Development of an Integrated Hydrologic-Hydraulic Model for the Lesser Slave River Basin

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Presentation Outline

- Project Objectives
- Overview of Modelling
- Data Preparation and Mike She Model Setup
- Data Preparation and Mike 11 Model Setup
- Model Calibration and Validation
- Conclusions and Further Works
Project Objectives

- The Lesser Slave Watershed Council is in the process of developing a sustainable water management plan for the Lesser Slave River watershed.

- A thorough understanding of the hydrologic and hydraulic response of the watershed is required to develop such a plan.

- In order to model the various components of a hydrologic cycle including interaction between surface water and groundwater, MIKE-SHE software has been selected for the integrated model development.

- The developed model will be utilized to assess various scenarios including land use changes and the configuration of the existing Lesser Slave Lake control structure on lake levels and outflows.

Overview of Modelling

- Two models have been built – MIKE SHE and MIKE 11 (software developed by DHI).

- Mike She Model computes surface runoff and baseflow based on climate and physical data.

- Mike 11 routes flows through rivers and lakes.

- Measured flows and water levels are compared against Mike 11 Modelled results (Calibration and validation).

- Calibrated models are then applied for scenario analysis.
Model Input Data Required

- Watershed Maps
- Digital Elevation Model (DEM)
- Landuse data
- Climate data (Precipitation, Temperature, Evaporation/Evapotranspiration)
- River and Lake Networks
- Cross sections of Rivers and Lakes
- Soil Type and Subsurface data
- Leaf Area Index and Root Depth
- Groundwater Elevation
Mike She Model Setup

Study Area

Drainage Area: 20,000 sq km
Model Cell Size: 1 sq km (changeable)
Number of Cells: 20,000
Ground elevation for each cell is obtained from processed DEM data
Landuse Input Data

Divided the drainage area based on landuse type

Climate Data Collection

- Inadequate historical climate data readily available for the study area
- Inadequate number of monitoring stations located in the study area
- Based on literature search, estimated historical climate data were obtained from Alberta Agriculture (1960-2005)
- Alberta Agriculture prepared historical climate data on a township basis
- Climate data were processed to meet model needs
- 30 Precipitation and Temperature locations were selected within the study area as shown in the following slide
The study area is divided into 30 subareas based on climate data included in the model.
Evaporation and Evapotranspiration data are computed to cover the period from 1960 to 2005

- Computed data were compared against the limited available data
- Estimated historical data were processed to meet the model needs

Estimated EVP and ET data matched well with AENV data
Soil Distribution

Study area is divided into sub areas based on 5 soil types.

Subsurface Flow Modelling

Subsurface division of the study area for shallow groundwater.
Subsurface Flow Modelling Continued

Subsurface division of the study area for base flow

Mike 11 Model Setup
### Mike 11 Model Network

<table>
<thead>
<tr>
<th>Main Rivers</th>
<th>Modelled River Length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Prairie</td>
<td>76,912</td>
</tr>
<tr>
<td>East Prairie</td>
<td>106,795</td>
</tr>
<tr>
<td>Drift Pile</td>
<td>82,057</td>
</tr>
<tr>
<td>Swan</td>
<td>109,781</td>
</tr>
<tr>
<td>Swanaw</td>
<td>73,109</td>
</tr>
<tr>
<td>Sauteaux</td>
<td>122,114</td>
</tr>
<tr>
<td>Driftwood</td>
<td>50,636</td>
</tr>
<tr>
<td>Faucett</td>
<td>81,106</td>
</tr>
<tr>
<td>Slave River</td>
<td>72,171</td>
</tr>
<tr>
<td>South Heart</td>
<td>154,802</td>
</tr>
<tr>
<td>Slave Lake</td>
<td>117,565</td>
</tr>
</tbody>
</table>

- **Natural Length of Slave River:** 79,680 m
- **Regulated Length of Slave River:** 72,171 m

### Cross Sections Input Data
Cross Sections for the Lake

- The lake is modelled as a river with wide cross sections
- 30 m wide weir with crest elevation of 575.5 m

Hydrometric Gauging Stations
Modelling Results

Simulated & Observed Outflows from Lesser Slave Lake

ME=-9.86927
MAE=15.9033
RMSE=18.972
STDres=16.2029
R(Correlation)=0.854637
R2(Nash_Sutcliffe)=0.552701
Simulated & Observed Water Levels at Lesser Slave Lake

Simulated & Observed Hydrographs - Swan River

ME=0.117701
MAE=0.247091
RMSE=0.298734
STDres=0.27457
R(Correlation)=0.803933
R2(Nash_Sutcliffe)=0.575724

ME=2.30063
MAE=10.0765
RMSE=21.9445
STDres=21.8236
R(Correlation)=0.704676
R2(Nash_Sutcliffe)=0.35767
Figure 13A - Comparison of Modelled and Measured Cumulative Discharges - Swan River, 1985 to 2004

Figure 14A - Comparison of Modelled and Measured Cumulative Discharges - Swan River, 1961 to 1981
Accumulated water balance from 1/09/1984 12:00:00 PM to 29/12/2004 12:00:00 PM. Data type: Storage depth [millimeter].
Flow Result File: D:\MIKESHEModelruns\Regulated\July_3\Regulated__30-station_DDC_Nov27_08.she - Result Files\Regulated__30-station_DDC_Nov27_08
Title: Text:

Accumulated water balance from 1/02/1961 12:00:00 PM to 3/07/1982 12:00:00 PM. Data type: Storage depth [millimeter].
Flow Result File: D:\MIKESHEModelruns\Natural\July_3\Natural__30-station_DDC_Nov27_08_60-04.she - Result Files\Natural__30-station_DDC_Nov27_08_60-04
Title: Text:

Accumulated water balance from 1/09/1984 12:00:00 PM to 29/12/2004 12:00:00 PM. Data type: Storage depth [millimeter].
Flow Result File: D:\MIKESHEModelruns\Regulated\July_3\Regulated__30-station_DDC_Nov27_08.she - Result Files\Regulated__30-station_DDC_Nov27_08
Title: Text:

Accumulated water balance from 1/09/1984 12:00:00 PM to 29/12/2004 12:00:00 PM. Data type: Storage depth [millimeter].
Flow Result File: D:\MIKESHEModelruns\Natural\July_3\Natural__30-station_DDC_Nov27_08.she - Result Files\Natural__30-station_DDC_Nov27_08
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Accumulated water balance from 1/02/1961 12:00:00 PM to 3/07/1982 12:00:00 PM. Data type: Storage depth [millimeter].
Flow Result File: D:\MIKESHEModelruns\Natural\July_3\Natural__30-station_DDC_Nov27_08.she - Result Files\Natural__30-station_DDC_Nov27_08
Title: Text:
**Hypothetical Scenario Analysis**
Comparison of Water Levels at Lesser Slave Lake
- Weir at 575.5 m (Existing)
- Weir at 575.8 m (Hypothetical)

**Hypothetical Scenario Analysis Contd.**
Comparison of Outflows from Lesser Slave Lake
- Weir at 575.5 m (Existing)
- Weir at 575.8 m (Hypothetical)
Conclusions and Further works

- The developed models simulated historical daily flow hydrographs and water levels in the Lesser Slave Lake reasonably well.

- The measured cumulative volumes (long term average values) are in close agreement with the modelled cumulative volumes for most of the rivers.

- Water balance analysis indicates that evapotranspiration accounts for the largest water loss from the study area.

- The ratio of base flow to total flow ranges from 28% to 60% indicating that surface water-ground water interaction play a significant roles in overall water balance of each sub-basin.

- The MIKE 11 model domain should be extended to include as many branches of all the rivers as possible.

- Interpolated ground elevations (1 km by 1km grid used) should be further reviewed to address any obvious discrepancy in the actual topography and the modelled topography.

- The developed model adopted a simplified approach to compute flows in the subsurface zone. The adoption of a detailed modelling approach for computing flows in the subsurface zone may further improve the model accuracy.

- The Lesser Slave River flows downstream of the weir structure may not be accurate since the tributary flows are not calibrated well due to limited data.
Conclusions and Further works Contd.

- Use of variable depressions storage and snow storage for the study area may further improve the model accuracy
- Use of a smaller grid size may further improve the model accuracy
- Computation of snowmelt using an energy balance model may further improve the model accuracy
- Collection of additional relevant field data for the calibration and verification of the model will further improve the model accuracy
- The model can be applied to assess the relative effect of various management scenarios
- Developed Models need to be refined through continuous calibration to further improve the model accuracy