	-19.38	-148.29
kt06 304	05/10/2006	NE 7 E	-18.4	-142.9
kt06 305	05/10/2006	NE 7 B	-17.79	-137.15
kt06 306	05/10/2006	NE 7 evap Pan	-7.62	-85.76
kt06 307	05/10/2006	NE 7 Lake	-15.2	-124.44
kt06 308	05/10/2006	NE 7 ppt east	-16.57	-125.21
kt06 309	05/10/2006	NE 7 A	-18.61	-142.81
kt06 310	06/10/2006	NE 7 D	-17.8	-137.45
kt06 311	06/10/2006	NE 7 C	-16.91	-132.47
kt06 312	06/10/2006	MP 2	-17.56	-136.22
kt06 313	06/10/2006	rill at tower	-17.42	-135.45
kt06 331	28/08/2006	NE 7 Lake	-15.84	-127.71
kt06 332	12/09/2006	NE 7 Lake	-15.43	-120.45
kt06 333	26/09/2006	NE 7 Lake	-15.13	-125.66
kt06 380	14/06/2006	NEF1	-18.92	-144.25
kt06 381	14/06/2006	NEF2	-18.95	-144.15
kt06 382	14/06/2006	NEF3	-18.87	-144.47
kt06 383	14/06/2006	NEF4	-18.82	-144.19
kt06 384	14/06/2006	NEF5	-19.23	-144.91
kt06 385	14/06/2006	NEF6	-19.12	-146.7
kt06 386	14/06/2006	NEF7	-19.19	-146.58
kt06 387	14/06/2006	NEF8	-19.13	-146.17
kt06 388	14/06/2006	NEF9	-19.18	-146.47
kt06 389	14/06/2006	NEF10	-19.22	-146.18
kt06 390	14/06/2006	NEF11	-18.82	-146.05
kt06 391	14/06/2006	NEF12	-19.24	-147.09
kt06 392	15/06/2006	NEFT1	-19.26	-147.03

NE7 and SM8 2006

sample id	date	location	δ^{18}O	δ^{2}H
NE7				
kt06 393	15/06/2006	NEFT2	-19.3	-146.54
kt06 394	15/06/2006	NEFT3	-19.59	-148.67
kt06 395	15/06/2006	NEFT4	-19.37	-148.37
kt06 396	15/06/2006	NEFT5	-19.09	-148.16
kt06 397	15/06/2006	NEFT6	-18.63	-146.28
kt06 398	15/06/2006	NEFT7	-18.1	-141.81
kt06 399	15/06/2006	NEFT8	-18.55	-144.59
kt06 400	15/06/2006	NEFT9	-18.92	-146.41
kt06 401	15/06/2006	NEFT10	-19.84	-152.09
sample id	date	location	δ^{18}O	δ^{2}H
SM 8				
KT06 09	09/06/2006	SM 8 ppt west	-15.23	-128.39
KT06 10	09/06/2006	SM 8 B	-17.14	-134.57
KT06 11	11/06/2006	SM 8 D	-17.99	-136.82
KT06 12	11/06/2006	SM 8 C	-18.68	-143.01
KT06 13	11/06/2006	SM 8 E	-18.66	-140.9
KT06 14	11/06/2006	SM 8 SE fen	-17.15	-133.97
KT06 15	12/06/2006	SM 8 F	-19.26	-148.1
KT06 16	12/06/2006	SM 8 Lake	-12.38	-113.29
KT06 17	12/06/2006	SM 8 A	-18.21	-138.86
KT06 72	15/07/2006	SM 8 D	-16.99	-129.64
KT06 73	15/07/2006	SM 8 H	-17.47	-134.3
KT06 74	15/07/2006	SM 8 P3B	-18.58	-143.06
KT06 75	15/07/2006	SM 8 A	-17.01	-131.9
KT06 76	16/07/2006	SM 8 P9B	-16.48	-128.82
KT06 77	16/07/2006	SM 8 P9A	-16.41	-132.31
KT06 78	16/07/2006	SM 8 B	-16.04	-126.76
KT06 79	16/07/2006	SM 8 ppt west	-14.23	-110.91
KT06 80	16/07/2006	SM 8 G	-17.16	-131.04
KT06 81	16/07/2006	SM 8 evap pan	-9.89	-98.23
KT06 82	16/07/2006	SM 8 lake	-11.31	-105.15
KT06 83	17/07/2006	SM 8 P6A	-18.42	-140.65
KT06 84	17/07/2006	SM 8 C	-16.81	-128.58
KT06 85	17/07/2006	SM 8 E	-17.58	-134.87
KT06 86	17/07/2006	SM 8 F	-18.19	-139.04
KT06 87	17/07/2006	SM 8 P7B	-20.16	-152.91
KT06 88	17/07/2006	SM 8 P7A	-19.26	-149
KT06 89	17/07/2006	SM 8 P1A	-18.72	-144.19
KT06 90	17/07/2006	SM 8 P1B	-18.05	-136.19
KT06 91	17/07/2006	SM 8 P2A	-18.46	-141.94
KT06 92	17/07/2006	SM 8 J	-16.73	-131.47
KT06 93	17/07/2006	SM 8 Pond 1	-11.65	-111.88
KT06 94	17/07/2006	SM 8 P5A	-17.5	-135.67

SM8 2006

sample id	date	location	δ^{18}O	δ^{2}H
SM 8				
KT06 95	17/07/2006	SM 8 P5B	-17.13	-134.28
KT06 97	19/07/2006	SE fen during walk about	-16.93	-130.43
KT06 98	19/07/2006	SM 8 Pond 2	-15.21	-120.48
KT06 123	27/07/2006	SM 8 J	-16.47	-131.51
KT06 124	27/07/2006	SM 8 I	-15.99	-125.75
KT06 125	28/07/2006	SM 8 P8B	-16.5	-133.24
KT06 126	28/07/2006	SM 8 P8C	-16.33	-132.26
KT06 127	28/07/2006	SM 8 P8A	-16.18	-130.17
KT06 128	28/07/2006	SM 8 K	-15.96	-130.01
KT06 129	28/07/2006	SM 8 C	-17.65	-133.21
KT06 130	28/07/2006	SM 8 E	-18.91	-144.28
KT06 131	29/07/2006	SM 8 B	-16.56	-128.74
KT06 132	29/07/2006	SM 8 ppt west	-16.4	-131.41
KT06 133	29/07/2006	SM 8 G	-17.59	-134.26
KT06 134	29/07/2006	SM 8 ppt east	-14.37	-119.41
KT06 135	29/07/2006	SM 8 evap pan	-7.49	-94.15
KT06 136	29/07/2006	SM 8 lake	-10.77	-104.15
KT06 137	29/07/2006	SM 8 F	-18.61	-141.49
KT06 138	30/07/2006	SM 8 H	-17.39	-133.71
KT06 139	30/07/2006	S 8 fen NW	-16.66	-128.98
KT06 140	30/07/2006	SM 8 L	-17.66	-133.69
KT06 141	30/07/2006	SM 8 D	-17.28	-131.92
KT06 142	30/07/2006	SM 8 A	-16.98	-130.49
KT06 157	15/08/2006	SM 8 C	-16.93	-129.33
KT06 158	15/08/2006	SM 8 E	-17.06	-129.62
KT06 159	15/08/2006	SM 8 F	-18.34	-142
KT06 160	15/08/2006	SM 8 I	-16.19	-125.54
KT06 161	16/08/2006	SM 8 H	-17.25	-131.61
KT06 162	16/08/2006	SM Q5 forest	-17.56	-135.93
KT06 163	16/08/2006	SM 8 L	-17.39	-132.57
KT06 164	16/08/2006	SM 8 D	-17.13	-131.76
KT06 165	16/08/2006	SM 8 A	-16.73	-130.88
KT06 166	17/08/2006	SM 8 K	-15.97	-131.05
KT06 167	17/08/2006	Collapse scar 1	-14.1	-120.94
KT06 168	17/08/2006	Collapse scar 2	-14.36	-119.26
KT06 169	17/08/2006	SM 8 Pond 3	-11.97	-112.19
KT06 170	17/08/2006	SM 8 J	-16.53	-132.14
KT06 171	17/08/2006	SM 8 pond 1	-11.44	-110.92
KT06 172	17/08/2006	SM 8 rill flow south	-15.86	-126.84
KT06 173	17/08/2006	SM 8 slough SE	-15.85	-126.34
KT06 174	17/08/2006	SM 8 LP 1	-15.32	-127.47
KT06 175	17/08/2006	squeezed from peat at LP 1	-17.39	-133.48
KT06 176	17/08/2006	SM 8 ppt east	-15.41	-120.66

SM8 2006

sample id	date	location	$\delta^{18}O$	$\delta^{2}H$
SM 8				
KT06 177	17/08/2006	SM 8 evap pan	-7.64	-90.84
KT06 178	17/08/2006	SM 8 Lake	-10.57	-101.89
KT06 179	18/08/2006	SM 8 B	-16.39	-128.6
KT06 203	26/08/2006	SM 8 H	-17.14	-133
KT06 204	26/08/2006	SM 8 Q5	-17.67	-136.92
KT06 205	26/08/2006	SM 8 L	-17.45	-133.17
KT06 206	26/08/2006	SM 8 D	-17.47	-133.15
KT06 207	26/08/2006	SM 8 A	-16.82	-131.18
KT06 208	26/08/2006	SM 8 K	-16.93	-131.45
KT06 209	26/08/2006	SM 8 I	-15.67	-125.04
KT06 210	26/08/2006	SM 8 C	-18.01	-137.17
KT06 211	26/08/2006	SM 8 F	-18.98	-144.7
KT06 212	26/08/2006	SM 8 E	-18.09	-141.97
KT06 213	27/08/2006	SM 8 pond 1	-11.25	-109.09
KT06 214	27/08/2006	SM 8 J	-16.8	-131.93
KT06 215	27/08/2006	SM 8 evap pan	-5.43	-80.49
KT06 216	27/08/2006	SM 8 Lake	-10.13	-101.38
KT06 217	27/08/2006	SM 8 ppt east	-10.25	-85.92
KT06 218	27/08/2006	SM 8 G	-17.49	-130.11
KT06 219	27/08/2006	SM 8 B	-16.57	-129.07
KT06 220	27/08/2006	SM 8 ppt west	-10.01	-83.68
KT06 221	27/08/2006	SM 8 LP 2	-13.36	-117.36
KT06 222	16/08/2006	SM F1 T1A	-15.03	-122.9
KT06 223	16/08/2006	SM F1 T2A	-16.17	-126.41
KT06 224	16/08/2006	SM F1 T3A	-15.72	-124.53
KT06 225	16/08/2006	SM F1 T4A	-15.64	-123.27
KT06 226	16/08/2006	SM F1 T5A	-15.64	-124.7
KT06 227	16/08/2006	SM F1 T6A	-15.96	-125.37
KT06 228	15/08/2006	SM F1 1A	-15.21	-121.95
KT06 229	15/08/2006	SM F1 2A	-13.5	-113.13
KT06 230	15/08/2006	SM F1 3A	-13.92	-116.77
KT06 231	15/08/2006	SM F1 4A	-12.57	-108.47
KT06 232	15/08/2006	SM F1 5A	-13.91	-117.39
KT06 233	15/08/2006	SM F1 6A	-14.62	-119.9
KT06 234	15/08/2006	SM F1 7A	-16.49	-127.41
KT06 235	15/08/2006	SM F1 8A	-16.74	-129.47
KT06 236	15/08/2006	SM F1 9A	-16.5	-126.37
KT06 237	15/08/2006	SM F1 10A	-16.23	-125.72
KT06 238	15/08/2006	SM F1 11A	-16.36	-126.55
KT06 239	16/08/2006	SM F1 12A	-15.97	-125.27
KT06 240	16/08/2006	SM F1 13A	-15.91	-123.65
KT06 241	16/08/2006	SM F1 14A	-15.62	-122.92
KT06 242	16/08/2006	SM F1 15A	-15.49	-125.93
KT06 243	16/08/2006	SM F1 16A	-15.19	-123.18

SM8 2006

sample id	date	location	$\delta^{18}O$	$\delta^{2}H$
SM 8				
KT06 244	16/08/2006	SM F1 17A	-15.27	-122.57
KT06 245	16/08/2006	SM F1 18A	-15.28	-121.56
KT06 246	16/08/2006	SM F1 19A	-15.67	-121.34
KT06 247	18/08/2006	SM F2 T1A	-14.47	-117.12
KT06 248	18/08/2006	SM F2 T2A	-14.89	-121.31
KT06 249	18/08/2006	SM F2 T3A	-15.51	-122.08
KT06 250	18/08/2006	SM F2 T4A	-15.87	-125.24
KT06 251	18/08/2006	SM F2 T5A	-16.64	-128.47
KT06 252	18/08/2006	SM F2 T6A	-16.47	-128.63
KT06 253	18/08/2006	SM F2 T6A	-17.01	-132.06
KT06 254	18/08/2006	SM F2 1A	-16.54	-129.04
KT06 255	18/08/2006	SM F2 2A	-17.22	-132.05
KT06 256	18/08/2006	SM F2 3A	-16.28	-126.64
KT06 257	18/08/2006	SM F2 4A	-16.1	-126.4
KT06 258	18/08/2006	SM F2 5A	-15.5	-122.45
KT06 259	18/08/2006	SM F2 6A	-14.17	-115.6
KT06 260	18/08/2006	SM F2 FA	-16.22	-126.18
KT06 261	18/08/2006	SML MW	-15.98	-124.05
KT06 290	18/08/2006	SM 8 ppt east	-15.55	-122.88
KT06 291	18/08/2006	SM 8 G	-17.46	-132.82
kt06 314	07/10/2006	SM 8 H	-17	-130.38
kt06 315	07/10/2006	SM 8 Q5	-17.62	-133.65
kt06 316	07/10/2006	SM 8 L	-17.45	-131.47
kt06 317	07/10/2006	SM 8 D	-17.09	-130.07
kt06 318	07/10/2006	SM 8 A	-16.76	-129.02
kt06 319	07/10/2006	SM 8 C	-17.25	-131.85
kt06 320	08/10/2006	SM 8 K	-15.13	-122.36
kt06 321	08/10/2006	SM 8 I	-16.02	-121.49
kt06 322	08/10/2006	SM 8 J	-16.18	-126.18
kt06 323	08/10/2006	Pond 1	-11.54	-108.99
kt06 324	09/10/2006	SM 8 G	-17.06	-129.41
kt06 325	09/10/2006	SM 8 evap pan	-8.19	-89.74
kt06 326	09/10/2006	SM 8 ppt east	-16.64	-124.24
kt06 327	09/10/2006	SM 8 lake	-10.58	-102.42
kt06 328	09/10/2006	SM 8 B	-16.47	-126.62
kt06 329	07/10/2006	SM 8 E	-17.69	-135.24
kt06 330	07/10/2006	SM 8 F	-19.03	-144.43
kt06 356	11/06/2006	SMF1-T1	-16.19	-128.87
kt06 357	11/06/2006	SMF1-T2	-16.94	-133.15
kt06 358	11/06/2006	SMF1-T3	-17.3	-132.65
kt06 359	11/06/2006	SMF1-T4	-16.73	-132.62
kt06 360	11/06/2006	SMF1-T5	-17.01	-132.19
kt06 361	12/06/2006	SMF2-T1	-15.41	-123.98

SM8 2006

sample id	date	location	$\delta^{18}O$	$\delta\,^{2}H$
SM 8				
kt06 362	12/06/2006	SMF2-T2	-15.85	-125.17
kt06 363	12/06/2006	SMF2-T3	-16.22	-128.13
kt06 364	12/06/2006	SMF2-T4	-16.52	-130.37
kt06 365	12/06/2006	SMF2-T5	-17.47	-132.12
kt06 366	12/06/2006	SMF2-T6	-17.05	-132.14
kt06 367	12/06/2006	SMF2-T7	-18.01	-138.21
kt06 368	11/06/2006	SMF1-1	-17.29	-133.8
kt06 369	11/06/2006	SMF1-2	-17.15	-133.15
kt06 370	11/06/2006	SMF1-3	-16.17	-128.39
kt06 371	11/06/2006	SMF1-4	-16.75	-130.07
kt06 372	12/06/2006	SMF2-1	-17.68	-135.94
kt06 373	12/06/2006	SMF2-2	-17.84	-136.56
kt06 374	12/06/2006	SMF2-3	-17.41	-134.26
kt06 375	12/06/2006	SMF2-4	-16.97	-131.85
kt06 376	12/06/2006	SMF2-5	-16.22	-129.1
kt06 377	12/06/2006	SMF2-6	-15.72	-123.78
kt06 378	12/06/2006	SMF2-F	-17.35	-133.99
kt06 379	12/06/2006	SM08	-12.5	-113.41

Appendix 5 Major Ion geochemistry data

Major Ion Geochemistry

Sample ID	Na	K	Mg	Ca	HC03	Cl	SO_4	DOC	pH	Cond
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	ppm		µScm^{-1}
NE7 A	3.23	0.56	0.63	2.11	17.00	2.74	5.52	NA	5.81	44.30
NE7 C	0.64	0.27	1.00	2.07	0.00	0.43	0.11	6.53	4.54	31.10
NE7 D	2.99	0.63	2.52	10.19	76.00	3.07	0.18	33.39	6.20	78.40
NE7 Lake	0.51	0.00	2.77	0.18	7.00	1.32	0.52	47.47	5.52	23.17
NE7 P1A	5.45	0.36	11.56	50.99	183.00	2.33	0.80	30.76	7.37	282.30
NE7 P2A	4.07	1.51	19.13	70.72	239.00	1.60	6.05	7.14	7.85	209.20
NE7 P5B	5.44	1.98	13.03	54.95	212.00	3.11	13.09	4.89	5.96	75.40
NE7 P7A	7.18	5.46	12.60	54.13	239.00	5.15	6.21	NA		NA
NE7 P7B	5.03	3.78	26.45	107.38	368.00	4.05	0.55	NA	6.71	596.00
NE7 P8A	3.61	0.93	7.76	80.66	237.00	2.27	0.40	NA	7.00	349.00
SM8 B	1.15	0.00	1.15	0.52	0.00	0.67	0.06	51.11	3.97	32.40
SM8 E	0.83	0.00	1.89	0.68	0.00	0.35	2.64	40.39	4.99	83.30
SM8 G	0.92	0.00	0.81	0.18	0.00	0.37	0.22	64.08	3.65	86.10
SM8 T3 ppt	0.01	0.00	0.15	0.10	6.00	0.25	0.49	2.75	5.04	14.20
SM8 L1 ppt	0.00	0.00	0.14	0.06	3.00	0.11	0.49	2.22	6.09	16.80
SM8 P5B	12.61	0.01	70.49	1.49	272.00	1.43	0.16	20.57	6.78	330.00
SM8 P6A	14.75	0.02	79.57	1.38	263.00	0.61	21.83	3.15	7.48	367.00
SM8 P8C	3.15	0.00	1.70	0.56	7.00	0.40	0.06	69.65	4.32	43.30
SM8 P9A	8.82	0.00	62.63	2.34	213.00	0.44	0.15	11.30	6.92	256.10

Appendix 6 Regional Water Yield Estimates

				2005	0.25	0.75	2005	1
site	lake area /m2	catchment/m2	minus lake	precip mm	snow mm	rain mm	Evap mm	Runoff snow mm
NE1	652300	13111800	12459500	530	133	398	535	66
NE2	336700	16987500	16650800	530	133	398	535	66
NE3	1162400	15978100	14815700	539	135	404	518	67
NE4	581800	6635400	6053600	572	143	429	453	71
NE5	1894900	19573200	17678300	530	133	398	535	66
NE6	372900	10682600	10309700	541	135	406	527	68
NE7	111900	4073300	3961400	530	133	398	535	66
NE8	114600	6470400	6355800	541	135	406	527	68
NE9	3154800	20090300	16935500	544	136	408	559	68
NE10	4188000	27669900	23481900	560	140	420	566	70
NE11	5753200	68918300	63165100	526	131	394	532	66
SM1	2369500	7085700	4716200	567	142	426	595	71
SM2	1973800	24292300	22318500	548	137	411	568	69
SM3	1861300	7677300	5816000	536	134	402	572	67
SM4	525600	11998500	11472900	536	134	402	572	67
SM5	1061000	6291900	5230900	551	138	413	569	69
SM6	699200	3393600	2694400	536	134	402	572	67
SM7	1476100	5782400	4306300	559	140	419	577	70
SM8	1912500	9719800	7807300	536	134	402	572	67
SM9	1071400	9470800	8399400	536	134	402	572	67
SM10	1352100	17390500	16038400	536	134	402	572	67
WF1	3203400	24212800	21009400	561	140	421	569	70
WF2	755100	23370200	22615100	561	140	421	569	70
WF3	2163500	38142700	35979200	603	151	452	580	75

	0	Area				balance		JB's E/I
site	Runoff rain mm	precip on lake m3	R snow m3	R rain m3	E lake m3	I	E/I	2005
NE1	40	346036	826199	495719	348889	1667955	0.209	0.108
NE2	40	178615	1104127	662476	180087	1945219	0.093	0.101
NE3	40	626095	997509	598506	601847	2222110	0.271	0.185
NE4	43	332527	432490	259494	263632	1024511	0.257	0.171
NE5	40	1005218	1172262	703357	1013506	2880837	0.352	0.348
NE6	41	201808	697434	418460	196673	1317702	0.149	0.160
NE7	40	59361	262684	157610	59851	479655	0.125	0.075
NE8	41	62020	429959	257975	60442	749954	0.081	0.137
NE9	41	1715692	1151266	690759	1764844	3557717	0.496	0.554
NE10	42	2346709	1644734	986841	2370367	4978284	0.476	0.610
NE11	39	3024472	4150757	2490454	3057938	9665682	0.316	0.250
SM1	43	1344564	334524	200714	1410210	1879801	0.750	0.541
SM2	41	1082358	1529828	917897	1120312	3530083	0.317	0.815
SM3	40	998012	389811	233886	1064753	1621710	0.657	0.437
SM4	40	281822	768958	461375	300669	1512155	0.199	0.359
SM5	41	584336	360109	216065	604079	1160510	0.521	0.475
SM6	40	374905	180589	108353	399976	663847	0.603	0.367
SM7	42	824906	300817	180490	852426	1306214	0.653	0.663
SM8	40	1025465	523275	313965	1094042	1862706	0.587	0.405
SM9	40	574475	562960	337776	612892	1475211	0.415	0.295
SM10	40	724984	1074956	644973	773466	2444913	0.316	0.269
WF1	42	1798492	1474419	884652	1822042	4157563	0.438	0.668
WF2	42	423937	1587106	952263	429489	2963307	0.145	0.763
WF3	45	1303547	2709762	1625857	1254313	5639166	0.222	0.502

				2005	0.25	0.75	2005	1
site	area /m2	catchment/m2	minus lake	precip mm	snow mm	rain mm	Evap mm	Runoff snow mm
WF4	34200	1790600	1756400	504	126	378	555	63
WF5	234500	6887800	6653300	532	133	399	564	66
WF6	182300	5121700	4939400	567	142	425	567	71
WF7	85000	1711700	1626700	567	142	425	567	71
WF8	2025000	27074100	25049100	532	133	399	564	66
BM1	17029700	51318200	34288500	456	114	342	515	57
BM2	43974800	119642300	75667500	456	114	342	515	57
BM3	965600	28621000	27655400	429	107	321	495	54
BM4	4264100	34097900	29833800	429	107	321	495	54
BM5	2636900	27892300	25255400	429	107	321	495	54
BM6	1290200	18397900	17107700	443	111	332	521	55
BM7	676900	7812200	7135300	446	112	335	507	56
BM8	1215100	32684100	31469000	425	106	319	491	53
BM9	3484800	30261500	26776700	425	106	319	491	53
BM10	393700	5094600	4700900	452	113	339	512	56
BM11	55000	1478900	1423900	438	109	328	509	55
CM1	1600400	23934700	22334300	467	117	350	486	58
CM2	9550300	37926800	28376500	430	108	323	429	54
CM3	2300100	25257900	22957800	460	115	345	438	58
CM4	2627800	35818200	33190400	460	115	345	438	58
CM5	552300	2575500	2023200	428	107	321	431	53
S1	3404900	13398600	9993700	455	114	341	452	57
S2	1025200	110260700	109235500	456	114	342	460	57
S3	1447900	29694400	28246500	457	114	342	455	57
S4	1416300	123079400	121663100	457	114	342	455	57
S5	316700	4477400	4160700	456	114	342	460	57

	0	Area				balance		JB's E/I
site	Runoff rain mm	precip on lake m3	R snow m3	R rain m3	E lake m3	I	E/I	2005
WF4	38	17223	110562	66337	18988	194122	0.098	0.701
WF5	40	124718	442316	265389	132292	832423	0.159	0.591
WF6	43	103306	349884	209930	103312	663120	0.156	0.321
WF7	43	48168	115228	69137	48171	232532	0.207	0.324
WF8	40	1076986	1665280	999168	1142395	3741435	0.305	0.745
BM1	34	7762887	1953776	1172266	8776183	10888928	0.806	0.186
BM2	34	20045649	4311572	2586943	22662224	26944164	0.841	0.676
BM3	32	413896	1481781	889068	478017	2784745	0.172	0.124
BM4	32	1827769	1598500	959100	2110929	4385369	0.481	0.078
BM5	32	1130284	1353188	811913	1305389	3295386	0.396	0.462
BM6	33	571234	946800	568080	672805	2086114	0.323	0.059
BM7	33	302046	397989	238793	342858	938829	0.365	0.121
BM8	32	516626	1672467	1003480	596255	3192574	0.187	0.065
BM9	32	1481639	1423088	853853	1710007	3758580	0.455	0.223
BM10	34	177865	265470	159282	201554	602616	0.334	0.888
BM11	33	24077	77916	46750	28001	148743	0.188	0.131
CM1	35	747754	1304405	782643	777567	2834803	0.274	0.080
CM2	32	4109542	1526319	915791	4096439	6551651	0.625	0.199
CM3	35	1058197	1320261	792157	1008416	3170615	0.318	0.161
CM4	35	1208960	1908720	1145232	1152087	4262912	0.270	0.081
CM5	32	236257	108183	64910	238062	409350	0.582	0.294
S1	34	1548001	567941	340765	1537876	2456707	0.626	0.255
S2	34	467890	6231732	3739039	471208	10438660	0.045	0.103
S3	34	661025	1611960	967176	658156	3240160	0.203	0.134
S4	34	646599	6943019	4165812	643792	11755429	0.055	0.218
S5	34	144538	237362	142417	145563	524318	0.278	0.271