# GROUNDWATER MODELING OVERVIEW

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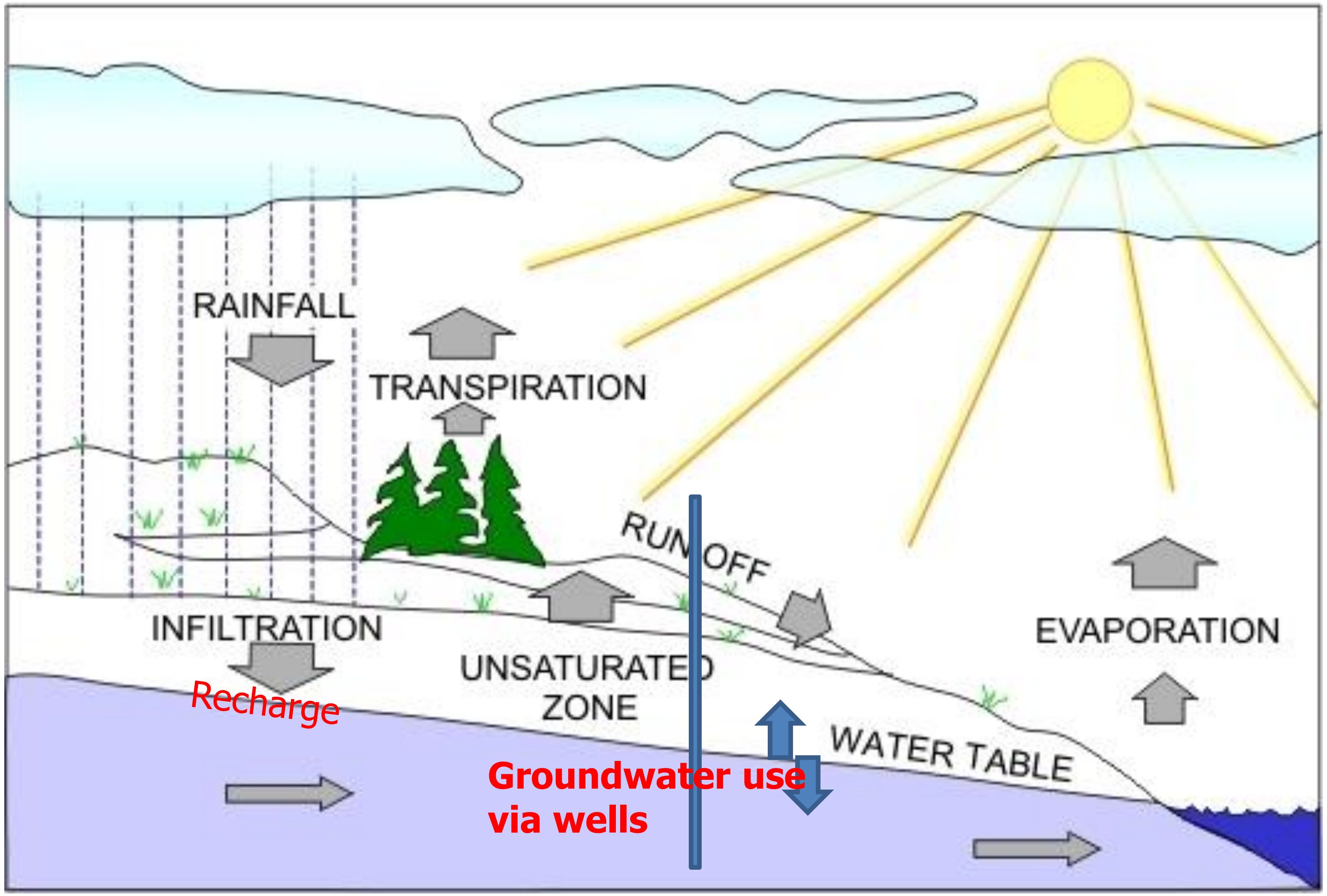
# Outline

- Definitions
- Modeling objectives
- The modeling process
- Data requirements
- Model application Process
- Model limitations
- Conclusions

# Hydrologic Cycle




Recharge = Rainfall – Evapotranspiration - Runoff

# Definitions

- What is a model?
  - Conceptual model: A non-unique representation of reality
  - Numerical model: A computer program representing a conceptual model (e.g., MODFLOW/MODPATH), or data/results manipulation (e.g., GMS)
- Why is it needed?
  - Understanding processes
  - Guiding data collection
  - Predictions

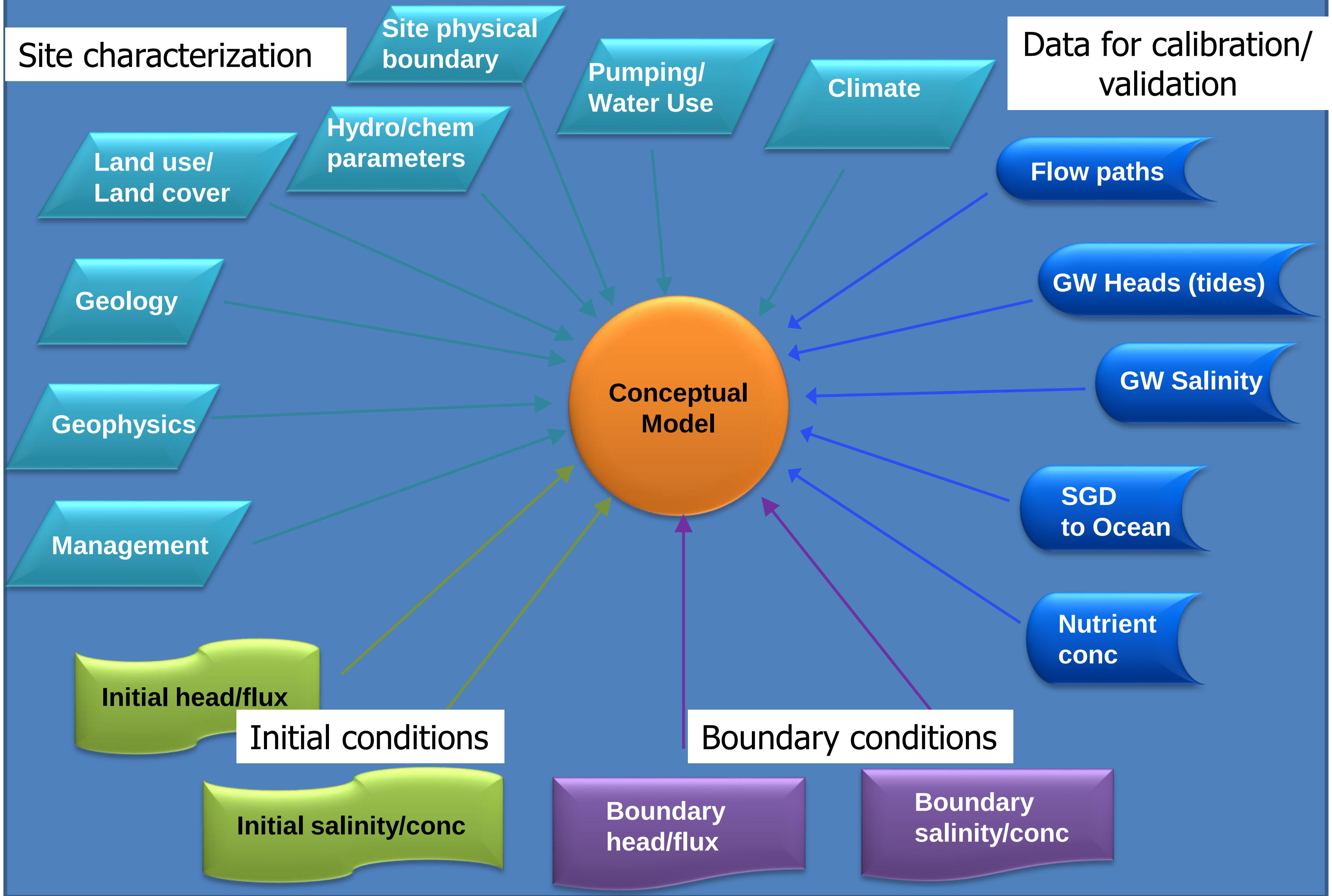
# Examples

- Water allocation and sustainable yield assessment
- Risk assessment
- Best cleanup scenario
- Delineation of source protection area

# The modeling process

- Site characterization/data collection
- Model development/choice
- Model verification/calibration/ validation
- Model application

# Conceptual Model Components

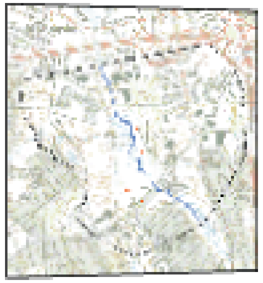


# Groundwater Modeling System (GMS)

# GMS Overview

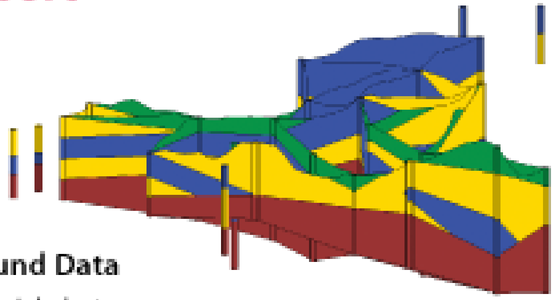
GMS Process | Applications | Features | Modules | Models

## Conceptual Modeling for Groundwater Flow & Transport



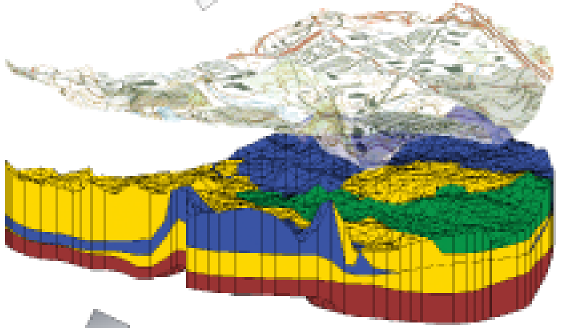
### Import Background Data

- Topo maps and aerial photos
- AutoCAD and GIS data
- Surface elevations



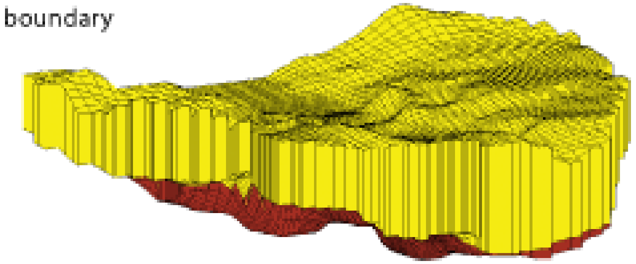
### Define Stratigraphy

- Import borehole or scatter data
- Interpolate layer boundaries
- Define cross-sections
- Create solids



### Create Conceptual Model

- Determine model domain
- Define hydraulic material zones and layers
- Define boundary conditions
- Enter source/sinks

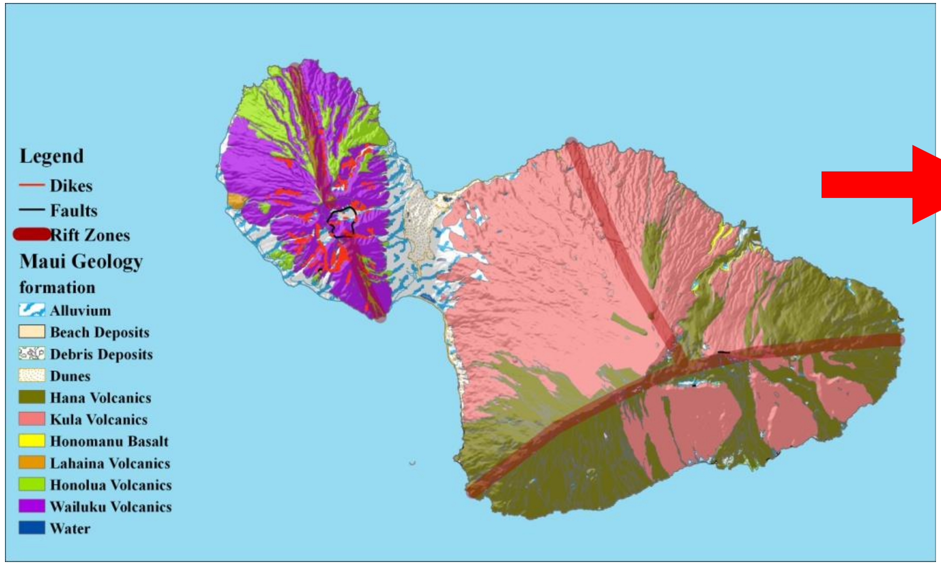


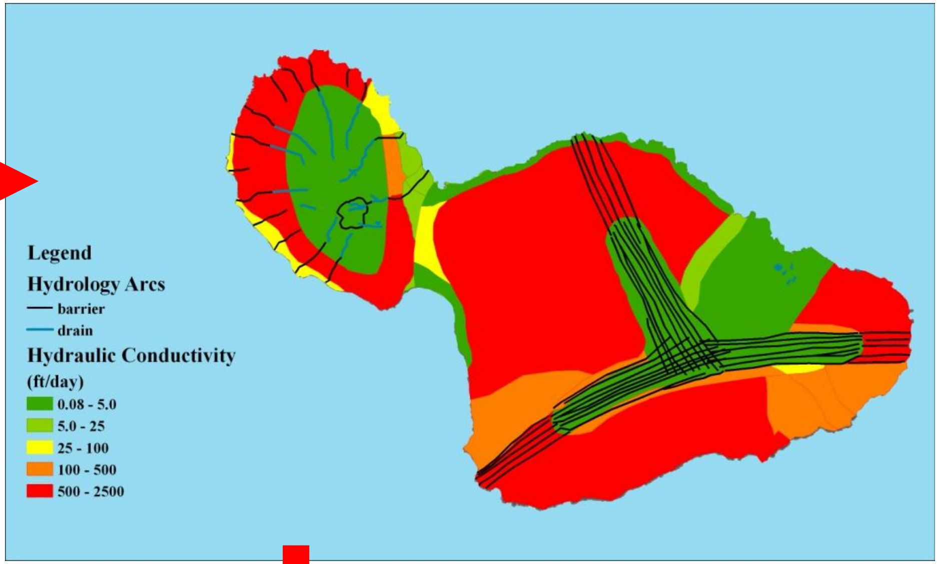
### Generate & Run Numerical Model

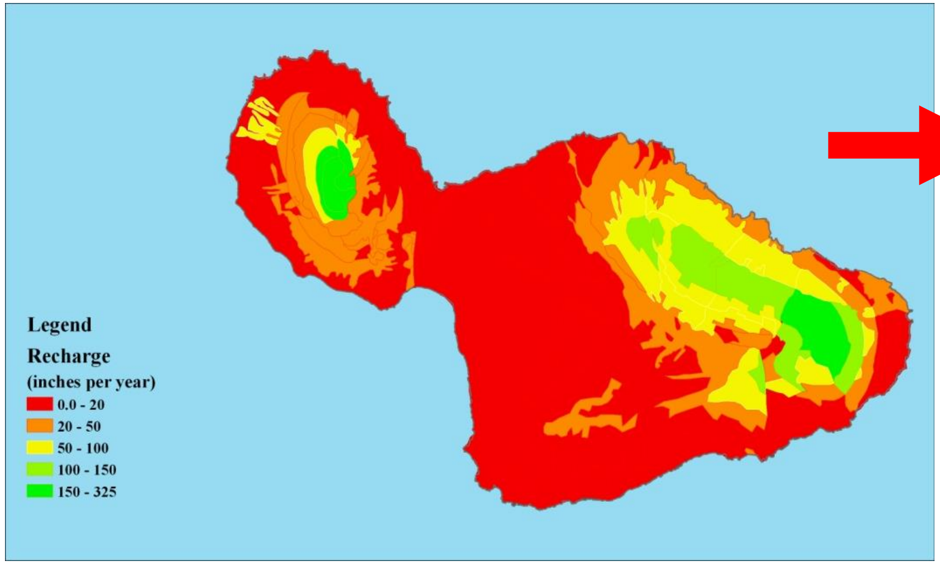
- Automatically generate grid or mesh
- Map layer data and boundary conditions
- Run Model
- Visualize results
- Calibrate model

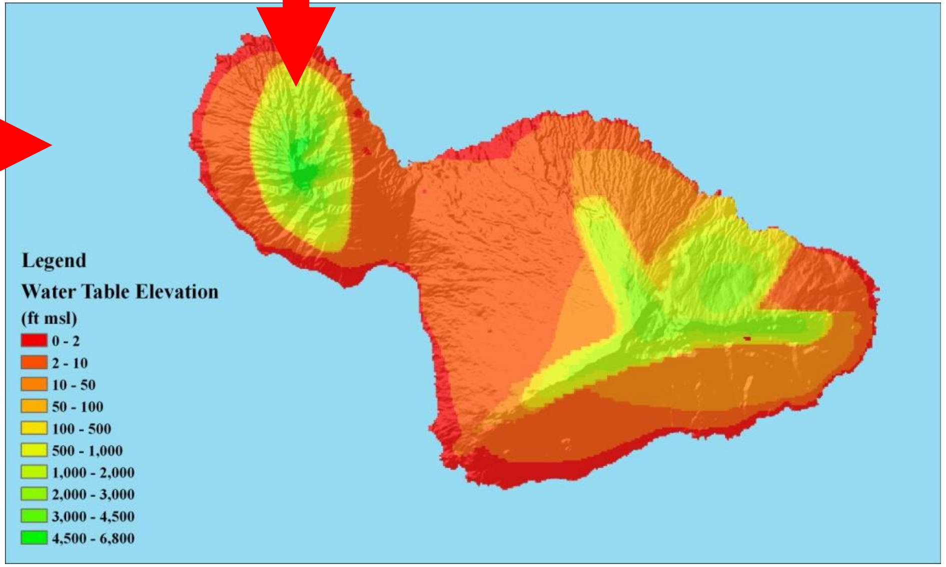
# Example

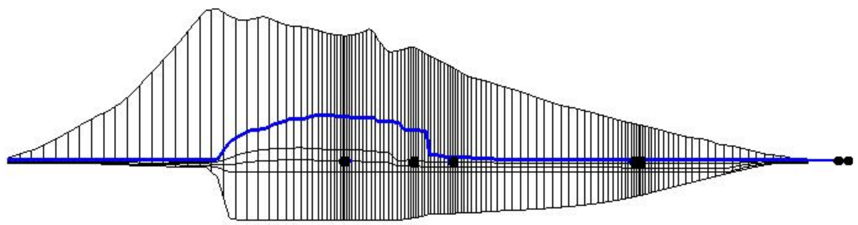
# Factors Affecting Groundwater Flow



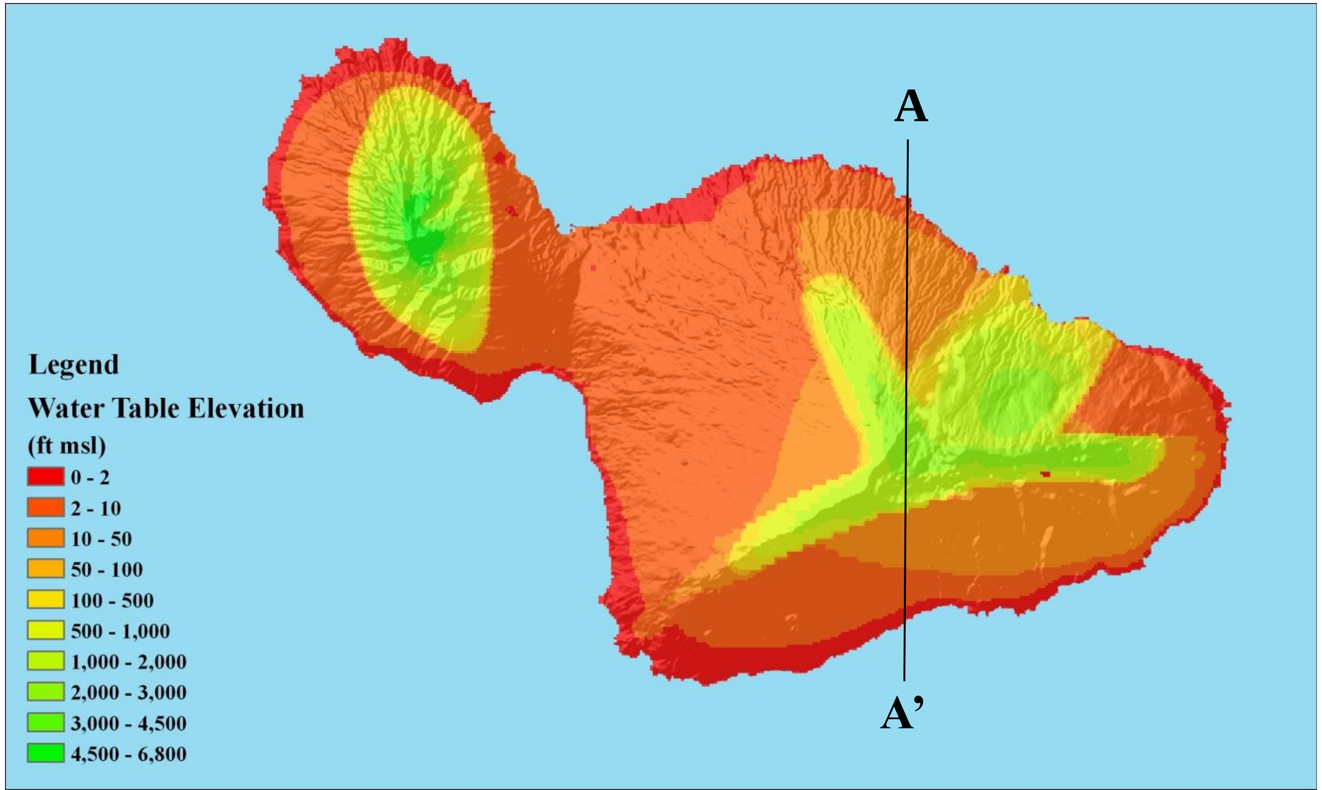



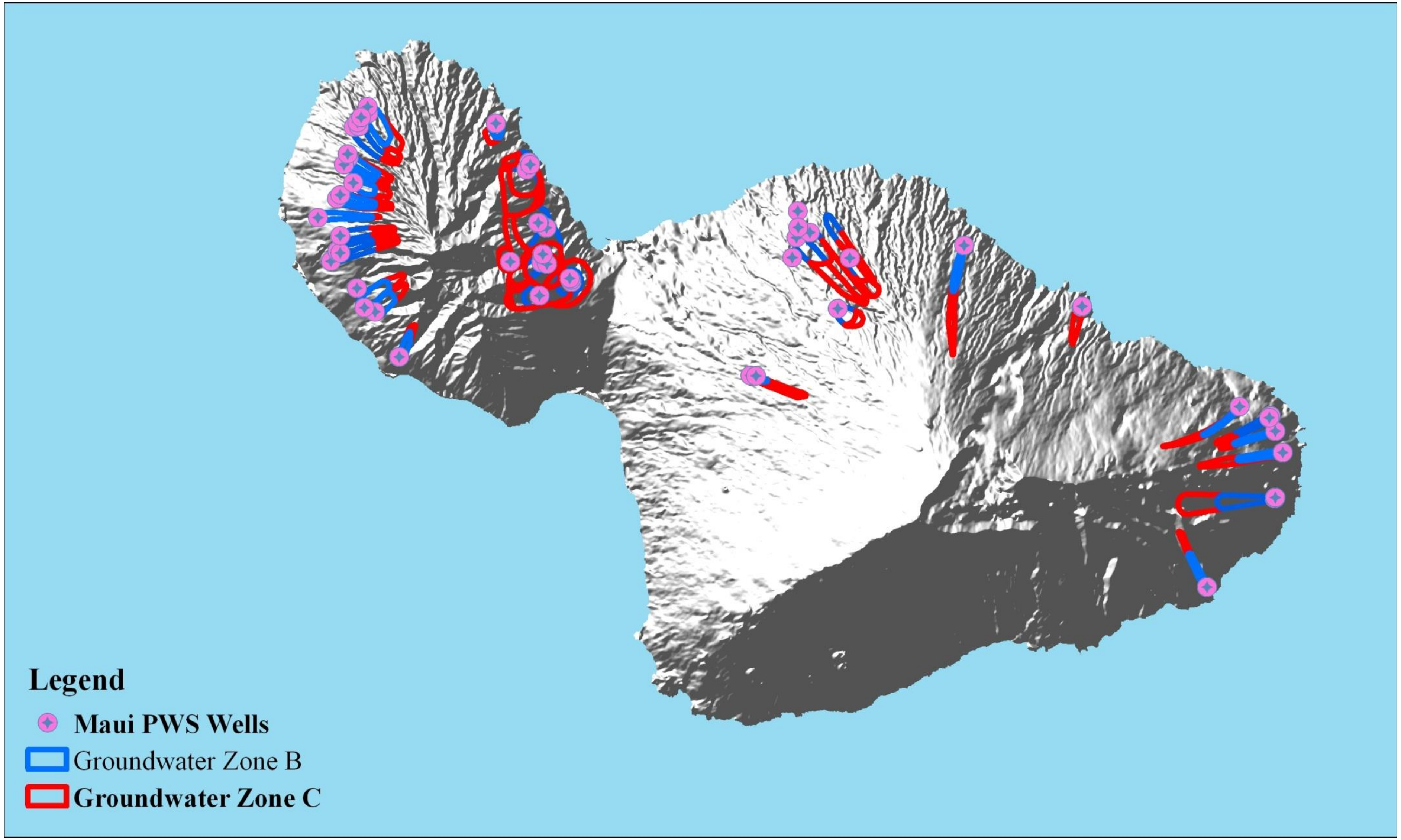





Sec A-A’


A
A’
Legend
Water Table Elevation
(ft msl)
0 - 2
2 - 10
10 - 50
50 - 100
100 - 500
500 - 1,000
1,000 - 2,000
2,000 - 3,000
3,000 - 4,500
4,500 - 6,800

# Groundwater Capture Zone Delineations



# Data requirements

- Boundary Conditions
  - Flow
    - water levels (rivers, lakes, arbitrary boundary)
    - Flux
      - Flow (spring, arbitrary boundary)
      - No flow (impermeable boundary, arbitrary streamline)
    - Head-dependent flux
  - Chemical transport
    - Concentration value (e.g. at source)
    - Solute flux
      - flux (e.g., from unsaturated zone)
      - No flux boundary
    - Concentration-dependent flux

# Data requirements

- Initial conditions

  State of system variables at start of simulation
- Parameters for physical system
  - aquifer geometry
  - aquifer parameters (hydraulic conductivity, storage coefficient, dispersivity, porosity, etc.)
  - location of sources and sinks (wells)
  - fluid conditions (density, viscosity)
  - velocities
  - chemical reactions, decay

# Data requirements

- Numerical data
  - Node and grid information
  - Time step sequence
  - Error and stability criteria
- Prediction and optimization analysis
  - Economic information on water supply and demand
  - Legal and administrative rules
  - Environmental factors
  - Other social considerations

# Sources of data

- Office work
- Field work

# GIS Maps

- extent and boundaries of aquifers and non-water-bearing rocks
- topography, surface water bodies, and land use
- water-table, bedrock-configuration, and saturated-thickness
- parameters
- wells
- recharge
- etc.

# Data processing

- Data storage
- Data checking for measurement and  transmission errors
- Interpretation of field data
- Storing of processed data
- Model gridding
- Assignment of data to nodes and elements/cells

# Model application Process

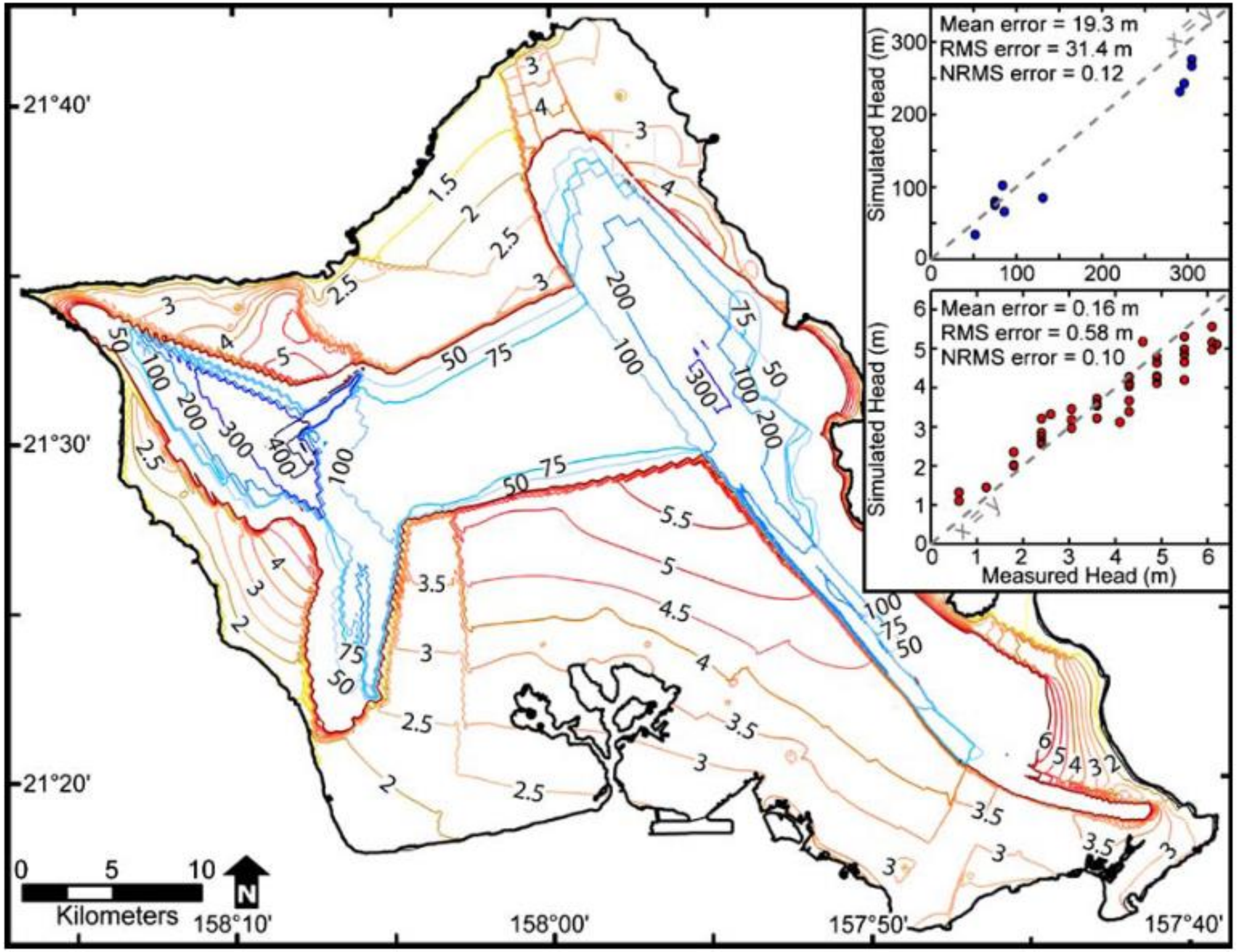
- Verification: assessing model numerical accuracy
- Calibration: fitting to real life with parameter adjustment
- Validation: fitting without parameter adjustment

# Calibration/history matching

- A trial and error procedure matching calculated values with observed data:
  - to refine initial estimates of aquifer properties (parameters)
  - to determine boundaries
  - to determine flow and transport conditions at the boundaries

# Calibration data

- Water-level change maps and hydrographs
- Streamflow, including gain and loss measurements
- History of pumping rates and distribution of pumpage


Mean error = 19.3 m
RMS error = 31.4 m
NRMS error = 0.12
Simulated Head (m)
x = y
Mean error = 0.16 m
RMS error = 0.58 m
NRMS error = 0.10
Simulated Head (m)
Measured Head (m)
21°40'
21°30'
21°20'
0 5 10
Kilometers
N
158°10'
158°00'
157°50'
157°40'

# Modeling results

- Check input data for errors
- Check water and mass balance error
- Check computed variables for reasonability (head, drawdown, travel times, velocities, fluxes, concentrations)
- Perform hand calculations
- Check model assumptions for consistency with results
- Rework results for presentation to management

# Model uncertainty

- Sources of error
  - natural heterogeneity which cannot be completely described with a limited number of field samples
  - measurement errors
  - differences between real world and the model

# Model uncertainty

- Determination of uncertainty in prediction or accuracy in statistical terms

  (e.g., estimate probability that the model's predictions deviate from reality by more than a specified amount at any given time or location)

- Use sensitivity analysis to study effects of parameter variability (e.g. Monte Carlo Analysis or ad. Hoc approach)

# Model limitations

- Data quantity, quality
- In certain areas, models do not exist, or are inadequate
  - lack of scientific understanding
  - inadequate mathematical solution techniques
  - insufficient computer capabilities
- Model accessibility
- Model documentation
- Trained experts
- Model credibility
- Decision-making is not based solely on predictions/screening done with models

# Conclusions

- Models do not replace hydrogeologic analysis
- Effectiveness of models depends on quality of input
- Modeling is one of the tools the technical expert has available to assist decision-making
- Best decisions are based on integrated use of resources