Prairie Hydrological Model Study Progress Report, April 2008

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This report is an update on the progress made over the first 12 months of the Prairie Hydrological Model Study and corresponds to Milestone #3. In summary, we have characterized the 2007-2008 Hydrological Year for modeling by installing weather, soil moisture, rainfall and pond level recording stations, observing summer evaporation, fall freeze-up and winter snowpack development to the start of melt. We have also made progress on wetland and basin characterization using remote sensing and other spatial information, and begun analysis of hydrometeorological data.

Work has focussed on three major research topics and on outreach to the Smith Creek community via open house meeting in Langenburg in November 2007:

1. Data Collection and Instrumentation
The field stations in Smith Creek (Figure 1) have three components: a main meteorological station, rain gauge station, and water level transducers.

1). The main meteorological station (SC-1) was set up in Smith Creek near the farmyard of Don Werle in July 2007. The meteorological station (SC-1) shown in Figure 2 includes automated measurements of:

- air temperature
- relative humidity
- short and longwave radiation
- wind speed
- wind direction
- volumetric soil moisture content (0-10 cm & 10-40 cm)
- soil temperature (0-5 cm & 0-20 cm)
- snow depth
- rainfall
- snowfall

Some of these observations are shown in Figure 3 over the current period of record. These data will be used in CRHM to simulate watershed hydrology processes including snow redistribution by wind, snowmelt, infiltration, evaporation, soil moisture change, runoff, and streamflow discharge. They will also be used to verify transfer algorithms from nearby Environment Canada weather stations so that Smith Creek meteorology can be reconstructed in the past. The meteorological data from this station are now downloaded via telemetry by cellular modem to a university computer and then displayed on the website, http://www.usask.ca/hydrology/ch_researchpj_smith.htm as daily weather summaries (Figure 4). The data is able to inform both investigators and farmers about recent weather in Smith Creek.

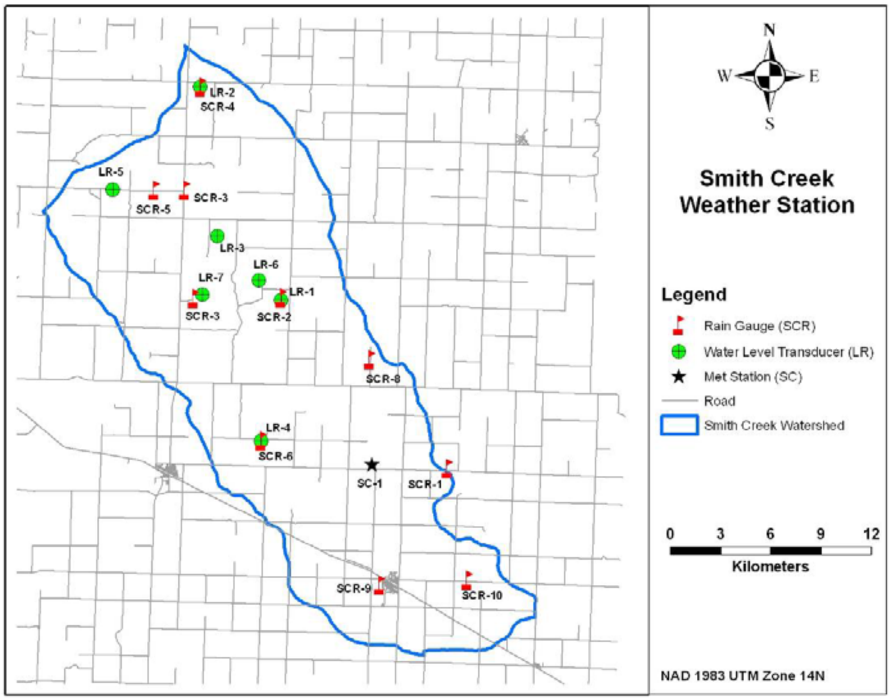


Figure 1. Smith Creek weather station.

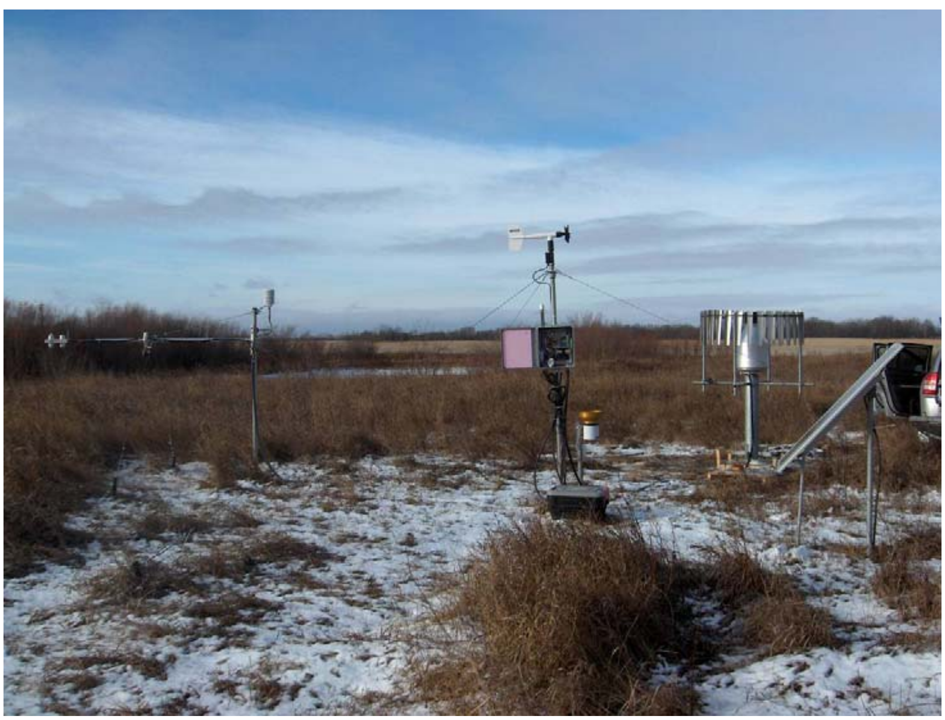
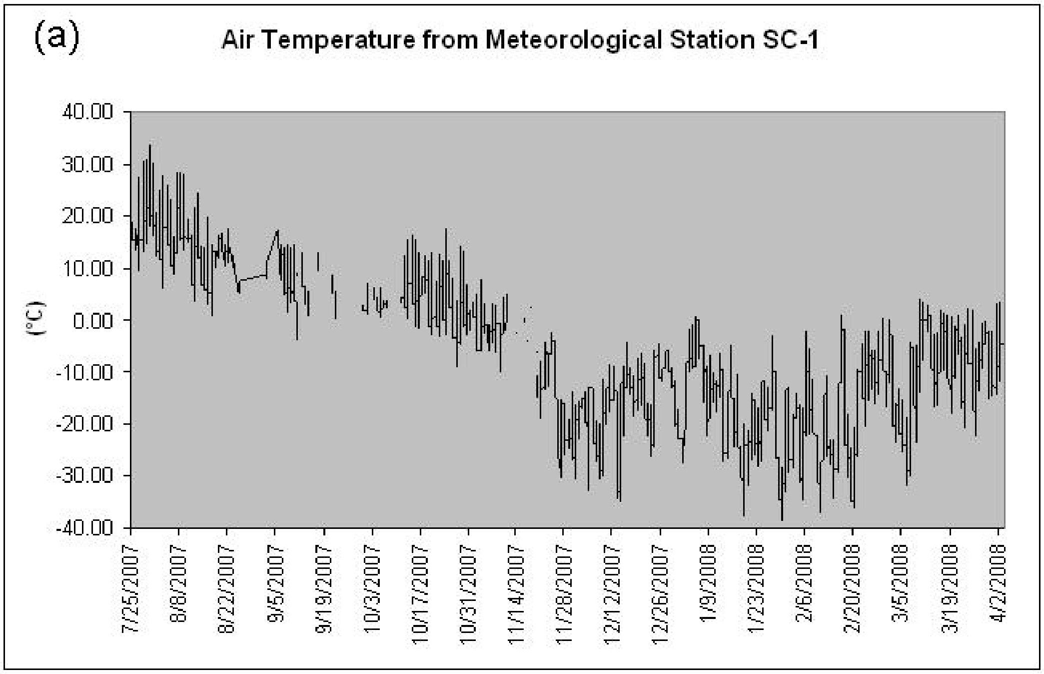


Figure 2. Smith Creek meteorological station SC-1.



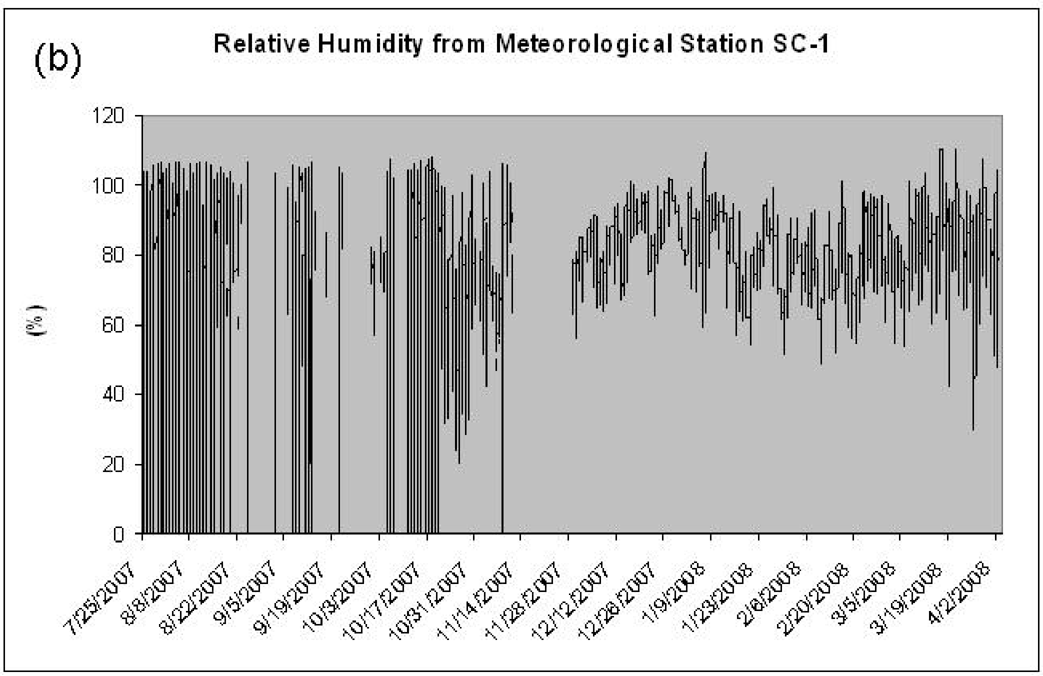
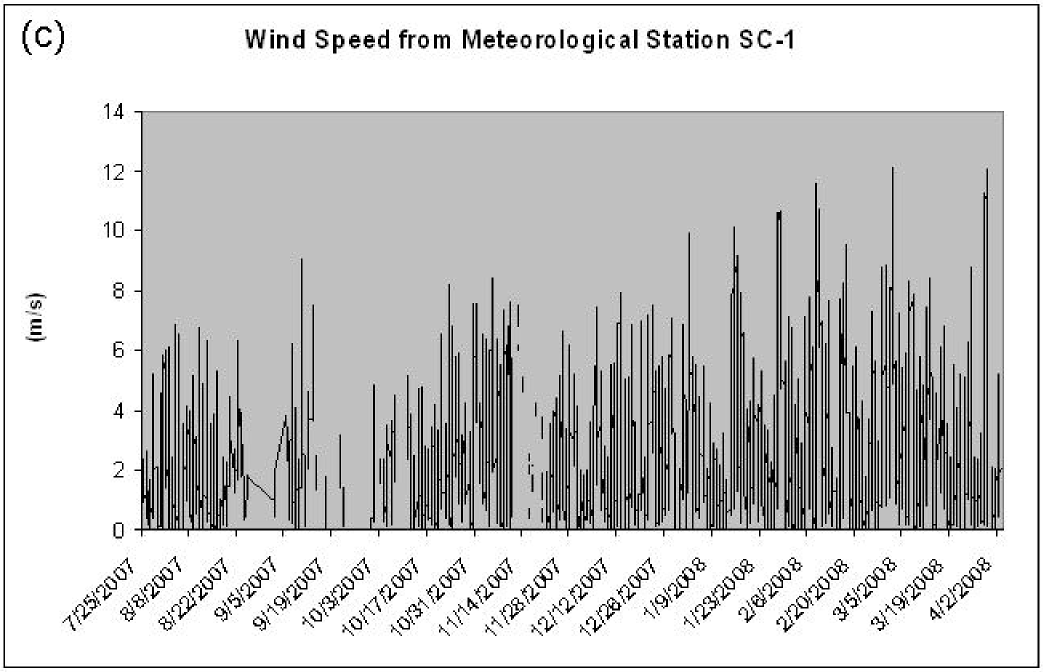


Figure 3. Smith Creek meteorological data: (a) air temperature (b) relative humidity (c) wind speed (d) rainfall (e) soil temperature (f) soil moisture (g) snowfall (h) snow depth.



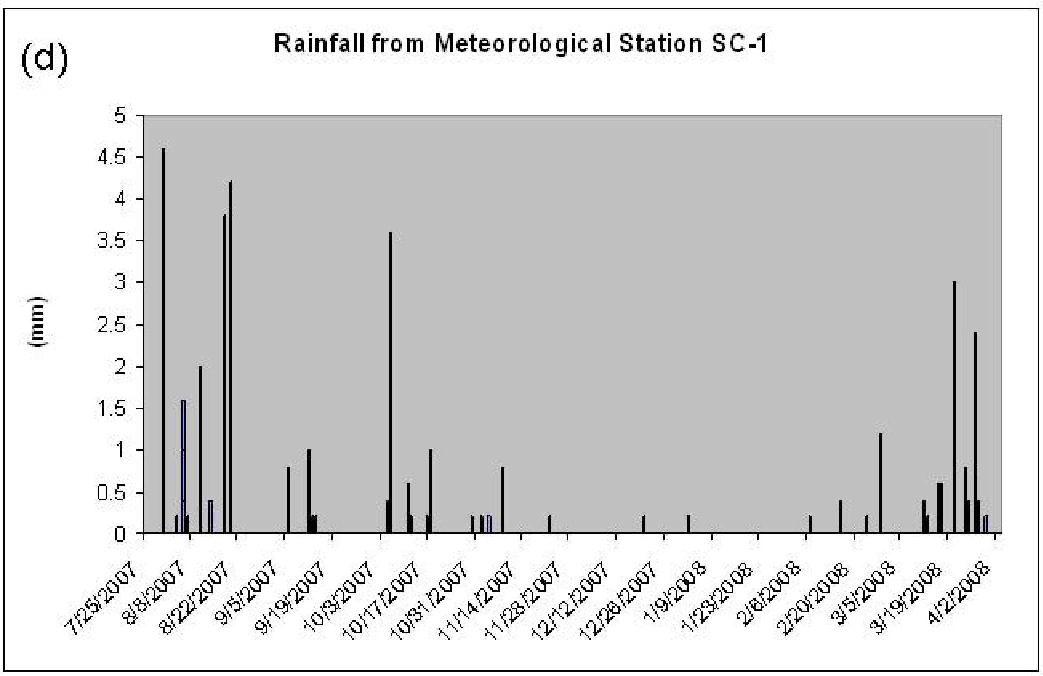


Figure 3. *Continued*.

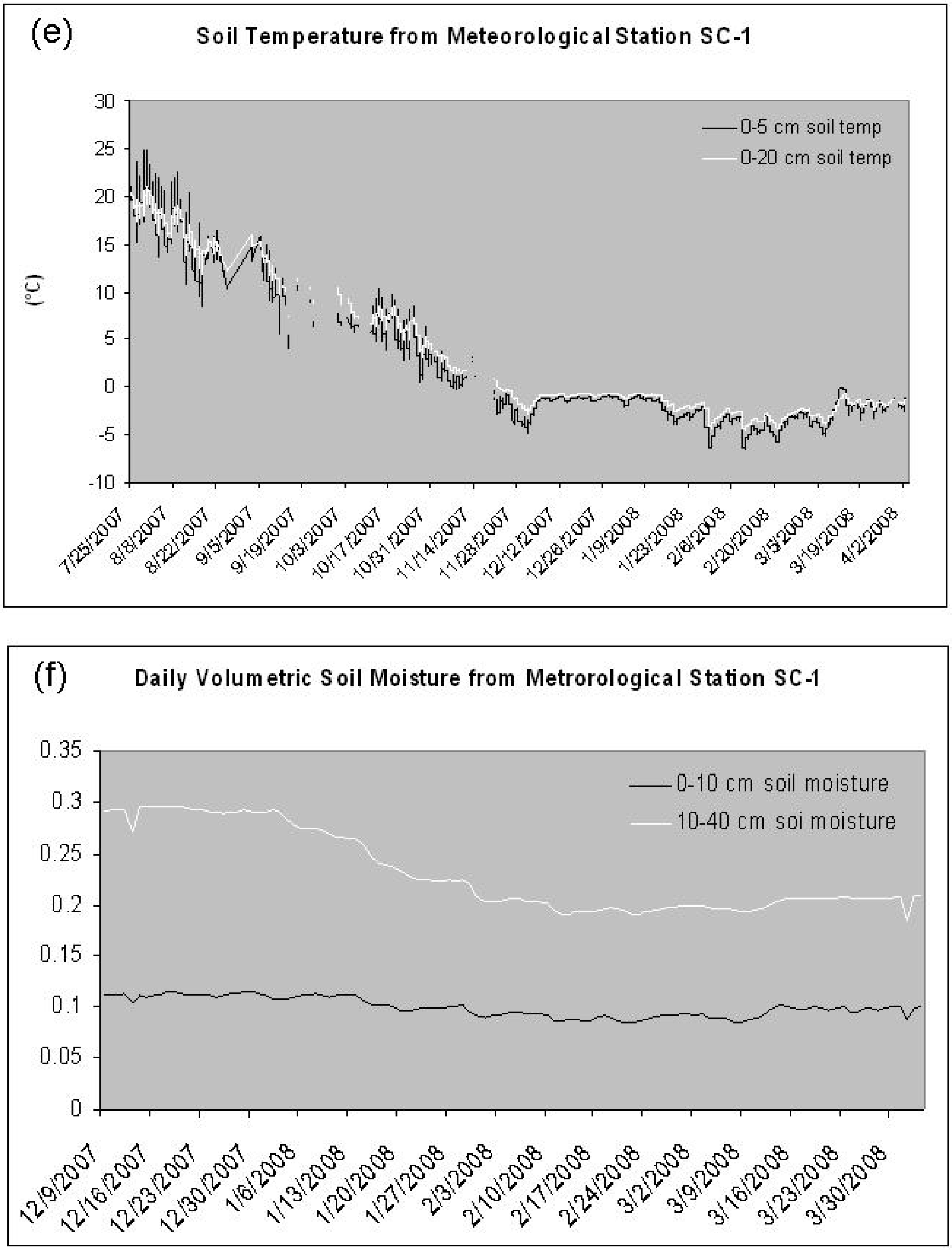
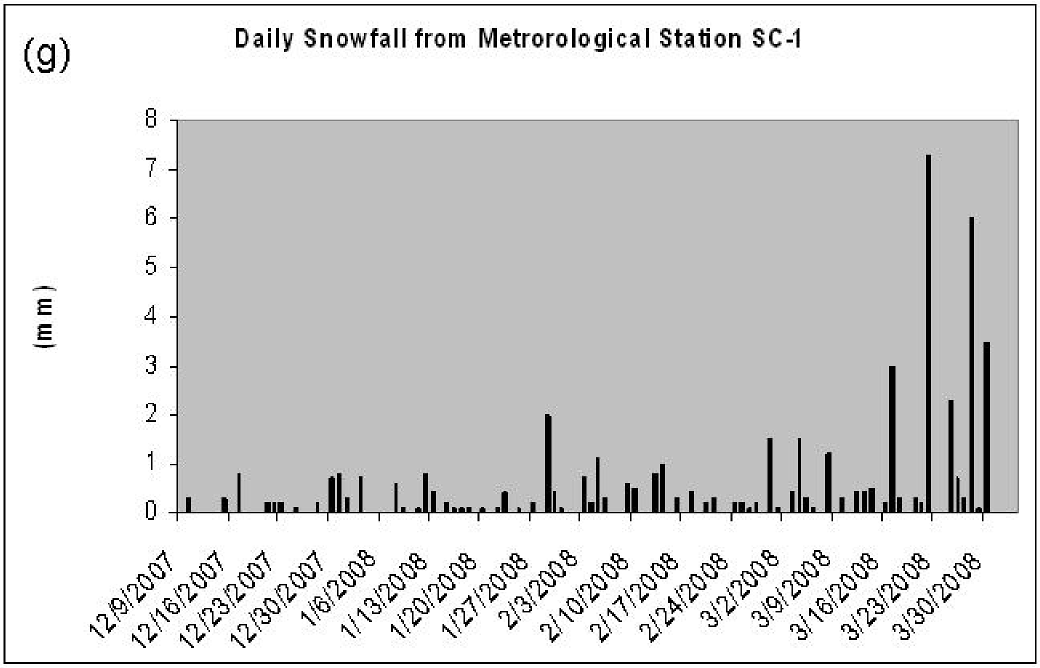


Figure 3. *Continued*.



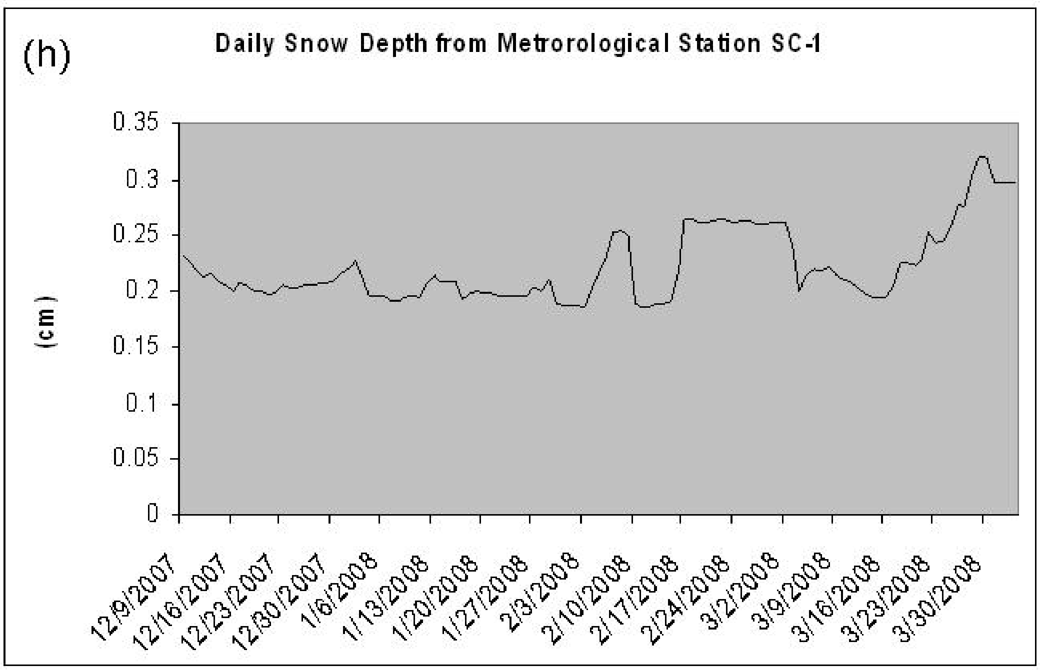


Figure 3. *Concluded*.

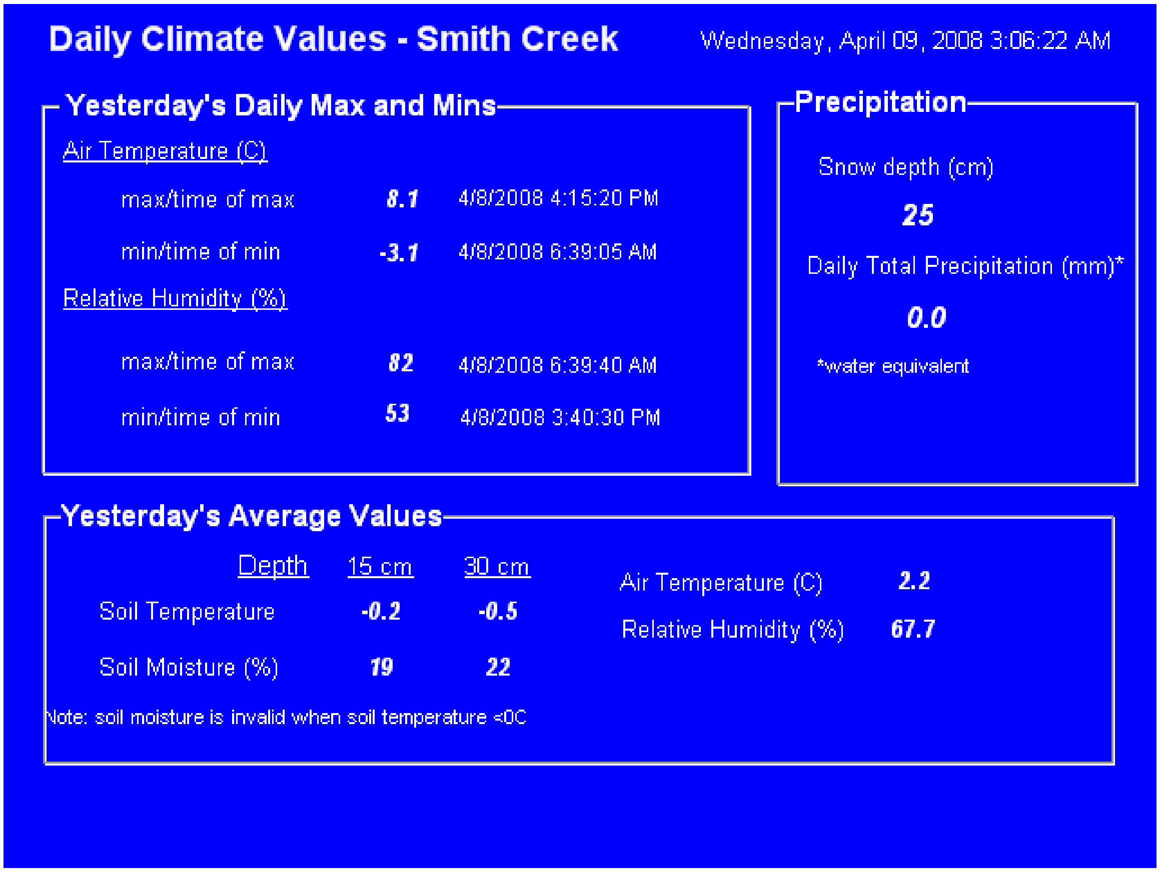


Figure 4. Website weather information in Smith Creek.

2). There are 10 rainfall stations in Smith Creek basin that were launched in the summer 2007. These stations are shown in Figure 5 and include both a tipping bucket raingauge and a storage raingauge. The tipping bucket raingauge has the ability to automatically record and store 5-mintue rainfall data over time but does not have good cumulative accuracy. The storage raingauge measures cumulative rainfall accurately over a period of time but cannot resolve short-term rainfall events. These stations recorded rainfall up to the fall of 2007 and provided useful information on the spatial variability of rainfall over the basin.

3). There are 7 water level stations in wetlands and lakes of Smith Creek basin that were launched in the summer of 2007 (Figure 6). These are instrumented with electronic pressure transducers that are able to automatically measure hourly water levels and water temperature and record them over time. These transducers continued to measure until the fall of 2007 and provided the “just-before freeze-up” water levels.

Soil properties and vegetation were surveyed in the fall of 2007 (Figure 7). In the soil survey, soil samples were collected from 18 field transects, located across the basin. These transects were selected in order to represent characteristic basin land uses such as summer fallow, grain stubble, grassland, woodland, and wetland. Soil samples were later analyzed in the Centre for Hydrology laboratory and volumetric soil moisture and porosity were derived from gravimetric measurements. Vegetation height, type, and density were collected from the same field transects. Fall soil moisture, soil porosity and vegetation height are important parameters for hydrological modelling of the basin.

To date, three sets of snow surveys were taken over the winter of 2007-2008. For each set, 420 samples of snow depth and 102 samples of snow density were collected from 18 field transects (Figure 8). These transects are located across basin and represent a variety of land uses such as summer fallow, grain stubble, grassland, woodland, wetland, river channel, and roadside ditch. The snow depth and density information is used to calculate snow accumulation which is important in evaluating the accuracy of hydrological models.

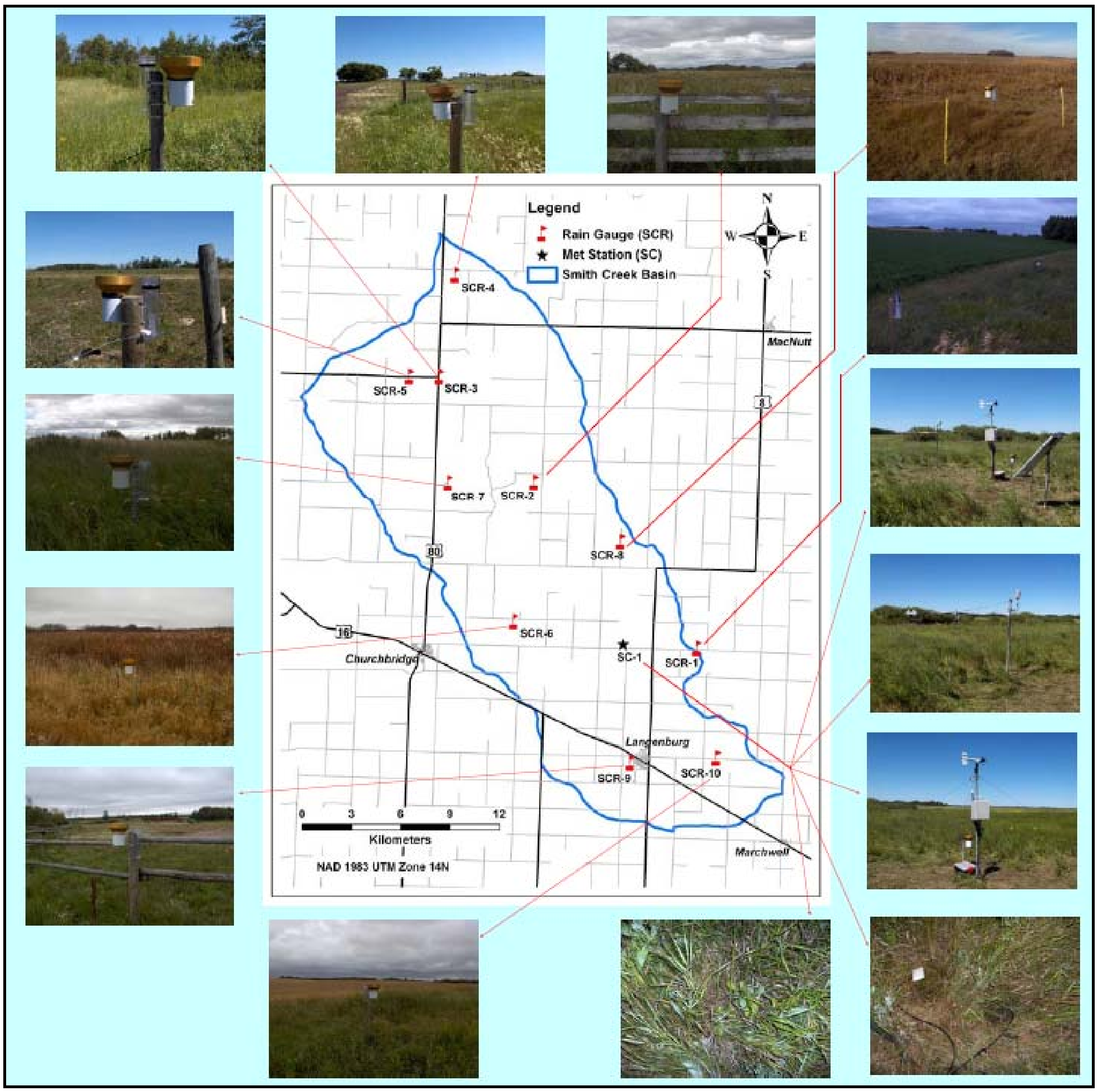


Figure 5. Rain gauge stations in Smith Creek.

Archived weather data from the 1950s to the present time were found from Yorkton, Langenburg, and Russell, MB and obtained from Environment Canada's database. These data include air temperature, relative humidity, wind speed, precipitation, and sunshine hour for either hourly or daily time intervals. In addition, historical streamflow data was obtained from the Water Survey Canada database and includes daily discharge at the outlet of Smith Creek near Marchwell during 1975-2006. Some of these historical data are shown in Figure 9 and will be used to simulate the historical hydrology of the basin.

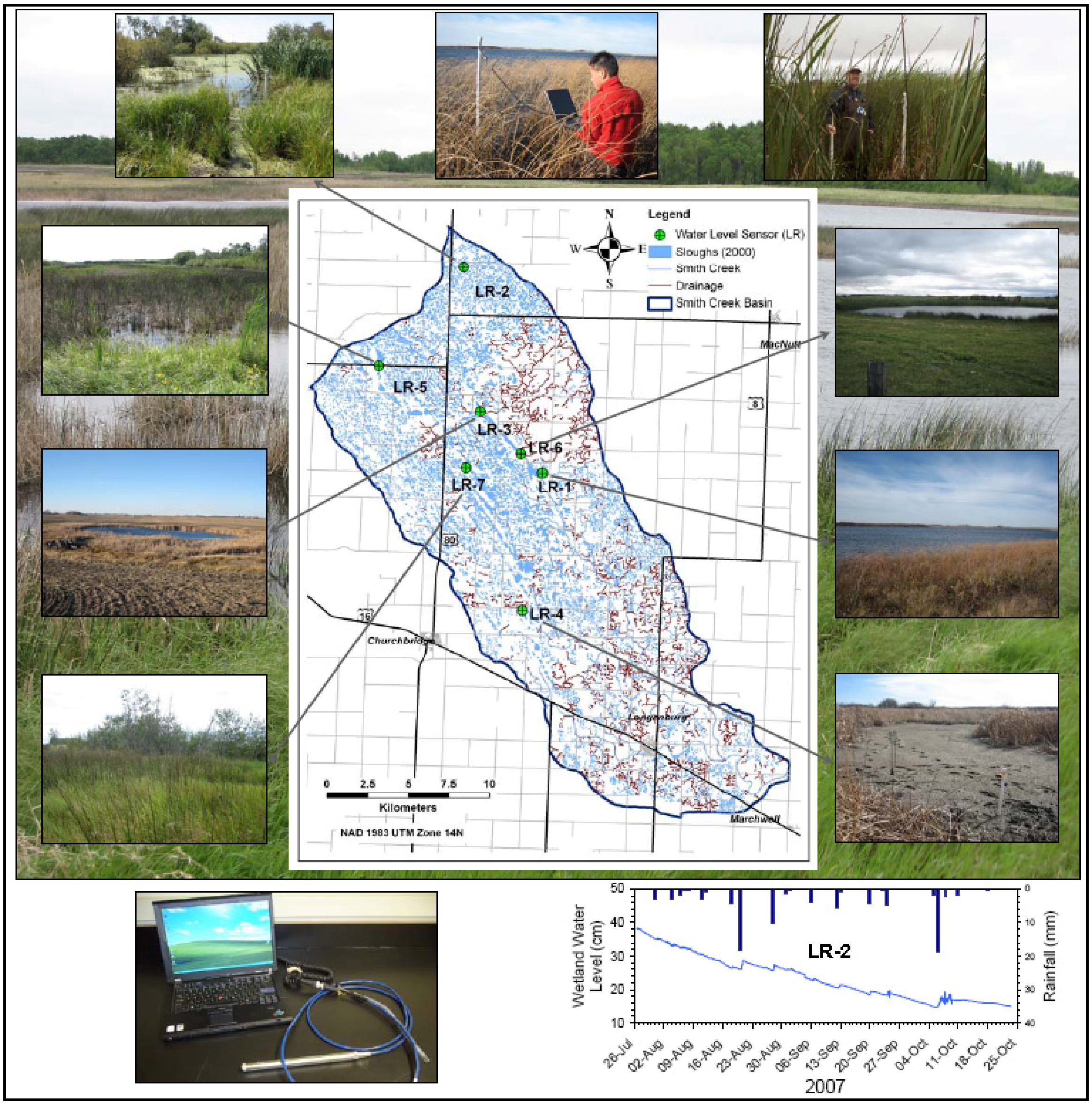


Figure 6. Wetland water level transducers in Smith Creek.

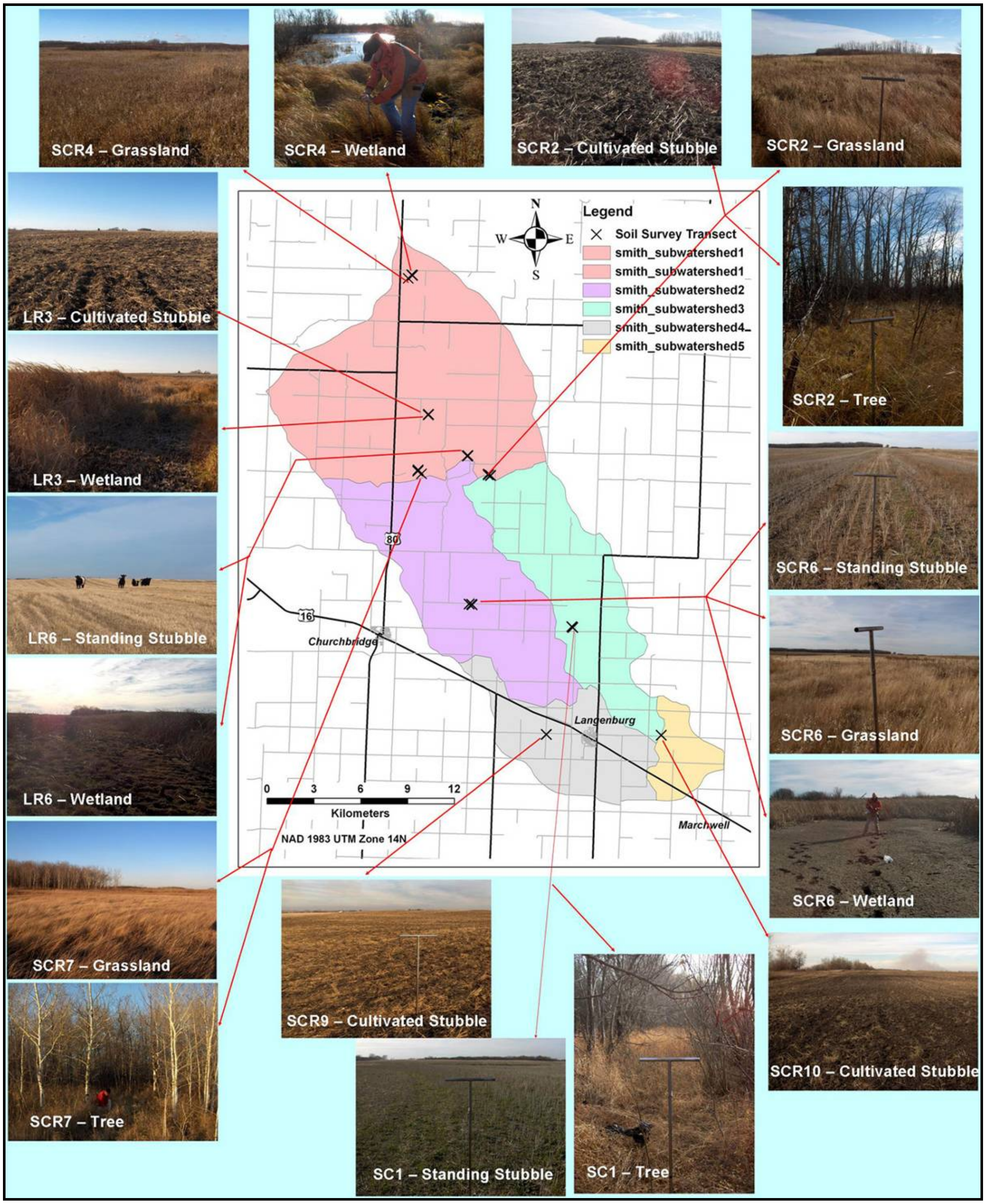


Figure 7. Soil and vegetation surveys in Smith Creek.

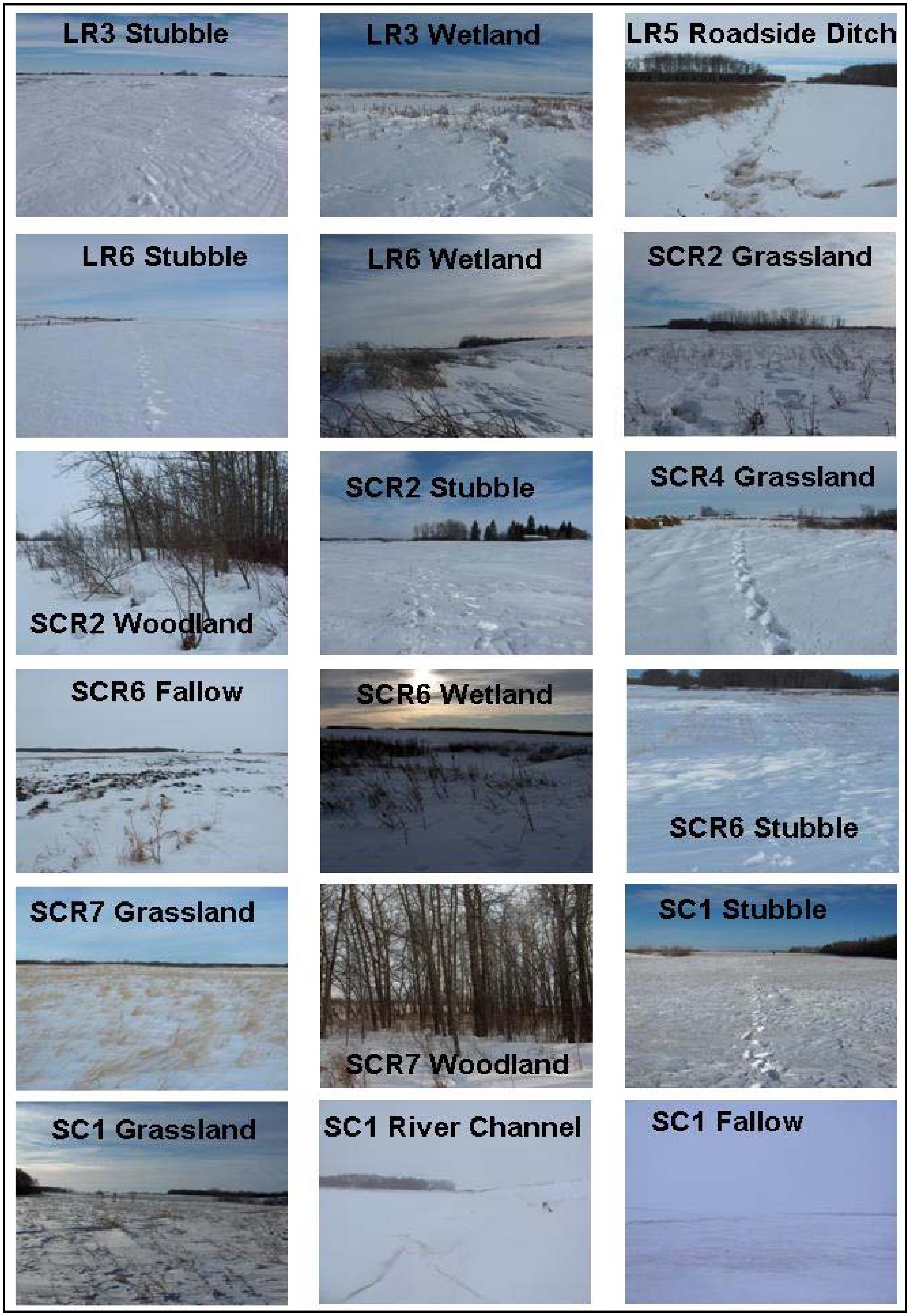


Figure 8. Snow survey transects in Smith Creek.

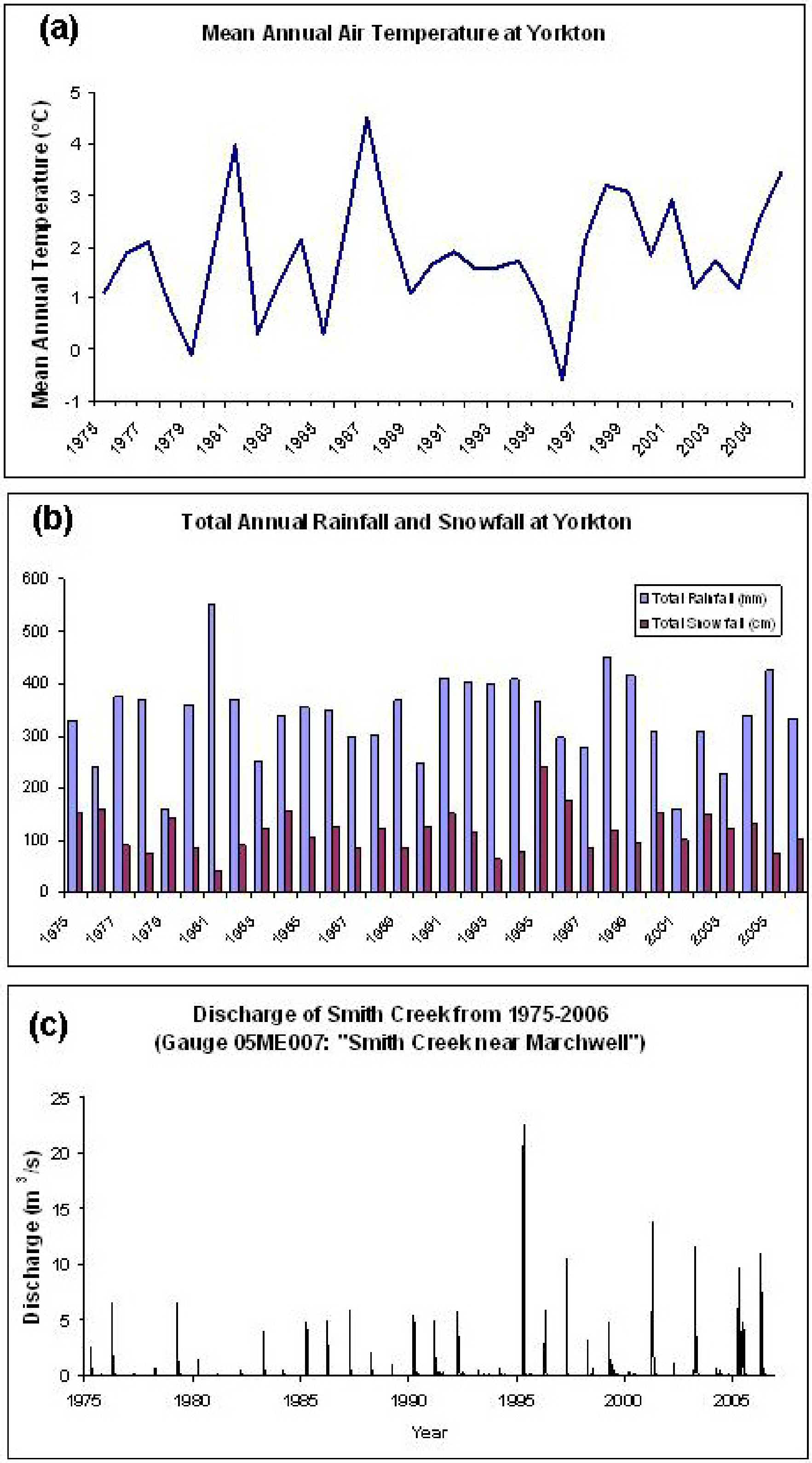


Figure 9. Historical data during 1975-2006: (a) mean annual air temperature from Yorkton (b) total annual precipitation from Yorkton (c) daily discharge in Smith Creek near Marchwell.

2. Land Use Classification and Basin Delineation

Initial efforts to delineate the basin area, drainage network and sub-basins used various existing automated GIS terrain preprocessing techniques including those in TOPAZ, Topographic Wetness Index, and HEC-HMS. These techniques did not generate reasonable results. The main reason is that GIS-based techniques do not work well in low relief prairie environments and relatively coarse DEMs. Manual delineation techniques were therefore employed. Smith Creek was broken down into five sub-basins based on information derived from a combination of the automated GIS techniques and from examinations of DEM, aerial photography, and satellite imagery.

Remote sensing was used to derive both historical and current land use classifications in Smith Creek. The information for the historical land use was acquired from Ducks Unlimited Canada (DUC) and the classification was conducted using historical aerial photography from 1958. For the current classification, SPOT 5 imagery taken in summer 2007 was used in PCI Geomatica to conduct an unsupervised classification of the images. Ground truthing information was obtained from site visits and from conversations with local farmers. Ground truthing permitted the identification of the classification features. Both historical and current land use classifications (Figure 10) provide the basis for setting parameters in CRHM such as basin area, HRU area, HRU soil type, HRU surface cover and so on.

In addition, datasets consisting of historical (1958) and current (2000) channels and wetlands were obtained from DUC. These datasets were used to create the historical and current drainage networks (Figure 11), which will be used to set up parameters in CRHM such as channel length, channel shape, slope of channel reach, wetland area, wetland storage and so forth.

The experience of delineating the basin has been instructive. There remain considerable uncertainties in the flow network and basin area that cannot be resolved with the current digital topography available. It would be desirable to obtain a high resolution digital elevation model for Smith Creek, such as that which is possible from an airborne LiDAR survey. Such information would permit a much more reliable calculation of water flow direction and storage and provide a baseline for further changes in drainage in the basin. While the cost of LiDAR is high (several $10s of thousands), it might be possible to include Smith Creek in LiDAR surveying of nearby areas. The scientists ask the Committee to identify any opportunities to obtain LiDAR for Smith Creek including funding support for the same.

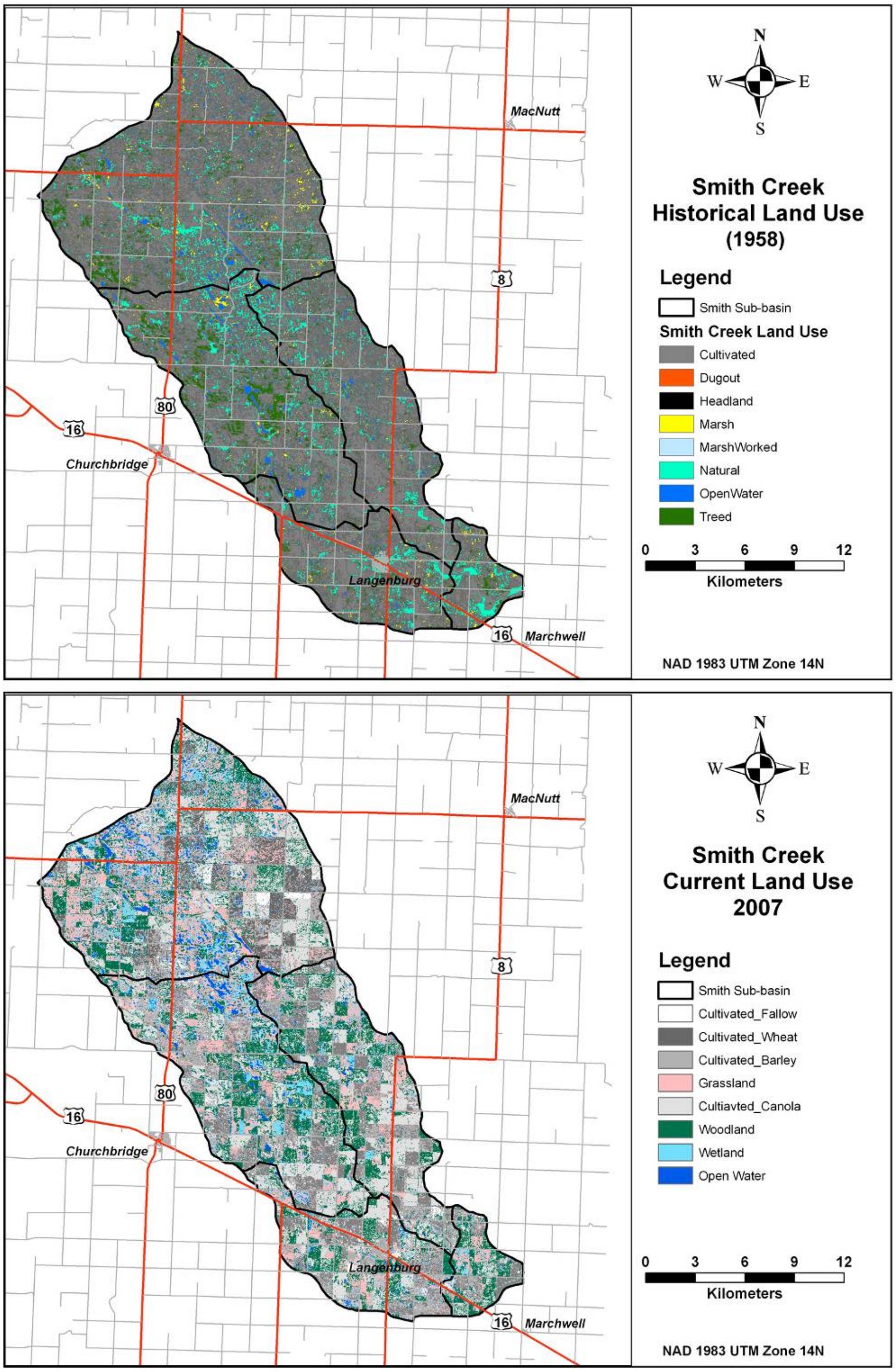


Figure 10. Smith Creek historical and current land use.

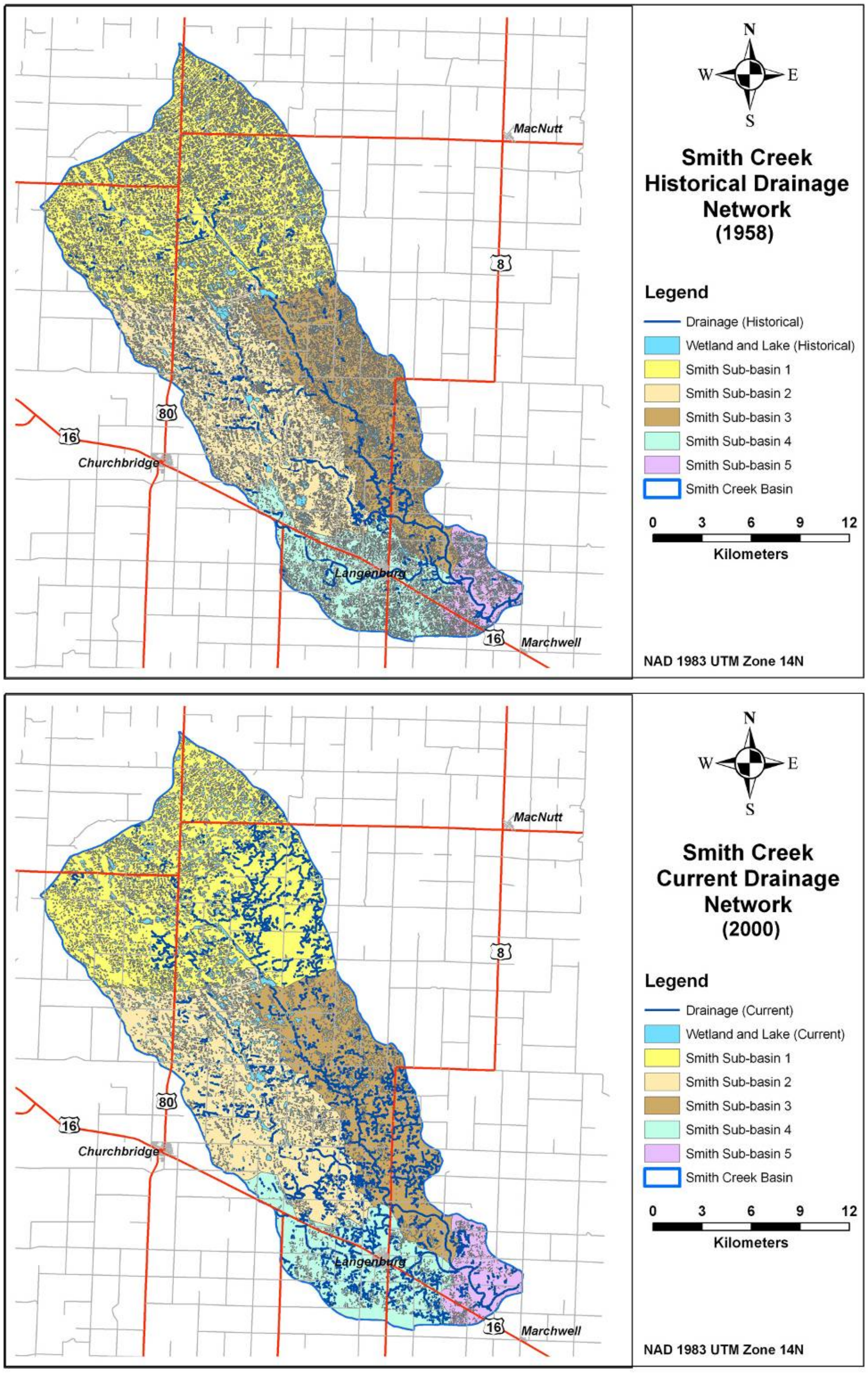


Figure 11. Smith Creek historical and current drainage network.

3. Improvements to CRHM – Prairie Hydrological Model

A new development in CRHM-PHM (Figure 12) is the ability to link typical sub-basins as Representative Basins (REB). REBs characterize well drained, wooded, wetland, and lake sub-basins and then are linked by CRHM using a kinematic wave routing system with allocation for network wetlands and lakes. The ponding routines in CRHM have also been improved so that sub-hydrological response unit (HRU) depressional storage is represented realistically. Within-basin routing now has a Muskingum routing option which permits setting routing characteristics based on basin properties. Improvements have also been made to the soil moisture routines, evaporation calculations and snowmelt routines. Changes to the soil routine permit a HRU to be declared a "pond" which can drain slowly or display "fill and spill" behaviour as observed for upland till ponds in the St Denis wetlands.

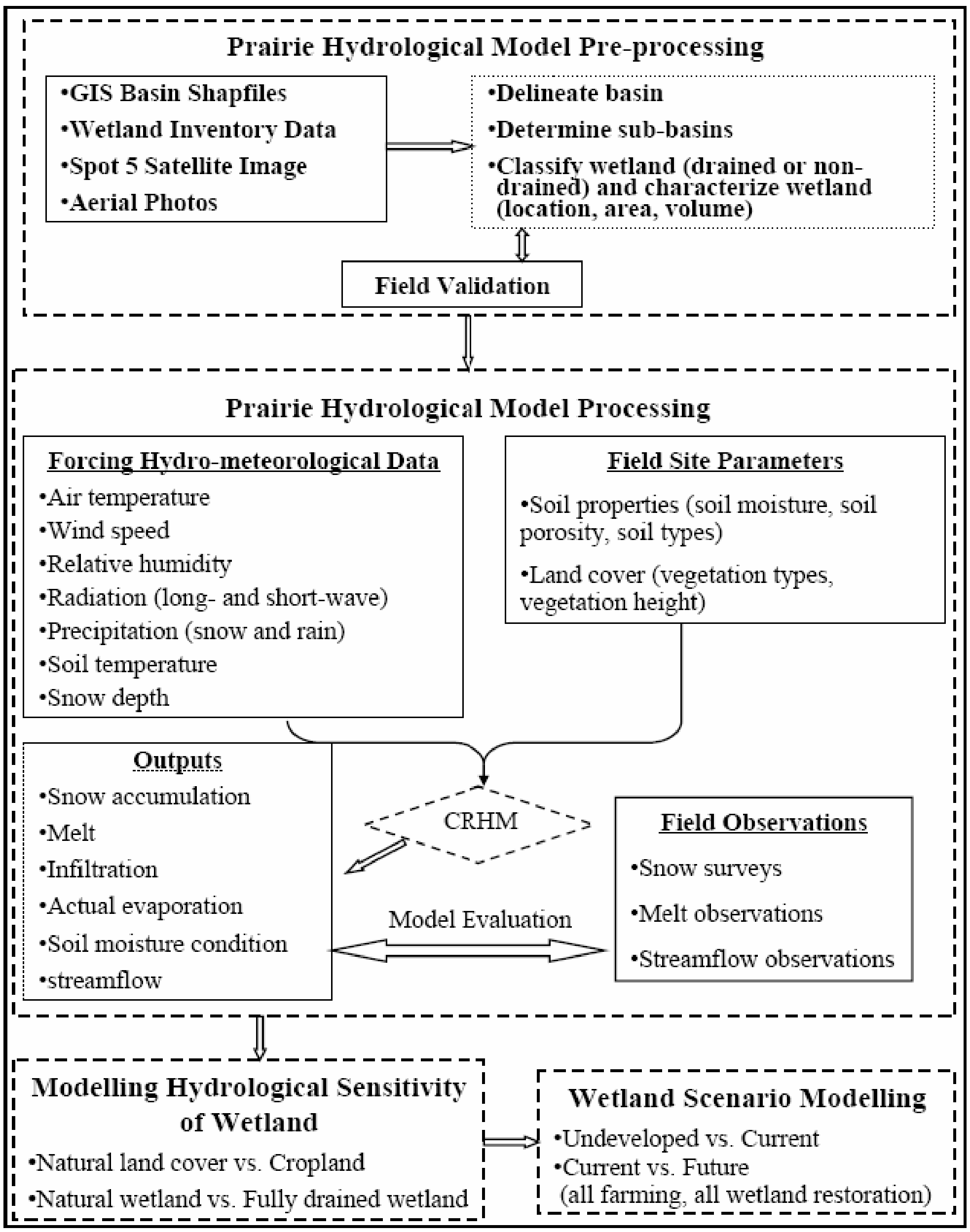


Figure 12. CRHM-PHM methodology.

A preliminary test run was conducted using CRHM-PHM driving with archival meteorological data from 1965-66. Seven HRUs: fallow, stubble, grassland, river channel, open water, woodland, and wetland were set up for sub-basin 1 which is a REB. The physical parameters such REB area, HRU area, HRU location, channel length, soil type, surface cover, wetland storage were derived from historical land use and historical drainage network as mentioned in last section. The simulated winter snow accumulation is shown in Figure 13. The results are encouraging and show the landscapes where snow accumulates in Smith Creek; that is, snow is blown from land uses with low surface roughness such as fallow, stubble and open water to land uses with high surface roughness such as wetlands, woodlands and river channels, forming snow drifts.

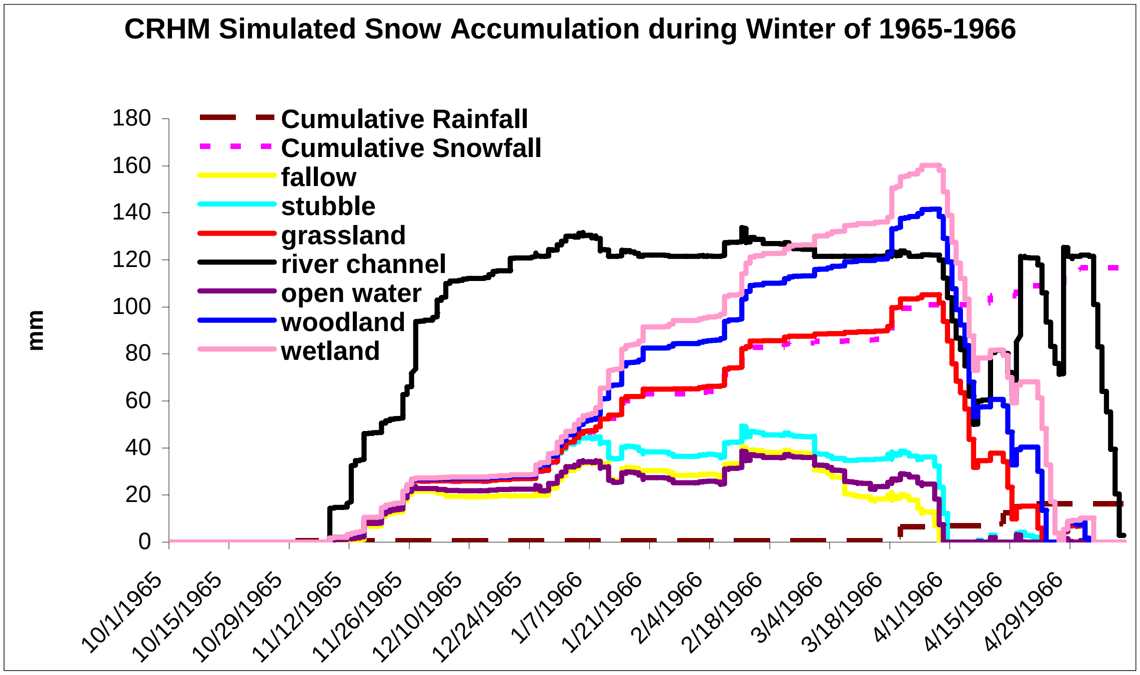


Figure 13. Preliminary test of CRHM-PHM: snow accumulation during winter 1965-66.