Canadian Foundation for Climate and Atmospheric Sciences (CFCAS)
Fondation canadienne pour les sciences du climat et de l'atmosphère (FCSCA)

Final Progress Report

Project Title: (Insert Title)

DRI Investigator: Garth van der Kamp

1.0 Project Work

1.1 Provide a summary description of a) the objectives of the study, b) the scientific findings and c) the project work undertaken.

a) Objectives of the study

Overall Objective: To study the relationship of groundwater levels to soil moisture and surface water.

Methodology

1. Assemble and help to analyze hydrologic data on groundwater levels, streamflow, lake levels and wetland water levels in Saskatchewan. Most of these records go back at least 40 years and are up-to-date through the recent drought. This work will be carried out in conjunction with the same work for Alberta (Hayashi) and Manitoba (Woodbury).
2. Document and make available the long-term vertical water balance information contained in observation well records, and help to relate these to soil moisture and snow conditions, particularly for initializing and calibrating soil moisture models.
3. Study groundwater and drought processes on the 6 km2 research site of St Denis National wildlife Area near Saskatoon, where a great deal of hydrologic research has been done and is on-going. The site encompasses many wetlands within closed drainage basins, and various types of upland cover. This work will be carried out in conjunction with surface hydrology studies at the site (Pomeroy, Granger) and will be done in consultation with similar investigations within the Nose Creek watershed in Alberta (Hayashi) and the Assiniboine Delta site in Manitoba (Woodbury).

b) Scientific findings

A conference proceedings paper (Anochikwa et al 2009) and a journal paper (Anochikwa et al, 2010 – submitted) introduces the concept of geological weighing lysimeters to the Canadian and global geotechnical engineering community. These papers show that changes of groundwater levels in a deep aquifer may be largely due to changes of the total moisture above the aquifer, transmitted to the aquifer as changes of stress due to changes of the weight of water above the aquifer.

Some of the deep observation wells have been identified as acting like geological weighing lysimeters which provide information on changes of total moisture over large areas. Data from these wells are being compared with the moisture budgets derived from GRACE satellite data and with the results of simulations with a hydrologic model (Marin et al, 2010), particularly with regard to how well the models simulate evapotranspiration during the drought when soil moisture stress is extreme and deep-rooted vegetation tends to draw on deeper groundwater stores. It was found that the model that was tested does not allow for deep-rooted vegetation to draw water from the water table and thus the model failed to simulate evapotranspiration during extreme drought when soil moisture is near zero.

Evapotranspiration from prairie grasslands is strongly suppressed during drought, so that most of the net radiation energy is returned to the atmosphere as sensible heat, whereas the evapotranspiration from the forest is only mildly reduced during drought (Zha et al., 2010.).

ET losses from the BERMS fen during the last year of the drought (2003) were not significantly lower than in the following very wet years, but net carbon uptake was minimal in 2003 (Sonnentag et al., 2010).

c) Project work undertaken

Groundwater observation well data from across the prairies (MB, SK, AB) have been compiled in a consistent monthly format. The data for shallow water table wells show how groundwater storage was depleted during the drought and how it recovered afterwards. These data will be incorporated in a paper(s) to characterize the drought (Hanesiak et al., in prep).

A commercially available numerical model for flow and deformation in porous media has been adapted for the analysis of pore pressure data obtained from geological weighing lysimeters at the BERMS/Fluxnet Old Aspen site and at the Kernen Farm grassland site near Saskatoon (Anochikwa, MSC thesis, U of Saskatchewan, February 2010). This technique will allow improved hour-by-hour characterization of precipitation and evapotranspiration over an area of about 10 hectares for the period 1998-present which includes the drought.

Water and energy flux data from the BERMS/Fluxnet forest sites in SK and from the grassland Fluxnet site in southern Alberta have been compared with particular emphasis on the water and energy fluxes during the drought years

Flux data for a fen in the BERMS area (southern boreal forest, SK) have been compiled and analyzed with regard to variability of the fluxes during and after the drought.

1.3 **Describe the tangible results or the measurable outputs generated by the project and how these results have been taken up by user groups for policy development or operational improvements.**

The results consist of published journal and conference papers, compiled data sets, and training of several graduate students and post-doctorate fellows.

2.0 Impact

2.1 Describe in broad terms how your work has contributed to the overall objectives of DRI and to our scientific understanding of drought.

The work has provided new insight into the exchanges of water and energy between the ground surface and the atmosphere during drought, and into how these can be modeled. It is demonstrated that the fluxes from the boreal forest bordering the prairie ecozone do not change a great deal between wet and drought years, implying the forest zone moderates the onset and duration of prairie drought. Prairie grasslands on the other hand have strongly suppressed evapotranspiration during drought so that little moisture is returned to the atmosphere.

2.2 Describe the significance / impact of the results in terms of some or all of the following areas:

- **The impact of the project on government policy development (federal, provincial or municipal);**
- **How the project has expanded contacts in partner organizations, or increased cross-disciplinary cooperation;**
- **Whether and how it has enhanced or improved the reliability of predictive methods related to the science;**
- **The impact of the project on your own institution (e.g. helped attract new students or personnel);**
- **Whether it has improved or increased the acquisition of funds from other agencies, or led to new partnerships;**
- **Any links with international initiatives and the potential impact of these (e.g. profile of Canadian science, influence on international programs);**
- **Any commercial or social application the results may have had or could have;**
- **The anticipated impact of the work on Canadians and their well-being;**

The geological weighing lysimeter method is showing increasing recognition for wide application in testing hydrological models, for real-time assessments and forecasting of droughts and floods, and for tracking of land-atmosphere moisture exchanges in relation to climate and weather prediction models.
The compiled observation well records across the prairie region are being shared with the provincial groundwater agencies, and are being discussed in relation to how groundwater levels respond to drought and climate variability.

6.0 Dissemination

6.1 Provide information on the dissemination of the research results (publications, including journal names and whether refereed), conference contributions, seminars, workshops or videos, websites or other methods of transferring the results.

Papers in refereed journals

Barr, A. G. , G. van der Kamp, T. A. Black, J. H. McCaughey, N. Hedstrom and Z. Nesic, A. G. 2010. Comparing Water and Energy Balance Closure at the BERMS Flux Towers 1999-2009. Submitted to Agr and Forest Meteorology, December 2010.

Shaw D. A., G. van der Kamp, and M. Conly, 2010. The fill-spill hydrology of prairie pothole complexes during drought and deluge. For submission to Hydrologic Processes

Anochikwa, C., G. van der Kamp and L.S. Barbour, 2010. Use of a coupled flow and stress model to simulate the effects of mechanical loading by surface moisture on pore pressures in saturated media. Submitted to Canadian Geotechnical Journal, December 2010.

Zha, T., A.G. Barr, G. van der Kamp, T.A. Black, J. H. McCaughey and L. B. Flanagan, 2010. Interannual variability in evapotranspiration from forest and grassland ecosystems in western Canada in relation to drought. Agricultural and Forest Meteorology, 150, 1476-1484. [doi:10.1016/j.agrformet.2010.08.003].

Sonnentag O, van der Kamp G, Barr AG, Chen JM, 2010. On the relationship between water table depth and water vapor and carbon dioxide fluxes in a minerotrophic fen. Global Change Biology, 16, 1762-1776. [doi: 10.1111/j.1365-2486.2009.02032].

Minke, A.G., Westbrook, C.J., and van der Kamp, G., 2010. Simplified volume-area-depth method for estimating water storage of prairie potholes. Wetlands 30, 541-551.

Marin, Saul, G. van der Kamp, A. Pietroniro, B. Davison and B. Toth, 2010. Use of Geological Weighing Lysimeters to Calibrate a Distributed Hydrological Model for the Simulation of Land-Atmosphere Moisture Exchange. In Press, J of Hydrology.

Toth, B., D.R.Corkall, D.J. Sauchyn, G.van der Kamp, E. Pietroniro, 2009. The Natural Characteristics of the South Saskatchewan River Basin, Climate, Geography and Hydrology. Prairie Forum-Special Climate Change Issue, 34 (1), 95-127.
Bruneau, J, D.R. Corkal, E. Pietroniro, B. Toth, and G. van der Kamp , 2009. Human activities and water use in the South Saskatchewan river basin. Prairie Forum-Special Climate Change Issue, 34 (1), 129-152.

Papers in Conference Proceedings and Non-refereed Journal Papers

Anochikwa, C.I., G. van der Kamp and S. L. Barbour, 2009. Numerical Simulation of Observed Pore-Pressure Changes in an Aquitard due to Changes of Total Soil Moisture. Proceedings of the 10th Joint Groundwater Conference of the Canadian Geotechnical Society and the Canadian National Chapter of the International Association of Hydrogeologists (CGS/IAH-CNC), Halifax NS, September 20-24, 2009, 1600-1606.

Bruneau, J., D. R. Corkal, E Pietroniro, B Toth, and G van der Kamp, 2008. Human Activities and Water Use in the South Saskatchewan River Basin, Climate 2008/Klima 2008 Online conference, Germany, Nov 3-7, 2008.

Conference Presentations

van der Kamp, G. and M. Hayashi, 2010. An overview of the processes that control the water balance and salinity of prairie wetlands. **Invited Keynote Presentation**, Symposium on Wetlands: Transfers and Transformations, Canadian Society of Soil Science Conference, June 20-24, 2010, Saskatoon SK.
van der Kamp G. and A. G. Barr, 2010. The CCP-Fluxnet Canada network and the interplay between energy, water and carbon uptake in the landscape. **Invited presentation**, Session on carbon cycling of Canadian forests and peatlands, CGU-CMOS conference, May 30-June 4, 2010, Ottawa.

van der Kamp, G. and M. Hayashi, 2010. Groundwater and drought in the prairies – what observation well data can tell us. Session on Drought and society, CGU-CMOS conference, May 30-June 4, 2010, Ottawa.

Ehsanzadeh, E., C. Spence and G.van der Kamp, 2010. Use of available hydrometric data to characterize depressional storage and ever-changing effective drainage areas in North American Prairie watersheds, CGU-CMOS conference, May 30-June 4, 2010, Ottawa.

van der Kamp, G., 2010. The Groundwater connection. **Invited presentation**, CFCAS-EC Symposium on Water Security, Ottawa, May 27-28, 2010.
van der Kamp, G. 2010. Hydrology, Climate and the Threat to Wetlands. **Invited Keynote Presentation**. International workshop on Wetlands Management, Economics and Policy, Victoria, BC, January 13-15, 2010.
van der Kamp, G., 2009. Long-term water-level changes of prairie lakes – century scale variations of water availability. **Invited presentation**. DRI Prairie Hydrology workshop, Saskatoon, Nov 18, 2009
van der Kamp G. 2009. Ecohydro(geo)logy of the southern boreal forest in Saskatchewan: From piezometers to eddy-flux towers and everything between. **Invited seminar**, Dept of Earth and Environmental Sciences, U of Waterloo, Sept 18, 2009.
Anochikwa, C.I., G. van der Kamp and S. L. Barbour, 2009. Numerical Simulation of Observed Pore-Pressure Changes in an Aquitard due to Changes of Total Soil Moisture. Proceedings of the 10th Joint Groundwater Conference of the Canadian Geotechnical Society and the Canadian National Chapter of the International Association of Hydrogeologists (CGS/IAH-CNC), Halifax NS, September 20-24, 2009.
van der Kamp, G., 2009. Long-term water level changes in closed-basin lakes of the Canadian prairies and the role of groundwater. **Invited keynote** presentation at the Annual Conference of Alberta Environment Provincial Water Act held in Banff, AB, March 22-24, 2009.
van der Kamp, G., M. Hayashi, 2009. Prairie Wetlands and their Catchments: Hydrological Understanding and Management Implications for Drainage and Groundwater Recharge. **Invited keynote** presentation at the Annual Conference of Alberta Environment Provincial Water Act held in Banff, AB, March 22-24, 2009.

6.2 Describe data management/sharing activities including organization of the metadata. Also, are the data being archived, and how will they be made available to other researchers?

Groundwater observation well data for the three prairie provinces have been compiled in a consistent monthly format and are archived.

6.3 Comment on any outreach or public information activities, including press interviews or other media interest or reports. Has the project helped to popularize science or increase public awareness?

Short article on flow of the South Saskatchewan River for the Saskatoon Sun, March 1, 2009, emphasizing that the flows in the river are reasonably secure as long as we do not greatly increase the amount of water being removed, mainly for irrigation. A similar short article on April 22, 2010 describing the importance of groundwater during drought for water supply, for deep-rooted vegetation and for maintaining flow in streams and springs.

7.0 <u>Training</u>

7.1 Quantify student and PDF involvement (indicate the level of each: undergraduate, masters, doctorate or PDF). If possible and within the Federal Privacy Act rules governing the collection of personal information, provide a general indication of their subsequent employment (i.e., university, industry, government, other, etc.), and indicate whether the employment was foreign or domestic.

1 master'student (modeling and analysis for geological weighing lysimeters)
1 post-doctoral fellow (1/3 time): comparison of forest and grassland fluxes during drought