COHYST 2010

Groundwater Model Development for Integrated Water Management

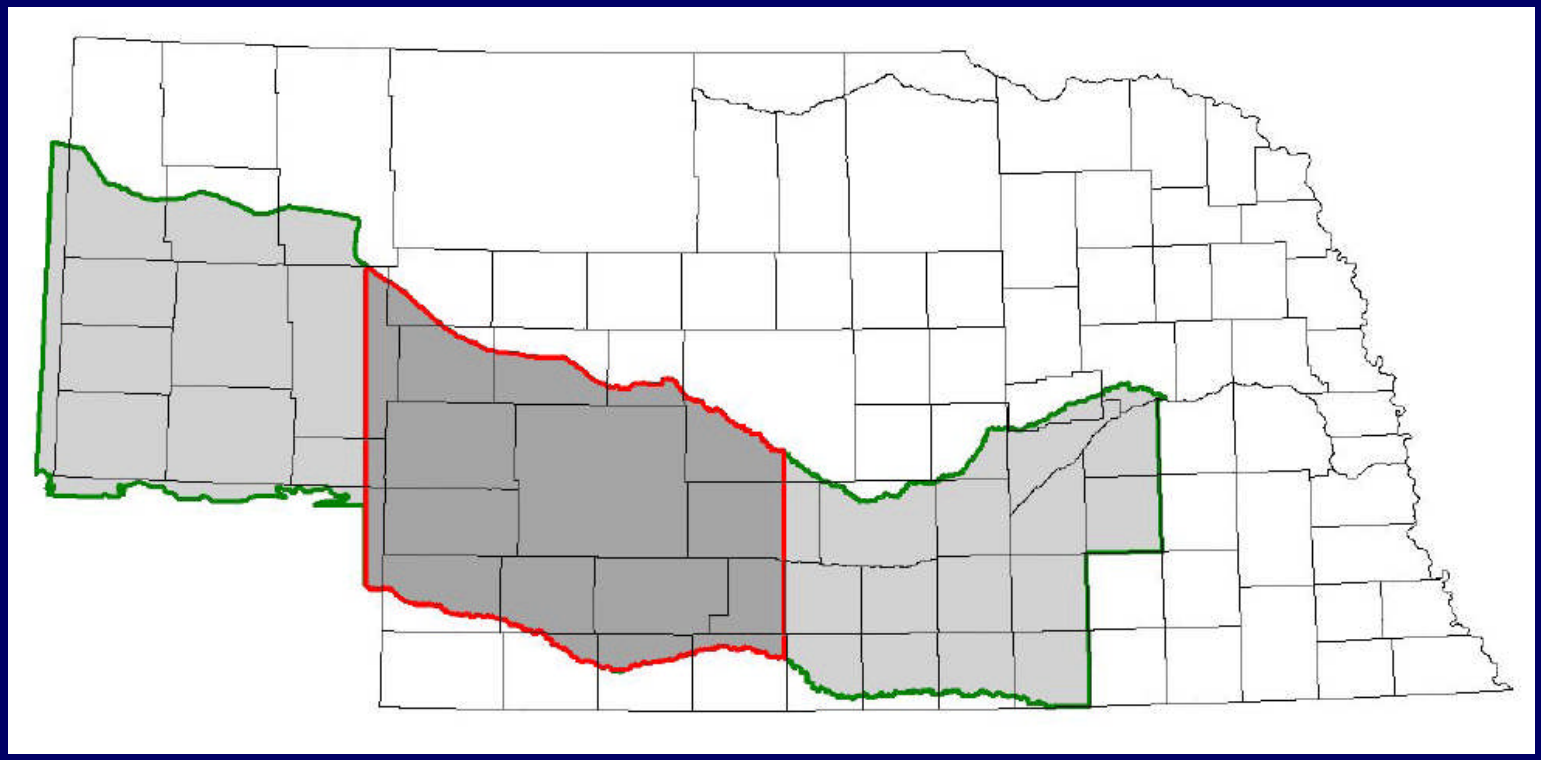
Mahesh Pun– Nebraska Department of Natural Resources

Presentation Outline

- Introduction and Background
- Objectives
- Model Framework
- Model Datasets
- Model Interaction and Calibration
- Preliminary Explorative Results
- Summary

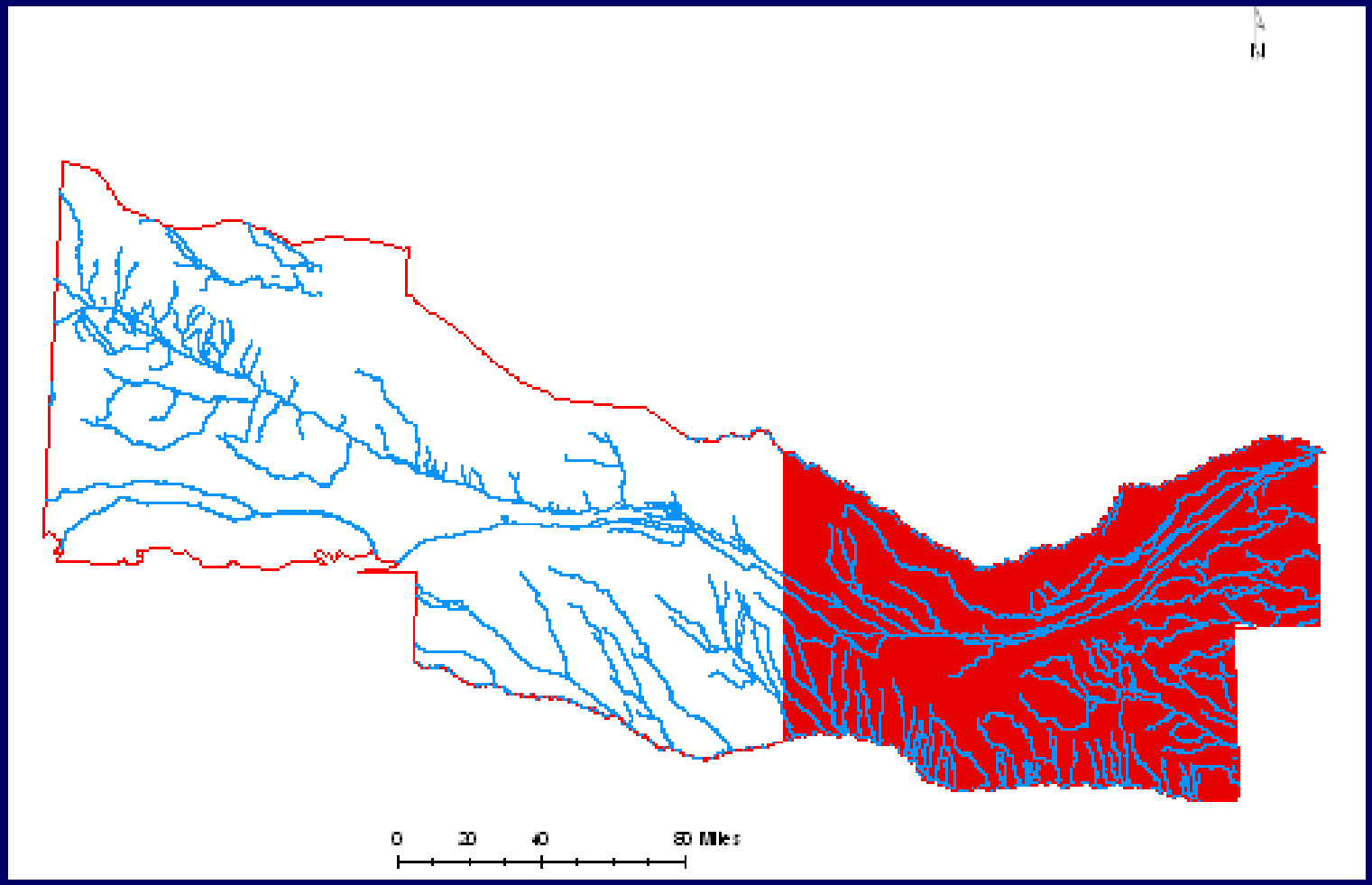
Introduction and Background

- Previous COHYST Modeling Efforts
- Multi-units and multi-layers



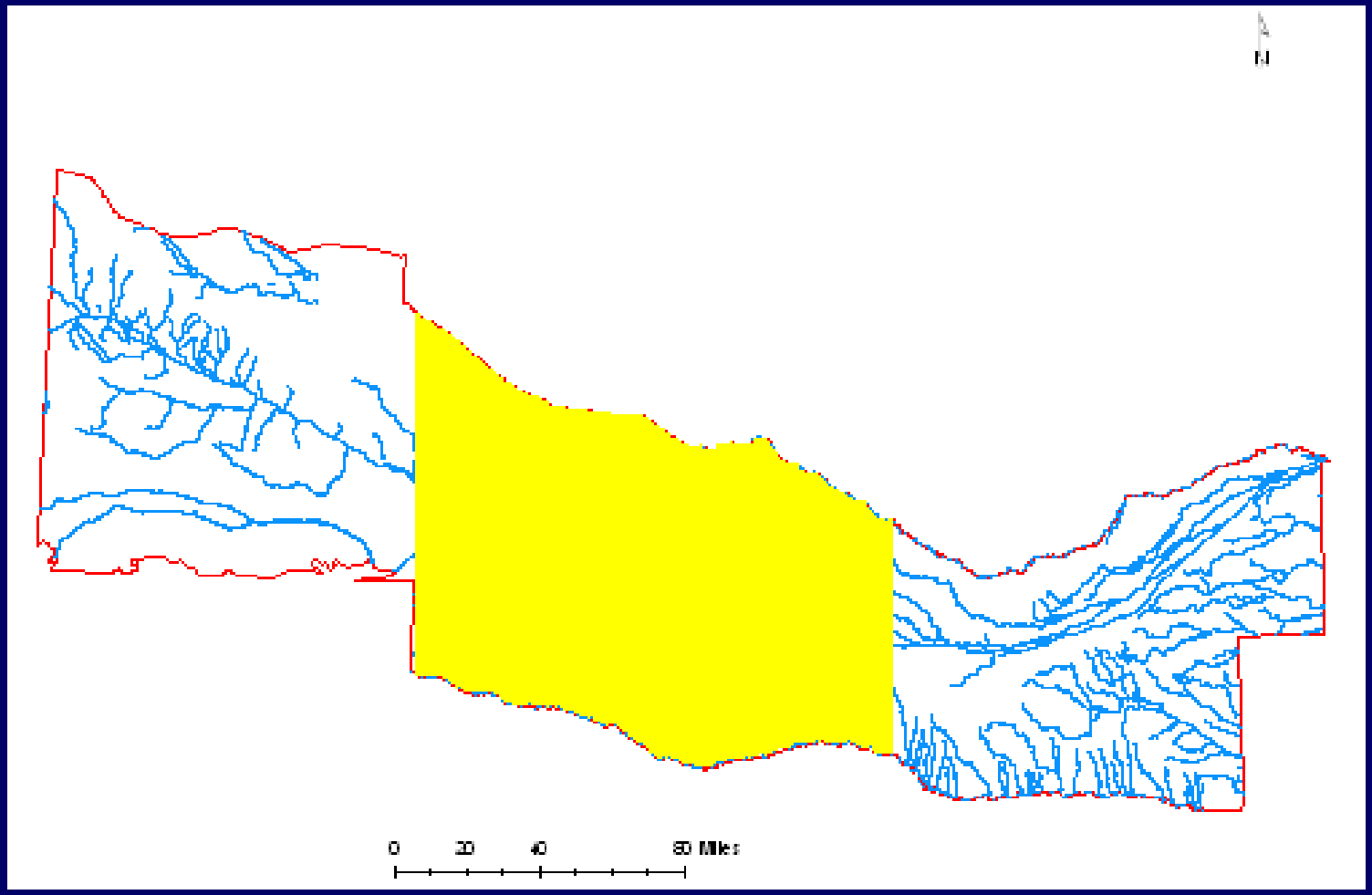
Introduction and Background

- Eastern Model Unit (Five Layers)



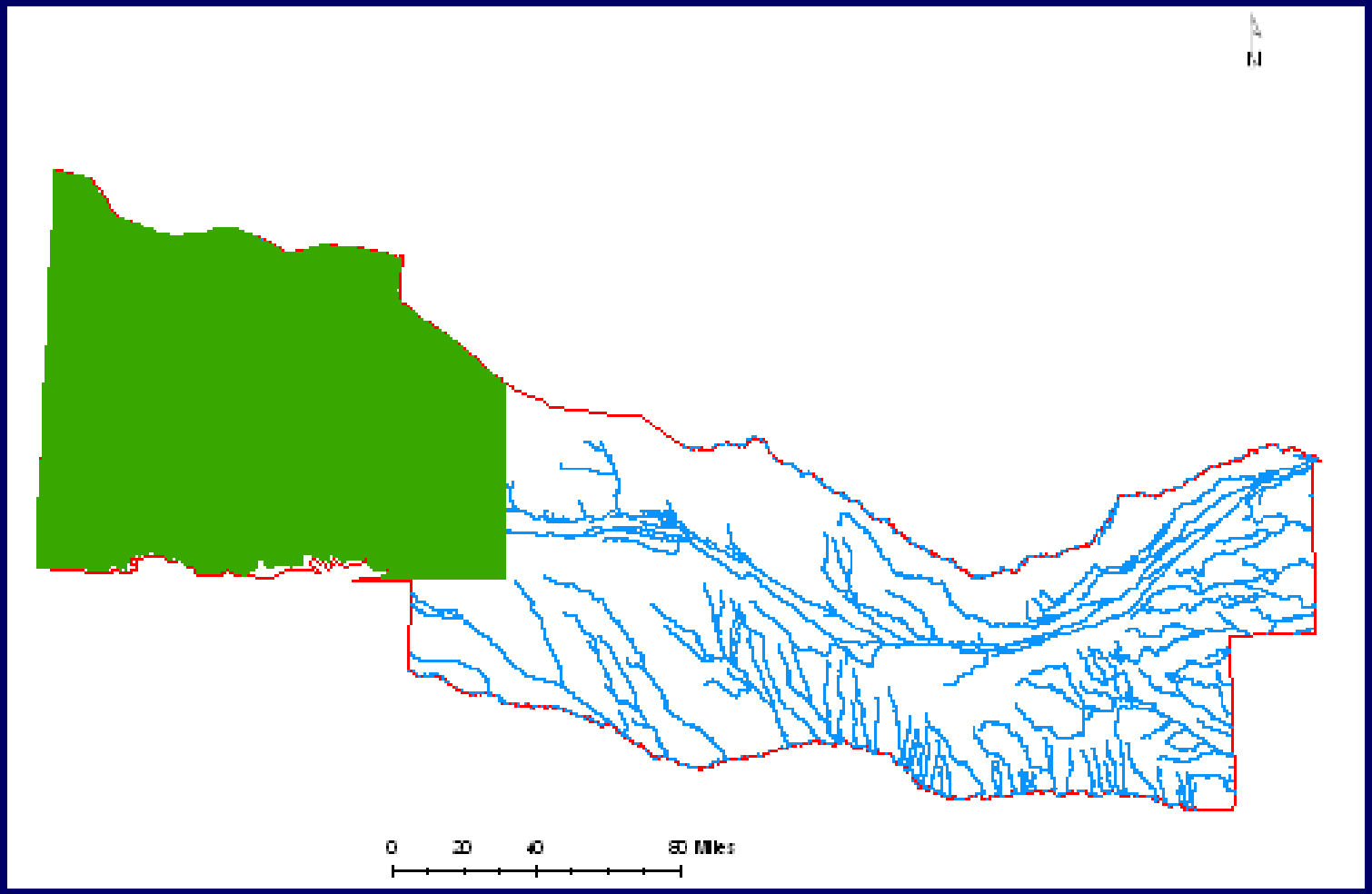
Introduction and Background

- Central Model Unit (Six Layers)



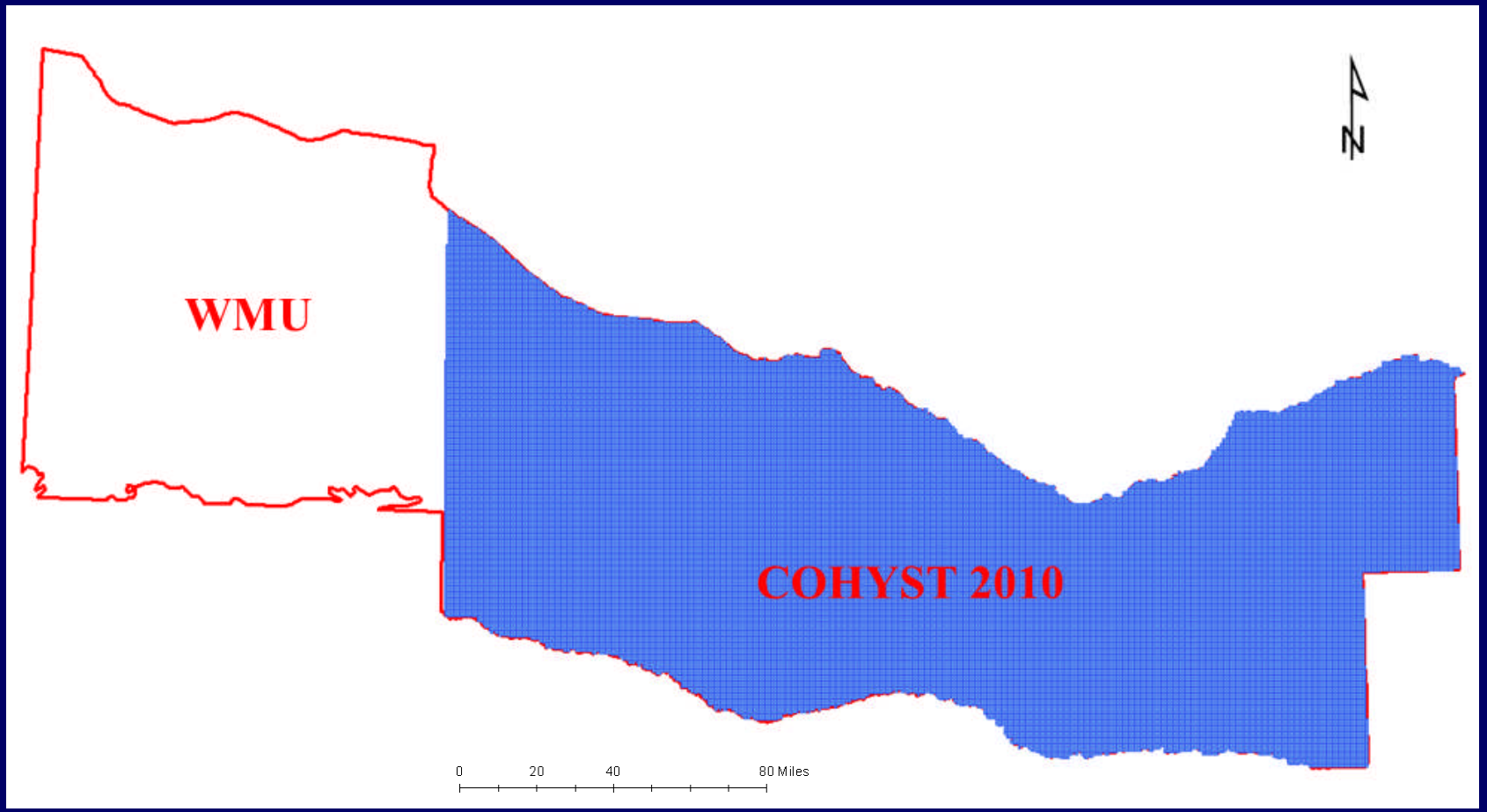
Introduction and Background

- Western Model Unit (One Layer)



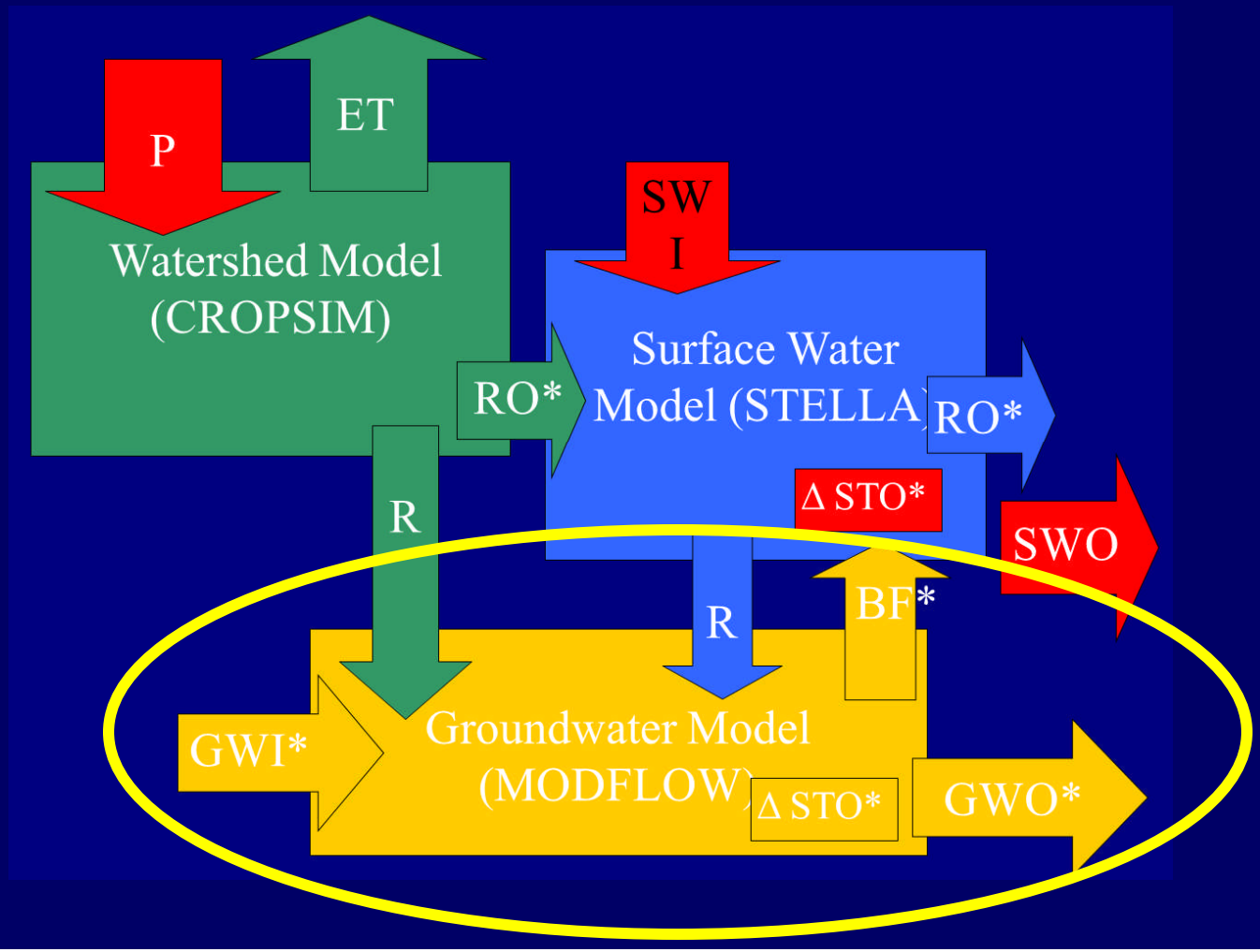
Objectives

- Different management needs and strategies



Objectives

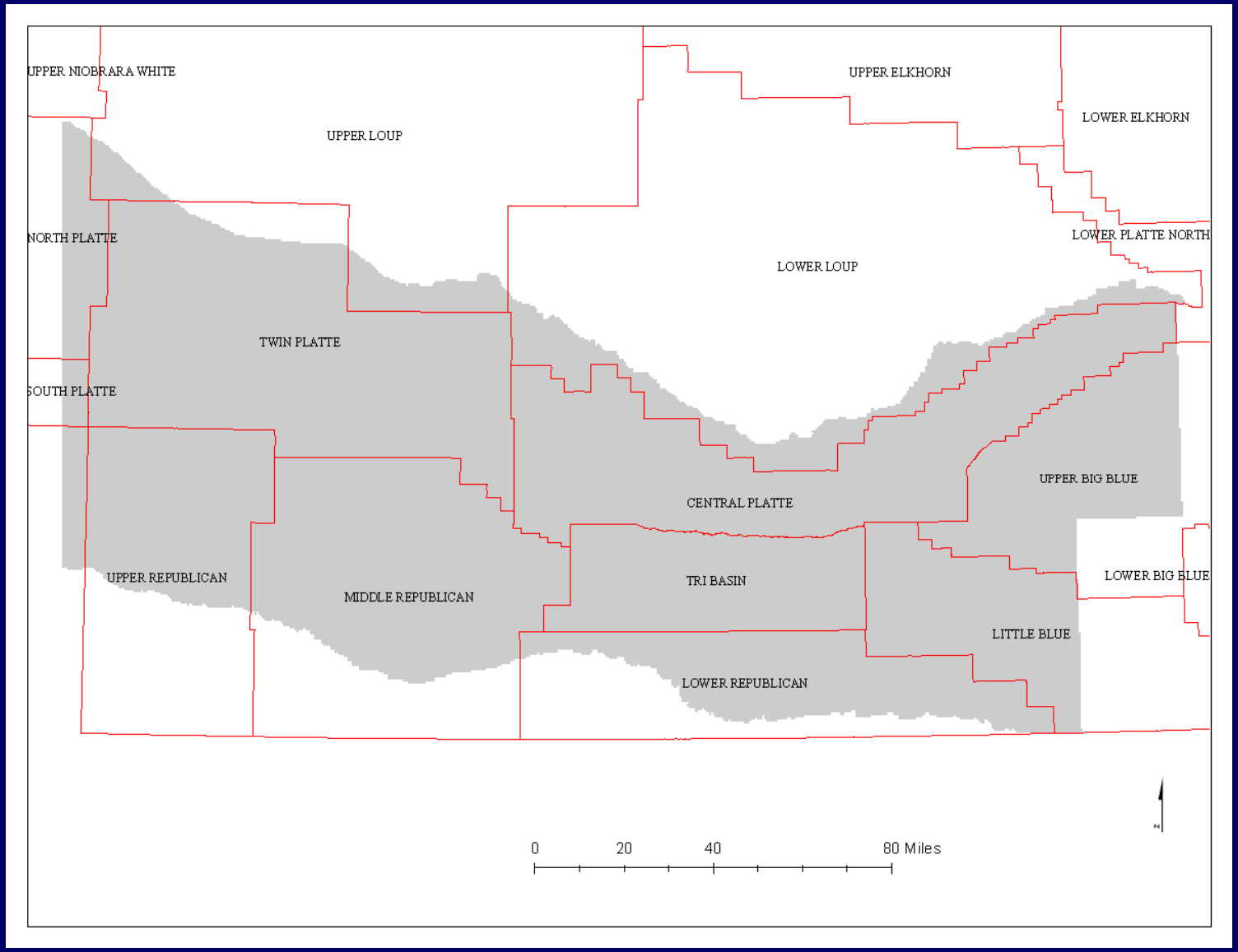
- Active interactions between components during modeling, calibration, and analysis process



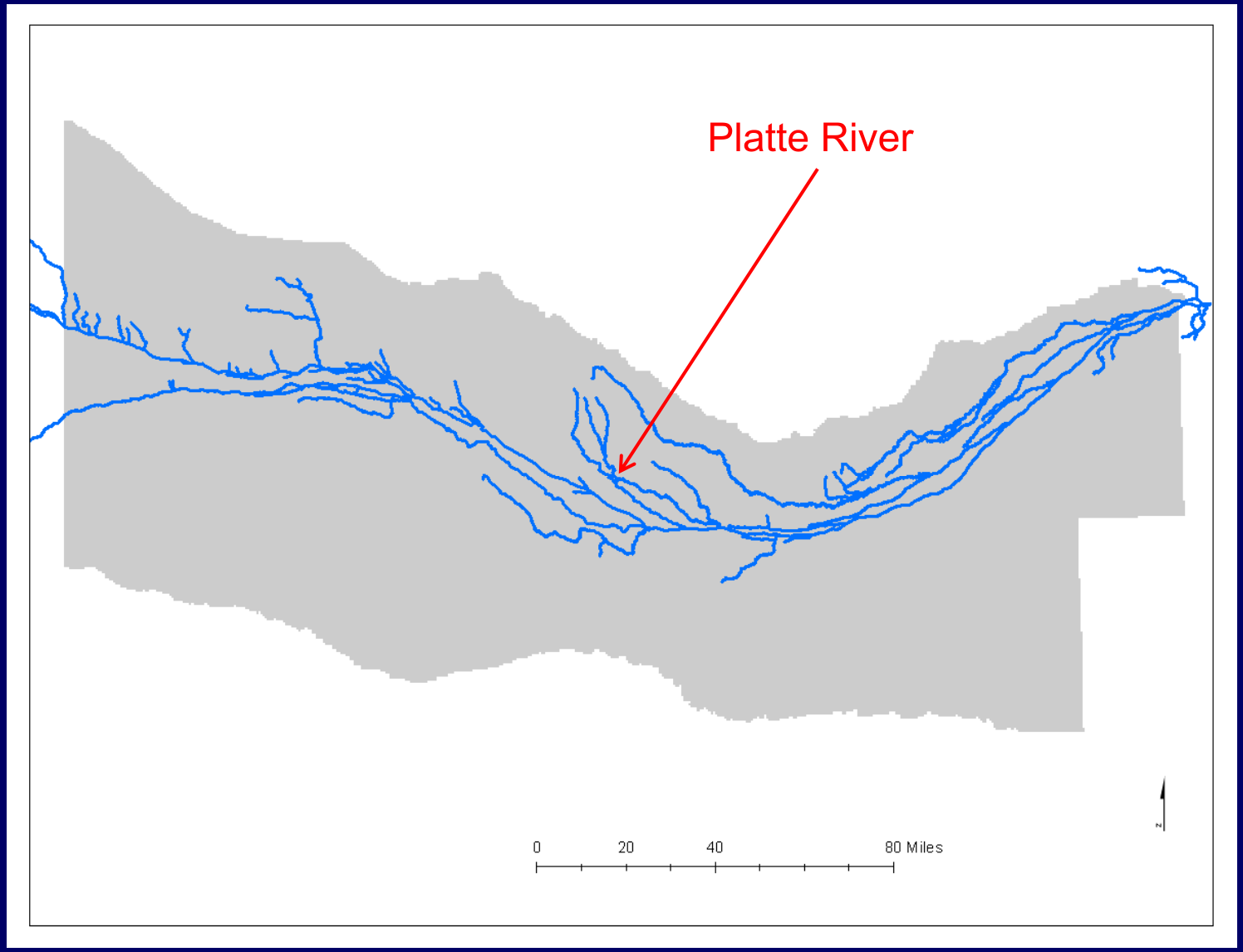
Objectives

- Phase I: Water Budget
- Phase II: Develop a suite of modeling tools
- Phase III: Develop applied tools

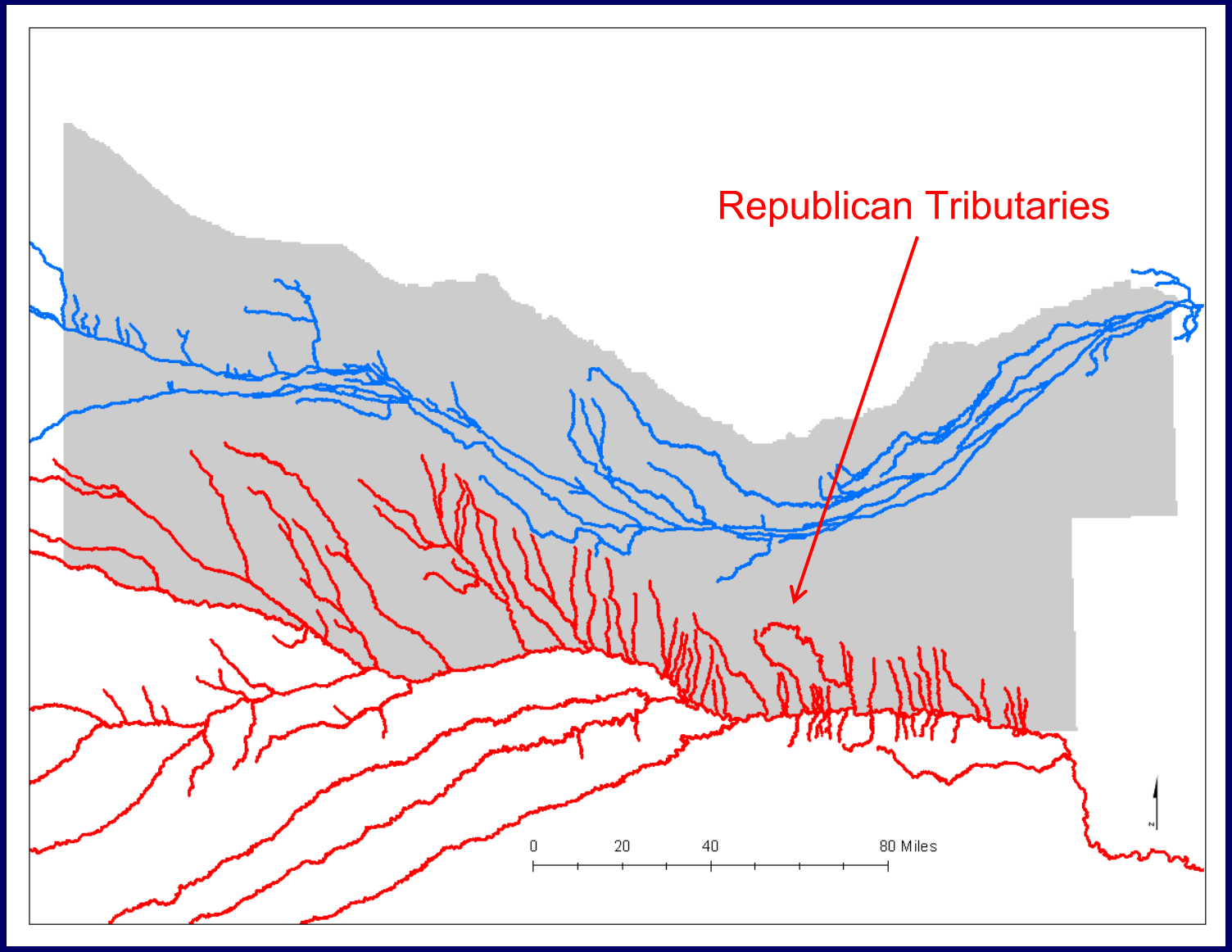
Model Framework



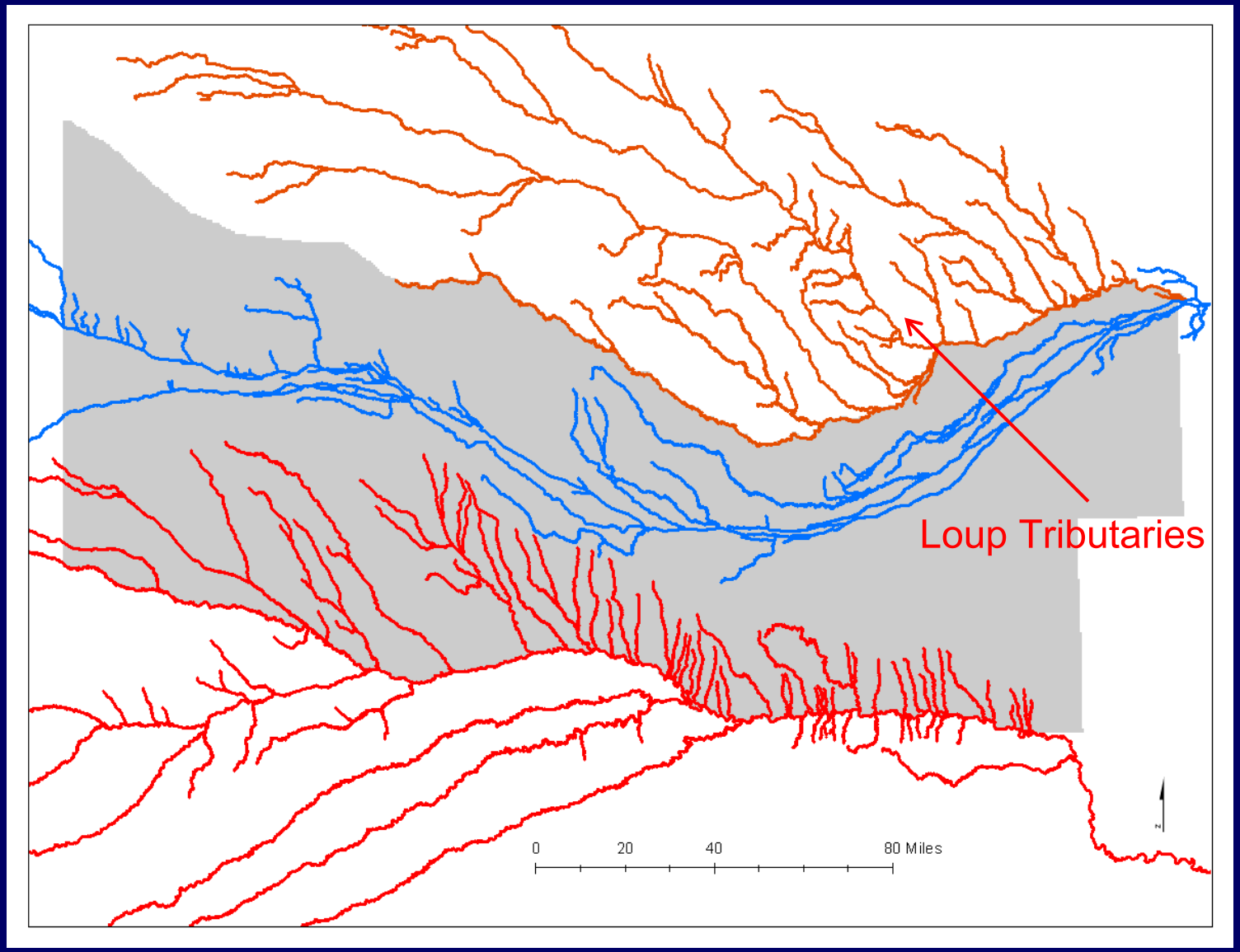
Model Framework



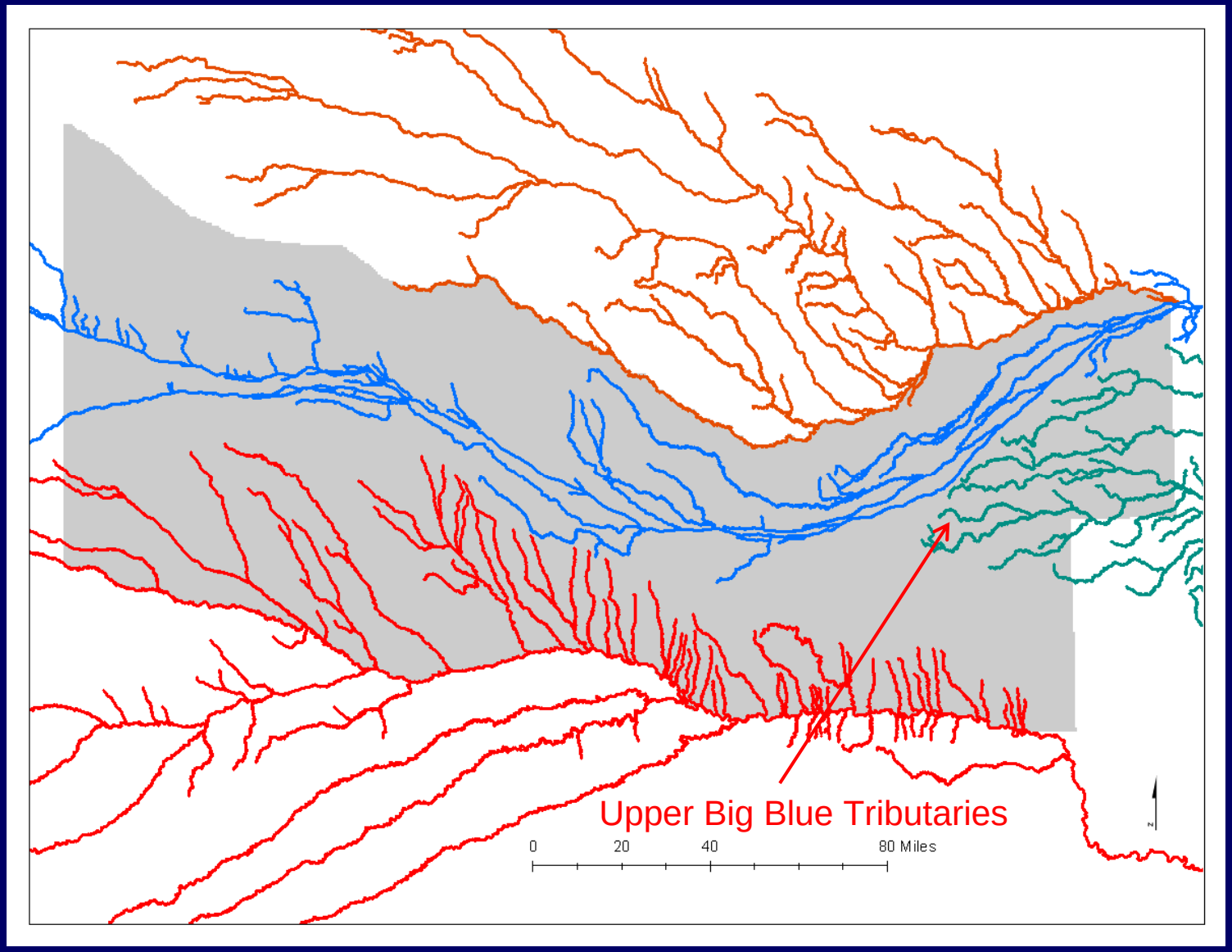
Model Framework



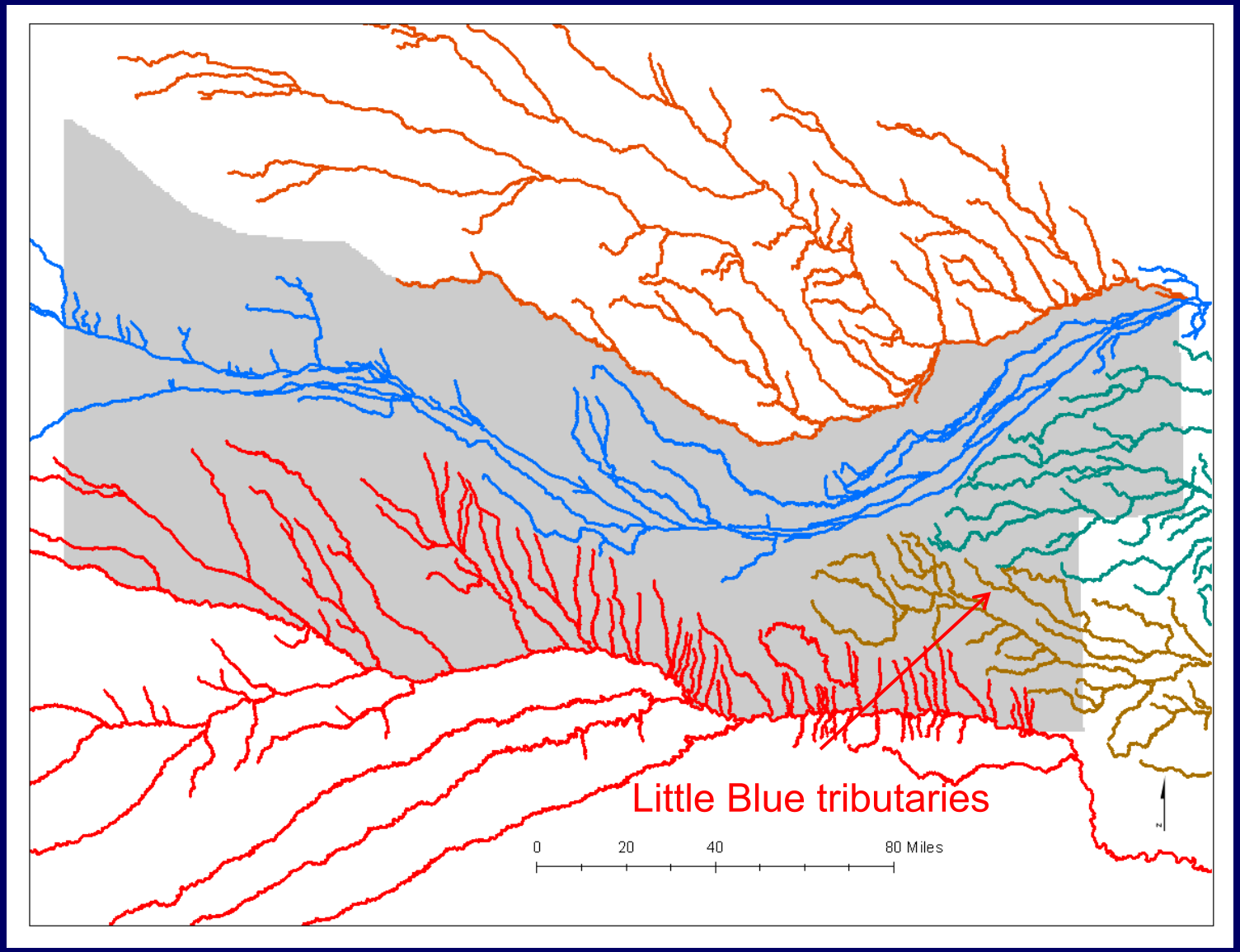
Model Framework



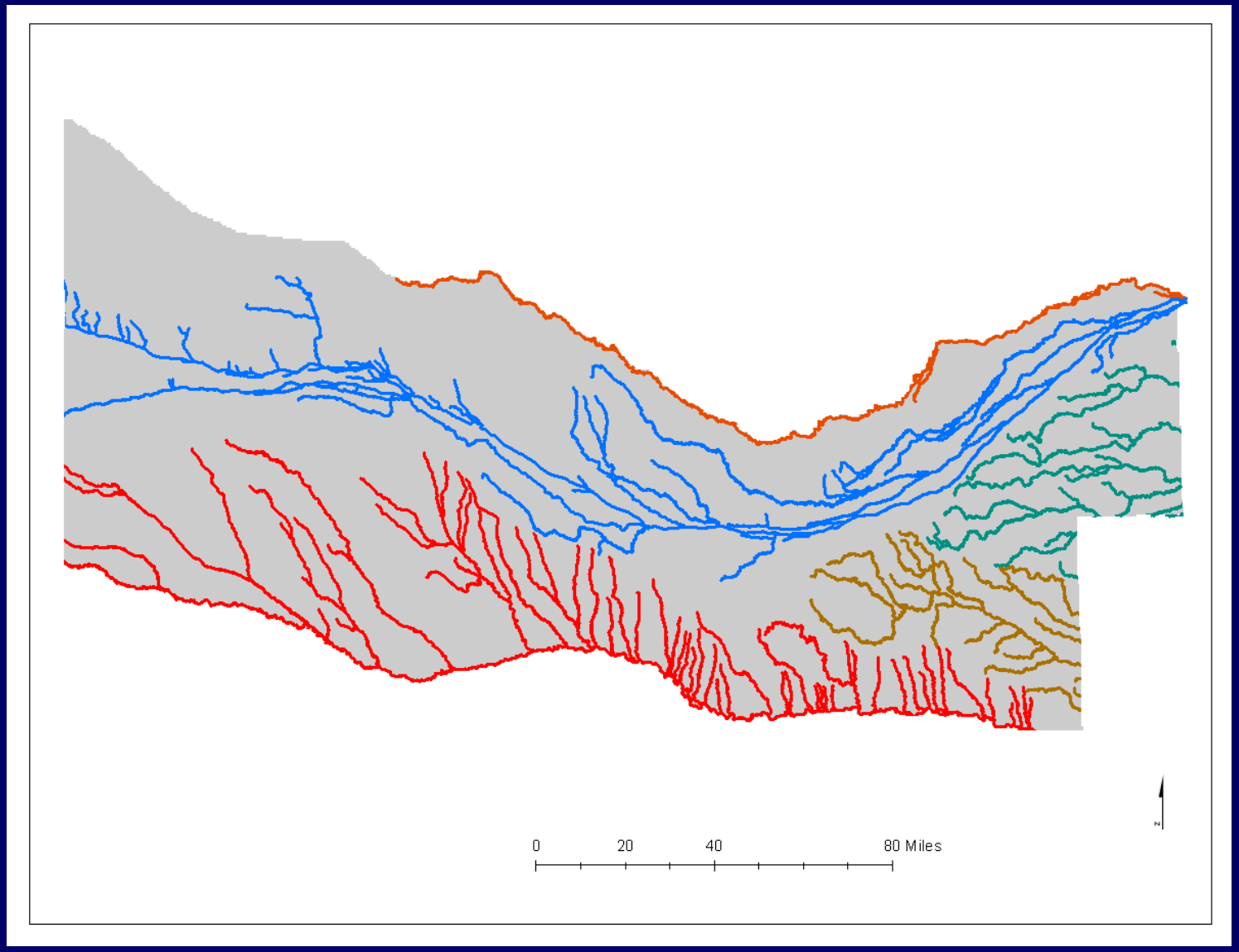
Model Framework



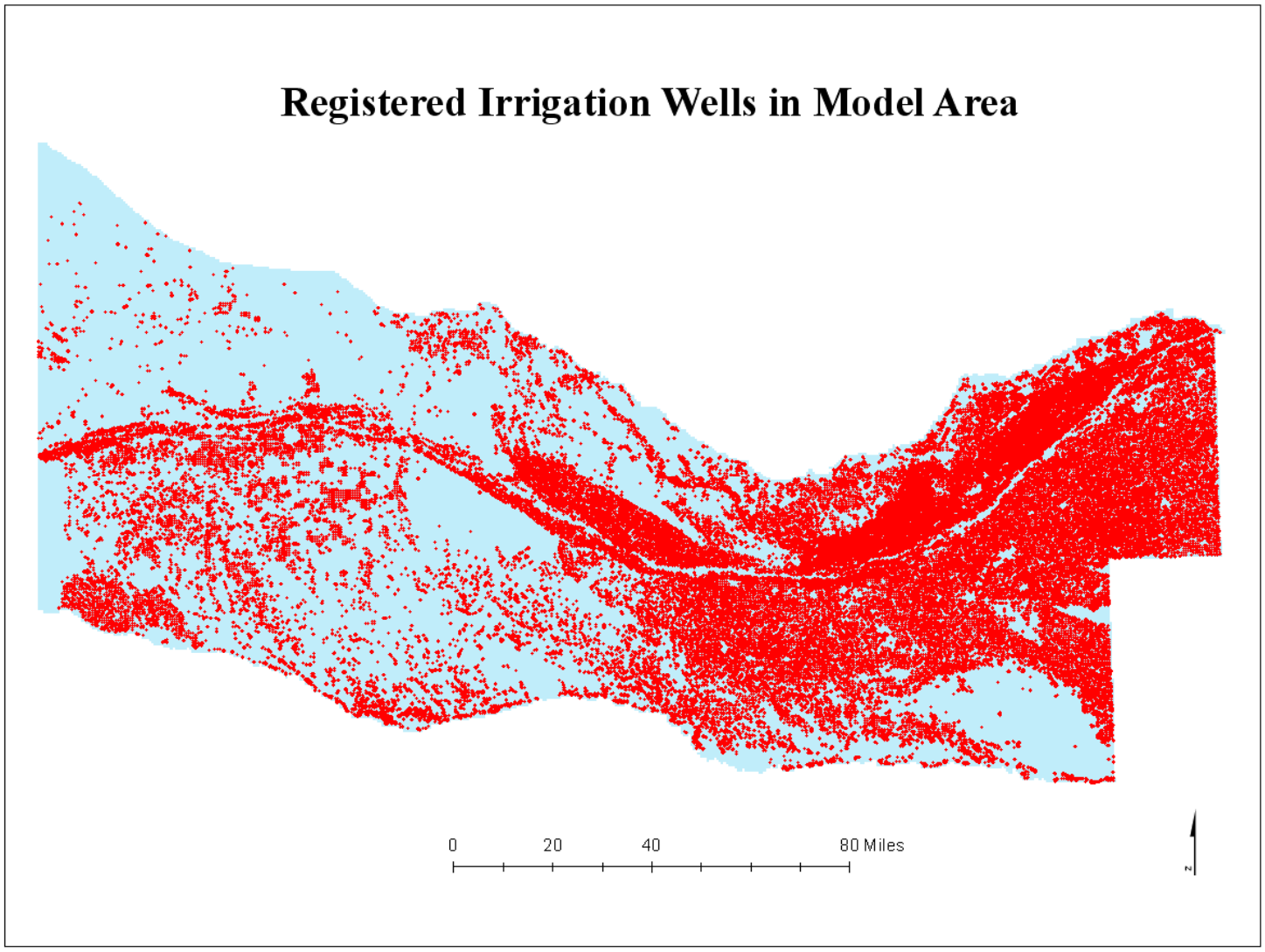
Model Framework



Model Framework

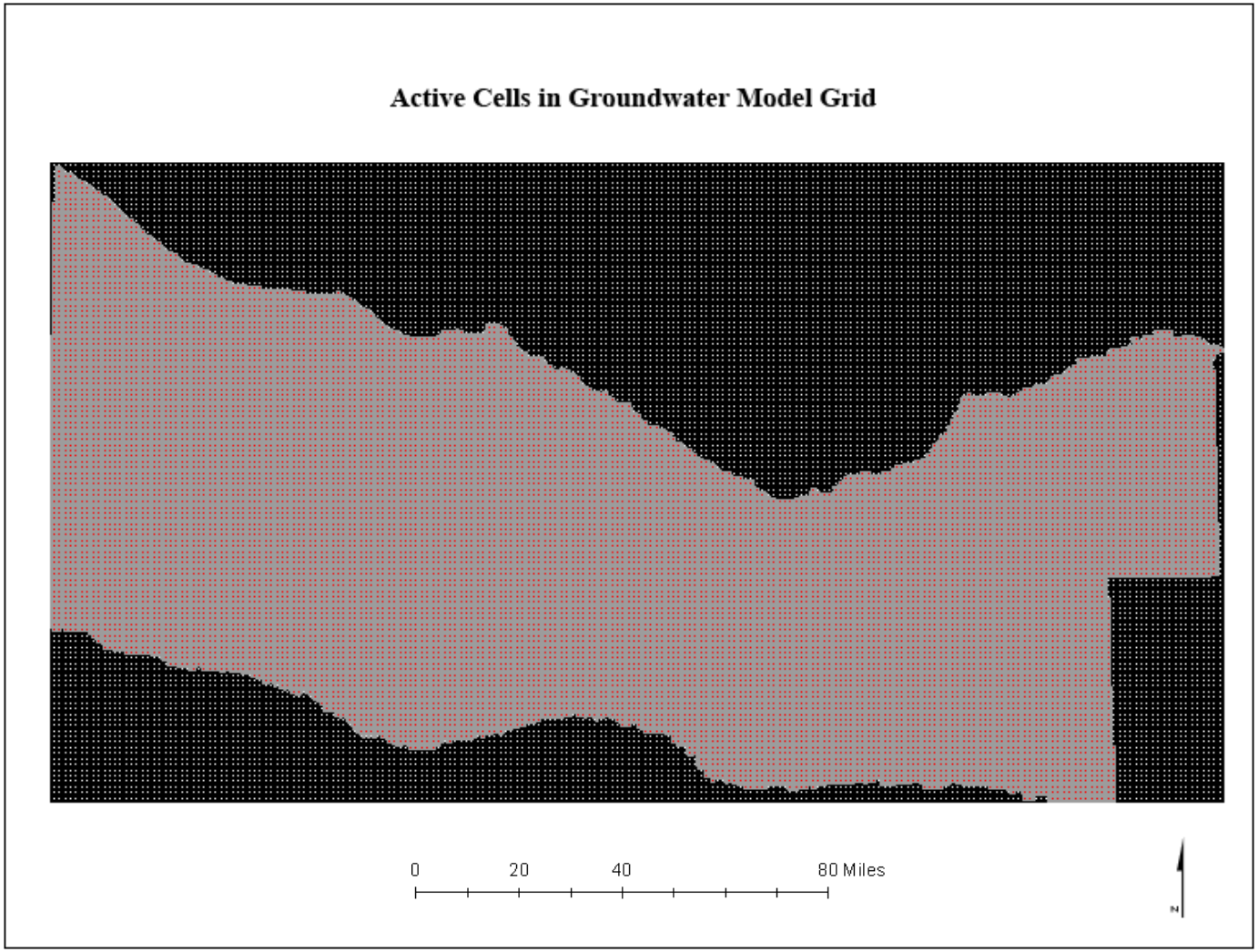


Model Framework

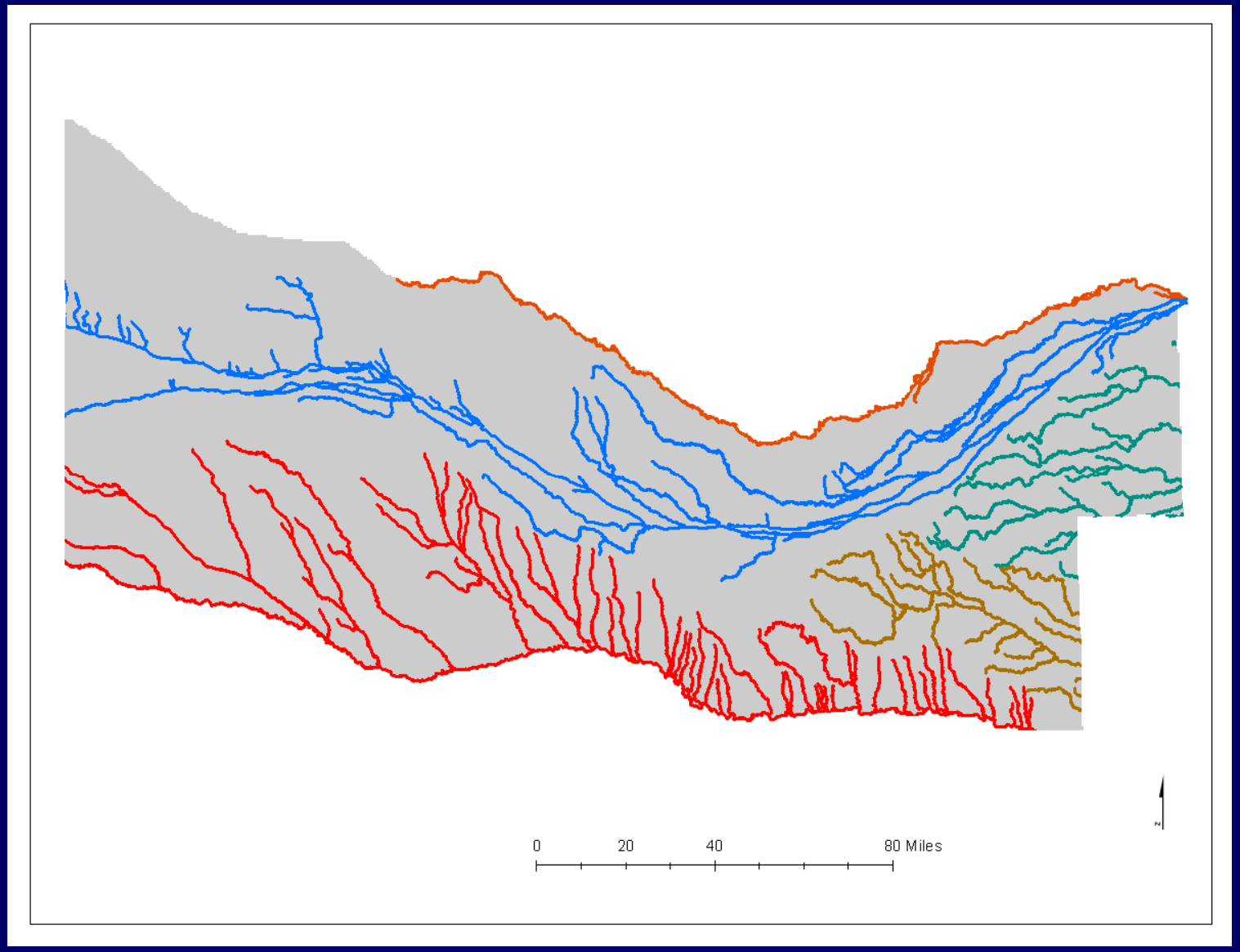


Model Framework

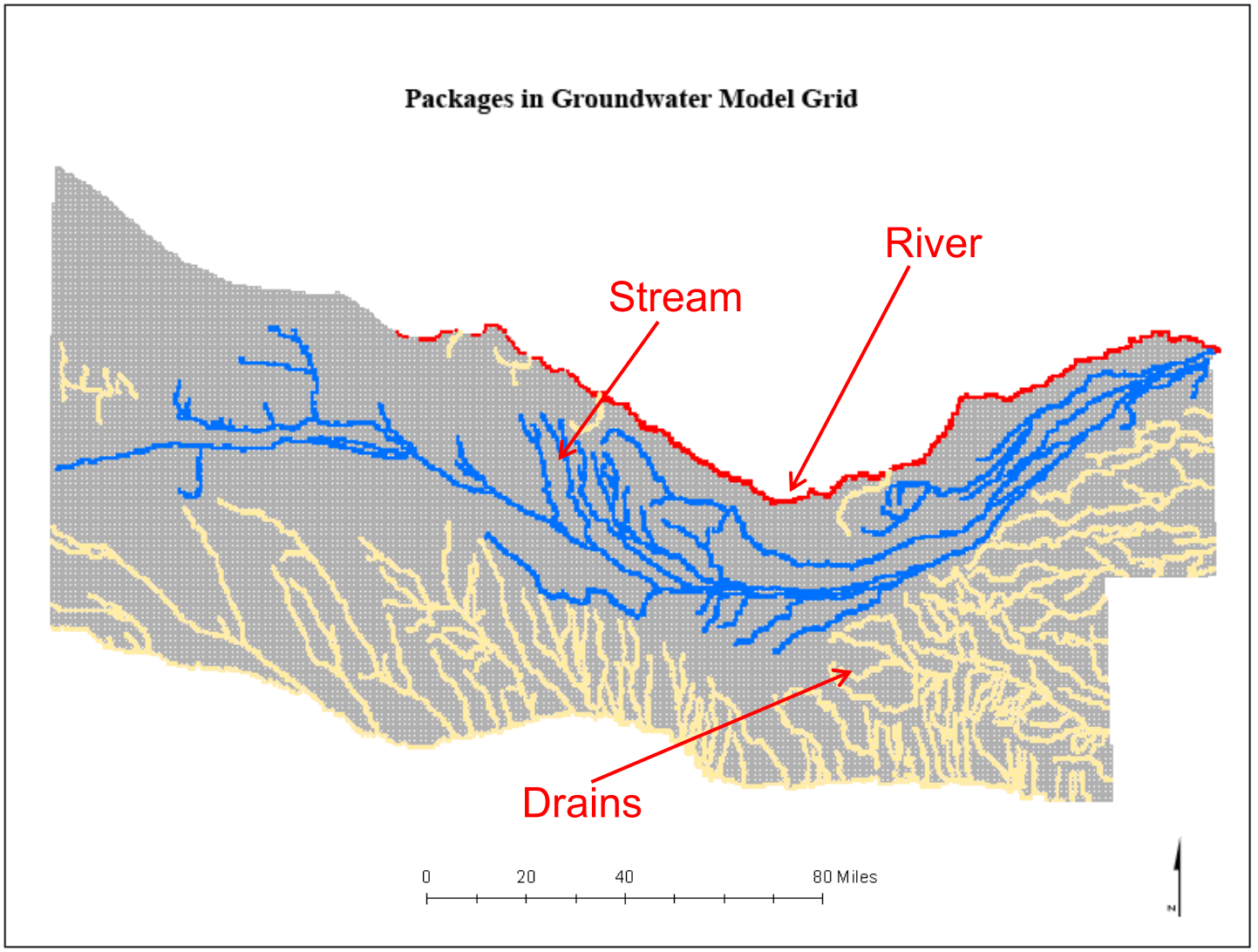
Model Framework



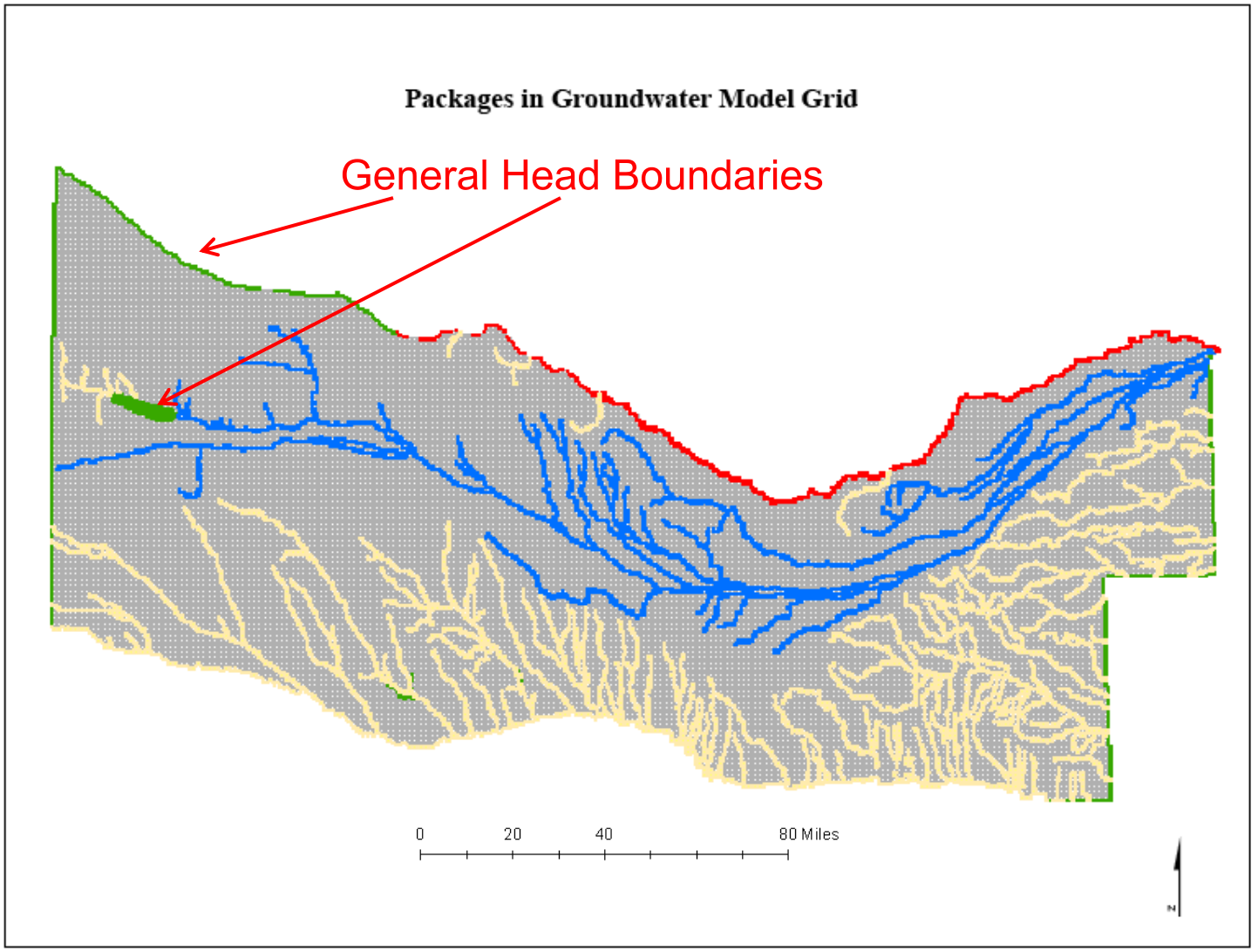
Model Framework



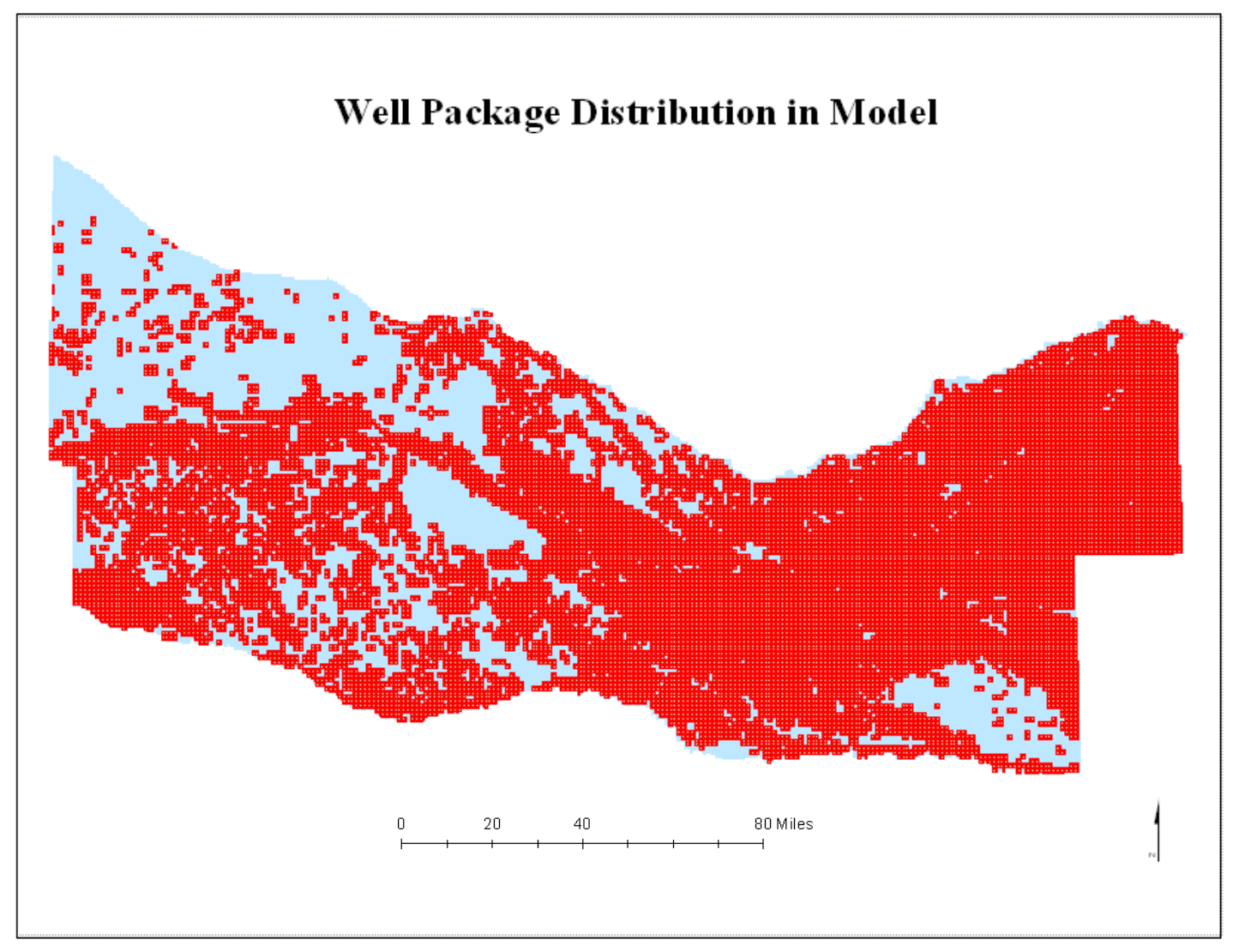
Model Framework



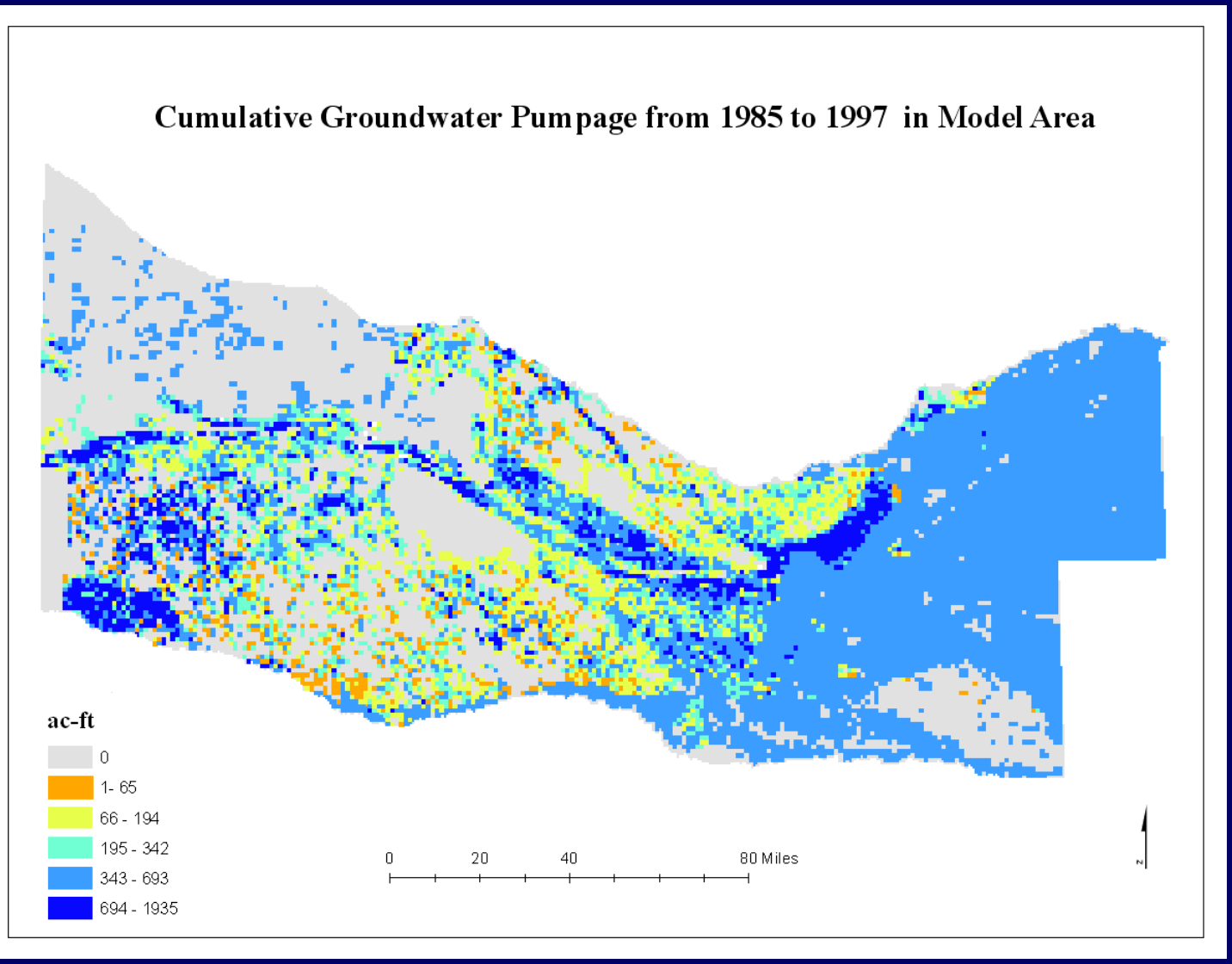
Model Framework



Model Framework



Model Framework

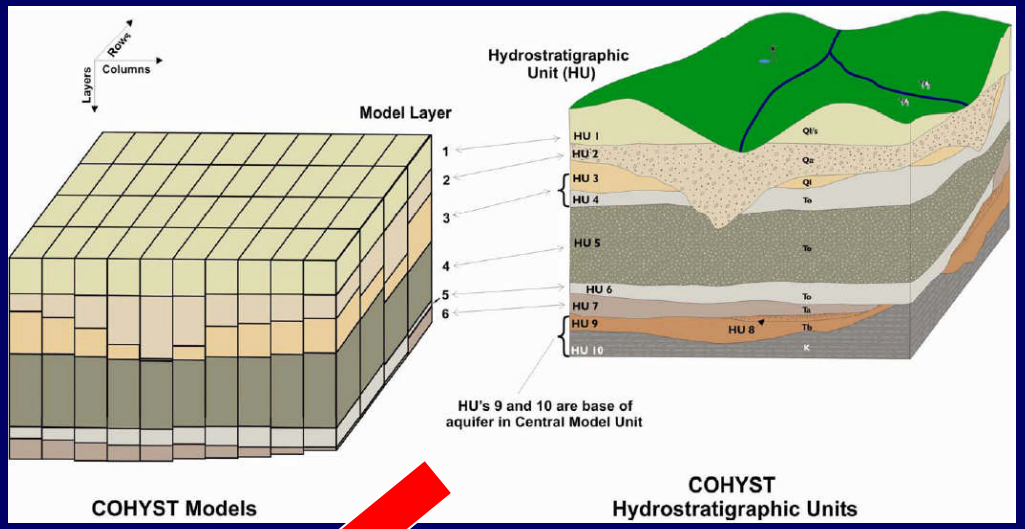


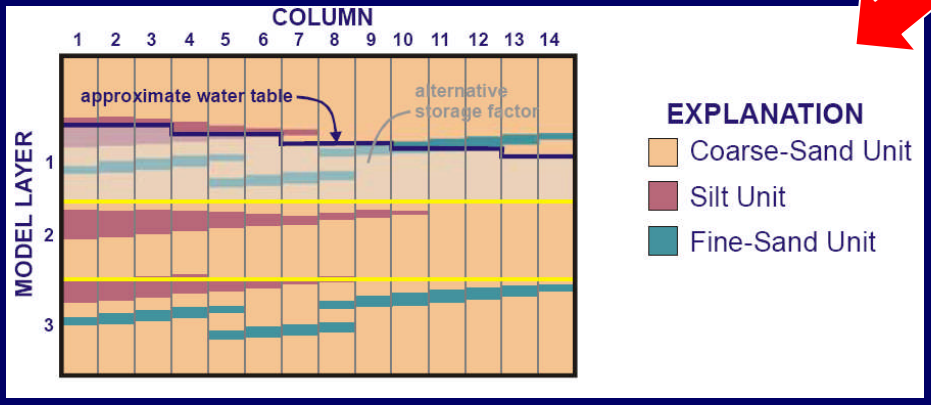
Model Framework

- Framework consistent with the previous COHYST modeling effort
- Hydro stratigraphic units representation
- LPF package Vs. HUF package
- Model simulation results storage

Model Framework

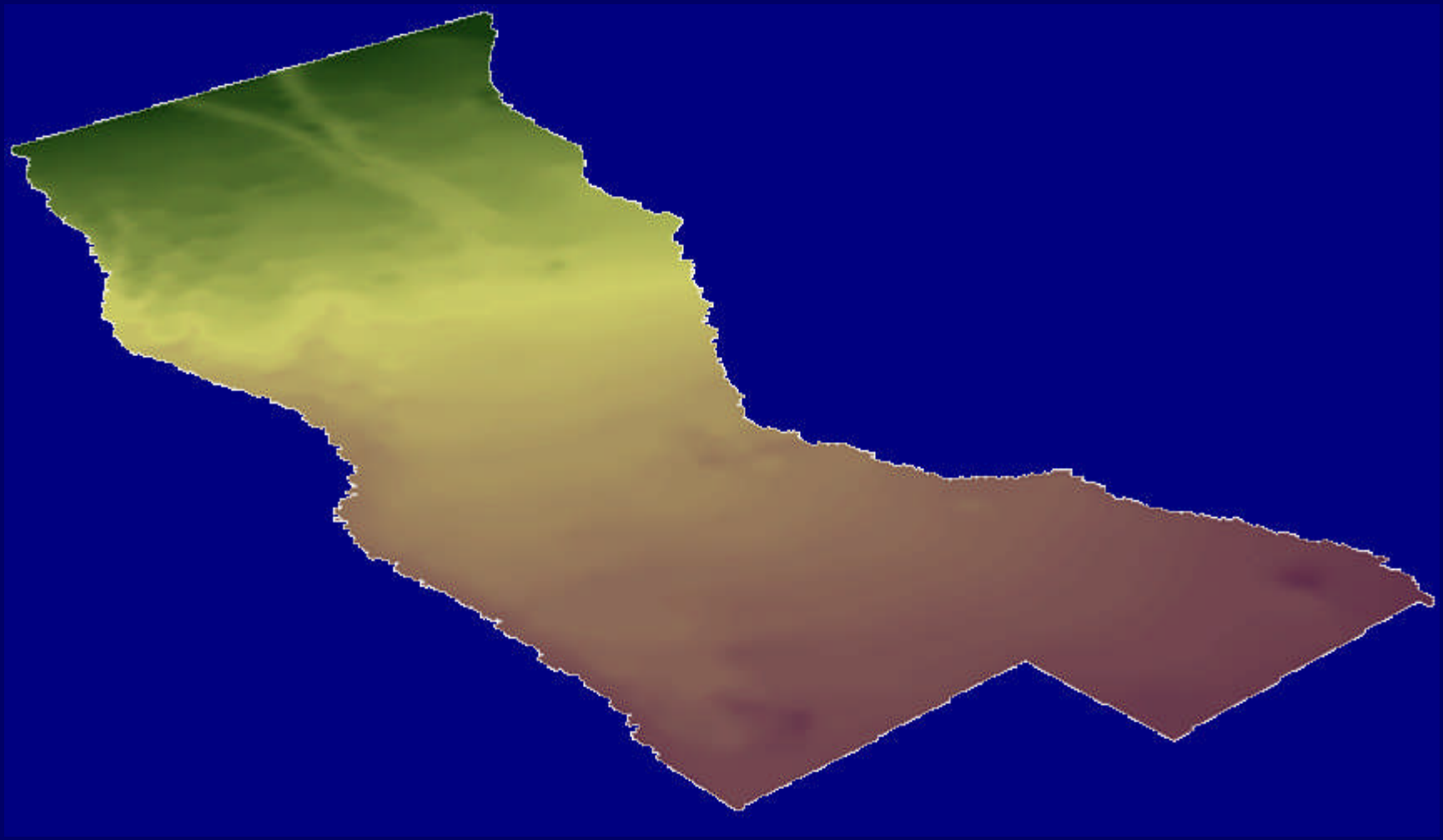
- Use of HUF package to represent various hydro stratigraphic units instead of adding layers in model





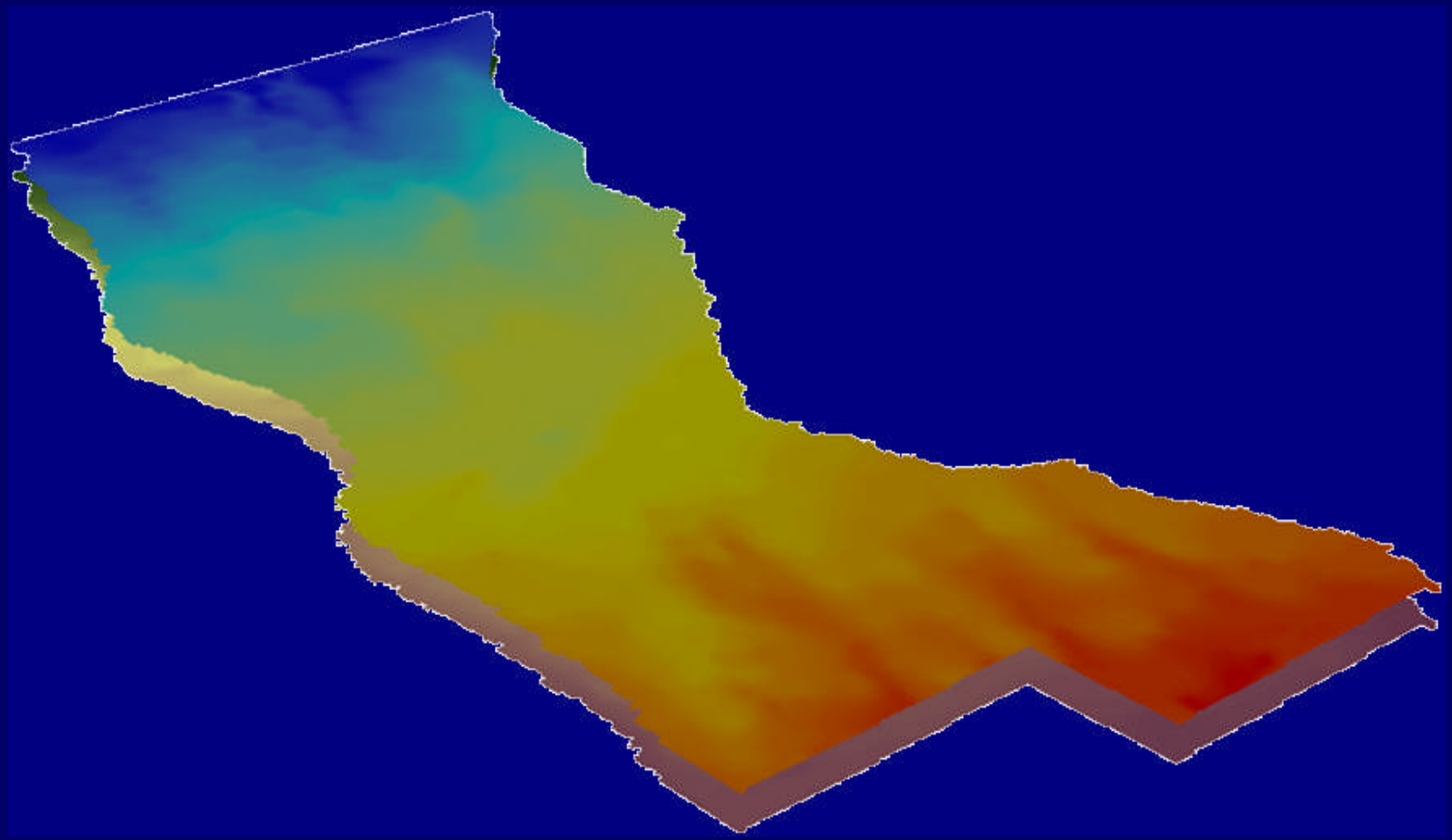
Model Framework

Bottom of the Aquifer



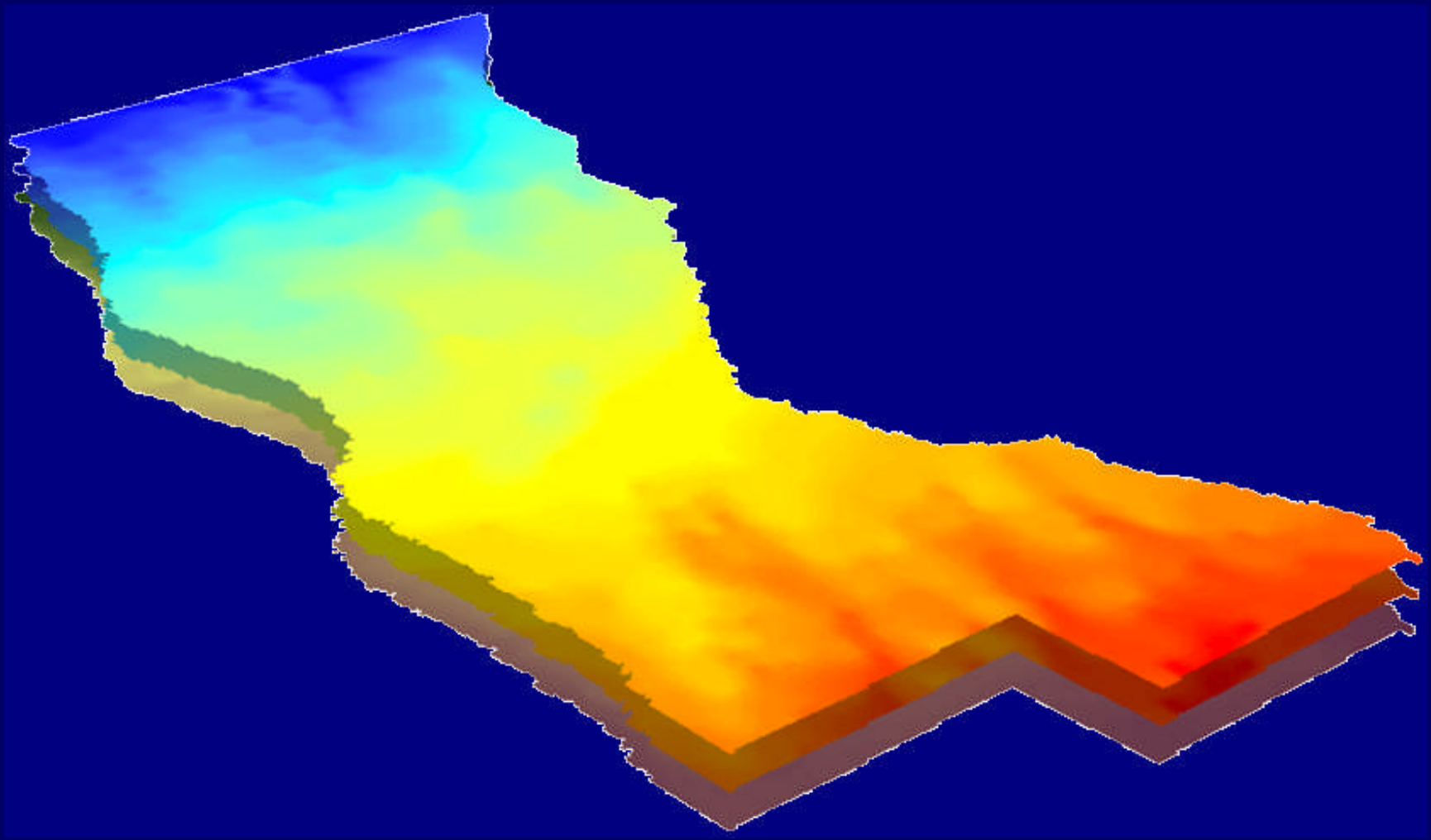
Model Framework

Hydrostratigraphic Unit 7



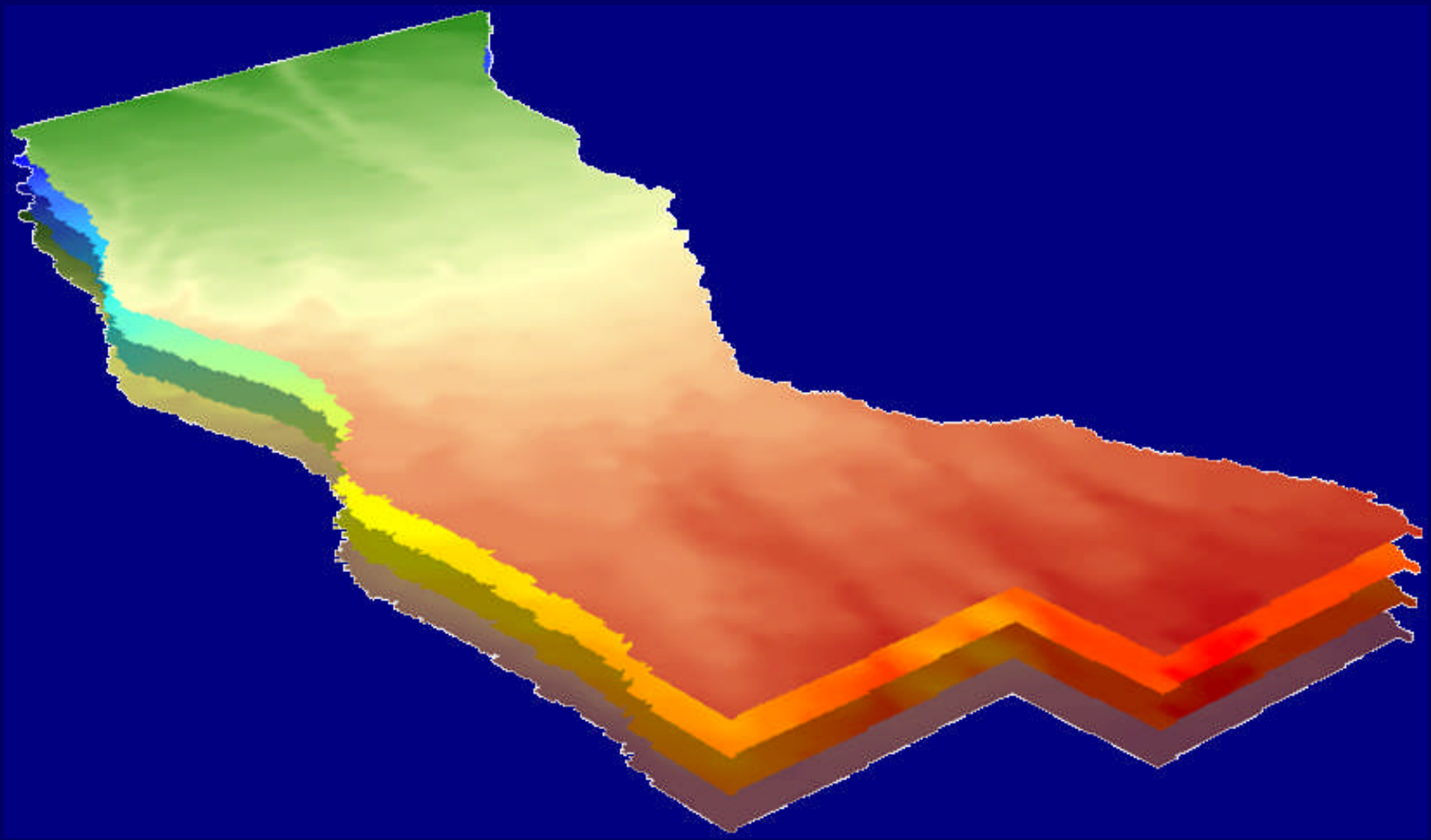
Model Framework

Hydrostratigraphic Unit 6



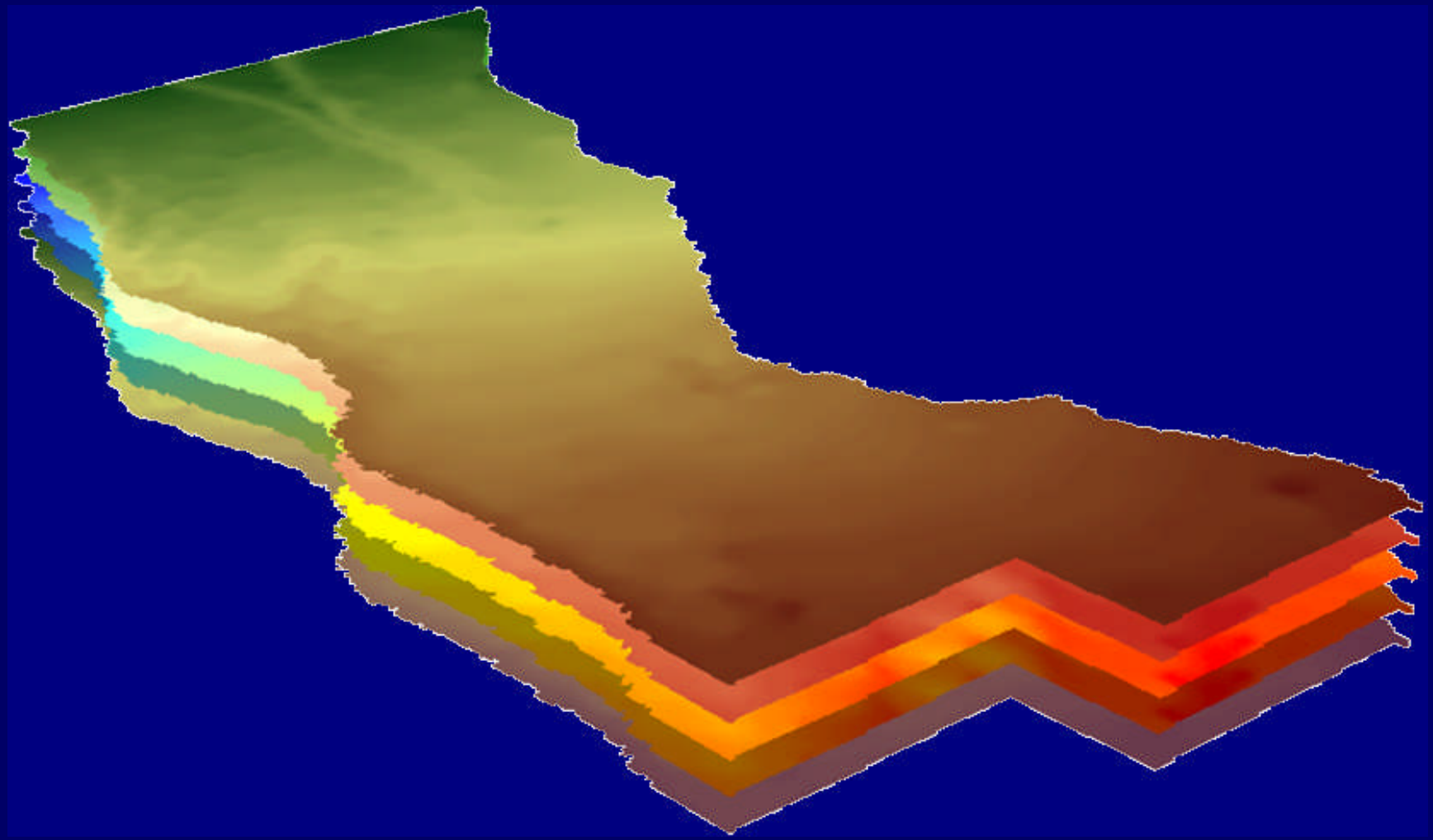
Model Framework

Hydrostratigraphic Unit 5



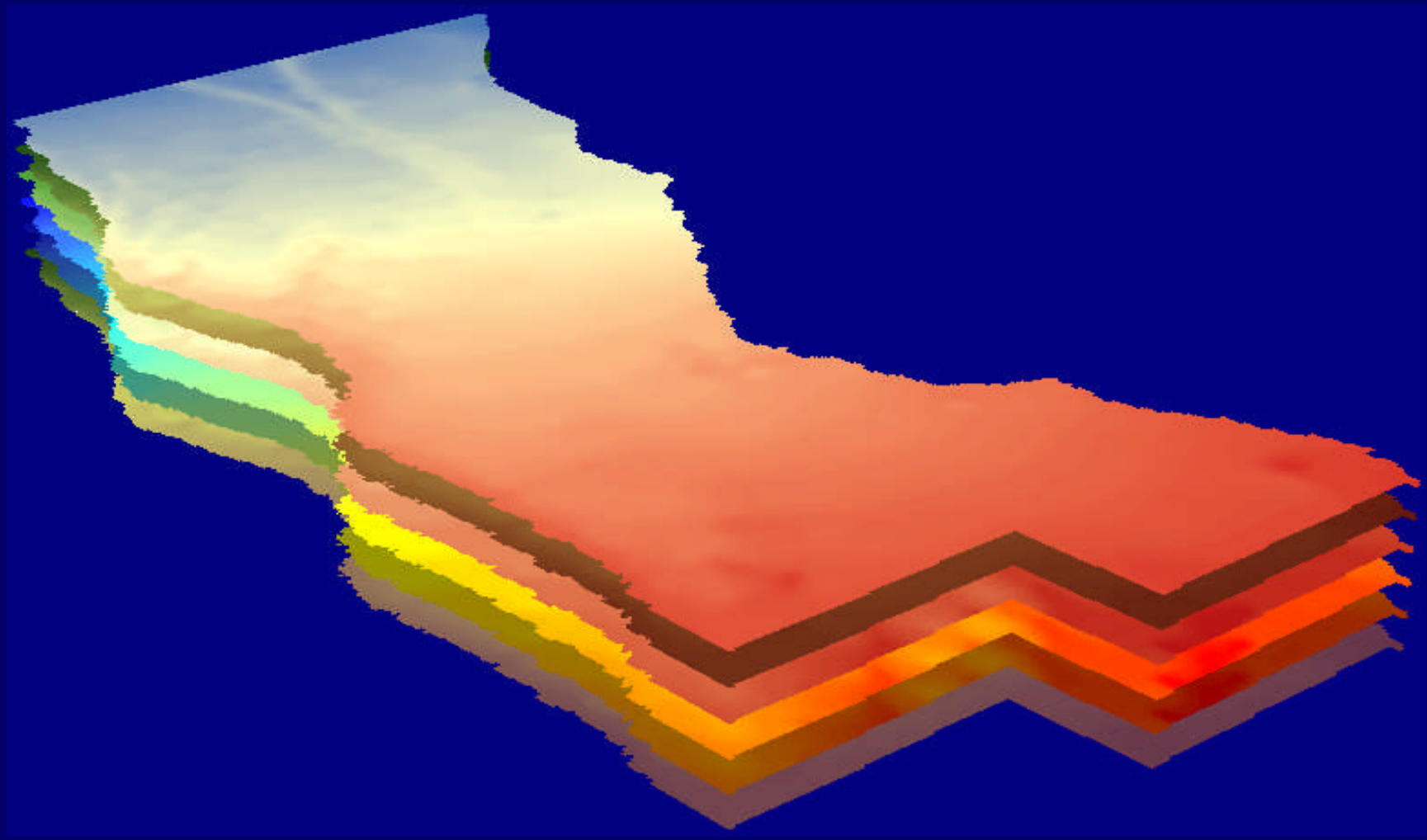
Model Framework

Hydrostratigraphic Unit 3 and 4



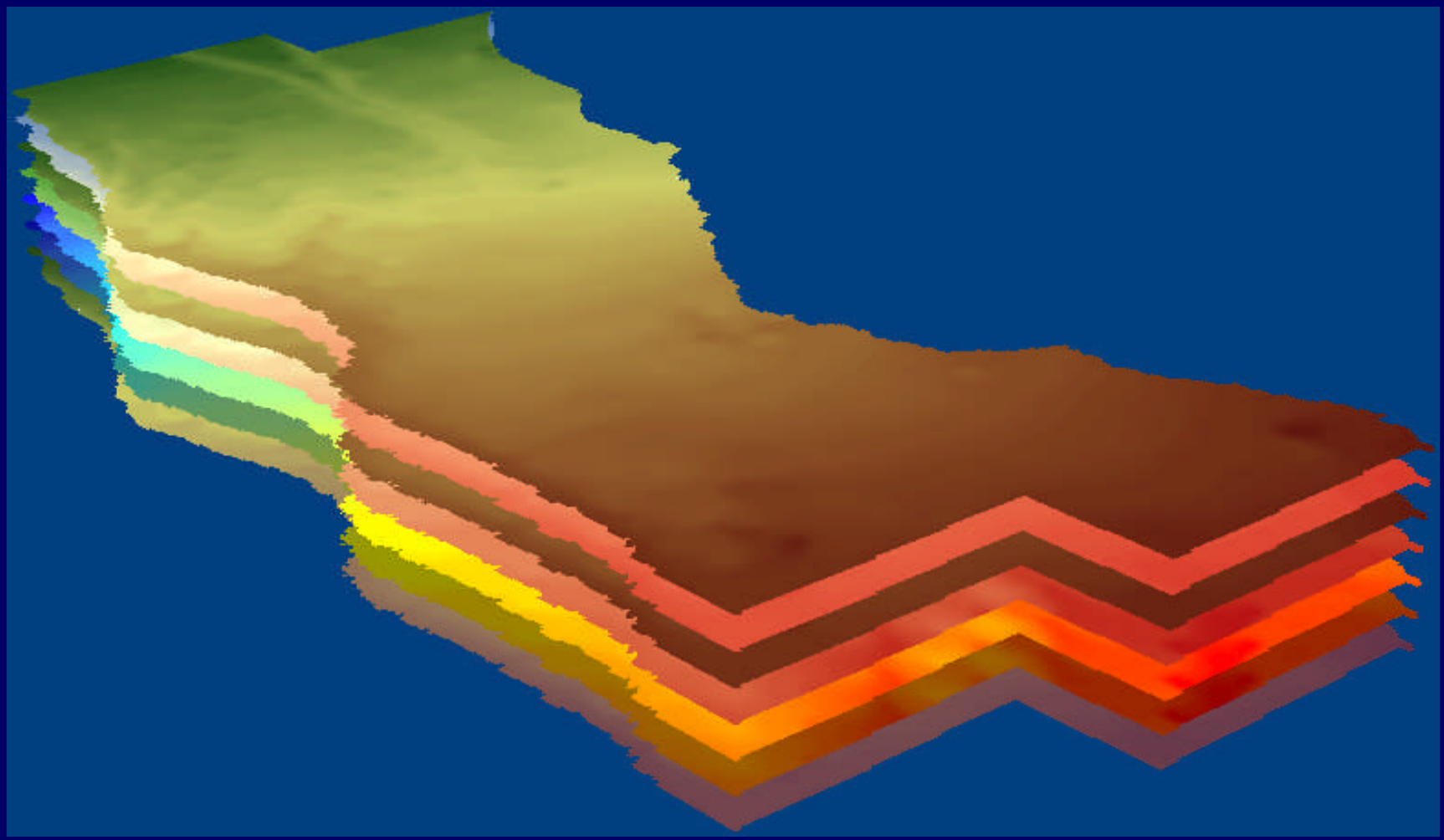
Model Framework

Hydrostratigraphic Unit 2

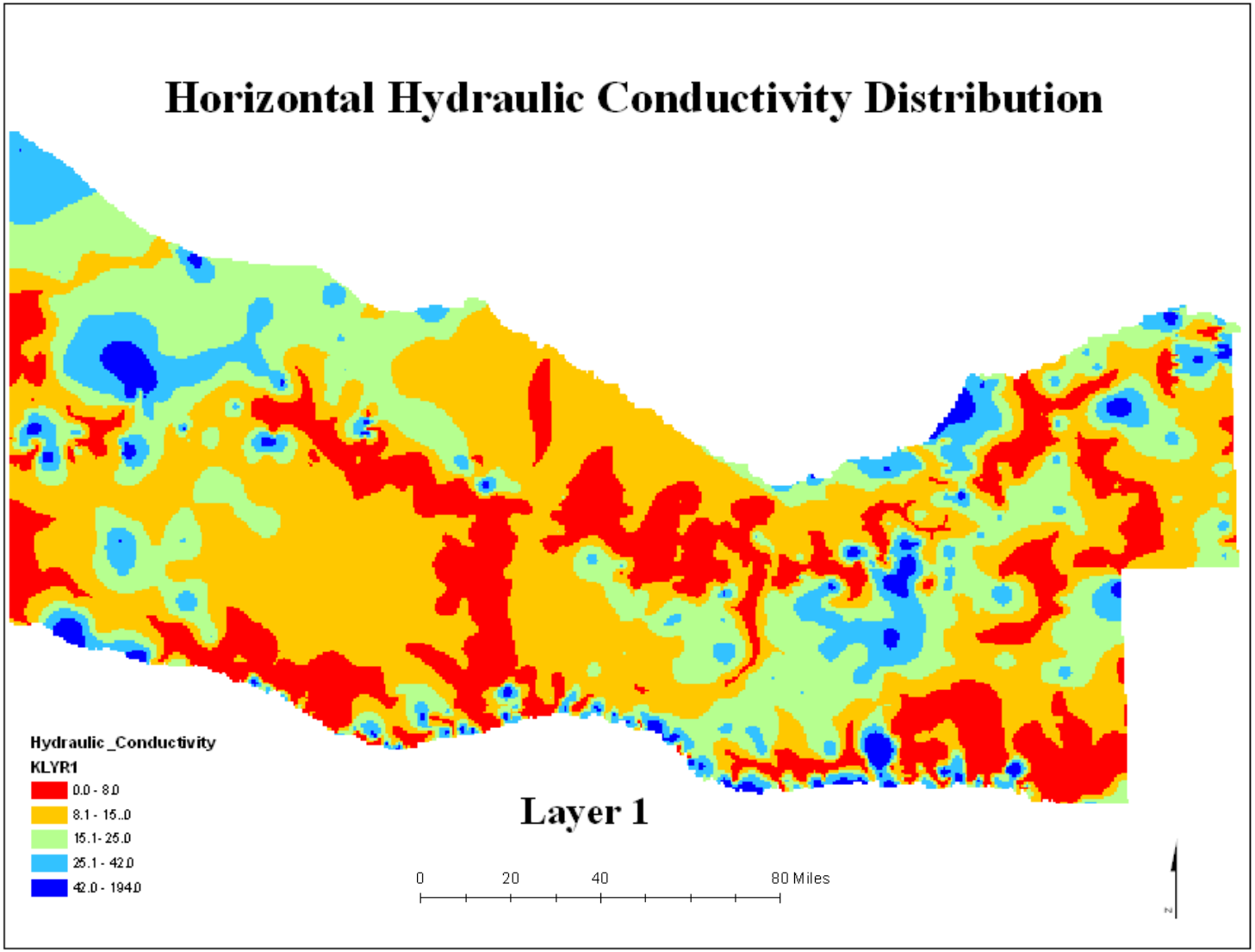


Model Framework

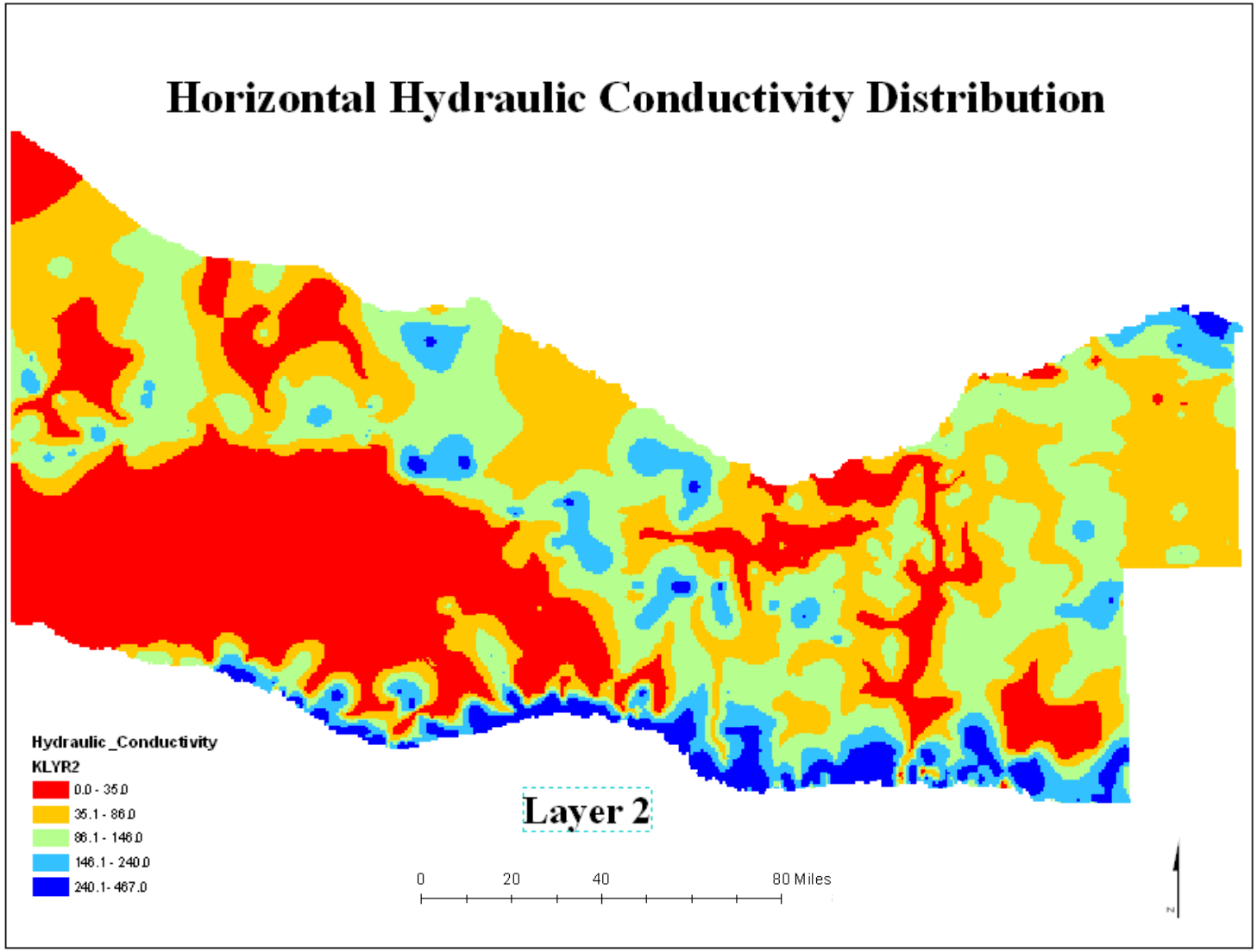
Hydrostratigraphic Unit 1



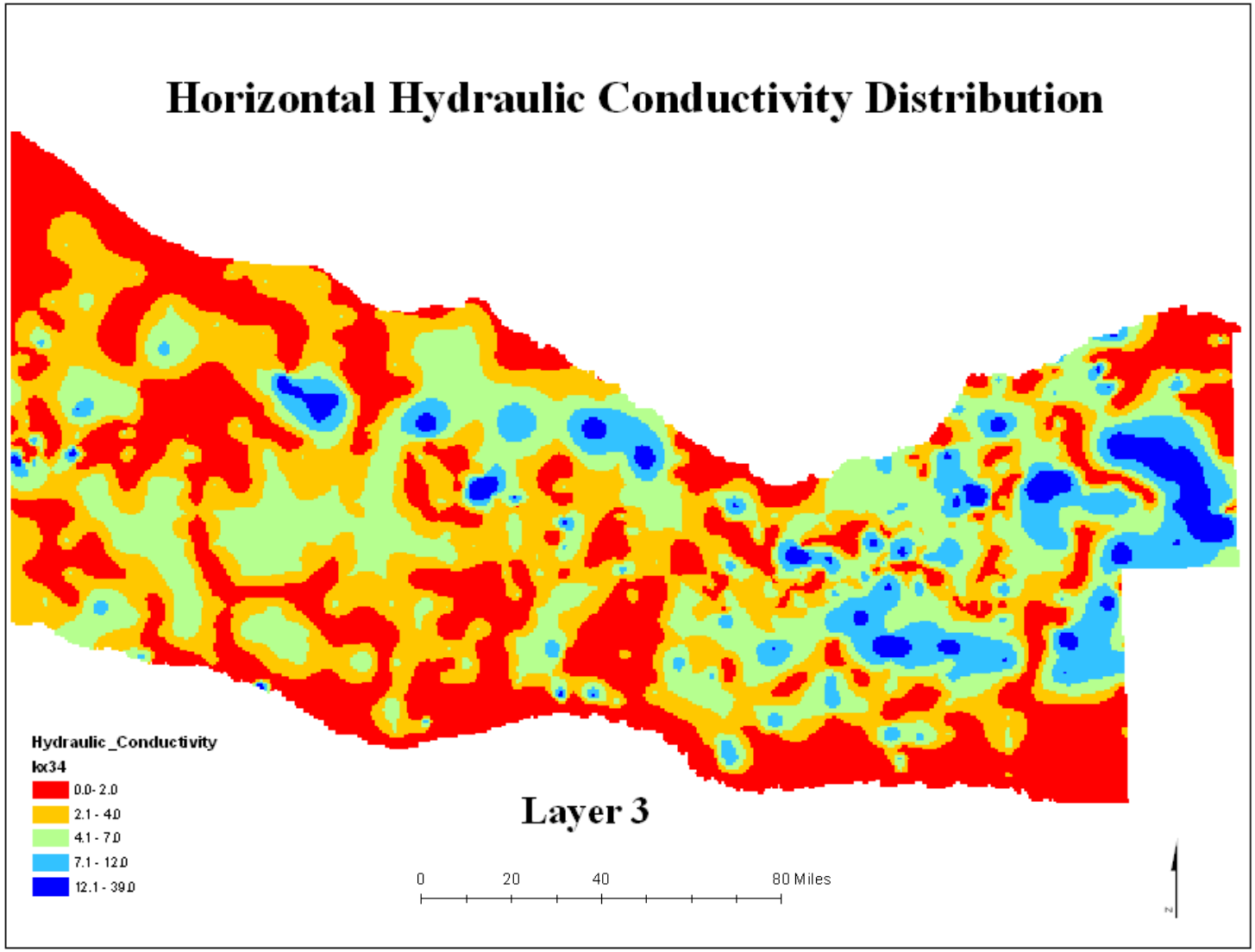
Model Datasets



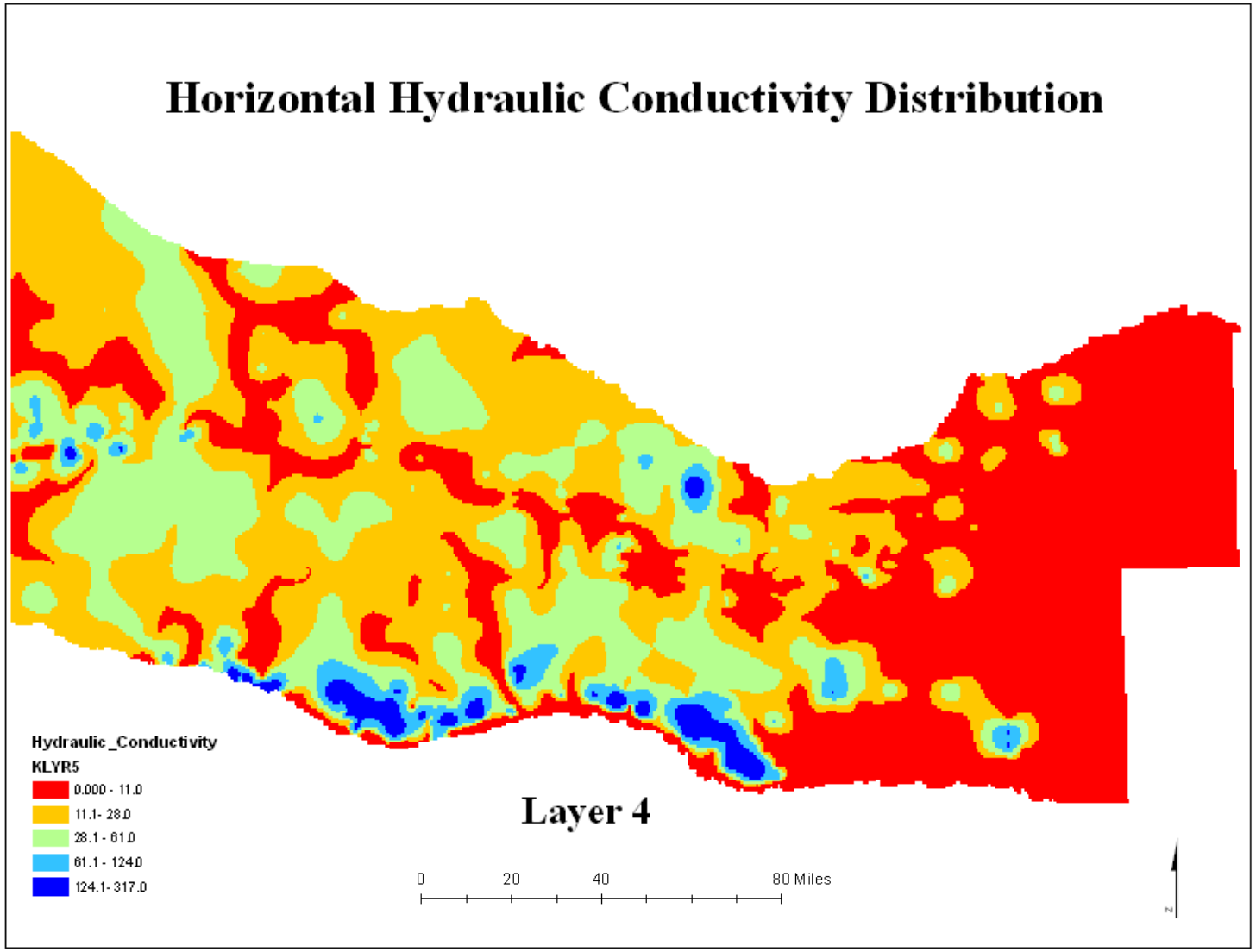
Model Datasets



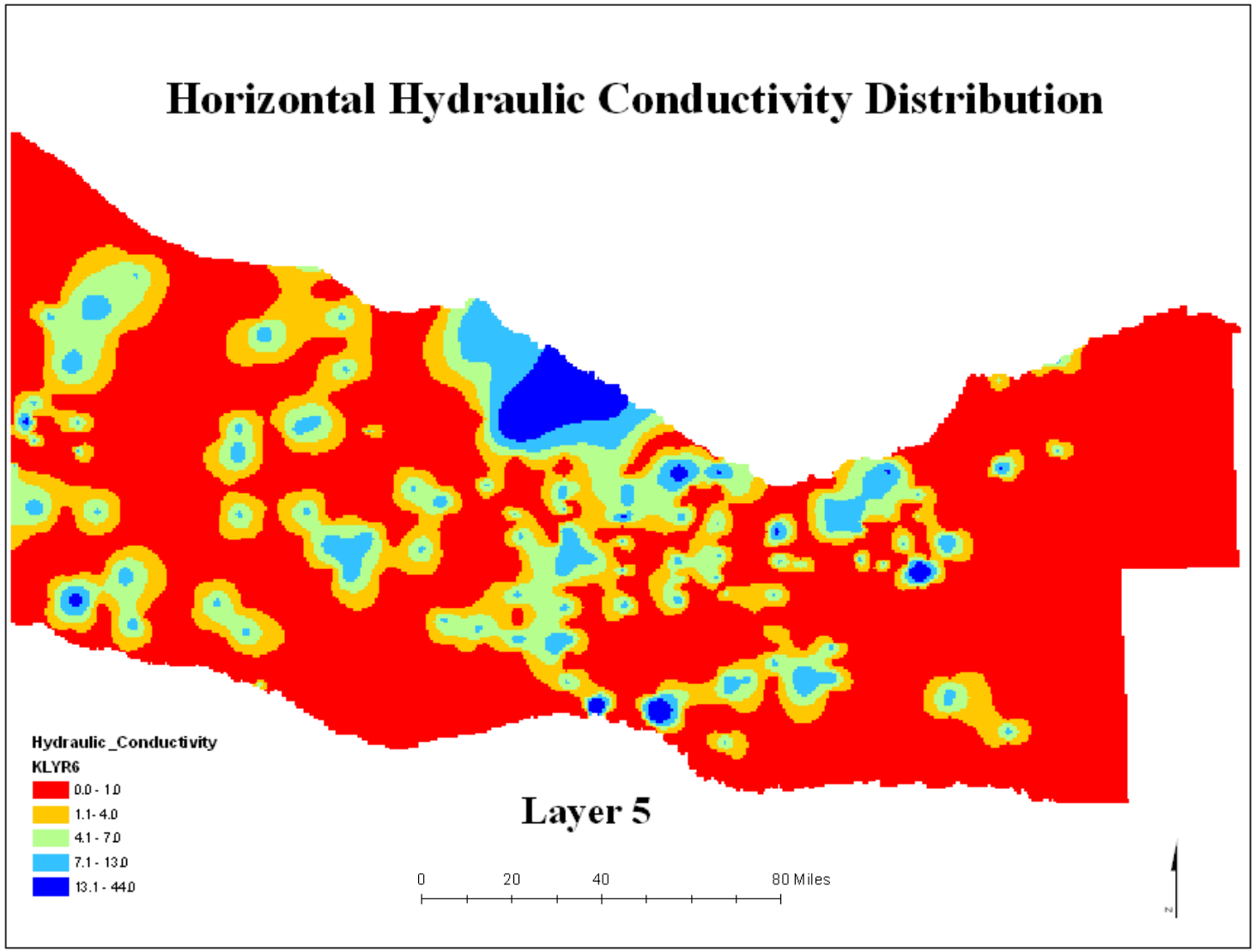
Model Datasets



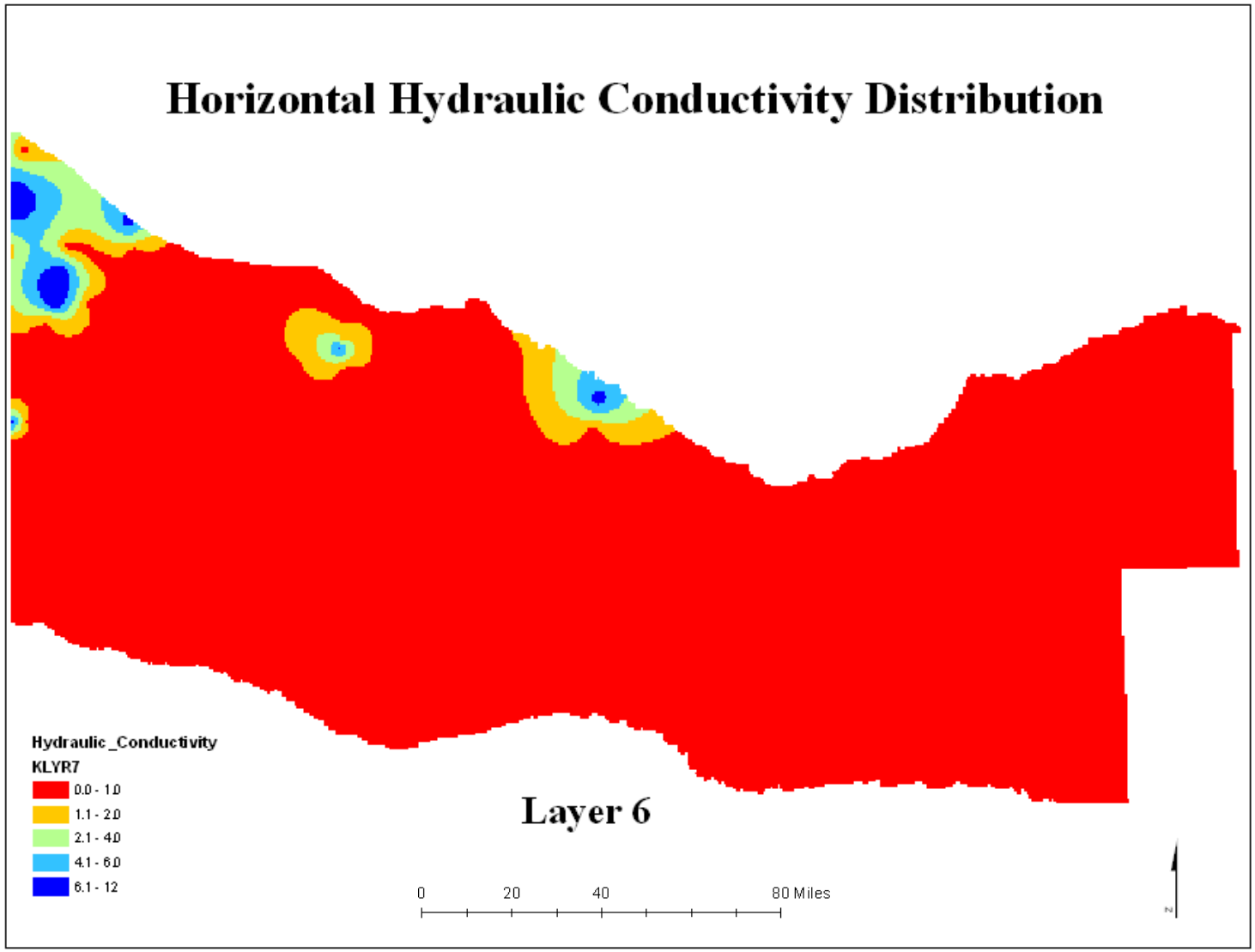
Model Datasets



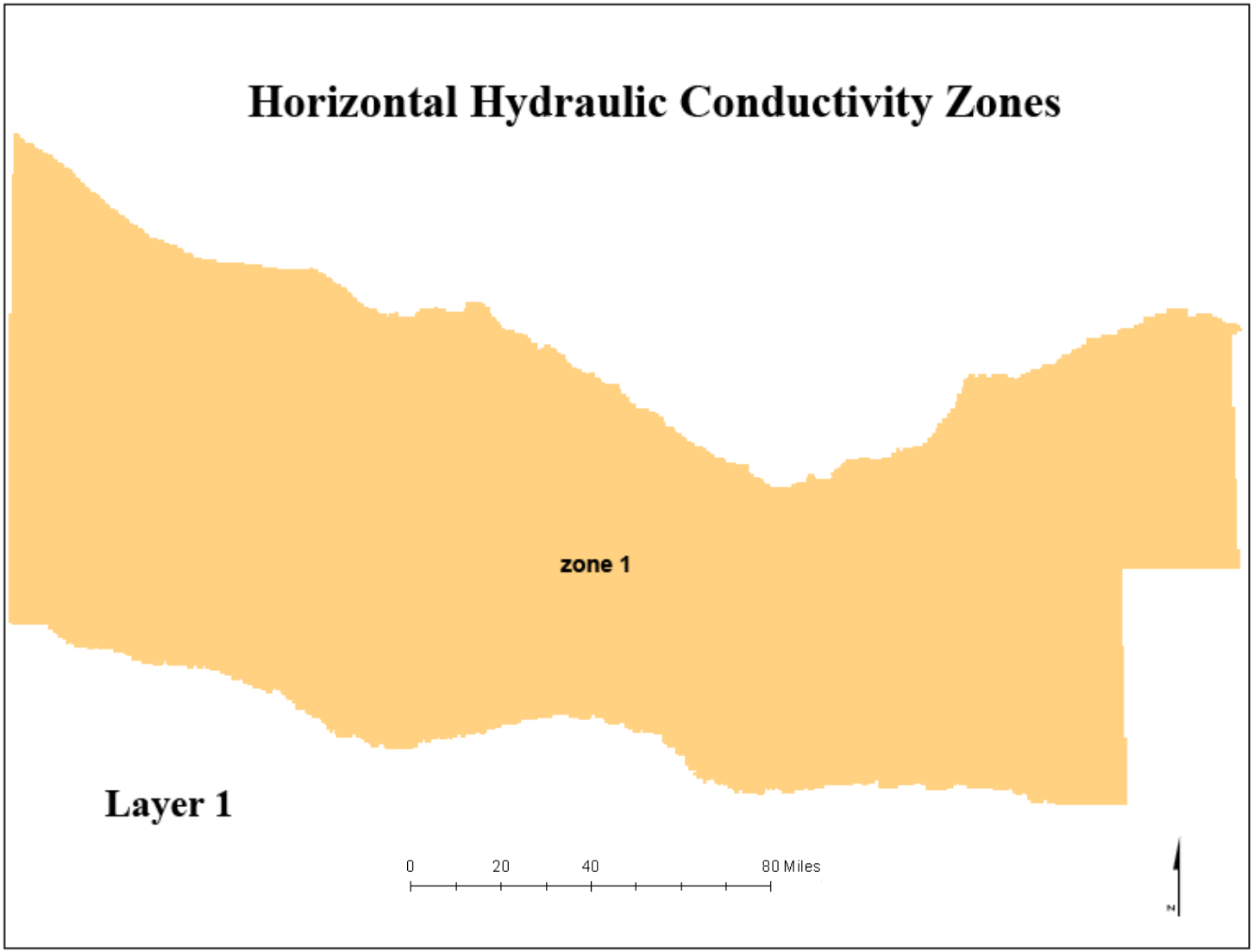
Model Datasets



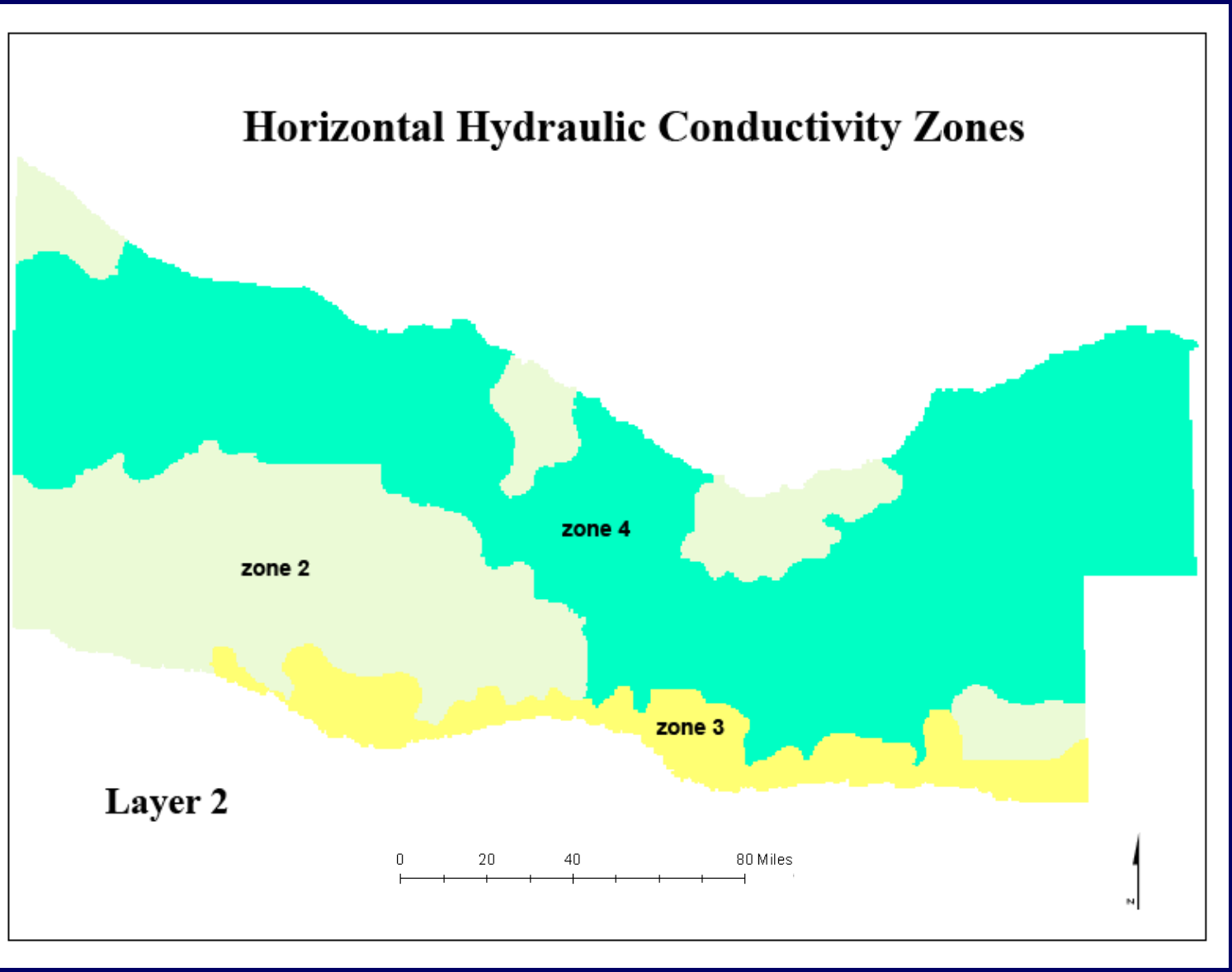
Model Datasets



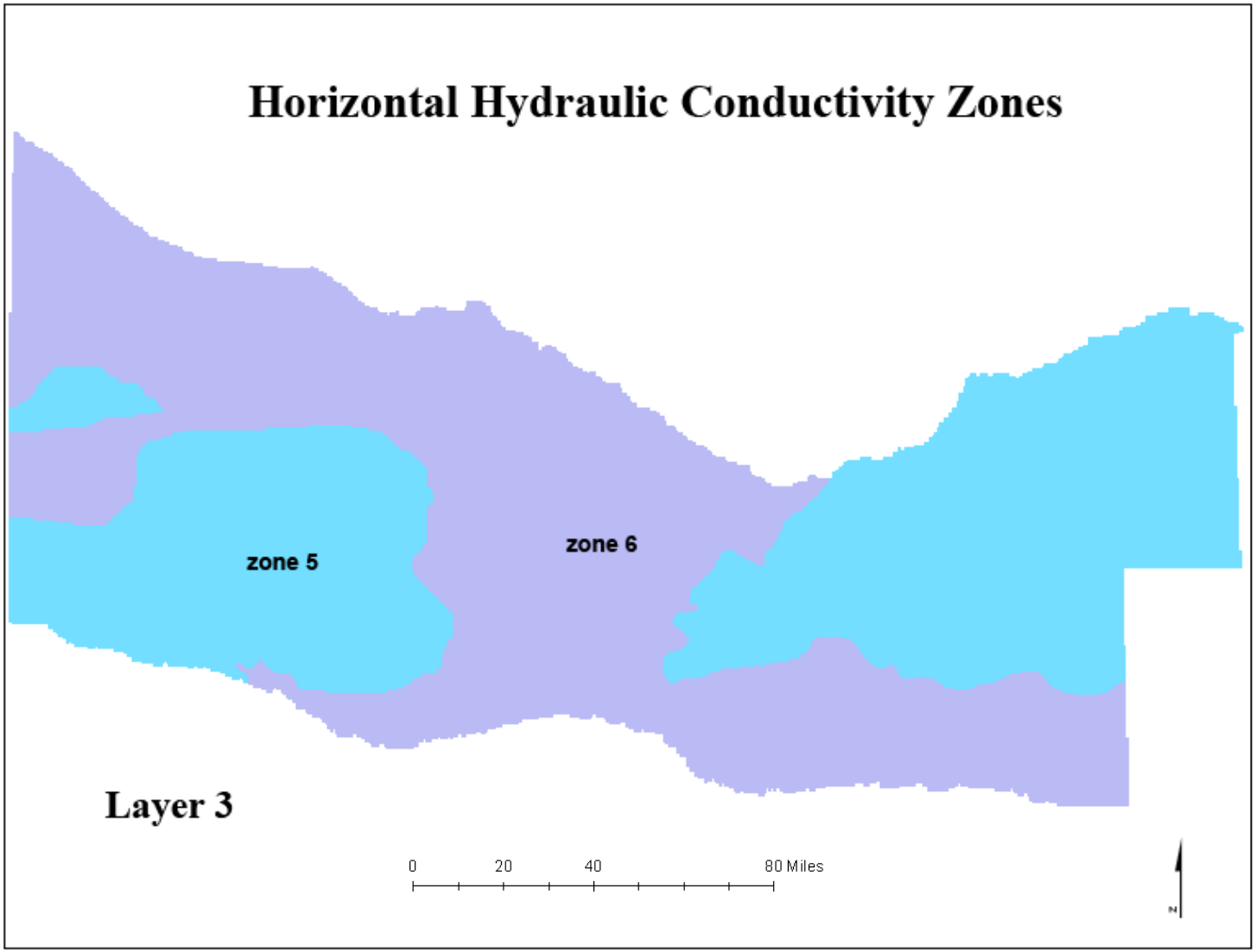
Model Datasets



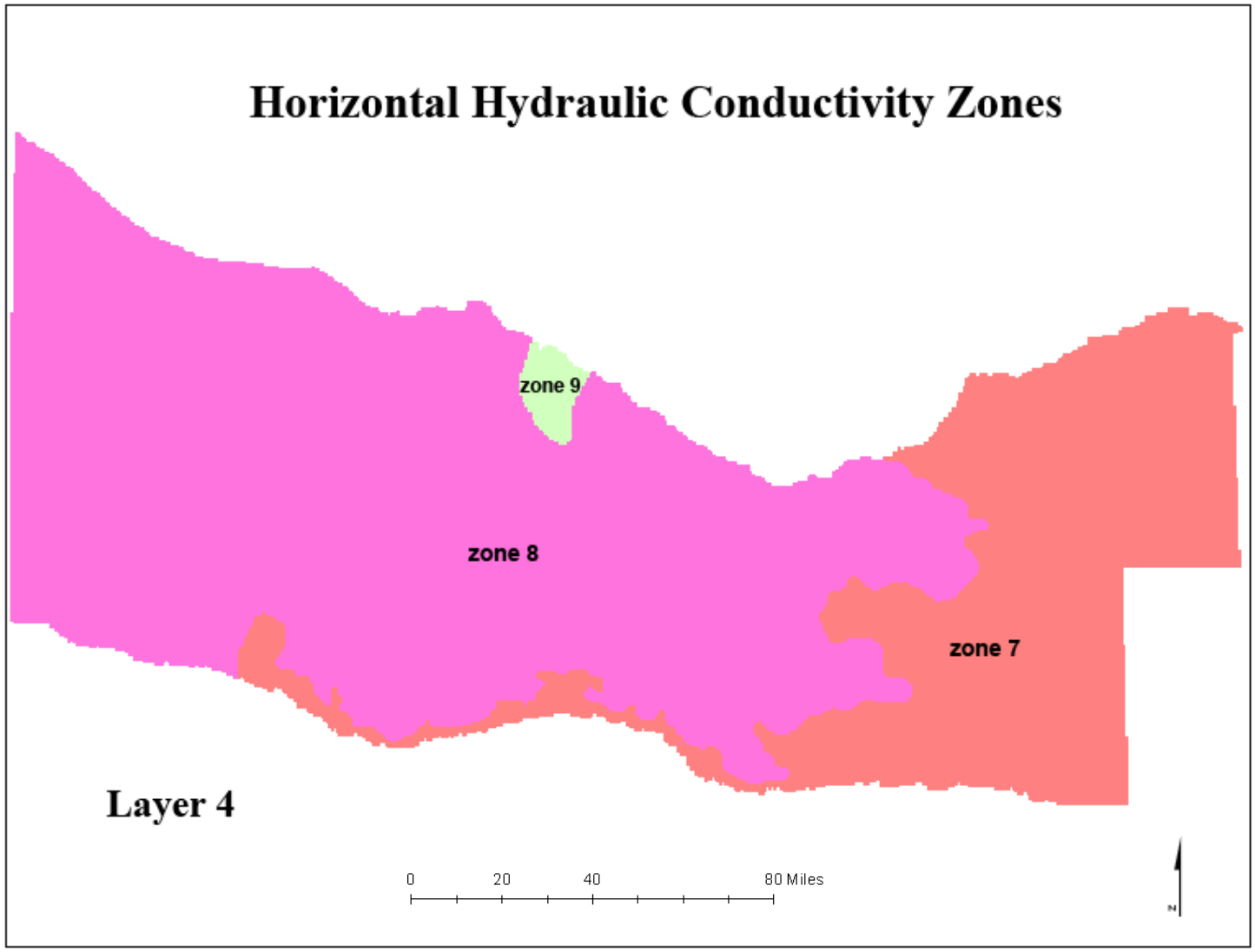
Model Datasets



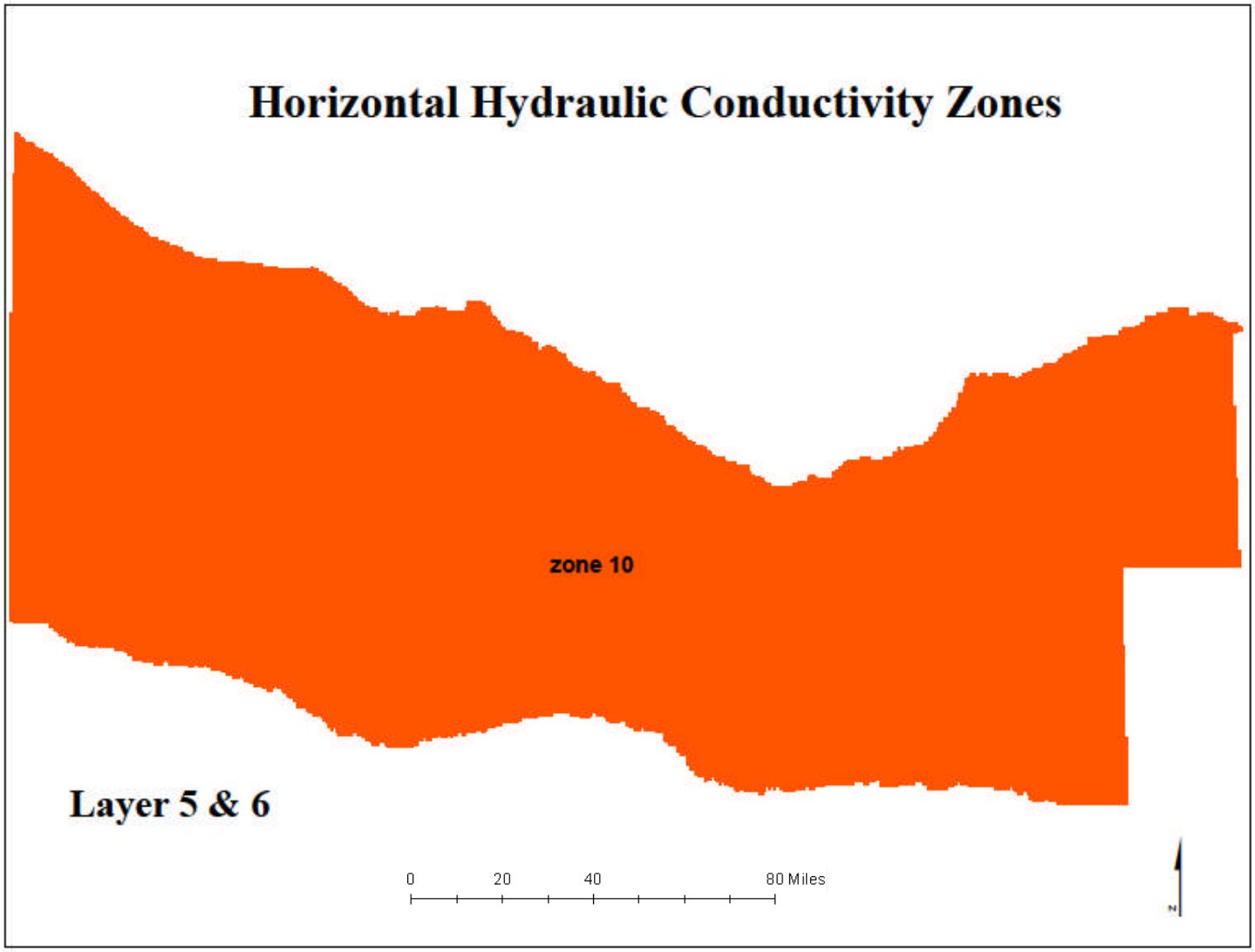
Model Datasets



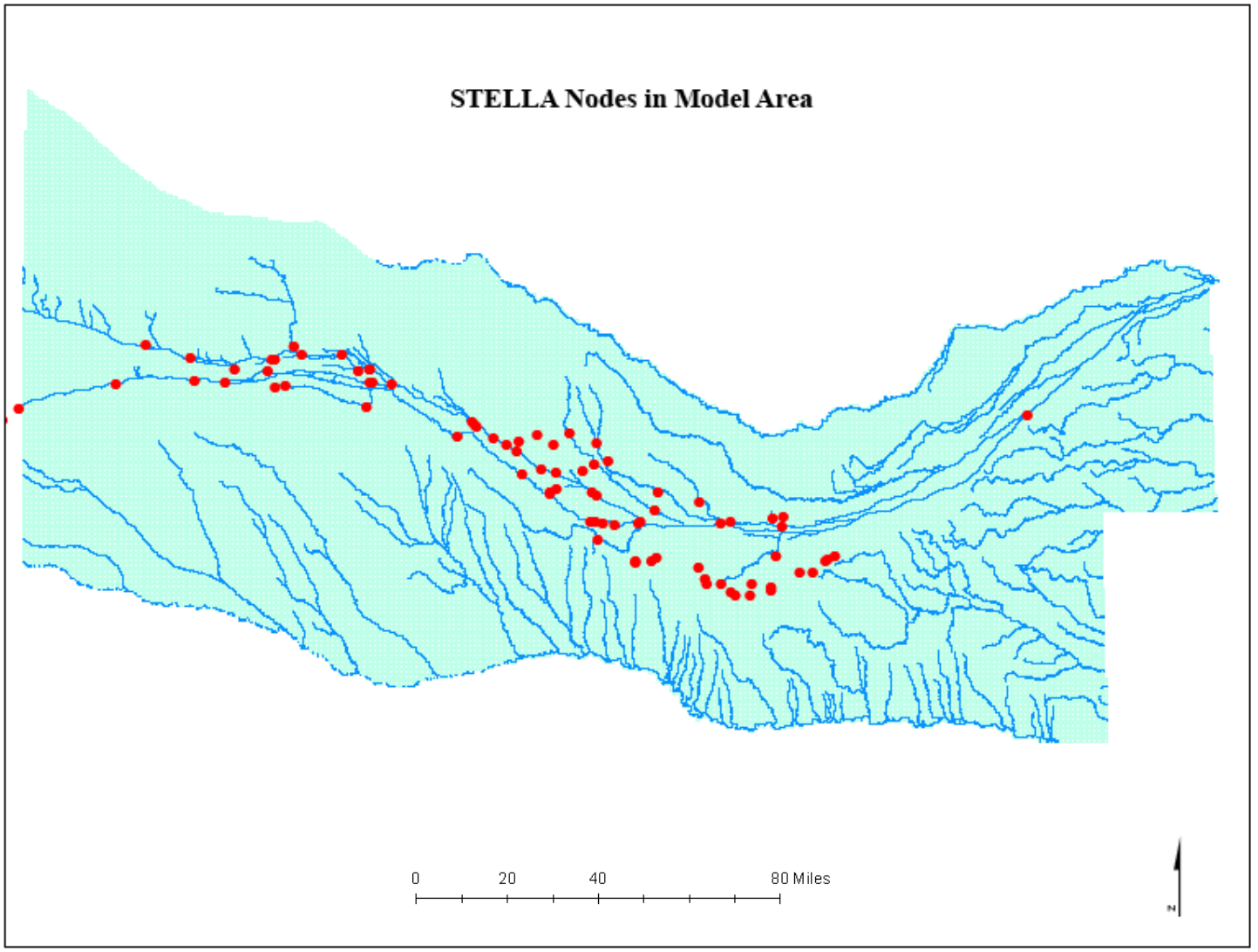
Model Datasets



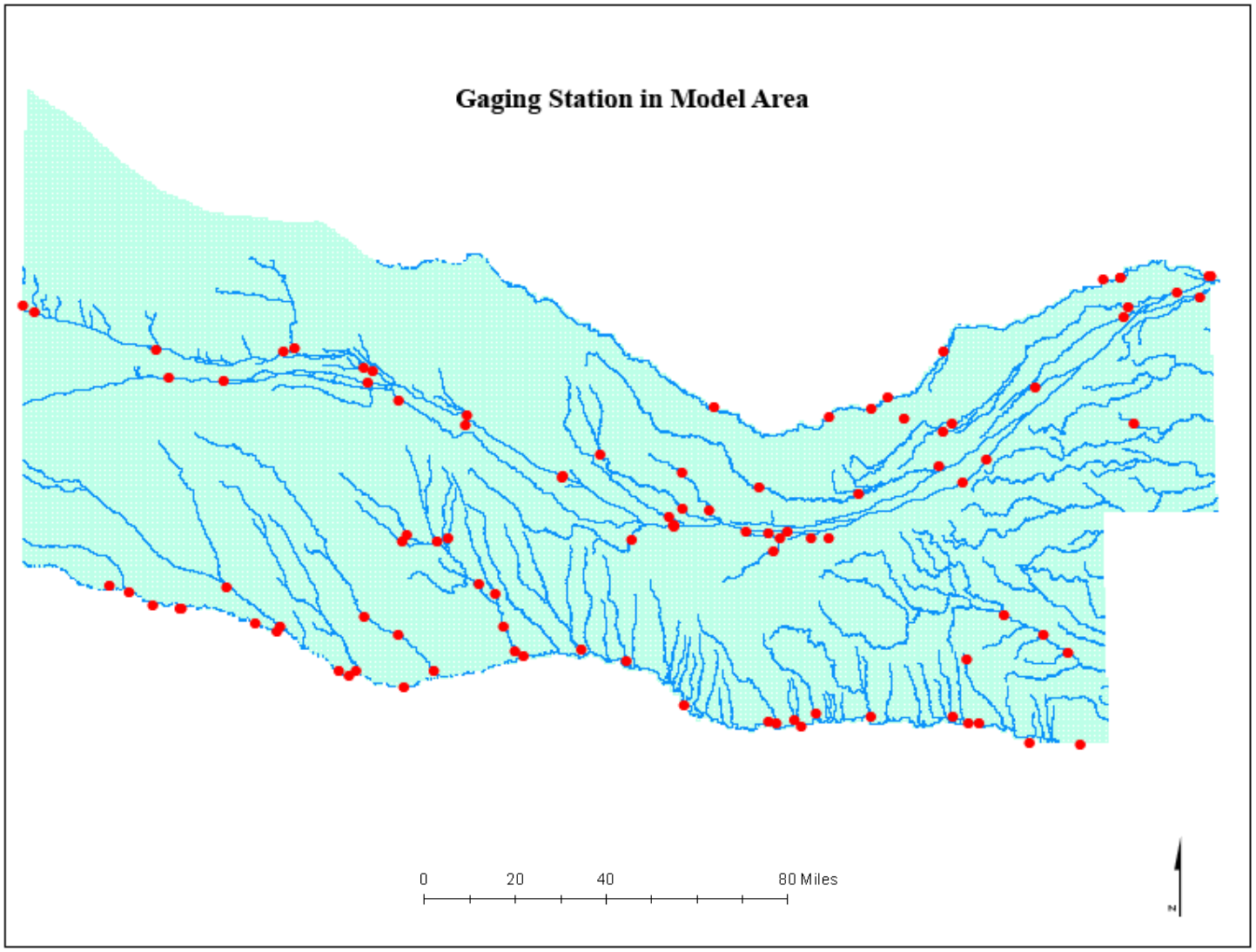
Model Datasets



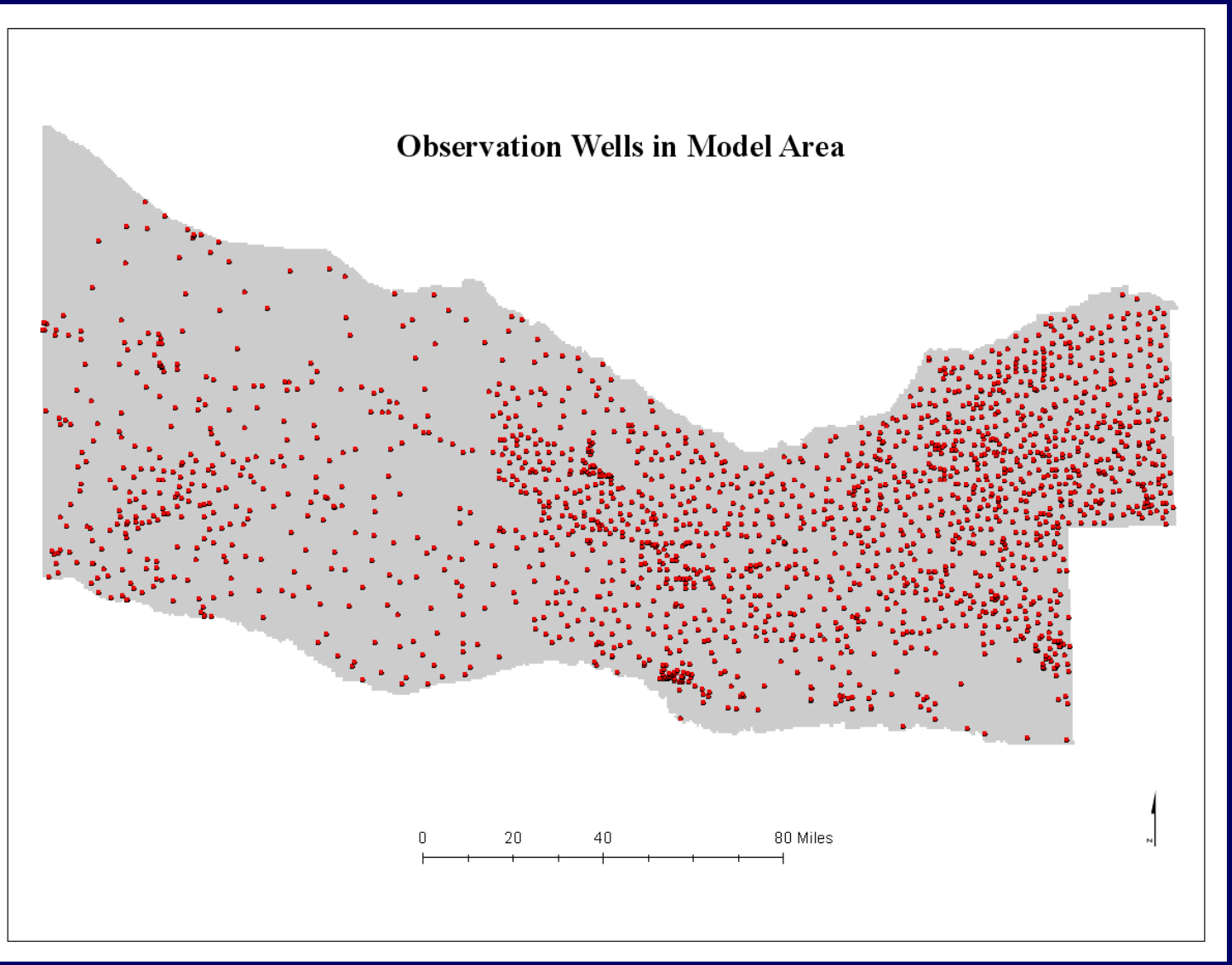
Model Interaction and Calibration



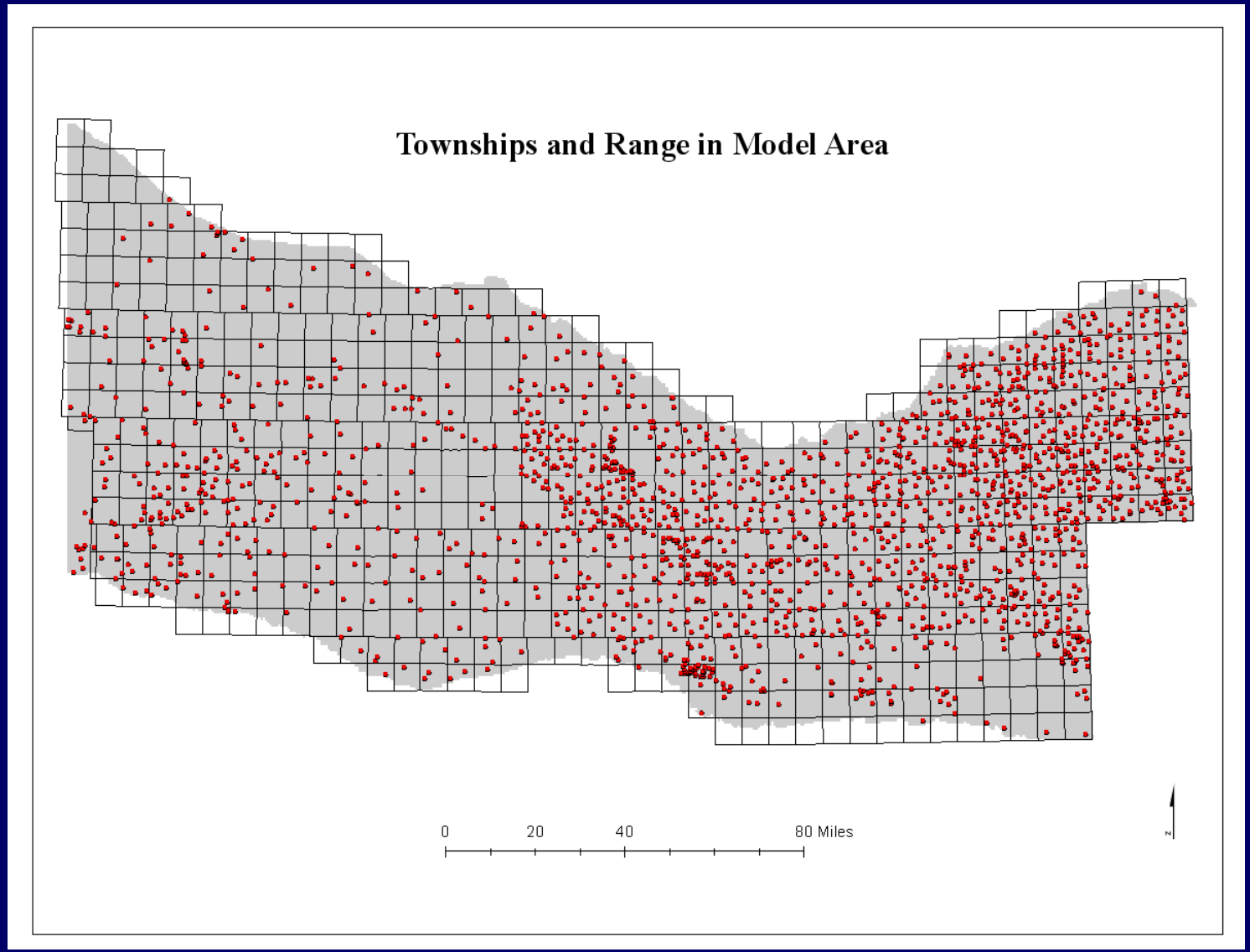
Model Interaction and Calibration



Model Interaction and Calibration

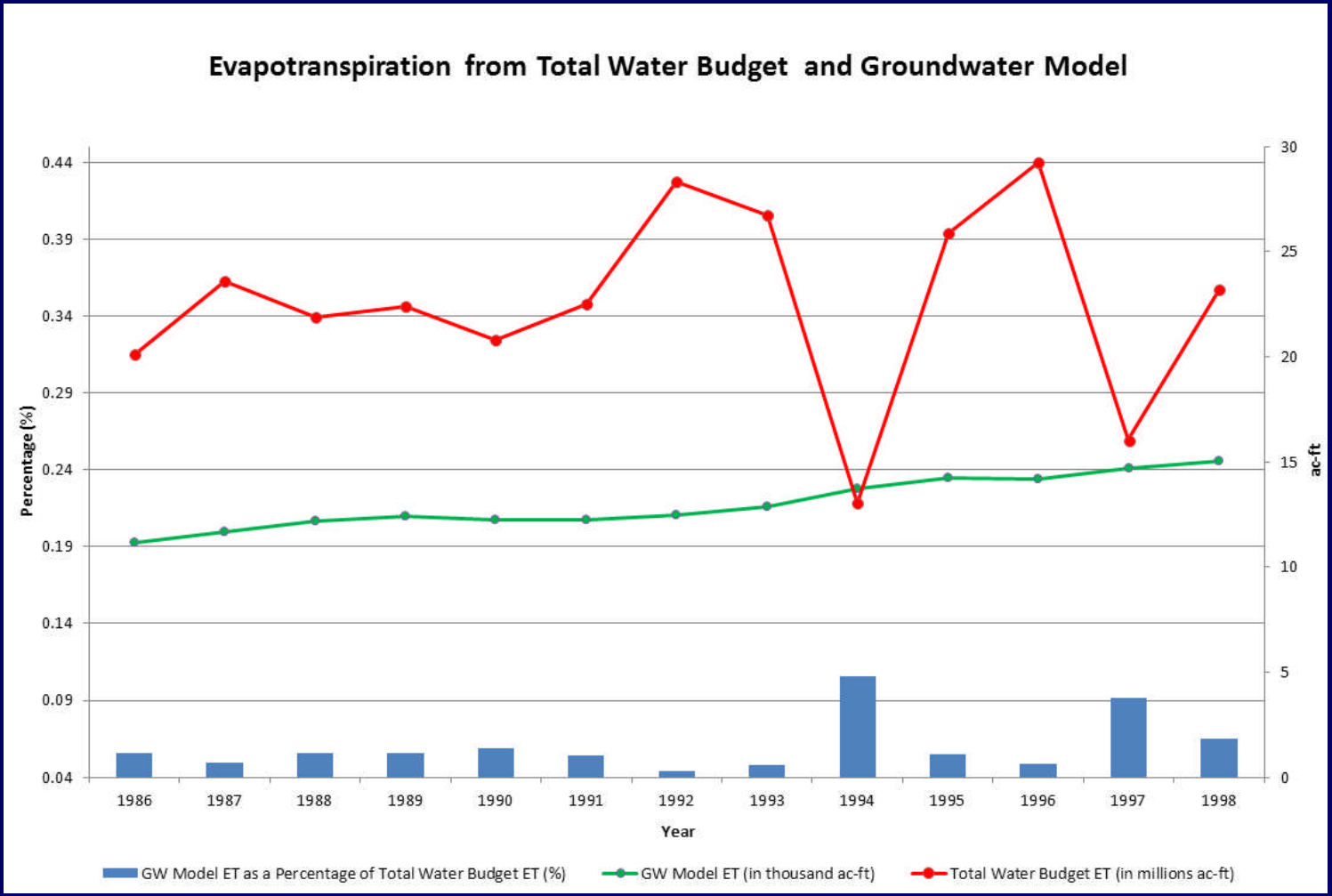


Model Interaction and Calibration



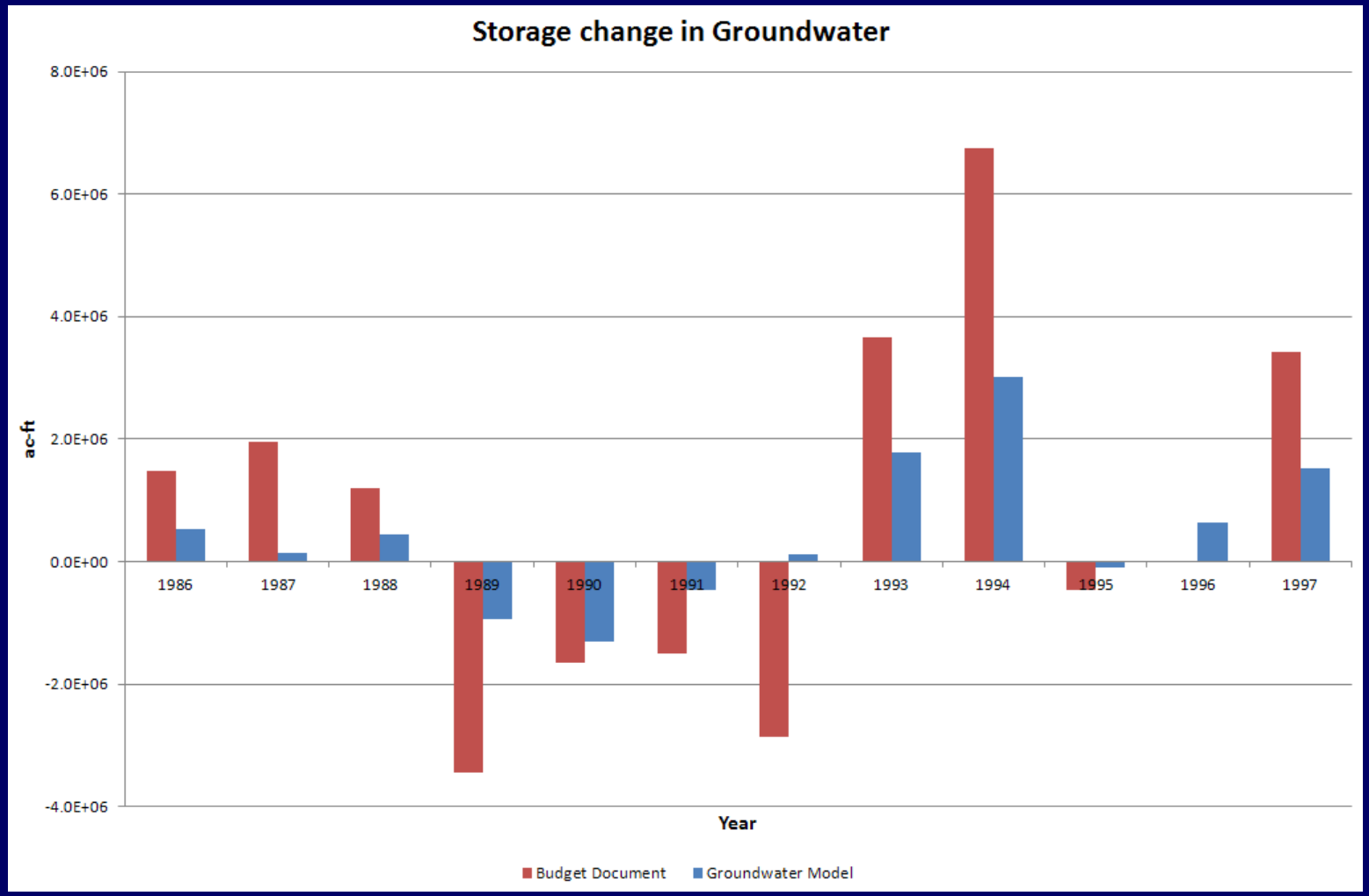
Preliminary Explorative Results

- Comparison with Phase I Water Budget



Preliminary Explorative Results

- Comparison with Phase I Water Budget



Summary

- Consistent with the previous COHYST models
- Interactions with different components of water flow
- Hydrogeologic-Unit Flow (HUF) package with zones parameters
- Datasets update in progress
- Future work ahead for model calibration, validation, and analysis

Any Questions?

Mahesh Pun, EIT
Groundwater Modeler
Nebraska Department of Natural Resources
301 Centennial Mall South – 4th Floor, State Office Building
Lincoln, NE 68509-4676

402-471-3959
Mahesh.Pun@Nebraska.gov

- **Vertical Leakance**

MODFLOW – components and packages

$$Vcont_{i,j,k+\frac{1}{2}} = \frac{K_{z\ i,j}}{\Delta z_{k+\frac{1}{2}}}$$

$\Delta z_{k+\frac{1}{2}}$ = vertical distance between nodes

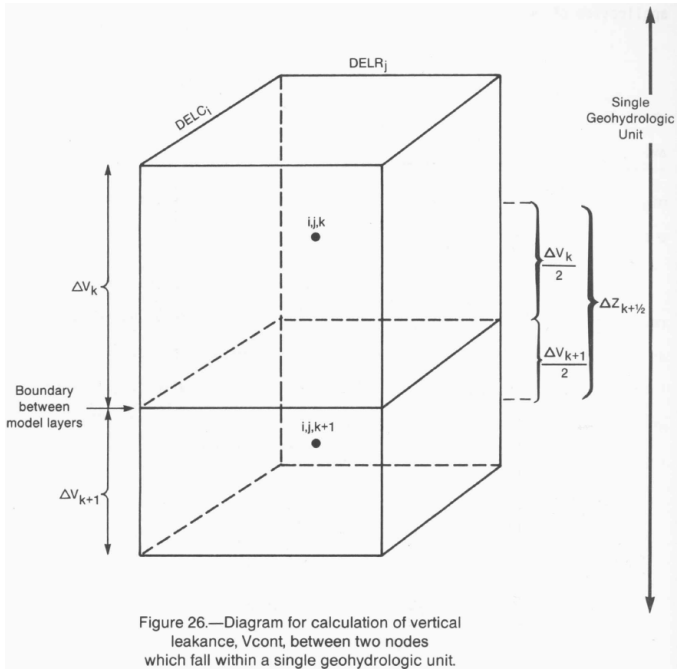


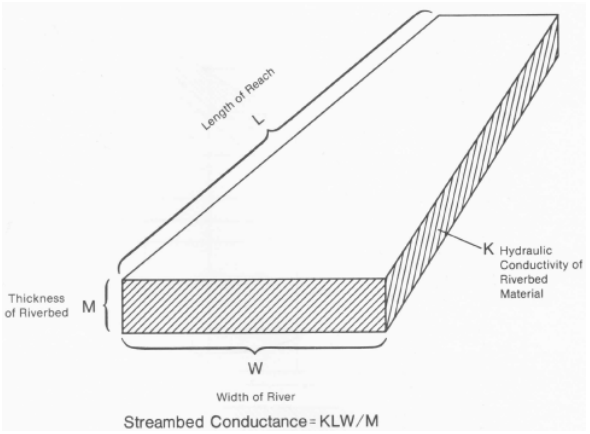
Figure 26.—Diagram for calculation of vertical leakance, Vcont, between two nodes which fall within a single geohydrologic unit.

MODFLOW – components and packages

- **River Package**

- Relationship of flow between river and aquifer:

$$QRIV = \frac{KLW}{M}(HRIV - h_{i,j,k})$$

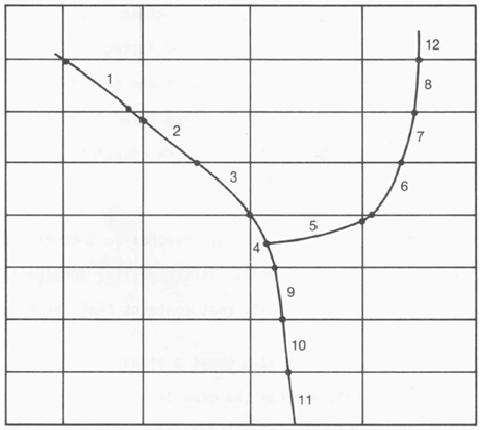


QRIV = flow between river and aquifer

KLW/M = hydraulic conductance of the river-aquifer interconnection

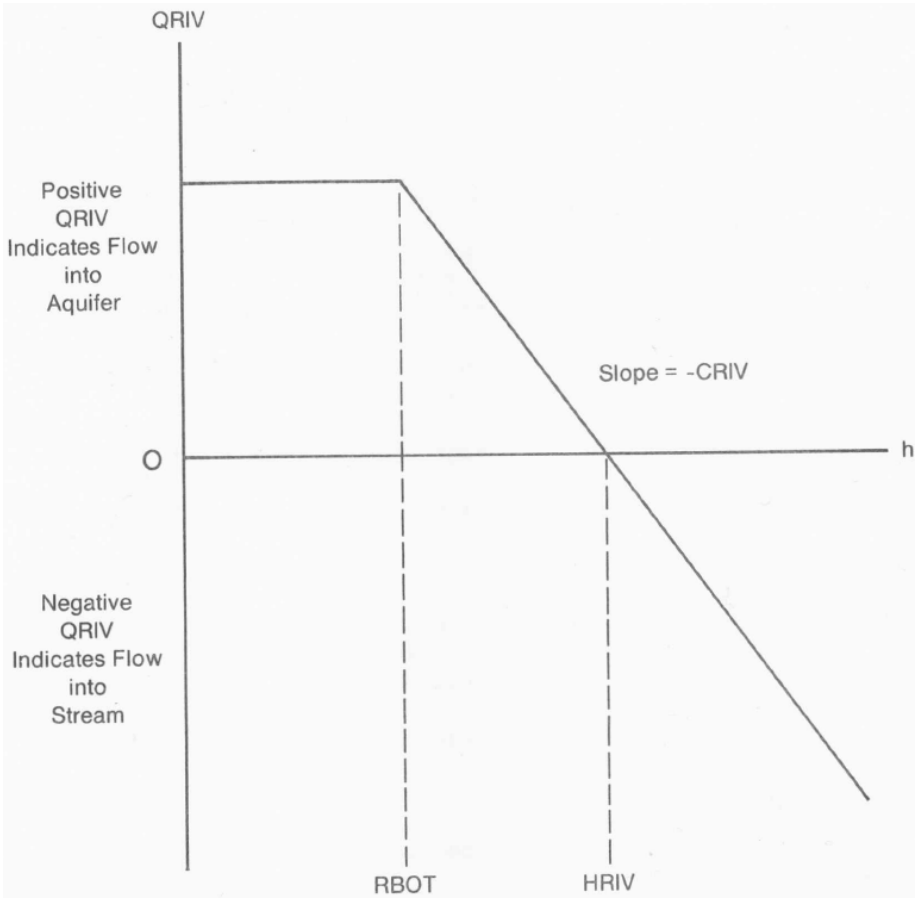
HRIV = head in the river

hi,j,k = head of the cell underlying the river.



MODFLOW – components and packages

- **River Package**



- **Drain Package**

MODFLOW – components and packages

- Simulate the effects of agricultural drains

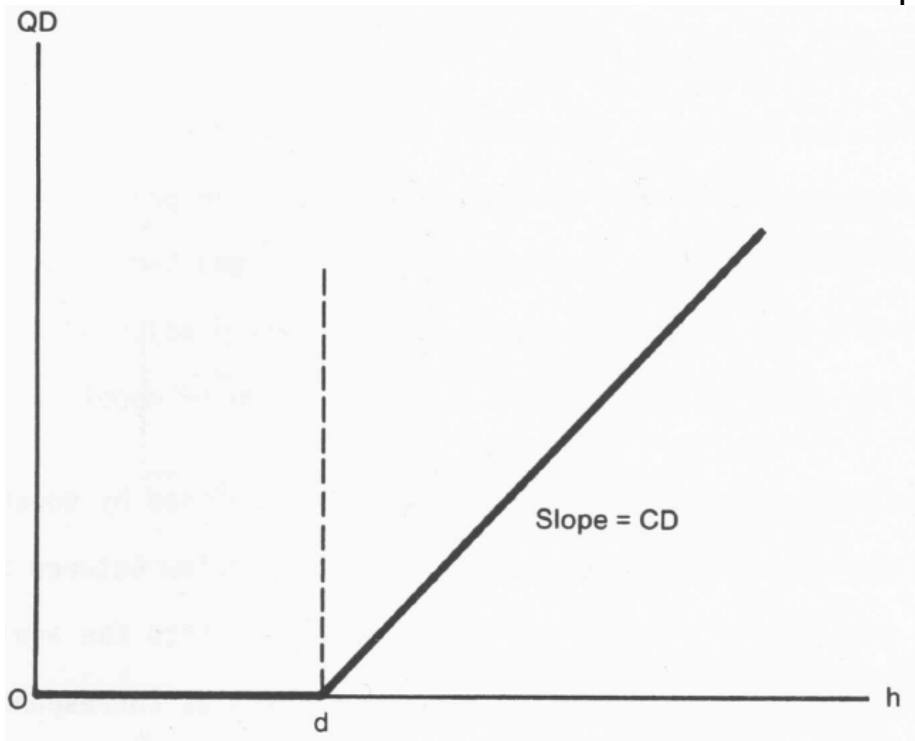
$$Q_{Di,j,k} = CD_{i,j,k}\left(h_{i,j,k} - d_{i,j,k}\right) \quad \text{for} \quad h_{i,j,k} > d_{i,j,k}$$

$$Q_{Di,j,k} = 0 \quad \text{for} \quad h_{i,j,k} < d_{i,j,k}$$

$Q_{Di,j,k}$ = Drain discharge (L^3/T)

$h_{i,j,k}$ = Head in the cell (L)

$d_{i,j,k}$ = Drain elevation (L)



MODFLOW – components and packages

- **General head Boundaries Package**

- Relationship between flow into the cell and the head in a cell:

$$Q_{bi,j,k} = C_{bi,j,k}(h_{bi,j,k} - h_{i,j,k})$$

$Q_{bi,j,k}$ = flow into cell i,j,k from the source

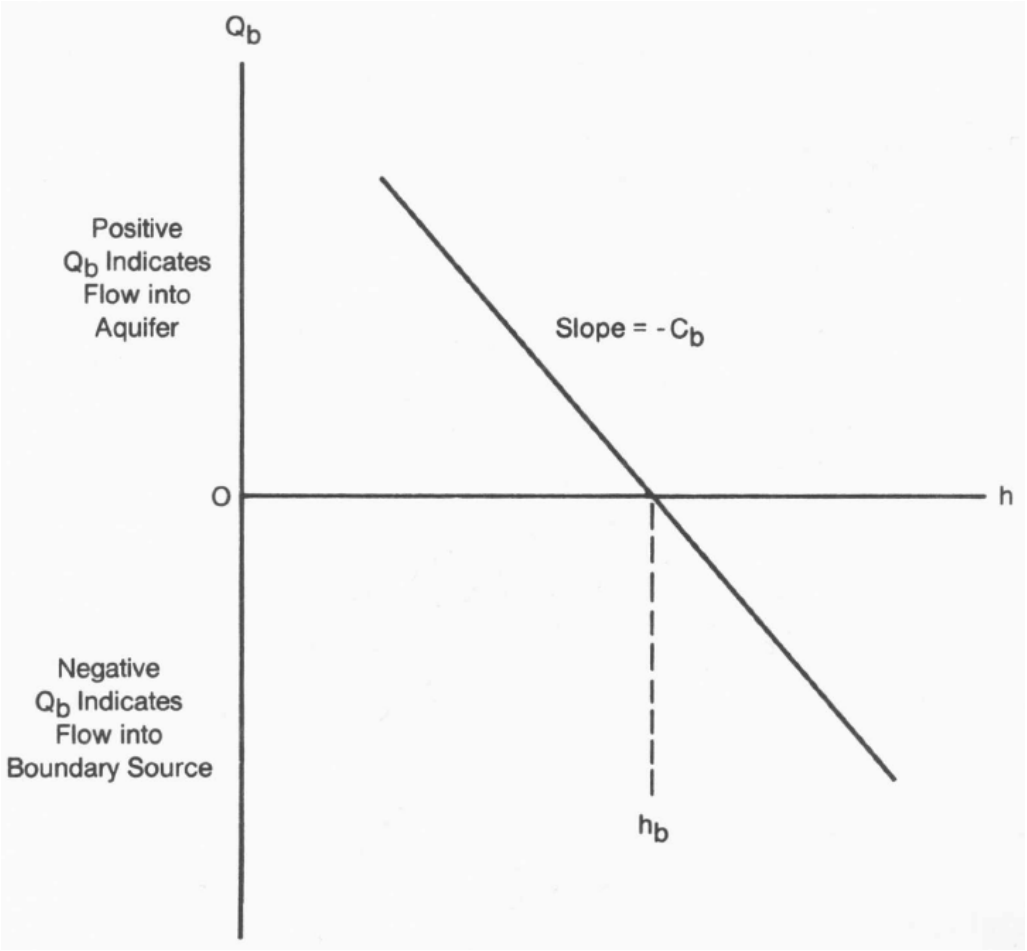
$C_{b,i,j,k}$ = conductance between the external source and cell i,j,k

$h_{bi,j,k}$ = head assigned to the external source

$h_{i,j,k}$ = head in cell i,j,k.

MODFLOW components and packages

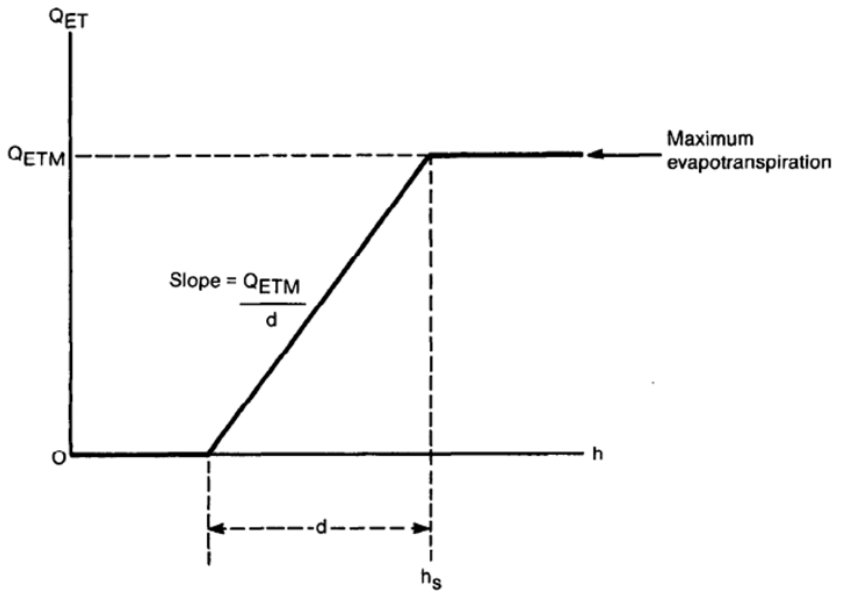
- **General head Boundaries Package**



MODFLOW – components and packages

- **Evapotranspiration Package**

$$Q_{ETi,j} = Q_{ETMi,j}\left(\frac{h_{i,j,k} - (h_{si,j} - d_{i,j})}{d_{i,j}}\right)$$



$Q_{ETi,j}$ = Evapotranspiration (L^3/T)

$Q_{ETMi,j}$ = Maximum evapotranspiration (L^3/T)

$h_{i,j,k}$ = head in the cell (L)

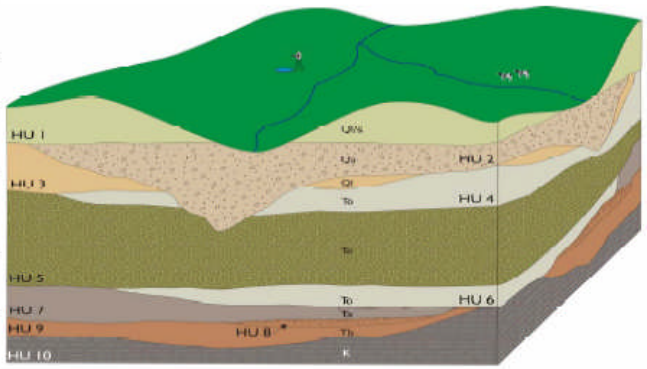
$h_{si,j}$ = the water table elevation at which maximum value of ET loss occurs (L)

$d_{i,j}$ = Cutoff or extinction depth (L)

Table 1. Stratigraphic description of geologic and hydrostratigraphic units used in the Cooperative Hydrology Study

System	Series	Geologic Unit	Hydrostratigraphic Unit	Description	Water Supply
Quaternary	Holocene	Valley-fill deposits	Unit 2	Gravel, sand, silt, and clay with coarser materials more common. Generally stream deposits. Upper fine material, if present, is assigned to Hydrostratigraphic Unit 1. Lower fine material, if present, is assigned to Unit 3.	Source of major supply of water in the alluvial valleys. Usually in direct communication with active streams.
	Pleistocene and Holocene	Dune sand	Unit 1	Generally fine sand but may contain some medium and even coarse sand. May also contain some finer material. Wind blown deposits.	Source of water to livestock and domestic wells. Usually shallow water table related to evapotranspiration areas in the models. Often in communication with shallow lakes within the sand hills.
		Loess deposits	Unit 1 when above Unit 2, otherwise Unit 3	Generally silt, but may contain some very fine sand and clay. Deposited as wind blown dust.	Unit generally low transmissivity with occasional fractures. Rarely used as water source for low yielding wells.
	Pleistocene	Alluvial deposits	Unit 2	Gravel, sand, silt, and clay with coarser materials more common. Generally stream deposits. Upper fine material, if present, is assigned to Hydrostratigraphic Unit 1. Lower fine material, if present, is assigned to Unit 3.	Major source of water for all uses throughout cohyst area. Limited to alluvial valleys and channel deposits in the west and extensive deposits in the east. Often in hydrologic connection with active streams. Generally of good quality for all uses.
Tertiary	Pliocene	Broadwater Formation	Unit 2	Coarse fluvial gravel and sand dominate with some silt and clay. Assigned to Hydrostratigraphic Unit 2. Generally found in channel deposits north of the North Platte and Platte River.	Major source of water where saturated thickness is sufficient for large capacity wells. Occasionally in communication with Pleistocene sediments.
	Upper and middle Miocene	Ogallala Group	Units 4-6	Heterogeneous mixture of gravel, sand, silt, and clay. Generally stream deposits but also contains wind blown deposits. Upper fine material, if present, is assigned to Hydrostratigraphic Unit 4. Center coarse material, if present, is assigned to Unit 5. Lower fine material, if present, is assigned to Unit 6. Often sandstone and conglomerate layers exist through our area.	Major source of water throughout much of the study area. Does not exist in eastern part of eastern model area or the northwest corner of the western model area. Generally yields sufficient water for all uses. Occasionally in communication with Pliocene and Pleistocene sediments.
	Lower Miocene and upper Oligocene	Arikaree Group	Unit 7	Predominately very fine to fine-grained sandstone but may also contain siltstone. Locally, may contain conglomerate, gravel, and sand.	Major source of water in the northwestern part of the western model unit where sufficient saturated thickness exists to supply large capacity wells. Used for livestock and domestic wells. Generally in communication with upper and middle Miocene sediments
	Lower Oligocene	Brule Formation of White River Group	Unit 8 of High Plains aquifer or Unit 9 below High Plains aquifer	Predominately siltstone, but may contain sandstone and channel deposits. Sometimes highly fractured with areas of fracturing difficult to predict. Upper part of Brule Formation is included in High Plains aquifer and Hydrostratigraphic Unit 8 only if fractured or contains sandstone or channel deposits, otherwise it is Unit 9 and is excluded from the High Plains aquifer. Wind-blown volcanic deposits with some fluvial deposits.	Generally an aquiclude except where fractured or alluvial channel deposits exist. Fractures and channel deposits generally are only identified in the western model unit along drainage basins. High capacity wells are common where these conditions exist and where they are in communication with overlying saturated sediments that have sufficient transmissivity to supply water at the rate of withdrawal. Often used as stock and domestic wells.
	Upper Eocene	Chadron Formation of White River Group	Unit 9; below the High Plains aquifer	Silt, siltstone, clay, and claystone. Generally forms impermeable base of High Plains aquifer. Fluvial deposits and wind-blown volcanic deposits.	Generally an aquiclude except for basal fluvial sediments. These sediments exist as channel deposits in the western and central model areas. They are generally deep and used for domestic or livestock where no other supply exists. Rare high capacity wells exist in the western model unit.
Cretaceous	Undifferentiated	Undifferentiated	Unit 10; below the High Plains aquifer	Shale, chalks, limestone, siltstone, and sandstone. Except for a few minor areas of Fox Hills Sandstone in the extreme western part of the COHYST area and the Dakota Group in the extreme eastern part of the area, generally forms an impermeable base of High Plains aquifer. Deep marine deposits to beach deposits.	Generally an aquiclude except for sand deposits. Often used as domestic or livestock wells where no other supply exists.

Figure 12. Stratigraphic display of geologic and hydrostratigraphic units used in the Cooperative Hydrology Study



Formation/Group Description		Hydrostratigraphic Unit (HU)
Qvs	Upper Quaternary Fines (Loess or Dune Sand)	1
Qa	Quaternary Alluvial/ Valley Fill Deposits	2
Qi	Lower Quaternary Fines (Loess/Silt)	3
To	Tertiary Ogallala Group Silts/Siltstones	4,6
Ta	Tertiary Ogallala Group Sands/Sandstones	5
Ta	Tertiary Arikaree Group Sandstones/Siltstones	7
Tb1	Tertiary White River Group Fractured Brule Fm. Siltstones	8
Tb	Tertiary White River Group Brule Fm. Siltstones/Sandstones	9
K	Undifferentiated Cretaceous Units - (Base of Aquifer)	10

Note: Table 1 was adapted from Gutentag and others, 1984
The word communication as used in table 1 means a direct connection to an adjacent HU and or stream