Literature Review

Surface Water & Shallow Hydrogeology

Integrated Assessment of Water Resources for Unconventional Oil and Gas Plays, West-Central Alberta

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Prepared by:
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EXECUTIVE SUMMARY

The Integrated Assessment of Water Resources for Unconventional Oil and Gas Plays, West-Central Alberta, is a multi-stakeholder project that is building a regional understanding of surface water, groundwater and deep saline water resources and disposal zones in a large portion of west-central Alberta.

The project is compiling existing data and research results, interpreting key factors controlling water availability, and integrating the results from surface to deep subsurface zones.

An initial phase of the project involved a survey of existing knowledge in the form of publically available research products. This report summarizes the results of this survey, in the form of an annotated bibliography for selected references and additional listed references for follow up on specific items of interest.

In parallel to the literature review, compilation was undertaken for spatial data related to aspects of both surface water and groundwater systems. Information on the provenance of these data sources is available under separate cover in companion with the data itself. There exists some overlap, however, particularly in cases where journal articles or government publications relating to the development of specific data products are included.
## CONTENTS

### Annotated Bibliography

1. Current and Future Water Use in Alberta, Alberta Environment 2007. .................................................. 1

### Other references of interest:

- Climate .................................................................................................................................................. 18
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Comments:

- Study looking at current water allocations, use and use forecasts for 12 major river basins in Alberta.
- Major sectors considered include municipal, agriculture, commercial, petroleum, and industrial.
- Relevant to the study area are: Red Deer, North Saskatchewan, Battle, Athabasca, and Peace/Slave.
- Distinguishes between licensed and actual water use.

Comments:

"Characterizing the current state of one’s watershed, its problems, and the pressures upon it can provide the basis for developing effective management strategies to meet watershed goals. This, along with the desired Water for Life outcome that “Albertans have the knowledge, tools, and motivation to implement actions that will maintain or improve the province’s water resources,” was the impetus behind drafting the document"

- basic process for any scale or any landscape, for gathering and evaluating information to develop an understanding of past and current watershed conditions and their influencing factors.

- objectives are to assess environmental conditions and setting and achieving environmental outcomes within watershed

- analysis of how landscape and hydrologic systems interact and function within the watershed. examining history of the watershed

  - scientific interpretation of watershed information and data, leading to conclusions about watershed condition
  - objective tool that uses available data and information to assess conditions and concerns within a watershed, as well as identify information gaps
  - a report on the analysis and findings of the watershed assessment that by identifying factors potentially contributing to concerns within the watershed, can be used to develop appropriate actions; and
  - component of a watershed management package that leads to planning, implementation and evaluation

- not a plan or endpoint

- understanding how natural features and processes influence watershed conditions

- insight into linkages between watershed health and land and water uses

  a) purpose
     - provide background for future planning
     - identify sensitive or at-risk areas
     - identify information and knowledge gaps
  b) scale
  c) format

(1) Plan the watershed assessment - purpose, focus, plan
(2) characterizing watershed - data and gaps
(3) analyzing and presenting data - context is key
(4) integrate information - interactions and relationships between themes
(5) drafting report
(6) using information for decision making
Intro:

- Objective: Gain understanding of the current water supply or water yield from basins in Alberta through an analysis of existing records of stream flow data and other information.
- Surface water and ground water
- Secondary objective, path forward to assess potential effects of climate change on future water yield
- Hydrologic regionalization of Alberta, accounting for non-contributing areas that are relevant in some manly east-central and southern watersheds
- Compilation and analysis of flow data based on hydrologic regions
- Regions based on topography, climate, hydrology, drainage, geology, and soils.
- Groundwater: elementary estimates of recharge, discharge and sustainable yield
  - Baseflow separation
  - Aquifer vulnerability index map for agricultural areas of Alberta, ERCB/AGS map Natural suitability of geological setting for waste management, Alberta Canada.
- Sustainable yield as 15% of difference between total open-water baseflow and the total (8 mo) ecological portion of open-water baseflow equivalent to the 20th percentile of the average of the winter monthly mean flows.
  - Winter baseflow 4.8 billion m$^3$
  - Assuming winter baseflow = minimum recharge, annualized recharge = 14.6 billion m$^3$
  - Accounting for increases in open-water baseflow, baseflow = 25 billion m$^3$
  - Different approaches would put baseflow range between 15 and 30 billion m$^3$
  - Surficial geology interpretation estimate 27.1 billion m$^3$
  - Using above method, sustainable groundwater yield would be 1.9 billion m$^3$

- Identified North Saskatchewan River and Battle River as basins showing supply-demand constraints during part of the year
- Identify larger natural variability of water supply than recorded since European settlement -> increased adaptation capacity required

Body:

- Average annual ppt < et for most of the southern part of the province.
- Groundwater allocations only 3% of licenses. But primary source for substantial portion of rural Alberta.
- Saline water source push coming from oil sands
- Reliable, quality water supplies to include:
  o Dependability
  o Sustainability, for now and future generations and growth of the province
  o Suitability for all practical uses
  o Maintenance of the health of aquatic ecosystems and environmental sustainability
  o Water supply that is well understood, wisely managed, protected from quantity and quality impacts, and can be passed on with suitable quantity and quality to downstream stakeholders.
- Supply and demand in balance form basic tenet of reliability, and assurance that sufficient water supplies are available under most, if not all conceivable conditions.
- Can demand growth be mitigated through efficiency and productivity alone, or are new more elaborate (expensive) measures such as reservoirs and storage needed.
- Hydrologic response a function of drainage area, slope, precipitation, temperature, evapotranspiration and infiltration.
- Looked at relationship between drainage area and mean annual runoff, 2 yr and 10 yr flood, mean Feb flows
- Prairie hydrology makes a distinction between effective drainage area which is area that contributes runoff during 2 year flood, and gross drainage area which contributes runoff only during very wet conditions and is topography based.
- Groundwater recharge locally concentrated in low lying areas collecting more snow and runoff or from streams, ponds, lakes that fill above water table in parts of the year. For majority of year, groundwater flows by gravity from high to low elevations, typically discharging into surface water bodies. Groundwater provides base flow to streams and rivers and may be the only source of flow during dry or winter months.
- Estimate 22mm of recharge below phreatic surface to deeper groundwater stores (still in communication with SW but year to decade or longer transit time)
- Connection between groundwater and surface water makes it only one resource – with different replenishment times. Conjunctive management of the resource might allow groundwater to be pumped at greater rates when surface supplies are reduced, and then aquifers allowed to recharge when surface water is more abundant.
- Sustainable groundwater yield of 4-9mm per year, average 5.2mm.
- Climate change study suggested reduction of flows of -13% to -4%.

Included in the paper are additional presentations from a workshop:

- Kevin Shook
  o Prairie hydrological processes:
    ▪ Transport of water in liquid, vapour and frozen – runoff, percolation, evapotranspiration, sublimation, blowing snow
    ▪ Phase changes in snow and snows – snowmelt, infiltration in frozen soils, soil freeze thaw
    ▪ Snow and rain interception
- Episodic flow between soil, groundwater, ponds and streams
- Variable storage, drainage and contributing areas
- Land use changes

- DH Burn presentation
  - Issues with water supply include non-stationarity, trending series
  - Use LOESS
  - T-test, Mann-Kendall test for trend
- Sauchyn pres
  - Carbon dynamics don’t support direct link between growth and drought – see drought evapotranspiration studies.
- Use 15% of MAF as reasonable allocation limit

**Additional references from within publication:**


Comments:

Metrics on:

- Land Use
  - Riparian health
  - Linear development
  - Land use inventory
  - Livestock density
  - Wetland inventory
- Water quality
  - Surface water quality index (AENV)
  - E. coli
  - Phosphorous
  - Pesticides
- Water quantity
  - Water allocations by sector
  - Groundwater extraction
- Biological indicator
  - Aquatic macrophytes
  - Fish (population estimates)
  - Vegetation types (Alberta vegetation inventory)
  - Benthic invertebrates

- Focus on land use and water quality impacts
- Some info on natural regions - foothills, fescue, etc.
- Limited commentary on indicator impact on hydrology

Additional references from within publication:


Comments:

- Red Deer River joins S. Saskatchewan 8km into Saskatchewan.

6 indicators:

- Wetland loss - condition
- Riparian health - condition
- livestock manure production - risk
- urban, rural and recreational development - risk
- linear developments - condition indicator
- oil and gas activities - risk indicator

Additional references from within publication:


Additional references from within publication:


Comments:
- Prolonged droughts outside of gauged record.
- Assumption of stationarity in hydrometric data is undermined by observations preceding and future projections.
- May 1796, no water in the river at Edmonton to export furs - Sauchyn 2003.
- Tree ring reconstruction linked to past hydro-climate
- Future extreme fluctuations partly represent natural variability that exceeds the range measured over the instrumental period.
- Evidence for extended droughts not in gauged record.

Additional references from within publication:


Comments:
- Catchment a series of interlinked reservoirs, each of which has components of recharge, storage and discharge. Recharge dependent on precipitation, storage and discharge complex functions of catchment physiographic characteristics. Processes usually operate in the vicinity of the river channel zones as opposed to the full range of hydrological processes that operate over larger parts of catchments during periods of higher discharge.
- For low flows to be sustainable, the draining aquifer must be recharged seasonally with adequate amounts of moisture, the water table must be shallow enough to be intersected by the stream and the aquifers size and hydraulic properties must be sufficient to maintain flows throughout the dry season.
- Low flows may be sustained by drainage of a saturated top soil zone throughflow rather than by deeper groundwater (Anderson 1980)
- Near channel storage, alluvial or channel bank storage may or may not be in contact with phreatic surface and is not technically groundwater.
- Effects of groundwater pumping near the head of a perennial river may result in gw table depletion through interception of recharge water and induced recharge of the aquifer from the river itself. Results in substantial environmental degradation of the river habitats etc.
- Use log-normal for FDC
- Monthly window acceptable for FDC – Mngodo 1997
- 7Q10 and 7Q2 most widely used in USA
- Reviews of baseflow separation techniques
- Most significant parameters with regard to low flows – drainage density, ratio of length of tributaries to length of main channel, percent of drainage area w/ ne aspect, average weighted slope.

Additional references from within publication:


Comments:
- Wapaba model based on Budyko framework.
- Uses consumption curves to partition water
- No disadvantage to not considering within month variability.
- Supports use of monthly water balance models for applications where one is primarily interested in monthly, seasonal and annual streamflow volumes
- Monthly model to translate catchment characteristics (rainfall, PET) into simulation and prediction of streamflow
- Parsimonious models are those with as few parameters as necessary, central to the “top-down” approach
- Processes only added to the model when they lead to meaningful increases in the explanatory power of the model and largely determined by the availability of data.
- Shuffled complex evolution for calibration (Duan 1994)

Additional references from within publication:


Comments:
- Water quality generally good in upper reaches, declines due to increased suspended solids, nutrients and metals, turbidity.
- Highest groundwater yields found in Grimshaw and other buried valley aquifers
- many surficial aquifers vulnerable to contamination from underlying saline waters
- Canada-Alberta Environmentally sustainable agriculture agreement (CAESA) groundwater studies?
- Wapiti River provides groundwater source twp 66 to 76, west to BC.
- Some "other" water allocations are based on evapotranspirative loss from waterbody. Some older ones over estimate the increase in evapotranspiration due to the works (lake stabilization, etc) and license volume is based on the evapotranspiration for the whole waterbody.
- Fox Ck stabilization project at Iosegun Lk., Ducks Unlimited at Gift Lake.

Additional references from within publication:

Hatch. 2010. Update on Alberta's hydroelectric energy resources. Final report for Alberta Utilities Commission, Calgary, Alberta. accessed:

Additional references from within publication:

Other references of interest:

Climate


Groundwater


Hydrogeological consultants ltd. (hcl), 1999. County of Barrhead No. 11, Parts of the Pembina and Athabasca River Basins, Parts of Tp 056 to 063, R 01 to 08, W5M, Groundwater Potential Evaluation. Prepared for County of Barrhead No.11 in conjunction with AAFC and PFRA. hcl File No. 97-103.


Hydrogeological consultants ltd. (hcl), 1999. M.D. of Brazeau No. 77, Part of the North Saskatchewan and Athabasca River Basins; Parts of Township 045 to 050, Range 03 to 11, W5M; Revised Regional Groundwater Assessment 1999. Prepared for M.D. of Brazeau No.77 in conjunction with AAFC and PFRA. hcl File No. 97-232.

Hydrogeological consultants ltd. (hcl), 1999. Parkland County, Part of the North Saskatchewan and Athabasca River Basins, Parts of Tp 050 to 054, R 25, W4M to R 08, W5M Regional
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Hydrogeological consultants ltd. (hcl), 2004. Clearwater County, Part of the North Saskatchewan and South Saskatchewan River Basins, Tp 031 to 047, R 04 to 11, W5M Regional Groundwater Assessment, February 2004 EASTERN HALF. Prepared for Clearwater County in conjunction with AAFC and PFRA. hcl File No. 02-221.

Hydrogeological consultants ltd. (hcl), 2004. Ponoka County, Part of the North Saskatchewan and South Saskatchewan River Basins, Tp 041 to 044, R 22 to 28, W4M & Tp 041 to 045, R 01 to 05, W5M Regional 044, R 22 to 28, W4M & Tp 041 to 045, R 01 to 05, W5M Regional Groundwater Assessment, May 2004. Prepared for Ponoka County in conjunction with AAFC and PFRA. hcl File No. 02-191.


**Hydrology**


Landuse

Modeling


