

HESA and GIS-Based Groundwater Resources Evaluation Delta County, Colorado

OAK MESA AREA

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for**

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What did we do?

- Performed a **HESA** (Hydrologic and Environmental System Analysis) and formulated conceptual models of representative hydrogeologic subsystems of the **Oak Mesa** area
- Developed **GIS maps and data bases** of hydrological and hydrogeological characteristics from existing data for use in the HESA and as a cost-effective planning/management/educational tool

Why do this?

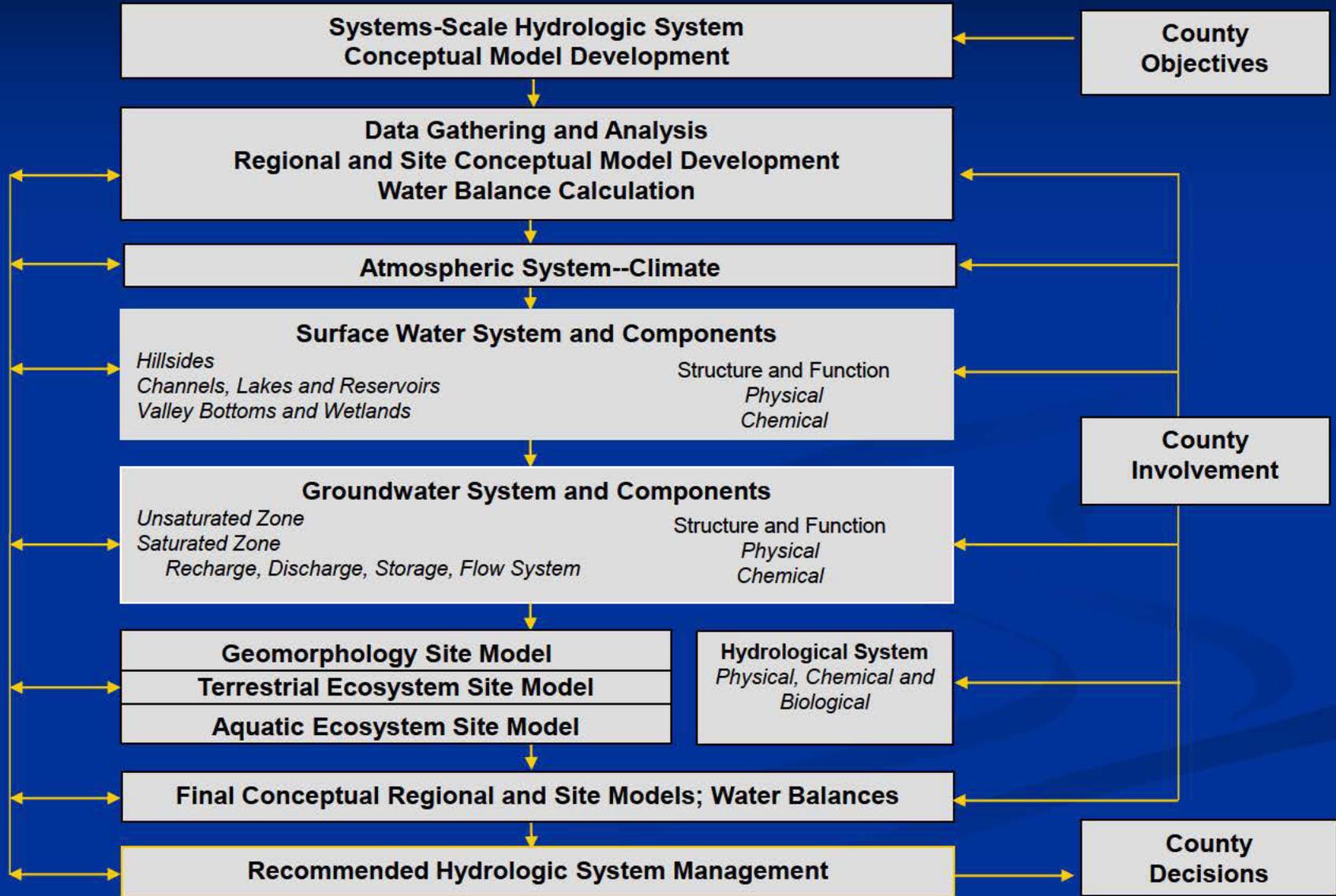
- Source water assessment and protection (municipal and communal water supply systems)
- Sustainability of water supply sources
- Adequate water quantity and quality to sustain land development
- Effects of coal mining
- Effects of gas and oil development
- ISDS and well setbacks
- Protection of groundwater-fed wetlands.
- Groundwater contribution to in-stream flows and water quality
- Effects of land use changes (agriculture to mining and urbanization)

What is HESA?

Hydrologic and Environmental Systems Analysis

- HESA is an approach used to conceptualize and characterize relevant features of hydrologic and environmental systems, integrating relevant considerations of climate, topography, geomorphology, groundwater and surface water hydrology, geology, ecosystem structure and function, and the human activities associated with these systems into a **holistic, three-dimensional dynamic conceptual site model** (CSM).
- Using HESA, all relevant controlling factors of a particular environment can be identified at the planning/characterization stage, leading to more **focused, cost effective strategies and better decision-making** throughout water resources related management

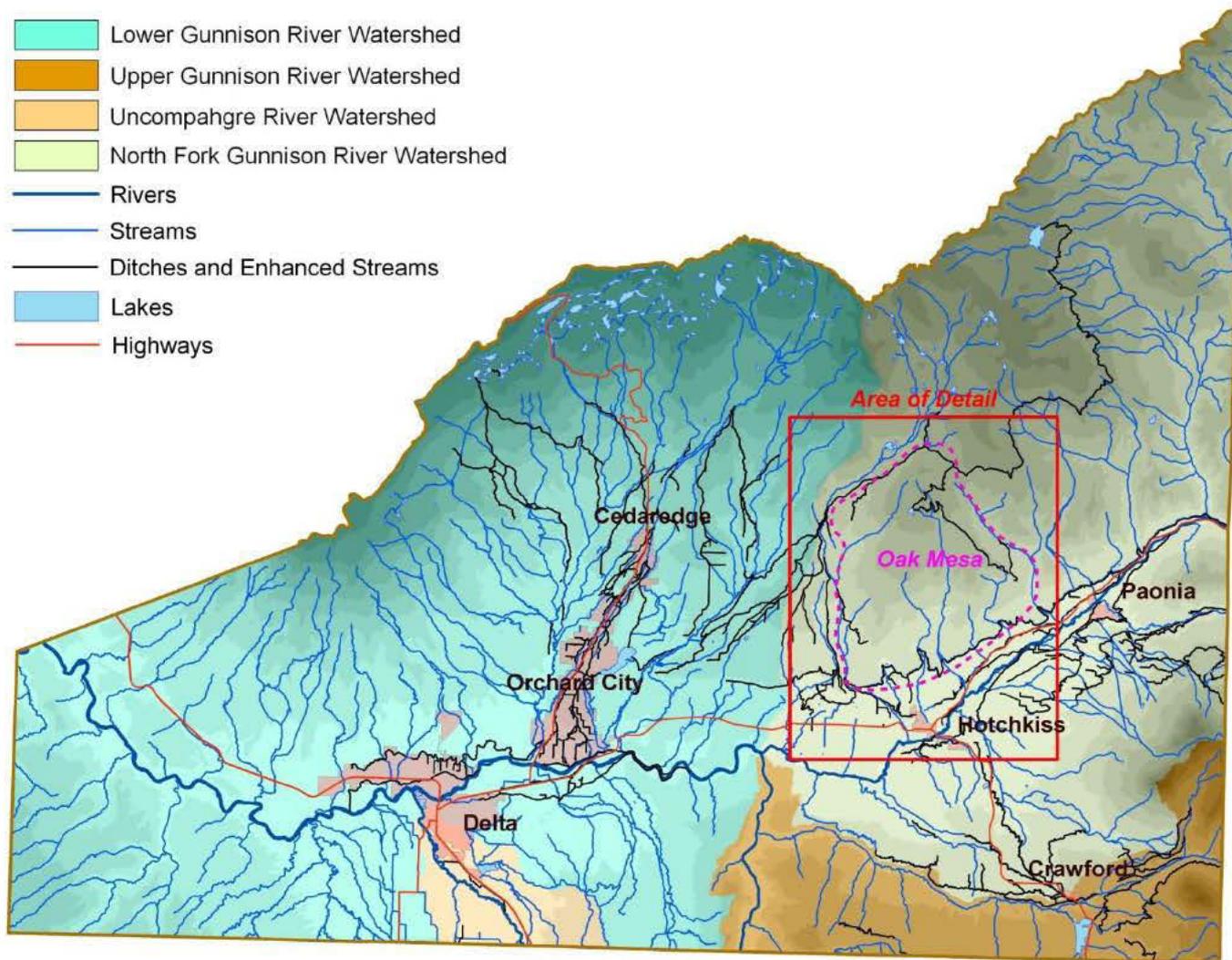
HESA Flowchart



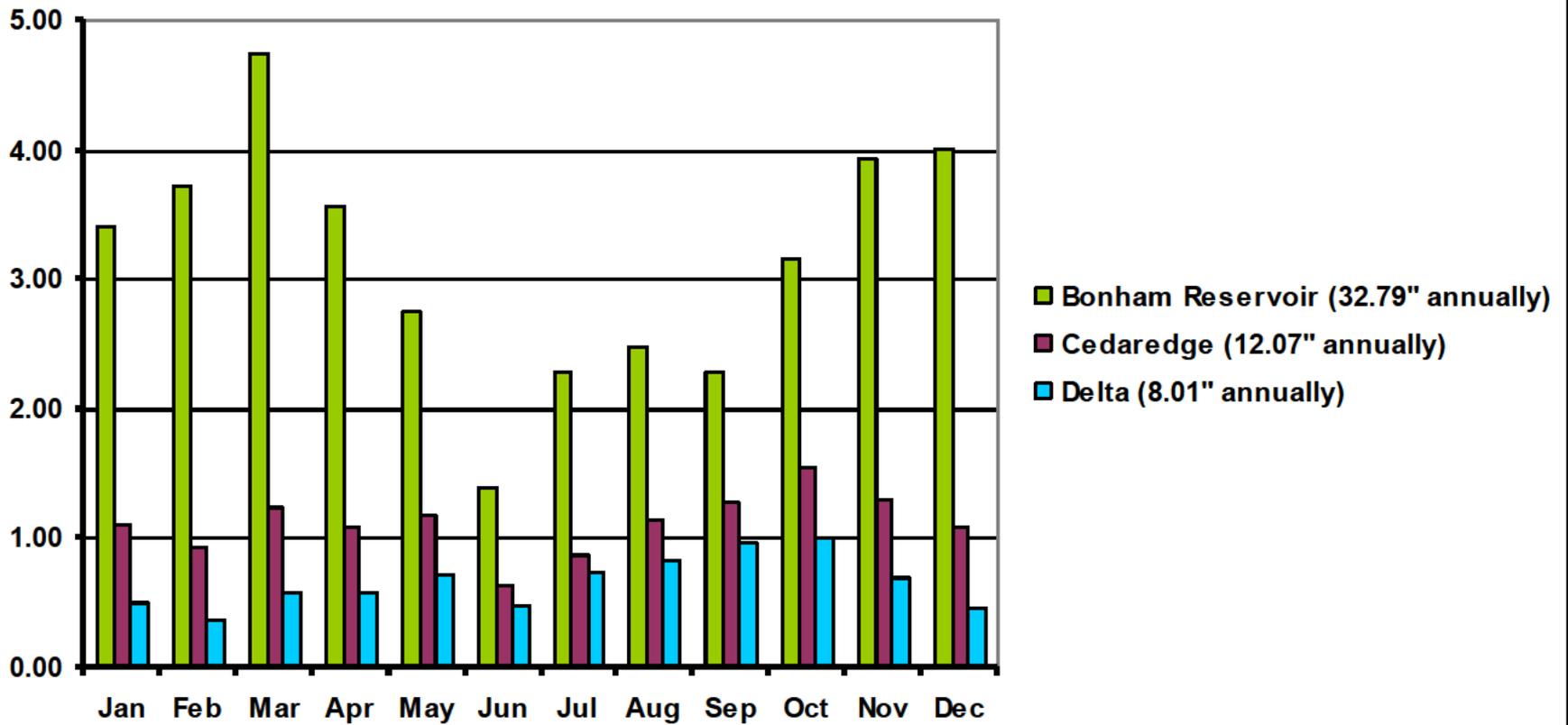
HESA Elements in Oak Mesa Study

- **Surface characterization**
 - Climate, vegetation, soils, geomorphology, topography, surface water, and land use and other anthropogenic elements
- **Subsurface characterization**
 - Geologic framework, hydrogeologic framework, hydrogeologic properties
- **Groundwater flow system characterization**
 - Flow paths, velocities, recharge, discharge, water budget
- [Ground water quality/chemistry characterization]
- [Ground water modeling]

Study Area Location

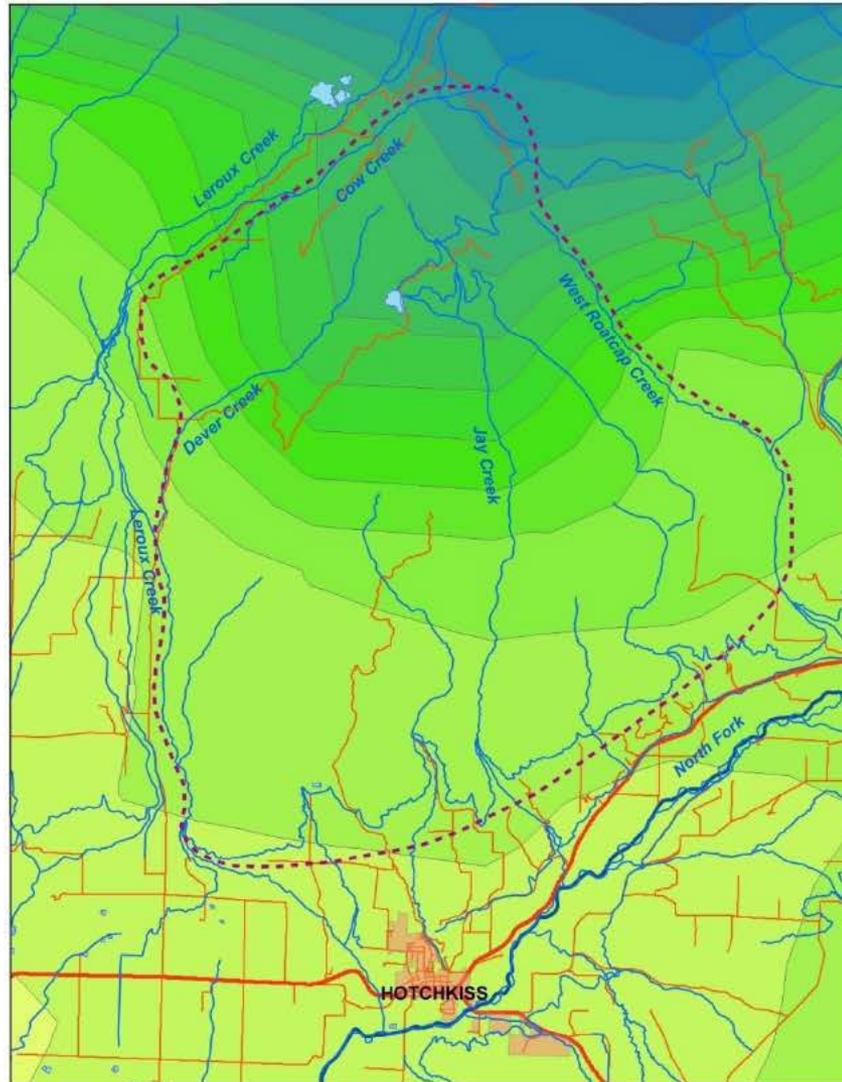
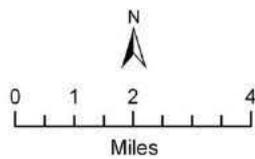


Climate

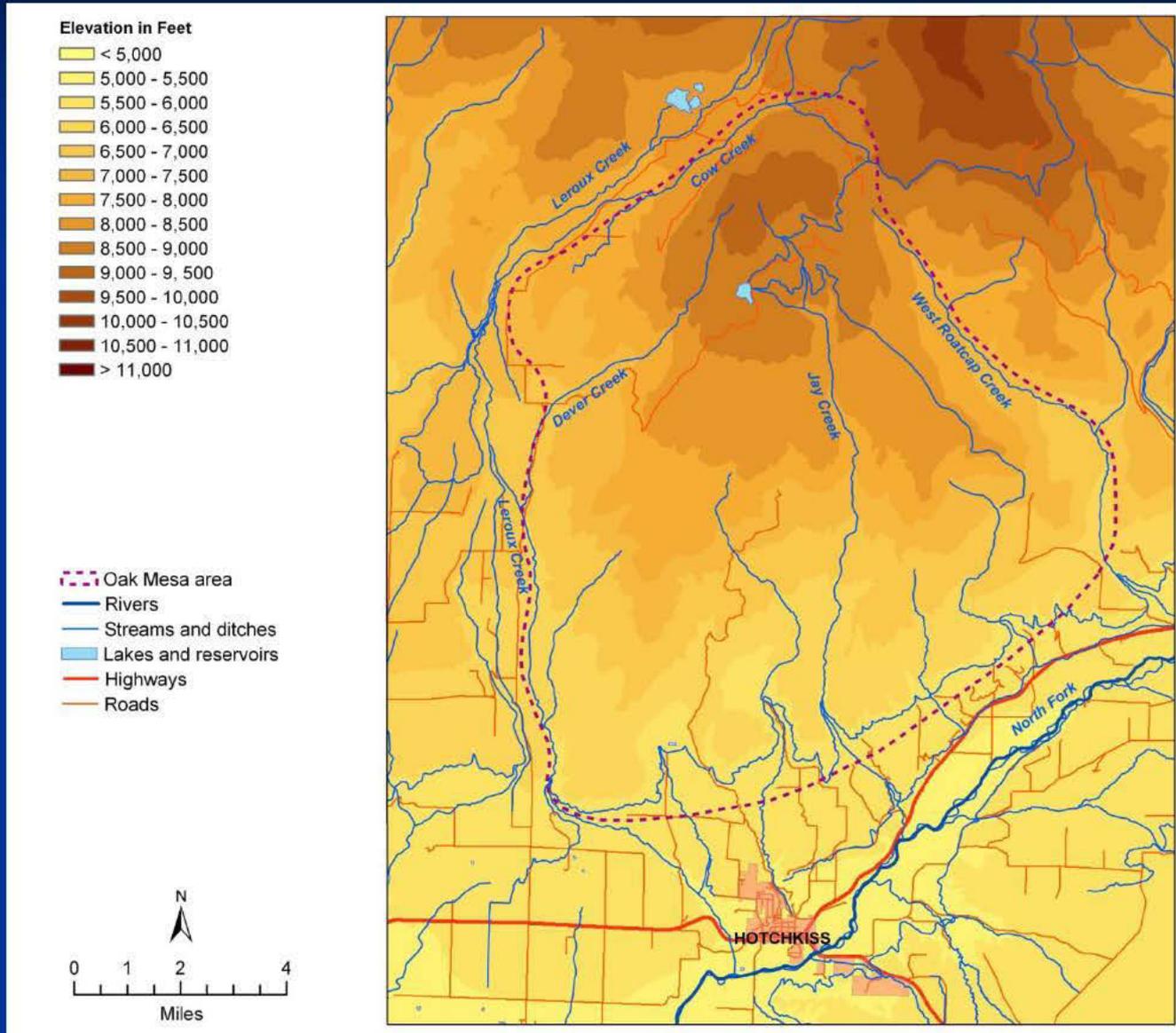


Climate

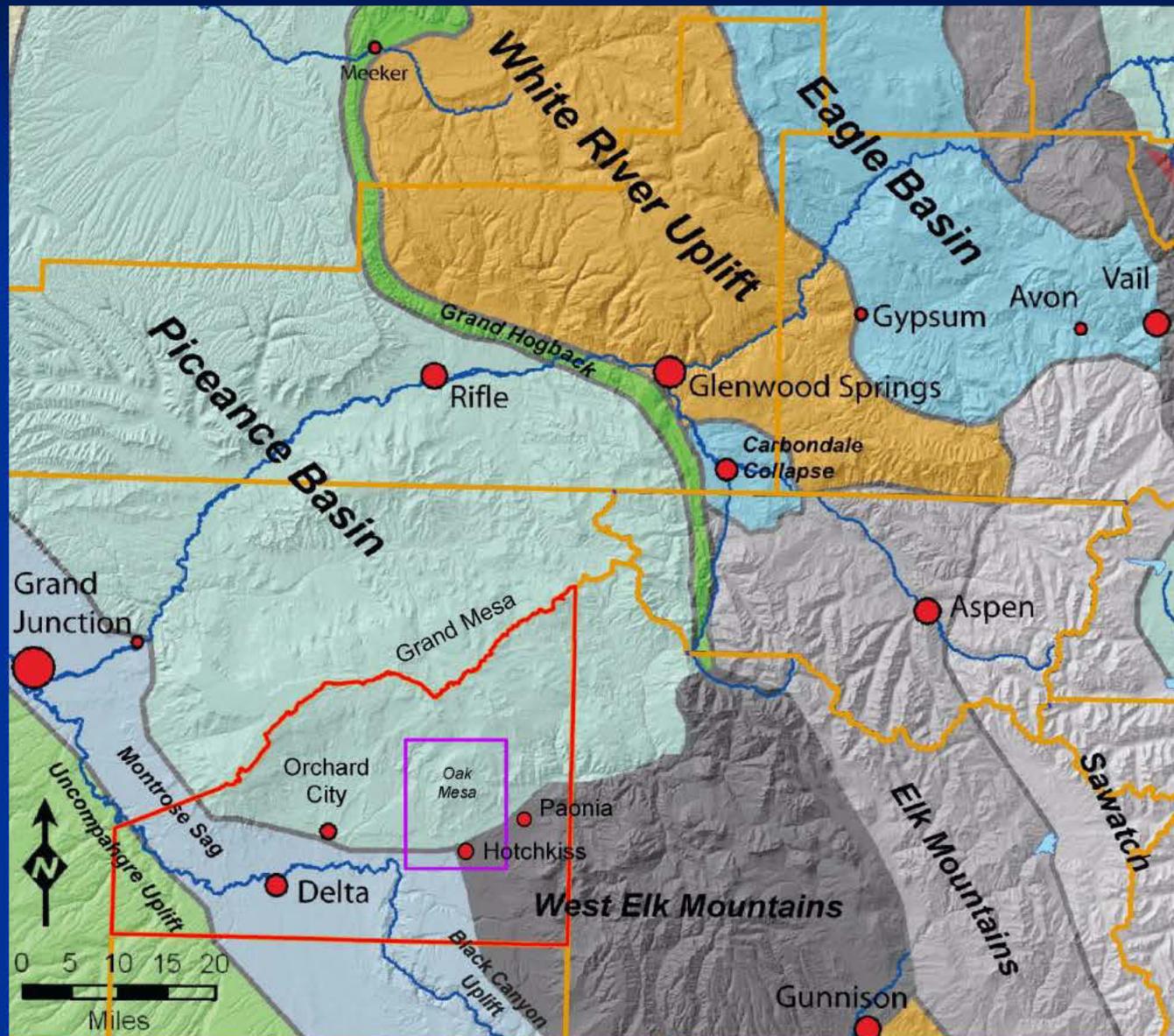
Precipitation [in/yr]



Topography and Surface Water



Regional Geologic Setting



Correlation of Geological and Hydrogeological Units in Delta County - 1

Geological Unit	Geological Subunit	Hydrogeological Unit	Hydrogeological Unit Symbol	Composition	Hydrogeological Characteristics	Permeability/Storativity	Depth to Water (small/moderate/large/highly fluctuating)	Extent (local/sub-regional/regional)	Recharge Type (natural/anthropogenic)
Alluvium (Qa); alluvium and eolian deposits (Qae)		Alluvium	Qa1	Poorly sorted riverine gravel, sand and silt deposited mainly in stream channels and floodplains in major stream valley bottoms; moderately to well bedded deposits	Generally good local phreatic aquifer with matrix based permeability; limited variations in groundwater levels; often sustained by local and sub-regional discharge to adjacent stream or directly by stream.	high matrix-permeability; high storativity	small	local	natural
Younger gravel (Qg, Qgy)		Younger valley gravels	Qgy	Poorly sorted sands and gravels; pebbles and cobbles in sand to silt matrix	Potentially good, spatially continuous phreatic aquifer with high matrix based permeability; may be supported by underlying bedrock.	high matrix-permeability; high storativity	highly fluctuating	local	natural and anthropogenic
Glacial drift, till, moraine (Qd, Qm, Qpt)		Quaternary glacial deposits	Qd	Heterogeneous, poorly sorted deposits of boulders, gravel, sand, silt and clay	Potentially good local phreatic aquifer with variable matrix based permeability and high water table gradients.	high matrix-permeability; high storativity	highly fluctuating	local	natural and anthropogenic
Landslide deposits, colluvium, mudflow deposits, talus (Ql, Qcl, Qs, Qls, Qta); unconsolidated deposits derived from the Wasatch Formation and Basalt cap on Grand Mesa (Quw)		Hillside (slope) deposits	Qs	Loose gravels and rock debris with mixed matrix composition (sand-clay) on valley sides, valley floors and hillslopes; deposited by gravitational processes	Potentially good, highly localized phreatic aquifer with high matrix based permeability and high water table gradients.	high matrix-permeability; high storativity	highly fluctuating	local	natural and anthropogenic
Old/older gravels (Qgo, Qgd)		Older mesa top gravels	Qgo	Poorly sorted sands and gravels; pebbles and cobbles in sand to silt matrix	Potentially good, spatially continuous phreatic aquifer with high matrix based permeability; may be prone to significant (seasonal) water table fluctuations; tends to recharge bedrock systems	high matrix-permeability; high storativity	moderate	local	natural and anthropogenic
Middle gravel (Qgm) and fans (Qf)		Fans and lower mesa gravels	Qgf	Poorly sorted sands and gravels; pebbles and cobbles in sand to silt matrix	Although having high matrix based permeability, location in topography precludes any significant groundwater presence.	high matrix-permeability; high storativity	highly fluctuating	local	natural and anthropogenic
High level alluvium (Qat); younger terraces (Qad); alluvial gravels (Qga)		Younger river terraces	Qat	Poorly sorted sands and gravels; pebbles and cobbles in sand to silt matrix; forms terraces above current North Fork level	Potentially good, spatially continuous phreatic aquifer with high matrix based permeability.	high matrix-permeability; high storativity	highly fluctuating	local	natural and anthropogenic

Correlation of Geological and Hydrogeological Units in Delta County - 2

<i>Geological Unit</i>	<i>Geological Subunit</i>	<i>Hydrogeological Unit</i>	<i>Hydrogeological Unit Symbol</i>	<i>Composition</i>
Alluvium (Qa); alluvium and eolian deposits (Qae)		Alluvium	Qal	Poorly sorted riverine gravel, sand and silt deposited mainly in stream channels and floodplains in major stream valley bottoms; moderately to well bedded deposits
Younger gravel (Qg, Qgy)		Younger valley gravels	Qgy	Poorly sorted sands and gravels; pebbles and cobbles in sand to silt matrix
Glacial drift, till, moraine (Qd, Qm, Qpt)		Quaternary glacial deposits	Qd	Heterogeneous, poorly sorted deposits of boulders, gravel, sand, silt and clay

Correlation of Geological and Hydrogeological Units in Delta County - 3

<i>Hydrogeological Unit Symbol</i>	<i>Hydrogeological Characteristics</i>	<i>Permeability/Storativity</i>	<i>Depth to Water</i> (small/ moderate/ large/ highly fluctuating)	<i>Extent</i> (local/ sub-regional/ regional)	<i>Recharge Type</i> (natural/ anthropogenic)
Qal	Generally good local phreatic aquifer with matrix based permeability; limited variations in groundwater levels; often sustained by local and sub-regional discharge to adjacent stream or directly by stream.	high matrix-permeability; high storativity	small	local	natural
Qgy	Potentially good, spatially continuous phreatic aquifer with high matrix based permeability; may be supported by underlying bedrock.	high matrix-permeability; high storativity	highly fluctuating	local	natural and anthropogenic
Qd	Potentially good local phreatic aquifer with variable matrix based permeability and high water table gradients; sustainability depends on local natural and/or anthropogenic recharge mechanisms.	high matrix-permeability; high storativity	highly fluctuating	local	natural and anthropogenic

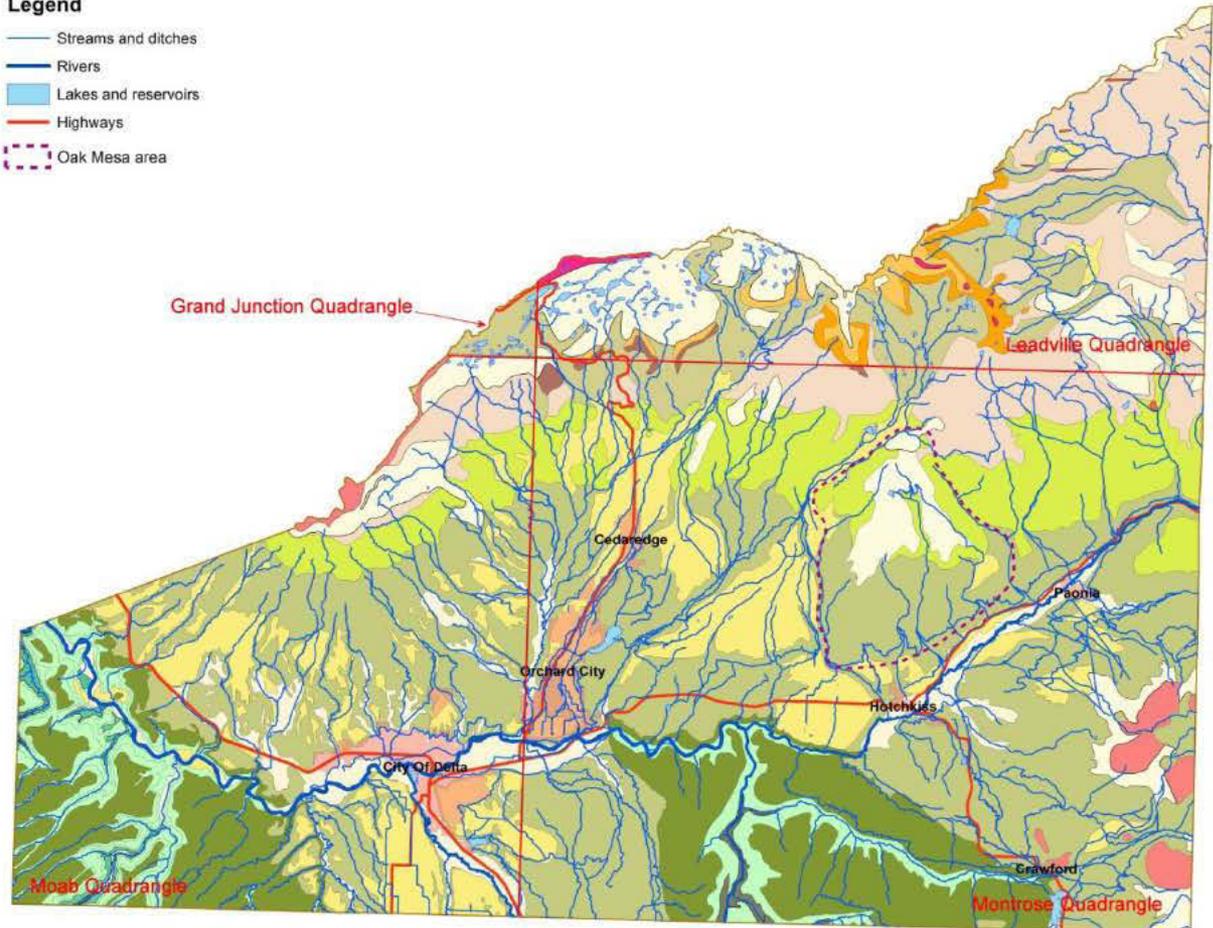
Geological Map of Delta County

Geological Units

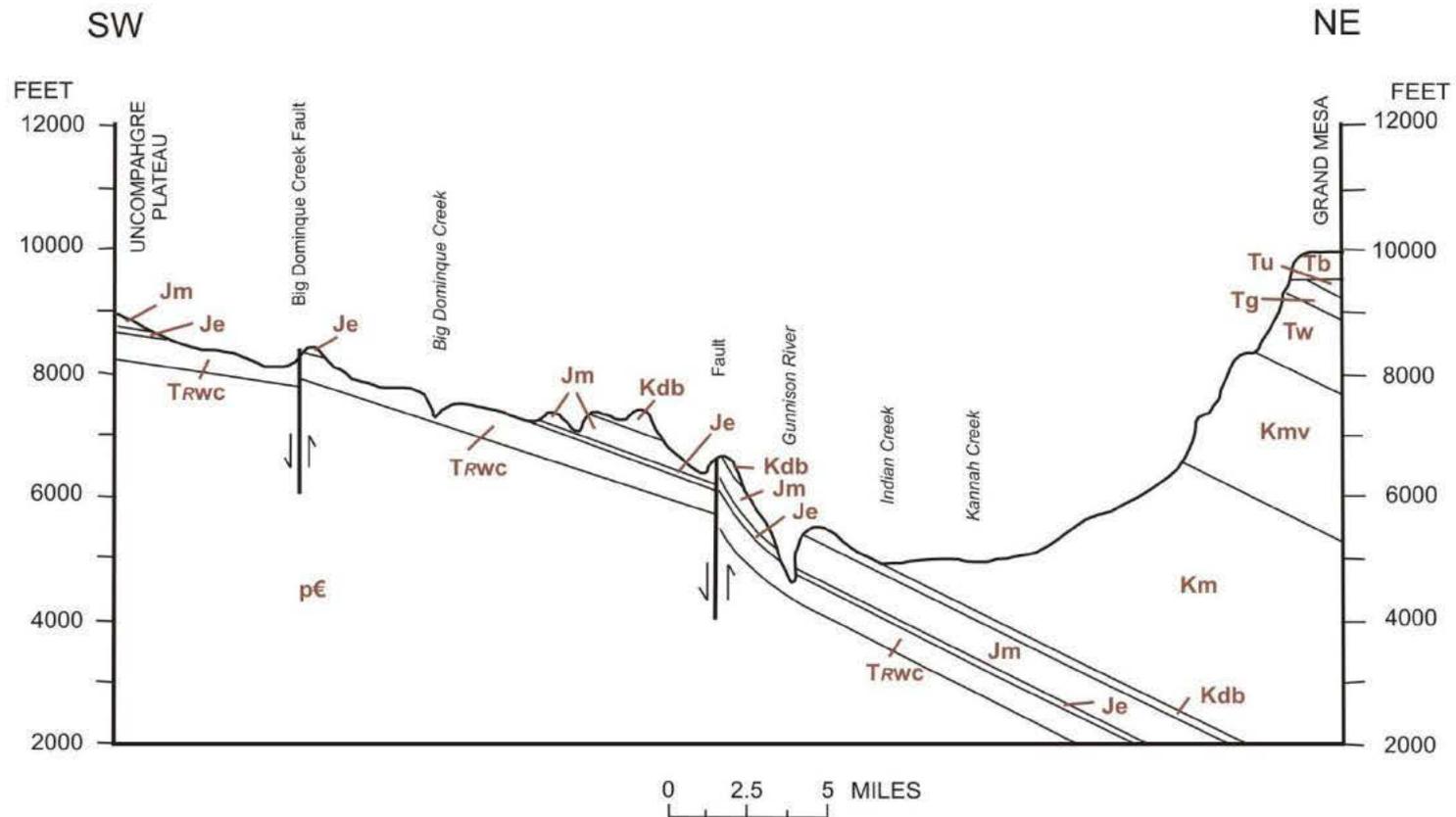
- Qa - Alluvium
- Qb - Basalt [Lava flows]
- Qd - Glacial Drift [Till]
- Qe - Eolian Deposits
- Qg - Young Gravels [Terraces, fans, outwash deposits]
- Qgo - Old Gravels [On ridge and mesa tops]
- Qls - Landslide Deposits [Colluvium, talus]
- Tb - Basalt [Lava flows]
- Tbi - Basalt Dikes and Plugs [Intrusions]
- Tg - Green River Formation
- Tgp - Green River Formation - Parachute Creek Member
- Tmi - Mid-Tertiary Intrusions [Stocks, dikes, sills, laccoliths]
- Tu - Uinta Formation
- Tw - Wasatch Formation
- Two - Wasatch and Ohio Creek Formations
- Kdb - Dakota Sandstone and Burro Canyon Formation
- Km - Mancos Shale
- Kmv - Mesa Verde Group or Formation
- Jmb - Morrison Formation - Brushy Basin Member
- Jms - Morrison Formation - Salt Wash Sandstone Member
- Jmwe - Morrison and Wanakah Formations and Entrada Sandstone
- Jse - Summerville Formation and Entrada Sandstone
- TRc - Chinle Formation
- TRw - Wingate Sandstone
- pC - Precambrium Crystalline Rock

Legend

- Streams and ditches
- Rivers
- Lakes and reservoirs
- Highways
- ⋯ Oak Mesa area



NE-SW Geological Cross Section



Tb - Tertiary Basalt
 Tu - Uinta Formation
 Tg - Green River Formation
 Tw - Wasatch Formation
 Kmv - Mesaverde Formation
 Km - Mancos Shale

Kdb - Dakota Sandstone and
 Burro Canyon Formation
 Jm - Morrison Formation
 Je - Entrada Sandstone
 Trwc - Wingate Sandstone and
 Chinle Formation
 p€ - Precambrian

Hydrogeology of Oak Mesa Area

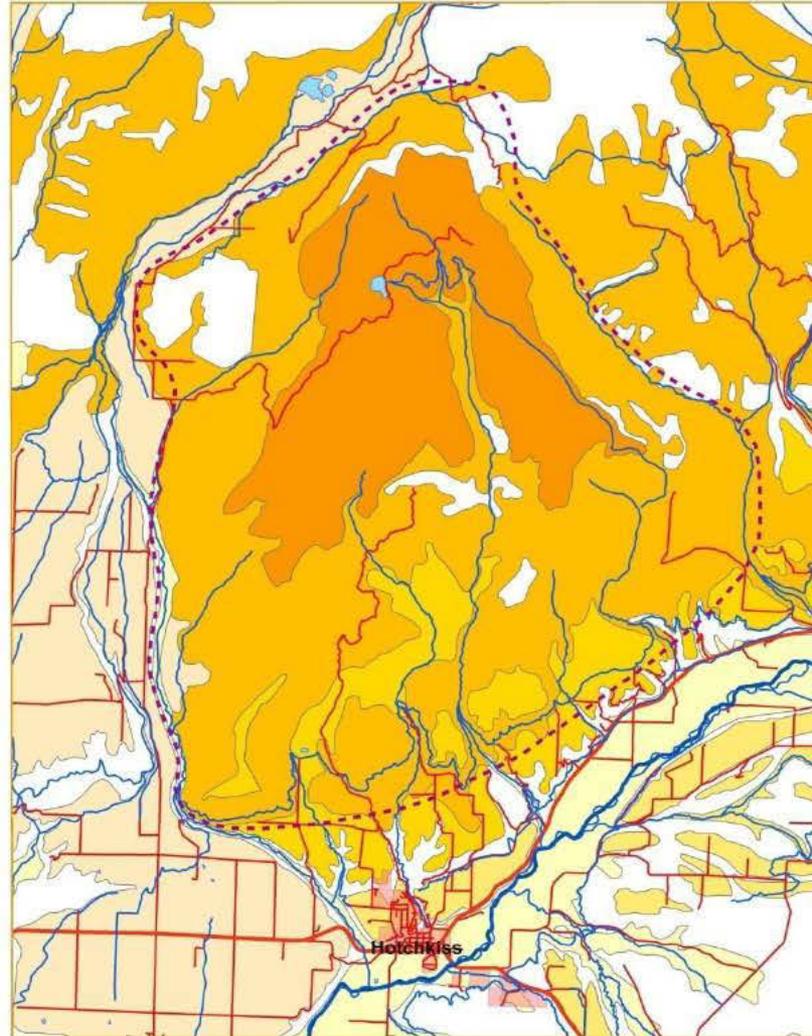
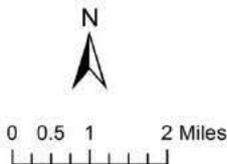
Shallow Unconsolidated Units

Unconsolidated Hydrogeological Units

- Alluvium (Qal)
- Younger Valley Gravels (Qgy)
- Younger River Terraces (Qat)
- Fans and Lower Mesa Gravels (Qgf)
- Hillside (Slope) Deposits (Qs)
- Older Mesa Top Gravels (Qgo)
- Bedrock

Legend

- Streams and ditches
- Rivers
- Lakes and reservoirs
- Highways
- Roads
- Oak Mesa area



Hydrogeology of Oak Mesa Area

Bedrock Units

Bedrock Hydrogeological Units

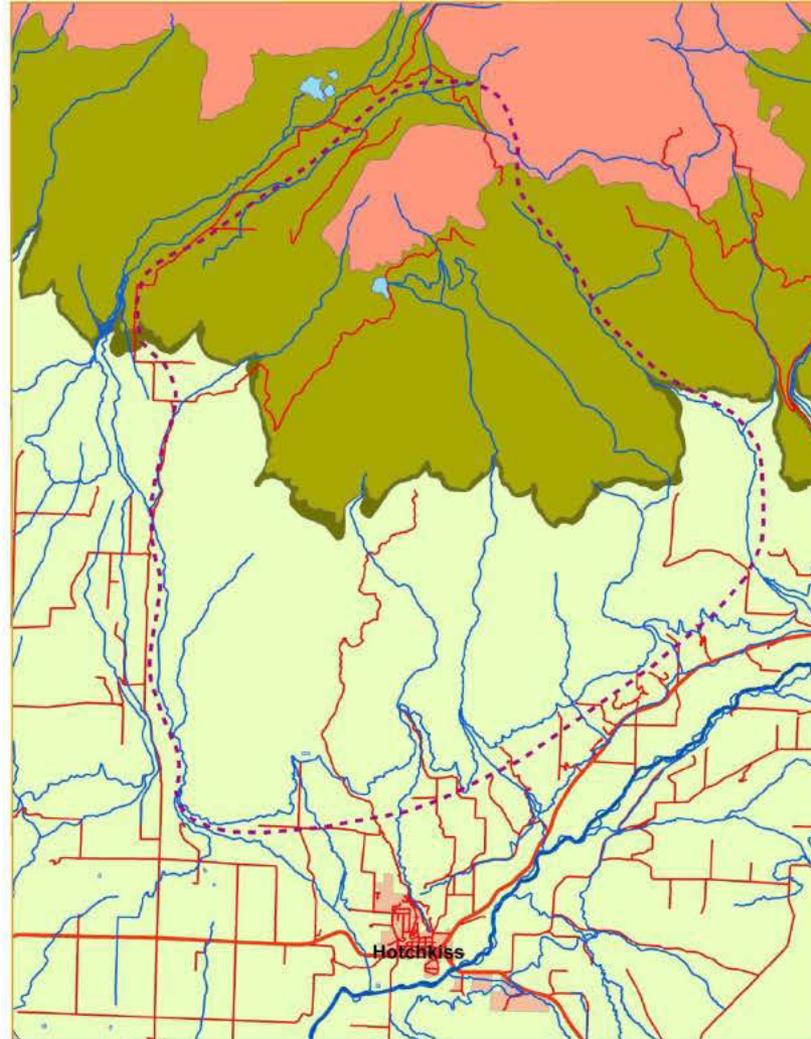
- Wasatch Formation (Tw)
- Mesa Verde Formation incl. Ohio Creek Member (Kmv)
- Rollins Sandstone (Kmr)
- Mancos Shale (Km)
- Dakota-Burro Canyon (Kdb)

Legend

- Streams and ditches
- Rivers
- Lakes and reservoirs
- Highways
- Roads
- Oak Mesa area



0 0.5 1 2 Miles

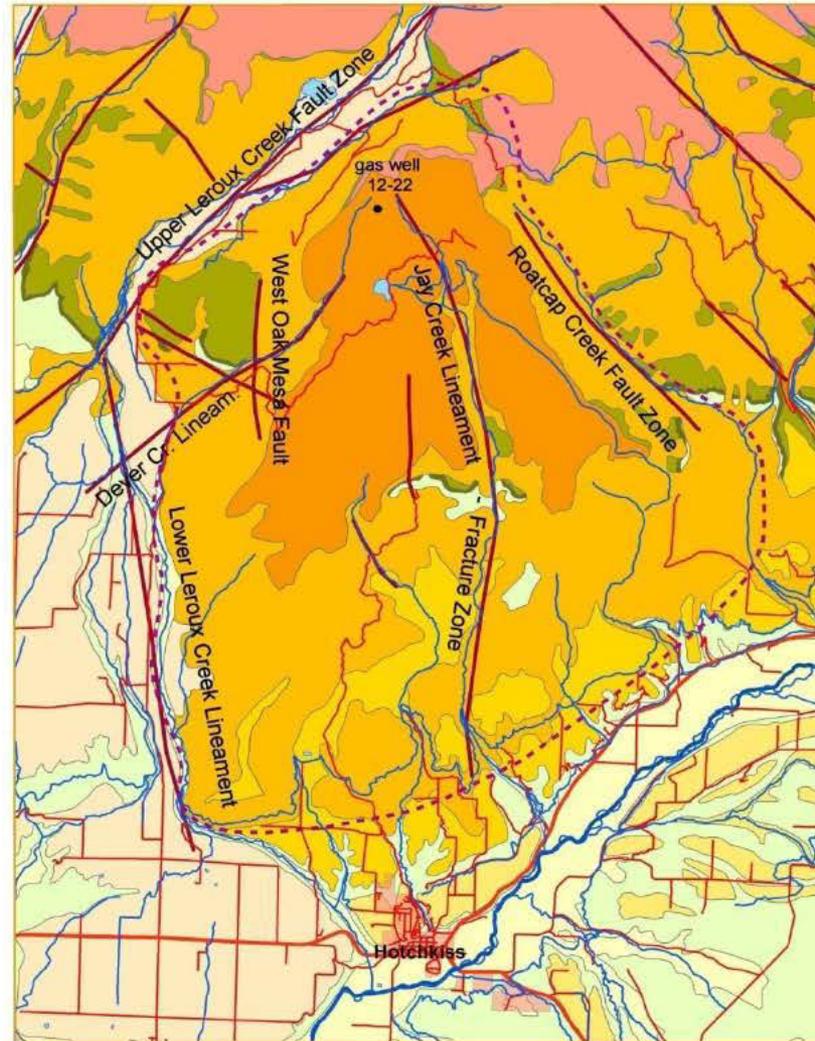


Hydrogeology of Oak Mesa Area

Hydrostructures

Legend

- Streams and ditches
- Rivers
- Lakes and reservoirs
- Highways
- Roads
- Oak Mesa area
- Hydro-structures

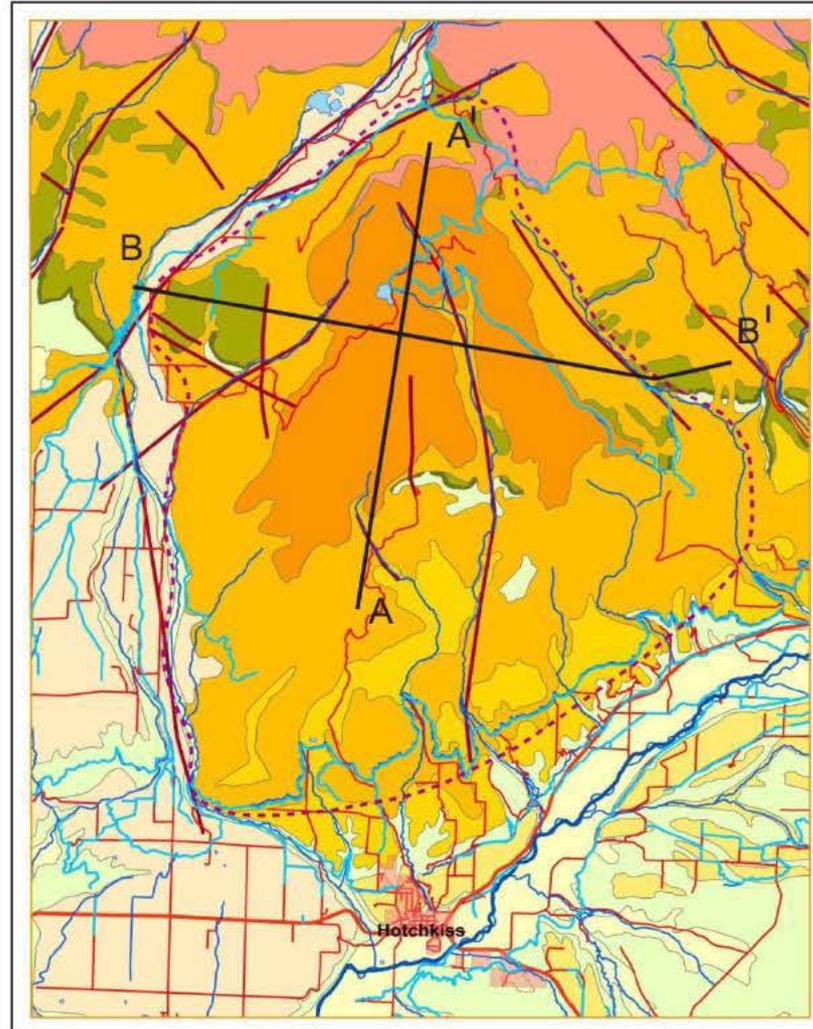
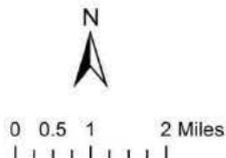


Hydrogeology of Oak Mesa Area

Location of CSM Cross Sections

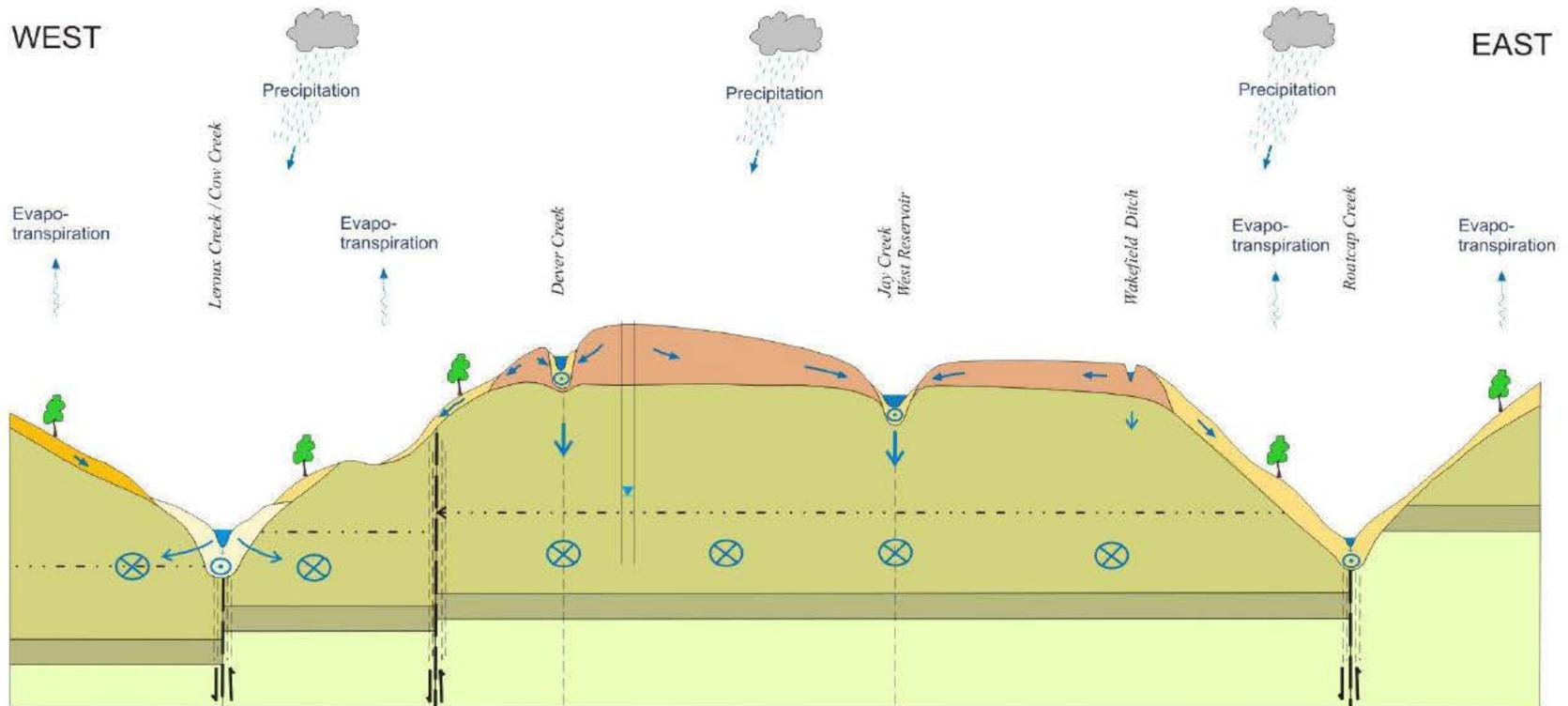
Legend

- Oak Mesa area
- Ditches and enhanced streams
- Rivers
- Streams and ditches
- Lakes and reservoirs
- Towns
- Highways
- Roads
- Oak Mesa hydro-structures
- Alluvium [Qal]
- Younger Valley Gravels [Qgy]
- Younger River Terraces [Qat]
- Fans and Lower Mesa Gravels [Qgf]
- Hillside (Slope) Deposits [Qs]
- Older Mesa Top Gravels [Qgo]
- Wasatch Formation [Tw]
- Mesaverde Formation [Kmv]
- Rollins Sandstone [Kmv]
- Mancos Shale [Km]
- Dakota-Burro Canyon [Kdb]



Hydrogeology of Oak Mesa Area

Shallow Aquifer Subsystem – X-section



B

- Qgy - Younger Valley Gravels
- Qs - Hillside Deposits
- Qgo - Older Mesa Top Gravels
- Kmv - Mesaverde Formation
- Kmvr - Rollins Member of Mesaverde F.
- Km - Mancos Shale
- Top Coal-bearing Members

- Groundwater Flow
- Groundwater Flow into Plane of Cross-section
- Groundwater Flow out of Plane of Cross-section
- Fault (arrows indicate direction of movement)
- Fracture Zone
- Lineament
- Static Groundwater Level in Well

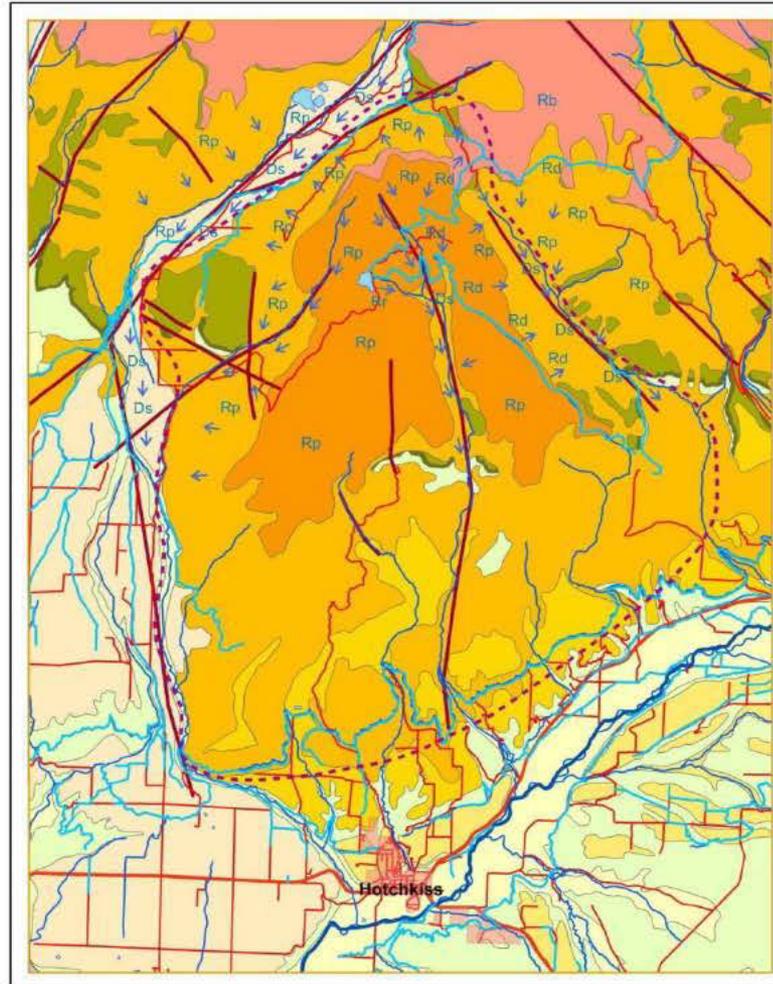
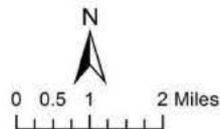
B'

Hydrogeology of Oak Mesa Area

Shallow Aquifer Subsystem – Plan View

Legend

-  Oak Mesa area
 -  Ditches and enhanced streams
 -  Rivers
 -  Streams and ditches
 -  Lakes and reservoirs
 -  Towns
 -  Highways
 -  Roads
 -  Oak Mesa hydro-structures
 -  Alluvium [Qal]
 -  Younger Valley Gravels [Qgy]
 -  Younger River Terraces [Qat]
 -  Fans and Lower Mesa Gravels [Qgf]
 -  Hillside (Slope) Deposits [Qs]
 -  Older Mesa Top Gravels [Qgo]
 -  Wasatch Formation [Tw]
 -  Mesaverde Formation [Kmv]
 -  Rollins Sandstone [Kmv]
 -  Mancos Shale [Km]
 -  Dakota-Burro Canyon [Kdb]
-
-  Rp - Recharge from precipitation into gravel and through gravel into bedrock
 -  Rd - Recharge from leaky ditch
 -  Rb - Recharge from precipitation directly into bedrock
 -  Rr - Recharge from reservoir/lake
 -  Ds - Discharge to stream
 -  → - Direction of groundwater flow



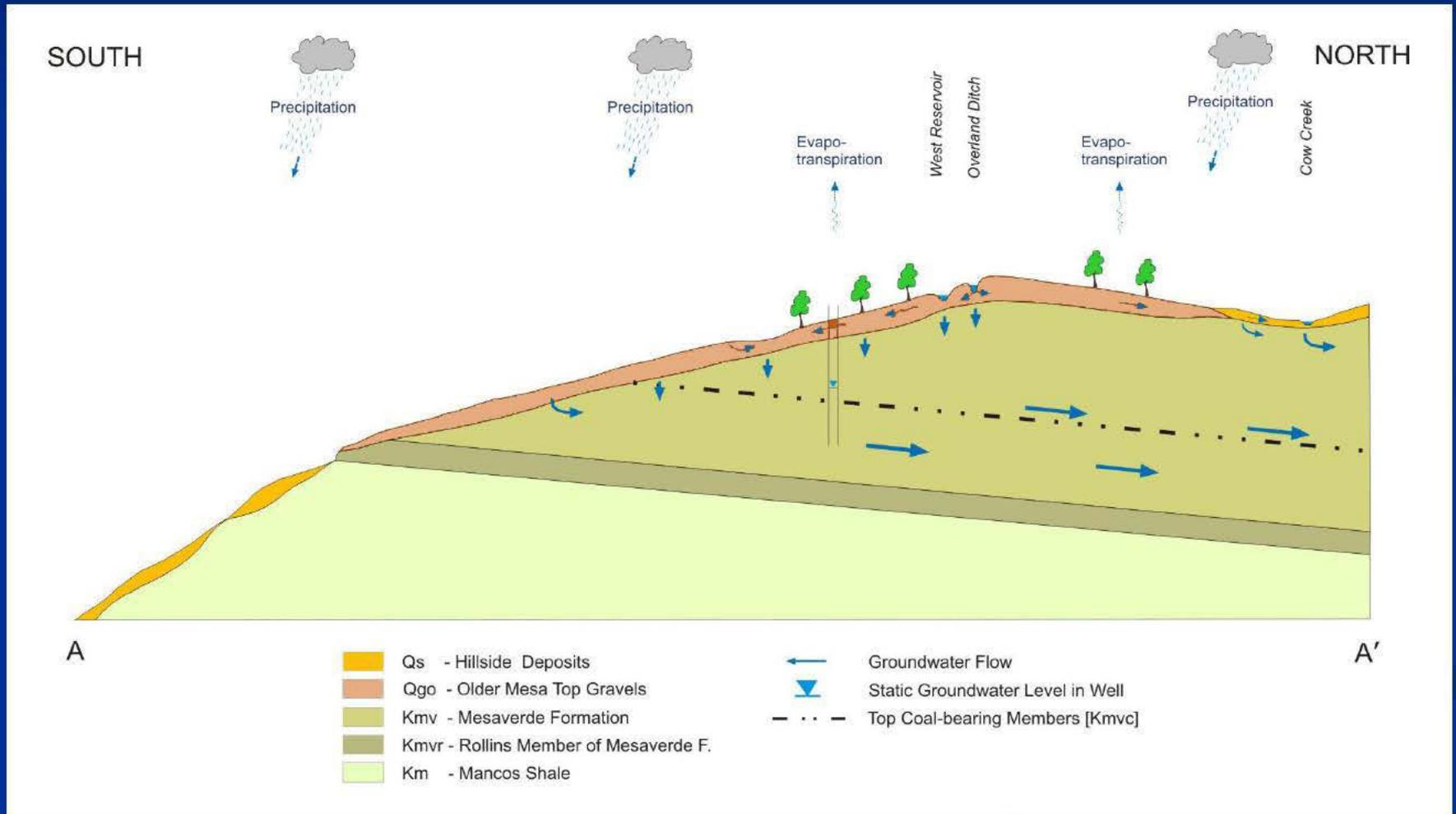
Hydrogeology of Oak Mesa Area

Shallow Aquifer Subsystem – Google Earth View



Hydrogeology of Oak Mesa Area

Regional Bedrock Subsystem – X-section



Hydrogeology of Oak Mesa Area

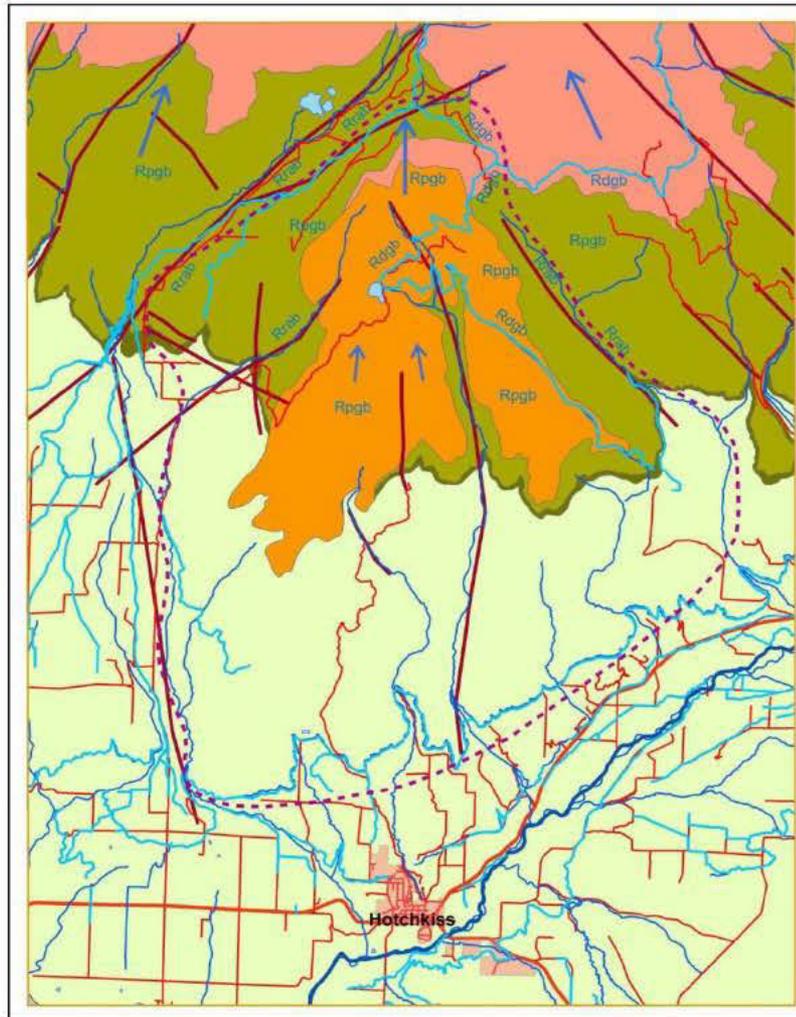
Regional Bedrock Subsystem – Plan View

Legend

-  Oak Mesa area
 -  Ditches and enhanced streams
 -  Rivers
 -  Streams
 -  Lakes and reservoirs
 -  Towns
 -  Highways
 -  Roads
 -  Oak Mesa hydro-structures
 -  Older Mesa Top Gravels [Qgo]
 -  Wasatch Formation [Tw]
 -  Mesaverde Formation [Kmv]
 -  Rollins Sandstone [Kmv]
 -  Mancos Shale [Km]
 -  Dakota-Burro Canyon [Kdb]
-
-  Rpgb - Recharge from precipitation through gravels to bedrock
 -  Rrab - Recharge from leaky river through alluvium into bedrock
 -  Rdgb - Recharge from leaky ditch through gravels into bedrock
 -  → - Direction of groundwater flow



0 0.5 1 2 Miles



Hydrogeology of Oak Mesa Area

Anthropogenic Elements – Google Earth View

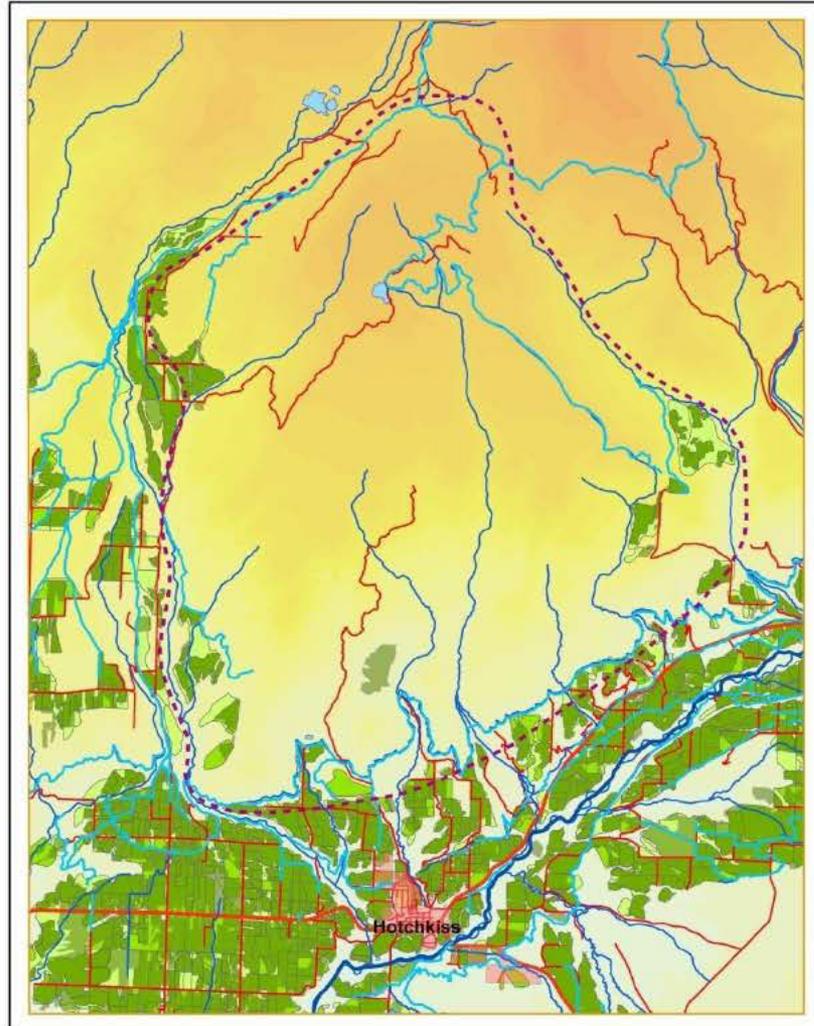
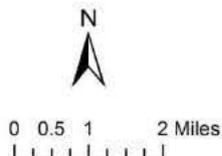


Hydrogeology of Oak Mesa Area

Anthropogenic Elements – Irrigation

Legend

- Oak Mesa area
- Ditches and enhanced streams
- Rivers
- Streams and ditches
- Lakes and reservoirs
- Towns
- Highways
- Roads
- Irrigated_Parcel 1993 [CDSS Div 5]
- Irrigated_Parcel 2000 [CDSS Div 5]
- Irrigated_Parcel 2005 [CDSS Div 5]

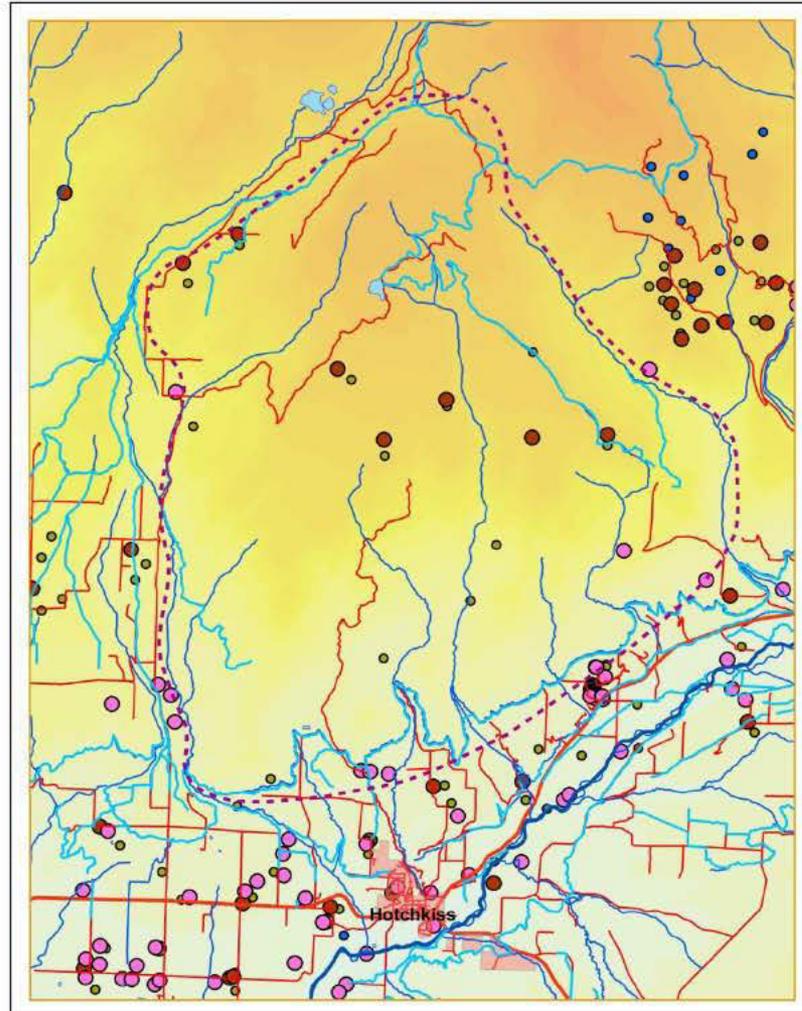
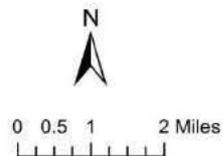


Hydrogeology of Oak Mesa Area

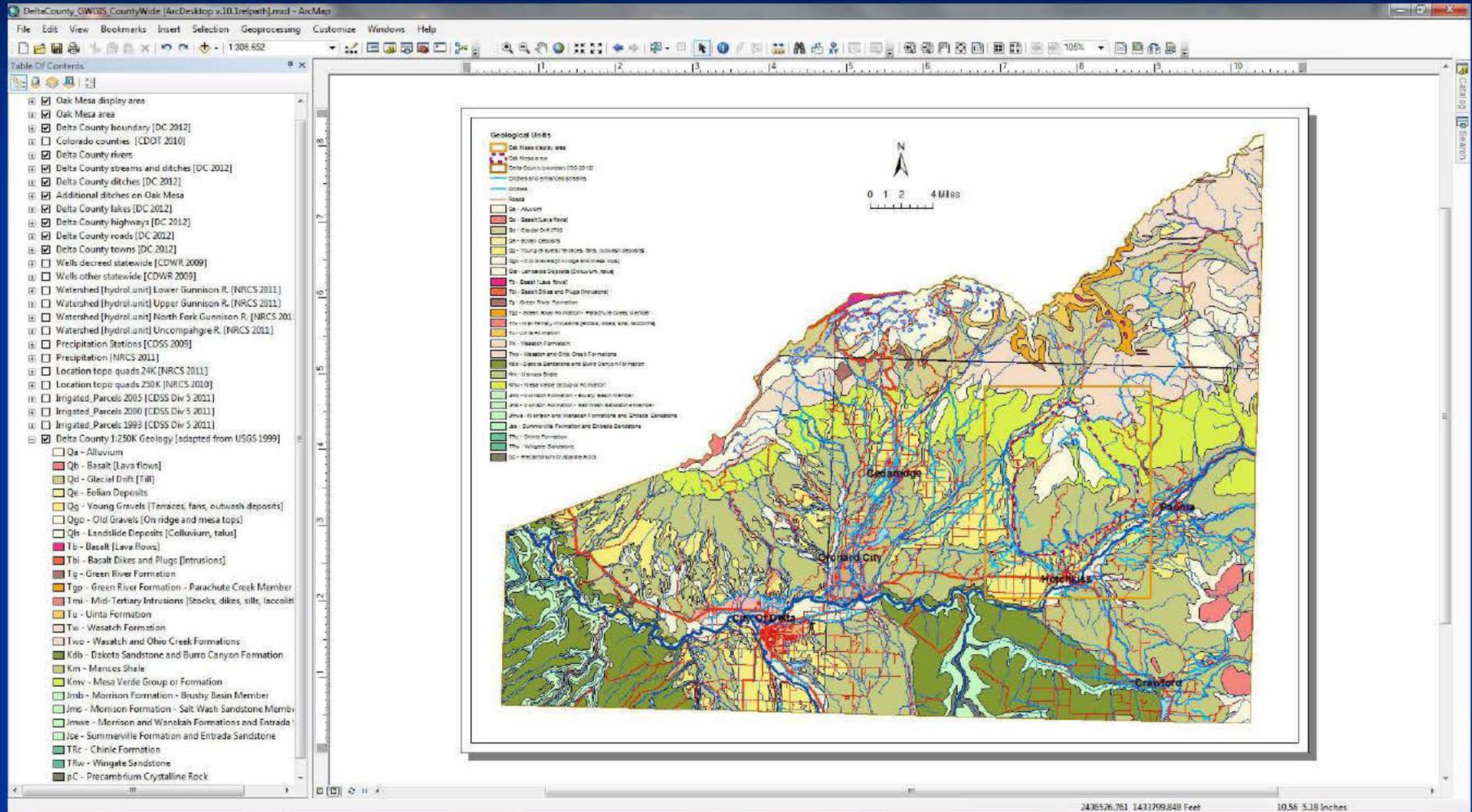
Anthropogenic Elements – Wells

Legend

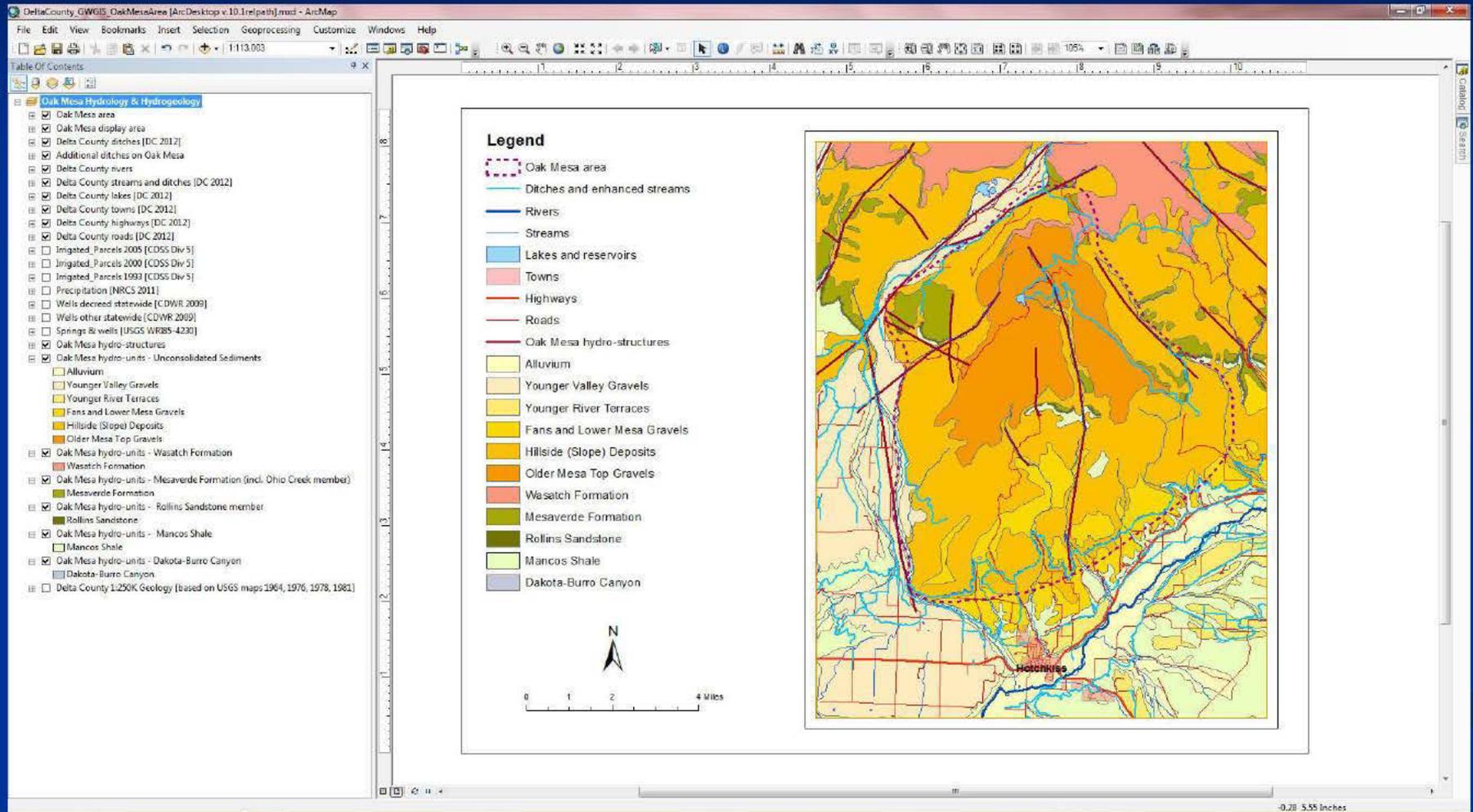
- Oak Mesa area
- Ditches and enhanced streams
- Rivers
- Streams and ditches
- Lakes and reservoirs
- Towns
- Highways
- Roads
- Wells - decreed [CDWR database 2009]
- Wells - other [CDWR database 2009]
- Selected wells [from USGS WRI85-4230]
- Selected springs [from USGS WRI85-4230]



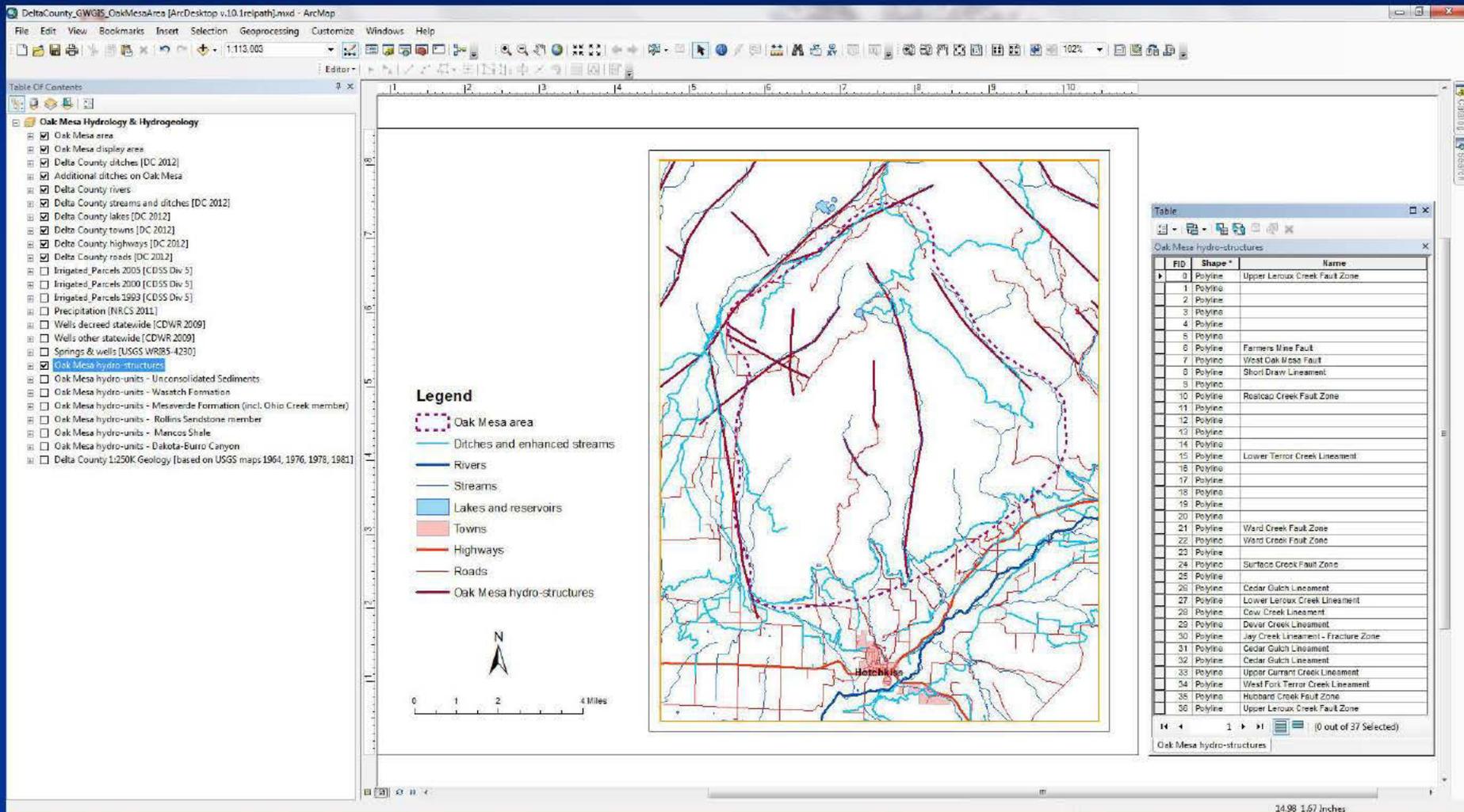
GIS MAPS: Delta County



GIS MAPS: Oak Mesa Area



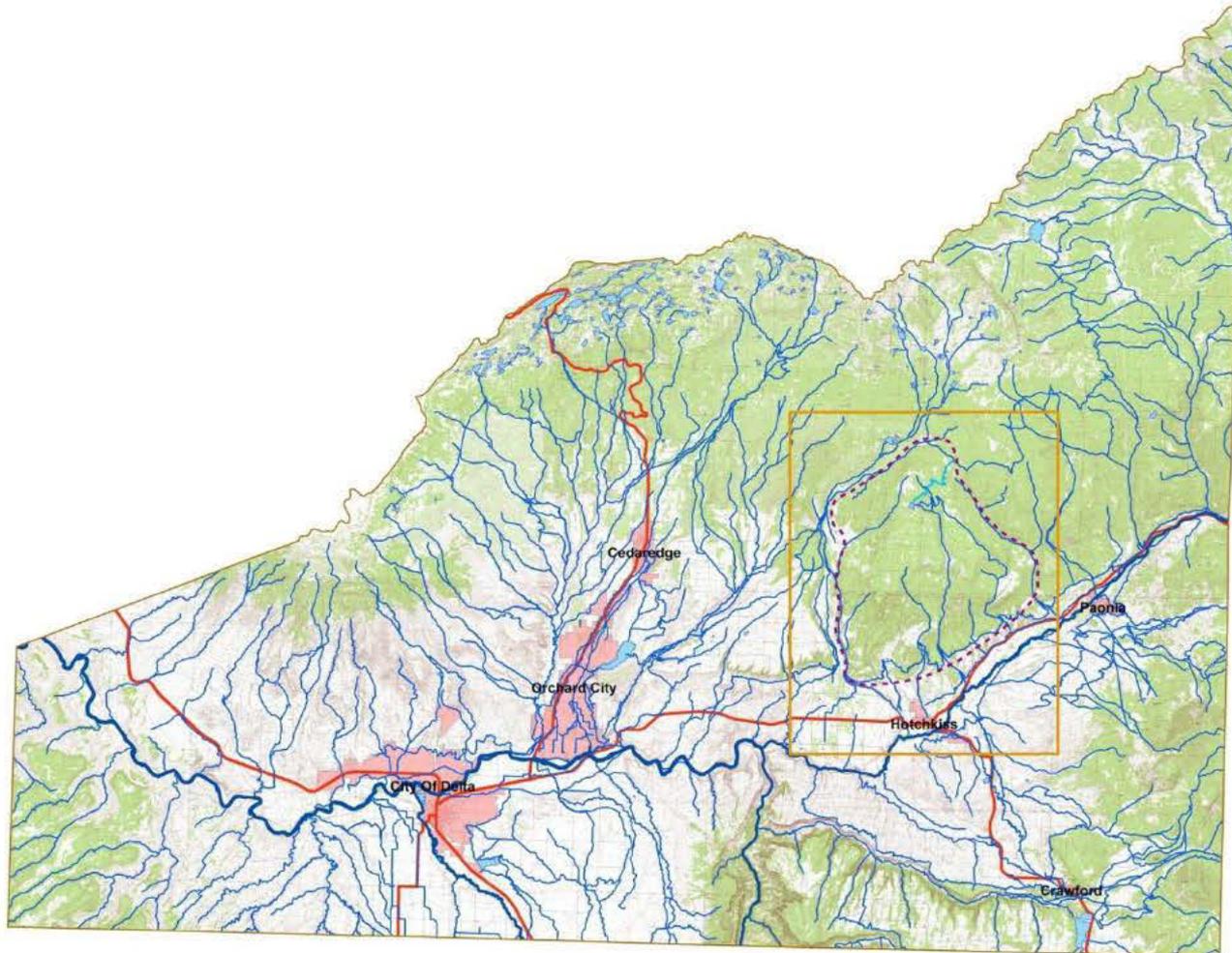
GIS MAPS: Database Detail



Summary

- Combining Hydrologic and Environmental Systems Analysis (HESA) with GIS provides an efficient, low cost approach to study and describe a county's hydrogeology and groundwater resources using existing data sources.
- Systematic, step-wise evaluation of groundwater resources, facilitated by the HESA/GIS approach, provides a quick assessment of presence, sustainability, and vulnerability of local groundwater resources.
- The HESA/GIS methodology provides a solid basis for planning and decision-making regarding local groundwater resources.

Future HESA Analysis



What Other Applications?

- Groundwater-surface water interaction
- Groundwater and wetlands, discharge zones
- Groundwater quality evaluations
- Groundwater and snow hydrology
- Groundwater levels, water table, depth to water
- Groundwater budget/balance
- Hydrogeologic parameters, models

QUESTIONS?



THANK YOU

