Louisiana Aquifer Seminar

October 16, 2024

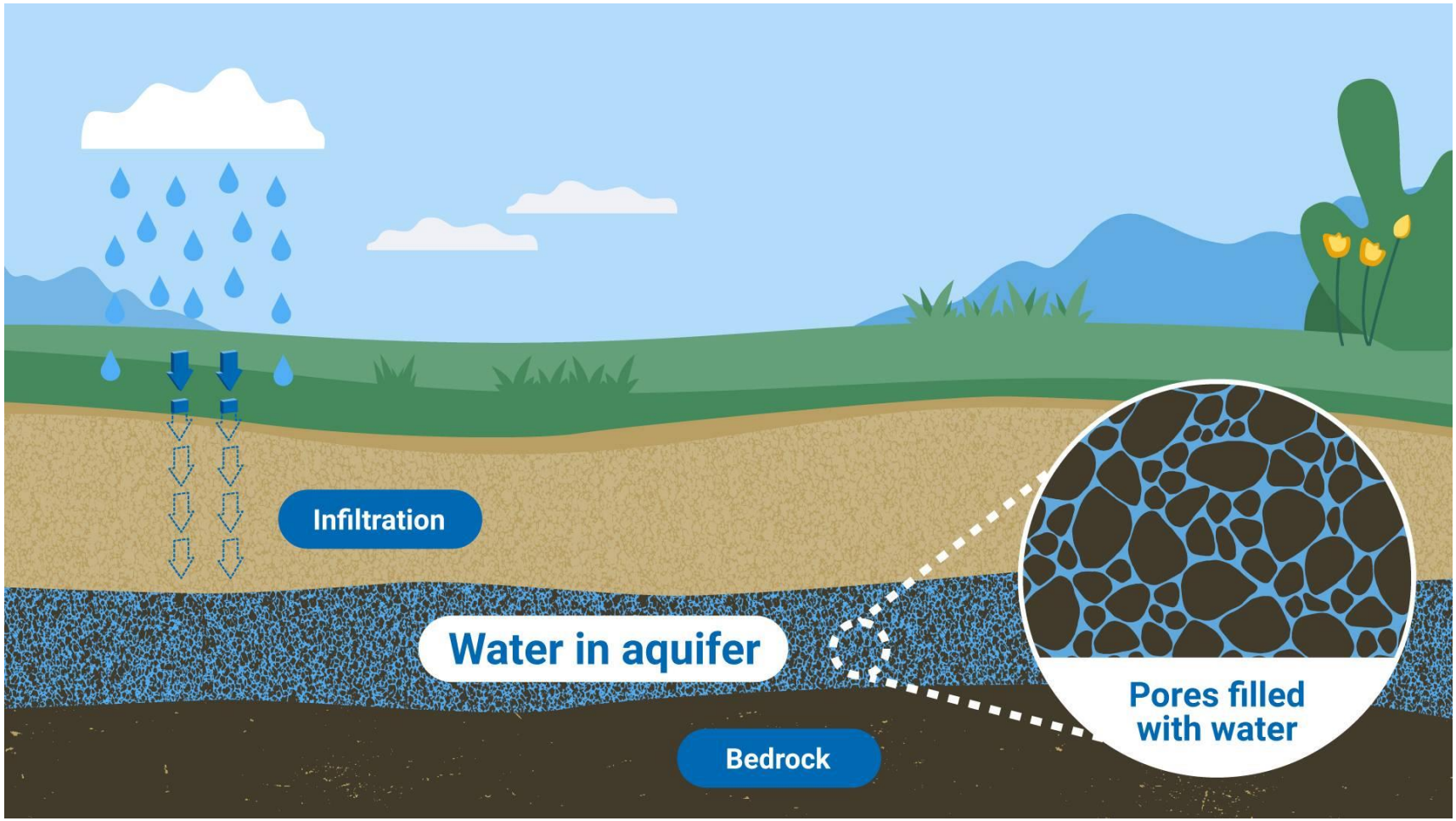
Presented by Jesse Means
Aquifer Evaluation & Protection Unit

Groundwater 101

LOUISIANA DEPARTMENT OF **ENVIRONMENTAL QUALITY**
: FOR ALL YOUR ENVIRONMENTS

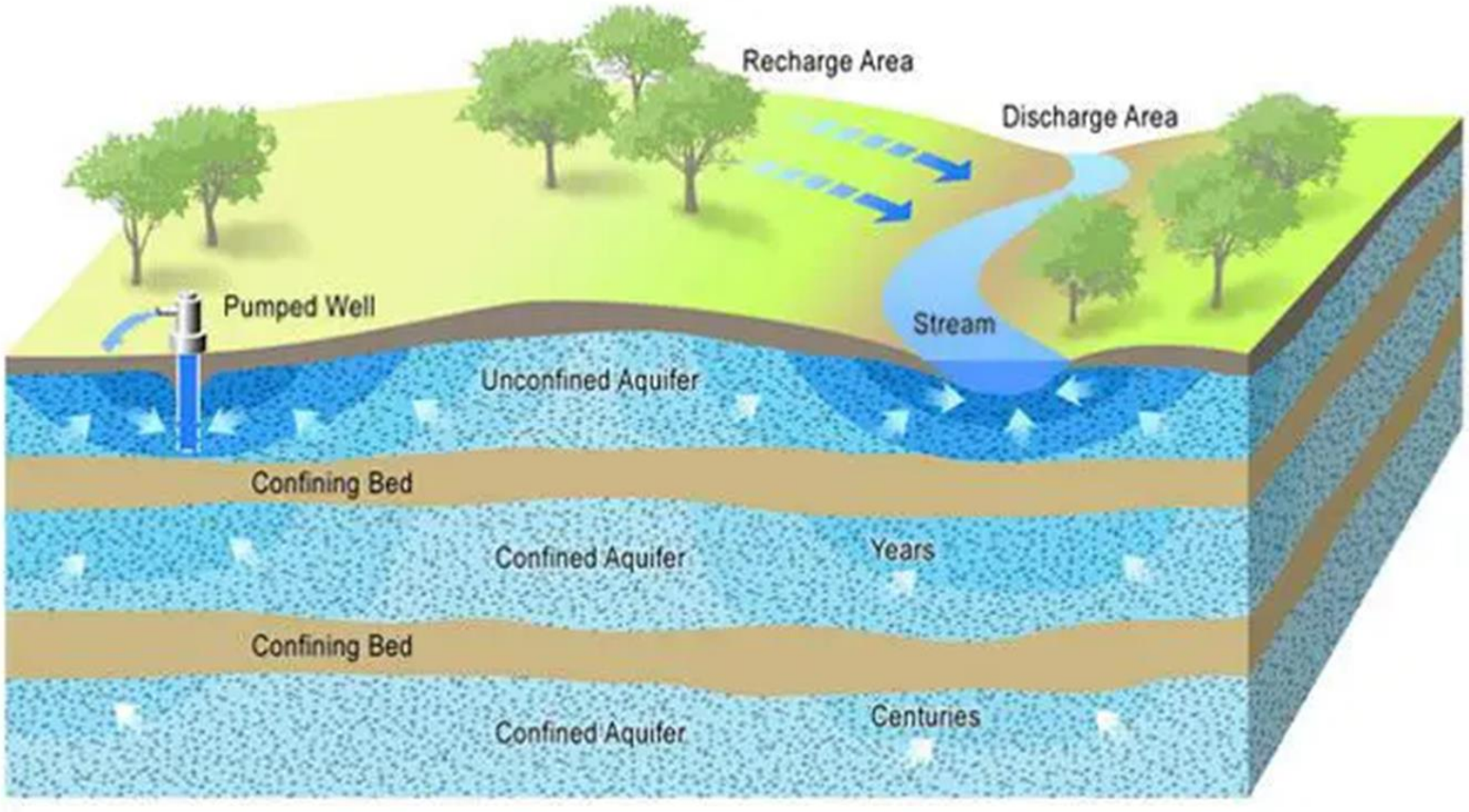
Groundwater

Water beneath Earth's surface in soil pore spaces and in the fractures of rock formations.

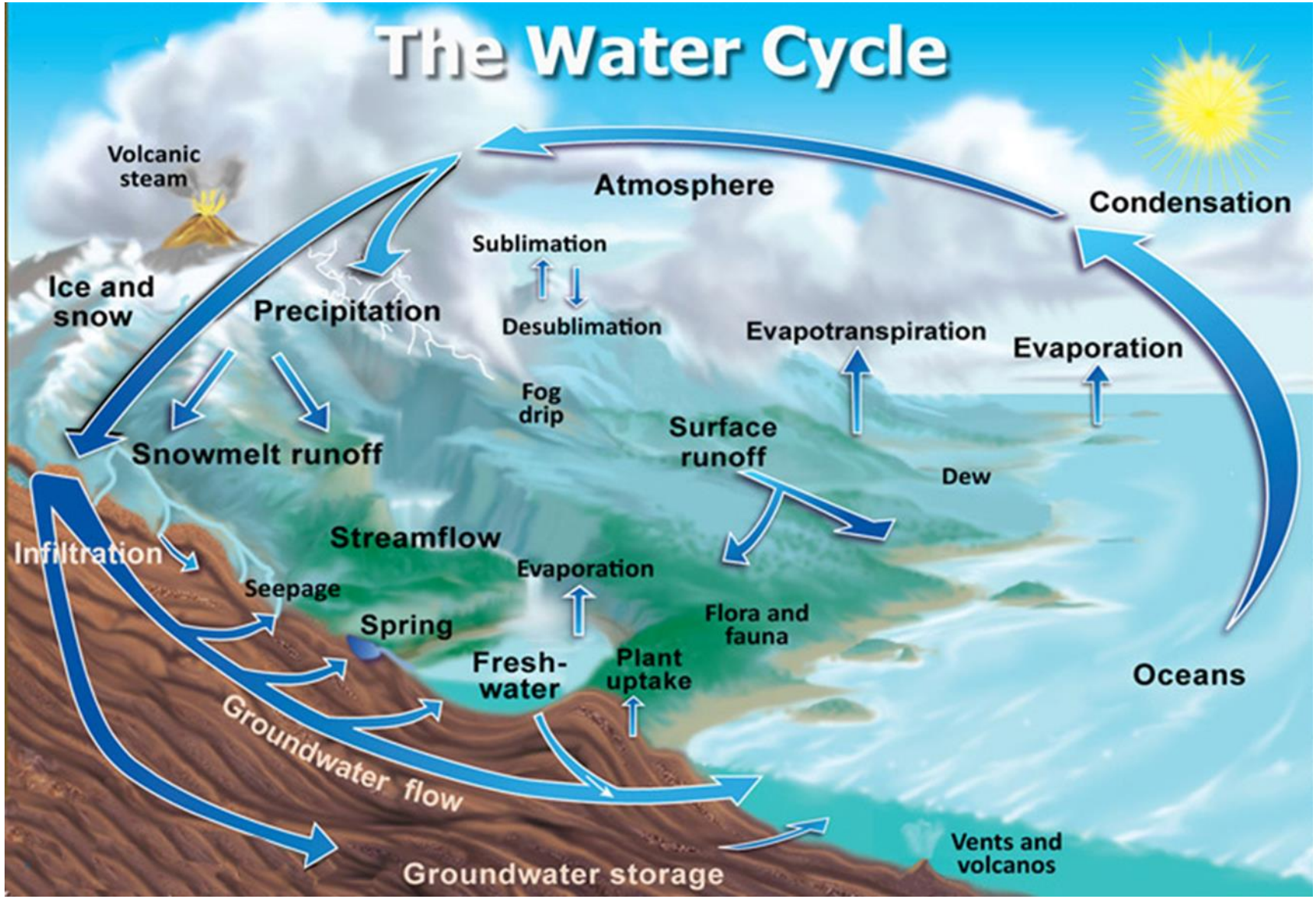


Aquifers

An underground layer of water-bearing, permeable rock, rock fractures, or unconsolidated materials (gravel, sand, or silt).

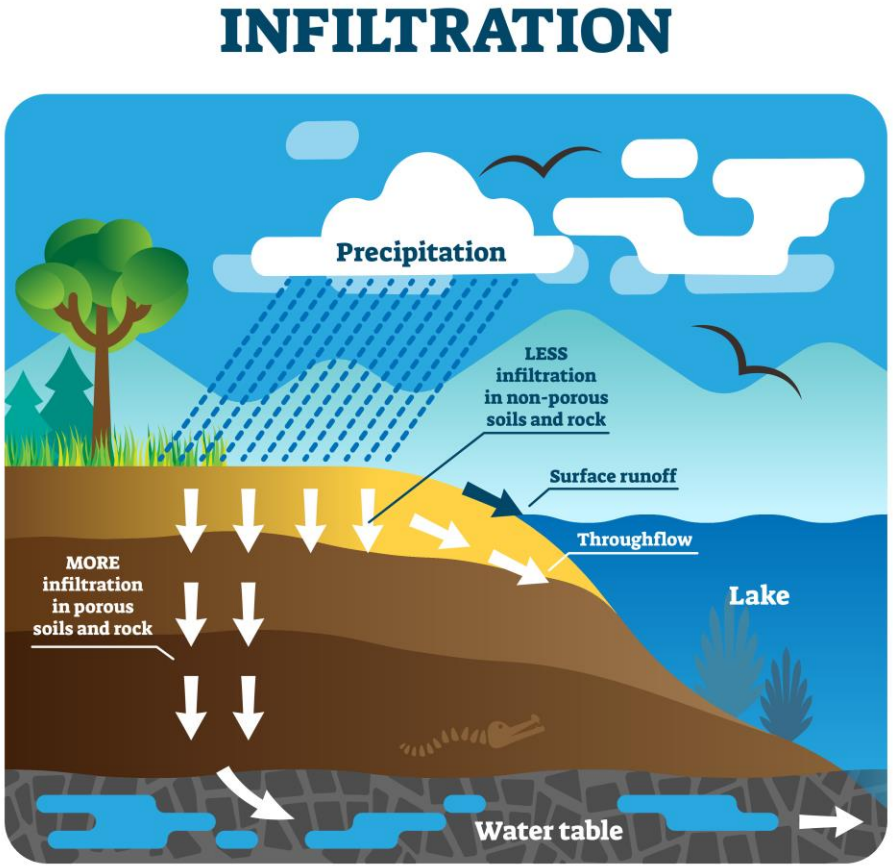


Hydrologic Cycle



Infiltration and Groundwater Recharge

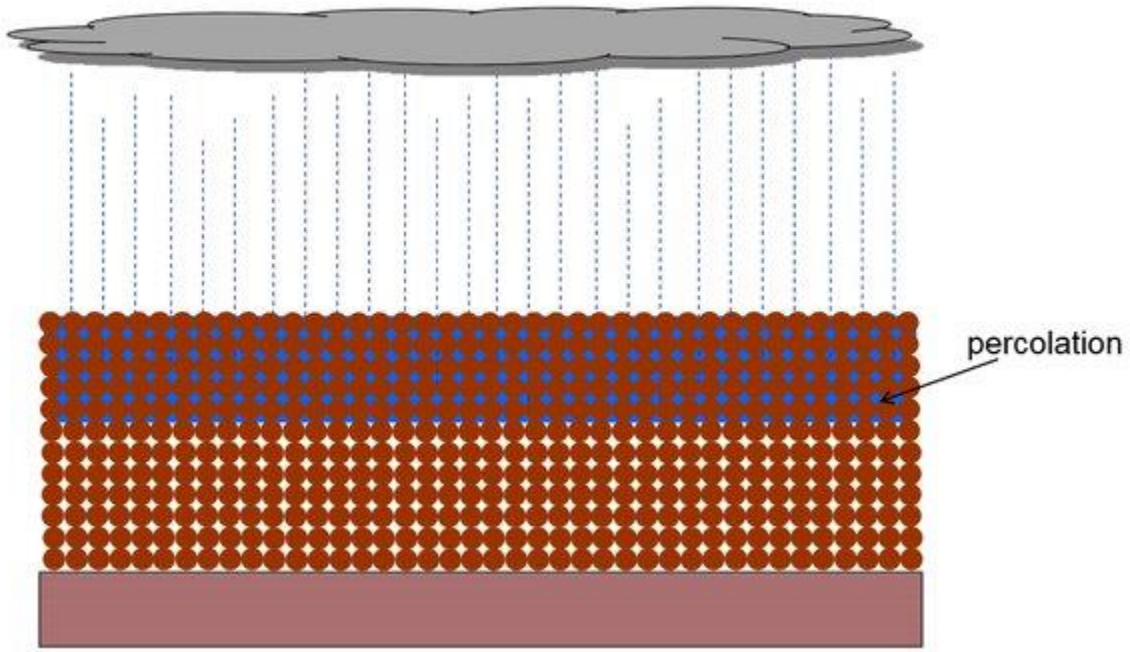
Recharge occurs as precipitation falls on the land surface, infiltrates into soils, and moves through pore spaces down to the water table.



Groundwater Recharge

Direct recharge from soil moisture excess and direct vertical **percolation** through the unsaturated zone

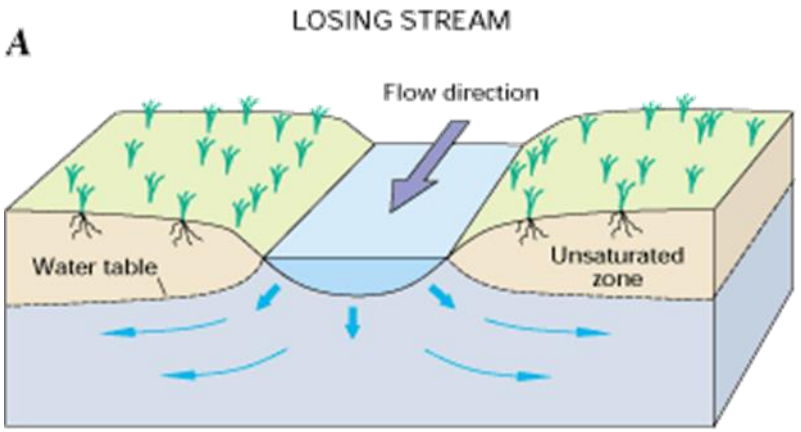
Percolation is the movement of water WITHIN the soil matrix.



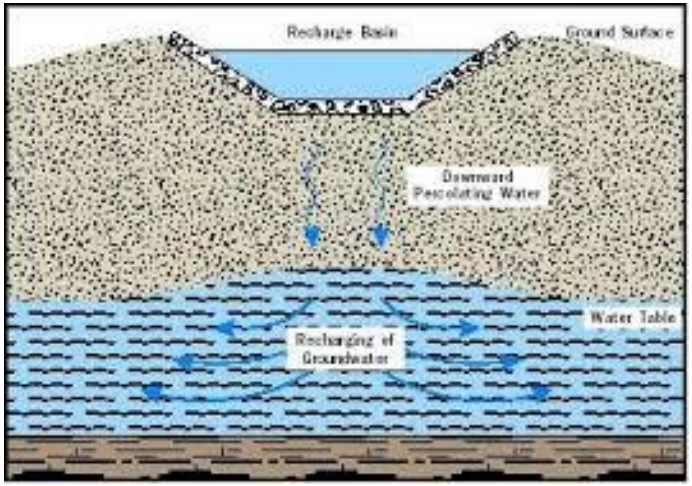
Groundwater Recharge

Indirect recharge that infiltrates and percolates through river beds or lakes, or artificial recharge (like infiltration from runoff)

Losing Stream - Altitude of water table lower than altitude of stream-water surface -- surface water *recharges* groundwater

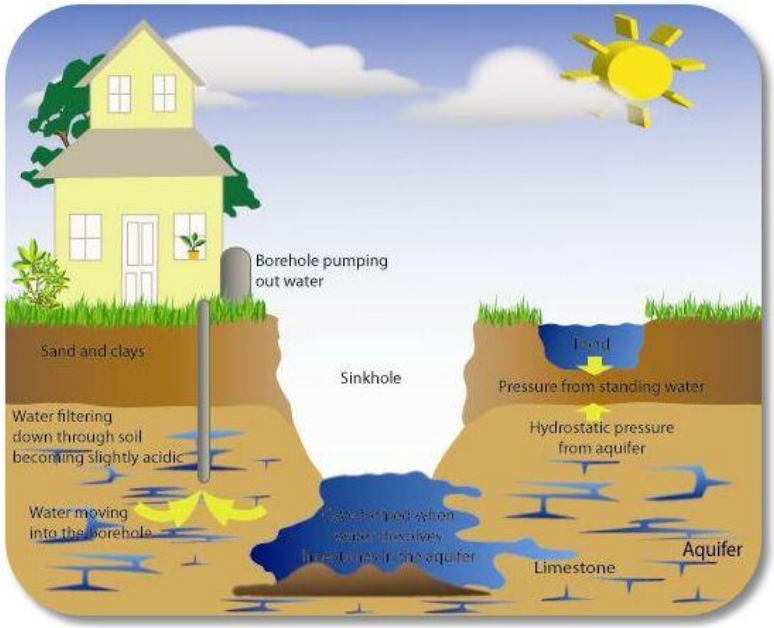


Artificial recharge - practice of increasing the amount of water that enters an aquifer through human-controlled means
(canals, infiltration basins, ponds, irrigation furrows or sprinkler systems, injection wells.



Groundwater Recharge

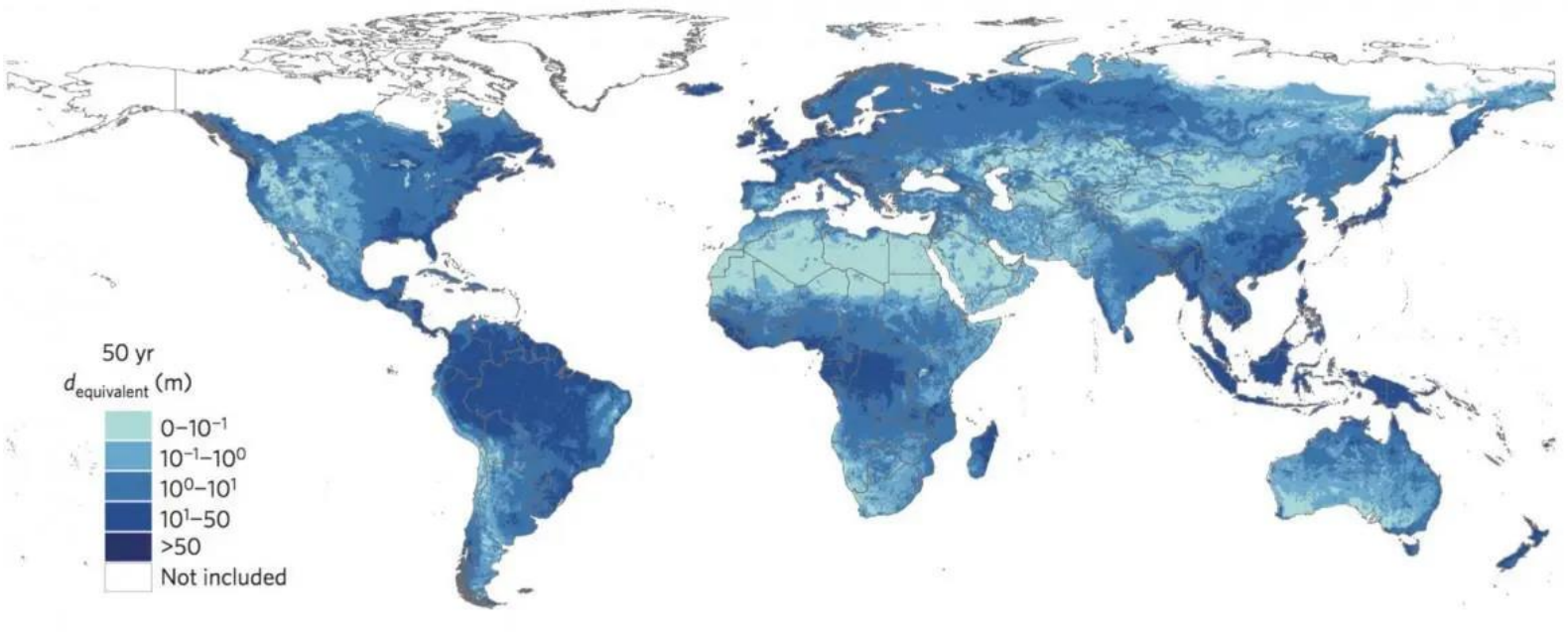
Focused or localized recharge that results from local horizontal near(surface) concertation of infiltrating water, for instance through joints, depressions, sink holes or rivulets (not river beds or lakes).



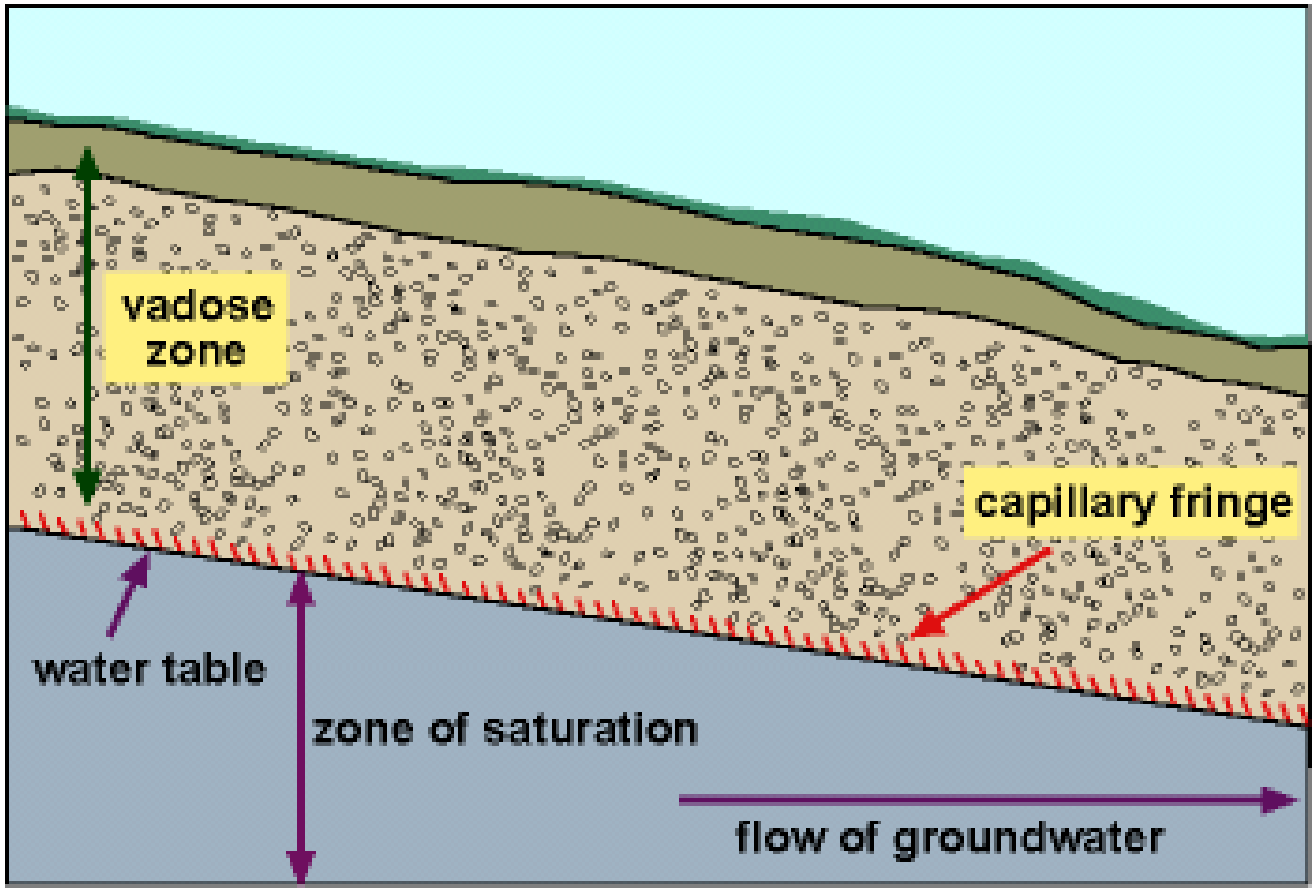
Groundwater

About 30% of readily available freshwater in the world

In Louisiana, two-third of public water systems use groundwater



Water Table

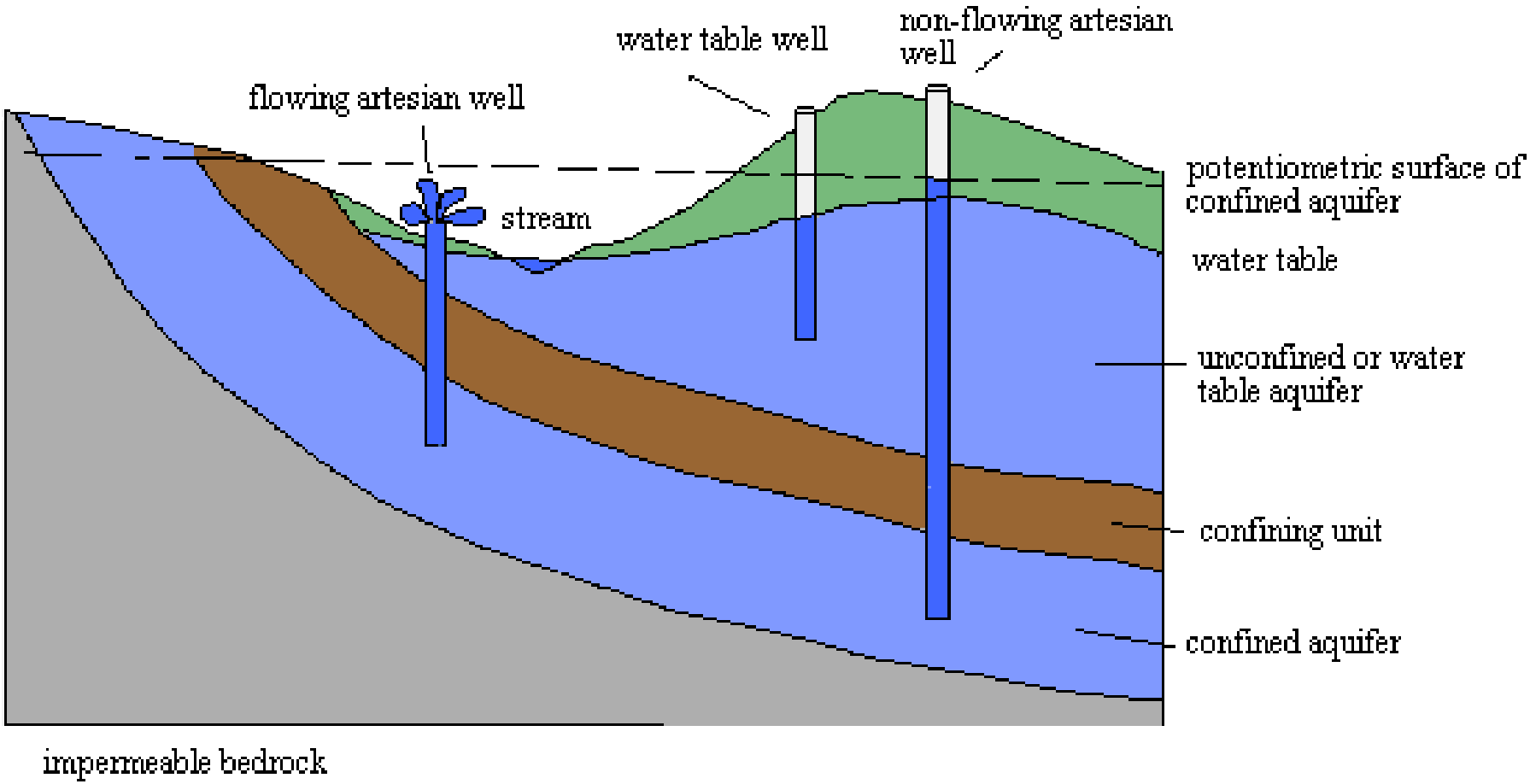


Vadose (unsaturated) zone – water at atmospheric pressure partially fills pore spaces

Capillary fringe – water seeps up from water table by capillary action

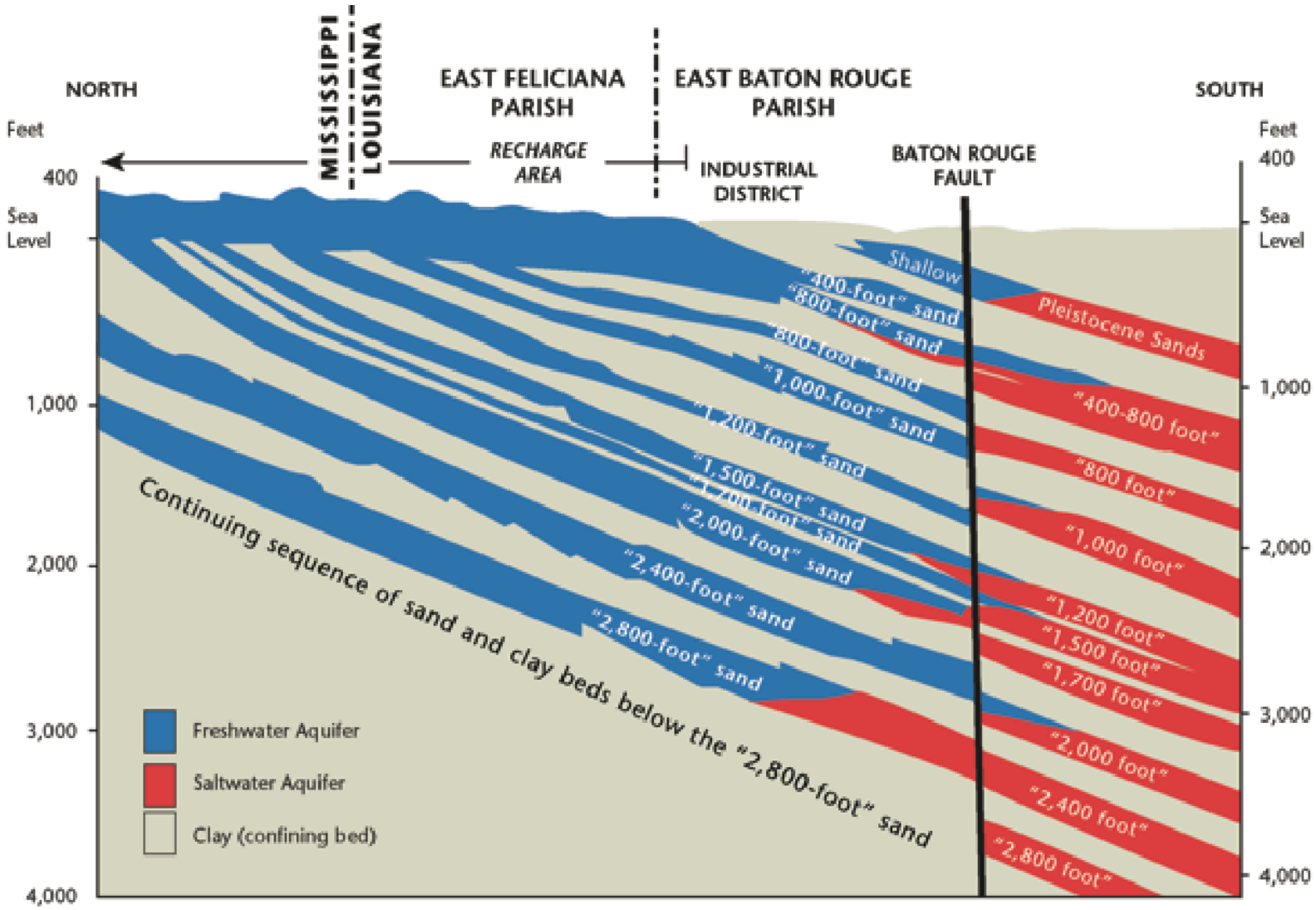
Phreatic(saturated) zone - all pores are filled; water table is upper boundary

Aquifers



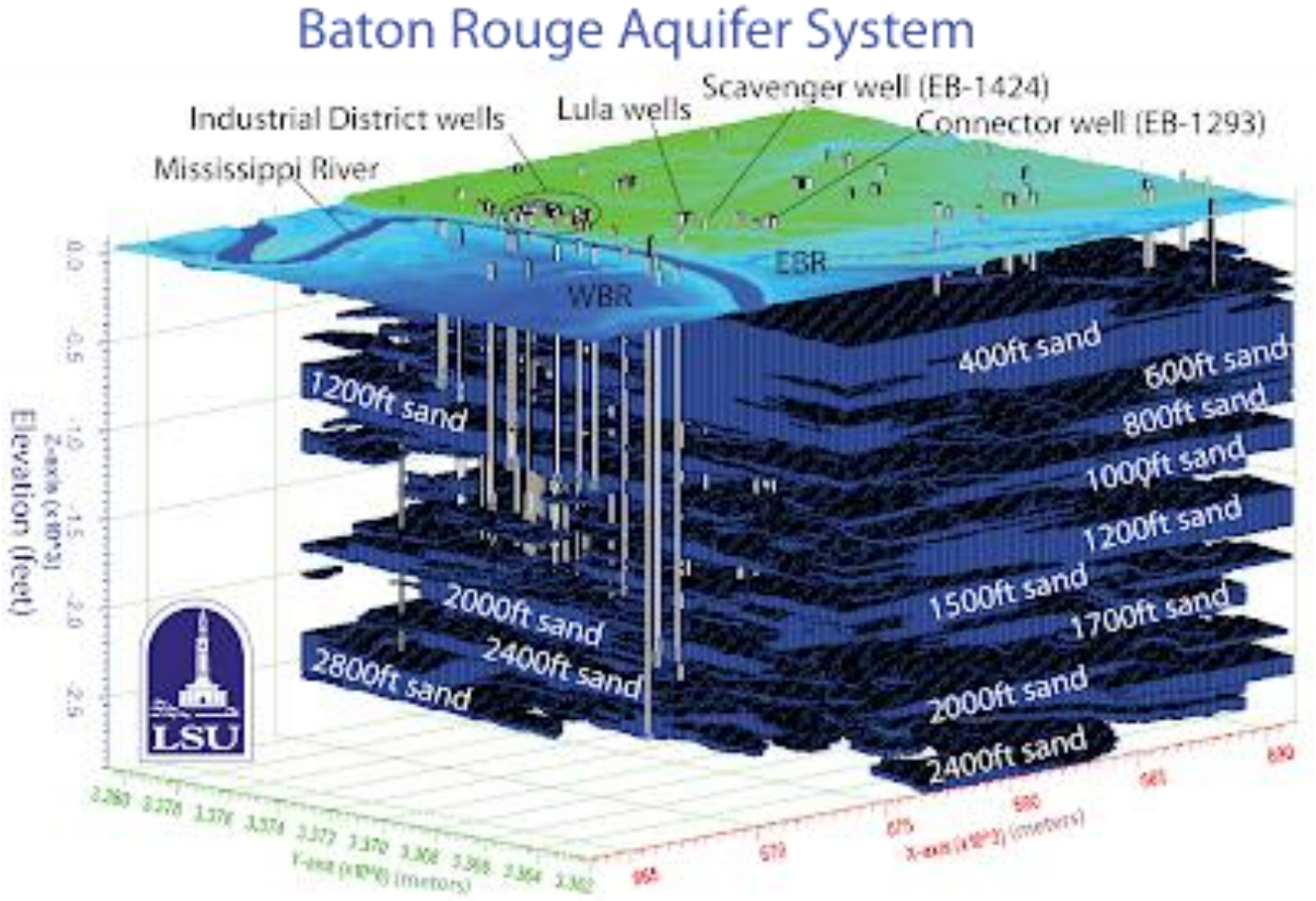
To be an aquifer, the stored water must be accessible at a usable rate/yield a significant quantity of water to wells.

Aquifers



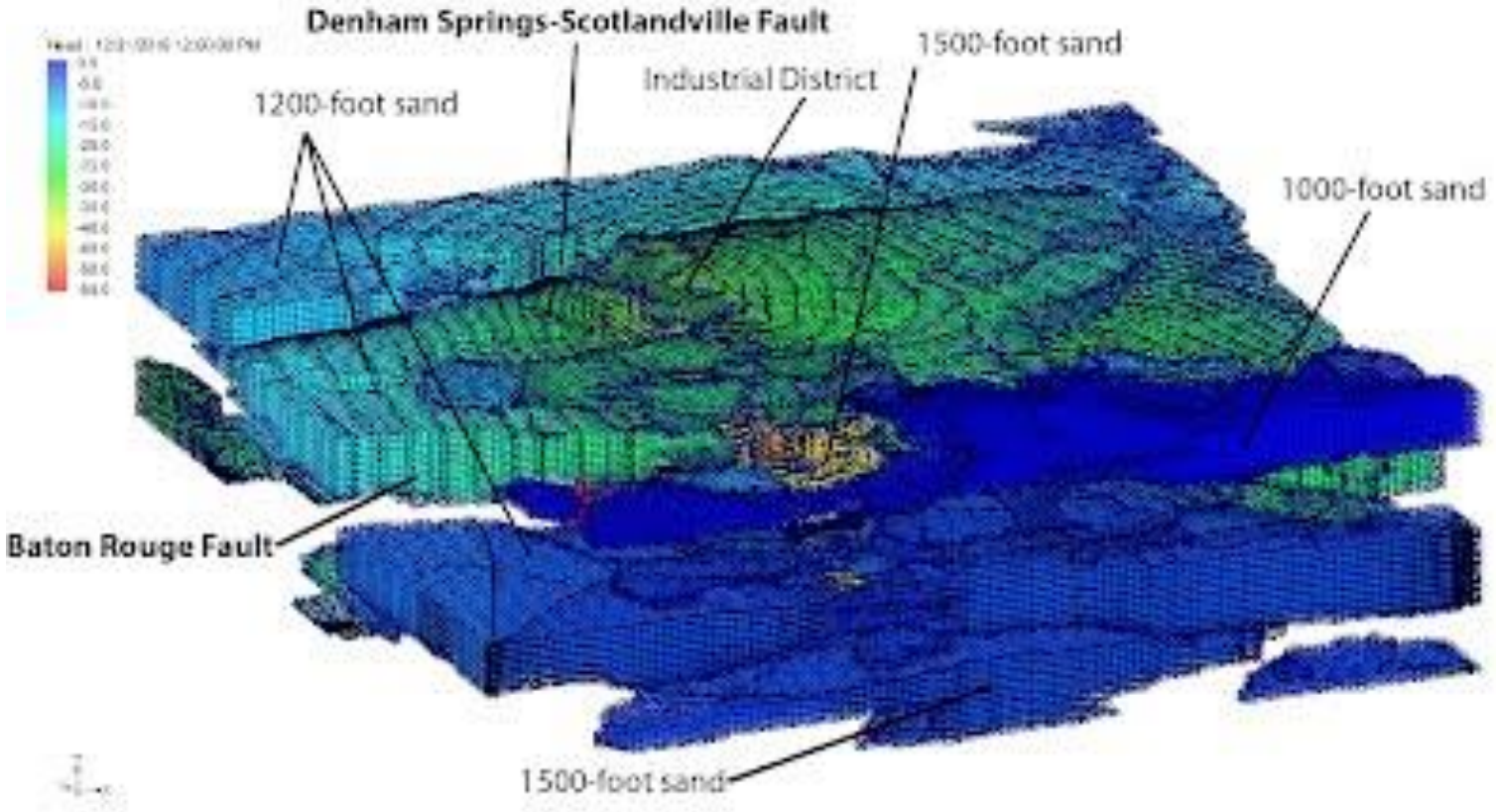
Depth of aquifers below the Industrial District of Baton Rouge, LA

Aquifers

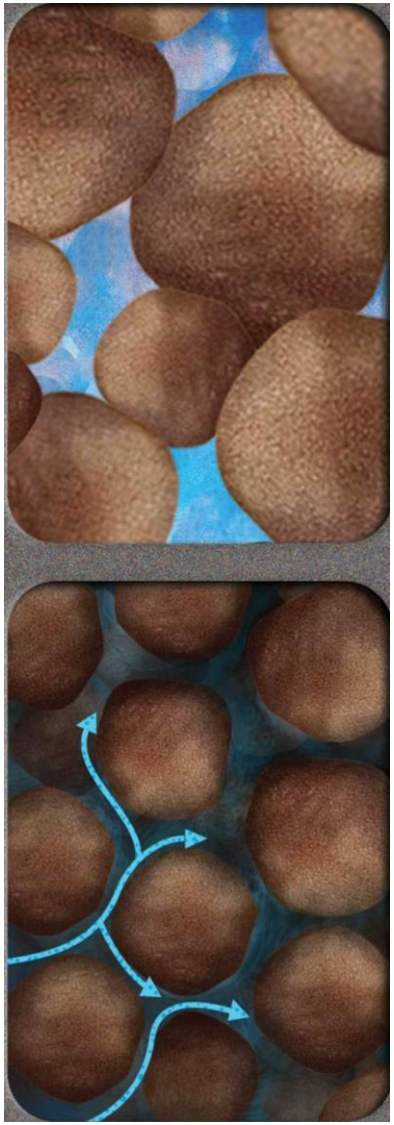

Baton Rouge Aquifer System
Industrial District wells
Lula wells
Scavenger well (EB-1424)
Connector well (EB-1293)
Mississippi River
EBR
WBR
400ft sand
600ft sand
800ft sand
1000ft sand
1200ft sand
1500ft sand
1700ft sand
2000ft sand
2400ft sand
1200ft sand
2000ft sand
2400ft sand
2800ft sand
LSU
Elevation (feet)

Aquifers

Three-dimensional simulated ground water head distribution for the "1,200-foot", "1,500-foot", and "1,700-foot" sands, Dec/31/2010



Porosity & Permeability



Porosity is the percentage of a material occupied by void space or “pores.”

Permeability is a measure of the interconnectedness of the pore space allowing the material to transmit water.

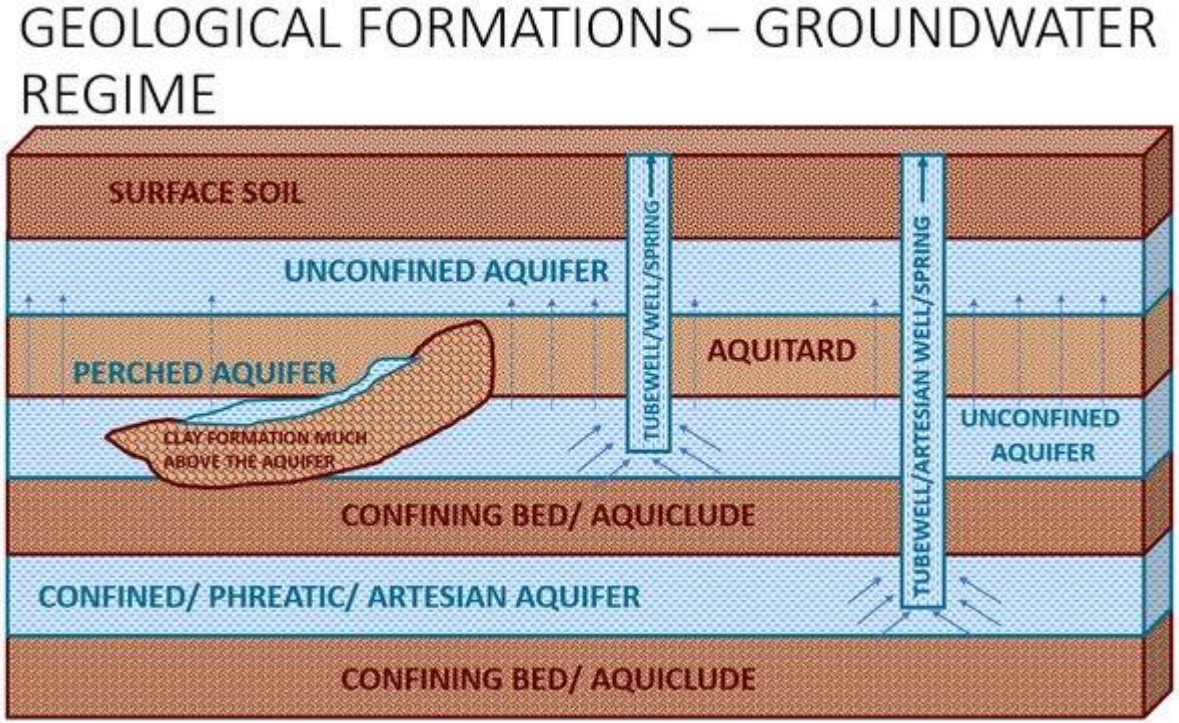
The rate at which a material transmits water depends on its total porosity **and** the size of the interconnections between voids (permeability).

Clay has higher porosity than sand or gravel but the lowest permeability

Aquitards and Aquicludes

Aquitard - saturated, permeable geologic unit which cannot transmit significant quantities of water (but can transmit small quantities). Also called a semi-pervious formation or leaky formation.

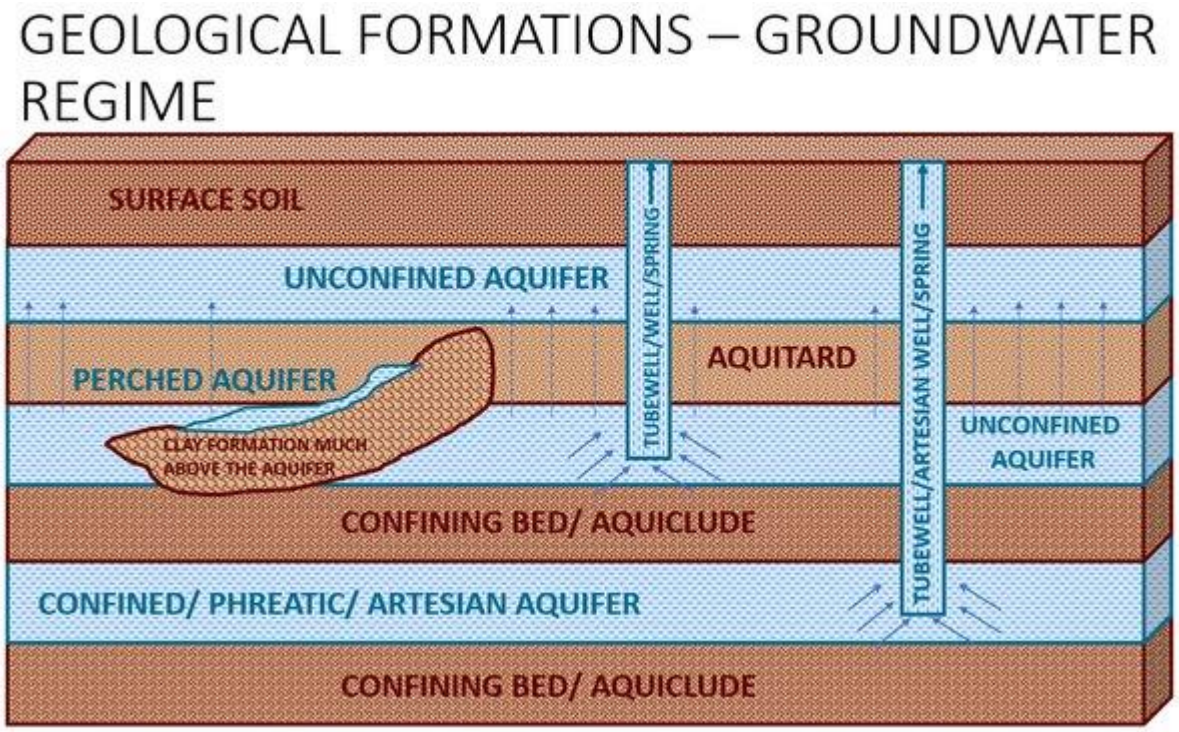
Aquiclude - solid, impermeable area underlying or overlying an aquifer, the pressure of which could create a confined aquifer



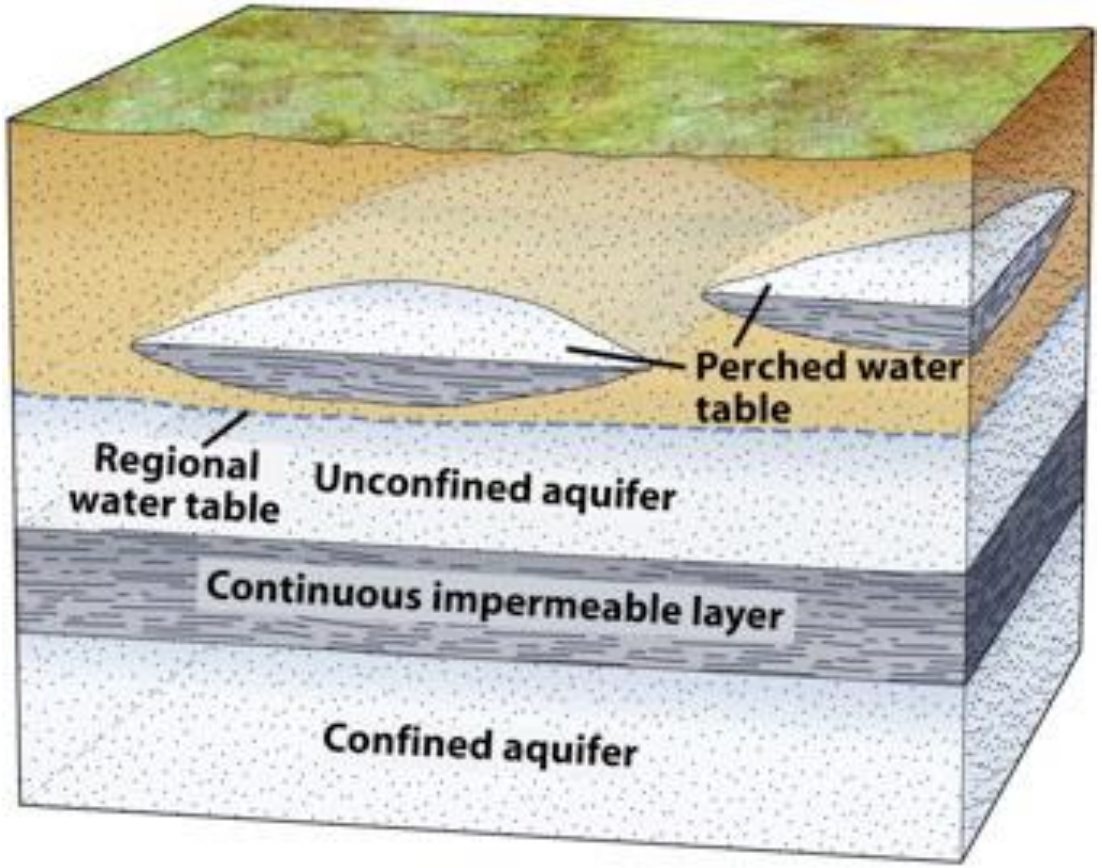
Unconfined and Confined

Unconfined aquifer - an aquifer which has the water table as its upper boundary. Unconfined aquifers can occur near the ground surface.

Confined aquifer - an aquifer that is bounded above and below by confining beds.

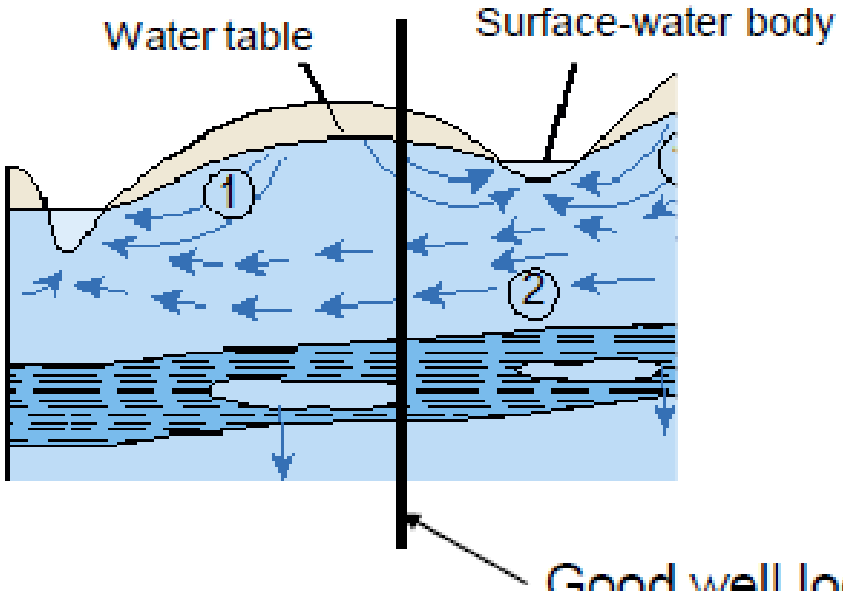


Perched Water Table



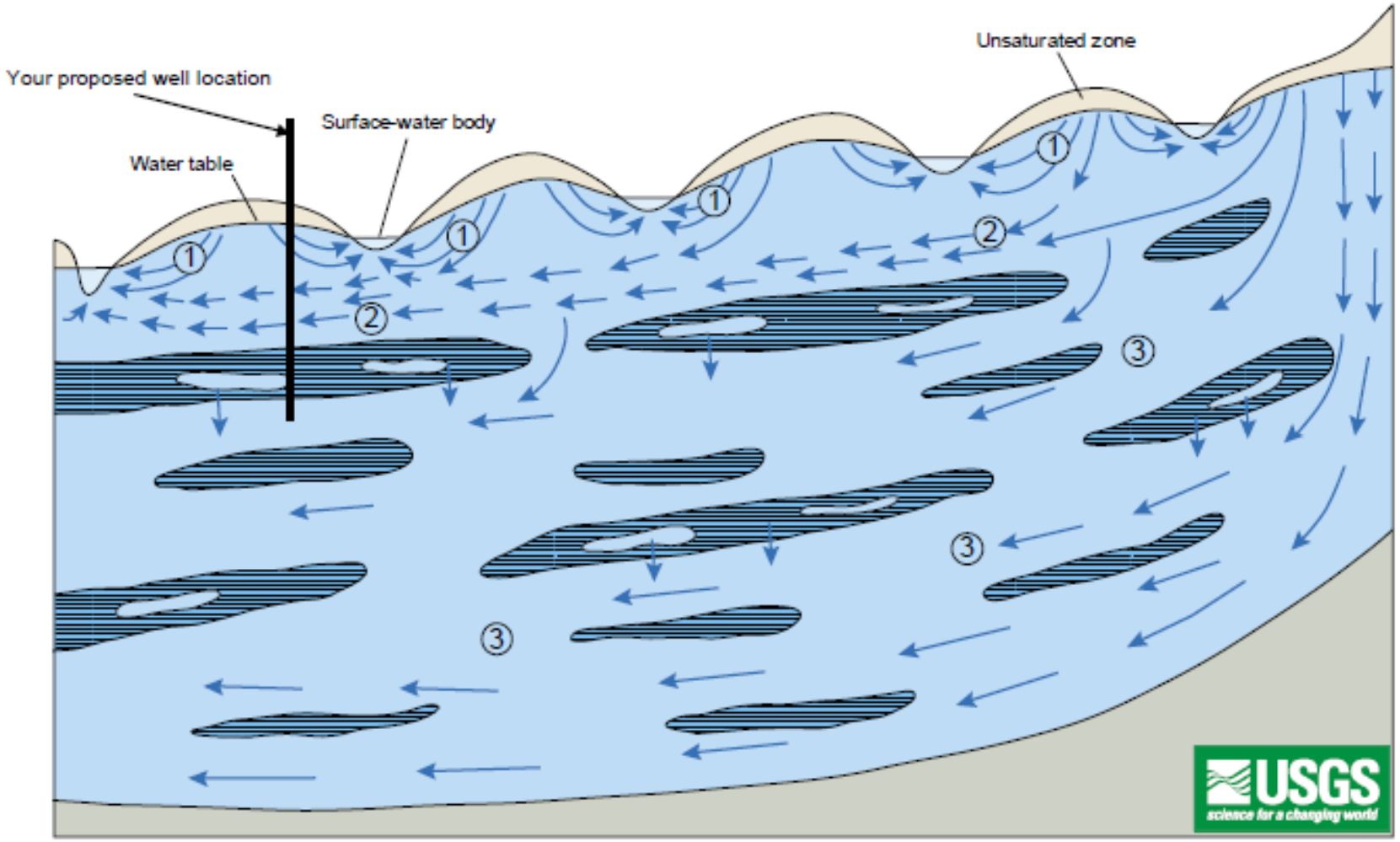
- Discontinuous aquitards can form a perched or “false” water table
- Overlie unsaturated material and arrest downward infiltration to the water table in a localized area

Confined Aquifers: How confined is confined?



Good well location?
Looks like it may be.
There is a relatively thick confining unit...
No readily identifiable sources of contamination...
So, what's the catch?
Well, what exactly does "local" mean?
Zoom out to the next level...

Still confined?



What happened to your “confined” aquifer? Most aquifer systems may contain many “locally” confined aquifers, but few (if any) are regionally confined.

Groundwater Discharge

Groundwater discharge is the volumetric flow rate of groundwater through an aquifer.

$Q = dh/dl\ KA$

Q is the total groundwater discharge as reported through a specified area

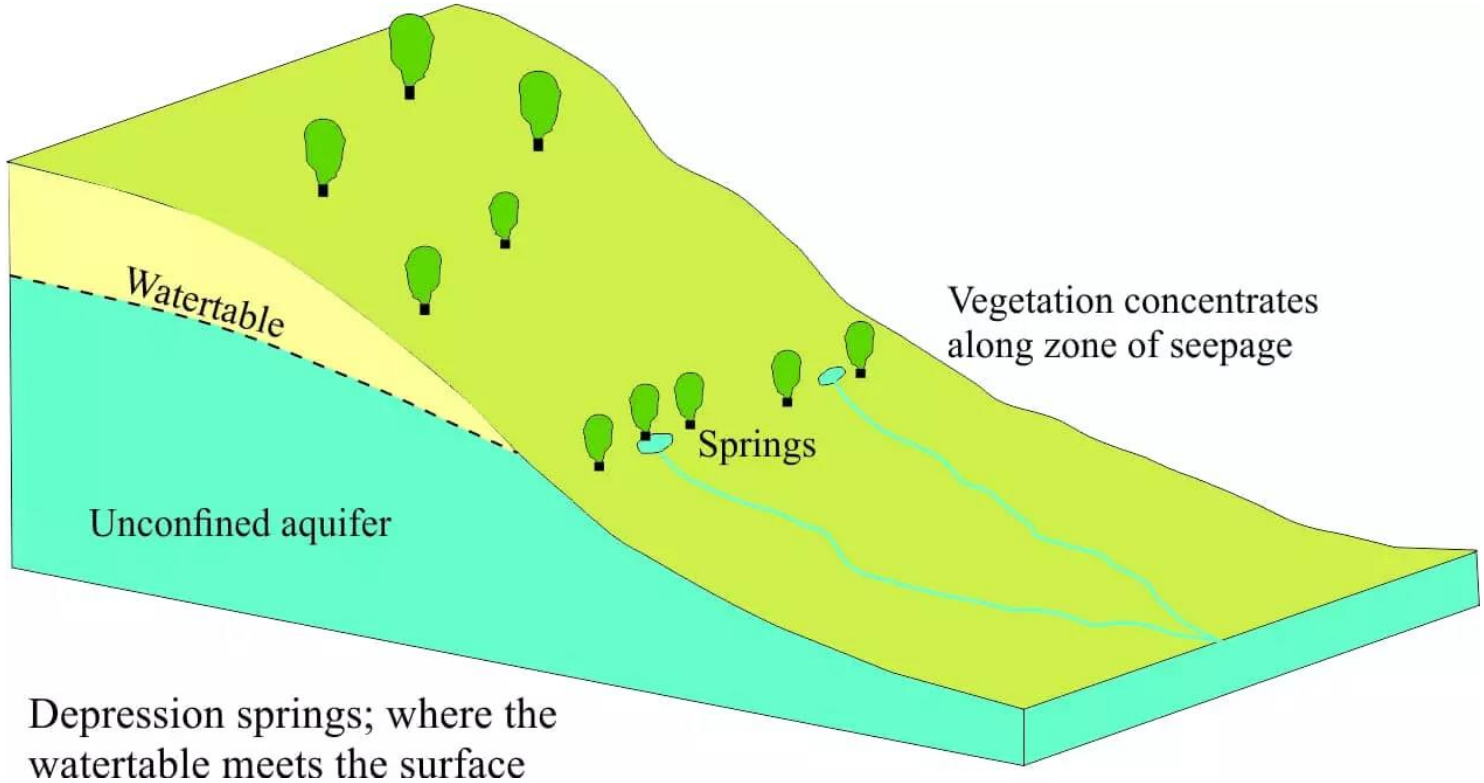
dh/dl is the hydraulic gradient

K is the hydraulic conductivity of the aquifer

A is the area which the groundwater is flowing through

Groundwater Discharge

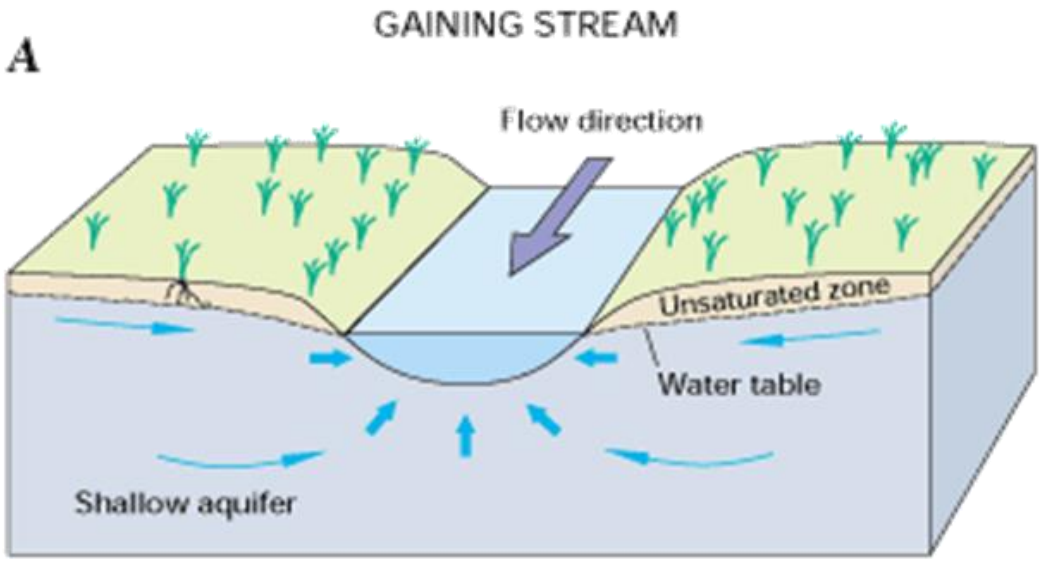
Springs



Groundwater Discharge

Gaining Streams

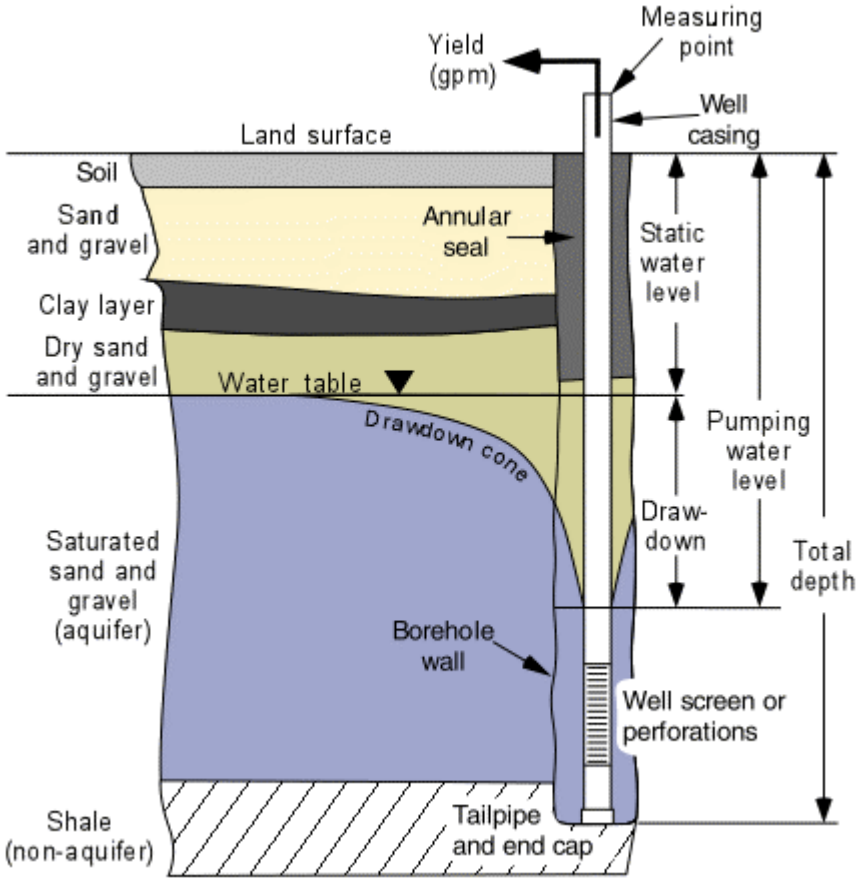
Altitude of water table higher than altitude of stream-water surface -- groundwater *discharges* to stream



Groundwater Discharge

Pumping Wells

Water does not flow, and has not flowed, naturally to the surface, but has to be raised, or has been raised, by pumping or other artificial means



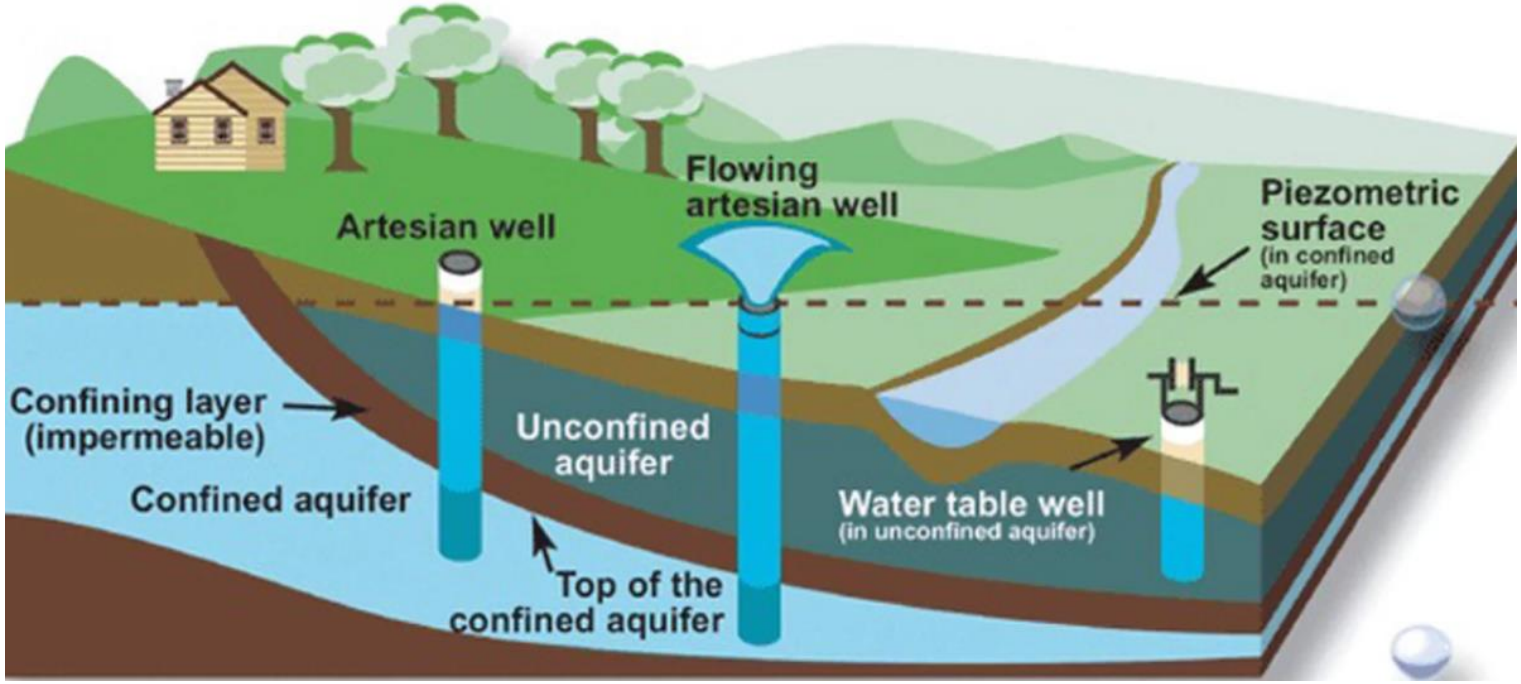
Groundwater Discharge

Artesian Wells

Water flows under natural pressure without pumping

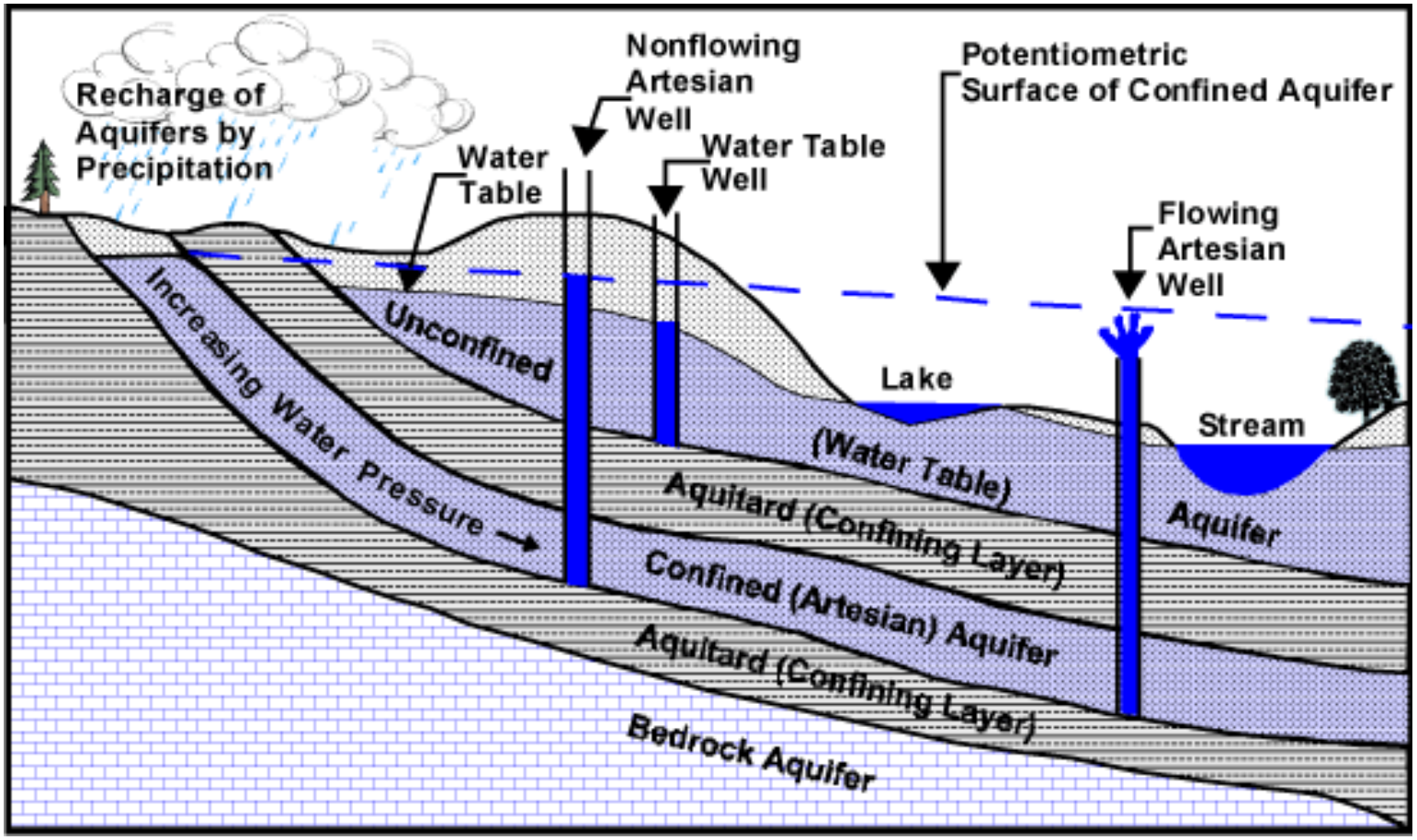
May have to be pumped or pulled to get water to the surface

Water Table Wells and Dug Wells



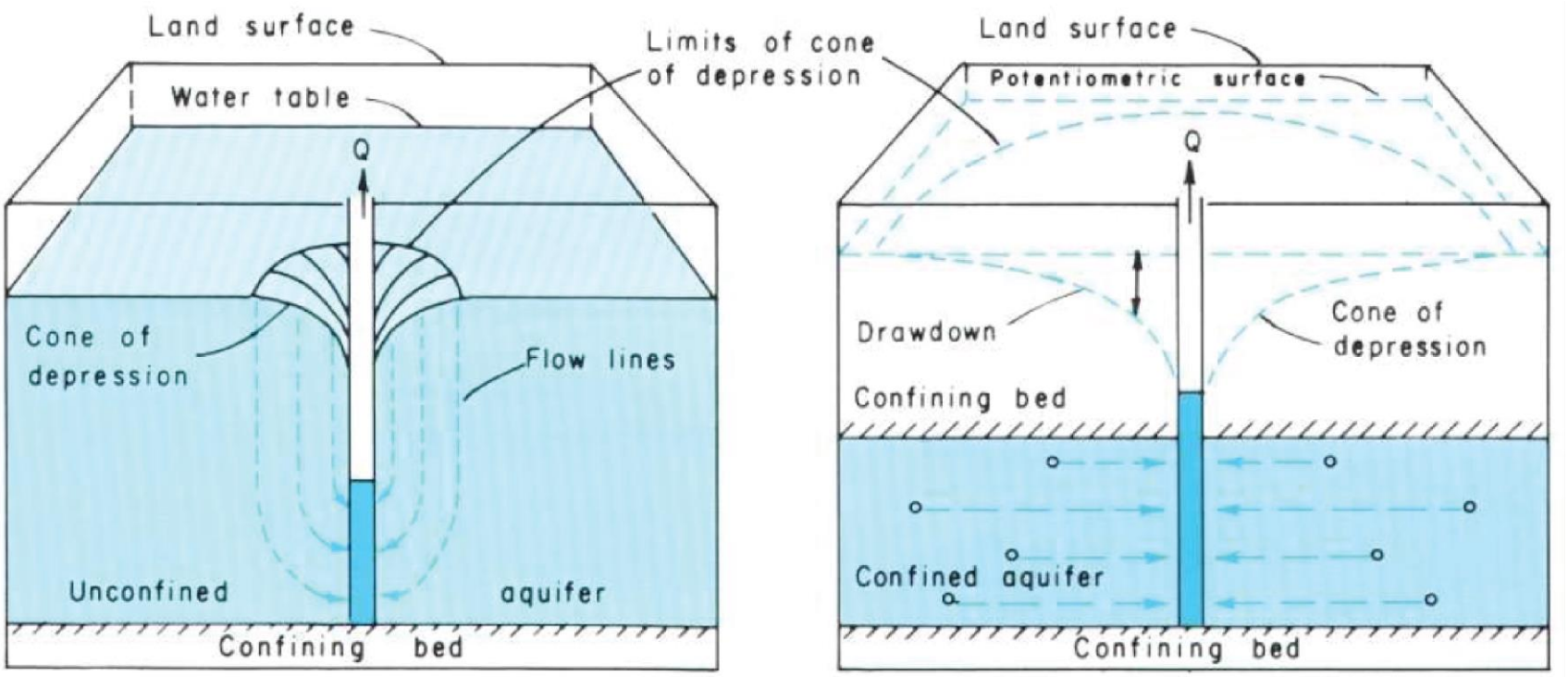
Potentiometric/Piezometric Suface

The level to which water will rise in tightly cased wells.



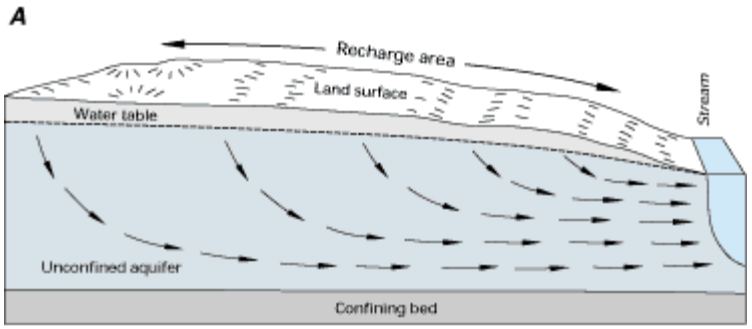
Effects of Wells

Pumping water from an aquifer lowers the water table or potentiometric surface around the well. In an unconfined aquifer, the water table is lowered as water is removed from the aquifer near the well. In a confined aquifer, the pressure around the well is reduced. The amount of change from before pumping to pumping level is termed **drawdown**. Drawdown is the greatest nearest the well, resulting in a concentric pattern of drawdown termed the **cone of depression**.

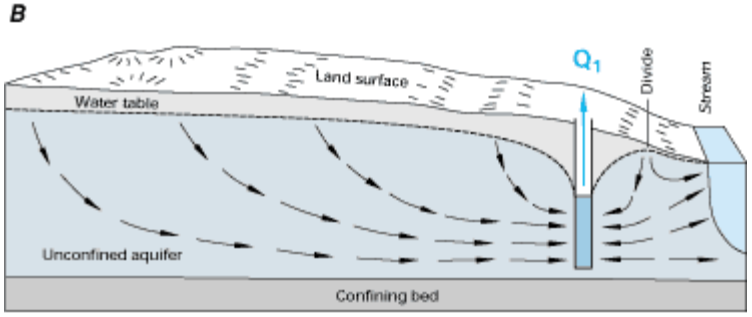


Effects of Wells

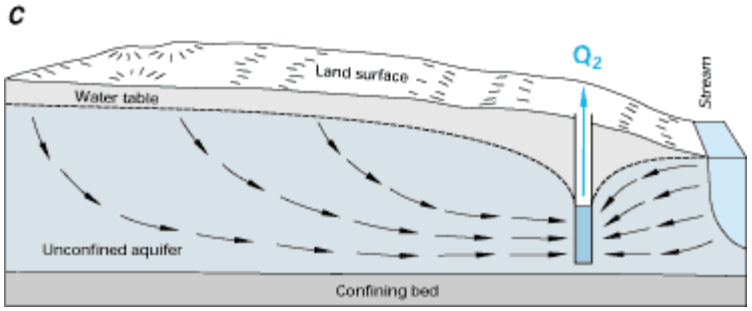
Surface Water Interaction



Groundwater discharges to stream under natural conditions

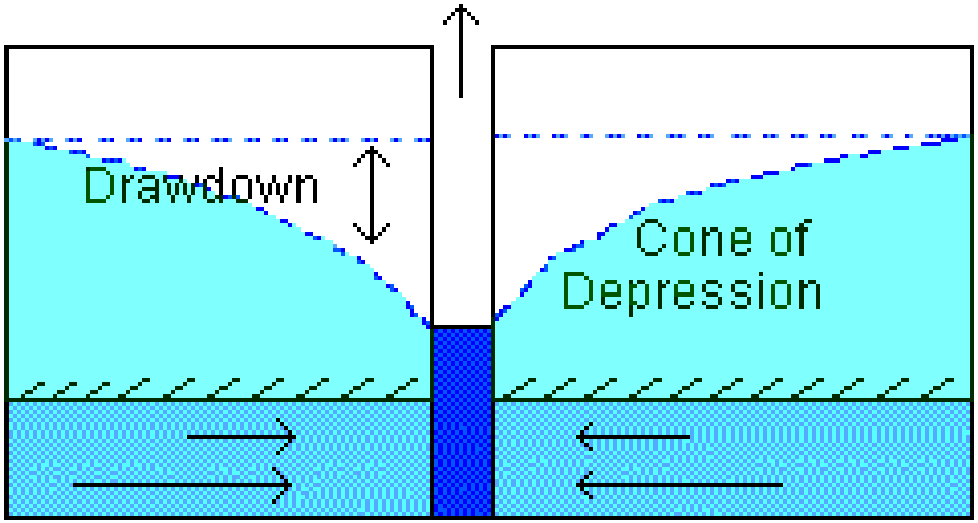


Pumping well at rate of Q1 intercepts some of groundwater that would have discharged to stream



Pumping well at rate of Q2 intercepts additional water and draws water from stream (Q2 > Q1)
**Stream quality affects groundwater quality

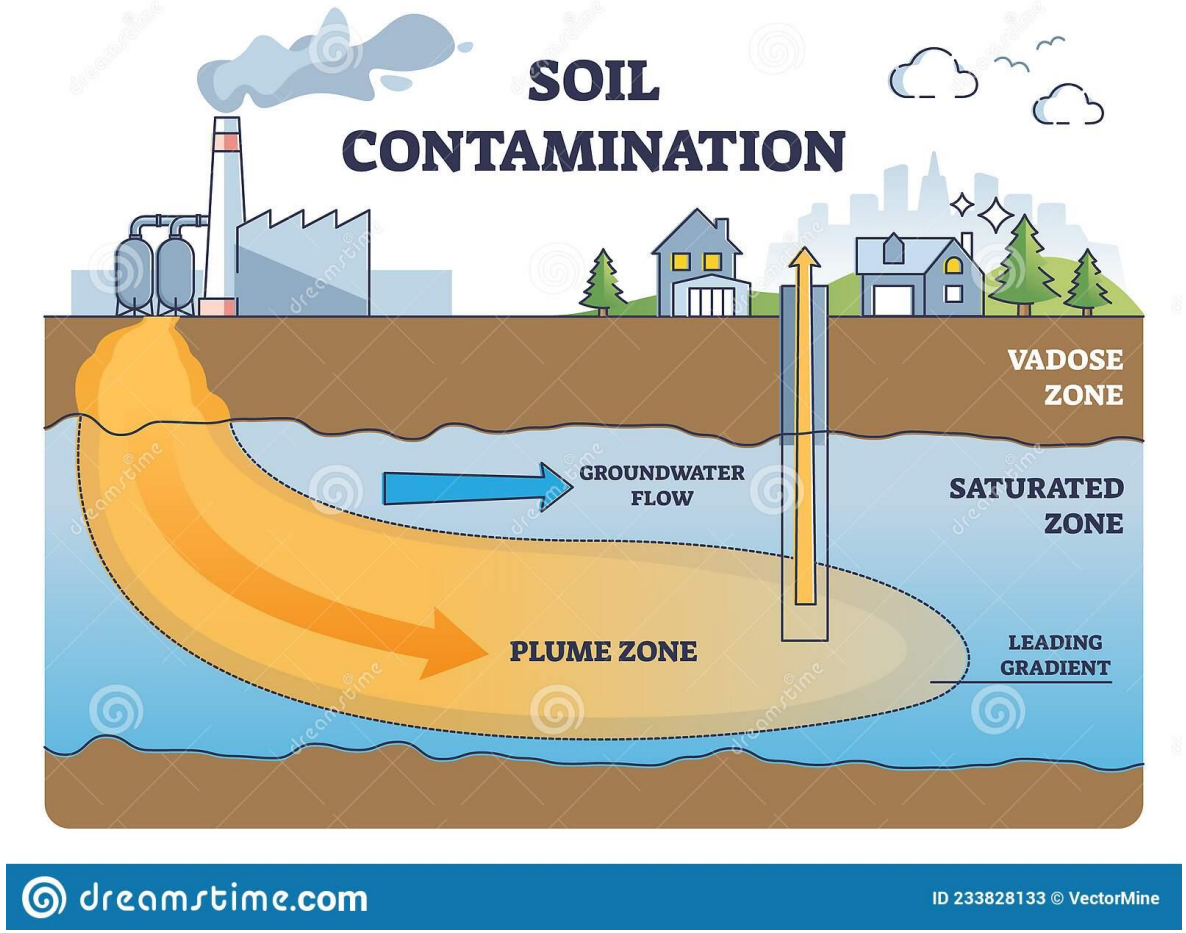
Drawdown



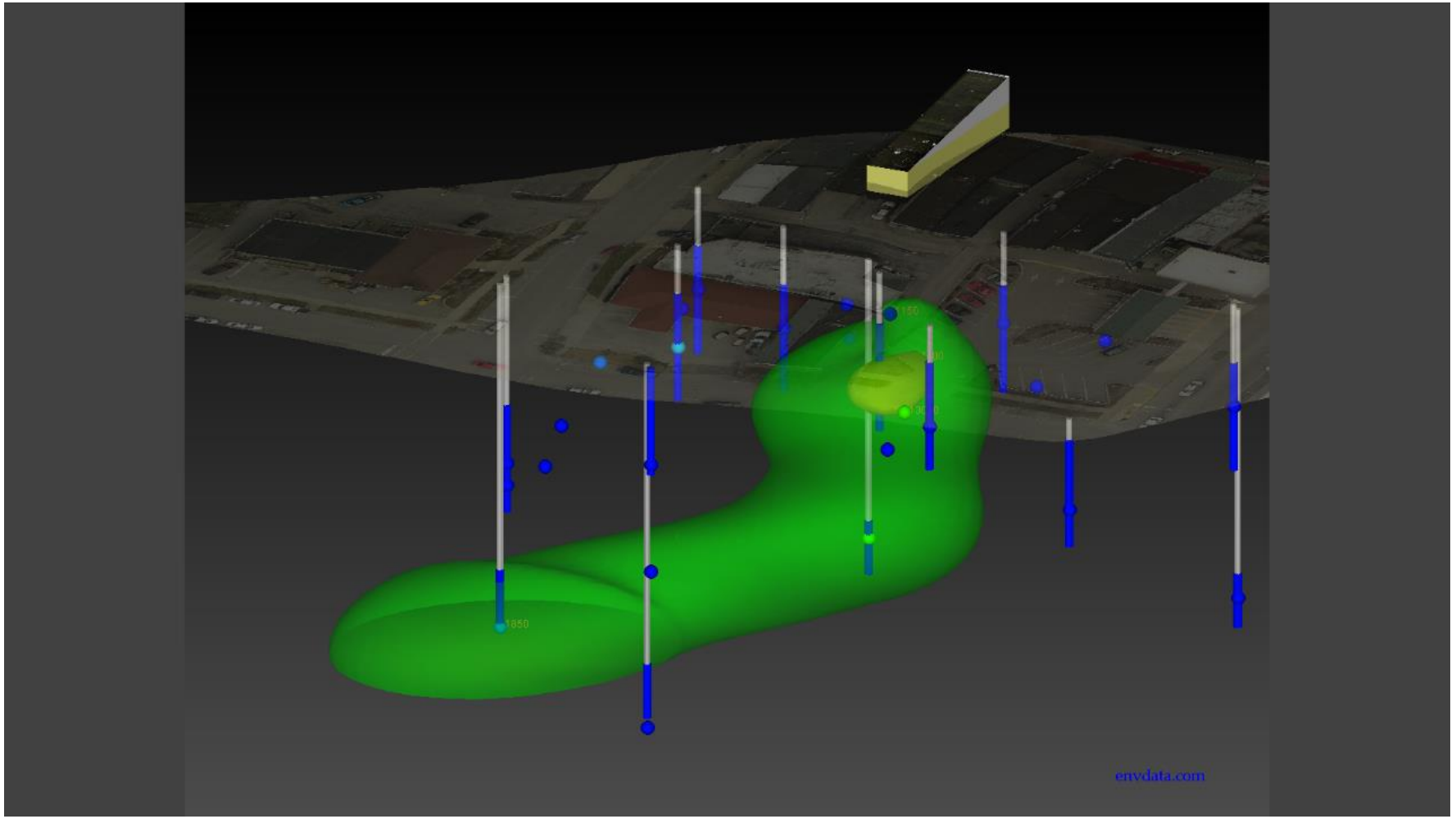
Understanding drawdown/cone of depression is important to:

- Ensure continuous supply of water (avoid “dry wells”)
- Management of overlying land area (vulnerability)
- Identify source of ground water (water once discharging to a stream may now be drawn into a well)

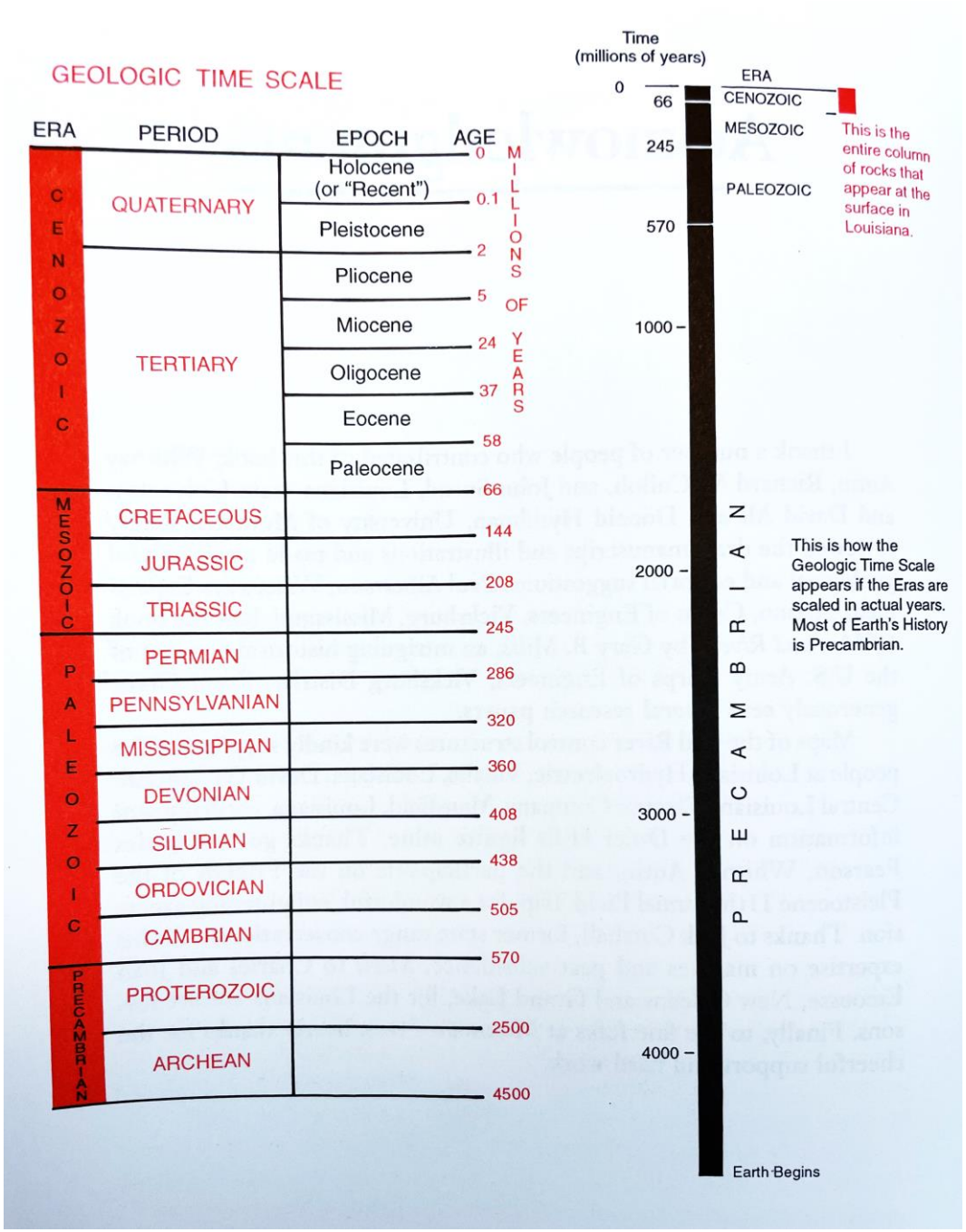
Groundwater Contamination



Groundwater Contamination



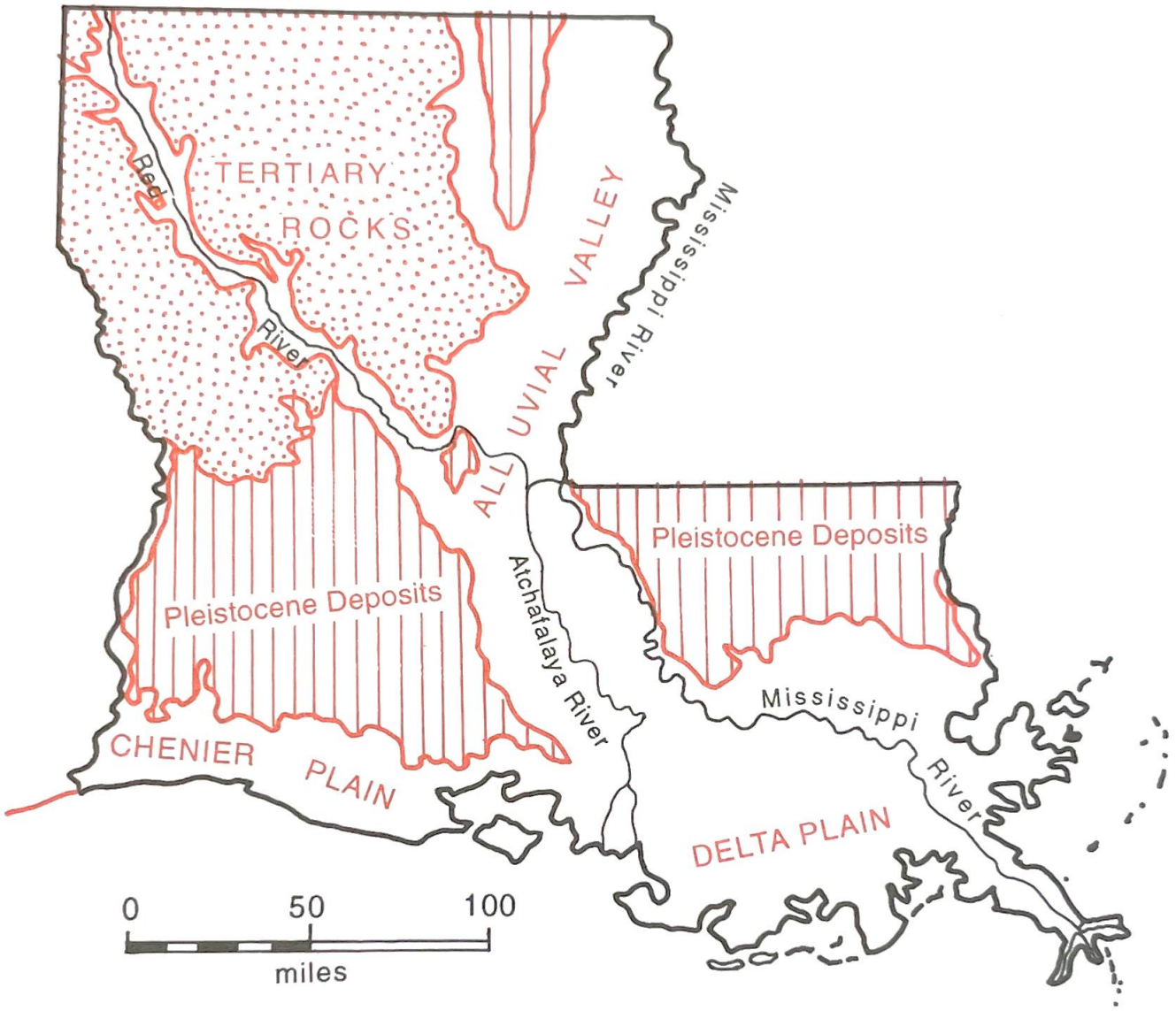
Geology and Hydrogeology of Louisiana



Louisiana is geologically a "youngster"

From Roadside Geology of Louisiana. Spearing, 2007

Basic Geology of Louisiana

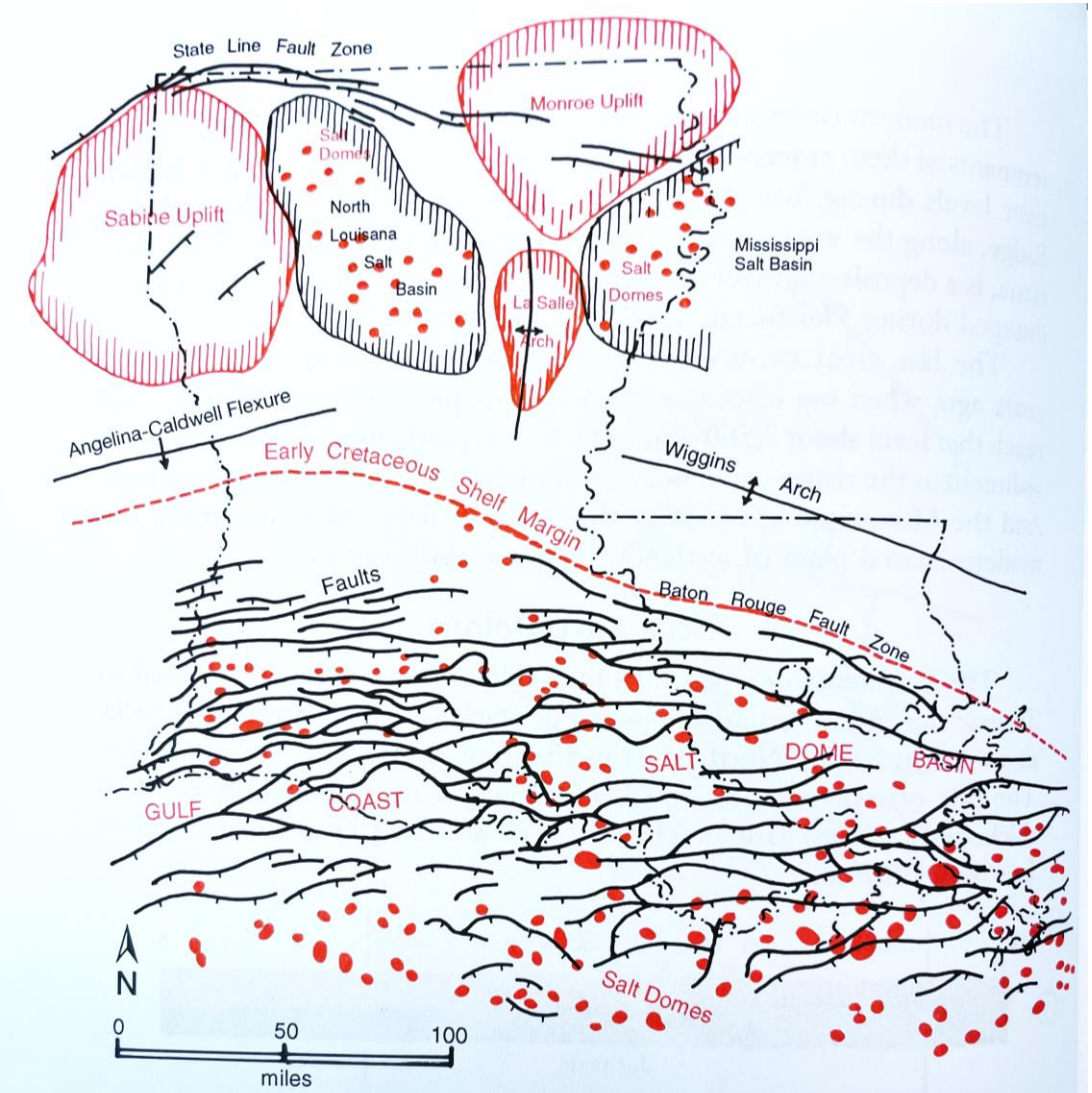


From Roadside Geology of Louisiana.
Spearing, 2007

Hydrogeologic Setting

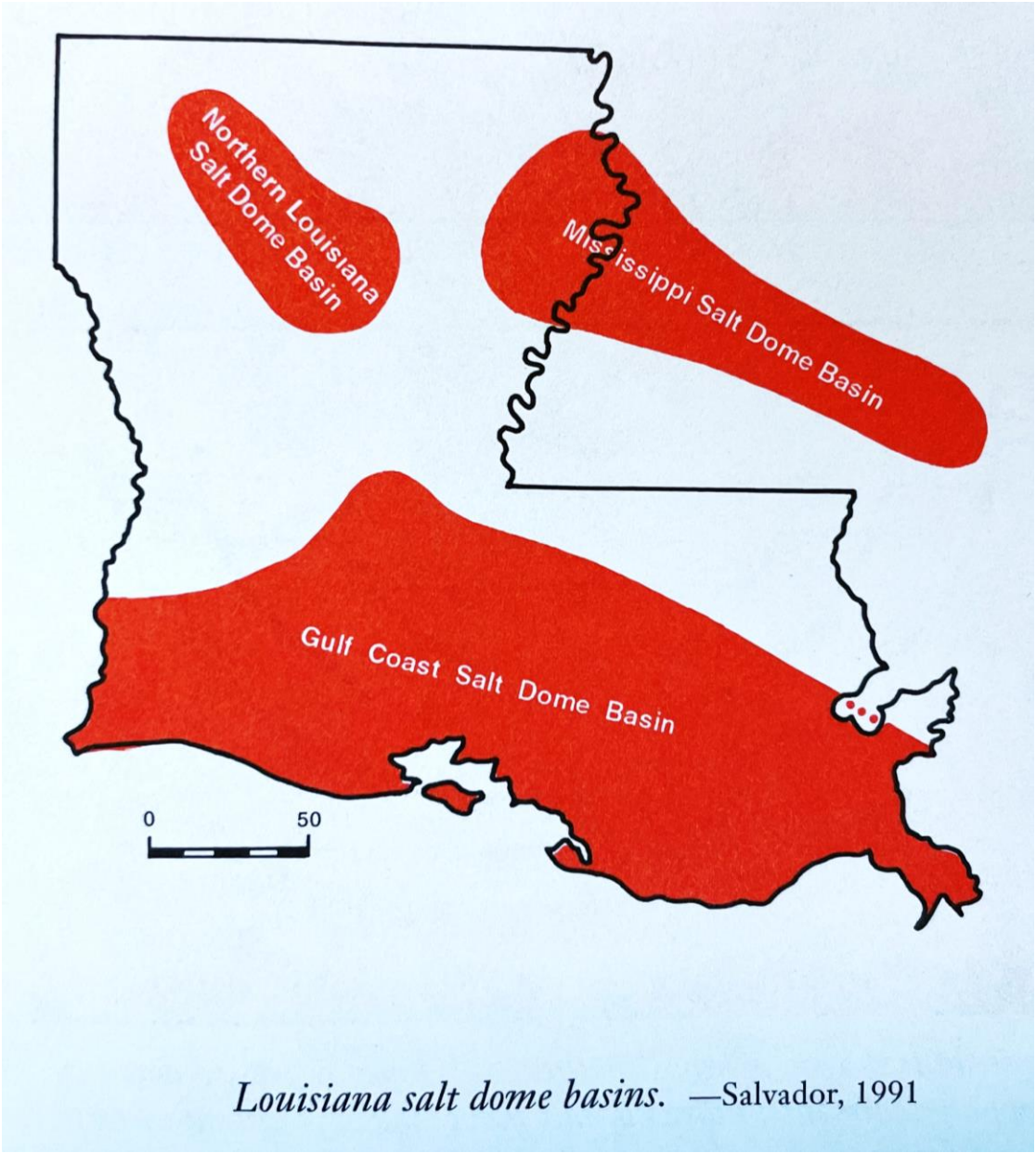
- The aquifer systems in Louisiana are comprised of Paleocene and younger sediments that were deposited in deltaic, fluvial, and marine environments
- Sediments consist of alternating sand, silt, gravel, and clay that thicken toward the south
- Major subsurface structural features of Louisiana controlled depositional patterns and aquifer formations

Major Structures



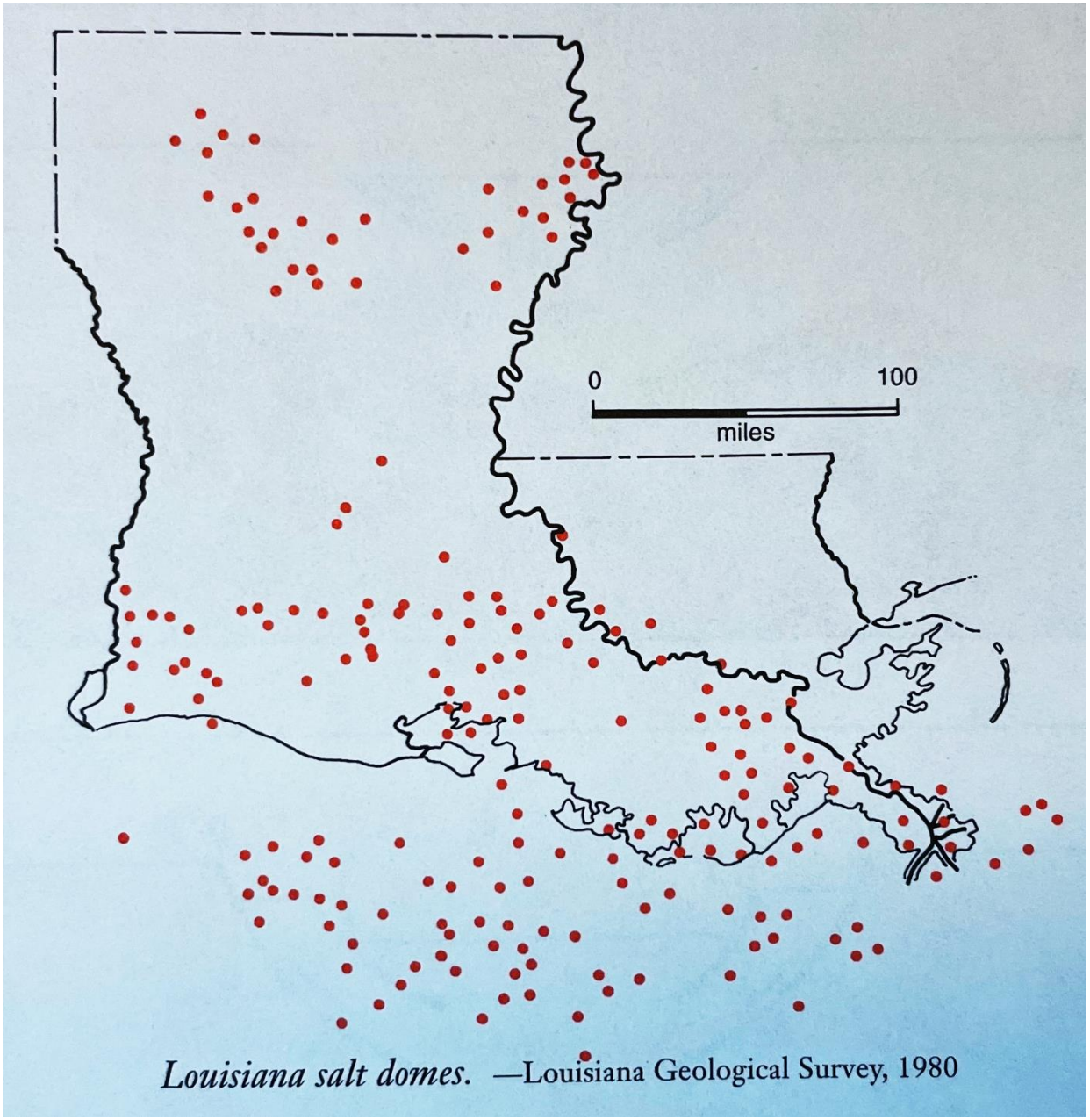
Major structures of Louisiana. Most are subsurface structures, but they affect many surface geologic features. Surface offset can be observed along the Baton Rouge fault, for example. —Salvador, 1991

Salt Dome Basins



Louisiana salt dome basins. —Salvador, 1991

Salt Domes



Louisiana salt domes. —Louisiana Geological Survey, 1980

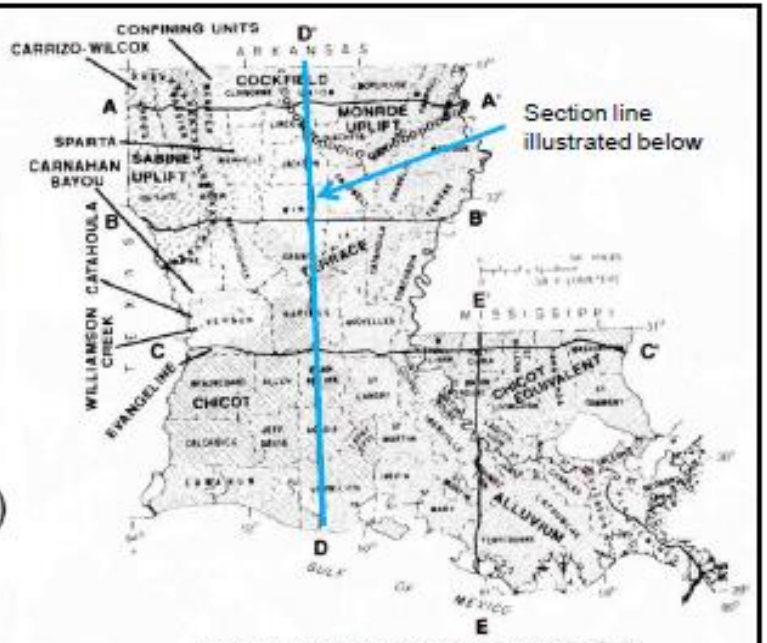
The ground beneath your feet…

May be quite old to us, but is young geologically.

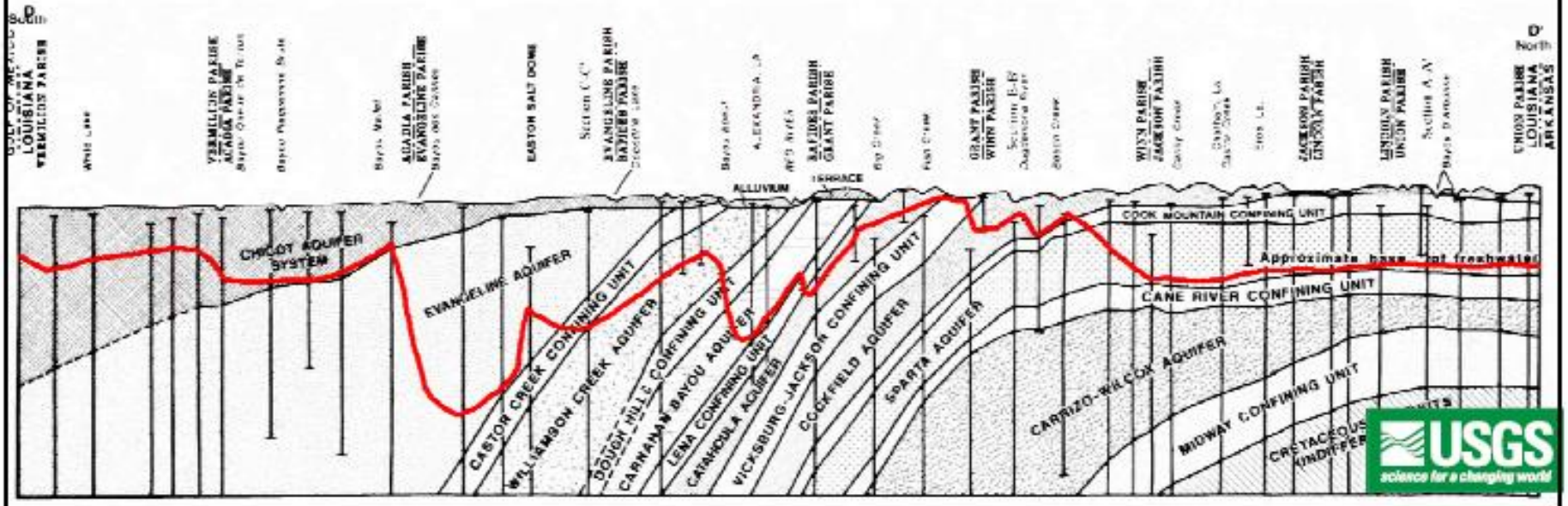
Is not necessarily flat or horizontal, even if the surface looks like it.

Was generally deposited in a marine or coastal environment (shallow seas, deltas, beaches, etc.)

The red line indicates the approximate base of freshwater along the section line.



INDEX MAP SHOWING GEOHYDROLOGIC SECTIONS, GENERALIZED GEOHYDROLOGIC UNITS, MONROE UPLIFT, AND SABINE UPLIFT, LOUISIANA



USGS science for a changing world

Major Aquifers/Aquifer Systems

Age:	Pleistocene	Pliocene	Miocene	Eocene-Paleocene

- Red River Alluvial
- MS River Alluvial
- N LA Terrace
- Chicot
- Chicot Equivalent*
- Evangeline
- Evangeline Equivalent*
- Williamson Creek**
- Carnahan Bayou**
- Jasper Equivalent*
- Catahoula
- Cockfield
- Sparta
- Carrizo-Wilcox

*Southern Hills Aquifer System (formerly Southeast LA Aquifer System)

**Jasper Aquifer System

GEOHYDROLOGIC UNITS OF LOUISIANA

System	Series	Stratigraphic Unit	Hydrogeologic Unit								
			Northern Louisiana	Central Louisiana		Southwestern Louisiana		Southeastern Louisiana			
			aquifer or confining unit	aquifer system or confining unit		aquifer or confining unit		aquifer system or confining unit [1]	aquifer or confining unit [2]		
						Lake Charles area	rice growing area		Baton Rouge area	St. Tammany, Tangipahoa, and Washington Parishes	New Orleans area and lower Mississippi River Parishes [3]
Quaternary	Pleistocene	Red River alluvial deposits Mississippi River alluvial deposits Northern Louisiana terrace deposits Unnamed Pleistocene deposits	Red River alluvial aquifer or surficial confining unit Mississippi River alluvial aquifer or surficial confining unit Upland terrace aquifer or surficial confining unit	Alluvial aquifer, undifferentiated or surficial confining unit Prairie aquifer Montgomery aquifer Williana-Bentley aquifer	Chicot aquifer system or surficial confining unit	"200-foot" sand "500-foot" sand "700-foot" sand	Upper sand unit Lower sand unit	Chicot equivalent aquifer system or surficial confining unit	Mississippi River alluvial aquifer or surficial confining unit Shallow sand "400-foot" sand "600-foot" sand	Upland terrace aquifer Upper Pontchatoula aquifer	Gramercy aquifer Norco aquifer Gonzales-New Orleans aquifer "1,200-foot" sand
Tertiary	Pliocene	Fleming Formation: Blounts Creek Member	units absent	Evangeline aquifer or surficial confining unit				Evangeline equivalent aquifer system or surficial confining unit	"800-foot" sand "1,000-foot" sand "1,200-foot" sand "1,500-foot" sand "1,700-foot" sand	Lower Pontchatoula aquifer Big Branch aquifer Kentwood aquifer Abita aquifer Covington aquifer Slidell aquifer	
	?										
	Miocene	Fleming Formation: Castor Creek Member		Castor Creek confining unit				unnamed confining unit	"2,000-foot" sand "2,400-foot" sand "2,800-foot" sand	Tchefuncte aquifer Hammond aquifer Amite aquifer Ramsay aquifer Franklinton aquifer	
		Fleming Formation: Williamson Creek Member Dough Hills Member Carnahan Bayou Member		Jasper aquifer system or surficial confining unit	Williamson Creek aquifer Dough Hills confining unit Carnahan Bayou aquifer			Jasper equivalent aquifer or surficial confining unit			
		Fleming Formation: Lena Member		Lena confining unit				unnamed confining unit			
	?										
	Oligocene	Catahoula Formation		Catahoula aquifer				Catahoula equivalent aquifer system or surficial confining unit			
	Eocene	Vicksburg Group, undifferentiated	Vicksburg-Jackson confining unit	no freshwater occurs in deeper units							
		Jackson Group, undifferentiated									
		Claiborne Group: Cockfield Formation	Cockfield aquifer or surficial confining unit								
		Claiborne Group: Cook Mountain Formation	Cook Mountain aquifer or confining unit								
		Claiborne Group: Sparta sand	Sparta aquifer or surficial confining unit								
		Claiborne Group: Cane River Formation	Cane River aquifer or confing unit								
		Claiborne Group: Carrizo sand	Carrizo-Wilcox aquifer or surficial confining unit								
	?										
	Paleocene	Wilcox Group, undifferentiated	Wilcox aquifer								
		Midway Group, undifferentiated	Midway confining unit								

[1] The interval containing the four aquifer systems is refered to as the Southern Hills aquifer system.
[2] Clay units separating aquifers in southeastern Louisiana are discontinuous, unnamed, and not listed herein.
[3] The interval containing the four aquifers is refered to as the New Orleans aquifer system.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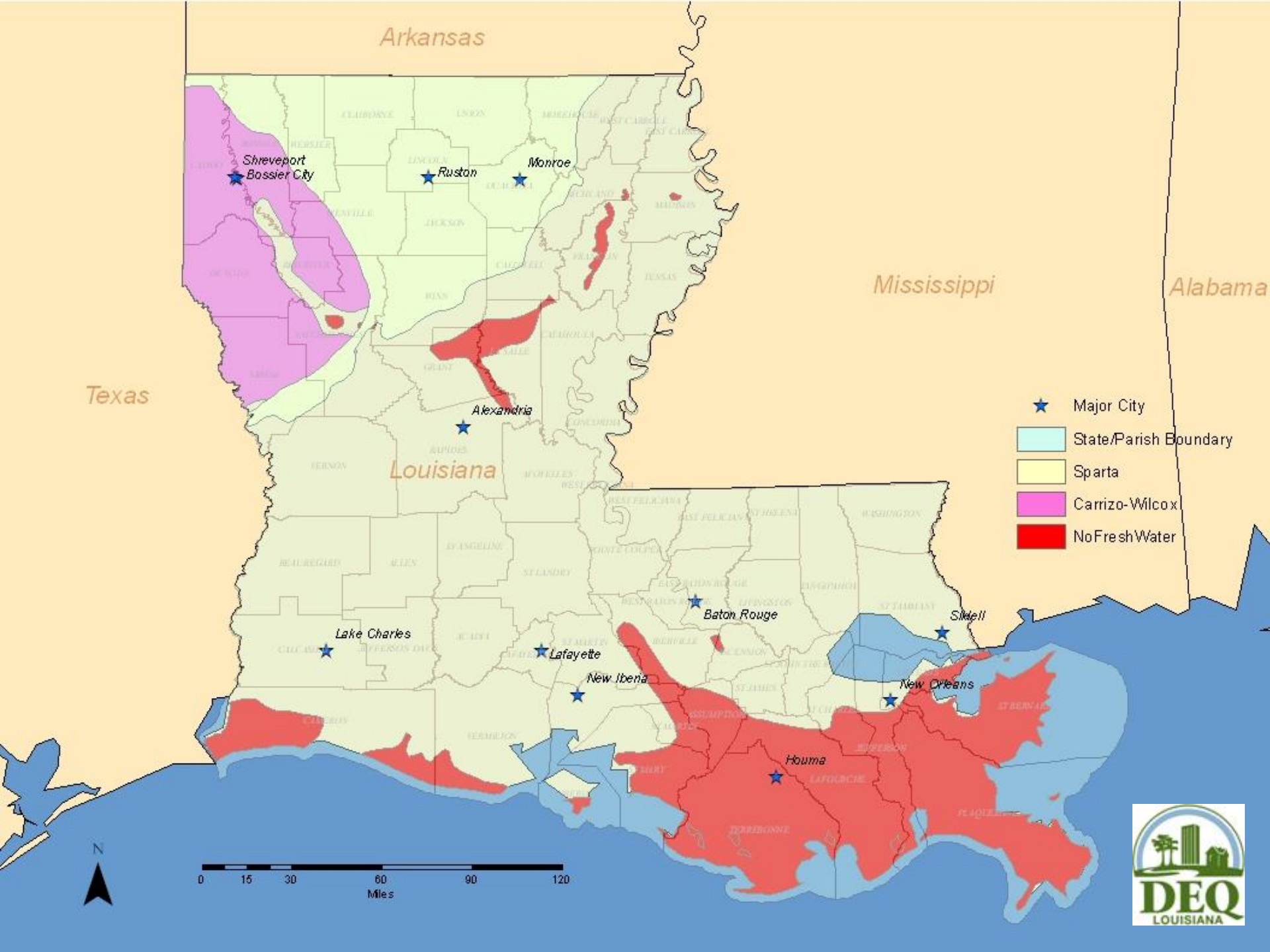
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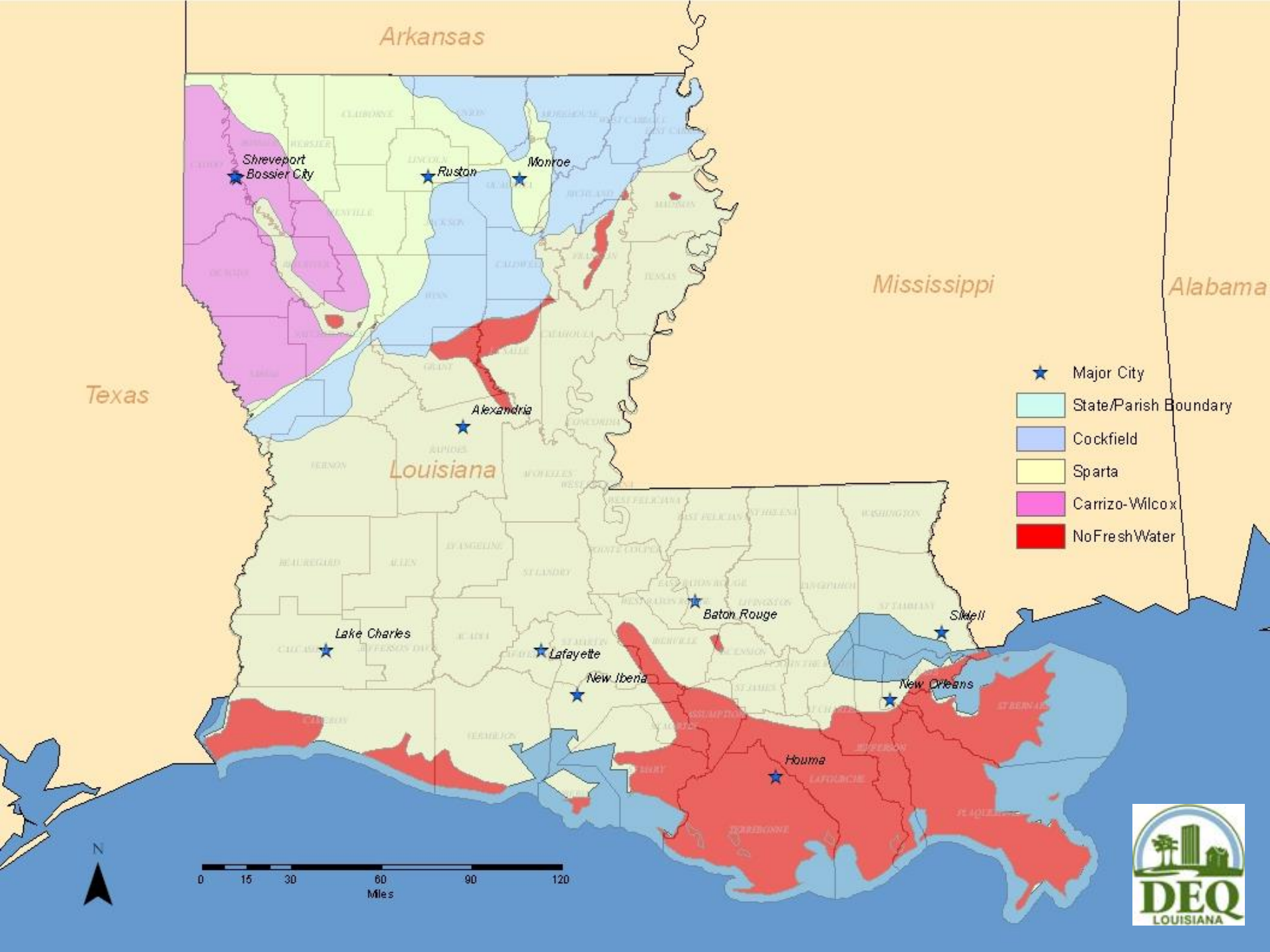
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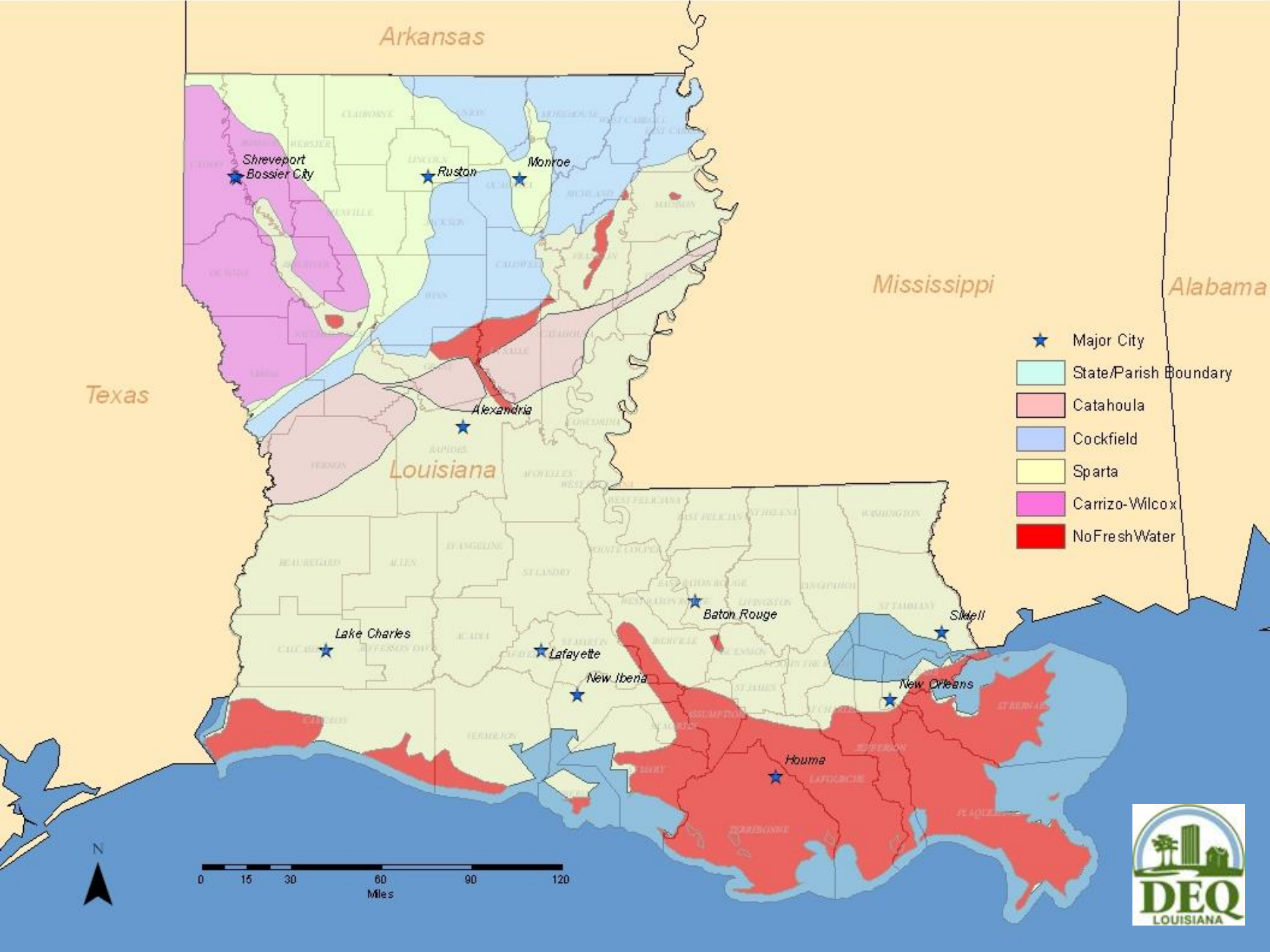
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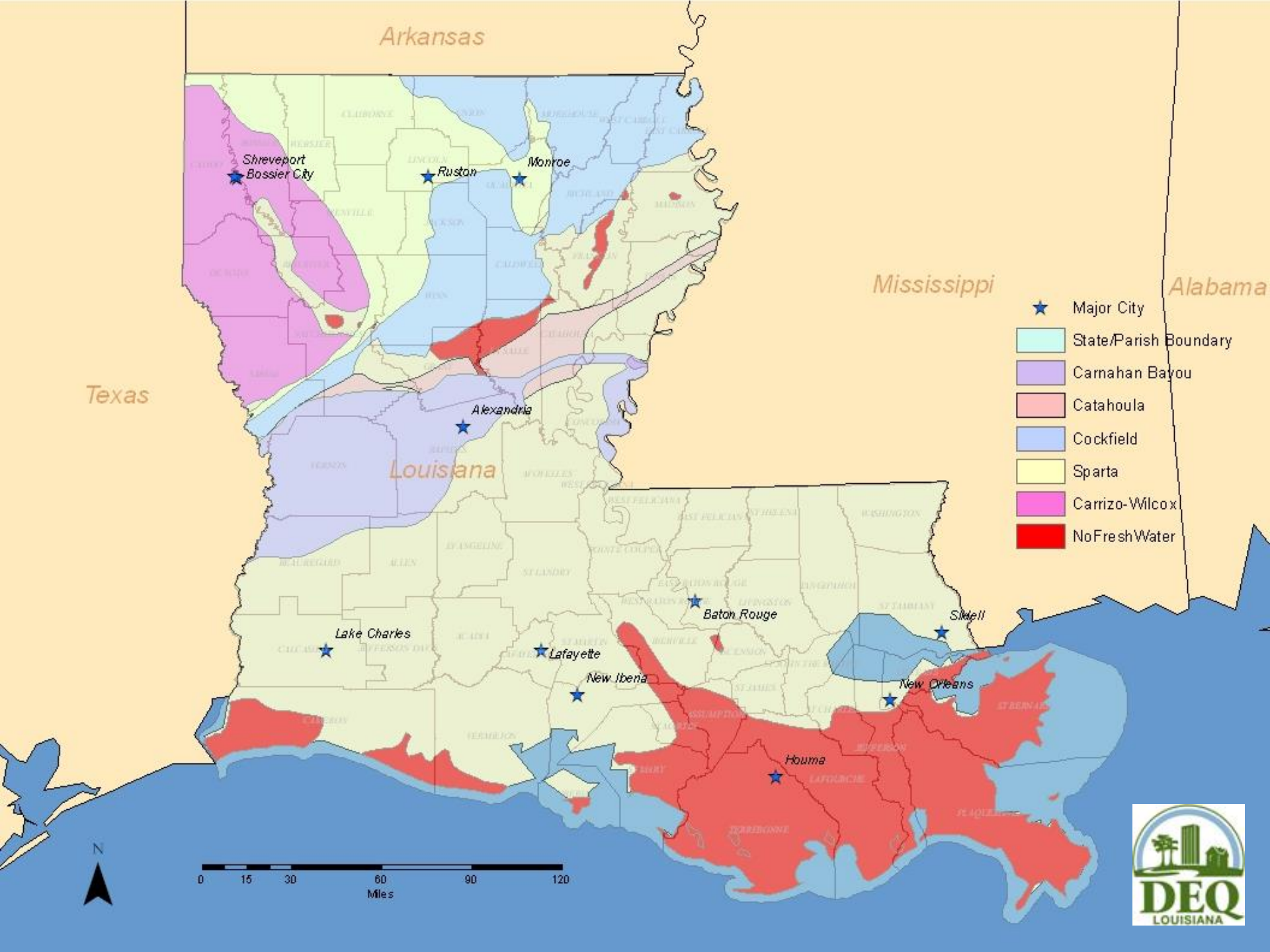
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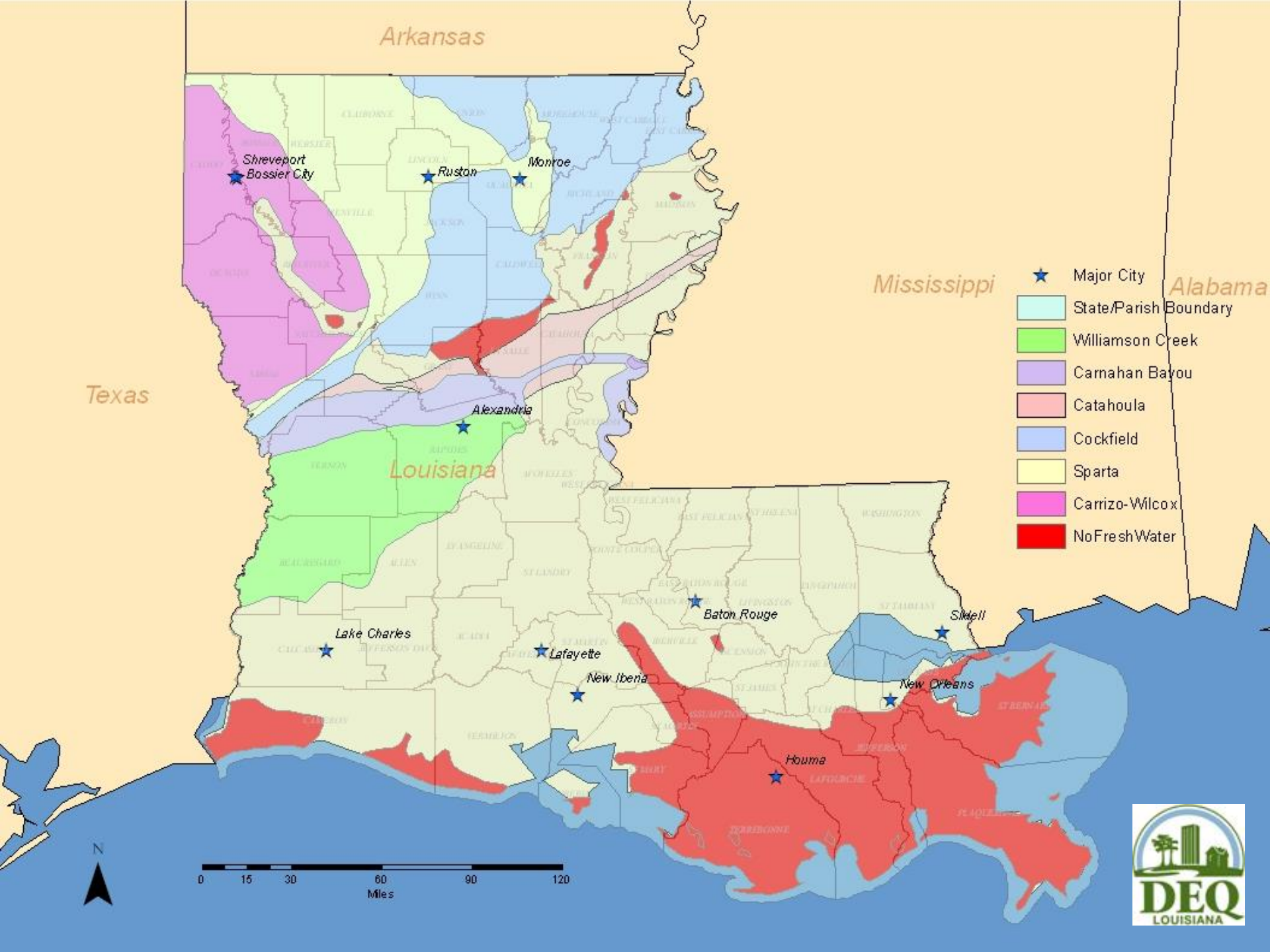
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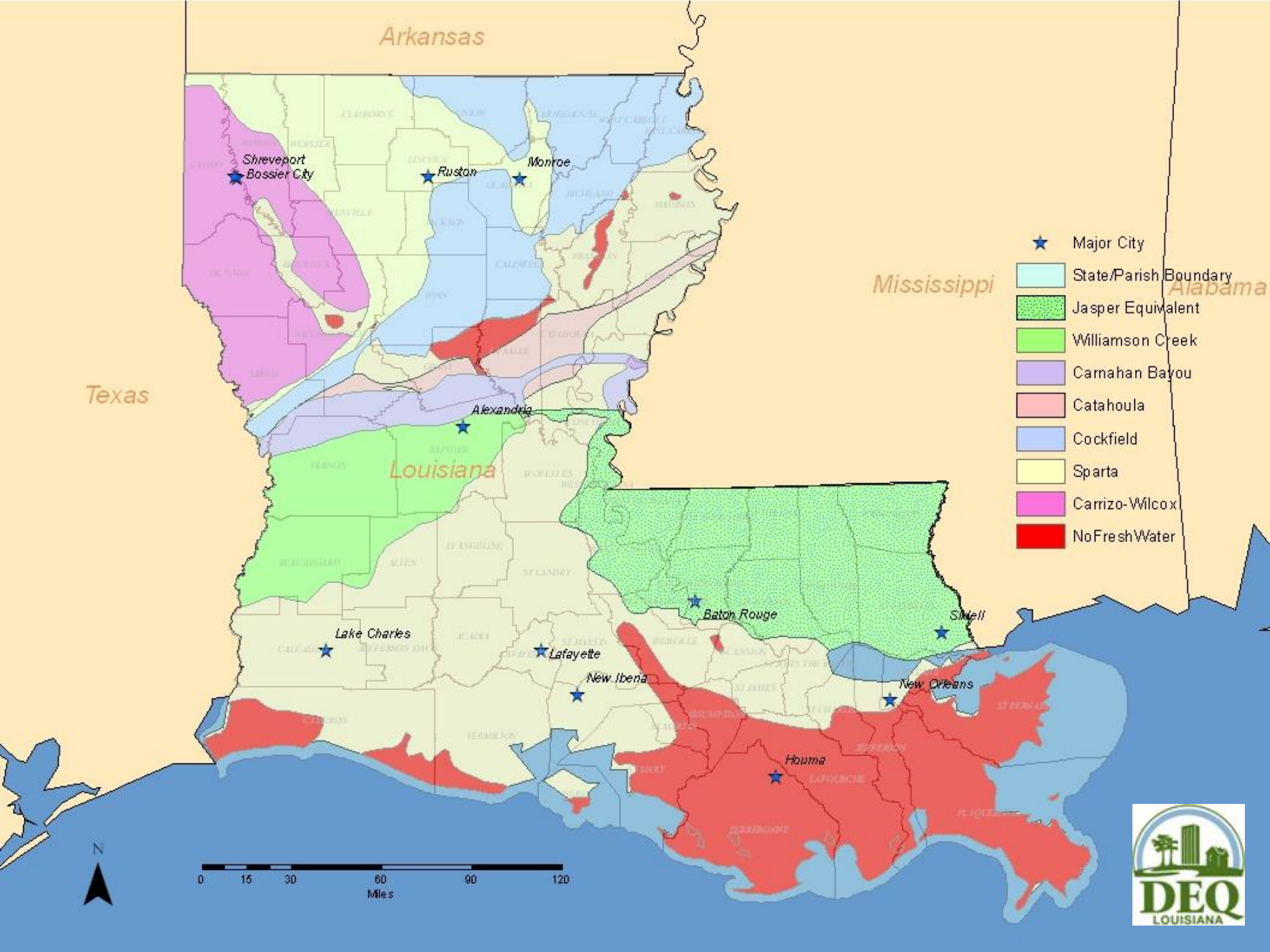
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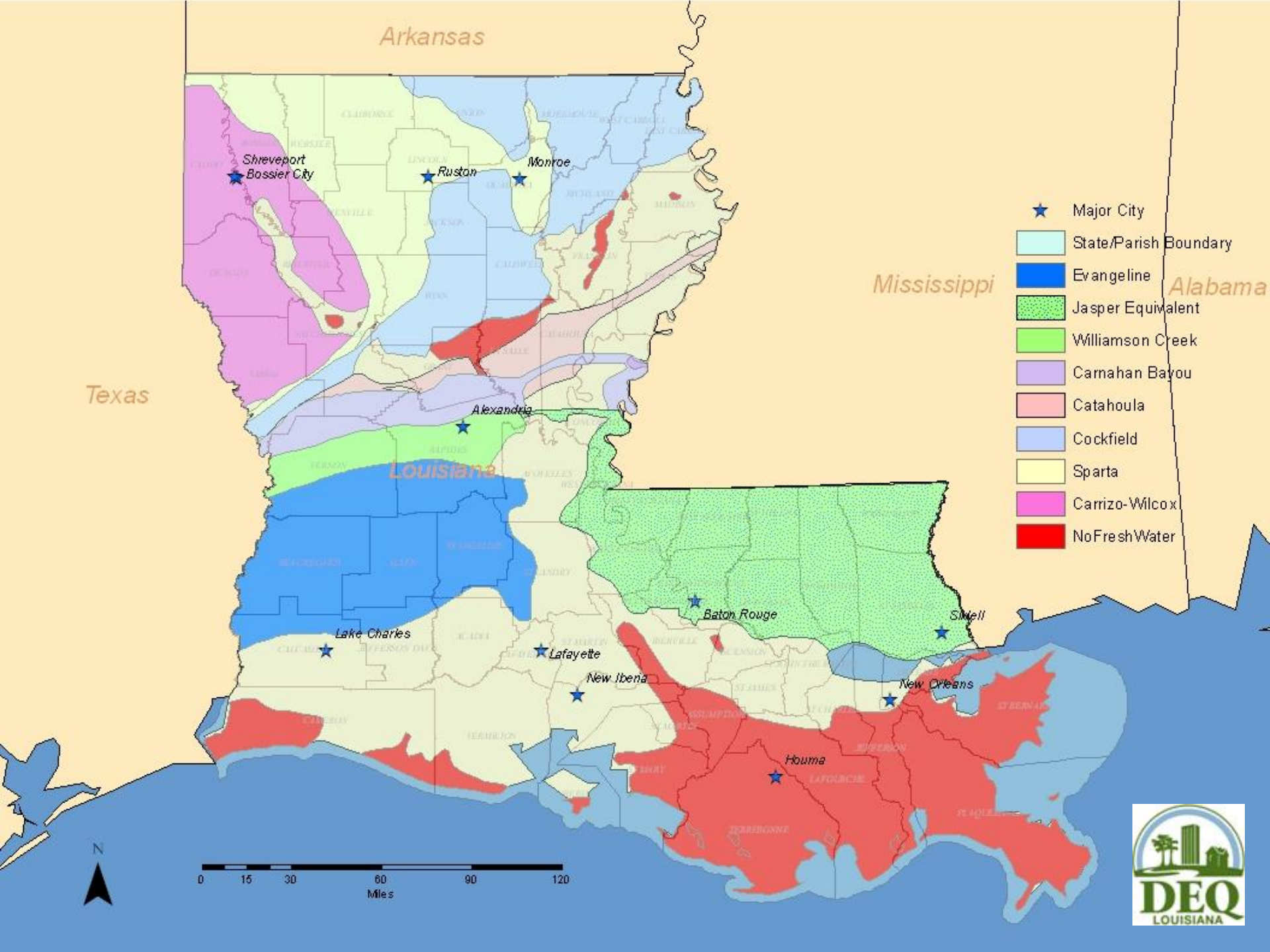
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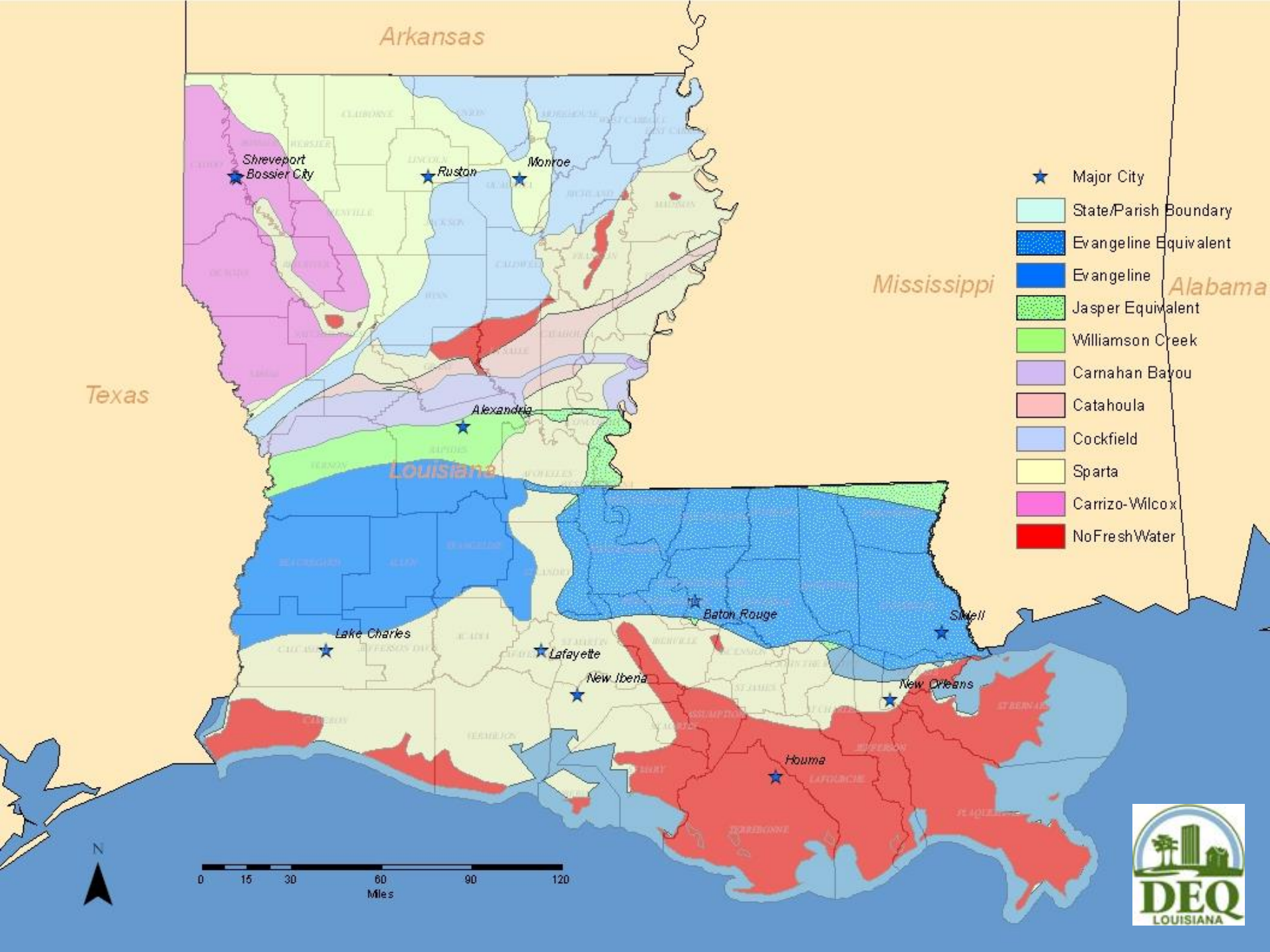
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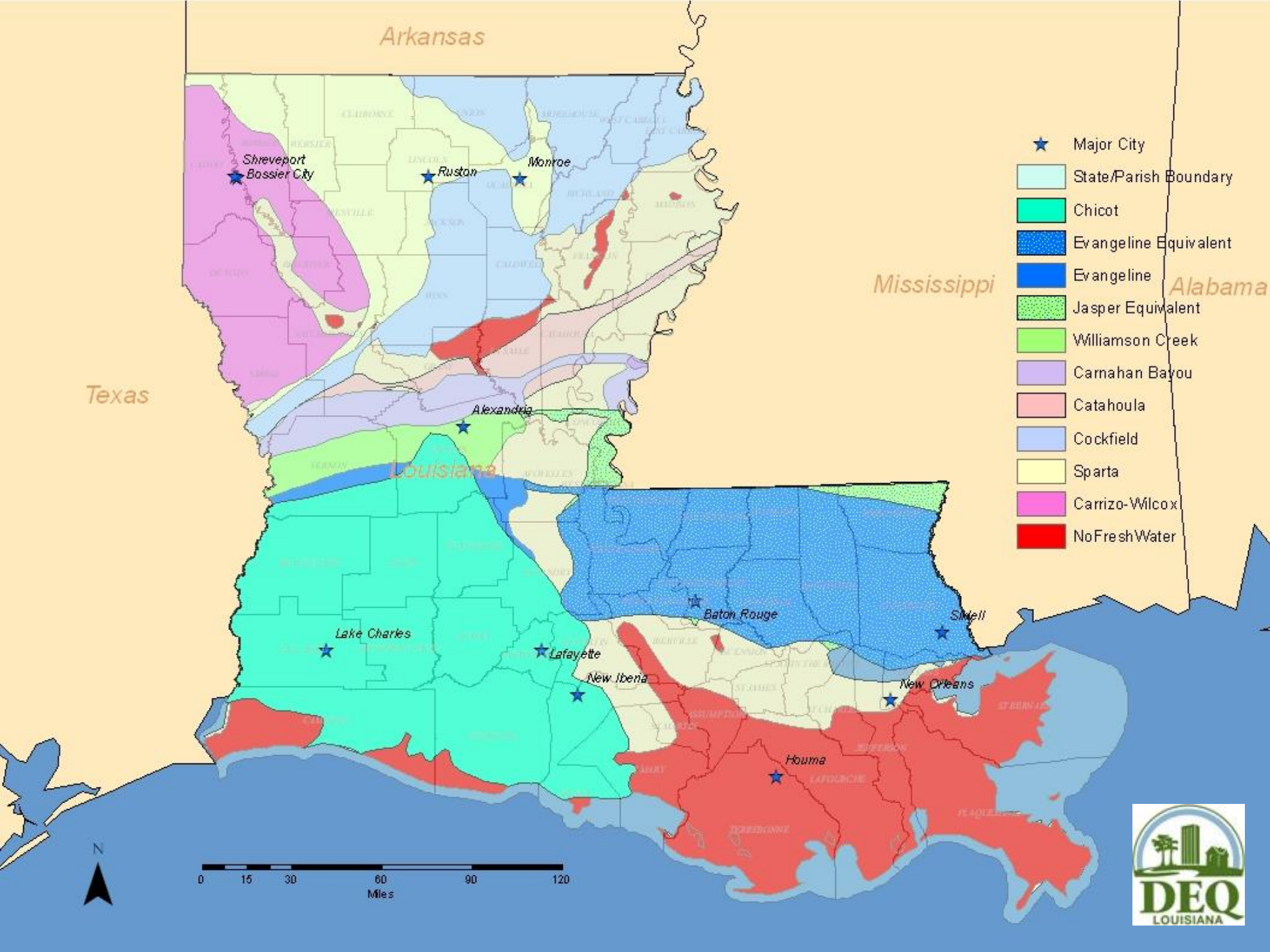
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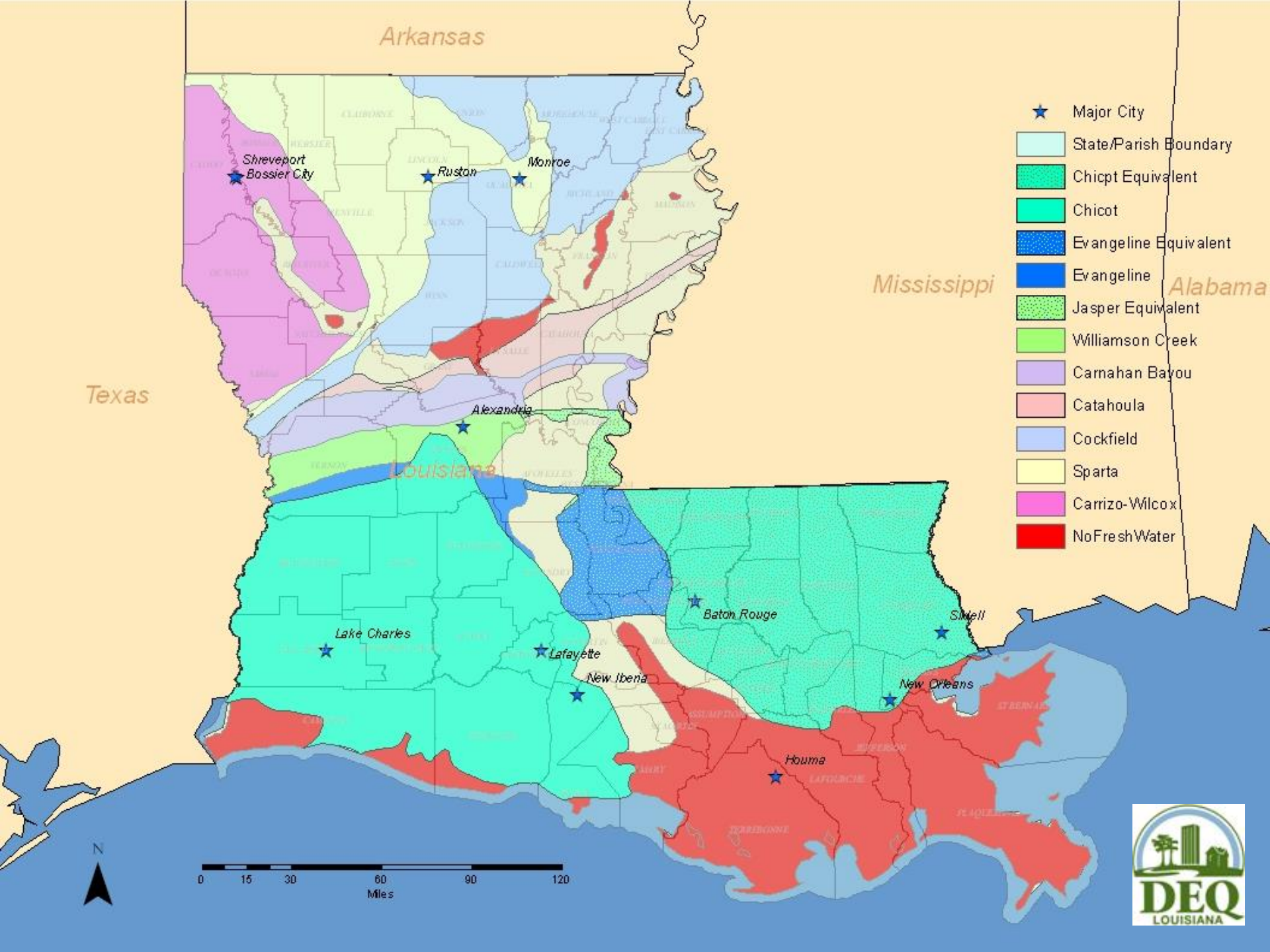
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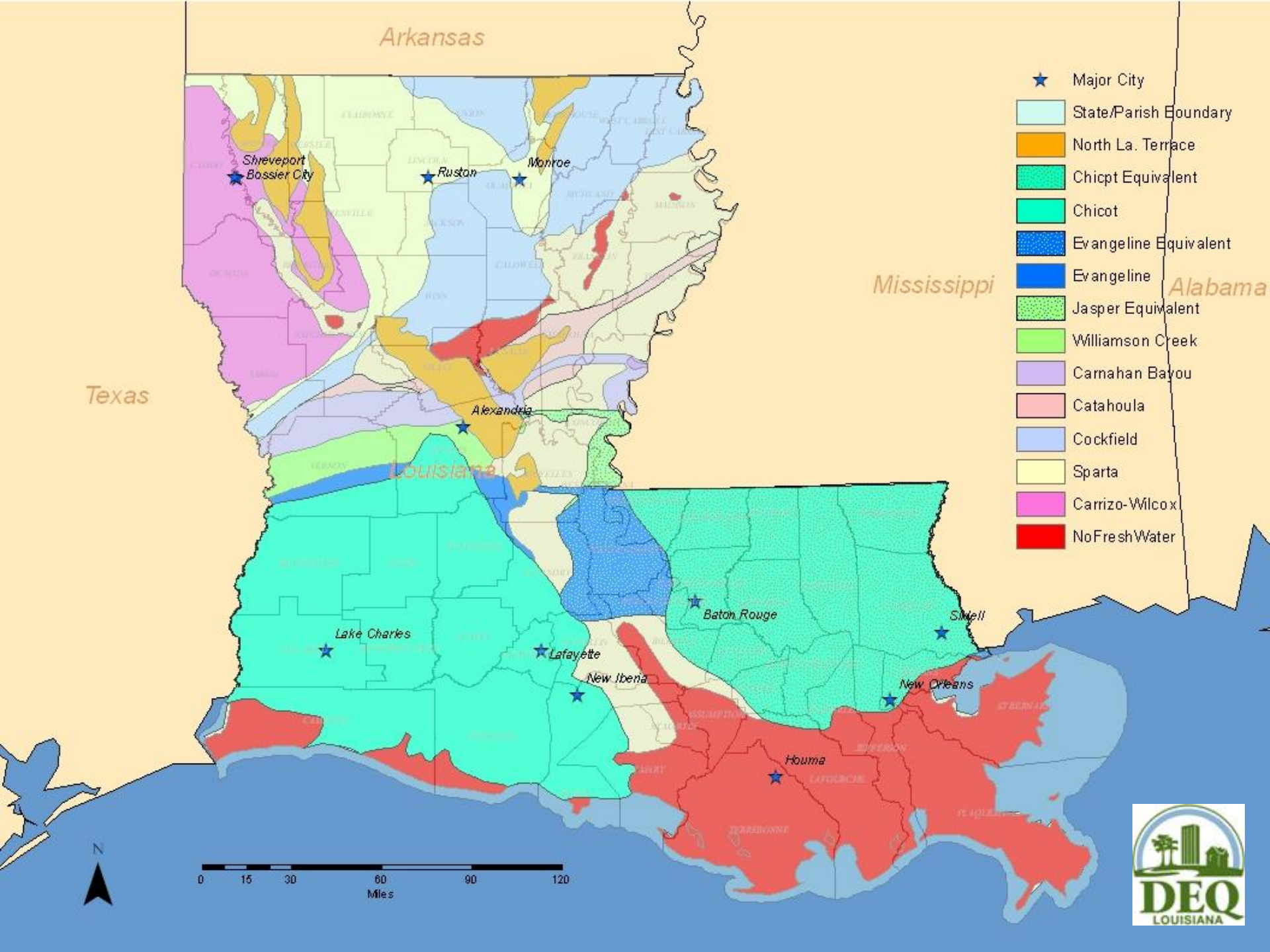
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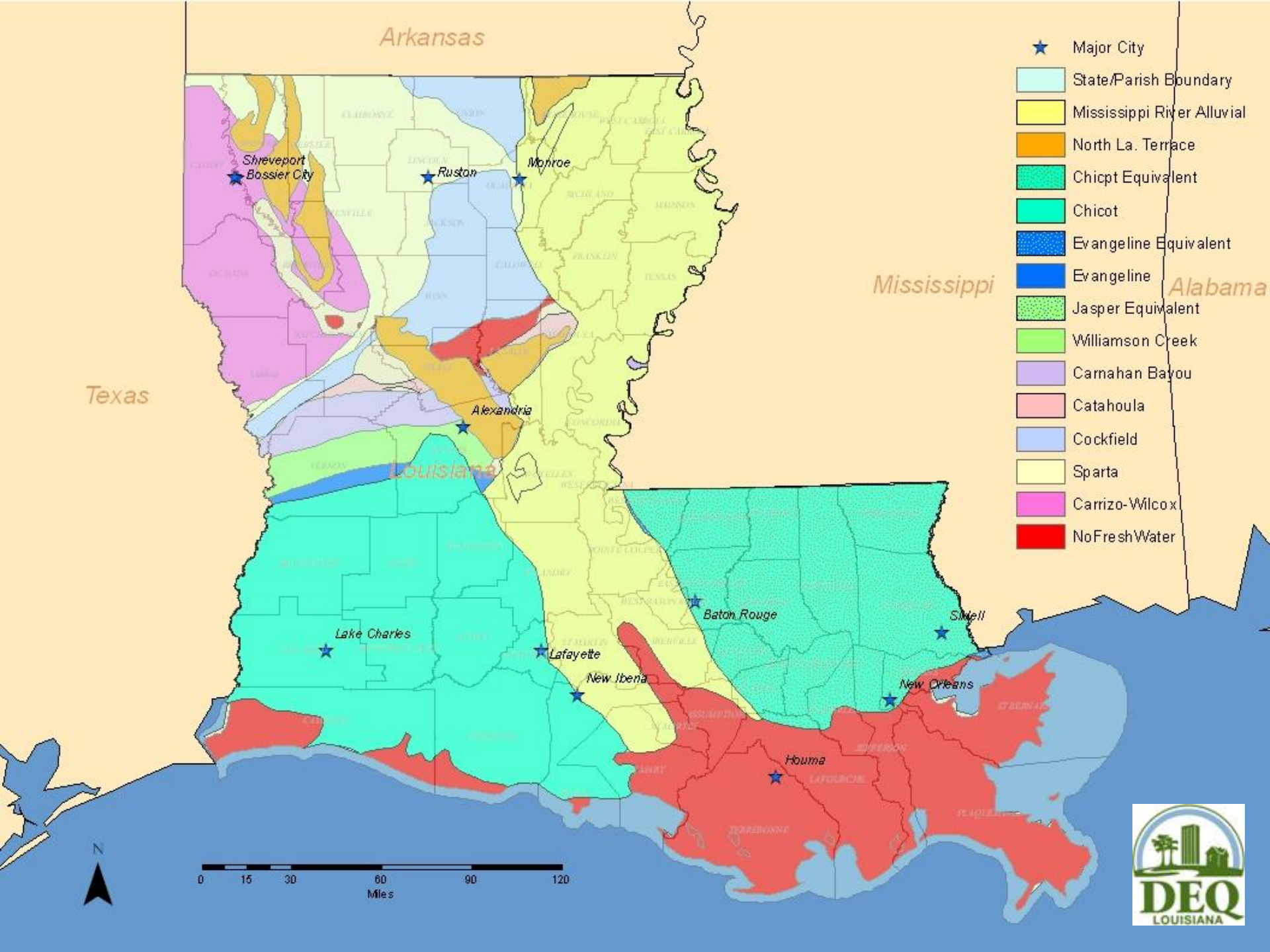
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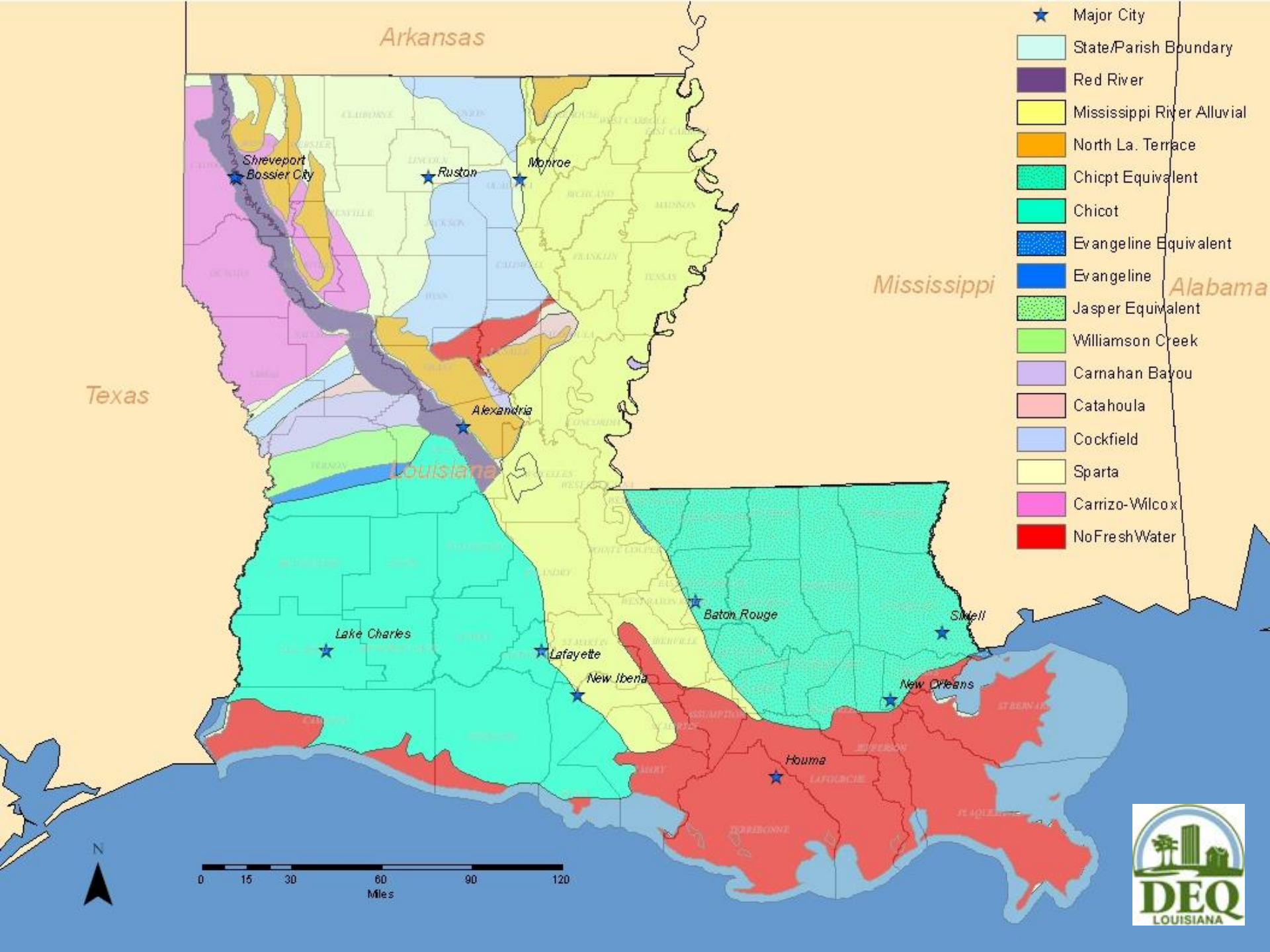
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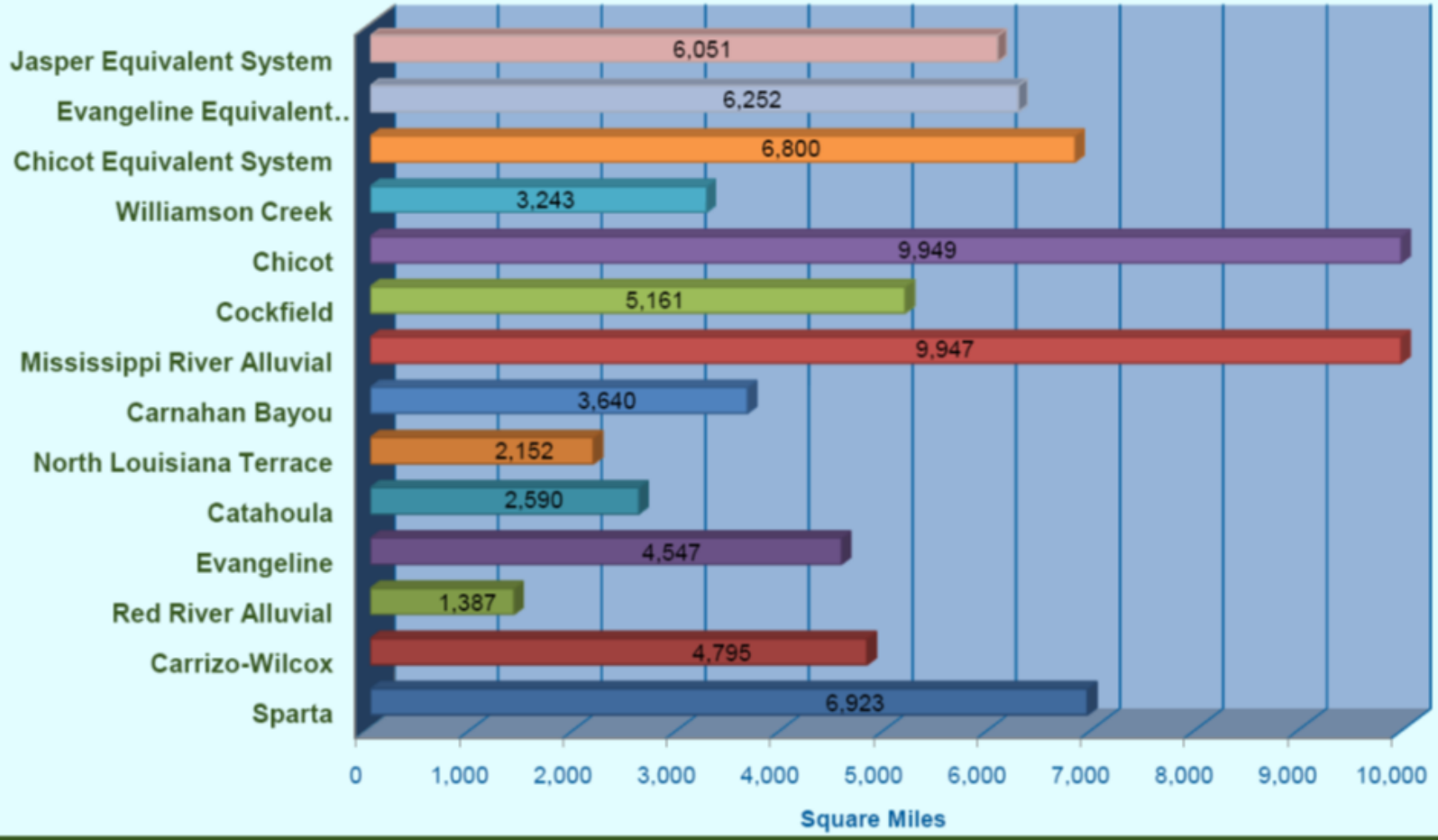
Areal Extent of Aquifers/Aquifer Systems




N
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Carrizo-Wilcox

Carrizo-Wilcox

- Sediments fine-medium sand, silt, clay, lignite
- Thickness 50 - 850 feet, increasing to south and southeast
- Recharge from rainfall on surficial sediments
- Well depths 100 - 650 feet
- Water levels range from slightly above to 200 feet bls; generally 50 - 100 feet
- Yields 30 - 150 gpm, large capacity wells 400 gpm; thin and fine sands restrict well yields
- Discharges to Red and Sabine Rivers
- Used for public supply, domestic, farm supply

Carrizo-Wilcox Water Quality

- Typically suitable for drinking with little or no treatment
- Freshwater section 50 - 80 feet thick
- High in color in southern part of recharge area
- Unsuitable for irrigation – high sodium
- Soft, generally low iron
- Locally high concentrations iron and hydrogen sulfide

Outcrop in Caddo Parish

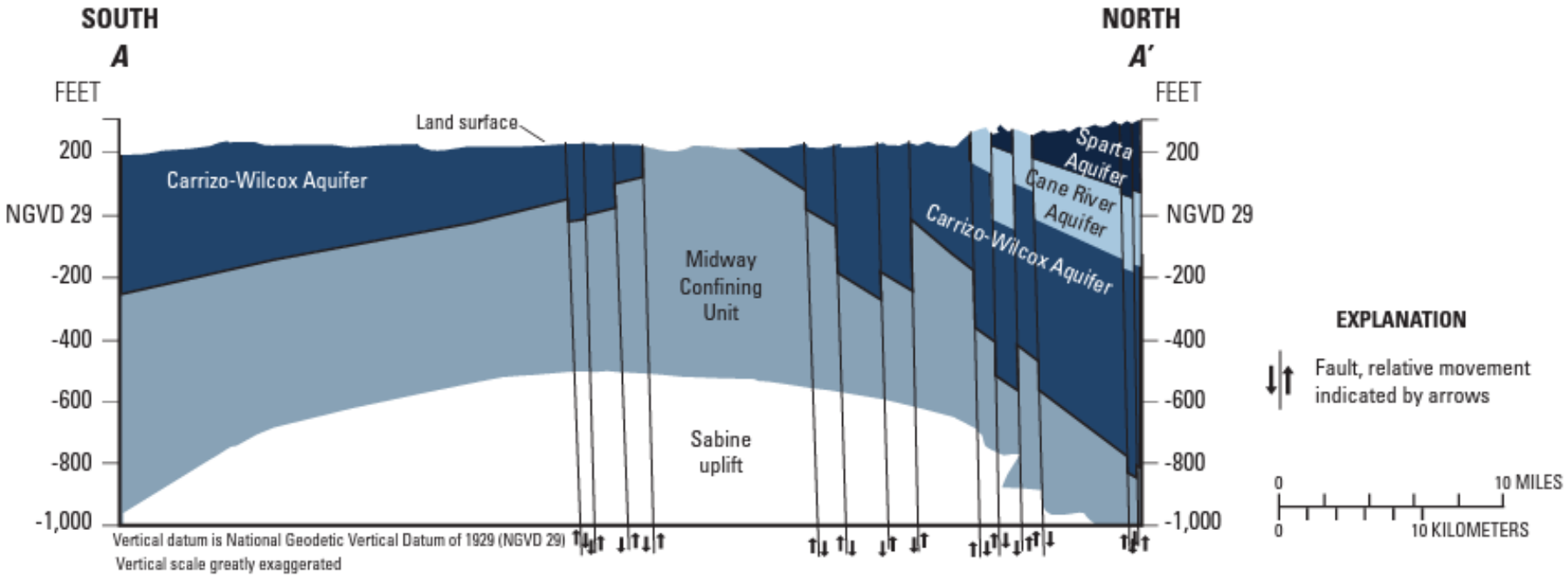

Figure 3. Generalized north-to-south hydrogeologic section through Caddo Parish, Louisiana (Rapp, 1996). Trace of section shown on figure 1.

https://pubs.usgs.gov/fs/2011/3086/
Caddo Parish doc

Overlain by Upland Terrace and RRA in Red River Parish

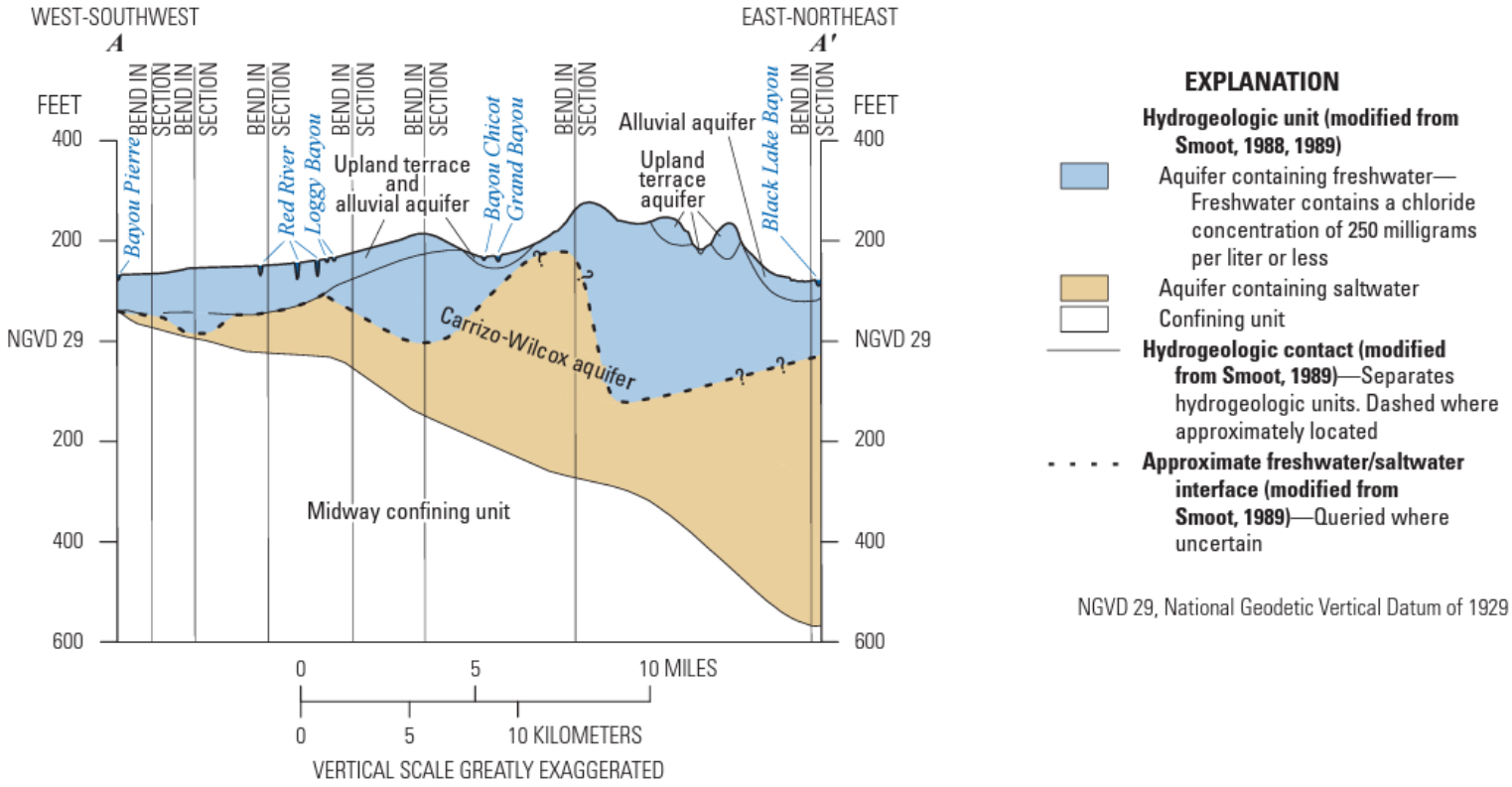

Figure 3. Idealized west-to-east hydrogeologic section through Red River Parish, Louisiana, showing aquifer and confining unit intervals (individual sand and clay layers not shown). Modified from Newcome and Page (1962). Trace of section shown on figure 1.

https://pubs.er.usgs.gov/publication/fs20203053
Bienville Parish


N
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Sparta

Sparta

- Sediments very fine to medium sand, interbedded with clay and lignite
- Thickness 50 - 700 feet, increases toward south and southeast
- Recharge from rainfall on outcrop area and water moving downward through terrace deposits in Bossier, Webster, Bienville; leakage from overlying Cockfield and underlying Carrizo-Wilcox
- Well depths 200 - 900 feet
- Water levels 15 - 320 feet bls

Sparta (continued)

- Yields 100 - 1,800 gpm
- Used for industry and public supply
- Major pumping centers: Hodge, Monroe, Ruston, Springhill, LA and El Dorado and Magnolia, AR

Sparta Water Quality

- Soft, hardness less than 60 md/L
- Treatment required to reduce iron and corrosiveness from western half of aquifer extent
- Salinity increases with depth and toward southeast
- High sodium in eastern part of aquifer makes it unsuitable for irrigation
- Locally high in color and concentrations of fluoride, sodium, hydrogen sulfide, and dissolved solids

Overlain by Cockfield Aquifer and Cook Mountain Confining Unit in Jackson Parish

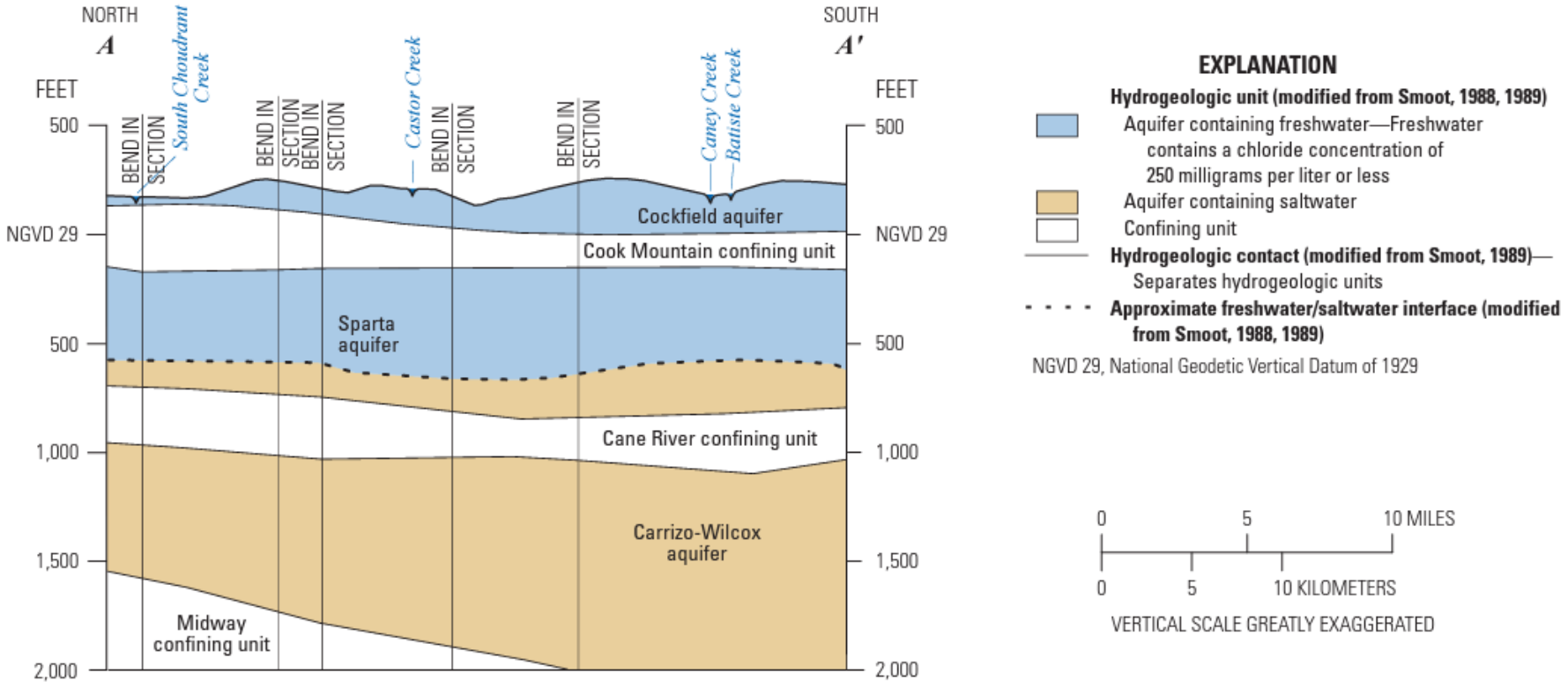


Figure 3. Idealized north-to-south hydrogeologic section through Jackson Parish, Louisiana, showing aquifer and confining unit intervals (individual sand and clay layers not shown). (Modified from Smoot, 1988, 1989). Trace of section shown on figure 1.

https://pubs.er.usgs.gov/publication/fs20193020

To the east in Ouachita Parish - interbedded clay and presence of saltwater

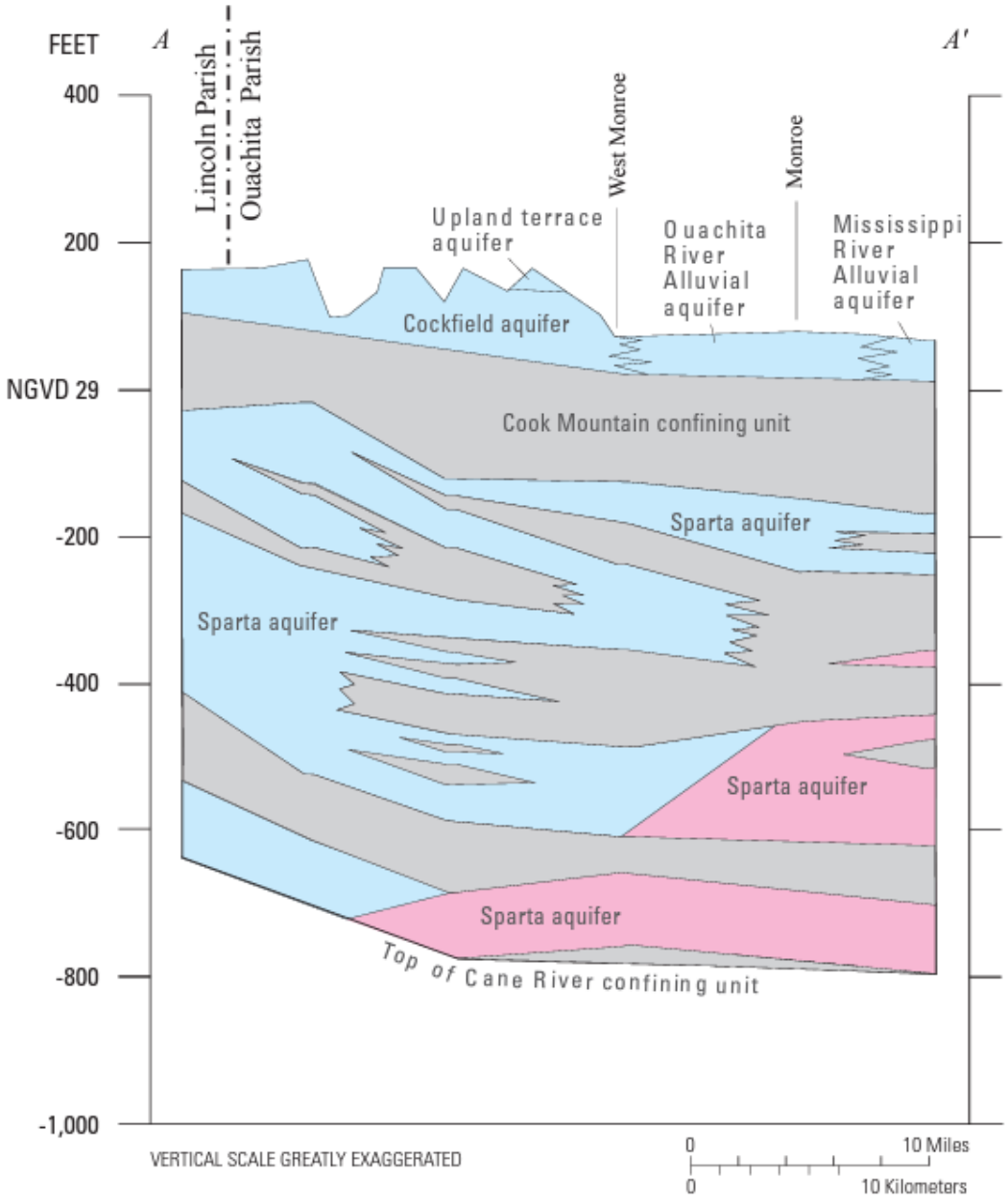
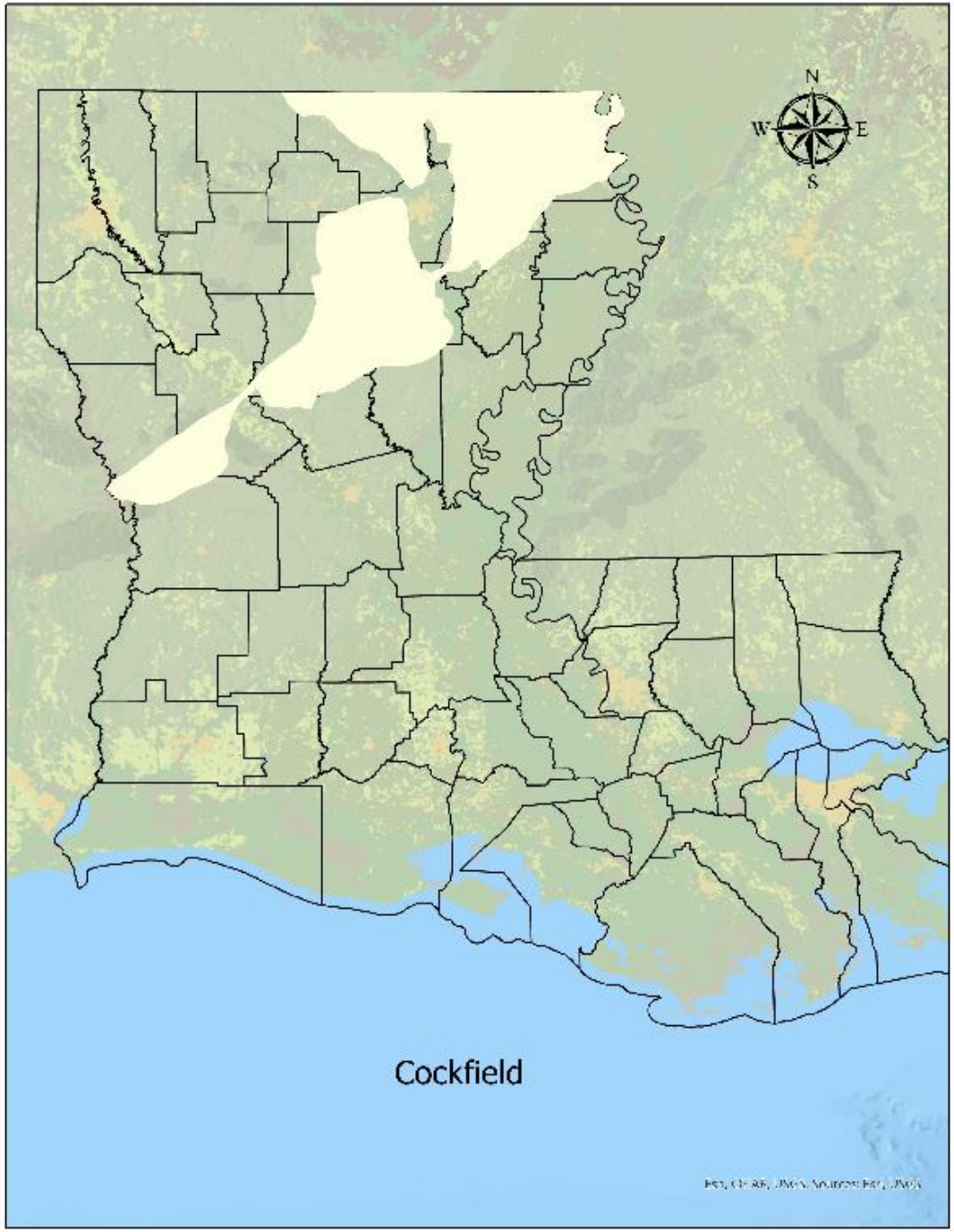


Figure 3. Generalized west-to-east hydrogeologic section through Ouachita Parish, Louisiana (Brantly and others, 2002).

https://pubs.usgs.gov/fs/2009/3086/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Cockfield

Cockfield

- Sediments very fine to fine sand
- Thickness 50 - 600 feet
- Recharge from rainfall on outcrop, leakage from overlying MRAA and underlying aquifers
- Well depths 200 - 2,000 feet, deepest in west
- Water levels generally less than 30 feet bls
- Yields 50-500 gpm, large capacity wells 700 gpm (relatively low yield)
- Primary use public supply
- Water movement eastward and southeastward

Cockfield Water Quality

- Freshwater section 50-600 feet thick
- Locally high in color and hardness and concentration of iron
- Leakage from MRAA causes excessive hardness and iron concentration
- Treatment may be required for public supply

Outcrop in Jackson Parish

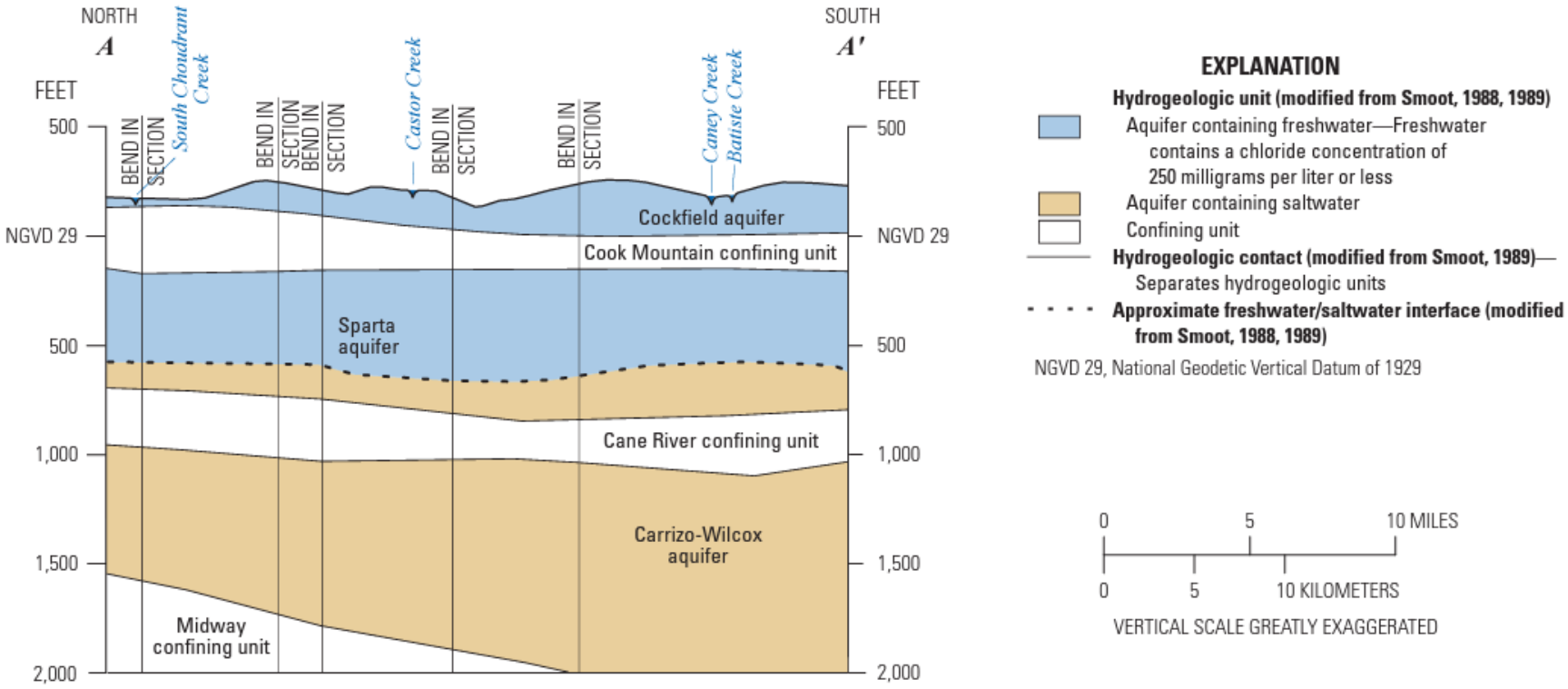
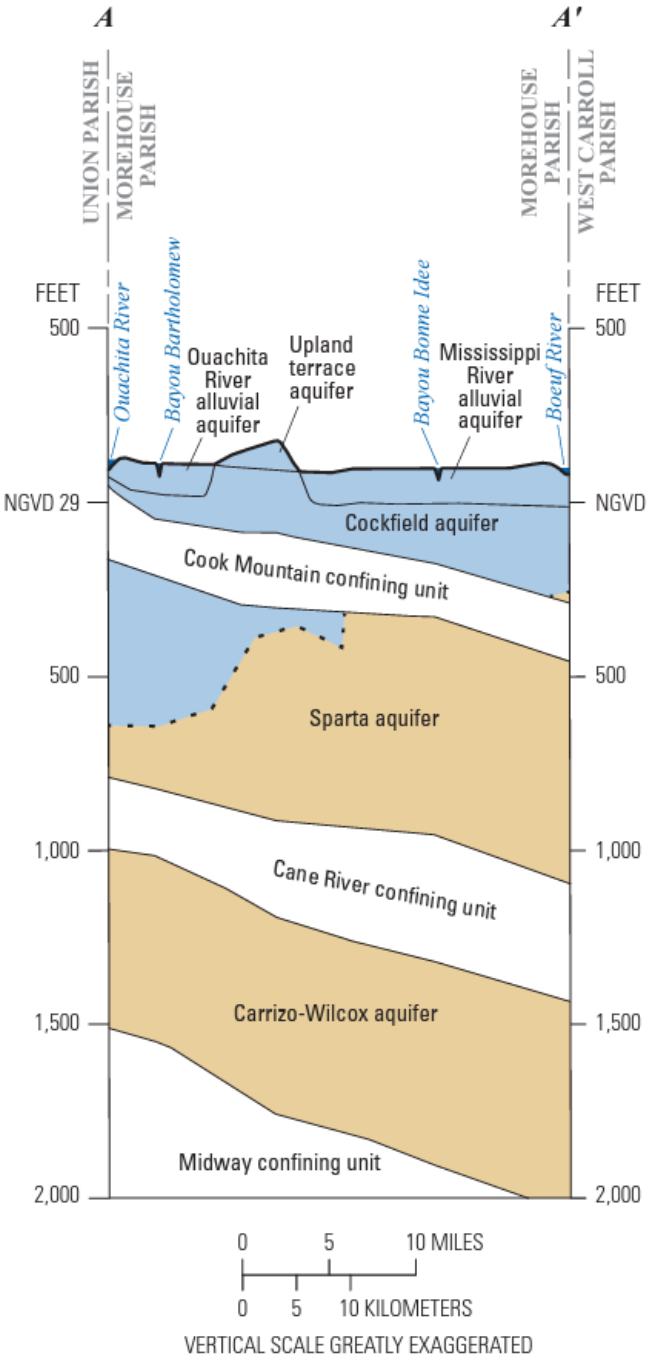


Figure 3. Idealized north-to-south hydrogeologic section through Jackson Parish, Louisiana, showing aquifer and confining unit intervals (individual sand and clay layers not shown). (Modified from Smoot, 1988, 1989). Trace of section shown on figure 1.

https://pubs.er.usgs.gov/publication/fs20193020

To the east in Morehouse Parish – overlain by Upland Terrace and MRAA



EXPLANATION

Hydrogeologic unit (modified from Smoot, 1988, 1989)

- Aquifer containing freshwater—Freshwater contains a chloride concentration of 250 milligrams per liter or less
- Aquifer containing saltwater
- Confining unit

Hydrogeologic contact (modified from Smoot, 1989)—Separates hydrogeologic units

Approximate freshwater/saltwater interface (modified from Smoot, 1988, 1989)

NGVD 29, National Geodetic Vertical Datum of 1929

Figure 3. Idealized west-to-east hydrogeologic section through Morehouse Parish, Louisiana, showing aquifer and confining unit intervals (individual sand and clay layers not shown). Trace of section shown on figure 1.

https://pubs.er.usgs.gov/publication/fs20183068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Catahoula

Catahoula

- Sediments fine to medium sand, forms sandstone in places (cemented with Louisiana Opal in part of Vernon parish)
- Thickness 50 - 450 feet, increases to south
- Recharge from rainfall on outcrop and percolation through overlying alluvial and terrace deposits
- Well depths 100 - 1,800 feet
- Water levels 20 - 200 feet bls
- Yields 50 - 400 gpm
- Primary use public supply

Catahoula Water Quality

- Freshwater section 50-450 feet thick
- Soft with high concentrations of iron in Vernon and Natchitoches parishes
- Saltwater away from recharge area

Outcrop in Sabine Parish

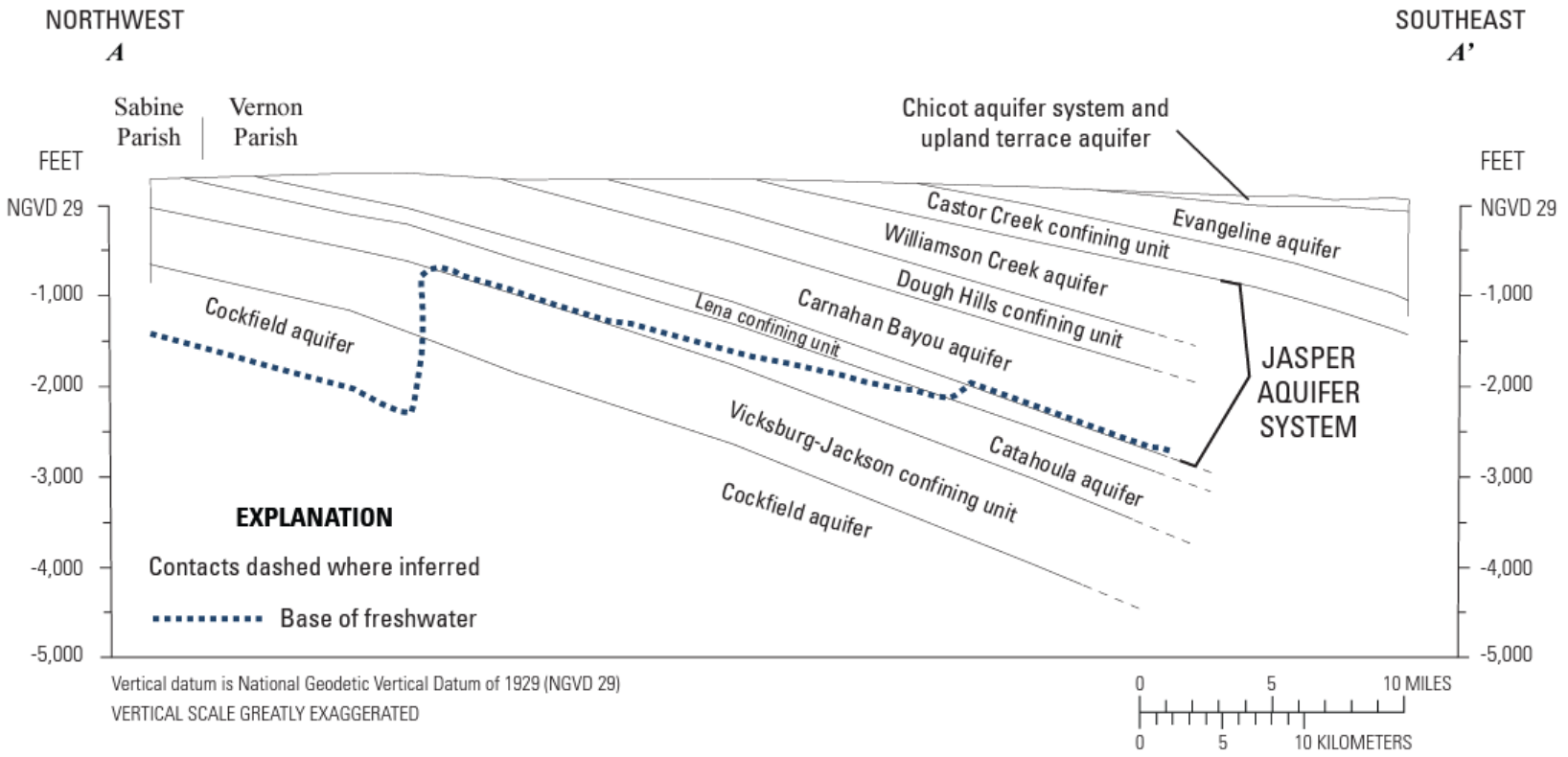
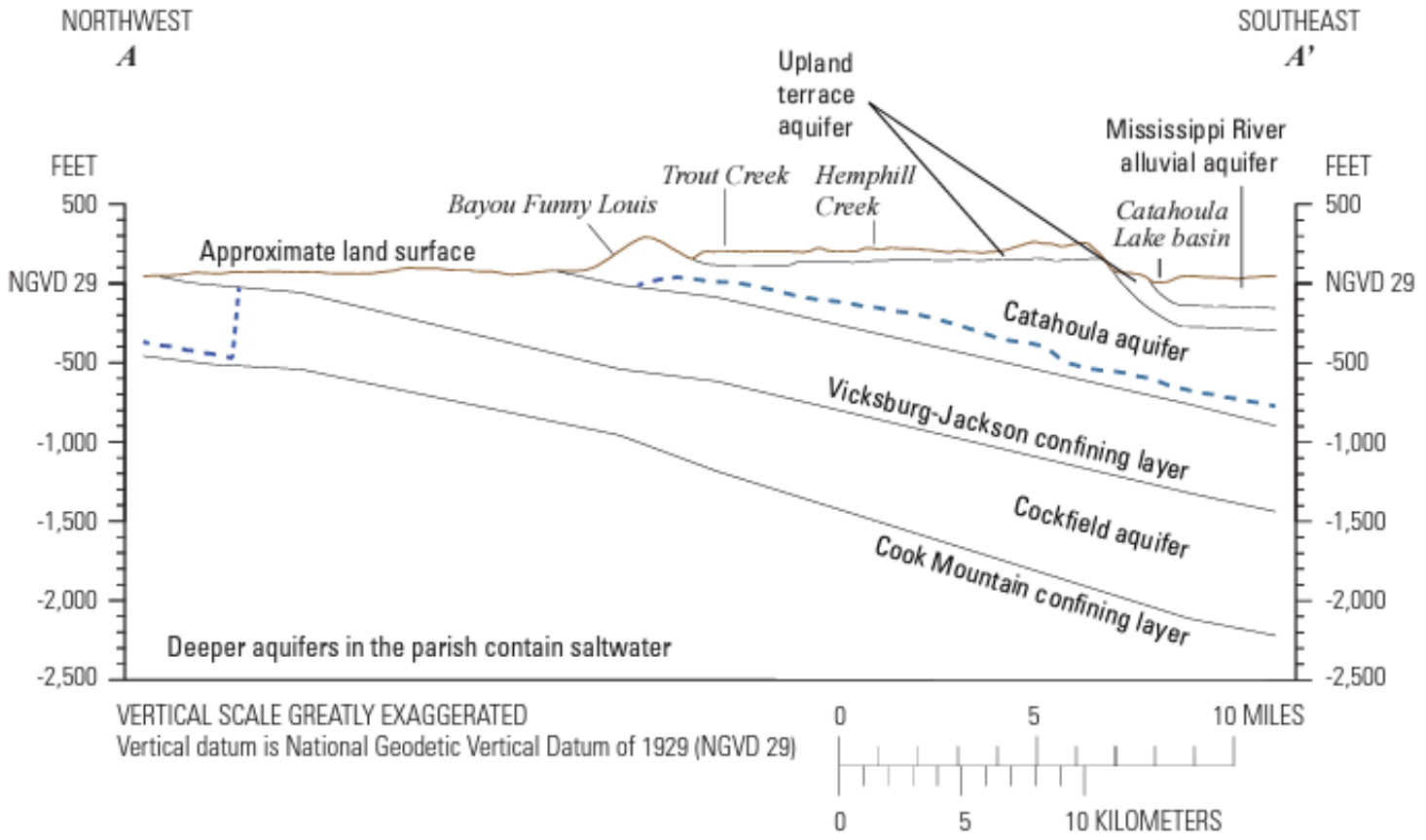


Figure 3. Generalized northwest to southeast geologic section through Vernon Parish, Louisiana (modified from Rogers and Calandro, 1965). Trace of section shown on figure 1.

https://pubs.usgs.gov/fs/2012/3063/

Outcrop in LaSalle Parish with some portions overlain by Upland Terrace and MRAA



EXPLANATION

Base of freshwater

Figure 3. Generalized northwest-to-southeast hydrogeologic section through La Salle Parish, Louisiana, showing aquifer and confining layer intervals (individual sand and clay layers not shown; modified from Fisk, 1938). Trace of section shown on figure 1.

https://pubs.er.usgs.gov/publication/fs20143089

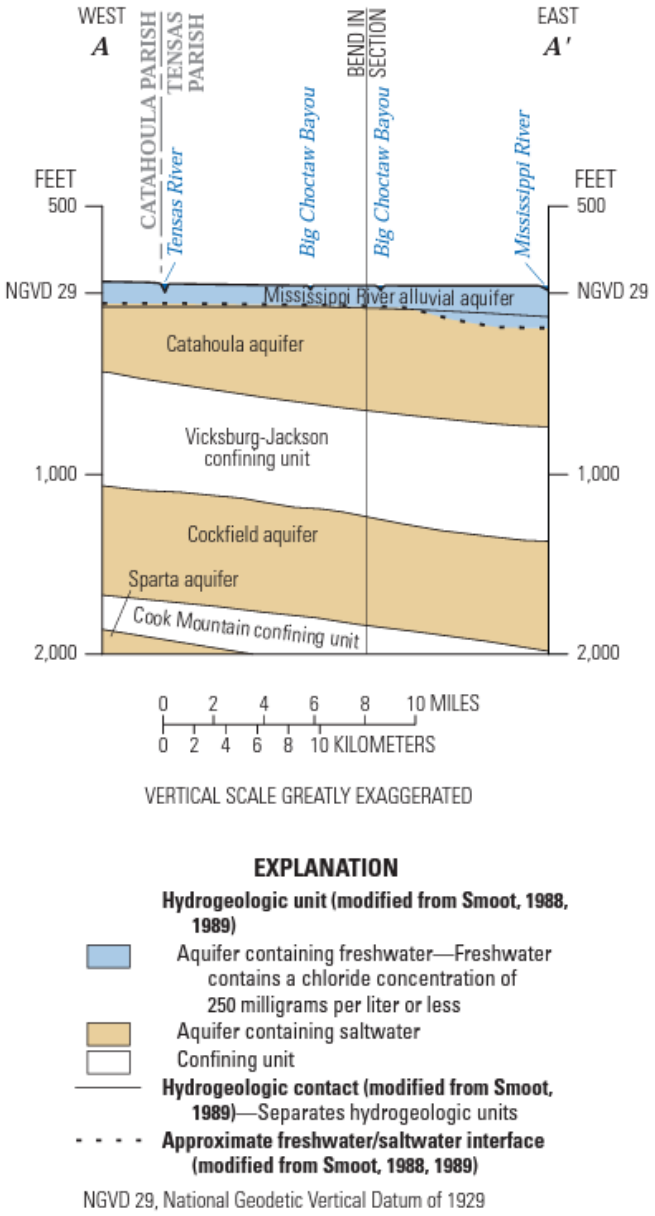


Figure 3. Idealized west-to-east hydrogeologic section through Tensas Parish, Louisiana, showing aquifer and confining unit intervals (individual sand and clay layers not shown). Modified from Smoot (1988, 1989). Trace of section shown on figure 1.

Overlain by MRAA in Tensas Parish

https://pubs.er.usgs.gov/publication/fs20193004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Carnahan Bayou

Carnahan Bayou (Jasper)

- Lower Jasper unit
- Sediments fine to medium sand interbedded w/green-gray clay
- Extensive clay layers separate Jasper system from overlying and underlying aquifers
- Crops out in northern Vernon, southern Natchitoches, northwestern Rapides, and southern Grant; dips to southeast
- Thickness 450 – 1,100 feet
- Well depths 40 – 2,151 feet
- Water levels generally <60 feet BLS
- Yields 40 – 800 GPM
- Primary use public supply

Carnahan Bayou Water Quality

- Soft water, slightly harder than Williamson Creek aquifer
- Iron generally <0.5 mg/L
- Freshwater section up to 2,500 feet thick
- Suitable for drinking with little or no treatment
- Local occurrence relatively high color and concentrations of iron, fluoride, hydrogen sulfide

Overlain by other aquifers and confining units in most of Rapides Parish

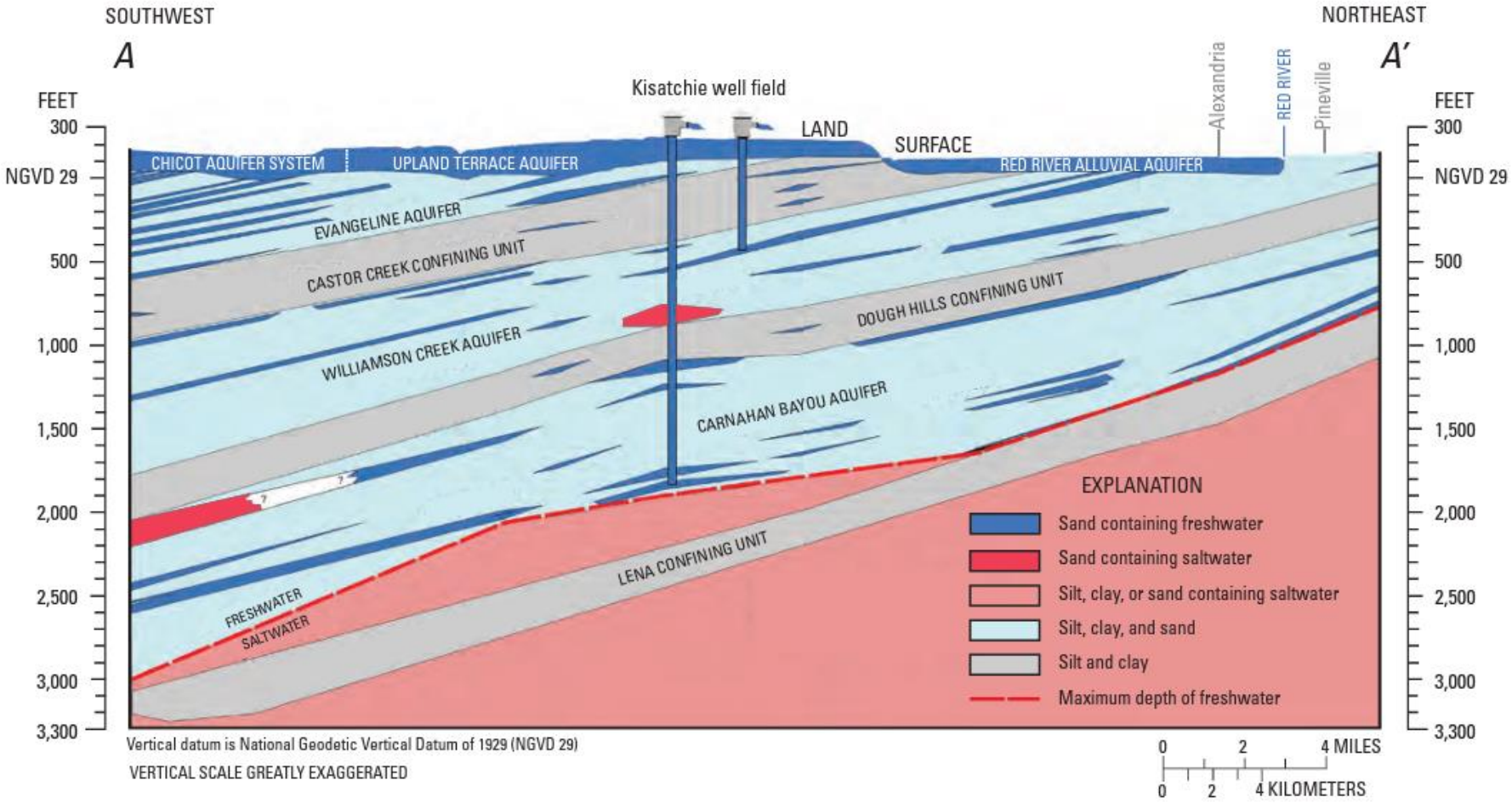

Figure 3. Generalized southwest-to-northeast hydrogeologic section through Rapides Parish, Louisiana (Tomaszewski, 2007). Trace of section shown on figure 1.

https://pubs.usgs.gov/fs/2009/3056/

To the east - overlain my MRAA in Concordia Parish

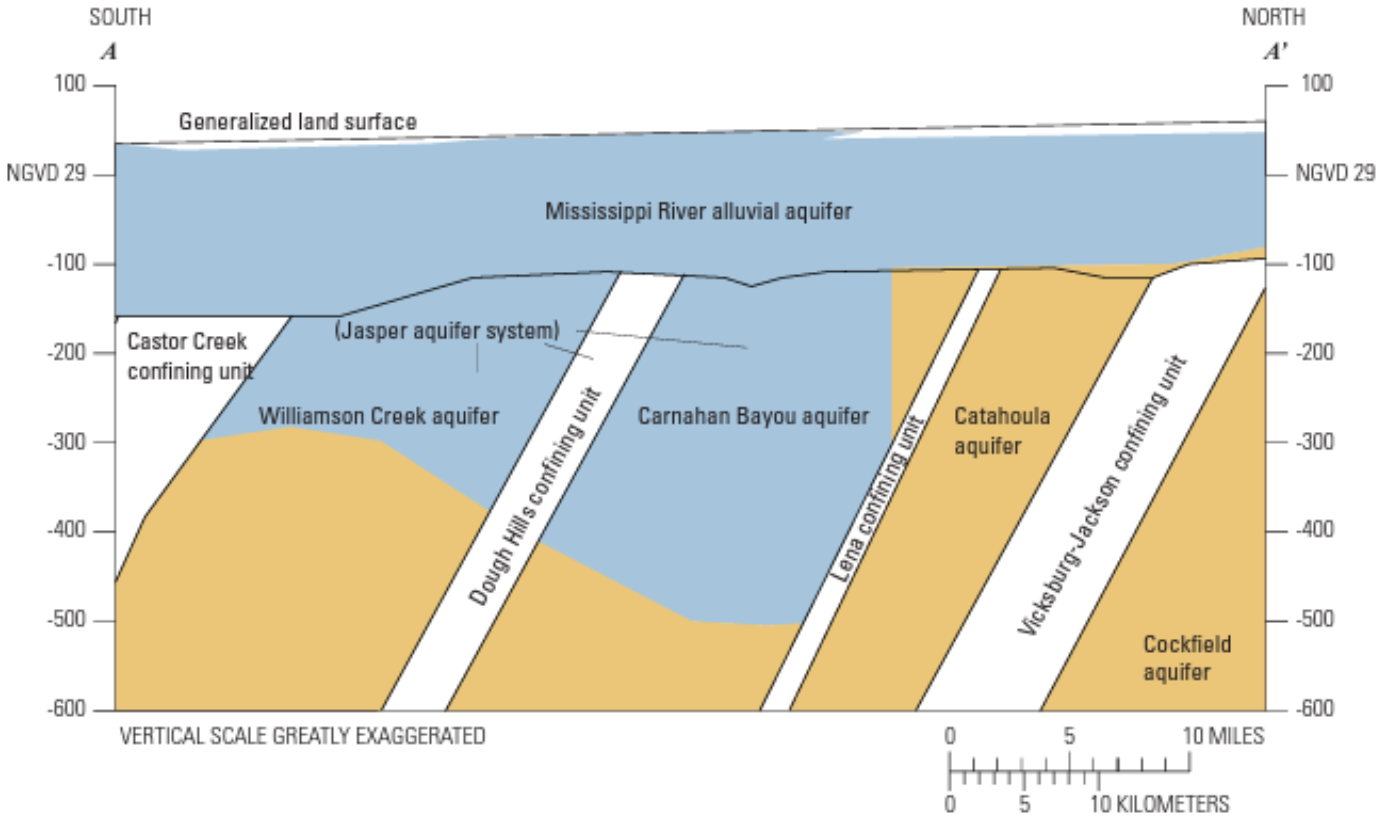

Figure 3. Idealized south-to-north hydrogeologic section through Concordia Parish, Louisiana, showing aquifer and confining layer intervals (individual sand and clay layers not shown; modified from Whitfield, 1975, and Smoot, 1988, 1989). Trace of section shown on figure 1.

https://pubs.er.usgs.gov/publication/fs20163099


N
W
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Williamson Creek

Williamson Creek (Jasper)

- Upper Jasper Unit
- Sediments fine to medium sand interbedded w/green-gray clay
- Crops out in Vernon and Rapides parishes
- Thickness 400 – 900 feet
- Well depths 50 – 1,008
- Water levels generally <60 feet BLS
- Yields 40 – 800 GPM, large capacity wells 3,000 GPM
- Primary use public supply

Williamson Creek Water Quality

- Soft water, slightly softer than Carnahan Bayou aquifer
- Iron generally <0.5 mg/L
- Freshwater section up to 2,500 feet thick
- Suitable for drinking with little or no treatment
- Local occurrence relatively high color and concentrations of iron, fluoride, hydrogen sulfide

Outcrop in Vernon Parish, overlain by Castor Creek Confining Unit southward

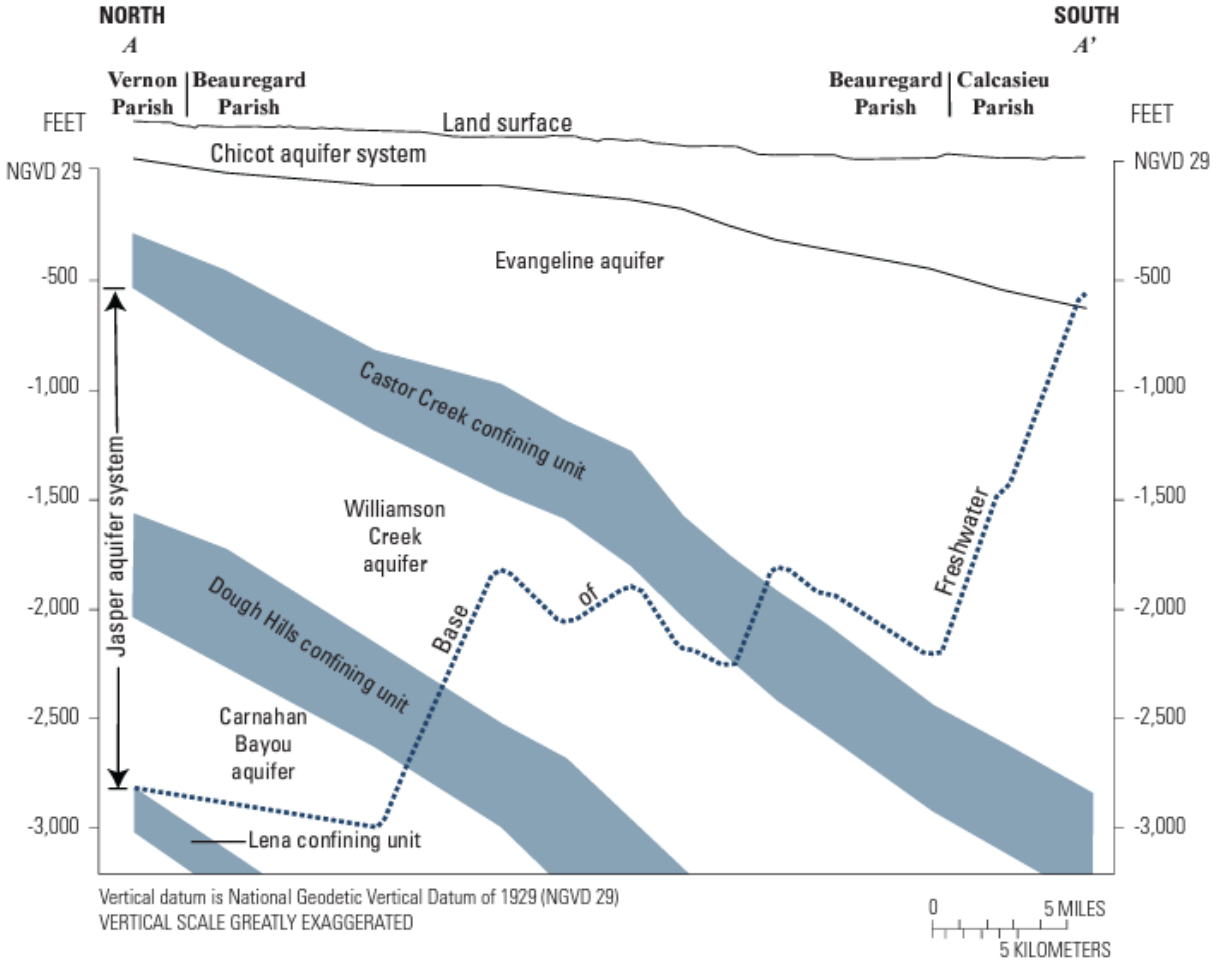


Figure 3. Generalized north-to-south hydrogeologic section showing aquifer and confining unit intervals (individual sand and clay layers not shown) from Vernon Parish to Calcasieu Parish, Louisiana (modified from Whitfield, 1975, plate 3). Trace of section shown on figure 1.

https://pubs.er.usgs.gov/publication/fs20123065

Rapides Parish - overlain by Castor Creek Confining Unit in southwest and RRA in the northeast. Crops out in Alexandria/Pineville area

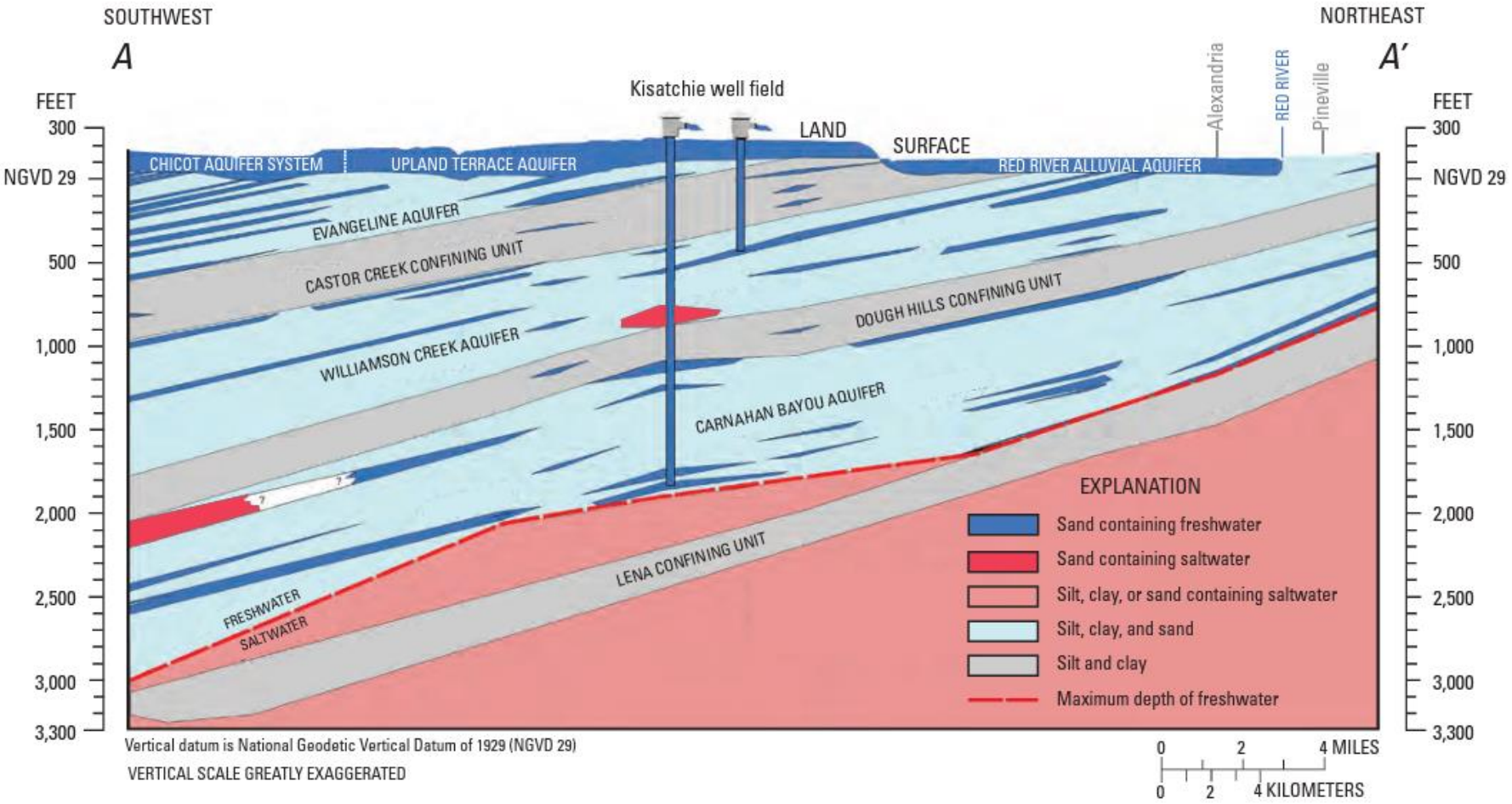
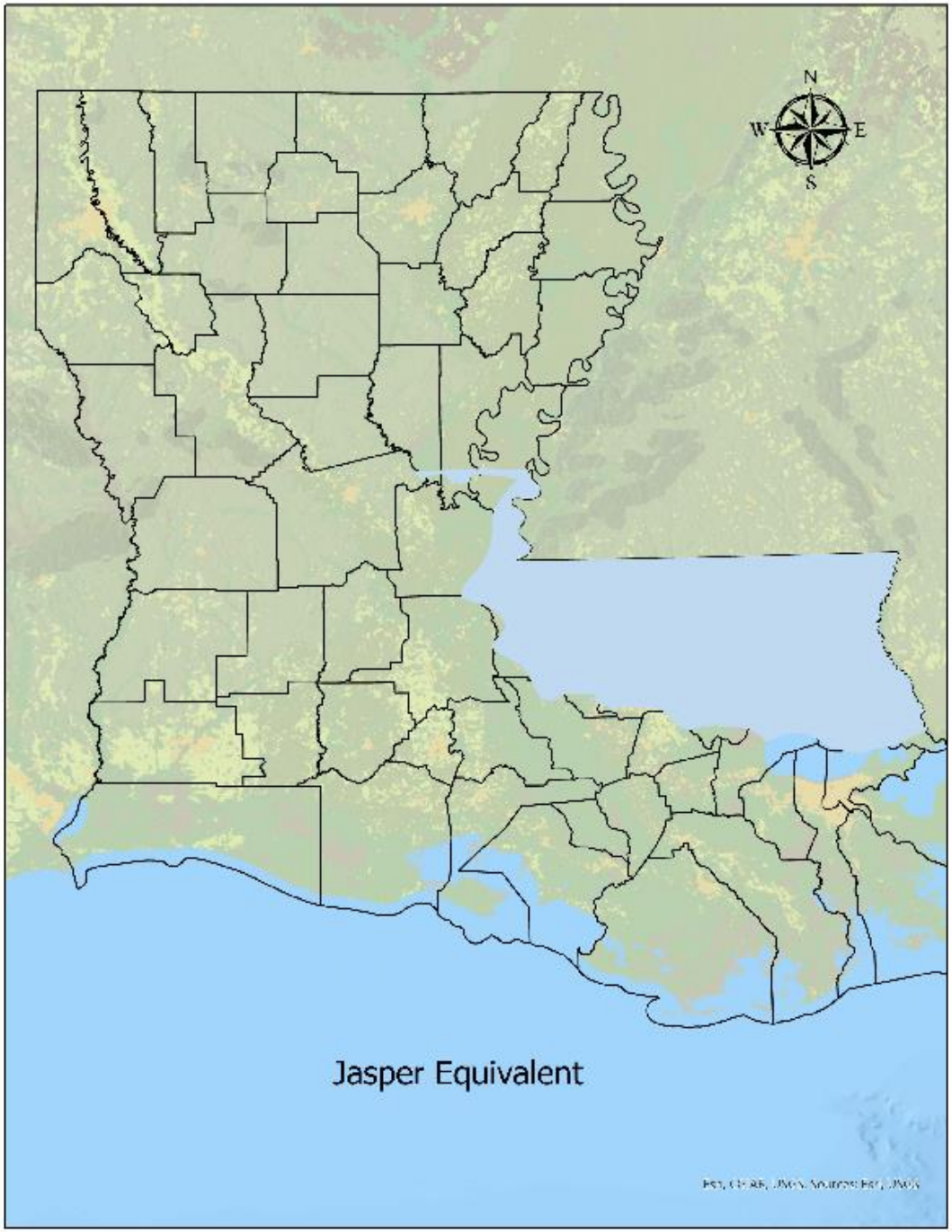


Figure 3. Generalized southwest-to-northeast hydrogeologic section through Rapides Parish, Louisiana (Tomaszewski, 2007). Trace of section shown on figure 1.

https://pubs.usgs.gov/fs/2009/3056/


N
W
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Jasper Equivalent

Jasper Equivalent

Southeastern Louisiana			
aquifer system or confining unit [1]	aquifer or confining unit [2]		
	Baton Rouge area	St. Tammany, Tangipahoa, and Washington Parishes	New Orleans area and lower Mississippi River Parishes [3]
Chicot equivalent aquifer system or surficial confining unit	Mississippi River alluvial aquifer or surficial confining unit Shallow sand "400-foot" sand "600-foot" sand	Upland terrace aquifer Upper Pontchatoula aquifer	Gramercy aquifer Norco aquifer Gonzales-New Orleans aquifer "1,200-foot" sand
Evangeline equivalent aquifer system or surficial confining unit	"800-foot" sand "1,000-foot" sand "1,200-foot" sand "1,500-foot" sand "1,700-foot" sand	Lower Pontchatoula aquifer Big Branch aquifer Kentwood aquifer Abita aquifer Covington aquifer Slidell aquifer	
unnamed confining unit	"2,000-foot" sand "2,400-foot" sand "2,800-foot" sand	Tchefuncte aquifer Hammond aquifer Amite aquifer Ramsay aquifer Franklinton aquifer	
Jasper equivalent aquifer or surficial confining unit			
unnamed confining unit			
Catahoula equivalent aquifer system or surficial confining unit			

Jasper Equivalent

- Sediments fine to coarse sand
- Thickness 1,200 – 2,300 feet
- Recharge from rainfall on surficial sands in southwest Mississippi and leakage from overlying aquifers
- Well depths 560 – 3,350 feet
- Water levels 40 als – 150 bls
- Pumping centers in Baton Rouge and Bogalusa
- Yields 200 – 3,400 gpm
- Primary uses industry and public supply

Jasper Equivalent Water Quality

- Soft and low iron concentration
- Generally requires little or no treatment
- Iron and manganese concentrations higher north of Independence and Abita Springs
- Amite aquifer locally contains hydrogen sulfide
- Deepest presence of freshwater in Louisiana – 3,500 feet in southeastern Tangipahoa parish

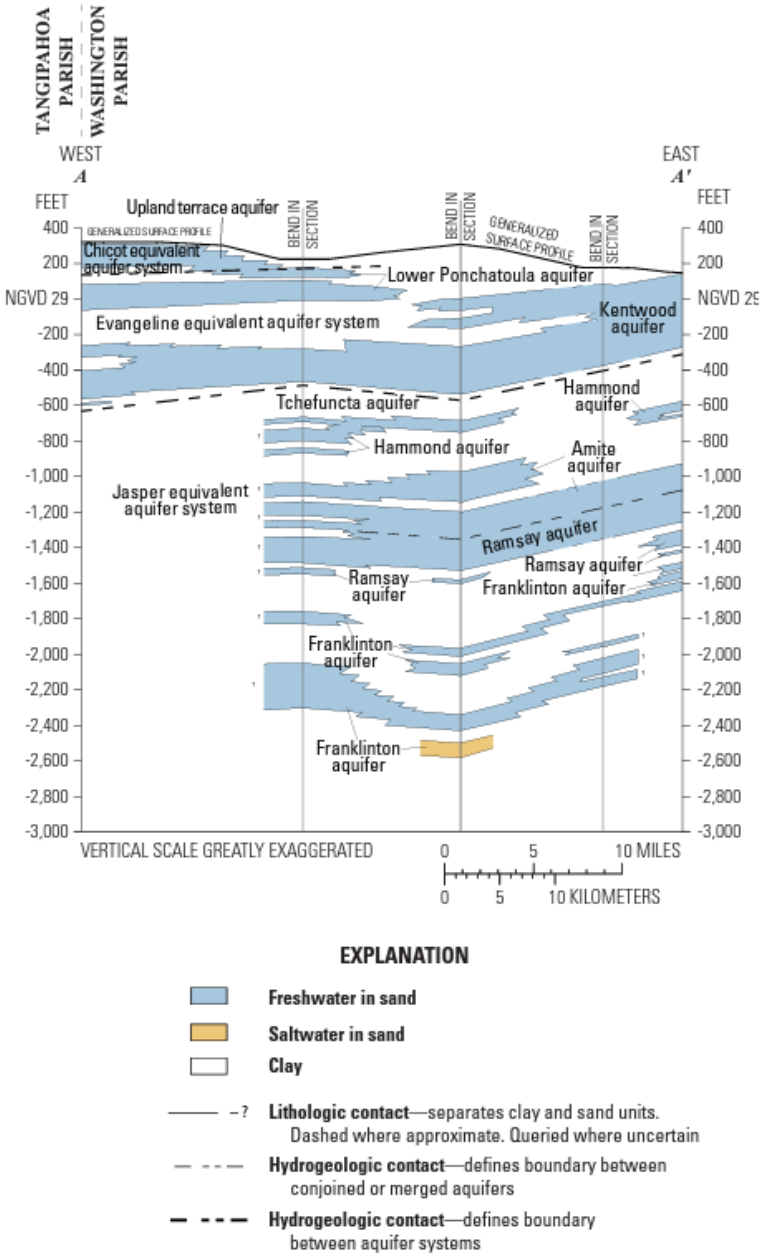

Figure 3. Generalized west-to-east hydrogeologic section through Washington Parish, Louisiana (modified from Griffith, 2003). Trace of section shown on figure 1.

Interbedded sands overlain by Evangeline Equivalent Aquifer System in Washington Parish

https://pubs.er.usgs.gov/publication/fs20153083
Washington Parish

Sands are interbedded and discontinuous from north to south in Tangipahoa Parish

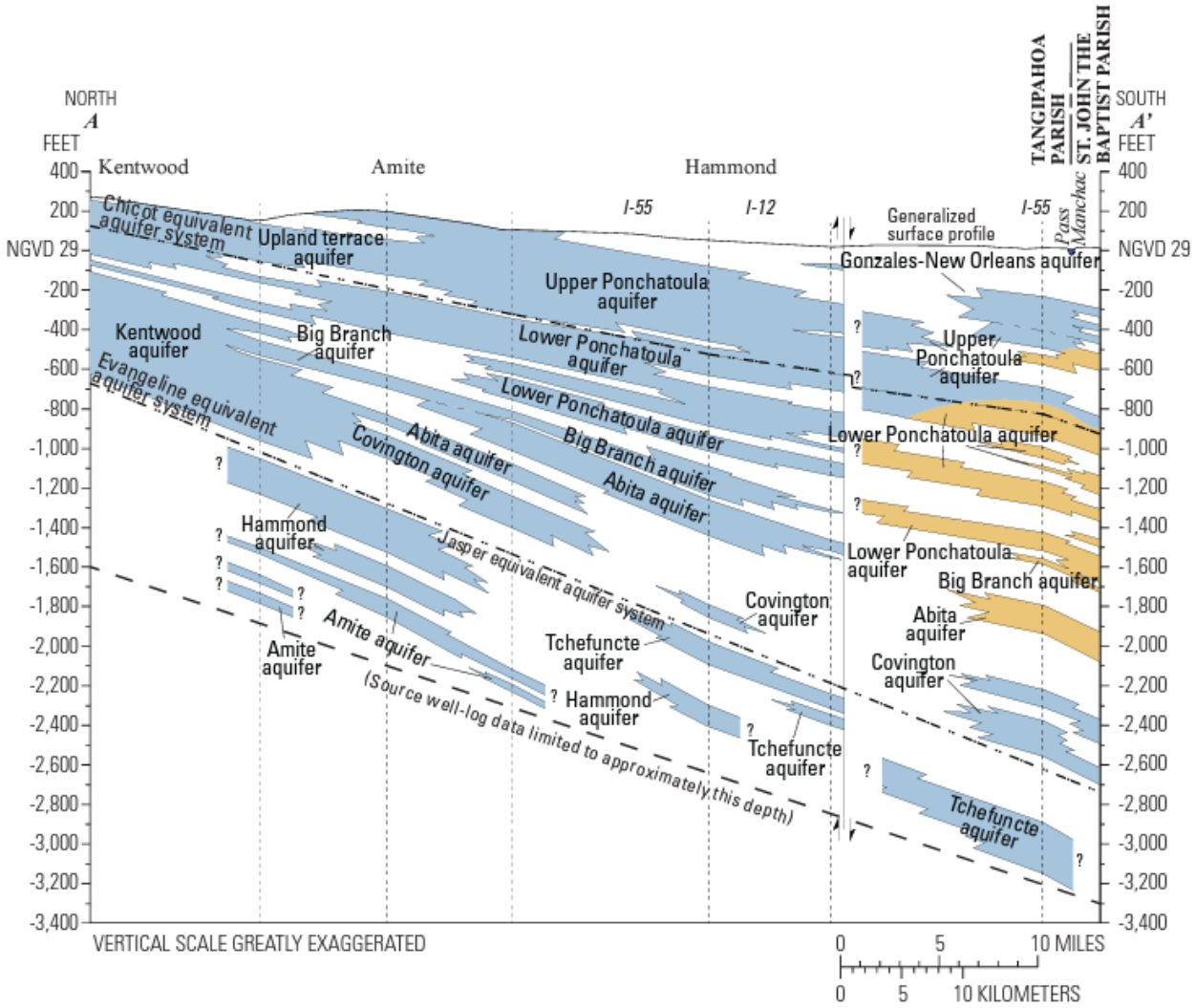

Figure 3. Generalized north-to-south hydrogeologic section through Tangipahoa Parish, Louisiana (modified from Griffith, 2003). Trace of section shown on figure 1.

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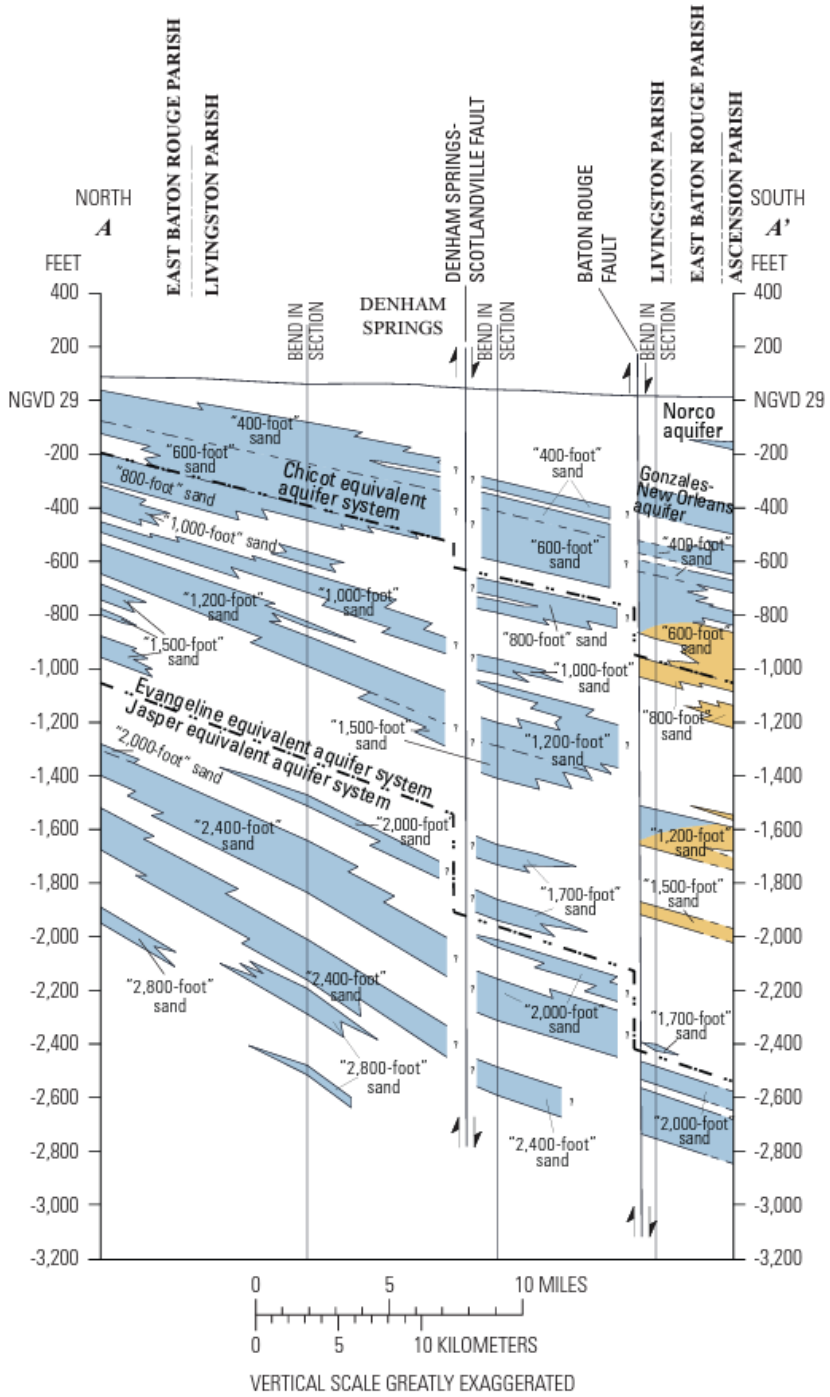
Tangipahoa Parish



Sands are interbedded and discontinuous from north to south from EBR through Livingston to Ascension Parishes. They are also offset by the DS-Scotlandville and BR faults

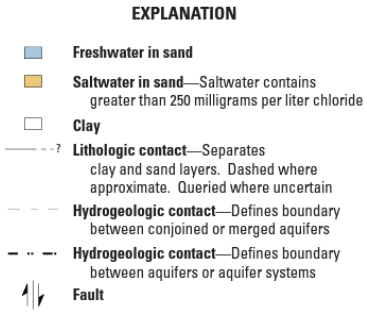


Figure 3. Generalized north-to-south hydrogeologic section through parts of western Livingston Parish, Louisiana (modified from Griffith, 2003). Trace of section shown on figure 1.

https://pubs.er.usgs.gov/publication/fs20163048

Livingston Parish


N
W
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Evangeline

Evangeline

- Sediments generally fine to medium sand, sand units separated by clay
- Thickness 50 – 1,900 feet, increases toward south and southeast, thickest in SE St. Landry
- Recharge from rainfall in Vernon, Avoyelles and Rapides parishes, leakage from Chicot in north Beauregard, leakage from underlying aquifers
- Well depths 100 – 2,400 feet
- Water levels generally <60 feet bls, locally affected by pumping from Chicot
- Yields 200 – 1,000 gpm; large capacity 3,000 gpm
- Primary use public supply

Evangeline Water Quality

- Generally soft with low iron concentrations
- Iron generally <0.2 mg/L
- Suitable for use with little or no treatment
- Local presence of high color, fluoride, iron
- Freshwater section 50 – 1,900 feet thick

Outcrop in Vernon Parish and overlain by the Chicot Aquifer to the south in Beauregard and Calcasieu Parishes

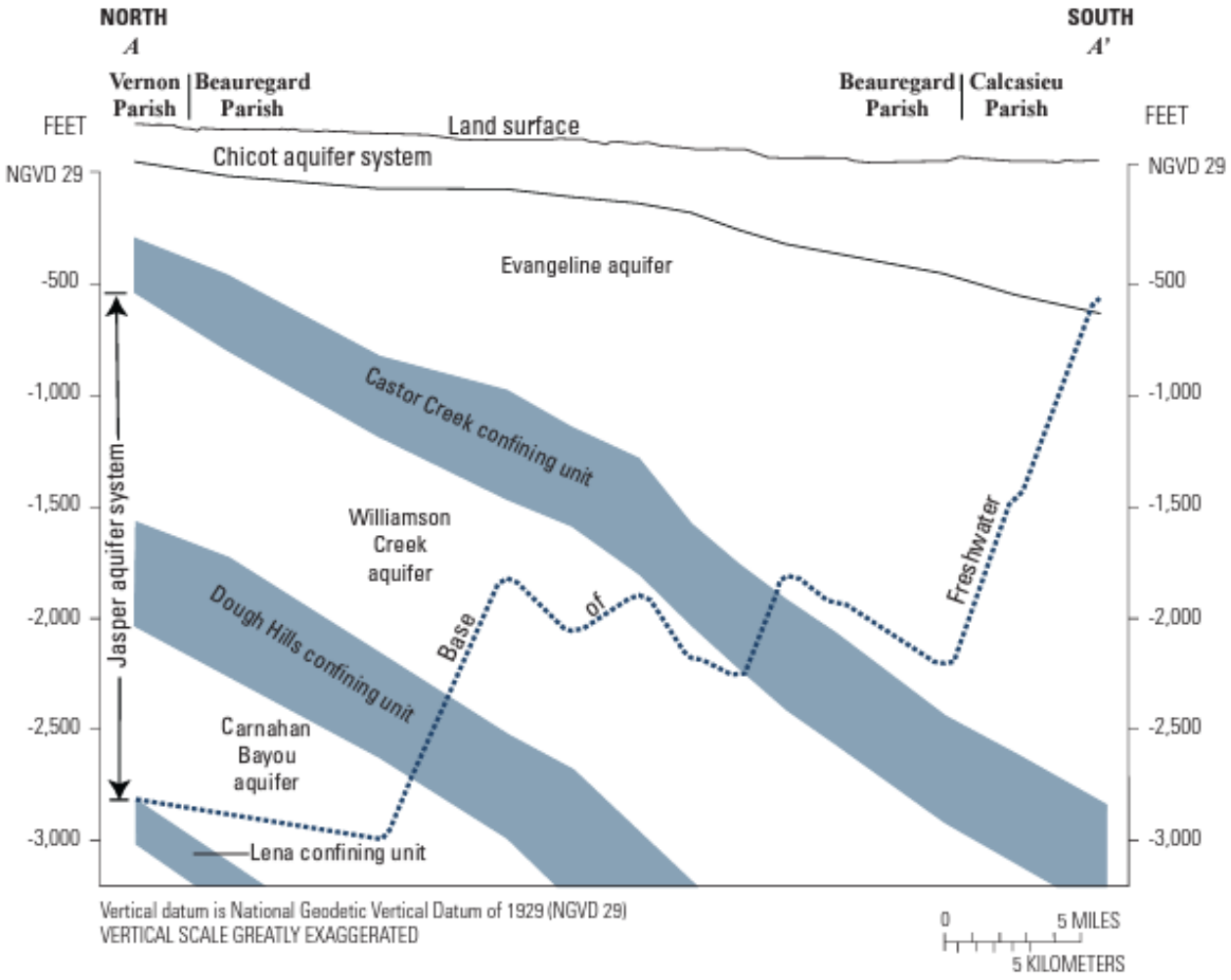

Figure 3. Generalized north-to-south hydrogeologic section showing aquifer and confining unit intervals (individual sand and clay layers not shown) from Vernon Parish to Calcasieu Parish, Louisiana (modified from Whitfield, 1975, plate 3). Trace of section shown on figure 1.

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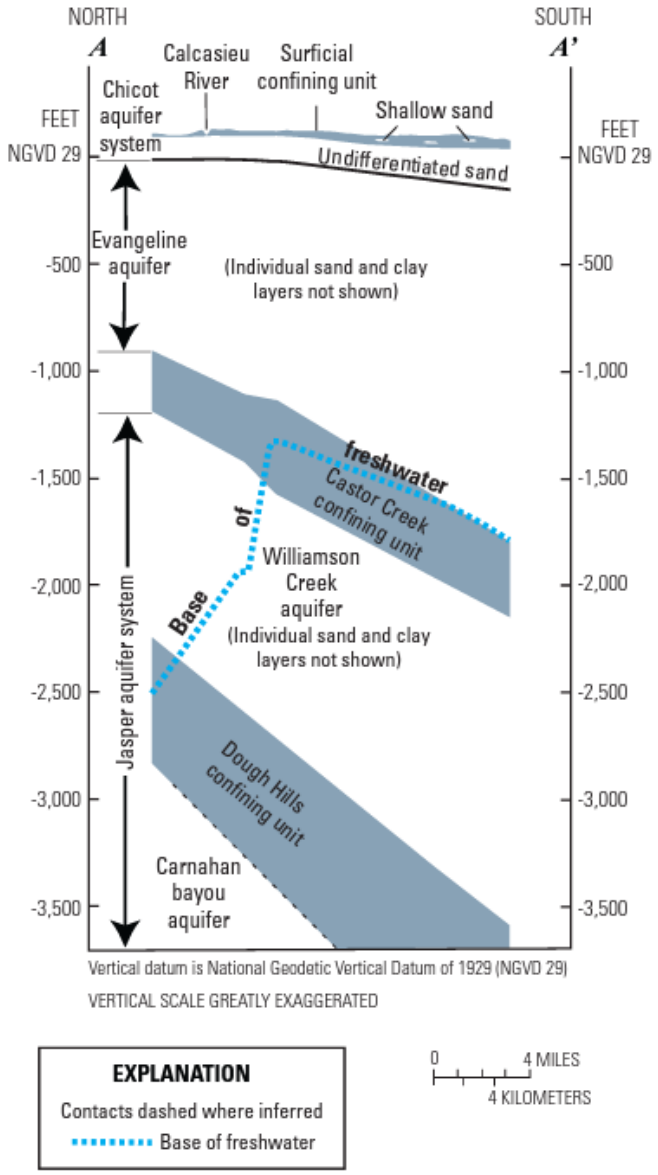

Figure 3. Generalized north-to-south hydrogeologic section through Allen Parish, Louisiana, showing aquifer and confining unit intervals (modified from Whitfield, 1975, pl. 4). Trace of section is shown on figure 1.

Allen Parish – overlain by undifferentiated shallow sands; generally base of fresh water in middle to southern portion of the parish

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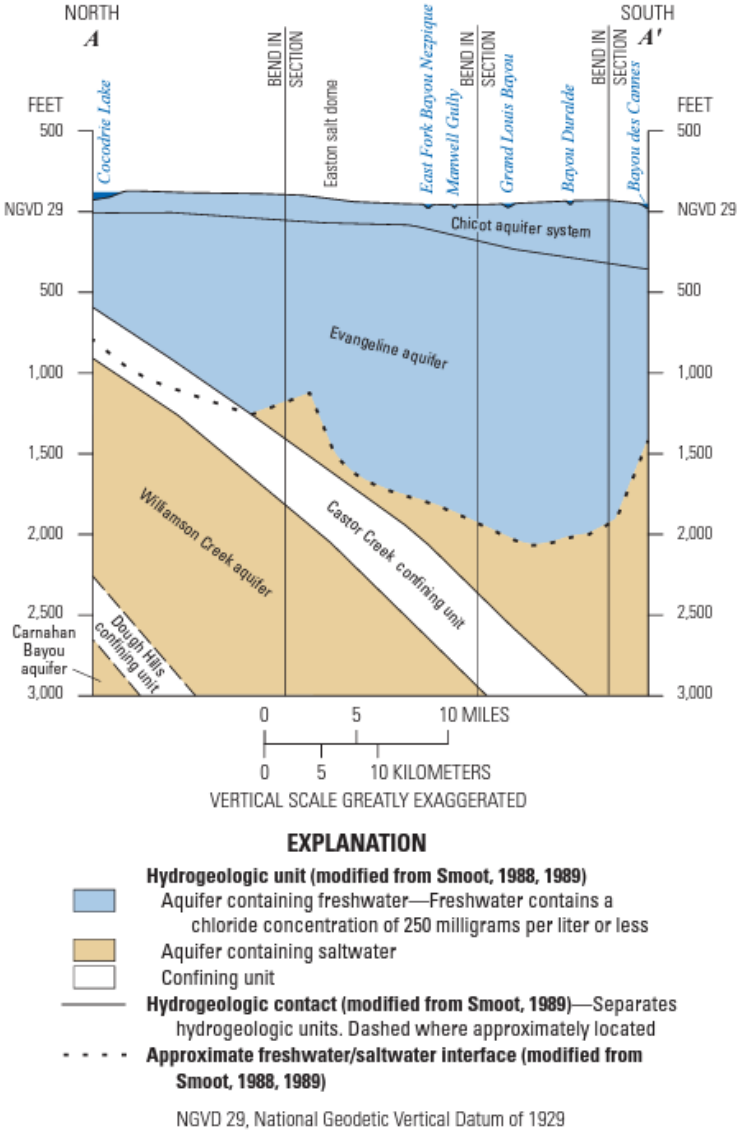

Figure 3. Idealized north-to-south hydrogeologic section through Evangeline Parish, Louisiana, showing aquifer and confining unit intervals (individual sand and clay layers not shown). Modified from Smoot (1988, 1989). Trace of section shown on figure 1.

Overlain by Chicot Aquifer in Evangeline Parish

https://pubs.er.usgs.gov/publication/fs20203020


N
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Evangeline Equivalent

Evangeline Equivalent

Southeastern Louisiana			
aquifer system or confining unit [1]	aquifer or confining unit [2]		
	Baton Rouge area	St. Tammany, Tangipahoa, and Washington Parishes	New Orleans area and lower Mississippi River Parishes [3]
Chicot equivalent aquifer system or surficial confining unit	Mississippi River alluvial aquifer or surficial confining unit Shallow sand "400-foot" sand "600-foot" sand	Upland terrace aquifer Upper Pontchatoula aquifer	Gramercy aquifer Norco aquifer Gonzales-New Orleans aquifer "1,200-foot" sand
Evangeline equivalent aquifer system or surficial confining unit	"800-foot" sand "1,000-foot" sand "1,200-foot" sand "1,500-foot" sand "1,700-foot" sand	Lower Pontchatoula aquifer Big Branch aquifer Kentwood aquifer Abita aquifer Covington aquifer Slidell aquifer	
unnamed confining unit Jasper equivalent aquifer or surficial confining unit unnamed confining unit	"2,000-foot" sand "2,400-foot" sand "2,800-foot" sand	Tchefuncte aquifer Hammond aquifer Amite aquifer Ramsay aquifer Franklinton aquifer	
Catahoula equivalent aquifer system or surficial confining unit			

Evangeline Equivalent

- Sediments fine – medium sand
- Thickness 50 – 1,000 feet
- Recharge from rainfall on surficial sands in south-central and SW Mississippi
- Well depths 300 – 2,000 feet
- Water levels 80 ft als to 120 feet bls, generally >25 ft als; in BR >80 feet bls
- Yields 200 – 4,000 gpm
- Primary use is public supply
- Water generally moves southward

Evangeline Equivalent Water Quality

- Soft
- Iron concentrations from 0.01 – 2.2 mg/L
- Highest iron in eastern quarter and west central area
- Requires little to no treatment
- Saltwater encroachment in 1,500-foot sand in BR
- Local occurrence of hydrogen sulfide in St. Tammany, Tangipahoa, and Washington parishes

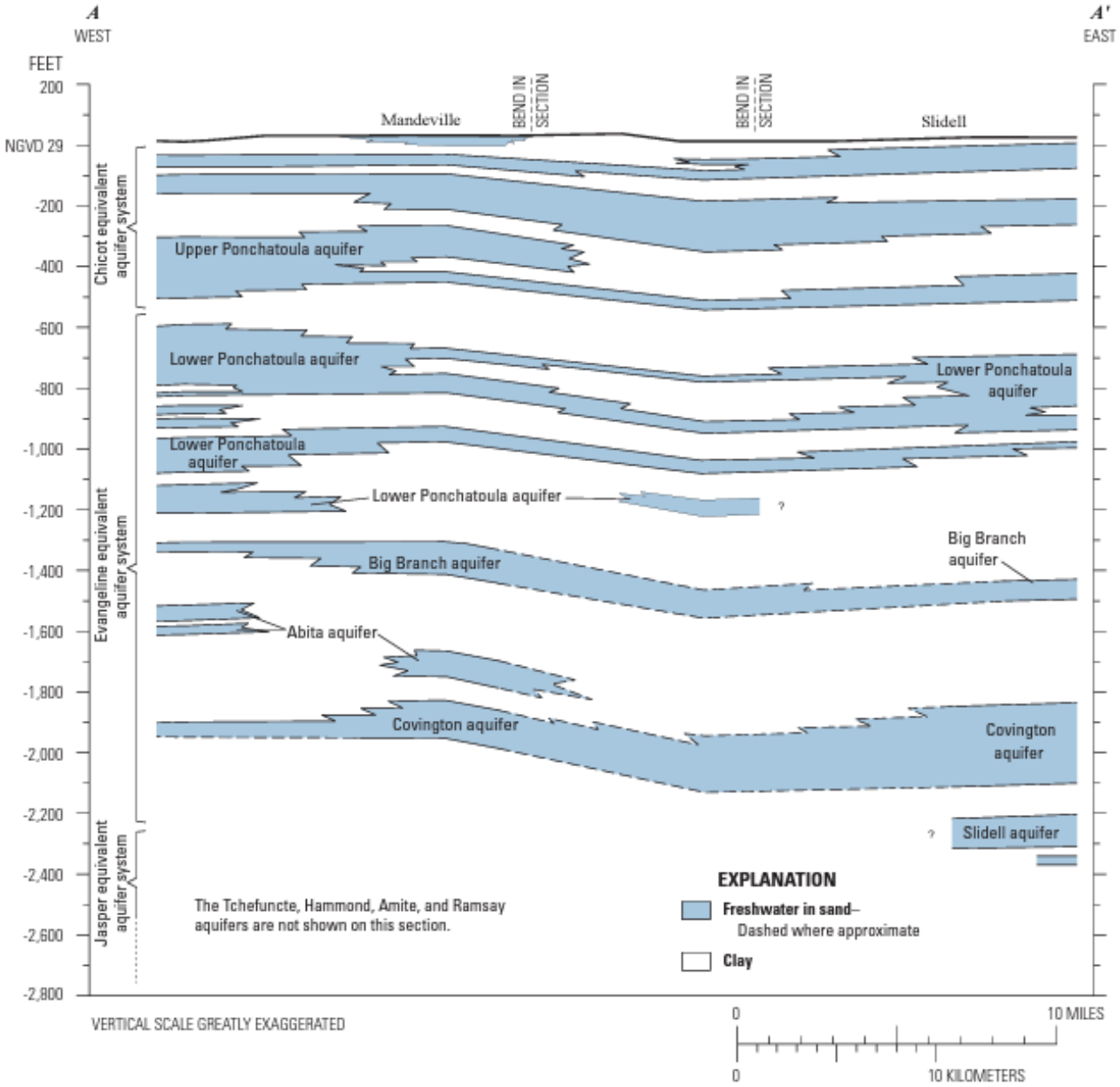


Figure 3. Generalized west-to-east hydrogeologic section through St. Tammany Parish, Louisiana (Griffith, 2003). Trace of section shown on figure 1.

Sands are discontinuous and interbedded with clay in St. Tammany Parish

https://pubs.er.usgs.gov/publication/fs20093064

St. Tammany Parish

Sands are interbedded and discontinuous from north to south in Tangipahoa Parish to SJB Parish. Most units contain saltwater south of Hammond and the fault.

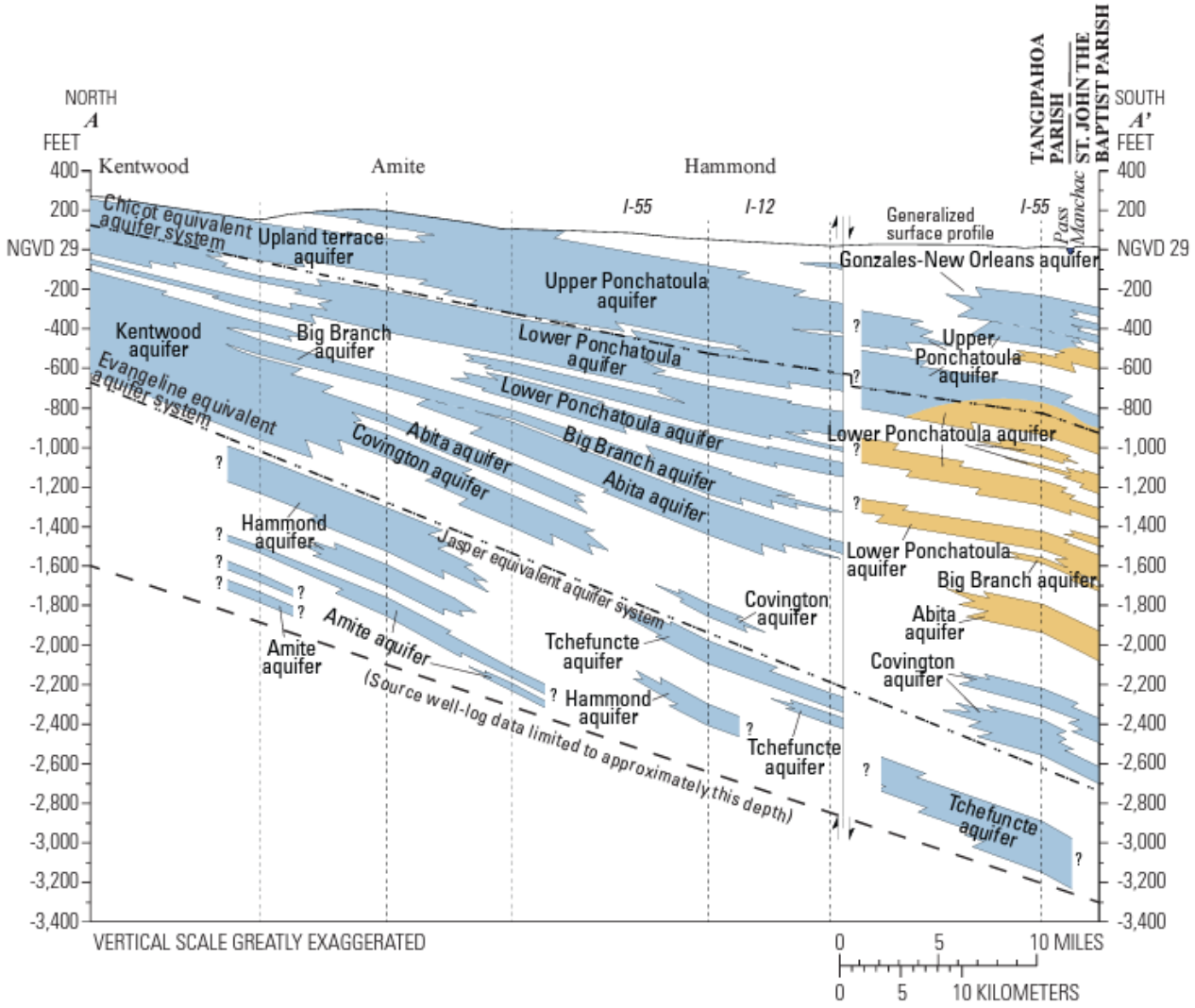
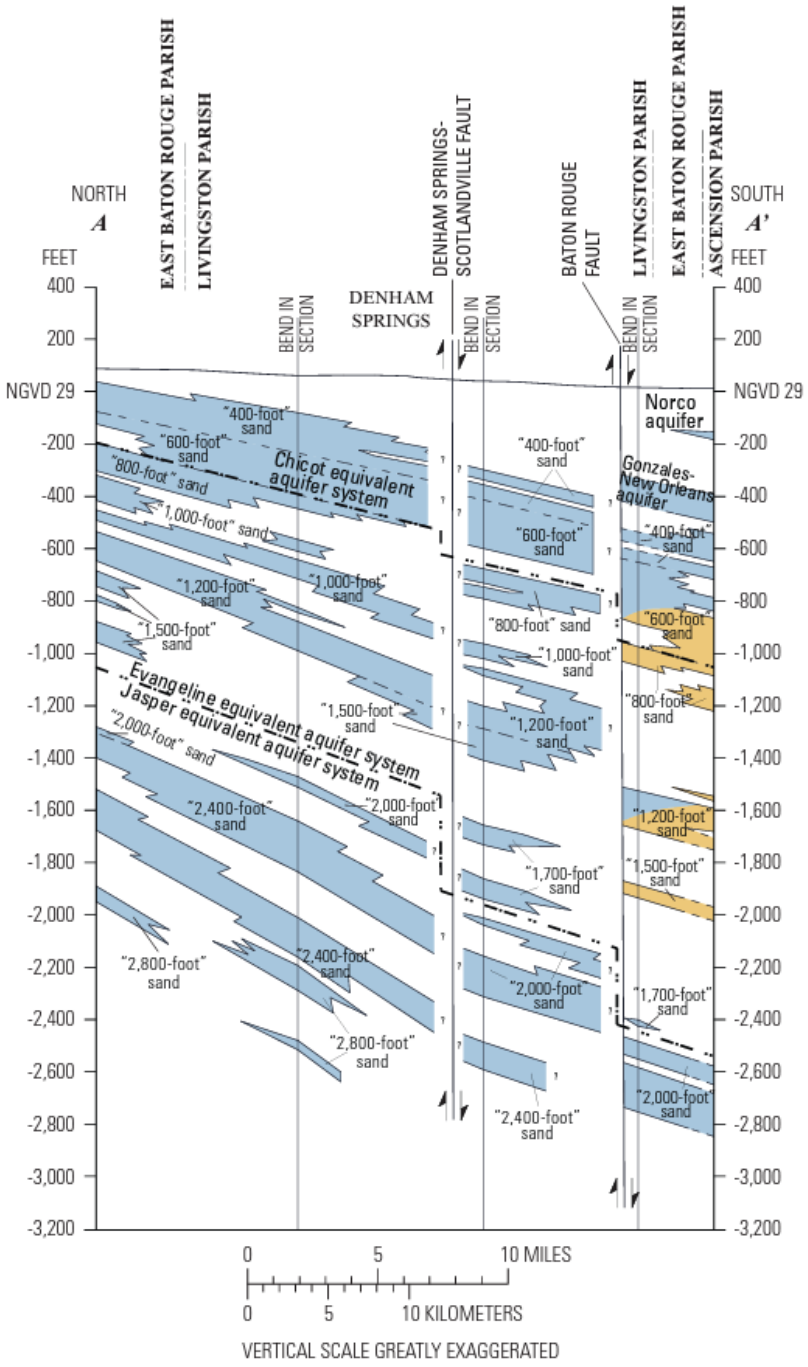


Figure 3. Generalized north-to-south hydrogeologic section through Tangipahoa Parish, Louisiana (modified from Griffith, 2003). Trace of section shown on figure 1.

https://pubs.er.usgs.gov/publication/fs20163049

Tangipahoa Parish



Sands are interbedded and discontinuous from EBR Parish to south in Ascension Parish. They are also offset by the DS-Scotlandville and BR faults. Most units contain saltwater south of Livingston and the fault.

EXPLANATION

- **Freshwater in sand**
- **Saltwater in sand**—Saltwater contains greater than 250 milligrams per liter chloride
- **Clay**
- **Lithologic contact**—Separates clay and sand layers. Dashed where approximate. Queried where uncertain
- **Hydrogeologic contact**—Defines boundary between conjoined or merged aquifers
- **Hydrogeologic contact**—Defines boundary between aquifers or aquifer systems
- **Fault**

Figure 3. Generalized north-to-south hydrogeologic section through parts of western Livingston Parish, Louisiana (modified from Griffith, 2003). Trace of section shown on figure 1.

https://pubs.er.usgs.gov/publication/fs20163048

Livingston Parish


N
W
E
S
Chicot

Chicot

- Coarse sand and gravel
- Thickness 50 – 1,050 feet, increase to south
- Recharge from rainfall in Allen and Beauregard parishes, leakage from overlying and underlying aquifers
- Well depths 20 – 1,100 feet, avg 290 feet
- Water levels slightly bls to 100 feet bls, generally 25 – 75 feet bls
- Yields 500 – 2,500 gpm, large capacity wells 4,000 gpm, most heavily pumped aquifer in state
- Primary use irrigation, sole source for public supply
- Water movement generally to south, pumping centers in Acadia, Jeff Davis, Vermilion, Calcasieu

Chicot Water Quality

- Hardness 20 – 270 mg/L (soft to very hard)
- Softer in recharge area and deeper units to south, harder in central and southeastern areas
- Iron >1.0 mg/L
- Saltwater in basal part of aquifer in southern Cameron, SW Vermilion, SE St. Mary parishes
- Most suitable for irrigation – important for agriculture and aquaculture in acadiana

Calcasieu Parish – 200-, 500-, and 700-foot sands interbedded with clay

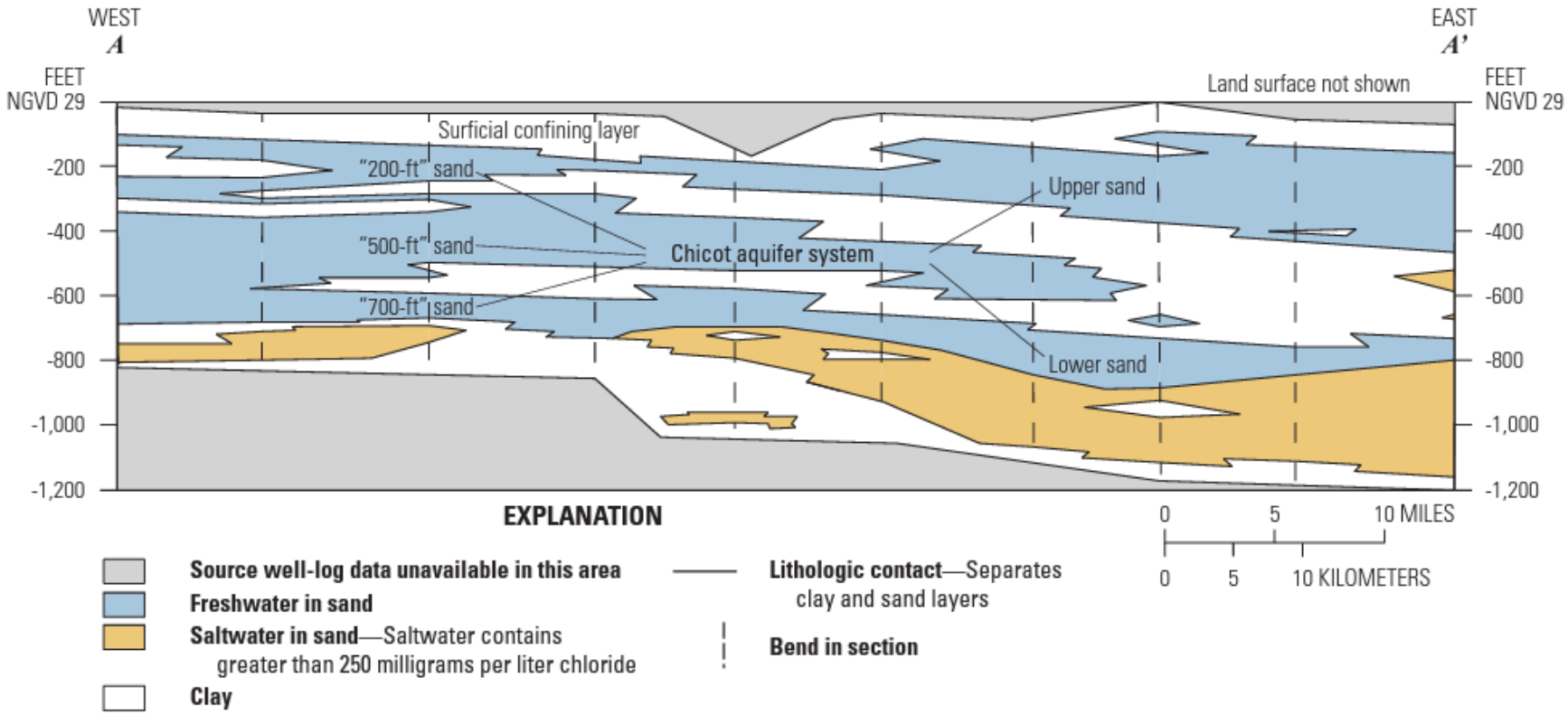


Figure 3. Generalized west-to-east hydrogeologic section A–A' through Calcasieu Parish, Louisiana (modified from Nyman, 1984). Trace of section shown on figure 1.

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Lafayette Parish – Upper and Lower sands with less clay interbedding

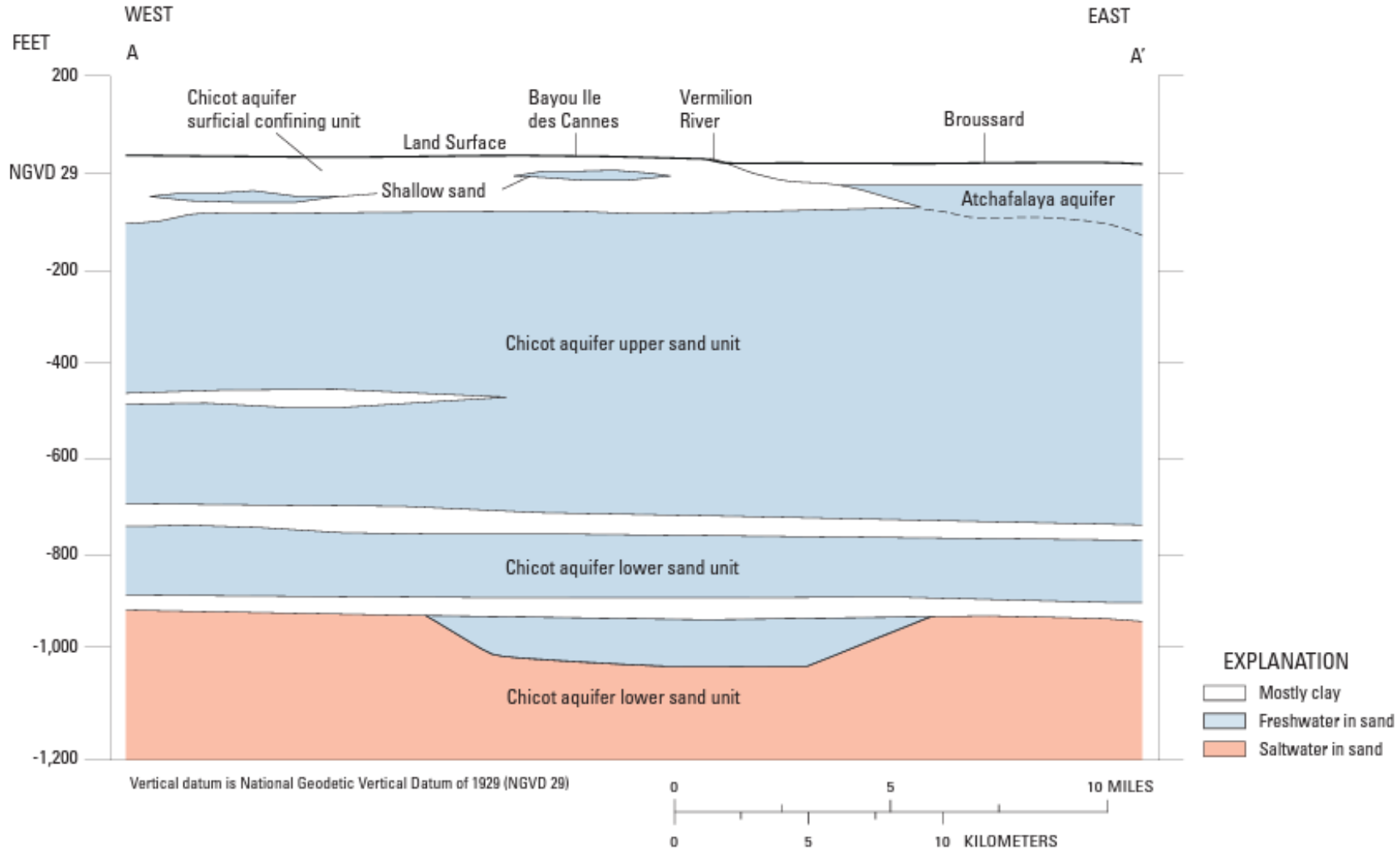


Figure 3. Generalized west-to-east hydrogeologic section through Lafayette Parish, La. (modified from Lovelace, 1999). Trace of section shown on figure 1.

https://pubs.er.usgs.gov/publication/fs20103048


N
W
E
S
Chicot Equivalent

Chicot Equivalent

Southeastern Louisiana			
aquifer system or confining unit [1]	aquifer or confining unit [2]		
	Baton Rouge area	St. Tammany, Tangipahoa, and Washington Parishes	New Orleans area and lower Mississippi River Parishes [3]
Chicot equivalent aquifer system or surficial confining unit	Mississippi River alluvial aquifer or surficial confining unit Shallow sand "400-foot" sand "600-foot" sand	Upland terrace aquifer Upper Pontchatoula aquifer	Gramercy aquifer Norco aquifer Gonzales-New Orleans aquifer "1,200-foot" sand
Evangeline equivalent aquifer system or surficial confining unit	"800-foot" sand "1,000-foot" sand "1,200-foot" sand "1,500-foot" sand "1,700-foot" sand	Lower Pontchatoula aquifer Big Branch aquifer Kentwood aquifer Abita aquifer Covington aquifer Slidell aquifer	
unnamed confining unit	"2,000-foot" sand "2,400-foot" sand "2,800-foot" sand	Tchefuncte aquifer Hammond aquifer Amite aquifer Ramsay aquifer Franklinton aquifer	
Jasper equivalent aquifer or surficial confining unit			
unnamed confining unit			
Catahoula equivalent aquifer system or surficial confining unit			

Chicot Equivalent

- Sediments fine to coarse sand and gravel
- Thickness 50 – 1,100 feet, increases to south
- Recharge from rainfall along LA-MS state line
- Leakage from surficial sands and underlying aquifers
- Well depths 60 – 1,000 feet
- Water levels above land surface to 260 feet bls, generally 50 – 100 feet bls
- Yields 500 – 1,000 gpm, large capacity wells 3,500 gpm
- Primary use industrial
- Water generally moves southward

Chicot Equivalent Water Quality

- Soft, low dissolved solids
- Local presence of iron in 400- and 600-foot sands
- Local presence of saltwater and color
- Excellent for drinking water purpose
- Saltwater moves northward across BR fault into 600-foot sand
- 1,200-foot sand in New Orleans area is saline

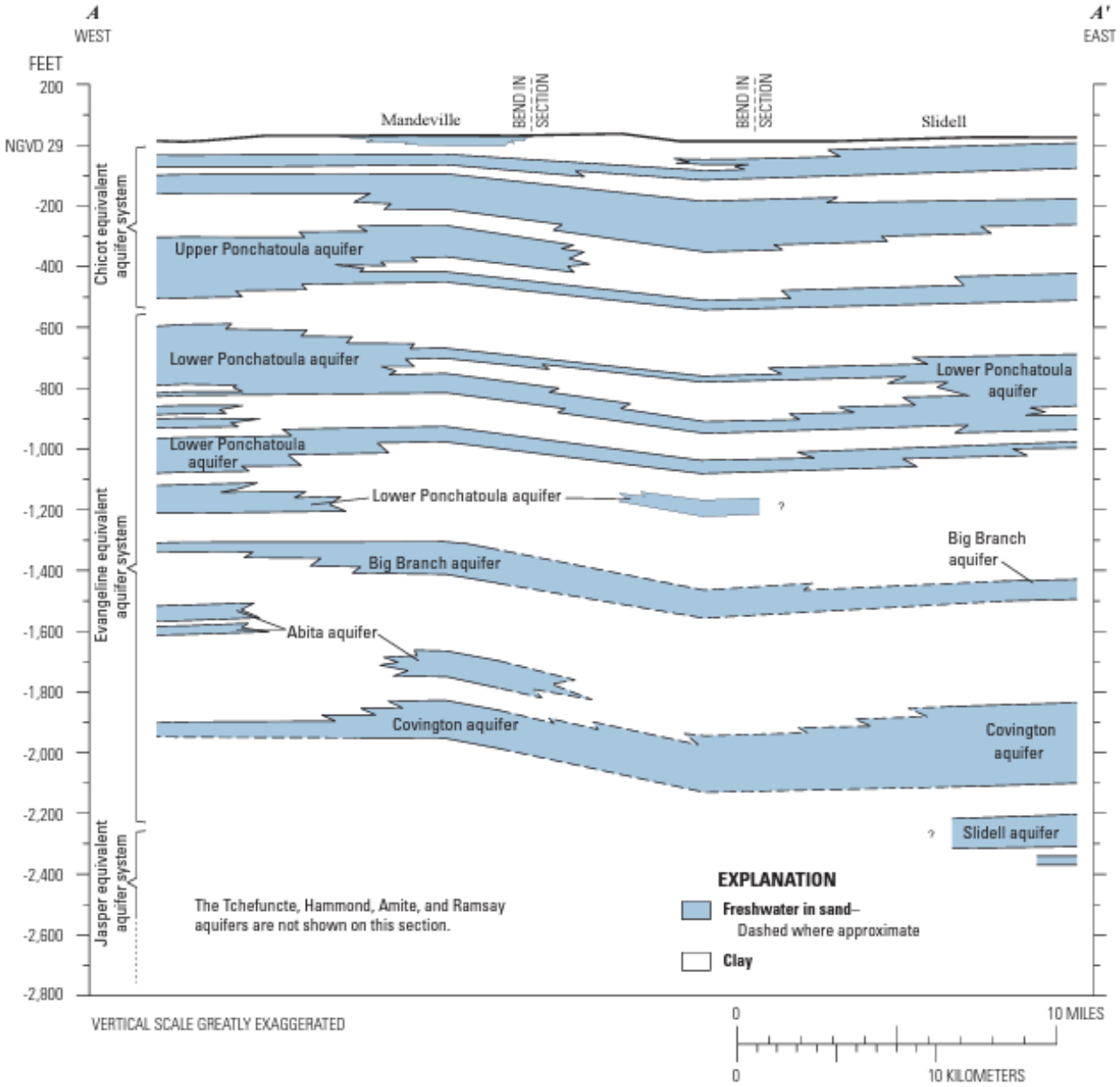


Figure 3. Generalized west-to-east hydrogeologic section through St. Tammany Parish, Louisiana (Griffith, 2003). Trace of section shown on figure 1.

Sands are discontinuous and interbedded with clay in St. Tammany Parish

https://pubs.er.usgs.gov/publication/fs20093064

St. Tammany Parish

Sands are interbedded and discontinuous from north to south in Tangipahoa Parish to SJB Parish

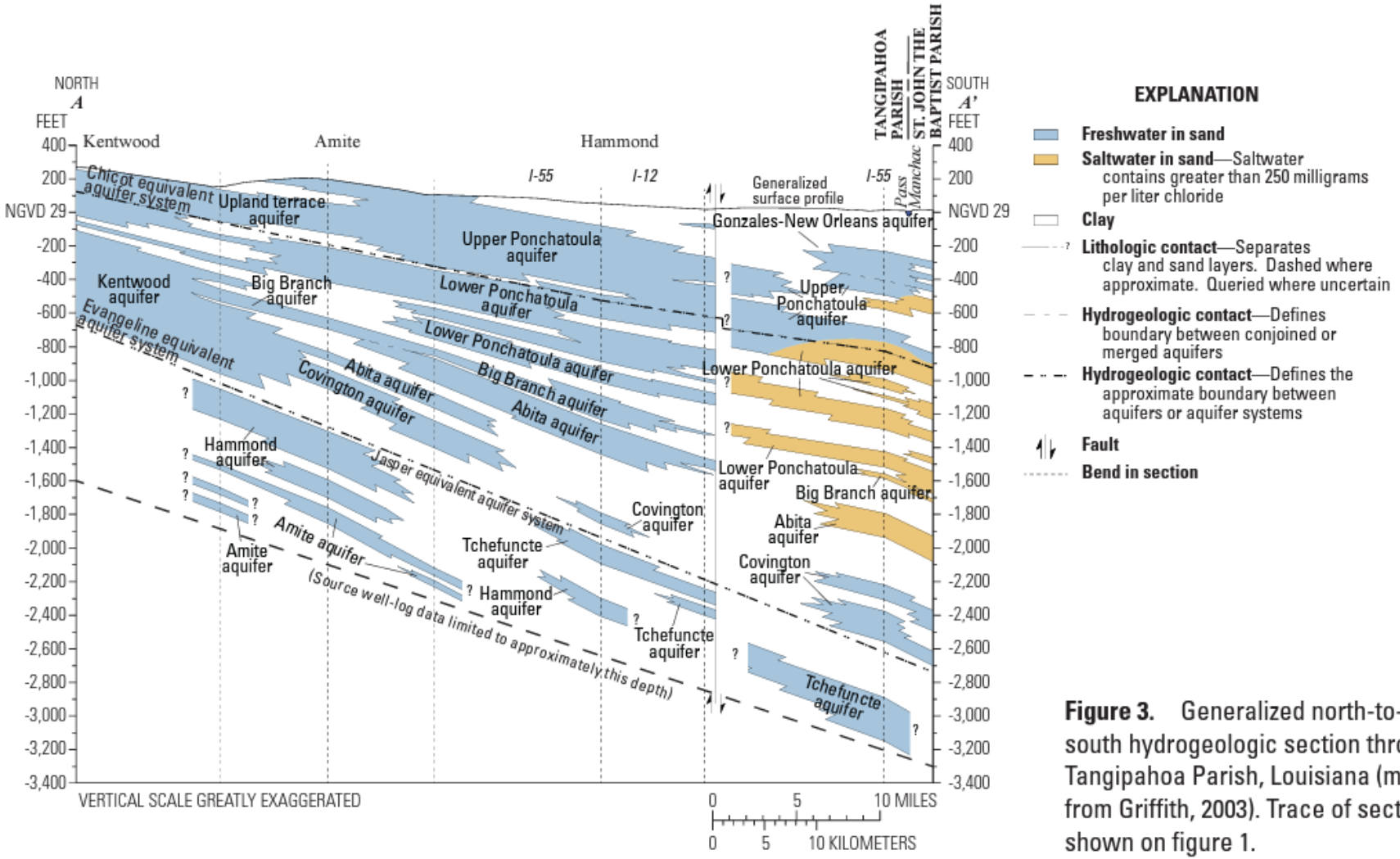
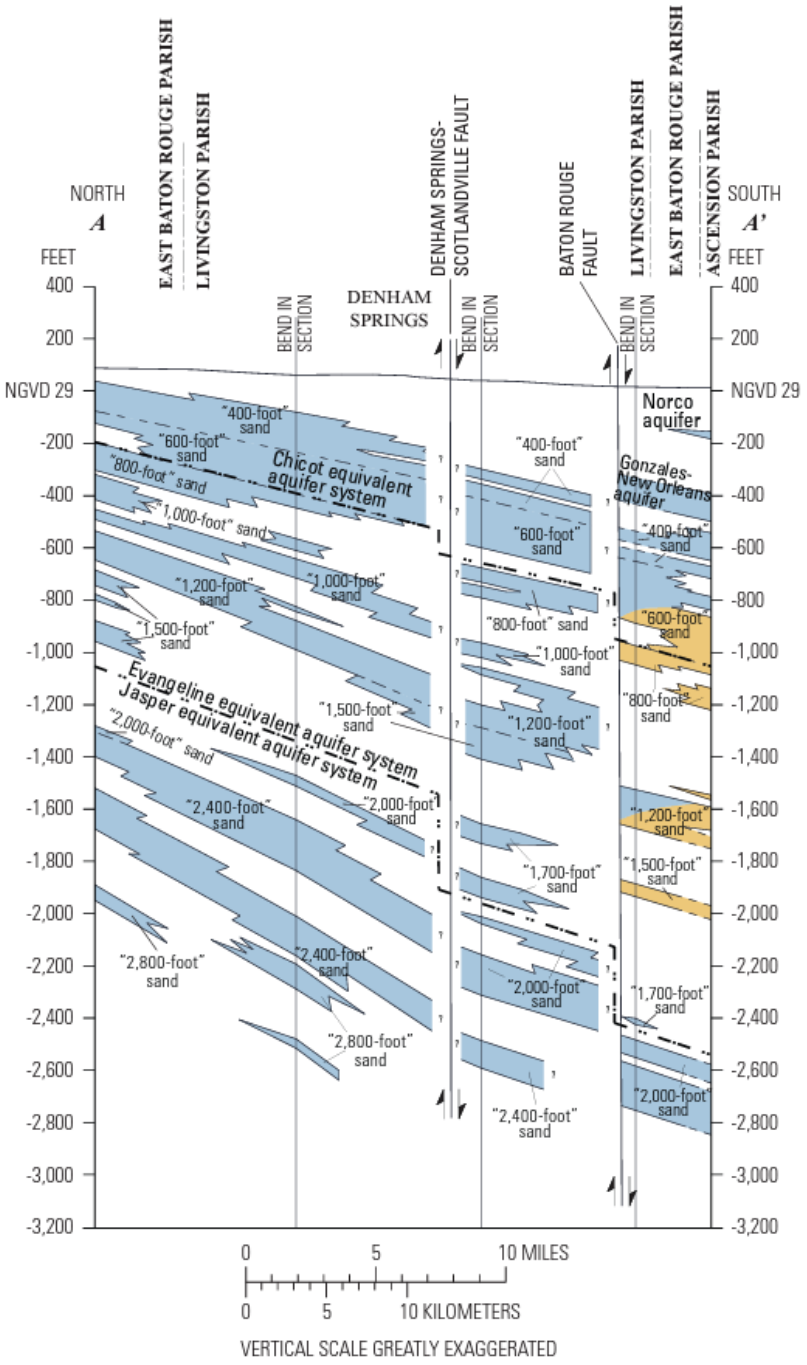


Figure 3. Generalized north-to-south hydrogeologic section through Tangipahoa Parish, Louisiana (modified from Griffith, 2003). Trace of section shown on figure 1.

https://pubs.er.usgs.gov/publication/fs20163049
Tangipahoa Parish



Sands are interbedded and discontinuous from EBR Parish to south in Ascension Parish. They are also offset by the DS-Scotlandville and BR faults.

EXPLANATION

- **Freshwater in sand**
- **Saltwater in sand**—Saltwater contains greater than 250 milligrams per liter chloride
- **Clay**
- **Lithologic contact**—Separates clay and sand layers. Dashed where approximate. Queried where uncertain
- **Hydrogeologic contact**—Defines boundary between conjoined or merged aquifers
- **Hydrogeologic contact**—Defines boundary between aquifers or aquifer systems
- **Fault**

Figure 3. Generalized north-to-south hydrogeologic section through parts of western Livingston Parish, Louisiana (modified from Griffith, 2003). Trace of section shown on figure 1.

https://pubs.er.usgs.gov/publication/fs20163048

Livingston Parish


N
W
E
S
North Louisiana Terrace

North Louisiana Terrace (Upland Terrace)

- Sediments clay, silt, fine sand grading to coarse sand and gravel at bottom
- Thickness 25 – 240 feet, increasing to south
- Recharge from rainfall on surficial sediments, leakage from underlying aquifers
- Well depths 20 – 150 feet => shallow wells
- Water levels near land surface to 80 feet bls; avg 40 feet bls, fluctuate seasonally, long term trends relate to rainfall trends, 2 feet south-central; 10 feet north-central
- Yields 100 – 1,700 gpm
- Primary uses public supply, industry

N LA Terrace Water Quality

- Soft, generally <60 mg/L
- Low iron concentrations, <0.3 mg/L
- Water is corrosive due to low pH
- Local occurrence of saltwater, iron, hardness

Overlies Carnahan Bayou and Catahoula Aquifers in Grant Parish

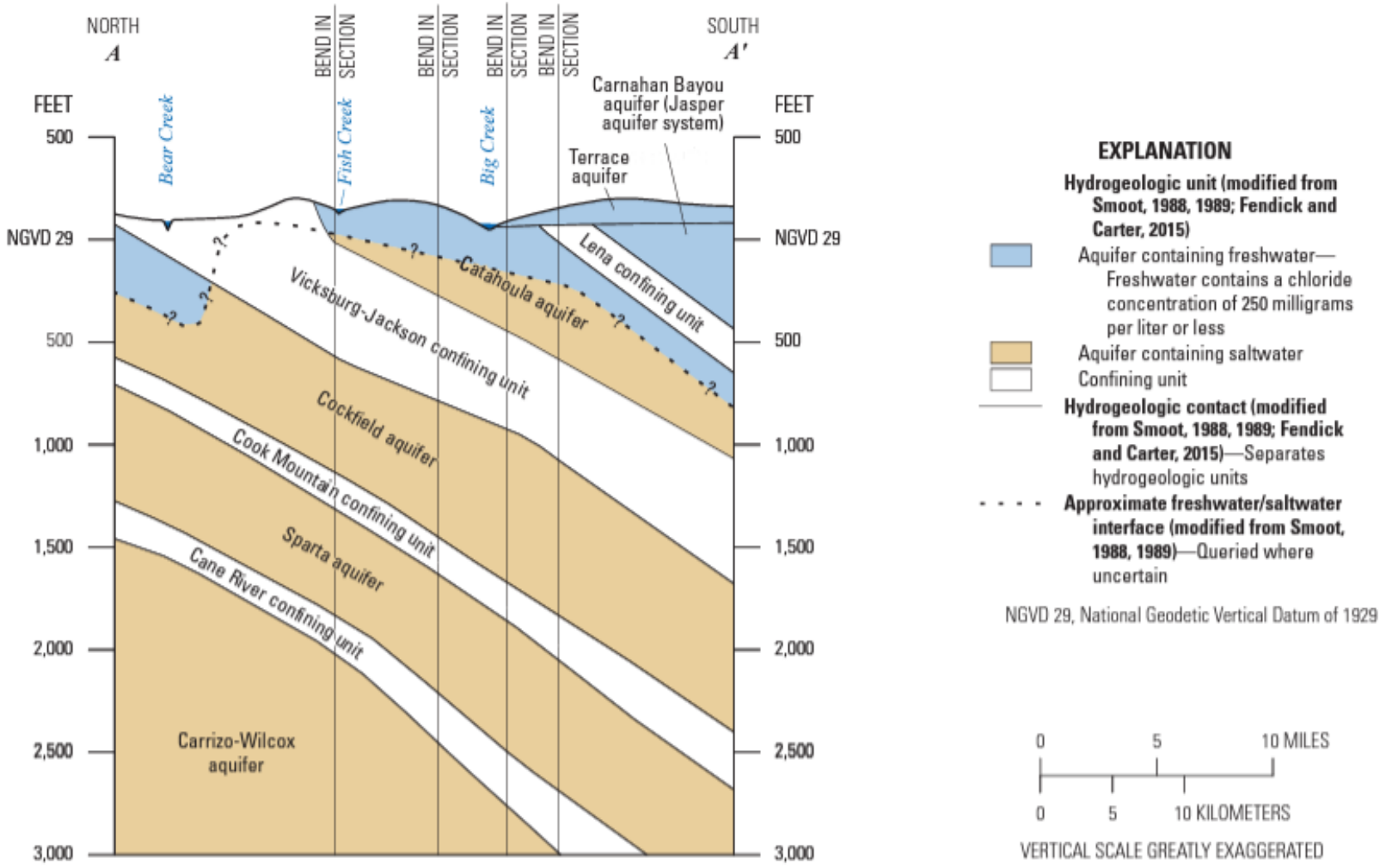


Figure 3. Idealized north-to-south hydrogeologic section through Grant Parish, Louisiana, showing aquifer and confining layer intervals (individual sand and clay layers not shown; Smoot, 1989). Trace of section shown on figure 1.

https://pubs.er.usgs.gov/publication/fs20203064


N
W
E
S
Mississippi River Alluvial Aquifer

Mississippi River Alluvial

- Sediments sand and gravel, fining upward
- Confined by overlying fine sand, silt, clay (0 - 150 ft thick)
- Thickness 50 – 500 feet, increases to SE
- Recharge from rainfall on entire surface, leakage from underlying aquifers, locally from MS River near pumping centers
- Well depths 100 – 350 feet, average 116 feet
- Water levels typically <30 feet bls
- Yields 500 – 4,000 gpm, large capacity wells 7,000 gpm…largest yields in the state

Mississippi River Alluvial (cont.)

- Water generally moves southward
- Some discharge into major streams
- Primary use irrigation
- Largest source of fresh ground water in northeastern LA and in a large part, the only source

MRAA Water Quality

- Generally high hardness and concentrations of iron
  - Hardness 44 – 480 mg/L
  - Iron concentrations 0.02 – 15 mg/L, generally >1.0 mg/L
- Water requires treatment for hardness and iron for domestic and public supply use
- Freshwater generally occurs throughout extent; local areas of saltwater
- Dissolved metals including arsenic detected in localized areas


N
W
E
S
Red River Alluvial

Red River Alluvial

- Sediments clay, silt, fine sand grading to coarse sand and gravel the bottom
- Thickness 50 – 200 feet, increasing downstream
- Recharge from rainfall on fine-grained surficial sediments, leakage from underlying aquifers
- Well depths 100 – 250 feet
- Water levels generally <30 feet bls, fluctuate seasonally, larger fluctuations near streams
- Yields 500 – 2,800 gpm
- Primary use aquaculture
- Largest source of fresh groundwater in RR Valley

Red River Alluvial Water Quality

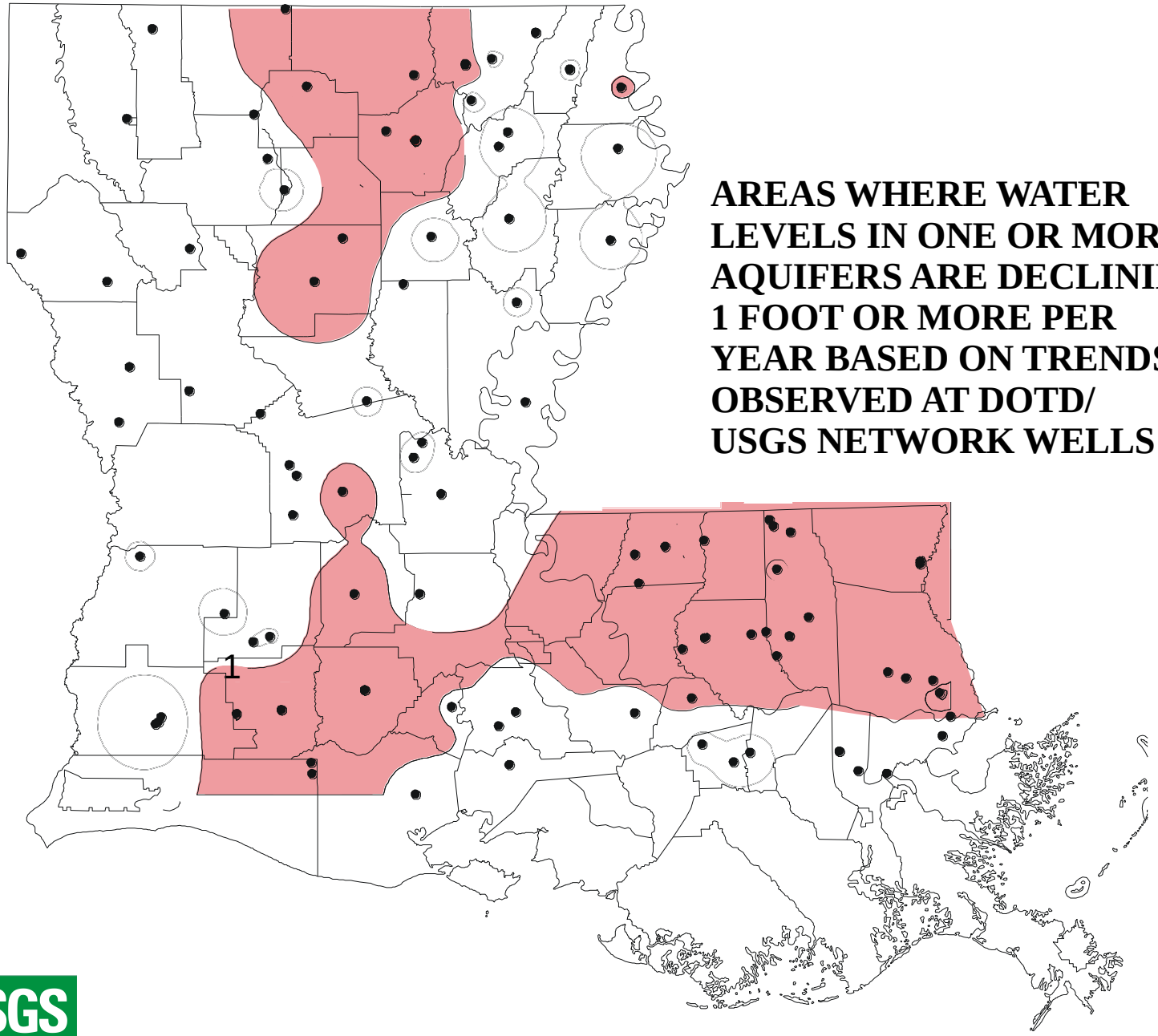
- Hard to very hard, 100 – 2,300 mg/L
- High iron concentrations, generally >1.0 mg/L
- Chloride generally < 50 mg/L
- Local areas of saltwater
- Treatment required for most uses
- Dissolved metals including arsenic detected in localized areas

Sole Source Aquifers

- EPA may designate an aquifer as the “sole or principal source” of drinking water for an area if it supplies more than 50% of the drinking water for that area and there are no other reasonably available alternative sources if the aquifer becomes contaminated
- Chicot and Southern Hills Aquifer systems are sole source aquifers covering 25 parishes
- Designation protects groundwater resource through EPA review of projects which are proposed for federal financial assistance (such as loans, grants, loan guarantees, etc.)

Water Level Declines

- Ground-water **withdrawals** are lowering water levels in Louisiana aquifers.
- In certain areas, these withdrawals are creating conditions favorable for saltwater encroachment.
- Major aquifers affected are the Sparta, Chicot, and Southern Hills aquifer systems.



AREAS WHERE WATER LEVELS IN ONE OR MORE AQUIFERS ARE DECLINING 1 FOOT OR MORE PER YEAR BASED ON TRENDS OBSERVED AT DOTD/ USGS NETWORK WELLS

USGS science for a changing world

DOTD

Management of Sparta

- Creation of Sparta Commission
- Owners of each non-domestic well shall submit a monthly report showing the amount of water pumped on a monthly basis and the purpose for which it was used.
- Aggressive education program on conservation & protection
- Users of Sparta ground water shall vigorously seek alternate sources of potable water to alleviate excess usage of the Sparta aquifer.

Management of Chicot

- Sabine River Diversion Channel and Distribution System in Calcasieu Parish
  - ➢ Supplies water to numerous industries in the Sulphur area
  - ➢ Supplies water for irrigation
  - ➢ Lessens dependency on Chicot Aquifer

- Attempts being made to establish Chicot Aquifer Stakeholders group (similar to Sparta Commission)

Management of Southern Hills

- Capital Area Groundwater Conservation Commission established.
- Reserves 1000-, 1500-, 1700-foot sands for public supply.
- Limits pumpage in 2000-foot sand; moratorium on wells in some areas.
- Connector well completed in 1999 – connects 800- and 1500-foot sands to raise water level in 1500 ft sand and inhibit movement of saltwater

Finding Information

Resources

- ASSET – aquifer sampling data (LDEQ)
- Recharge Potential Maps (LDEQ)
- LDNR – water well registration
- USGS sampling data and water resources reports, parish fact sheets
- LGS Publications

ASSET

AQUIFER SAMPLING AND ASSESSMENT PROGRAM

(fka: BASELINE MONITORING PROGRAM)

ASSET

- Statewide, ambient GW monitoring program, began in 1991 to determine and monitor quality of ground water in principal aquifers and aquifer systems of Louisiana
  - Currently funded by CWA Section 319 Nonpoint Source Program
  - Data utilized in Water Quality Integrated Report to Congress
  - Tracks change (or lack thereof)
- Every 3 years sample:
  - Approx. 200 water wells (domestic, industrial, irrigation, observation, public supply- use types)
  - Number of wells dependent upon areal extent of aquifer
  - 14 Aquifers/Aquifer System (Major freshwater aquifers as designated by USGS)
  - 150 + Parameter measured/analyzed each site
- Participation is voluntary, no cost to well owner
- Data Uses
  - Sent to owners
  - Summary of individual aquifer
  - “Triennial Report” for each 3 year cycle
  - State and Feds, Industry, Contractors, Consultants, University studies

ASSET

Does Not:

- Target Specific Well Use-types
- Target Known GW Contamination
- Enforce the Safe Drinking Water Program
  - LDHH/OPH Responsibility
- Have Regulatory Enforcement Authority
  - Data can be used by the enforcing authority

ASSET

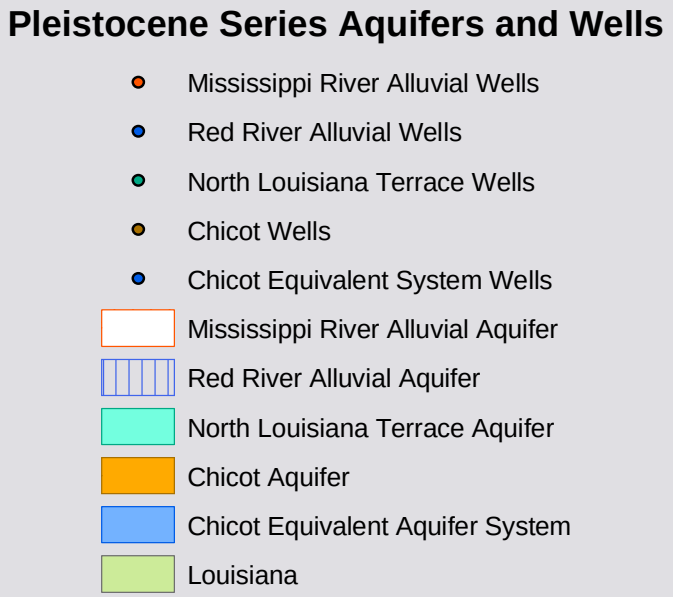
Parameters Sampled @ Each Site

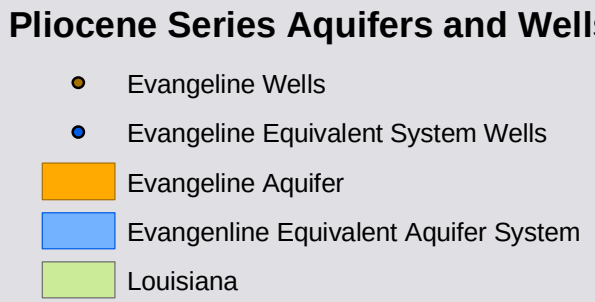
- GPS Location
- 5 Field Parameters
  - Temp, pH, Sp. Cond, Salinity, TDS
- 150+ Analytical Parameters
  - Conventionals (Water Quality and Nutrients)
  - Inorganics (Total Metals)
  - VOCs
  - Semi-VOCs
  - Pesticides and PCBs

Well Use-types

- 99 Public Supply
- 45 Domestic
- 32 Industrial
- 20 Irrigation
- 4 Observation
- 2 Power Generation
- 1 Monitor
- 1 Recovery (as designated by LDNR)
- 1 “Other” (as designated by LDNR)

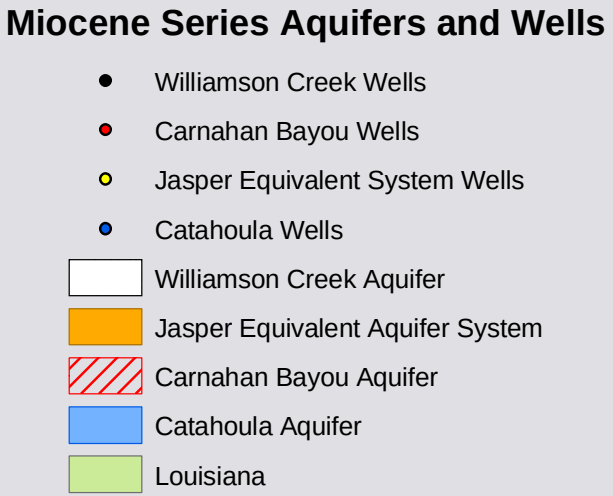
- Pleistocene Age (98 wells)
  - Mississippi River Alluvial (25)
  - Red River Alluvial (5)
  - North Louisiana Terrace (11)
  - Chicot (27)
  - Chicot Equivalent System (30)

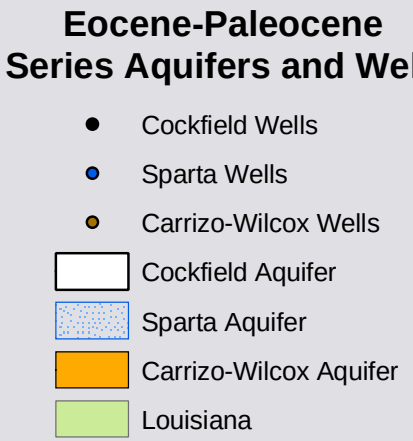




- Pliocene Age (27 wells)
  - Evangeline (12)
  - Evangeline Equivalent System (15)

- Miocene Age (39 wells)
  - Williamson Creek (7)
  - Carnahan Bayou (11)
  - Catahoula (5)
  - Jasper Equivalent System (16)

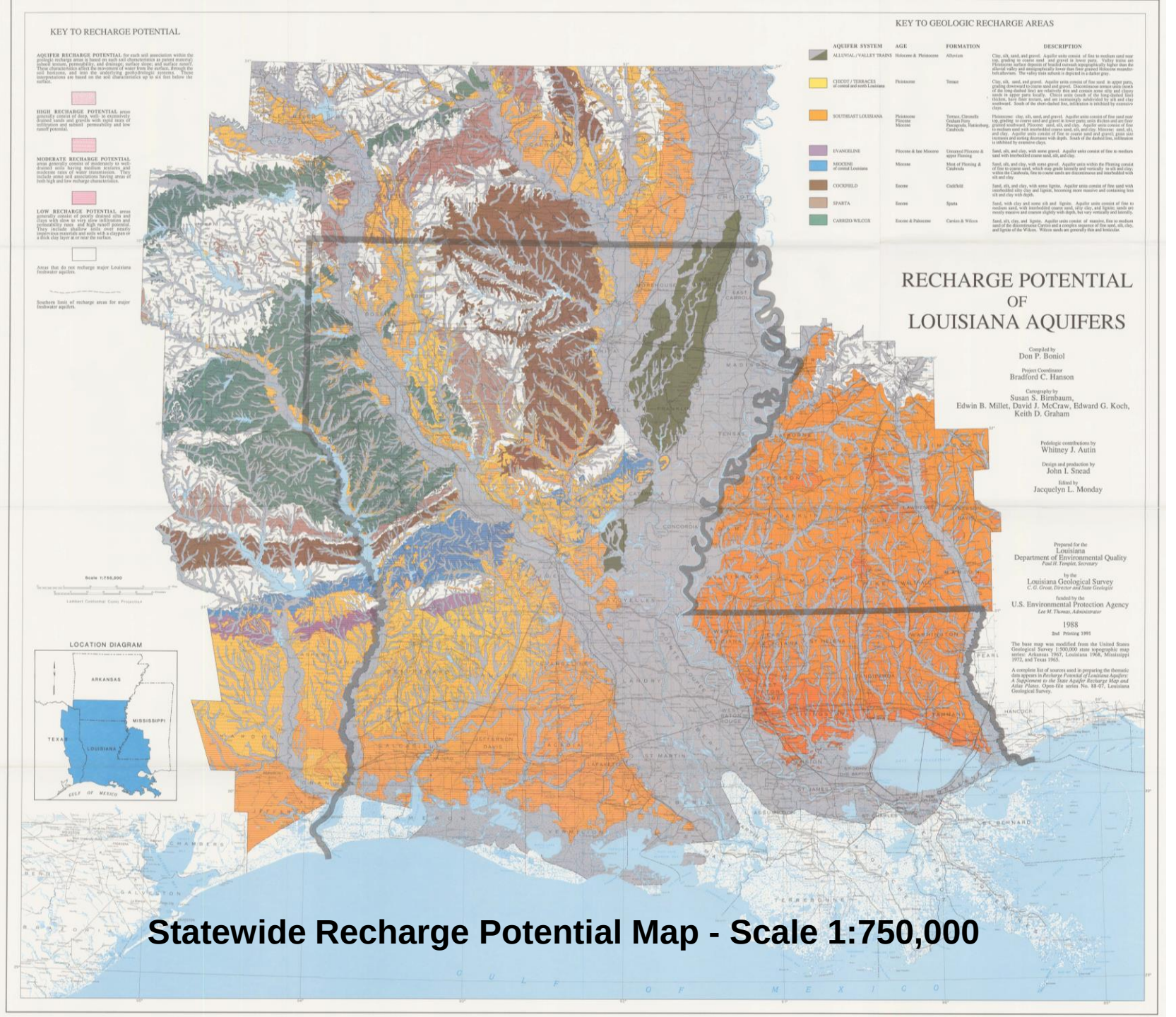




- Eocene-Paleocene (41 wells)
  - Cockfield (15)
  - Sparta (14)
  - Carrizo-Wilcox (12)

Recharge Potential Maps

- Surface extent with recharge potential of aquifers
- Map set includes statewide map, 16 quadrangle maps, supplemental report
- Available from DEQ Aquifer Evaluation & Protection Unit

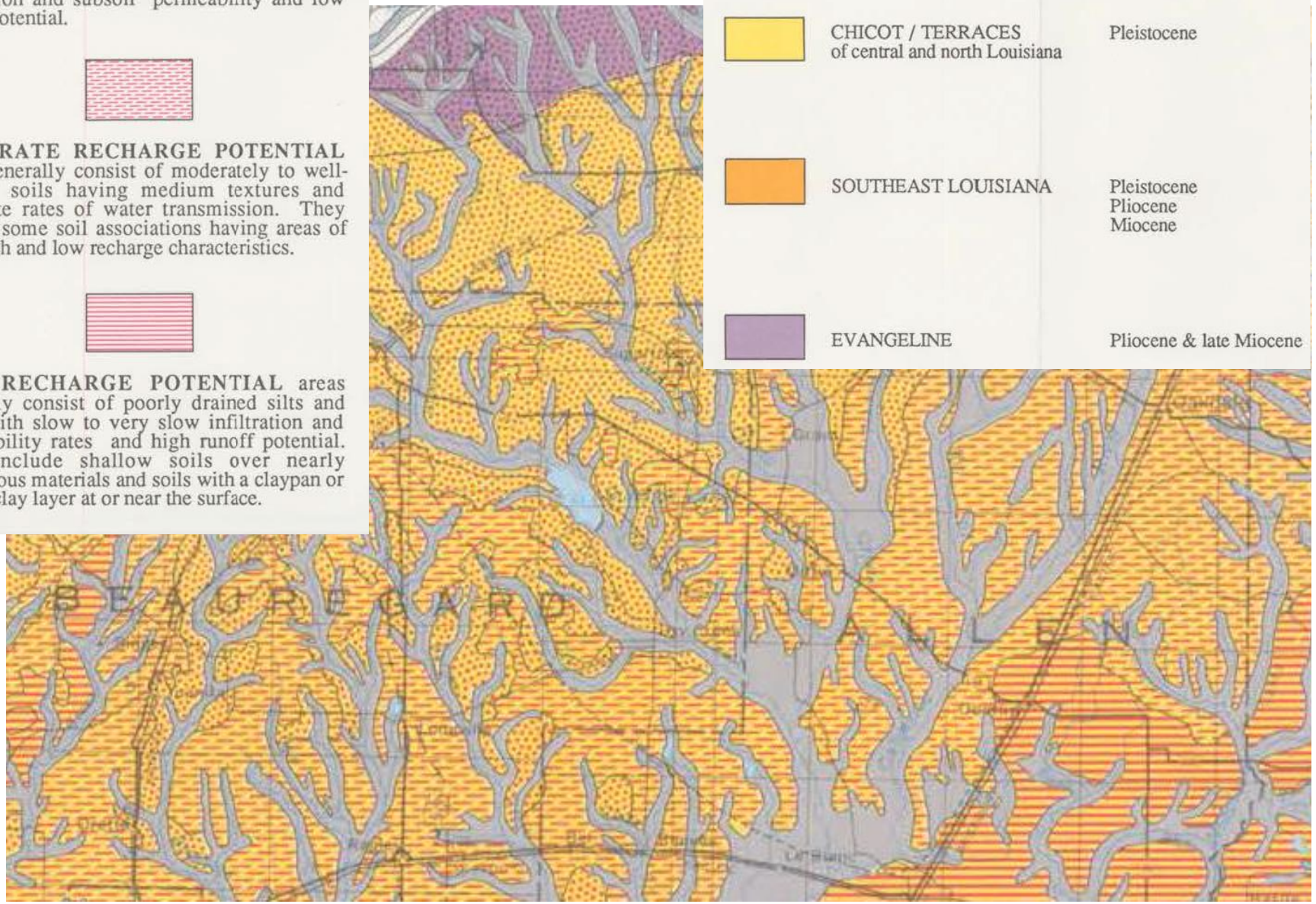


Statewide Recharge Potential Map - Scale 1:750,000

HIGH RECHARGE POTENTIAL areas generally consist of deep, well- to excessively drained sands and gravels with rapid rates of infiltration and subsoil permeability and low runoff potential.

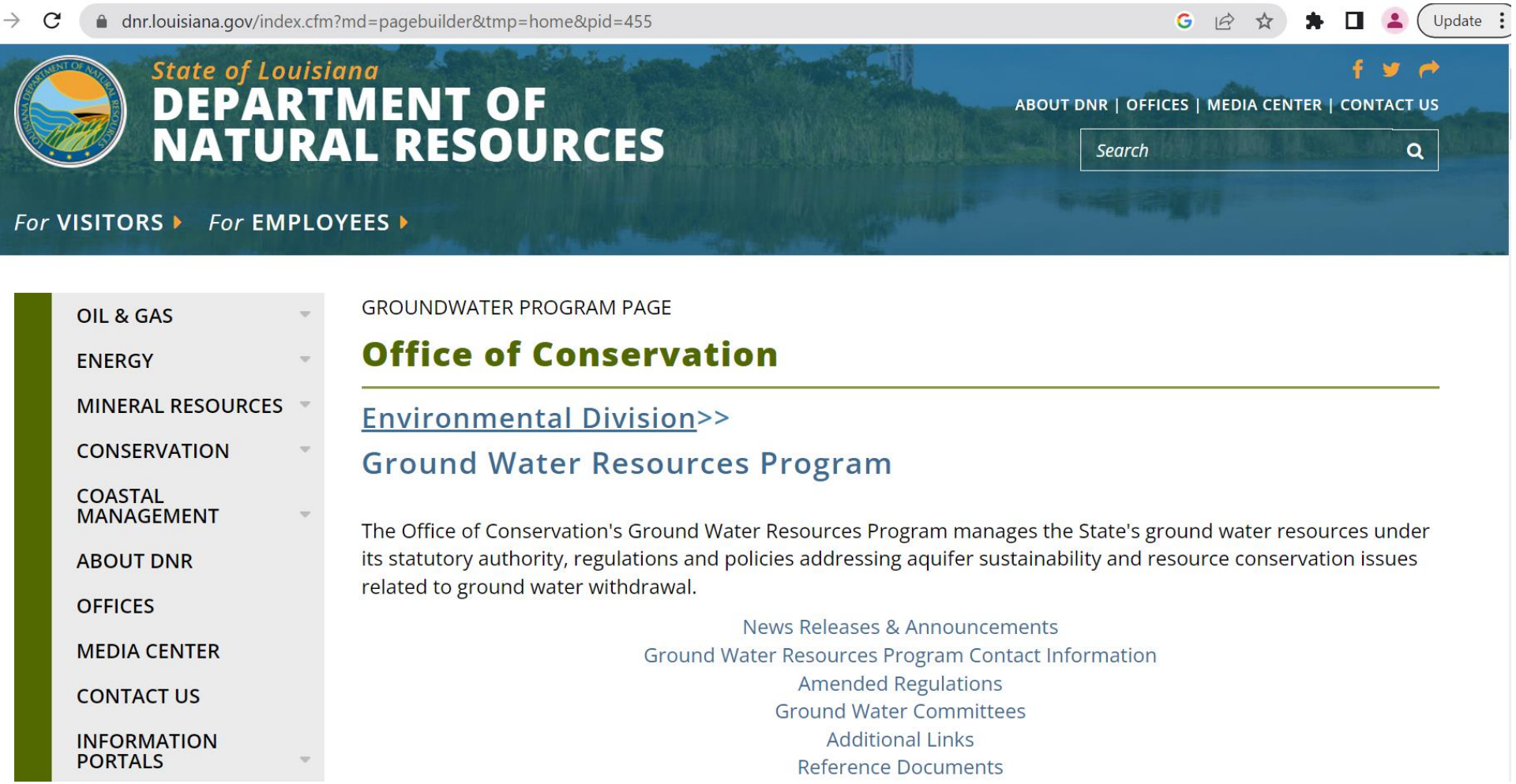
MODERATE RECHARGE POTENTIAL areas generally consist of moderately to well-drained soils having medium textures and moderate rates of water transmission. They include some soil associations having areas of both high and low recharge characteristics.

LOW RECHARGE POTENTIAL areas generally consist of poorly drained silts and clays with slow to very slow infiltration and permeability rates and high runoff potential. They include shallow soils over nearly impervious materials and soils with a claypan or a thick clay layer at or near the surface.



Quadrangle Atlas Maps - Scale 1:250,000

LDNR Office of Conservation Environmental Division



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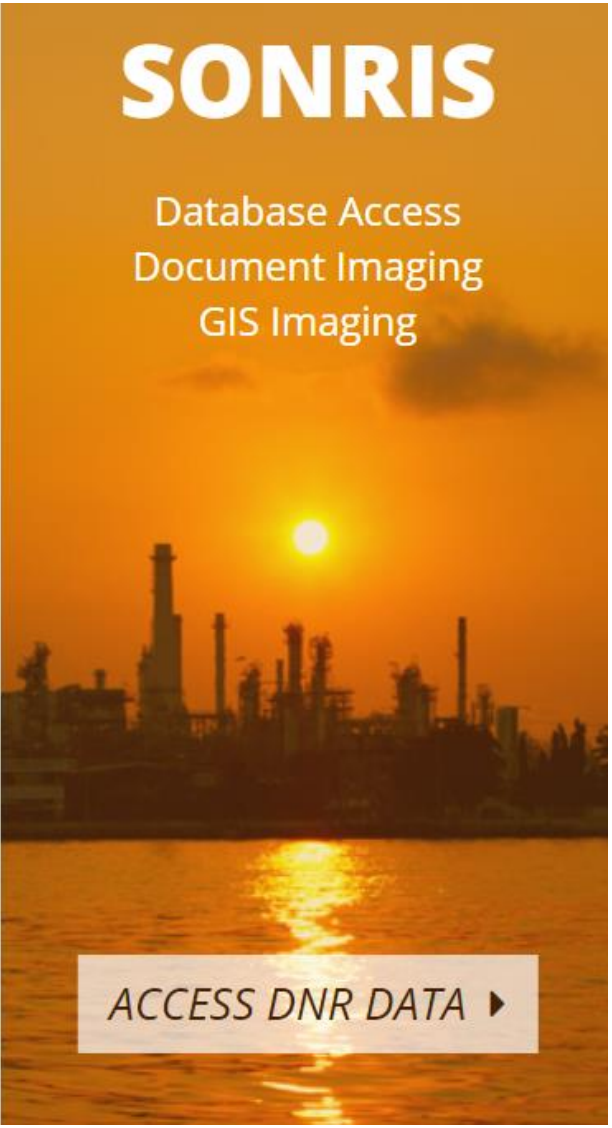
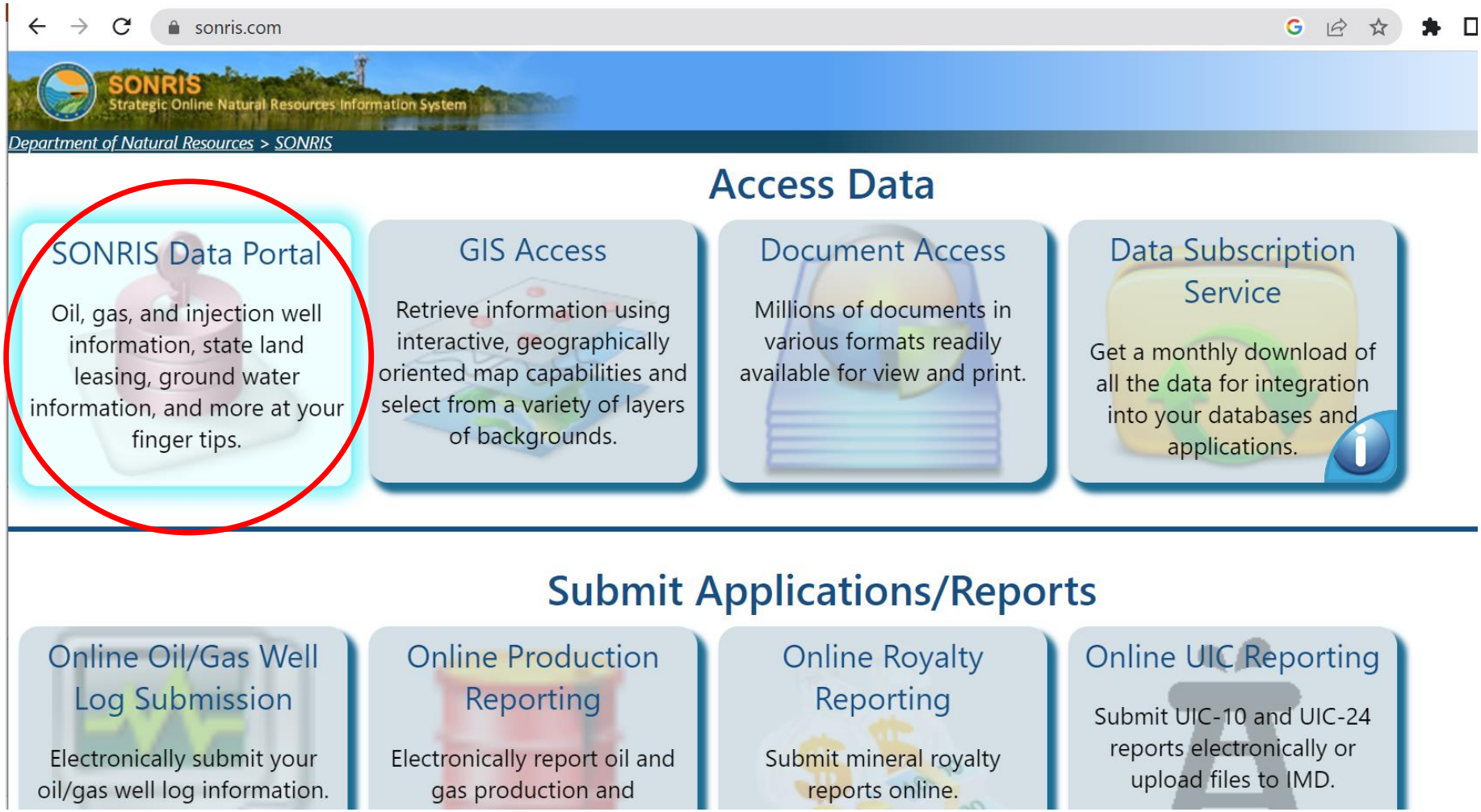
LDNR SONRIS



- Strategic Online Natural Resources Information System
- Water well registration database – owner, depth, completion date, driller, aquifer unit, lat/long, and more



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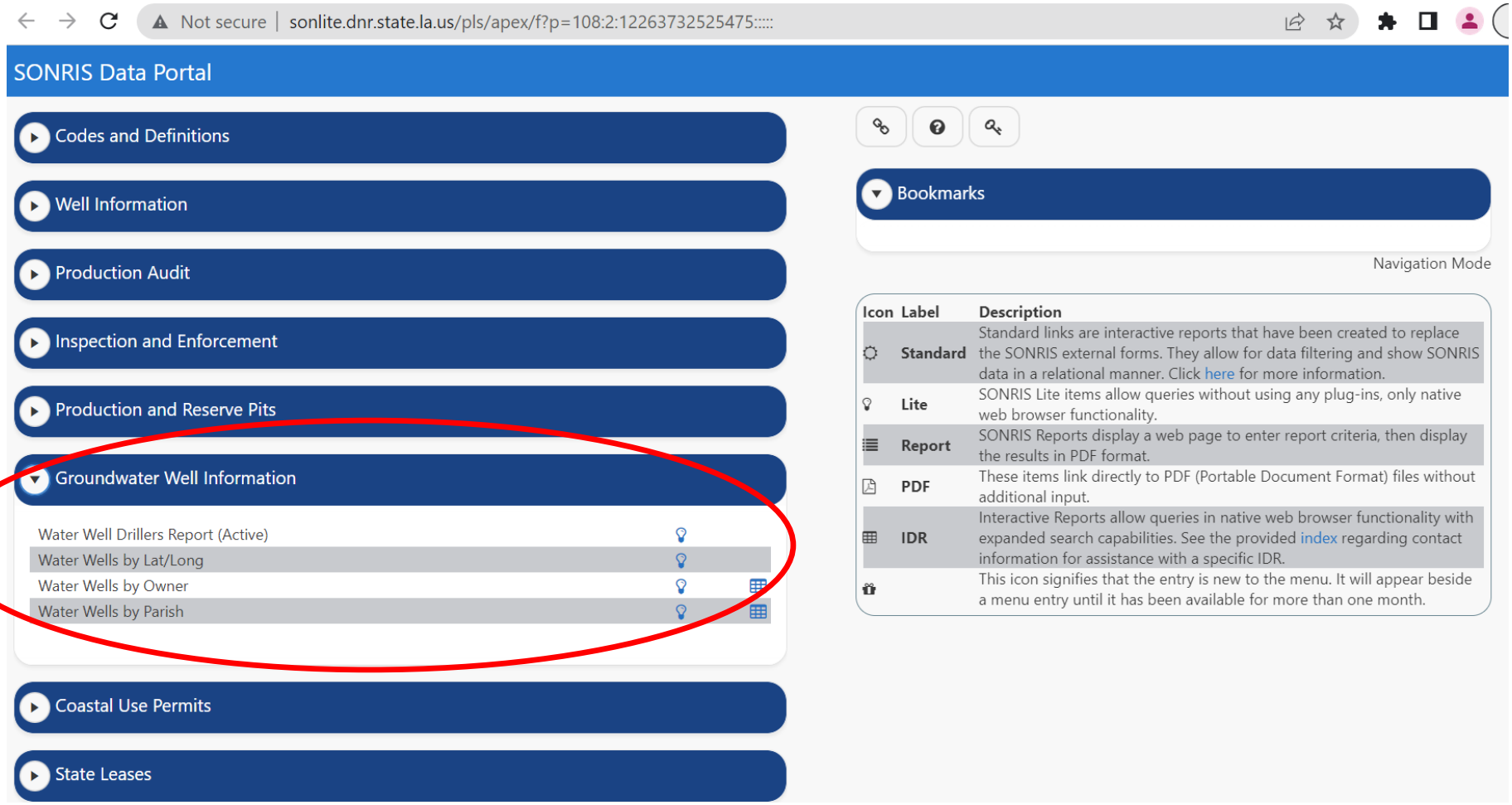
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This icon signifies that the entry is new to the menu. It will appear beside a menu entry until it has been available for more than one month.

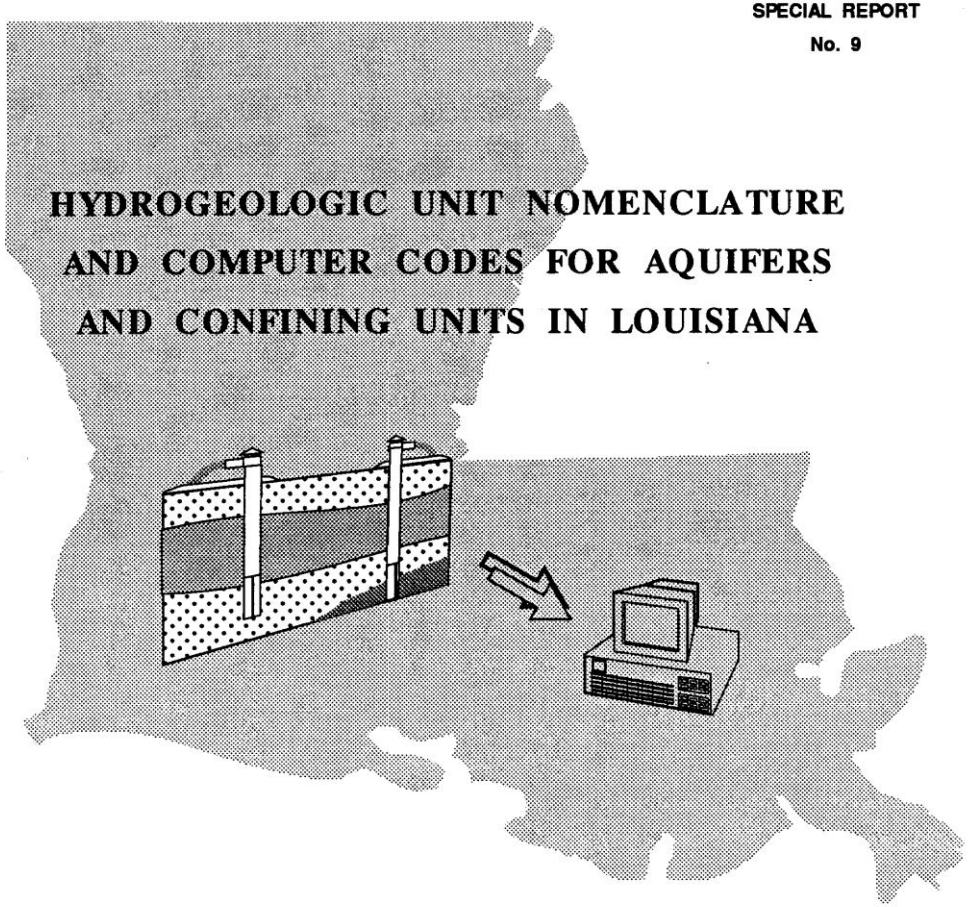
Water Well Ownership Report

SECTION	TOWNSHIP	RANGE	DNROWNERID	OWNERS_NUMBER	OWNERS_NAME	PARISH_NAME	PARISH_NUM	LOCAL_WELL_NUM	WELL_USE	DESCRIPTION	WELL_STATUS	DRILLERS_NAME	WELL_DEPTH	CASING_DIAMETER	DATE_COMPLETED	WATER_LEVEL	DATE_MEASURED	GEOLOGIC_UNIT	LATITUDE	LONGITUDE
001	06S	10E	6774	LAKE HILLS	TAMMANY UTILITIES	SAINT TAMMANY	103	1143	P	Public Supply	Active	UNKNOWN	850	8	09/80	0.00		121PNCLL	303332	900908
001	08S	11E	6774	HWY 1088	TAMMANY UTILITIES	SAINT TAMMANY	103	780	P	Public Supply	Active	SUMMERS, D. K. , WATER WELL CONTRACTORS	1965	8X4X4	09/81	60.00	10/01/80	120ABIT	302241	900241
004	07S	10E	6774	FOX BRANCH	TAMMANY UTILITIES	SAINT TAMMANY	103	1146	P	Public Supply	Active	CHABRECK, RICHARD, WATER WELL SERVICE	300	10	07/02	12.00	07/12/02	112PNCLU	302735	901225
004	07S	10E	6774	SAVANNAH TRACE	TAMMANY UTILITIES	SAINT TAMMANY	103	1133	P	Public Supply	Active	GILL (JACK) WATER WELL	1050	8	07/99	32.30	07/20/99	121PNCLL	302809	901236

STATE OF LOUISIANA
DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
PUBLIC WORKS AND FLOOD CONTROL DIRECTORATE
WATER RESOURCES SECTION

WATER RESOURCES
SPECIAL REPORT
No. 9

HYDROGEOLOGIC UNIT NOMENCLATURE AND COMPUTER CODES FOR AQUIFERS AND CONFINING UNITS IN LOUISIANA



Prepared by
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
In cooperation with
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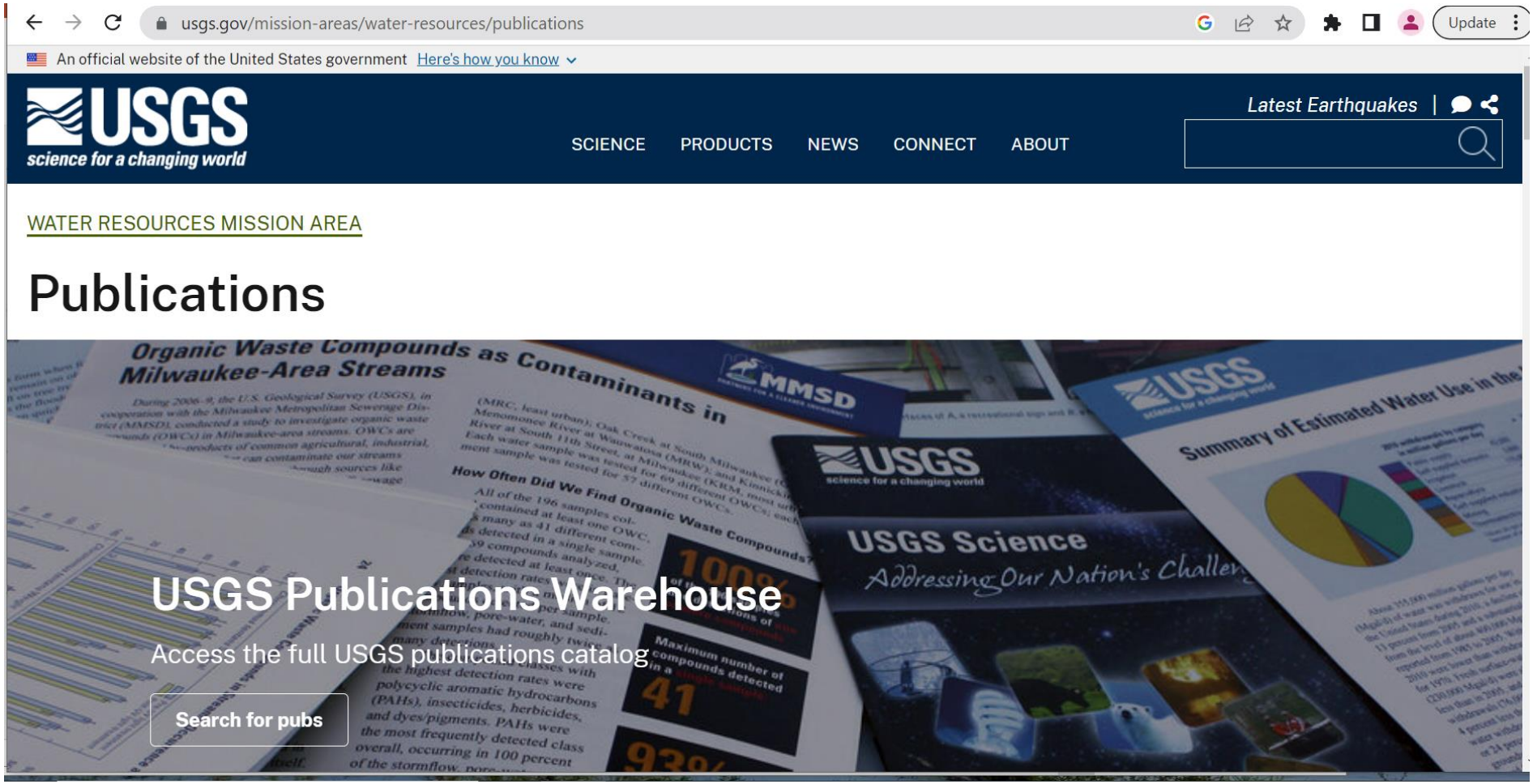

https://www.usgs.gov/mission-areas/water-resources/publications

Water Resources of Louisiana's Parishes

ACTIVE

By Lower Mississippi-Gulf Water Science Center September 5, 2011

The USGS is summarizing basic information on water resources for each parish in Louisiana and presenting the information in fact-sheet format. Information presented includes groundwater and surface-water availability, quality, development, use, and trends. These brief summaries of water resources will provide parish officials, local officials and concerned citizens with information needed to make decisions about current and future development in their parish. The work is cooperatively funded by the Louisiana Department of Transportation and Development and the U.S. Geological

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Phone: 225-298-5481 Ext: 3216

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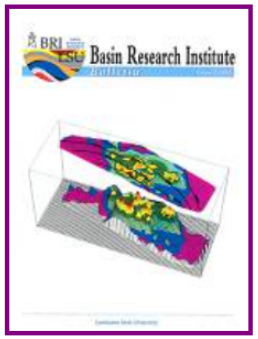
Anthropological Study Series

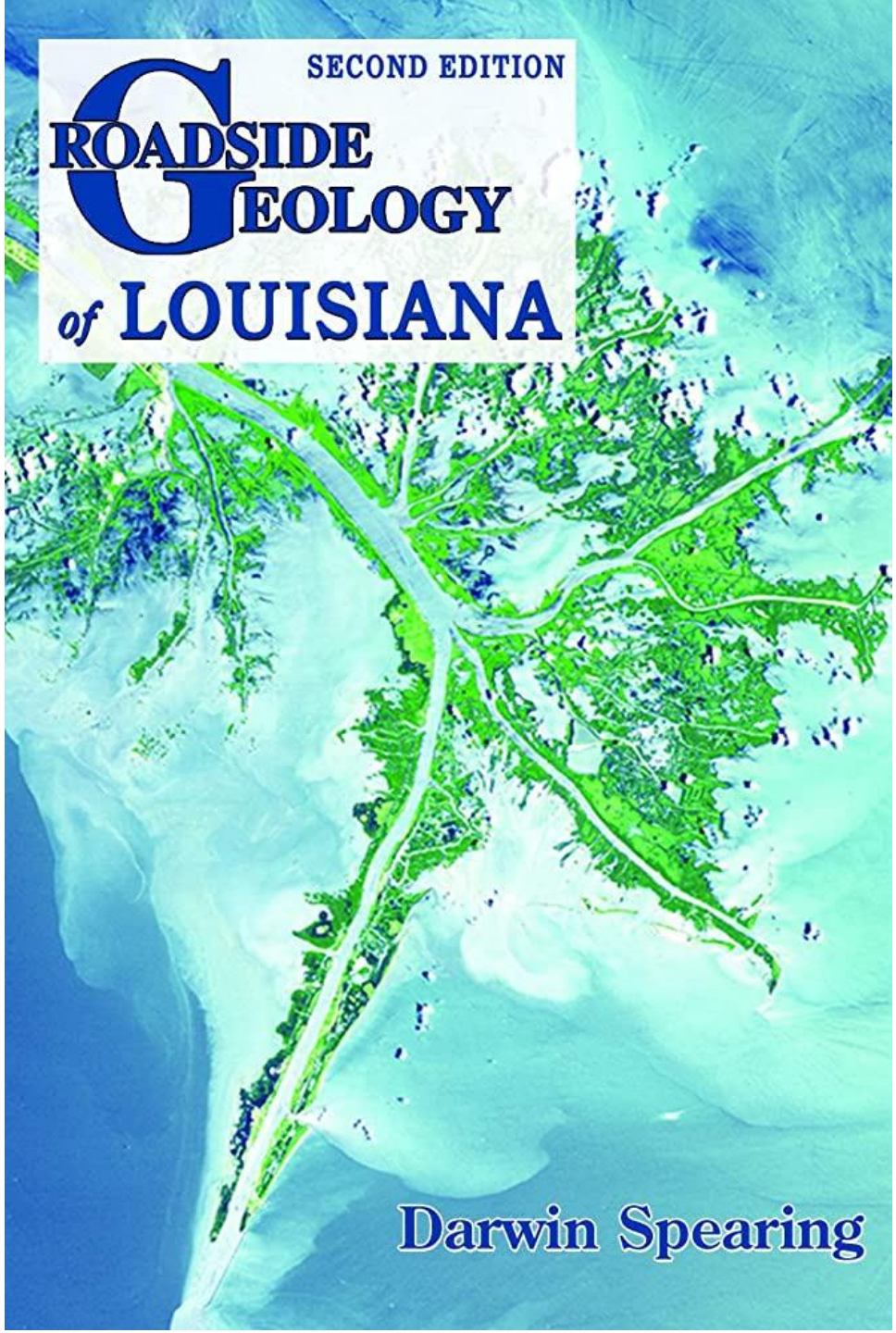


Basin Research Institute Bulletins

Clay Resource Bulletins

https://www.lsu.edu/lgs/publications/Digital-catalog.php

*There is a charge for most publications


SECOND EDITION
ROADSIDE GEOLOGY of LOUISIANA
Darwin Spearing

Fun Fact

There ARE rocks in Louisiana!

Quartzitic Sandstone
Kisatchie Hills Wilderness
Natchitoches Parish