Ottawa County Water Resources Study – Phase-2

Methodology

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Ottawa County Water Resources Study – Phase-2

- Ottawa County Planning and Performance Improvement developed a list of water resource information needs.
- Ottawa County received funding from local stakeholders and Michigan Department of Agriculture and Rural Development.
- OCPPI asked the Institute of Water Research at MSU to develop a study plan to address these needs.

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- **Based on needs developed by Ottawa County, the Phase-2 study has 7 Goals.**
  - **4 Goals are specific to Ottawa County**
  - **3 Goals focus on the regional lowlands of Southern Michigan**

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❑ Goals specific to Ottawa County

- Goal 1: Quantify the *current sustainability* of groundwater quantity in Ottawa County's glacial and bedrock aquifers.

- Goal 2: Quantify the *current sustainability* of Ottawa County's aquifers based on chloride concentrations.

- Goal 3: Estimate the *future sustainability* of Ottawa County's glacial and bedrock aquifers based on projected water quantity and chloride concentrations at 5, 10 and 20 years into the future.

- Goal 4: Develop and recommend *best practices, policies and/or other solutions* to address and mitigate any likely groundwater shortages or problematic chloride concentrations in Ottawa County.

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- Goals focused on the regional lowlands of Southern Michigan
  - Goal 5: Characterize the *apparent sustainability* of glacial and bedrock aquifers in the regional lowlands of Southern Michigan based on available water quantity (by county).
  - Goal 6: Characterize the *apparent sustainability* of glacial and bedrock aquifers in the regional lowlands of Southern Michigan based on chloride concentrations (by county).
  - Goal 7: Develop an action plan for MDARD outlining priority investigations for counties experiencing significant declines in SWL and/or elevated chloride concentrations in groundwater supplies in the regional lowlands of Southern Michigan.

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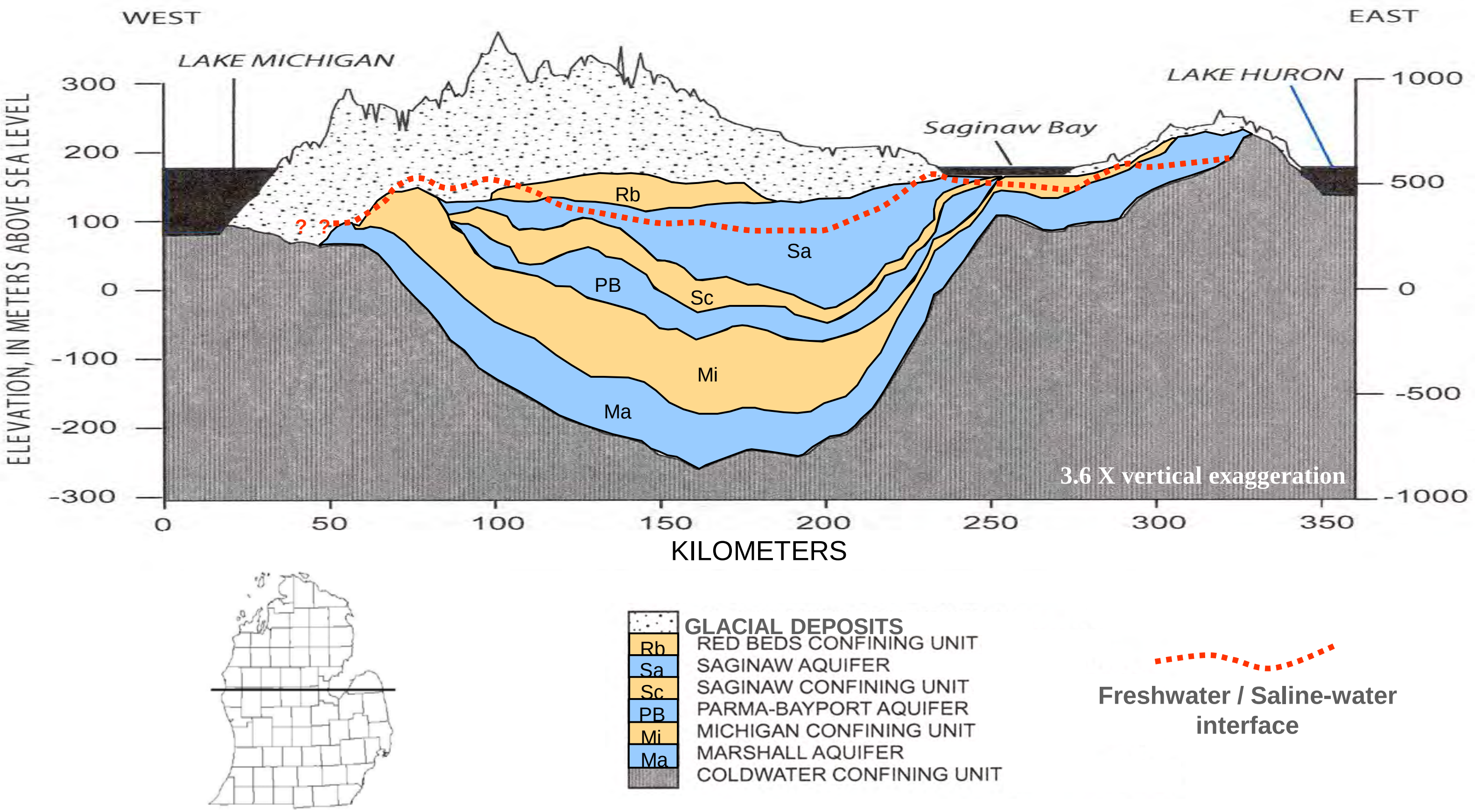
❑ Why focus on the regional lowlands of Southern Michigan?

➢ Only 3 major bedrock aquifers in Southern Peninsula



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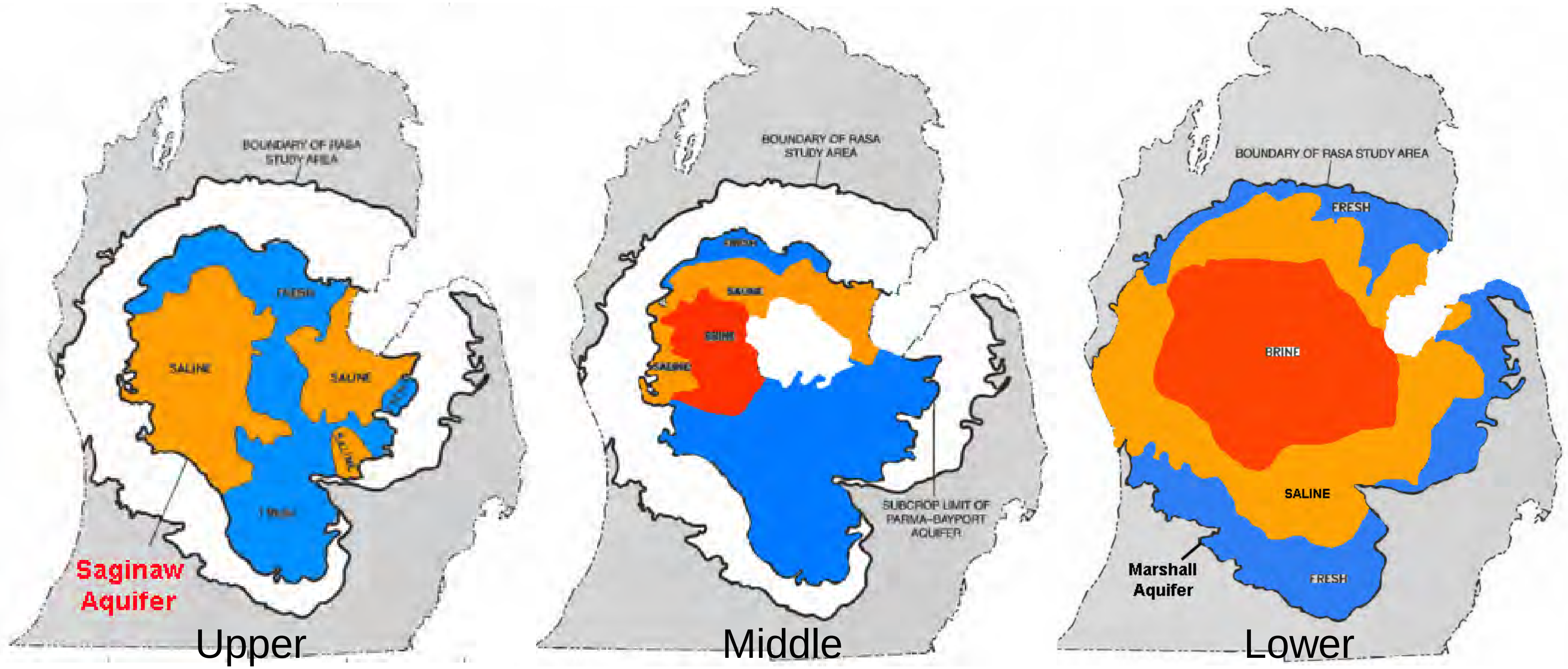
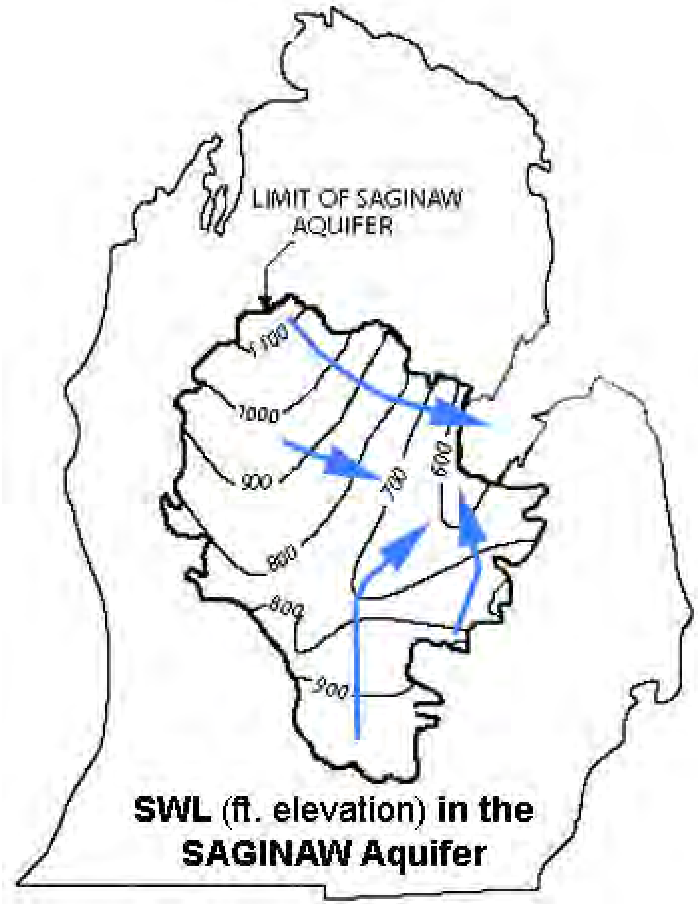
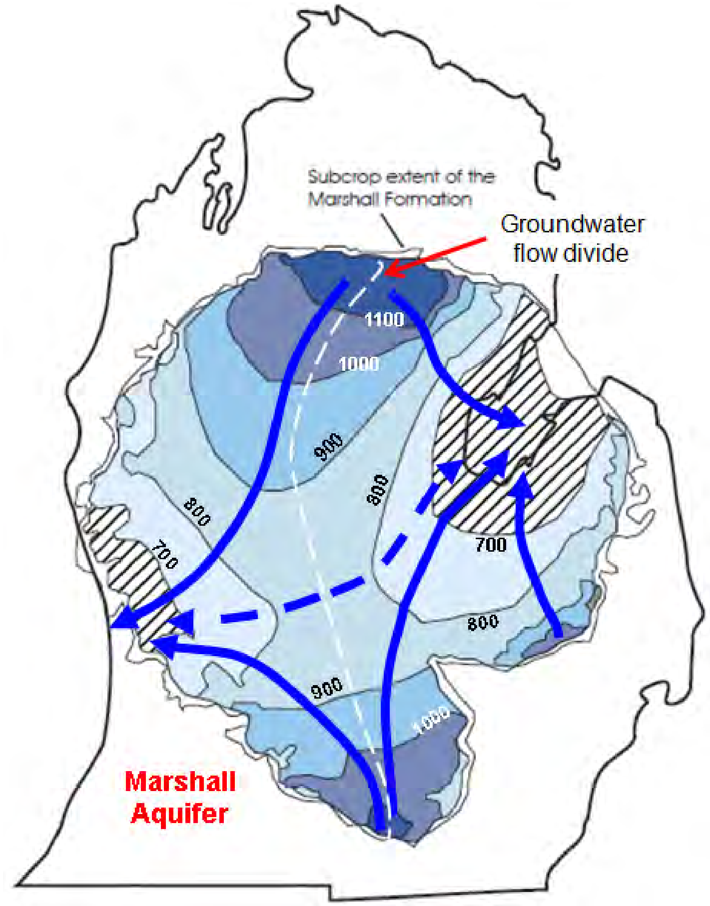
- **Why focus on the regional lowlands of Southern Michigan?**
  - **All three bedrock aquifers contain saline and brine groundwater**



❑ Why focus on the regional lowlands of Southern Michigan?

- ➢ All three bedrock aquifers discharge to regional lowlands





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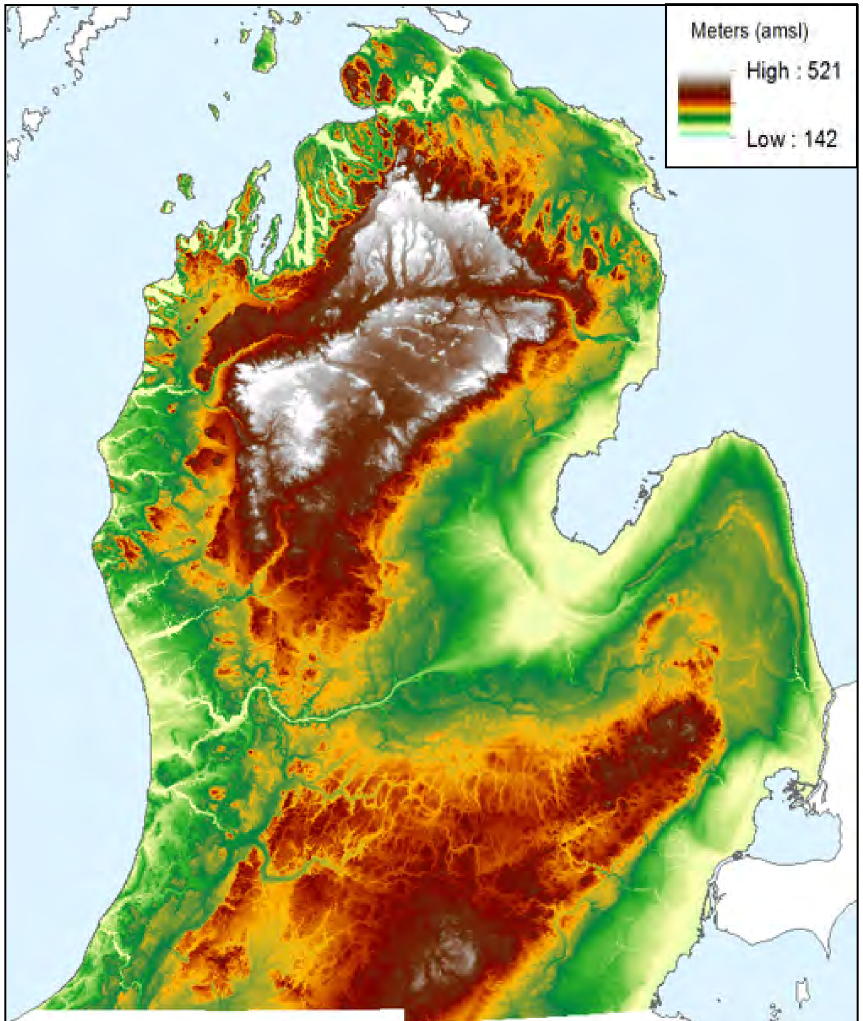
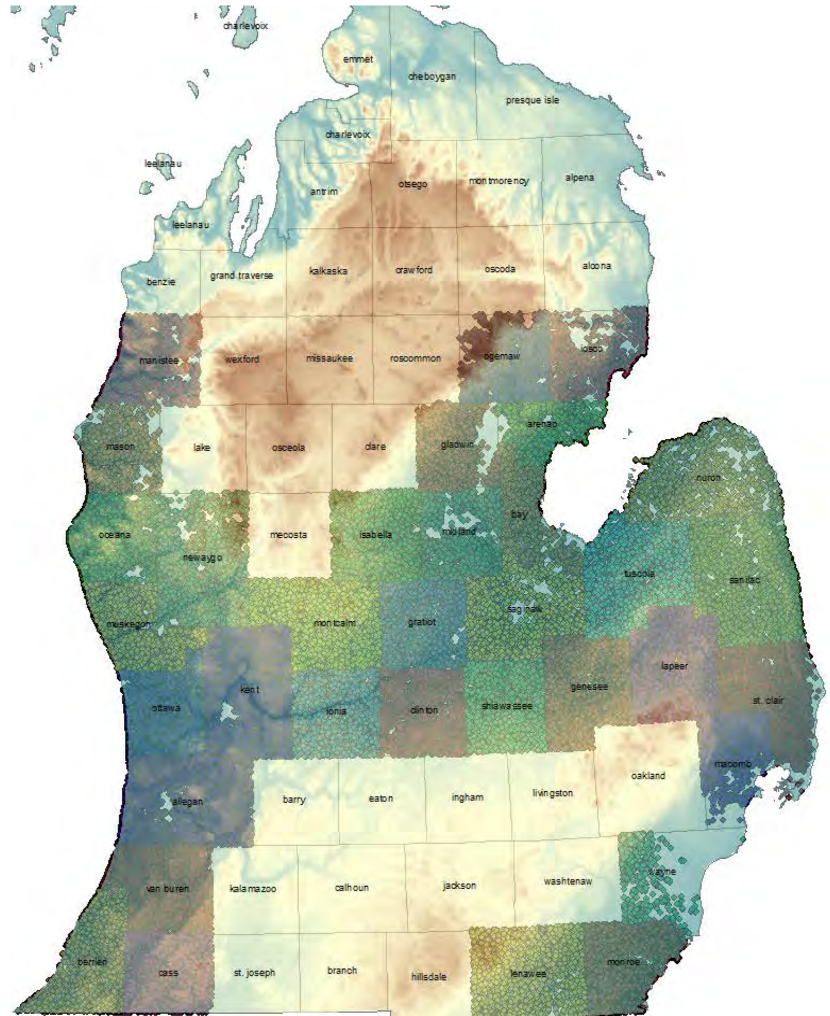
❑ Regional lowlands of Southern Michigan study area





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- **The study will use cutting-edge modeling software developed at MSU**
  - **PAWS – Process-based Adaptive Watershed Simulator**
  - **IGW – Interactive Ground Water**

Groundwater Flow Modeling

- **Step 1: Conceptual model summarizing the major components of the system and the processes that link them.**
  - aquifers and their extent
  - surface-water bodies
  - stresses of pumping and recharge
  - physical process of water moving through porous media.
- **Step 2: Quantify the conceptual model with a mathematical model: a set of equations representing the physics, properties, stresses, geometry, etc. of the system.**
  - The solution of the mathematical model yields the hydraulic heads and flow rates corresponding to the conceptual model, which can be used to simulate aquifer responses to projected stresses.

❑ Groundwater Flow Modeling

- The irregular geometries and spatial variability of aquifers and surface-water bodies will be modeled using the finite-difference method.
- The modeled region and its aquifers will be divided into 3D blocks, each one representing an aquifer volume of homogeneous properties, where the hydraulic head will be determined.
- The hydraulic head in each block is governed by classical equations for mass conservation and flow in porous media that depend on the aquifer properties and the hydraulic head in the surrounding blocks.

Groundwater Flow Modeling

- **Boundary conditions will be added to the model to represent sources, sinks, and aquifer limits (*i.e.*, recharge, wells, rivers, etc.).**
- **The hydraulic head in each block depends on the head in the surrounding blocks, so the interrelated set of equations for each block must be solved simultaneously and yield a solution for the hydraulic head at each block center and the flow rates among all components of the modeled system.**

❑ Groundwater Flow Modeling

- Changes in the system with time can be estimated by repeating the finite difference solution for a series of time steps.
- In this transient solution, the hydraulic head in the blocks during each time step depends on changes in the boundary conditions (*e.g.*, pumping rates), the amount of water released from storage, and the hydraulic heads of the previous time step.
- Obviously, the computational burden increases dramatically with the number of blocks in the model and the number of time steps in the transient simulation.

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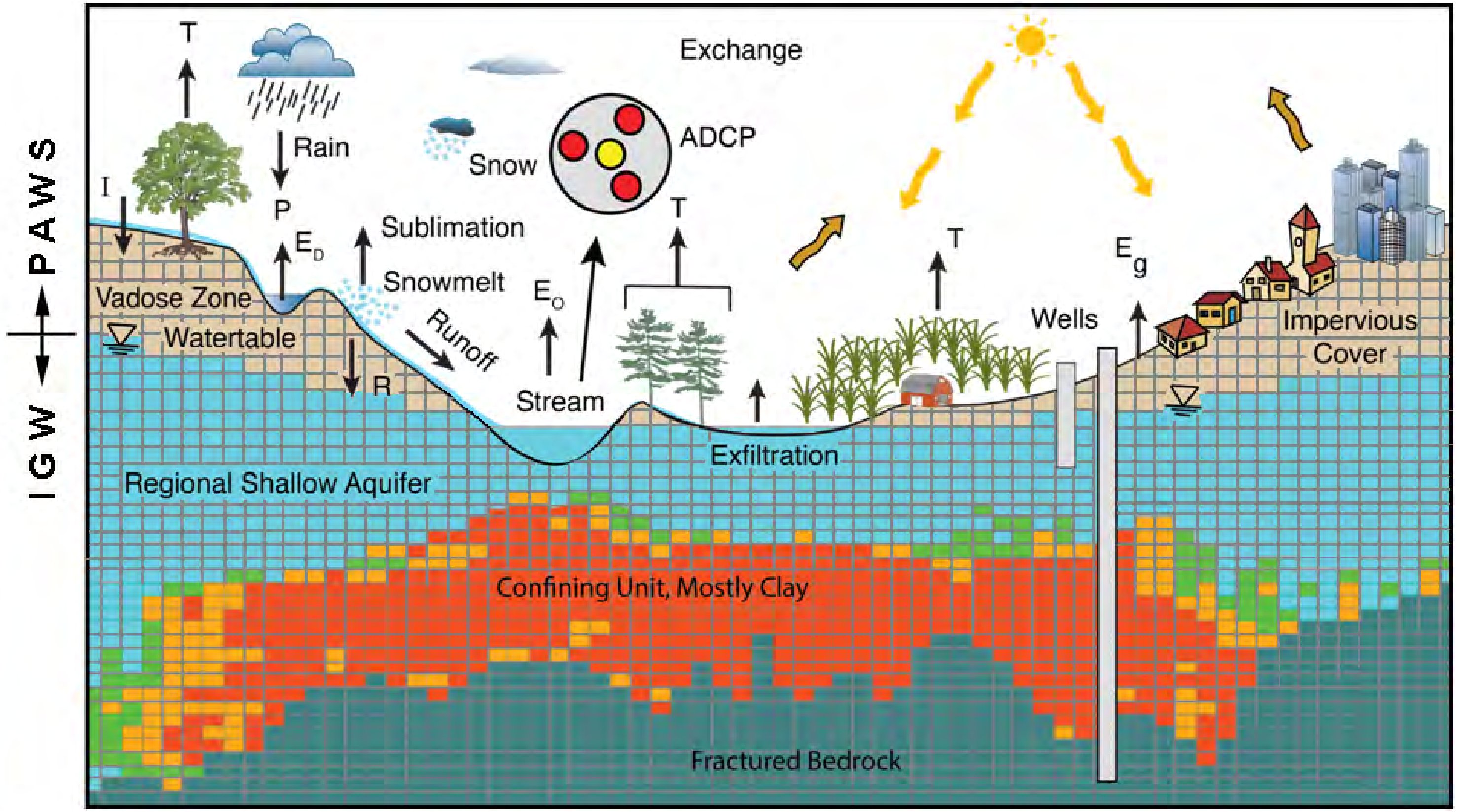
❑ Two-model Project Methodology

- **PAWS** model for recharge and surface water budget.
- **IGW** model for groundwater flow and chloride concentration mapping.



PAWS - Process-based Adaptive Watershed Simulator

- Solves physically-based conservation laws for the major processes of the hydrologic cycle within eight compartments:
  - surface ponding layer
  - canopy storage layer
  - impervious cover storage layer
  - overland flow layer
  - snowpack
  - soil moisture
  - groundwater aquifers
  - stream channels

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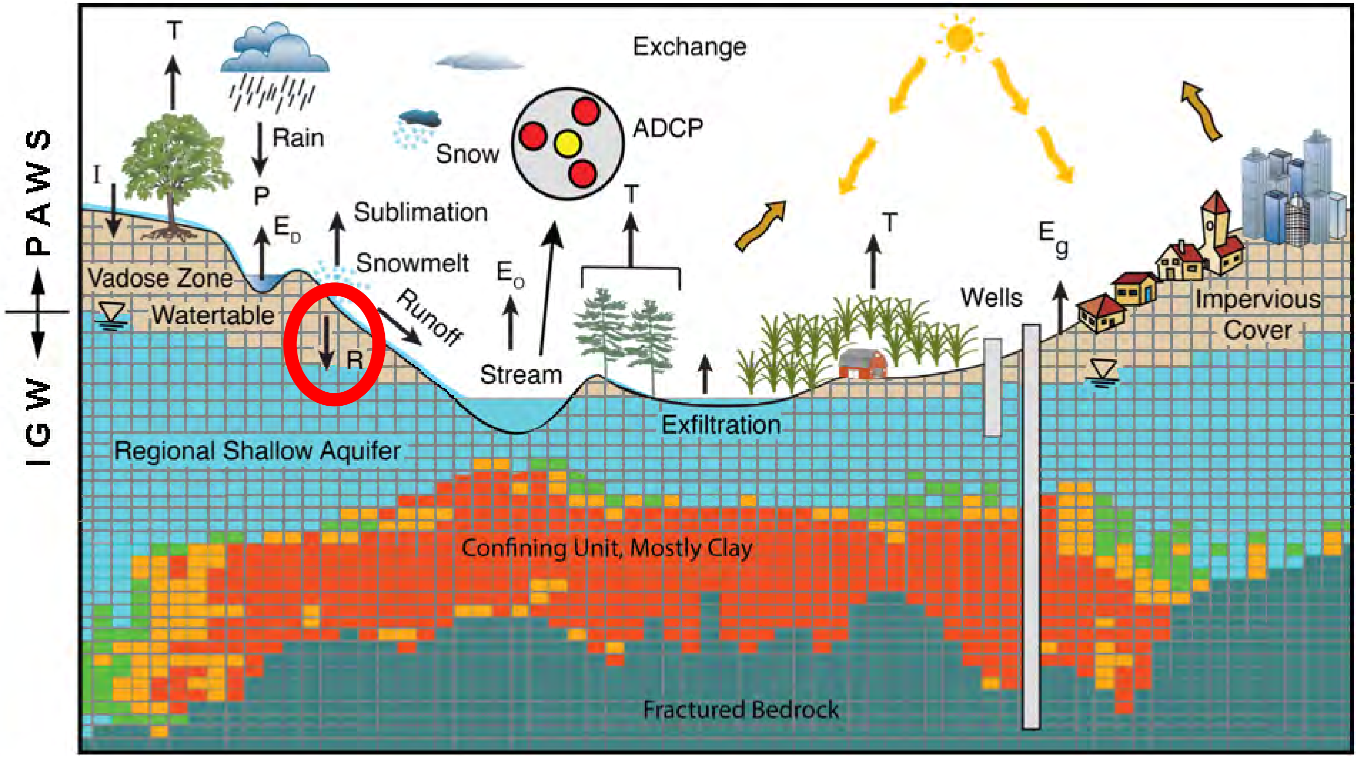
❑ PAWS - Process-based Adaptive Watershed Simulator

- ➢ **The vadose zone modules handle infiltration into the soil under both normal and heavy rainfall conditions.**
- ➢ **PAWS estimates a recharge flux for every water table cell which will be passed to the IGW model as an input variable.**



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❑ Inputs to the PAWS Model

- **Topography** (Ottawa Co. LiDAR DEM)
- **Stream Network, Ponds** (National Hydrography Dataset)
- **Land Use /Land Cover** (CDL / NLCD)
- **Soils** (NRCS gSSURGO)
- **Climate Data** (NCDC & MAWN; daily or sub-daily, if available)
- **Streamflows** (USGS + subset of field measurements)
- **Groundwater Heads** (USGS + Wellogic SWL data)
- **Subsurface Heterogeneity** (Transition Probability realizations from Wellogic lithology)

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- **Calibration data for the PAWS Model**
  - **Streamflows / Baseflows** (Measured from all stream segments)
  - **Groundwater Heads** (Measured from volunteer wells)
- **Model cell resolution will be 300 m x 300 m (about 22 acres).**

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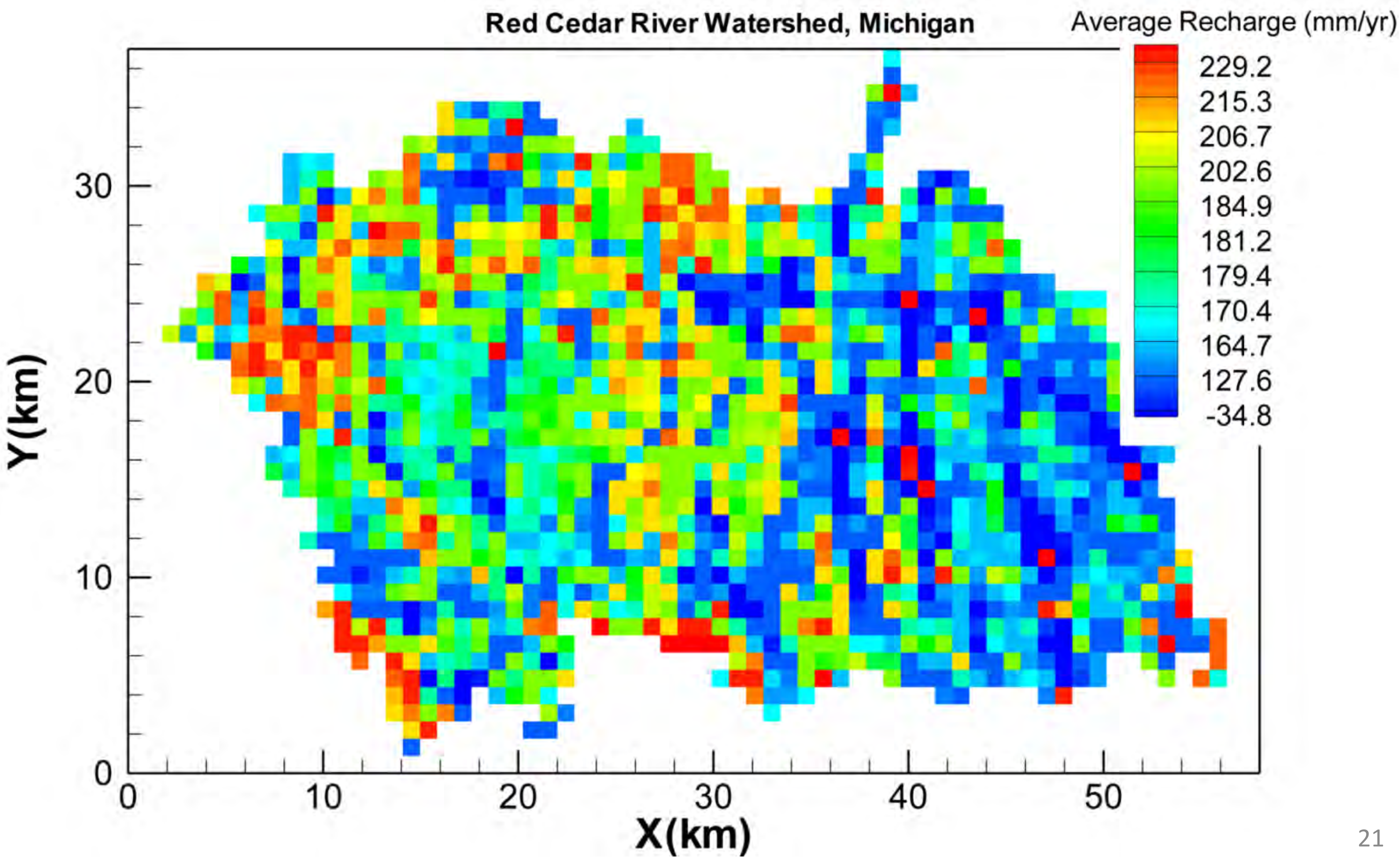
❑ Outputs from the PAWS Model

- Recharge to the water-table aquifer (input to IGW)
- Water Balance of the Glacial Aquifer
- Detailed Spatio-temporal maps of:
  - Evapotranspiration (ET)
  - Infiltration
  - Runoff
  - Recharge
  - Streamflows
  - Soil Moisture
  - Depth to the water table
  - Spatial resolution of outputs for management support is 1000 m x 1000 m (about 250 acres)

❑ Example output from the PAWS Model

- ➢ **Recharge**



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❑ IGW – Interactive Ground Water

- An integrated groundwater modeling suite utilizing a powerful parallel computing methodology with computational steering and dynamic visualization to provide dynamic integration of flow and transport modeling.

- IGW couples flow modeling, transport modeling, sub-scale modeling, particle tracking, and water budget analyses and models them simultaneously.

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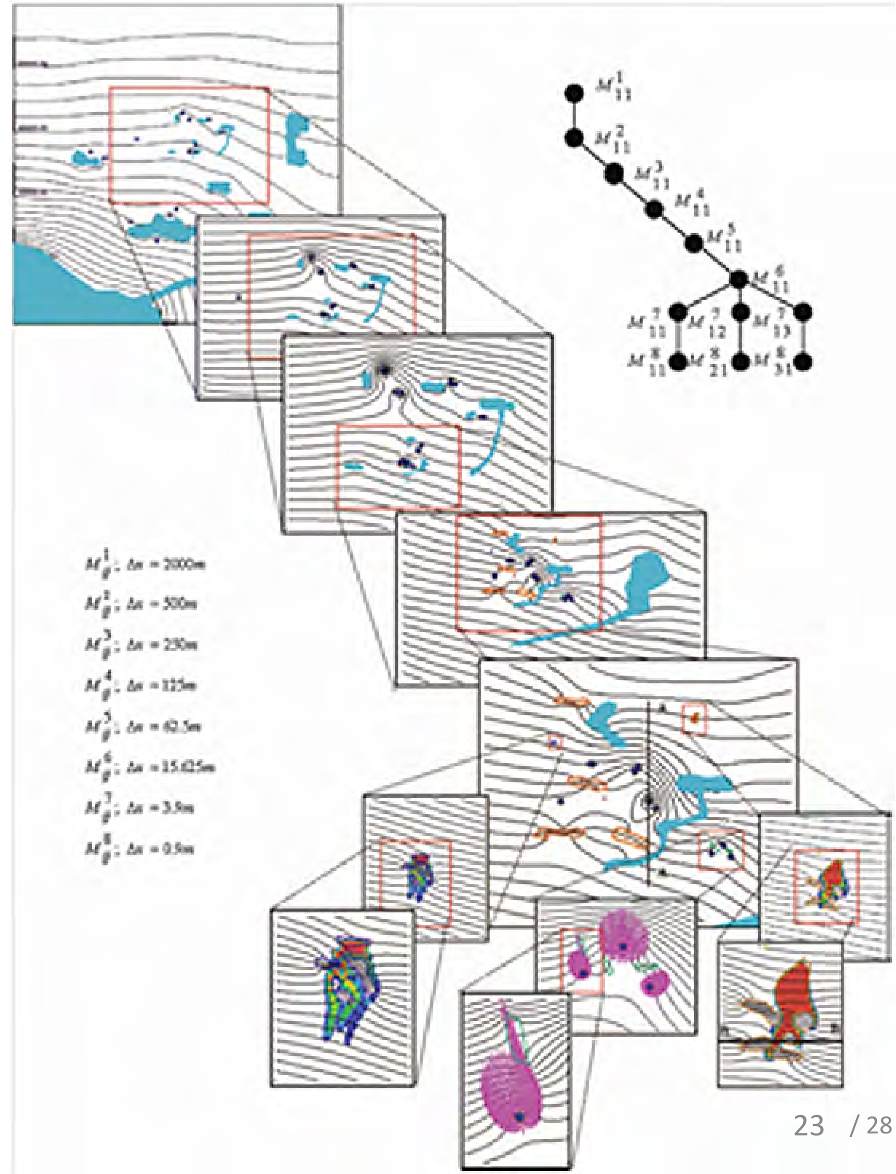
❑ IGW – Hierarchical Multi-Scale Modeling

- ➢ In the nested set of parent and child models, the child models are linked to their parent model by a 2-way hydraulic head coupling mechanism.
- ➢ The child models derive their boundary conditions from the parent model and the parent model is updated with local information from the child models.



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Inputs to IGW

- **Well lithology** (from Wellogic database)
- **Stream network** (from Michigan Framework)
- **Lakes/ponds** (from Michigan Framework)
- **Digital elevation model** (LiDAR from Ottawa County)
- **Bedrock framework** (MDEQ GWIM database + USGS RASA reports)
- **Recharge** (from PAWS model)
- **Water use** (from MDEQ / MDARD Water Use Program)
- **Initial Cl concentrations** (in-situ samples from volunteer wells)

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- **Calibration Data for IGW**
  - **Baseflow, synoptic** (from streamflow measurements on all stream segments)
  - **Baseflow, time series** (12 monthly streamflow measurements on 15 streams)
  - **Static water levels** (from in-situ samples from volunteer wells)
  - **Static water level and Cl concentration time series** (from the single test well (4 days) and two monitoring wells (2 weeks)
- **Model cell resolution will be 300 m x 300 m (about 22 acres).**

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Outputs from IGW

- Aquifer Depth and Thickness Maps and 3D Graphics
- Static Water Level Maps and 3D Graphics
- Lateral Groundwater Inflow Maps
- Groundwater Discharge to Streams Map
- Vertical and Lateral Outflow Data Map(s)
- Current Water Quantity Severity Rating Map(s)
- Chloride Depth Map(s) and 3D Graphic(s)
- Chloride Concentration Map(s)
- Chloride Migration Analysis Results
- Current Chloride Severity Rating Map(s)

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Outputs from IGW

- Maps of Projected Change in Groundwater Quantity at 5, 10, and 20 years
- Maps of Projected Change in Chloride at 5, 10, and 20 years
- Projected Groundwater Quantity Severity Rating Map(s) at 5, 10, and 20 years
- Chloride Rating Maps at 5, 10, and 20 years
- Spatial resolution of outputs for management support will be 1000 m x 1000 m (about 250 acres)

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