LONG-TERM STRATEGIC PLAN FOR THE CAPITAL AREA GROUND WATER CONSERVATION COMMISSION

Phase 2A Final Report

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Produced for and Funded by: The Capital Area Ground Water Conservation Commission

January 14, 2022

LONG-TERM STRATEGIC PLAN FOR THE CAPITAL AREA GROUND WATER CONSERVATION COMMISSION: PHASE 2A FINAL REPORT

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With assistance from:
The Water Institute of the Gulf
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07/06/2023

07/07/2023

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SUGGESTED CITATION

Di Leonardo, Diana, Alyssa Dausman, Ryan Clark, Michael Runge, Soupy Dalyander, Scott Hemmerling, Audrey Grismore, Jason Afinowicz, Philip Taucer, Jordan Skipwith, Frank Tsai (2022). Long-term strategic plan for The Capital Area Ground Water Conservation Commission: Phase 2A Final Report. The Water Institute of the Gulf. Prepared for and funded by the Capital Area Ground Water Conservation Commission.

PREFACE

The Capital Area Ground Water Conservation Commission (CAGWCC) oversees the use of groundwater in six parishes in Louisiana. In carrying out its statutory responsibilities and authorities, the CAGWCC recognizes the complexity of its decisions: the long-term objectives it is seeking are multifaceted; the actions it can choose from are numerous and interdependent; and the understanding of the hydrogeological, economic, and social systems affected by its actions is limited. To navigate this complexity, the CAGWCC is developing a long-term strategic plan to guide its activities and to serve as a primary mode of communication to stakeholders and the public. This document details the technical work done thus far in Phase 2 to support the development of a long-term strategic plan.

Questions and comments from the CAGWCC on this report are welcomed. The goal of Phase 2 is to provide the CAGWCC with the information and data necessary to support future complex decisions about management of the aquifer. Feedback from the CAGWCC is needed to accomplish this goal.

Phase 2A will conclude in early 2022 with the submission of this report.

Mission Statement[1]

The mission of the Capital Area Ground Water Conservation Commission is to provide for the efficient administration, conservation, orderly development, and supplementation of groundwater resources in the parishes of Ascension, East Baton Rouge, East Feliciana, Pointe Coupee, West Baton Rouge, and West Feliciana.

The Capital Area Ground Water Conservation Commission will develop, promote, and implement management strategies to provide for the conservation, preservation, protection, recharging, and prevention of waste of the groundwater resources, over which it has jurisdictional authority, for the benefit of the people that the Capital Area Groundwater Conservation District serves.

[1] The mission statement is taken from the CAGWCC's web site (https://www.cagwcc.com/site2015/aboutus-mission.htm).

ACKNOWLEDGEMENTS

The Louisiana Department of Natural Resources, Office of Conservation is acknowledged for providing electrical logs and well registration data for this study. Potentiometric elevation and chloride data were provided by the USGS Lower Mississippi-Gulf Water Science Center. Pumping data were obtained from the Capital Area Ground Water Conservation Commission. Subsurface geology data were provided by Dr. Frank Tsai at Louisiana State University.

The surveys described in this report were organized and implemented by the Water Institute of the Gulf, Freese and Nichols, Inc., and the Capital Area Ground Water Conservation Commission and were not conducted on behalf of the U.S. Geological Survey. The Institutional Review Board for the Protection of Human Subjects in Research (IRB) has deemed that the public survey and interview research and procedures are compliant with the University of Alabama, the University of New Orleans, and federal guidelines and meet the standard for being exempt from further IRB review.

This report was prepared for and funded by the Capital Area Ground Water Conservation Commission.

EXECUTIVE SUMMARY

The Capital Area Ground Water Conservation Commission (CAGWCC; hereafter "Commission") engaged the Water Institute of the Gulf to aid in creating a strategic plan for proactive management of the Southern Hills Aquifer System (SHAS), within the Capital Area Groundwater Conservation District (CAGWCD) in southeastern Louisiana. In Phase 1 of this work, the CAGWCC developed, with help from the U.S. Geological Survey (USGS) and the Institute, five fundamental objectives to guide management decisions and the development of a strategic plan.

In addition, three high level management strategy alternatives were identified for consideration and modeling of outcomes. Preliminary performance metrics, used to compare the modeled results of the different management alternatives, were drafted in Phase 1.

Table I. The fundamental objectives developed in Phase 1 of the development of a long-term strategic plan for the Southern Hills Aquifer System of southeastern Louisiana, USA, to describe the long-term outcomes the Capital Area Ground Water Conservation Commission (CAGWCC) aims to achieve, and the performance metrics developed to render the fundamental objectives operational to evaluate different strategies for reaching the long-term outcomes. CAGWCD, Capital Area Groundwater Conservation District (see Figure II for mapped location).

	Fundamental Objective	Performance Metric
1	Achieve and maintain sustainable and resilient groundwater withdrawal rates from the Southern Hills Aquifer System within the CAGWCD boundaries.	Mean potentiometric elevation across the CAGWCD at equilibrium, separately for each sand.
2	Manage the aquifer to maximize availability of healthy, high-quality drinking water equitably to all residents of the CAGWCD indefinitely.	Individual subjective and objective metrics representative of drinking water quality, quantity, and cost.
3	Manage the aquifer to maximize availability of clean and inexpensive water to commercial and industrial users in the CAGWCD indefinitely.	Composite unit cost of water supply for industrial users; this cost includes the cost of water treatment to meet required standards.
4	Reduce the movement of saltwater into the Southern Hills Aquifer System and slow or halt the advance of the existing saltwater plumes.	The mass of salt (chloride ion) in groundwater in all sands within the spatial bounds of the CAGWCC authority after 50 years, corresponding to the planning horizon of the long-term strategic plan.
5	Minimize the risk of subsidence.	Amount of subsidence at wells in the CAGWCD.

Under Phase 2A, detailed in this report, these metrics were further developed, and specific methods for calculating the metrics were drafted. Data analysis and modeling to evaluate the outcomes of the management alternatives and calculate the performance metrics were also refined and begun during this phase. In addition, forums were held to engage the CAGWCC and further facilitate discussion of strategic plan development. The research activities engaged in during Phase 2 were separated into tasks (e.g., Task 2A.1, Task, 2A.3) to aid in project organization. The report is similarly organized to aid the reader. This report details Phase 2A; Tasks 2.2, 2.7, 2.8, and 2.10 exist only in Phase 2B, and will be detailed in following reports.

BACKGROUND AND GEOLOGY OF THE SOUTHERN HILLS AQUIFER SYSTEM

The Southern Hills Aquifer System (SHAS) underlies approximately 14,000 mi^2 of southeastern Louisiana and occurs as far north as Vicksburg, Mississippi (Figure I). It is referred to as an aquifer system because it consists of many confined, but interdependent, aquifer units (Hemmerling et al., 2016). The SHAS ranges between 200–2,800 ft deep in the CAGWCD (which includes seven parishes surrounding Baton Rouge, Fig. II) (Buono, 1983). The aquifer system has been divided into as many as 13 aquifers (referred to as “sands”), although in the CAGWCD, 10 are primarily recognized (400-foot, 600-foot, 800-foot, 1000-foot, 1200-foot, 1500-foot, 1700-foot, 2000-foot, 2400-foot, and 2800-foot sands). The aquifer layers dip to the south at an approximate slope of 40 ft/mile but can vary between 10 to 120 ft/mile (Meyer & Turcan Jr., 1955).

The SHAS is a confined aquifer system with multiple overlapping sand and clay units. Historically, prior to the beginning of the pumping era in the late 1800s, the SHAS had been classified as artesian in the Baton Rouge area, meaning a well that tapped the aquifer would freely flow above the land surface. In 1914, oil-refineries began to open in the Baton Rouge area and industrial pumping began (Meyer & Turcan Jr., 1955). The parishes that are part of the Capital Area Ground are East Baton Rouge (EBR) and West Baton Rouge (WBR), East and West Feliciana, Pointe Coupee, and Ascension (Figure II).

Faults in Baton Rouge and the Capital Area Groundwater Conservation District

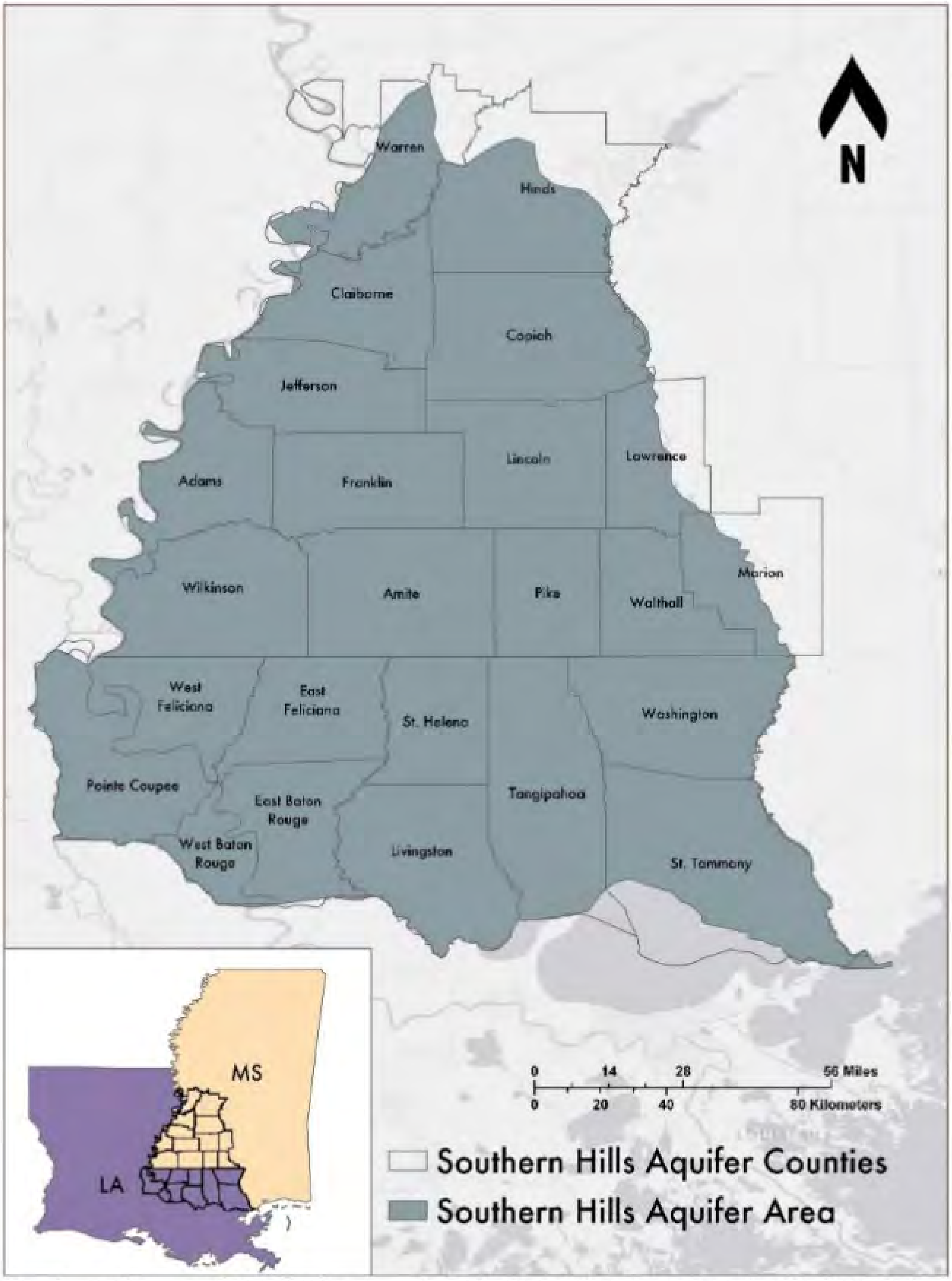
Within the CAGWCD, there are two primary faults, the Denham Springs-Scotlandville Fault and the Baton Rouge Fault (Fig. III). A fault is the boundary between two blocks of sediment or rock that move relative to one another. Both the Denham Springs-Scotlandville and Baton Rouge faults are active, but are not known to be able to cause earthquakes. The Baton Rouge Fault is the approximate southern limit of freshwater in the SHAS. South of the Baton Rouge Fault, the water in the aquifer system is generally saline and not usable for potable water. The Baton Rouge Fault generally has a low permeability that impedes horizontal flow across the fault (Pham & Tsai, 2017), except at certain high permeability areas known as “leaky windows;” the implications of these leaky windows are investigated as part of Phase 2.

Recharge and Discharge of the Southern Hills Aquifer System

Outcrops of the SHAS—areas of exposed bedrock or areas of permeability where water can enter for groundwater recharge—are primarily located south of Jackson, Mississippi, and in southwestern Mississippi (Figure I). Recharge for the SHAS is primarily from direct percolation of precipitation to the water table in the outcrop areas while discharge is primarily due to pumping (Buono, 1983). Prior to the pumping era, discharge of the SHAS occurred as stream runoff or evaporation near the Baton Rouge Fault. After the start of the industrial pumping era, in the early 1900s, groundwater began to be intercepted as flow to pumped wells. Currently, the major discharge of aquifers in the SHAS is induced by pumped wells. Groundwater storage in the aquifer is closely correlated with pumping rates as seen in historical data (e.g., lower pumping rates led to increased well levels between 1975 and 1985) and modeling studies (Hai Pham & Tsai, 2017).

History of Saltwater Intrusion

Saltwater in Baton Rouge aquifers was first found in 1950 (Meyer & Turcan Jr., 1955). Since then, several wells have seen increasing chloride concentrations throughout the SHAS near the Baton Rouge Fault (Rollo, 1969; Tomaszewski et al., 2002). In 2007, USGS published a study that revealed eight out of the ten major aquifers north of the Baton Rouge Fault were observed to have had an increase in chloride levels (Lovelace, 2007). Saltwater intrusion within the Baton Rouge sands is attributed to high groundwater withdrawal rates in the Baton Rouge area (Rollo, 1969).



Data Source: Census.gov & https://archive.epa.gov/pesticides/region4/water/groundwater/web/html/r4ssa.html
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

Figure I. Boundaries of the Southern Hills Aquifer System (SHAS) in Louisiana (LA) and Mississippi (MS), United States, with county and parish boundaries shown.

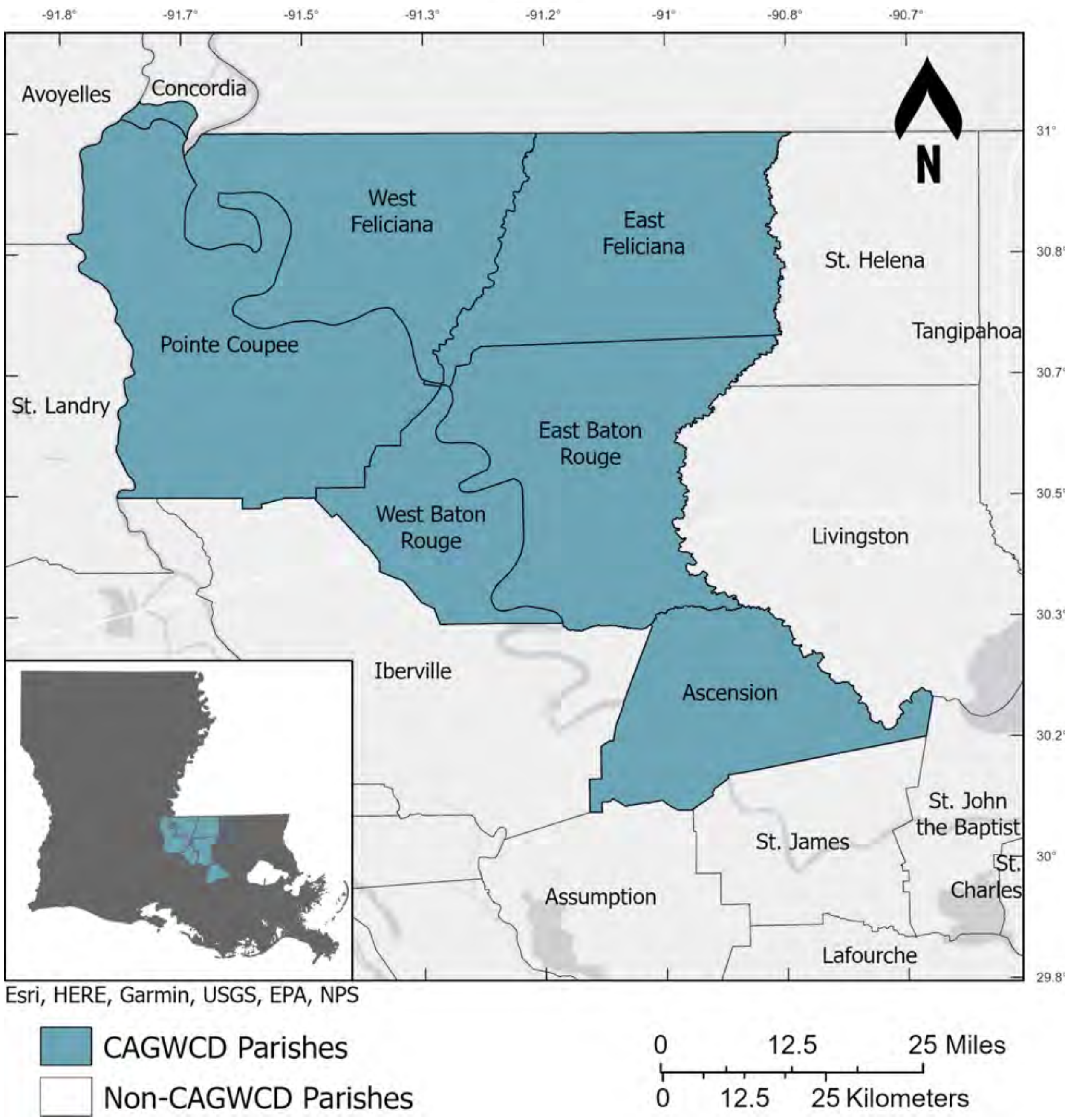


Figure II. The Louisiana parishes that are part of the Capital Area Groundwater Conservation District (CAGWCD).

TASK 2A.1

To make informed decisions about aquifer management, the CAGWCC can benefit from an understanding of the current state of the SHAS and its underlying geology. Information and data from Task 2A.1 inform Performance Metrics 1 (sustainable groundwater withdrawal), 4 (saltwater intrusion), and 5 (subsidence) (Table I). Cones of depression in the potentiometric surfaces can be seen in the water level monitoring data for 2020 in every sand except the 400-foot and 1000-foot sands. Large cones of depression, more than 10 miles across, can be seen in the 1200-foot, 1500-foot, 1700-foot, 2000-foot, 2400-foot, and 2800-foot sands (e.g., Figure III; Figure IV). These cones of depression exist both near the center of industrial activity north of Baton Rouge and elsewhere, wherever large amounts of pumping occur. The presence of these cones of depression has many implications for the aquifer health. The reduced aquifer pressures inside the cones of depression near the Baton Rouge Fault induce saltwater flow across the fault and result in saltwater intrusion into the sands. Saltwater intrusion is difficult and expensive to remediate; prevention is easier and less expensive. Several wells in the CAGWCD approach or exceed the U.S. Environmental Protection Agency (USEPA) Secondary Standard for chloride, 250 mg/L, as of December 2020 (Figure V). Monitoring of the saltwater plume will be crucial for managing this threat to drinking water. Only a few wells are sampled for chloride in most sands. Over-pumping of groundwater resources can also lead to aquifer compaction and land surface sinking, known as subsidence. Compared to 1975, at the beginning of the CAGWCC's management of the aquifer, the total amount of groundwater pumped annually has increased, along with an increase in the number of active wells, and the area over which pumping occurs (Figure VI).

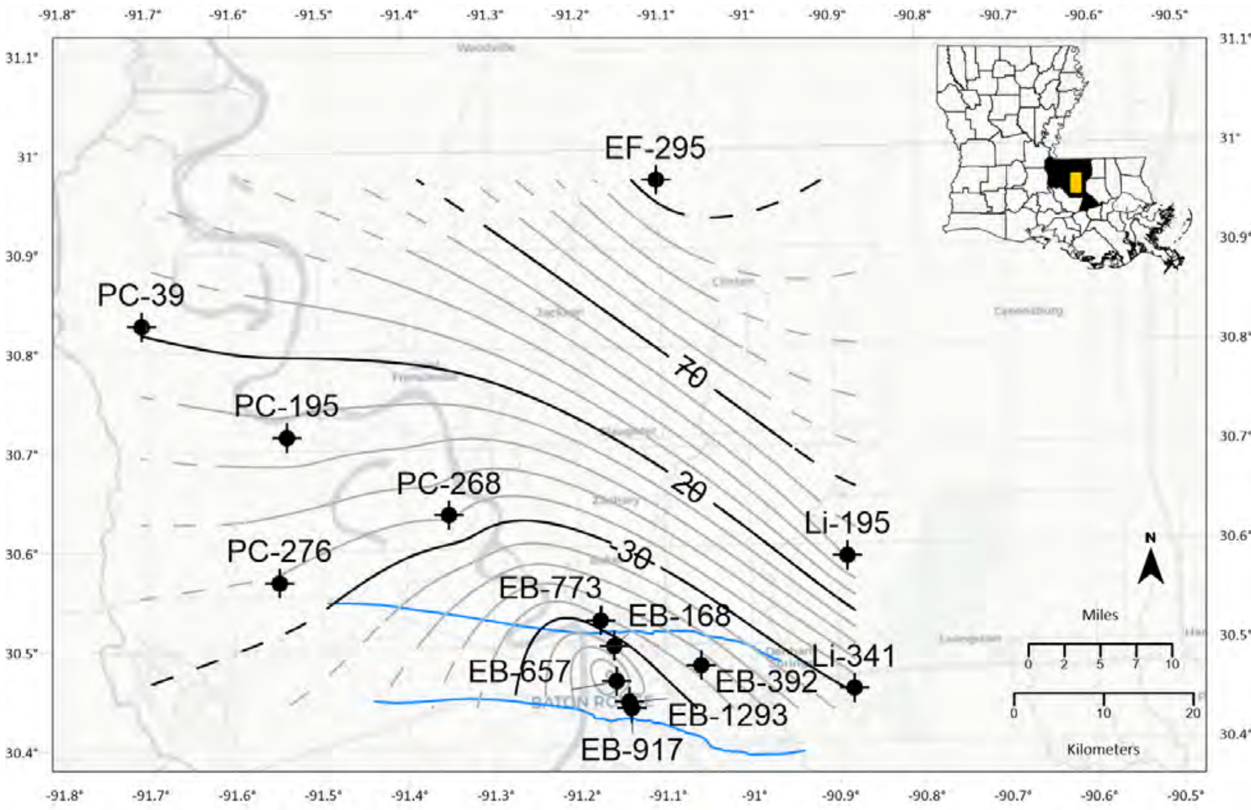


Figure III. Potentiometric surface contour map for the 1500-foot sand using data from June 2020 through December 2020 collected by the USGS. All data are in feet above the National Geodetic Vertical Datum of 1929 (NGVD29). Points show the locations of wells from which water level data were used to create the contours; the first two letters of a well name indicate the parish in which is located (PC, Point Coupee; EF, East Feliciana; EB, East Baton Rouge; Li, Livingston). Contour interval is 10 ft. Contours are drawn as solid lines within the area in which there are available data and as dashed lines outside this area. The blue lines represent the Denham Springs-Scotlandville fault to the north and the Baton Rouge Fault to the south.

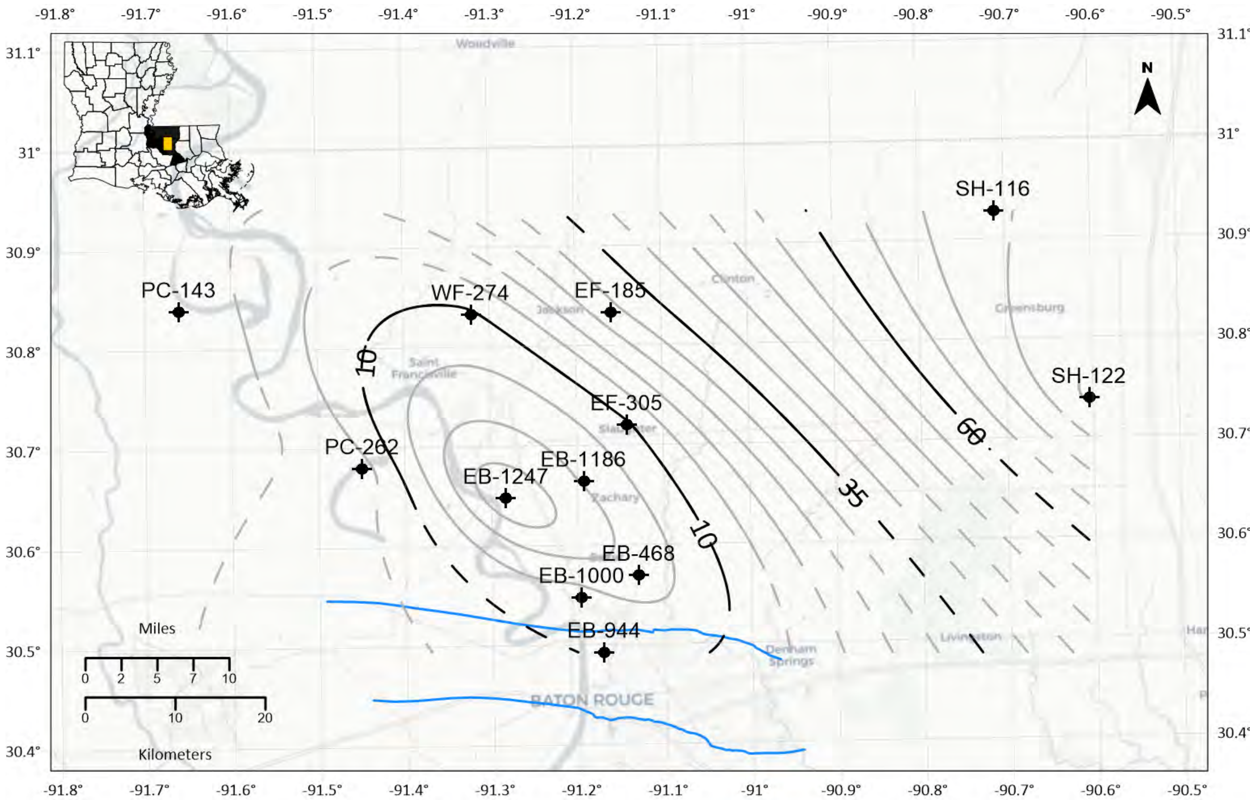


Figure IV. Potentiometric surface contour map for the 2800-foot sand using data from June 2020 through December 2020 collected by the USGS. All data are in feet above the National Geodetic Vertical Datum of 1929 (NGVD29). Points show the locations of wells from which water level data were used to create the contours; the first two letters of a well name indicate the parish in which is located (PC, Point Coupee; EF, East Feliciana; EB, East Baton Rouge; Li, Livingston). Contour interval is 5 ft. Contours are drawn as solid lines within the area in which there are available data and as dashed lines outside this area. The blue lines represent the Denham Springs-Scotlandville fault to the north and the Baton Rouge Fault to the south.

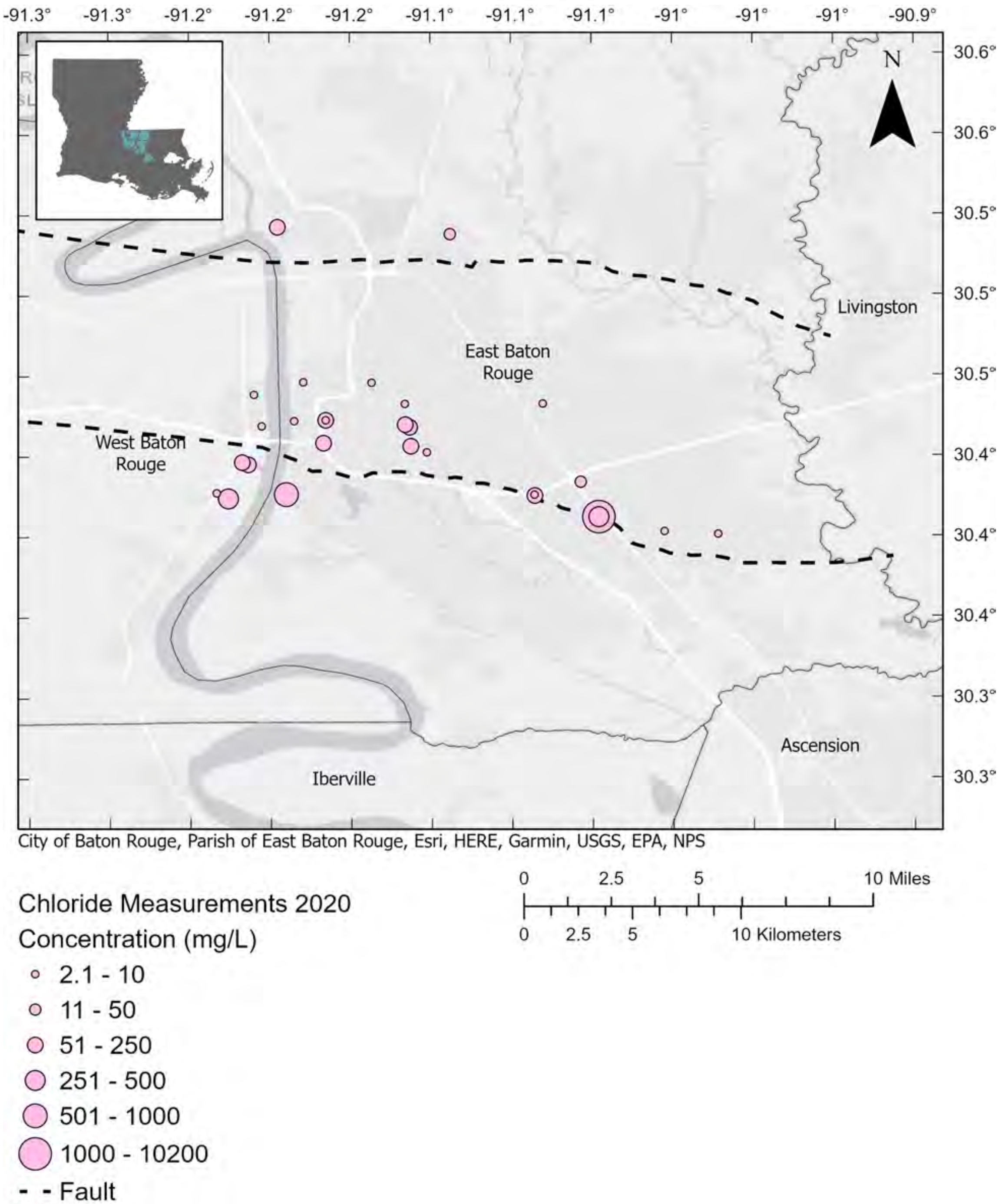


Figure V. Chloride measurement locations from June 2020 to December 2020 collected by the USGS. Each point is sized by its chloride concentration. The dashed lines show the Denham Springs-Scotlandville (north) and Baton Rouge faults (south).

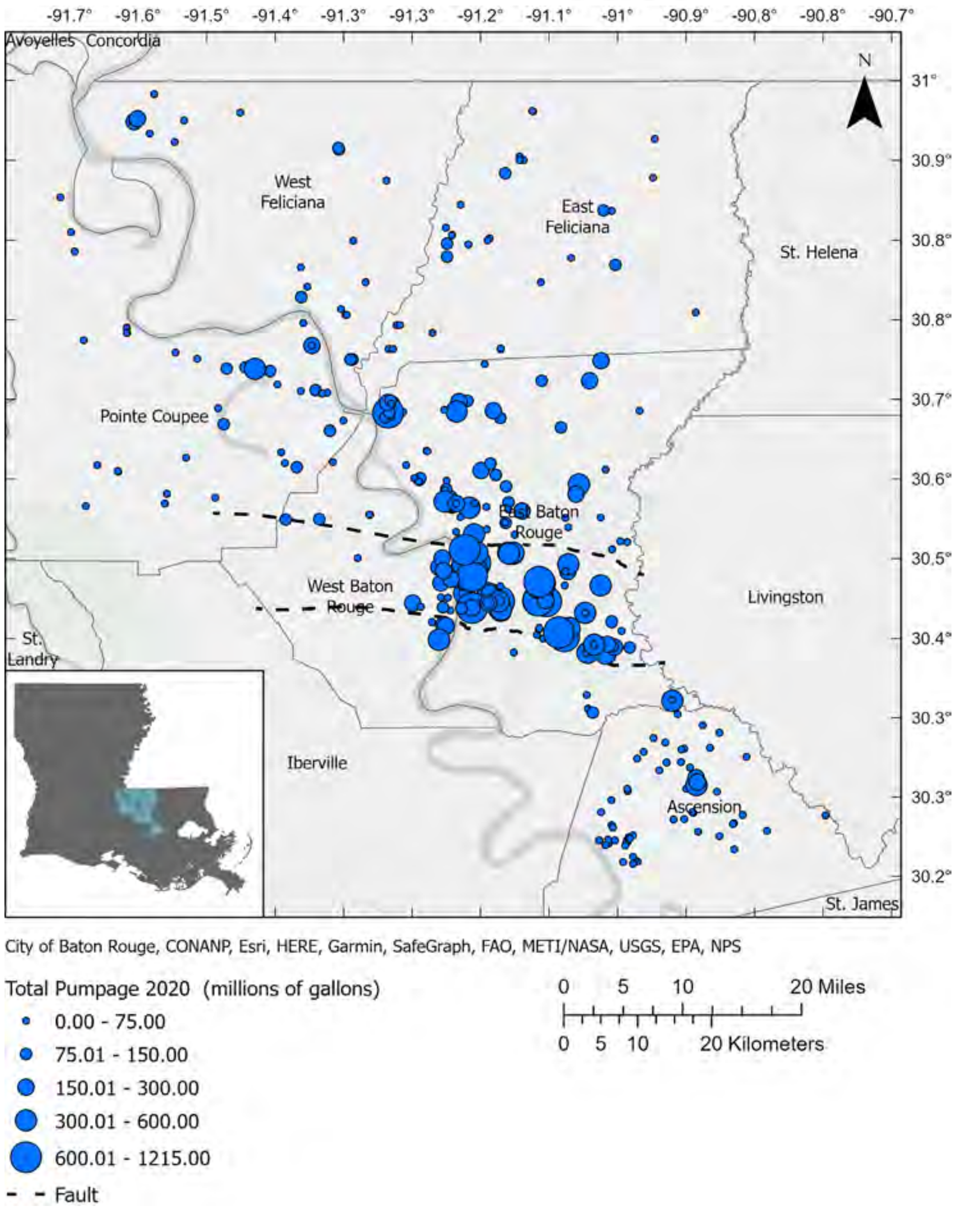


Figure VI. Total pumpage as reported to the Capital Area Ground Water Conservation Commission (CAGWCC) across the Capital Area Groundwater Conservation District in 2020. Each well that reported pumpage to CAGWCC during this year is represented by a circle. The size of the circle indicates how much water was pumped at each well. Units are in millions of gallons. The total amount of water pumped is a combination of the industrial and public uses of water.

TASK 2.2

This task is part of Phase 2B, not Phase 2A, and will be covered in a future report.

TASK 2A.3

To make informed decisions about the alternative management strategies, the CAGWCC will also need to weigh the economic data and information, as well as have an understanding of the historical and future demand for water in the CAGWCD. Information and data from Task 2A.3 inform Performance Metrics 2 (drinking water) and 3 (commercial water) (Table I). All sources of water (groundwater and surface water) were included in the analysis; both domestic and industrial water use was considered. Water use reports from USGS suggest that public supply is limited to groundwater sources in five of the six parishes; some systems in Ascension Parish use a surface water supply. Groundwater exports from EBR Parish also play an important role in meeting domestic water demand in Ascension Parish. Estimated average per-capita demand for public supply water from 2010 to 2020 at the parish level was between approximately 135 and 290 gallons per-capita per day. Total estimated groundwater withdrawals for public supply in the CAGWCD in 2020 were approximately 32,000 million gallons (Figure VII).

Total industrial demand for water in 2020 was estimated to be slightly more than 600 million gallons per day (MGD), with about 60 MGD coming from groundwater (Figure VIII). These numbers reflect a large drop in groundwater demand since 2018, due to decreased withdrawals from a major facility in East Baton Rouge Parish. For 2010 through 2018, estimated industry demand for groundwater was approximately 100 MGD. The Water Institute of the Gulf also conducted a survey of industrial water users to gain information on current water use and treatment, as well as treatment costs, to better understand and predict how water costs to industry may be impacted by the different management decisions (see Appendix E). The survey response rate was low, with only 19 out of 80 surveys providing complete or partial data responses, with an additional four providing basic facility identification data. Over 80 percent of the industrial entities surveyed utilize groundwater; the most commonly utilized sands were the 1200-foot sand and 400-foot sand (Figure IX). Treatment needs were variable, with fewer than half the respondents with groundwater supplies indicating 100 percent treatment of groundwater.

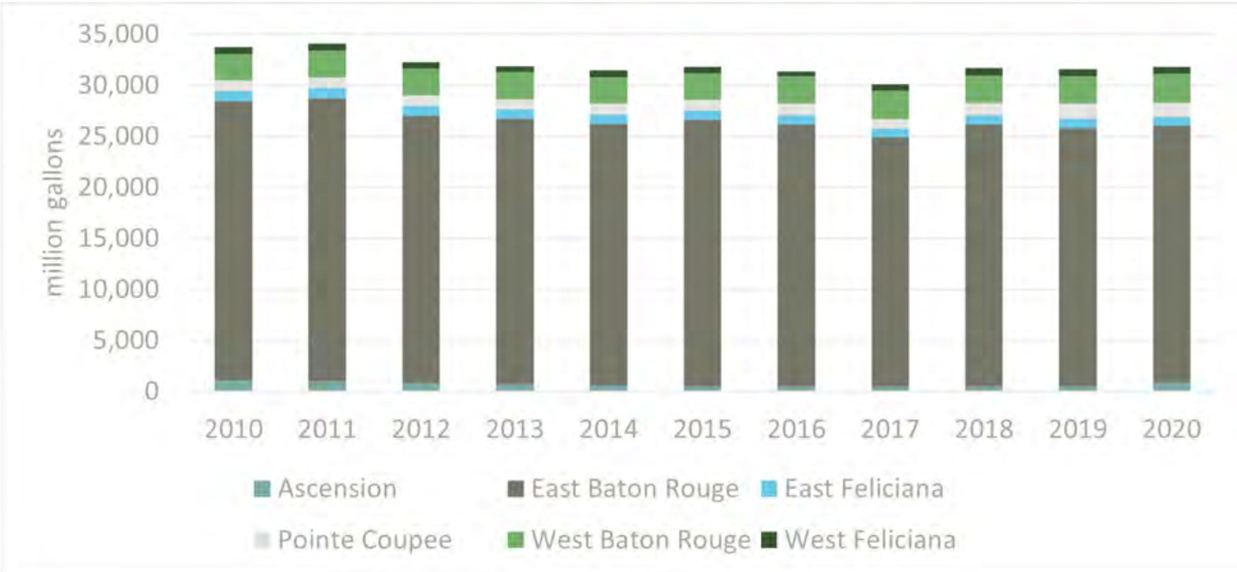


Figure VII. Estimated Groundwater Withdrawals for Public Supply in District parishes from 2010 to 2020. (See Fig. II for location of the parishes.) •Estimated withdrawals shown in the figure are based primarily on estimated usage reported to CAGWCC as public supply. The analysis is described in greater detail in the main body of the report under Task 2A.3.

Figure VIII. Estimated Year 2010 through 2020 partitioning of total groundwater and surface water usage for Industry across District parishes. Partitioning estimates were developed using usage data reported by respondents in the Industrial Water User Survey performed as part of this study, usage reported to CAGWCC, and information from USGS and Louisiana Department of Transportation and Development (LA DOTD) cooperative reports on water use and the SHAS (Collier & Sargent, 2018; Lovelace, 1991; Lovelace & Johnson, 1996; B. P. Sargent, 2002, 2007; P. B. Sargent, 2011). The analysis is described in greater detail in the main body of the report under Task 2A.3.

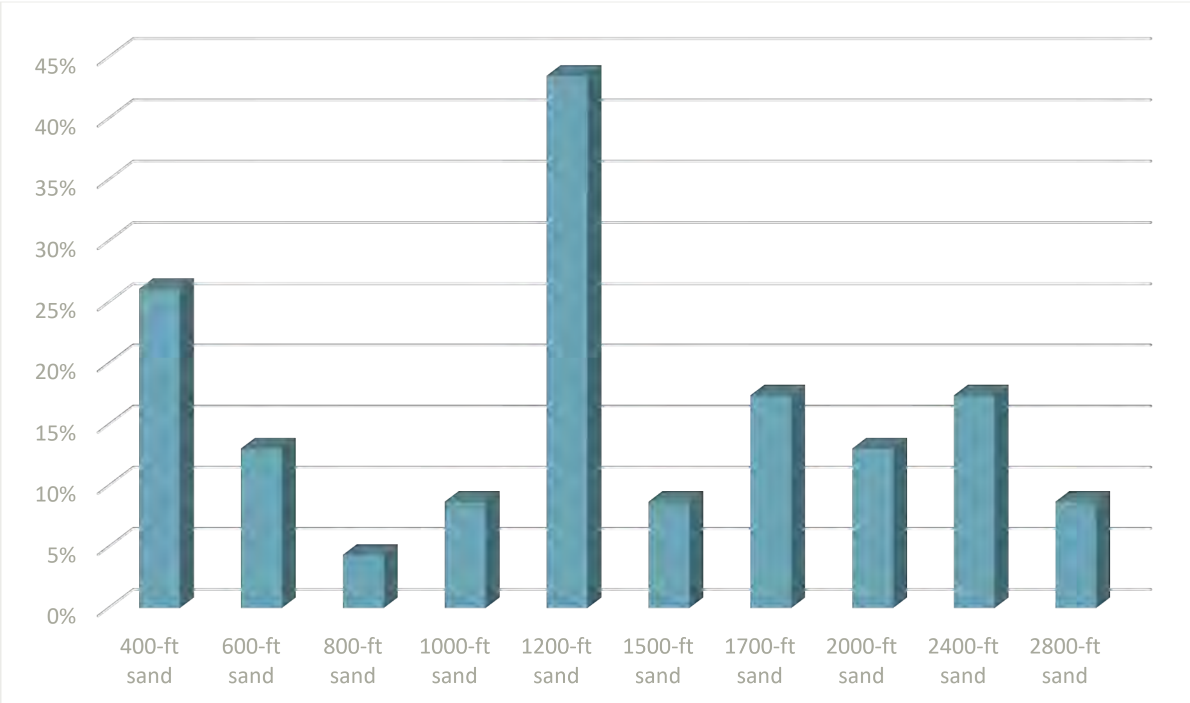


Figure IX. Stakeholder-identified sands in the Southern Hills Aquifer System (SHAS) where groundwater source originates as percent of respondents indicating use. Percentages were developed utilizing information reported by respondents in the Industrial Water User Survey performed as part of this study as described in detail in Task 2A.3.

TASK 2A.4

Understanding public knowledge and perceptions of groundwater in the CAGWCD will also aid the CAGWCC in their decision making. Information and data from Task 2A.4 will inform Performance Metric 2 (drinking water) (Table I). The problem of saltwater intrusion has been drawing increased public attention since 2010. In 2012, citizens requested a plan for Baton Rouge water management to ensure a sustainable future (Louisiana Department of Natural Resources, Public Meeting, March 12, 2012). The industry stakeholders urged the CAGWCC to make decisions based on science but recognized the need for a sustainable future (Public Hearing RE: Water Table Under East Baton Rouge Parish, 2012; Saltwater Encroachment Public Meeting, 2012). Previous public surveys have shown low levels of awareness of both the sources of drinking water and the threats to drinking water (Magellan Strategies BR 2012a, 2012b, 2014). The Water Institute of the Gulf conducted a new survey in 2021 to assess the current level of public awareness and knowledge as well as gain an understanding of the public perceptions of water cost, quality, and quantity. According to this survey, public perceptions of household water quality are very favorable in the CAGWCD (Figure X), yet many still rely on bottled water for drinking. The majority of respondents (72%, n = 305 respondents) did not know the source of household water was groundwater, and 78% had not heard about water management in their area. Respondents were divided as to whether or not they view saltwater intrusion as a pressing problem (Figure XI). These survey results suggest the need for an awareness and engagement effort that extends to the entire District.

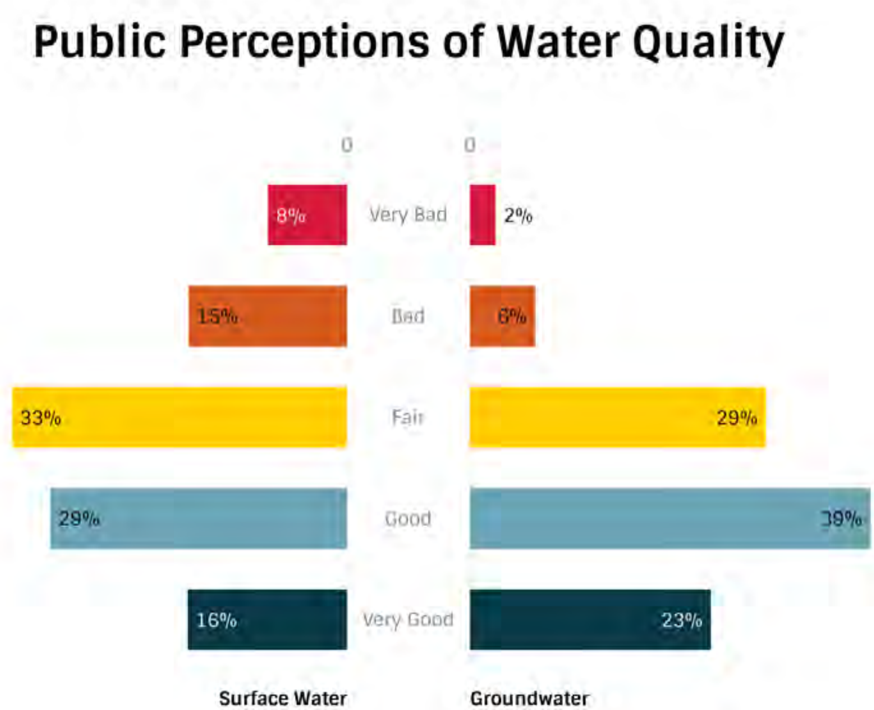


Figure X. Public perceptions of water quality in the Capital Area Groundwater Conservation District as measured by a survey conducted by the Water Institute of the Gulf in 2021, with 305 respondents (Appendix F).

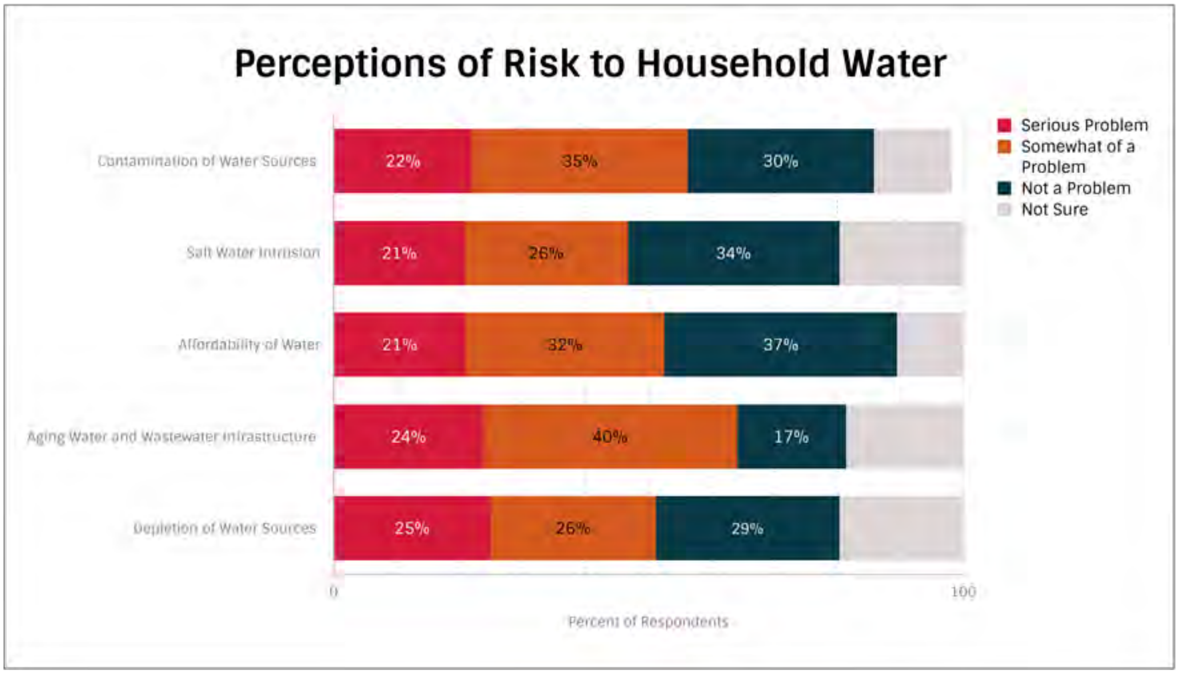


Figure XI. Public perceptions of risk to household water in the Capital Area Groundwater Conservation District as measured by a survey conducted by the Water Institute of the Gulf in 2021, with 305 respondents (Appendix F).

TASK 2A.5

Providing future water supply for domestic and industrial uses is one of the CAGWCC's objectives. Information and data from Task 2A.5 inform Performance Metrics 2 (drinking water) and 3 (commercial water) (Table I). Thirteen concept portfolios, including a Status Quo scenario, for alternative water supply and estimated planning-level costs associated with each were researched to aid the CAGWCC in considering different options. The Status Quo scenario considered costs related to continuing the current groundwater usage as is; this scenario estimates the costs for treatment of groundwater as the saltwater plume continues to encroach on the aquifer. These planning-level analyses allow the CAGWCC to assess the characteristics of supply options, key considerations for development, possible implementation challenges, and anticipated relative magnitude of cost. The thirteen supply options considered provided a range of water volumes from 0.5 million gallons per day (MGD) to 20 MGD, to be supplied from a combination of water sources; the volume estimates are based on aggregations of historical groundwater use by industrial users and included both potable and non-potable sources. On an annual cost basis, the Status Quo scenario was the most expensive, followed by a 20 MGD potable surface water project utilizing the Mississippi River (Figure XII; Figure XIII); however, surface water treatment had among the lowest estimated unit costs per volume produced of the concepts examined. On a unit cost per 1,000-gallon basis, brackish groundwater desalination was the most expensive. Water reclamation of both industrial and municipal supplies were also considered. Industrial reclamation had a higher unit cost, but municipal reclamation had a high annual cost. A combination of supply options is likely to serve the CAGWCD best, and several potential portfolios of options were examined. Multiple funding development options, including grants, loans, and public-private partnerships for water supply supplementation, have also been analyzed to inform the CAGWCC's decisions.

Figure XII. Estimated project concept capital cost in millions of dollars (October 2021 cost index). The analysis is described in greater detail in the main body of the report under Task 2A.5 and in Appendix G. MGD, millions of gallons per day at maximum capacity; SW, surface water; ASR, aquifer storage and recovery; GW Desal., groundwater desalination; Mun., municipal; Ind., industrial effluent; Inst., institutional effluent.

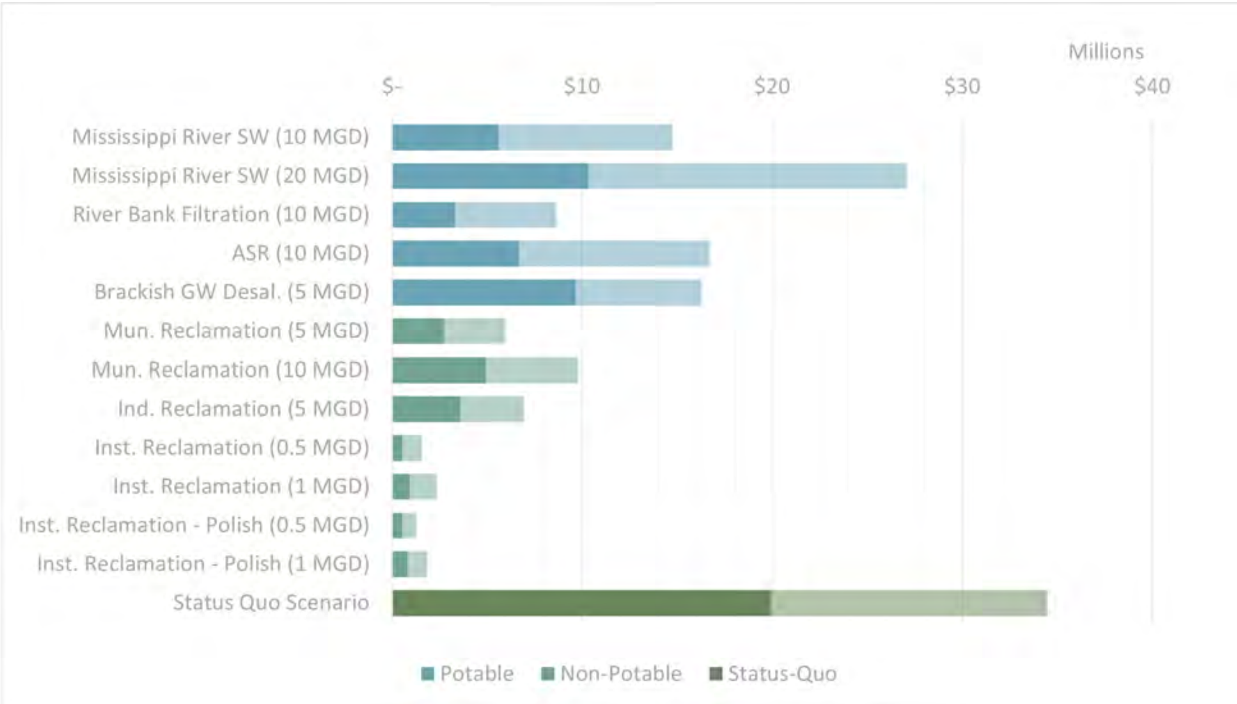


Figure XIII. Estimated project concept annual cost in millions of dollars per year (October 2021 cost index). Solid shading reflects energy and operations and maintenance components, with debt service shown in semitransparent shading. MGD, millions of gallons per day at maximum capacity; SW, surface water; ASR, aquifer storage and recovery; GW Desal., groundwater desalination; Mun., municipal; Ind., industrial effluent; Inst., institutional effluent. See Appendix G.

TASK 2A.6

A robust aquifer monitoring network is necessary to provide data to the CAGWCC to inform decision making; this task assessed the ability of the current network to provide such data. Information and data from Task 2A.6 will inform Performance Metrics 1 (sustainable groundwater withdrawal), 4 (saltwater intrusion), and 5 (subsidence) (Table I). The state of the current aquifer monitoring network was found to be generally good for monitoring the spatial extent of, and changes to, water levels and cones of depression, but areas for improving monitoring were identified for specific sands. The 1,000-foot sand was identified as needing the most improvement. Currently, 74 wells are monitored quarterly for water levels on the USGS CAGWCC network. Collection of water level is most important around the fault line, around the wells that are withdrawing groundwater, and around the saltwater plumes. Specific suggestions for improving the monitoring network are given in the main body of the report (section Task 2A.6).

The chloride monitoring network was also evaluated for its ability to adequately inform the CAGWCC on the state of saltwater intrusion. Prior to 2021, 42 wells were sampled for chloride concentration once per year by the USGS for chloride. A new agreement, beginning in FY2021, has increased the frequency of measurement to twice per year for all chloride network wells. A total of 48 wells were suggested as additions to the chloride monitoring network by the USGS and Dr. Tsai of Louisiana State University (Baton Rouge, LA). The addition of these wells to the chloride monitoring network would better constrain the location and movement of the saltwater plumes which is important for predicting the extent and timing of saltwater intrusion into the aquifer sands.

Over-pumping of the aquifer has reduced aquifer pressures; this has led to saltwater intrusion, but also to compaction of the aquifer and land sinking (subsidence). Subsidence has been seen in the CAGWCD since at least the 1960s (Davis & Rollo, 1969). Leveling studies (1960s and 1970s), extensometer studies (1975–1979 and 2001–2015), and Continuously Operating Reference System (CORS) GPS measurements (2014–2021) were compiled to evaluate the relationship between water levels and subsidence (see main body, section Task 2A.6 for citations of these studies). Extensometer measurements and currently available CORS data are limited to the area around the Industrial District of Baton Rouge. The effects of subsidence induced by groundwater extraction could affect the CAGWCD as a whole, not just the area of greatest pumpage (Figure XIV). Results from a 1978 study suggest that 1100 square miles was affected. The area affected by subsidence also seems to correspond with the area of the cone of depression in the aquifer sands. The most recent extensometer measurements agree with earlier work that subsidence will continue for several years after water levels stabilize. A table of subsidence rates measured in the CAGWCD is provided in Table II. The lack of consistent, regional subsidence monitoring in the District hampers efforts to understand the relationship between water levels and compaction. A regional strategy for monitoring subsidence will be an important component of future aquifer management.

Saltwater intrusion across the Baton Rouge Fault is recognized to occur across ‘leaky windows’ (areas of high permeability) in this overwise low permeability zone. Using electrical and drillers logs, these leaky windows were mapped to gain a better understanding of where monitoring may help to increase knowledge of the movement of the saltwater plume (Figure XV). In East Baton Rouge Parish and areas adjacent to the Mississippi River in West Baton Rouge Parish, 67 leaky windows were identified. Five priority areas are indicated for increased monitoring and potential addition of new monitoring wells to improve the understanding of where and how saltwater plumes cross the Baton Rouge Fault: Priority 1 area is from the Mississippi River to College Dr; Priority 2 area is from Lobdell Hwy to the Mississippi River; Priority 3 area is from College Dr to Essen Ln; Priority 4 area is from Essen Ln to Bluebonnet Blvd; Priority 5 area is from Sherwood Forest Blvd to Hickory Ridge Blvd (Figure XVI). Priority area 1 targets the current saltwater intrusion problem in the 1500-foot sand and 2000-foot sand near the fault. Wells in Priority area 2 would help to investigate if saltwater plumes are migrating from the west side of the Mississippi River. Priority areas 3 and 4 target potential saltwater intrusion in the 1200-foot sand. Priority area 5 would be used to investigate saltwater intrusion to the 1700-foot sand.

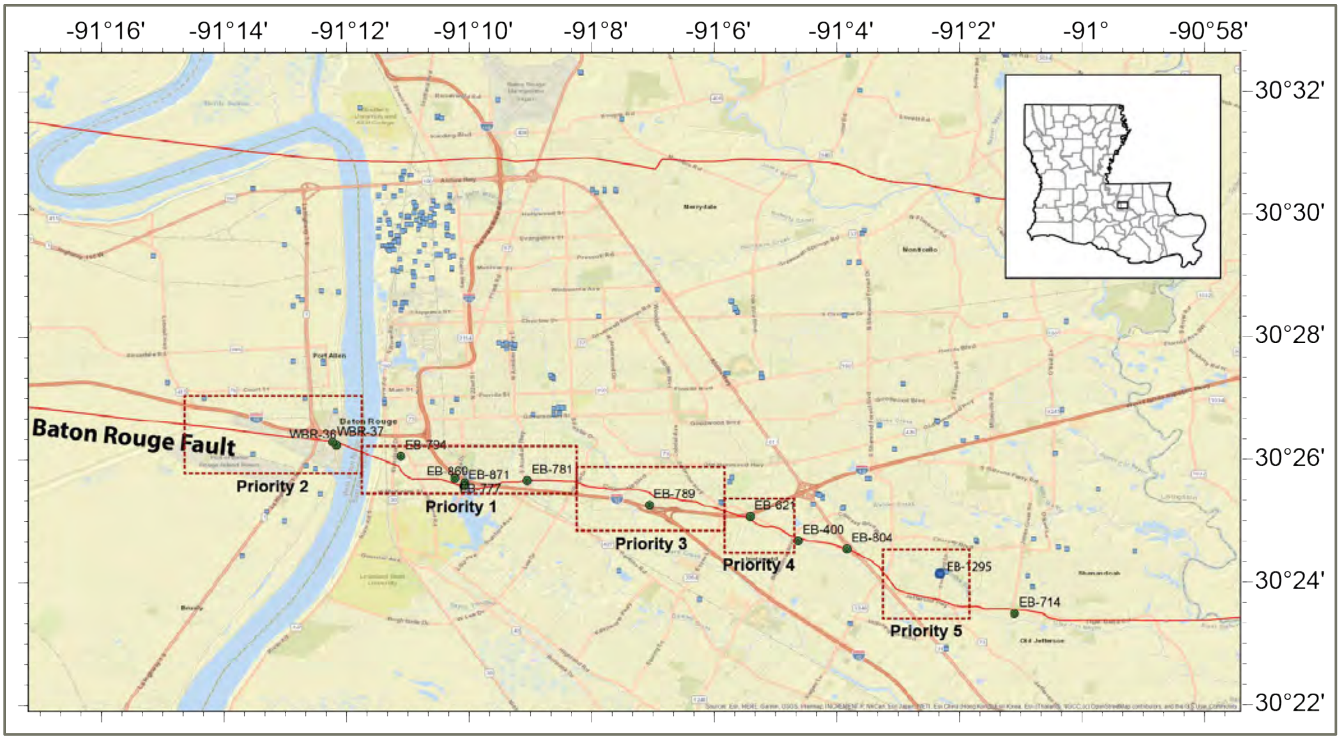


Figure XVI. Priority areas for establishment of new monitoring wells. The map shows the location of existing monitoring wells (labelled as West Baton Rouge [WBR] or East Baton Rouge [EBR] with identifying numbers) and location of pumping wells (blue squares). A total of 23 new wells were identified to improve monitoring of the saltwater plume in these priority areas (see Task 2.6 of this report).

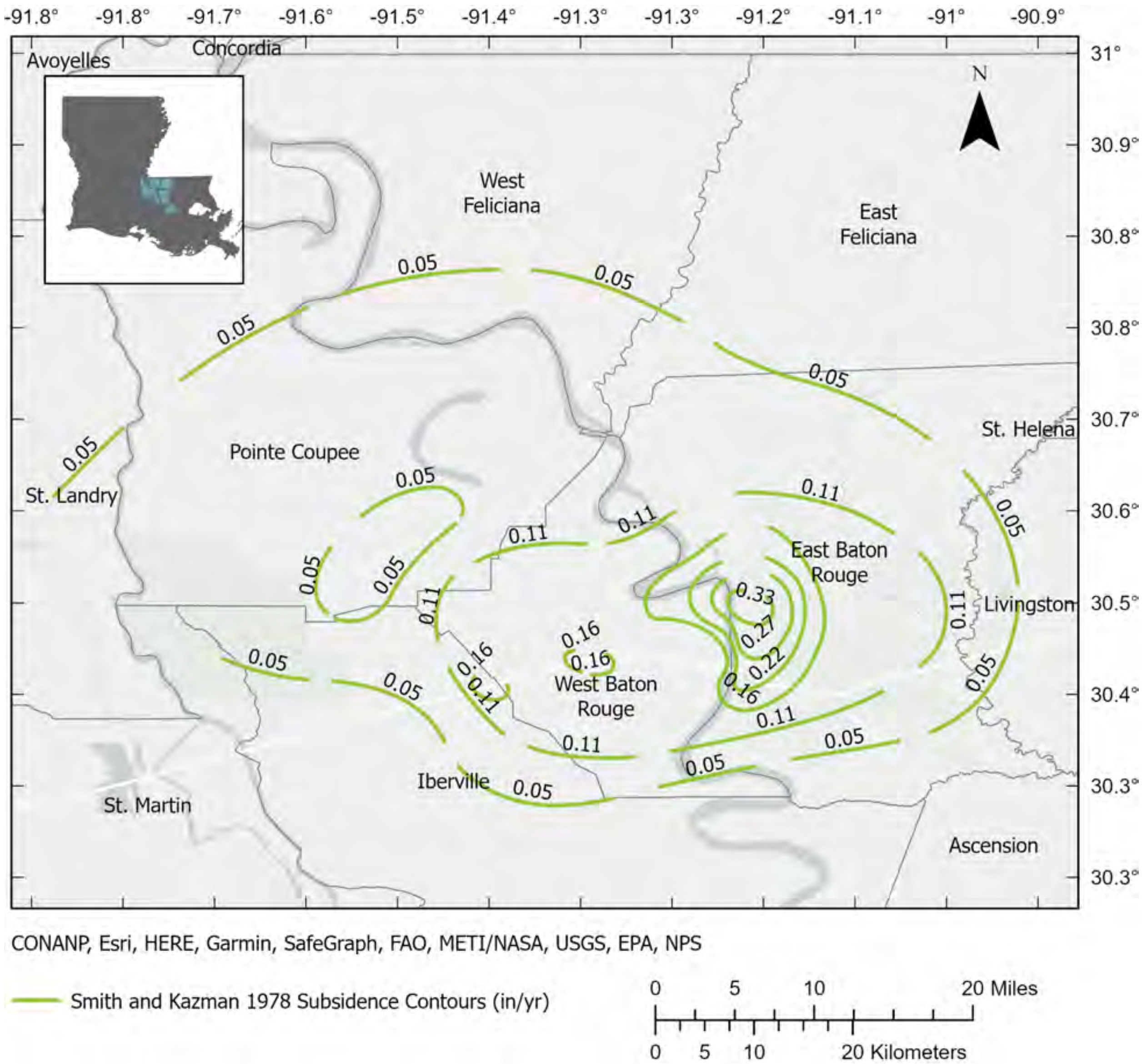


Figure XIV. Contours of subsidence rate measured as in/yr in the CAGWCD. Modified from Fig 4 in Smith and Kazmann (1978).

Table II. Summary of subsidence rates in and around the Industrial District resulting from groundwater withdrawal. The regional subsidence rate was subtracted from the rate determined by leveling and continuously operating reference stations (CORS). These rates are given as a range to indicate uncertainty in the regional subsidence rate (0.055 in/yr to 0.12 in/yr). Total subsidence is the estimated excess subsidence over and above regional subsidence for the time period. Note that the time periods vary considerably between the different measurements.

Time period	Subsidence Rate due to groundwater withdrawal (in/yr)	Total Subsidence due to groundwater withdrawal (ft)	Measurement Type	Data Source
1900-1965	0.06 – 0.13	0.33 – 0.70	Leveling	Davis and Rollo 1969
1938-1964	0.42	0.9*	Leveling	Wintz Jr et al.1970
1934-1976	0.36 – 0.43	1.26 – 1.51	Leveling	Smith and Kazmann 1978
1975-1979	0.15	0.05	Extensometer	Whiteman 1980
2001-2015	0.082	0.10	Extensometer	USGS 2021 data; analysis in this report
2014-2021	0.01 – 0.075	0.0058 – 0.044	DOTD CORS	Abdalla 2021

**Wintz Jr et al. (1970) report this as the total subsidence attributable to groundwater extraction.*

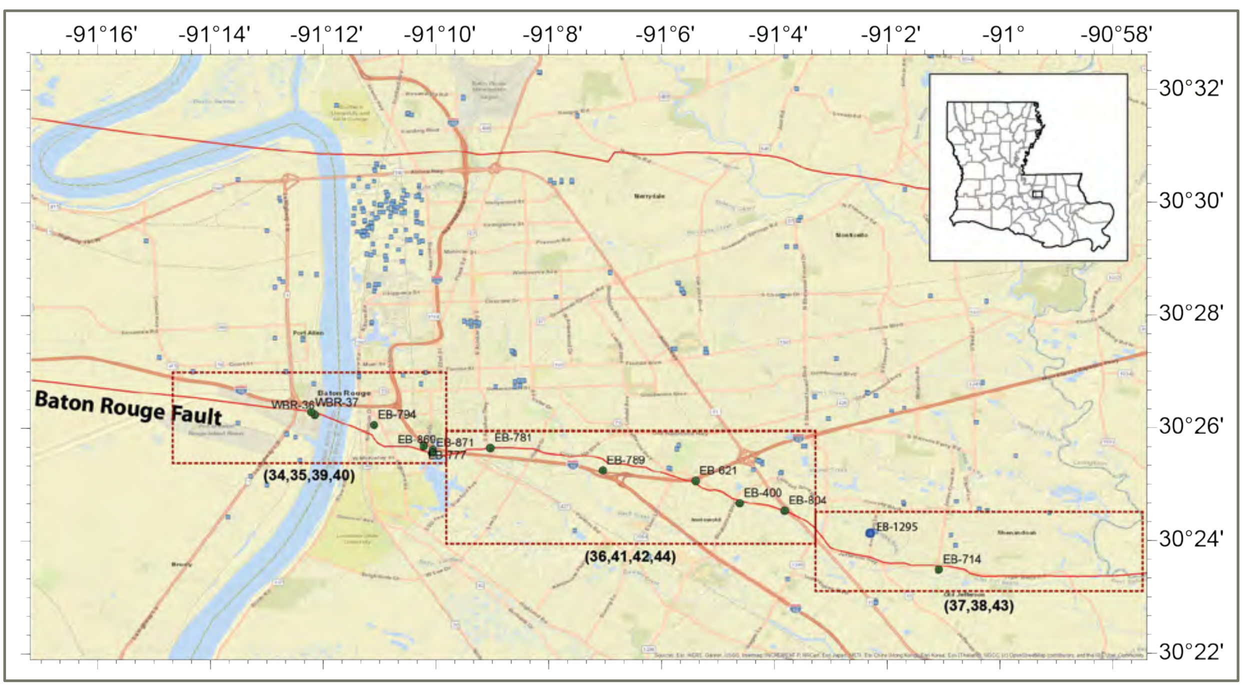


Figure XV. Leaky windows and their IDs for the 1500-foot sand in the Baton Rouge area of the CAGWCD. Leaky windows exist in multiple aquifer sands and facilitate saltwater intrusion into the SHAS.

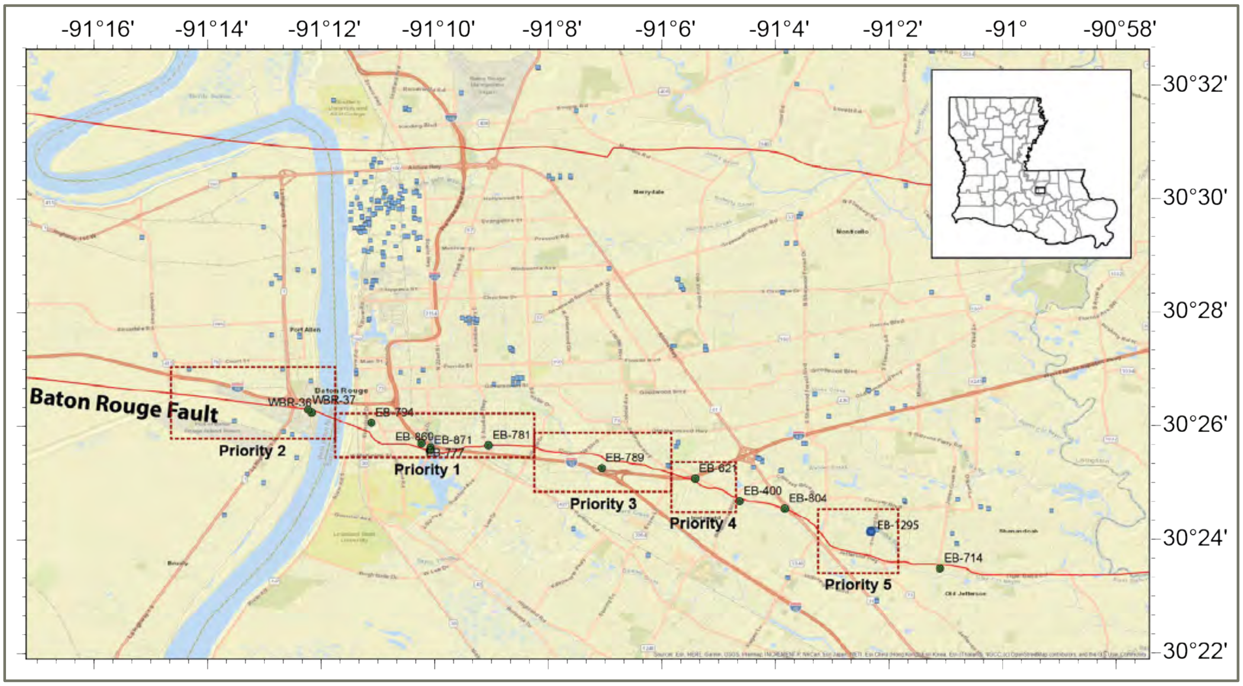


Figure XVI. Priority areas to acquire more geological information and chloride data in the Baton Rouge area of the CAGWCD. (See Task 2.6 of this report.)

TASK 2.7

This task is part of Phase 2B, not Phase 2A, and will be covered in a future report.

TASK 2.8

This task is part of Phase 2B, not Phase 2A, and will be covered in a future report.

TASK 2A.9

Facilitated Forums are being held throughout all phases of strategic plan development. These forums, hosted by The Water Institute of the Gulf for the CAGWCC, are intended to provide the CAGWCC with the necessary background to make informed decisions about the management of the aquifer, and a forum for questions and discussions related to the strategic planning process. Three Facilitated Forums were held in Phase 2A to discuss the following topics: legal overview; economics; and environmental modeling and data. During the first Facilitated Forum (held virtually, October 28, 2021), the Institute reviewed the CAGWCC's legal authority, including their authority to set groundwater use priorities and define "research data" and "detailed research." These discussions provided a foundation for understanding how the CAGWCC can exercise its legal authority and powers. The industrial water analysis was presented during the second Facilitated Forum (also held virtually on October 28, 2021) by Freese and Nichols, Inc. During the third Facilitated Forum (held virtually, November 30, 2021), the Institute presented on an equilibrium analysis of the potentiometric surface consistent with current pumping rates and well data (known as a "Darcy flow analysis"), and Dr. Tsai presented information on how a groundwater availability model is constructed and how it can be used to inform decisions. More details about the facilitated forum are presented in the section on Task 2A.9 in the main body of this report.

During Phase 2B the entire project team will continue to work with the CAGWCC to provide data, information, and guidance on the development of a strategic plan for the CAGWCD. Phase 2B tasks include the development of a Groundwater Availability Model to inform the CAGWCC on water supply, a forecast of water demand across the CAGWCD, further economic analyses of alternatives, analysis of public attitudes towards the alternatives, and a legal and policy analysis. The Institute looks forward to working with the CAGWCC and our project partners on the important work to come.

TASK 2.10

This task is part of Phase 2B, not Phase 2A, and will be covered in a future report.

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COMMON UNITS

Throughout this report, we have reported the units that are commonly in use for the various metrics by scientists and partners in the CAGWCD. These units include a mix of measurements from the Internatioal System of Units, from other metric systems, from the British Imperial system, and from the United States customary system. We have chosen to continue to report the metrics in the ways that are locally familiar to people, rather than create a consistent set from a single system of measurement.

Abbreviation	Term
°F	Degrees Fahrenheit
ft	Feet
gpcd	Gallons per-capita daily
gpm	Gallons per minute
in	Inches
kg	Kilograms
km	Kilometers
kWh	Kilowatt-hour
m	Meters
m^3	Cubic meters
Mgal	Millions of gallons
MGD	Millions of gallons per day
mi^2	Square Mile
mg/L	Milligrams per liter
mm/yr	Millimeters per year

LIST OF ACRONYMS AND ABBREVIATIONS

Acronym	Term
ACS	American Community Survey
AEP	Annual Exceedance Probability
ASR	Aquifer Storage and Recovery
BFE	Base flood elevation
BOD	Biochemical oxygen demand
BR	Baton Rouge
C4G	Center for Geoinformatics, Louisiana State University
CAGWCC	Capital Area Ground Water Conservation Commission
CAGWCD	Capital Area Ground Water Conservation District
CDBG	Community Development Block Grant
COD	Chemical oxygen demand
CORS	Continuously Operating Reference Station
CWEF	Community Water Enrichment Fund
CWSRF	Clean Water State Revolving Fund
DBB	Design-bid build
DBF	Design, build, and finance
DBFOM	Design, build, finance, operate, and maintain
DBO	Design, build, operate
DBOM	Design, build, operate, and maintain
DO	Dissolved oxygen
DOTD	Department of Transportation and Development
DWRLF	Drinking Water Revolving Loan Fund
DWSRF	Drinking Water State Revolving Fund
EBR	East Baton Rouge
FEMA	Federal Emergency Management Agency
FNI	Freese and Nichols, Inc.

Acronym	Term
GAM	Groundwater Availability Model
GPS	Global Positioning System
GRP	Groundwater reduction plan
GTUA	Greater Texoma Utility Authority
HUD	U.S. Department of Housing and Urban Development
IIJA	Infrastructure Investment and Jobs Act
InSAR	Interferometric Synthetic Aperature Radar
LA DOTD	Louisiana Department of Transportation and Development
LDEQ	Louisiana Department of Environmental Quality
LDNR	Louisiana Department of Natural Resources
LGAP	Local Government Assistance Program
LMG-WSC	Lower Mississippi Gulf-Water Science Center, U.S. Geological Survey
LSU	Louisiana State University
MRAA	Mississippi River Alluvial Aquifer
NGS	National Geodetic Survey
NWIS	National Water Information System
O&M	Operations and Maintenance
OCD	Office of Community Development
P3	Public-Private Partnership
PWS	Public Water System
REAP	Regional Economic Analysis Project
SHAS	Southern Hills Aquifer System
SONRIS	Strategic Online Natural Resources Information System
SRF	State Revolving Fund
TDS	Total Dissolved Solids
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

Acronym	Term
WBR	West Baton Rouge
WIFIA	Water Infrastructure Finance and Innovation Act

PHASE 1 SUMMARY

In June 2018, the Capital Area Ground Water Conservation Commission (hereafter, CAGWCC) contracted with The Water Institute of the Gulf (hereafter, the Institute) to facilitate and undertake a three-phase project (hereafter “the project”) to develop a long-term strategic plan for the management of the Southern Hills Aquifer System (SHAS) within the Capital Area Groundwater Conservation District (CAGWCD) in southeastern Louisiana. During Phase 1 of the project, which was completed in 2020, a framework for the long-term strategic plan was developed (Runge et al., 2020). The Institute worked with the U.S. Geological Survey (USGS) to facilitate five public meetings with the CAGWCC and used the principles of structured decision making (Gregory et al., 2012) to elicit and develop the elements of this framework with the CAGWCC. Much of the discussion within these facilitated meetings occurred directly with Commissioners, but members of the public in attendance also had the opportunity to provide comment. Phase 1 resulted in five fundamental objectives for the management of groundwater by the CAGWCC, as well as the development of broadly defined alternative strategies for meeting these objectives. Additional information on Phase 1 can be found in Runge et al. (2020). The fundamental objectives will guide the work and research in Phase 2 and the development of the long-term strategic plan.

PHASE 2 GOALS

In Phase 2 of the project, the Institute and other experts are evaluating alternative strategies as they relate to the fundamental objectives developed in Phase 1 so as to provide a better understanding of the efficacy of each alternative, and the trade-offs that need to be balanced when assessing the alternatives. This analysis is occurring in two stages. First, initial analyses are being conducted to quantify the expected demand for water within the Capital Area Ground Water Conservation District (hereafter CAGWCD) via socioeconomic forecasting and the available, sustainable supply of water from the sands within the aquifer (via Darcy flow analysis; [Darcy, 1856]). In addition, options for water supplementation are being examined in terms of cost, availability, and other relevant concerns. From this information, it is possible to estimate the water surplus or deficit over time and develop details for each alternative strategy (e.g., the timing of production caps and the location of production zones). Second, a consequence analysis will be used to evaluate the performance of those alternative strategies as they relate to the fundamental objectives, including articulating and quantifying the uncertainties associated with each alternative.

Phase 2 was initiated in 2021 and will occur over multiple years in multiple phases: Phase 2A, Phase 2A1, and Phase 2B (Figure 1). The technical work within Phase 2A includes initial data gathering and analyses that will be used in Phase 2A1 and Phase 2B. These latter parts of Phase 2 include economic analyses, community outreach, and the development of the Groundwater Availability Model (GAM). Phase 2A includes Tasks 2.1, 2.3, 2.4, 2.5, 2.6, and 2.9 (but not Tasks 2.2, 2.7, 2.8, and 2.10); Phase 2B includes Tasks 2.2, 2.3, 2.4, 2.5, 2.7, 2.8, 2.9, and 2.10 (but not Tasks 2.1 and 2.6).

PURPOSE OF THIS REPORT

This report serves as the final written update to the CAGWCC for Phase 2A of the project. It details the Phase 2A work conducted and describes the next steps that will be part of Phase 2B. At the beginning of each task section, there is a task description—modified from the Scope of Work—for reference.

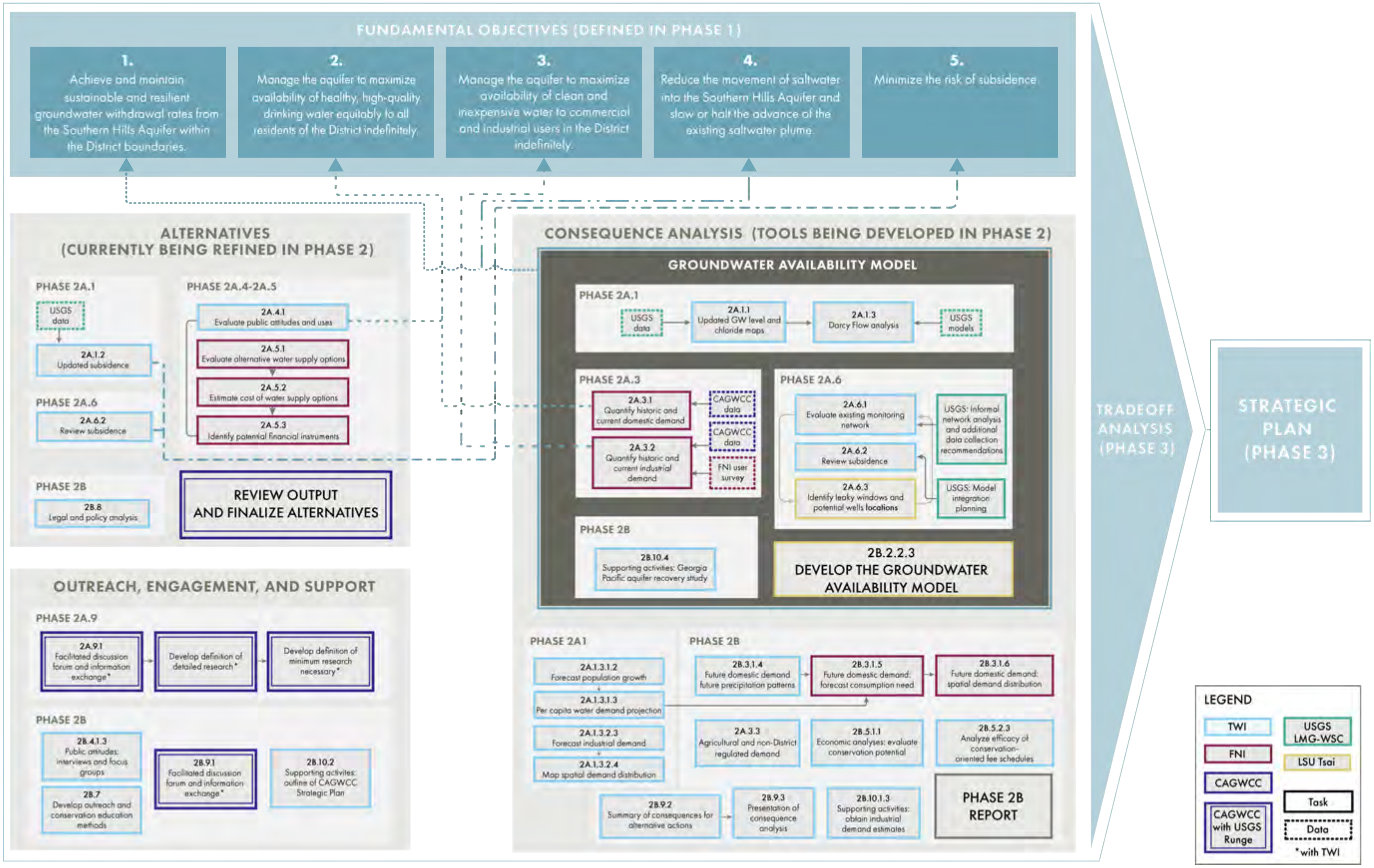


Figure 1. This flow chart details how each task of Phase 2 interacts to support the fundamental objectives and the development of a strategic plan. Freese and Nichols (FNI) and Dr. Frank Tsai from Louisiana State University (LSU Tsai) are project partners with the Institute (TWI). The USGS Lower Mississippi-Gulf Water Science Center (LMG-WSC) is also participating in this work through its long-standing agreement with CAGWCC.

FUNDAMENTAL OBJECTIVES

The fundamental objectives describe the long-term outcomes that the CAGWCC aims to achieve through its activities, including outcomes important to stakeholders. All work, throughout all phases, is guided by the fundamental objectives, and thus it is useful to review them, in brief, here. For a more detailed discussion see (Runge et al., 2020). “The District” refers to the CAGWCD in the fundamental objectives.

1. *Achieve and maintain sustainable and resilient groundwater withdrawal rates from the Southern Hills Aquifer System within the District boundaries.*

2. *Manage the aquifer to maximize availability of healthy, high-quality drinking water equitably to all residents of the District indefinitely.*

3. *Manage the aquifer to maximize availability of clean and inexpensive water to commercial and industrial users in the District indefinitely.*

4. *Reduce the movement of saltwater into the Southern Hills Aquifer System and slow or halt the advance of the existing saltwater plume.*

5. *Minimize the risk of subsidence.*

PERFORMANCE METRICS

> *As part of Phase 1, the CAGWCC, in consultation with the Institute and USGS, drafted a set of performance metrics. These metrics render the fundamental objectives operational for evaluating the different alternatives. They will be finalized in Phase 2.*

Performance metrics are quantitative or qualitative scales that enable the alternative strategies to be objectively evaluated based on how well those strategies are advancing the fundamental objectives. As such, performance metrics are a key component in both selecting the alternate strategy most likely to have the preferred outcomes and, later, in evaluating how successful the strategy was after implementation.

During Phase 2, each of the metrics proposed in Phase 1 is being refined and the Institute is working with project partners to develop the calculation methods specific to each metric. Thus far, the Institute has held multiple meetings with the different project partners to refine the performance metrics. Calculation methods for all metrics are being drafted and discussed. The USGS Lower Mississippi-Gulf Water Science Center (LMG-WSC) and Louisiana State University (LSU) have been involved in the discussions related to Performance Metrics 1 and 4, which reference potentiometric surface elevations and mass of salt in the aquifer, respectively. Because these two metrics will be calculated using outputs from the GAM developed in Phase 2, it is important to ensure these metrics are understood by the project partners and that they can be calculated from model inputs. The Institute is refining Performance Metric 2, targeted toward maintaining public access to drinking water and based on data relating to cost, quantity, and quality. Performance Metric 3, cost to industrial users, was drafted by Freese and Nichols, Inc. (FNI) and is based, in part, on the data that are available to support calculation and includes consideration of the cost of treatment and the quantity of water that will be treated. Performance Metric 5 (“Minimize the risk of subsidence”), is being developed by the Institute based on historical records of water levels, pumping, and subsidence rates.

The proposed performance metrics for each of the fundamental objectives are described below. All of these metrics are still under development and feedback from the CAGWCC is welcomed.

Objective 1:

Achieve and maintain sustainable and resilient groundwater withdrawal rates from the Southern Hills Aquifer System within the District boundaries.

Performance Metric:

Mean potentiometric elevation across the CAGWCD at equilibrium, separately for each sand.

This objective will be achieved when the withdrawal rate in each sand is less than or equal to the recharge rate for that sand. If this happens and the spatial distribution of withdrawal is fixed, then the pressure levels throughout the sand would be expected to stabilize over time, along with the water levels at each well. As such, stable water levels in wells or a stable potentiometric surface are sufficient indicators of withdrawal rates that are sustainable with respect to water level (but not water quality or land subsidence which are considered in other performance metrics). These indicators, however, may not be necessary, because the spatial distribution of withdrawal need not be static; the locations of production wells may change over time. Instead, it would be sufficient for the average water level across the sand to be stable. This water level could be measured using water level data from wells in each of the sands, mapping the potentiometric elevation and integrating over the area of the sand. This objective could then be visualized as the shape, character, and spatial extent of the cone of depression. The proposed summary metric is the mean water level, calculated as:

$$\bar{p} = \frac{\int_S \, p(S)\, dS}{\int_S \, dS} \tag{1}$$

where:

$p(S)$ is the potentiometric elevation that varies by spatial location (S) and the integration is taken over the extent of the CAGWCD.

It is proposed to calculate this metric separately for each sand. An integrated metric across sands (e.g., by adding the volumes of the respective cones of depression) could obscure impacts of concern within a particular sand. During Phase 3, methods of tradeoff analysis incorporating the performance metrics of individual sands will be developed.

The primary consideration for this objective is sustainability. Since sustainability cannot be calculated directly, the metric is based on potentiometric elevation. An underlying assumption in using potentiometric elevation to evaluate sustainability when comparing management alternatives is that the potentiometric elevation has reached equilibrium at the end of the 50-year planning horizon. If a given alternative shows that the potentiometric elevation is dropping at the end of the 50-year planning horizon, it would be considered less sustainable than an alternative for which the potentiometric elevation that has stabilized.

Because of the potential for the potentiometric elevation to change over time, two questions that will be asked to serve as checks on this performance metric include:

Have the water withdrawals (within each sand) stabilized within the planning period?

Have the mean potentiometric elevations (within each sand) stabilized, in turn, within the planning period?

Many different mean water levels could meet these two checks, but they may not all confer the same degree of resilience. Further work will be needed in Phase 3 to define the desired levels at which to hold the average water level in each sand.

Objective 2

> *Manage the aquifer to maximize availability of healthy, high-quality drinking water equitably to all residents of the District indefinitely.*
>
> **Performance Metric:**
>
> *Individual subjective and objective metrics representative of drinking water quality, quantity, and cost.*

Drinking water metrics can be broken down into categories based on issues related to accessibility and reliability (quantity), acceptability (quality), and affordability (cost). Both subjective and objective metrics are necessary to provide an accurate baseline of drinking water quality. Subjective metrics are calculated based on the public attitudes about groundwater that were collected as responses to the survey conducted for Task 2A.4. The survey was designed to capture the public perception of the quantity, quality, and cost of water resources in the study area using 33 water-related questions, and was administered to 300 respondents using the *Qualtrics* platform (see Appendix E). While the subjective metrics are based on survey responses, it is important to note that the majority of survey respondents have not read or heard anything regarding groundwater management, suggesting that 78 percent of respondents are not aware of any type of quantity, quality, or cost issue.

The subjective metrics, which were captured in the survey conducted in Fall 2021, provide a baseline to systematically assess the changes in the perceptions to groundwater management and quality across the CAGWCD every five years. The subjective metric for water quantity will be derived from survey question 24: “Please rate the following local water related issues on a scale of not a problem to very serious”. To assess the public perception of water quantity issues, question 24 specifically asked respondents to rate their perceptions of the seriousness of the depletion of water sources. The subjective metric for quality is derived from the groundwater survey responses to question 14: ‘What do you think of the following aspects (taste, odor, appearance, and feel) of the water in your household?’ The respondents were asked to rank each of these aspects on a four-point scale ranging from “bad” to “excellent.” The subjective metric for cost is derived from survey question 29: “What do you think of your current water bills?” for which the respondents were asked to select from either “low,” “about right,” and “high”.

There are also objective measures for each category (quantity, quality, and cost). The quantity metric incorporates the per capita consumption (gallons per person per day), the size of the population served by the water system, and the fraction of time there are service disruptions.

$$Water\ Quantity = Per\ Capita\ Consumption \times Population\ Served \times (1 - Disruption\ of\ Service) \quad (2)$$

where

- Per Capita Consumption = (Total Volume of Domestic Water Produced / Pumped Daily)/ Total Number of People Served
- Population Served = Total Number of Persons Served by the Domestic Water Supply
  - Total population based on census
    or
  - Number of Service Connections × 2.5
    - Where 2.5 represents the standard occupancy factor per service connection
- Disruption of Service = Number of Service Calls / Number of Connections

The objective metric for quantity represents the actual quantity used by households, whereas the quantity of water available in the aquifer will be calculated by the GAM. Objective measures of drinking water quality are best calculated using a minimum of ten variables from the following five classes: oxygen level, eutrophication, health aspects, physical characteristics, and dissolved solids (Tyagi et al., 2020). These water quality variables can be combined using a weighted arithmetic water quality index method which classifies the water quality by degree of purity (Tyagi et al., 2020). Based on the available well sampling information, the quality metric incorporates pH, specific conductance, chlorides, temperature, total dissolved solids, alkalinity, color, hardness, salinity, nitrates, and total phosphorus.

$$Water\ Quality = \frac{\sum Q_i W_i}{\sum W_i} \quad (3)$$

where

- Q_i *= the quality rating scale for each parameter*
- *i* represents the value related to a specific parameter

$$Q\_i \ = 100 \left[\frac{\mathrm{V_i} \ - \ \mathrm{V_o}}{\mathrm{S_i} - \mathrm{V_o}}\right]$$

(4)

where

- V_i is the estimated concentration of i[th] parameter in the sample
- V_o is the ideal value of this parameter in pure water
  - $V_o = 0$ (except pH = 7. and dissolved oxygen (DO) = 14.6 mg/L)
  - *Pure water represents the ideal value, not the best measurement of local water quality*
  - *The ideal value is based on EPA Drinking Water Quality standards*
- S_i is the recommended standard value of the ith parameter

$$W_i = \frac{K}{S_i}$$

(5)

where

- *K = proportionality constant and is calculated in Equation 6*
- S_i is the recommended standard value of the ith parameter

$$K = \frac{1}{\Sigma\left(\frac{1}{S_i}\right)}$$

(6)

where

- S_i is the recommended standard value of the ith parameter

The cost objective metric incorporates the service affordability, monthly cost, and consumption levels.

$$Water\ Affordability\ = \frac{Average\ Monthly\ Water\ Bill\ \times\ 12}{Median\ Household\ Income}$$

(7)

When a water bill increases above 2.5 percent of the median household income, the bill is considered to have a significant impact on the household (The Pacific Institute & The Community Water Center, 2012). The U.S. Environmental Protection Agency (USEPA) considers a combined annual water bill and wastewater bill that is less than 4.5 percent of the median household income to be affordable (Stratus Consulting, 2013).

Objective 3:

Manage the aquifer to maximize availability of clean and inexpensive water to commercial and industrial users in the District indefinitely.

Performance Metric:

Composite unit cost of water supply for industrial users.

The performance metric for Objective 3 will provide context for industrial supply alternatives or portfolios of alternatives examined in the study. The two major supply drivers for industries in the study area, and which are incorporated into the language of Objective 3, are water quality and cost. Commercial and industrial users have requirements for water quality which can be met by water treatment at their facilities. Water quality and cost are directly linked through the cost of treating water (to achieve the appropriate quality) and the connection to potential future alternate sources of supply. Due to this linkage, the proposed performance metric examines composite unit treatment cost for industry under each supply alternative scenario relative to current composite unit cost as shown in Equation (8):

$$Cost\ Factor = \frac{(Composite\ Unit\ Cost)_{scenario}}{(Composite\ Unit\ Cost)_{current}} \quad (8)$$

$$Composite\ Cost = \frac{\sum_{i=1}^{X} V_i * C_i}{\sum_{i=1}^{X} V_i} \quad (9)$$

where

- V_i is the volume of treated water for each source
- C_i is the treated water cost per volumetric unit of that source
- i reflects the existing industrial entities considered in the analysis
- X is count of entities

Evaluation of this metric is applied in the context of the industrial water users as a whole. Note that no data are presented at the individual entity or facility level, in order to retain anonymity for individual industrial water users.

Objective 4.

Reduce the movement of saltwater into the Southern Hills Aquifer System and slow or halt the advance of the existing saltwater plume.

Performance metric:

The mass of salt (chloride ion) in groundwater in all sand layers within the spatial bounds of the CAGWCC authority after 50 years, corresponding to the planning horizon of the long-term strategic plan.

The total mass of salt in each sand layer is a measure of the degree of intrusion. Continued intrusion will increase the mass while mitigation strategies such as scavenger wells will decrease the mass (scavenger wells are designed to remediate the intrusion of saltwater by selectively removing it; Duplechin, 2013). The desire would be for the mass of salt to stabilize in each sand layer, so there is no continued increase in net salt. The proposed metric would add the mass of salt across each sand layer, without weighting, to calculate a total salt mass for the aquifer.

The mass of salt is calculated as an unweighted sum of all sand layers after 50 years, corresponding to the planning horizon of CAGWCC.

$$m_s = 10^{-3} \sum_{n=1}^{N} \overline{\rho_{n,50}} \; V_n \qquad (10)$$

where

- m_s = total mass of chloride ions (Cl^-) in groundwater within the spatial bounds of CAGWCC authority, in kg.
- n = sand layer
- N = total number of sand layers
- V_n = volume of sand layer n, in m^3
- $\overline{\rho_{n,50}}$ = average concentration of Cl^- in sand layer n at 50 years, in mg/L
- 10^{-3} is the unit conversion factor from mg/L to kg/m^3

The chloride ion (Cl^-) concentration is used as a measure of salt concentration in calculation of this metric because the GAM can calculate it readily, monitoring data are available for calibrating and validating this parameter in the model, and it is well-correlated with total salt concentration. While the dominant cation is sodium (Na^+), there are other potential cations (Ca^{2+}, Mg^{2+}, and others), but the precise mix of cations is not needed to measure the magnitude of saltwater intrusion.

This calculation methodology only considers the total mass of salt present at 50 years, which is the planning horizon for the CAGWCC long-term strategic plan. This calculation method may not be the best approach if different management strategies have the same concentration of salt at the end of the 50-year period but different trajectories over time. In addition, the total mass of salt within the aquifer is calculated as the unweighted sum of mass within each of the sand layers. Calculating the concentration of salt within individual sands may be necessary to inform the fundamental objective of "Reduce the movement of saltwater into the SHAS and slow or halt the advance of the existing saltwater plume" if the salt concentration of one sand layer is changing drastically while the others are stable, or if the salt concentration increases in some sand layers while decreasing in others.

To account for this potential change in salt concentrations, two checks of the performance metric will be conducted:

1. Evaluation of the shape of the time-series of salt mass within the aquifer under varying management alternatives, and
2. Evaluation of the trajectory of the salt in each sand layer over time under varying management alternatives.

In the first check, the mass of salt at the end of 50 years will be retained as the calculation method if the overall shape of the curve is similar for the management alternatives. If the shape of the curve varies for different management alternatives, however, the average mass of salt per year will be used as a more appropriate metric. In the second check, the trajectory of the salt in each sand layer over time will be calculated. If the concentration of salt within the sand layers are well-correlated with each other, the unweighted sum of the mass of salt in each sand layer will be kept as the calculation method (Eq. (10]). If there is inconsistency in the behavior of mass of salt within each sand layer, the calculation methodology will be revisited based on that analysis. For example, a single sand layer or subset of sand layers may be identified as being most indicative of the status of the saltwater plume in the aquifer, in which case the calculation method will be updated to limit calculation to only those sand layer(s) or to weight the influence of those sand layers within the calculation more heavily.

Objective 5.

Minimize the risk of subsidence.

Proposed Performance Metric:

Amount of subsidence at wells in the CAGWCD.

A detailed review of subsidence data for the region is presented in the section, "Review of current subsidence measurement activities." Subsidence effects from groundwater pumping are highly localized and thus should be calculated at well locations rather than averaged across the CAGWCD. However, due to the deep nature of groundwater withdrawal and resulting broad cone of depression, the result of subsidence can be broadly conceptualized to be a bowl-shaped depression of the land surface covering a large portion of the CAGWCD, centered on the Industrial District (Figure 2). The metric would ideally be calculated at all wells to monitor across the CAGWCD for subsidence hotspots which may change with changes in the location of areas of large pumpage.

The relationship between water levels and measured subsidence will be used to calculate the subsidence metric. The extensometer data provided by USGS is expected to provide the information for this calculation as it provides the longest and most detailed record at any location in the CAGWCD. Careful consideration will be given to how to apply the relationship between subsidence and water levels determined in the Baton Rouge Industrial District to the wider CAGWCD. Analysis of the extensometer data has been performed, and the data inform the next step in defining this metric. Analysis of the historical subsidence record has provided a range of subsidence rates, from a minimum observed value in the 1980s of approximately 0.055 in/yr to a peak observed value of 0.54 in/yr in the 1960s; these rates result in very different potential amount of total subsidence over time (Figure 3). As discussed in more detail later in this document (Task 2A.6 Evaluate the Existing Aquifer Monitoring Framework), historical time lag between pumping and apparent effects on subsidence show a time lag of 5.5 to 9 years in the Baton Rouge area, and subsidence can continue for decades after reductions in pumpage, due to the time necessary for interbedded clay strata to re-equilibrate with rebounding groundwater pressures.

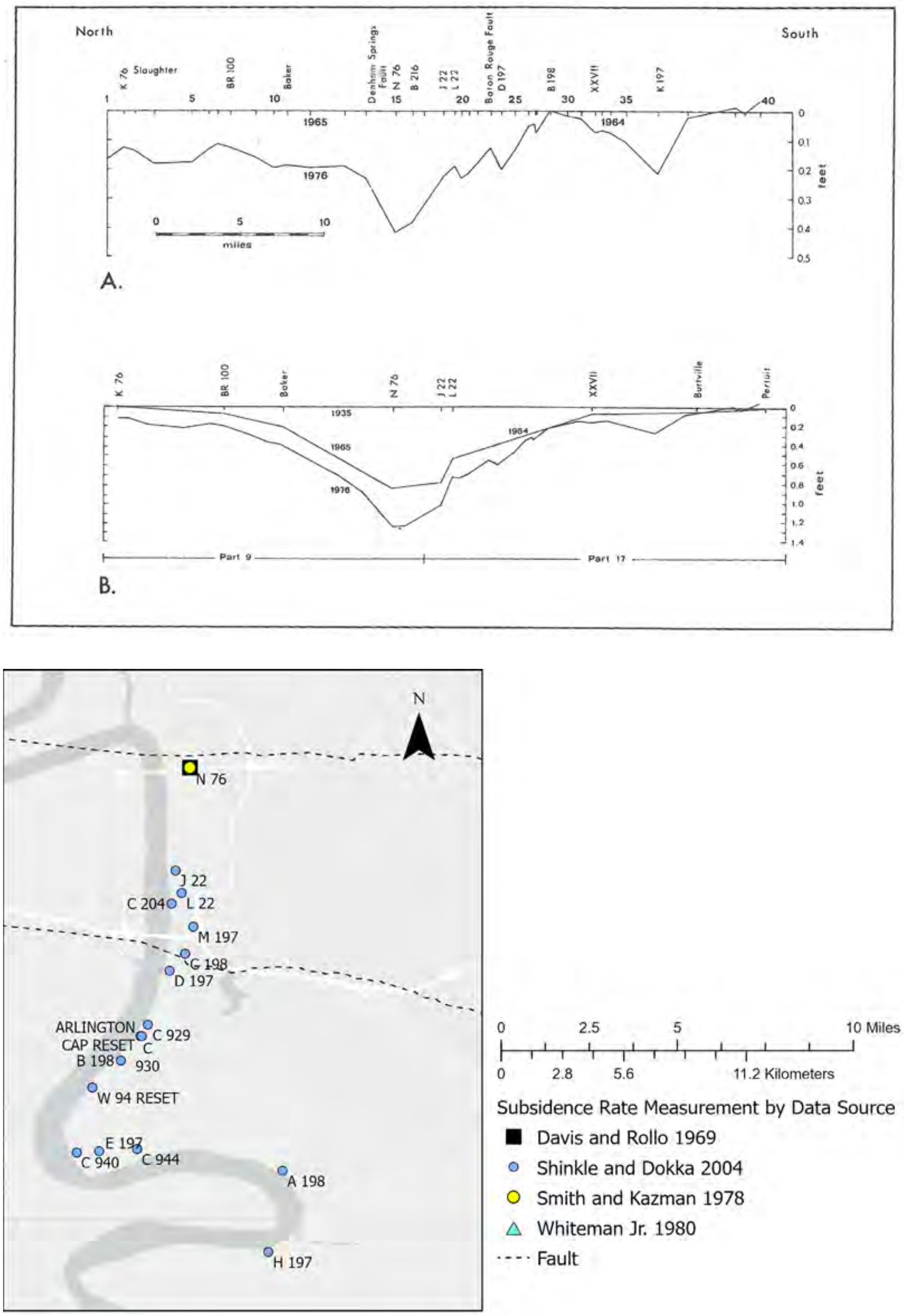


Figure 2. Top: Reproduced from Smith and Kazmann (Figure 5; 1978) showing a North-south subsidence profile through Baton Rouge. Two periods are shown: 1964/65 to 1976 (A) and 1935/38 to 1976 (B). Bottom: The location of survey monuments along this transect. A survey monument is a permanent marker set by a land surveyor to reference a point on the landscape. Not all monument locations from the original study were located.

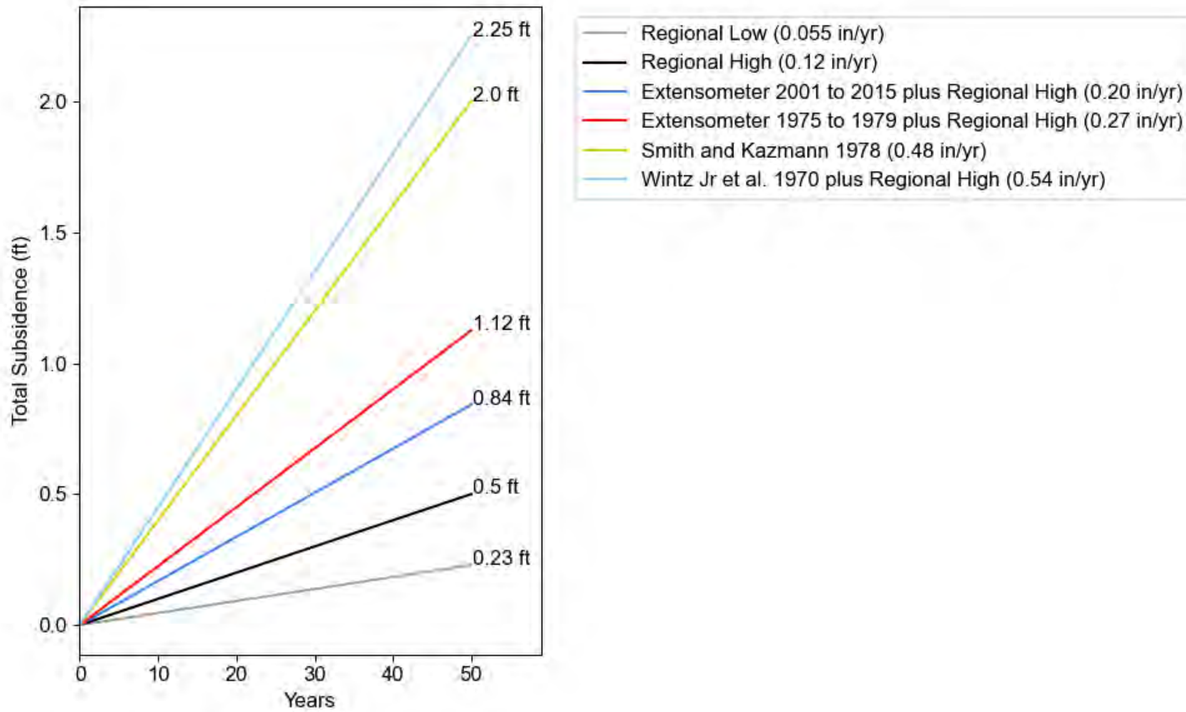


Figure 3. Total subsidence extrapolated over 50 years for different subsidence rates in the CAGWCD. The high estimate for regional subsidence was added to the extensometer measurements to make them comparable with the leveling measurement. The high estimate of regional subsidence was also added to the rate from Wintz J et al. (1970) because the report defines the reported subsidence value as the subsidence attributable to groundwater extraction. The total subsidence at the end of the 50-year period is labeled at the end of each line. The subsidence rate associated with each line is listed in the legend.

In order to define a performance metric for subsidence, it is important to determine the effects of groundwater pumping on subsidence rates within the CAGWCD using the potentiometric surface modeled by the GAM. It is also important to determine the potential effects of subsidence within the CAGWCD, for example the effects on infrastructure, homes, and quality of life. These effects may be directly damaging, through the impacts on regional-scale infrastructure such as highways, pipelines, railroads, etc., or indirectly damaging, through the increased impacts of flooding on homes, and quality of life impacts such as submerged roads.

There are several options to define a subsidence performance metric that will be explored and refined in Phase 2B of the project. One performance metric that will be further evaluated is subsidence in terms of downward movement of the land surface per unit time (inches per year, for example). The rate of this metric could be benchmarked against a rate of subsidence that is deemed acceptable to the CAGWCC with respect to the direct and indirect damages mentioned above.

One direct linkage of this metric to stakeholder concerns within the CAGWCD is related to flood hazards. Figure 4 and Figure 5 show Federal Emergency Management Agency (FEMA)-estimated 1 percent and 0.2 percent Annual Exceedance Probabilities (AEP; 100 and 500-year) flood depths for a neighborhood near the Industrial District. In this example, the 0.2 percent annual chance flood depth is approximately 1.5 ft deeper than the 1 percent annual chance event, and is used as a proxy for subsidence of that amount, equivalent to a rate of 0.6 in/yr. This value falls within the middle to upper part of the historically observed subsidence rates for the area (0.2–0.8 inches/year). The FEMA maps show increased flood depths in the area, which could lead to increased flood damages to homes and businesses, as well as more impassable roads and other flood-related hazards. Figure 6 shows the increased extent of the flooded area (shown in dark purple), which illustrates the potential for additional homes and businesses being exposed to increased flood risk, including potential impacts to flood insurance requirements and costs to affected homeowners.

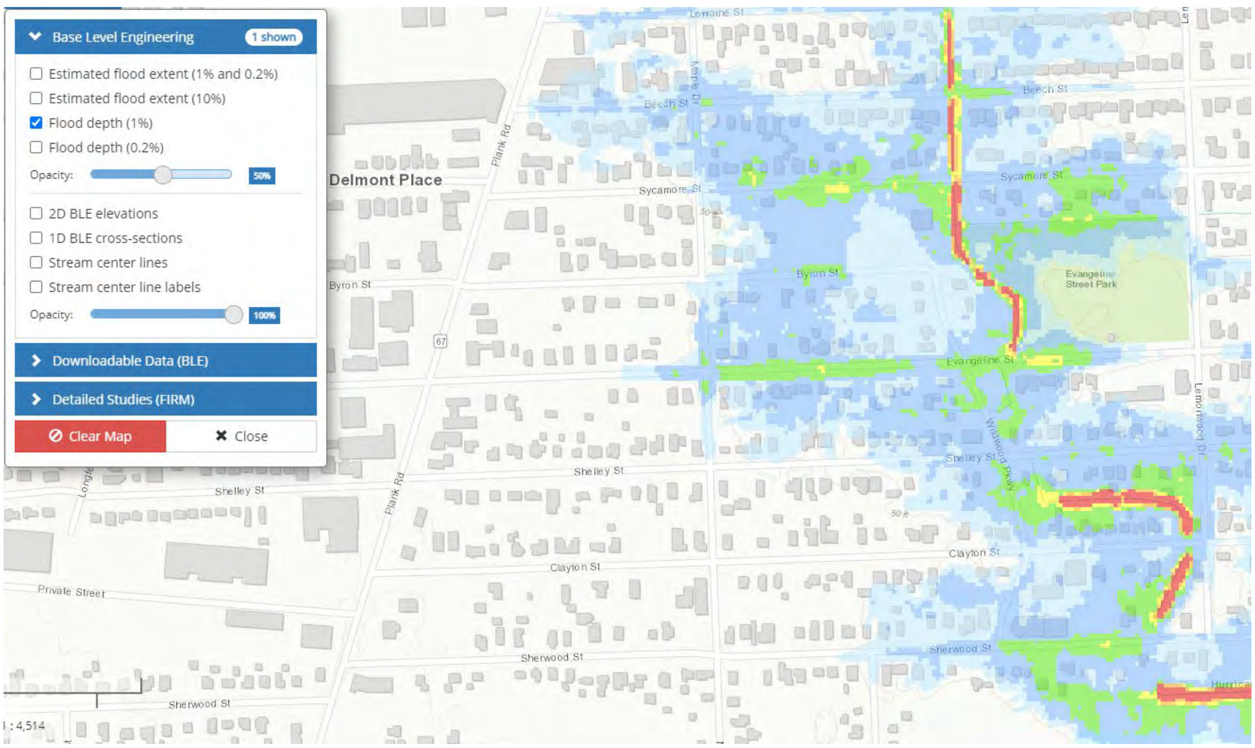


Figure 4. FEMA-estimated 1 percent AEP (100-year) flood depth for a neighborhood near the Industrial District. Warm colors (red) indicate deeper water, and cool colors (blue) indicate shallower water.

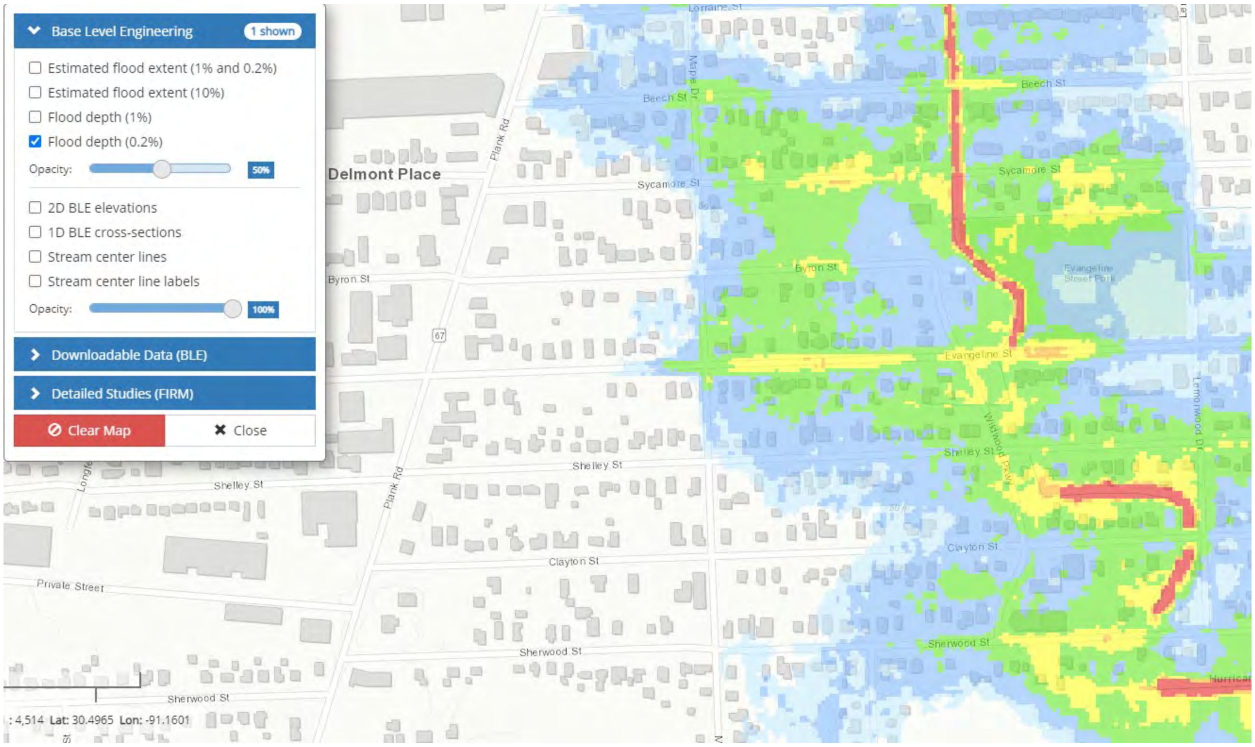


Figure 5. FEMA-estimated 0.2 percent AEP (500-year) flood depth for a neighborhood near the Industrial District. Warm colors (red) indicate deeper water, and cool colors (blue) indicate shallower water. The 0.2 percent annual chance flood depth is ~1.5 ft deeper at this location, and is used as proxy for ~1.5 ft subsidence for demonstration purposes.

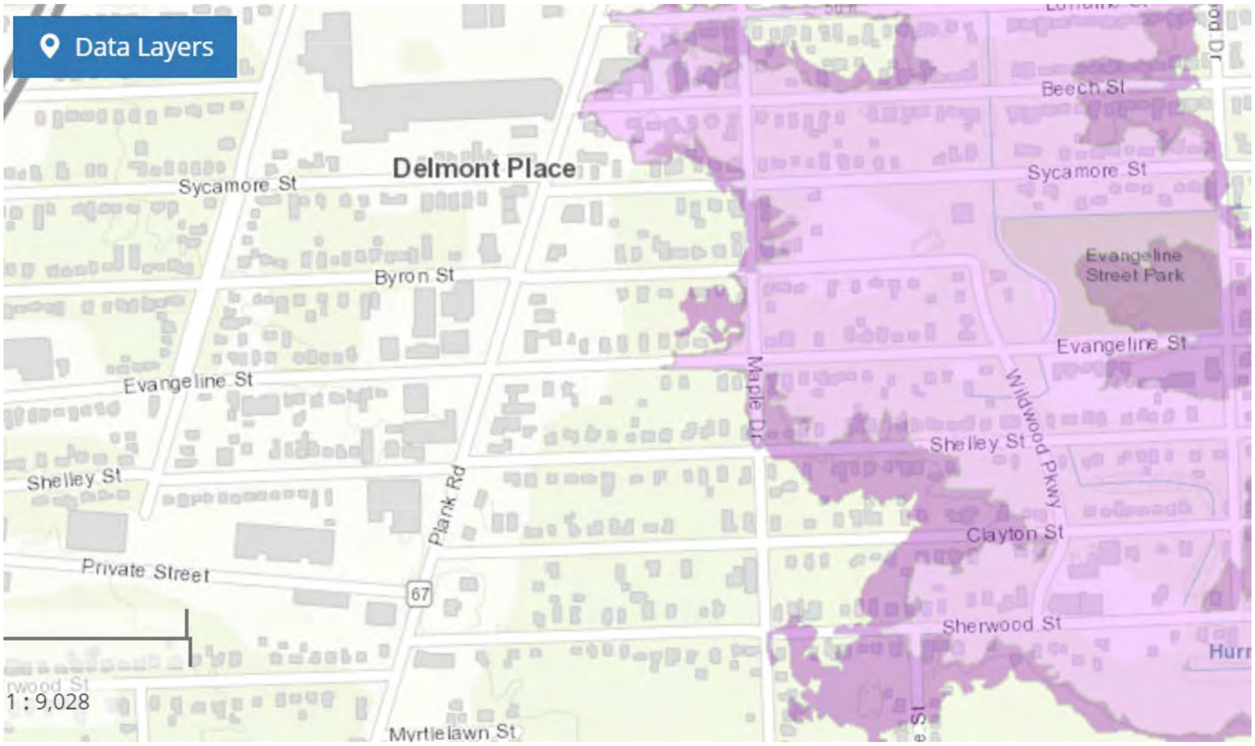


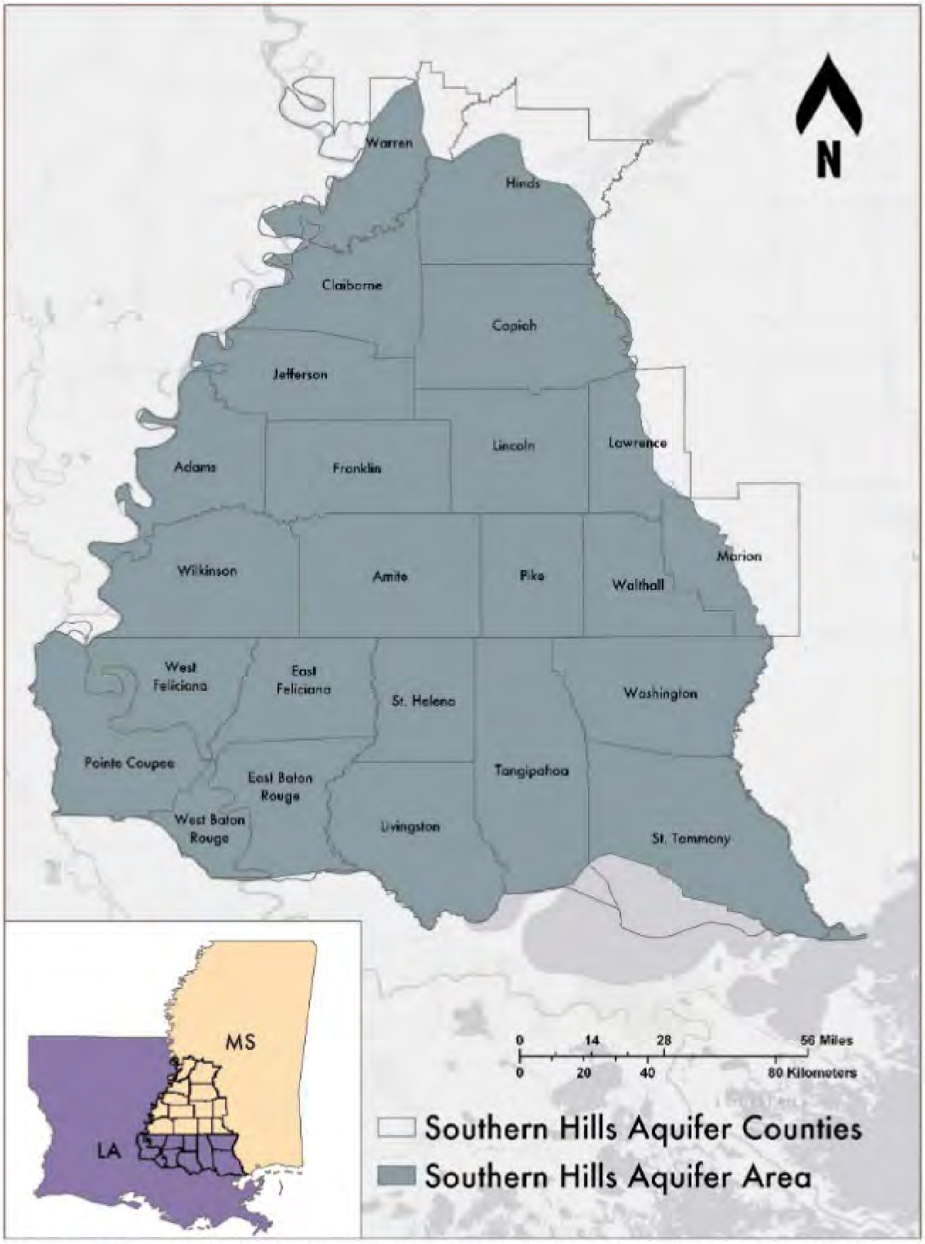
Figure 6. FEMA flood extents for the 1 percent (light purple) and 0.2 percent (dark purple) AEP flood events for a neighborhood near the Industrial District.

This relationship to potential flooding impacts can be used to benchmark the performance metric of groundwater pumpage-related subsidence (objective 5). This metric, combined with evaluation of the other four performance metrics, allows for the consequences of potential management alternatives to be weighed and tradeoffs to be considered. In addition, the CAGWCC could directly use this metric to set limits on pumping based on modeled subsidence, under a range of pumping conditions, that falls below a threshold of acceptability determined by the CAGWCC. For example, the threshold could be set to not exceed subsidence anywhere in the CAGWCD greater than one foot over the time period of a 30-year mortgage (0.4 in/yr) or six inches over the same time period (0.2 in/yr).

BACKGROUND AND GEOLOGY OF THE SOUTHERN HILLS AQUIFER SYSTEM

This section provides a brief overview of the geologic background of the South Hills Aquifer System (SHAS) as context for this report. A detailed summary of the geologic background of the SHAS was produced in Phase 1 and is provided in the report *State of the Science to Support Long-Term Water Resource Planning* (McInnis et al., 2020).

The SHAS underlies approximately 14,000 mi^2 of southeastern Louisiana and occurs as far north as Vicksburg, Mississippi (Figure 7). It is referred to as an *aquifer system* because it consists of many confined, but interdependent, aquifer units (Hemmerling et al., 2016). The SHAS ranges between 200–2,800 ft deep in the Baton Rouge area (Buono, 1983). The aquifer system has been divided into as many as 13 aquifers (referred to as *sands*), although in the Baton Rouge area, 10 are primarily recognized (referred to as the 400-foot, 600-foot, 800-foot, 1000-foot, 1200-foot, 1500-foot, 1700-foot, 2000-foot, 2400-foot, and 2800-foot sands). The aquifer layers dip to the south at an approximate slope of 40 ft/mile but this slope can vary between 10 to 120 ft/mile (Figure 8; Meyer & Turcan Jr., 1955). A general summary of the geologic ages and names of major water-bearing sand units in the SHAS is included in Table 1. The parishes that are part of the CAGWCD are East Baton Rouge, West Baton Rouge, East Feliciana, West Feliciana, Pointe Coupee, and Ascension (Figure 9).



Data Source: Census.gov & https://archive.epa.gov/pesticides/region4/water/groundwater/web/html/r4ssa.html
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

Figure 7. Boundaries of the Southern Hills Aquifer System (SHAS) in Louisiana (LA) and Mississippi (MS), United States, with county and parish boundaries shown.

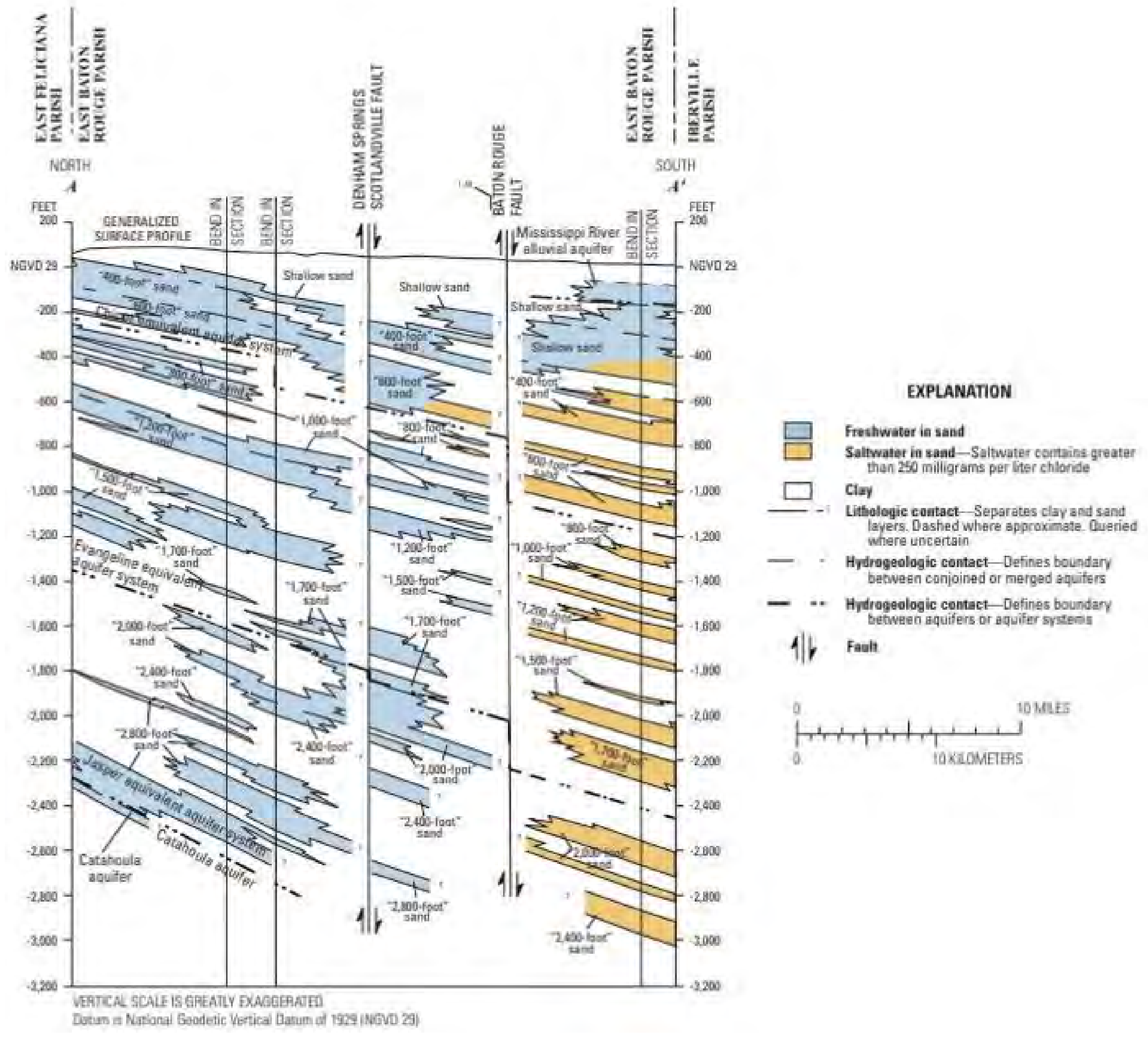


Figure 8. Generalized north-to-south hydrogeologic section of the SHAS. Cross section goes through East Baton Rouge Parish, Louisiana (Griffith, 2003).

Table 1. Geology of major sand units in the SHAS (LGS, n.d.)

Geologic Time			**Hydrogeologic Unit**	
Age (Years Before Present)	**System**	**Series**	**Aquifer System**	**Baton Rouge Area Aquifer Unit**
12,000 to 2.58 million	Quaternary	Pleistocene	Chicot Equivalent	400-ft sand
				600-foot sand
2.58 to 23.03 million	Tertiary	Pliocene (possibly at top) Miocene	Evangeline Equivalent	800-foot sand
				1000-foot sand
				1200-foot sand
				1500-foot sand
				1700-foot sand
			Jasper Equivalent	2000-foot sand
				2400-foot sand
				2800-foot sand

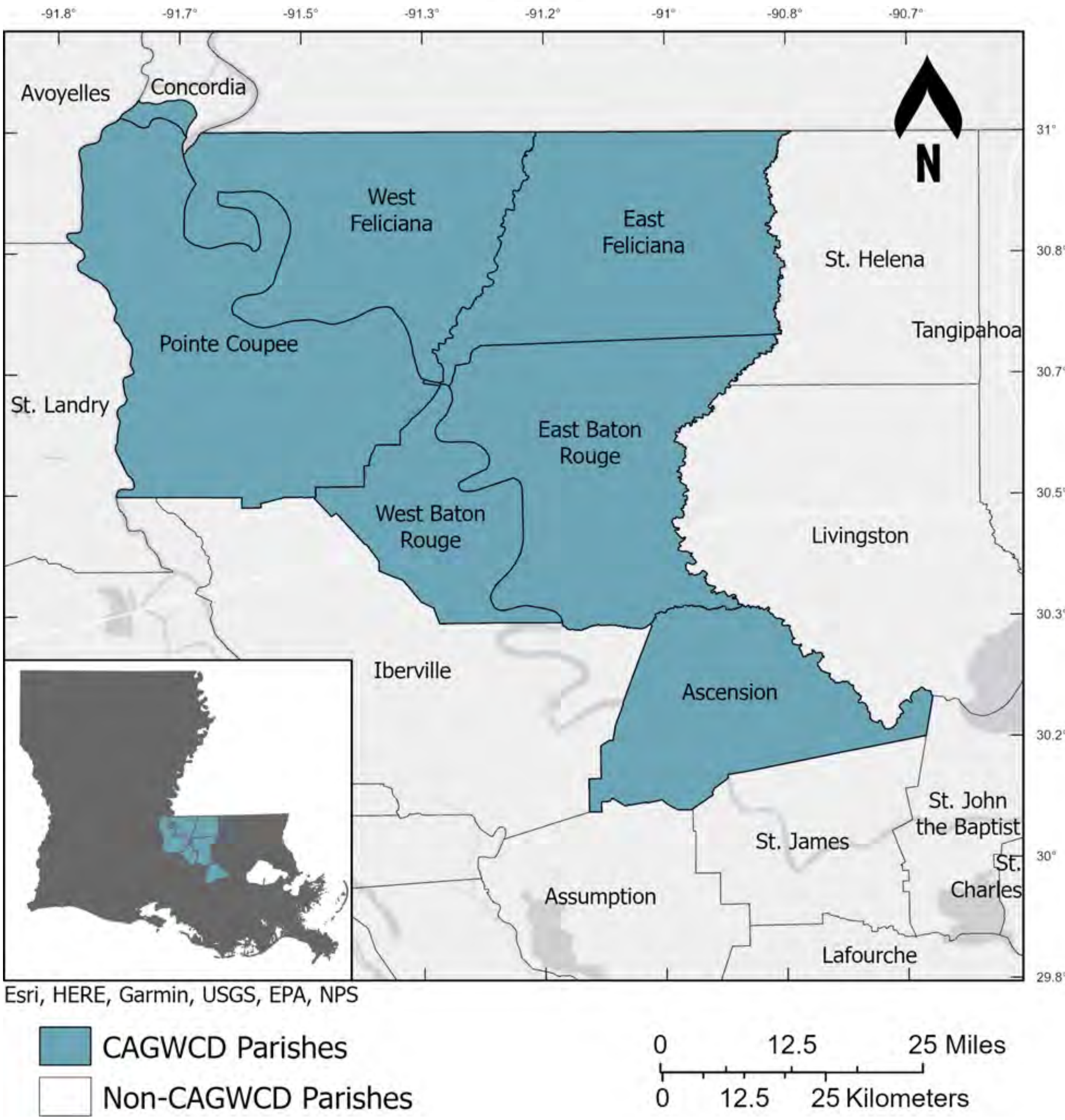
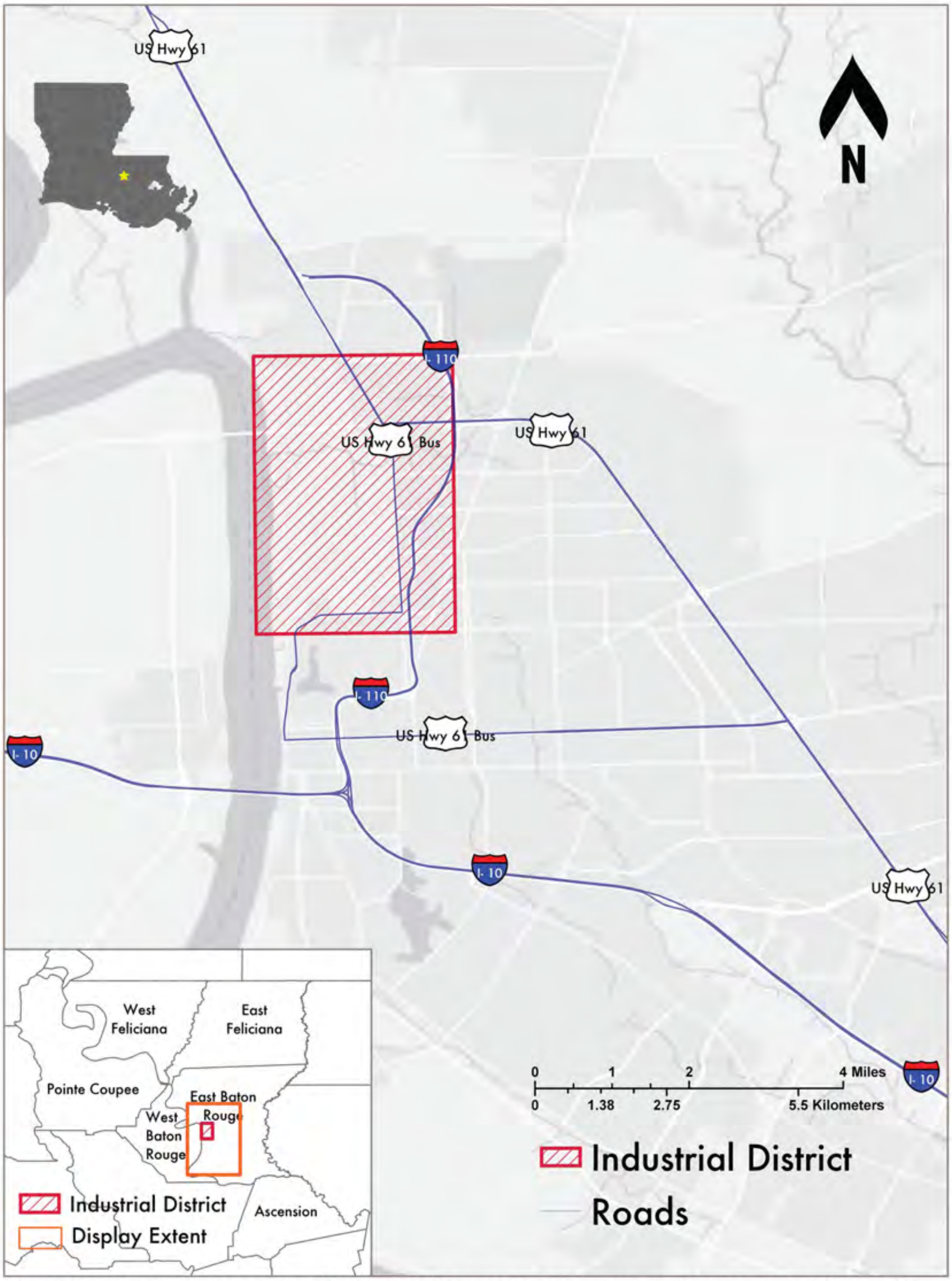


Figure 9. The Louisiana parishes that are part of the Capital Area Groundwater Conservation District (CAGWCD).

The aquifer names commonly used to refer to the sands in the Baton Rouge area were determined by their position relative to surface elevation in the Baton Rouge Industrial District (Figure 10). The Industrial District is an area adjacent to the Mississippi River and north of downtown Baton Rouge where several industries are located and withdraw groundwater from the SHAS for their operations (Meyer & Turcan Jr., 1955).



Data Source: https://catalog.data.gov/dataset/tiger-line-shapefile-2016-nation-u-s-primary-roads-national-shapefile
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

Figure 10. Approximate location of the Industrial District in East Baton Rouge Parish. The depth of each aquifer within the Industrial District yielded aquifer names, i.e., 1000, 1500, 2,000-foot aquifers.

The SHAS is a confined aquifer system with multiple overlapping sand and clay units. Prior to the introduction of pumping in the late 1800s and early 1900s (Whiteman Jr., 1980; Meyer & Turcan Jr., 1955) the SHAS was classified as artesian in the Baton Rouge area, meaning a well that tapped the aquifer would freely flow above the land surface. All aquifers below the 600-foot sand in the Industrial District for the SHAS were at one point artesian before the pumping era. The first-known constructed well in the Baton Rouge area was a public supply well in 1892; records indicated that the well was drilled to 758 ft and that the water would rise to within 6 ft of the surface elevation (Harris, 1905). In 1914, the first oil refineries opened in the Baton Rouge area and industrial pumping began (Meyer & Turcan Jr., 1955).

Within the SHAS there are individual sand and clay beds that vary in size. The sand layers are generally around 75–200 ft thick. Clay intervals between the sand layers are usually 100 ft thick and can be 400–500 ft thick (Whiteman Jr., 1980). The 1500-foot and 2000-foot sand layers generally dip and thicken to the south and consist of sand intervals between 65 ft and 300 ft thick.

Faults in Baton Rouge and the Capital Area Groundwater Conservation District

Within the CAGWCD, there are two primary faults, the Denham Springs-Scotlandville Fault and the Baton Rouge Fault (Figure 11). A fault is the boundary between two blocks of sediment or rock that move relative to one another. Both the Denham Springs-Scotlandville and Baton Rouge faults are active, but are not known to be able to cause earthquakes. Activity along these faults was determined by breaks in foundations and cracks in roads or slabs along the fault lines (Wintz Jr et al., 1970).

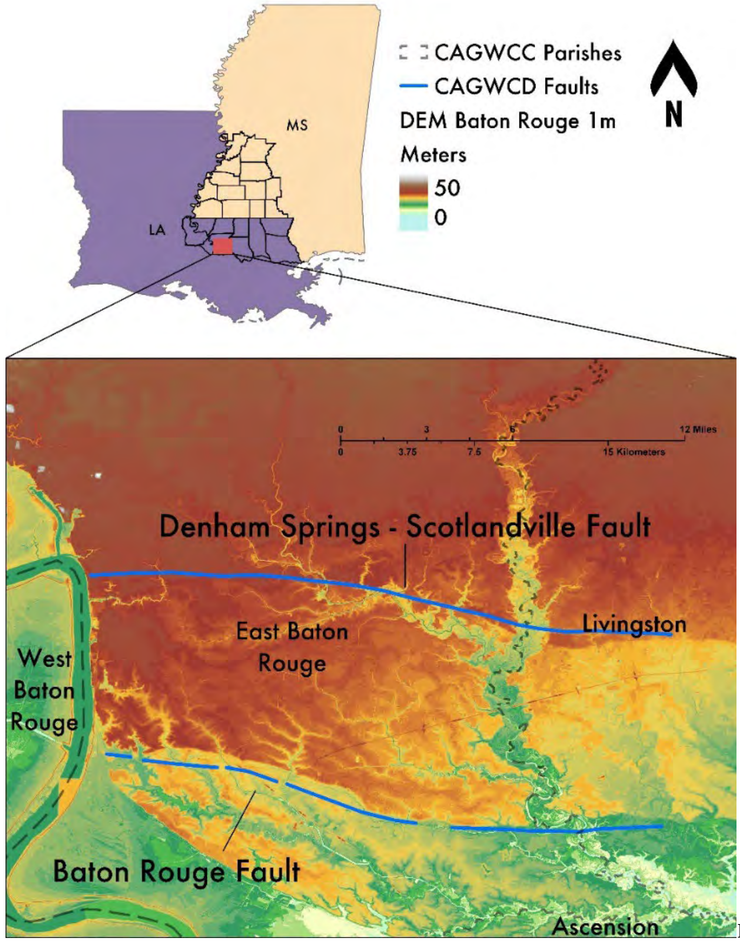


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*Figure 11. The approximate location of two faults in the Baton Rouge area that impact the SHAS on a 1 m digital elevation map (DEM). The northern fault is the Denham Springs-Scotlandville Fault, and the southern fault is the Baton Rouge Fault. Saltwater intrusion into the SHAS occurs across the Baton Rouge Fault.*Vertical offset of geologic layers occurs across faults that have relative motion in the vertical direction. This type of motion occurs along the Baton Rouge Fault, resulting in offset of the aquifer sand layers across the fault. This can be seen in Figure 8, where sands north of the Baton Rouge Fault (left side of the figure) occur at shallower depths than the same layer on the south side of the fault (right side of the figure). Sands on the south side of the fault have experienced relative motion to the south and down as a result of motion along the Baton Rouge Fault.

The Baton Rouge Fault is the approximate southern limit of freshwater in the SHAS. South of the Baton Rouge Fault, the water in the aquifer system is generally saline and not usable for potable water. The Baton Rouge Fault generally has a low permeability that impedes horizontal flow across the fault (Pham & Tsai, 2017), except at certain high permeability areas known as *leaky windows*; the implications of these leaky windows are investigated as part of Phase 2. The western extent of the SHAS is marked by a zone of saline water within the Pliocene and Miocene sediments (corresponding to the Evangeline and Jasper equivalent 800-foot to 2,800-foot sands, Table 1) that lie beneath the Mississippi River alluvial valley (Hemmerling et al., 2016).

Recharge and Discharge of the Southern Hills Aquifer System

Outcrops of the SHAS—areas of exposed bedrock or areas of permeability where water can enter for groundwater recharge—are primarily located south of Jackson, Mississippi, and in southwestern Mississippi (Figure 7). The farthest northern extent of the outcrops for the SHAS is around Vicksburg, Mississippi, in Warren County (Figure 7). Recharge for the SHAS is primarily from direct percolation of precipitation to the water table in the outcrop areas while discharge is primarily due to pumping (Buono, 1983). Estimates of recharge in the SHAS have high uncertainty. A recent modeling study estimated that a large proportion of total inflow (recharge) likely comes from the east and west (Hai Pham & Tsai, 2017). Within the model domain, the Baton Rouge area simulated a total average annual inflow of 580,000 m^3/day (~150 million gallons per day) between the Denham Springs-Scotlandville and Baton Rouge faults (Hai Pham & Tsai, 2017). Approximately 581,000 m^3/day was estimated as flow leaving the Baton Rouge area that was heavily associated with pumping of groundwater via wells (Hai Pham & Tsai, 2017).

Prior to the pumping era, discharge of the SHAS occurred as stream runoff or evaporation near the Baton Rouge Fault. After the start of the industrial pumping era, in the early 1900s, groundwater began to be intercepted as flow to pumped wells. Currently, the major discharge of aquifers in the SHAS is induced by pumped wells. Groundwater storage in the aquifer is closely correlated with pumping rates as seen in historical data (e.g., lower pumping rates lead to increased well levels between 1975 and 1985) and modeling studies (Hai Pham & Tsai, 2017).

History of Saltwater Intrusion

Saltwater, typically identified using chloride levels as a proxy, in Baton Rouge aquifers was first found in well EB–123 screened in the 600-foot sand when chloride levels surged from 7 ppm in 1943 to 710 ppm in 1950 (Meyer & Turcan Jr., 1955). Since then, several wells have seen increasing chloride concentrations throughout the SHAS near the Baton Rouge Fault (Rollo, 1969; Tomaszewski et al., 2002). In 2007, USGS published a study that revealed eight out of the ten major aquifers north of the Baton Rouge Fault were observed to have had an increase in chloride levels (Lovelace, 2007).

Saltwater intrusion within the Baton Rouge sands is attributed to high groundwater withdrawal rates in the Baton Rouge area (Rollo, 1969). There are two schools of thought on the sources of saltwater intrusion into the Baton Rouge aquifers (Anderson, 2012; Bray & Hanor,1990). The first school of thought is that saltwater has migrated up the Baton Rouge Fault, from older halite, commonly known as rock salt, formations. The second school of thought is that brine associated with fractures in salt domes south of the Baton Rouge Fault has moved north along Miocene sands to the Baton Rouge aquifers.

TASK 2A.1 EVALUATION OF EXISTING DATA AND INFORMATION

> *Task Summary: For the CAGWCC to proceed with long-term planning, additional background knowledge of the aquifer is needed. The Institute will provide the requisite background materials as well as a preliminary assessment of aquifer dynamics. Piezometric water levels will be used to construct potentiometric surfaces. Conductivity and chloride measurements, well locations, and groundwater pumping data will also be compiled and mapped.*

CURRENT STATE OF THE SOUTHERN HILLS AQUIFER SYSTEM

A key component of the technical work in Phase 2 is the creation of synoptic potentiometric surface maps to provide information on the current state of water levels in SHAS. The Institute has compiled USGS data that were measured between June 2020 through December 2020. This period was chosen to maximize the number of observations for each sand layer of the SHAS, while not extending the data period beyond the range that is reasonable for a synoptic map. The number of measurements in each sand layer during this time period ranges from four to 15 data points. For an area as large as the CAGWCD, this is a relatively small number of points with which to construct a potentiometric surface. A kriging interpolation method provides reasonable results and was used to construct the potentiometric surface for all the sand layers. The software used to construct these maps was Surfer® (2021), a program designed for scientific gridding. Examples of potentiometric surface maps for the 1500-foot sand and 2800-foot sand are provided in Figure 12 and Figure 13; these maps reference National Geodetic Vertical Datum of 1929 (NGVD29). Maps for all the sand layers can be found in Appendix A. The potentiometric surface maps provided are a useful aid for the CAGWCC's understanding of the current state of the aquifer and the current extent of data collection. These surfaces will also be used in the Darcy flow analysis, which will provide the CAGWCC with a preliminary understanding of the sustainable withdrawal levels in each sand layer.

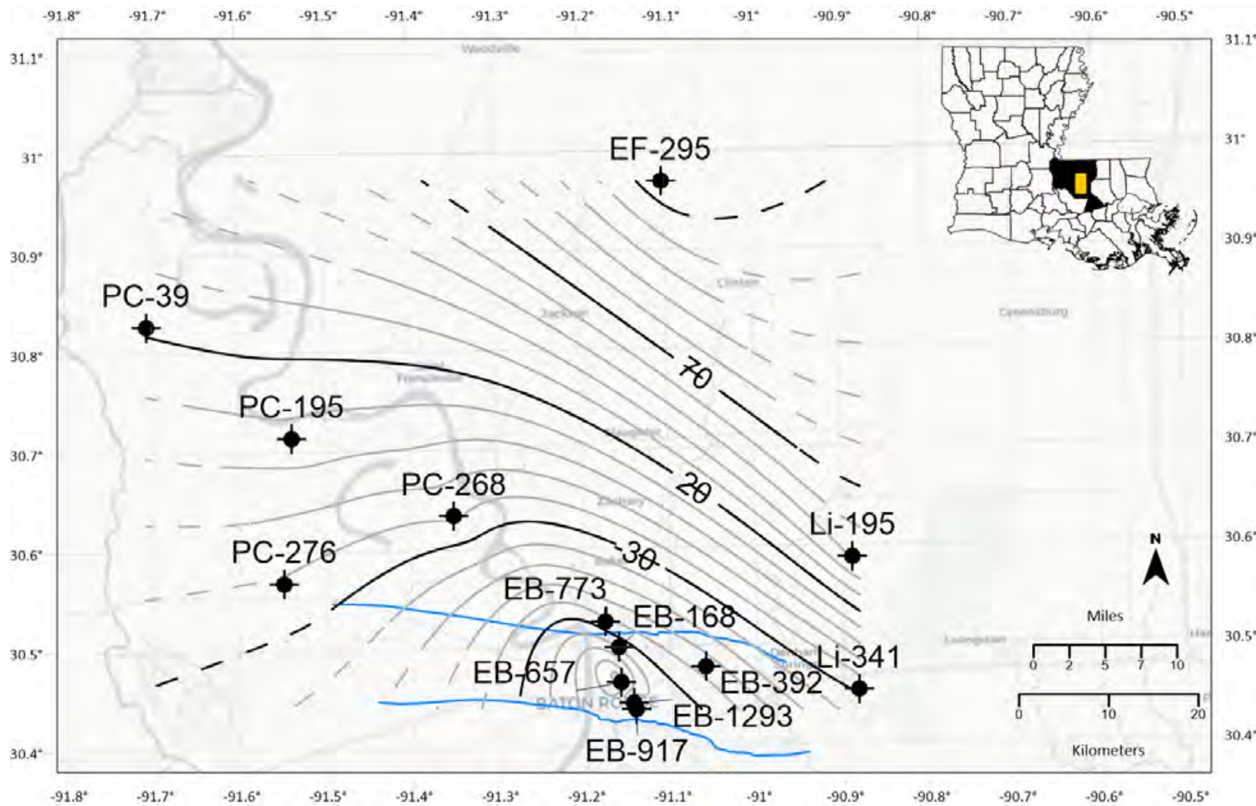


Figure 12. Potentiometric surface contour map for the 1500-foot sand using data from June 2020 through December 2020 collected by the USGS. Points show well locations with water level data used to create the contours. Contour interval is 10 ft. Contours are drawn as solid lines are within the area in which there is available data and as dashed lines outside this area. The blue lines represent the Denham Springs-Scotlandville Fault to the north and the Baton Rouge Fault to the south. The vertical datum is NGVD29.

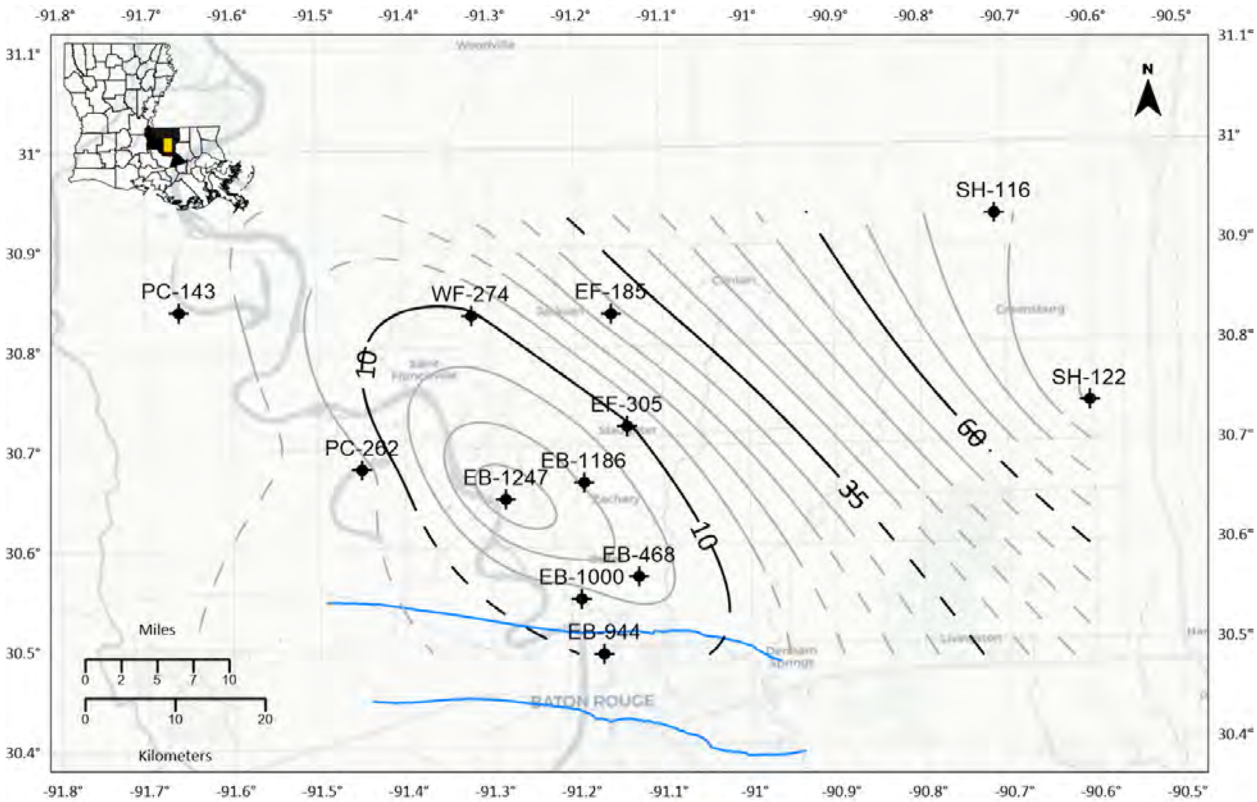


Figure 13. Potentiometric surface contour map for the 2800-foot sand using data from June 2020 through December 2020 collected by the USGS. Points show well locations with water level data used to create the contours. Contour interval is 5 ft. Contours are drawn as solid lines are within the area in which there is available data and as dashed lines outside this area. The blue lines represent the Denham Springs-Scotlandville Fault to the north and the Baton Rouge Fault to the south. The vertical datum is NGVD29.

Data on chloride measurements has also been compiled—in a manner similar to the synoptic potentiometric surface maps—to provide an understanding of the current condition of the chloride plume in the aquifer. The compiled data are composed of USGS chloride level data collected in each aquifer from June 2020 through December 2020. Fewer wells are sampled by USGS for chloride than for water level. Additionally, chloride is currently only sampled once a year, but will be sampled twice a year for 2022 through 2024, according to a new agreement between the CAGWCC and USGS. During 2020, 30 wells within the SHAS sand layers were sampled for chloride concentration. The number and spatial distribution of chloride measurements in the sand layers (Figure 14; Figure 15) were insufficient to create contour maps; instead, the maps provided in Figure 16–Figure 18 show the location of chloride measurements with graduated symbol sizes to show concentrations. The highest concentration reported was 10,200 mg/L in well EB-805 in the 1000-foot sand. This well is located slightly north of the Baton Rouge Fault (Figure 14). The lowest concentration reported (2.12 mg/L) was also found in the 1000-foot sand in well EB-632. This well is located approximately 2.75 miles from the Baton Rouge Fault (Figure 15). The majority of SHAS sand layers have fewer than five wells sampled for chloride. The exception is the 1500-foot sand, which has eight chloride measurements recorded during 2020, ranging from approximately 2 mg/L to 298 mg/L (Figure 16). Maps of the chloride measurements and concentrations for all sand layers can be found in Appendix C.

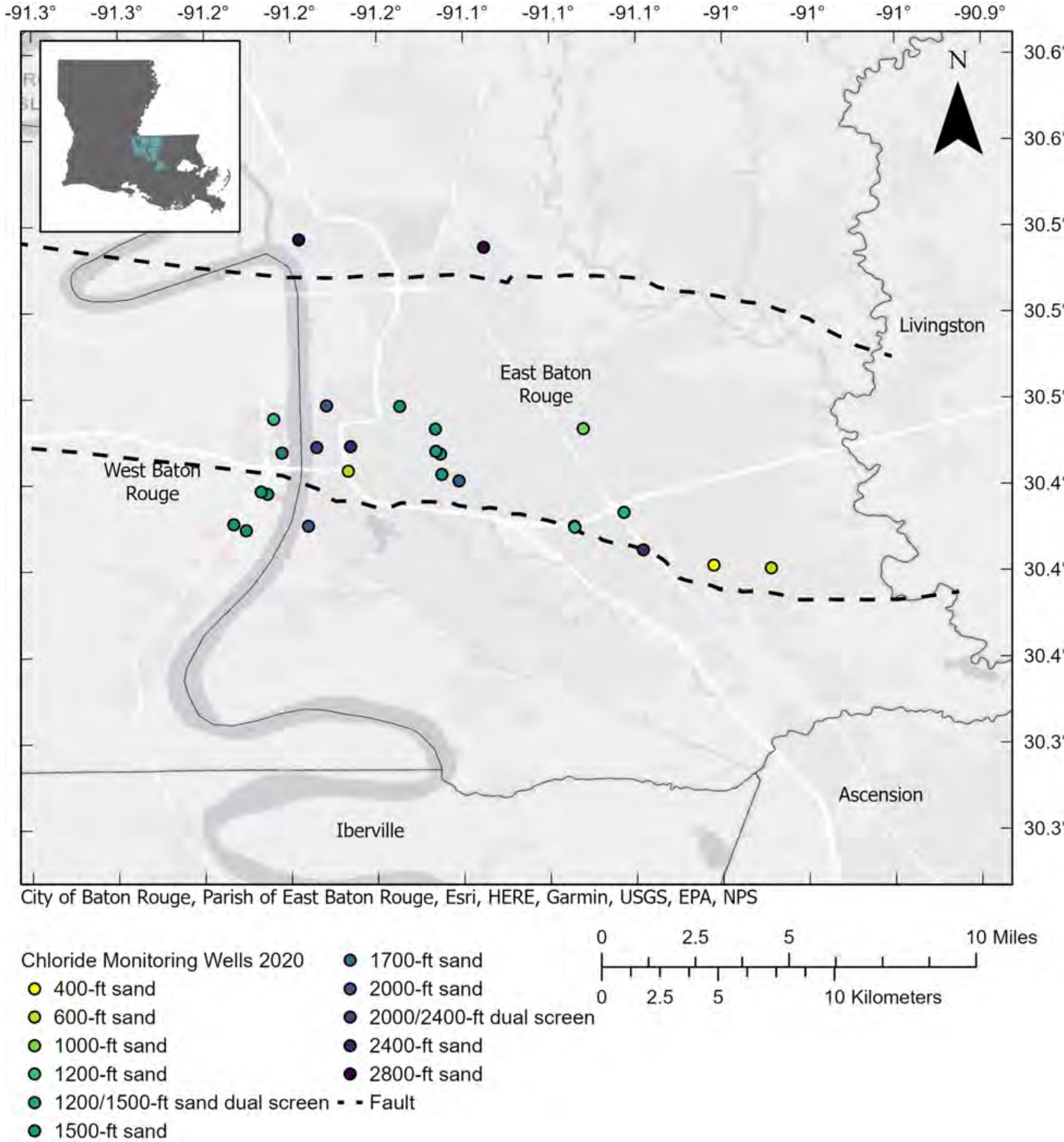


Figure 14. Chloride measurements within the CAGWCD from June 2020 through December 2020 collected by the USGS. Each point is colored to reflect the sand layer within which it was measured.

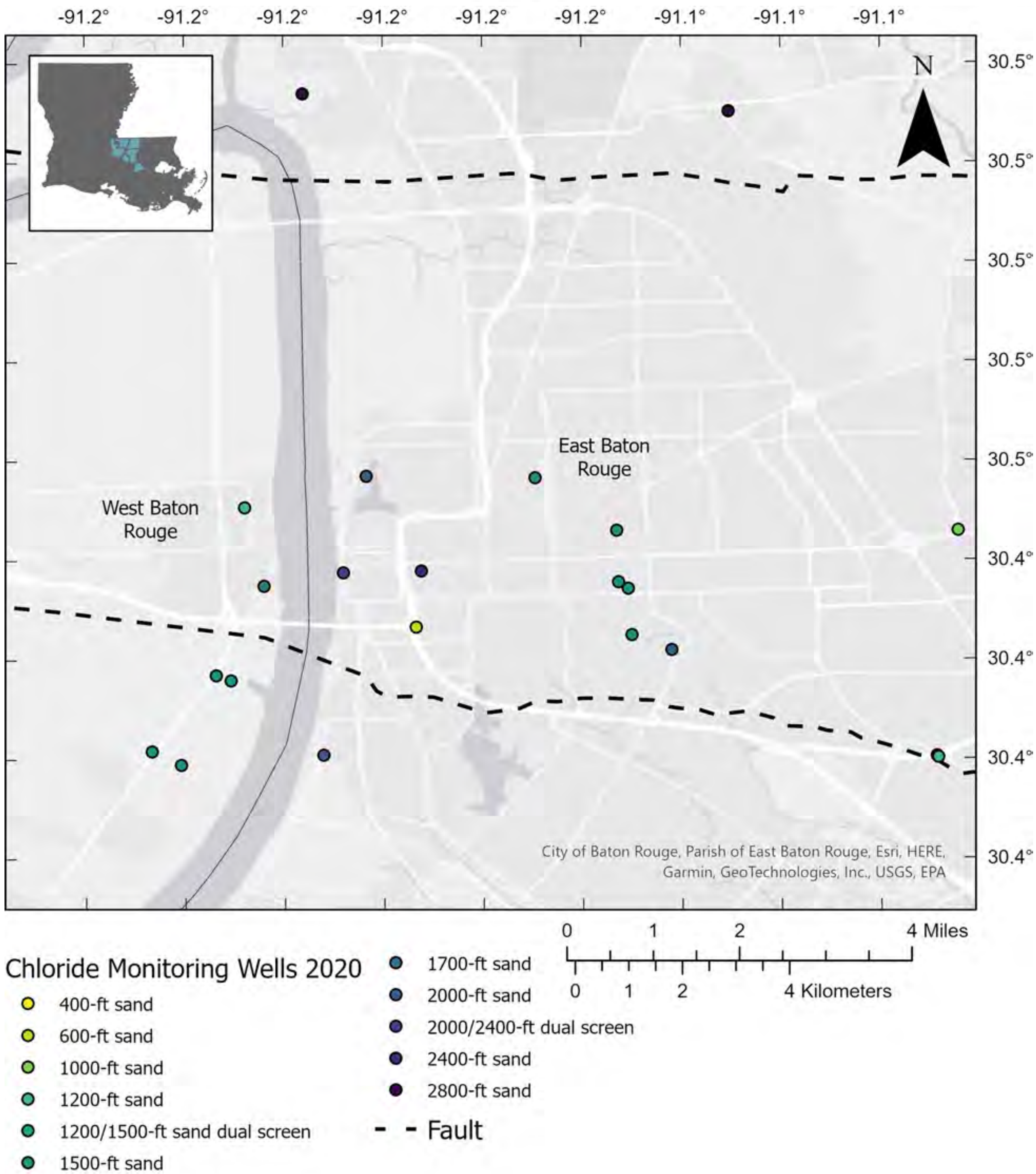


Figure 15. Chloride measurements with the Industrial District from June 2020 through December 2020 collected by the USGS. Each point is colored to reflect the sand layer within which it was measured.

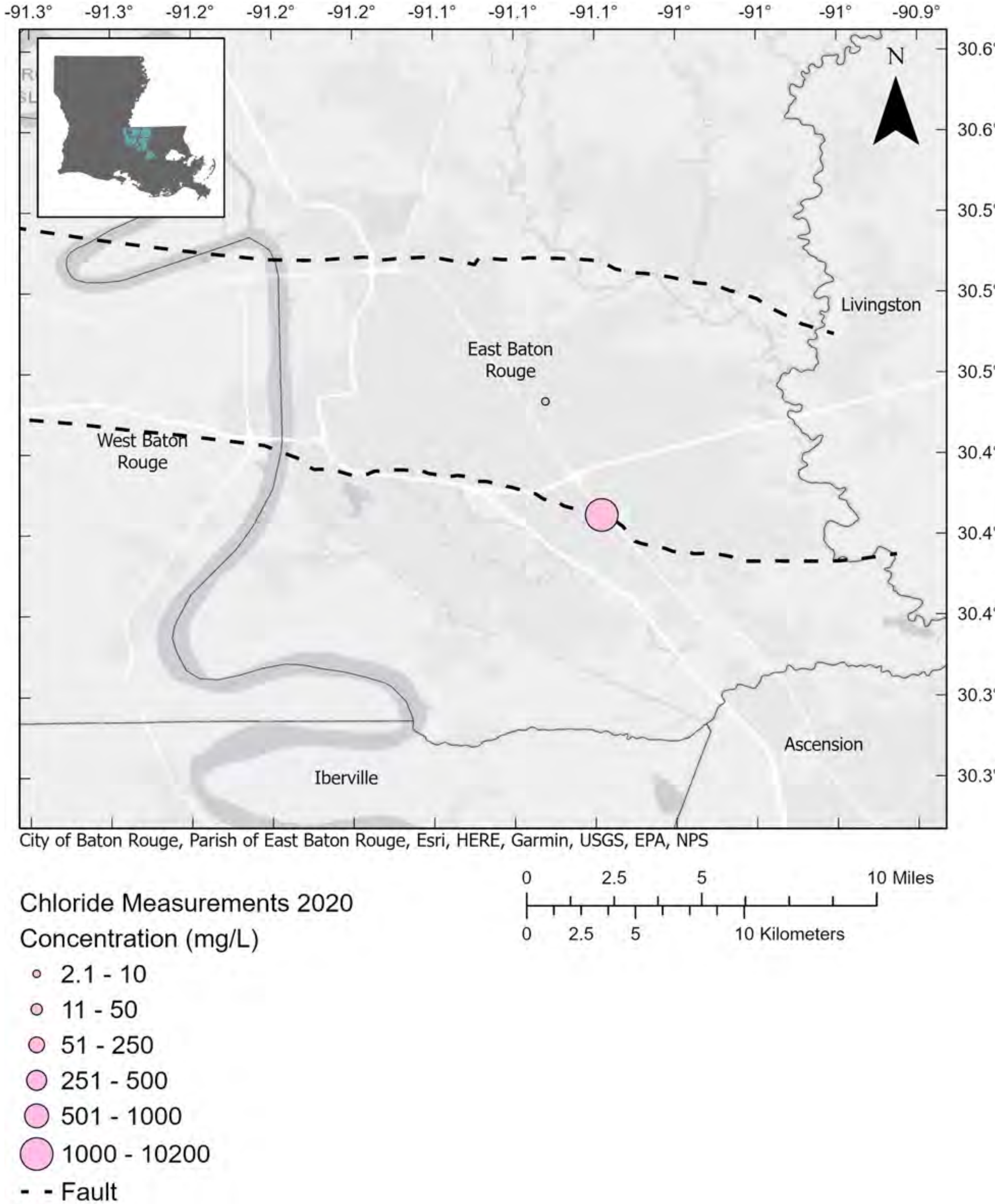


Figure 16. Chloride measurement locations in the 1000-foot sand from June 2020 to December 2020 collected by the USGS.

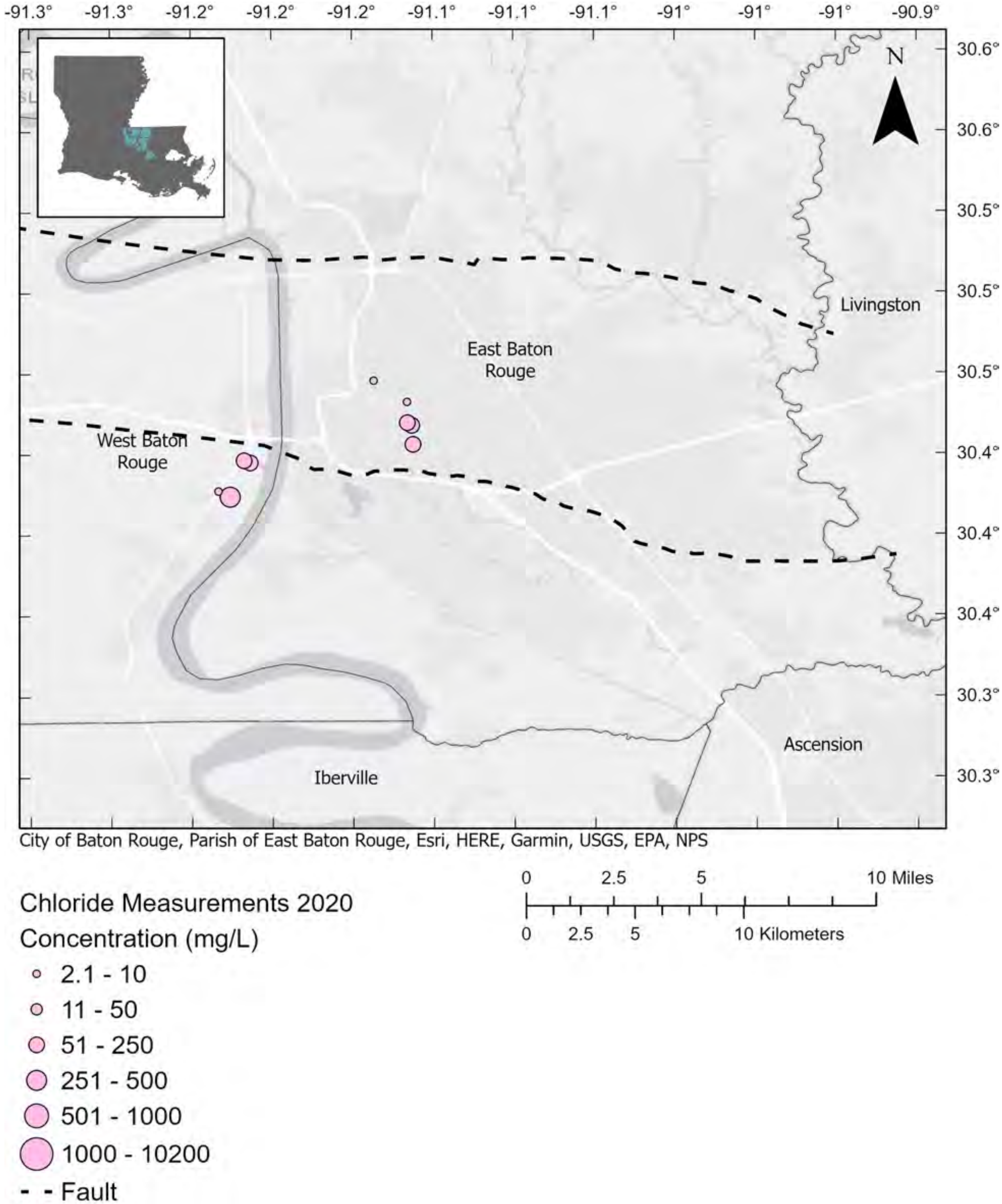


Figure 17. Chloride measurements from the CAGWCD in the 1500-foot sand, measured between June 2020 and December 2020 collected by the USGS.

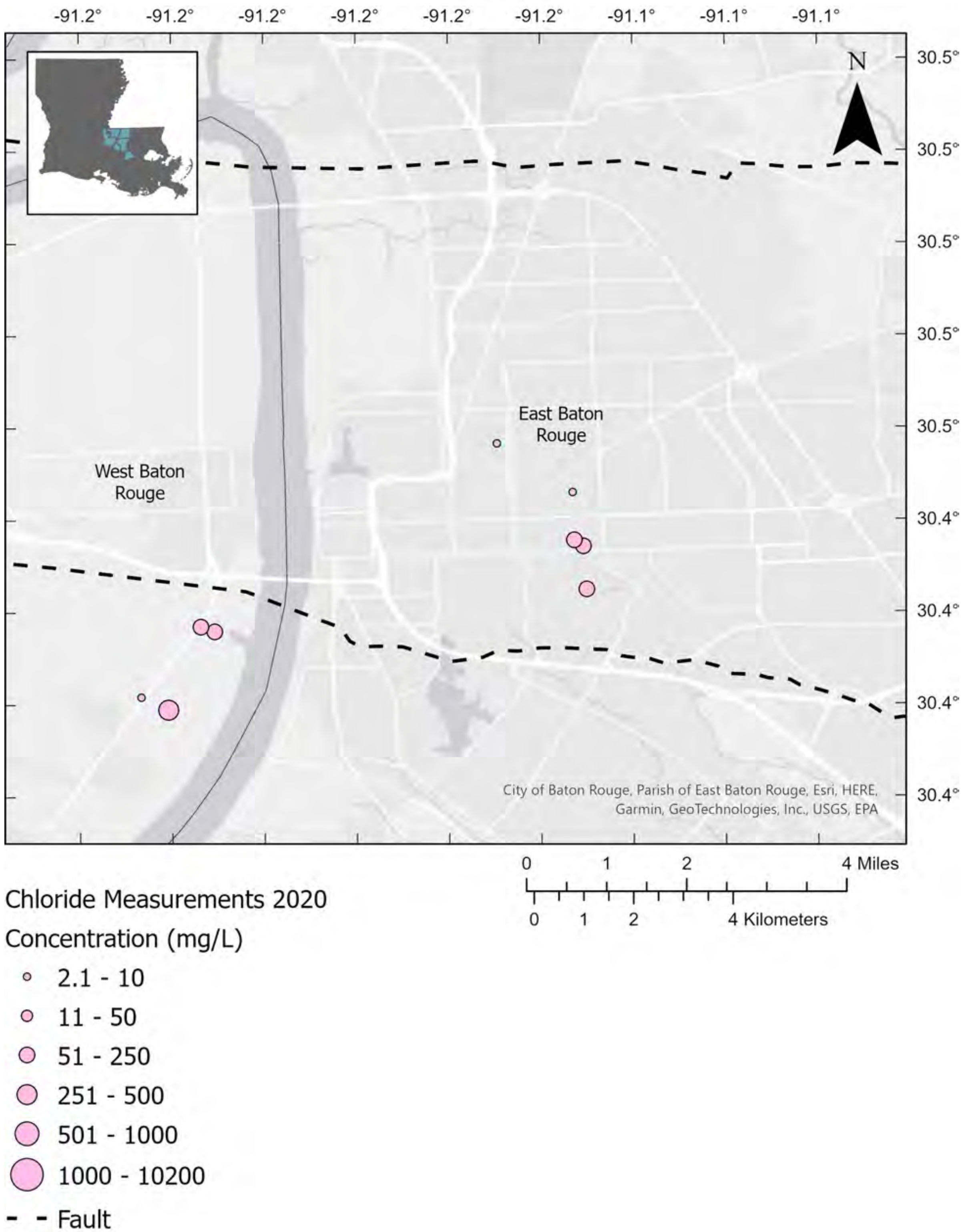


Figure 18. Chloride measurements within the Industrial District in the 1500-foot sand, measured between June 2020 and December 2020 collected by the USGS.

DARCY FLOW ANALYSIS

By the end of Phase 2B, a GAM will be developed that will allow the CAGWCC to predict how different management decisions affect the SHAS; however, Phase 2B is a multi-year phase. In the near-term, the CAGWCC needs estimates of sustainable yields for each sand layer to support aquifer management. The Institute has been conducting a Darcy flow analysis to address this need. Darcy flow analysis can provide initial estimates of the groundwater yield for each sand layer and support preliminary water budget calculations, which in turn support science-based management decisions in the near-term. This analysis uses estimates of hydrogeologic parameters, such as aquifer transmissivity, to estimate withdrawal amounts that can be sustained in the short term (Brown, 2002; Darcy, 1856). During Phase 2, the Institute has been testing a method for the Darcy flow analysis using datasets from the USGS model (e.g., Heywood et al., 2014, 2019; Heywood & Lovelace, 2015) and incorporating subsurface geology data from LSU. Institute staff have met with USGS to discuss the Darcy flow method, the input parameters for the method, and how the parameters in the USGS model might help to define the parameters for the Darcy flow analysis. The potentiometric surface maps are an important input to the analysis and were completed to provide input to the Darcy flow analysis. There is uncertainty in the input parameters, and thus it is anticipated that there will be uncertainty in the estimates of sustainable yield. Uncertainty is expected to be quantified by investigating how changes to the input parameters change the end result.

The analysis uses Darcy's Law (Darcy, 1856), the principle that governs how fluid moves through porous media such as rock in the subsurface. It is stated by the equation:

$$Q = -KA\frac{dh}{dl} \qquad (11)$$

where:

- *Q = rate of groundwater flow (volume per time);*
- *K = hydraulic conductivity (physical parameter that accounts for how easily the fluid can move through the pore space of the material);*
- *A = column cross sectional area; and*
- *dh/dl = hydraulic gradient, that is, the change in head over the length of interest.*

The equation was based on a series of experiments designed to determine the flow rate of a fluid through an inclined column of porous media, as illustrated in Figure 19.

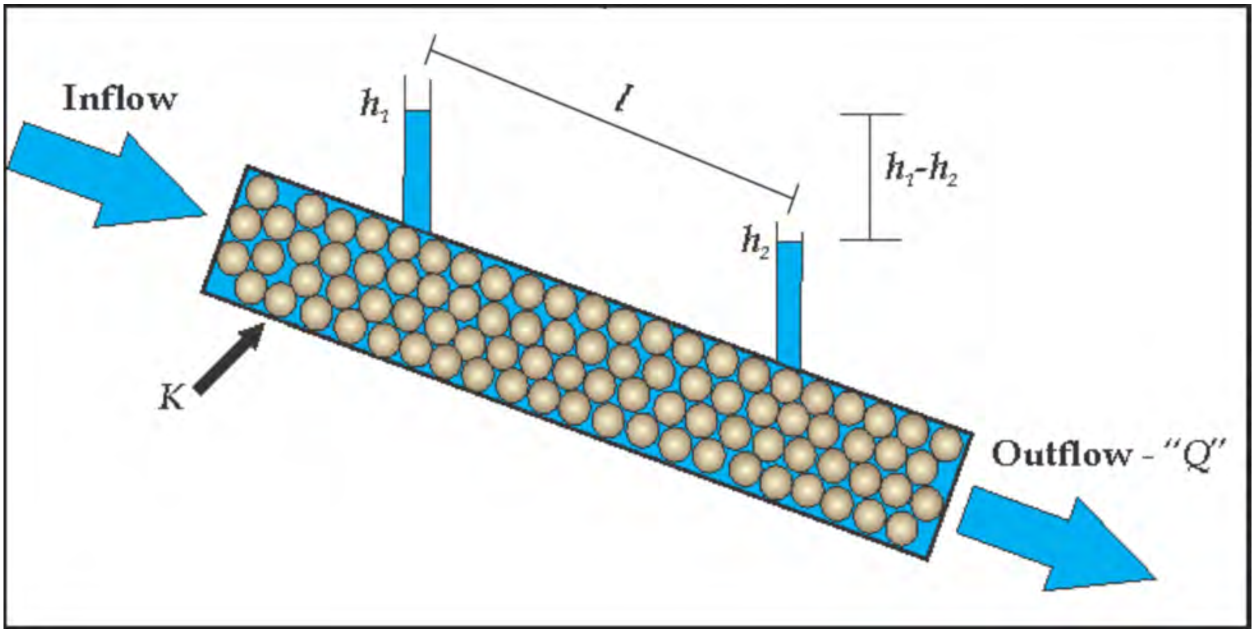


Figure 19. Schematic diagram of apparatus used in Darcy's flow experiments, modified from Herod (2013).

The Darcy flow calculations are being performed using the Groundwater Toolset of ArcGIS Pro (ESRI, version 2.8.5). The tool uses the following inputs: groundwater head raster (potentiometric surface); effective formation porosity raster; saturated thickness raster (sand unit thickness); and formation transmissivity raster (hydraulic conductivity*saturated thickness, K*b). An example of output from a simulation for the 2,000-foot sand is shown in Figure 20. It illustrates flow magnitude and direction using gold vector arrows, and Residual volume at each voxel in MGD.

The next steps in this process are to calculate the sum of residuals (Darcy flux) for each sand layer, which can provide an initial estimate of groundwater availability for preliminary water budgeting.

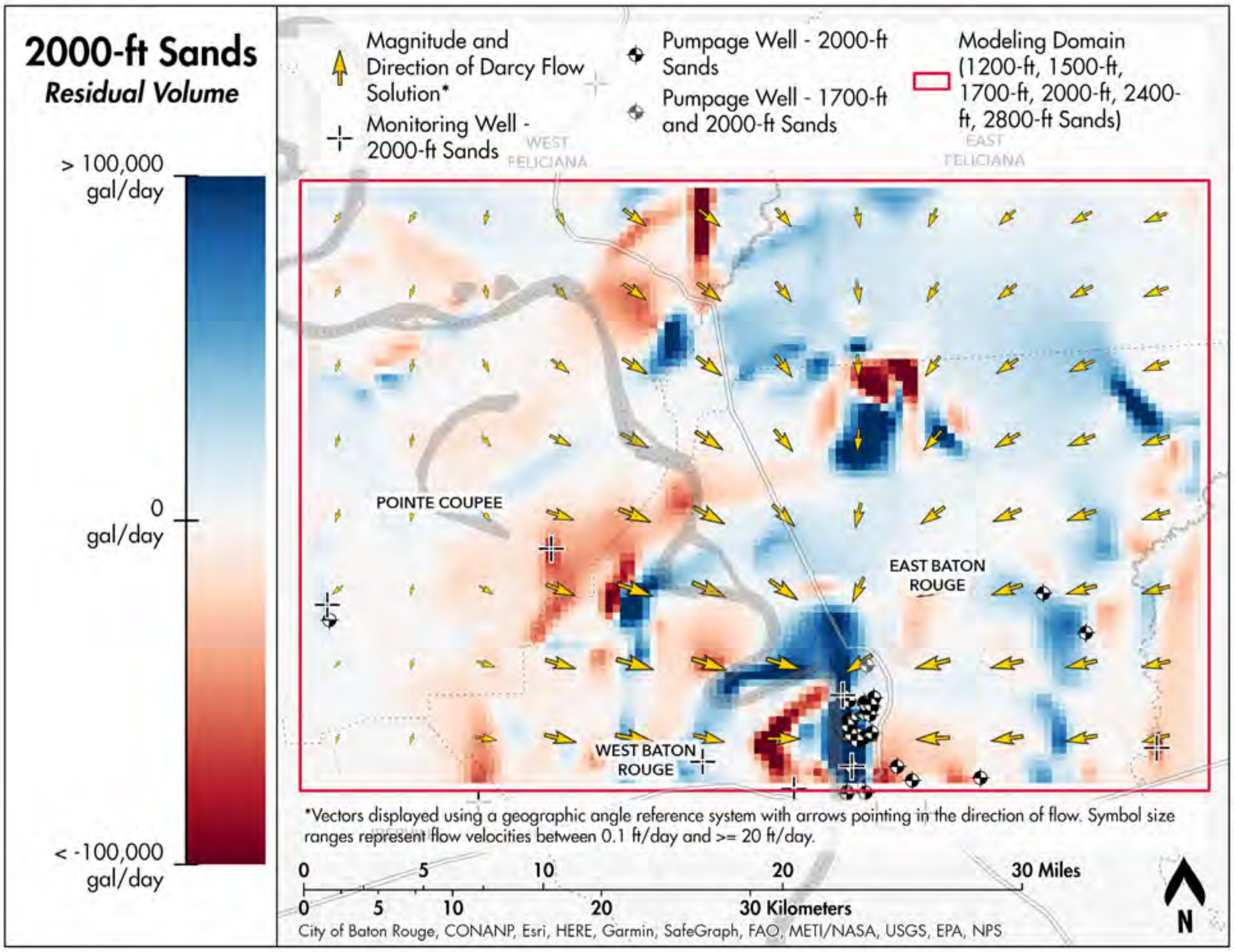


Figure 20. Darcy flow output example for the 2,000-foot sand.

PUMPING DATA IN THE CAGWCD

Wells have been pumped in what is now CAGWCD since the late 1800s (Davis & Rollo, 1969; Wintz Jr et al., 1970). Since the establishment of CAGWCC, it is required that pumpage from wells within the CAGWCD be reported to CAGWCC. Currently, the pumpage is self-reported (also called voluntary reporting) by users and the wells are not metered by the CAGWCC. The amount of water and the rate at which it is pumped from the aquifer, and from each sand, is directly related to the potentiometric surface height of each sand layer. An understanding of where this pumpage occurs and how pumpage patterns have changed through time is necessary for the planning efforts of the CAGWCC.

Data prior to the establishment of CAGWCC were obtained from Davis and Rollo (1969) and Wintz Jr. et al. (1970). These data are a single estimated total for the entire Baton Rouge area; no information on specific wells is available. Data from 1975 through 2020 were obtained from CAGWCC; the pumpage from specific wells is available from this data. The pumping data were reviewed to ensure consistency of format and data completeness. It was particularly important to reference the CAGWCC Well Number with a location so that the spatial variability of pumping could be represented on a map. The CAGWCC database had incomplete information on well locations. All wells in the CAGWCC database are identified by a Well Number (e.g., 22005-274). This number is composed of the Louisiana state code (22), the parish number (e.g., Ascension Parish is 005), and the local well number (e.g., 274) found in the Strategic Online Natural Resources Information System (SONRIS) Well Registration database kept by the Louisiana Department of Natural Resources (LDNR; Louisiana Department of Natural Resources, 2021). Using this information, the Institute was able to pair each well with its latitude and longitude location. During this process two wells in different locations were found to have the same Well Number in the CAGWCC database. The Aquifer Code from the CAGWCC database (known as the Geologic Unit in the SONRIS database) provides information on the specific geologic unit of SHAS that a well pumps water from, defined at the time of drilling. Data from SONRIS was used to fill gaps in the CAGWCC database; where the two data sources conflicted, the CAGWCC database was used. Beyond the Industrial District of Baton Rouge the geologic units are less well defined, which leads to uncertainty in determining the Aquifer Code. In these areas, the code assigned when the well was drilled is useful in understanding pumping patterns at a high level.

Total pumpage per year in CAGWCD has increased from approximately 1,000 Mgal of water in the late 1800s to nearly 65,000 Mgal in 2011 at the peak of pumpage (Figure 21). The total amount of water pumped is a combination of the industrial and public uses of water. Total pumpage has decreased in the CAGWCD from 2018 to 2020; a portion of this decrease may be attributable to the closure of the Georgia-Pacific facility north of the Industrial District. Between 1975 (Figure 22) and 2020 (Figure 23), the spatial extent of pumping has expanded in all directions. The number of pumped wells in all parishes has increased, and Ascension Parish has been added to the CAGWCD. Additionally, the spatial pattern of pumping has changed. In 1975 pumping was concentrated in the Industrial District of Baton Rouge (Figure 24). By 2020, large amounts of pumping occur outside the Industrial District as well as within it (Figure 25). Additional maps of pumpage are provided in Appendix B. These maps are provided for 1975, 1980, 1990, 2000, 2010, 2015, 2016, 2017, 2018, 2019, and 2020. Data are available to map the pumping distribution for any year between 1975 and 2020.

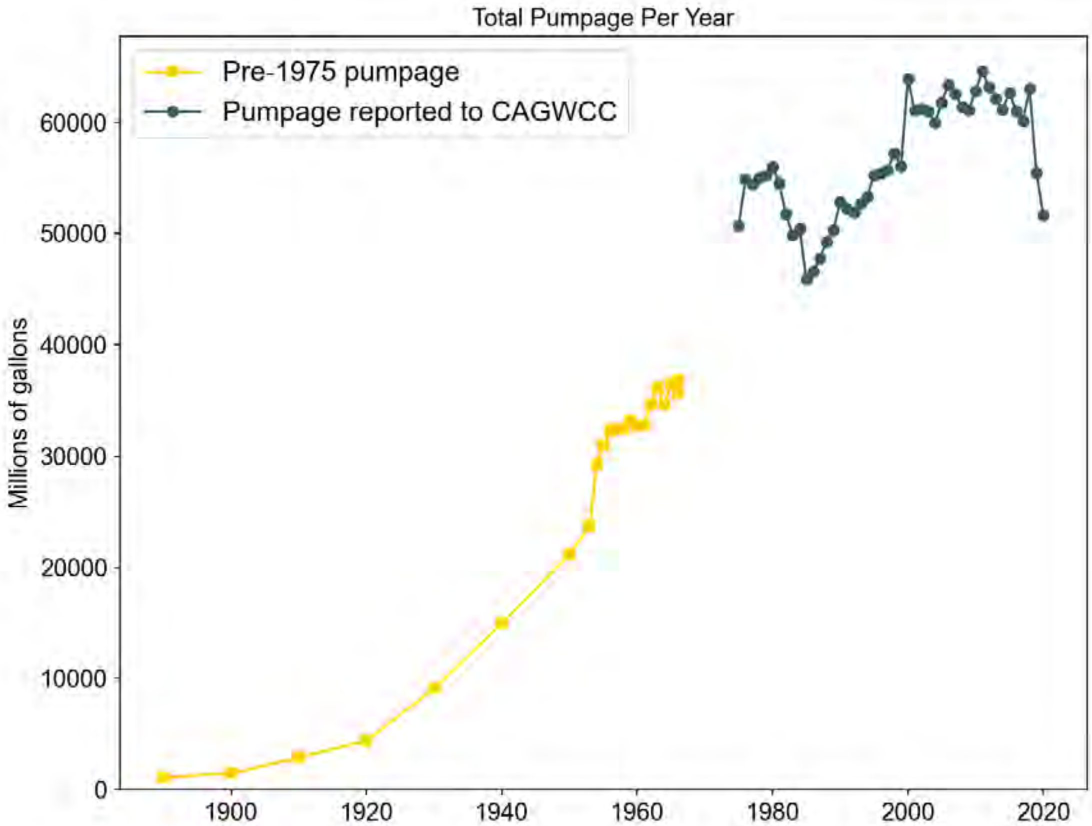


Figure 21. Total pumpage in CAGWCD both before and after the establishment of CAGWCC. Data prior to the establishment of CAGWCC were obtained from Davis and Rollo (1969) and Wintz Jr et al.(1970). The total amount of water pumped is a combination of the industrial and public uses of water.

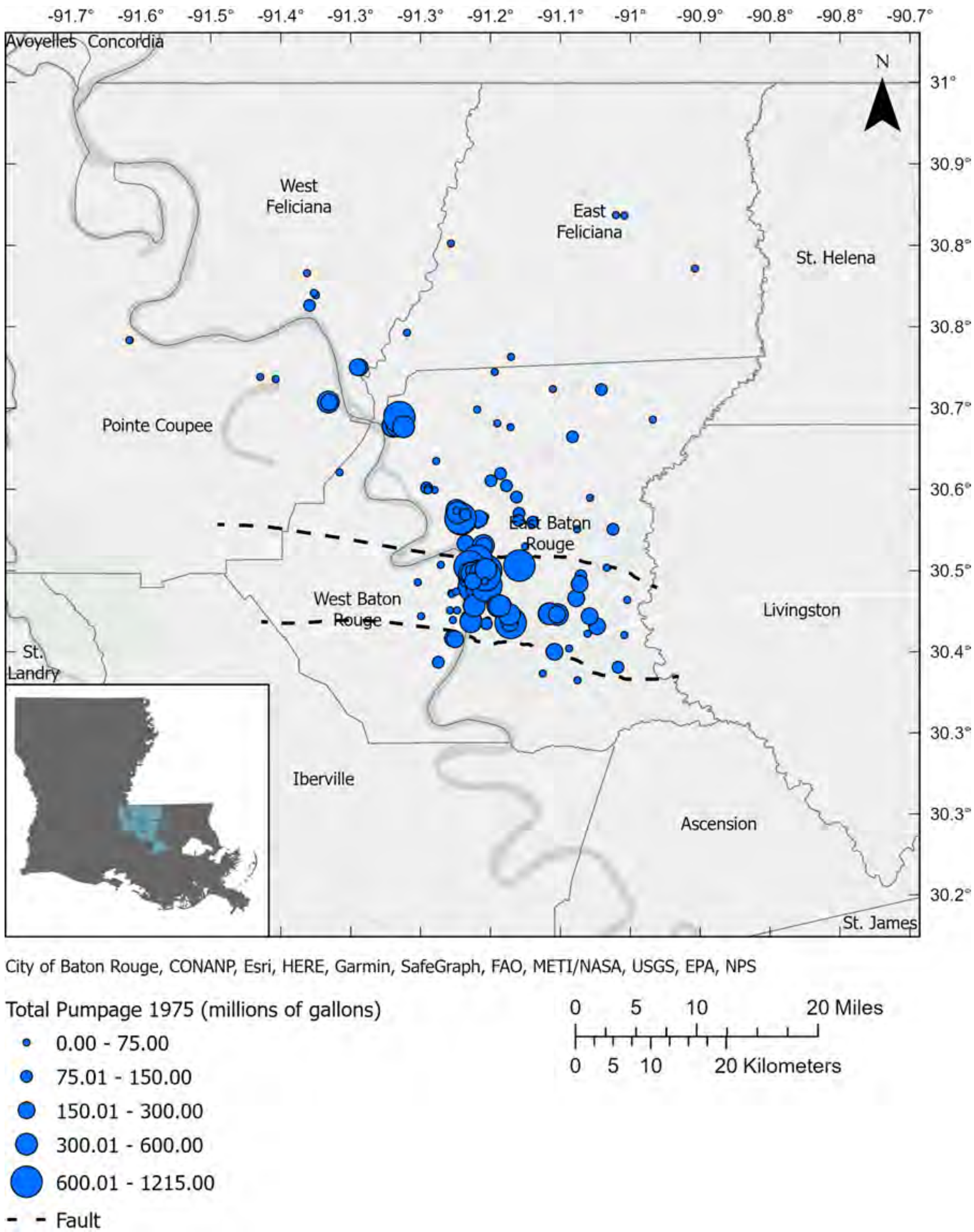


Figure 22. Total pumpage as reported to CAGWCC across the CAGWCD in 1975. Each well that reported pumpage to CAGWCC during this year is represented by a circle. The size of the circle indicates how much water is pumped at each well. Units are in millions of gallons. The total amount of water pumped is a combination of the industrial and public uses of water.

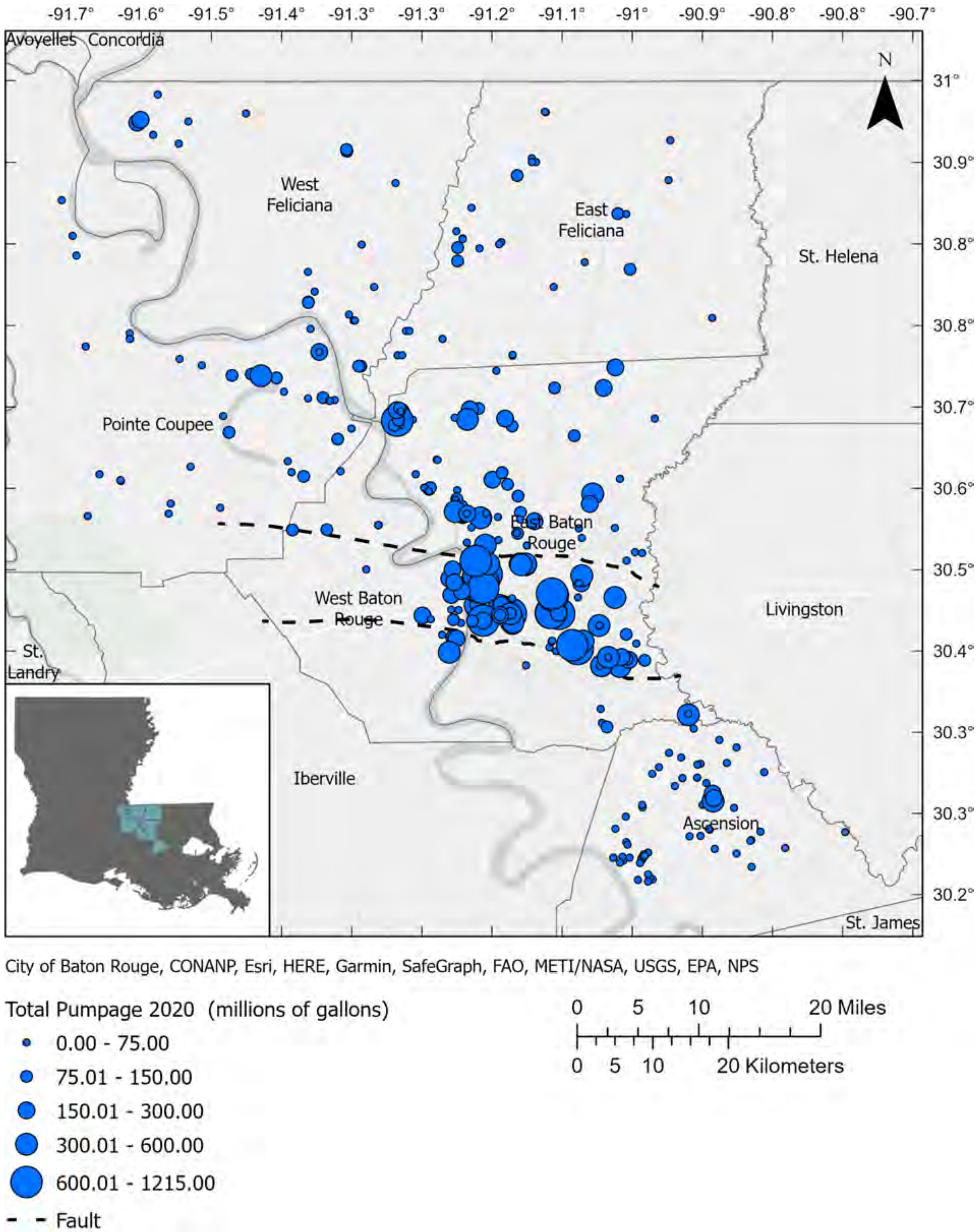


Figure 23. Total pumpage as reported to CAGWCC across the CAGWCD in 2020. Each well that reported pumpage to CAGWCC during this year is represented by a circle. The size of the circle indicates how much water is pumped at each well. Units are in millions of gallons. The total amount of water pumped is a combination of the industrial and public uses of water.

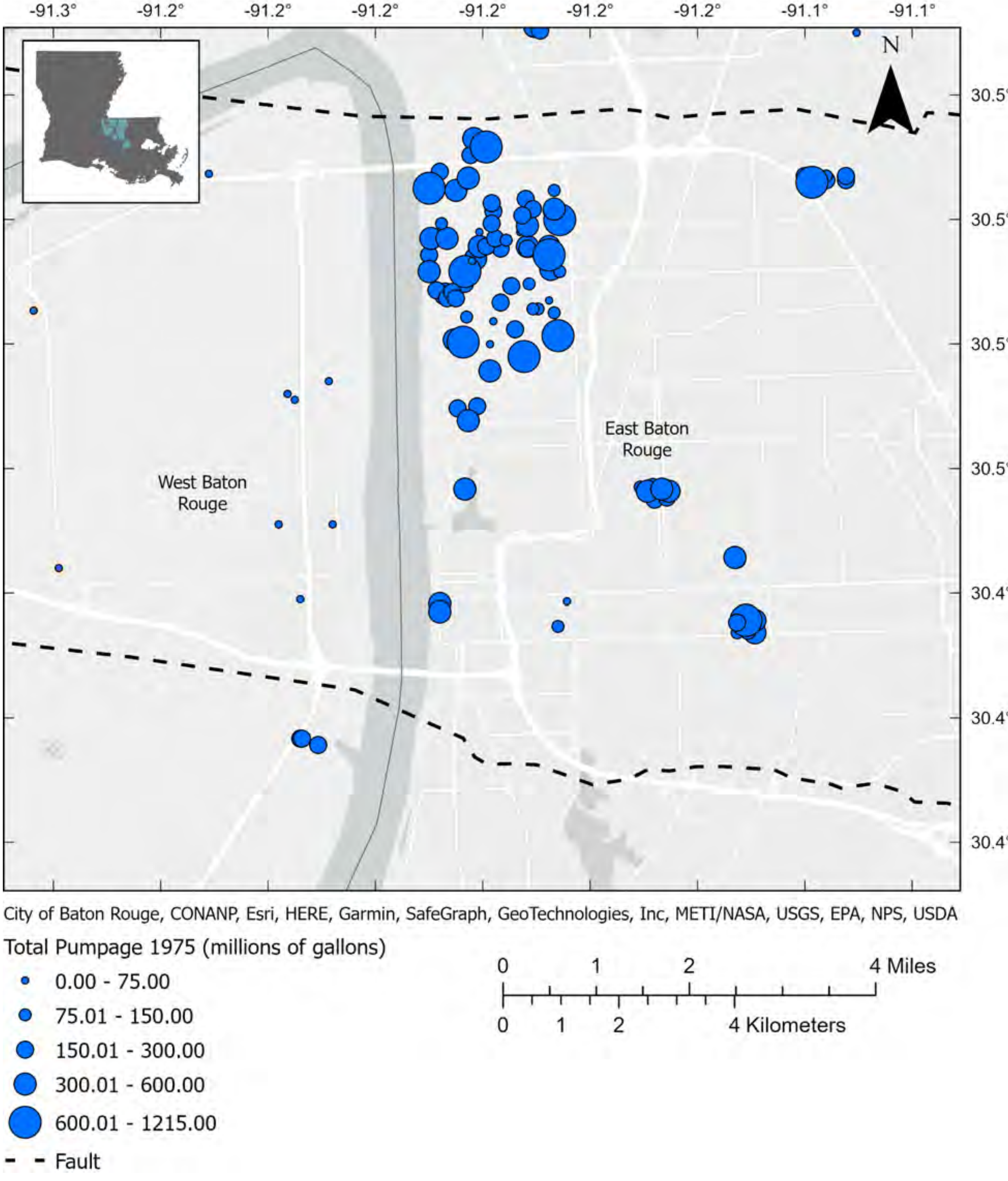


Figure 24. Total pumpage as reported to CAGWCC in the Baton Rouge Industrial District in 1975. Each well that reported pumpage to CAGWCC during this year is represented by a circle. The size of the circle indicates how much water is pumped at each well. Units are in millions of gallons.

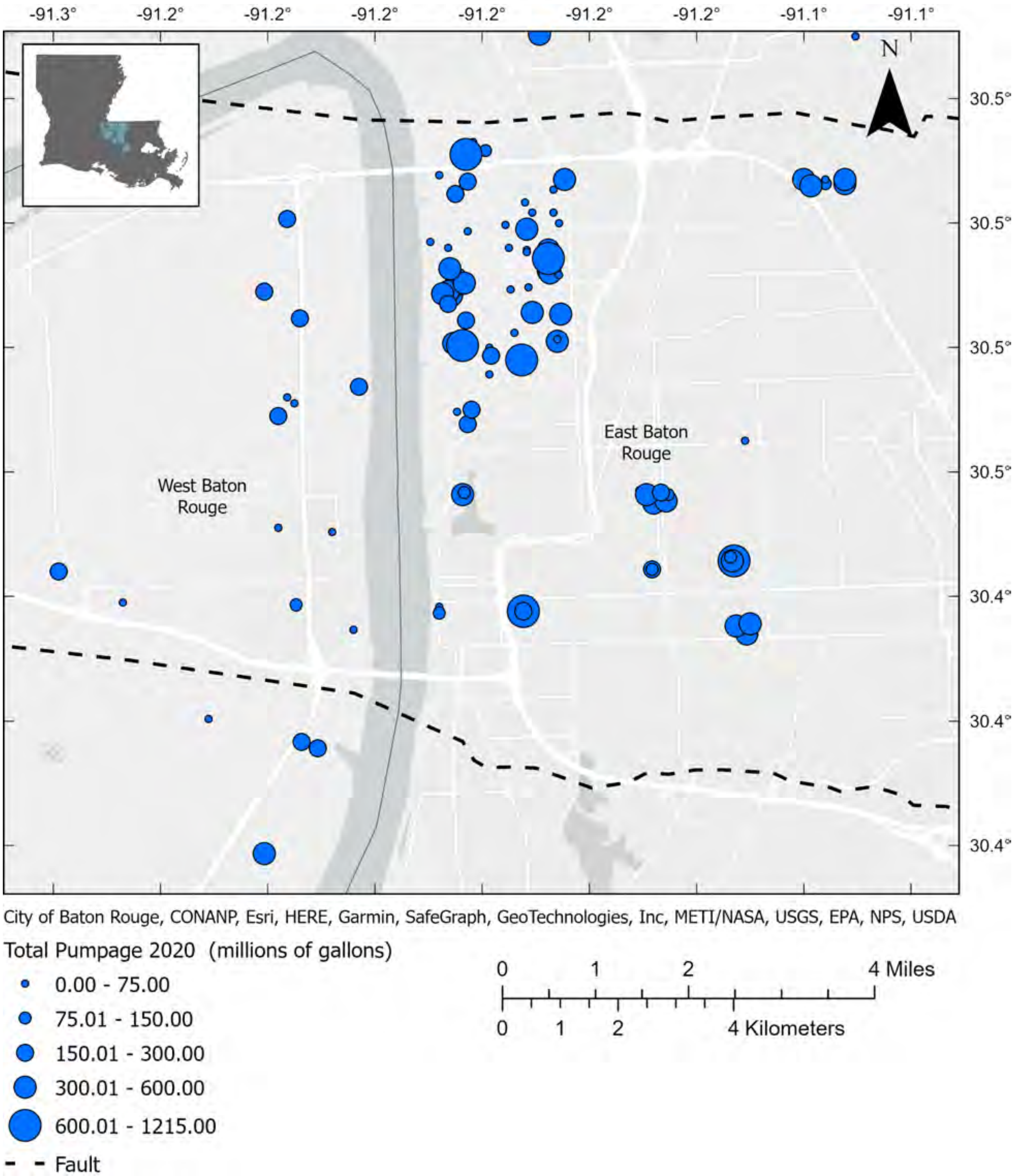


Figure 25. Total pumpage as reported to CAGWCC in the Baton Rouge Industrial District in 2020. Each well that reported pumpage to CAGWCC during this year is represented by a circle. The size of the circle indicates how much water is pumped at each well. Units are in millions of gallons.

When considering the problem of saltwater intrusion, both the location of pumping and the specific sand layer from which water is pumped are important factors. Using the Aquifer Code to map the locations of pumping provides the ability to show which aquifers are being pumped throughout the CAGWCD (Figure 26; Figure 27; Figure 28; Figure 29). Only the SHAS sand layers were specifically mapped. Many of the new wells added between 1975 and 2020 were drilled in the deeper sand layers (Figure 26, Figure 27). New wells in East Baton Rouge (EBR) and West Baton Rouge (WBR) parishes were also drilled in the shallower sand layers (600-foot sand to 1500-foot sand). New wells in the Industrial District were largely drilled in the shallower sand layers (400-foot sand to 600-foot sand; Figure 28; Figure 29). Maps of this type were created for 1975 and 2020, but can be created for any year between 1975 and 2020. The overall pattern of well development has broadened across the CAGWCD to include an increased number of wells across a larger geographic area including Pointe Coupee, East Feliciana, West Feliciana, and Ascension Parishes. The wells in Ascension Parish are shown as “all other values” because they are not located in the SHAS aquifers of most concern for this project and the CAGWCC.

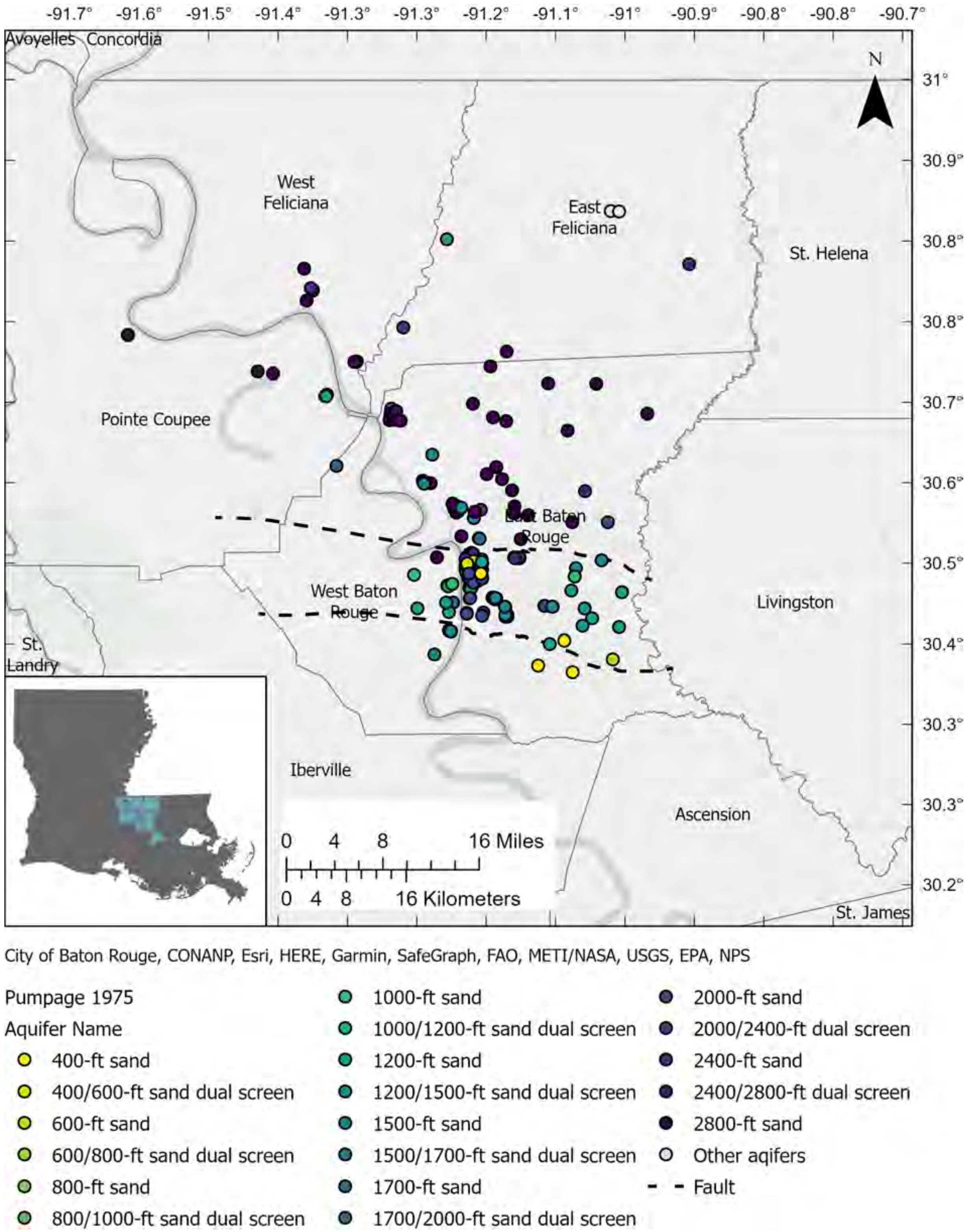


Figure 26. Pumpage from the 10 primary SHAS aquifers of most concern for strategic planning across the CAGWCD according to CAGWCC records from 1975.

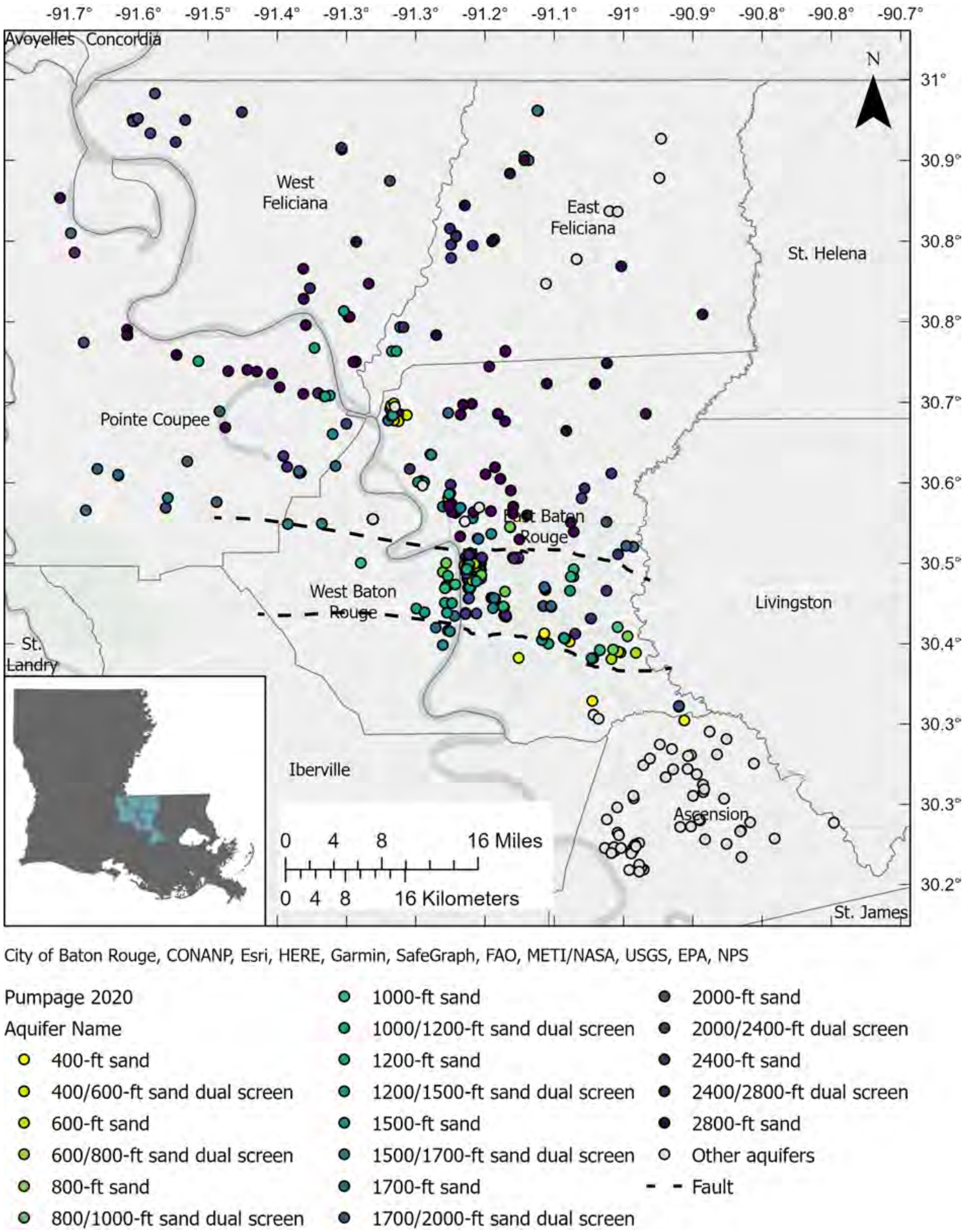


Figure 27. Pumpage from the 10 primary SHAS aquifers of most concern for strategic planning across the CAGWCD according to CAGWCC records from 2020.

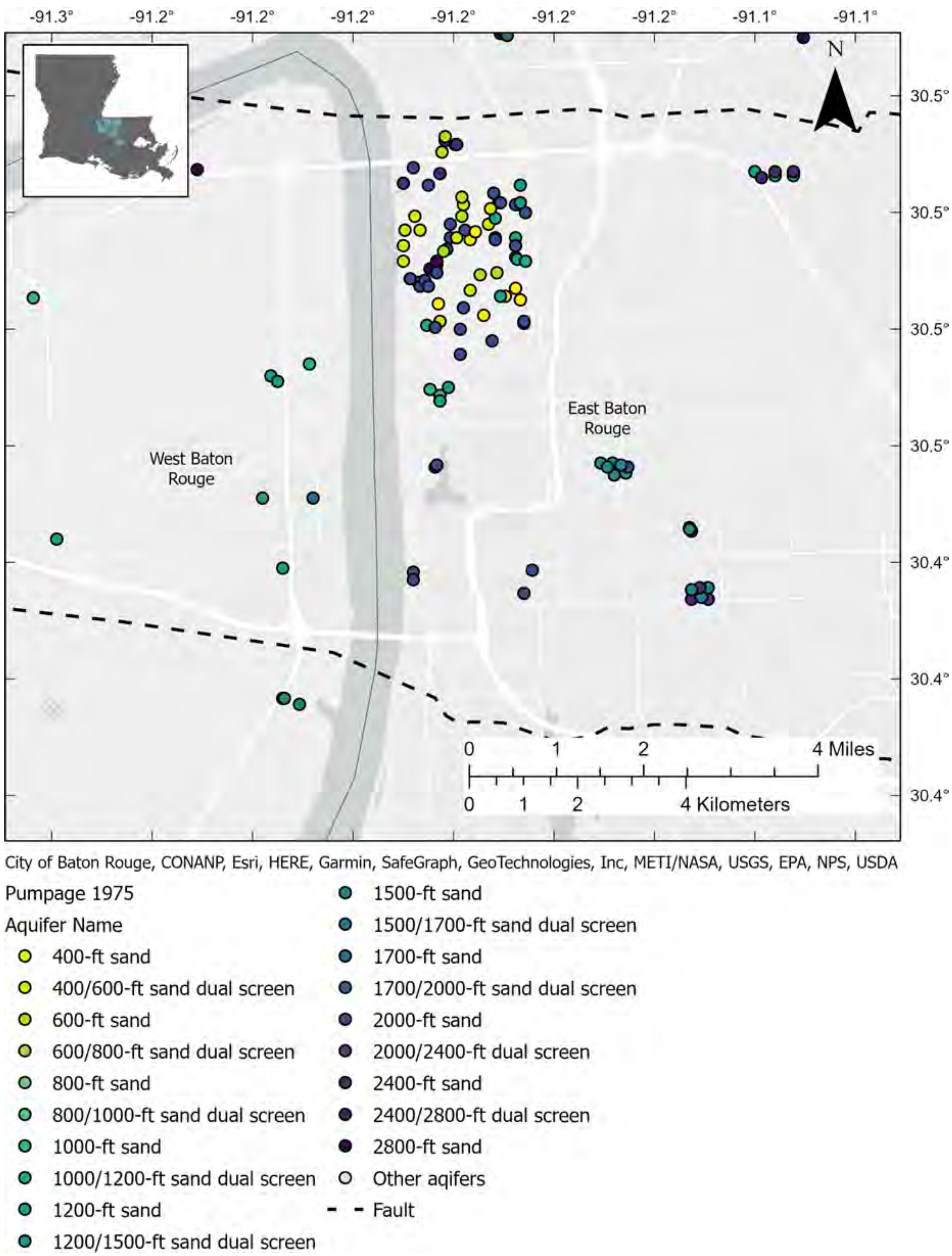


Figure 28. Pumpage from 10 primary SHAS aquifers in the Baton Rouge Industrial District according to CAGWCC records from 1975.

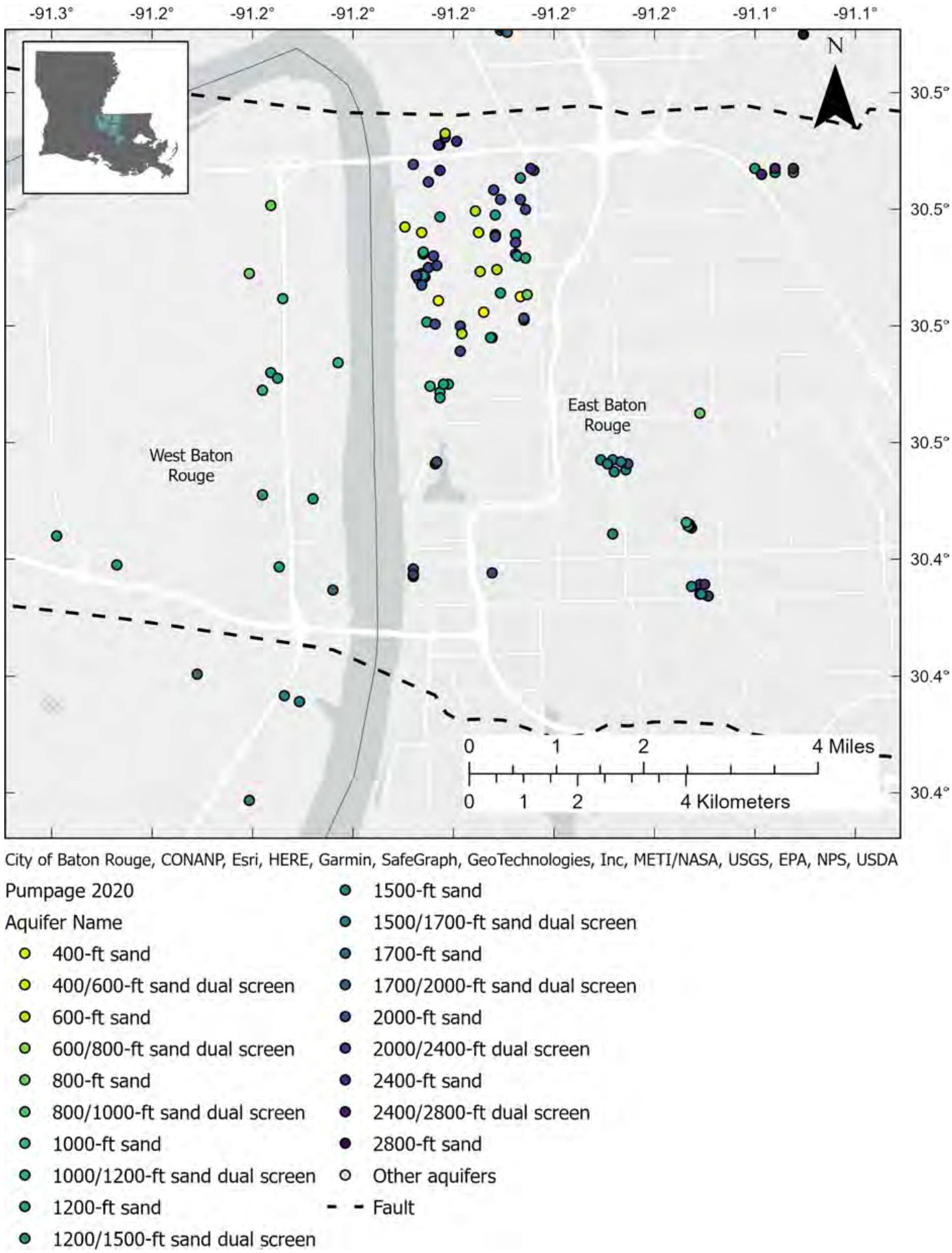


Figure 29. Pumpage from the 10 primary SHAS aquifers in the Baton Rouge Industrial District according to CAGWCC records from 2020.

TASK 2.2 QUANTIFYING GROUNDWATER SUPPLY FOR THE CAPITAL REGION

This task is part of Phase 2B, not Phase 2A, and will be covered in a future report.

TASK 2A.3 EVALUATING WATER DEMAND ACROSS THE CAPITAL REGION

> *Task Summary: Water demand is dynamic, with factors such as population and economic growth, technology, weather and consumer behavior affecting patterns of use. Long term planning requires an appreciation of its dynamic nature, and the appropriate means for evaluating demand considers such factors. For use in strategic decision making and modeling, factors will need to be quantified and estimated through a range of possible outcomes, first looking at historical demand and evaluation of water use.*

UNDERSTANDING HISTORICAL AND CURRENT DOMESTIC DEMAND

Evaluation of historic and current domestic water demand is a vital component in developing an understanding of the overall regional water needs and potential future demand growth. The following report subsections document the available references on water use within the CAGWCD, the detailed methodologies utilized to estimate domestic and industrial water demands, and efforts undertaken as part of the study to collect additional data regarding industrial water use characteristics.

Overview and Data Sources

While characterization of domestic water demand may be relatively straightforward in areas with a single water provider, for more complex regions, multiple factors influence both water use characteristics and the availability of detailed data. Domestic water supply and use characteristics within the CAGWCD are diverse, incorporating areas of suburban and urban development supplied by a number of water suppliers of varying size, system age, pricing structures, and data management practices, with additional substantial rural areas and associated self-supplied groundwater.

To inform the assessment of domestic use, available data sources related to population, water use, and well information in the CAGWCD parishes and the State of Louisiana were reviewed, including:

- Groundwater well pumpage summaries by well owner developed by the Institute and CAGWCC, available annually from 1975 to 2020;
- Groundwater Well Registration database from the LDNR SONRIS data portal (accessed 2021);
- USGS and Louisiana Department of Transportation and Development (LA DOTD) cooperative reports on water use and the SHAS (Lovelace, 1991; Lovelace and Johnson, 1996; Sargent, 2002; Sargent, 2007; Sargent, 2011; Collier and Sargent, 2018);
- National water use data reported by source (surface water, groundwater) and category (e.g., public supply, industrial) from the USGS National Water Information System (NWIS), available every five years from 1985 to 2015;
- Louisiana House Concurrent Resolution (HCR) No. 115 (2016) groundwater study report (LDNR, 2017);
- Findings of the Louisiana Parish Population Projections Series, 2010–2030 developed by LSU (Blanchard, 2007);
- Findings of the Water Resources Assessment for Sustainability and Energy Management performed by the Institute (Hemmerling et al., 2016);
- The Louisiana Public Service Commission 2017 Water Rates in Louisiana report (Purpera et al., 2017);
- Population estimates in the Regional Economic Analysis Project, developed by the U.S. Bureau of Economic Analysis Regional Income Division; and
- Population and housing data from the U.S. Census and the American Community Survey (U.S. Census Bureau, 2019).

Historical Population Trends and Distribution

Populations within the CAGWCD were assessed at the parish level for each decade for 1980–2010 and annually for 2011–2020. Table 2 demonstrates the years in which data are available from various sources.

Although American Community Survey (ACS) data are available on an annual basis for 2010 and later, they were not used in the assessment of municipal demands. ACS five-year estimates represent data collected over a five-year period and therefore are not always up to date when estimating total population counts of a geographical area. ACS one-year estimates generally have higher accuracy, but because less data are available from a single year, summary data are not available for geographical areas with a population of less than 65,000, so data are not available within the CAGWCD except for the two more populous parishes (Ascension and EBR). Both the Regional Economic Analysis Project (REAP) and the five-year ACS estimates indicated a growth curve that fell behind the decennial Census counts by 2020, suggesting that the methodologies of the annual datasets underestimated growth rates. Decennial Census data provide the most detailed look at population distributions. Figure 30 highlights areas of growth across the CAGWCD from 2010 to 2020 using decennial Census counts. From 2010 to 2020, Ascension Parish and EBR Parish grew rapidly, with average growth rates of +1,929 and +1,661 persons/yr, respectively. WBR Parish grew more modestly, gaining 341 residents per year on average, and the three remaining parishes lost population.

Table 2: Population data availability by source and year.

Data Type	Source Dataset	Source	1980	1990	2000	2010	2011-2014	2015	2016-2019	2020
Population	Decennial Census	U.S. Census Bureau	✓	✓	✓	✓				✓
	1-Year ACS	U.S. Census Bureau				✓	✓	✓	✓	
	5-Year ACS	U.S. Census Bureau				✓	✓	✓	✓	
	Regional Economic Analysis Project	Regional Income Divisions, Bureau of Economic Analysis	✓	✓	✓	✓	✓	✓	✓	
	Water Use in Louisiana reports	LA DOTD in cooperation with USGS		✓	✓	✓		✓		
Population served by public supply	Water Use in Louisiana reports	LA DOTD in cooperation with USGS		✓	✓	✓		✓		
	Appendix E[(1)]	Purpera et al. (2017)						✓		

(1) Population served by each public water supply system reported in Purpera et al. (2017) is assumed to be population served in 2015, but the source document does not clarify the date of the population estimate.

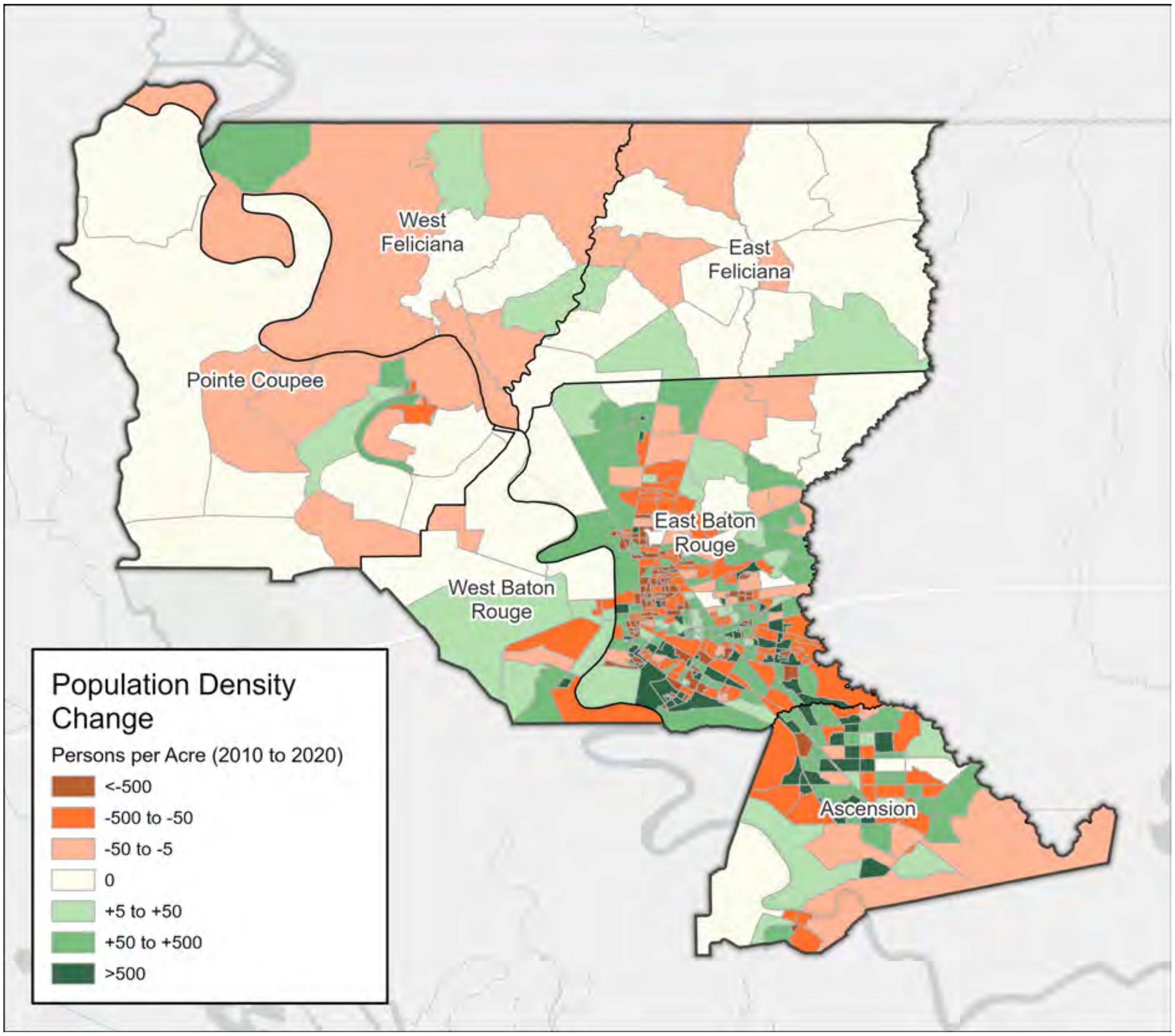


Figure 30. Population Density Change in District parishes (2010 to 2020).

The *Water Use in Louisiana* reports, published by USGS and LA DOTD every 5 years, also report parish populations; these populations are available for every parish and match 1-year ACS data where they are available. Because the REAP and ACS datasets did not ultimately align with growth indicated by the 2020 Census, those data were not used. Instead, municipal demand estimates for 2010 to 2020 were based on decennial Census counts and USGS-LA DOTD parish populations in 2015, with linear interpolation applied from 2010 to 2015 and from 2015 to 2020.

The USGS-LA DOTD reports also include an estimate of the total number of residents served by public water supply systems in each parish. Purpera et al. (2017) provided an estimate of populations served by some of the larger public supply systems in the area. However, the associated year of the system-level population estimates reported by Purpera et al. (2017) was unclear, and these population estimates did not align well with total estimates of publicly supplied population in the USGS-LA DOTD "Water Use in

Louisiana" report (2015). Because the system-level population data did not appear to align with USGS data, population and water use were not assessed at the system level.

Domestic Water Demand Analysis Methodology and Estimates

Historical and current domestic water demands were estimated using the population data discussed in the previous section, in conjunction with water use estimates from CAGWCC and USGS (Table 3). Domestic demand discussed here includes water for residential, commercial, or institutional use provided through a public water supply system as well as self-supplied water for residential use pumped from private groundwater wells. Population, per-capita water consumption, public supply groundwater withdrawals, and total estimated domestic demand were estimated on an annual basis at the parish level from 2010 to 2020. Limited data and associated documentation were available at the water system level, and as a result, demands were not estimated at the water system level.

Table 3: Domestic water use data availability by source and year

Data	Source Dataset	Source	2010	2011-2014	2015	2016-2019	2020
Groundwater Use for Public Supply	Annual groundwater pumpage, by parish and by well owner	CAGWCC	✓	✓	✓	✓	✓
	Water Use in Louisiana reports, by parish	LA DOTD in cooperation with USGS	✓		✓		
Surface Water Use for Public Supply	Water Use in Louisiana reports, by parish	LA DOTD in cooperation with USGS	✓		✓		
Population served by public supply or self-supplied	Population served by public supply or by self-supply, by parish	LA DOTD in cooperation with USGS	✓		✓		
	Appendix E(1)	Purpera et al. (2017)			✓		

(1) Population served by each public water supply system reported in Purpera et al. (2017) is assumed to be population served in 2015, but the source document does not clarify the date of the population estimate.

Records of groundwater withdrawals are not available for private residential wells, and data on surface water usage for public supply were not available, with the exception of USGS estimates in 2010 and 2015. Because detailed, annual groundwater pumpage information was available from CAGWCC, this was the primary data source for estimating per-capita demands. Per-capita demand was estimated each year in each parish for all users of publicly supplied water based on the groundwater withdrawals reported to CAGWCC and the estimated population using publicly supplied groundwater. The number of residents using surface water in each parish were estimated using 2010 and 2015 estimates from USGS NWIS. The population of surface water users was interpolated between these values in 2011 through 2014. Due to lack of information regarding growth of surface water use, the 2015 value was extended through 2020 rather than assuming any change in usage. This surface water user population was subtracted from the total publicly supplied population such that per-capita demand could be based on groundwater public supply users only. Then, that per-capita demand was applied to the surface water users to estimate the approximate amount of surface water demand (this primarily applied to Ascension Parish, but USGS NWIS data showed a few surface water users in West Feliciana Parish prior to 2015). Finally, the population estimated to use self-supplied groundwater was multiplied by an assumed constant per-capita demand and added to the public supply groundwater pumpage and estimated surface water use to estimate the total annual domestic water demand in each parish for years 2010 to 2020.

Two approaches were used to estimate the number of residents in each parish using private wells rather than public supply, and per-capita demand rates for public supply systems were estimated from the remaining population. Due to the uncertainty of publicly supplied and self-supplied population estimates, both results from the two approaches are presented here to indicate a likely range of per-capita demand.

- Approach A: The self-supplied population in each parish was calculated as the number of domestic self-supply wells multiplied by the average household size in that parish. Number of wells was based on those listed as currently active and used for domestic self-supply in the LDNR SONRIS groundwater well database. The typical household size was derived from parish-level estimates in the 2019 ACS 5-year dataset, and this household size was assumed to be a reasonable estimate for all years 2010 through 2020.

- Approach B: Domestic self-supplied population by parish was reported in the USGS NWIS in 2010 and 2015. The trend between these years was assumed to be linear and to continue into the future to 2020.

Approach B estimated a higher number of residents using self-supplied groundwater instead of public supply compared to Approach A, particularly in Ascension Parish. This difference in estimates could be due to incomplete well data in SONRIS due to wells not reported to DNR by owners or drillers but could also be the result of varying household sizes and the estimation approach used by USGS, which relies on estimates of publicly supplied populations from the U.S. Census Bureau's American Housing Survey.

The estimated range of average annual per-capita water demand from 2010 to 2020 by parish is shown in Figure 31. Figure 32 illustrates groundwater pumping for public supply over time by parish in the CAGWCD. Several factors should be considered in examining these estimates:

- Information in these figures is based on estimated usage reported to CAGWCC as public supply.

- For some water systems, a portion of public supply may serve end uses other than direct domestic consumption, such as common areas, non-industrial commercial development, or small-scale manufacturing.

- Usage reported to CAGWCC as public supply by correctional facilities and prisons was recategorized for assessment with industrial demands because the types of strategies developed for industrial use are considered to be more relevant to these institutions. As a result, these demands are excluded from this discussion of municipal and domestic demand.

- It should be noted that due to the considerations described above, Figure 31 does not reflect direct household-level domestic use, but rather an overall high-level estimate of per-capita public supply demand (excluding users with private groundwater wells).

- Ascension Parish became a member of CAGWCD in 2018, with reporting of pumpage data becoming available beginning in 2019. Groundwater withdrawals for public supply reported by LA DOTD and USGS were used to estimate pumpage in the parish prior to 2019.

- Water use reports from USGS suggest that public supply is limited to groundwater sources only in five of the six parishes; some systems in Ascension Parish use a surface water supply. Available surface water withdrawal data were small relative to estimates of surface water user populations in the same dataset (USGS NWIS), so the surface water withdrawal data were not used. Instead, the population estimated by USGS to use surface water supplies was multiplied by the same per-capita demand developed for groundwater users in Ascension Parish to estimate historical demand for surface water supply.

- Groundwater exports from EBR Parish play an important role in meeting domestic water demand in Ascension Parish; therefore, Ascension Parish and EBR Parish were evaluated together to estimate a combined per-capita demand rate, since much of the pumping from EBR Parish has been used to satisfy a large component of domestic water demand in Ascension Parish, but the volume of that transferred supply is not known in all years.

- Water demands by self-supplied domestic users, including rural residents with small household wells, have been estimated based on an assumed per-capita demand of 80 gallons per-capita daily (gpcd), which is an equivalent value to that used in Collier and Sargent (2018).

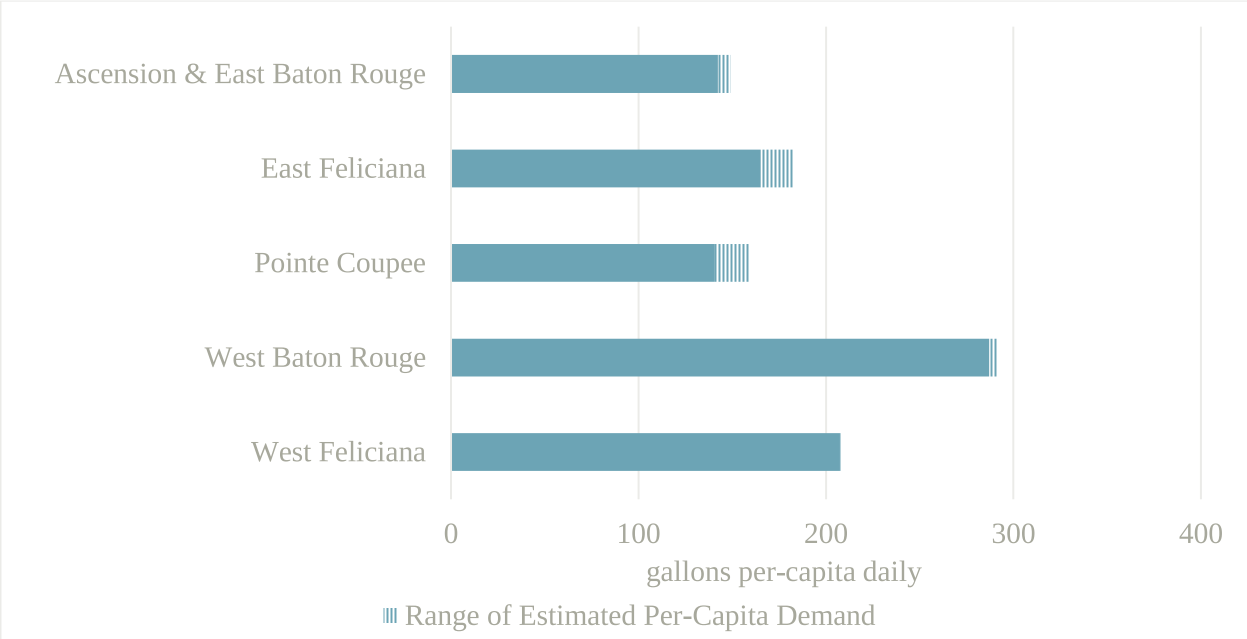


Figure 31. Average Per-Capita Demand for Public Supply from 2010 to 2020 (excludes self-supplied groundwater use).

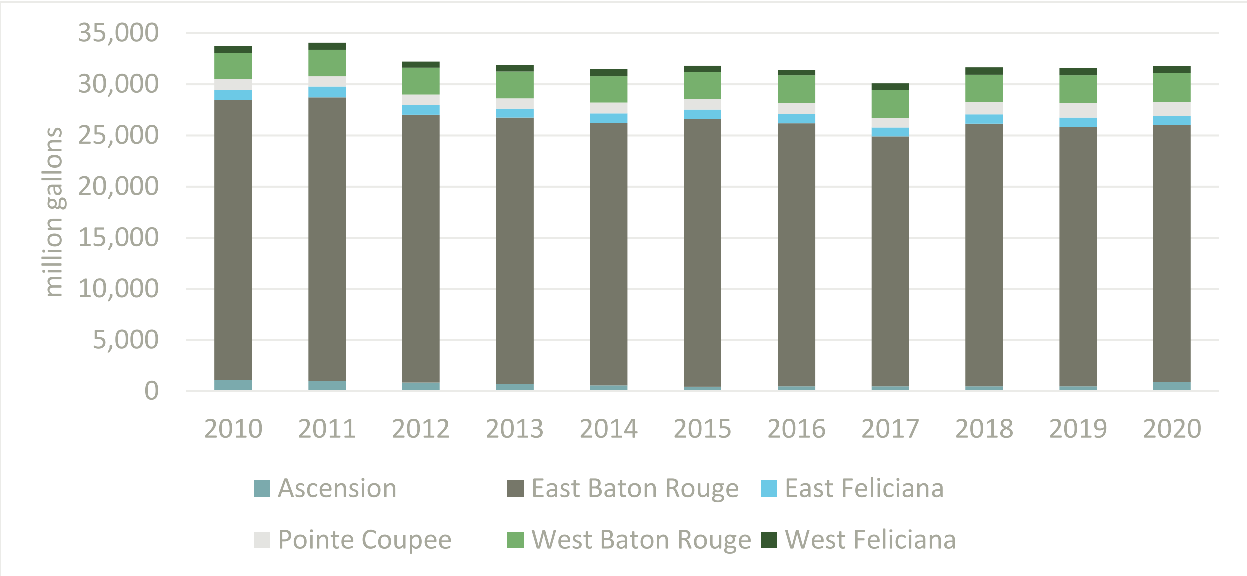


Figure 32. Estimated Groundwater Withdrawals for Public Supply in District parishes from 2010 to 2020.

Population and Demand Projection and Data Refinement

While Task 2A.3 is focused primarily on developing an understanding of historic and current levels of water use, subsequent analyses under Phase 2A1 and 2B of the study will utilize this information in examining potential future water needs through a projection process anticipated to incorporate:

- Extrapolation of Census and ACS population trends through a multi-decade horizon;
- Projection of future water use to be compared against sustainable groundwater production;
- Estimation of the future spatial distribution of water demands based on Census and ACS trends as well as current build-out; and
- Consideration of variability in future unit demand forecasts.

Similar to the assessment of historic and current water use, estimation of potential future water needs will examine municipal demands for all District parishes and consider available data for usage from multiple water source types. While groundwater production is vital to the area and the ultimate focus of the study, the water supply landscape within the CAGWCD is complex; for example, Ascension Parish includes a combination of surface water, locally produced groundwater, and externally produced groundwater to meet demand. This combination of water supply sources necessitates an inclusive approach to supply examination.

In order to enhance domestic water use study data, refine estimates of household and per-capita use, and integrate these data and estimates with associated study components, the project team and CAGWCC staff have coordinated regarding distribution of a detailed data request letter to the water providers within the CAGWCD. The list of requested items includes details related to system intake, volumetric usage by demand category, billing amounts and structures, service area boundary and population, and water supply quality and reliability indicators. In addition to refining understanding of current domestic demand and facilitating water demand projections, this information is anticipated to support the evaluation of Performance Metric 2 related to public water supply. As additional data become available, estimates of population, water use, and household-scale water usage may be refined as appropriate for the study area in order to facilitate future demand estimation.

UNDERSTANDING HISTORICAL AND CURRENT INDUSTRIAL DEMAND

Overview and Data Sources

Quantification of industrial water use is key to long-term planning of water resources in the CAGWCD, driven both by the major role that industry plays in the local economy and an associated reliance of many facilities on groundwater for all or part of their water supply. Due to the limited availability of detailed data on water use by industrial facilities in the CAGWCD, Phase 2 of the study included a survey of industrial water users (Industrial Survey). This survey was developed to fill information gaps and allow estimation of the magnitudes and sources of current industrial water use, and evaluation of potential future strategies. In particular, the Industrial Survey was intended to facilitate the following:

- Development of estimates of historical and current industrial water use;
- Detection of trends in industrial water use and partitioning of trends into groundwater and surface water components;
- Identification of industrial water user locations, current use of industrial water, and current plans for expansion of alternative (non-groundwater) supplies; and
- Development of an estimate of the water cost for current supplies used by the industry. This cost represents a baseline to compare to other potential future water supply alternatives in order to assess Performance Metric 3 (evaluated as part of Subtask 2A.5).

Due to the sensitivity of industrial stakeholders to the potential release of facility-specific data, the project partners have and will continue to maintain confidentiality of detailed survey results and provide summaries of water use, cost, and other relevant data in a consolidated format based on overall industrial sector, general location of industrial aggregations, or similar factors.

In addition to the Industrial Survey, available data sources related to industrial water use and well information in District parishes and the state of Louisiana were reviewed to evaluate historical industrial demands including**:**

- Groundwater well pumpage summaries by well owner developed by the Institute and CAGWCC, available annually from 1975 to 2020;
- Groundwater Well Registration database from the DNR SONRIS data portal (accessed in 2021);
- USGS and LA DOTD cooperative reports on water use, published every five years from 1960 to 2015 (Snider and Forbes, 1961; Bieber and Forbes, 1966; Dial, 1970; Cardwell and Walter, 1979; Walter, 1982; Lurry, 1987; Lovelace, 1991; Lovelace and Johnson, 1996; Sargent, 2002; Sargent, 2007; Sargent, 2011; Collier and Sargent, 2018);
- National water use data reported by source (surface water, groundwater) and category (e.g., industrial, power generation) from the USGS NWIS available every five years from 1985 to 2015;
- Water withdrawals by source and category in Louisiana parishes, 2014-2015 (Collier, 2018).

Survey Development, Distribution, and Response

As part of the industrial demand estimation effort, FNI developed a preliminary survey question list, along with a study-specific definition of industrial use, a list of targeted industrial sectors, and an overview of study risks and data sensitivity. The Institute and FNI reviewed and revised these components, and discussed approaches to both survey content and stakeholder outreach to promote data collection while maintaining facility confidentiality, which is important to industrial water users. Following these discussions, an online Industrial Water User Survey form that allows user-friendly collection of data was developed and tested. Feedback from the Institute and CAGWCC staff and board members facilitated further refinement of the online survey tool to incorporate local expertise and familiarity with the concerns of many of the intended recipients. Based on a recipient list provided by CAGWCC, FNI developed entity-specific survey links and provided end user guidance on survey navigation and the process for requesting additional custom survey links for additional facilities.

In the context of this study, "industry" was defined as: commercial facilities engaged in non-retail manufacturing, material processing, material production, or bulk transportation activities and partially or wholly self-supplied with water. This definition is intended to focus analyses on the portion of industrial, commercial, and institutional activities that are larger-scale within the CAGWCD and are predominantly self-supplied with groundwater. While this definition narrows down the focus of the analysis, it still covers a wide range of industrial sectors. Potential target industrial types identified for the Industrial Survey include:

- Chemical (petroleum processing and refining (crude oil or natural gas), petroleum production, other);
- Correctional institutions;
- Electrical power generation;
- Food processing;
- Manufacturing and fabrication;
- Mining (petroleum exploration, petroleum extraction/production wells, sand/gravel/concrete production, other);
- Shipping (port facilities, rail facilities);
- Wood products (pulp and paper, timber); and
- Other.

The recipient list provided by CAGWCC was primarily composed of users in these industrial sectors, but also included some public supply (municipal) and non-industrial commercial sectors that use groundwater as a source in the CAGWCD.

The survey was distributed via email by CAGWCC in early June 2021, with a requested response window of approximately two to three weeks. Responses were examined and organized as they were received, with FNI coordinating with respondents as appropriate to clarify unclear or suspected erroneous data and compare reported usage and infrastructure capacities against available historic data. Due to a limited initial response rate, CAGWCC staff engaged in additional outreach to non-responding entities to encourage survey participation. As of December 2021, 19 of the 80 entities surveyed have provided complete or partial responses, with the amount and level of detail of data varying among respondents. Four other entities provided incomplete surveys containing only facility locations and contact information. While the response rate is limited, the participating entities do represent a broad range of water uses (Figure 33) and demand levels. Sixteen of the entities that responded to the survey meet the industrial use classification defined in this study, while the other seven respondents were either public supply or domestic users ("water supply/distribution" in Figure 33). Analysis was focused on the industrial respondents.

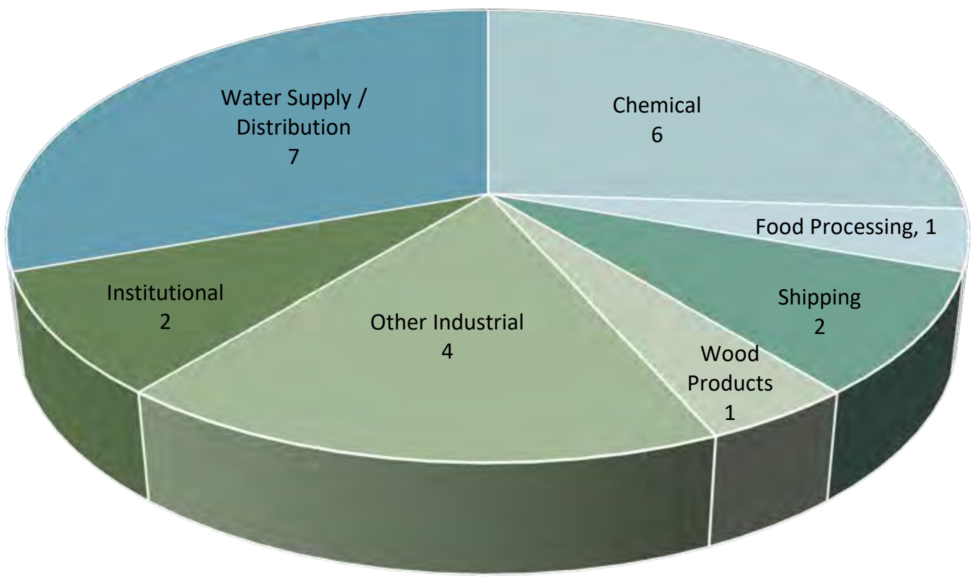


Figure 33. Number of Industrial Water User Survey respondents by facility type.

While the Industrial Water User Survey is an important component of Phase 2 of the project, it should be noted that a limited response rate does not prevent or invalidate planned analyses of water demands, potential future supply strategies, or evaluation of Performance Metric 3. A large number of survey responses and high rates of completion for individual questions would undoubtedly provide a valuable resource for assessing potential future strategies at a finer spatial scale and with more specificity for target users. Where necessary, however, a more general approach to study parameters combining available stakeholder data with carefully considered assumptions still allowed for meaningful analyses of industrial supply and project options at a regional scale. The project partners have utilized approaches to executing Phase 2 project analyses in the context of available data, both for quantification of existing water use and for economic analyses associated with Task 2A.

Industrial Stakeholder Sources, Quality Needs, and Supply Plans

Of the 19 entities that responded, over 80 percent utilize groundwater, with approximately 17 percent indicating at least some access to alternate sources including surface water, emergency interconnect facilities, or alternate groundwater supplies. Groundwater withdrawn by the 16 industrial respondents comprise nearly 45 percent of the total industrial pumpage reported to the CAGWCD over the past 10 years (2011–2020). The frequency with which survey respondents identified any given sand layer of the SHAS as a groundwater source is shown in Figure 34.

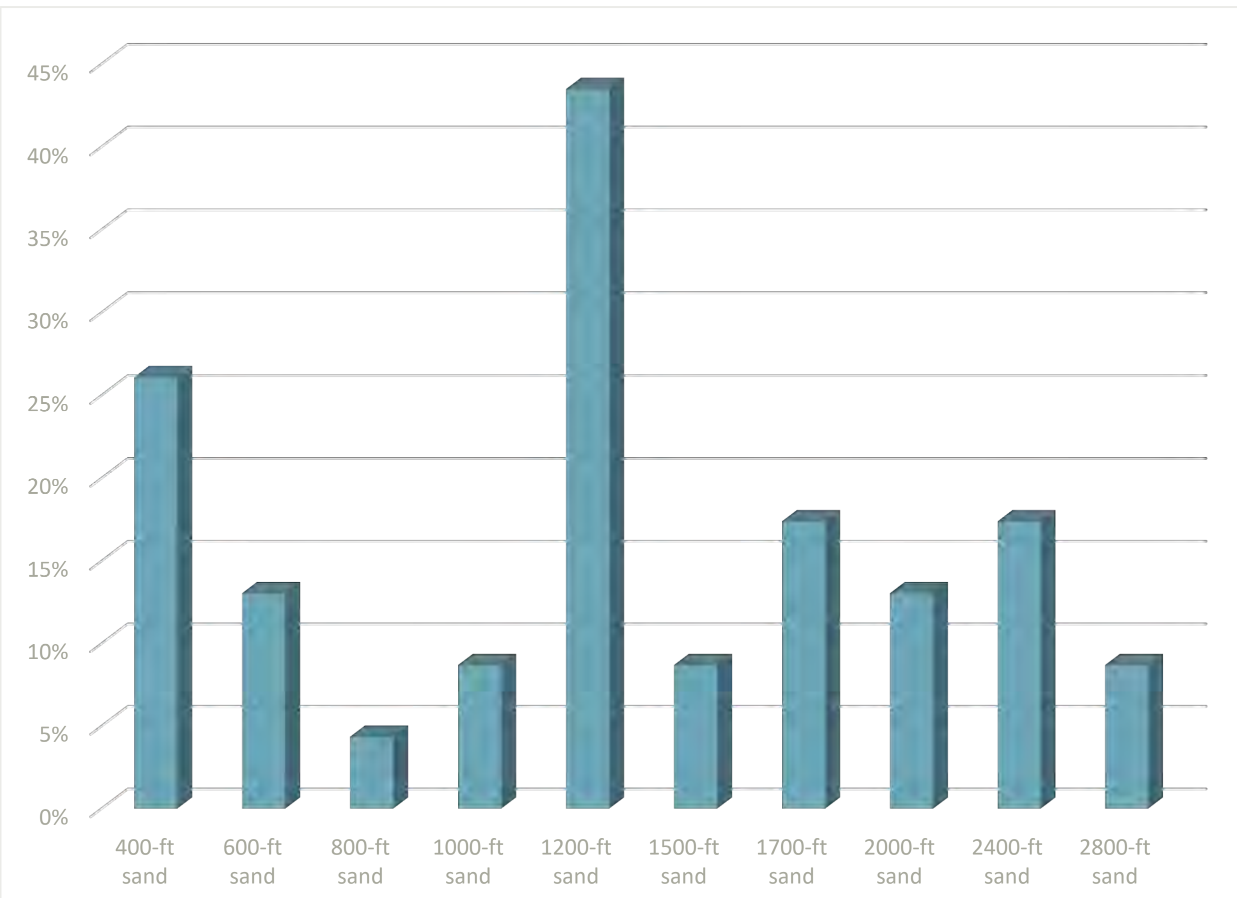


Figure 34. Stakeholder-identified sand layers in the SHAS where groundwater source originates.

Fewer than half of the respondents with groundwater supplies indicated 100 percent treatment of groundwater source supplies, with the remainder either not indicating treatment or indicating that only a small percentage of groundwater is treated. Limited data have been received on current treatment costs, with reported values ranging from $0.02 to $7.00 per 1,000 gallons. Based on the limited information available to date, it appears that in areas not yet impacted by saltwater intrusion, treatment needs may be limited for most of the uses, and in some cases treatment components could be integrated into facility processes and systems. Approximately one-third of respondents indicated one or more water quality parameters of interest for current or potential future supplies, with the parameters identified and associated percentage of these respondents illustrated in Figure 35.

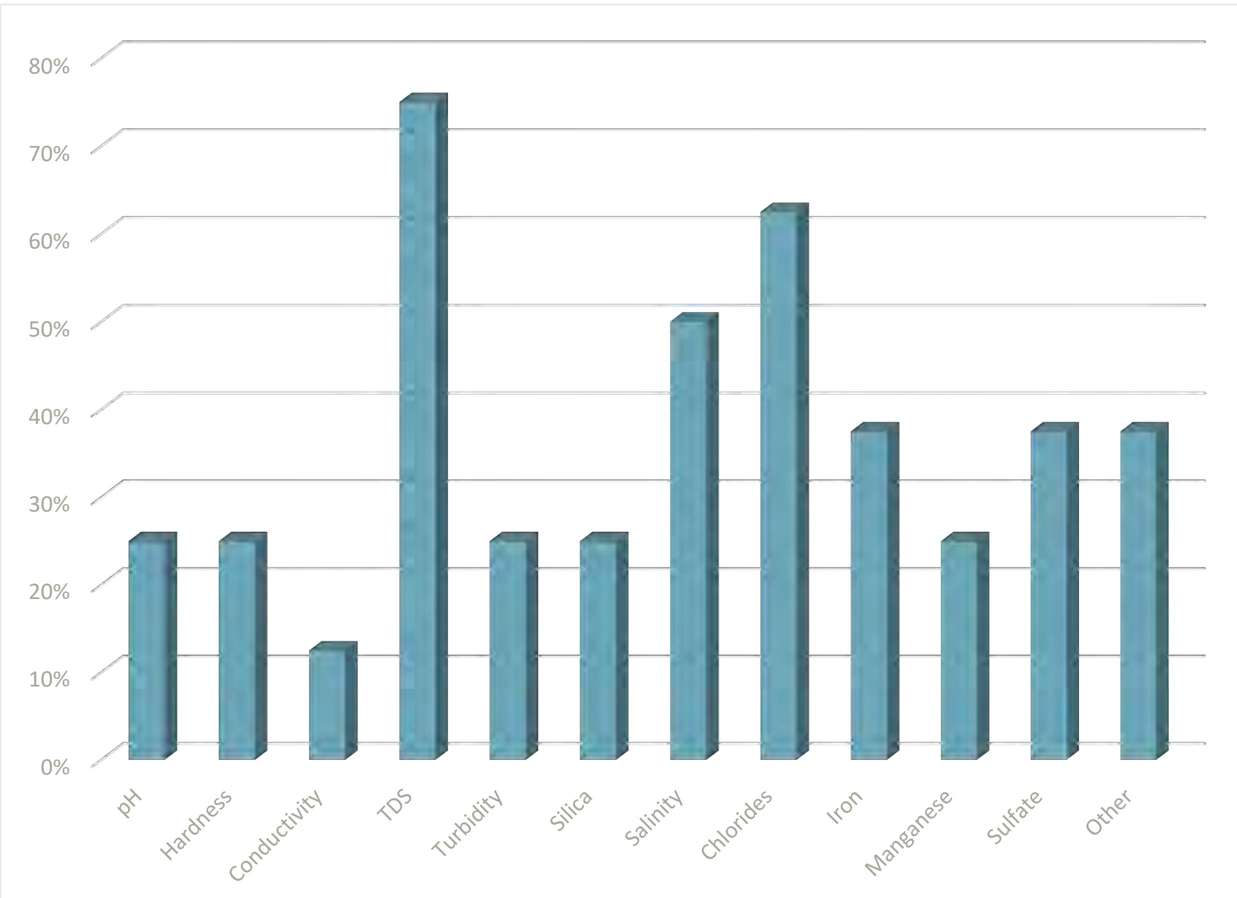


Figure 35. Stakeholder-identified water quality parameters of interest and frequency by responding entities. TDS stands for total dissolved solids.

Six respondents indicated that their facility has not reached its maximum development, three of which indicated the need for additional water supplies to support their facility at maximum development. If a new water supply was brought online, important water quality considerations mentioned in the survey included conductivity, calcium, chlorine, hardness, iron, manganese, and for reuse supply, chemical oxygen demand (COD) / biochemical oxygen demand (BOD). Some respondents indicated that the required water quality will ultimately be dependent on the end use type. As of December 2021, none of the survey respondents indicated an interest in utilizing an alternative water supply. Of those who provided a response as to why they are not interested, the respondents mentioned current use of a reliable surface water supply or minimal overall water use. Four respondents indicated that they have a 5-year water supply plan or similar document. One respondent provided a diagram that outlines their long-range water supply plan for various processes; a timetable for this plan was not included.

Industrial Water Demand Analysis Methodology and Estimates

Annual industrial water demand estimates were developed at the parish level from 2010 to 2020 using information from the Industrial Survey, in conjunction with historical water use information from the CAGWCC, USGS, and LA DOTD. These estimates were used to identify trends in industrial water use data and partition usage into groundwater and surface water components. Water use data between the various data sources are reported at different intervals, span different time periods, and report different source data (groundwater only or both surface water and groundwater), as shown in Table 4.

Table 4: Industrial Water Data Availability by Source and Year.

Data	Source Dataset	Source	1960-1975	1975-1985	1985-2010	2011-2013	2014	2015	2016-2019	2020
Groundwater, Surface Water, and Other Use for Industrial Supply	Annual groundwater and surface water use by facility for most recent year	Industrial Survey								✓
Groundwater Use for Industrial Supply	Annual groundwater pumpage, by parish and by well owner	CAGWCC		✓	✓	✓	✓	✓	✓	✓
Groundwater and Surface Water Use for Industrial Supply	Water Use in Louisiana reports, by parish, published every 5 years	LA DOTD in cooperation with USGS	✓	✓	✓			✓	✓	
	Water Use in Louisiana from Water Use Data for the Nation, by parish, reported every 5 years	USGS NWIS			✓			✓		
	Water Use in Louisiana, by parish, 2014-2015	USGS (Collier, 2018)					✓	✓		

As described in Task 2A.1, CAGWCC maintains a database of groundwater well data in the CAGWCD, which includes annual groundwater pumping by well from 1975 through 2020. These pumping data were used in conjunction with the SONRIS Well Registration database to pair each well with a geographic location and other well characteristics described in the database. For this analysis, groundwater well pumping data from the CAGWCC were aggregated to the parish level, based on well locations identified by CAGWCC and SONRIS. The locations and magnitudes of groundwater withdrawals are consistent with the annual pumping data maps shown in Appendix B.

Industrial Survey responses regarding groundwater and surface water use provided a snapshot of annual use in the most recent year of data (2020) at specific facility locations. While the limited response rate to the survey precludes aggregation of individual user data to the parish level for this analysis, responses to the survey can be used as a resource to compare to existing data available at the individual industrial water user scale (e.g., annual groundwater pumping data) and supplement the knowledge base developed as part of this study regarding industrial water users across the CAGWCD (e.g., existing system capacity, annual surface water demands). Current groundwater use data submitted by industrial users through the Industrial Survey are generally consistent with what has been reported to the CAGWCC.

The USGS-LA DOTD cooperative reports and USGS NWIS show annual groundwater and surface water withdrawals at the parish level (the scale of this analysis), and as such no aggregation of these data were needed. For most parishes and source types, the USGS-LA DOTD cooperative reports and USGS NWIS were consistent; however, some data reported were slightly different; in these cases, the data sources were evaluated separately. The 2015 water use data reported by Collier (2018) corresponds with the year 2015 water use reported in the 2015 USGS-LA DOTD cooperative report (Collier and Sargent, 2018).

Due to these differences in data availability, a generalized approach was applied to determine which data source to use to estimate annual demands for each parish from 2010 to 2020 and partition out to source types (groundwater, surface water):

- If historical groundwater pumpage data reported to CAGWCC were available throughout the analysis period (2010–2020) and contained minimal outlier values, this dataset was used to estimate demands on an annual basis.

- If there were sparse or no annual industrial pumpage data from CAGWCC, which was the case for groundwater in Ascension Parish and surface water in all District parishes, then the USGS-LA DOTD cooperative reports or USGS NWIS datasets were used to estimate demands. The demands in reported years (2010, 2014, 2015) were set to their respective withdrawal rates. Demands in unreported years (2011–2013; 2016–2020) were estimated based on trends in data during recent reported years. For most cases, values from 2011 to 2013 were estimated by interpolating the withdrawals reported in years 2010 and 2014. From years 2016 through 2020, trends in historical use were assessed on an individual parish-source type basis to estimate an annual demand. Since there were no water use data available during this period (2016–2020) from these datasets and the annual variability is unknown, the demands estimated during this period were assumed to be constant.

- If no withdrawal or pumpage data were reported for a source type in a given parish over the past 10 years in any of the data sources, then it was assumed that there is no current demand.

When industrial water use data were available across multiple datasets in a given year for the same source type, historical industrial usage was not always consistently reported across datasets. For example, the industrial groundwater pumpage reported to CAGWCC in East Feliciana and West Feliciana parishes exceed the pumpage reported in the USGS NWIS database and the USGS-LA DOTD cooperative reports in 2010 and 2015 due to reclassification of the water use from correctional facilities from public supply to industrial (see details in the following paragraph). Conversely, industrial groundwater withdrawals reported in the USGS-LA DOTD cooperative reports in Ascension and Point Coupee parishes exceed those reported in the USGS NWIS database and CAGWCC records in 2010 and 2015. In most cases, the largest reported usage value was used in the demand estimates. If groundwater withdrawal data were approximately the same from all data sources (e.g., industrial groundwater pumpage in East Baton Rouge parish), the CAGWCC pumpage data were used since annual data are available.

Based on these data sources and assumptions, annual industrial demands were estimated from 2010 to 2020 for District parishes and were partitioned to groundwater and surface water components. Figure 36 and Figure 37 illustrate the estimated industrial demands for groundwater and surface water by parish, respectively. Figure 38 shows the partitioning of total water use between groundwater and surface water across the CAGWCD. Several factors should be considered in examining these estimates:

- Information in these figures is based on usage data reported by respondents in the Industrial Survey and estimated usage reported to CAGWCC, USGS, and USGS-LA DOTD as industrial.
  - Some of these industrial water systems may serve other end uses, such as on-site potable, commercial, or other non-industrial uses.

No sources of industrial surface water use data were identified at the parish-level after 2015. There are also limited industrial groundwater use data reported by users in certain parishes (Ascension, Pointe Coupee) after 2015. Thus, trends in historical data reported by the various datasets were used to estimate industrial demands for these parishes and source types from 2016 through 2020. Ultimately, the actual surface water and groundwater use from parishes with no or limited data during this period will not be the same as the estimates in this analysis. Water use in these parishes during recent years also may not follow historical trends. Furthermore, due to the uncertainty attributed to the lack of data, estimated demands during the 2016–2020 period were assumed to be constant. Similar to the groundwater pumping, surface water use is variable from year to year, so estimates from this analysis do not capture this variability.

As discussed in the previous subsection, there were various potential targeted sectors defined as "industry" for this analysis, including chemical production, correctional institutions, electrical power generation, food processing, manufacturing, mining, shipping, and wood products. Other sources of data have different categorizations for these "industrial" sectors to the categories defined in this study. For example:

  - The CAGWCC database categorizes water usage from correctional institutions or prisons as the "public supply" use type. CAGWCC also categorizes some individual wells from owners that fall under the "industry" definition as "public supply" or "other" use categories.
  - CAGWCC, USGS, and USGS-LA DOTD classify water withdrawals from electrical power generation users as its own individual water use category ("power generation") which is separate from industrial use.

To remain consistent with the definition of "industry" in this study, water usage data from electrical power generation, correctional institutions, and other applicable individual industry users in the CAGWCC, USGS, and USGS-LA DOTD datasets were recategorized to industrial use type. Water usage from these sectors were incorporated into estimates of total industrial demands, as described subsequently in this section.

Two correctional institutions, located in East Feliciana and West Feliciana parishes, have historically reported groundwater production to CAGWCC. Data sources indicate that these facilities are reliant on groundwater as their self-supplied water supply source and utilize no surface water. Due to the recategorization of correctional institutions to the industry use type, annual groundwater pumpage data reported to the CAGWCC from these institutions were removed from the public supply groundwater use totals in East Feliciana and West Feliciana parishes and incorporated into the industrial groundwater use totals in these parishes. No public supply surface water use data were reclassified.

Since the different water use datasets categorize the “power generation” use type as a separate category from industrial use, annual power generation demands were estimated separately from what other data sets classify as “industrial”, but using the same assumptions described in this section. Power generation demands were estimated at a parish-level and by source type (groundwater, surface water) from 2010 to 2020. These estimates were then added to the industrial use estimates (i.e., those categorized as “industrial” in other datasets and excluding power generation use) to calculate total industrial demands for each District parish and source type from 2010 to 2020.

Illustrated usage is based upon systems reporting to CAGWCC, USGS, or USGS-LA DOTD. These numbers do not necessarily reflect 100 percent of the groundwater or surface water production within the CAGWCD parishes. Scattered unreported wells, unmetered systems, estimated pumpage, and other factors introduce uncertainty.

Ascension Parish became a member of CAGWCD in 2018, with reporting of groundwater pumpage data becoming available beginning in 2019. Reported pumpage data and other references indicate limited groundwater production in Ascension Parish relative to the overall District pumpage, due in part to saltwater issues in much of the parish. However, groundwater exports from EBR Parish play an important role in meeting Ascension Parish water demand.

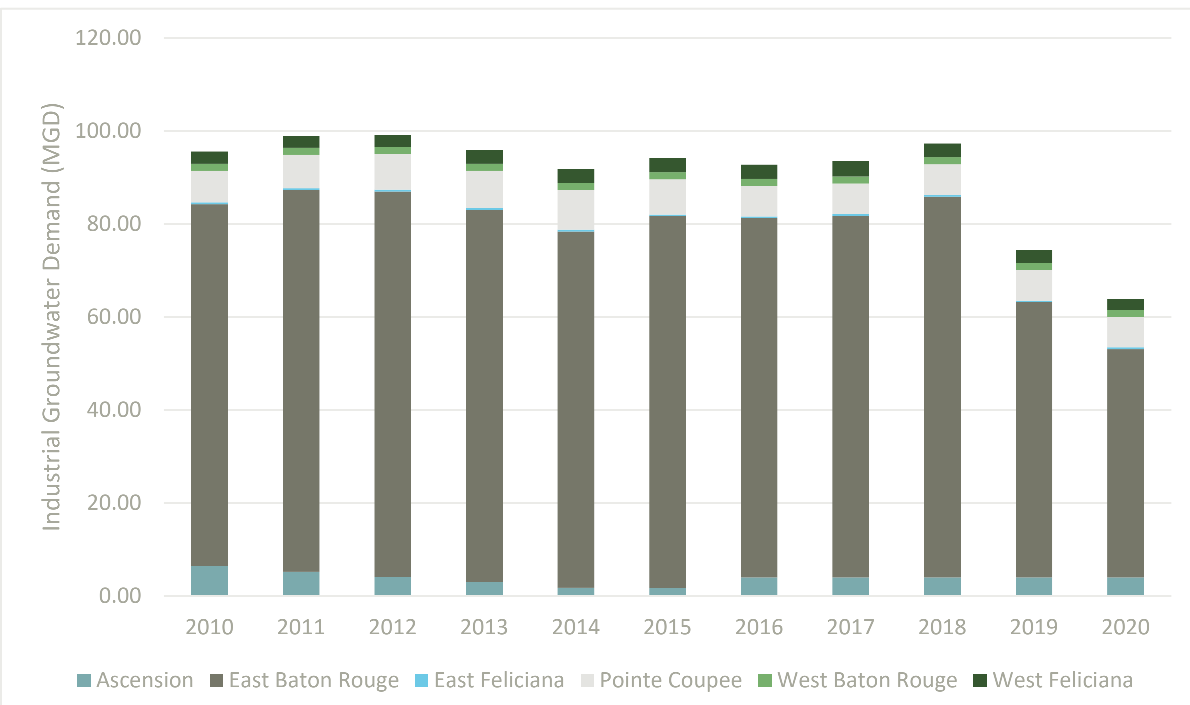


Figure 36. Estimated Year 2010 through 2020 industrial groundwater production for District parishes.

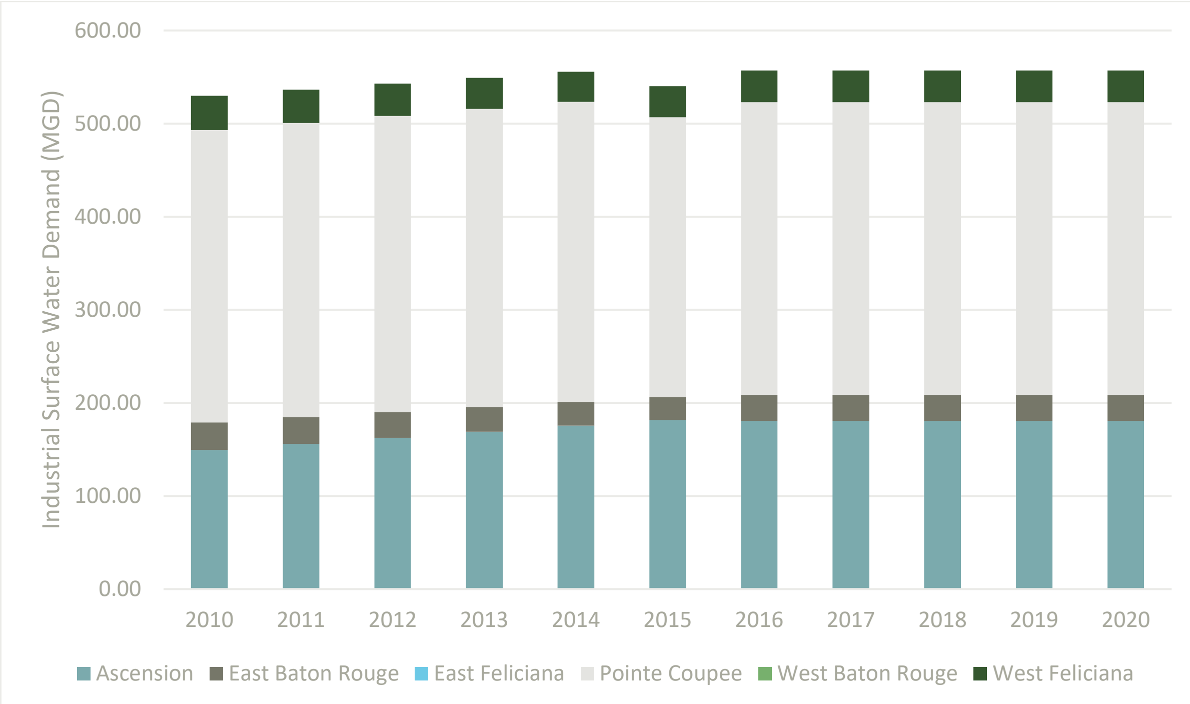


Figure 37. Estimated Year 2010 through 2020 industrial surface water production for District parishes.

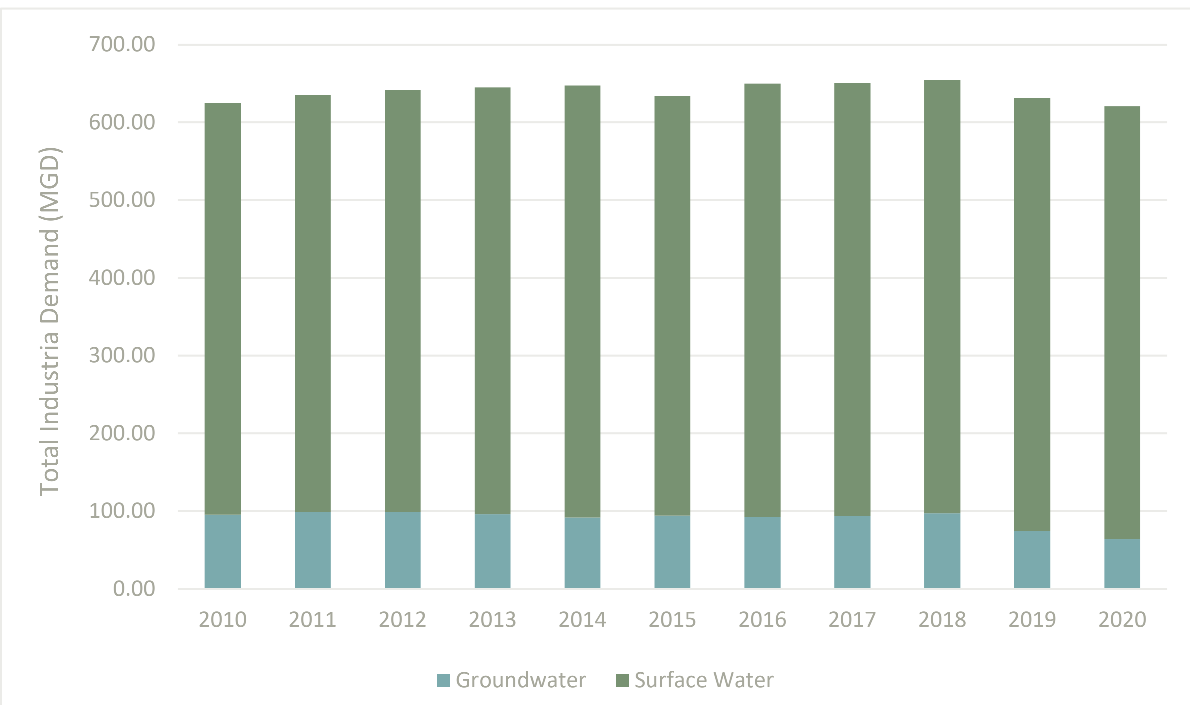


Figure 38. Estimated Year 2010 through 2020 partitioning of total groundwater and surface water usage across District parishes.

Demand estimates show that industrial groundwater use declined considerably from 2018 to 2020. A significant portion of this decline is attributed to decreased groundwater withdrawals from Georgia Pacific, a major facility located in EBR Parish north of the Industrial District. In March 2019, the owner reduced their operations at this facility, thus decreasing their groundwater demands. It is not expected that the user will return to the historical volume of water usage indicated in preceding years. Without annual data past 2020, it is unknown whether groundwater use in EBR Parish will continue to decline or will begin to move towards more stable levels after 2020. Groundwater use reported in WBR Parish in 2010, 2014, and 2015 (average of 1.53 MGD) is noticeably less than the historical average pumpage (4.27 MGD) reported in the USGS-LA DOTD cooperative reports. Groundwater use in all other District parishes do not show any noticeable trends over the past 10 years; however, as more annual pumpage data from Ascension Parish is reported to the CAGWCC, additional trends may become discernable.

Analyzing detailed trends in surface water data over the past 10 years may not be appropriate for this analysis as most years during this period (2010–2020) do not have reported values. However, the surface water use data from the LA DOTD and USGS, reported every five years at the parish-level, can be evaluated for general historical trends, e.g., increases, decreases, or same level with annual variability. For instance, industrial surface water use in West Feliciana Parish has decreased from the average use reported from 1985 to 2005 (47.8 MGD) to the average in the most recent years of 2010, 2014, and 2015 (34.1 MGD). Meanwhile, industrial surface water use in Pointe Coupee Parish, which is attributed to power generation, has steadily increased from the first two decades for which use was reported (268.2 MGD average from 1985 to 2005) to the average in the most recent years of 2010, 2014, and 2015 (312.4 MGD). Increased surface water use for power generation in EBR Parish has also been reported in recent years (8.08 MGD in 2010 and 2015), whereas previous decades did not show any water use (1990 through 2005).

Demand Projection and Refinement

Task 2A.3 of the study is primarily focused on developing an understanding of historic and current industrial water use. Subsequent analyses under Phase 2A1 and 2B of the study will utilize this information to examine potential future industrial water demands through a projection process that is anticipated to incorporate:

- Comparisons between water use trends developed for industrial users with census data and ACS employment data;
- Correlations between historic employment data and industrial water use data to forecast industrial demands over a 50-year planning horizon;
- Survey information collected from industrial users and other relevant studies conducted in the region that capture future growth patterns for industry;
- Information from the economic bureau and trends in cities or municipalities with similar conditions, as available, to develop estimates for future growth patterns; and

- Consideration of variability in future unit demand forecasts.

Similar to the assessment of historic and current water use, estimation of potential future water needs will examine industrial demands for all District parishes and consider available data for usage from multiple water source types (groundwater, surface water). As additional data become available, estimates of industrial water usage may be refined as appropriate for the CAGWCD in order to facilitate future demand estimation.

TASK 2A.4 PUBLIC UNDERSTANDING OF GROUNDWATER RESOURCES

> *Task Summary: To engage public as part of conservation and understanding of long-term groundwater management, one first must survey the public for their current and historical views. This task includes developing and implementing a series of survey instruments, interviews, and targeted focus groups to gauge public awareness, attitudes and preferences for water management strategies, potable water supply, and willingness to conserve water resources.*

A key component of Phase 2 is to conduct an assessment of public attitudes regarding groundwater and groundwater management. This assessment is being conducted in multiple stages and will include targeted focus groups composed of different stakeholders organized through community organizations, trade and business associations, and other local entities, as well as through a distributed survey to understand public views on the uses of local groundwater and alternatives as those are developed.

Before a public survey is distributed, existing research and data on public understanding of the economic and social consequences of saltwater intrusion and groundwater management in the Baton Rouge area is being summarized. Given the paucity of published research on this topic, this information has been assessed through a review of prior outreach and engagement activities by the LDNR Office of Conservation, including two public surveys and materials developed for the agency's "Water-Wise in BR" [Baton Rouge] campaign to improve and refresh classroom education initiatives and water-related curricula. Additional data were compiled through a review of public comments and minutes from CAGWCC public meetings. These data will be used to guide the development of the public surveys, interviews, and focus groups and assure that the CAGWCC long-term strategic plan addresses issues relevant to sustainability.

PREVIOUS ASSESSMENTS OF PUBLIC UNDERSTANDING OF GROUNDWATER ISSUES IN THE CAPITAL AREA

Despite efforts to mitigate saltwater intrusion into SHAS, the problem has persisted and by 2010 began to draw increased public attention. There have been prior efforts to evaluate and improve public understanding, but as these efforts have not been synthesized in the context of CAGWCC decision making this is the focus of Task 2A.4.

As a result of requests from the Metropolitan Council of Baton Rouge and the Capital Region Legislative Delegation in late 2011 and early 2012, LDNR held a public meeting on March 8, 2012, and a hearing on April 12, 2012, to provide information to the public on saltwater intrusion and provide interested parties with an opportunity to provide comment. These meetings included statements from CAGWCC members, Baton Rouge City Officials, industry stakeholders, advocacy groups, citizens, scientists, and LDNR Office of Conservation officials. The public meeting and the public hearing were both transcribed and all documents and/or evidence presented has been made available online by LDNR (http://www.dnr.louisiana.gov/index.cfm?md=pagebuilder&tmp=home&pid=922).

In addition to outreach and engagement efforts of LDNR, CAGWCC holds several public meetings per year, including bi-monthly meetings of the Board of Commissioners for CAGWCD. Other administrative, executive, planning, and technical meetings are held throughout the year to address specific issues related to the sustainability and management of SHAS. As with the LDNR public meetings, the CAGWCC meetings and public hearings are recorded and transcribed, with all documents provided on the CAGWCC's public website (https://www.capitalareagroundwater.com/). In order to assess and monitor the effectiveness of these outreach efforts, LDNR commissioned a series of surveys to gauge public awareness about threats to the sustainability of SHAS.

This section presents an overview and analysis of the surveys, meetings, public hearing transcripts, and public outreach conducted previously by CAGWCC and LDNR to determine the public's understanding of the social and economic consequences of saltwater intrusion in the CAGWCD. The review of CAGWCC meetings, public hearing transcripts, surveys conducted (Figure 39 to Figure 55), and the material/media sent to the public as part of community outreach were keyword searched, with the questions brought forward and general themes identified. The responses were divided by stakeholder type to determine the level of knowledge on social and economic consequences depending on how respondents use and value SHAS. The stakeholder types were industry representatives, citizens, government officials, scientists, and nonprofit advocacy groups. Additionally, state audits and annual reports were reviewed for recommendations to determine known points for improvement.

Previous Public Meetings and Hearings

During the 2012 LDNR public meeting, hearing, and collection of written commentary, there were 34 comments (see: *Public Hearing Re: Water Table Under East Baton Rouge Parish*, 2012; *Saltwater Encroachment Public Meeting*, 2012; *Written Comments*, 2012). The individual citizen responses (8) called for the state to act rather than continue to collect data. Thirteen respondents wanted a formal plan to resolve or prevent the saltwater intrusion. One citizen suggested the need for better coordination with other state agencies and officials. Two commentors thought the groundwater issue was especially important and that more public outreach and education needed to be done, so that more people would be aware of the situation facing the drinking water supply. Nonprofit advocacy groups spoke on their members being concerned about saltwater intrusion, but also noted that the information provided to the public regarding the matter was inadequate and lacked the basic facts to show the public that the issue was of importance. The public officials, ranging from Baton Rouge Metropolitan Council members to a representative from the Mayor's office, all echoed the citizens' sentiment for acting and developing a plan based on existing knowledge. Council members from Ascension Parish, which also draws water from SHAS via the Baton Rouge Water Company, submitted a resolution requesting the LDNR Commissioner of Conservation to declare EBR Parish an area of concern and begin to form a plan to reduce the encroachment of saltwater on the drinking water system. The industry stakeholders urged CAGWCC to make decisions based on science, and recognized the need for a sustainable future for the SHAS.

Previous Public Surveys (2012-2014)

LDNR has conducted three surveys of public knowledge about Baton Rouge area groundwater resources. Two surveys were conducted via phone by a contractor and the other was conducted during a "Water-Wise in BR" teacher training workshop. In Spring 2012, 300 participants across six Senate districts in EBR Parish provided responses to nine survey questions and four demographic questions (Magellan Strategies BR, 2012a, 2012b, 2014). Just over half of the participants believed water is sourced from a below ground aquifer, and 30 percent did not know where the water is sourced from (Figure 39 and Figure 40). Only 11 percent thought a special commission regulated the groundwater resources, while 64 percent expected regulatory control to lie with either the state or city/parish government (Figure 41). When asked about potential threats and what is the most serious threat, 76 percent were not aware of any serious threats and the majority of these respondents believed industrial pollution or contamination to be the biggest threat of those that existed (Figure 42 and Figure 43). In terms of managing a potential threat, 36 percent would most trust a special commission to manage a serious threat, whereas just over half would trust either the state or city/parish government (Figure 44). This study concluded that residents are largely unaware of the threat of saltwater intrusion to Baton Rouge's water supply. Additionally, the survey company recommended that a parish wide public relations campaign be developed. Senate Districts 14 and 15 were particularly notable as 28 percent rated the water quality as very bad (Figure 45), 53 percent could not identify the source of Baton Rouge's drinking water, and 53 percent were not aware of any serious threats.

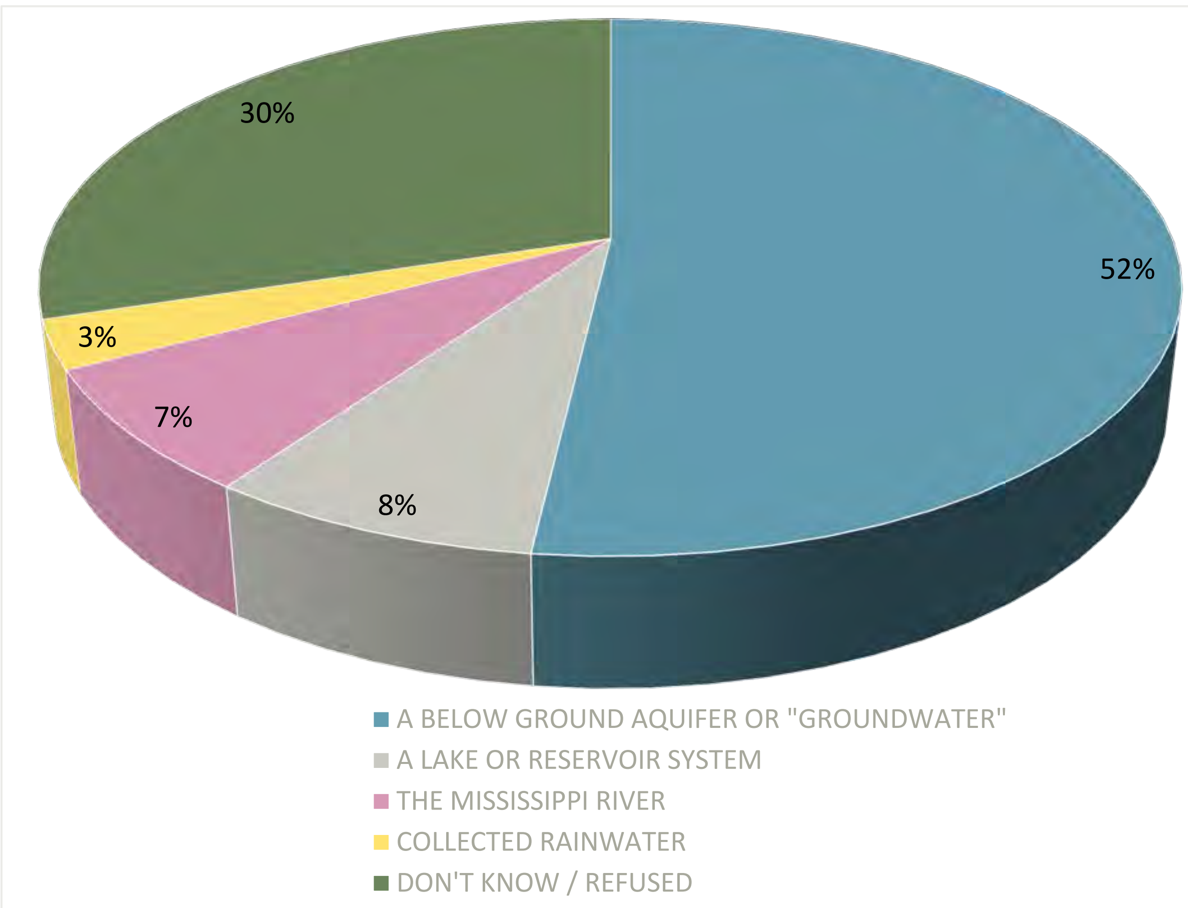


Figure 39. In 2012, a slight majority (52 percent) of respondents believes that most water originates from a below ground aquifer, while 30 percent did not know (adapted from Magellan Strategies BR, 2012b).

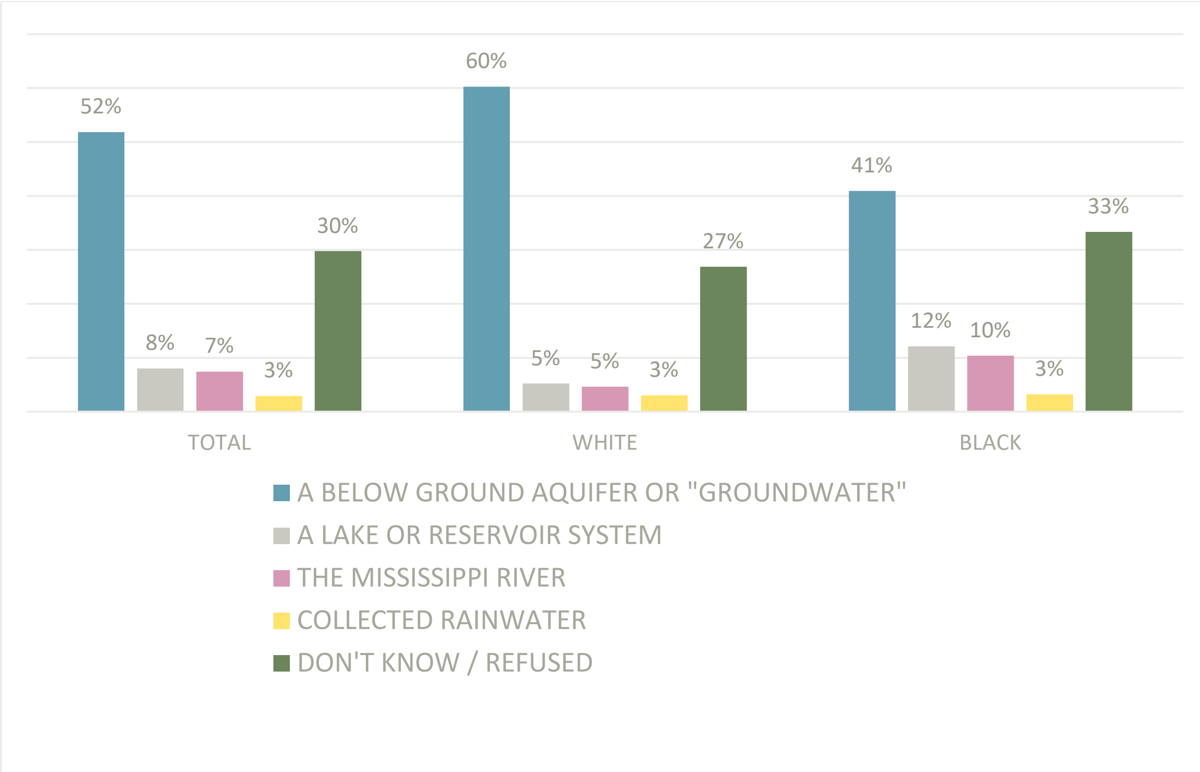


Figure 40. In 2012, 60 percent of white respondents stated, "a below ground aquifer," compared to 41 percent of the Black respondents (19 percent difference) (adapted from Magellan Strategies BR, 2012b).

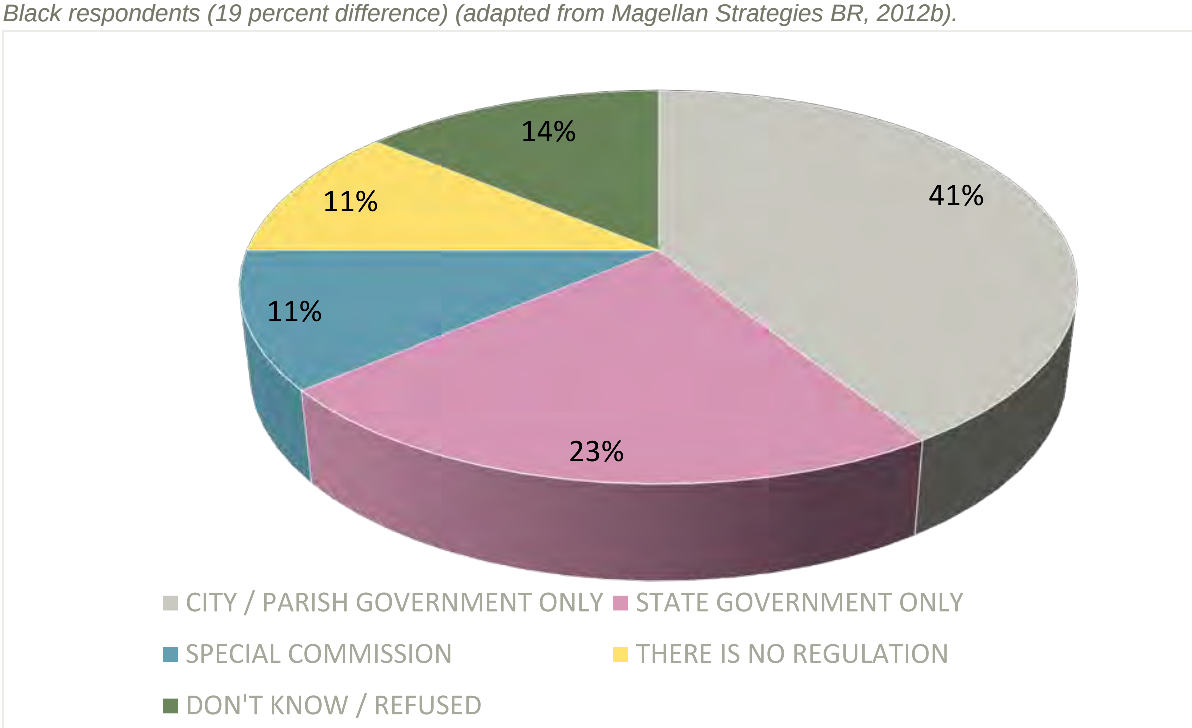


Figure 41. In 2012, 11 percent of the total respondents thought a special commission regulated the groundwater resources, while 64 percent expected regulatory control to lie with either the state or city/parish government (adapted from Magellan Strategies BR, 2012b).

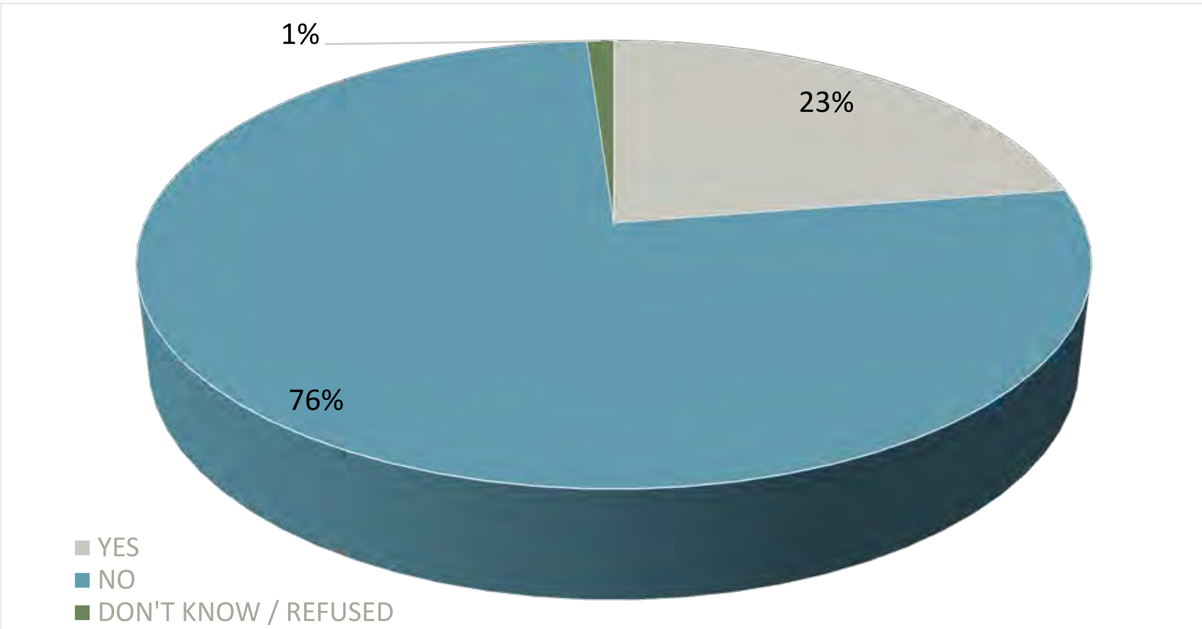


Figure 42. In 2012, 23 percent of respondents are aware of a serious threat to Baton Rouge's groundwater resources. An overwhelming majority, 76 percent are not aware of any threat (Magellan Strategies BR, 2012b).

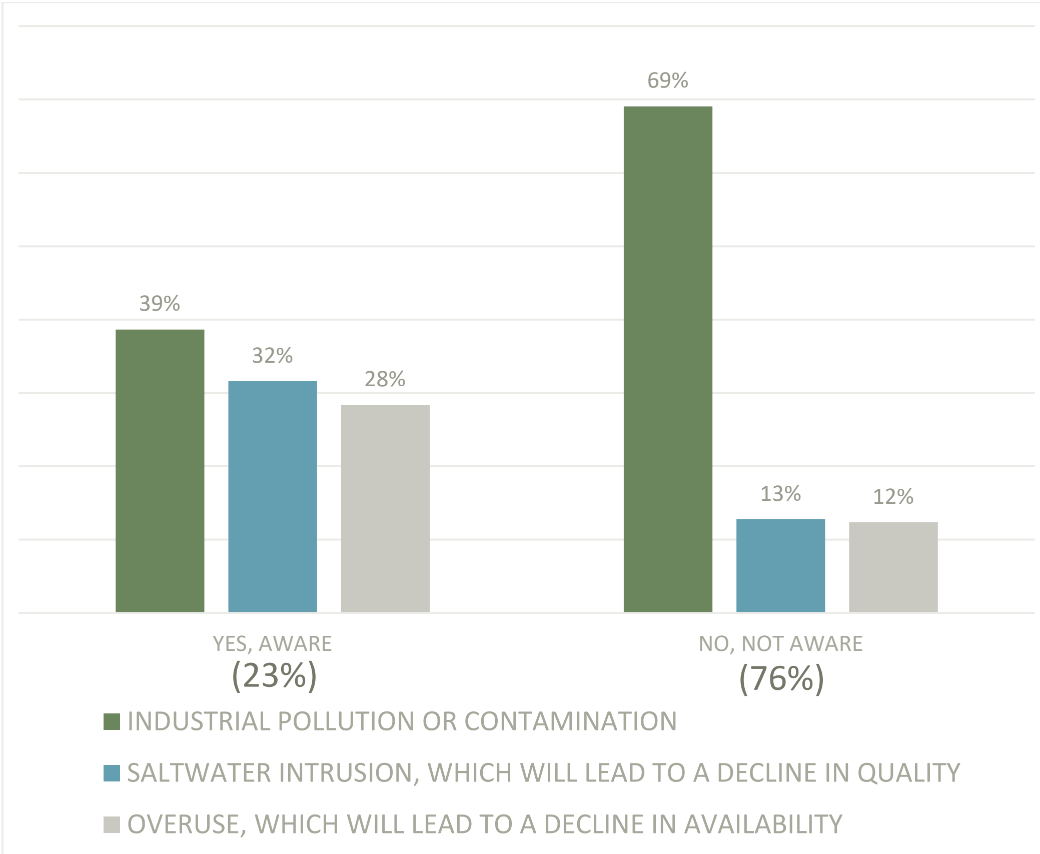


Figure 43. In 2012, among the 23 percent of respondents who were aware of a serious threat, responses are almost evenly distributed. Among this group, 32 percent believe saltwater intrusion is the most serious threat. Among survey participants who are not aware of any current serious threats, 69 percent percent of respondents stated that industrial pollution is the most significant potential threat (adapted from Magellan Strategies BR, 2012b).

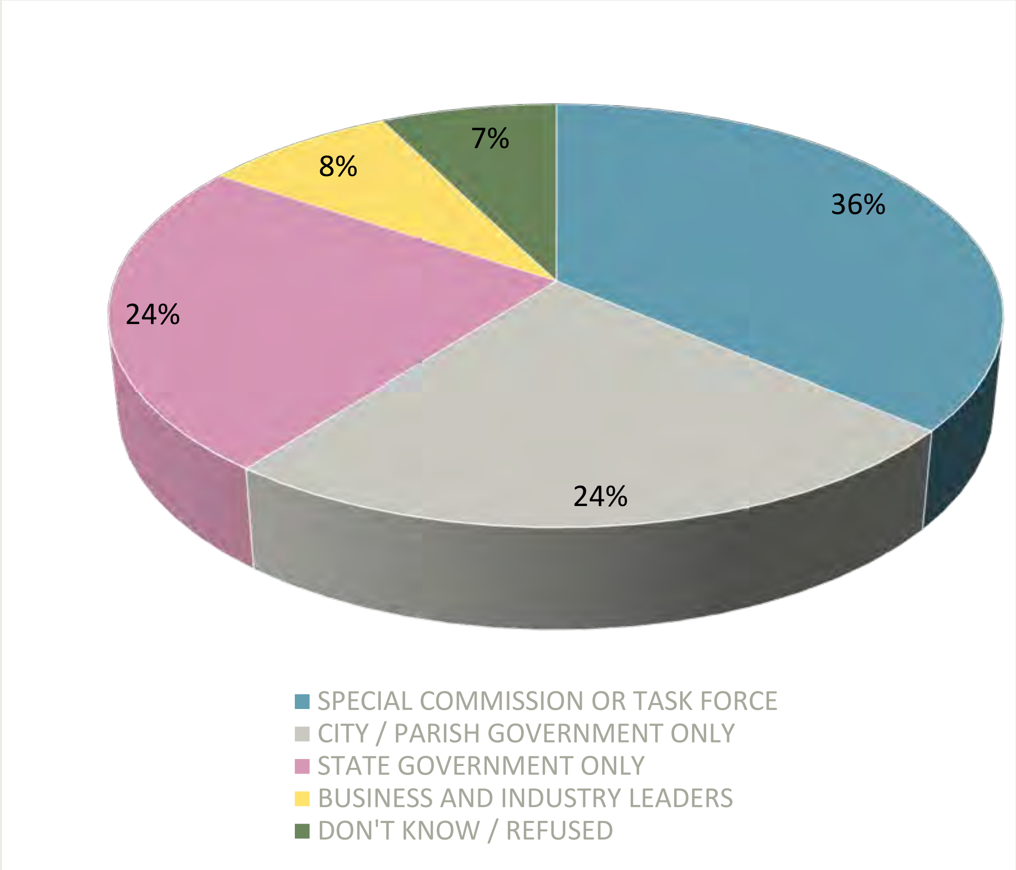


Figure 44. In 2012 36 percent would most trust a special commission to manage a serious threat, whereas just over half would trust either the state or city/parish government (adapted from Magellan Strategies BR, 2012b).

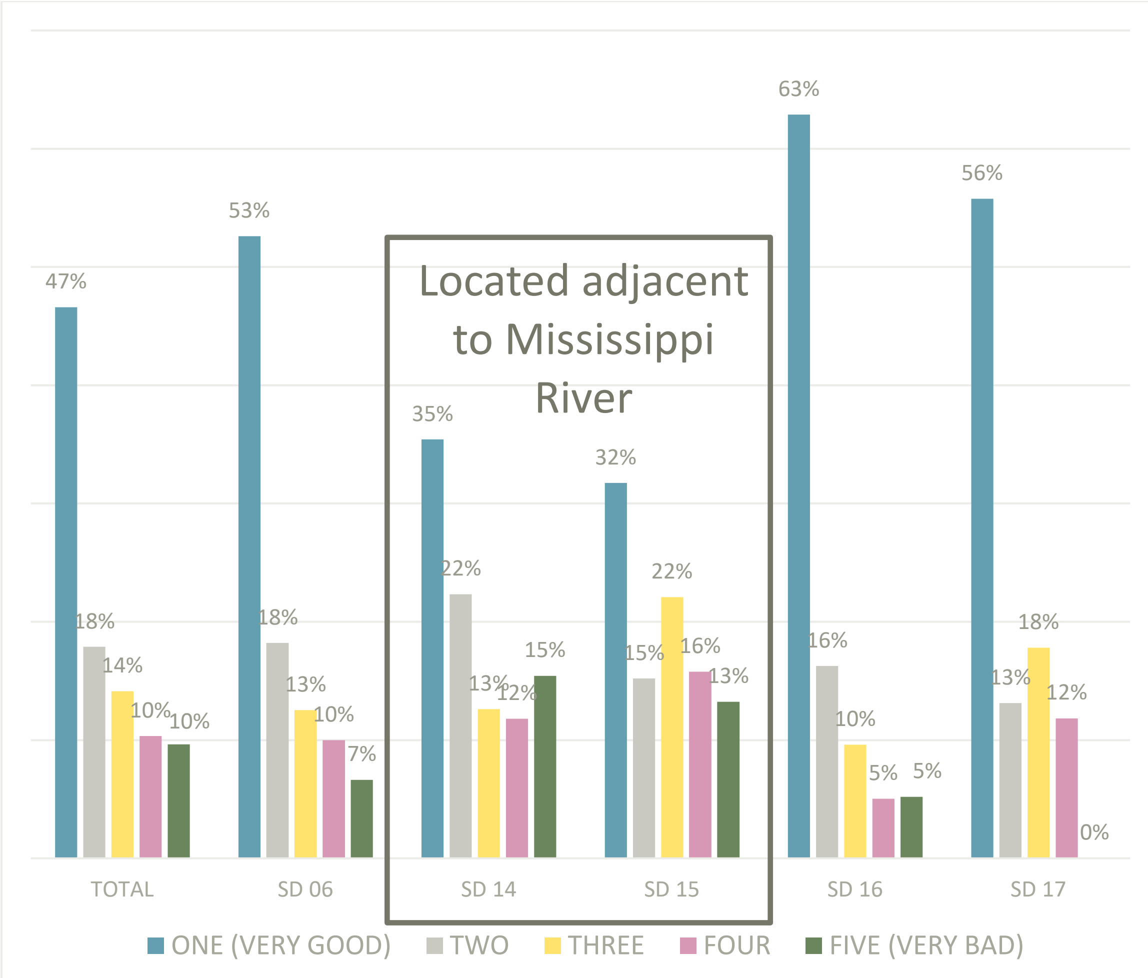


Figure 45. In 2012, the senate districts (SD) in close proximity to the Mississippi River rated the quality of water lower than respondents in the remaining districts (adapted from Magellan Strategies BR, 2012b).

In July 2014, a survey of 26 math, science, and social studies teachers was conducted as part of a Water-Wise in BR (Baton Rouge) workshop convened by the Louisiana Office of Conservation. Of the 26 teachers who attended the workshop, five were elementary school teachers, seven were middle school teachers, and fourteen were high school teachers. The survey consisted of seven water resources questions and six curriculum questions (see: Reonas, 2014). Almost 77 percent of respondents were not aware of Baton Rouge's reliance on groundwater and the problem of saltwater intrusion in the aquifer (Figure 46). Over 90 percent had not heard of scavenger wells being used in Baton Rouge and 40 percent had not seen references to groundwater or "drinking water" in newspapers, magazines, or television (Figure 47 and Figure 48). After the workshop, every participant, except one who was already aware of groundwater management issues, stated that they were going to pay more attention to groundwater and drinking water issues. However, the majority of those surveyed were not aware of either CAGWCC (80.1 percent; Figure 49) or the LDNR Office of Conservation (57.7 percent; Figure 50). The workshop did provide curriculum information that 84 percent of the teachers were going to utilize, and 69 percent rated the quality and effectiveness of presentations during the workshop as excellent.

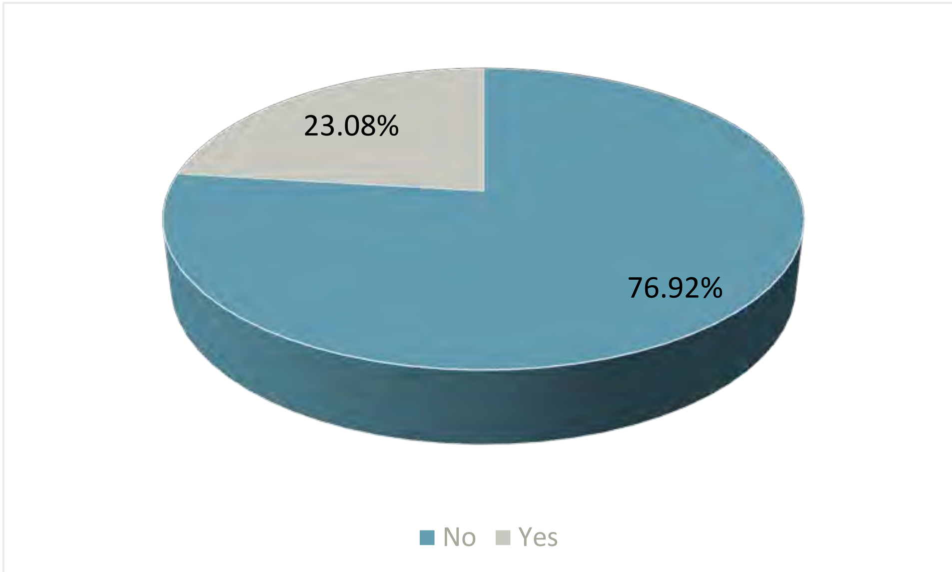


Figure 46. In July of 2014, almost 77 percent of respondents were not aware of Baton Rouge's reliance on groundwater and saltwater intrusion in the aquifer (adapted from Reonas, 2014).

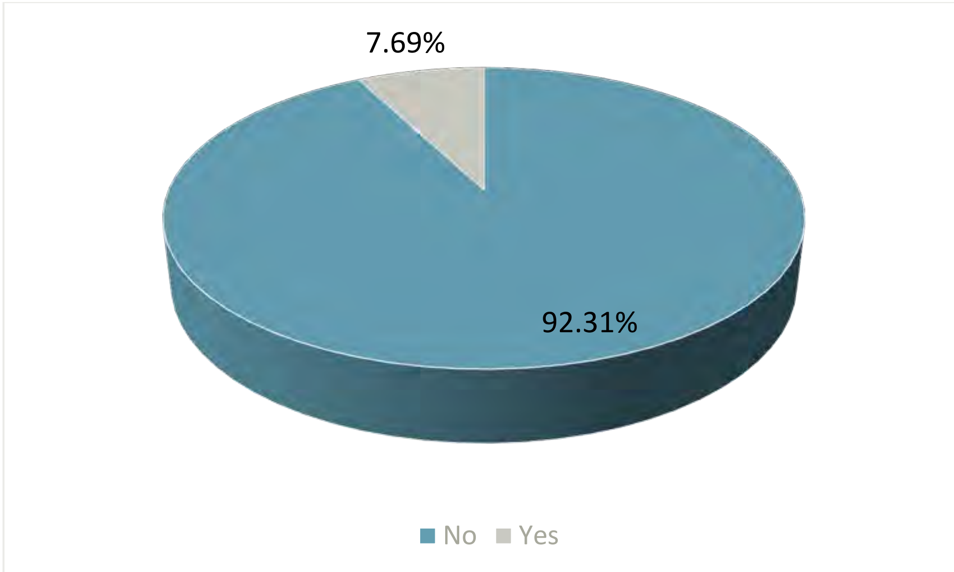


Figure 47. In July of 2014, over 90 percent of workshop participants had not heard of scavenger wells being used in Baton Rouge (adapted from Reonas, 2014).

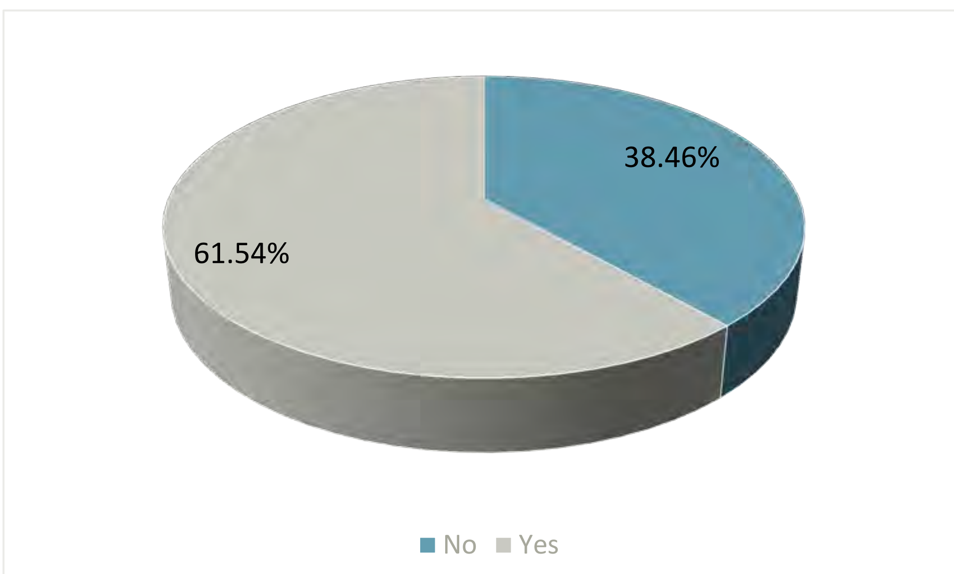


Figure 48. In July of 2014, significantly more respondents had seen references to groundwater or "drinking water" in newspapers, magazines, or television in the past year (adapted from Reonas, 2014).

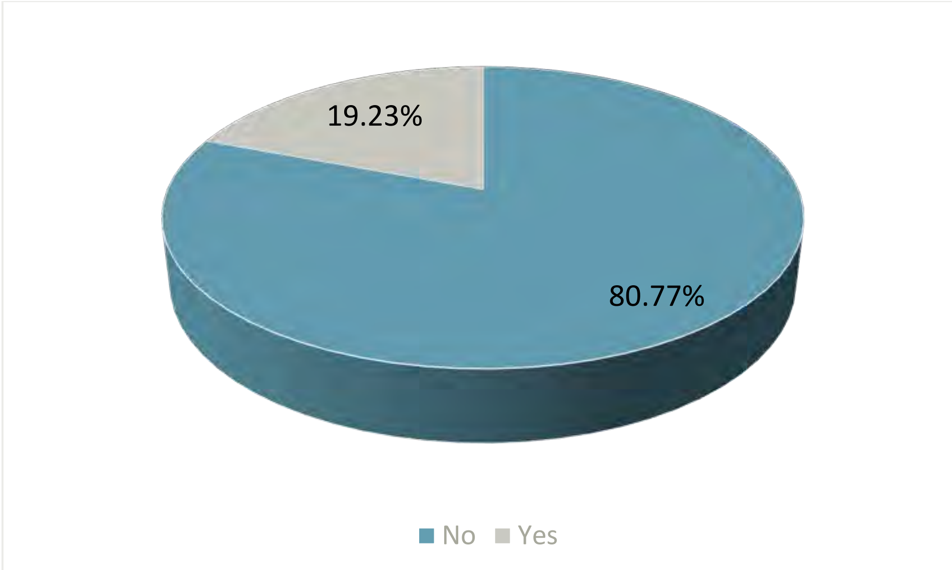


Figure 49. In July of 2014, approximately 80 percent of respondents had not heard of CAGWCC (adapted from Reonas, 2014).

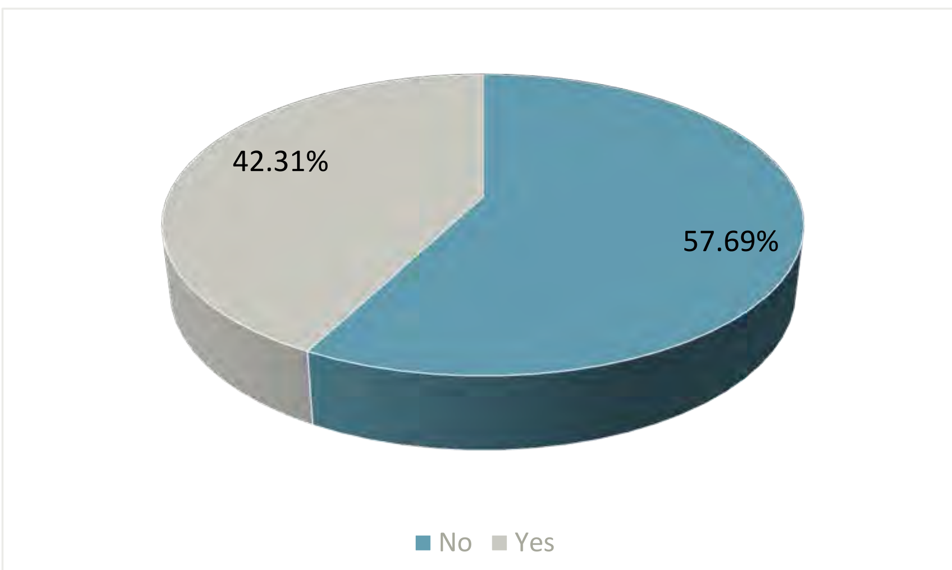


Figure 50. In July of 2014, just below 60 percent of respondents had not heard of the Louisiana Department of Natural Resources, Office of Conservation (adapted from Reonas, 2014).

In September 2014, a follow-up to the 2012 public survey was conducted. In this second survey, 961 people were asked 18 questions related to water resources and five demographic questions (see: Magellan Strategies BR, 2014). In the two years between surveys, the ability of respondents to correctly identify Baton Rouge's water source had improved by 26 percent, with 78 percent of individuals knowing the drinking water source was an aquifer or groundwater (Figure 51). Perceptions about the quality of water had also improved by 22 percent, with 86.7 percent of respondents viewing the drinking water as high quality as compared to other locations they had been. In terms of threat awareness, the numbers had not improved significantly. One third of the respondents had not heard of saltwater intrusion as a threat to groundwater, another third did not believe it was a threat, and the last third believed it was a threat (Figure 52). When asked about the measures to prevent the threat, 68 percent had not heard of any measures taken to prevent saltwater intrusion. Of the 32 percent who were aware of preventive measures, 23 percent were aware of the actions of CAGWCC including the scavenger well system or scientific modeling of saltwater intrusion (Figure 53). In terms of managing a potential threat, 49 percent would most trust a special commission to manage a serious threat, whereas just 37 percent would trust either the state or city/parish government (Figure 54). When asked about organizations or public awareness campaigns active in Baton Rouge water resource issues, only 25 percent had knowledge of CAGWCC, 18 percent knew about the Save BR Water campaign, and 7 percent knew about the LDNR's Water-Wise in BR campaign (Figure 55). Despite the larger sample size, there were some issues with the demographics of the survey (*Minutes: Capital Area Ground Water Conservation Commission - December 9, 2014*, 2014). The results did indicate that the public did not have a lot of knowledge about CAGWCC and their two main management activities (*Minutes: Capital Area Ground Water Conservation Commission - December 9, 2014*, 2014.)

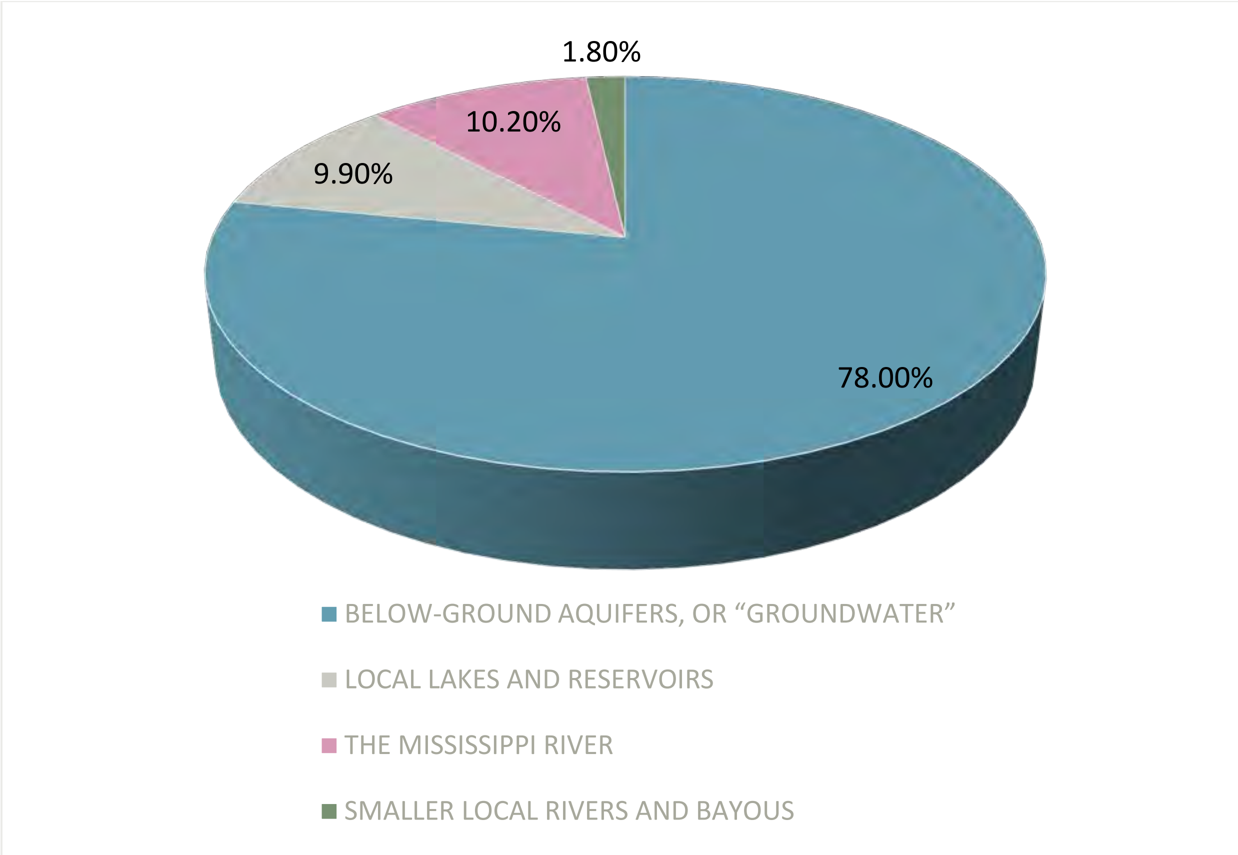


Figure 51. In September of 2014, 78 percent of individuals knew the source of Baton Rouge's water was an aquifer or groundwater (adapted from: Magellan Strategies BR, 2014).

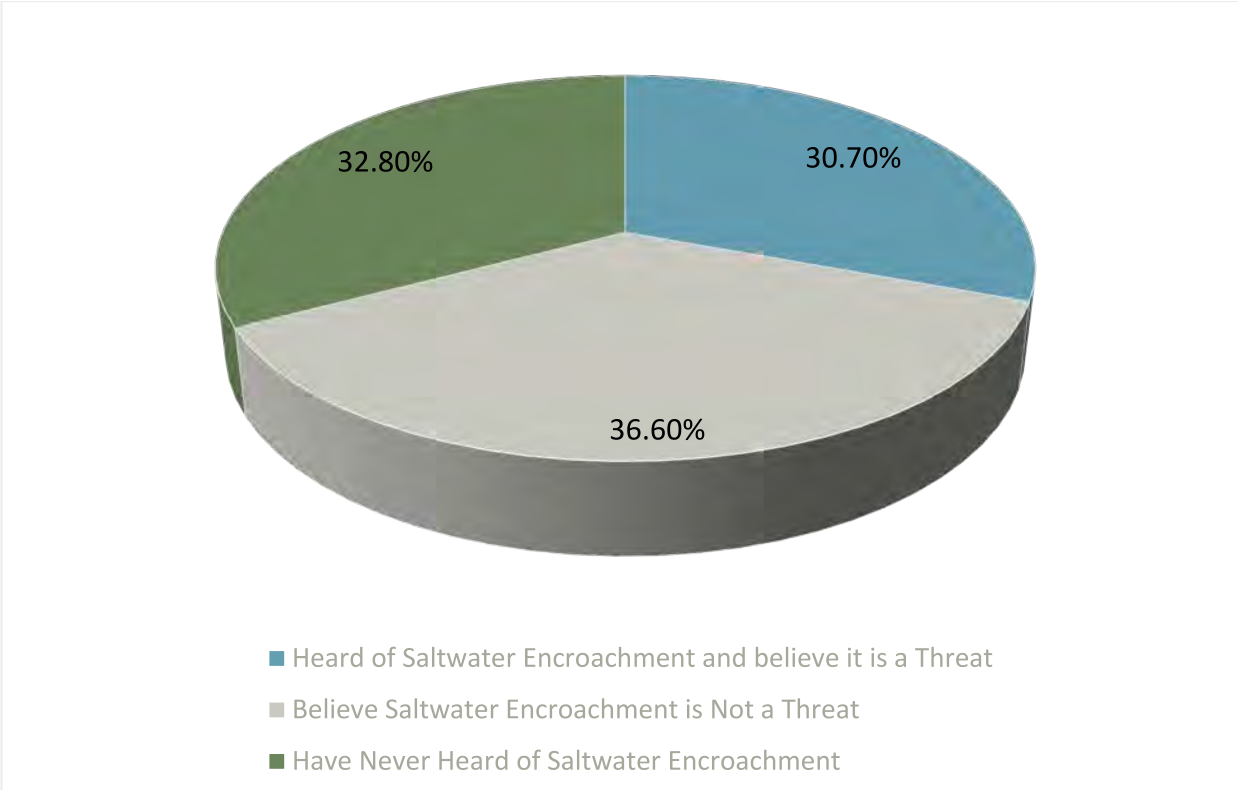


Figure 52. In September of 2014, one-third of respondents had not heard of salt intrusion as a threat to groundwater. The other third does not believe it was a threat and the last third believe it was a threat (adapted from: Magellan Strategies BR, 2014).

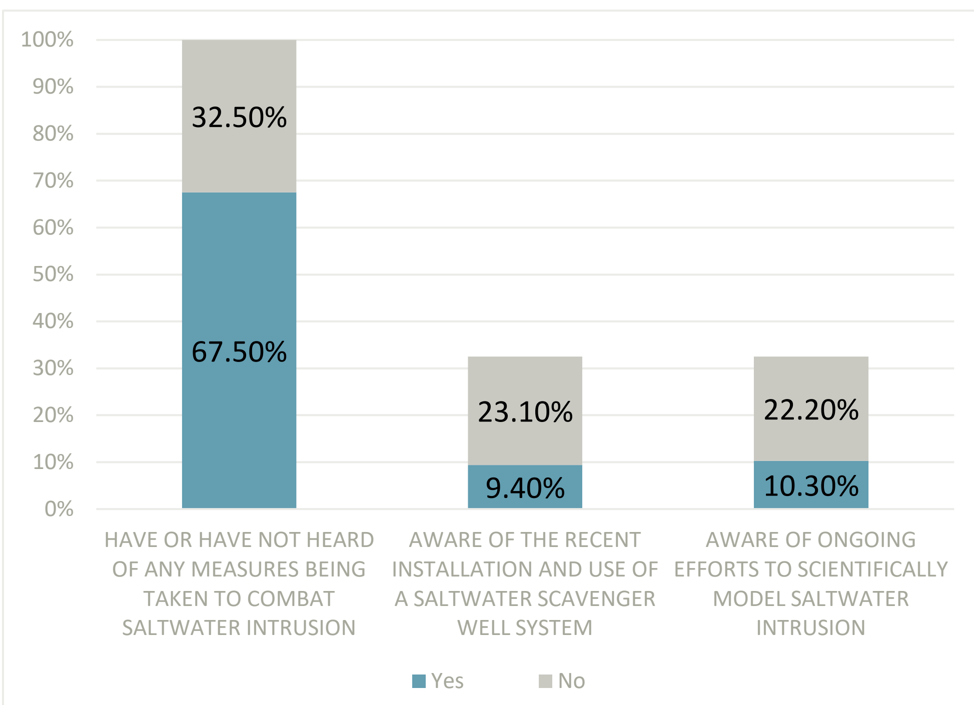


Figure 53. In September of 2014, 68 percent have not heard of any measures taken to prevent saltwater intrusion. Of the 32 percent who were aware of preventive measures, 23 percent were aware of the actions of CAGWCC including the scavenger well system or scientific modeling of saltwater intrusion (adapted from Magellan Strategies BR, 2014).

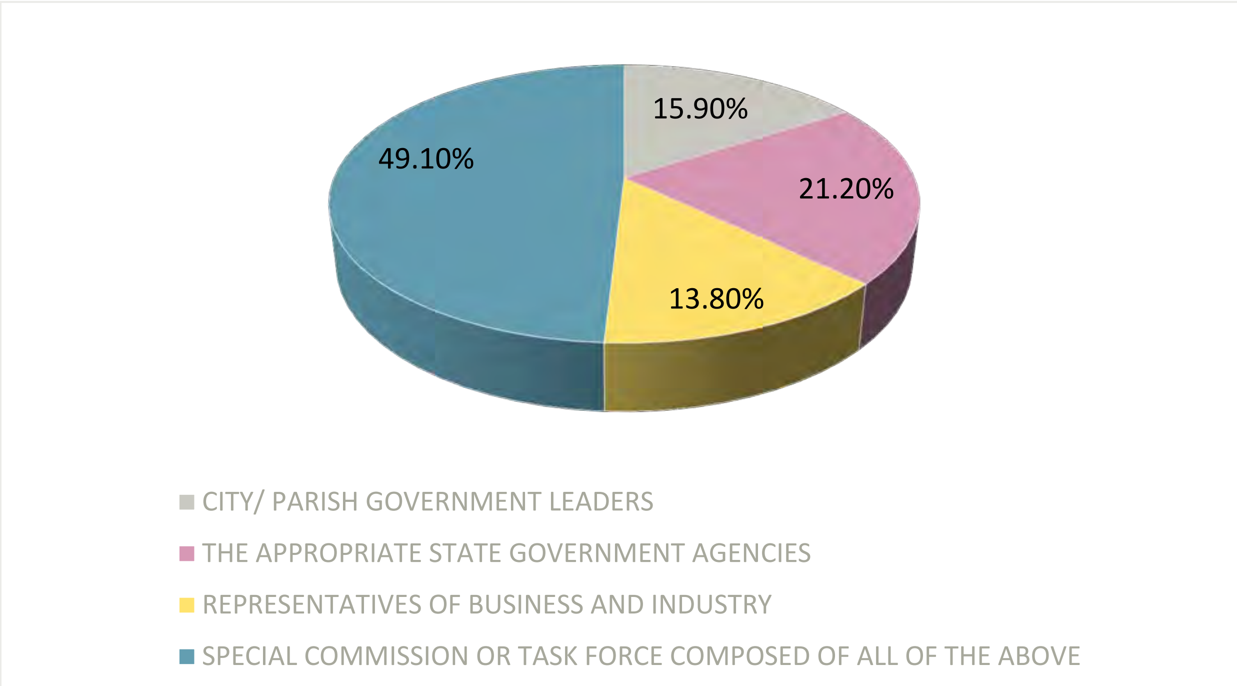


Figure 54. In September of 2014, 49 percent would most trust a special commission to manage a serious threat, whereas just 37 percent would trust either the state or city/parish government (adapted from Magellan Strategies BR, 2014).

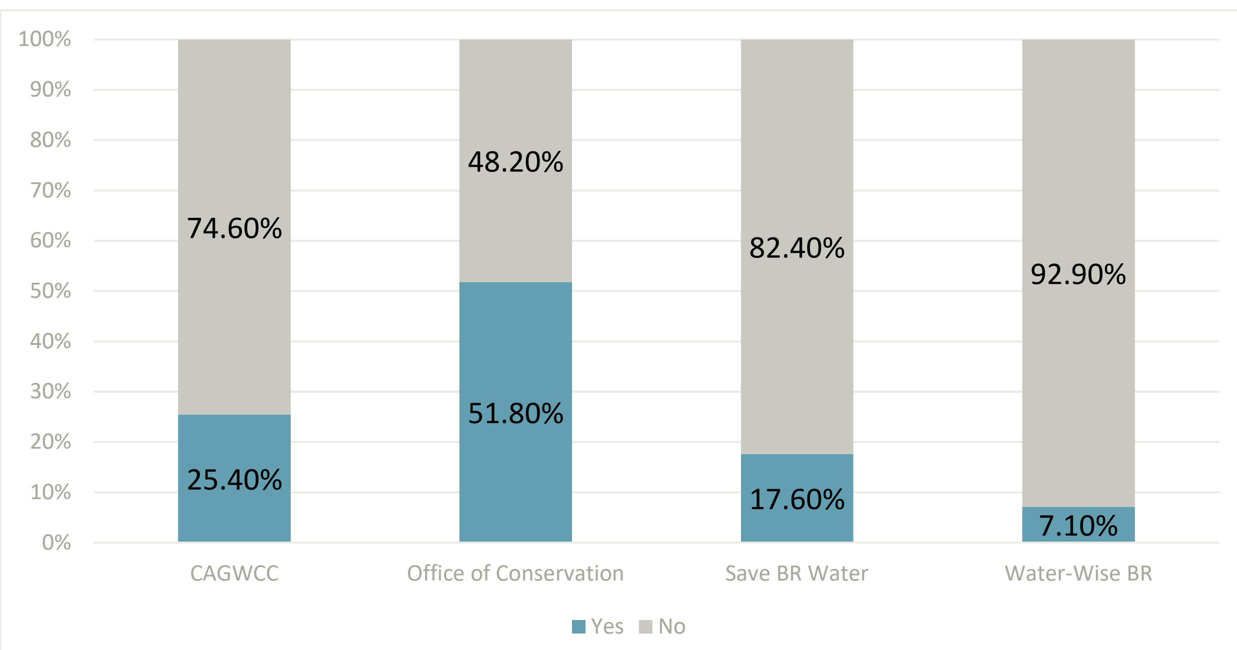


Figure 55. In September of 2014, only 25 percent had knowledge of CAGWCC, 18 percent knew about the Save BR Water campaign, and 7 percent knew about LDNR's Water-Wise in BR campaign (adapted from Magellan Strategies BR, 2014).

Previous Outreach Efforts

The Water-Wise in BR campaign was launched in November 2012 when—following the spring LDNR 2012 survey—the Commissioner of Conservation, James Welsh, issued an order mandating a groundwater conservation and aquifer awareness public education initiative for the Baton Rouge area (Order Concerning Management Planning Strategy and Agency Actions to Address Sustainability of the Southern Hills Aquifer System Underlying the City of Baton Rouge and Surrounding Areas, 2012). Water-Wise in BR included the development of a website, a workshop for elementary, middle, and high school teachers, and creating a traveling exhibit for schools and libraries (Reonas, 2012). The LDNR Office of Conservation launched an advertising campaign in March 2013 encouraging residents to "Be Water-Wise" and gather additional information from the new website. A "Water-Wise in BR" brochure was developed by the LDNR Office of Conservation through funding from Baton Rouge Water Company, Georgia Pacific, ExxonMobil, and Entergy that was managed by the Baton Rouge Area Foundation (*Minutes: Capital Area Ground Water Conservation Commission - December 9, 2014*, 2014). In late 2016, the LDNR Office of Conservation released a film geared towards 5th through 11th graders to align with existing "Water-Wise BR" earth and science lesson plans (*Minutes: Capital Area Ground Water Conservation Commission - December 13, 2016*, 2016).

In September 2014, a study to improve CAGWCC's communication with the public was proposed, and it was determined the study would be conducted by internal staff (*Minutes: Capital Area Ground Water Conservation Commission - September 17, 2013*, 2013). The need for communication about CAGWCC and its mission became clear when the CAGWCC was repeatedly confused (and used interchangeably) with the LDNR Office of Conservation during a series of 2016 Louisiana House and Senate Committee Hearings (*Minutes: Capital Area Ground Water Conservation Commission - June 28, 2016*, 2016). In June 2016, it was suggested that CAGWCC could do more to engage and educate the public, which would also help to build public trust in the organization (Capital Area Ground Water Conservation Commission, 2016b). A final communications plan was approved by CAGWCC at the December 2016 meeting (*Minutes: Capital Area Ground Water Conservation Commission - March 15, 2016*, 2016)

Lastly, the issue of access to meetings by the public was raised in the March 2017 Commission meeting. At that time, CAGWCC meetings were held mid-morning on Tuesdays, which was described as making attendance prohibitive for those other than retirees, vendors, and paid contractors and project employees to attend (*Minutes: Capital Area Ground Water Conservation Commission - March 21, 2017*, 2017). It was noted that there were numerous people interested attending the meetings and aware of the issues facing the drinking water supply but were unable to attend because of the time (*Minutes: Capital Area Ground Water Conservation Commission - March 21, 2017*, 2017). In September 2019, CAGWCC voted to change future meeting times to 6 pm, which would allow access to wider audience (*Minutes: Capital Area Ground Water Conservation Commission - September 25, 2019*, 2019). Despite this plan to move meeting times to the evening, subsequent meetings (including administrative, board, executive, and technical meetings) continued to take place during the mornings and afternoons. However, these meetings are recorded and posted on the CAGWCC website.

Summary of Previous Assessments of Public Understanding of Groundwater Resources

Understanding the effectiveness of prior public outreach efforts is a key component of future qualitative research planning as there may be institutional knowledge that was not captured in the surveys or the other government sources. The public's knowledge of sustainability issues is key because it will provide necessary support for changed infrastructure or understanding for the need to implement conservation measures.

This preliminary analysis conducted as part of Task 2A.4 of public comments and survey results establishes a need for improved public engagement and further development of outreach and education materials. Such enhanced efforts may benefit both the citizens of the Capital Area and CAGWCC itself. This need was noted in a Legislative Auditor report from May 2019, which explicitly noted that CAGWCC should consider investing in educating the public on the need for water conservation and how to reduce withdrawals (Water Resources Commission, 2020). This report also called for a more public outreach and suggested that CAGWCC may need to create a specific budget line item for it (Water Resources Commission, 2020). The review of public understandings of groundwater sustainability in the Capital Area conducted under Task 2A.4 of this study reinforces the findings of the Legislative Auditor, and supports the earlier findings that improved public education and knowledge of the issues could create a better relationship for CAGWCC with the public and improve trust.

This initial review of public outreach efforts and public understanding of groundwater sustainability issues reveals several opportunities to enhance future qualitative data collection efforts and better support CAGWCC. Between the 2012–2014 surveys, the LDNR Office of Conservation implemented a water education program which, as discussed, showed an improvement in the public knowledge in the 2014 survey about drinking water source, but the majority of people still did not know about the issues with the SHAS. Particularly concerning, however, is that the survey of teachers suggests that there was less awareness of groundwater issues and the region's reliance on groundwater among the teachers surveyed compared to the general public. While the results of the two public surveys and the teacher survey cannot be directly compared due to different methodologies (i.e., a random phone survey of the general public compared with a survey of teachers attending a workshop) and questions asked of them, this discrepancy still raises a number of potential problems with earlier outreach and engagement efforts. Understanding this discrepancy in knowledge dissemination represents a key opportunity for future research and can assure that future engagement efforts will explicitly reach key population groups in the CAGWCD.

PUBLIC UNDERSTANDING OF GROUNDWATER RESOURCES

During Phase 2A, the Institute has synthesized previous outreach and engagement efforts and has built on these efforts by conducting qualitative research with public water users and other stakeholders in the CAGWCD. This research involves a mixed methods approach combining an additional web-based public survey (beyond the surveys described in the previous section), interviews, and focus groups to assess the effectiveness of prior educational efforts, knowledge of groundwater sustainability issues, and best public outreach methods. The internet-based public survey attempted to reach all segments of the population in the CAGWCD.

Following completion of the internet-based public survey in 2021, the Institute will conduct interviews and focus-groups. The participants of these will be identified through the assessment of prior public engagement and education efforts. Participant selection will focus on major groundwater producers, public stakeholders, and other interested parties.

Internet-based Public Survey

The Institute and its project partners designed an internet-based survey using software called Qualtrics. Qualtrics is a commonly used survey platform for scientific surveys. The survey will reach residents in Ascension, EBR, East Feliciana, Pointe Coupee, WBR, and West Feliciana parishes, which are all included in CAGWCD's jurisdiction. This survey expands the geographic footprint beyond the original surveys, which were only conducted in EBR Parish, and will gather knowledge and opinions from the breadth of residential users of CAGWCD resources. While the surveys conducted in 2012 and 2014 were primarily focused on issues directly related to the public's knowledge and understanding of groundwater in EBR Parish, the internet-based survey places an additional focus on the public perceptions of water cost, quality, and quantity. These additional questions will provide CAGWCD with data that can be used to gauge public opinions related to ongoing and future groundwater management and conservation strategies and the willingness to pay for or support these strategies.

Internet-based Survey Method

The internet-based survey has been structured to provide values that will directly feed the weighted subjective portion of the metric that was used to display the results of the survey questionnaire (Appendix C) which consists of eleven demographic questions and 33 water-related questions. The survey was administered from October 19, 2021 to November 1, 2021 and resulted in 305 responses to assure statistical significance of the responses.

Survey respondents were drawn from the Qualtrics sample pool, which consists of both traditional and actively managed market research panels. These panels were composed of individuals who decide to participate in online surveys through a double opt-in registration process, first random selection via an ad or email link then the survey panel member opting in to take a designated survey, rendering online surveys non-probability surveys. With consistent low response rates found in traditional probability surveys, non-probability surveys have gained growing popularity in recent years due to its cost-effective and timely features. Additional benefits associated with online surveys are they can elicit honest and accurate responses to sensitive questions that traditional phone survey mode cannot due to individuals willingness to respond openly (Chang & Krosnick, 2009).

In this particular survey, screening questions included parish residence (Ascension, EBR, East Feliciana, Pointe Coupee, WBR, West Feliciana), age, race, ethnicity, and gender. Each respondent who completed the survey received $5 in monetary compensation for their time. There were 305 complete responses.

There were some noticeable discrepancies of compositions in gender, age group, and ethnicity between the sample and the population. To account for the characteristics of non-probability in online surveys, modeling such as ranking adjustment, matching and propensity were used (Kennedy et al., 2016). Despite being the most basic weighting method, ranking has been found to perform as well as more sophisticated methods in weighting online opt-in samples (Mercer et al., 2018). A stepwise adjustment known as iterative proportional ranking was thus utilized to obtain probability weights for point estimates in this study (Bergmann, 2011).

Results of Internet-based Public Survey

Survey results suggest that public perceptions of household water in the CAGWCD are favorable. When questioned about specific characteristics of their household water quality (Figure 56), an overwhelming majority of respondents indicated that taste (72 percent), appearance (88 percent), odor (77 percent), and feel (85 percent) are good or excellent overall. When asked how the quality of drinking water had changed over the past five years, 68 percent of respondents stated it was ‘the same,’ with 15 percent stating that it was ‘better’ now than before (Figure 57).

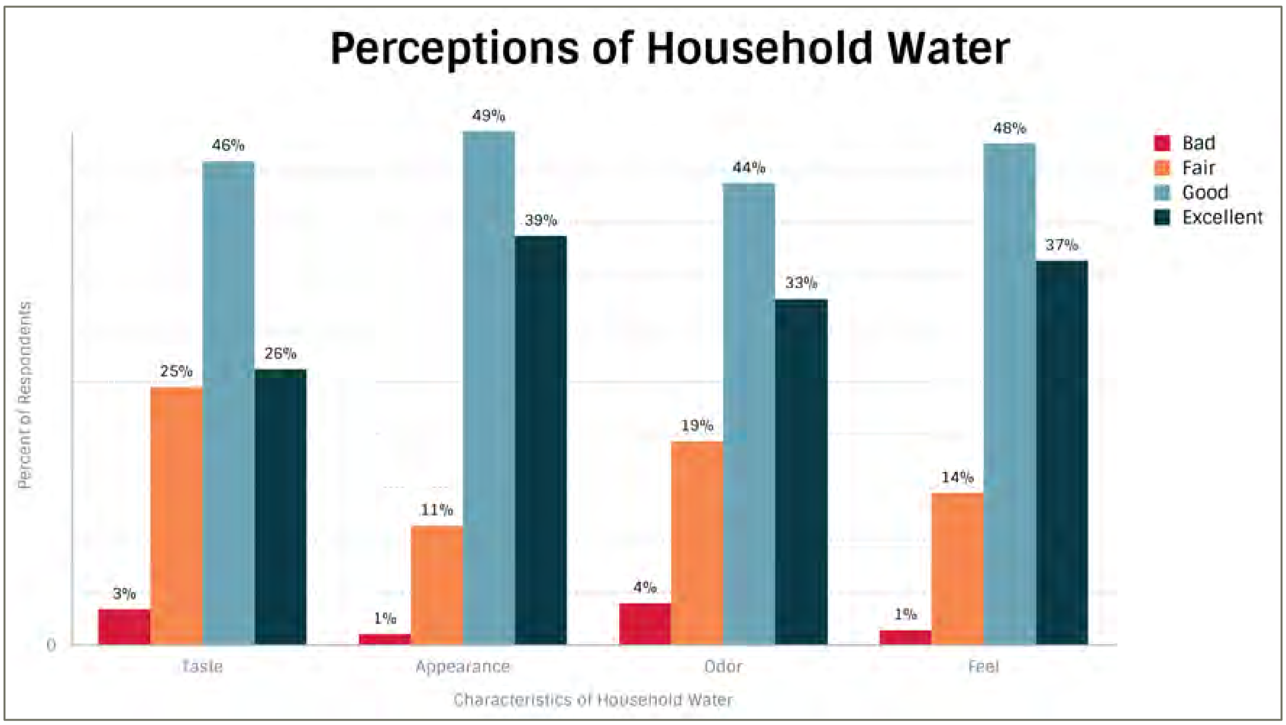


Figure 56. Public Perceptions of Household Water Characteristics.

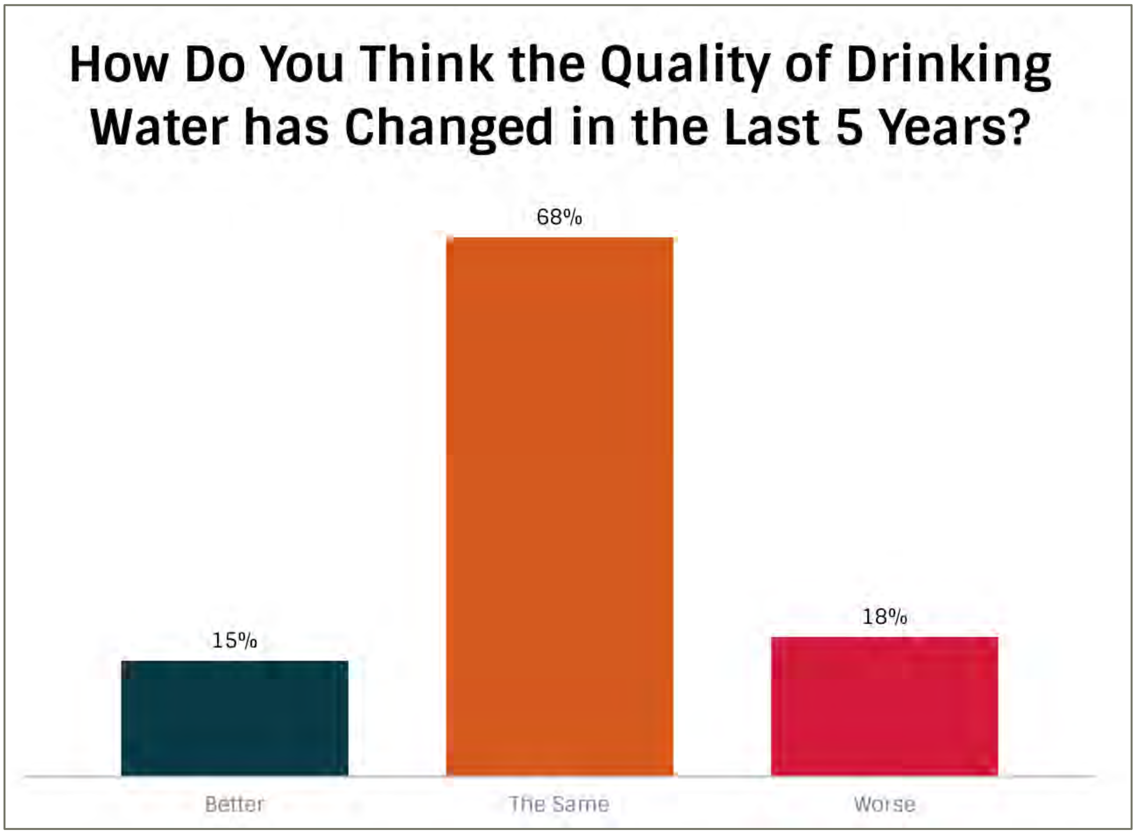


Figure 57. Public Opinion on Changes to Water Quality in Past Five Years.

The public perception of water quality sourced from groundwater was more favorable than surface water (62 percent stated quality of groundwater was either ‘good’ or ‘very good’ versus 45 percent who indicated the same re: surface water; see Figure 58). Despite respondents ranking both surface water (45 percent) and groundwater (62 percent) as good or very good, 58 percent were unsure of the source and 14 percent incorrectly identified the source of their own household water supply (Figure 59). While 58 percent of respondents do not know the source of their drinking water, almost 80 percent know that their household tap water is supplied by a private water company, such as Baton Rouge Water Company, Ascension Water Company, or M&S Water Supply. Additionally, although respondents largely indicated their water quality was good, 37 percent still filter their tap water (Figure 60) and 66 percent primarily use bottled water for drinking (Figure 61).

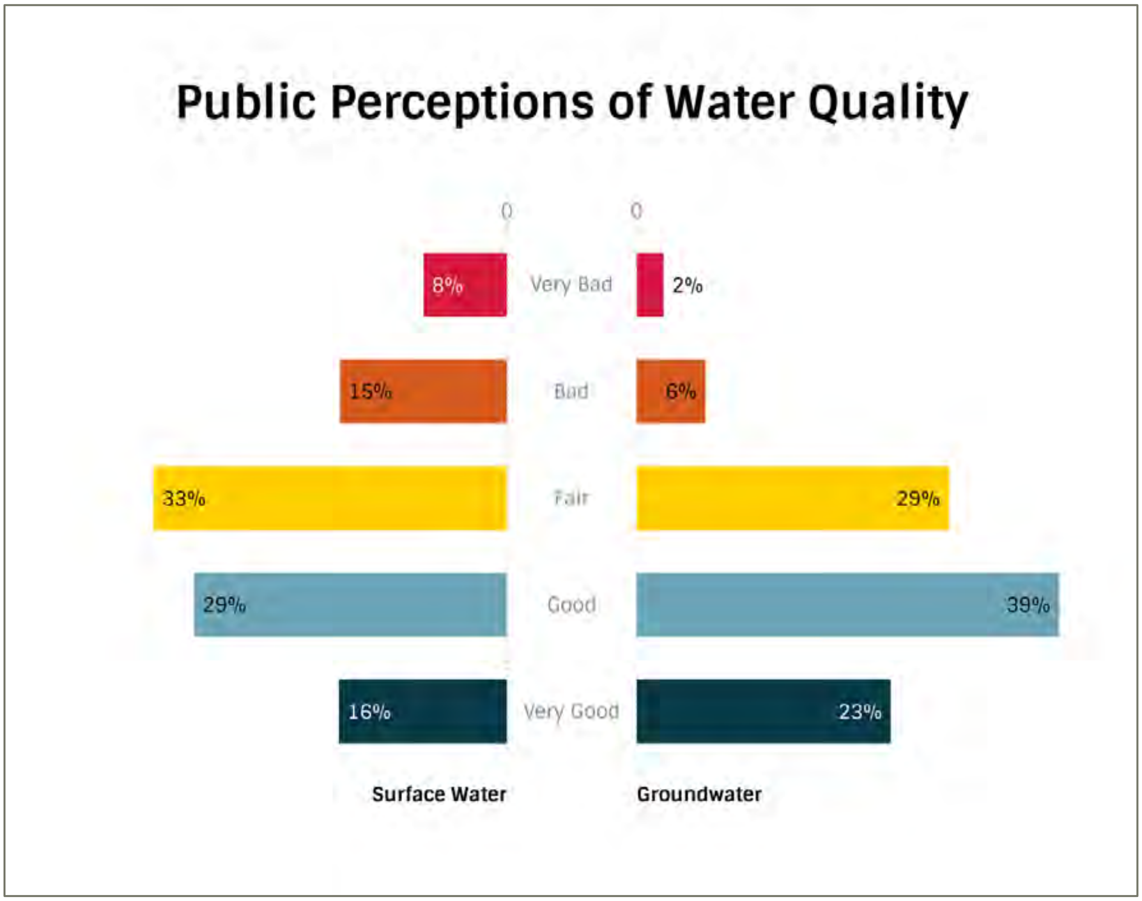


Figure 58. Public Perceptions of Water Quality

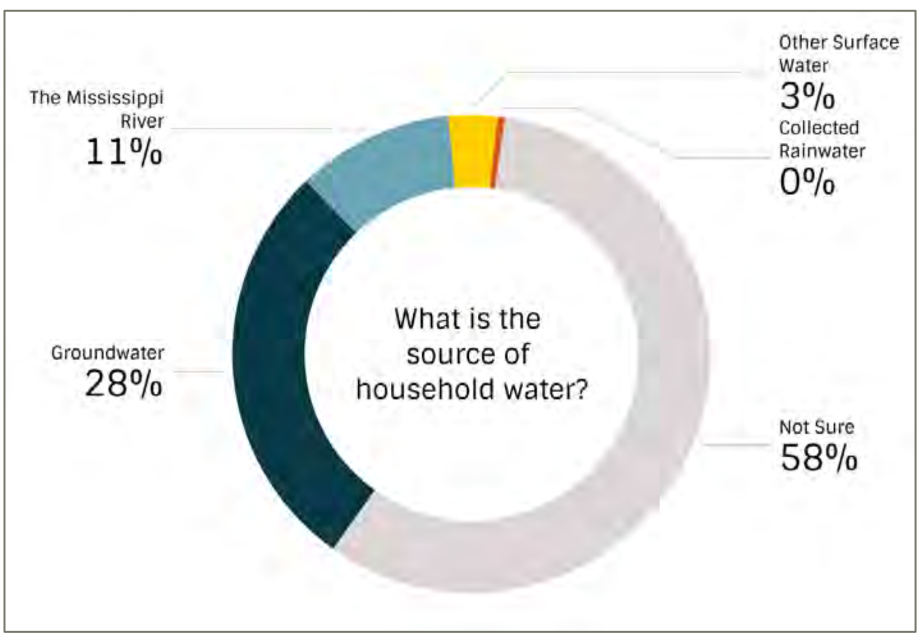


Figure 59. Public Perceptions of Household Water Source

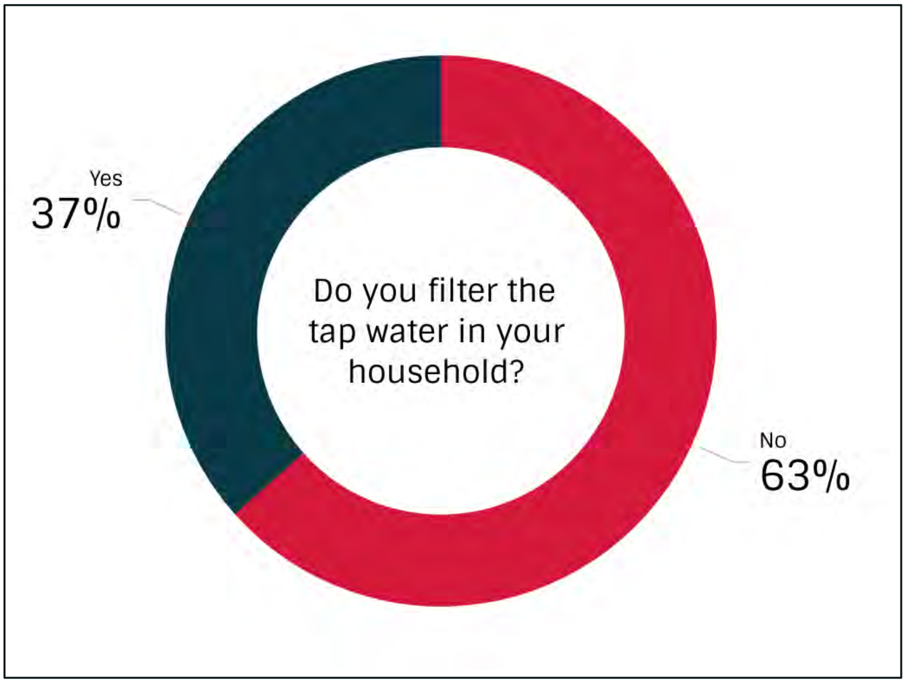


Figure 60. Public Use of Filtered Water.

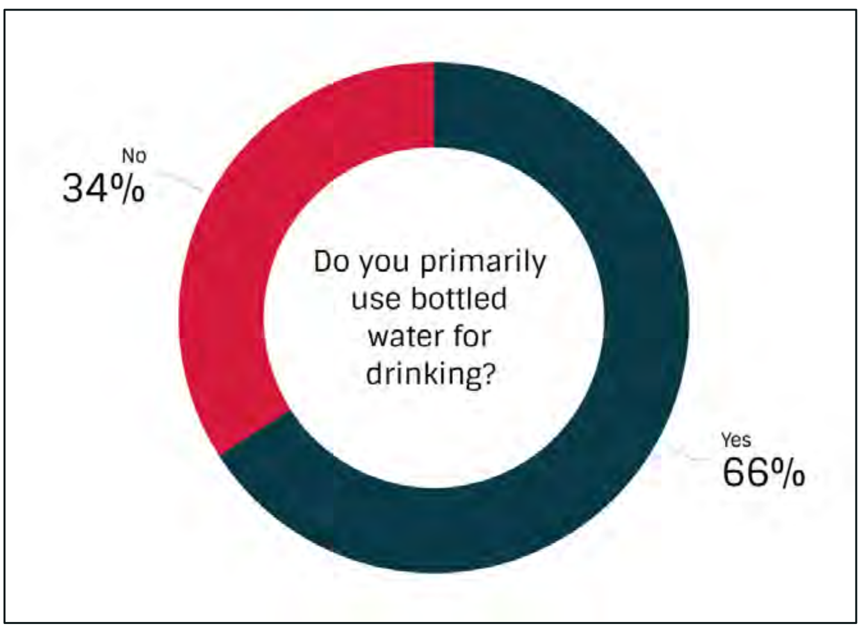


Figure 61. Public Use of Bottled Water for Drinking.

Although a relatively large proportion of respondents (42 percent) stated that they were not at all concerned about the quality of drinking water in their area (Figure 62), this was only a slightly higher percentage than those who were somewhat concerned (41 percent) about it. When combining the 'somewhat concerned' group with their 'very concerned' counterparts, it reveals that a sizable majority (58 percent) expressed at least some degree of concern about the quality of drinking water in their area.

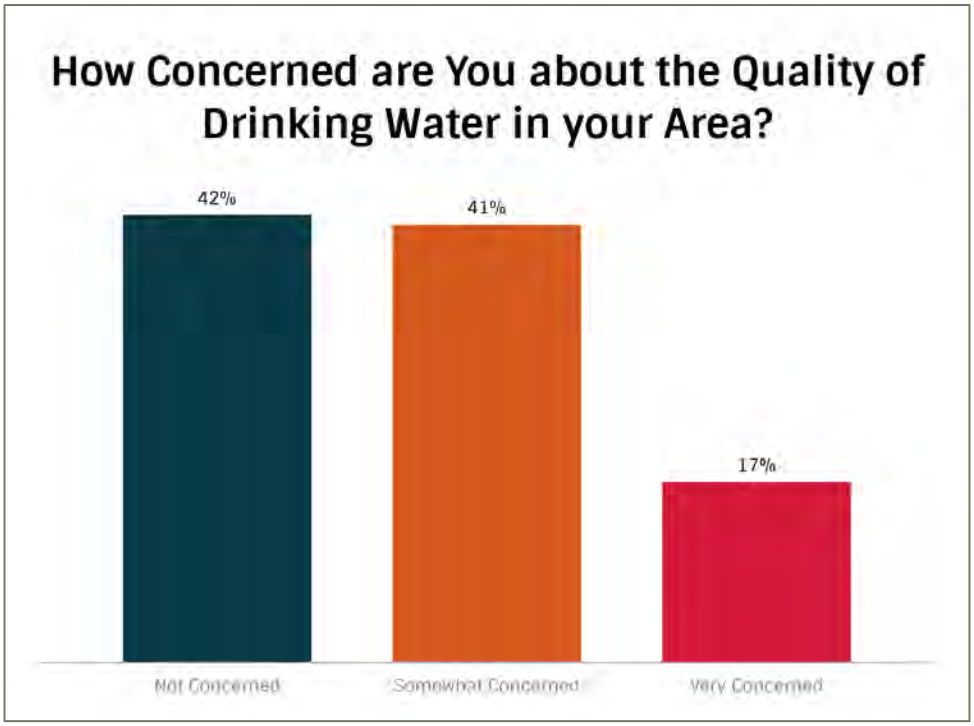


Figure 62. Level of Concern re: Water Quality

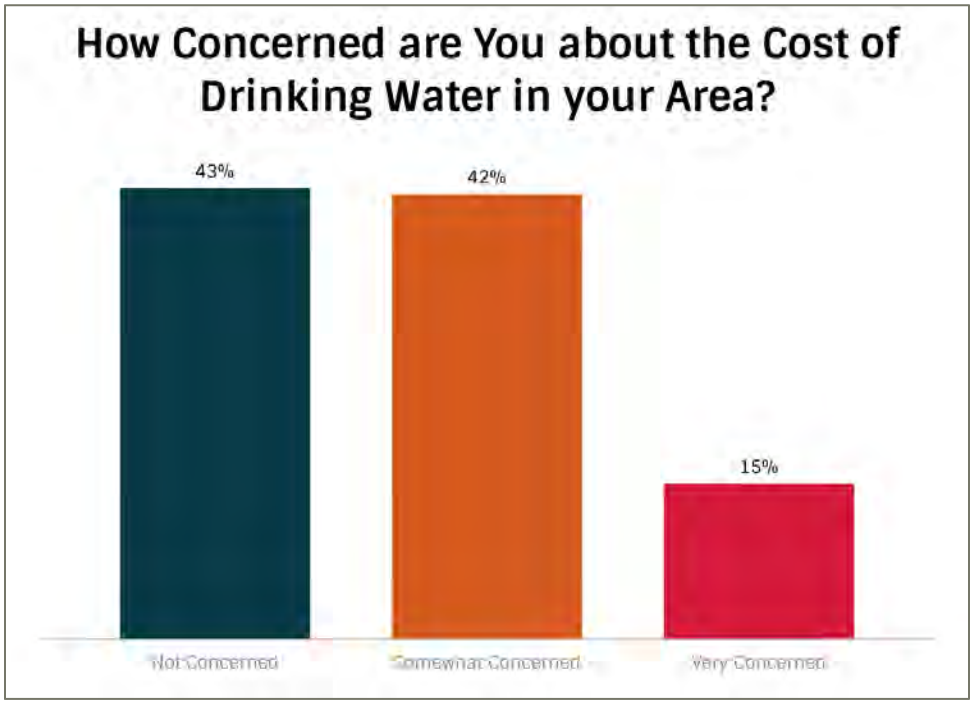


Figure 63. Level of Concern re: Water Cost

Respondents replied similarly when asked about water affordability. Although 43 percent of respondents were not concerned about the cost of drinking water in their area, 57 percent indicated they were either somewhat concerned or very concerned about affordability (Figure 63, above). However, when asked about the cost of their water bills, 61 percent of respondents thought they were “about right” and five percent stated their bills were “low” (Figure 64, below). Just over 50 percent of respondents reported that they would be willing to pay more to guarantee safe drinking water (Figure 65) Of these, nearly half (49 percent) stated a willingness to pay $5 more per month, with 19 percent claiming they would pay $5 to $10 more per month to guarantee safe drinking water (Figure 66), indicating that drinking water safety is a priority among most respondents.

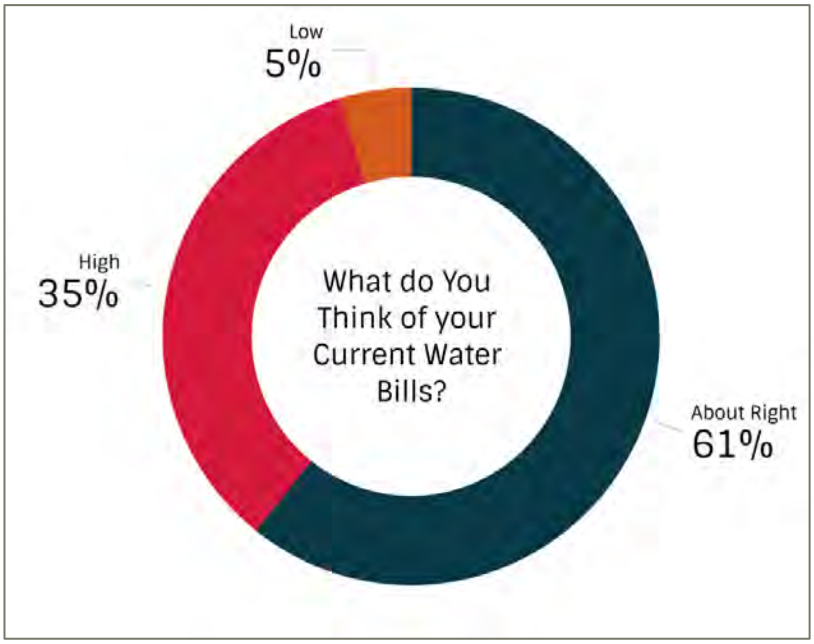


Figure 64. Perceptions on Cost of Water Bills.

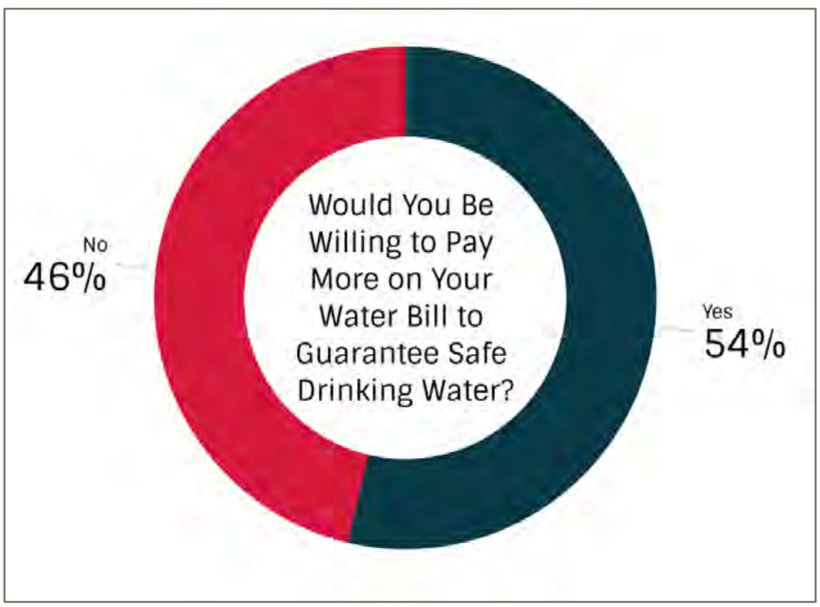


Figure 65. Perception on Willingness to Pay More.

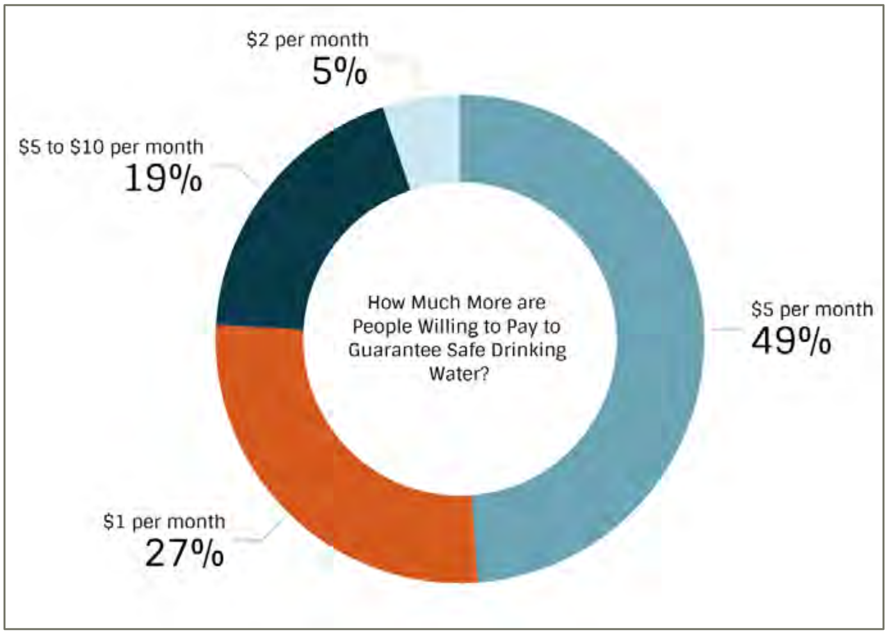


Figure 66. Perceptions on Amount Willing to Pay.

Availability of drinking water does not appear to be a concern among a substantial proportion (57 percent) of respondents (Figure 67). When asked specifically about whether they perceive depletion of their household water source as a problem (Figure 68), 49 percent of respondents either indicated that it was not a problem at all (29 percent), or they were unsure (20 percent) whether it was a problem.

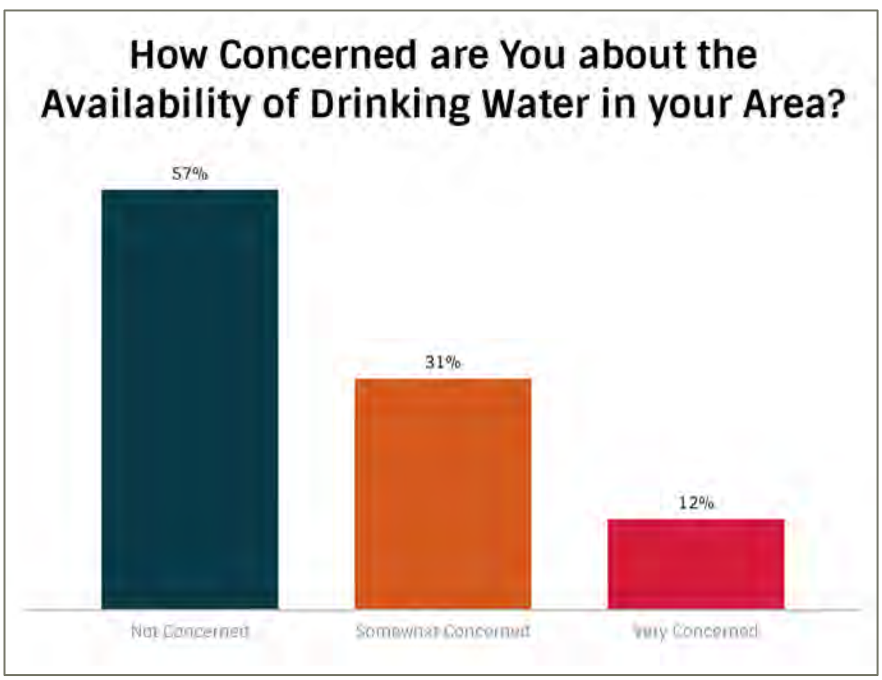


Figure 67. Public Level of Concern Regarding Water Availability.

Survey respondents were also asked about the perceived risk of contamination of water sources, saltwater intrusion, affordability, aging water and wastewater infrastructure were to their household drinking water (Figure 68). On average 46 percent of respondents did not perceive any risks or were not sure about the risks. While an average of 54 percent of respondents perceived some or a serious risk to their household drinking water. Depletion of water sources (25 percent) and aging water and wastewater infrastructure (24 percent) were identified as the most serious problems of the five presented. Aging infrastructure and wastewater infrastructure (40 percent) and contamination of water sources (35 percent) were identified as the highest risk that respondents viewed as somewhat of a problem. While affordability of water (37 percent) and saltwater intrusion (34 percent) were noted most as not a problem.

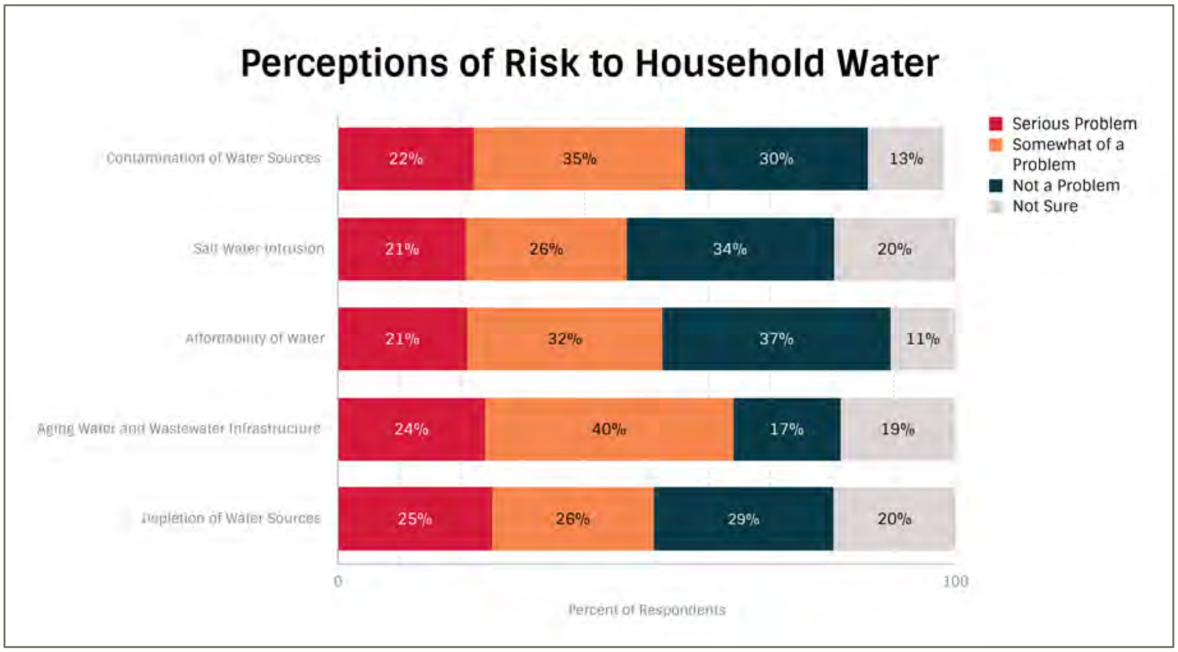


Figure 68. Public Perceptions of Risk to Household Water

These data indicate a wide range of attitudes surrounding household water-related issues and public perceptions of risk. When asked about whether they had heard or read about groundwater management in their area, 78 percent of respondents replied that they had not (Figure 69). Of the 22 percent of respondents who claimed they had heard about groundwater management in their area, 48 percent received their information from newspapers and another 23 percent received information from television (Figure 70), indicating a gap in public awareness and understanding of water management issues as well as an opportunity for public outreach and education.

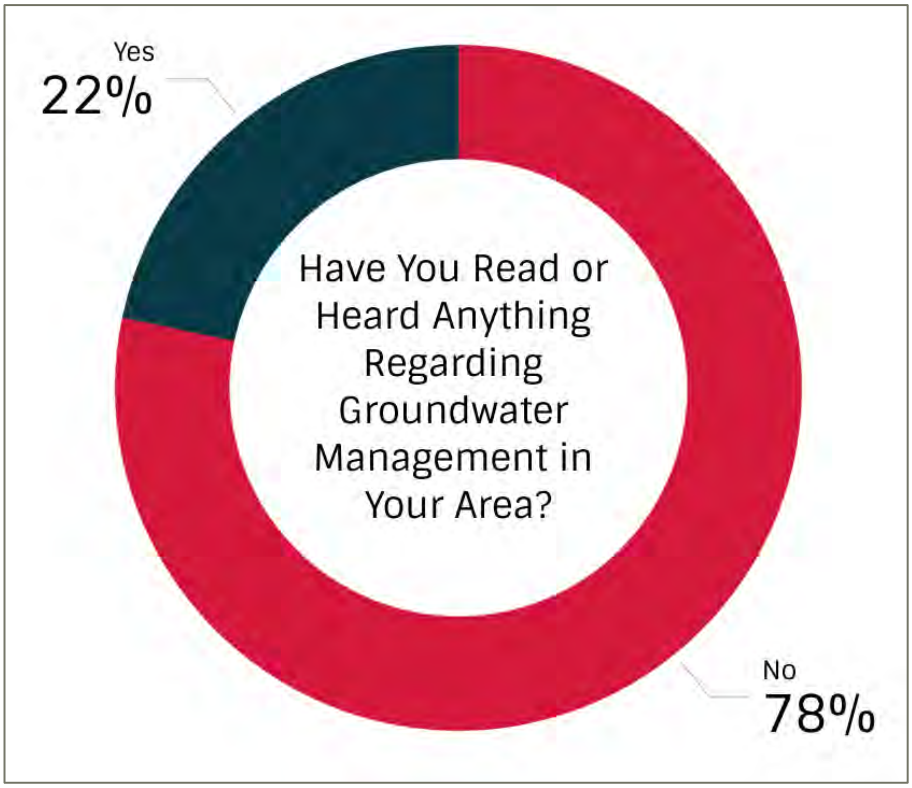


Figure 69. Groundwater Management Awareness.

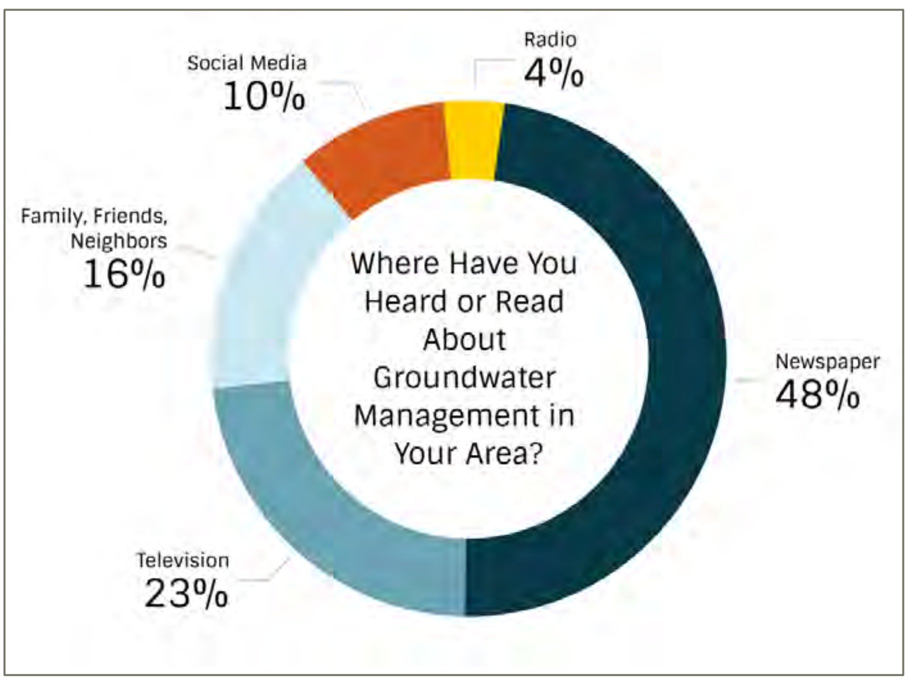


Figure 70. Information sources used by the 22% of respondents (Figure 69) who had heard or read about groundwater management.

There was also a broad spectrum of perceptions on which sector is the heaviest user of water, as well as which authority should be trusted to manage groundwater. Nearly half (47 percent) of respondents believed that public supply was the biggest consumer in the area, followed by industry at 26 percent (Figure 71). When asked who should manage a serious risk to groundwater, 18 percent thought a special commission, eight percent of respondents trusted business and industry leaders, and 12 percent trusted the state government to manage potentially serious threats to groundwater (Figure 72). City and parish government garnered the highest amount of trust among respondents, as 30 percent, while an almost equal number of respondents (31 percent) were unsure as to which authority should be trusted to handle these issues.

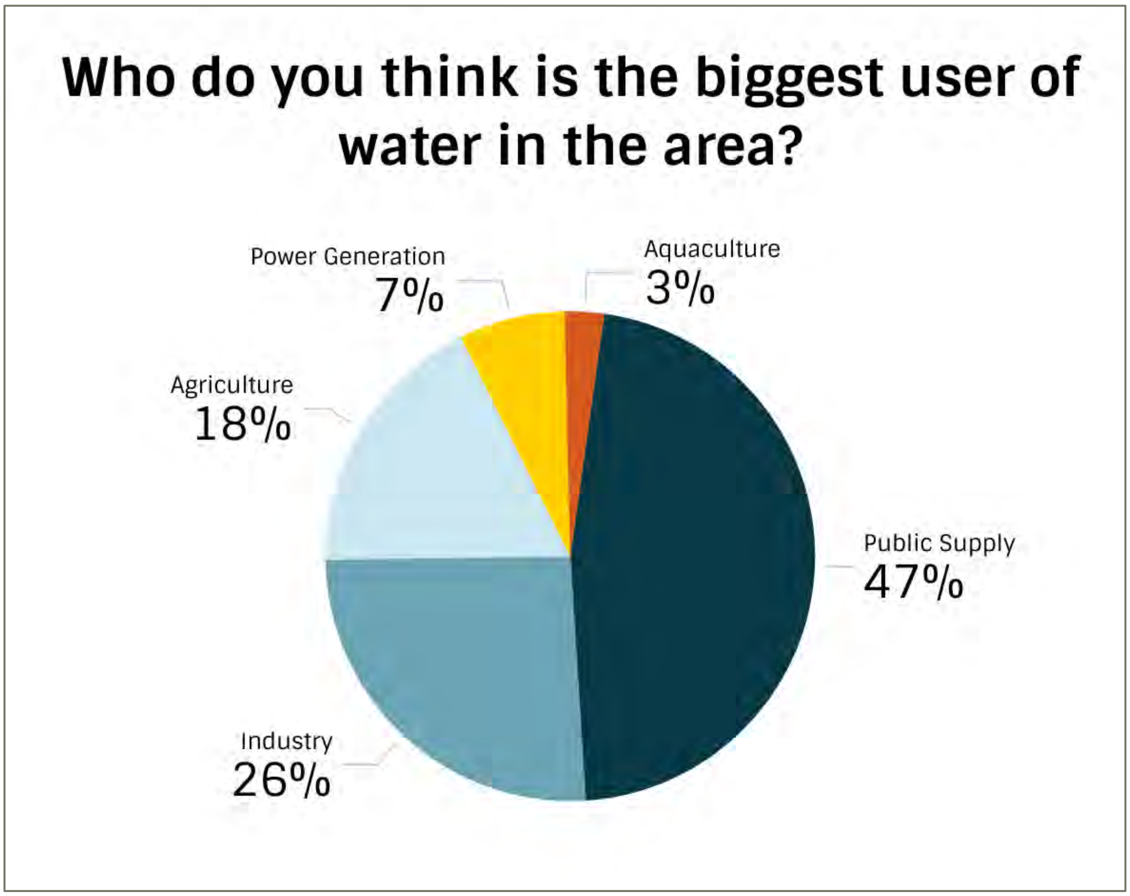


Figure 71. Biggest Consumer of Water.

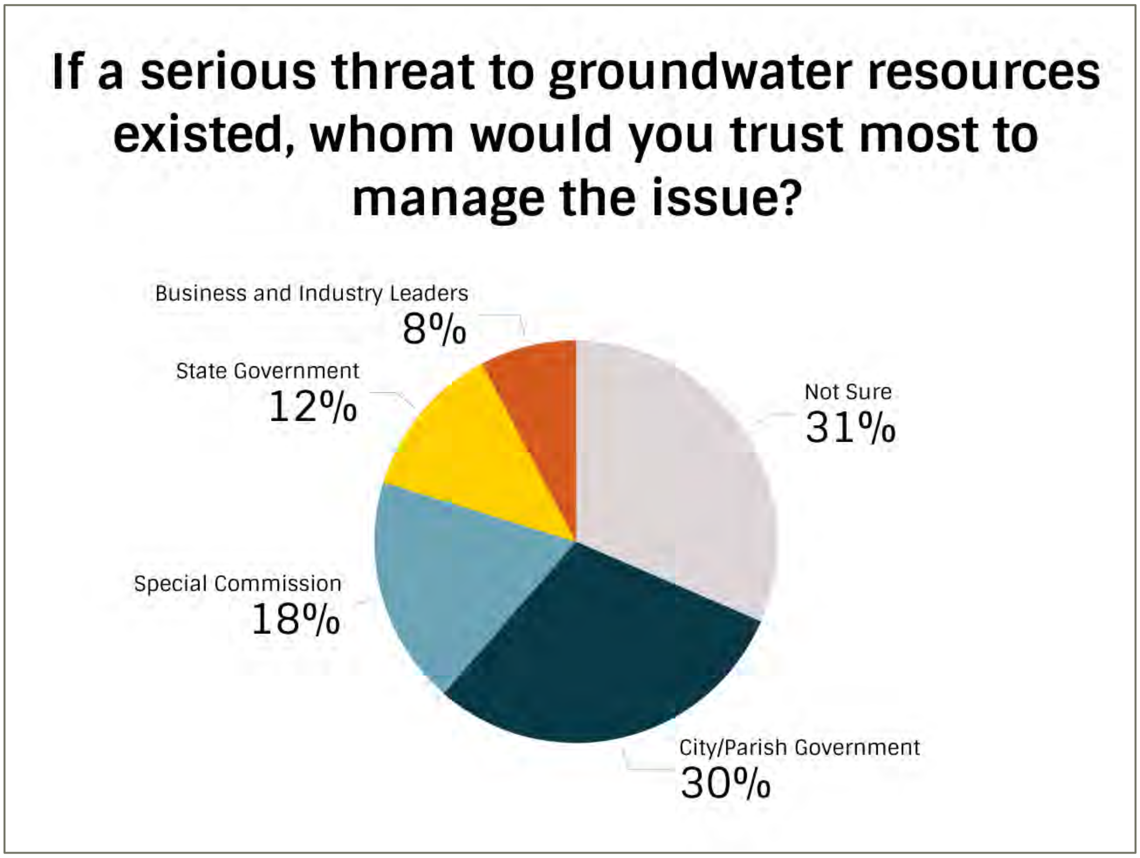


Figure 72. Most Trusted Entity to Manage Groundwater.

When asked about possible policy options for managing water, respondents seemingly favored incentives over regulations (Figure 73). The most popular management option was investment in groundwater monitoring (56 percent), followed by incentivizing water efficient equipment (50 percent) and conducting educational campaigns (42 percent) to increase public awareness of water management-related issues. Regulatory options to increase rates for large volume users and impose caps on non-essential uses received the least amount of support among respondents, with slightly over a quarter of respondents in support of them and 25 percent and 21 percent outright opposing them, respectively.

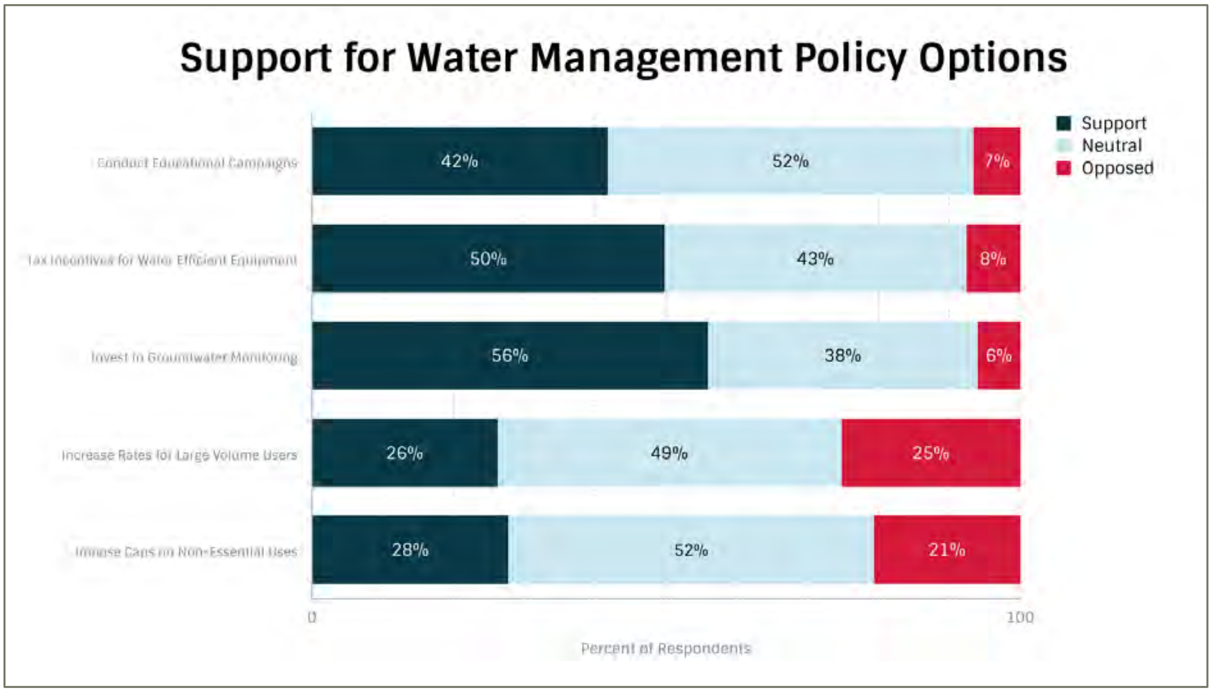


Figure 73. Level of Public Support for Water Management Policy Options.

Overall, these results indicate that the public is largely unaware of issues concerning their water supply and there is a wide array of opinions regarding how best to manage it. However, a substantial proportion of respondents supported outreach and education on water management-related issues, which presents an opportunity to further engage the public regarding policy options to manage the existing and future risks to their water supply.

CONCLUSIONS AND NEXT STEPS FOR INTERVIEWS AND FOCUS-GROUPS

A direct comparison of the results of the internet-based survey to the previous surveys is not feasible due to the change in sample area from EBR Parish in 2012 and 2014 to the CACWCD in 2021. By expanding the survey area there is no longer a baseline of knowledge. However, general comparisons about the public's knowledge can still be made and future directions can be informed. The change between 2012 and 2014 in respondent awareness as to the source of drinking water in EBR was attributed to the Water Wise campaign being implemented in EBR schools and the parish. When the survey area is expanded to the surrounding parishes, the knowledge of where drinking water comes from falls to 28 percent, which is less than the 2012 survey in which 52 percent of respondents in EBR Parish knew the water came from an aquifer.

In terms of the understanding of potential threats to the aquifer, the 2014 survey only examined saltwater intrusion as a threat to the drinking water refraining from asking respondents about any other potential threats. Thirty-one percent thought saltwater intrusion was a 'big threat' while 37 percent thought it was not a threat and 33 percent 'had never heard of saltwater intrusion or saltwater encroachment'. In the 2021 survey, a similar percentage (34 percent) thought saltwater intrusion was not a threat and only 20 percent were unsure. 21 percent of respondents thought saltwater intrusion was a serious threat to drinking water, while 26 percent thought the threat was somewhat serious. In both the 2014 and 2021 surveys, over 50 percent of respondents did not perceive saltwater intrusion as a threat, nor had they heard of it. The overall public understanding of threats to the drinking water supply is very low in both surveys. Less than 33 percent were aware of any potential threats or of groundwater management issues, whereas more than 68 percent were unaware of any potential issues.

Both the 2014 and 2021 surveys showed that greater than 50 percent of respondents had not read or heard anything regarding groundwater management, saltwater intrusion, or drinking water from newspapers, magazines, billboards, radio, or on television. Both surveys also confirmed that overall, greater than 50 percent of respondents view their drinking water as fair, good, or very good. Less than 10 percent in both surveys view the drinking water as bad or very bad.

Given that both a high number of respondents rated the water favorably yet have little knowledge about potential issues with the water supply suggests the need for an awareness and engagement effort that extends to the entire District. To identify the most appropriate materials for an awareness effort, further work with focus groups will be done to identity the best way to communicate with all residents, since in the 2021 survey almost 50 percent said they had not read or heard about water management in the newspaper. The number of people who receive news from newspapers has been on the decline in the digital age (Nielsen & Reuters Institute for the Study of Journalism, 2019), so information consumption needs to be incorporated into the stakeholder engagements.

Additionally, a multi-year education and outreach effort, similar to the one undertaken in 2012-2014, followed by a survey that is consistent with the one conducted in 2021, could be helpful to determine if the proposed awareness and engagement efforts were successful in reaching and informing the public. Consistency in questions asked between the 2021 survey and any future surveys could provide direct points of comparison and ultimately better understanding of the public's awareness. The responses collected in 2021 provide a baseline of public understanding for the entire District, which is important as 68 percent of respondents were not aware of any issues related to water supply. Therefore, the willingness to pay more, concern about water cost, and other monetary driven questions might have responses driven by people's lack of knowledge of water management issues.

Surveys like those conducted in 2012, 2014, and 2021 are appropriate for measuring public opinion, attitudes, and beliefs but less useful for explaining them. Future actions by the Institute include conducting a series of small focus-groups and interviews to better understand the relationships that this survey work uncovered. Public stakeholders, major groundwater producers, and interested parties from across the CAGWCD will be identified and asked to participate. Through this process, participants will enable the Institute to collect specific information about the public's knowledge and understandings about issues and the viability of potential solutions.

TASK 2A.5 ECONOMIC ANALYSES

Task Summary: Some of the alternatives for sustainable water management of the SHAS require the development of alternative water supplies. An important part of the long-term plan is evaluating the different options for water supplies as well as the costs associated with each. Potential sources of project funding for the development of alternative water supplies will also be evaluated.

EVALUATE ALTERNATIVE WATER SUPPLY OPTIONS

Addressing the region's future supply needs and achieving long-term management objectives requires an understanding of the potential water sources and strategies which could supplement or reduce reliance on groundwater and provide long-term diversification to the region's water source profile. While this study is not intended to mandate a particular project, a greater understanding of the key considerations for various supply options could provide a valuable reference for both CAGWCC and the entities within the CAGWCD. Based on the characteristics of the study area, CAGWCC and project partners identified a number of potentially feasible projects anticipated to be evaluated as part of the study:

- Mississippi River Surface Water: Development of a traditional surface water supply project including diversion and treatment of a portion of the substantial flow of the Mississippi River.
- River Bank Filtration (Alluvial Groundwater): Use of wells in the Mississippi River Alluvial Aquifer (MRAA) or other shallow sand layers to leverage abundant surface water while benefiting from natural filtration as pre-treatment.
- Aquifer Storage and Recovery (ASR): Use of surface water development and treatment in conjunction with injection wells, creating subsurface storage in lieu of a traditional reservoir to increase supply reliability.
- Brackish Groundwater Desalination: Production of groundwater from non-traditional supply formations with high dissolved solids and salinity, and application of desalination treatment to produce a high-quality treated source for direct use or blending.
- Municipal Effluent Reclamation: Repurposing treated municipal wastewater treatment plant effluent for beneficial supply use through additional advanced treatment and conveyance to demand centers.
- Industrial Effluent Reclamation: Repurposing treated industrial facility wastewater effluent for beneficial supply use through additional advanced treatment.

- Institutional Effluent Reclamation: Diverting a portion of the wastewater stream from educational or correctional institutions—possibly supplemented by municipal wastewater—for treatment and utilization for green space irrigation or other non-potable water demands.

- The “Status Quo” Scenario: Not a true supply project, but rather the potential for increased treatment requirements as a result of saltwater intrusion caused by maintaining or increasing levels of production from traditional local source sand layers.

The planning-level analyses, which were performed as part of Phase 2A of the study, characterize the potential water supply strategies for entities within the CAGWCD including conceptual supply strategy technical evaluation, estimation of current costs for industrial groundwater supply, evaluation of Performance Metric 3 (cost to industrial users) for individual project concepts, evaluation of Performance Metric 3 for multi-project portfolios, and consideration of the various funding approaches and programs which may be available to support development of alternative water supplies. Analyses performed as part of Task 2A.5 are discussed in greater detail in the following report subsections.

Conceptual Supply Strategy Evaluation

Planning evaluation of the identified water supply concepts requires consideration of multiple aspects of project development. While both capital and unit costs are important considerations for evaluating potential supply options, there are other factors which also bear examination in order to provide context for the feasibility and viability of water supply projects. Additional quantitative or qualitative considerations anticipated to be considered in developing project assessments include:

- Water quality: Quality influences the overall suitability of a source for certain uses and impacts project cost directly through treatment needs.

- Reliability: The reliable quantity of water that can be produced from a source influences what portion of demands can be met from the source and impacts project volumetric unit cost.

- Implementation feasibility: All projects may face potential implementation challenges of an economic, sociopolitical, or environmental nature.

- Permitting, Development, and Environmental Considerations: All projects will require some level of construction permitting, and may have specific requirements based on source type, quality, or infrastructure components. Some projects may also have environmental impacts that must be assessed and mitigated.

- Potential for other benefits: Beyond water supply, some projects may offer opportunities for partnerships with local entities, training opportunities for students or water industry personnel, or support local job creation.

It should be noted that the project concepts for the Phase 2A study are planning-level analyses and not intended for construction, bid, or permitting purposes. However, while planning-level analysis is more general than a detailed feasibility analysis or preliminary engineering report for a site-specific project, it is extremely valuable in assessing the characteristics of supply options, key considerations for development, possible implementation challenges, and anticipated relative magnitude of cost. The following report subsections provide additional detail on the general considerations, assumptions, cost estimation procedures, and estimated cost results. The discussions in these subsections examine project concepts in the context of supplies developed primarily by industry or institutions for their own water demands, due to the importance of these activities on the local economy and the need to assess the applicable performance metric in the context of existing and possible future water supply costs. While not examined in detail in this report, the potential supply options discussed for industry could potentially also be implemented through other arrangements such as municipal supply or shared municipal-industrial joint sources. Evaluations are also documented in a technical memorandum in Appendix G for each project concept.

Notes on Concept Sizing and Identification of Industrial Aggregations

The project concepts evaluated by the study could each be developed across a wide range of potential facility sizes, with implications for implementation logistics and economic economy of scale. It is therefore important to consider what would be likely to constitute a reasonable project size based on characteristics of water demand and source availability. The CAGWCC's Long-Term Strategic Planning program includes multiple elements intended to enhance the science and knowledge base for multiple aspects of water demand, including evaluation of historic, current, and potential future domestic and industrial water demand, as well as investigating how demand could drive continued subsurface saltwater intrusion and land surface subsidence. While the CAGWCC has not yet established a particular regulatory limit for sustainable average groundwater production, CAGWCC groundwater database records and the analyses from Task 2A.3 provide insights into potential aggregations of industrial water demands that can be used to inform reasonable project size intervals for addressing industry needs.

Historical pumpage records and well information (e.g., aquifer codes) from the CAGWCC database were used in conjunction with well location data from the LDNR SONRIS Well Registration database to identify major clusters of one or more adjacent industrial facilities that currently produce groundwater from the SHAS, specifically those that produce from the primary sand layers of concern (the 1,500-foot and 2,000-foot sands). Fourteen major industrial clusters were identified in parishes across the CAGWCD. The annual groundwater produced from the industrial entities in these clusters, as reported to CAGWCC, were aggregated to evaluate potential industrial project size intervals across the CAGWCC. Figure 74 and Figure 75 illustrate the distribution of the aggregated groundwater production (total pumpage across the CAGWCD and pumpage from primary sand layers of concern in the SHAS, respectively) in 2020 by the identified major industrial clusters.

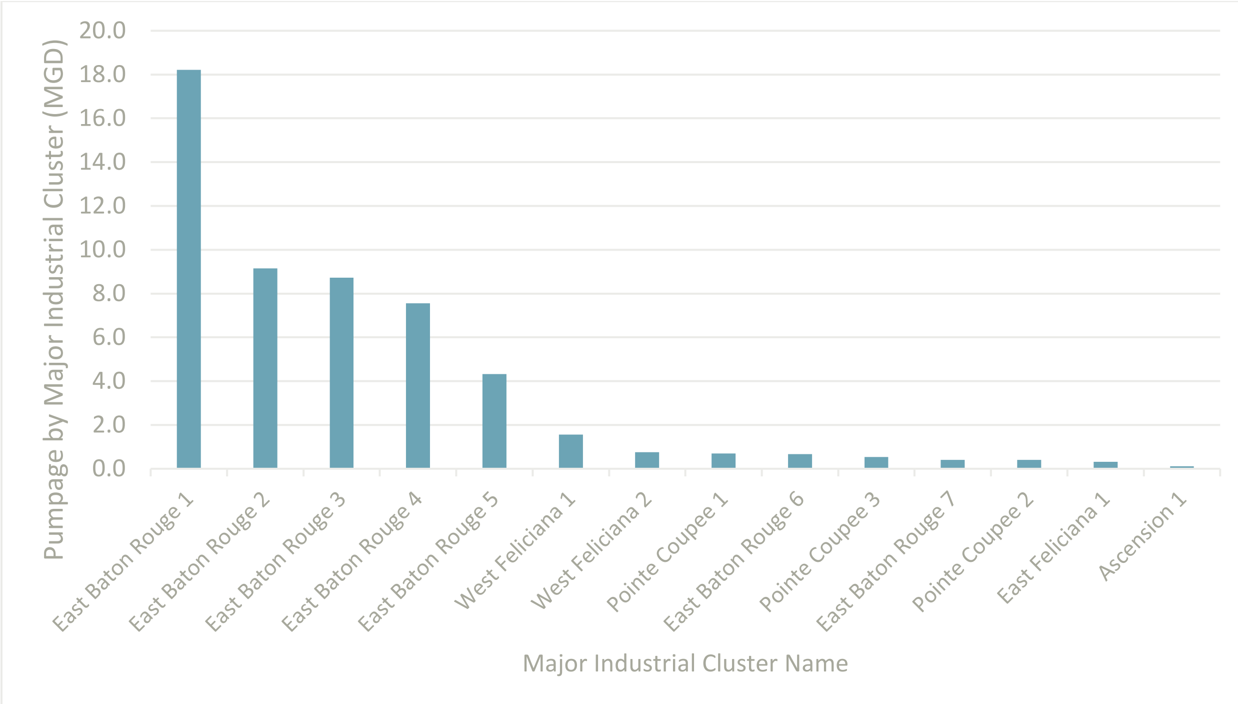


Figure 74. Distribution of total aggregated groundwater pumpage by identified major industrial clusters, as reported across the CAGWCD in 2020.

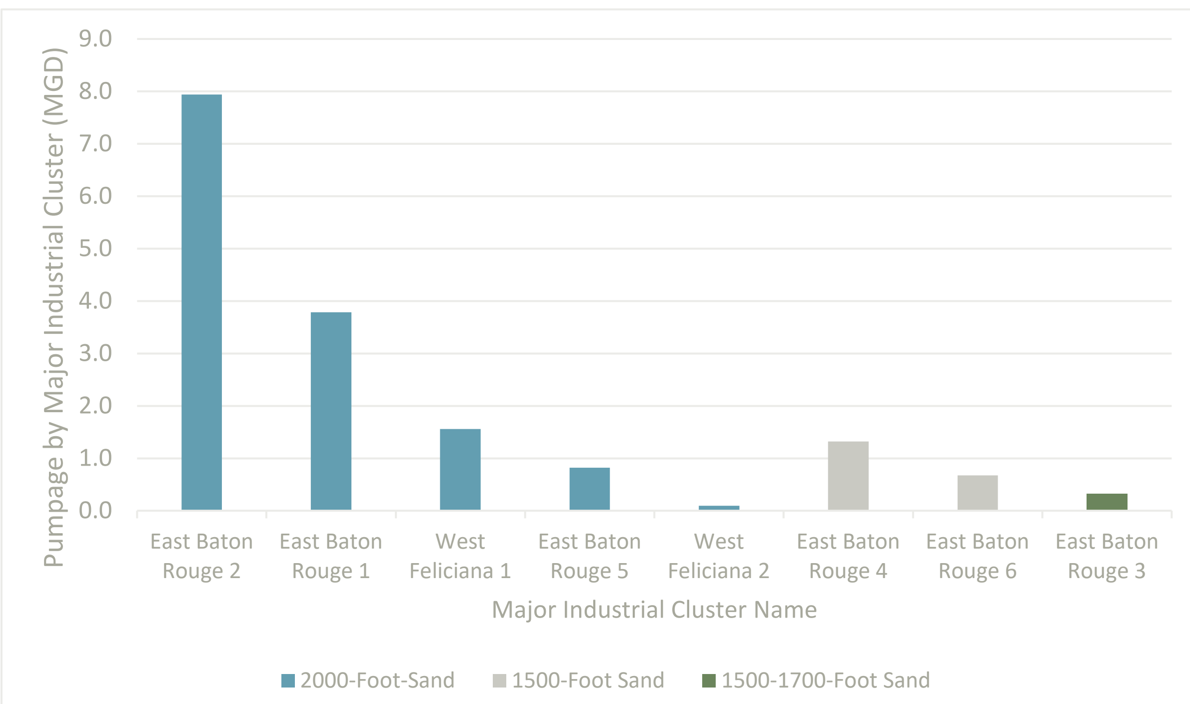


Figure 75. Distribution of aggregated groundwater pumpage from primary sand layers of concern in the SHAS (1500-foot and 2000-foot sands) by identified major industrial clusters, as reported across the CAGWCD in 2020. Note: only 8 of the 14 identified major industrial clusters produce groundwater from these sand layers.

The categorization of "industrial" facilities was consistent with the demand analysis in Task 2A.3, and included those in the CAGWCC records as corresponding with industrial, power generating, and correctional institution facilities.

Overall, the combined pumpage from the facilities in these clusters encompassed over 99 percent of the overall pumpage in the SHAS and pumpage from the primary sand layers of concern by industrial entities reported to CAGWCC. The Industrial District of Baton Rouge contains several industrial facilities with wells that produce a significant volume of water. Rather than evaluating the Industrial District as one large industrial cluster, geographic boundaries (streams, roads) were used to divide the Industrial District into multiple clusters of adjacent facilities. This allowed for evaluation of project size intervals that could be applied across the CAGWCD parishes.

In general, the groundwater volumes produced from these industrial clusters indicate project sizing between approximately five and 20 MGD would be reasonable for meeting either some or all water demand at one or more industrial sites. Institutional sites, which are considered for some projects, would likely support smaller project concepts. It should also be noted that demand centers vary not only in demand volume but also in potability requirements. Due to a limited number of detailed responses to the Industrial Water User Survey, sufficient data are not available at this time to partition industrial demands into clear potable and non-potable categories. Project analyses for this study therefore do not apply produced water type as a limiting factor in project sizing.

In addition to demand, source availability influences the practical size of a project due to the need for future sources to maintain a high degree of reliability. Source availability can vary widely by source type, and in some cases may require detailed study to quantify. For the project analyses for the Phase 2 study, source availability was considered in a general context based on available data, and in cases of higher uncertainty project sizing was generally limited to five or 10 MGD.

ESTIMATING COSTS ASSOCIATED WITH PROVIDING SUPPLEMENTARY WATER SUPPLIES

Costing Tool and Key Assumptions

To facilitate the economic analyses, a planning-level costing tool has been developed to estimate capital and life-cycle costs for potential project alternatives. An example of the summary output table generated by the tool is shown in condensed form in Figure 76. The tool is intended to develop planning-level cost estimates in a consistent manner for alternative water supply options rather than extremely fine-scale listings and costs for all minor valves, fittings, and other project appurtenances. However, it is also intended to be robust and reasonable, with costing of infrastructure components adapting methodologies and extensive actual bid tab data from the Texas Water Development Board Unified Costing Model (HDR & Freese and Nichols, 2018). The tool was also designed to allow flexibility, with many parameters such as energy costs, per-acre land cost, loan durations, and interest rates capable of being user-adjusted to capture local considerations. Values from reference cost tables were escalated to October 2021 cost indices to estimate costs in an approximately current context. It should be noted that detailed economics and the behavior of materials markets are not readily predictable, and future changes in project economics could future influence cost. Major cost components examined through the tool include:

- Capital Costs
    - Construction costs for infrastructure including intakes, pump stations, pipelines and pipeline crossings, tanks and impoundments, production or injection wells, various levels of water treatment and wastewater treatment, as well as other components.
    - Engineering, financial, and legal services and contingency costs associated with designing, permitting, and developing projects.
    - Purchase of land or easements for infrastructure components, along with associated survey costs.
    - Environmental studies and mitigation.
    - Interest accrued during construction, particularly for large projects or those with an anticipated long construction timeline.
- Annual Costs
    - Debt service on project funding, calculated based upon anticipated repayment terms and interest rates.
    - Annual operations and maintenance costs for each infrastructure component, with associated cost rates varying by component type.
    - For projects with pumping facilities, energy costs estimated based on electric rates, facility size, pipeline properties, and anticipated water supply volumes.
    - The purchase cost of source water where applicable.

Planning-Level Project Cost Estimate					September 2021
STRATEGY:	***EXAMPLE PROJECT***				

PROJECT CAPITAL COST SUMMARY

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	CONSTRUCTION COST	1	LS	$4,154,828	$4,154,828
2	ENGINEERING, FINANCIAL, AND LEGAL SERVICES AND CONTINGENCIES	1	LS	$1,432,657	$1,432,657
3	LAND AND EASEMENTS	1	LS	$568,920	$568,920
4	ENVIRONMENTAL - STUDIES AND MITIGATION	1	LS	$25,000	$25,000
5	INTEREST DURING CONSTRUCTION	1	LS	$344,925	$344,925
	PROJECT CAPITAL COST				**$6,526,330**

ANNUAL COST SUMMARY

ITEM	DESCRIPTION	ANNUAL TOTAL
1	DEBT SERVICE (20 YEARS AT 3.5% INTEREST)	$459,200
2	OPERATION AND MAINTENANCE (O&M)	$56,160
3	PUMPING ENERGY COSTS	$13,239
	TOTAL ANNUAL COST - DURING DEBT SERVICE	**$528,598**
	TOTAL ANNUAL COST - AFTER DEBT SERVICE	**$69,399**

UNIT COST SUMMARY

ITEM	DESCRIPTION	ANNUAL TOTAL
1	ESTIMATED YIELD (ACRE-FEET PER YEAR)	1,120
2	ANNUAL COST - DURING DEBT SERVICE	$528,598
3	ANNUAL COST - AFTER DEBT SERVICE	$69,399
	TOTAL UNIT COST DURING DEBT SERVICE ($ PER ACRE-FOOT PER YEAR)	**$472**
	TOTAL UNIT COST AFTER DEBT SERVICE ($ PER ACRE-FOOT PER YEAR)	**$62**

CONSTRUCTION COST SUMMARY

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	PUMP STATIONS	1	LS	$974,100	$974,100
2	PIPELINES	1	LS	$430,667	$430,667
3	WATER STORAGE TANKS	1	LS	$1,014,732	$1,014,732
4	OTHER	1	LS	$1,735,329	$1,735,329
	PROJECT COST				**$4,154,828**

OPERATION AND MAINTENANCE (O&M) COST SUMMARY

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
1	PUMP STATIONS	2.5	%	$974,100	$24,353
2	PIPELINES	1.0	%	$430,667	$4,307
3	WATER STORAGE TANKS	1.0	%	$1,014,732	$10,147
4	OTHER	1.0	%	$1,735,329	$17,353
	ANNUAL OPERATION AND MAINTENANCE COST				**$56,160**

Figure 76. Example planning-level costing tool condensed summary output.

Major components considered by the costing tool and generalized methods applied are summarized in Table 5 and Table 6. Note that not all available tool components apply to the projects as currently conceptualized for the study but could provide value in future studies as available data are refined.

Table 5: Capital cost components

Parameter	Costing Methods and Considerations
Pump stations	Estimated required horsepower, with separate reference data for intake and booster pump station types.
Pipelines	Length, calculated diameter for target flow rate, urban or rural setting, and soil or rock subsurface.
Pipeline crossings	Length, calculated diameter for target flow rate, soil or rock subsurface, and tunneling or directional drilling methods.
Water treatment plants	Capacity and treatment method (disinfection, groundwater, direct filtration, conventional [surface water], brackish groundwater, or seawater)
Advanced water treatment facilities	Capacity and advanced treatment methodology
Wastewater treatment plants	Capacity and treatment method (Disinfection, tertiary, secondary + tertiary, membrane)
Water storage tanks	Calculated volume for target hours of storage, tank type (ground storage with roof, ground storage without roof, or elevated storage)
Dams and reservoirs	Estimated storage volume
Off-channel reservoirs	Estimated storage volume
Stilling basins	Estimated cubic feet per second capacity required
Well fields	Well type (public supply, irrigation, ASR, or injection), capacity, and depth
Relocations	Project-specific for more detailed tool applications
Other	Project-specific components for more detailed tool applications
Engineering, financial, and legal services and contingency	Percentage of physical infrastructure cost, varying by component types
Land and easements	Estimated by major physical component, considering setting, whether sites are owned, and applying a percentage cost for survey
Environmental studies and mitigation	Based upon land and easement area, with separate considerations for pipelines and other components
Interest during construction	Calculated from other capital costs, development duration, and interest and discount rates

Table 6: Annual cost components

Parameter	Costing Methods and Considerations
Debt service	Calculated for estimated debt term (based on project type) and interest rate
Operations and maintenance	Calculated as a percentage of capital cost by major infrastructure component
Pumping energy	Estimated pumping rate, duty cycle, and unit energy cost
Purchase cost of water	Project-specific assumption based on available seller data

Key assumptions applied to project cost estimation are summarized in Table 7 through

Table 9. Additional project-specific details are included in the Technical Memoranda in Appendix G.

Table 7: Major Cost Estimation Assumptions (Basic Parameters) Adapted from HDR Engineering and Freese and Nichols, Inc (2018) using expert judgement.

Costing Parameters		Assumption
Basic Parameters	Build time (months)	12-24
	Engineering - Pipelines (% of infr. cost)[1]	30
	Engineering - Other (% of infr. cost)[1]	35
	Debt term (years)[2]	20
	Loan rate (%)	3.5
	Interest During Construction - Interest Rate (%)	3
	Interest During Construction - Return Rate (%)	0.5
	Urban land cost ($/ac)[3]	$435,600.00
	Energy cost ($/kw-h)	$0.08
	Pump connection cost ($/HP)	$150.00
	Environmental - Pipeline ($/mile)[4]	$25,000.00
	Environmental - Other	100% of land cost
	Survey - Reservoir	N/A
	Survey – Other[5]	10% of land cost
	Water purchase cost ($/ac-ft)[6]	$0.00

1. Includes estimated cost for engineering, financial, and legal services, and contingency. Capital cost for this category is estimated as a percentage of associated physical infrastructure cost.
2. Costing analyses for the study assume that the project sponsor(s) utilize loan programs to assist in financing the project.
3. Conceptual project development within the study area is anticipated to be associated with urbanized settings and/or highly developed industrial aggregations
4. Includes estimated cost for environmental studies and mitigation. For non-pipeline components, this is estimated as a percentage of associated land cost, including equivalent cost for project development acreage not requiring purchase.
5. Survey cost for development of non-reservoir survey components is estimated as a percentage of associated land cost, including equivalent cost for project development acreage not requiring purchase.
6. This component is assumed to be zero for the strategy analyses for this study.

Table 8: Major Cost Estimation Assumptions (Infrastructure) Adapted from HDR Engineering and Freese and Nichols, Inc (2018) using expert judgement.

Costing Parameters		Assumption
Wells	Max well size before new site (gpm)	1,800
	Spacing (ft)	1,320–2,640
	Duty cycle (%)[1]	80 (100 for ASR)
	Peaking Factor[1]	1.5 (1.0 for ASR)
	Wire to water efficiency (%)	80
	Residual pressure (psi)	50
	Land per well (ac)	0.5
	Requires land purchase?	No
Treatment	Peaking Factor	1.5
	Land per MGD capacity	0.5
	Requires land purchase?	No
Storage	Storage type	Ground Storage w/ Roof
	Volume	4 hrs at peak
	Max tank size before new tank (MG)	2
	Land per tank (ac)	1
	Requires land purchase?	No
Pump Station and Pipeline	Intake?	No
	Duty cycle (%)[2]	80-100
	Land per site (ac)	5
	Peaking Factor	1.5 (1.0 for ASR)
	C Factor	120
	Wire to water efficiency (%)	70
	Elevation change (ft)	0 (70 for river water)
	Residual pressure (psi)	50
	Easement width (ft)	50
	Crossings and relocations?[3]	No
	Requires land purchase?	No
1. Proposed parameters for aquifer storage and recovery (ASR) assume injection well and pipeline operation at a high duty cycle and constant rate during high source water flow events.		
2. For the project, surface water pump stations are assumed to operate at a high overall duty cycle. Individual pump units within the station would be expected to have some degree of down time.		
3. Infrastructure crossings and relocations are be assumed to be zero for the strategy analyses for this study.		

Table 9: Major Cost Estimation Assumptions (Operations and Maintenance Factors) Adapted from HDR Engineering and Freese and Nichols, Inc (2018) using expert judgement.

Parameter	Annual O&M % Factor[1]
Pump stations	2.5
Pipelines and crossings	1
Water or wastewater treatment	Varies[2]
Water storage tanks	1
On and off-channel reservoirs	1.5
Stilling basins	1
Well fields	1
Other	1
Pump stations	2.5
Pipelines and crossings	1
Water or wastewater treatment	Varies[2]
Water storage tanks	1
On and off-channel reservoirs	1.5

1. Annual operations and maintenance (O&M) costs are estimated by multiplying the construction cost of a component type by an assumed O&M factor.
2. O&M costs for treatment facilities vary with treatment type, level, and capacity.

Evaluating a Status Quo Scenario as Context for Project Costs

The planning level costing tool, used to develop estimates of existing groundwater costs, was adapted to calculate the future cost of industrial groundwater supplies for major groundwater users in the CAGWCD if groundwater usage continued at current rates. These estimates were labeled as “status quo” costs since they represent a portion of the potential future cost to industry if groundwater production in the traditional local source sand layers were to remain the same. The 2013 report prepared by the USGS on the “Simulation of Groundwater Flow in the “1,500-Foot” Sand and “2,000-Foot” Sand and Movement of Saltwater in the “2,000-Foot” Sand of the Baton Rouge Area, Louisiana” (Heywood & Griffith, 2013) created a groundwater flow and saltwater transport model to assess the migration of the saltwater plume created by groundwater withdrawals in the Baton Rouge area. The 2013 USGS study determined that the plume extends beyond the Baton Rouge Fault and is encroaching on industrial wells located 3 miles north of the fault, which include the southernmost industrial clusters. The industrial water users within these clusters were used in the future cost estimates to determine the predicted cost of treatment for saltwater intrusion.

The status quo cost estimates were developed at the individual water user level for each of the entities located within the general proximity of the predicted expanding saltwater plume. The status quo cost estimates utilized the same assumptions as the existing groundwater cost estimates, however, only operations and maintenance (O&M) costs for treatment of groundwater were accounted for in the costing tool; pumping costs were not accounted for. O&M costs for treatment of future groundwater supplies were estimated using the same maximum capacity (MGD) of each facility as used in the existing cost estimates, which was calculated for each entity by taking the maximum annual groundwater pumpage of that entity over the last 10 years (2011 through 2020). For each required treatment (e.g., disinfection, iron/manganese removal and disinfection, direct filtration, etc.), brackish groundwater desalination was used as the necessary future treatment in order to account for the predicted increased salinity of the groundwater. Additionally, the level of total dissolved solids (TDS) for water treatment was assumed to be 1,000 mg/L due to the saltwater plume. With the O&M cost of treated groundwater added into the costing tool, the future annual cost and project capital costs were calculated for each owner.

The annual cost produced by the status quo costing tool was then adjusted to account for the estimated existing O&M costs that are already paid by the entities. This adjustment was done by taking the existing O&M cost of each entity, which accounts for the estimated current water treatment O&M and pumping energy costs, and subtracting it from the future annual cost value produced by the status quo costing tool.

Summary of Estimated Concept Costs

The estimated project capital costs for the concepts examined here are presented in Figure 77, with annual costs illustrated in Figure 78. Annual costs for debt service are estimated for a 20-year debt term and would therefore contribute to a higher unit water cost during the initial two decades of project lifespan, after which annual costs would decrease to the amounts for energy and O&M, along with any purchase cost of water (assumed to be zero for this study). Long-term O&M costs are shown in solid shading in Figure 78, with debt service in semitransparent shading. Capital and annual unit costs for the Status Quo Scenario for an example impact area of industrial aggregations near Interstate 10 are also included for comparative purposes. Estimated composite unit costs for a hypothetical 50-year project lifespan are shown in Figure 79. Detailed unit cost and performance metrics for the Status Quo Scenario are not included in the analysis as calculated values are facility specific, and a Status Quo approach ultimately would have a cascading cost as continued production would draw increasingly saline supplies not only toward producing industries but also surrounding industries and municipalities Additional project-specific details are included in the Technical Memoranda in Appendix G.

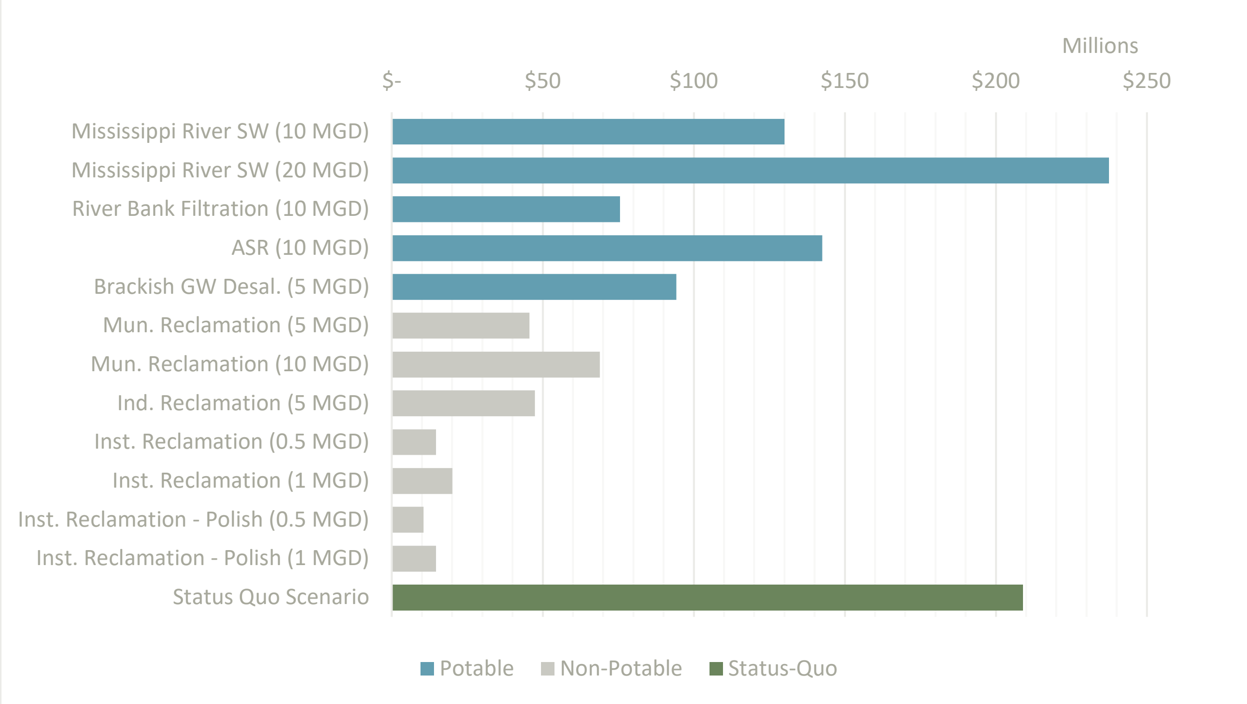


Figure 77. Estimated project concept capital cost in millions of dollars (October 2021 cost index). Potable and non-potable categories are included to cover varying water quality requirements for different uses.

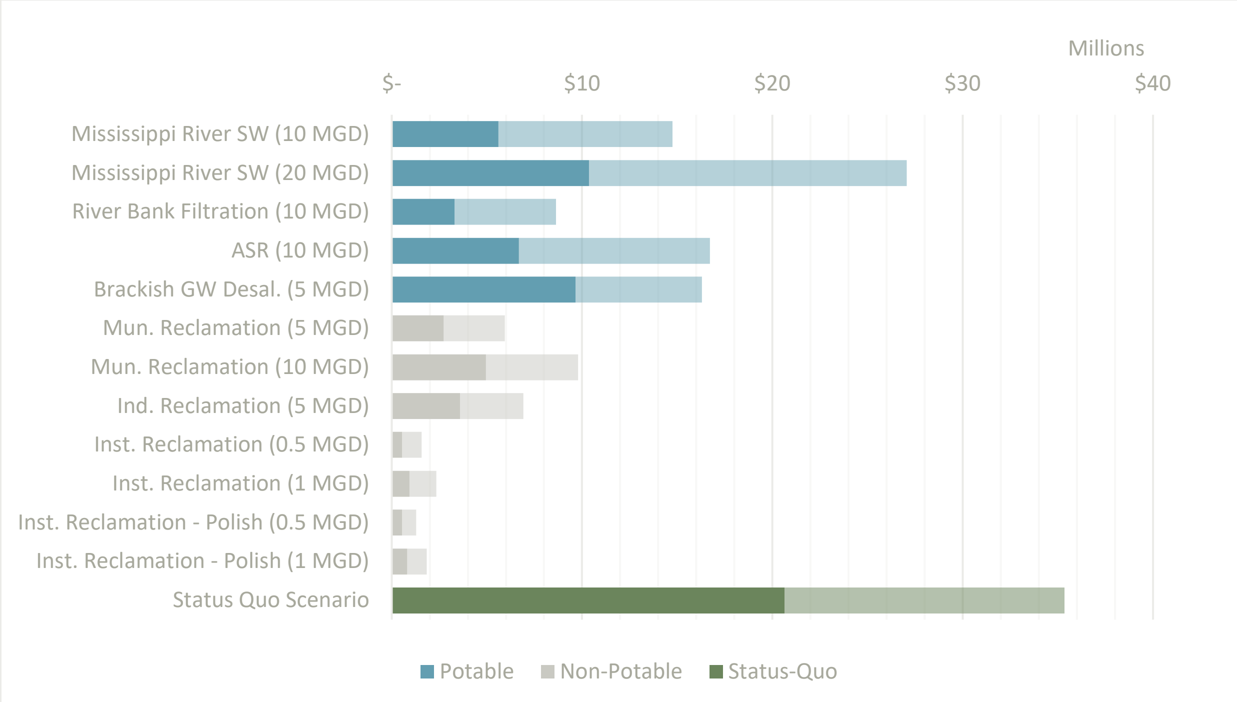


Figure 78. Estimated project concept annual cost in millions of dollars per year (October 2021 cost index). Solid shading reflects energy and operations and maintenance components, with debt service shown in semitransparent shading. Potable and non-potable categories are included to cover varying water quality requirements for different uses.

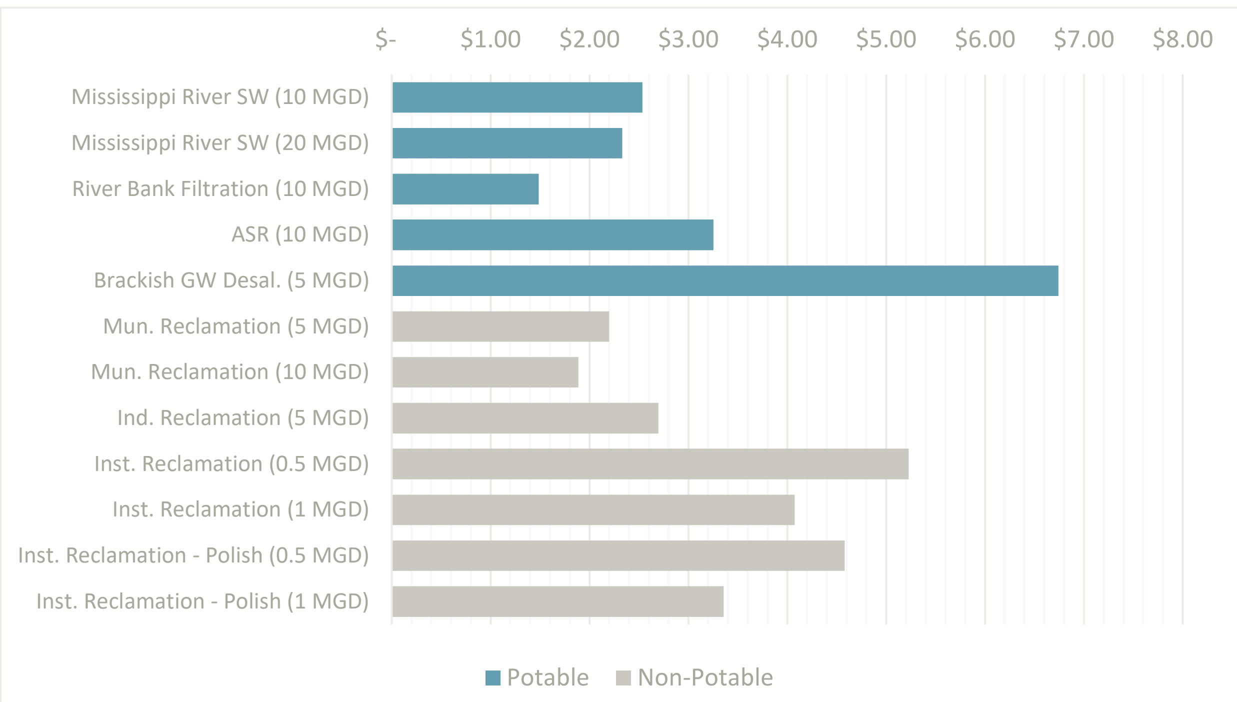


Figure 79. Estimated project 50-year composite unit cost in dollars per 1,000 gallons (October 2021 cost index).

In examining these costs both individually and comparatively, there are several key considerations to keep in mind. As noted previously, project concepts are envisioned and examined at a planning level, and site-specific considerations could impact cost dynamics. It is also of note that costs in this analysis are presented for a reference month of October 2021. National and international economic drivers and materials markets are prone to fluctuations which cannot always be accurately predicted and present a source of uncertainty regarding the cost of project development in the future. Costs presented for the study are examined in the context of each independent project. In real-world implementations, these supplemental supplies could be integrated with other supplies held by an entity and thus contribute to an overall system water rate; however, due to the need for strategy-specific evaluation and comparison and a lack of detailed information on existing water cost, an examination of potential combinations of existing and new supplies and the resulting costs was not conducted.

Estimating the Current Cost of Industrial Water Supply

Available data from the Industrial Water User Survey and identified assumptions and supplemental data were utilized to estimate the current cost of industrial water supplies. This information, in conjunction with planning-level estimates of potential future project costs, is a key component in evaluating Performance Metric 3 (water supply and cost for industry) and characterizing the cost of future supply concepts and portfolios relative to current supplies. Due to the focus of the study on regional or sub-regional supply opportunities and the desire to maintain industrial stakeholder data confidentiality, project analyses are presented for general aggregations of water users rather than for individual facilities or water users, with the level of aggregation reflective of the quantity and level of detail of local stakeholder data available.

The Industrial Water Use Survey in Task 2A.3 yielded limited, highly variable responses regarding the current unit cost of on-site treatment for water sources (groundwater, surface water, etc.) for industry. This precluded the ability to directly use survey information to develop an aggregated cost estimate of industrial water supplies across the CAGWCD. Nevertheless, the survey data that was received provided some data regarding existing water use, important water quality parameters, and cost of water treatment for specific facilities, which could be used to infer treatment quality and costs for these entities and other industrial users in similar subcategories.

Due to the limitations of the Industrial Water Use Survey data, an alternative approach was used to estimate the current cost of industrial water for the Performance 3 Metric evaluation. This alternative approach involved leveraging existing data with available tools to estimate the two fundamental components of a treated water supply unit cost: (1) the annual cost to retrieve and treat the water; and (2) the volume of treated water produced. To estimate the first component (annual cost), existing information on groundwater wells from CAGWCC and LDNR SONRIS, such as historical pumpage, location, depth, and specific capacity, were used in conjunction with the planning-level costing tool used for the strategy concepts, to develop estimates of annual costs that major industrial groundwater users in the CAGWCD pay to develop treated groundwater on an individual, facility level basis. To estimate the second component (volume), historical groundwater well pumpage data (2010 through 2020), used in the demand evaluation analysis in Task 2A.3, were compiled by well owner to estimate the average groundwater production by industrial facility. These two components were used to estimate individual unit costs by major industrial facility and were then aggregated to estimate a composite unit cost of current industrial water supply for the CAGWCD. More detailed discussion of this approach is included in the following subsections.

The focus of this alternative approach was specifically limited to groundwater, rather than other sources, due to lack of facility level industrial water use data from other sources, as shown in Task 2A.3, and lack of costing information for these sources. Furthermore, honing this estimate toward groundwater is in line with the overall focus of Commission's fundamental objectives to maintain sustainable use and maximize the heath of groundwater in the SHAS.

Multiple existing datasets were used to obtain information used in the approach to estimate a current cost of industrial water. The CAGWCC database provided data for individual wells, such as well numbers, current owner or entity names, well depths, use categories (industrial, public supply, etc.), aquifer codes (geologic unit), and annual pumping data from 1975 through 2020. The LDNR SONRIS Well Registration database was primarily used to identify well latitude and longitude locations. However, it was also used to obtain additional well information or fill in any gaps in the CAGWCC database for information, such as the well status (e.g., plugged vs active), well depth, aquifer codes, and well specific capacity (reported as "yield" on well application to the LDNR). If data from the CAGWCC database and LDNR SONRIS database conflicted, the CAGWCC database was used. As discussed in Task 2A.3, the Industrial Water Use Survey provided locations and current water usage by source (groundwater, surface water, purchased water, etc.) for 16 industrial facilities in the CAGWCD. This information was used to verify the total current groundwater use estimated for these facilities.

The historical pumping data from the CAGWCC database was used in conjunction with the LDNR SONRIS Well Registration database and Industrial Water Use Survey from Task 2A.3 to estimate recent annual average industrial groundwater usage (2010 through 2020) by individual industrial entities across the CAGWCD. In addition to pumping data, these sources were used to obtain individual well parameters that could be input into the planning-level costing tool to estimate current costs to develop treated water by individual entities. Well data were filtered to include industrial production wells. The categorization of "industrial" wells was consistent with the demand analysis in Task 2A.3, e.g., pumpage of wells classified as industrial in the CAGWCC database, in addition to pumpage from power generation facility and correctional institution wells. The owner or entity names identified in the CAGWCC database were assumed to represent the most up to date ownership of wells and were used as a uniform source to identify which groundwater wells and pumpage were associated with an industrial entity. This information was used to compile the groundwater use by individual industrial entities.

The planning-level costing tool, used to develop estimates for potential project alternatives, was leveraged to develop estimates of the current costs of industrial groundwater supplies for major groundwater users in the CAGWCD. Costs were evaluated at the individual owner/entity level in order to provide the most accurate representation of the cost of industrial water supply at a finer scale. Since water infrastructure (pipelines, wells, water treatment facilities, pump stations, storage, etc.) at these individual facilities are already in place, this analysis focused solely on evaluating annual costs associated with developing treated groundwater at these facilities, which includes annual O&M of water treatment facilities and wells and pumping energy costs from individual wells.

Of the total number of industrial groundwater users across the CAGWCD, most of the current total reported pumpage is conducted by a select number of major industrial entities. To focus this analysis on those major entities, cost estimates for individual entities were limited to owners that have recently produced groundwater above a certain threshold. In this analysis, the top producing industrial owners in the CAGWCD were identified by calculating the most recent 10-year (2011 through 2020) average pumpage by entity. Entities were selected for this costing analysis based on the average annual pumping threshold of 50,000 gallons per year. In all, 22 industrial entities met this threshold. These 22 entities comprise approximately 99 percent of the annual industrial groundwater pumpage reported in the CAGWCC database.

The study costing tool was adapted to estimate current groundwater costs for these top 22 industrial groundwater users, scaled to an October 2021 cost index. Pumping energy costs were assumed to be $0.08 per kWh. Land was not accounted for in the cost estimates, assuming that all land was previously purchased and owned by these entities. Additionally, the costing tool did not account for energy costs of infrastructure types other than pumping from wells (e.g., transmission pipelines, storage, pump stations, etc.), as the focus of this analysis was to assess the cost of developing treated water, which precludes any distribution.

Individual information on active wells for each of the industrial owners assessed were input into the planning-level costing tool to develop estimates of O&M and pumping energy costs of the well system for each owner. A few key assumptions were applied to constrain the current cost estimates to include only active wells that contribute to recent groundwater pumpage by the major industrial entities:

- If an owner had not used a well over the last 10 years (e.g., there was no pumpage reported since 2010), then it was assumed that the well was out of service and was not accounted for in the current groundwater cost estimates.
- If an owner had not used a well over the last five years (e.g., there was no pumpage reported since 2015) and the well was designated as "Plugged and Abandoned," "Abandoned," "Inactive," or "Destroyed" in the LDNR SONRIS database, then it was assumed that it was out of service and was also not accounted for in the current groundwater cost estimates.
- If a well was located in a parish other than the parish in which the majority of wells owned by an entity were located, then the well was excluded from the current groundwater cost estimates.
- Otherwise, any active industrial production wells that have pumped over the last 10 years were included in the current groundwater cost estimates.

The planning-level costing tool requires five well parameter inputs to estimate groundwater well O&M and pumping energy costs: well maximum capacity (gpm), depth, type, wire-to-water efficiency, and a well peaking factor (e.g., peak flow over average flow). The input for well maximum capacity was calculated using the maximum value between the historical pumpage reported in CAGWCC records (1975 to 2020) and the specific capacity (yield) reported by SONRIS. The depth for each well was based on the reported depth in the CAGWCC database, in conjunction with the data from SONRIS where it was not available in the CAGWCC database. For well type, the planning-level costing tool does not specifically include an industrial well type. Instead, a public supply well type was used as a more conservative cost estimate, as opposed to other well types built into the tool (e.g., ASR, irrigation, or injection well types). An 80 percent wire-to-wire efficiency was selected based on standard cost assumptions for wells used for the strategy concept. Well energy costs account for average pumping. The average pumping for energy costs was calculated by dividing the well capacity by a peaking factor. This peaking factor was calculated for each well by dividing the inputted maximum well capacity by the average non-zero pumpage over the last 10 years (2011–2020), providing a ratio of the maximum flow to the average 10-year flow. These well parameters were input into the costing tool to estimate the cost of O&M and pumping energy for individual wells owned by an industrial entity, which the costing tool could compile into a total composite cost for all wells owned by an entity

O&M costs for treatment of groundwater supplies were also estimated in the costing tool for each of the major industrial groundwater users. To estimate O&M costs for water treatment, the costing tool requires two inputs: the maximum capacity (MGD) of the facility and the treatment type (disinfection, iron/manganese removal and disinfection, direct filtration, etc.). Maximum treatment capacities were estimated for each entity by calculating the maximum annual groundwater pumpage by that entity over the last 10 years (2011 through 2020). The Industrial Survey was used to estimate the treatment type needed for groundwater for individual users, where applicable. Treatment levels designated by a respondent in a specific industrial subcategory were assumed to be applicable to other entities in that same subcategory. For example, if a survey respondent was in the pulp and paper industrial subcategory and designated a treatment quality needed for their water supply, then that same treatment quality level was assigned to entities in the same subcategory. For most entities, as a conservative estimate, iron/manganese removal and chlorine disinfection were assumed to be appropriate to treat existing groundwater supplies. Direct filtration treatment was assumed for electric generating facilities. The costing tool also has an option to adjust for the level of total dissolved solids (TDS) for water treatment. If a respondent provided information on existing TDS levels of their groundwater, adjustments were made to the O&M cost estimates for treatment.

The total O&M and pumping energy costs for current water treatment and wells per entity, generated with the planning-level costing tool, were used to calculate a total annual cost per entity. The total annual cost per entity was divided by the 10-year (2011 through 2020) non-zero, average groundwater pumpage by that entity to calculate a total unit cost per entity. The unit cost per entity was multiplied by the total pumpage per owner over the last 10 years and summed to produce an aggregated 10-year cost. This total 10-year cost was divided by the sum of the total pumpage of all owners over the last 10 years to produce a volume- weighted, composite unit cost of current industrial groundwater across the CAGWCD parishes. This composite unit cost was calculated to be $1.05 per 1,000 gallons.

This composite unit cost represents an estimate of the CAGWCD-wide cost to develop treated industrial water supplies, which was compared to the unit cost of the strategy concepts in order to assess Performance Metric 3 (cost to industrial users). Ultimately, the true cost of treated water supply for individual facilities across the CAGWCD parishes could be lower or higher than estimated costs presented in this report. Responses to the Industrial Water Use Survey regarding the current cost to produce treated water supply (as of December 2021) ranged from $0.02 to $7.00 per 1,000 gallons. The composite unit cost calculated in this analysis falls within this range. As more information on treatment needs and costs for water supplies is obtained by CAGWCC, this estimate can be used to further refine the assumptions and methods built into this estimate.

Performance Metric 3 Evaluation for Individual Supply Concepts

The Fundamental Objectives and Performance Metrics sections of the Phase 2A study report provide an overview of the long-term strategic planning objectives identified by the CAGWCC and the associated performance metrics established to evaluate alternatives through consistently applied and meaningful quantitative or qualitative procedures. As noted in these sections, Performance Metric 3 is based upon a composite unit cost of water for industrial users and is intended to help characterize the ability of potential alterative water supply concepts to support management of the aquifer to maximize long-term availability of clean and inexpensive water to industry and commercial entities.

As explained in greater detail in the Performance Metrics section of this report, Performance Metric 3 is calculated as a ratio of the composite unit cost for a project concept (or portfolio of concepts) to the estimated current cost of producing and treating water supply for industry (Equation 8). The analyses of estimated project concept costs and existing industrial groundwater costs therefore provide the necessary inputs to evaluate Performance Metric 3 for the individual project concepts and concept size variants examined in this study. Resultant values for evaluating Performance Metric 3 for a 50-year hypothetical project life cycle are summarized in Figure 80.

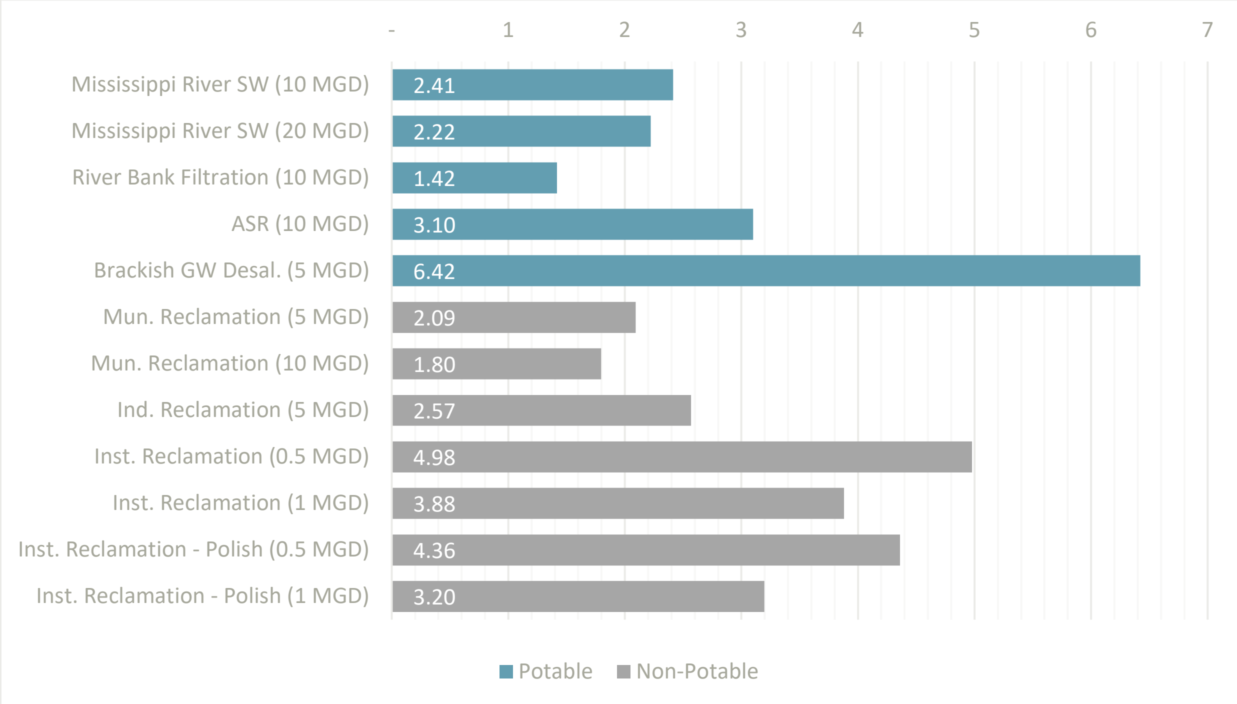


Figure 80. Estimated project 50-year composite Performance Metric 3 cost ratios. Performance Metric 3 reflects a ratio of estimated project cost to estimated current industrial water supply cost (top axis). Higher values correspond to greater long-term costs relative to current supplies and other supply concepts with lower values.

In examining the results shown in Figure 80 both in terms of individual project concepts and comparatively among concepts, it is important to view Performance Metric 3 values in context, including that the various options produce differing supply types and for a range of purposes. Treated surface water projects could meet the majority of water demand types in the area, and generally have relatively low cost ratios. Brackish groundwater desalination shows the highest estimated ratio, but also would be expected to produce a very high-quality treated supply. The use of brackish groundwater desalination may provide an option for more isolated locations where other solutions could be impractical. Therefore, a high cost ratio alone should not be the only parameter to consider to classify an option as inapplicable. Municipal and industrial reclamation projects generally display moderate factors for the analysis but would produce non-potable supplies which may not be suitable for all users but that may be viable options for some industrial aggregations. The cost ratios for institutional effluent reclamation are higher than the other reuse options due in large part to limitations on economy of scale for a small facility size, but also offer potential social benefits that cannot be directly captured in a cost ratio analysis.

As shown in Figure 80, all project concepts have cost ratios greater than 1.0, and thus all have an estimated long-term unit cost exceeding the current estimated cost of groundwater. This outcome is to be reasonably expected, given the ability of existing groundwater to be produced by existing and largely already funded infrastructure, along with the historical high quality of groundwater available within much of the CAGWCD parishes. However, saltwater intrusion toward major industrial aggregations is ongoing, and if it continues unabated there will be a downgrade in groundwater quality and subsequent increase in treatment cost in order to maintain use of current groundwater formations.

Supply Concept Portfolios

The magnitude and complexity of water demands, and in particular industrial water demand, within the CAGWCD suggest that future supply diversification may not revolve around a single project or project type, but rather lead to a regional suite of various supply types to meet these diverse needs. For this reason, it is useful to examine project economics and Performance Metric 3 factors not only in the context of individual projects, but also in terms of potential project portfolios. Because a long-term sustainable regulatory limit on groundwater production has not yet been established for the sand layers in the CAGWCD and due to a lack of detailed data on proportions of potable and non-potable water needs for industry, the supply concept portfolio evaluation for this study utilizes a representative portfolio size of 20 MGD, with portfolios structured to examine a range of projects and treated supply percentages. Table 10 summarizes the portfolios considered for the study, the percentage of potable supply generated, and the constituent projects. Note that the portfolios do not include institutional effluent reclamation projects, which would generate relatively small supplies individually, but could be integrated with any of the portfolios and as previously noted have potential for considerable non-supply benefits.

Table 10: Supply concept portfolio composition

Portfolio	% Potable	Mississippi River SW (10 MGD)	Mississippi River SW (20 MGD)	River Bank Filtration (10 MGD)	ASR (10 MGD)	Brackish GW Desal. (5 MGD)	Mun. Reclamation (5 MGD)	Mun. Reclamation (10 MGD)	Ind. Reclamation (5 MGD)
1. Surface Water	100		✓						
2. Surface Water w/ Mun. Effluent and Brackish GW	75	✓				✓	✓		
3. Surface Water and Municipal Effluent	50	✓						✓	
4. Bank Filtration and Municipal Effluent	50			✓				✓	
5. ASR and Municipal Effluent	50				✓			✓	
6. Surface Water and Mixed Effluent	50	✓					✓		✓

Composite unit costs were calculated for each portfolio for a 50-year hypothetical project lifespan based on the costs and volumetric contribution of each project in the portfolio. These composite portfolio costs were then compared against estimated existing groundwater costs to generate Performance Metric 3 factors as summarized in Figure 81.

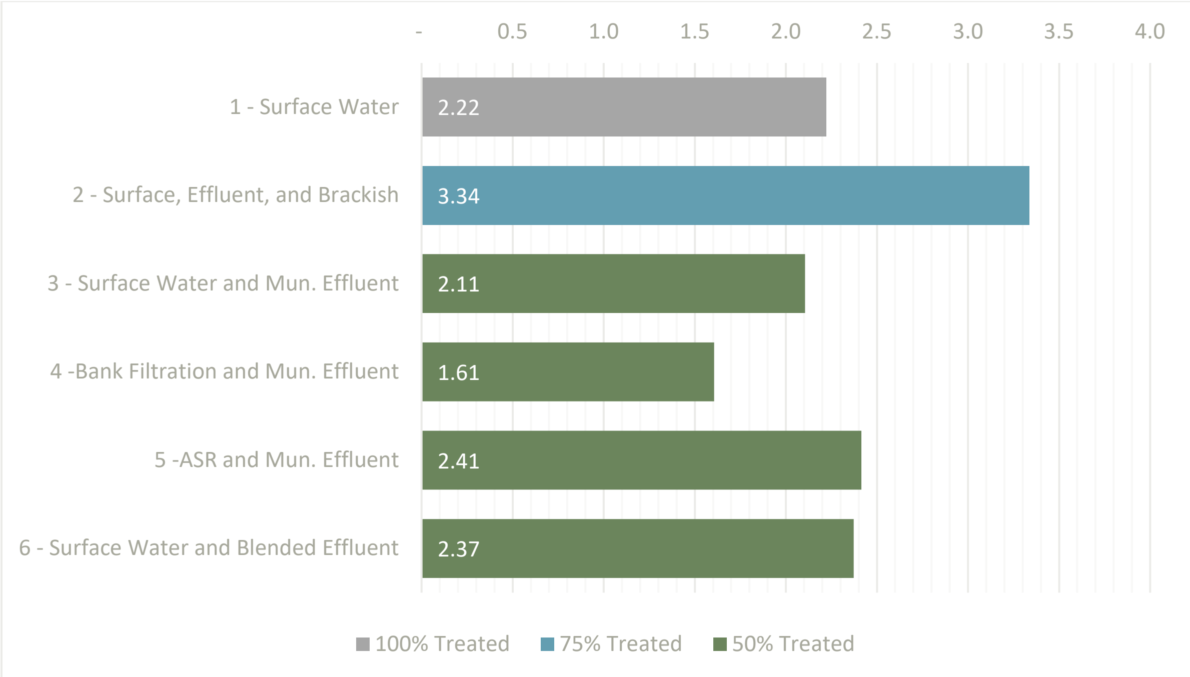


Figure 81. Estimated project portfolio 50-year composite Performance Metric 3 factors. Portfolios categorized as 100% Treated include only project concepts generating treated potable water supply. The 75% Treated category includes portfolios with 25 percent of the corresponding supply volume being non-potable, with the 50% treated category reflecting portfolios with supplies evenly split between potable and non-potable supply types.

IDENTIFYING POTENTIAL FINANCIAL INSTRUMENTS AND PROPOSE APPROACHES FOR PUBLIC-PRIVATE PARTNERSHIP (P3)

Overview of Funding Programs

Based on the outcomes of the alternative water supply options and the estimated costs of supplementary water supplies, potential options for providing project funding to proposed water supply alternatives were reviewed, potentially including available incentivized loan or grant programs, as well as opportunities for municipal or industrial demand sectors to utilize public-private partnership (P3) arrangements. This process identified existing federal, state, and local grant and loan programs that could potentially be applied to fund water supply infrastructure projects in Louisiana and address the additional supplementary water supply costs from the alternatives discussed in this study.

As of 2016, private water utilities accounted for approximately 15 percent of the municipal water sector in the U.S. (Bluefield Research, 2016). The remaining 85 percent is served by the local municipalities and communities. As a result, the financial burden to either provide improvements or construct new water infrastructure is primarily taken on by these local governmental entities, as well as by the state government. The federal government has established on-going funds to aid local government entities with financing water infrastructure, such as the Clean Water State Revolving Fund (CWSRF). Funds for the CWSRF are appropriated by the federal government and in Louisiana, are administered by the Louisiana

Department of Environmental Quality (LDEQ). This funding program provides state and local governments the opportunity to obtain low interest loans for eligible projects such as construction of publicly owned treatment facilities, decentralized wastewater treatment systems, and reuse or recycling of wastewater, stormwater, and drainage water (LDEQ, 2021). In Louisiana, the state is required to match at least 20 percent of the funds appropriated to LDEQ during a fiscal year.

There are other ongoing financial instruments that can be used for water infrastructure projects, such as the Water Infrastructure Finance and Innovation Act (WIFIA) program, established in 2014 and administered at the federal level by USEPA. The WIFIA program can fund the development and implementation for eligible projects, including those that are eligible for the CWSRF and Drinking Water SRF (DWRSF) programs, as well as individual water supply projects, such as brackish or groundwater desalination, aquifer recharge, alternative water supply, and water recycling, or combinations of projects submitted under one application (USEPA, 2021). The minimum project size for large communities (population greater than 25,000) is $20 million and WIFIA can provide up to 49 percent of eligible project costs.

In addition to the funding options identified, municipalities could also explore municipal bonds to finance water infrastructure projects. Funding from the private sector could also be an option, where private entities invest the capital required for water or wastewater infrastructure improvements or construction of new projects. Alternatively, private funding through a P3 could be a potential opportunity. P3s are discussed in greater detail in the Public-Private-Partnerships and Key Considerations for a P3 subsections of this report.

The list of programs contained in Table 11 provides an overview of current, on-going financial instruments available during Phase 2A of this study. New funding programs may become available and be applicable financial opportunities. For example, under the Infrastructure Investment and Jobs Act (IIJA), which was recently signed into law by the federal government in November 2021, Louisiana will expect to receive $580 million over five years to improve water infrastructure and ensure clean, safe drinking water for communities across the state (White House, 2021). This program will be based on the traditional state revolving fund (SRF) formula. However, at the time of this study, specific details to secure these funds, including the timing, availability, and application process in Louisiana are unknown. At the time of writing (2023), much of the water and wastewater infrastructure funding is anticipated to come through the programs identified in this report, such as the SRF programs or from the USEPA directly.

Table 11: Summary of Potential Funding Sources for Water Supply Alternatives (FNI, 2021; this report)

Source Type	Eligible Applicants	Agency /Grant Source	Program Name	Program Acronym	Summary	Assistance Type
State, Federal	Public Water Systems	LDH, USEPA	Drinking Water Revolving Loan Fund	DWRLF	Assists PWS in financing needed drinking water infr. Improvements. Consolidation of multiple PWS is also eligible.	Loans, Principal Forgiveness
State, Federal	Municipalities and Parishes	LDEQ, USEPA	Clean Water State Revolving Fund	CWSRF	Assists communities by providing low-cost financing for eligible projects like implementation of a non-point source pollution mgmt. program, water conservation, efficiency, or reuse.	Loan, Principal Forgiveness
Federal	Municipalities and Parishes	USDA - RD	Water & Waste Disposal Loan & Grant Program	USDA Loan / Grant	Provides funding for clean and reliable drinking water systems, sanitary sewage disposal, sanitary solid waste disposal, and storm water drainage to households and businesses in eligible rural areas.	Loans, Grants
State	Municipalities and Parishes	LA Div. of Admin.	Local Government Assistance Program	LGAP	Water, equipment, drainage, and reasonable engineering costs (10% of grant award for basic engineering services if associated with const. and 3% for insp. services)	Grants
Federal	Local, state, tribal, and federal government entities; Partnership and joint ventures; Corporations and trusts; Clean Water and Drinking Water SRF programs	USEPA	Water Infrastructure Finance and Innovation Act	WIFIA	Fund dev. and implementation activities. Projects that are eligible for the CWSRF, notwithstanding public ownership clause, Projects that are eligible for the DWSRF, Energy efficiency projects at drinking wastewater facilities. Alternate water supply. Acquisition of property if integral to project or mitigates environmental impact. Combination of projects secured by common security pledge or under one application by SRF.	Loans
State, Federal	Municipalities or Parishes	HUD, LA Div. of Admin.	Community Development Block Grant Program	CDBG	Provides grants to eligible activities under the Louisiana CDBG program, including projects to improve existing or construct new potable water systems.	Grants
State	Municipalities and parishes within LA identified by HUD as non-entitlement communities	OCD	Community Water Enrichment Fund	CWEF	Provide a source of funding to aid units of local government solely for the purpose of rehabilitation, improvement, and construction projects for community water systems to provide safe and clean drinking water.	Grants

Benefits and Drawbacks of Loans and Grants

When evaluating whether a loan or grant program is the most appropriate financial structure to fund a water infrastructure project, it is important to note the potential benefits and drawbacks of each. Table 12 provides some key potential benefits and drawbacks of loans and grants.

Table 12: Key Potential Benefits and Drawbacks of Loans and Grants

Funding Type	Benefits	Drawbacks
Loan	• Interest rates subsidized so typically lower than the applicant can get on the open market; • Loan repayment terms, up to 30 and in some cases, 40 years; • Typically, greater total funds available and available annually; • Less competitive than grants; • Application and requirements may be easier than grants; • Can typically fund Planning, Design, Acquisition, and Construction and include pre-award and management costs.	• Must be repaid with interest; • Many times, loan approvals depend on the overall financial, managerial, and technical capabilities of the applicant; • Agency review and approval timeframes (can be a year or more); • Applicants will normally need to hire a financial advisor, a bond counsel, and an engineer; • Typically, fewer loan programs than grant programs/opportunities; • Agency loans will typically impact (count against) a political subdivisions debt service capacity
Grant	• Grants do not have to be repaid; • Typically, more grant programs/opportunities than loan programs.	• Must meet priorities of the agency delivering the grant which can change by need and by year; • Many grants programs are not annual, some may only be available after a federal disaster; • Grants are typically more competitive; • Scoring criteria in applications can be lengthy and confusing; • Failure to follow requirements completely could result in a recapture, or claw-back, of grant funds under future audit; • Agency review and approval timeframes (can be a year or more) • Applicants will likely need to hire a grant management firm and an engineer; • Some grant programs do not allow pre-award or management costs; • Some grant programs may limit grant management and engineering fees.

Public-Private-Partnerships (P3s)

P3s have been used as a tool to enable private entities to assist the public sector with the design, build, and operation components of publicly owned water and wastewater infrastructure. It is estimated that P3s have accounted for 1 to 3 percent of infrastructure spending for transportation (highway, transit) and water sectors (U.S. Congressional Budget Office, 2020). The water supply alternatives evaluated in this study could potentially lend themselves to a P3 procurement process, where the municipal and industrial sectors share the risks, services, and asset life-cycle maintenance associated with the delivery of water infrastructure projects.

In a traditional approach for municipal water supply infrastructure development, often referred to as a "design-bid-build" (DBB), services are procured through a private firm to develop and construct an asset, but the majority of risk associated with delivery and operation of the asset are retained by the public sector (EY and AWWA, 2019). In contrast, a P3 typically constitutes a long-term, performance-based contractual agreement between a public sector entity and a private entity, where the public entity retains ownership of the asset, while the private entity is given control over more than one of the following components of the water infrastructure project: design, construction, financing, operations, or maintenance (Congressional Budget Office, 2020). There is a wide spectrum of approaches for a P3 that can be used to deliver water infrastructure, where risk is progressively transferred from the public partner to the private partner. This risk transfer occurs by combining the responsibility for multiple stages of a project so that the private partner bears the risk of potential increases to costs or other financial shortfalls. On the spectrum of potential approaches to a P3, common combinations include (from lowest to highest extent of risk and project financing transferred to the private partner):

- Design and build (DB);
- Operate and maintain (O&M);
- Design, build, and finance (DBF);
- Design, build, and operate (DBO)
- Design, build, operate, and maintain (DBOM); and
- Design, build, finance, operate, and maintain (DBFOM; Jamieson, 2013; EY and AWWA, 2019).

P3 arrangements can be financed through public funds, private funds, or various combinations of both options (Congressional Budget Office, 2020). With public financing, federal, state, or local governments can issue bonds that are tax exempt and typically offer lower interest rates than bonds without tax exemption. Private financing will not be tax exempt and will be subject to higher interest rates, which could make the cost of service higher than public financing. However, management and technical efficiencies added by having a private partner could counteract any savings from tax exemptions on municipal debt. In a P3 that uses private financing, the private partner is generally compensated in two ways: 1) private financing is repaid with payments from the government as the private partner constructs or maintains the infrastructure in a manner that meets specific criteria in a performance agreement; or 2) private financing is repaid with revenues generated by fees to the infrastructure users, such as water and sewer fees (Congressional Budget Office, 2020). Private financing will require a certain percentage of equity from the private investor, and financing terms will be based on the risk of the project. The greater equity or financial risk given to the private investor in a project, the more generous other terms in the contract will need to be, i.e., rewarding the private entity with greater tax incentives or subsidies, or to allowing higher fees to be charged to water users.

P3 arrangements have the potential to provide benefits that are not offered through a traditional infrastructure delivery and financing approach for municipal water supply projects. P3s can provide the private partner with incentives to complete a project more efficiently than the public sector, which could lead to technical innovations, accelerated design and construction timelines, improved operational efficiencies, and lower total life cycle costs (West Coast Infrastructure Exchange, 2016). In addition, a private partner could provide access to new sources of private financial resources and take on greater risks associated with financing, design and build, or O&M of a project. In parallel, there are potential barriers and drawbacks associated with P3s. Depending on the contractual agreement, the public sector could cede control over certain aspects of a project, such as technical control over assets or the authority to set water and sewer fees (Congressional Budget Office, 2020). Although a P3 could provide the private entity with incentives to reduce costs, the cost of the financing will not be impacted. As such, private partners could provide financing that lowers the up-front costs paid by the public sector for an infrastructure project, however, the private sector will be repaid by user fees or future tax revenues generated from the project.

In Louisiana, pursuant to Louisiana R. S. §§ 48:250.4, when determined to be in the best interest of the taxpayers and with approval of the Louisiana State House and Senate transportation, highways, and public works committees, LA DOTD may solicit proposals and enter into contracts for P3 projects for transportation facilities ("Public-private partnership projects," 2010). This policy has enabled the procurement of P3s for transportation projects across the state of Louisiana, such as the Belle Chasse Bridge and Tunnel replacement project (LA DOTD, 2018). Currently, there is no Louisiana state policy in place to grant a designated water authority(s) the ability to pursue P3s to fund water infrastructure projects. However, this does not preclude the ability of a municipal entity to pursue a P3 in the state of Louisiana.

Although P3s have been more commonly associated with large-scale transportation projects, there have been several P3 cases applied in the water sector (Hughes, 2017). The University of North Carolina at Chapel Hill Environmental Finance Center (EFC), with support of the EPA Water Infrastructure and Resiliency Finance Center and West Coast Infrastructure Exchange, conducted an assessment of the potential benefits of alternative water delivery project models (P3s) and highlighted case studies involving P3s for water and wastewater infrastructure (Hughes, 2017) . A few examples of P3s developed for water and wastewater infrastructure are discussed below.

- A regional surface water treatment facility was constructed through a joint effort by the City of Woodland, California, the City of Davis, California, the University of California at Davis, and Woodland Davis Clean Water Agency through a DBO service contract with a private partner (CH2M Hill). Initial financing for this project came from the public sector through SRF loans issued by the project sponsor. Services provided by the private partner included permitting, project design and construction, and on-going operation of the facility (Hughes, 2017).

- The City of Phoenix, Arizona constructed the Phoenix Lake Pleasant Water Treatment Plant, one of the first large-scale DBO water treatment plant projects in the U.S. The City joined into a service contract with multiple project partners, where each partner provided services for individual phases of the project (design, construction, and operations). Initial financing for this project came from revenue bonds (tax exempt) issued by the project sponsor (Hughes, 2017).

- The City of Santa Paula, California used an alternative delivery model to construct a new, privately-owned wastewater recycling facility that was designed, built, financed, and operated (DBFO) through private entities. Initial financing for the project came from private equity and privately placed loans issued by the service provider. Although the facility was initially privately-owned, the City issued debt (tax-exempt) to purchase the facility back after its completion due to perceptions of high costs of private capital (Hughes, 2017).

Public and private entities in the CAGWCD could develop similarly structured P3 agreements between partners (DBO, DBFO, DBFOM, etc.) to optimize the delivery of multiple stages of the alternative water supply projects evaluated in this study. The potential P3 structure for each alternative project type (surface water treatment plant, industrial or municipal wastewater reclamation, brackish groundwater, ASR) evaluated will ultimately be dependent on a multitude of factors, such as which public and private entities are involved, what phases of a project should be allocated to whom in the partnership, and what funding options are the most appropriate to fund the project (public, private, or both). Furthermore, the suitability of a P3 will ultimately depend on factors such as the ability for public and private partner to agree to terms, project scale, capital costs, technical complexity, financial risk, and public perception. The selection of the most appropriate P3 project delivery and financing approach could be evaluated based on an objective assessment of which approach can provide the greatest value for the cost over the duration of the infrastructure asset's life cycle (Jamieson, 2013).

Key Considerations for a P3

Before a potential P3 arrangement for a water infrastructure project can gain traction, there are a number of fundamental requirements and considerations (Dokko et al., 2016), including:

- Existence of a municipal entity (the project sponsor) that has legal ownership of a water source and has the authority to enter into contracts, finance, and design and build infrastructure;
- Mutual interest in a P3 for a water infrastructure project between the municipal entity and private entities or municipalities; and
- Service agreements or commitments between public and private sector partners.

A key prerequisite of a P3 is that there will need to be a municipal entity (the project sponsor) that has legal ownership of a water source in order to enter into contracts with private entities or other municipalities. Any leases or sales of a water supply require legal ownership of that water by the selling entity. In addition to legal ownership of a water source, the municipal entity must have the legal authority to finance water infrastructure and incur debt, and to design, build, and operate infrastructure to deliver treated water. If necessary, a municipal entity can be created to fulfill these roles and serve local municipalities in the CAGWCD (Douglas Herbst, DBIA, personal communication, November 17, 2021). For example, the Greater Texoma Utility Authority (GTUA) is a political subdivision of the State of Texas that was created to serve local municipalities served under their jurisdiction, referred to as their "member cities." GTUA has the authority to assist its member cities with financing and construction of water and wastewater facilities and the ability to incur debt supported by the revenue streams from the facility operations it finances (Texas Spec. Dist. Local Laws. Code, Title 6, Subtitle F, Chapter 8283; Texas Water Code, Title 4, Chapter 49). It also has the authority to enter into contracts to provide water and wastewater services, as well as to provide operations services for water or wastewater facilities by member cities and others.

A P3 will require a mutual interest in a water infrastructure project between both the public and private sectors (e.g., industry). Therefore, having some type of incentive for private entities to have interest in establishing a regional water supply option is essential. To gauge interest in a project and a potential P3, the procuring municipal entity, which meets the prerequisites discussed in the previous paragraph, could consider sending out a request for expression of interest to local private sector entities and municipalities. In general terms, this request could include questions, such as:

- If a regional water supply option were to be developed, would you be willing to sign a purchase agreement for this supply?
- Are there any specific conditions or pre-qualifications that would be required for this agreement?
- What are your current and future water supply needs and existing treated water quality standards?

If there are any entities that are interested in entering into a purchase agreement for that regional supply, the next step would be for the municipal entity to follow up to gauge interest in a potential P3. The municipal entity would need to re-convey the conditions that the interested parties mentioned would be essential to enter into an agreement, and pose the questions:

- If these conditions or pre-qualifications are met, would you be interested in a P3?
- In addition to the conditions listed, is there anything else needed?

If the municipal entity and interested entities can come to a purchase agreement for the water supply and there is mutual interest in the community for a P3, then there is a potential for a P3 to be procured. Otherwise, other funding options will likely need to be explored.

If there is mutual interest in a P3 between the public and private sectors, the next step is to come to terms on a long-term service agreement. To be able secure long-term financing for a water infrastructure project in a P3 arrangement, there has to be an ironclad commitment or service agreement between the municipal entity and entities in the private sector (or potentially other municipalities), typically in the form of a take-or-pay contract (Dokko et al., 2016). That is, private (or potentially other municipal) entities will need to enter into a long-term contract with the municipal project sponsor to purchase a specified volume and continue to pay for that contracted volume even if entities do not consistently use the full specified volume. This contract will ensure a revenue stream from the project.

A Cooperative Framework to Limit Regional Groundwater Use

In areas outside of Louisiana, joint groundwater reduction plans (GRPs) have proven to be successful cooperative efforts employed by water utilities to achieve regional groundwater reduction goals set by regulatory groundwater districts. In a GRP, two or more entities (public or private utilities, industries, etc.) in a regulated groundwater area enter into a contractual partnership to share costs or cooperate in ways that achieve reduction goals for total groundwater use and conversions to alternative water supplies. For example, through a GRP partnership, utilities that have access to alternative water supplies can convert wholly or partially to those supplies, allowing others that do not have access to these alternatives the ability to use or continue meeting water demands with groundwater so long as the composite groundwater use by participating entities meets regulations (Harris Galveston Subsidence District, 2021; Fort Bend Subsidence District, 2022). Similar cooperative efforts for a GRP could be leveraged by entities in the CAGWCD to pursue potential groundwater reduction goals set by the CAGWCD and incentivize the development of alternative water supply options to offset groundwater demand.

Joint GRP frameworks have proven to be successful in reducing groundwater withdrawals in areas across southeast Texas, including within the Harris-Galveston Subsidence District and Fort Bend Subsidence District, which have historically experienced subsidence from excess groundwater use that led to increased risk of coastal flooding flooding (Harris Galveston Subsidence District, 2021; Fort Bend Subsidence District, 2022). Subsidence districts were created to regulate groundwater withdrawals across these areas to address this concern. These subsidence districts have established policies to regulate groundwater withdrawal, which include costly disincentive fees if required conversion goals from groundwater to alternative water use are not met. The implementation of these policies has limited further subsidence across the region and led to the development of a multitude of alternative water supplies (surface water, reuse, etc.). To avoid disincentive fees, one of the alternatives offered to entities in a regulatory area by these groundwater districts is the option to cooperatively develop a Joint GRP, which has been implemented by utilities across the region to offer a cost-effective, reliable solution to decrease groundwater withdrawals.

TASK 2A.6 EVALUATE THE EXISTING AQUIFER MONITORING FRAMEWORK

> *Task Summary: The CAGWCC needs to be able to assess progress toward meeting specified management objectives, as well as adapt its management approach to changing conditions and needs. This includes monitoring water levels, chloride concentrations, and subsidence in the SHAS. A comprehensive and robust observation framework can also provide the learning necessary to refine and update the GAM, the primary tool for predicting the potential impacts of management.*

EVALUATE THE ADEQUACY OF THE EXISTING CHLORIDE MONITORING NETWORK

This activity aims to evaluate the adequacy of the existing monitoring well network for determining the spatial distribution and concentrations of salt throughout the SHAS, ensuring a current and synoptic view of all sand layers within the SHAS. It assesses whether additional data collection should be initiated to meet long-term fundamental objectives. In the current USGS monitoring program, 42 wells are sampled for chloride (pers. comm., Max Lindaman, USGS Lower Mississippi-Gulf Water Science Center, 2021). Two wells in WBR are sampled twice a year, and the remaining 40 have been sampled once per year. Recent (FY2021) rescoping of the contract between CAGWCC and USGS has increased the frequency of measurement to twice a year for all chloride network wells. A map showing the locations of wells monitored in 2020 is provided in Figure 14. Samples are collected using either an existing turbine pump (~62 percent of wells on current network) or by airlifting for non-production/monitoring wells (~38 percent of wells on current network). Airlifting requires an air compressor to force water out of the well, but also purges stagnant water in the well to provide a sample of the native aquifer water.

Valuable information is given by chloride samples from wells that are in the transition zone between the core of the saltwater plume and the freshwater portion of the aquifers. These wells can help to determine the movement and extent of saltwater. Most of these wells are already being monitored as part of the USGS network, but there are wells that could be added if they are available to be sampled. Some wells could be sampled less frequently, such as wells that appear to be relatively distant from the plume area and have historically yielded fresh water, or wells south of the Baton Rouge fault.

Continuous monitoring using in situ conductivity sensors may be difficult. The sensors would ideally need to be placed at the bottom of the well in the screened interval, since saltwater is dense and the water in the well might be stratified with depth. Many probes have pressure limits and cannot be submerged in exceedance of their pressure rating—for example, some brands of conductivity loggers may not be rated for pressures exerted by depths greater than 225 ft. The well screens for the aquifers in this area that have saltwater intrusion are much deeper than 225 ft. More research into the use of continuous systems in deep aquifers is needed if this option is to be explored. (pers. comm., Max Lindaman, USGS Lower

Mississippi-Gulf Water Science Center, 2021). One potential option is the use of sondes designed for use in deep oceanographic settings. Portable conductivity (not in situ) probes to test grab samples from production wells could be an inexpensive and quick chloride proxy, especially for wells that appear to be in the path of the movement of saltwater but are currently at a distance from the plume front. To increase the number of wells being monitored, it may be possible to use a grab sample approach to obtain chloride concentration in pumping wells. It may also be possible in non-pumping wells to both take grab samples semiannually and install a conductivity meter for continuous reading. Conductivity values can later be correlated with lab results (Tsai, pers. comm, 2021).

Thirty-nine wells have been identified by the Institute, Dr. Tsai (LSU), and Dr. Max Lindaman (USGS) as possible useful additions to those currently monitored for chloride concentration and could improve the ability for the CAGWCC to manage the aquifer. The wells were chosen by expert review of the well locations where data is currently regularly collected to identify existing wells that could be added to the network to increase the understanding of the chloride plume. The identified wells are a mix of production and monitoring/non-pumping wells and are listed in Table 13. These wells will have to be evaluated for their overall status and ability to be added to the network given potential damage or access constraints that have occurred since these wells were last sampled. Additional research could determine the necessity, locations, and depths of any additional wells that will be necessary to fill gaps in the dataset coverage. Additional detail added to future work could address the spatial distribution and temporal sampling frequency of monitoring in each of the units of the SHAS.

Table 13: Additional chloride monitoring wells in the CAGWCD identified as important for monitoring the chloride plume (Lindaman, 2021 pers. comm.) and (Tsai, 2021 pers. comm.).

Well Name	Strata (feet)	Well Type	Source
EB-825	400	Monitoring	Lindaman
EB-1442	600	Monitoring	Lindaman
EB-806A	600	Monitoring	Lindaman
EB-824	600	Monitoring	Lindaman
EB-782A	1000	Monitoring/ Non-Pumping	Tsai
EB-782A	1000	Monitoring	Lindaman
EB-1276	1000	Production	Lindaman
EB-1328	1000	Production	Lindaman
EB-146	1200	Production	Lindaman
EB-301/EB-618	1200	Production	Lindaman
EB-780A	1200	Monitoring/ Non-Pumping	Tsai
EB-621	1200	Monitoring/ Non-Pumping	Tsai

Well Name	Strata (feet)	Well Type	Source
EB-1287	1200	Monitoring/ Non-Pumping	Tsai
EB-1297	1200	Monitoring/ Non-Pumping	Tsai
EB-157	1500	Production	Lindaman
EB-1423	1500	Scavenger	Lindaman
EB-1424	1500	Scavenger	Lindaman/ Tsai
EB-1293	1500	Production (Connector well)	Lindaman/ Tsai
EB-1400	1500	Monitoring	Lindaman/ Tsai
EB-658	1500	Production	Lindaman/ Tsai
EB-771	1500	Monitoring/ Non-Pumping	Lindaman/ Tsai
EB-780B	1500	Monitoring	Lindaman/ Tsai
EB-782B	1500	Monitoring	Lindaman/ Tsai
EB-783A	1500	Monitoring	Lindaman/ Tsai
EB-789B	1500	Monitoring	Lindaman/ Tsai
EB-803A	1500	Monitoring	Lindaman/ Tsai
EB-807A	1500	Monitoring	Lindaman/ Tsai
EB-1295C	1500	Monitoring/ Non-Pumping	Lindaman/ Tsai
EB-1400	1500	Monitoring/ Non-Pumping	Lindaman/ Tsai
EB-774	2000	Production	Lindaman
EB-814	2000	Production	Lindaman
EB-855	2000	Production	Lindaman
EB-10183Z (Myrtle-Delpit)	2000	Test well	Lindaman/ Tsai

Well Name	Strata (feet)	Well Type	Source
EB-778	2000	Monitoring/ Non-Pumping	Lindaman/ Tsai
EB-807B	2000	Monitoring/ Non-Pumping	Lindaman/ Tsai
EB-1039	2400	Production	Lindaman
EB-1187	2400/2800	Production	Lindaman
EB-723	2800	Production	Lindaman
EB-730	2800	Production	Lindaman

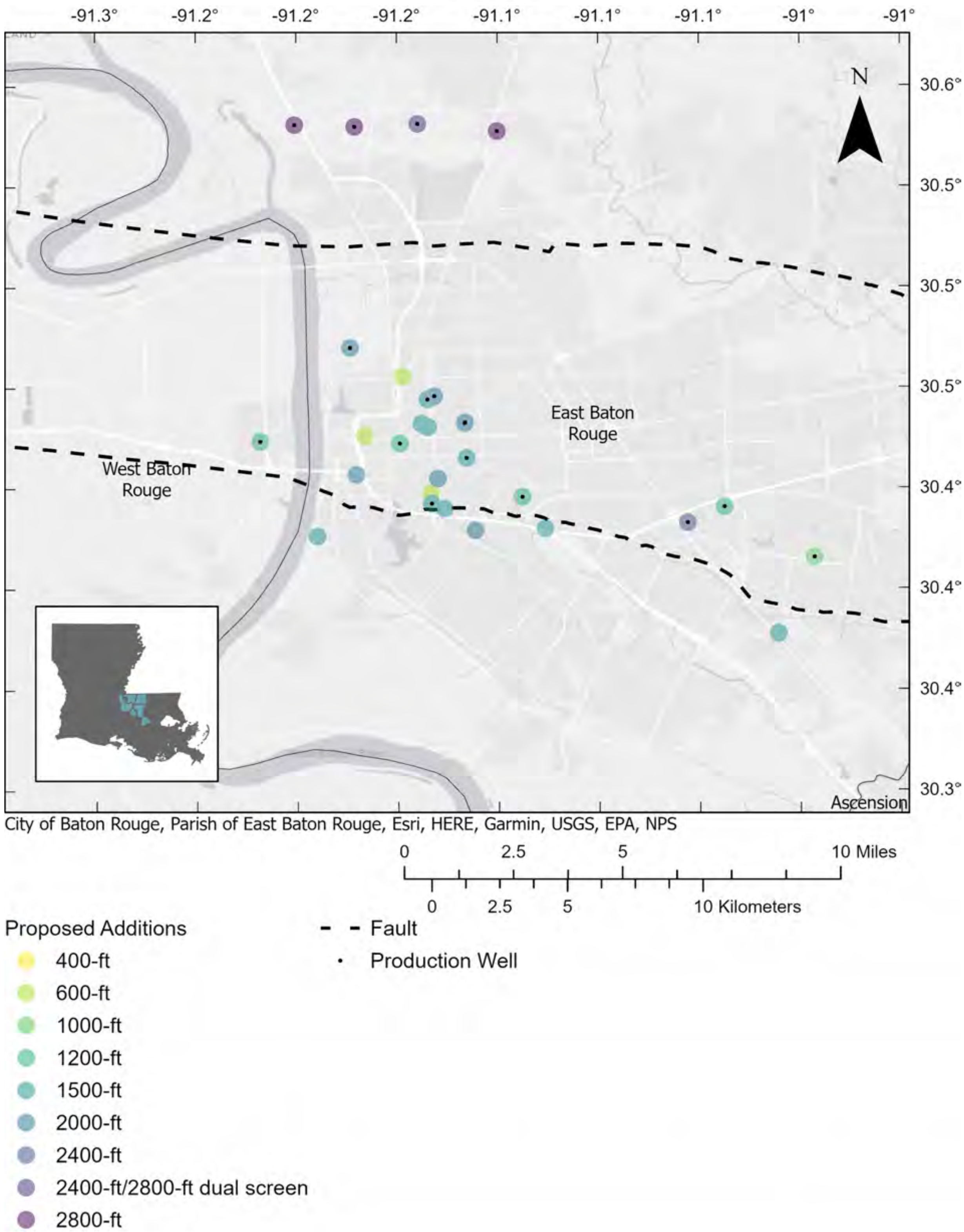


Figure 82. Proposed wells to be added to the chloride monitoring network (Lindaman, 2021 pers. comm.) and (Tsai, 2021 pers. comm.) from Table 13.

EVALUATE THE ADEQUACY OF THE EXISTING WATER LEVEL MONITORING NETWORK

This activity is intended to evaluate the adequacy of the existing monitoring well network for determining the spatial extent of, and changes to, water levels and cones of depression, and ensure a current and synoptic view of all sand layers within the SHAS. The Institute and project partners are assessing whether additional data collection should be initiated to meet long-term fundamental objectives. Currently, 74 wells are monitored quarterly for water levels on the USGS CAGWCC network (pers. comm., Max Lindaman, USGS Lower Mississippi-Gulf Water Science Center, 2021).

In order for water level data to best inform the modeling process, increased sampling could be valuable. Priority could be given to the general boundaries of CAGWCD, including the Louisiana-Mississippi border to the north, and the EBR-Livingston Parish boundary to the east. To model the saltwater intrusion problem, the most important areas to collect groundwater level data are around the fault line (both sides), around the wells that are withdrawing groundwater, and around the plumes. This could help to establish the groundwater flow paths that dictate the movement of saltwater. It is also useful to have a spatially dispersed network that extends beyond CAGWCD to help constrain recharge of groundwater to the CAGWCD itself. Areas with little development and withdrawals will not need to be sampled as frequently, because groundwater levels are not expected to vary as much as areas with significantly more development and withdrawals.

Spatial patterns of pumpage, in terms of location and volume, have changed over time throughout the CAGWCD. Figure 83 and Figure 84 show the change in distribution and magnitude of pumping in the CAGWCD from 1980 to 2020. These figures show an overall expansion of pumping across the CAGWCD. A review of the monitoring well network could ensure that the water level data collected is adequate to document the effects of pumpage in 2020 and beyond.

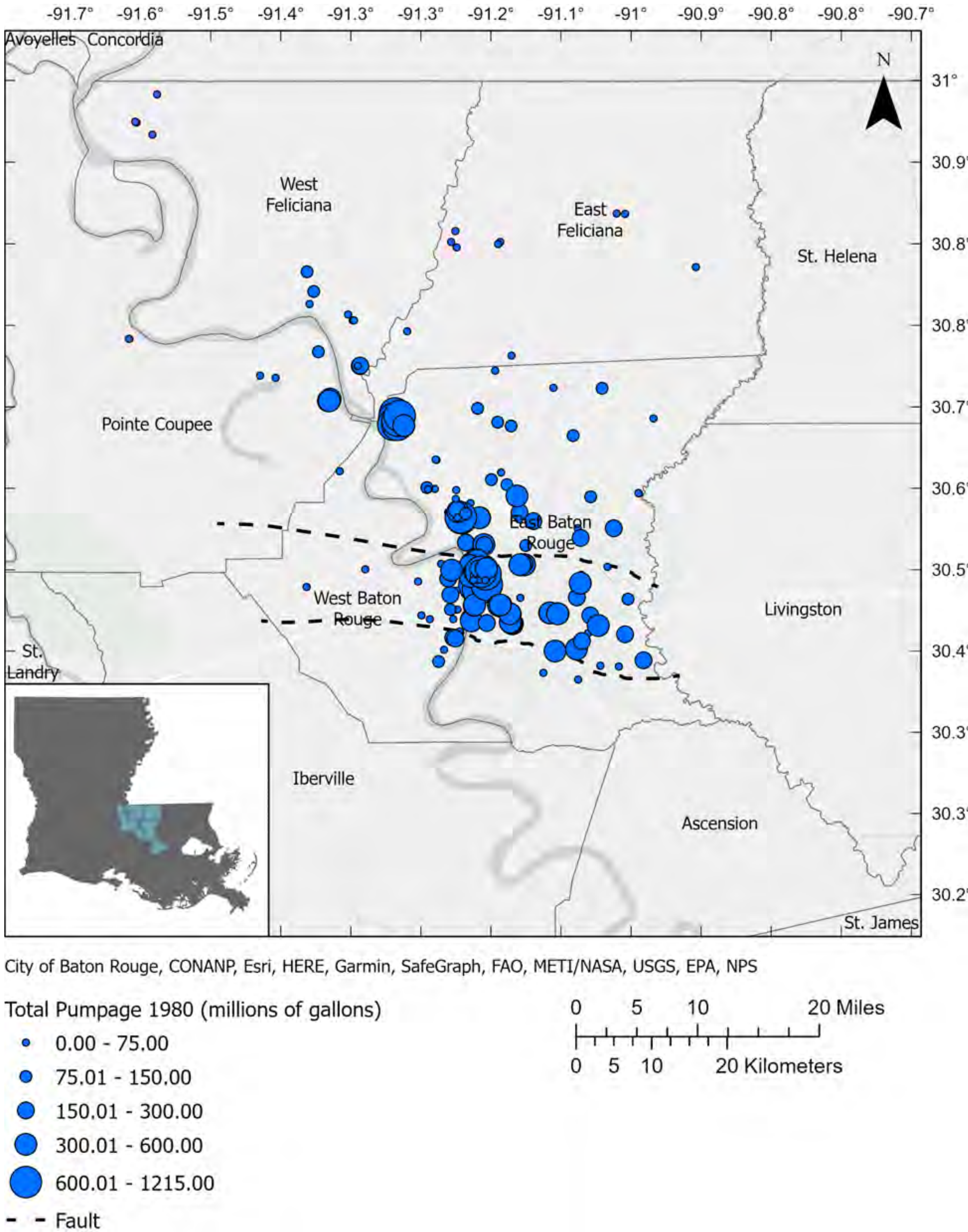


Figure 83. Total pumpage, in million gallons, as reported to the CAGWCC for wells in the CAGWCD in 1980.

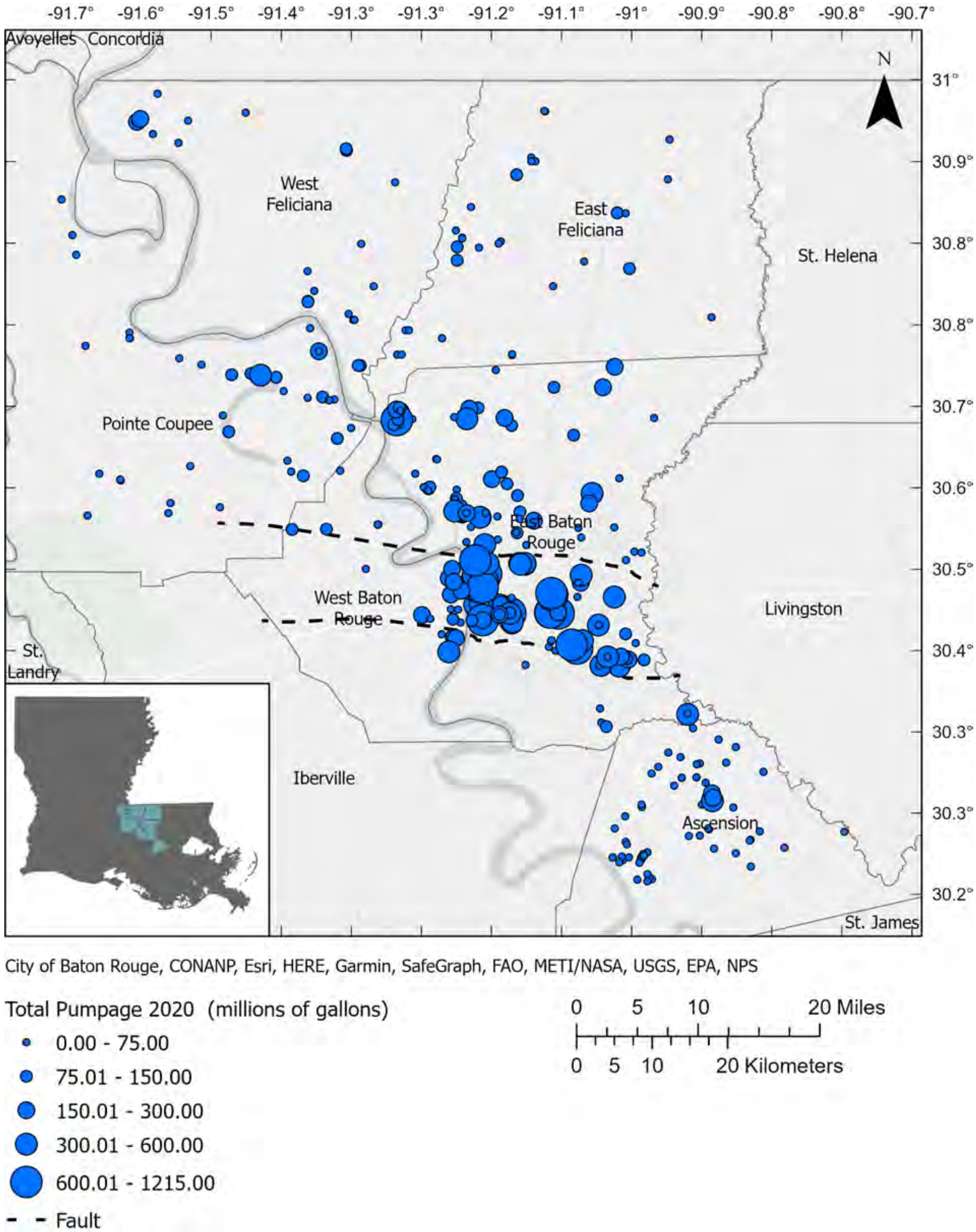


Figure 84. Total pumpage, in million gallons, as reported to the CAGWCC for wells in the CAGWCD in 2020.

Research has been conducted, by the Institute in collaboration with USGS and LSU, to determine the necessity, locations, and depths of any additional wells that will be necessary to fill any gaps in the water level dataset coverage. A preliminary analysis of the spatial distribution and temporal sampling frequency of monitoring in each of the units of SHAS was conducted. Maps depicting the spatial distribution of total pumpage from wells in 2020, and monitoring wells that were measured in 2019–2020, are included in Appendix D. A brief list of locations identified for water level monitoring is included in Table 14.

The current extent of the monitoring system for the sand layers of the SHAS enables an assessment of the current state of groundwater levels over most of the CAGWCD. Due to growth in demand spatially across the CAGWCD, as well as the need for data in critical locations, such as along the Baton Rouge Fault and in the Industrial District, additional monitoring wells as described in Table 14 could help inform the model and the ability to manage the aquifer.

Table 14. Wells identified for water level monitoring in the CAGWCD that could help inform the groundwater model development and aquifer management.

Aquifer Unit	Monitoring Status	Locations Identified for Monitoring
400-Foot Sand	Very good, with slight modifications recommended	1. Add monitoring well in southeast corner of East Baton Rouge Parish, or northernmost Ascension Parish to monitor growth in pumpage in that area. 2. If resources are limited, reconsider monitoring frequency (decrease) in Livingston Parish.
600-Foot Sand	Good, with slight modifications recommended	Add monitoring well(s) in southeastern East Baton Rouge Parish, along the Baton Rouge Fault, to monitor growth in pumpage in that area.
800-Foot Sand	Very good, with slight modifications recommended	Add monitoring well(s) in southeastern East Baton Rouge Parish, along the Baton Rouge Fault, to monitor growth in pumpage in that area.
1,000-Foot Sand	Needs Improvement	1. Add monitoring wells at pumping centers in central East Baton Rouge Parish. 2. Add monitoring wells in Industrial District and adjacent areas in West Baton Rouge Parish. 3. Add monitoring well(s) in southeastern East Baton Rouge Parish, along the Baton Rouge Fault, to monitor growth in pumpage in that area.
1,200-Foot Sand	Good, with modifications recommended	1. Add monitoring wells at pumping centers in central East Baton Rouge Parish. 2. Add monitoring well(s) in southeastern East Baton Rouge Parish, along the Baton Rouge Fault, to monitor growth in pumpage in that area.
1,500-Foot Sand	Very good, with slight modifications requested	Add monitoring well in northwestern East Baton Rouge Parish, between the Industrial District and Georgia Pacific, to better define a transect.
1,700-Foot Sand	Good, with modifications recommended	There is currently no monitoring in the Industrial District. Add monitoring in the Industrial District to verify no pumpage in that important area.

Aquifer Unit	Monitoring Status	Locations Identified for Monitoring
2,000-Foot Sand	Very good, with slight modifications recommended	1. Add monitoring well at pumping center in central East Baton Rouge Parish.
2,400-Foot Sand	Very good, with slight modifications recommended	1. Add monitoring well at northern end of Industrial District. 2. Add monitoring well at pumping center in central East Baton Rouge Parish.
2,800-Foot Sand	Very good, with slight modifications recommended	Add monitoring well at border of East Baton Rouge and East Feliciana Parishes, in the vicinity of the Comite River, to measure growth in pumpage in that area.

REVIEW OF CURRENT SUBSIDENCE MEASUREMENT ACTIVITIES

Subsidence due to groundwater withdrawals has been recognized in the CAGWCD since at least the 1960s (Davis & Rollo, 1969). Subsidence requires considerable effort to measure and has historically required repeat measurements of leveling lines (Davis & Rollo, 1969; Shinkle & Dokka, 2004; Smith & Kazmann, 1978; Wintz Jr et al., 1970). This task aims to collate historical estimates, update data where possible, and assess whether additional data collection should be initiated in other areas of the CAGWCD, outside of the central cone of depression.

Lessons from Other Locales

Overpumping of groundwater that leads to subsidence and infrastructure damage has been widely documented in many locations globally (e.g., Bertoldi, 1989; Davis & Rollo, 1969; Kasmarek et al., 2016; Kasmarek & Strom, 2002; Smith & Kazmann, 1978; Sneed et al., 2013; USGS, 2019; Whiteman Jr., 1980; Wintz Jr et al., 1970). The Houston-Galveston area of Texas and the San Joaquin Valley of California provide valuable insight into the magnitude of subsidence and the scale of costs that can result from overpumping groundwater, as described below.

The Gulf Coast aquifer system extends from Florida through Louisiana and Texas to Mexico (Kasmarek & Strom, 2002). The Evangeline and Chicot aquifers are confined aquifers in this aquifer system in the Houston-Galveston area that have been used to supply groundwater for the area (Kasmarek & Strom, 2002). The geology of the Houston area is very similar to the geology of the SHAS where the Chicot and Evangeline equivalent aquifer systems make up part of the SHAS (LGS, n.d.). Prior to 1975, groundwater withdrawal from the Chicot and Evangeline aquifers in the Houston-Galveston area was unregulated, and resulted in potentiometric surface declines tochecked and fixed 300 ft below NGVD29 in the Chicot and 350 ft below NGVD29 in the Evangeline (Gabrysch, 1979; Kasmarek et al., 2016).

By 1979, about 30 percent of the Houston-Galveston area had experienced more than 1 ft of subsidence, with up to 10 ft occuring in some areas (Coplin & Galloway, 1999). Model similations of the Chicot and Evangeline aquifers show that water withdrawals in excess of the aquifer recharge rate are withdrawn from storage in sand and clay layers (Kasmarek & Strom, 2002). Depressurizing and dewatering of aquifer layers, caused by potentiometric surface declines, results in the sediment matrix of the aquifer bearing more of the weight of the overlying sediments, causing compaction of the aquifer (Galloway et al., 1999; Kasmarek et al., 2016; Kasmarek & Strom, 2002). In the clay layers, this extra load causes the individual clay grains to reorient into a more compact matrix with a lower porosity and lower water storage ability. Compaction is almost entirely permanent in clay layers, and does not rebound with potentiometric surface recovery (Kasmarek et al., 2016; Kasmarek & Strom, 2002). Following regulation, water withdrawals decreased and compaction rates in the aquifers slowed (Kasmarek et al., 2016; Kearns et al., 2015); however in areas where the potentiometric surface is still below the preconsolidation levels, subsidence rates of up to 1 in/yr still occur (Kearns et al., 2015). There are more than 10 extensometer stations and 95 permanent GPS stations in the Houston-Galveston area that can be used to investigate subsidence trends (Kearns et al., 2015). Land subsidence has increased the frequency and extent of flooding and damaged buildings and transportation infrastructure in Houston (Kearns et al., 2015). Miller and Shirzaei (2019) found that flood severity in Houston during Hurricane Harvey (Category 4, August 2017) was exacerbated by subsidence.

Although the San Joaquin Valley has different geology from Baton Rouge and Houston, the consequences of subsidence are no less instructive. Overpumping of groundwater in the San Joaquin Valley has resulted in groundwater declines, aquifer compaction, and land subsidence in excess of 28 ft leading to permanent aquifer-system storage loss. (Bertoldi, 1989; USGS, 2019). Between 2008 and 2010, subsidence rates were up to 9.8 in/yr in some areas (Faunt et al., 2016, 2017). This subsidence has caused structural damage to canals requiring millions of dollars of repairs, with costs only increasing into the future (Sneed et al., 2013; USGS, 2019). A 2014 engineering study found that costs for subsidence related damage from 1955–1972 were in excess of $1.3 billion (Luhdorff and Scalmanini Consulting Engineers (LSCE) et al., 2014). Additional damage to aqueducts, roads, bridges, buildings, and well casings has been recorded (Bertoldi, 1989; Sneed et al., 2013). As seen in Houston, subsidence has also increased the potential for flooding in low lying areas (Bertoldi, 1989; Faunt, 2009). Compaction rates were slowed, in some cases to near zero, when groundwater levels were allowed to increase (Faunt, 2009).

Previous Studies on Subsidence in the CAGWCD

There have been several studies in the Baton Rouge area that consider the subsidence due to groundwater extraction (Davis & Rollo, 1969; Smith & Kazmann, 1978; Whiteman Jr., 1980; Wintz Jr et al., 1970). These studies mainly use releveling data from repeat measurements at survey benchmarks (Figure 85; Figure 86; Figure 87; Davis & Rollo, 1969; Shinkle & Dokka, 2004; Smith & Kazmann, 1978; Wintz Jr et al., 1970). Leveling studies measure the total change in the height of a benchmark relative to benchmarks in areas that are considered geologically stable. These studies cannot provide information about the depth at which subsidence is occurring; however, they provide information over a large geographic area. Extensometers measure the motion at the specific location of the instrument between the surface and the installation depth. Extensometers specifically measure compaction and expansion of the sediment column; compaction is the type of subsidence that is induced by groundwater extraction. This type of measurement is taken at a single location, at three different depths, in the CAGWCD (Whiteman Jr., 1980). The extensometer is located at the cyan triangle in Figure 85. Both leveling surveys and extensometer measurements are useful in understanding the subsidence due to groundwater extraction in the CAGWCD. Note that Shinkle and Dokka (2004) did not conduct new leveling in the Baton Rouge area; rather that report provides a compilation of leveling points from previous studies. The points shown in Figure 86 are from the 1960s through the 1980s.

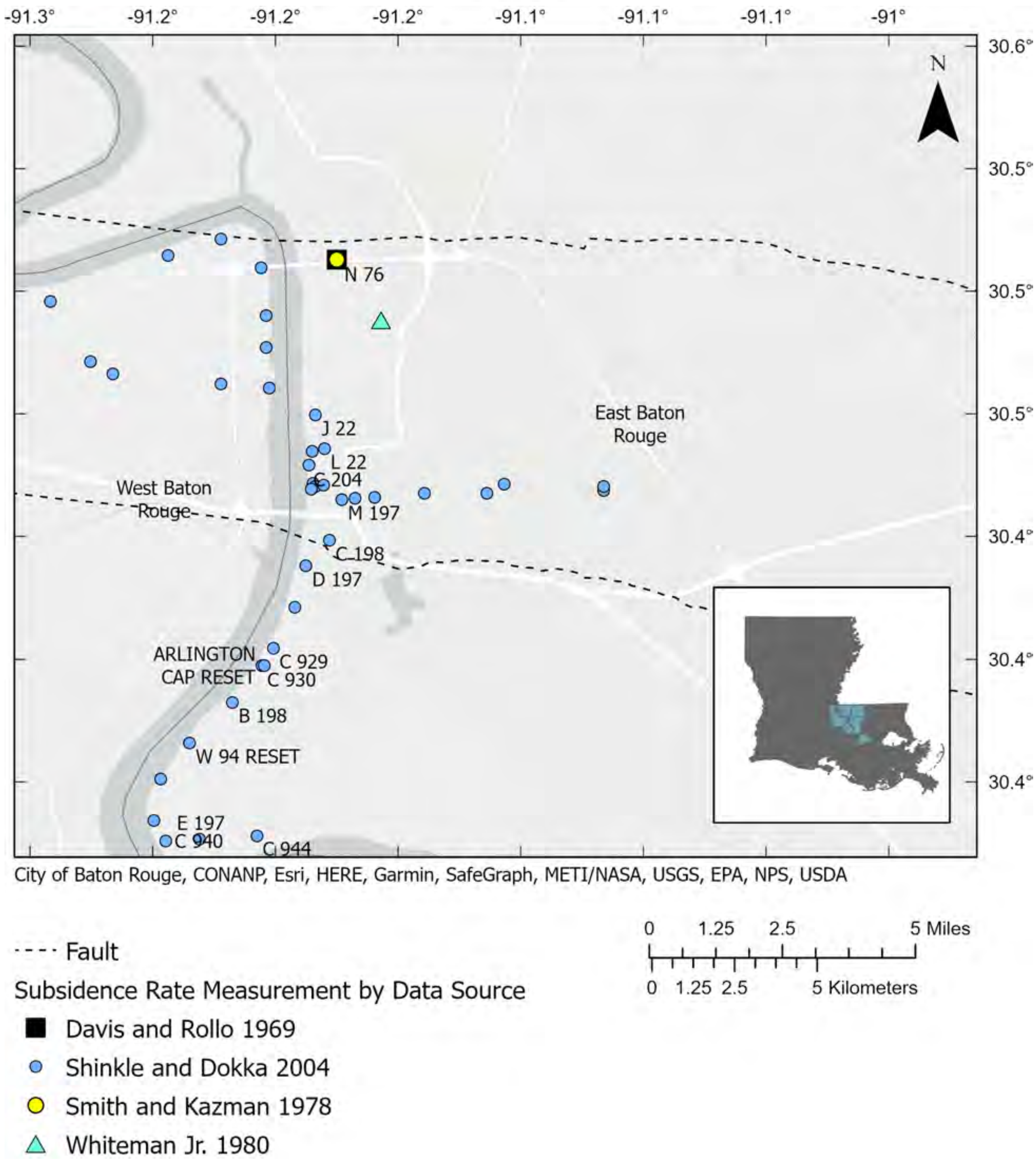


Figure 85. Subsidence measurement locations categorized by data source.

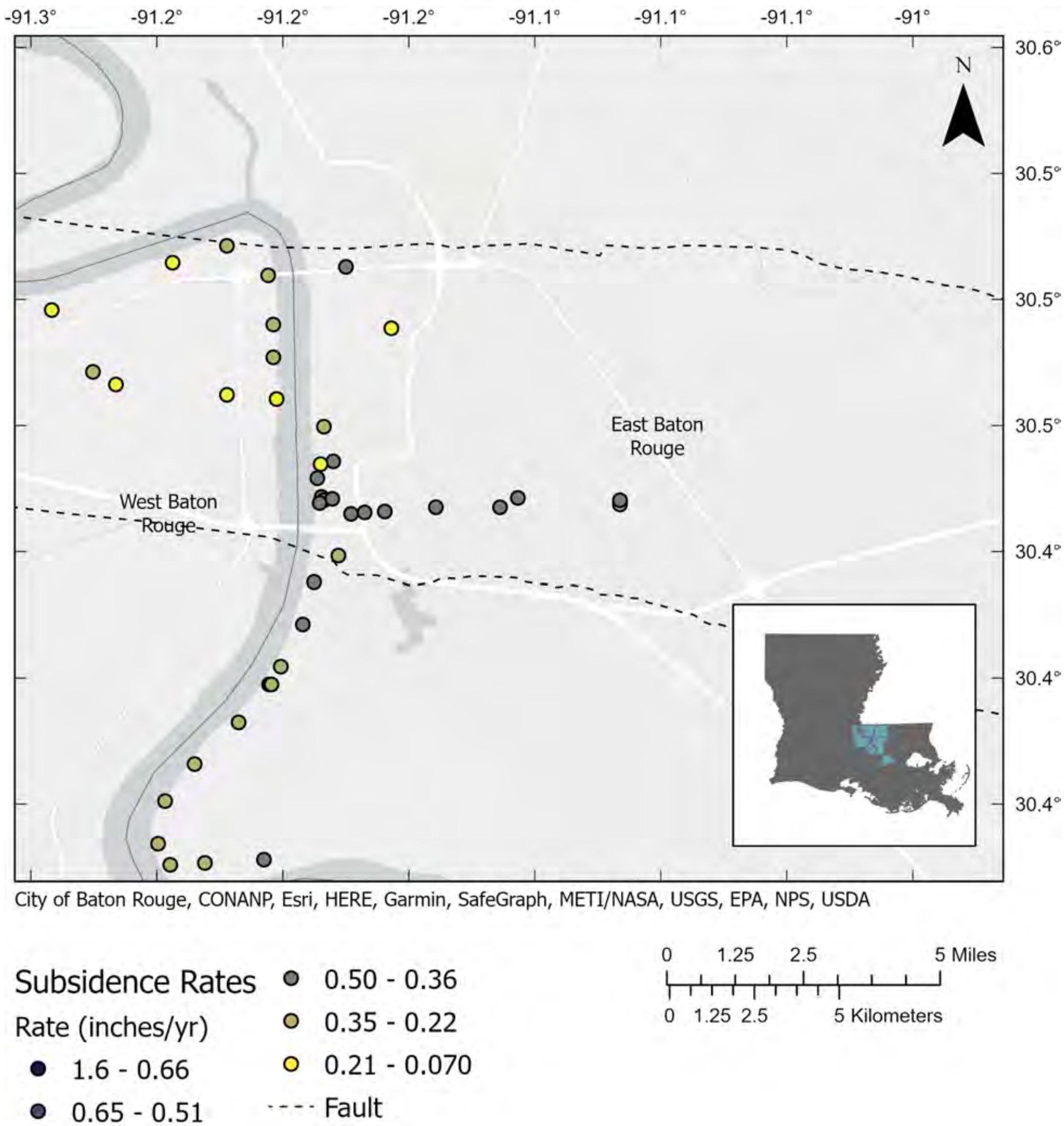


Figure 86. Subsidence measurements in the CAGWCD colored by subsidence rate. These data represent a combination of leveling studies and extensometer measurements. See Figure 85 for data sources.

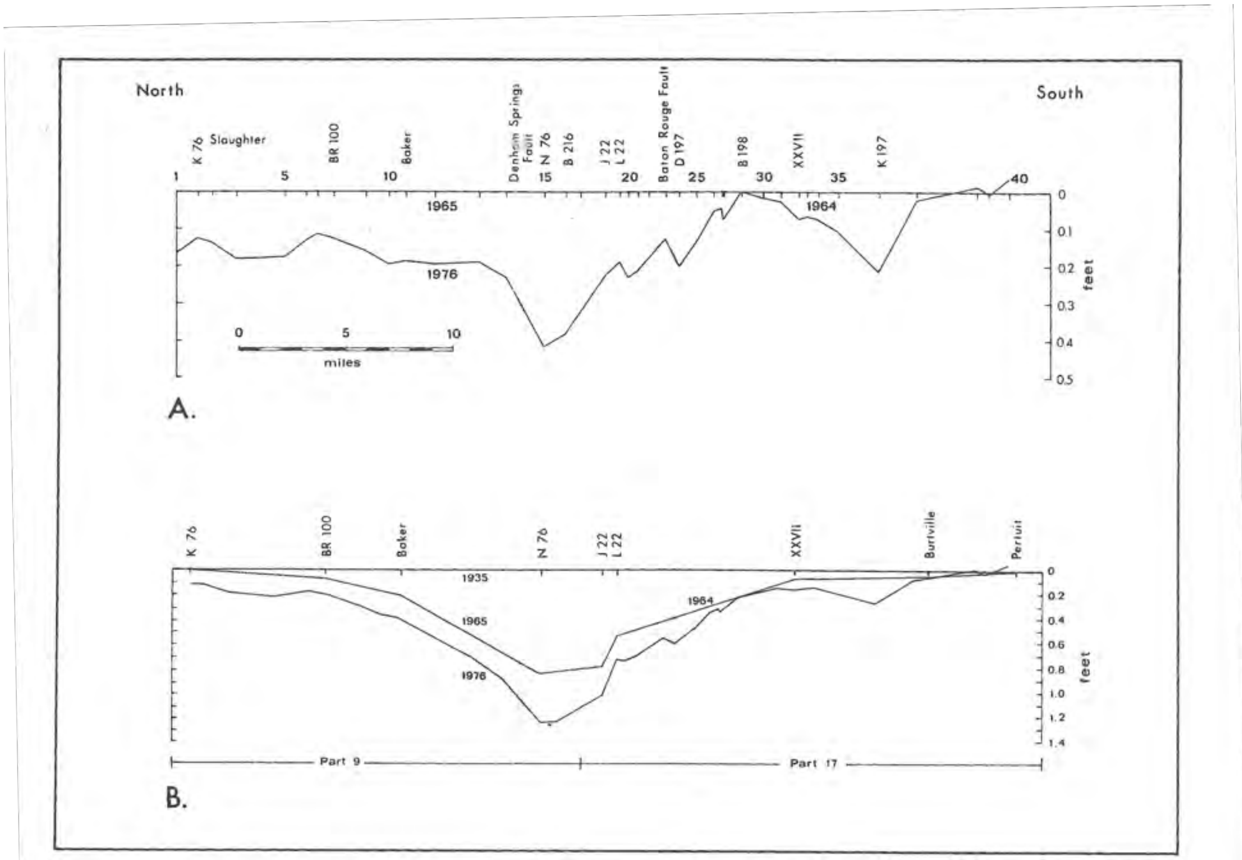


Figure 87. Subsidence profile reproduced from Smith and Kazmann (Figure 5; 1978) showing a North-south profile through Baton Rouge. The elevation is shown on the y-axis; datum is not referenced in the original figure, but is likely NGVD29. Two periods are shown: 1964/65 to 1976 (A) and 1935/38 to 1976 (B). Note that survey monument N76 is at the northern end of the Industrial District at the yellow circle in Figure 85 and that the transects are approximately 40 miles long. Figure 2 shows the locations of some of these monuments. A survey monument is a permanent marker set by a land surveyor as a reference point on the landscape.

Regional subsidence, unrelated to groundwater extraction, is known to occur in the Baton Rouge area. Estimates of this subsidence rate are used to differentiate the background subsidence rate from the subsidence rate induced by groundwater extraction. The regional subsidence rate for the Baton Rouge area has been estimated to be 0.12 in/yr (Holdahl & Morrison, 1974; Smith & Kazmann, 1978; Whiteman Jr., 1980) in the past from leveling studies. Estimates using Global Positioning System (GPS) technology can also be made. Continuously Operating Reference Stations (CORS) measure a precise position using GPS and can be used in modern studies of subsidence (Figure 88; Figure 89). The National Geodetic Survey (NGS) operates a CORS network (US Department of Commerce, https://geodesy.noaa.gov/CORS/, accessed 18 April 2023) with stations in Louisiana. Subsidence rates at two such stations to the east and west of Baton Rouge (Figure 88) that are expected to be well outside the influence of groundwater extraction, suggest that the regional rate of subsidence may be as low as 0.055 in/yr (average of the two sites) (Table 15). Regionally in Louisiana, subsidence rates tend to increase with decreasing latitude (Byrnes et al., 2019; Jankowski et al., 2017; Karegar et al., 2015); thus only CORS stations at a similar latitude to the Industrial District of Baton Rouge were used to calculate this rate (THHR and HAMM) (Table 15). These rates (0.12 in/yr and 0.055 in/yr) will be used as the minimum and maximum rates of regional subsidence when evaluating the contributions of regional geology and groundwater extraction to local subsidence.

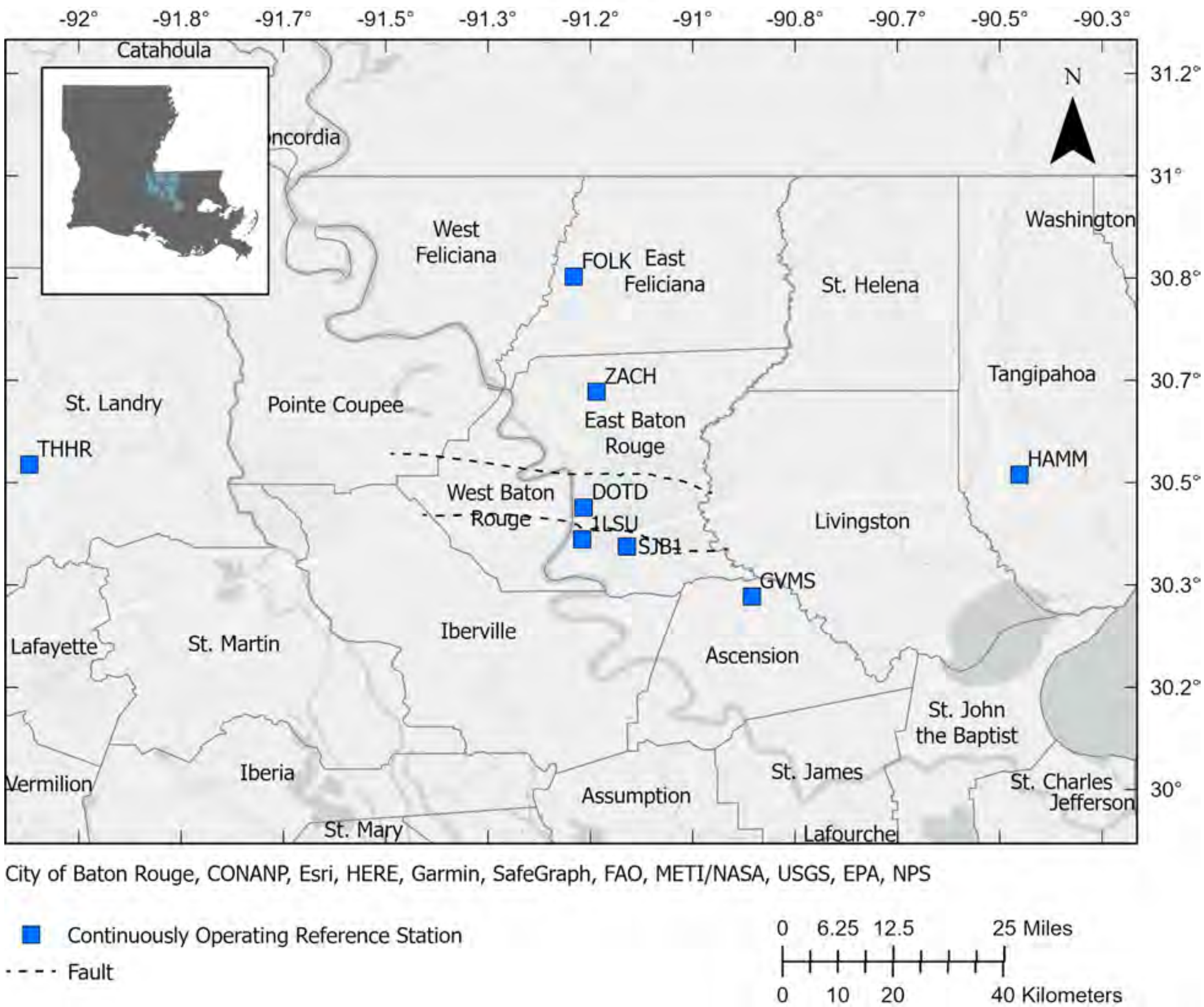


Figure 88. Continuously Operating Reference Stations (CORS) used in this study labeled with the station name. HAMM and THRR were used to estimate regional subsidence. DOTD provides a measurement of subsidence at that point near the Industrial District. See Table 15 for details of each station. Data from CORS are obtained from the National Geodetic Survey or the C4G network operated by LSU.

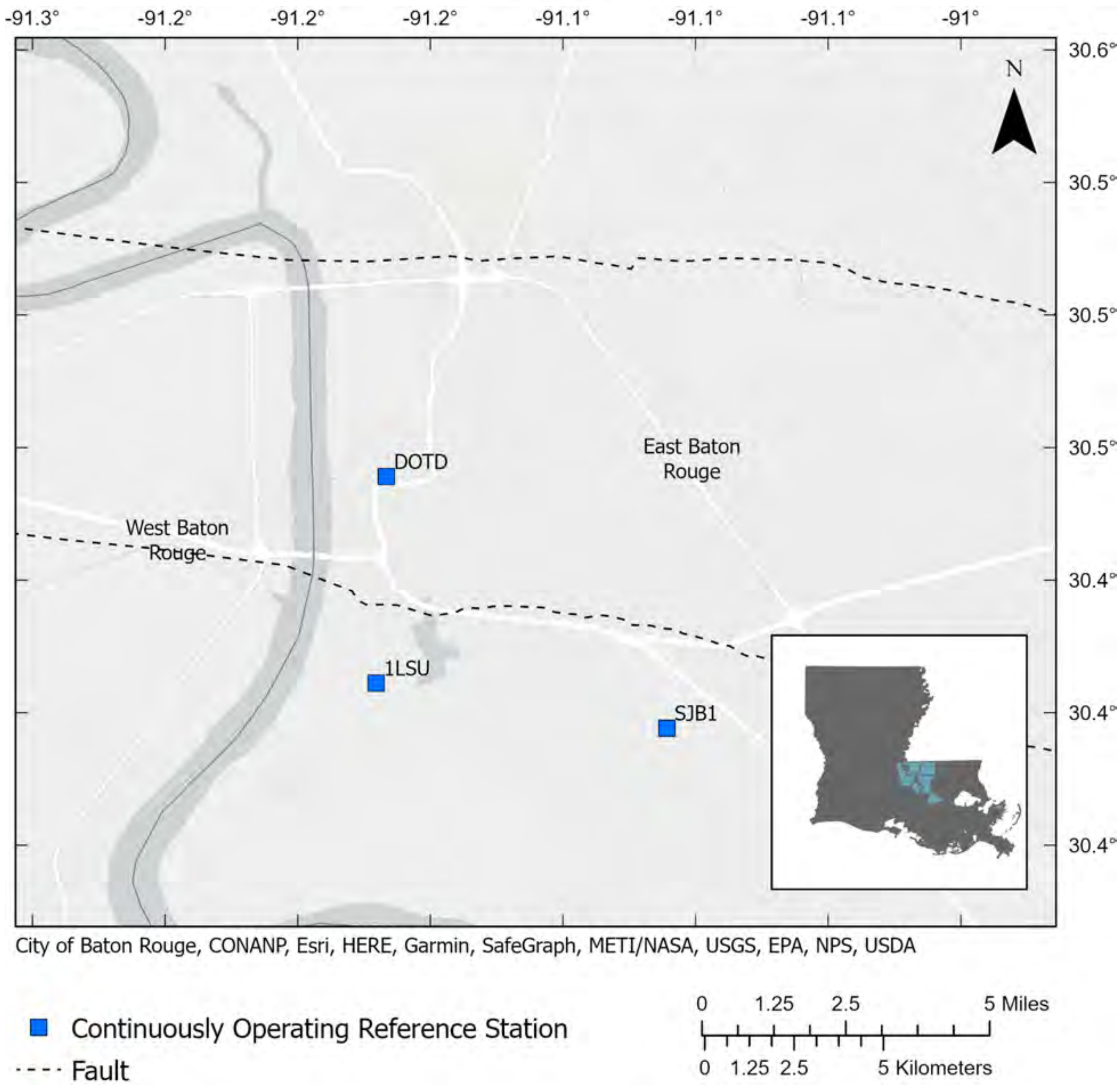


Figure 89. Continuously Operating Reference Stations (CORS) near the Industrial District. Only one station exists in the Industrial District. 1LSU and SJB1 are south of the Baton Rouge Fault and will include motion along the fault in their recorded movement. This single point measurement of subsidence cannot measure the spatial variability of subsidence. Data from CORS are obtained from the National Geodetic Survey or the C4G network operated by LSU.

Table 15. Summary of Continuously Operating Reference Stations used in this study. The network abbreviations are as follows: NGS - National Geodetic Survey (US Department of Commerce, n.d.), C4G - Louisiana State University Center for Geoinformatics (LSU Center for Geoinformatics, n.d.). Note this is not an exhaustive list of CORS in either network.

Station	Location Description	Latitude	Longitude	Vertical velocity (in/yr)	Network
HAMM	Hammond, LA	30.51308	-90.4676	-0.035	NGS; C4G
THHR	Opelousas, LA	30.52935	-92.0806	-0.075	NGS; C4G
1LSU	LSU Baton Rouge, LA	30.40742	-91.1803	-0.083	NGS; C4G
SJB1	Baton Rouge, LA	30.39607	-91.1072	-0.020	NGS; C4G
DOTD	DOTD Baton Rouge	30.45935	-91.1777	-0.13	C4G
FOLK	Jackson, LA	30.83554	-91.1939		C4G
ZACH	Zachary, LA	30.64814	-91.1565		C4G
GVMS	Galvez, LA	30.31439	-90.9036	-0.059	NGS; C4G

Between 1900 and 1965, the Baton Rouge area experienced as much as 0.98 ft (11.76 in) of subsidence (Davis & Rollo, 1969; Smith & Kazmann, 1978). Based on the estimates of regional subsidence, over this same time period subsidence of approximately 3.6 in to 7.8 in would be expected. There was approximately 4 in to 8 in of excess subsidence that was likely due to groundwater extraction. From 1934 to 1976, Smith and Kazmann (1978) found that the maximum subsidence in the Industrial District was 1.67 ft (20.04 in); this amount exceeds the expected regional subsidence by 15 in to 17.7 in.

Extensometers were placed at the local maximum of local subsidence in the Industrial District by USGS in 1975 at three depths to monitor compaction-induced subsidence down to 2,997 ft (Table 16; Figure 90; Whiteman Jr., 1980). The shallow extensometer measures compaction from the surface to 833 ft. The intermediate extensometer measures compaction from the surface to 1,700 ft. The deep extensometer measures compaction from the surface to 2,997 ft. The compaction between 833 ft and 1,700 ft and between 1,700 ft and 2,997 ft can be found by subtraction of the relevant compaction measurements (e.g., intermediate extensometer compaction – shallow extensometer compaction = compaction between the two measurements). Regional subsidence is expected to occur far below the extensometers and would not affect these compaction measurements. The extensometers collected data from 1975 to 1982, 1990 to 1999, and 2001 to 2015. Paper records covering the period 1975 to 1982 and 1990 to 1999 have unrecoverable issues with vertical control and cannot be used to calculate subsidence rates (pers. comm., Max Lindaman, USGS Lower Mississippi-Gulf Water Science Center, 2021). Whiteman (1980) reports on the data collected from 1975 to 1979, and though the data cannot be re-analyzed, the analyses from this report are expected to be reliable. The extensometer data from 2001 to 2015 is digital data that do not have the same issues with vertical control as earlier paper records. These digital data have passed the

USGS quality assurance review. Issues of instrument access and maintenance, as well as funding for these activities, can limit the usefulness of instruments such as extensometers; continual instrument maintenance is necessary to ensure reliable data collection.

Table 16. Extensometer and well details (Whiteman Jr., 1980). Sand represents the sand layer in which the well is drilled.

Well	Sand	Extensometer Depth	USGS Site Number
EB-945	600-ft	833 ft	302932091101902
EB-946	1200-ft	1700 ft	302932091101903
EB-944	2800-ft	2997 ft	302932091101901

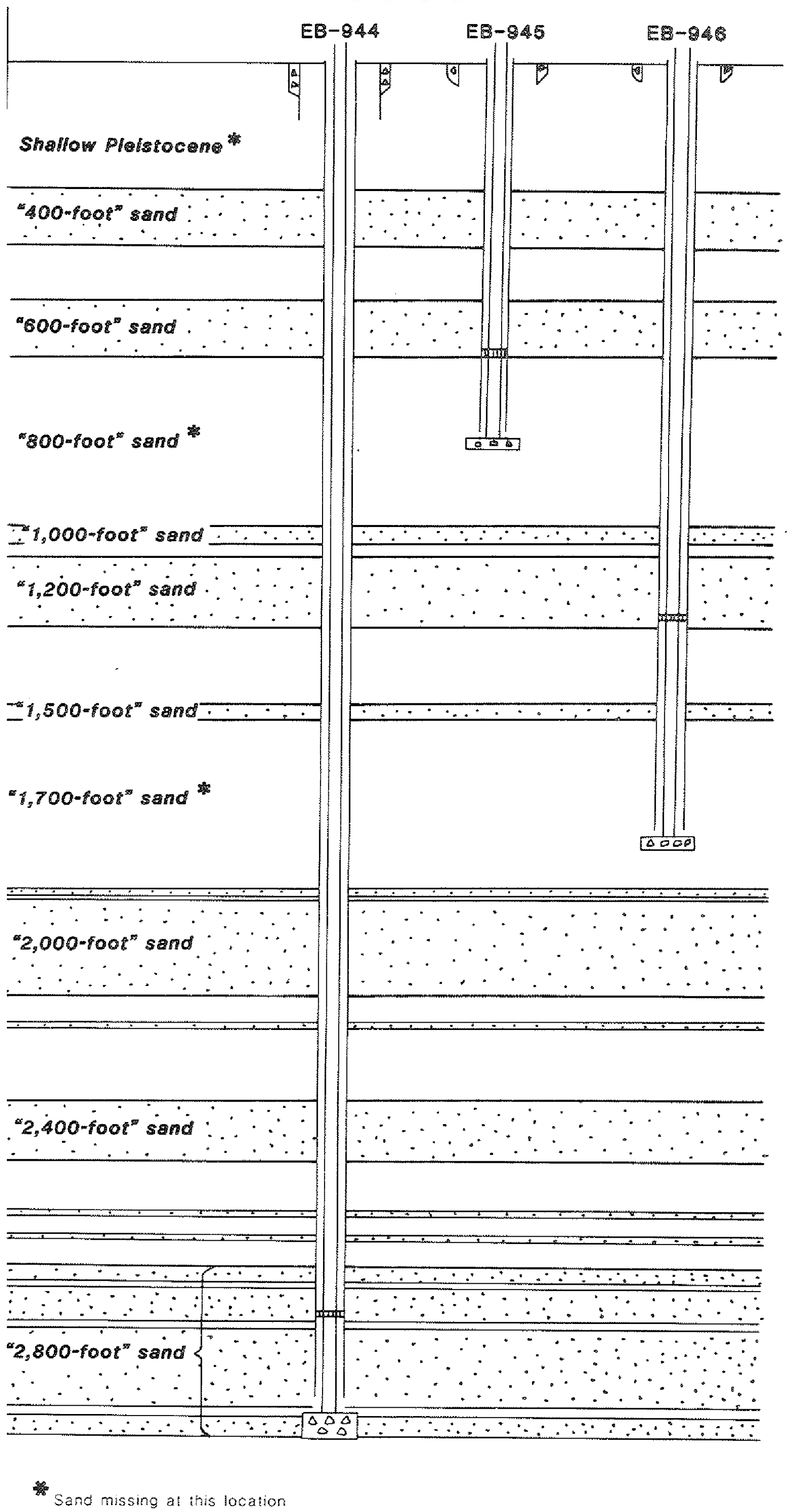


Figure 90. Extensometers installed in the Industrial District in relation to the aquifer sand layers. Modified from Whiteman (1980).

Between extensometer installation in 1975 and 1979, the shallow extensometer measured 0.1 ft (1.2 in or 0.3 in/yr) of elastic compaction and rebound (Figure 91); there was little to no long-term compaction (Whiteman Jr., 1980). The intermediate extensometer measured 0.02 ft (0.24 in or 0.06 in/yr) of compaction that Whiteman Jr (1980) interprets as probably permanent, and the deepest extensometer measures 0.03 ft (0.36 or 0.09 in/yr). These measurements are lower than those measured by previous leveling studies, and it should be noted that the extensometer measurements were taken at a time of stable water levels, while previous studies were conducted during sharply declining water levels. The extensometers remain in place; an analysis of the recent trends in these data follows in the next section.

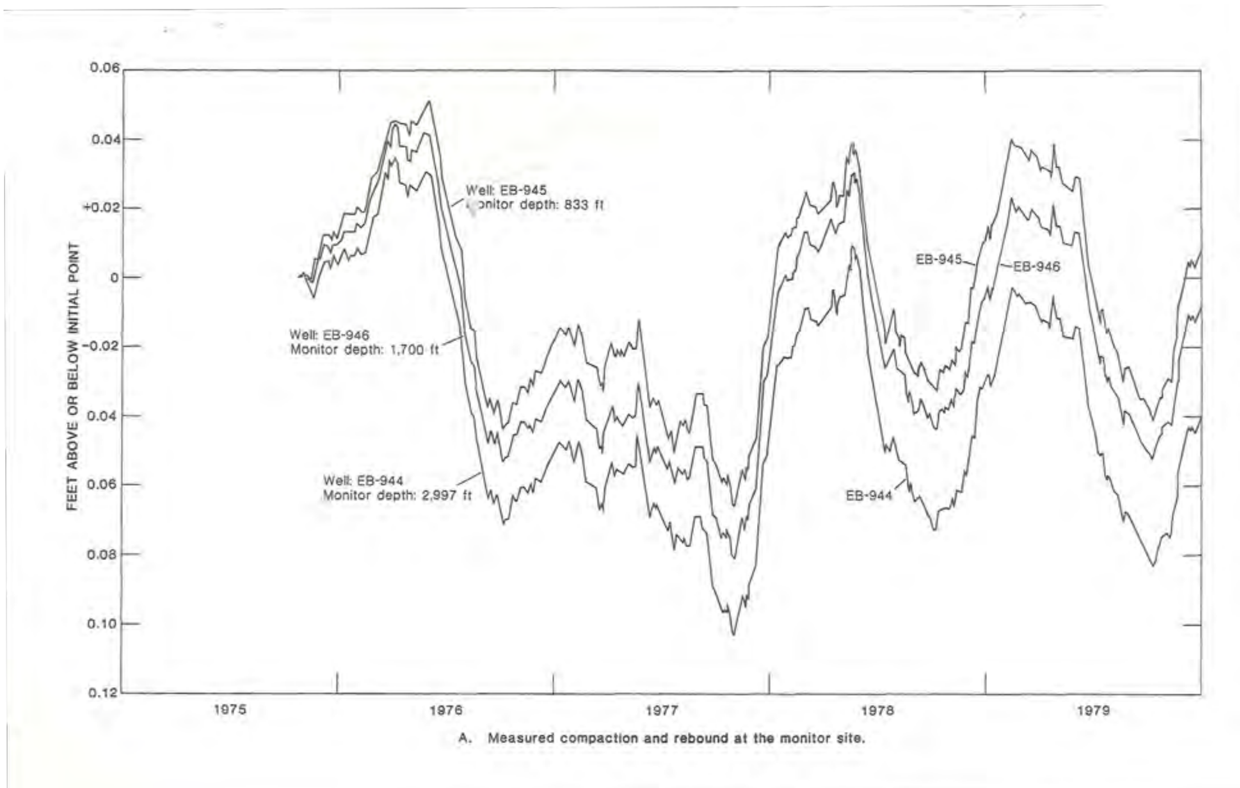


Figure 91. Measured compaction and rebound at the Industrial District extensometer. Modified from Whiteman (1980).

For every 100 ft of head decline in the aquifer as a whole, approximately 0.3 ft to 0.5 ft of subsidence should be expected, but subsidence >1 ft has also been recorded in some areas with 100 ft of head decline (Davis & Rollo, 1969; Wintz Jr et al., 1970). Additionally, subsidence can continue to occur even after water levels stabilize. Based on the similarity of the geology in Baton Rouge and Houston, Wintz Jr et al. (1970) suggest that there is a lag of approximately 5 years between water level declines and subsidence and that subsidence could continue for 20 years or more after water levels stabilize. The thick clay layers in the SHAS take much more time to equilibrate with the aquifer pressure than the coarser grained sand layers (Kasmarek et al., 2016; Kasmarek & Strom, 2002; Whiteman Jr., 1980); these layers have a high potential for additional compaction, especially as a mineralogy analysis of cores from the extensometer site show a high percentage of swelling clays that can be expected to have a higher potential for compaction than other types of clay (Whiteman Jr., 1980). Subsidence due to groundwater extraction in the SHAS occurs not only at the site of groundwater extraction, but across a large area comparable to the cone of depression (Figure 92; Figure 93; Figure 94; Figure 95; Davis & Rollo, 1969; Smith & Kazmann, 1978; Wintz Jr et al., 1970). Smith and Kazmann (1978) contoured the subsidence measured from 1934 to 1976 in the CAGWCD. Their outermost contour experienced 0.2 ft (2.4 in) of subsidence over this period. This subsidence rate (0.06 in/yr) is between the minimum and maximum values for regional subsidence rate in the CAGWCD and represents the potential boundary of the effect of groundwater extraction-induced subsidence. The entire area inside this contour represents the area that has potentially been affected by groundwater extraction-induced subsidence in the past. This contour encircles over 1100 square miles. The close correspondence between the location and severity of the cone of depression and the subsidence contours can be seen in Figure 94 and Figure 95, which show the cone of depression seen in the 2400-foot sand and the subsidence contours from Smith and Kazman, (1978). Note that subsidence is caused by the cones of depression in all the sand layers and should not be expected to precisely match with any single potentiometric surface.

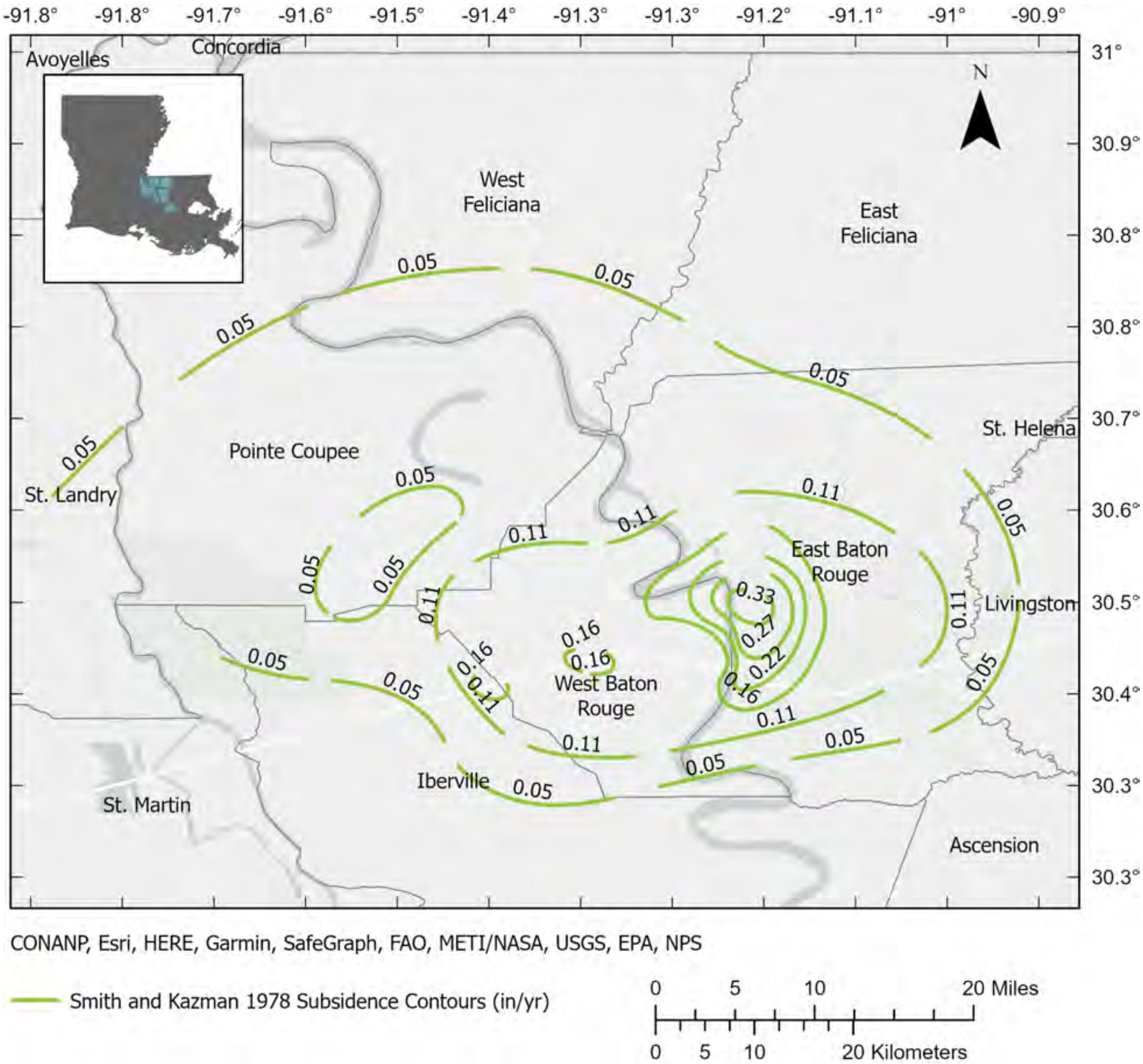


Figure 92. Contours of subsidence rate in the area of the CAGWCD measured as in/yr. Modified from Figure 4 in Smith and Kazmann (1978).

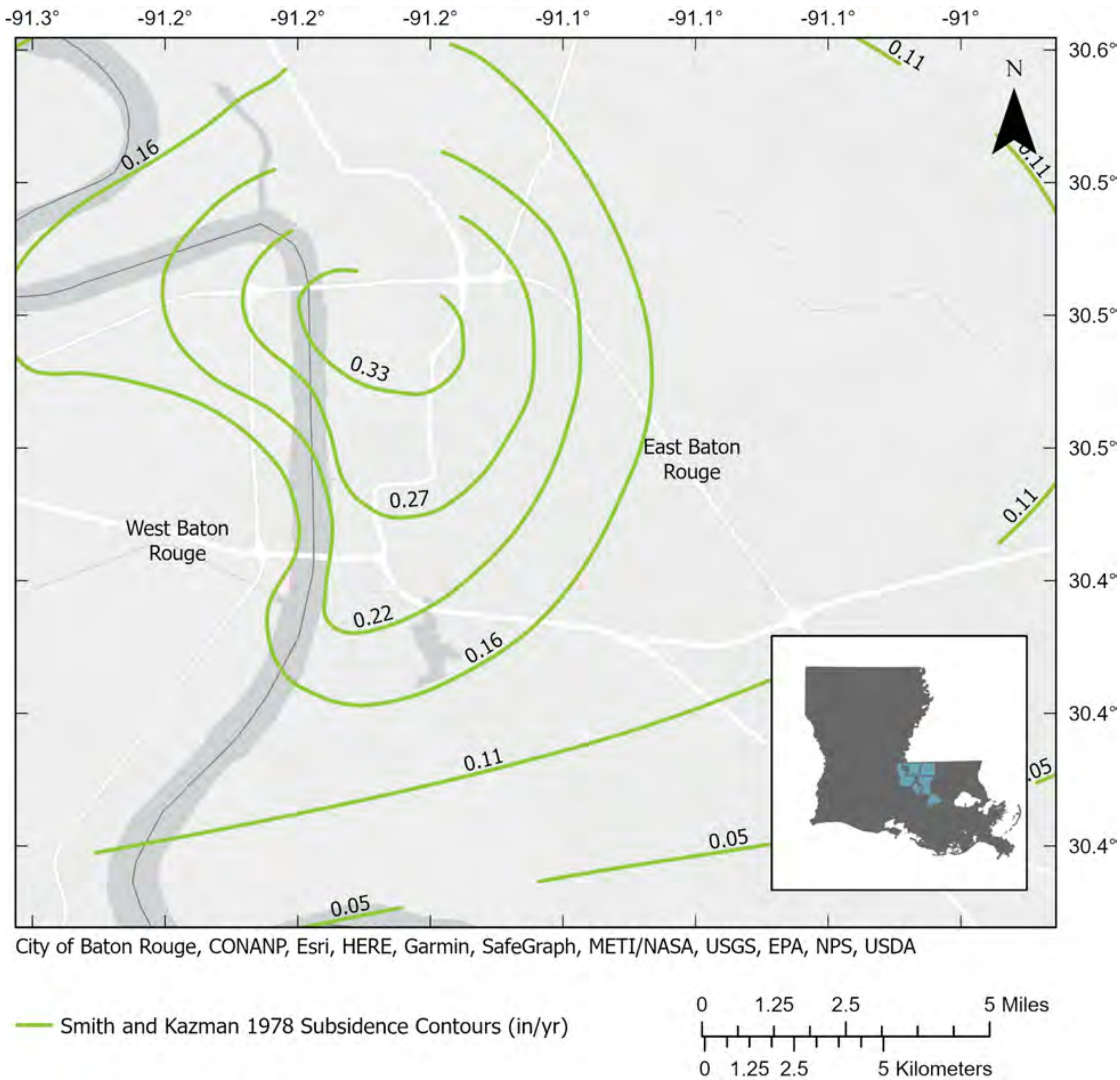


Figure 93. Contours of subsidence rate measured as in/yr in the Industrial District. Modified from Figure 4 in Smith and Kazmann (1978).

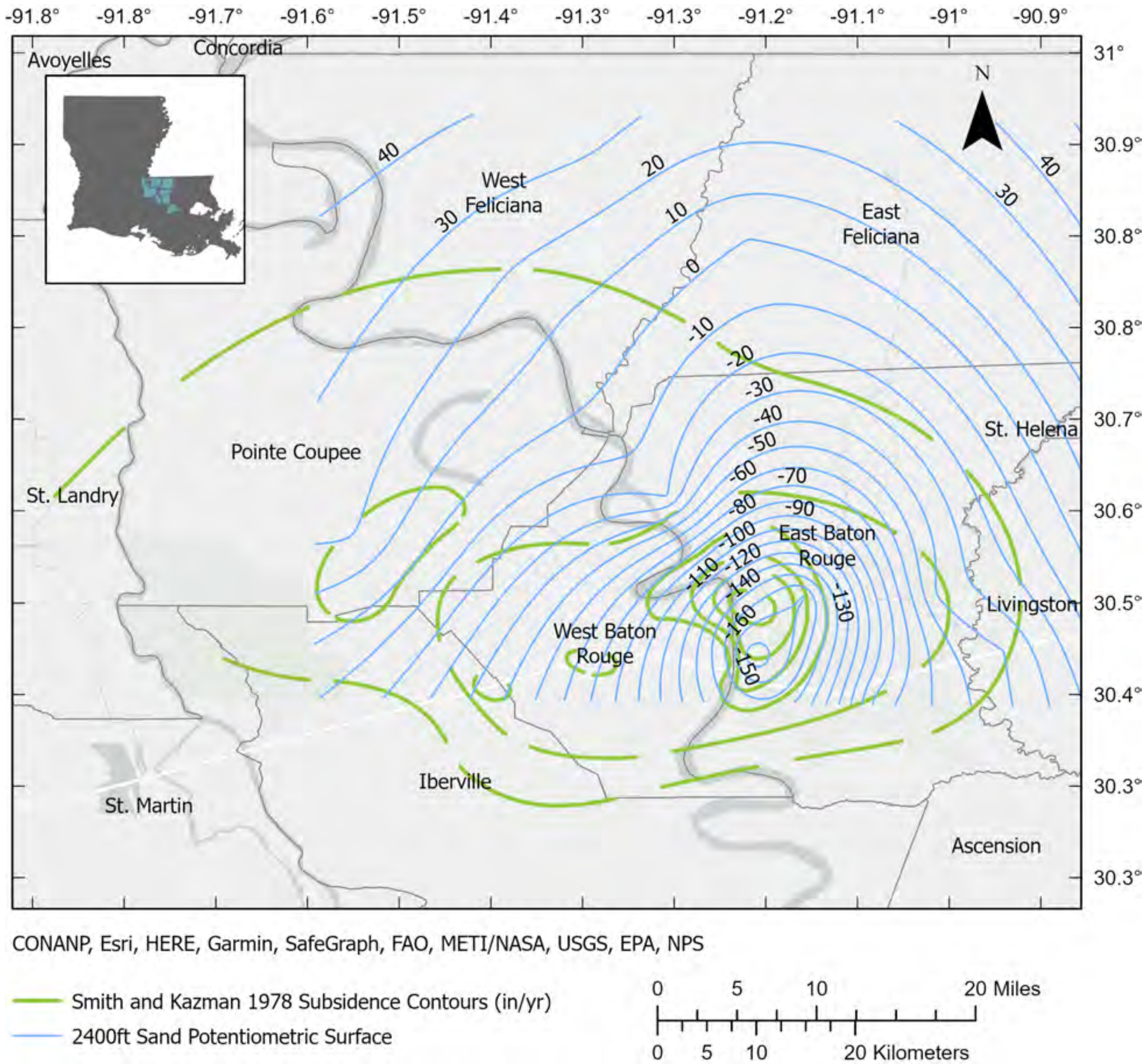


Figure 94. Contours of subsidence rate measured as in/yr, modified from Figure 4 Smith and Kazmann (1978) (black), and contours for the 2400-foot sand potentiometric surface from this report (blue). For clarity, only the

potentiometric surface contours are labeled. Reference Figure 92 for the values of the subsidence contours.

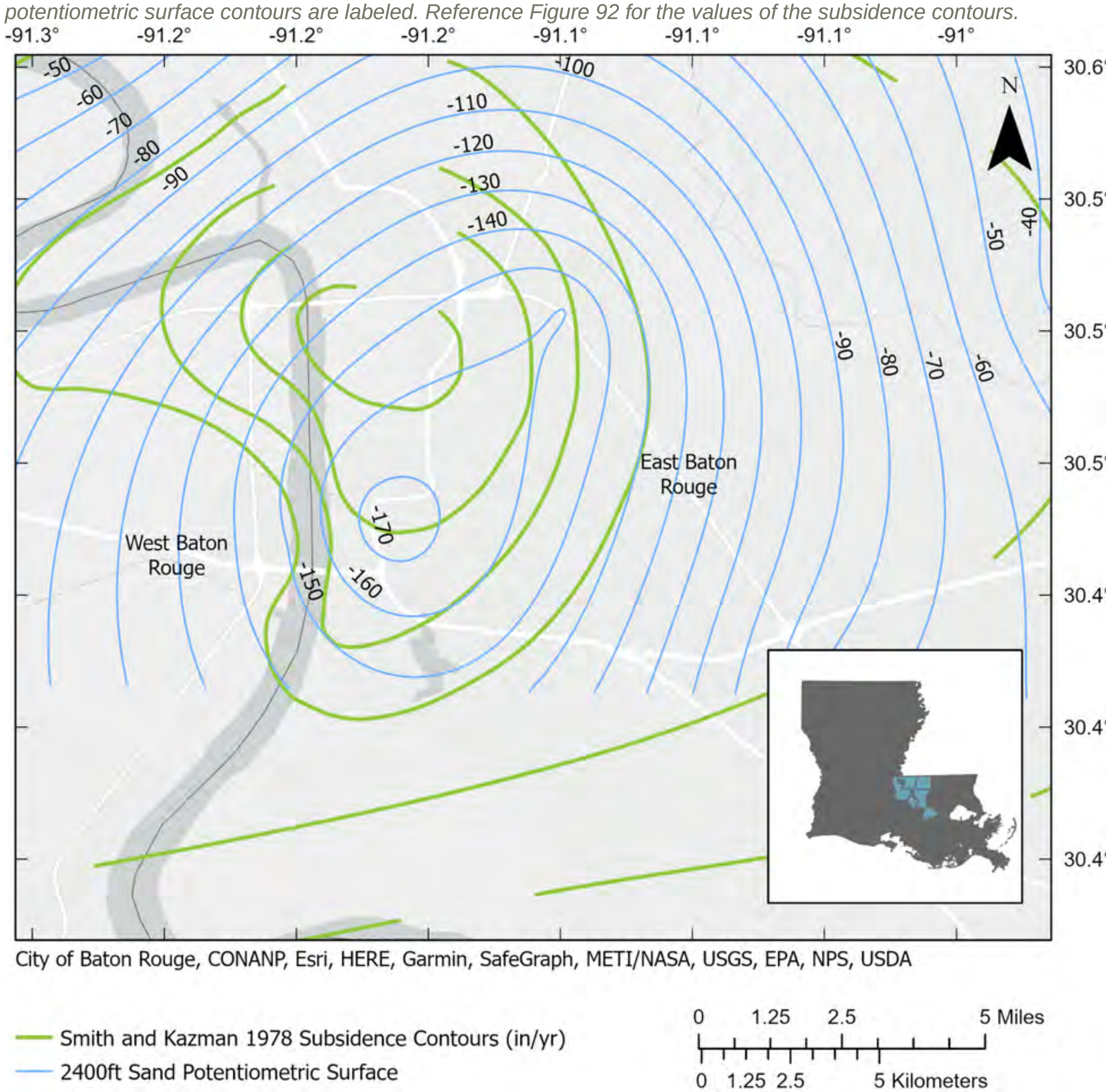


Figure 95. Contours of subsidence rate measured as in/yr, modified from Figure 4 Smith and Kazmann (1978) (black), and contours for the 2400-foot sand potentiometric surface from this report (blue) in the Industrial District. For clarity, only the potentiometric surface contours are labeled. Reference Figure 93 for the values of the subsidence contours.

All previous authors of the subsidence studies discussed here note that declining water levels and the resulting subsidence are cause for continued concern (Davis & Rollo, 1969; Smith & Kazmann, 1978; Whiteman Jr., 1980; Wintz Jr et al., 1970). Davis and Rollo (1969) conclude that "if subsidence continues unabated, which seems likely in view of increasing ground-water withdrawal, it may result in costly damage to structures that depend upon maintaining a uniform grade, such as sewers, levees, and channel and drainage works."

Key recommendations from Smith and Kazmann (1978) were:

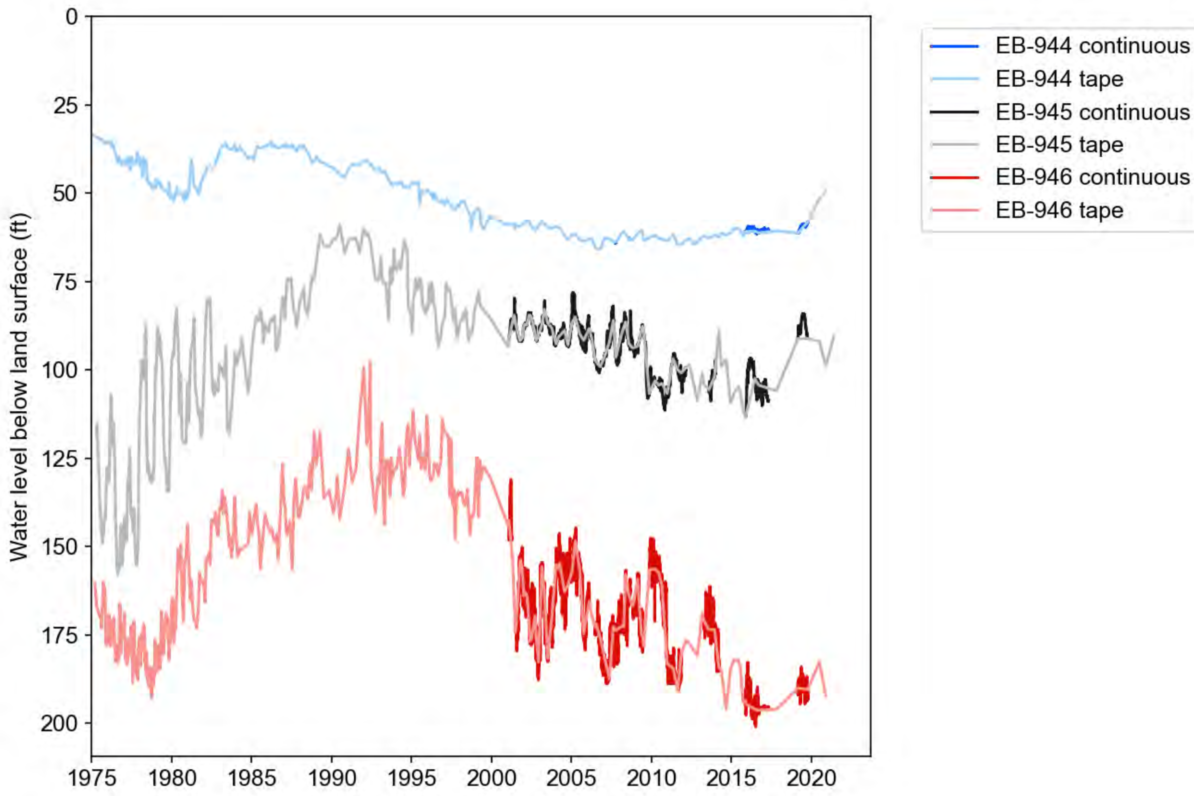
- Exxon extensometer is observed indefinitely
- Plans for installation of additional subsidence monitoring wells be considered on the perimeter of the area of concentrated pumpage
- First order leveling of selected key benchmarks should be scheduled on a 5-to-10-year basis and correlated with groundwater pumpage. The frequency should be dependent upon data obtained from subsidence monitoring wells and changes in groundwater pumpage rates and location.
- Local and other State governmental agencies should implement a plan for determining the amount and effects of subsidence associated with the BR fault.

Whiteman Jr (1980) notes that water level declines below the preconsolidation level could result in an abrupt increase in the subsidence rate. Declines below the preconsolidation level would subject the sediments to stress from the overlying sediments that is higher than what they have experienced before, potentially leading to large increases in stress induced compaction.

Current data in the CAGWCD

At the extensometers installed in the Industrial District, it is possible to analyze recent trends in water levels and compaction. Each extensometer is paired with a well to monitor water levels at a similar depth to the extensometer installation (Table 16). Water levels at these wells have been monitored both by periodic site visits by USGS personnel, and by continuous water level monitoring equipment. Site visit water levels are noted as 'tape' measurements.

Water levels in EB-944 peaked between 1983 and 1986 and water levels in EB-946 and EB-945 peaked in the early 1990s (Figure 96; Figure 97). Water levels at EB-946, in the 1200-foot sand, have been declining at the highest rate of the three wells, and have declined levels comparable with water levels in the 1970s; an increase in subsidence rates to rates comparable with the 1970s can be expected for this sand layer. Although measurements since the 2010s suggest that water levels may have started to stabilize, subsidence is likely to continue for some time due to the lag between water level declines and compaction.



Water level below land surface (ft)
0
25
50
75
100
125
150
175
200
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
EB-944 continuous
EB-944 tape
EB-945 continuous
EB-945 tape
EB-946 continuous
EB-946 tape

Figure 96. Water levels measured at the extensometers in the Industrial District. Note that the water level axis has been flipped so that water levels that are closer to the surface are near the top of the figure.

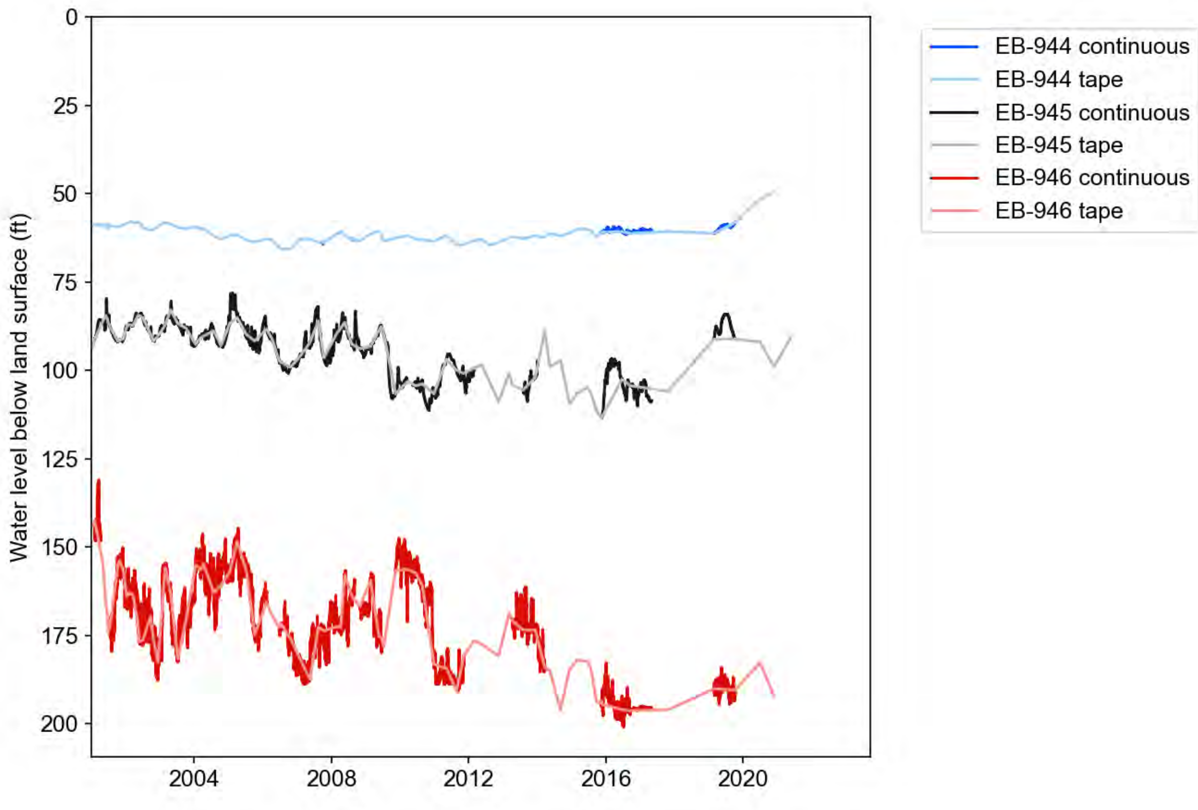


Figure 97. Water levels measured at the extensometers in the Industrial District for the time period of recent extensometer measurements (2001 to 2015). Note that the water level axis has been flipped so that water levels that are closer to the surface are near the top of the figure.

The measurements at all three extensometers were restarted in 2001 and continued until 2015. Recording was restarted at 0 ft of compaction. There is a period of about 5 years at the beginning of the record (2001-2006) when the small amount of measured compaction results in overlap and crossing of the measured compaction values at the different extensometers. It is not physically possible for the total compaction measured at the deep or intermediate extensometers to be less than the compaction measured at the shallow extensometer because each measures from the surface. The overlap and crossing are likely a result of the measurement uncertainty inherent in all measurements, especially those of very small values; in this type of measurement a significant source of uncertainty comes from friction of the extensometer pipe against the wall casing. As the measurement period increases, the signal of compaction increasingly overcomes the noise from measurement uncertainty. Because subsidence can be an extremely small quantity, often less than 1 in/yr, longer measurement intervals are crucial to accurate measurements.

All three extensometers in the Industrial District show periods of increasing and decreasing compaction throughout the record (Figure 98; Figure 99). At the shallowest extensometer (depth 833 ft), there was no sustained compaction over the measurement period; the total compaction over the record is approximately

0 ft. Both of the deeper extensometers show increasing compaction as well as some of the short-term fluctuations seen at the shallow extensometer. The deepest extensometer (depth 2,997 ft) shows the least amount of short-term fluctuations. The short-term fluctuations are potentially related to seasonal changes in the near surface, and not related to changes in the deeper confined aquifer. Over the period of measurement (2001 to 2015) there was 0.10 ft of total compaction. This represents the rate of compaction over the entire 2,997 ft depth (Table 17). The compaction rate at EB-944, over the whole record is 0.082 in/yr (Table 18). The compaction rates measured at EB-946 and EB-945 were similar (Table 17; Table 18) even though EB-946 had a larger water level decline. It is important to remember that these subsidence rates are exclusive of regional subsidence. The total subsidence measured at the surface would be higher because it would include regional subsidence.

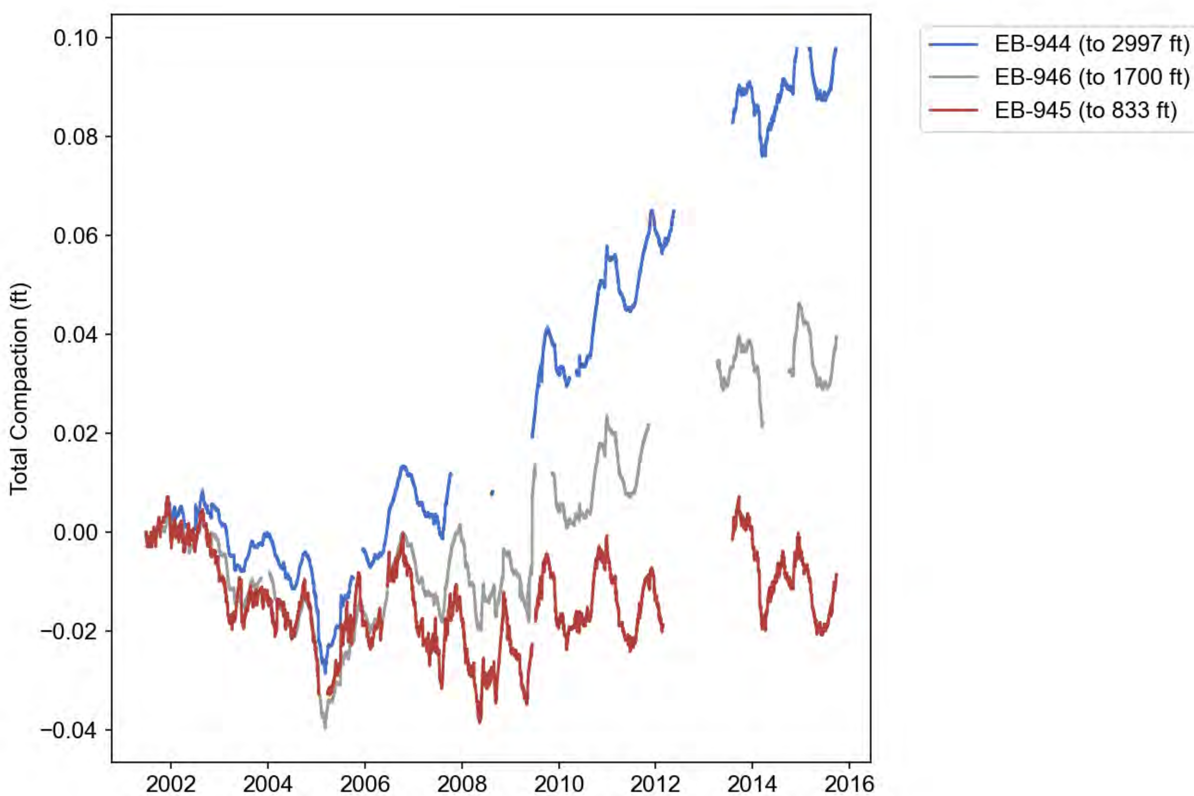


Figure 98. Total compaction measured at the extensometer in the Industrial District for each of the three extensometer depths. The extensometers were originally installed in 1975. This record begins in 2001, after

maintenance and restarting the recording.

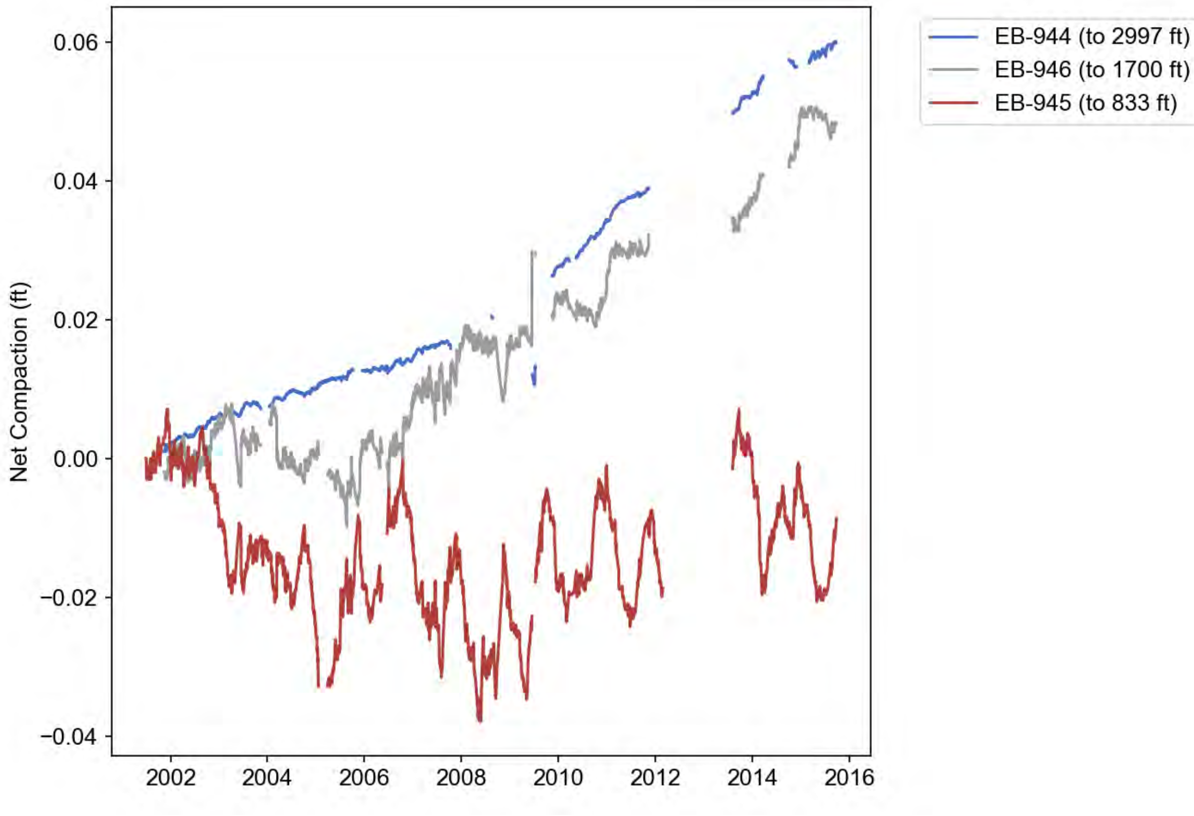


Figure 99. Net compaction in the Industrial District as measured by the extensometers. Net compaction is calculated by subtracting the compaction that occurred in all shallower intervals. The extensometers were originally installed in 1975. This record begins in 2001, after maintenance and restarting the recording.

Table 17. Compaction measured at the Industrial District extensometers from 2001 to 2015. Total compaction is from the surface to 2,997 ft. Net compaction is measured for the specific interval covered by a single extensometer.

Extensometer	Depth (ft)	Total Compaction (ft)	Net Compaction (ft)
EB-945	833	-	-0.0086
EB-946	1700	-	0.048
EB-944	2997	0.10	0.060

Table 18. Compaction rates at the Industrial District extensometers from 2001 to 2015. Total compaction rate is from the surface to 2,997 ft (and thus is only reported for the deepest extensometer). Net compaction rate is measured for the specific interval covered by a single extensometer.

Extensometer	Depth (ft)	Total Compaction Rate (in/yr)	Net Compaction Rate (in/yr)
EB-945	833	-	-0.0072
EB-946	1700	-	0.042
EB-944	2997	0.082	0.050

The continuous measurements of water level, combined with the continuous compaction measurements (both 2001-present), allowed the Institute to investigate the length of the time lag between water level declines and compaction at the extensometers. Wintz Jr et al. (1970) suggest that a time lag of 5 years would be reasonable based on data from Houston. The Institute conducted a cross correlation analysis between water levels at EB-946 and its paired extensometer over the period 2001 to 2015, the most recent available data for both data types. This analysis tests the correlation between the time series of water level and the time series of compaction for different amounts of time lag to investigate at which time lag the correlation between the two time series is greatest. The maximum correlation for these records occurs at approximately 8 years, while the correlations between approximately 5.5 and 9 years are generally high (Figure 100). These results agree well with the inferences made by Wintz Jr et al. (1970). While water level recovery will slow the rate of subsidence, it is important to note that subsidence may continue for several years after water levels stabilize.

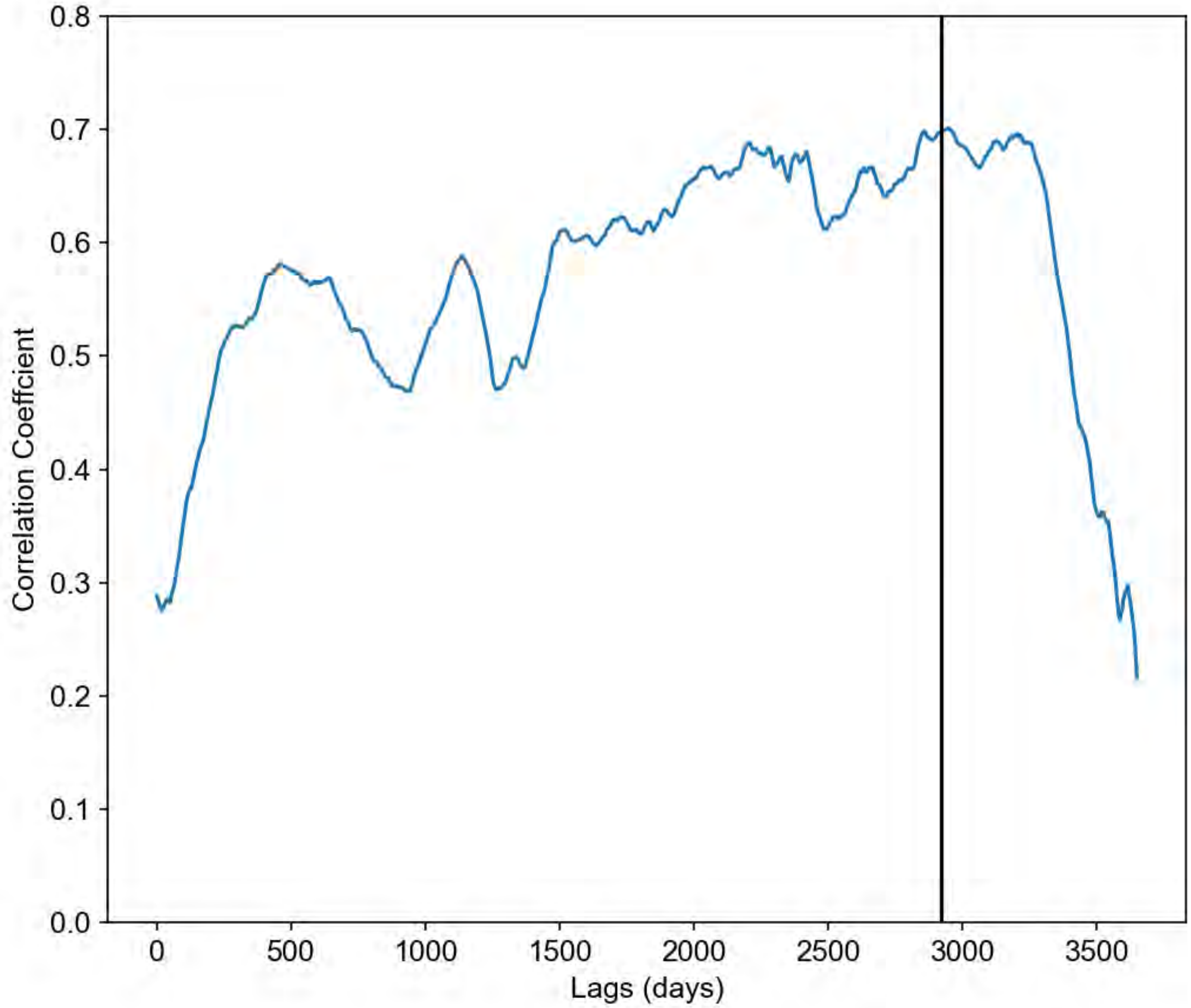


Figure 100. Cross correlation results for the compaction and water level data at EB-946. Compaction is lagged with respect to water level. The black line show the maximum correlation coefficient. This analysis method calculates the correlation between two time series of data with different time lags to find the time lag at which the maximum correlation exists. The maximum correlation for the water level and compaction data at this extensometer exists when compaction is lagged by approximately 8 years.

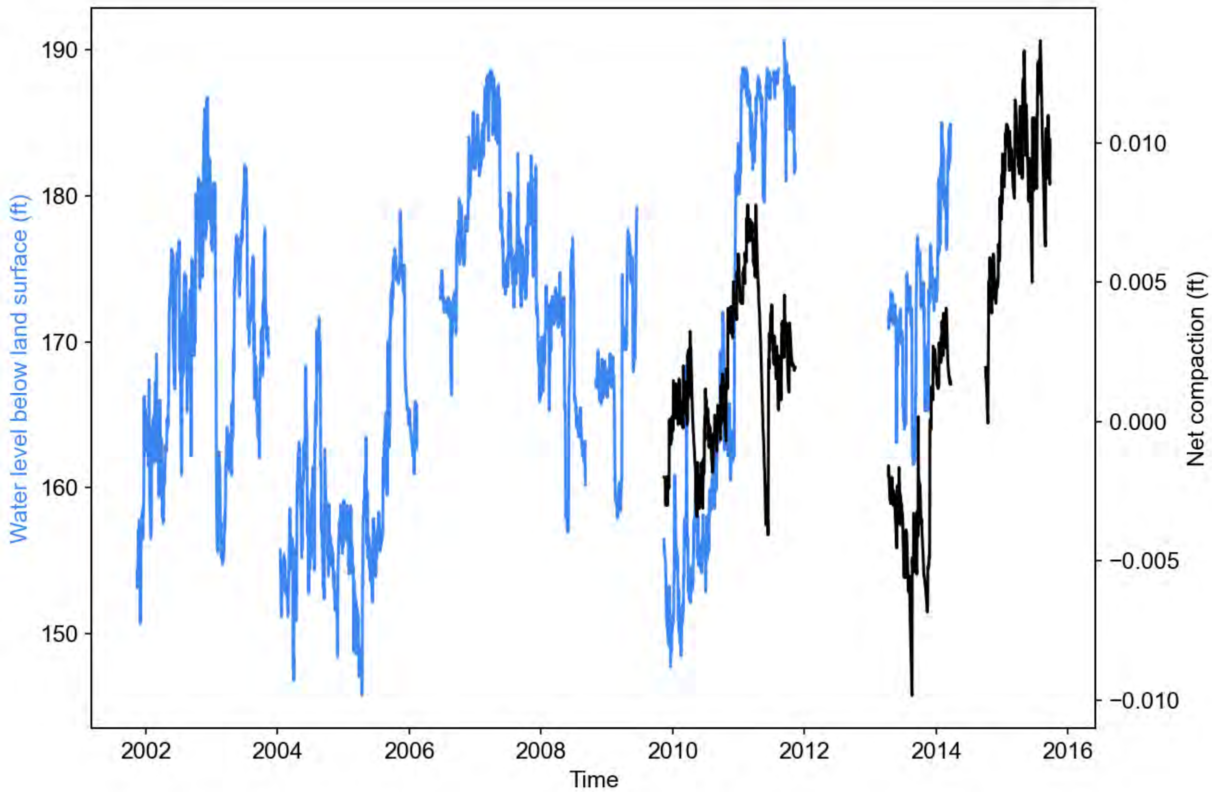


Figure 101. Water level and net compaction at EB-946, where net compaction is lagged by approximately 8 years with respect to water level. Water level and net compaction trend together. Lower water levels correspond with higher net compaction. Note that the water level axis has not been flipped; water levels closer to the bottom of the figure indicate water level closer to the surface. This allows easier comparison with net compaction trends.

The most recent mesurement of subsidence in the CAGWCD comes from the LSU Center for Geoinfomatics (C4G) CORS network. Efforts are currently underway to calculate the motion at each of their GPS stations (Abdalla, 2021). The DOTD station from this network is located near the center of the cone of depression. The rate calculated for this station through late 2021 shows that subsidence continues in the area; the DOTD station is subsiding at a rate of 0.13 in/yr +/- 0.0051 in/yr (Abdalla, 2021). This rate is calculated from late 2014 to early 2021.

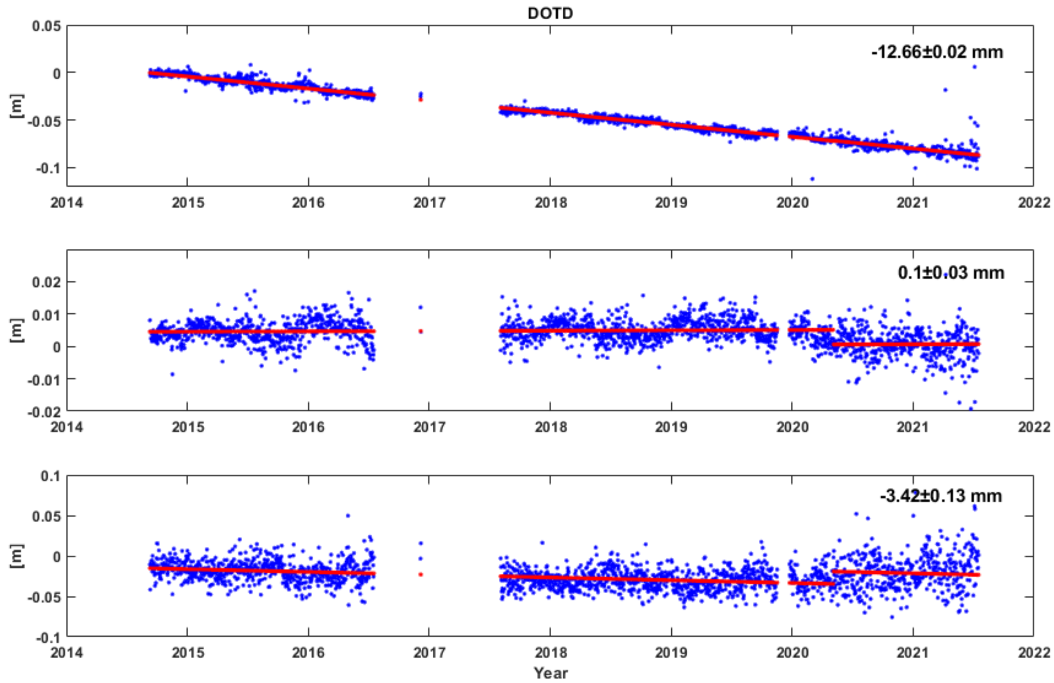


Figure 102. Calculated motions at the DOTD CORS (Abdalla, 2021). Top: Station velocity to the East. Negative velocity represents westward motion. Middle: Station velocity to the North. Bottom: Vertical station velocity. Negative values represent subsidence of the station. Blue dots show the observed points. Red lines show the modeled values from Abdalla (2021). The location of this station can be seen in Figure 88. Note that figure units are metric. Vertical velocity as in/yr can be found in Table 15.

Given the numerous measurement periods and measurement types, it is useful to compile the rates and time periods into comparable numbers. Table 19 lists the subsidence rates in the Industrial District area along with the data source and measurement type. For leveling and CORS measurements, the range of potential regional subsidence has been subtracted from the measured subsidence rate for a one-to-one comparison with the extensometer data. The extensometers measure compaction-induced subsidence between the surface and the bottom of the installation; the measurement does not include regional subsidence. Leveling studies and CORS measure all subsidence from the surface to depth, inclusive of regional subsidence. It is clear that the modern subsidence rates are lower than those seen earlier in the last century; nevertheless, water levels that continue to fall will cause subsidence rates to increase. Furthermore, as patterns of pumpage change in the CAGWCD, subsidence patterns can change. A consistent subsidence monitoring strategy could help to ensure the future health of the aquifer.

Table 19. Summary of subsidence rates in and around the Industrial District resulting from groundwater withdrawal. The regional subsidence rate was subtracted from the rate determined by leveling and CORS. These rates are given as a range to indicate uncertainty in the regional subsidence rate (0.055 in/yr to 0.12 in/yr). Total subsidence is the estimate excess subsidence over and above regional subsidence for the time period. Note that the time periods vary considerably between the different measurements.

Time period	Subsidence Rate due to groundwater extraction (in/yr)	Total Subsidence due to groundwater extraction (ft)	Measurement Type	Data Source
1900-1965	0.06 – 0.13	0.33 – 0.70	Leveling	Davis and Rollo 1969
1938-1964	0.42	0.9*	Leveling	Wintz Jr et al.1970
1934-1976	0.36 – 0.43	1.26 – 1.51	Leveling	Smith and Kazmann 1978
1975-1979	0.15	0.05	Extensometer	Whiteman 1980
2001-2015	0.082	0.10	Extensometer	USGS 2021 data; analysis in this report
2014-2021	0.01 – 0.075	0.0058 – 0.044	DOTD CORS	Abdalla 2021

**Wintz Jr et al. (1970) report this as the total subsidence attributable to groundwater extraction.*

Importance of Monitoring Subsidence in the CAGWCD

The current subsidence rates in the CAGWCD are lower than the rates observed in Houston and San Joaquin; however, these relatively small rates of subsidence could result in measurable land surface change when accumulated over 50 years (Figure 103). The CAGWCD has not yet reported infrastructure damage to roads or buildings that can be attributed to groundwater extraction-induced subsidence such as that seen in other locations (Bertoldi, 1989; Sneed et al., 2013); however these are not the only potential consequences. Subsidence induced by groundwater extraction occurs at different rates across the CAGWCD and across neighborhoods. Differential subsidence of even small amounts can result in changing water flow patterns, which can lead to new and increased depths of ponding water from heavy rainstorms; changes to topographic gradients and base flood elevations due to subsidence in Houston are suggested to have increased flood severity during Hurricane Harvey (2017; Miller & Shirzaei, 2019). Homes and businesses could see changing flood zone categories and increased flood risk.

The Federal Emergency Management Agency (FEMA) defines the base flood elevation (BFE) as "the elevation of surface water resulting from a flood that has a 1% chance of equaling or exceeding that level in any given year" (FEMA, 2021a). The BFE in EBR Parish near the Industrial District is 52 ft above NAVD88 (Figure 104) (FEMA, 2021b). According to USGS elevation data (U.S. Geological Survey, 20191106) for this area, land elevations are very close to this base flood elevation, even in Zone X which is outside the FEMA Special Flood Hazard Area. Subsidence of less than 1 ft over the course of 50 years has the potential to increase flood risk for homes and businesses in the CAGWCD, especially those closest to the Industrial District where subsidence rates are highest.

Figure 103 shows the total amount of subsidence that can be expected over 50 years with different subsidence rates that have been measured in the CAGWCD at different points in time (Holdahl & Morrison, 1974; Smith & Kazmann, 1978; Whiteman Jr., 1980; Wintz Jr et al., 1970). These rates are inclusive of regional subsidence and can be compared to the regional subsidence rate. At the highest rates, even assuming the highest regional subsidence rate, there is still 1.5 ft of subsidence more than what would be expected from regional subsidence rates. At the rates seen in recent extensometer measurements, there is 0.34 ft of additional subsidence over 50 years, over what would be expected from regional subsidence rates.

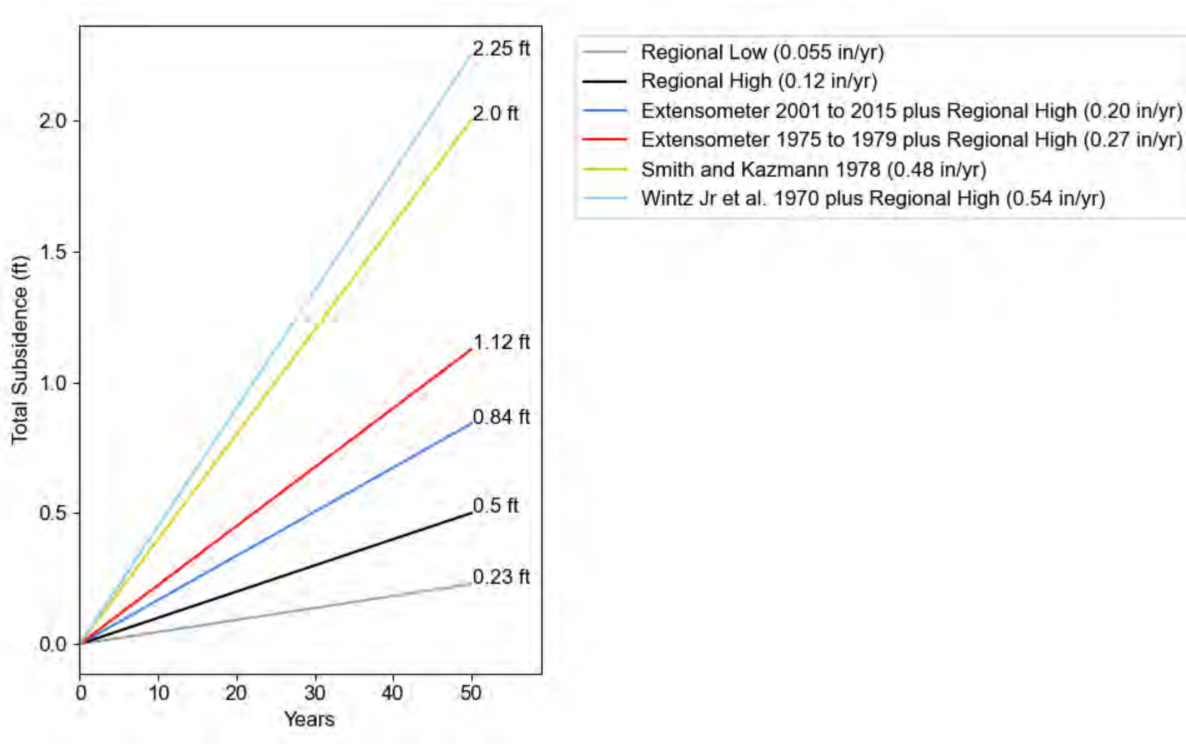


Figure 103. Total subsidence extrapolated over 50 years for different subsidence rates. The high estimate for regional subsidence was added to the extensometer measurements to make them comparable with the leveling measurement. The high estimate of regional subsidence was also added to the rate from Wintz J et al. (1970) because the report defines the reported subsidence value as the subsidence attributable to groundwater extraction. The total subsidence at the end of the 50-year period is labeled at the end of each line. The subsidence rate associated with each line is listed in the legend.

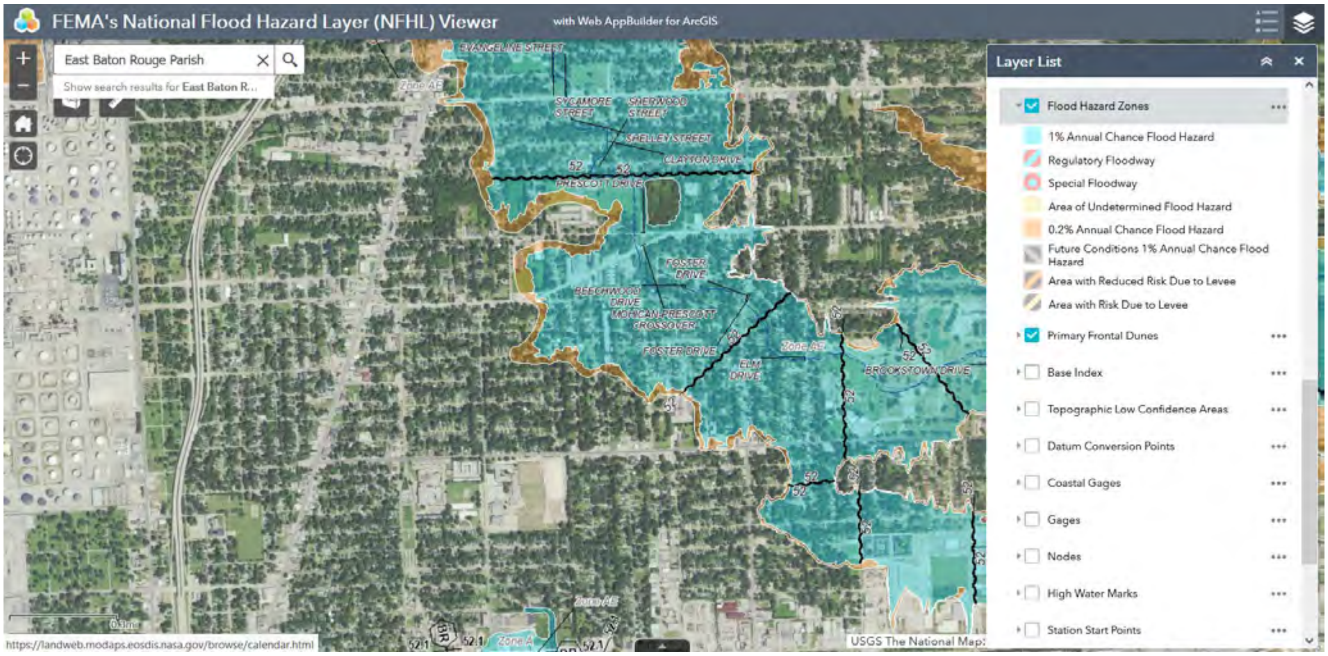


Figure 104. FEMA National Flood Hazard Layer for an area in East Baton Rouge. Blue shows the area of 1% annual chance flood hazard. Orange shows the 0.2% annual chance flood hazard. Base flood elevations are 52 ft NAVD88.

Potential Action by the CAGWCC

Current subsidence data collection is limited in spatial scale and lacks long-term measurements. The CAGWCC could increase monitoring of subsidence over the long-term both within and outside of the area of maximum pumpage to greater understand and inform decisions around groundwater management and subsidence. Improved monitoring within the area(s) of maximum pumpage could provide the CAGWCC with a more accurate and up to date estimate of the maximum subsidence rates occurring in the CAGWCD. The maximum subsidence rate is important to monitor because it is related to the severity of the potential impacts. Monitoring outside the area(s) of maximum pumpage could give the CAGWCC more accurate and up to date estimates of the spatial extent of subsidence occurring in the CAGWCD. An understanding of the spatial extent of subsidence is important because it affects the number of businesses and people that are potentially subjected to increased risk. Additionally, because subsidence is a slow process, long-term monitoring is essential to measuring rates and understanding long-term trends.

There are many techniques that can be employed to measure subsidence, each with its own benefits and challenges. Subsidence in Baton Rouge has been shown to be spatially variable and to occur far from the areas of groundwater pumpage (Figure 92; Figure 94); however not all types of subsidence measurements are well suited to making measurements over large areas. Subsidence has also been shown to occur at different rates in different layers of the aquifer (Figure 98;Table 18); not all types of subsidence measurements are capable of differentiating the subsidence occuring in different aquifer layers. By carefully considering their goals for aquifer management and all the available monitoring options presented within this report, the CAGWCC could develop a data collection strategy that best suits their goals. Four options for monitoring subsidence in the CAGWCD are discussed below (leveling studies, extensometers, Continuously Operating GPS Reference Stations, Interferometric Synthetic Aperature Radar). The Institue is available to answer questions about the monitoring options discussed.

As discussed above, past measurements of subsidence in Baton Rouge have been obtained almost exclusively through leveling studies. These types of studies require expertise to conduct, a reliable, long-established set of survey monuments, and access to the previous measurements and data. Survey expertise is likely the most easily found of these requirements; it is unknown whether the monuments used in the previous surveys are still present. The historical data from the reports may be located, but it may be difficult to find a complete dataset or fully documented methods. Without the historical data, the CAGWCC would need to conduct at least two leveling studies, separated in time, before subsidene could be estimated. A benefit of conducting leveling studies is that they can cover a large area as well as having previously been successfully accomplished in Baton Rouge. This type of study can only measure the total subsidence ocurring in the aquifer layer, and requires an assumption of the regional subsidence rate to differentiate regional subsidence from subsidence within the aquifer.

Extensometers are the other measure of subsidence that has been used in Baton Rouge to measure subsidence induced by groundwater extraction. This method can measure the compaction component of subsidence for different depth intervals in the aquifer. A precise, continuous record of compaction can be obtained with extensometers. As seen with the current installation, if the measurements are to be collected continuously and reliably, the extensometers must be maintained regularly. This type of measurement is located at a single point and many instruments are needed to cover a large spatial area. The Houston-Galvenston area installed 13 extensometers to monitor subsidence (Kasmarek et al., 2016). The depths at which they need to be installed can also make installation difficult and expensive. New extensometers may also need to be monitored for a period of time before they produce useful data. The CAGWCC currently relies on expertise at the USGS to provide data analysis and validation of the existing extensometers.

The C4G at LSU maintains a CORS network that can be used to monitor subsidence. These stations require expertise to install, maintain, and analyze the resulting data for subsidence monitoring. The GPS equipment is expensive and only measures subsidence at a single point. A network of instruments is needed to adequately monitor the spatially varying subsidence that occurs in Baton Rouge. The current CORS network may require supplemental stations to make it adequate for the CAGWCD. New CORS locations do not immediately yield subsidence data; they must be maintained for several years before they can accurately assess subsidence at any location. The existing data are currently being analyzed at LSU. The CAGWCC could review these data products to decide if the existing network meets their needs.

Another modern techinque used to study subsidence in many places including New Orleans, Houston, and California, is Interferometric Synthetic Aperature Radar (InSAR; e.g., Amelung et al., 1999; Aobpaet et al., 2013; Fan et al., 2011; Faunt et al., 2016, 2017; Galloway et al., 1998; Higgins et al., 2014; Jones et al., 2016; Miller & Shirzaei, 2019; Osmanoğlu et al., 2011; Sneed et al., 2013). Precise measurements of the time and phase of radar signals are used to measure the changes in position of radar reflectors, often buildings; InSAR satellites exist which can be used for these types of studies (National Aeronautics and Space Administration, n.d.). This technique excels in urban areas and in measuring subsidence across large areas. It does not require installation of any equipment. It does require high levels of expertise in order to conduct the studies. The Institute is available to aid the CAGWCC in seeking out such expertise which can be found at universities, private consulting companies, and the NASA Jet Propulsion Laboratory.

REVIEW OF MONITORING ALONG LEAKY WINDOWS OF THE BATON ROUGE FAULT

The Baton Rouge Fault has been known as a low-permeability fault that impedes horizontal flows (Pham & Tsai, 2017). 'Leaky windows' are high permeability areas along the fault that may allow migration of saltwater across the fault and result in the elevated chloride concentrations measured in several monitoring wells to the north of the fault. Early studies identified a few sand contact locations and depths at the fault (Rollo, 1969). Recent studies mapped the locations, width, and extent of the leaky windows in detail (Elshall et al., 2013; Pham & Tsai, 2017). This task aims to utilize the latest collection of electrical logs and drillers logs to delineate leaky windows at the Baton Rouge Fault and to recommend potential locations for monitoring chloride concentrations.

Electrical logs and drillers logs were collected from the LDNR Office of Conservation. There were 448 electrical logs compiled from EBR Parish and 109 electrical logs compiled from WBR Parish; numerous drillers logs were also compiled. Only the top 200 ft of drillers logs were employed to fill the gap in electrical logs and create the top strata.

The surficial Baton Rouge Fault trace is available from McCulloh and Heinrich (2013). In principle, the fault trace separates well logs such that hydrostratigraphy can be separately built for both sides of the fault. However, well logs south of the fault trace may penetrate a slightly inclined Baton Rouge Fault at certain depths. In this task, 13 electrical logs near the fault (Figure 105; Table 20) were carefully examined. Their locations are shown in Figure 105. Three wells (EB-400, EB-781, and EB-789) intersect the Baton Rouge Fault due to their depth. Fault intersections at wells EB-400 and EB-781 were confirmed by relatively high groundwater levels south of the fault. The fault intersection at well EB-789 was determined by comparison with surrounding electrical logs. Other wells to the south of the fault may not penetrate the Baton Rouge Fault due to their shallow bottom depth. Images of gamma ray, spontaneous potential, shallow resistivity curves, and sand picks of the 13 wells are shown in Appendix H. Aquifer names and their corresponding sand layer depths in the log images are given by USGS.

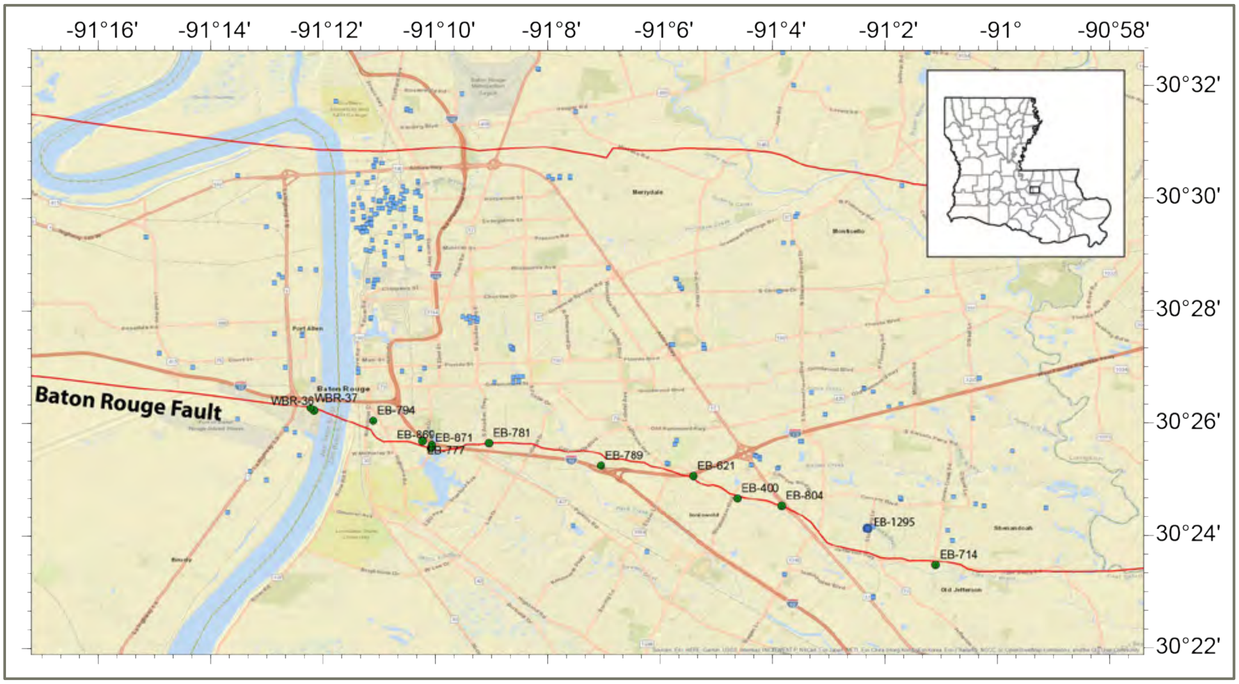


Figure 105. Locations of 13 electrical logs (labeled well names) near the Baton Rouge Fault and locations of past and current pumping wells (blue squares).

The depth to a sand layer near the Baton Rouge Fault is greater than that to the same sand layer in the north because the sand layers are southward-dipping. For additional background on the Baton Rouge Fault, please refer to the *State of the Science* report from Phase 1 (McInnis et al., 2020) which shows the depth range for sand layers at the north of the Baton Rouge Fault. Depth to the same sand layers to the south of the fault is much greater than in the north, especially for deep sand layers. The Baton Rouge Fault is a growth fault that continues to slowly move, increasing fault throw with time; thus, the deeper, older sand layers have experienced more motion.

Hydrostratigraphy modeling was conducted using the facies modeling techniques in Vahdat-Aboueshagh and Tsai (2021). The hydrostratigraphy at the Baton Rouge Fault (facing north) is shown in Figure 106. The research shows that, in general, the leaky windows across the Baton Rouge Fault are non-uniform and discontinuous. The complexity of the leaky windows is the result of fluvial-deltaic processes within the Gulf Coastal Plain and faulting occurring over millions of years.

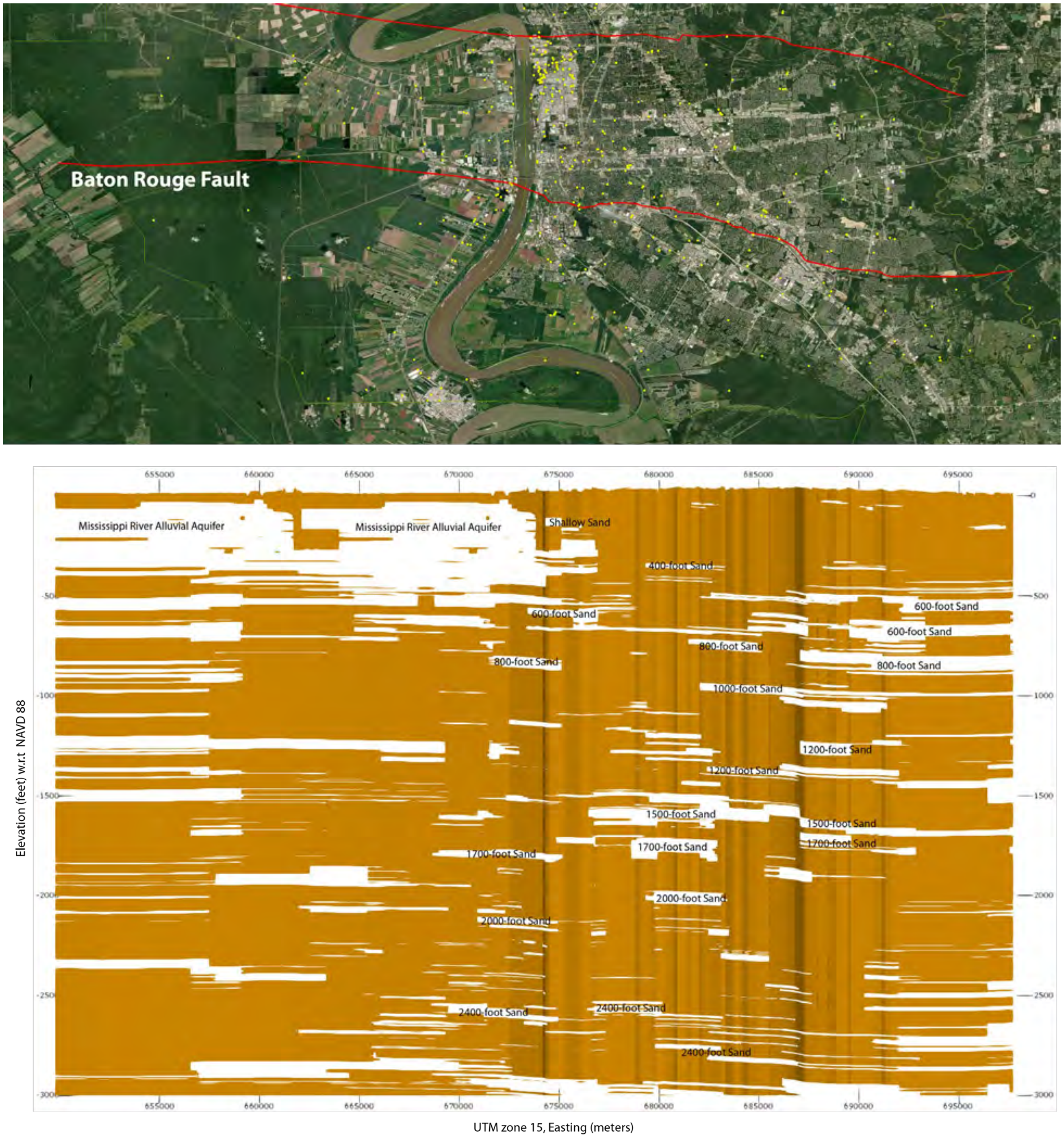


Figure 106. Upper figure shows Baton Rouge Fault (red line) and electrical logs (yellow dots). Lower figure shows leaky windows (white areas). Aquifer names in the lower figure are with respect to the aquifers north of the Baton Rouge Fault.

The MRAA and the 400-foot sand coalesce into an extremely thick sand in WBR Parish. Figure 106 shows no fault impact on the MRAA and indicates that the MRAA was created after the Baton Rouge Fault was formed.

All aquifers in EBR Parish have significant leaky windows at different locations and depths. For example, the height of the largest leaky window connecting the aquifers south of the Baton Rouge Fault to the 1200-foot sand to the north of the Baton Rouge Fault is estimated to be 65 ft. The heights of largest leaky windows that connect across the fault in other sand layers are as follows: in the 1500-foot sand it is approximately 160 ft high; in the 1700-foot sand it is approximately 120 ft high; in the 2000-foot sand it is approximately 70 ft high, and in the 2400-foot sand it is approximately 40 ft high.

This task labels 67 leaky windows in EBR Parish and areas adjacent to the Mississippi River in WBR Parish (Figure 107) for the purposes of investigating saltwater encroachment and developing a chloride monitoring network near the fault. Window heights less than 10 ft were not considered in the analysis. However, narrow windows can be included in the analysis if needed. Some leaky windows contain only one opening, while others may have two or more openings. Window size varies across the fault. The 1200-foot sand has a small leaky window in WBR Parish adjacent to the Mississippi River (Figure 108). There are several continuous leaky windows from the railroad eastward across the rest of EBR Parish. The 1500-foot sand has continuous leaky windows from Lobdell Hwy in WBR Parish to the entire EBR Parish (Figure 109). The 2000-foot sand has three discontinuous segments of leaky windows (Figure 110). The segment in the west has leaky windows in both EBR and WBR parishes. A small leaky window in the middle intersects Interstate 10. The third segment of leaky windows is located from the area around College Dr to EB-621.

The latest chloride concentration samples in 10 monitoring wells near the Baton Rouge Fault are listed in Table 22 and shown in Appendix I. Table 22 also shows the potential leaky window IDs associated with the elevated chloride concentrations in these wells.

Chloride data at EB-782A, EB-782B, and EB-781 indicate saltwater intrusion in the 1000-foot sand, 1500-foot sand and 2000-foot sand, respectively, in the area of S. Acadian Thruway. More geological information in the adjacent areas is needed in order to delineate the extent of the leaky windows in these sand layers.

Saltwater intrusion to the 2000-foot sand is of concern; however, there is only one chloride monitoring well (EB-781) near the fault. As leaky window 49 is to the west of EB-781, it is not certain if the saltwater plume comes from leaky window 49 or 48, or a zone between leaky windows 48 and 49.

Leaky windows 36 and 42 are large for the 1500-foot and 1700-foot sands. However, there are only two chloride monitoring wells (EB-782B and EB-789B) near the fault between the Mississippi River and the Interstate 10/Interstate 12 split. Moreover, it is evident that salt water is encroaching toward EB-1295C in the 1500-foot and 1700-foot sands. However, there is no monitoring well close to the fault trace to locate leaky windows.

Chloride data from EB-621 indicates potential saltwater intrusion towards the public supply wells at the intersection of Interstate 12 and Airline Hwy.

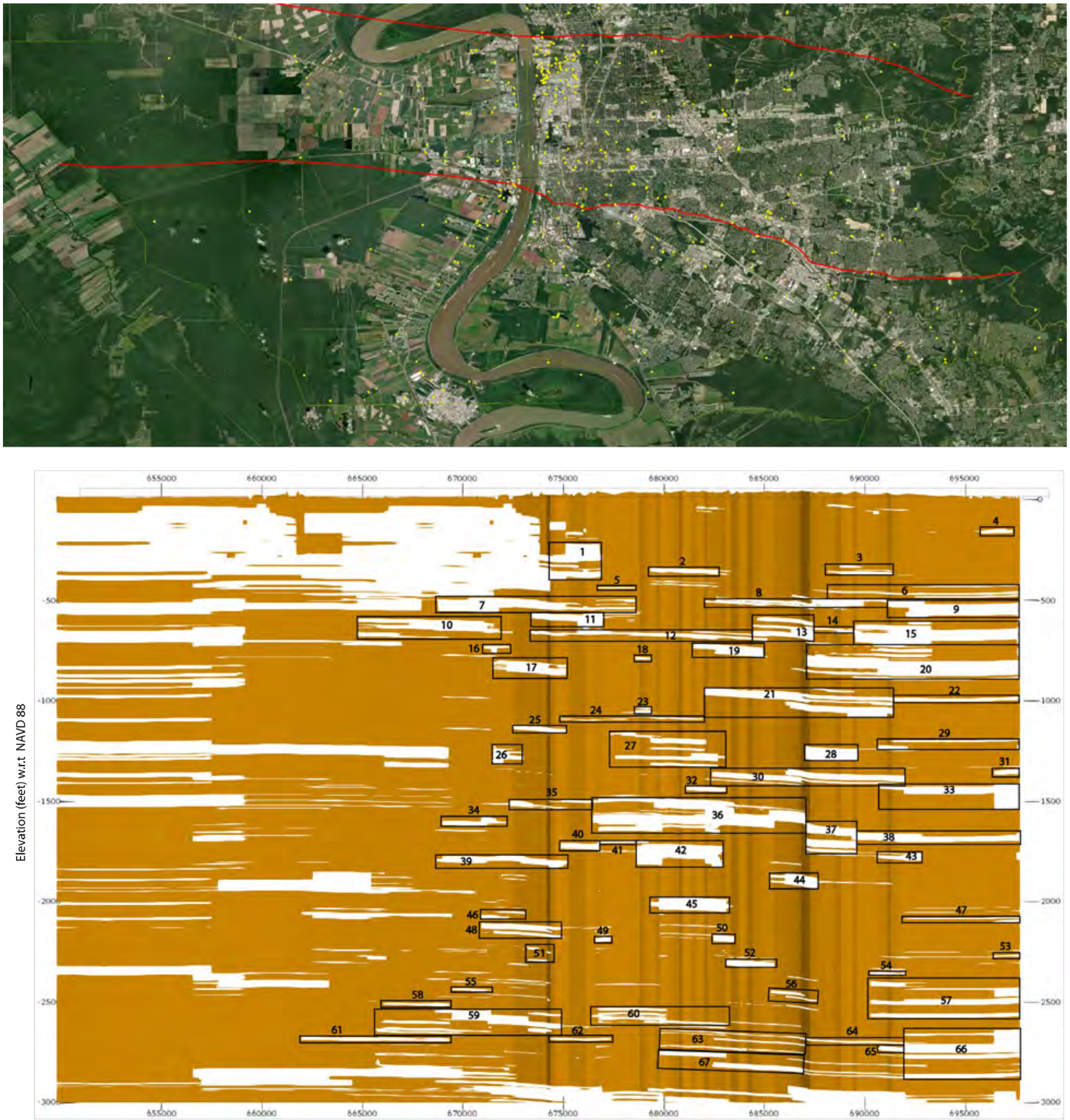


Figure 107. Identification numbers of leaky windows. Leaky windows with height less than 10 ft are not labeled.

EB-805 shows unusually high chloride concentration (>10,000 mg/L) in the 1000-foot sand. However, EB-804A (1000 ft below EB-805) has very low chloride levels (<10 mg/L). Noticeably, there are no pumping wells near EB-805 to withdraw groundwater at the 1000-foot sand. It would be informative to determine why there are particularly high chloride concentrations at this location.

Saltwater intrusion to the 600-foot sand underneath the City Park Lake was observed at EB-869 (and EB-871 and EB-876) in the 1970s with chloride levels greater than 3000 mg/L. Groundwater has not been sampled at these wells since the 1970s.

Chloride concentration at EB-794 rapidly increased between 1995 and 2002, indicating significant saltwater intrusion to the 2400-foot sand near the Mississippi River. No chloride data are available at this location after 2002.

Chloride data from EB-804B indicates saltwater intrusion in the 2400-foot sand near the intersection of Airline Hwy and Jefferson Hwy. There are two pumping wells (EB-1025 and EB-1039) within 1.5 miles of EB-804B to withdraw groundwater from the 2400-foot sand.

It is noted that both fresh water and salt water exist south of the Baton Rouge Fault. Freshwater pockets in the south were likely to be created prior to development in the Baton Rouge Area (before the 1940s). Therefore, both fresh water and salt water can flow northward through leaky windows. At many monitoring wells near the fault where low chloride concentrations were measured in the past, measurements were stopped. Restarting measurements at these locations may be important for understanding the current extent and modeling the future movement of the saltwater plume.

Potential Commission Action for additional Data Collection

This study lists five (5) priority areas (Figure 111) in which to gather more geological information and chloride data.

- Priority 1 area is from the Mississippi River to College Dr (about 3.8 miles). A few monitoring wells in the Priority 1 area suggest saltwater intrusion in multiple sand layers from the 600-foot sand to the 2400-foot sand. Reducing geological uncertainty and collecting more chloride data are paramount in this area. The study indicates five monitoring wells equally spaced along both sides of the fault for a total of 10 monitoring wells will improve the understanding of saltwater intrusion across the fault. Some of these wells would sample the 600-foot sand, while others would sample the 2400-foot sand.
- Priority 2 area is from Lobdell Hwy to the Mississippi River (around 2.9 miles). The study indicates three monitoring wells north of the fault will confirm if saltwater exists and if it would migrate into the 1200-foot sand, 1500-foot sand, and 2000-foot sand through WBR Parish. These wells can potentially be constructed so that each well samples all three sand layers.
- Priority 3 area is from College Dr to Essen Ln (about 2.5 miles). The study indicates three monitoring wells along both sides of the fault are needed to monitor and understand saltwater intrusion in the 1200-foot sand, 1500-foot sand, 2000-foot sand, and 2400-foot sand, a total of six monitoring wells. It is intended that multiple sand layers will be sampled from a single well. In addition, it is necessary to measure groundwater levels at depths between 2200 ft to 2230 ft to verify if the 2000-foot sand at well EB-789 or the nearby area is on the north side of the fault.
- Priority 4 area is from Essen Ln to Bluebonnet Blvd (about 1.3 miles). This study indicates two monitoring wells north of the fault are needed to monitor saltwater intrusion in the 1200-foot sand.
- Priority 5 area is from Sherwood Forest Blvd to Hickory Ridge Blvd (around 1.5 miles). This study indicates two monitoring wells north of the fault are needed to monitor saltwater intrusion in the 1500-foot sand.

All new wells are suggested to be drilled to a depth of at least 2350 ft to monitor up to the 2000-foot sand or to the depth of at least 2850 ft to monitor up to the 2400-foot sand. Table 23 lists the suggested numbers of monitoring wells. A total of 23 new monitoring wells are needed to collect additional data. The wells are also suitable for monitoring groundwater levels.

Table 20. Electrical logs near the Baton Rouge Fault.

Well Name	Location	Remark	Bottom Depth (ft)
EB-400	near Inniswold Rd	Across the Baton Rouge fault approximately at 1300 feet below land surface.	2598
EB-621	near Drusilla Dr	North of the Baton Rouge Fault	1487
EB-714	near Beautyberry Ave	South of the Baton Rouge Fault	666
EB-777	near Carolina St	North of the Baton Rouge Fault	3210
EB-781	near S. Acadian Thruway	Across the Baton Rouge fault approximately at 1359 feet below land surface.	3186
EB-789	near Murphy Dr	Across the Baton Rouge fault approximately at 2000 feet below land surface.	3175
EB-794	near Chatsworth St	North of the Baton Rouge Fault	2764
EB-804	Interception of Airline Hwy and Jefferson Hwy	North of the Baton Rouge Fault	2862
EB-869	near Dalrymple Dr	North of the Baton Rouge Fault	715
EB-871	near Dalrymple Dr	South of the Baton Rouge Fault	842
EB-1295	near Hidden Ridge Ln	South of the Baton Rouge Fault	1870
WBR-36	near Ernest Wilson Dr	South of the Baton Rouge Fault	1360
WBR-37	near Tower Rd	South of the Baton Rouge Fault	1388

Table 21. Top depth range of aquifers to the north of the Baton Rouge Fault.

Aquifer Name	Top Depth Range (ft)
MRAA	40-80
400-foot Sand	400-450
600-foot Sand	550-600
800-foot Sand	750-850
1000-foot Sand	950-1000
1200-foot Sand	1300-1350
1500-foot Sand	1600-1800
1700-foot Sand	1900-2000
2000-foot Sand	2100-2300
2400-foot Sand	2600-2650
2800-foot Sand	2950-3000

Table 22. Chloride concentration (mg/L) near the Baton Rouge Fault.

Well Name	Aquifer Name	Depth (ft)	w.r.t. Baton Rouge Fault	Concentration (mg/L)	Latest Sample Date	Leaky window ID
EB-621	1200-foot Sand	1487	North	56.3	11/12/2020	30, 32
EB-781	2000-foot Sand	2286	North	3910	12/15/2020	49
EB-782A	1000-foot Sand	1189	South	480	12/4/2003	27
EB-782B	1500-foot Sand	1681	North	710	9/21/1993	36
EB-789B	1500-foot Sand	1721	South	3650	10/25/2006	42
EB-794	2400-foot Sand	2709	North	270	12/26/2002	59, 62
EB-804B	2400-foot Sand	2762	North	334	12/10/2020	63, 67
EB-805	1000-foot Sand	1072	North	10200	12/10/2020	21
EB-869	600-foot Sand	599	North	3000	4/13/1978	11
EB-1295C	1500-foot and 1700-foot Sands	1840	North	370	11/5/2019	37

Table 23. Additional monitoring wells needed in the priority areas.

Priority Area	From	To	Length (miles)	Num. of wells N. of BR Fault	Num. of wells S. of BR Fault	Total Num.	Cumulative Total Num.
1	Mississippi River	College Dr	3.8	5	5	10	10
2	Lobdell Hwy	Mississippi River	2.9	3	-	3	13
3	College Dr	Essen Ln	2.5	3	3	6	19
4	Essen Ln	Bluebonnet Blvd	1.3	2	-	2	21
5	Sherwood Forest Blvd	Hickory Ridge Blvd	1.5	2	-	2	23

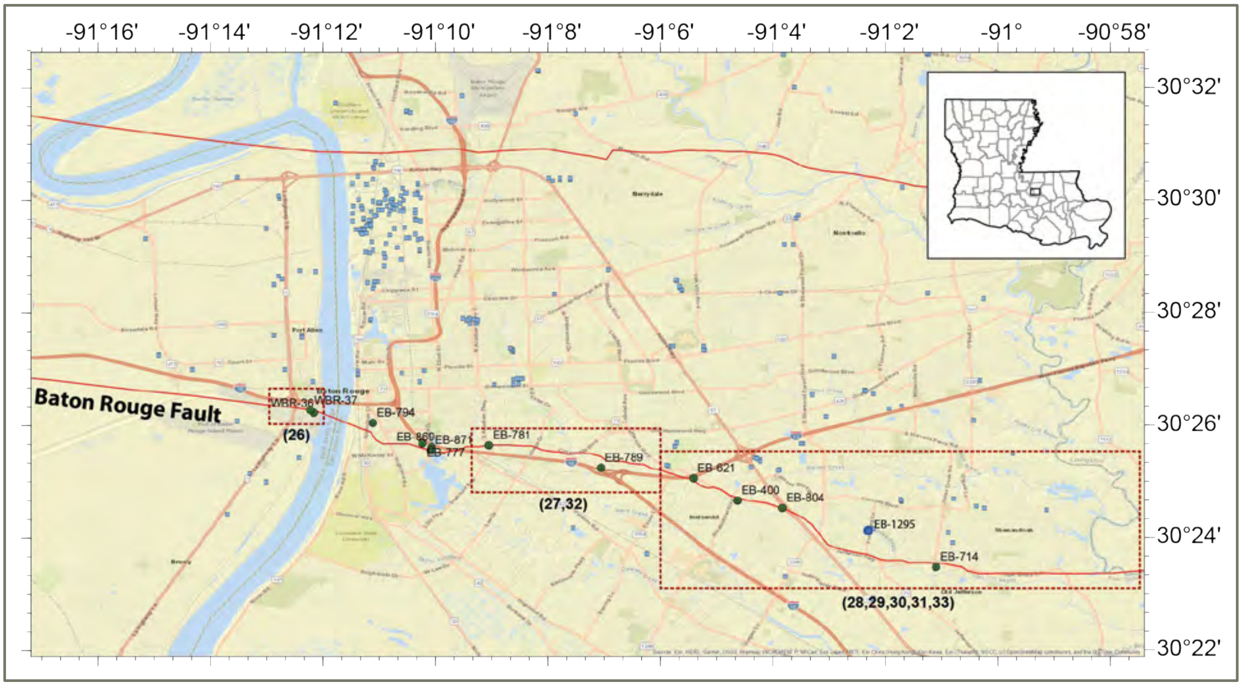


Figure 108. Leaky windows and their IDs for the 1200-foot sand.

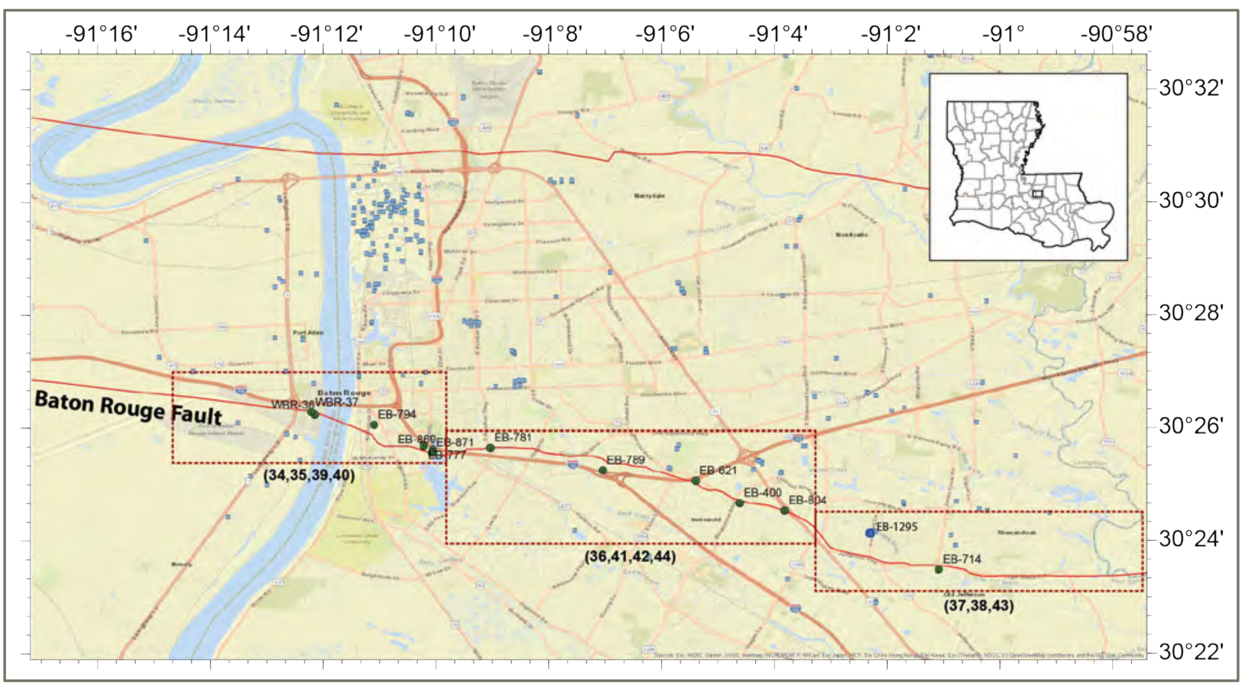


Figure 109. Leaky windows and their IDs for the 1500-foot sand.

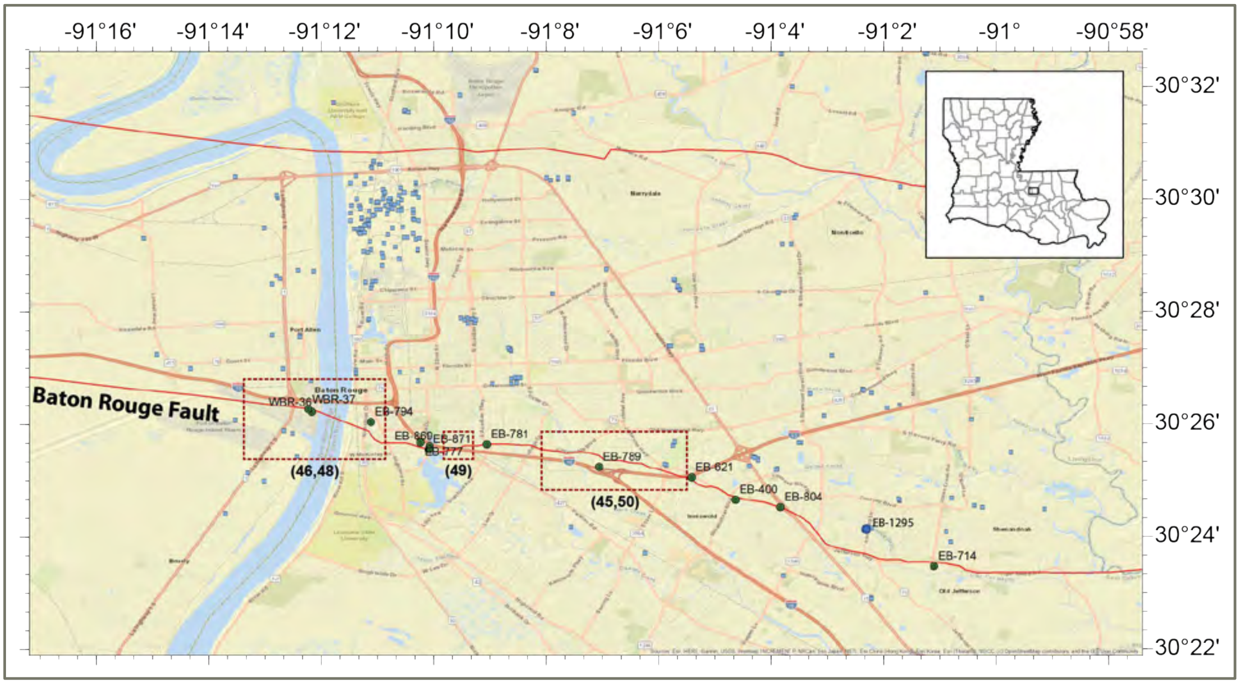


Figure 110. Leaky windows and their IDs of the 2000-foot sand.

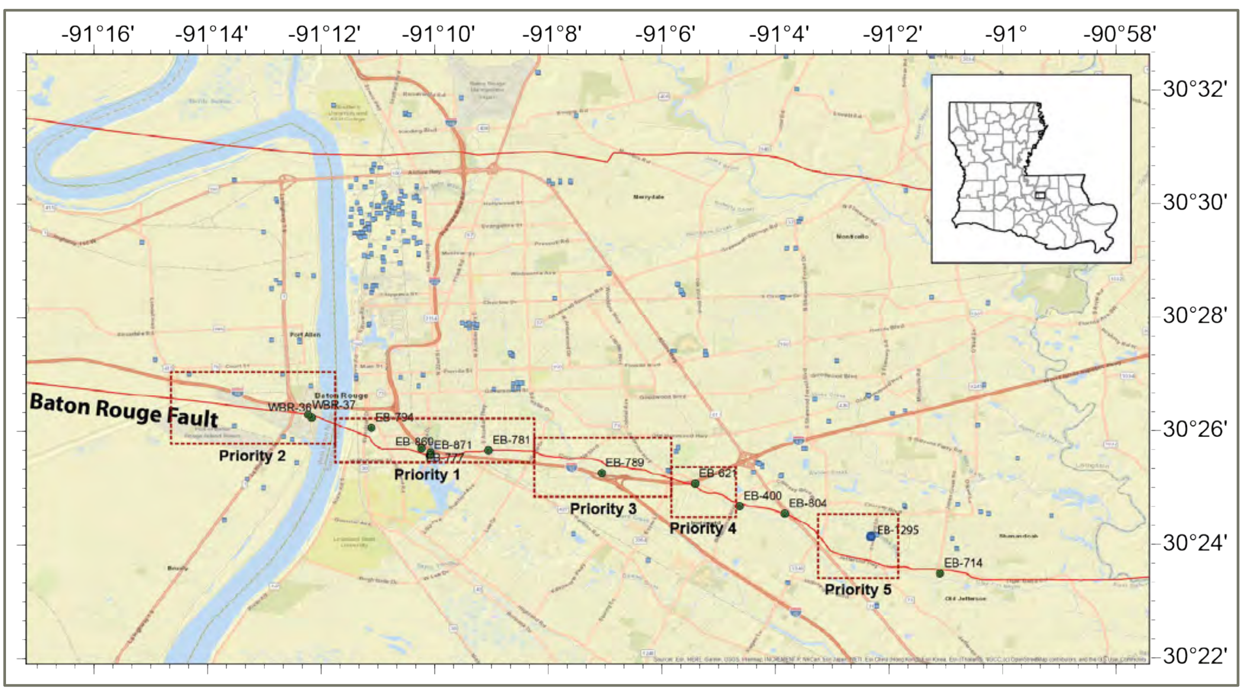


Figure 111. Priority areas to acquire more geological information and chloride data.

TASK 2.7 DEVELOPING OUTREACH AND CONSERVATION EDUCATION MATERIALS

This task is part of Phase 2B, not Phase 2A, and will be covered in a future report.

TASK 2.8 LEGAL AND POLICY ANALYSIS

This task is part of Phase 2B, not Phase 2A, and will be covered in a future report.

TASK 2A.9 FACILITATED DISCUSSION FORUMS AND INFORMATION EXCHANGE

> *Task Summary: The purpose of the facilitated forums is to provide the CAGWCC with the necessary background to make informed decisions about the management of the aquifer and to define "detailed research" and "research data" as they relate to the CAGWCC's legal authority. In the forums, Commission members will participate in discussions on the technical aspects of the evaluation process and the CAGWCC be provided with information on select topics related to aquifer management, modeling, decision analyses, and other technical tasks. These forums will also help the CAGWCC to finalize the alternatives that will be evaluated in the next phase of decision making.*

The Institute conducted three facilitated forums between October and November 2021. The first two forums were held on October 28, 2021 as part of a single session and included the Legal Overview and the Economics topics. The session began with a presentation reviewing the ongoing structured decision-making process being used to develop the CAGWCC's strategic plan, along with an overview of how the legal authority of the CAGWCC and the economics analysis link to that decision-making process. In depth presentations were then given on each of the two primary topics, with a facilitated discussion by Commission members after each. The presentations were provided to the CAGWCC for further review after the session.

The third facilitated forum was held on November 30, 2021 and included the Environmental Modeling and Data topic. The forum included presentations on the Darcy Flow analysis, which can inform decisions on permitting and groundwater withdrawal in the short-term; and the LSU groundwater availability model development, which provides a more comprehensive evaluation of the impacts of specific management actions on groundwater and the aquifer. The LSU groundwater model will be used in calculation of Performance Metric 1 (*Mean potentiometric elevation across the CAGWCD at equilibrium, separately for each sand*), Performance Metric 4 (*The mass of salt [chloride ion] in groundwater in all sands within the spatial bounds of the CAGWCC authority after 50 years, corresponding to the planning horizon of the long-term strategic plan*), and Performance Metric 5 (*Amount of subsidence at wells in the CAGWCD*).

A fourth facilitated forum, covering the Societal and Community Impacts analysis, will be held in early 2022.

The topics identified for the facilitated forums were:

1. **Legal Overview:** A forum on the CAGWCC's enabling legislation related to its legal authority and powers. This forum included a presentation and discussion around language in the enabling legislation that the CAGWCC needs to define, so that the CAGWCC can consider how they will use current and future data and models in the decision-making process. Section 3076 ("Powers of the Board") of the CAGWCC's enabling legislation provides a charge to "do all things necessary to prevent the waste of groundwater resources," and enumerates the authorities and necessary prerequisites of exercising those authorities. In order to fully exercise its legal authority, the CAGWCC could consider proactively establishing its "groundwater use priorities" (§3076(A)(12)) through administrative action. The statutes indicate that such priorities should be established "under conditions supported by research data, which indicate depletion of [ground]water." "Research data" are not defined by the legislation, but rather are left to the CAGWCC to interpret in making its determination of priorities. Additionally, if the CAGWCC determines that there is a need "to limit rates of production from any aquifer or aquifers," (as authorized by §3076(A)(19)), those decisions would also need to be "after detailed research." As with "research data," "detailed research" is not defined by the legislature and is left to the CAGWCC to interpret. This forum suggested that the interpretation of these terms is within the CAGWCC's legal authority and the intent of the Phase 2 report is to give the CAGWCC the technical bases from which to exercise its administrative authority.

2. **Economics:** A forum on the economics and potential economic impacts of water management decisions by the CAGWCC, including a discussion of cost-benefit analyses and trade-offs associated with aquifer management. This forum reviewed the cost of water for municipal and industrial purposes for both regulatory and baseline scenarios to evaluate the potential costs and benefits of management. The industrial analysis considers the availability of water for self-supplied facilities that currently produce groundwater for their processes. Potential future costs consider the cost of alternative water supplies (surface water, alluvial groundwater, reclamation, brackish groundwater, and aquifer storage and recovery) as well as the cost of using groundwater with a higher level of salinity over time. Data and prediction uncertainty, and the impact on the decision-making process, were discussed in the context of economics.

3. **Environmental Modeling and Data**: A forum on modeling and underlying data including aquifer dynamics and best practices for using model data. This forum covered both the groundwater availability model that is being developed by LSU and Darcy flow analysis being conducted by the Institute. The forum also included presentation and discussion on how the model can inform decisions in the short- and long-term.

4. **Societal and Community Impacts:** A forum on the societal and community impacts of water management decisions by the CAGWCC, including public awareness of aquifer and water supply issues. Building off a review of previous public engagement efforts related to groundwater in the Capitol Region, this assessment will take a mixed methods qualitative research approach, including focus groups and a public survey, to develop a more comprehensive understanding of the impacts of water management decisions on local stakeholders. The public survey is expected to be complete before this discussion; however, the focus groups will be conducted as part of Phase 2B. This research builds upon previous surveys conducted by the Office of Conservation. Societal and community impacts, economics, environmental modeling and data, and the legal authority of the CAGWCC will be discussed as they relate to each other and the decision-making process, as well as how they connect to the next steps in the development of a strategic plan for aquifer management.

In addition to the facilitated forums, the Institute supported the CAGWCC in their efforts in the following ways:

- Organizing and leading meetings with project partners;
- Providing update presentations to the CAGWCC;
- Meeting with and providing background information on Phase 1 to new Commissioners as well as an introduction to Phase 2.

TASK 2.10 SUPPORTING ACTIVITIES AND DATA NEEDS

This task is part of Phase 2B, not Phase 2A, and will be covered in a future report.

CONCLUSION AND NEXT STEPS

The Capital Area Ground Water Conservation Commission engaged the Water Institute of the Gulf to aid the CAGWCC in creating a strategic plan for proactive management of the Southern Hills Aquifer System. In Phase 1 of this work, the CAGWCC developed, with help from the U.S. Geological Survey and the Institute, five fundamental objectives to guide management decisions and the development of a framework for a strategic plan. During subsequent phases of development of the strategic plan, several alternative management strategies will be considered and modeled. Preliminary performance metrics, used to compare the modeled results of the different alternative management strategies, were drafted in Phase 1 and further developed in Phase 2A. Each metric has a specific calculation method that will be used in the analysis of the different alternatives.

The five objectives and associated performance metrics described above and developed in Phase 1 of this work include the following:

Objective 1:

Achieve and maintain sustainable and resilient groundwater withdrawal rates from the Southern Hills Aquifer System within the District boundaries

Performance Metric:

Mean potentiometric elevation across the CAGWCD at equilibrium, separately for each sand.

Objective 2

Manage the aquifer to maximize availability of healthy, high-quality drinking water equitably to all residents of the CAGWCD indefinitely

Performance Metric:

Individual subjective and objective metrics representative of drinking water quality, quantity, and cost.

Objective 3:

Manage the aquifer to maximize availability of clean and inexpensive water to commercial and industrial users in the District indefinitely

Performance Metric:

Composite unit cost of water supply for industrial users.

Objective 4.

Reduce the movement of saltwater into the Southern Hills Aquifer System and slow or halt the advance of the existing saltwater plume

Performance metric:

The mass of salt (chloride ion) in groundwater in all sands within the spatial bounds of the CAGWCC authority after 50 years, corresponding to the planning horizon of the long-term strategic plan.

Objective 5.

Minimize the risk of subsidence

Proposed Performance Metric:

Amount of subsidence at wells in the CAGWCD.

Data and information important to Phase 2B was also compiled and analyzed in Phase 2A. To make informed decisions about aquifer management, the CAGWCC needs a full understanding of the current state of the SHAS.

During Phase 2A of the study, the state of the current aquifer monitoring network related to water levels was found to be sufficient to provide information on the groundwater level, but suggestions for improving monitoring were also made for specific sand layers. The 1,000-foot sand was identified as needing the most improvement (Table 14). Cones of depression in the potentiometric surfaces can be seen in the monitoring data for 2020 in every sand layer except the 400-foot and 1000-foot sands (Task 2A.1; Figure 12; Figure 13). Large cones of depression, more than 10 miles across, can be seen in the 1200-foot, 1500-foot, 1700-foot, 2000-foot, 2400-foot, and 2800-foot sands (Appendix A). The presence of these cones of depression has many implications for aquifer health. The reduced aquifer pressures inside a cone of depression induces saltwater flow across the Baton Rouge Fault and results in saltwater intrusion into the sand layers. Saltwater intrusion is difficult and expensive to remediate; prevention is the easier and less costly solution. Several wells in the CAGWCD approached or exceeded the USEPA Secondary Standard for chloride, 250 mg/L, as of December 2020 (Task 2A.1; Figure 16; Figure 17; Figure 18).

The USGS samples wells in the CAGWCD for chloride once per year (however that sampling is expected to increase to twice yearly under a 2021 agreement), near the edge of the chloride plume. Additional monitoring of the saltwater plume will be crucial for managing the threat to drinking water. As of 2020, few wells were sampled for chloride in most sand layers. A total of 48 additional wells were suggested as additions to the chloride monitoring performed by the USGS and Dr. Tsai of Louisiana State University. The addition of these wells to the chloride monitoring network could better constrain the location and movement of the saltwater plume which is important for predicting the extent and timing of saltwater intrusion into the aquifer sands.

Although the Baton Rouge Fault is generally a low-permeability zone, there are ‘leaky windows’ (areas of high permeability) that allow migration of saltwater across the fault. Part of Task 2.6 was to map these leaky windows and indicate next steps in monitoring. Sixty-seven leaky windows were identified in EBR Parish and areas adjacent to the Mississippi River in WBR Parish using electrical logs and drillers logs. Five priority areas are indicated for monitoring and new wells: Priority 1 area is from the Mississippi River to College Dr; Priority 2 area is from Lobdell Hwy to the Mississippi River; Priority 3 area is from College Dr to Essen Ln; Priority 4 area is from Essen Ln to Bluebonnet Blvd; Priority 5 area is from Sherwood Forest Blvd to Hickory Ridge Blvd. A total of 20 new wells are suggested in these priority areas to better monitor the saltwater plume.

Reduced aquifer pressures can also induce compaction and subsidence over large areas; this type of subsidence has been seen in the CAGWCD since at least the 1960s. Leveling studies (1960s and 1970s), extensometer studies (1975–1979 and 2001–2015), and CORS GPS measurements (2014–2021) were compiled to evaluate the relationship between water levels and subsidence. Extensometer measurements and currently available CORS data are limited to the area around the Industrial District of Baton Rouge. The effects of subsidence induced by groundwater extraction are expected to affect a large area of the CAGWCD, not just the area of greatest pumpage. Results from a 1978 study suggested that 1100 sq. miles was affected. The area affected by subsidence also seems to correspond with the area of the cones of depression in the aquifer sands. The most recent extensometer measurements agree with earlier work that subsidence will continue for several years after water levels stabilize. The lack of consistent, regional subsidence monitoring in the CAGWCD hampers efforts to understand the relationship between water levels and compaction. A regional strategy for monitoring subsidence will be an important component of future aquifer management.

To make informed decisions about the alternative management strategies, the CAGWCC can also weigh the economic data and information, as well as have an understanding of the historical and future demand for water in the CAGWCD. FNI were contracted by the Institute to compile these data and provide this analysis for Task 2A.3 and Task 2A.5. All sources of water (groundwater and surface water) were included in the analysis, and both domestic and industrial water use were considered.

Water use reports from USGS suggest that public supply is limited to groundwater sources in five of the six parishes; some systems in Ascension Parish use a surface water supply. Groundwater exports from EBR Parish play an important role in meeting domestic water demand in Ascension Parish. Average per-capita demand for public supply water from 2010 to 2020 was between 150 and 300 gallons per-capita per day. The total estimated groundwater withdrawals for public supply in the CAGWCD in 2020 was approximately 32,000 million gallons. In Phase 2B this analysis will be expanded to include potential future water needs.

A survey of industrial water users was conducted to gain information on current water use and treatment, as well as treatment costs, to better understand and predict how water costs to industry may be impacted by the different management decisions. All data were aggregated to ensure that no individual entity could be identified. The survey response rate was poor with only 19 out of 80 surveys providing complete or partial responses. Over 80 percent of the industrial entities surveyed utilize groundwater; the most commonly utilized sand layers (highest percentage of respondents) were the 1200-foot sand and 400-foot sand. Treatment needs were variable with fewer than half the respondents with groundwater supplies indicating 100 percent treatment of groundwater. There were limited data on treatment costs and a wide range of costs indicated in the survey responses ($0.02 to $7.00 per 1,000 gallons). Total industrial demand for water in 2020 was estimated to be slightly more than 600 million gallons per day, with about 60 million gallons per day coming from groundwater. These number reflect a large drop in water demand since 2018, due to decrease withdrawals from a major facility in EBR Parish. In 2018, industry demand for groundwater was approximately 100 million gallons per day. Phase 2B will extend this analysis to include future projections.

Providing future water supply for domestic and industrial uses is one of the CAGWCC's objectives. Several options for alternative water supply and the costs associated with each were researched to aid the CAGWCC. The costs related to increased water treatment requirements associated with the Status Quo scenario were also considered. These planning-level analyses enable the CAGWCC to assess the characteristics of supply options, key considerations for development, possible implementation challenges, and anticipated relative magnitude of cost. The projects considered provided a range of water volumes from 0.5 million gallons per day to 20 million gallons per day. On an annual cost basis, the Status Quo scenario was the most expensive, followed by 20 million gallons per day of production from the Mississippi River Shallow Aquifer. On a unit cost per 1,000-gallon basis, brackish groundwater desalination was the most expensive. Water reclamation of both industrial and municipal supplied were also considered. Industrial reclamation had a higher unit cost, but municipal reclamation had a high annual cost. A combination of supply options is likely to serve the CAGWCD best, and several have been developed. Multiple funding development of options, including grants, loans, and public-private partnerships for water supply supplementation have also been analyzed to inform the CAGWCC's decisions.

To understand public knowledge and perceptions of groundwater in the CAGWCD, previous public surveys, public meetings, and outreach efforts were reviewed to provide a foundation for implementing new public surveys. The problem of saltwater intrusion has been drawing increased public attention since 2010. Citizens requested a plan for Baton Rouge water management as early as 2012 to ensure a sustainable future. Industry stakeholders have also recognized the need for a sustainable future for the aquifer. Past public surveys have shown low levels of awareness of drinking water sources and threats to drinking water. In addition to questions related to the public's knowledge and understanding of groundwater, a survey presented in this report places an additional focus on the public perceptions of water cost, quality, and quantity, which tie into the performance metrics. Public perceptions of household water quality are favorable in the CAGWCD, but most respondents did not know that this water was groundwater, and still used bottled water primarily for drinking. Respondents were split on whether or not they view saltwater intrusion as a pressing problem. A majority of respondents (78%) had not heard about water management in their area. These survey results suggest the need for an awareness and engagement effort that extends to the entire District. In Phase 2, the Institute will conduct interview and focus groups focused on major groundwater producers, public stakeholders, and interested parties.

The facilitated forums that will be held throughout the phases of this study are intended to give the CAGWCC the necessary background to make informed decisions about the management of the aquifer, and to provide a forum for questions and discussions related to the strategic planning process. Three facilitated forums were held during Phase 2A to discuss the following topics: legal overview; economics; environmental modeling and data. During the first facilitated forum, the Institute reviewed the CAGWCC's legal authority, including their authority to set groundwater use priorities and define "research data" and "detailed research." These discussions provided a foundation for understanding how the CAGWCC can exercise its legal authority and powers. The industrial water analysis was presented during the second facilitated forum by FNI. During the third facilitated forum, the Institute presented on the Darcy Flow analysis, and Dr. Tsai presented information on how a groundwater availability model is constructed and how it can be used to inform decisions. The facilitated forums will continue into Phase 2B, and will include topics such as the societal and community impacts of water management decisions.

Questions and comments from the CAGWCC on this report are welcomed. The goal of Phase 2 is to provide the CAGWCC with the information and data necessary to support future complex decisions about management of the aquifer. Feedback from the CAGWCC is needed to accomplish this goal.

Phase 2A will finish in early 2022 with the submission of this report. During Phase 2B the entire project team will continue to work with the CAGWCC to provide data, information, and guidance on the development of a strategic plan for the CAGWCD. Phase 2B tasks include the development of a groundwater availability model to inform the CAGWCC on water supply, a forecast of water demand across the CAGWCD, further economic analyses of alternatives, analysis of public attitudes towards the alternatives, and a legal and policy analysis. The Institute looks forward to working with the CAGWCC and our project partners on the exciting work to come.

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APPENDICES: SUPPLEMENTARY FIGURES AND SURVEYS

Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

APPENDIX A POTENTIOMETRIC SURFACE MAPS

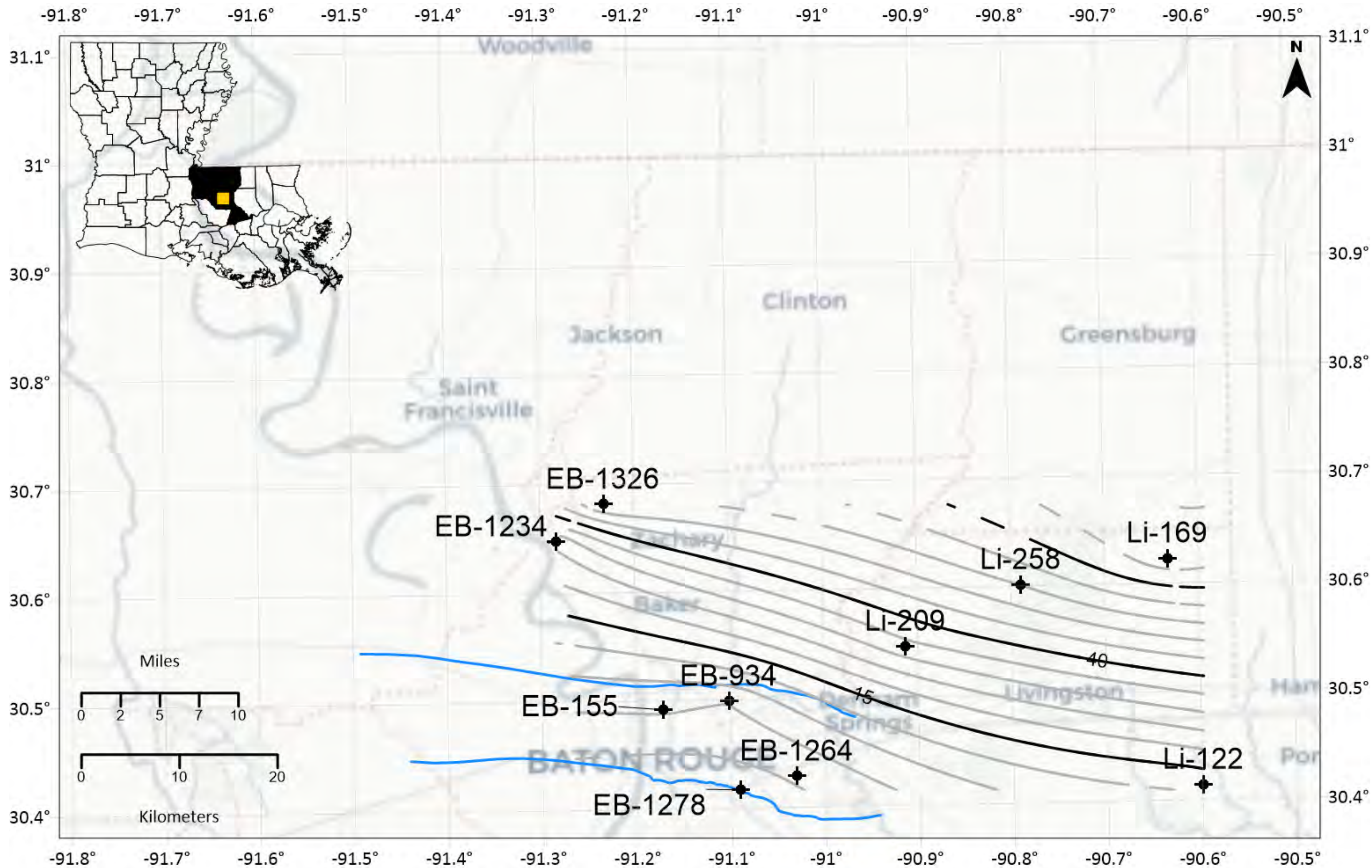

Figure A-1. Potentiometric surface contour map for the 400-foot sand using data from June 2020 through December 2020. Points show well locations with water level data used to create the contours. Contour interval is 5 ft. Contours are drawn as solid lines are within the area in which there is available data and as dashed lines outside this area. The blue lines represent the Denham Springs-Scotlandville fault to the north and the Baton Rouge Fault to the south. The vertical datum is NGVD29.

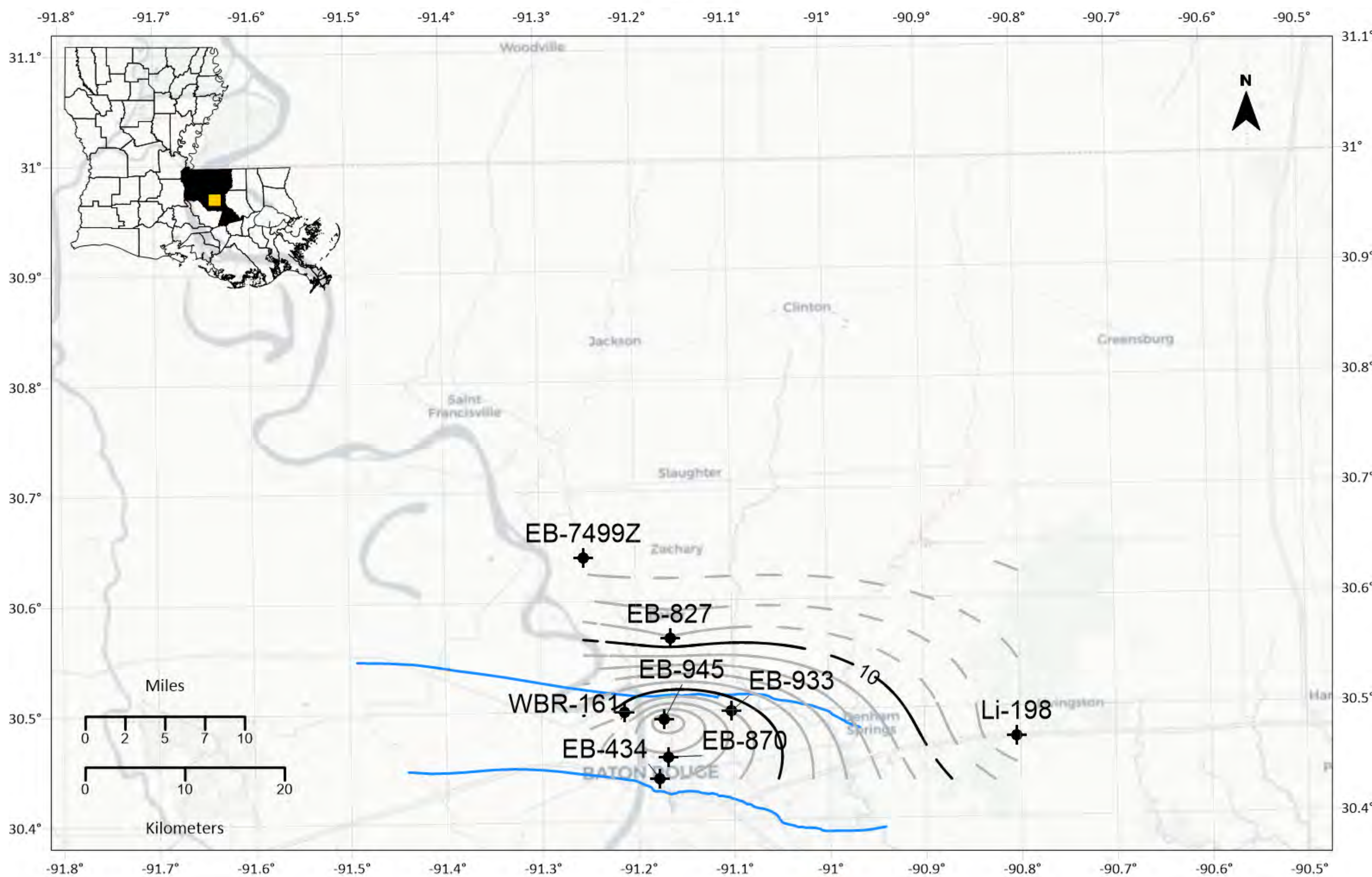

Figure A-2. Potentiometric surface contour map for the 600-foot sand using data from June 2020 through December 2020. Points show well locations with water level data used to create the contours. Contour interval is 5 ft. Contours are drawn as solid lines are within the area in which there is available data and as dashed lines outside this area. The blue lines represent the Denham Springs-Scotlandville fault to the north and the Baton Rouge Fault to the south. The vertical datum is NGVD29.

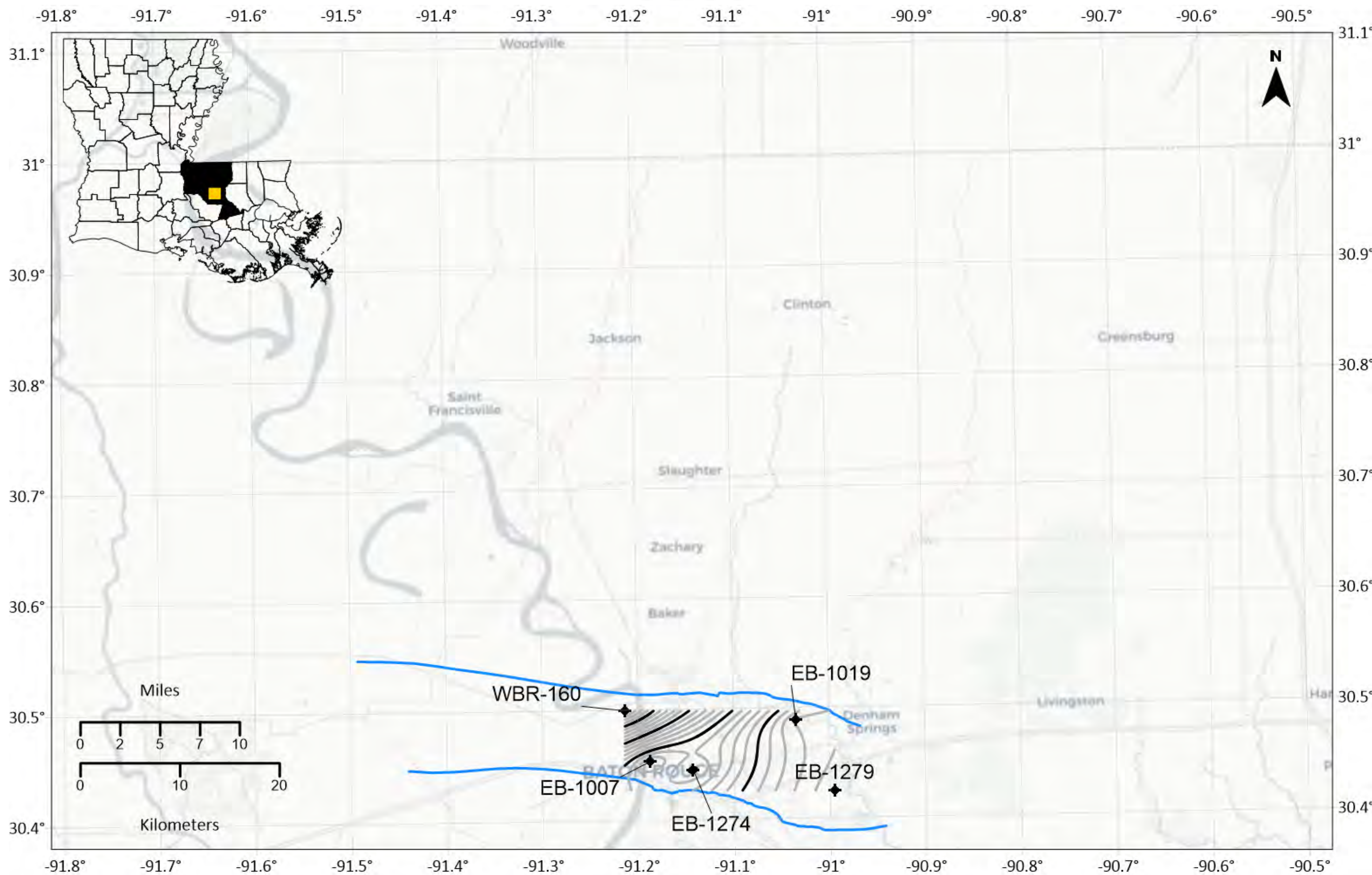

Figure A-3. Potentiometric surface contour map for the 800-foot sand using data from June 2020 through December 2020. Points show well locations with water level data used to create the contours. Contour interval is 5 ft. Contours are drawn as solid lines are within the area in which there is available data and as dashed lines outside this area. The blue lines represent the Denham Springs-Scotlandville fault to the north and the Baton Rouge Fault to the south. The vertical datum is NGVD29.

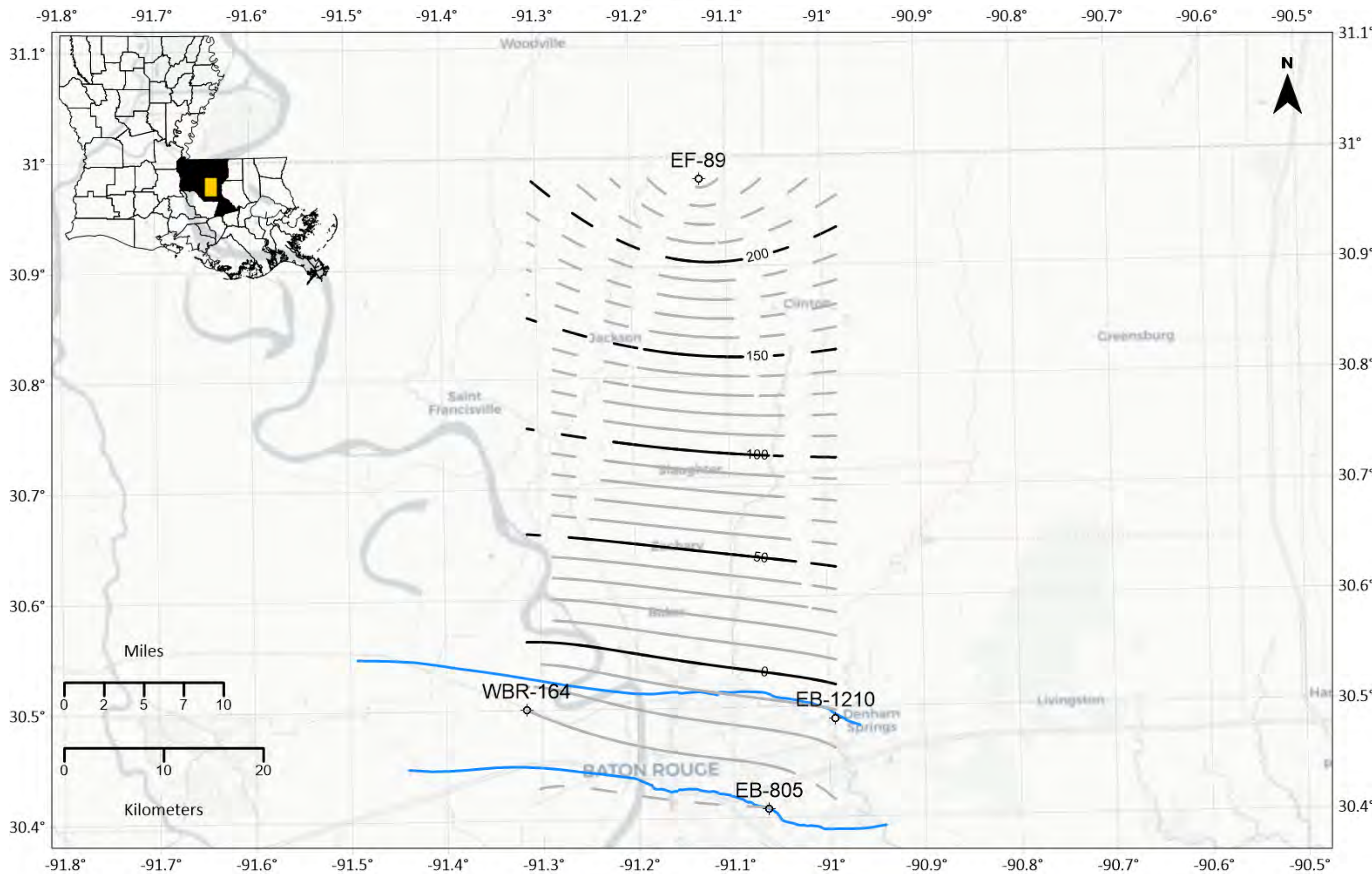

Figure A-4. Potentiometric surface contour map for the 1000-foot sand using data from June 2020 through December 2020. Points show well locations with water level data used to create the contours. Contour interval is 10 ft. Contours are drawn as solid lines are within the area in which there is available data and as dashed lines outside this area. The blue lines represent the Denham Springs-Scotlandville fault to the north and the Baton Rouge Fault to the south. The vertical datum is NGVD29.

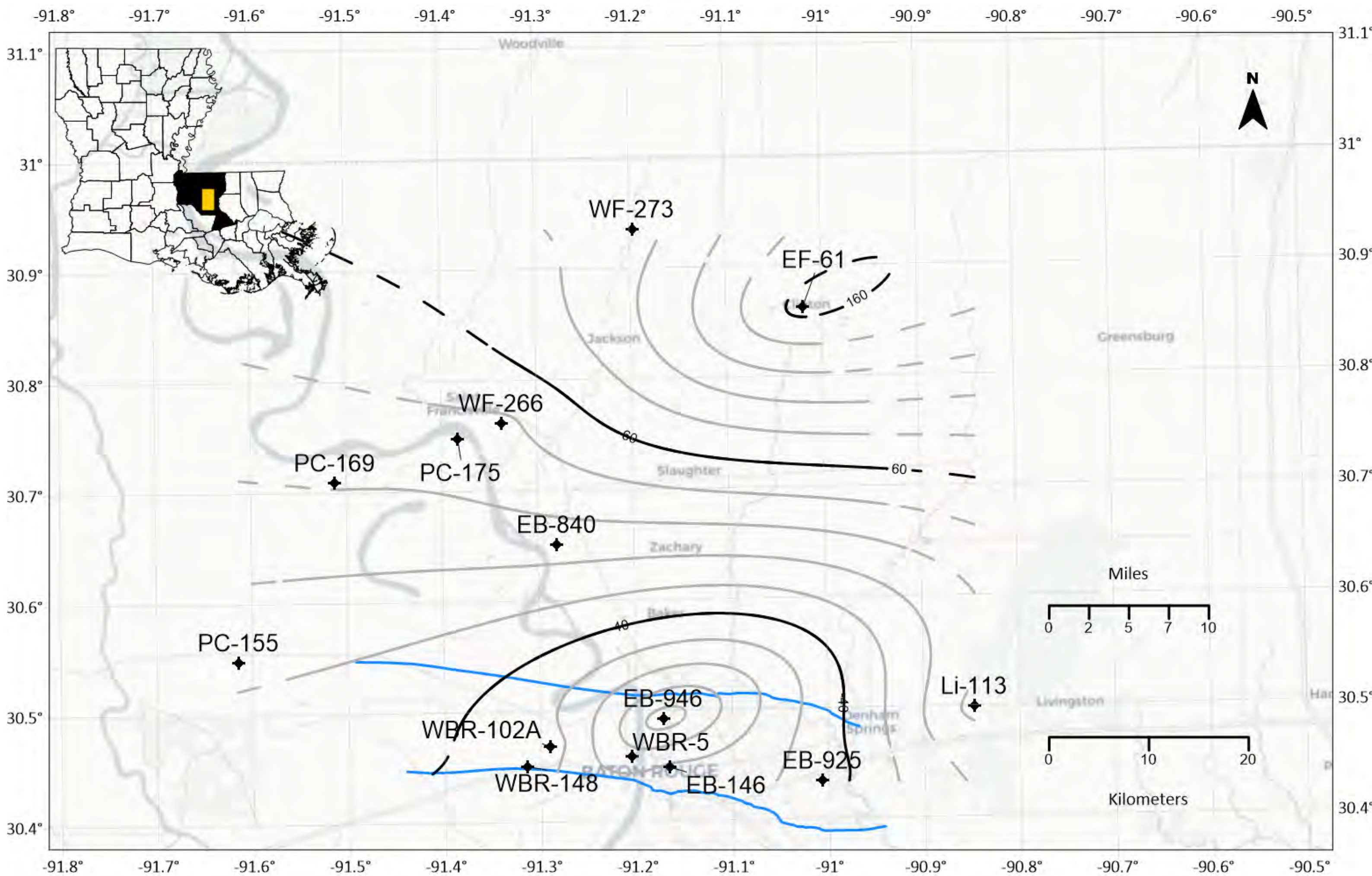

Figure A-5. Potentiometric surface contour map for the 1200-foot sand using data from June 2020 through December 2020. Points show well locations with water level data used to create the contours. Contour interval is 20 ft. Contours are drawn as solid lines are within the area in which there is available data and as dashed lines outside this area. The blue lines represent the Denham Springs-Scotlandville fault to the north and the Baton Rouge Fault to the south. The vertical datum is NGVD29.

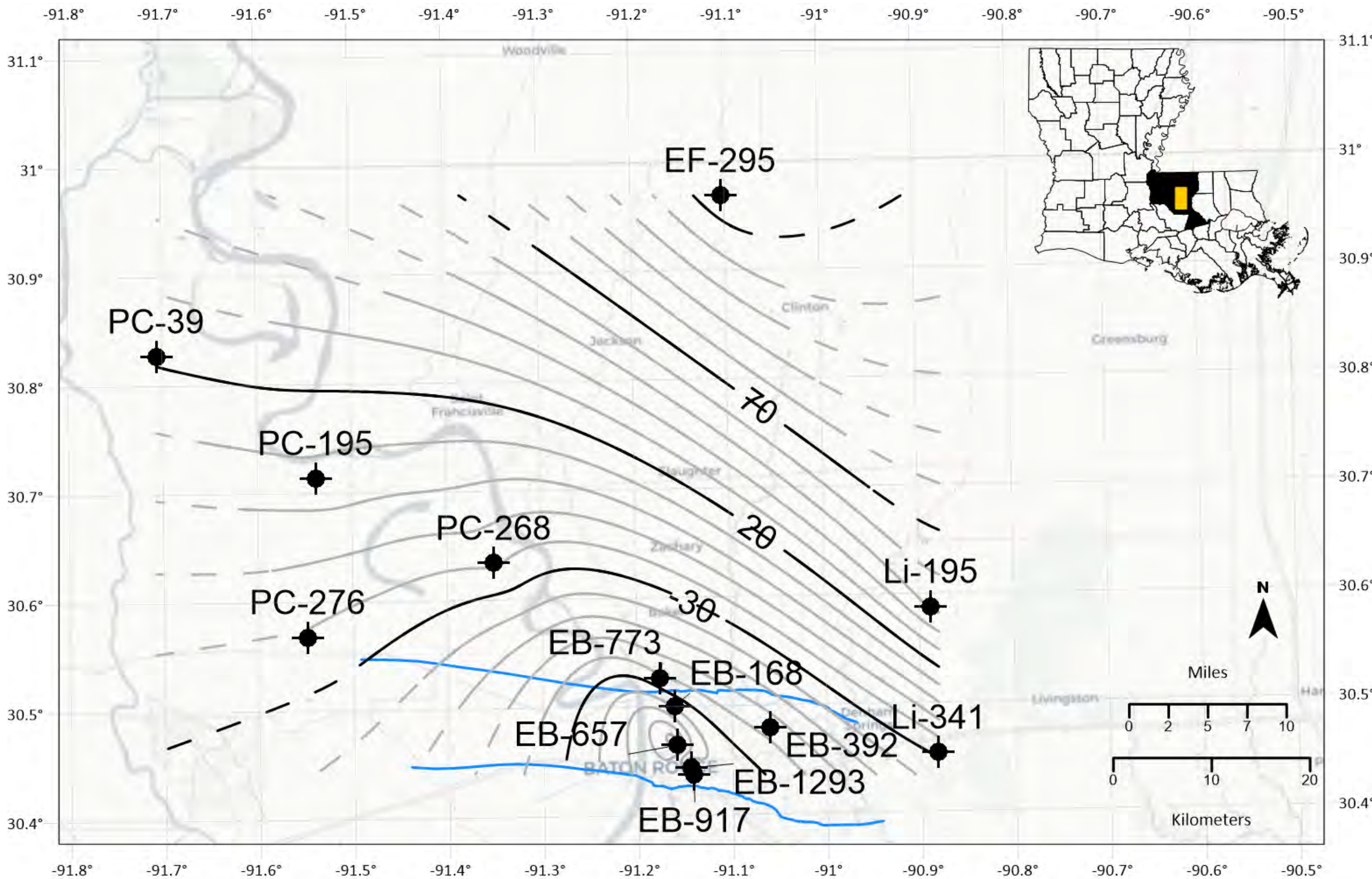

Figure A-6. Potentiometric surface contour map for the 1500-foot sand using data from June 2020 through December 2020. Points show well locations with water level data used to create the contours. Contour interval is 10 ft. Contours are drawn as solid lines are within the area in which there is available data and as dashed lines outside this area. The blue lines represent the Denham Springs-Scotlandville fault to the north and the Baton Rouge Fault to the south. The vertical datum is NGVD29.

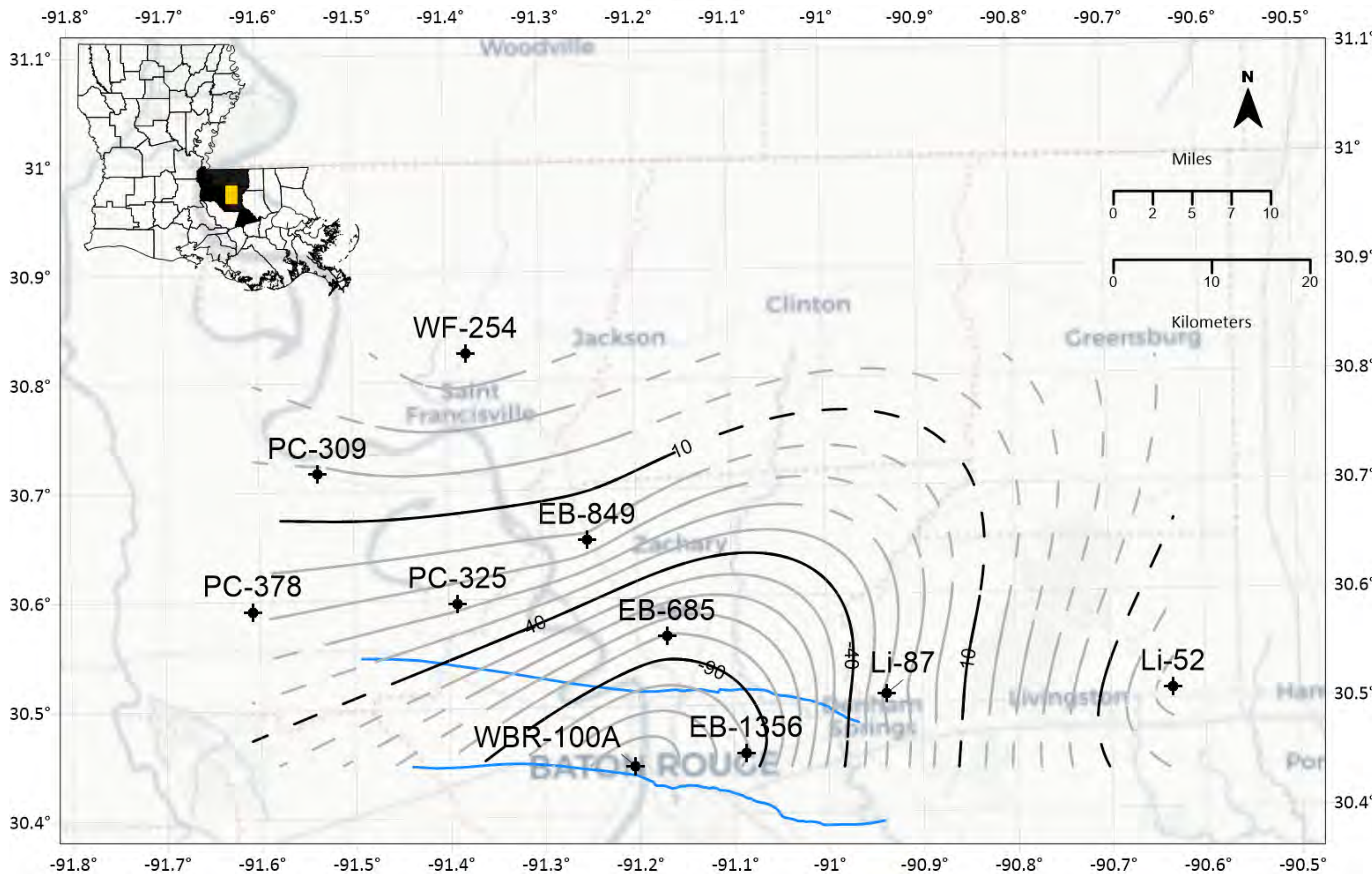

Figure A-7. Potentiometric surface contour map for the 1700-foot sand using data from June 2020 through December 2020. Points show well locations with water level data used to create the contours. Contour interval is 10 ft. Contours are drawn as solid lines are within the area in which there is available data and as dashed lines outside this area. The blue lines represent the Denham Springs-Scotlandville fault to the north and the Baton Rouge Fault to the south. The vertical datum is NGVD29.

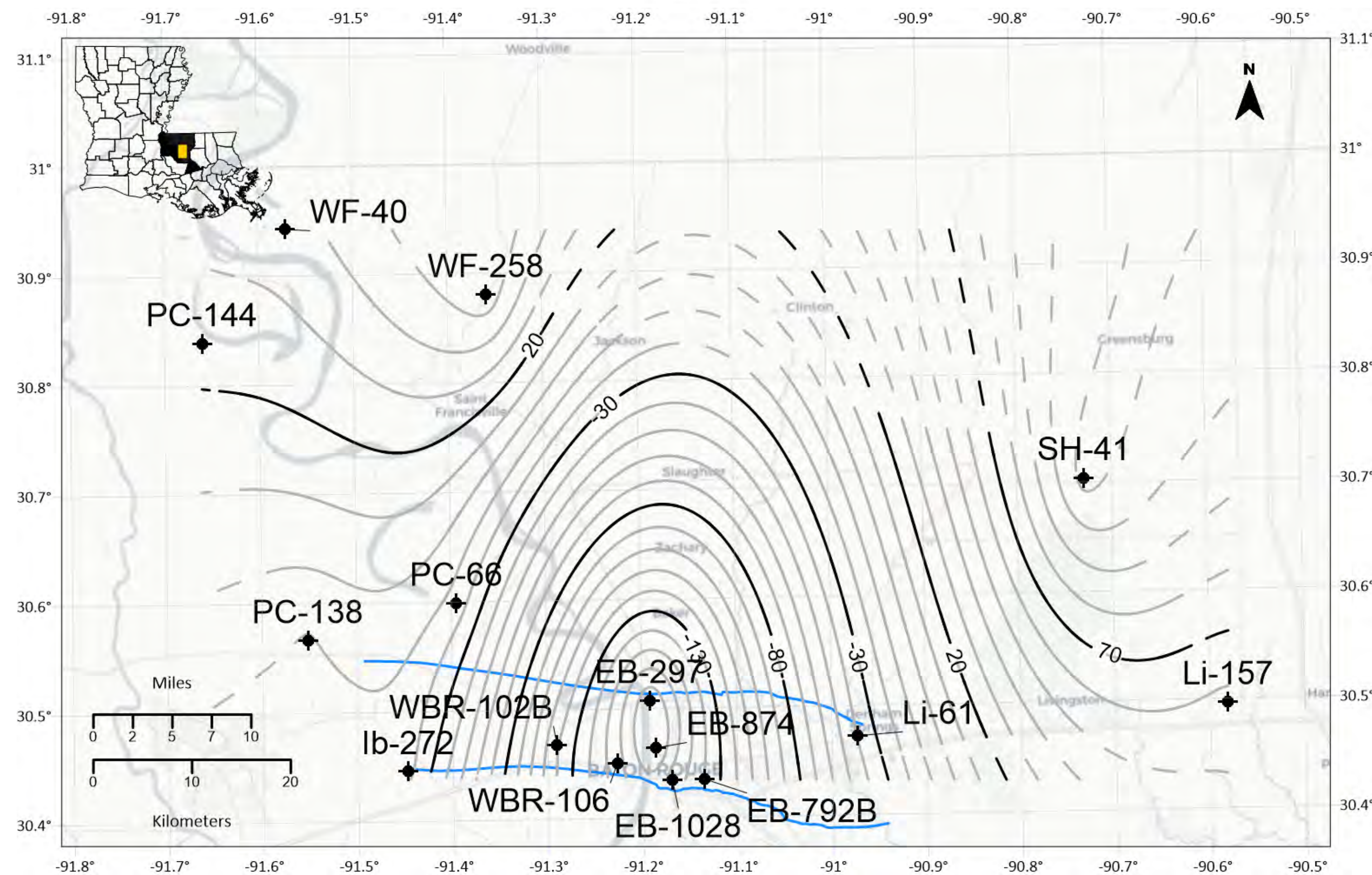

Figure A-8. Potentiometric surface contour map for the 2000-foot sand using data from June 2020 through December 2020. Points show well locations with water level data used to create the contours. Contour interval is 10 ft. Contours are drawn as solid lines are within the area in which there is available data and as dashed lines outside this area. The blue lines represent the Denham Springs-Scotlandville fault to the north and the Baton Rouge Fault to the south. The vertical datum is NGVD29.

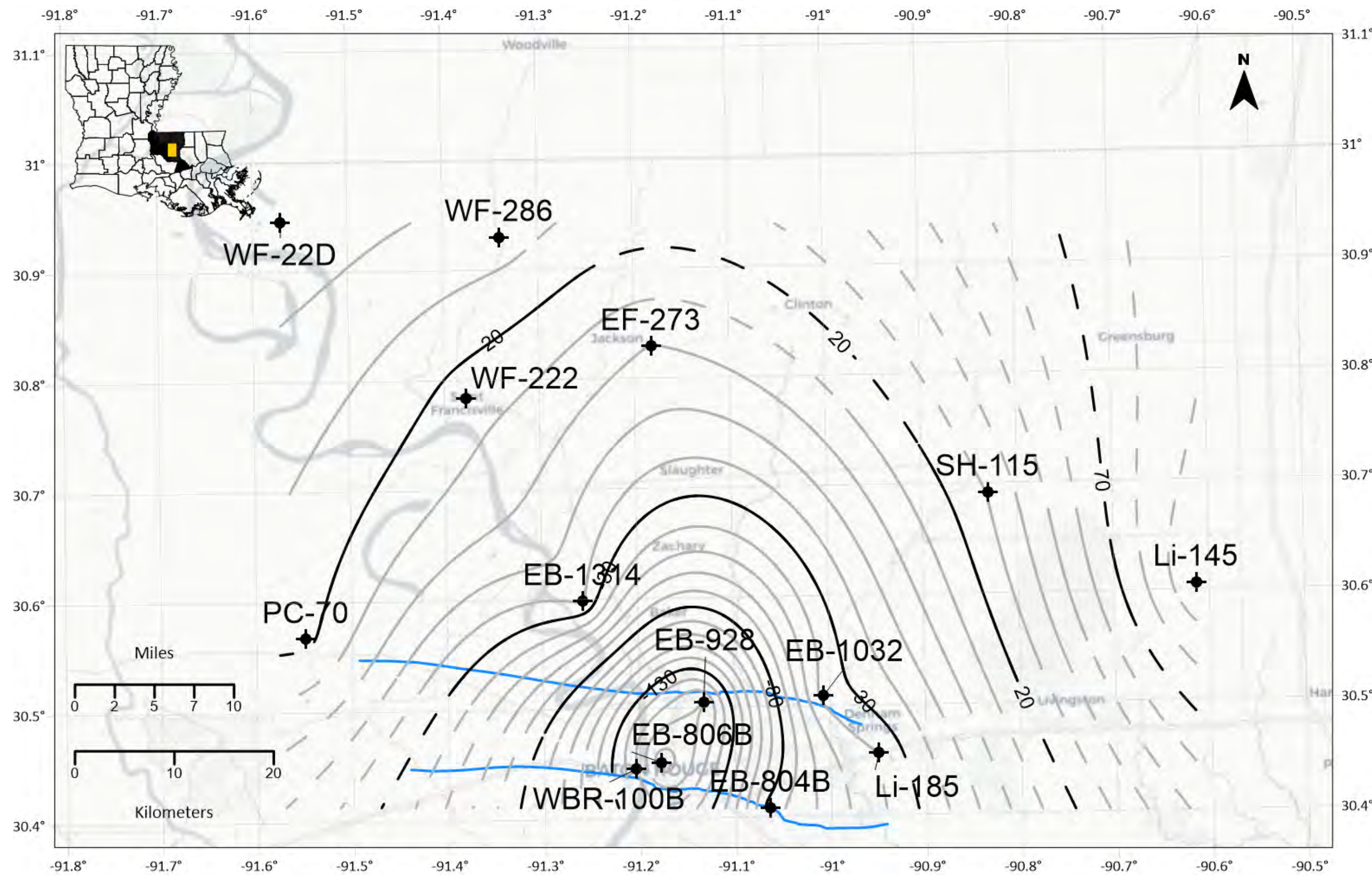

Figure A-9. Potentiometric surface contour map for the 2400-foot sand using data from June 2020 through December 2020. Points show well locations with water level data used to create the contours. Contour interval is 10 ft. Contours are drawn as solid lines are within the area in which there is available data and as dashed lines outside this area. The blue lines represent the Denham Springs-Scotlandville fault to the north and the Baton Rouge Fault to the south. The vertical datum is NGVD29.

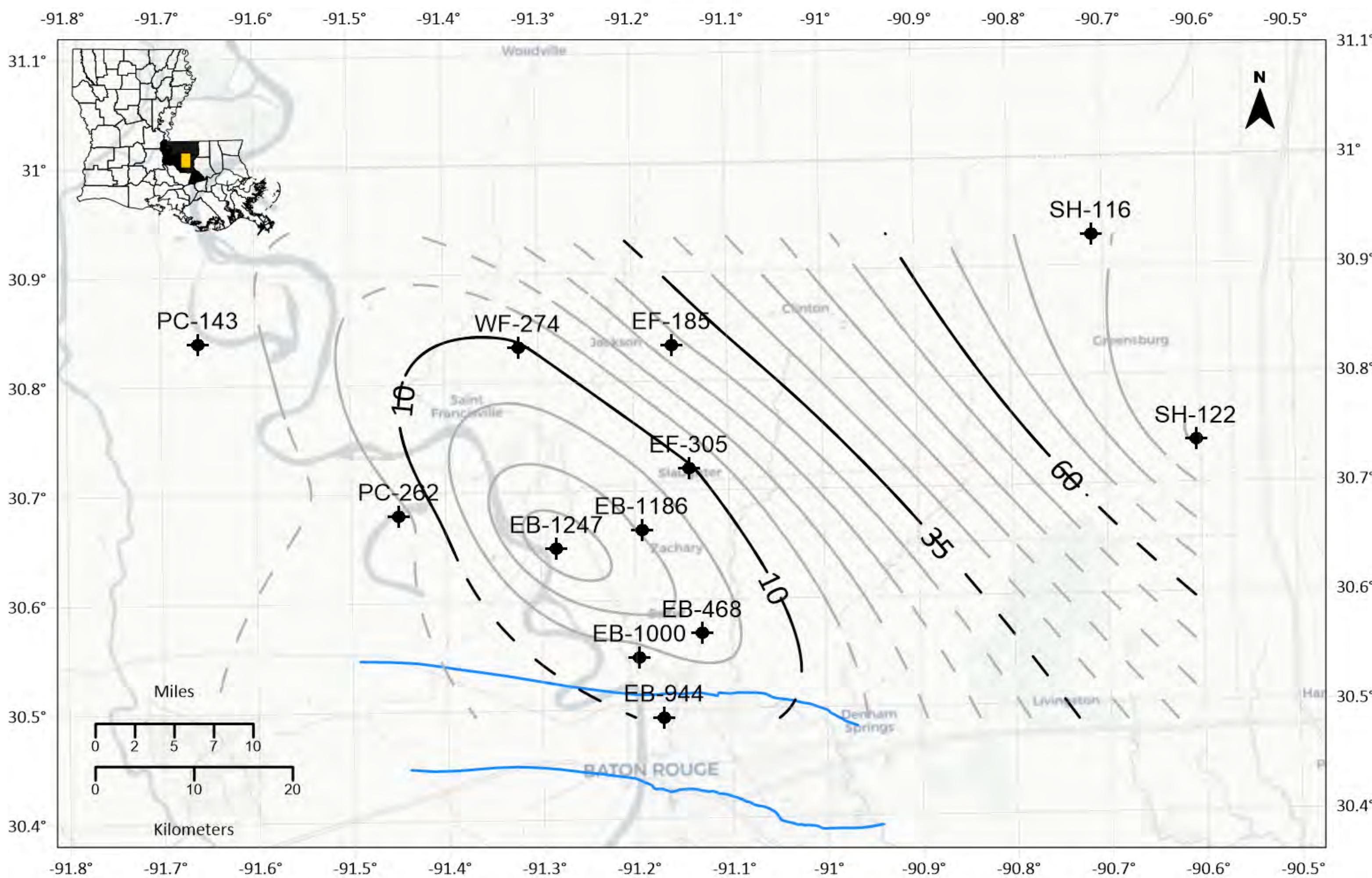

Figure A-10. Potentiometric surface contour map for the 2800-foot sand using data from June 2020 through December 2020. Points show well locations with water level data used to create the contours. Contour interval is 5 ft. Contours are drawn as solid lines are within the area in which there is available data and as dashed lines outside this area. The blue lines represent the Denham Springs-Scotlandville fault to the north and the Baton Rouge Fault to the south. The vertical datum is NGVD29.

APPENDIX B PUMPING DATA MAPS

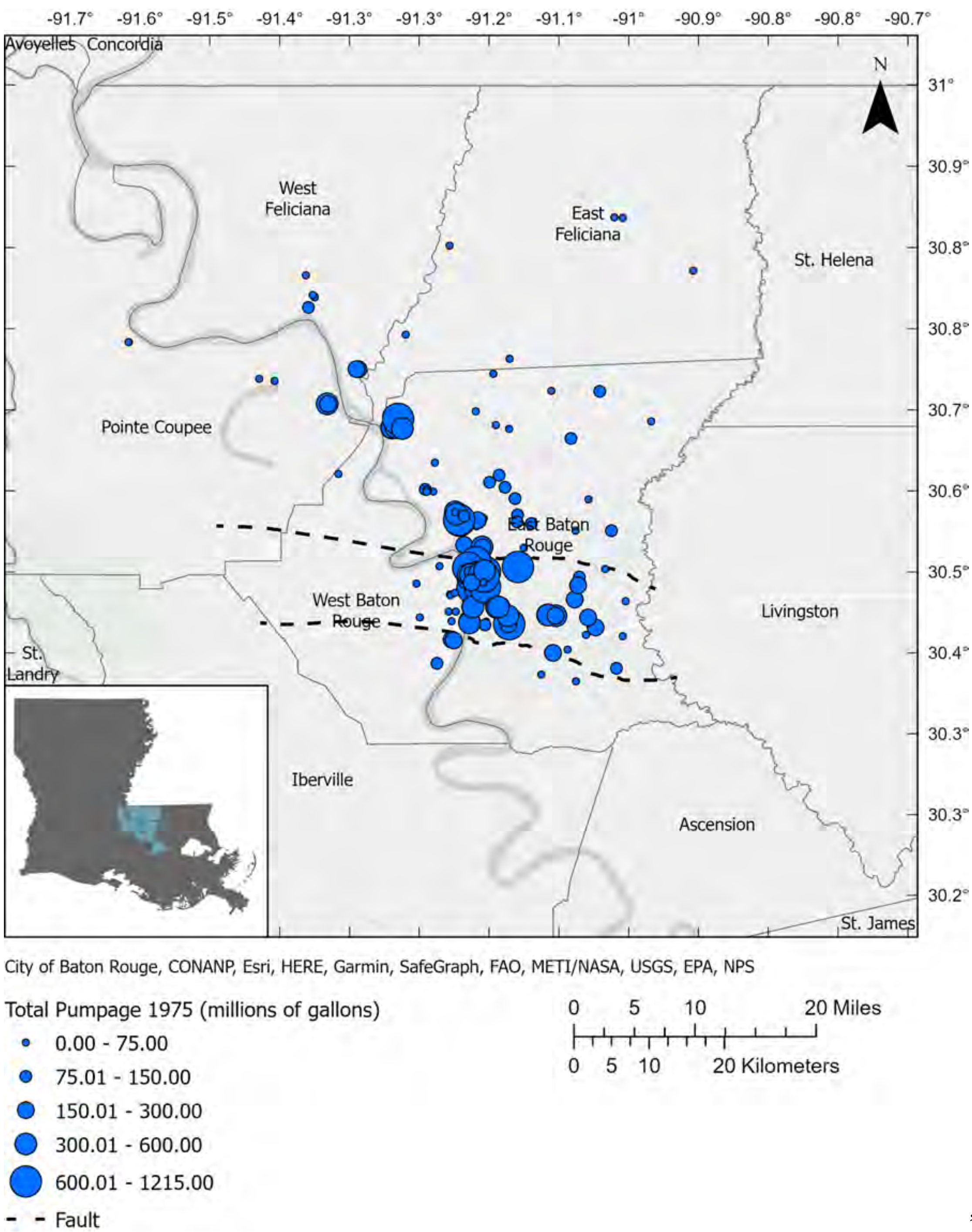

Figure B-1. Total pumpage reported to CAGWCC across the CAGWCD in 1975. Each well that reported pumpage to CAGWCC during this year is represented by a circle. The size of the circle indicates how much water is pumped at each well. Units are in millions of gallons. The total amount of water pumped is a combination of the industrial and public uses of water.

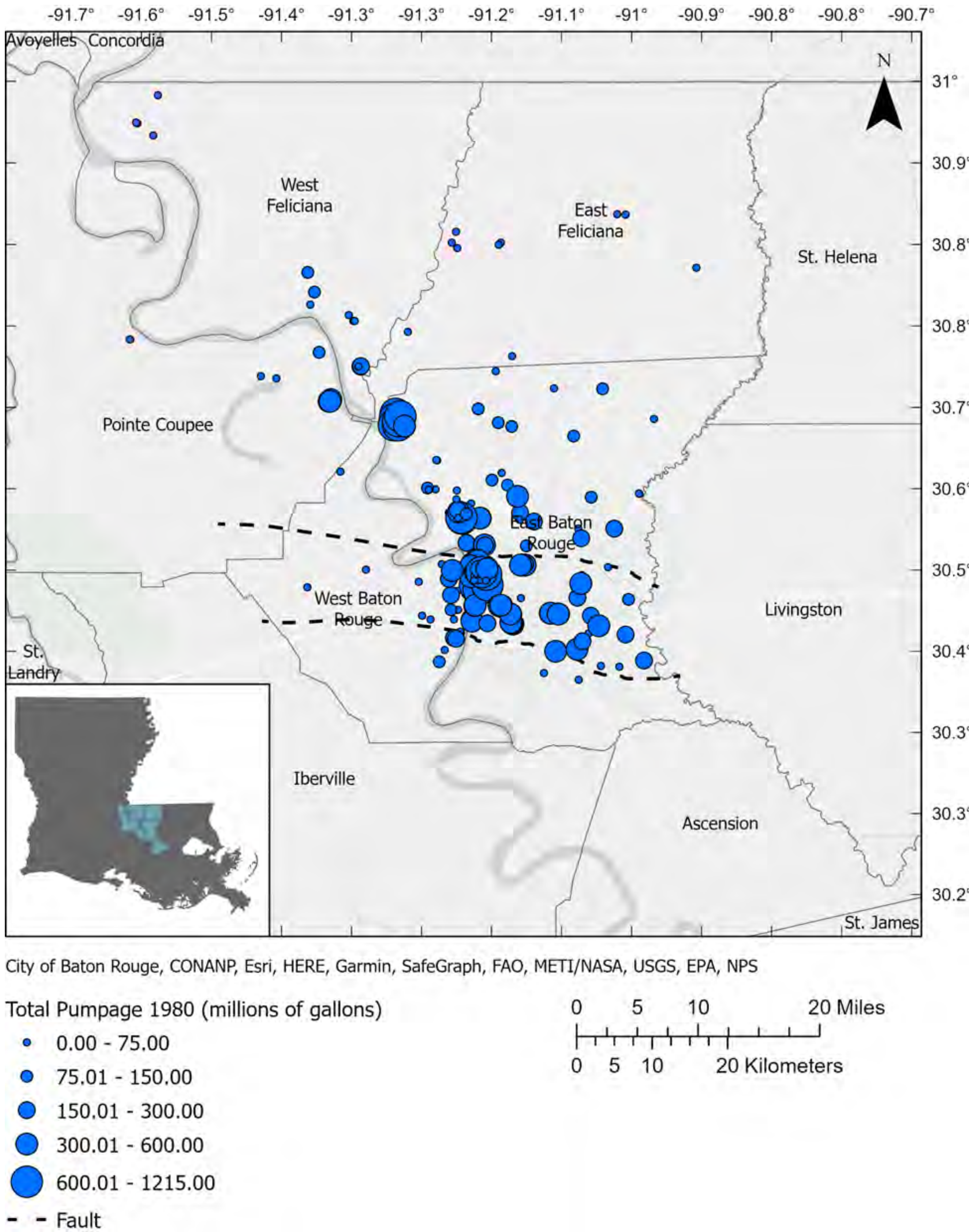

Figure B-2. Total pumpage reported to CAGWCC across the CAGWCD in 1980. Each well that reported pumpage to CAGWCC during this year is represented by a circle. The size of the circle indicates how much water is pumped at each well. Units are in millions of gallons. The total amount of water pumped is a combination of the industrial and public uses of water.

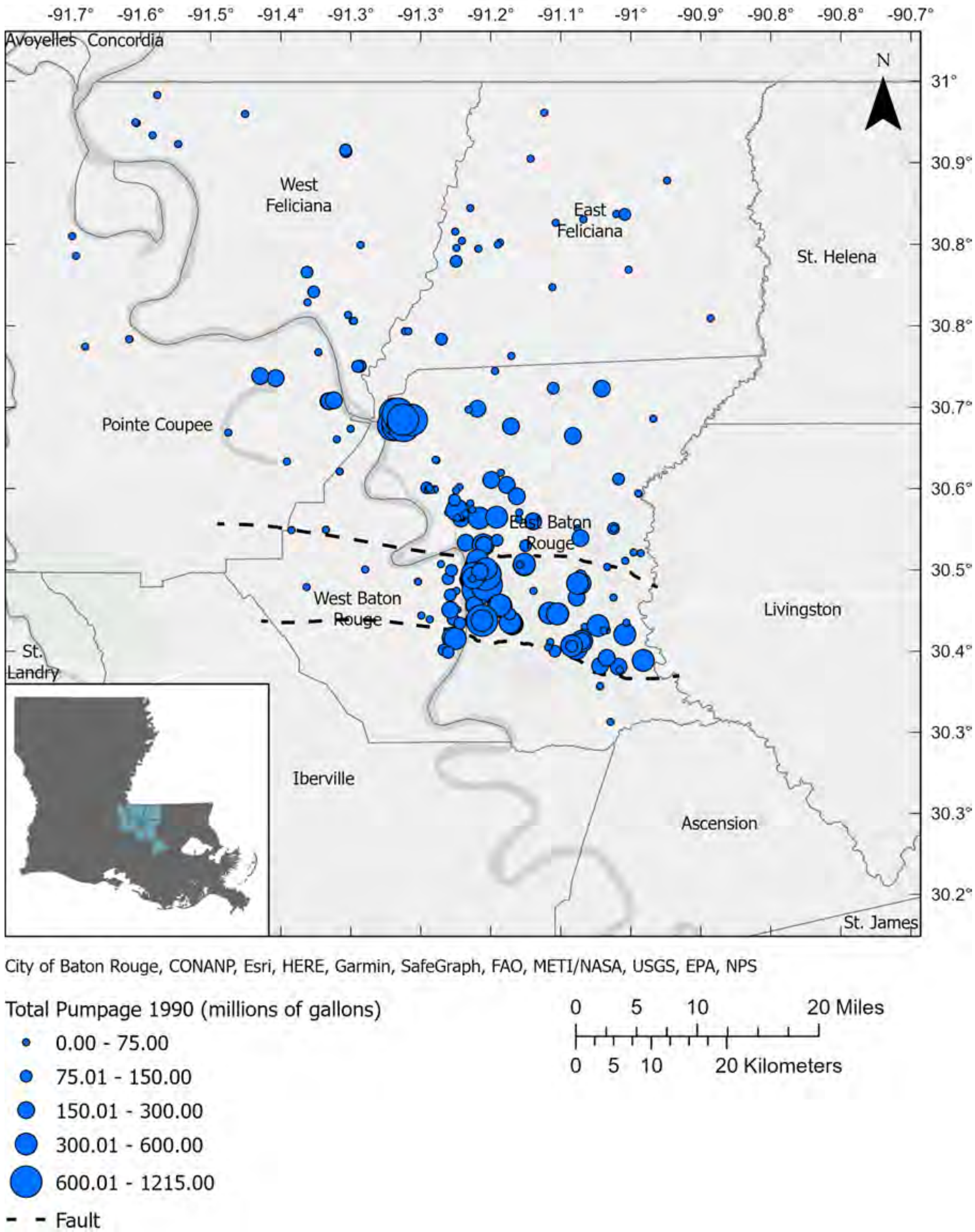

Figure B-3. Total pumpage reported to CAGWCC across the CAGWCD in 1990. Each well that reported pumpage to CAGWCC during this year is represented by a circle. The size of the circle indicates how much water is pumped at each well. Units are in millions of gallons. The total amount of water pumped is a combination of the industrial and public uses of water.

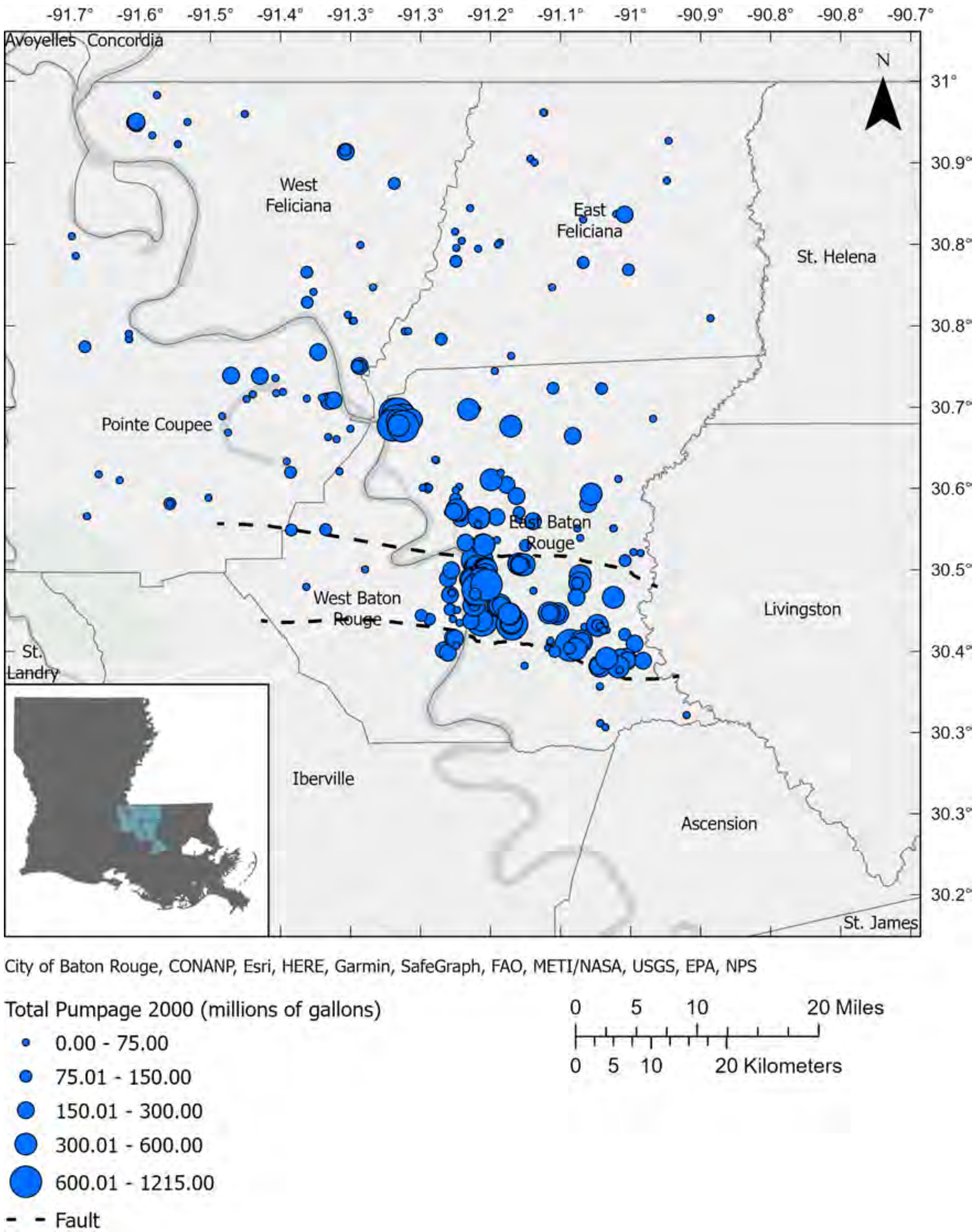

Figure B-4. Total pumpage reported to CAGWCC across the CAGWCD in 2000. Each well that reported pumpage to CAGWCC during this year is represented by a circle. The size of the circle indicates how much water is pumped at each well. Units are in millions of gallons. The total amount of water pumped is a combination of the industrial and public uses of water.

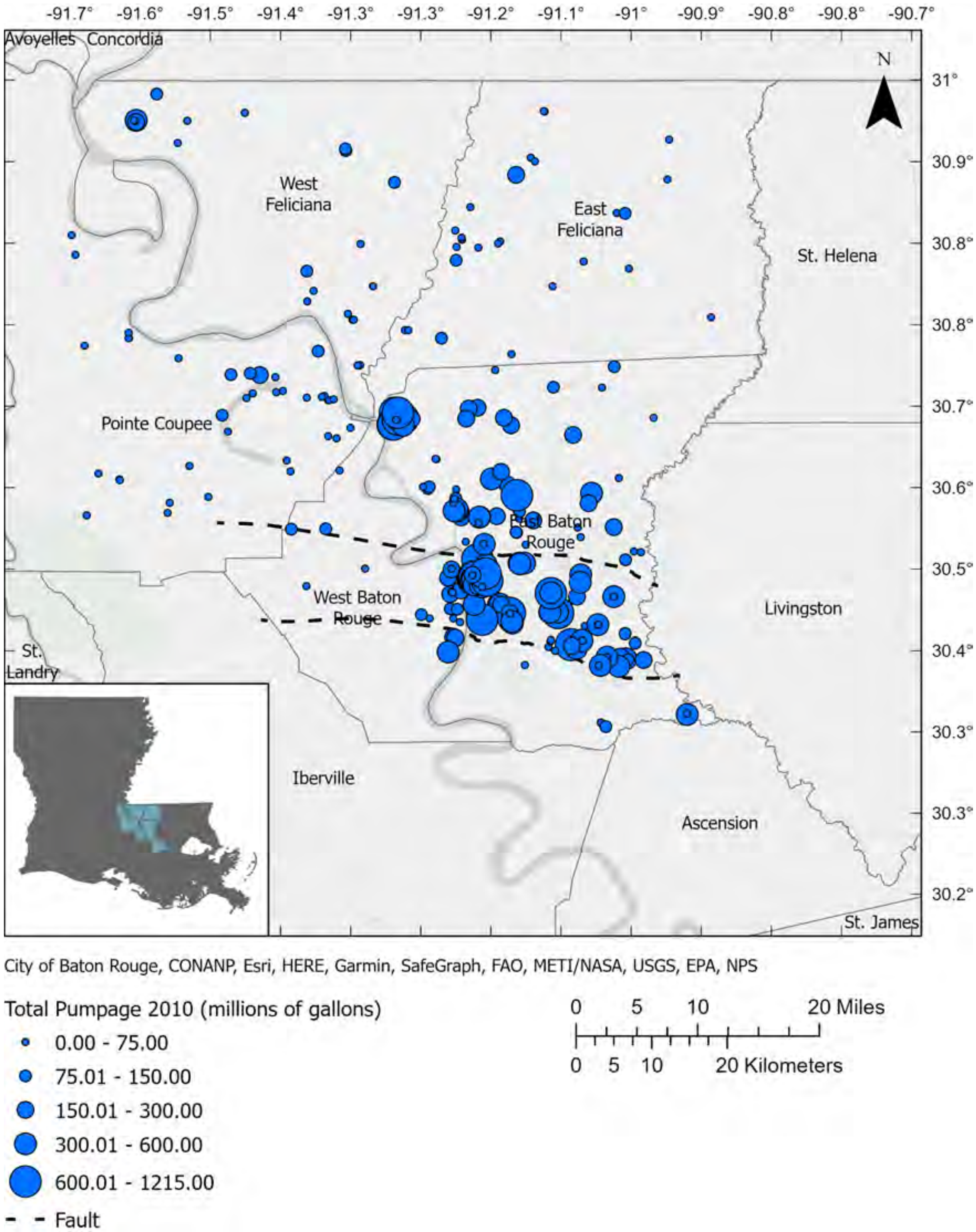

Figure B-5. Total pumpage reported to CAGWCC across the CAGWCD in 2010. Each well that reported pumpage to CAGWCC during this year is represented by a circle. The size of the circle indicates how much water is pumped at each well. Units are in millions of gallons. The total amount of water pumped is a combination of the industrial and public uses of water.

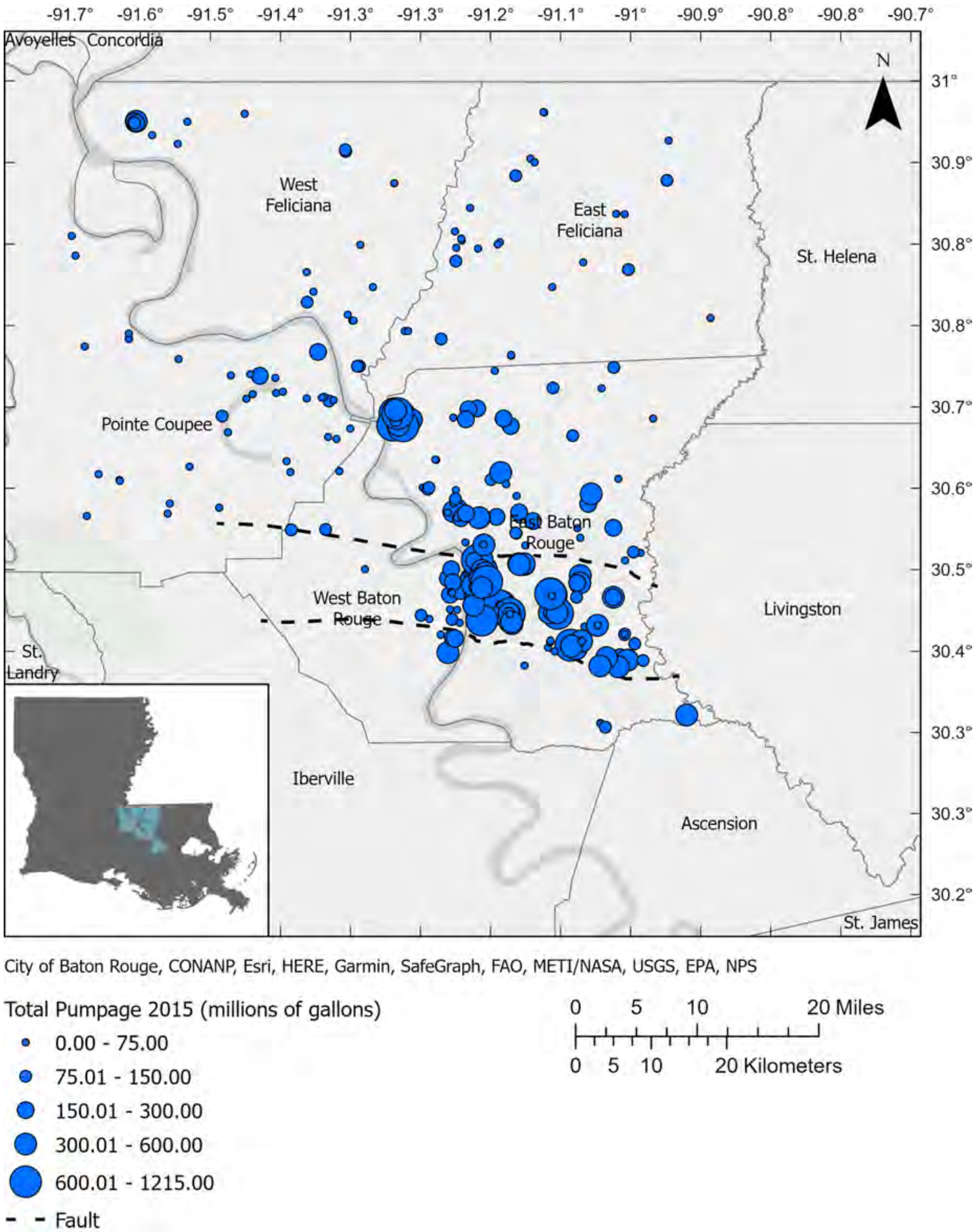

Figure B-6. Total pumpage reported to CAGWCC across the CAGWCD in 2015. Each well that reported pumpage to CAGWCC during this year is represented by a circle. The size of the circle indicates how much water is pumped at each well. Units are in millions of gallons. The total amount of water pumped is a combination of the industrial and public uses of water.

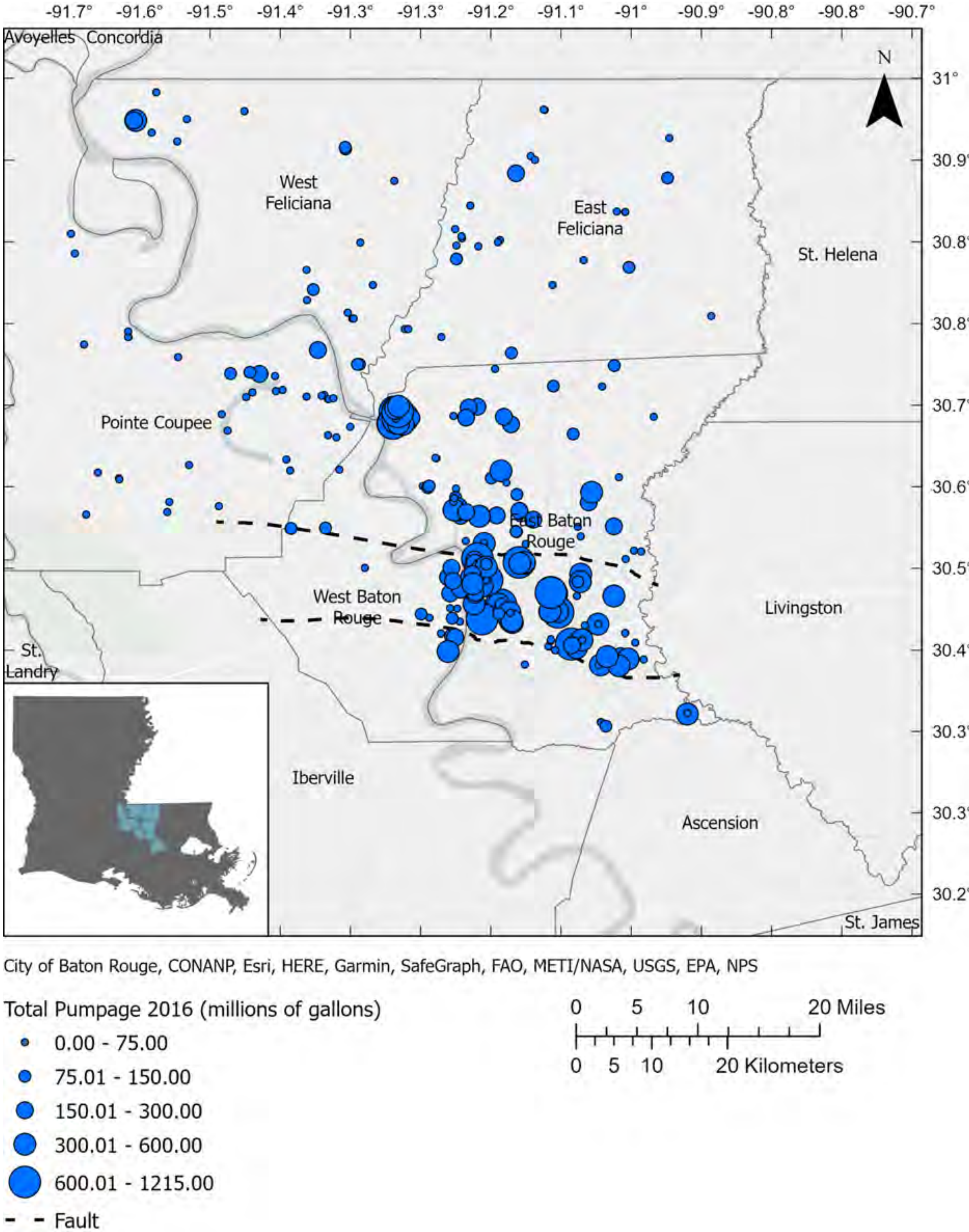

Figure B-7. Total pumpage reported to CAGWCC across the CAGWCD in 2016. Each well that reported pumpage to CAGWCC during this year is represented by a circle. The size of the circle indicates how much water is pumped at each well. Units are in millions of gallons. The total amount of water pumped is a combination of the industrial and public uses of water.

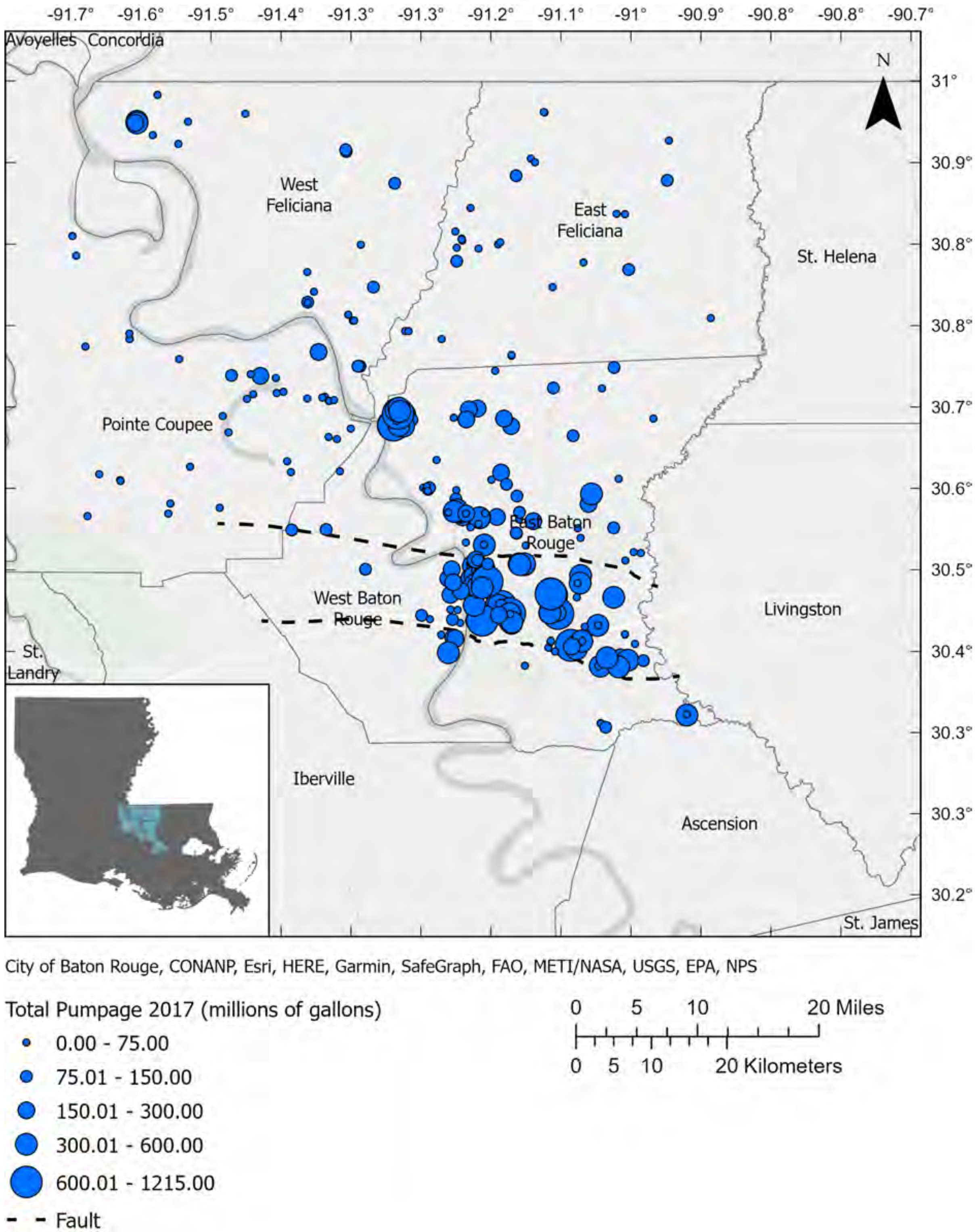

Figure B-8. Total pumpage reported to CAGWCC across the CAGWCD in 2017. Each well that reported pumpage to CAGWCC during this year is represented by a circle. The size of the circle indicates how much water is pumped at each well. Units are in millions of gallons. The total amount of water pumped is a combination of the industrial and public uses of water.

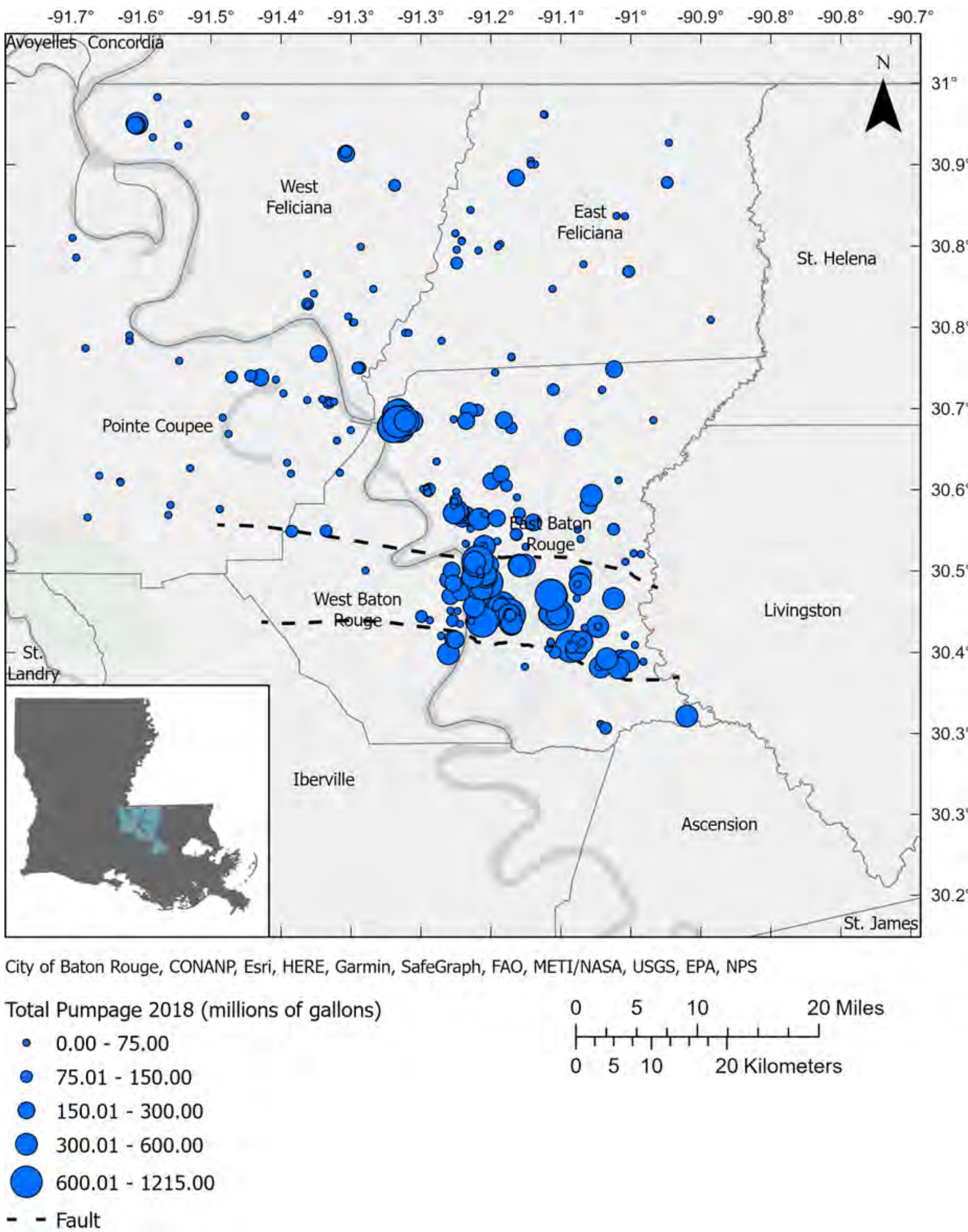

Figure B-9. Total pumpage reported to CAGWCC across the CAGWCD in 2018. Each well that reported pumpage to CAGWCC during this year is represented by a circle. The size of the circle indicates how much water is pumped at each well. Units are in millions of gallons. The total amount of water pumped is a combination of the industrial and public uses of water.

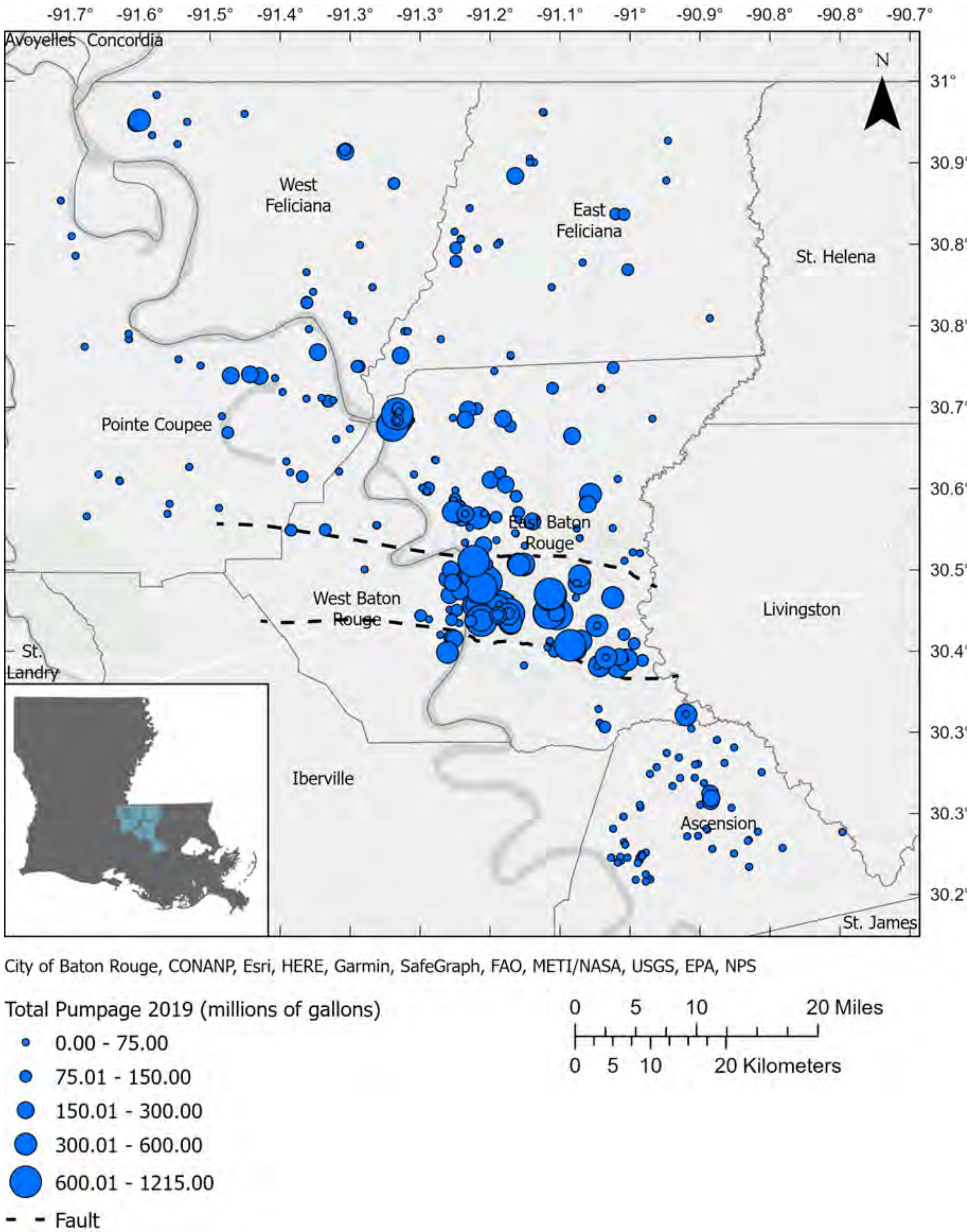

Figure B-10. Total pumpage reported to CAGWCC across the CAGWCD in 2019. Each well that reported pumpage to CAGWCC during this year is represented by a circle. The size of the circle indicates how much water is pumped at each well. Units are in millions of gallons. The total amount of water pumped is a combination of the industrial and public uses of water.

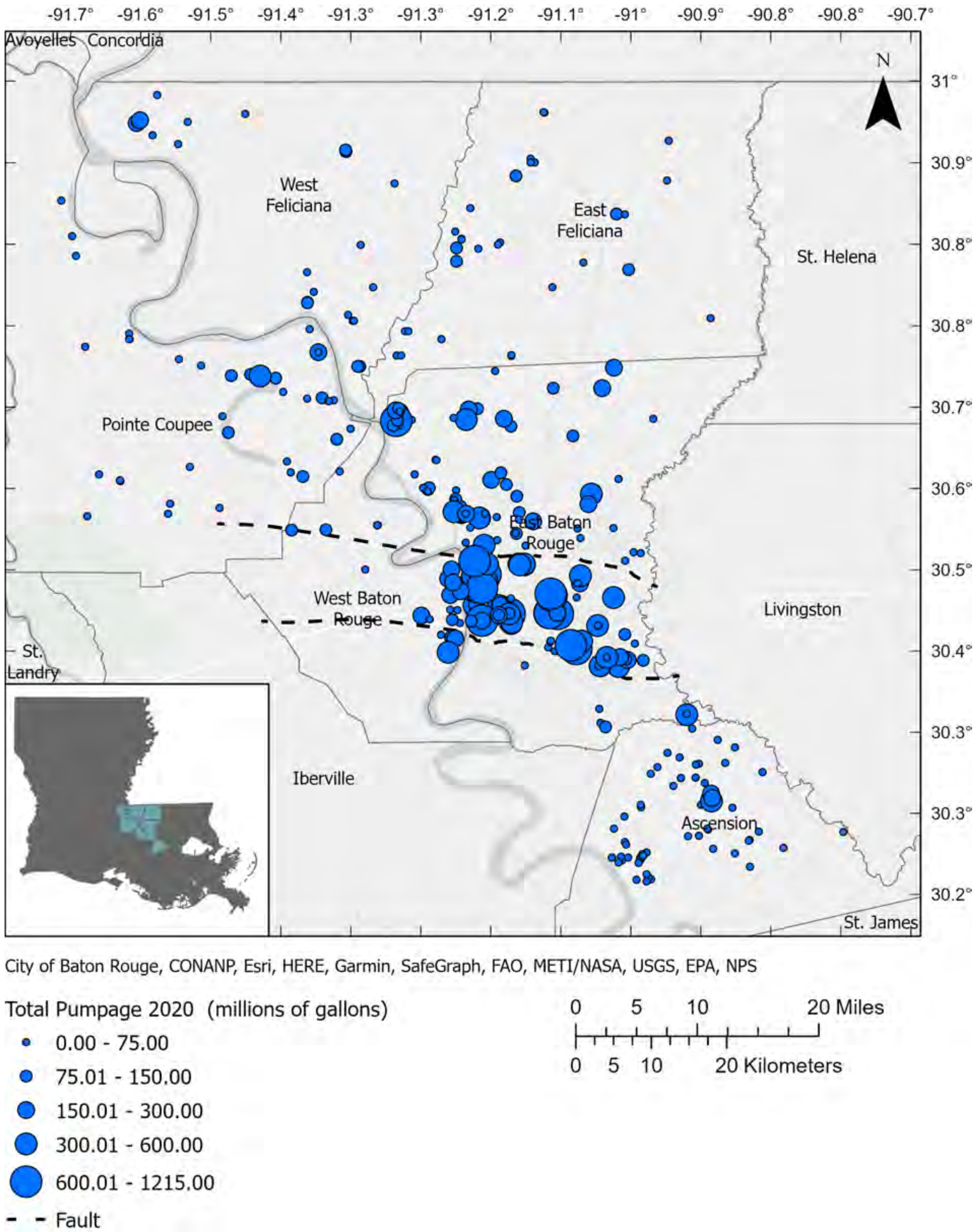

Figure B-11. Total pumpage reported to CAGWCC across the CAGWCD in 2020. Each well that reported pumpage to CAGWCC during this year is represented by a circle. The size of the circle indicates how much water is pumped at each well. Units are in millions of gallons. The total amount of water pumped is a combination of the industrial and public uses of water.

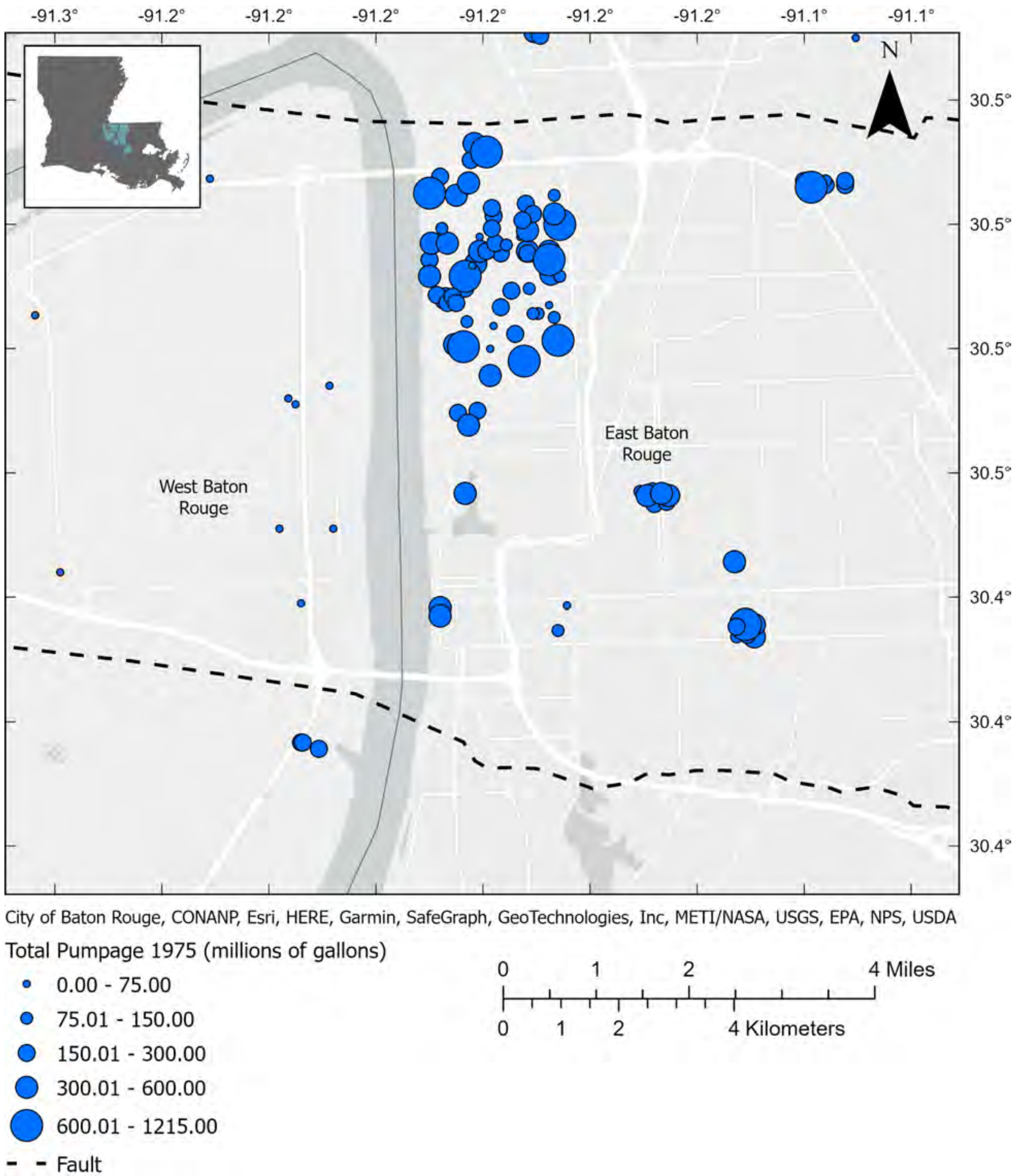

Figure B-12.Total pumpage reported to CAGWCC in the Baton Rouge Industrial District in 1975. Each well that reported pumpage to CAGWCC during this year is represented by a circle. The size of the circle indicates how much water is pumped at each well. Units are in millions of gallons.

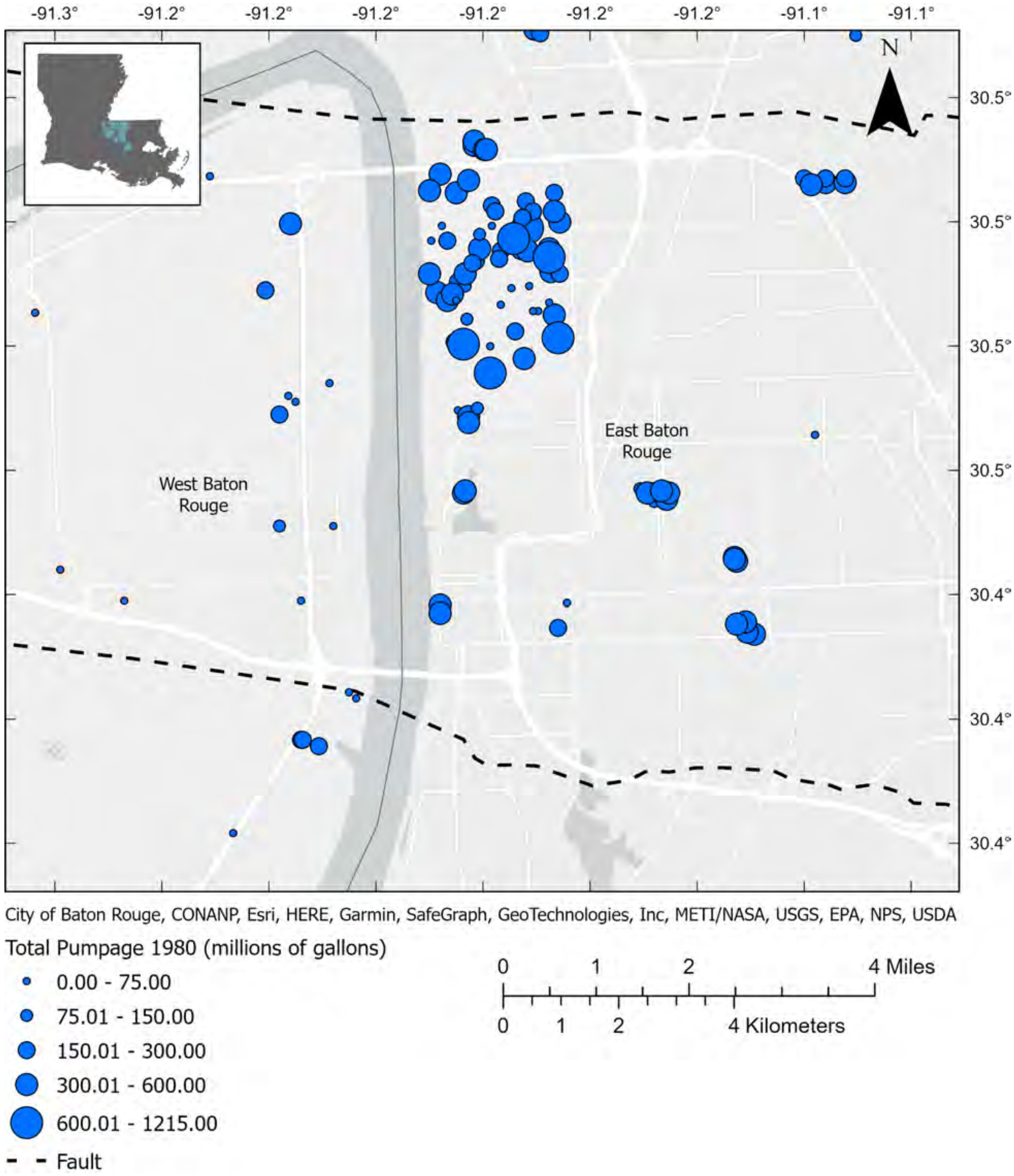

Figure B-13. Total pumpage reported to CAGWCC in the Baton Rouge Industrial District in 1980. Each well that reported pumpage to CAGWCC during this year is represented by a circle. The size of the circle indicates how much water is pumped at each well. Units are in millions of gallons.

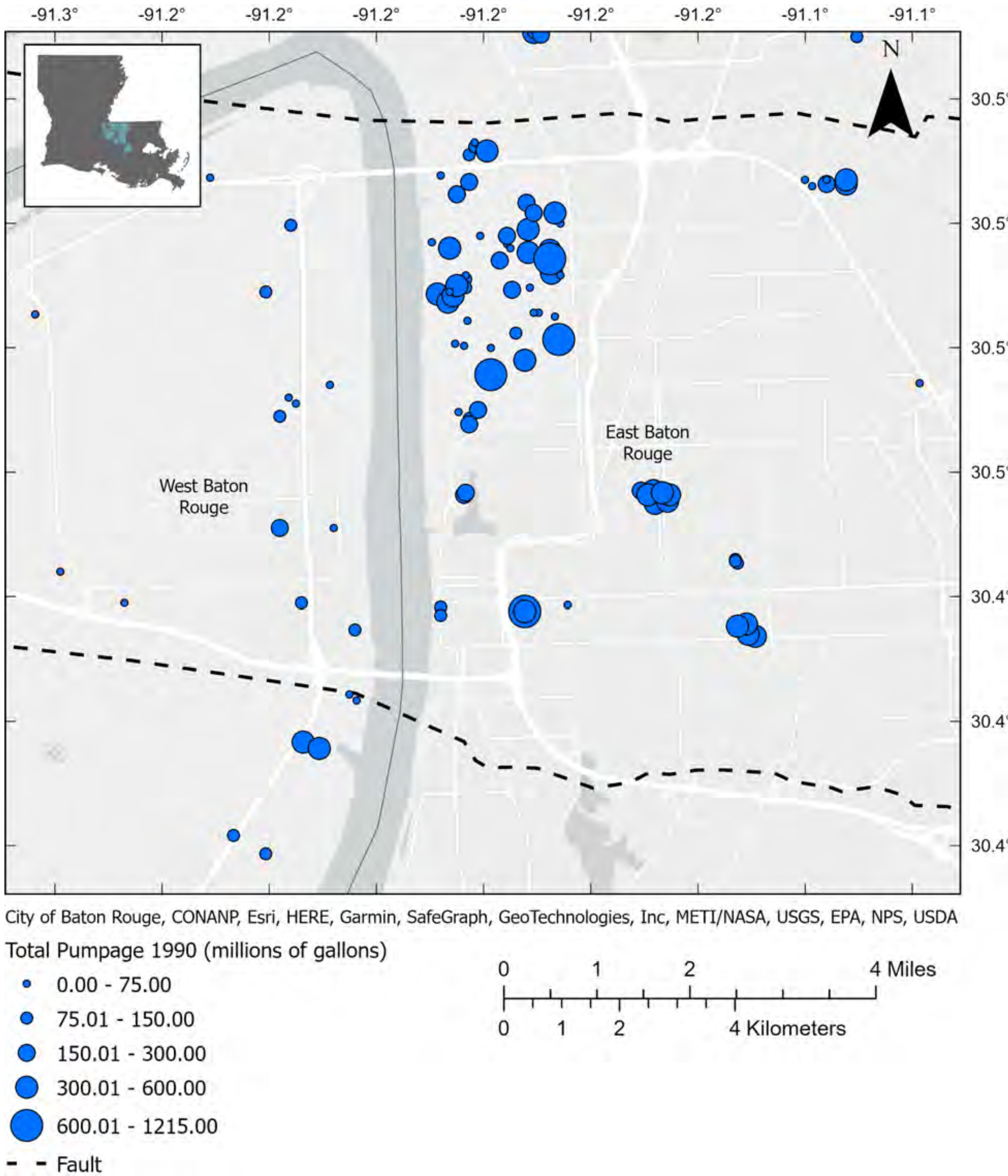

Figure B-14. Total pumpage reported to CAGWCC in the Baton Rouge Industrial District in 1990. Each well that reported pumpage to CAGWCC during this year is represented by a circle. The size of the circle indicates how much water is pumped at each well. Units are in millions of gallons.

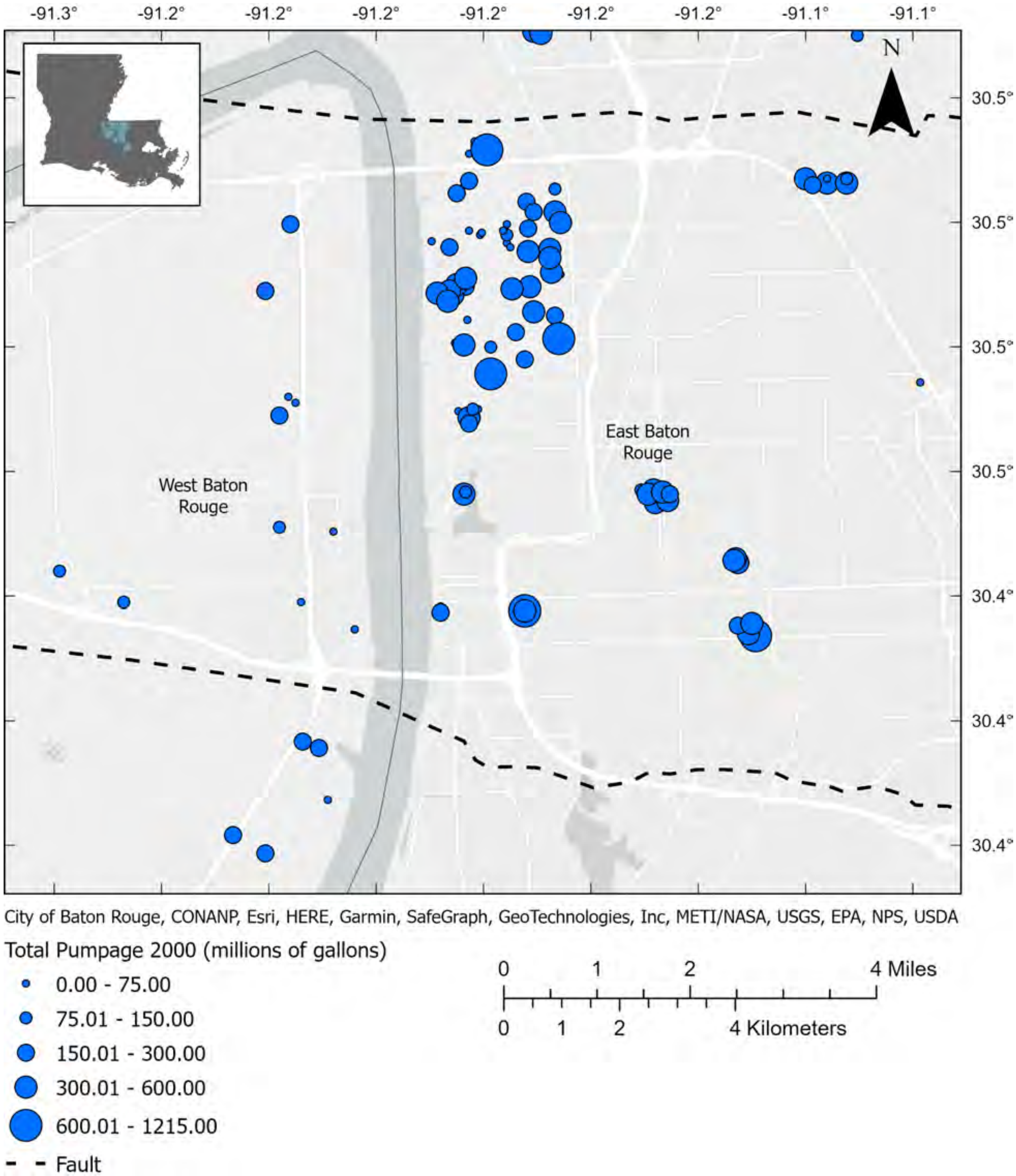

Figure B-15. Total pumpage reported to CAGWCC in the Baton Rouge Industrial District in 2000. Each well that reported pumpage to CAGWCC during this year is represented by a circle. The size of the circle indicates how much water is pumped at each well. Units are in millions of gallons.

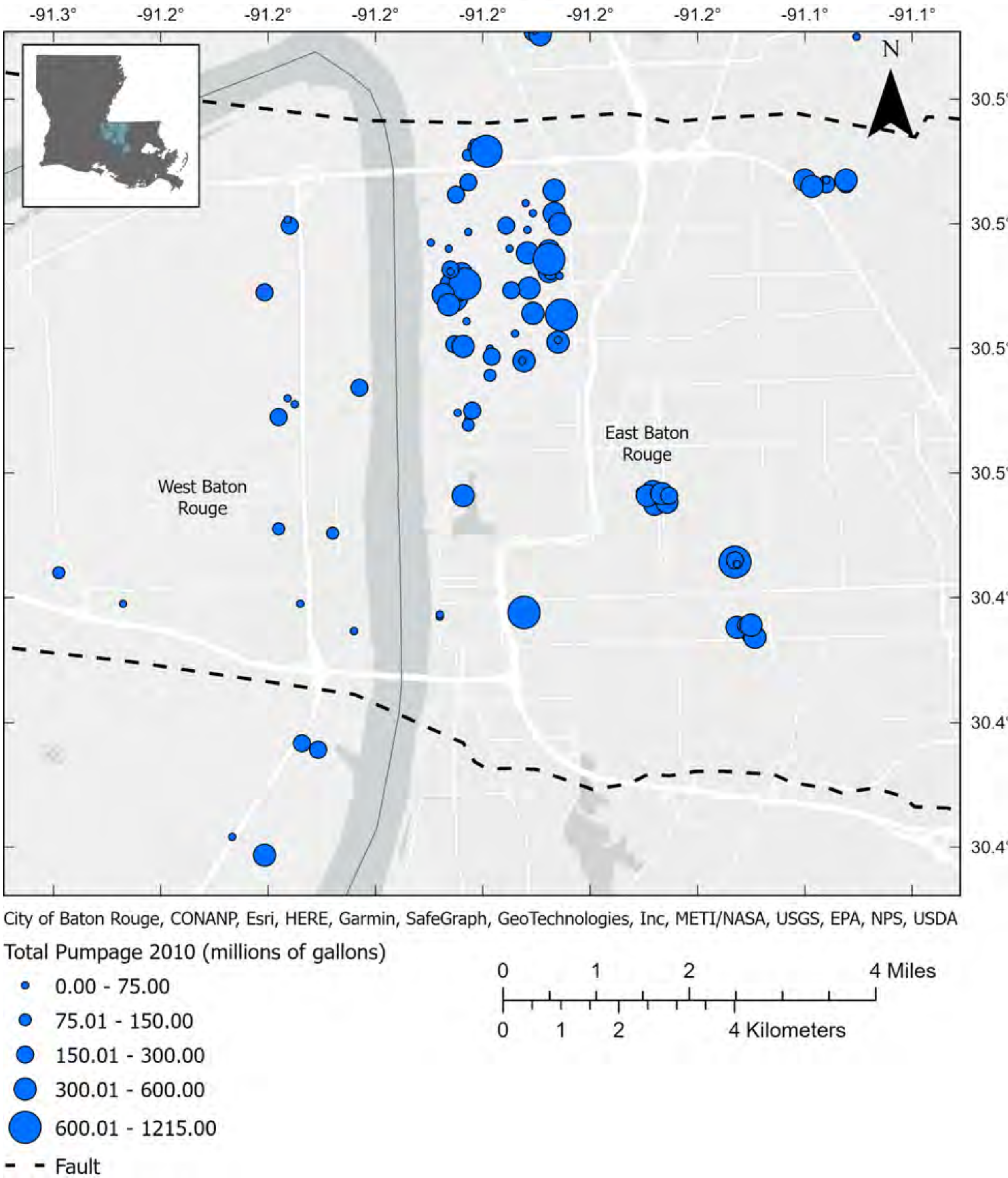

Figure B-16. Total pumpage reported to CAGWCC in the Baton Rouge Industrial District in 2010. Each well that reported pumpage to CAGWCC during this year is represented by a circle. The size of the circle indicates how much water is pumped at each well. Units are in millions of gallons.

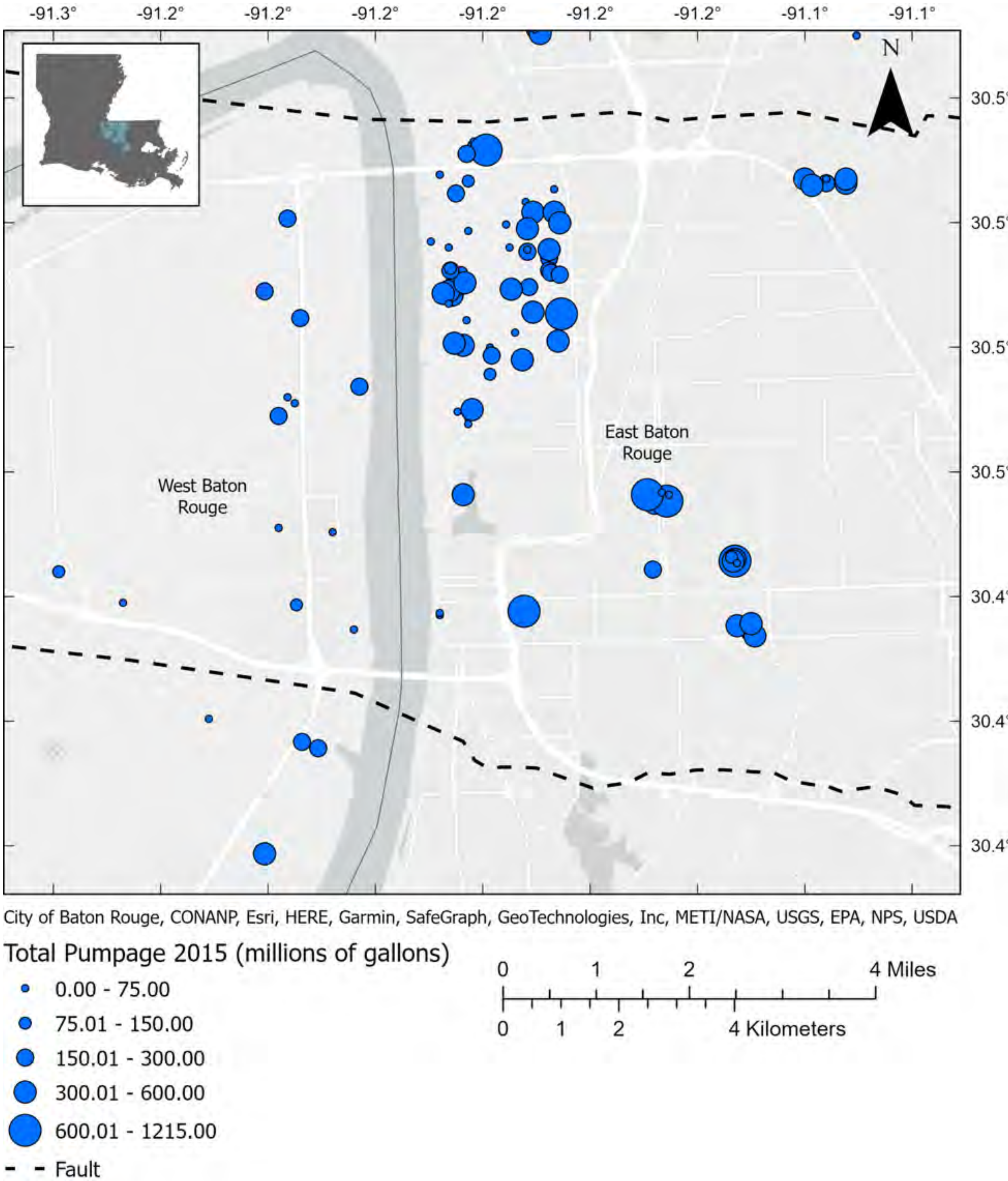

Figure B-17. Total pumpage reported to CAGWCC in the Baton Rouge Industrial District in 2015. Each well that reported pumpage to CAGWCC during this year is represented by a circle. The size of the circle indicates how much water is pumped at each well. Units are in millions of gallons.

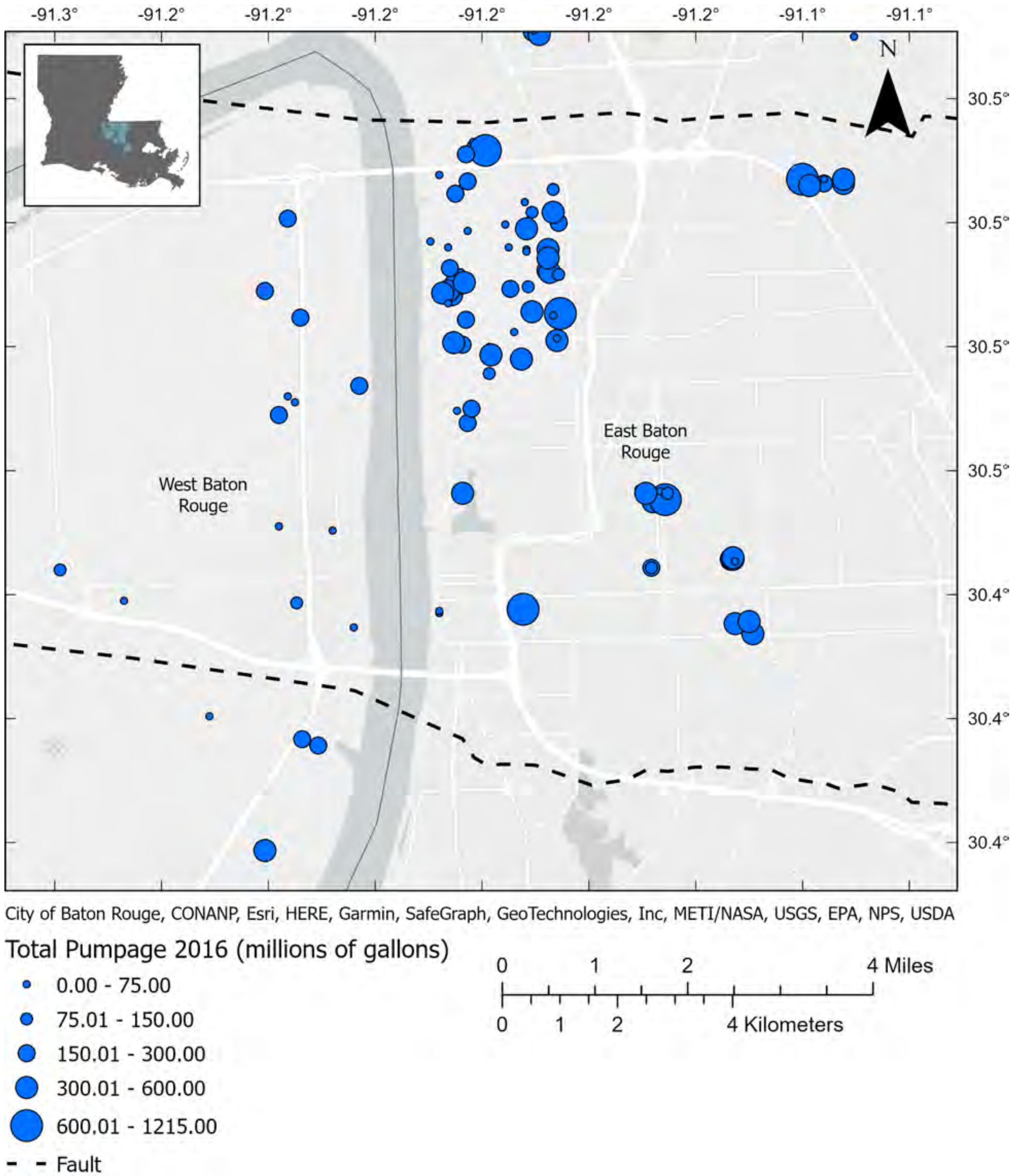

Figure B-18. Total pumpage reported to CAGWCC in the Baton Rouge Industrial District in 2016. Each well that reported pumpage to CAGWCC during this year is represented by a circle. The size of the circle indicates how much water is pumped at each well. Units are in millions of gallons.

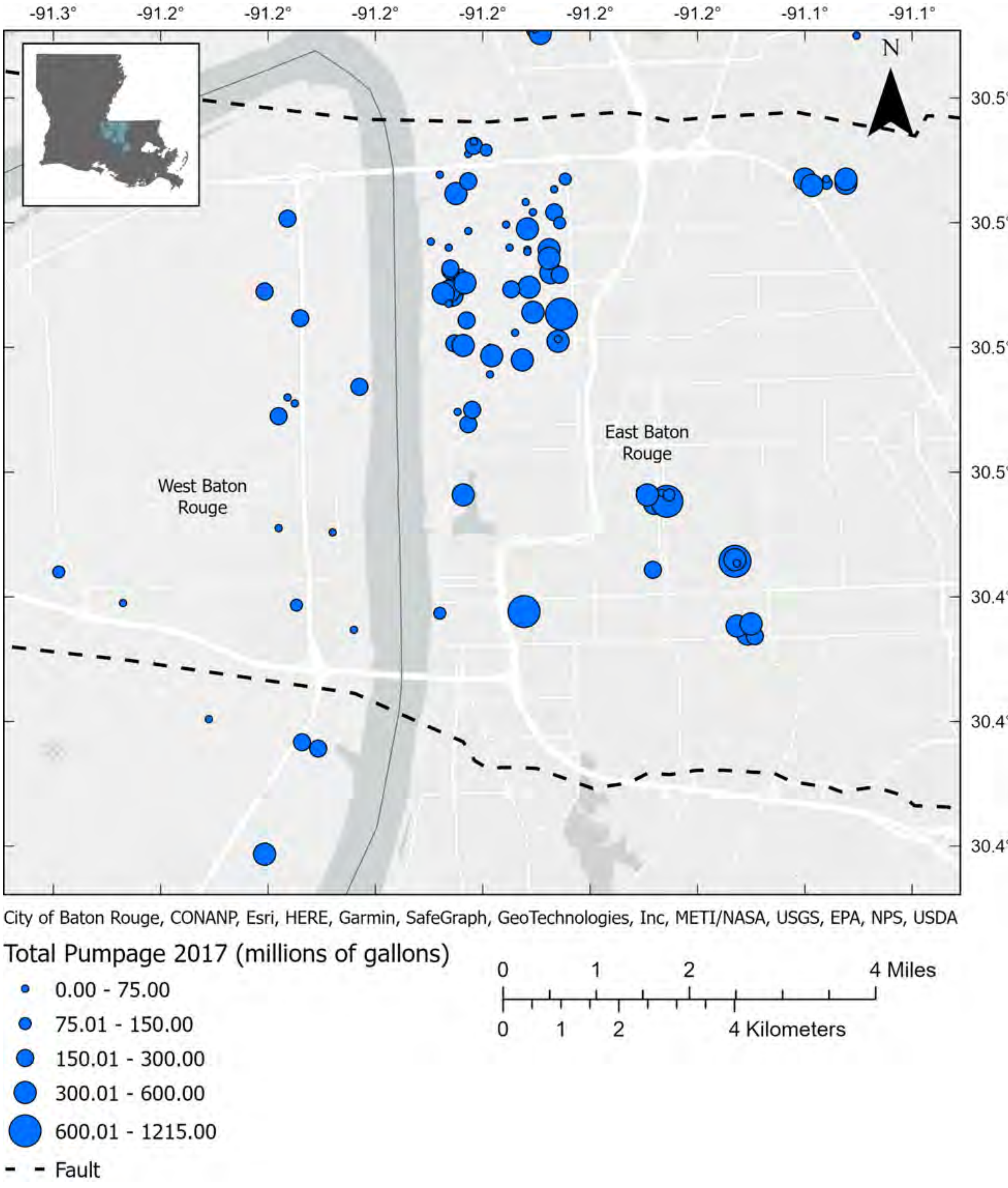

Figure B-19. Total pumpage reported to CAGWCC in the Baton Rouge Industrial District in 2017. Each well that reported pumpage to CAGWCC during this year is represented by a circle. The size of the circle indicates how much water is pumped at each well. Units are in millions of gallons.

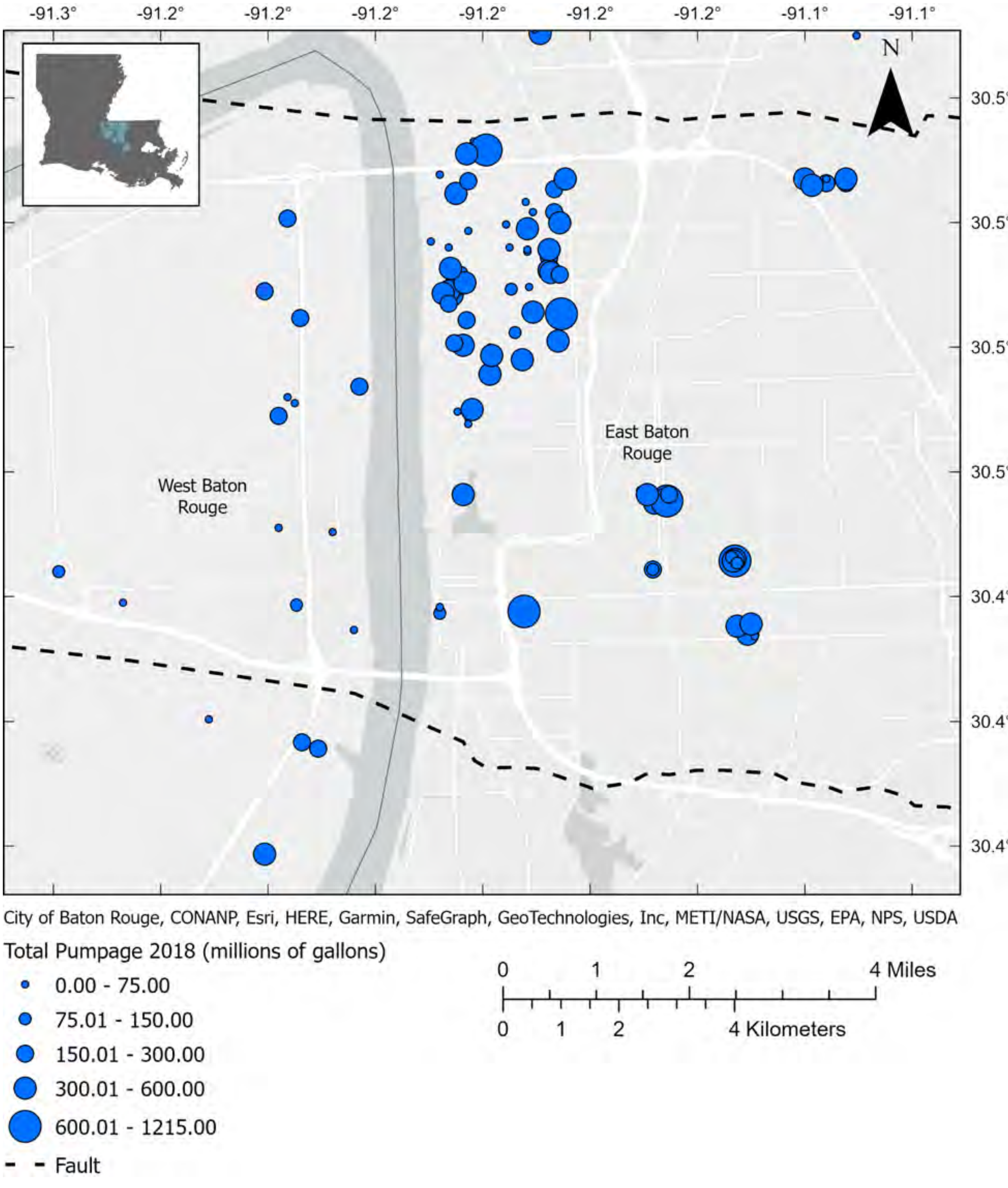

Figure B-20. Total pumpage reported to CAGWCC in the Baton Rouge Industrial District in 2018. Each well that reported pumpage to CAGWCC during this year is represented by a circle. The size of the circle indicates how much water is pumped at each well. Units are in millions of gallons.

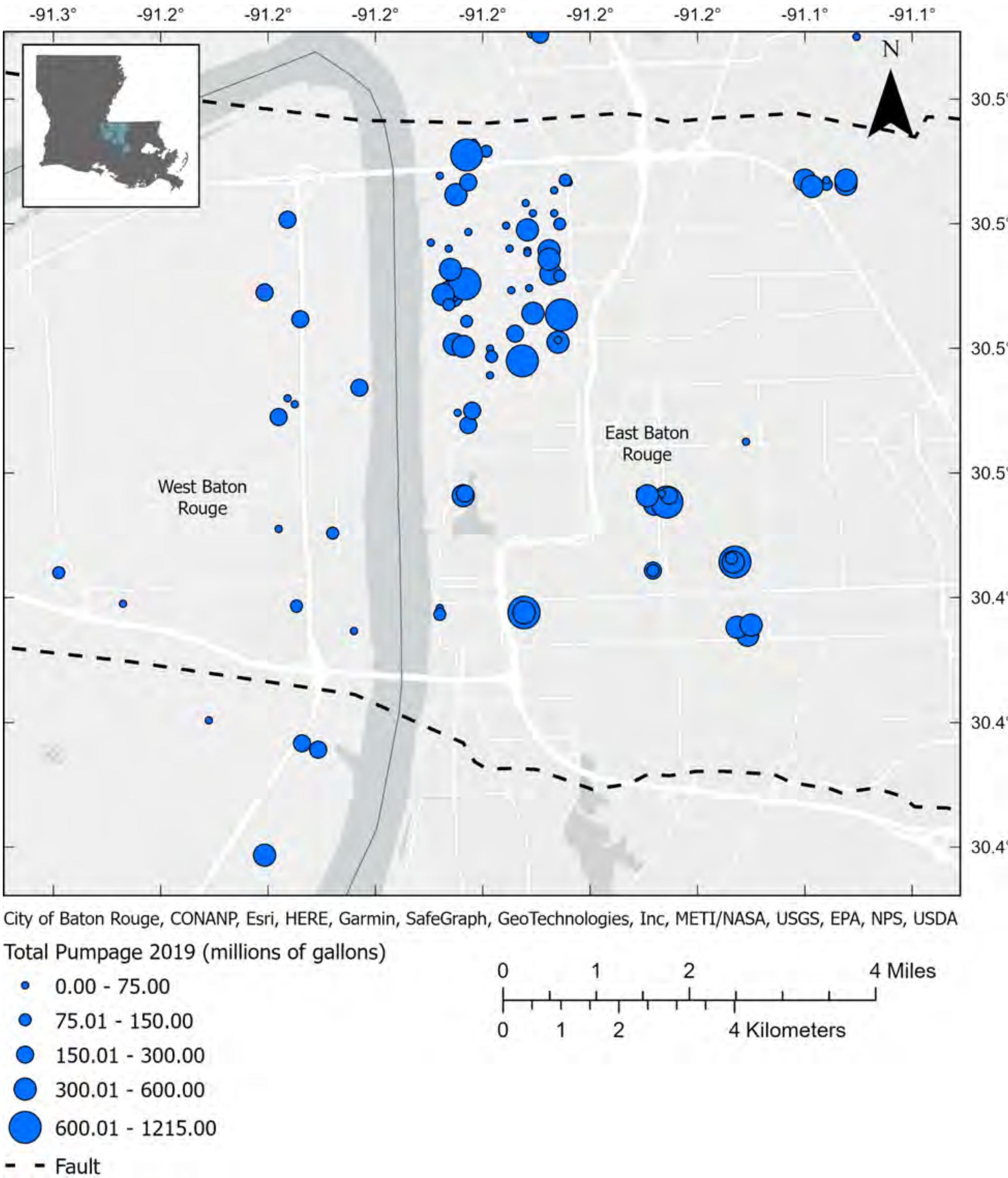

Figure B-21. Total pumpage reported to CAGWCC in the Baton Rouge Industrial District in 2019. Each well that reported pumpage to CAGWCC during this year is represented by a circle. The size of the circle indicates how much water is pumped at each well. Units are in millions of gallons.

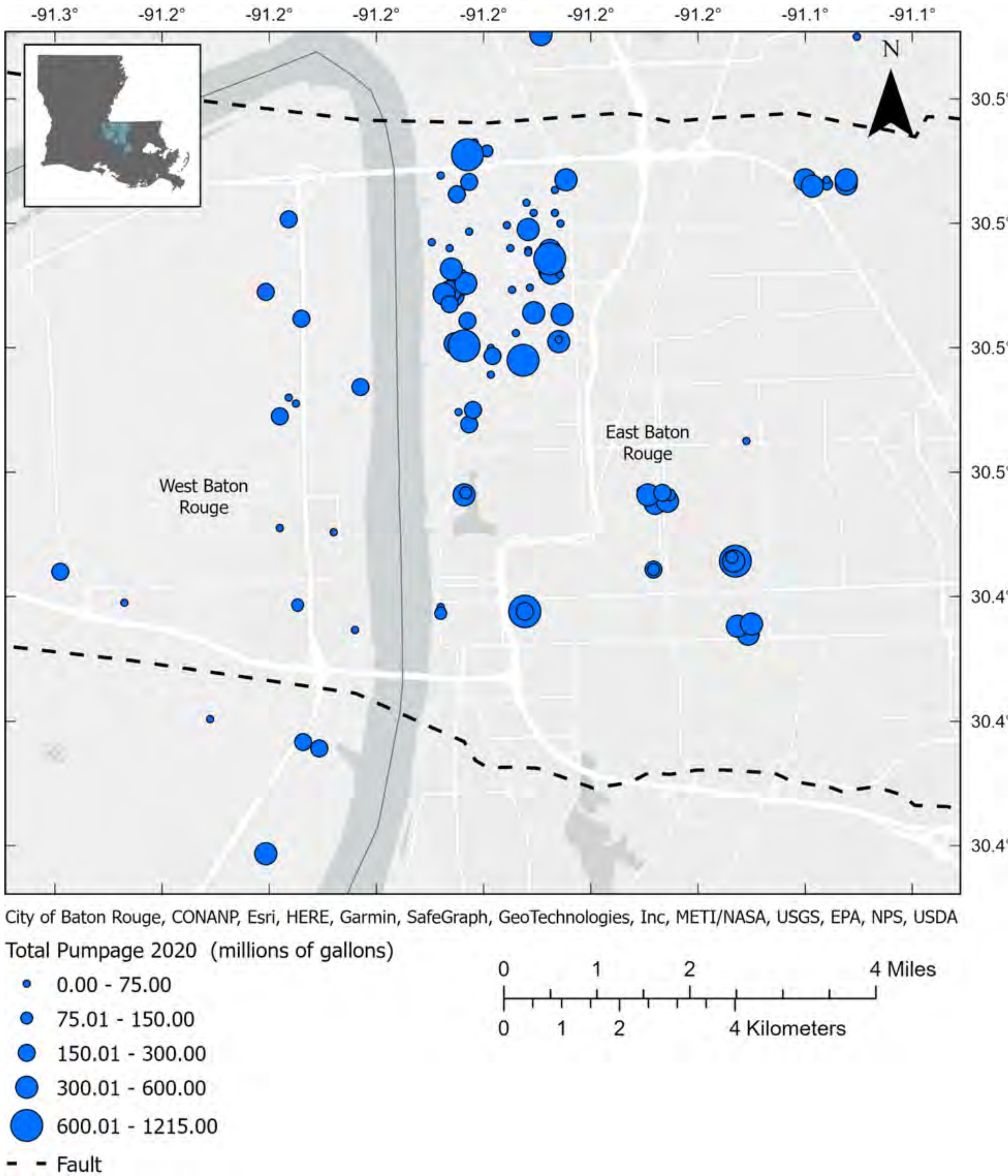

Figure B-22. Total pumpage reported to CAGWCC in the Baton Rouge Industrial District in 2020. Each well that reported pumpage to CAGWCC during this year is represented by a circle. The size of the circle indicates how much water is pumped at each well. Units are in millions of gallons.

APPENDIX C CHLORIDE MONITORING MAPS

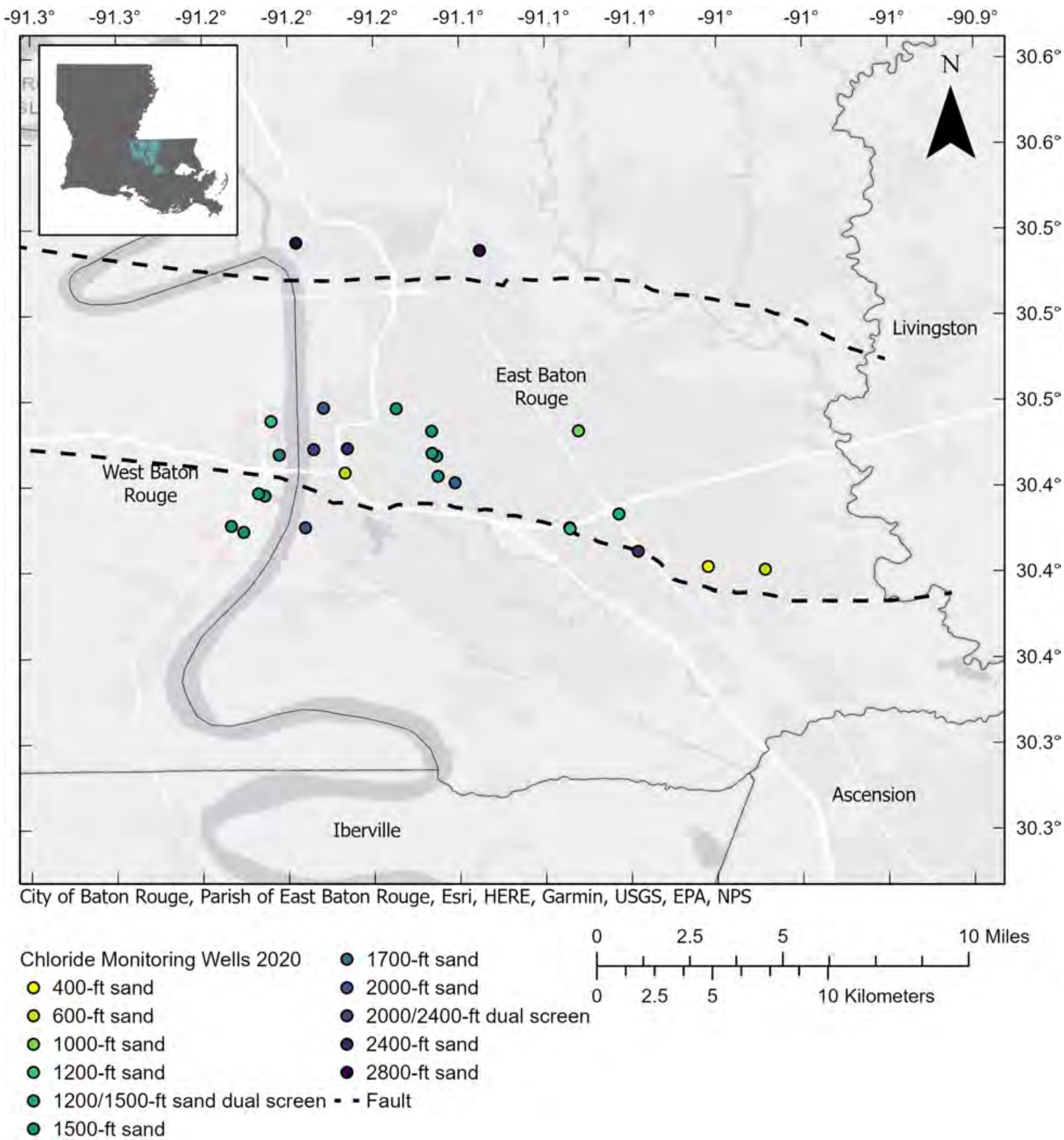

Figure C-1. Chloride measurements within the CAGWCD from June 2020 through December 2020. Each point is colored to reflect the sand within which it was measured.

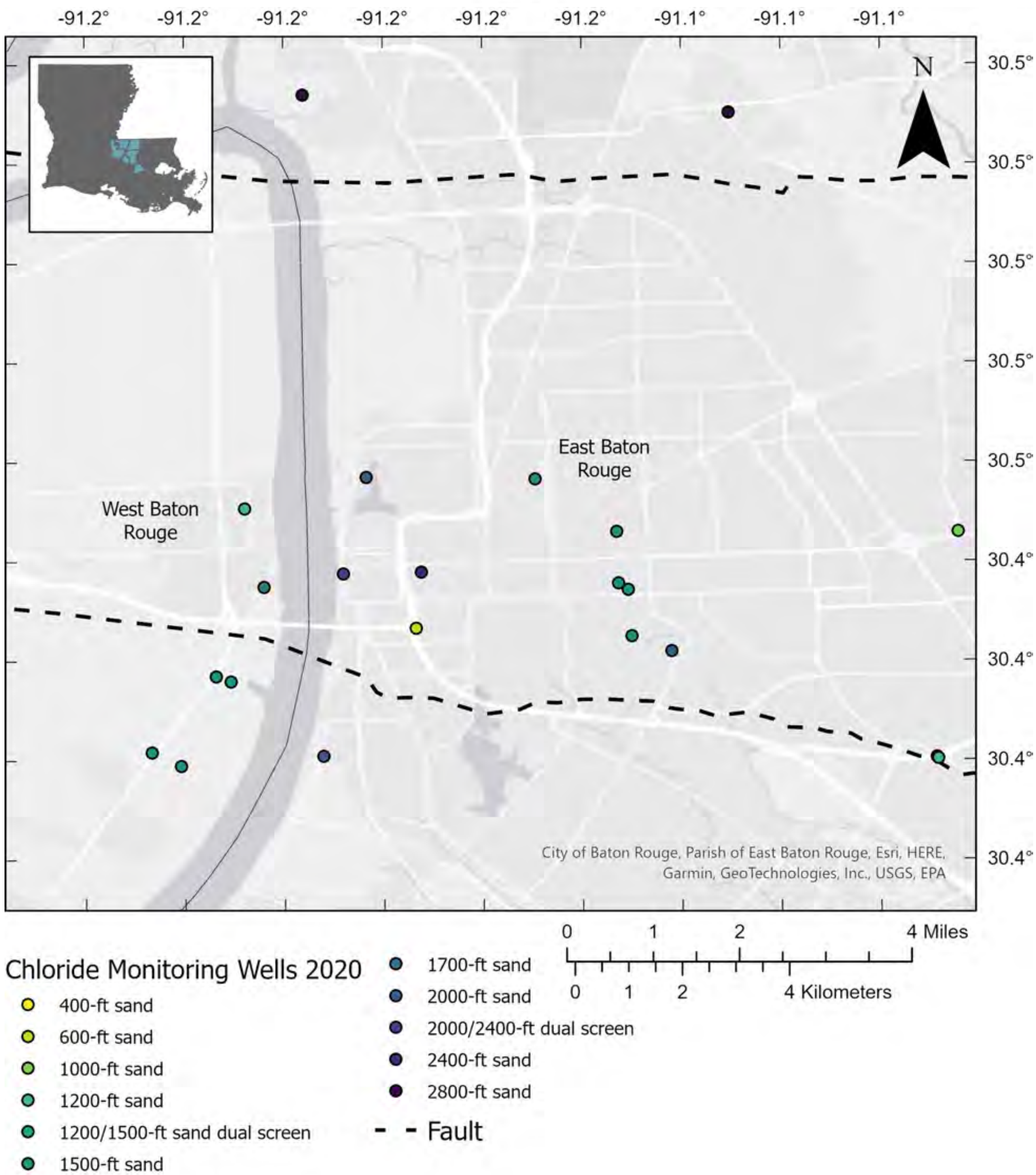

Figure C-2. Chloride measurements within the Industrial District from June 2020 through December 2020. Each point is colored to reflect the sand within which it was measured.

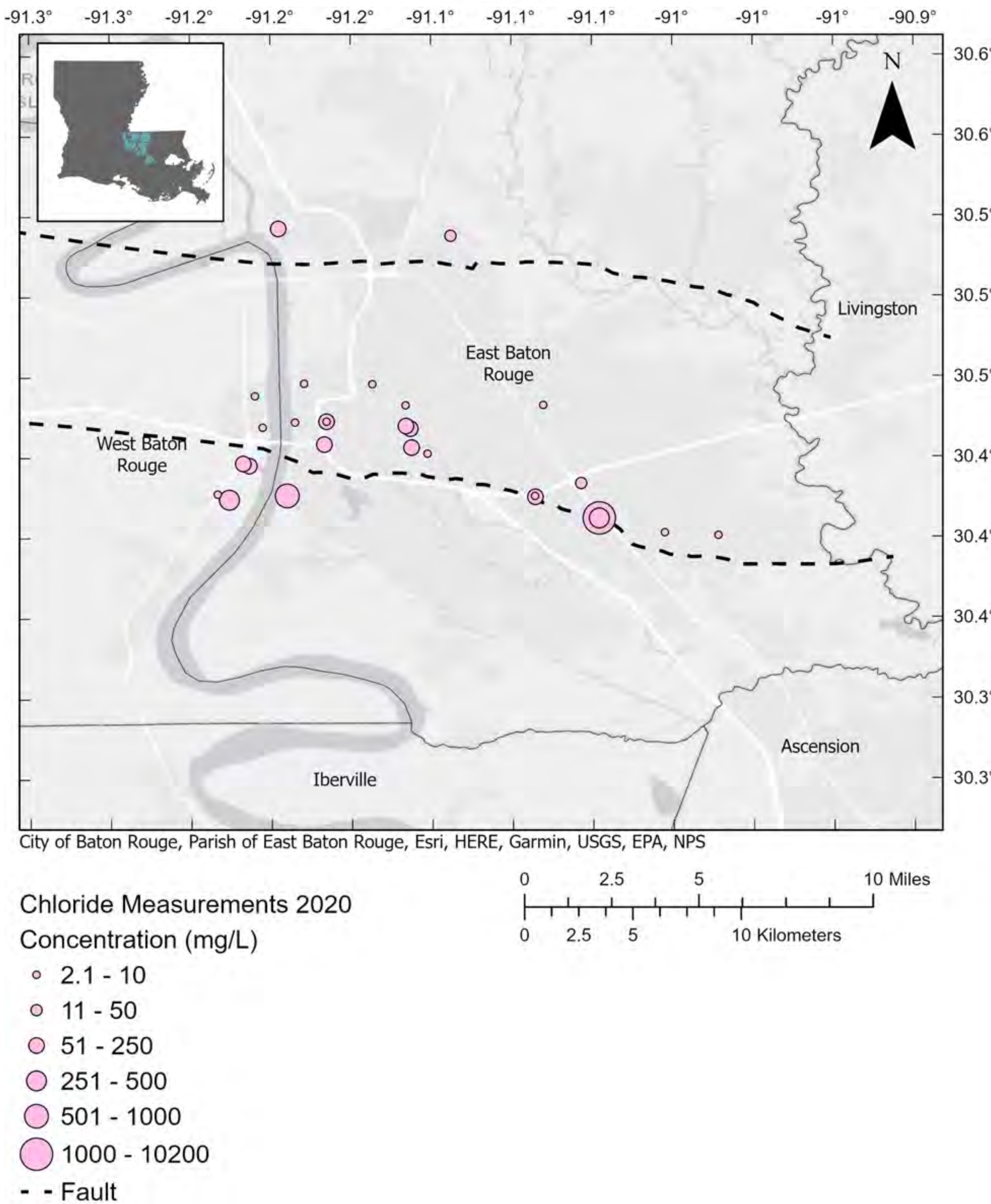

Figure C-3. Chloride measurements from the CAGWCD in all sands, measured between June 2020 and December 2020.

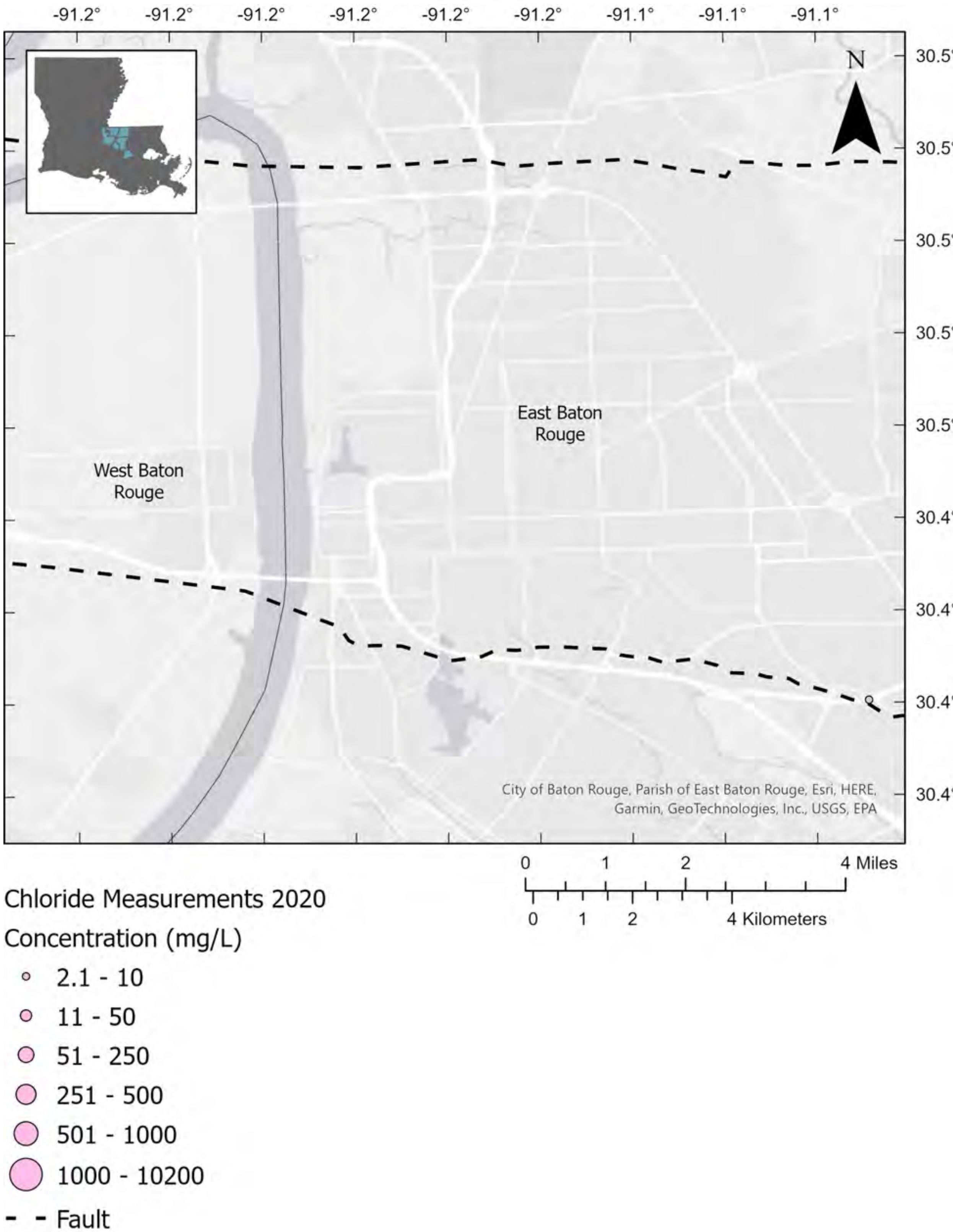

Figure C-4. Chloride measurements from the CAGWCD in the 400-foot sand, measured between June 2020 and December 2020.

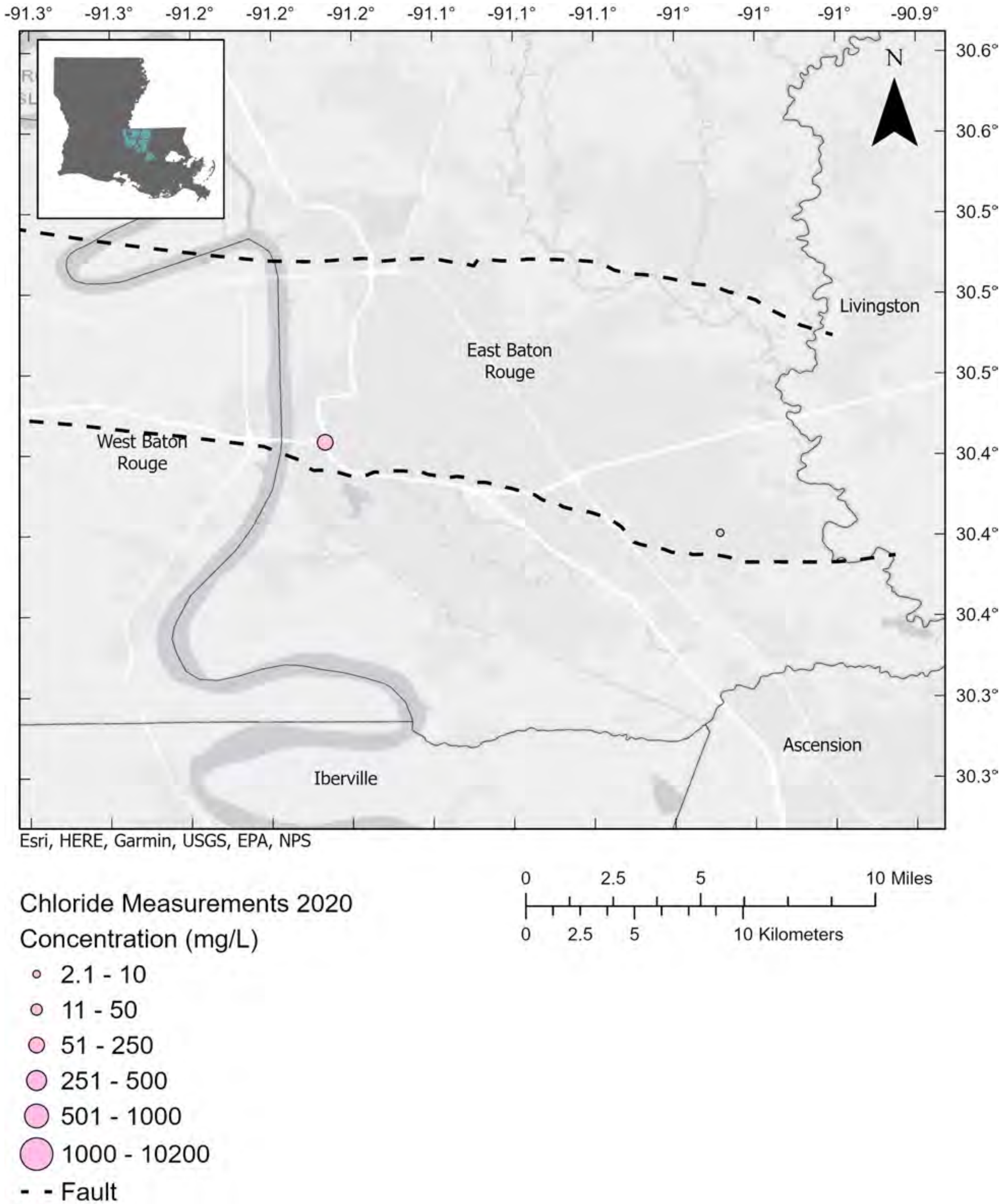

Figure C-5. Chloride measurements from the CAGWCD in the 600-foot sand, measured between June 2020 and December 2020.

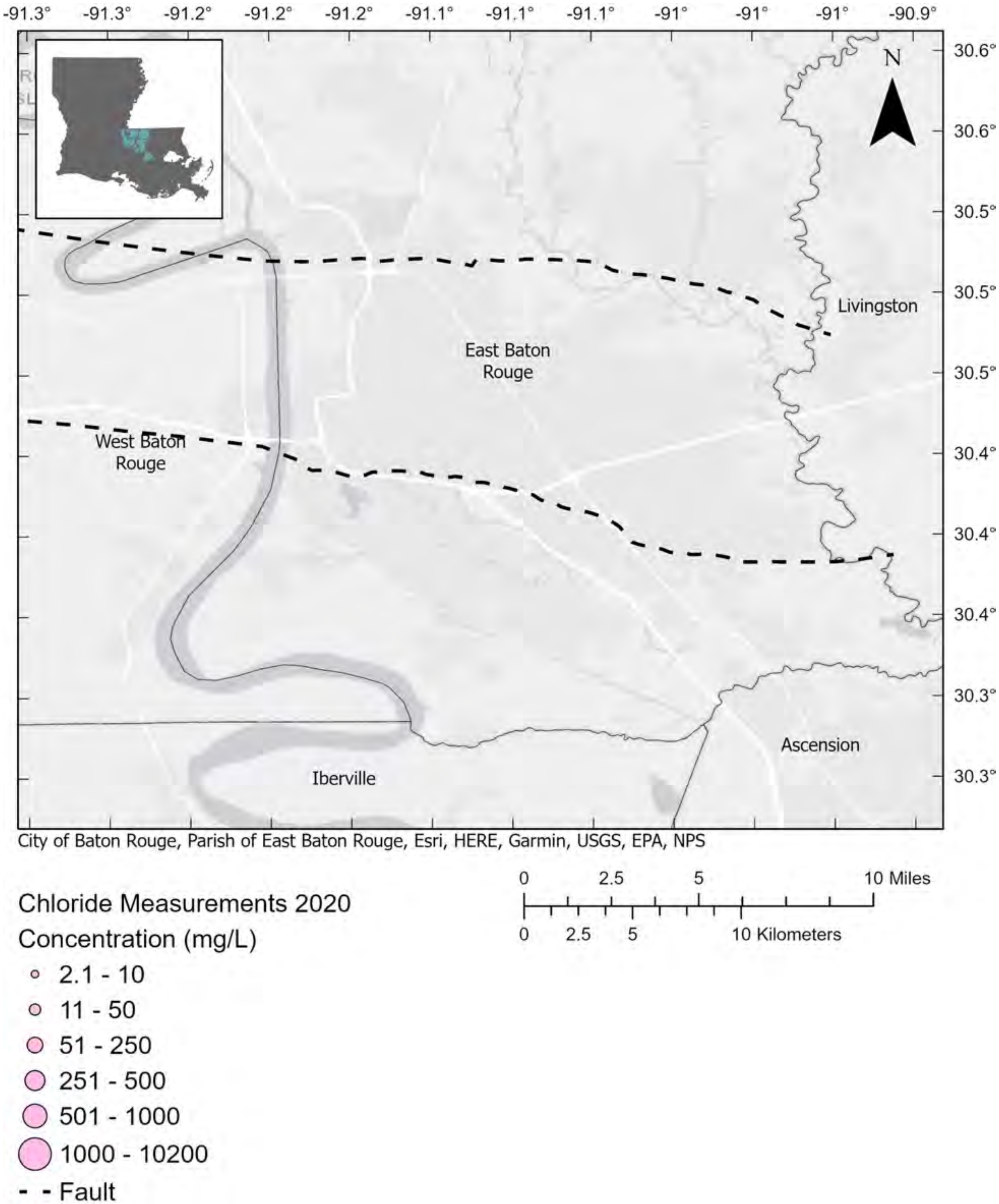

Figure C-6. Chloride measurements from the CAGWCD in the 800-foot sand, measured between June 2020 and December 2020

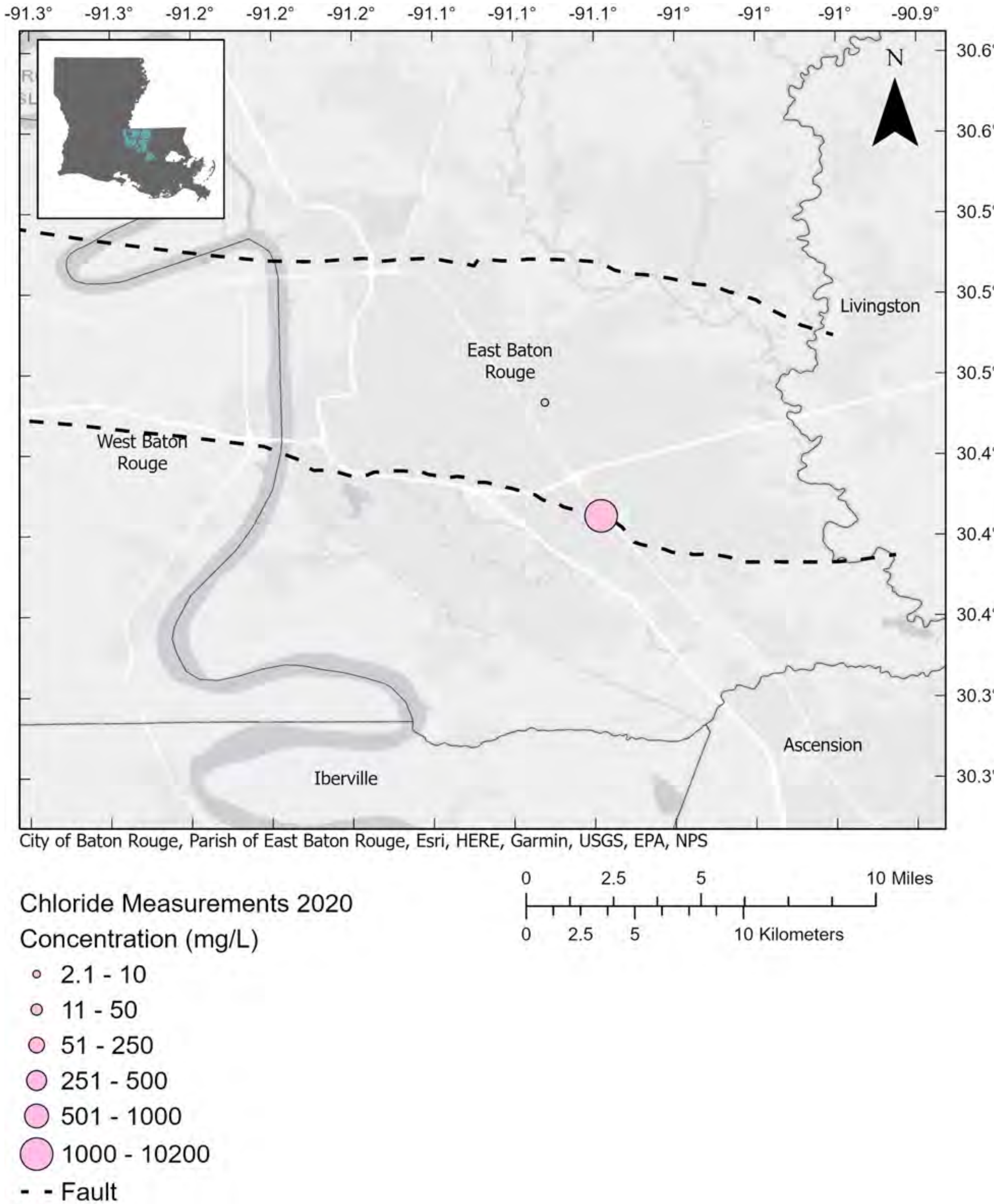

Figure C-7. Chloride measurements from the CAGWCD in the 1000-foot sand, measured between June 2020 and December 2020.

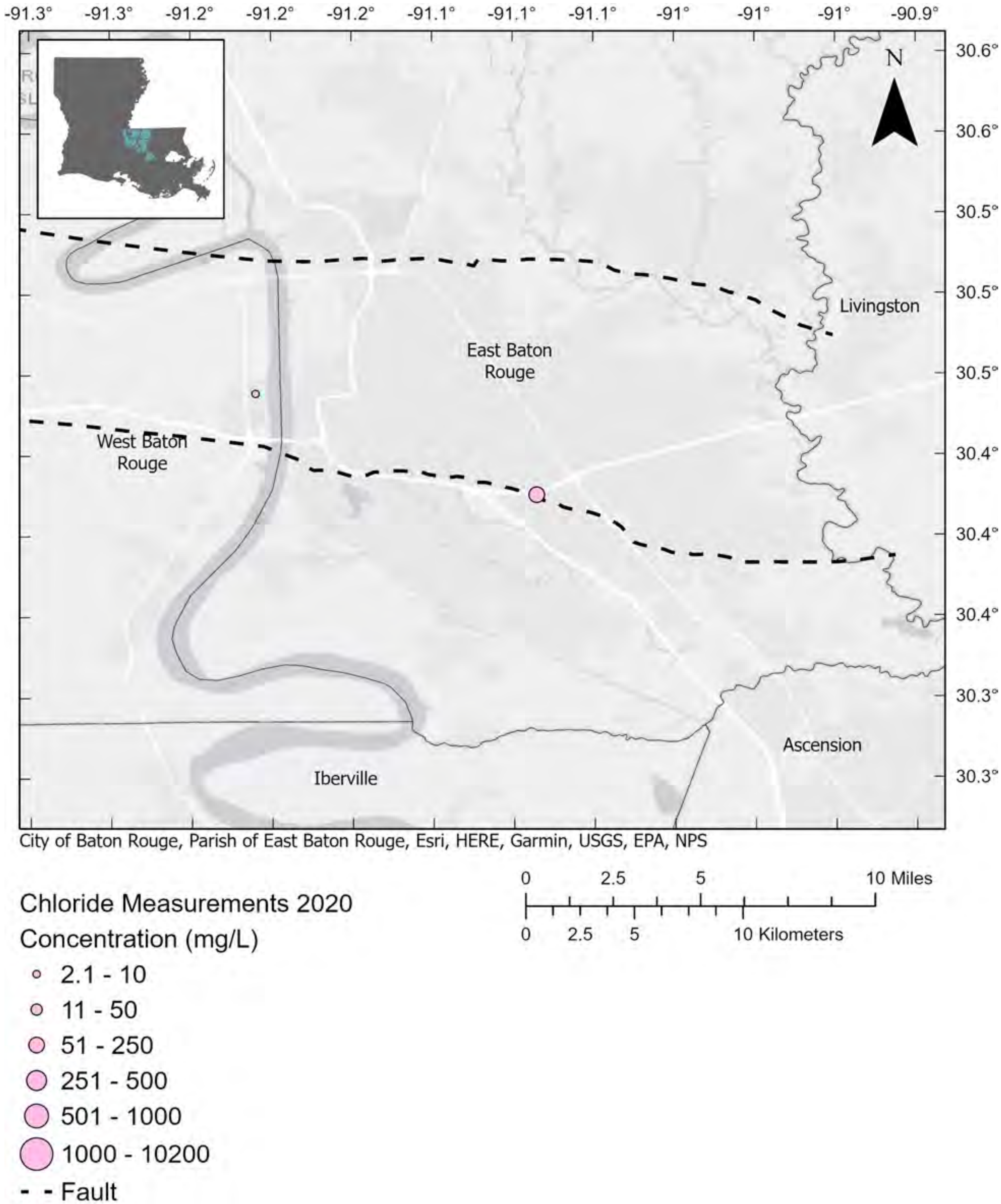

Figure C-8. Chloride measurements from the CAGWCD in the 1200-foot sand, measured between June 2020 and December 2020.

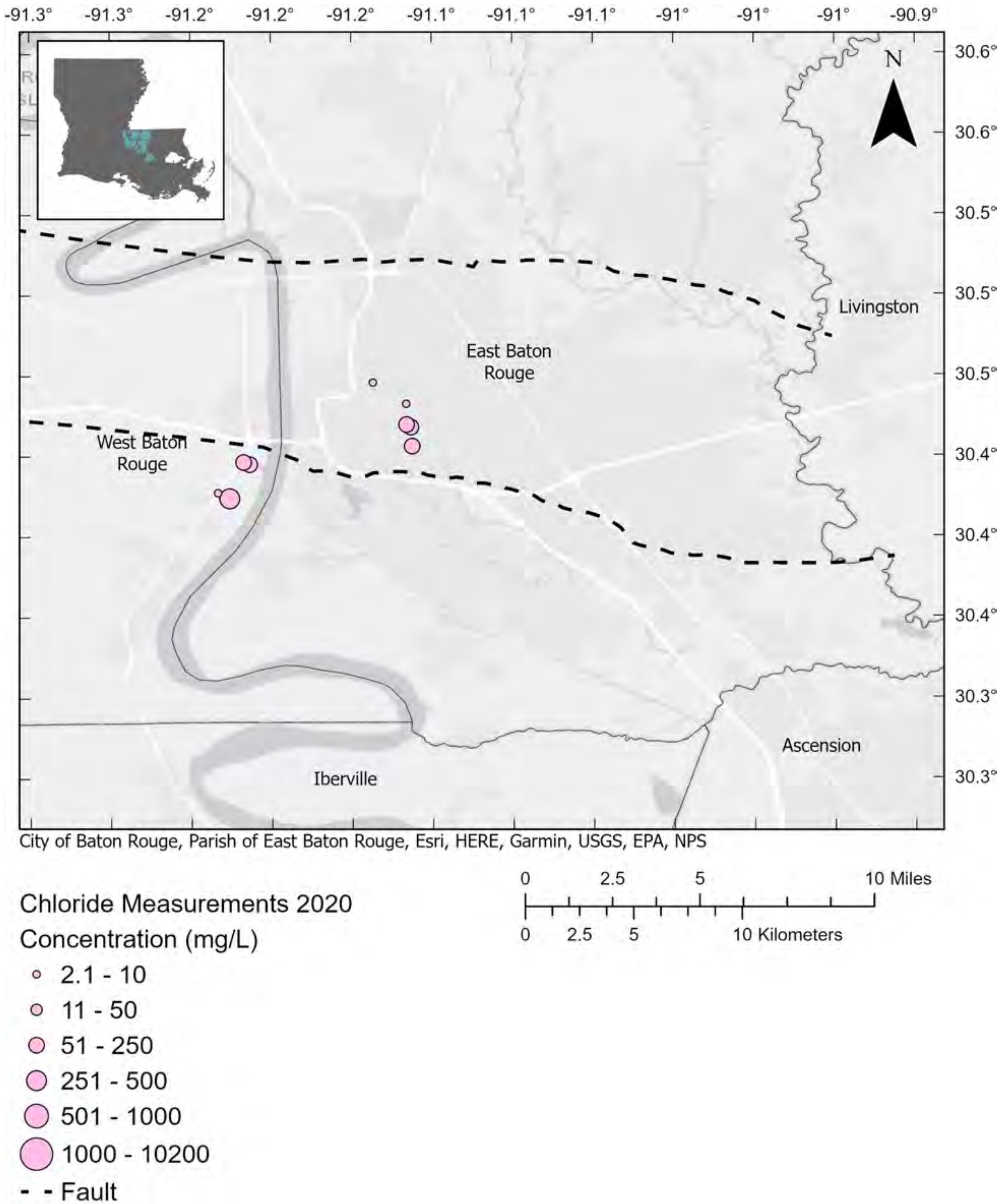

Figure C-9. Chloride measurements from the CAGWCD in the 1500-foot sand, measured between June 2020 and December 2020.

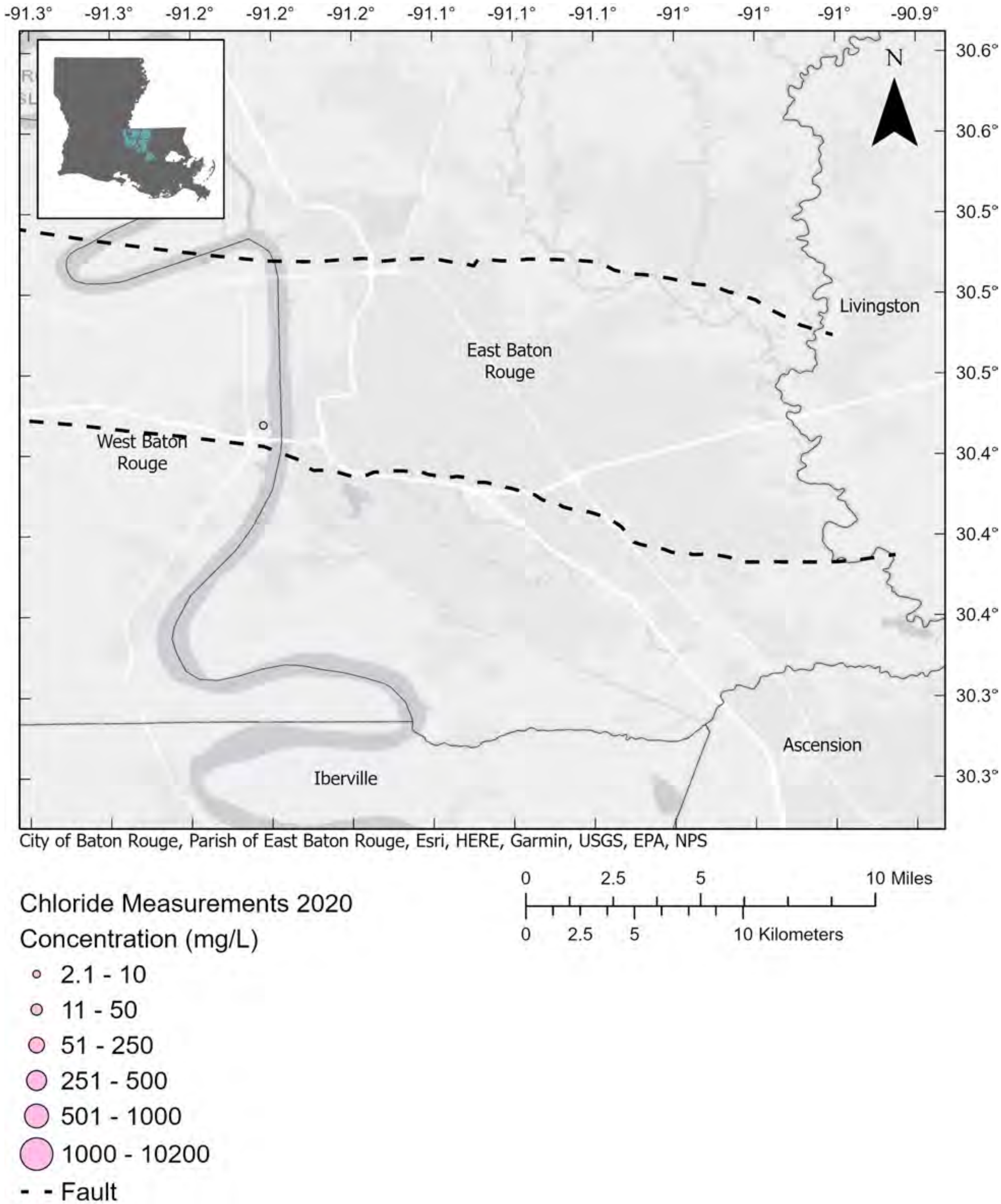

Figure C-10. Chloride measurements from the CAGWCD in the 1700-foot sand, measured between June 2020 and December 2020.

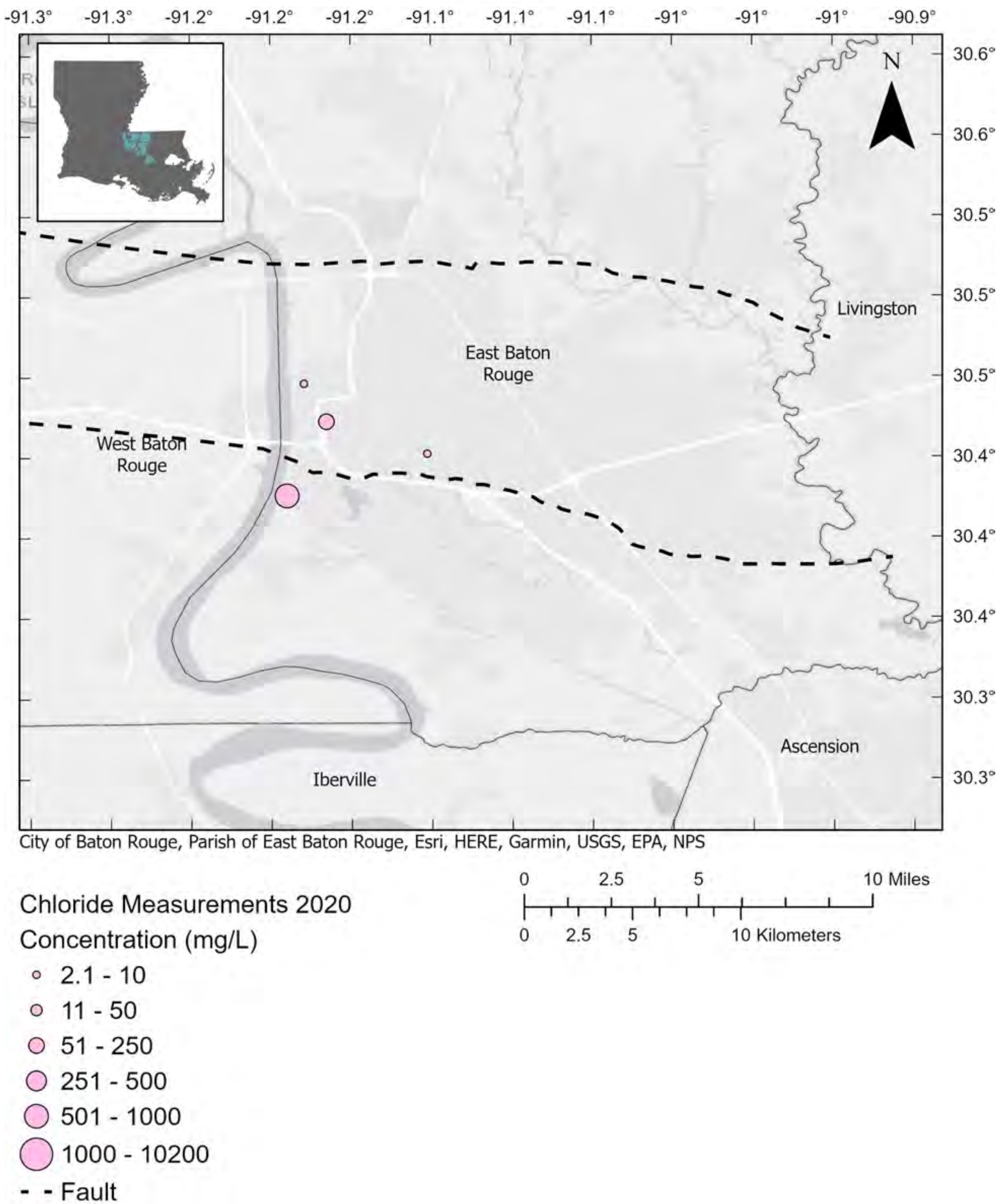

Figure C-11. Chloride measurements from the CAGWCD in the 2000-foot sand, measured between June 2020 and December 2020.

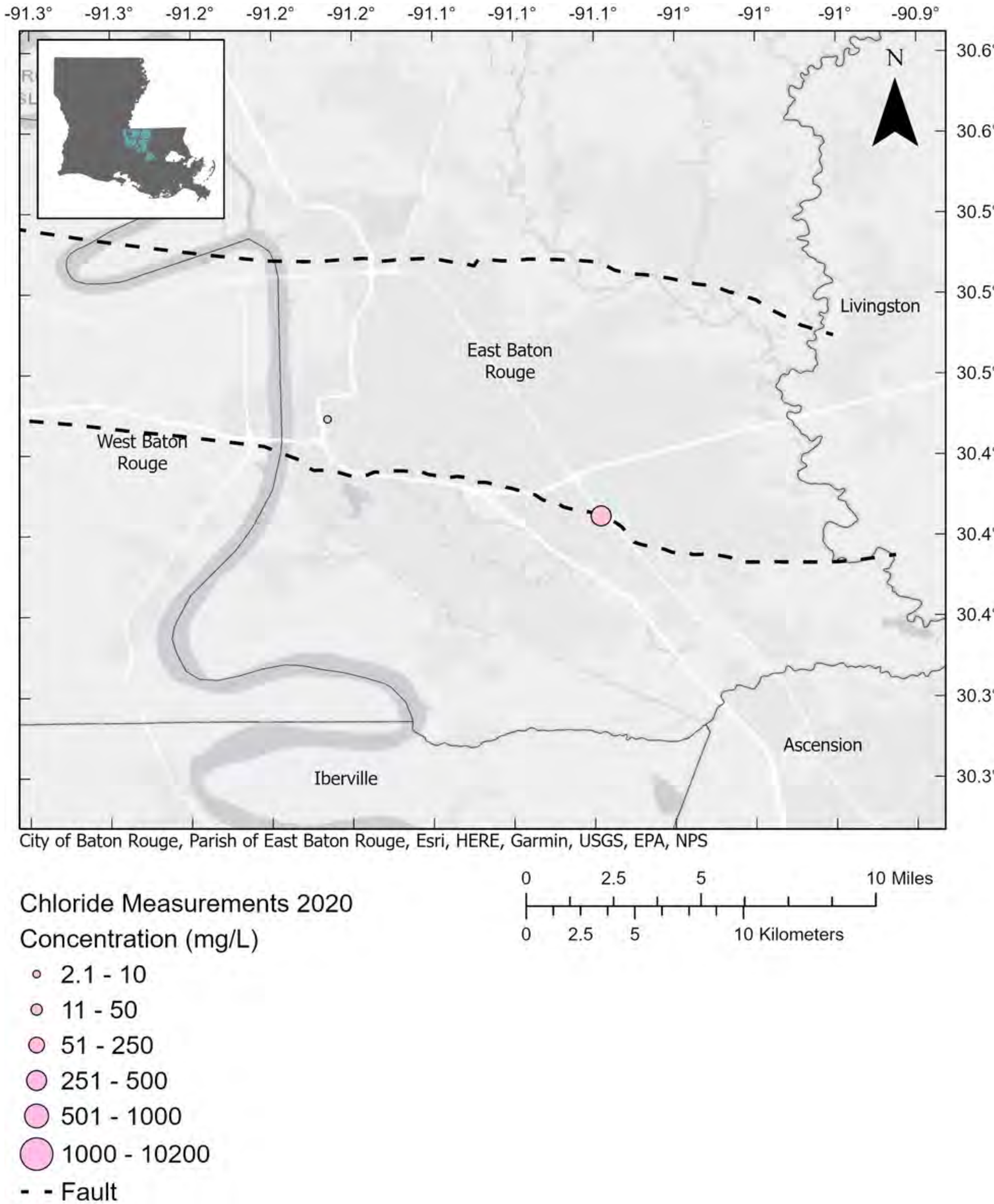

Figure C-12. Chloride measurements from the CAGWCD in the 2400-foot sand, measured between June 2020 and December 2020.

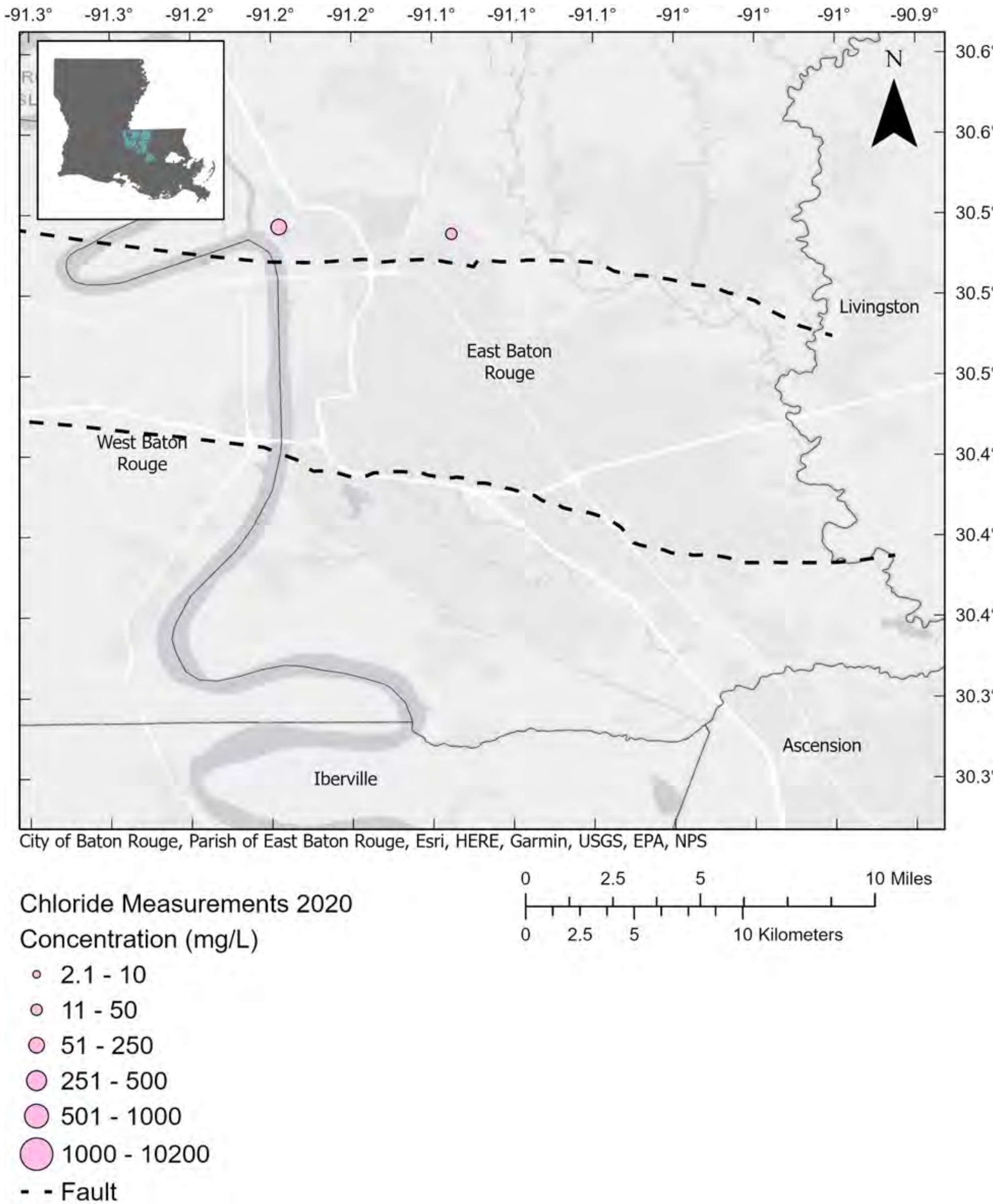

Figure C-13. Chloride measurements from the CAGWCD in the 2800-foot sand, measured between June 2020 and December 2020.

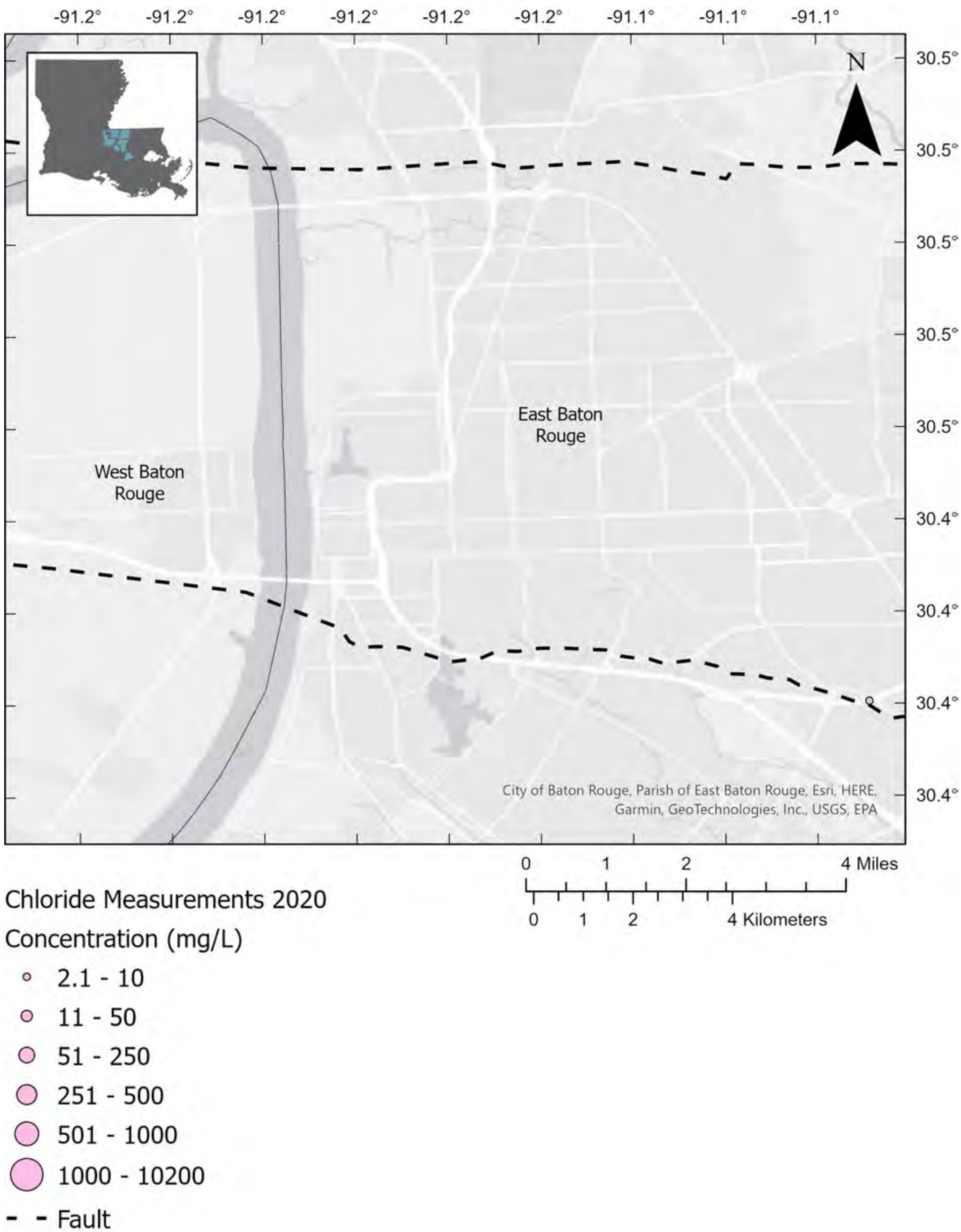

Figure C-14. Chloride measurements from the Industrial District in the 400-foot sand, measured between June 2020 and December 2020. There are no measurements in the 400-foot sand in the Industrial District.

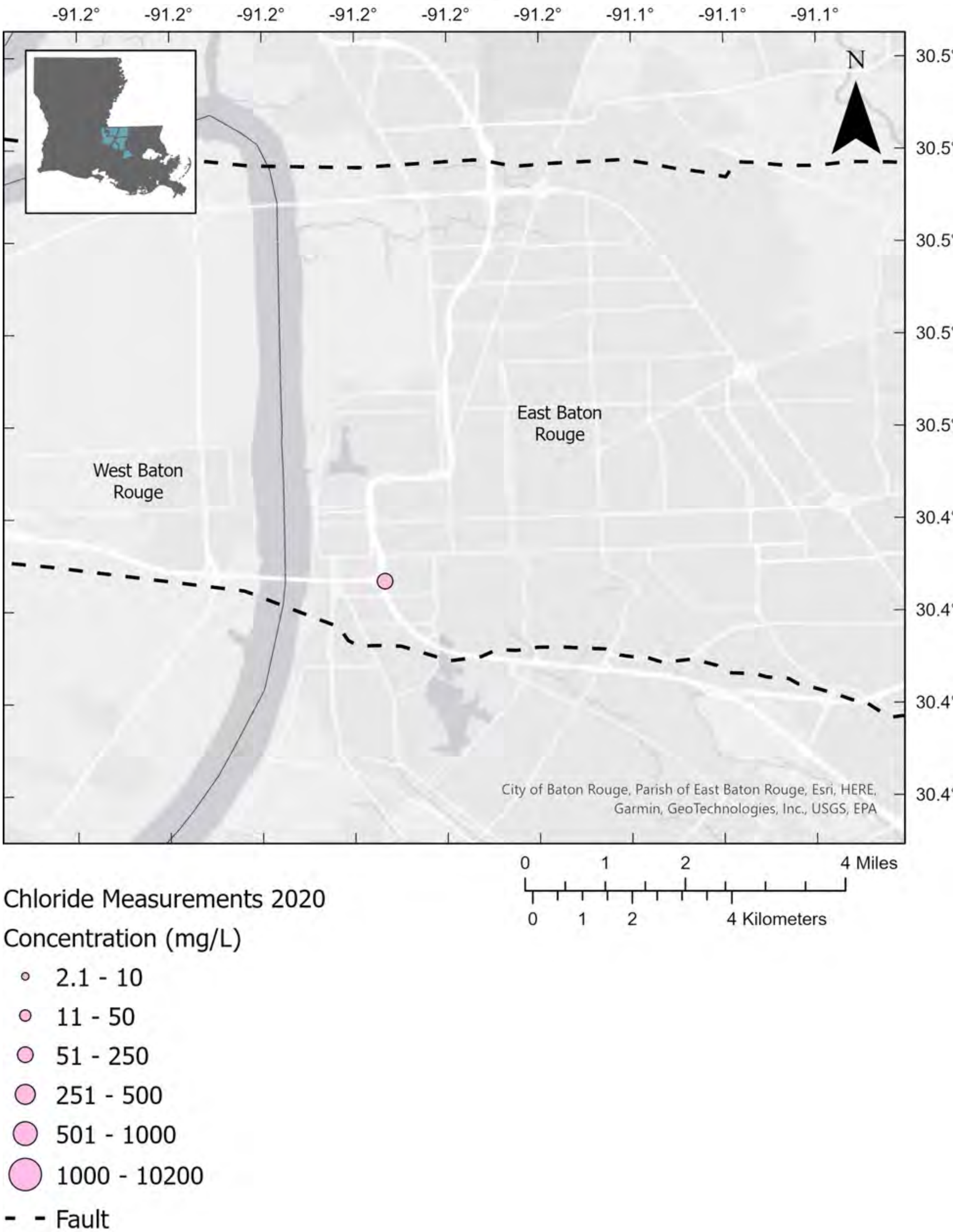

Figure C-15. Chloride measurements from the Industrial District in the 600-foot sand, measured between June 2020 and December 2020.

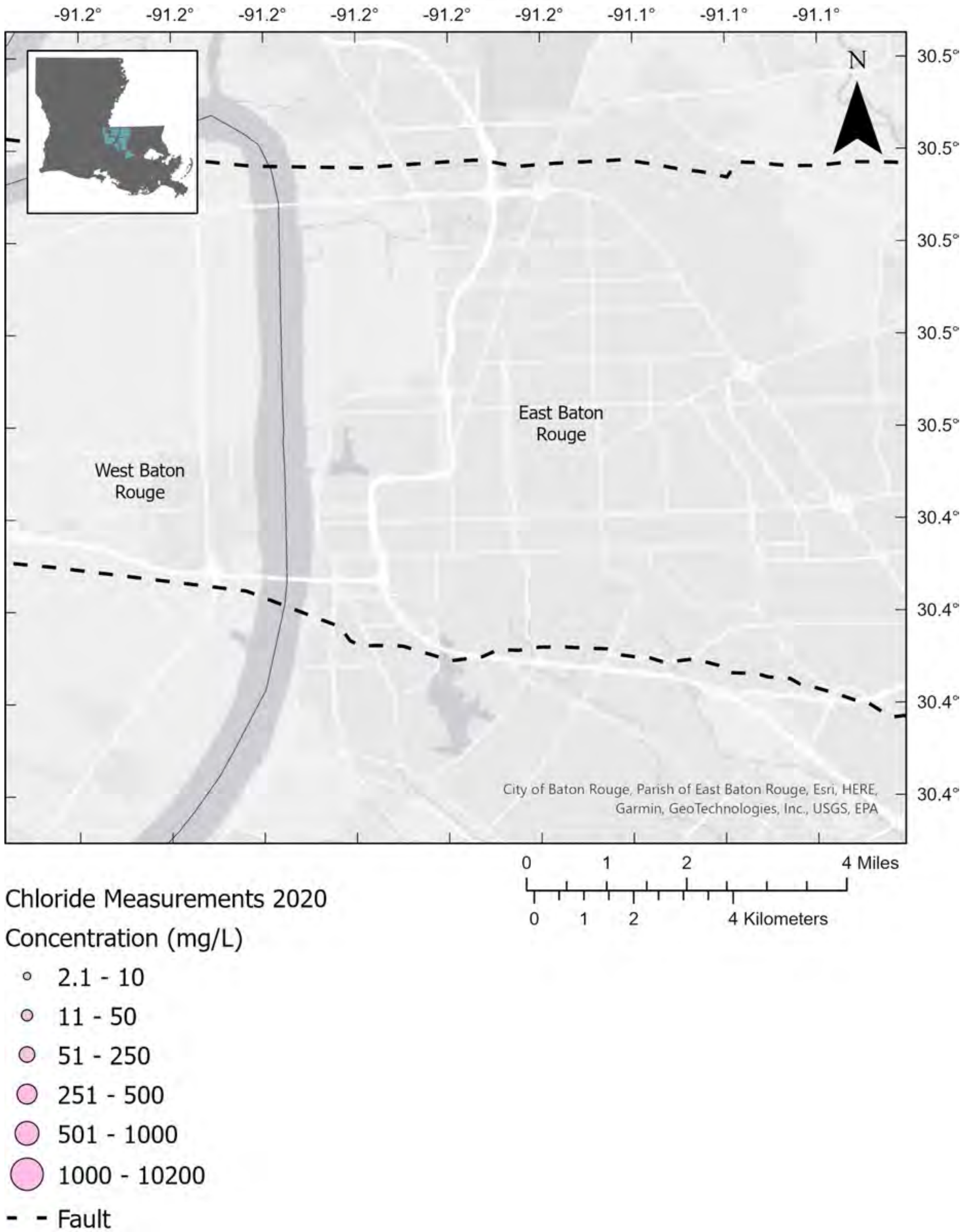

Figure C-16. Chloride measurements from the Industrial District in the 800-foot sand, measured between June 2020 and December 2020.

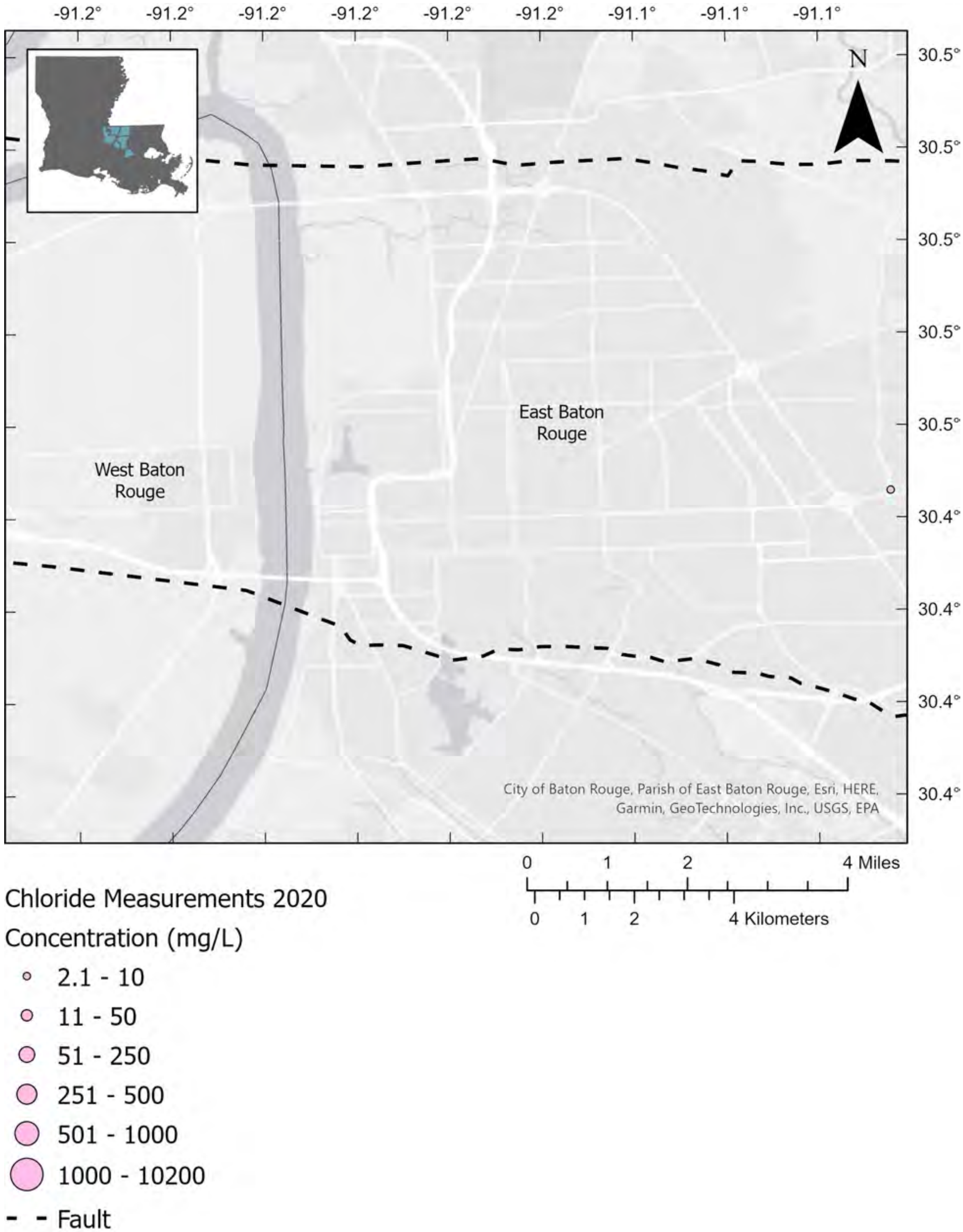

Figure C-17. Chloride measurements from the Industrial District in the 1000-foot sand, measured between June 2020 and December 2020. There are no chloride measurements in the 1000-foot sand in the Industrial District.

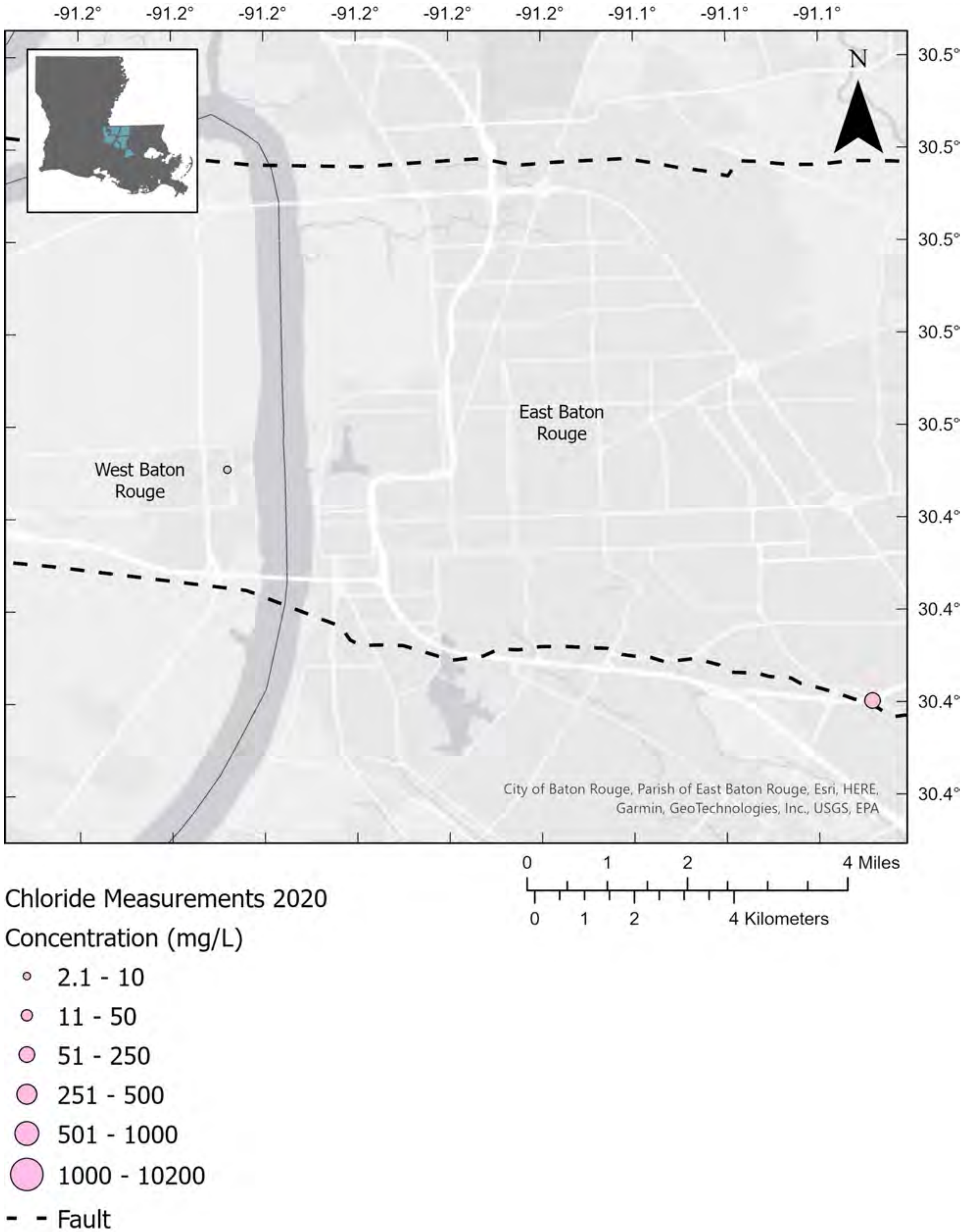

Figure C-18. Chloride measurements from the Industrial District in the 1200-foot sand, measured between June 2020 and December 2020.

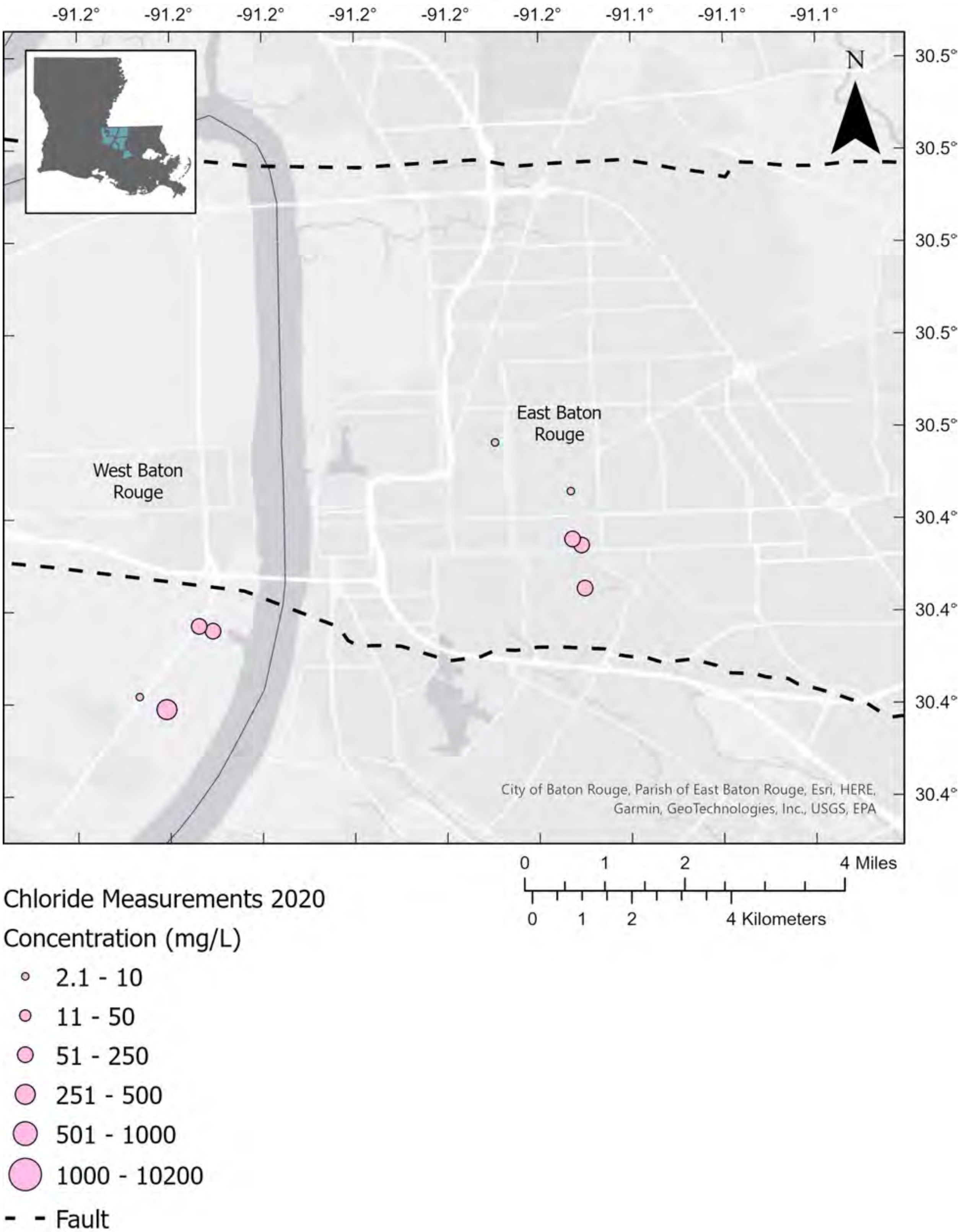

Figure C-19. Chloride measurements from the Industrial District in the 1500-foot sand, measured between June 2020 and December 2020.

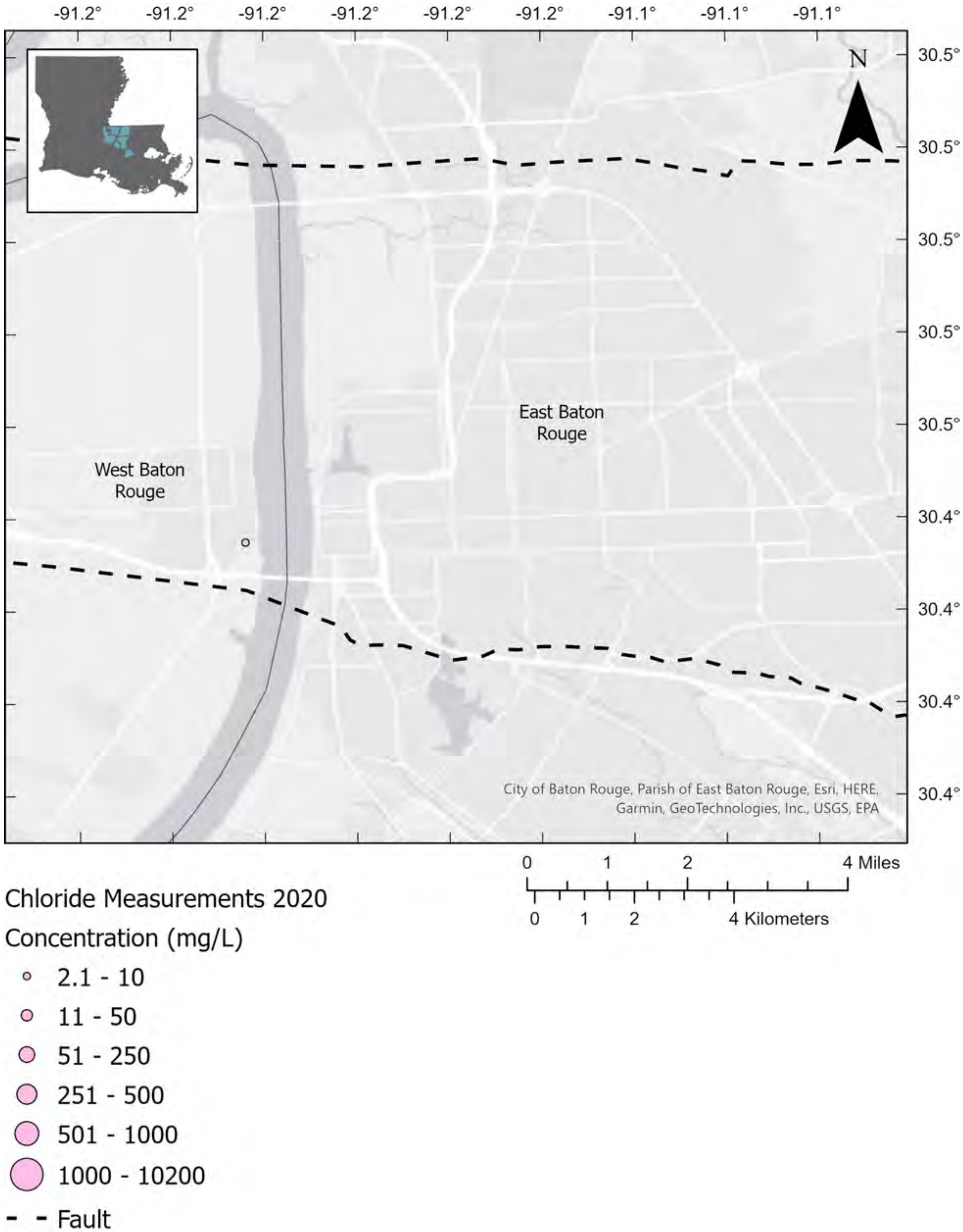

Figure C-20. Chloride measurements from the Industrial District in the 1700-foot sand, measured between June 2020 and December 2020.

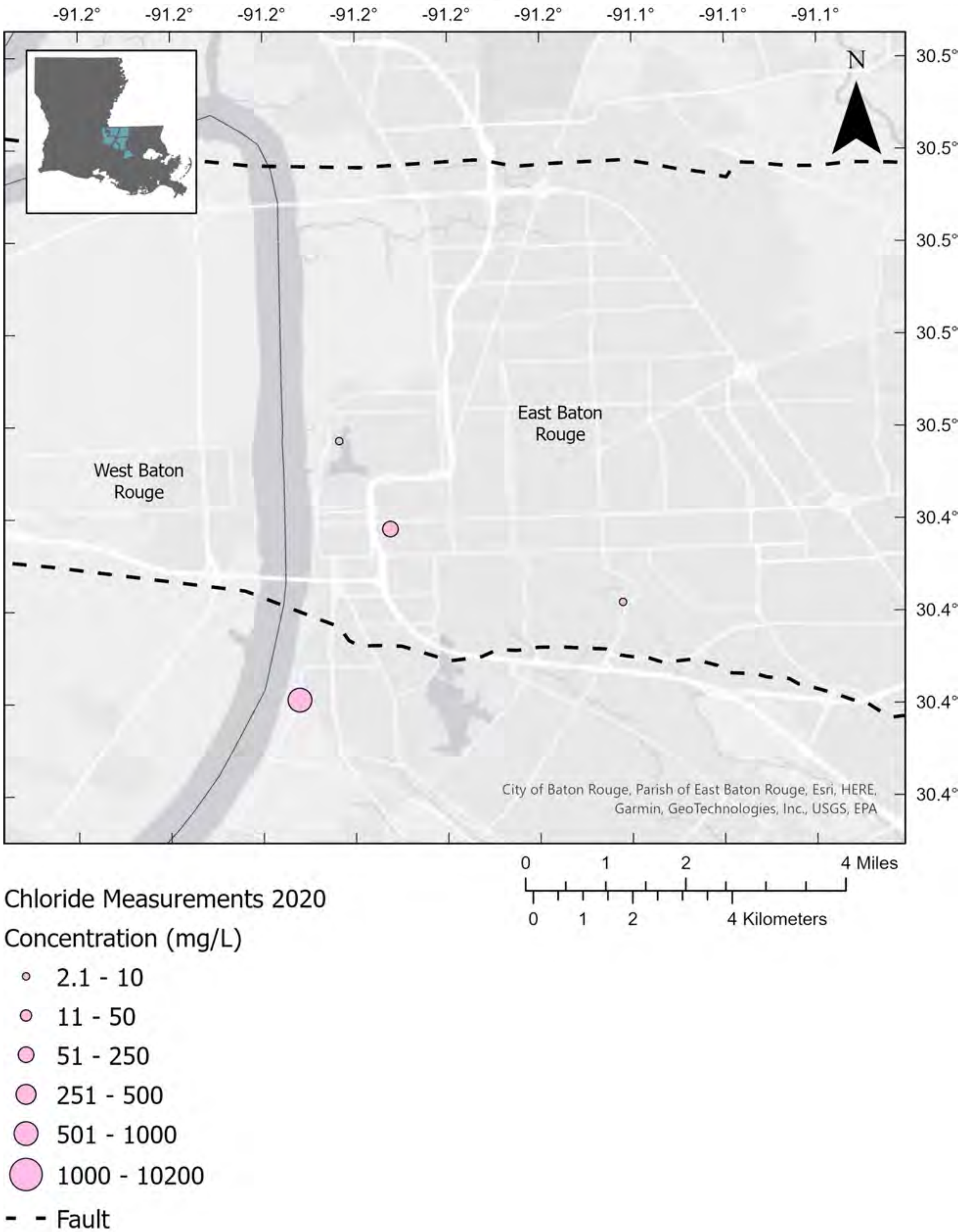

Figure C-21. Chloride measurements from the Industrial District in the 2000-foot sand, measured between June 2020 and December 2020.

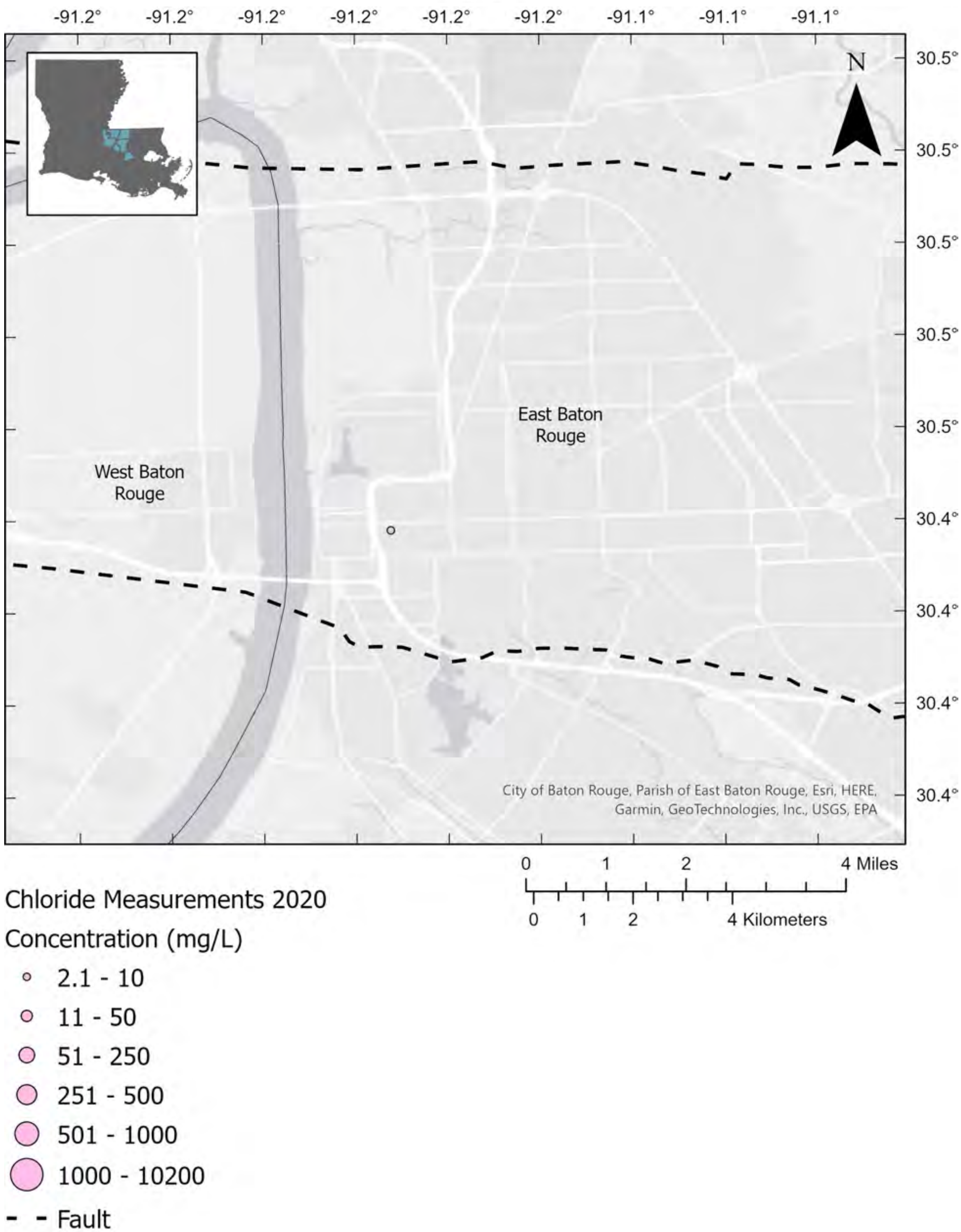

Figure C-22. Chloride measurements from the Industrial District in the 2400-foot sand, measured between June 2020 and December 2020.

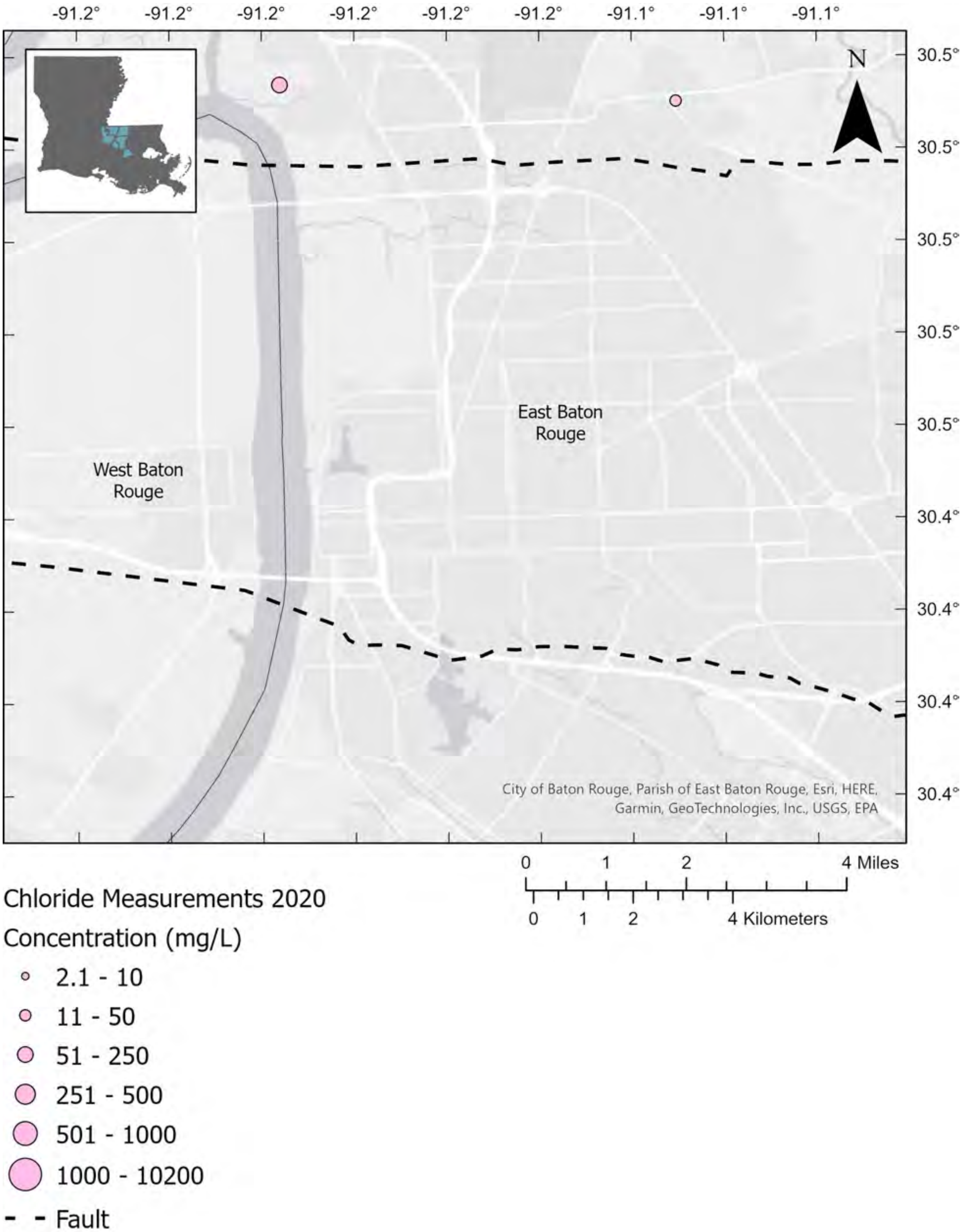

Figure C-23. Chloride measurements from the Industrial District in the 2800-foot sand, measured between June 2020 and December 2020.

APPENDIX D GROUNDWATER LEVEL MONITORING WELL MAPS

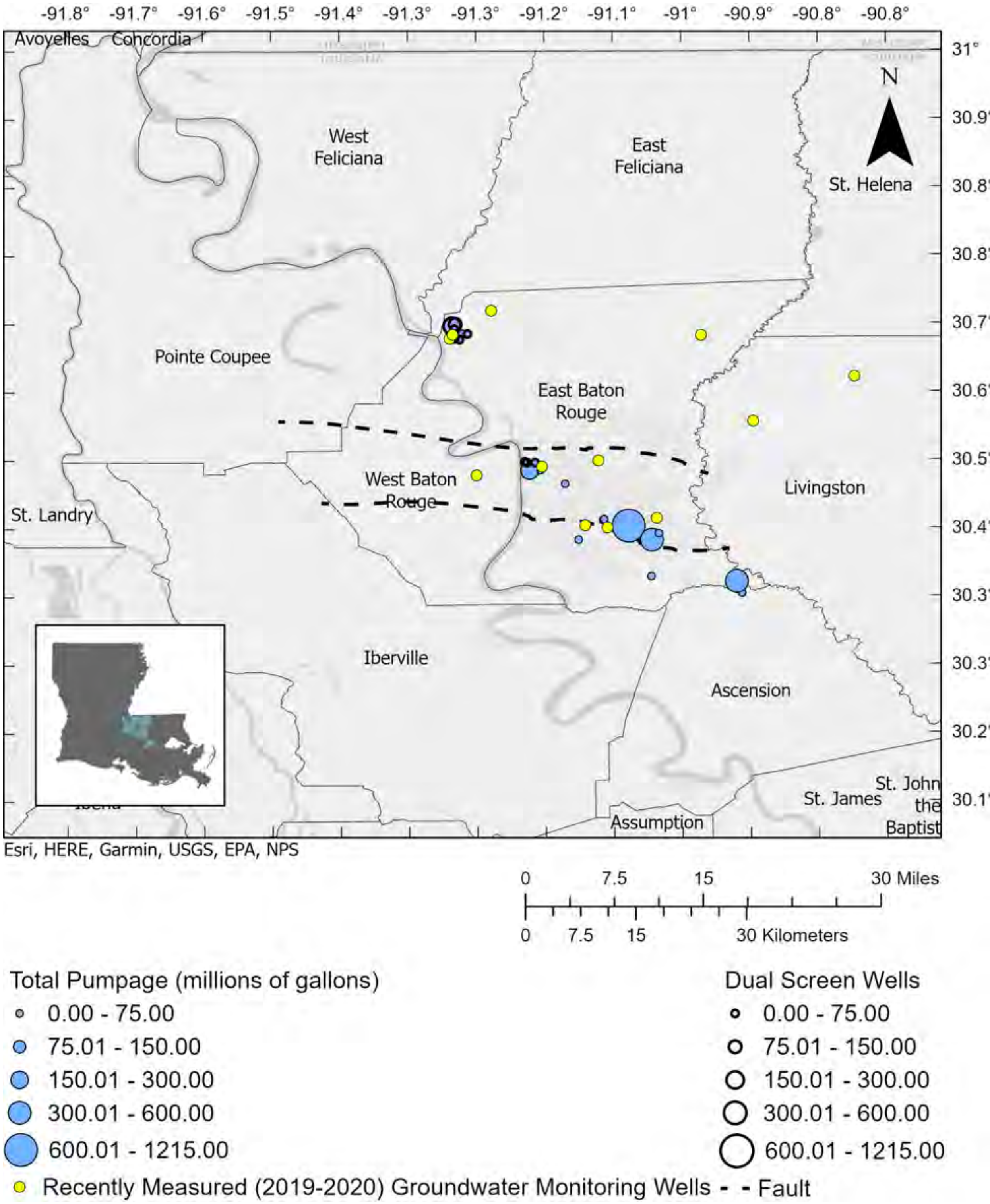

Figure D-1. Positions of groundwater level monitoring wells and pumping wells in the 400-foot sand.

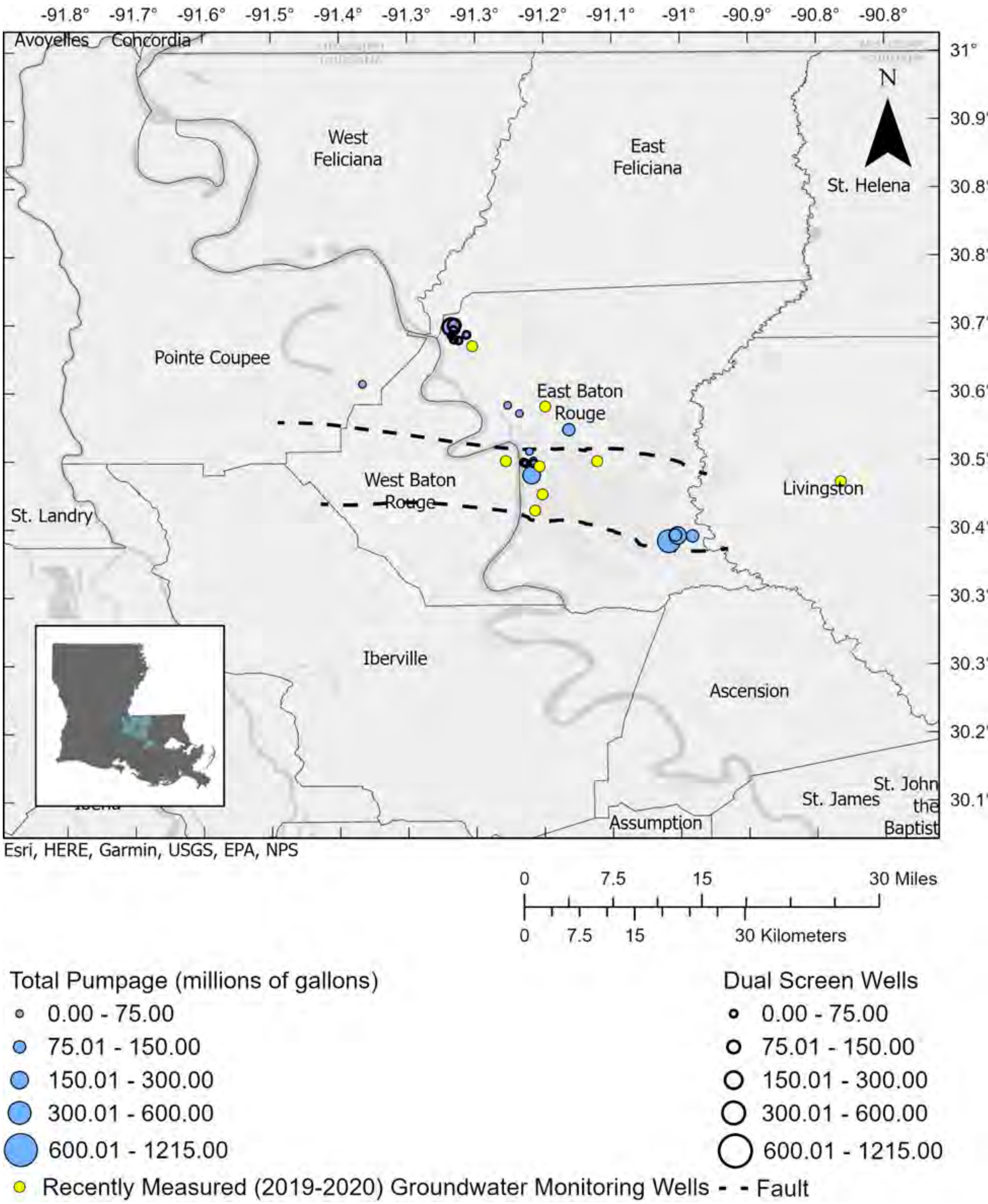

Figure D-2. Positions of groundwater level monitoring wells and pumping wells in the 600-foot sand.

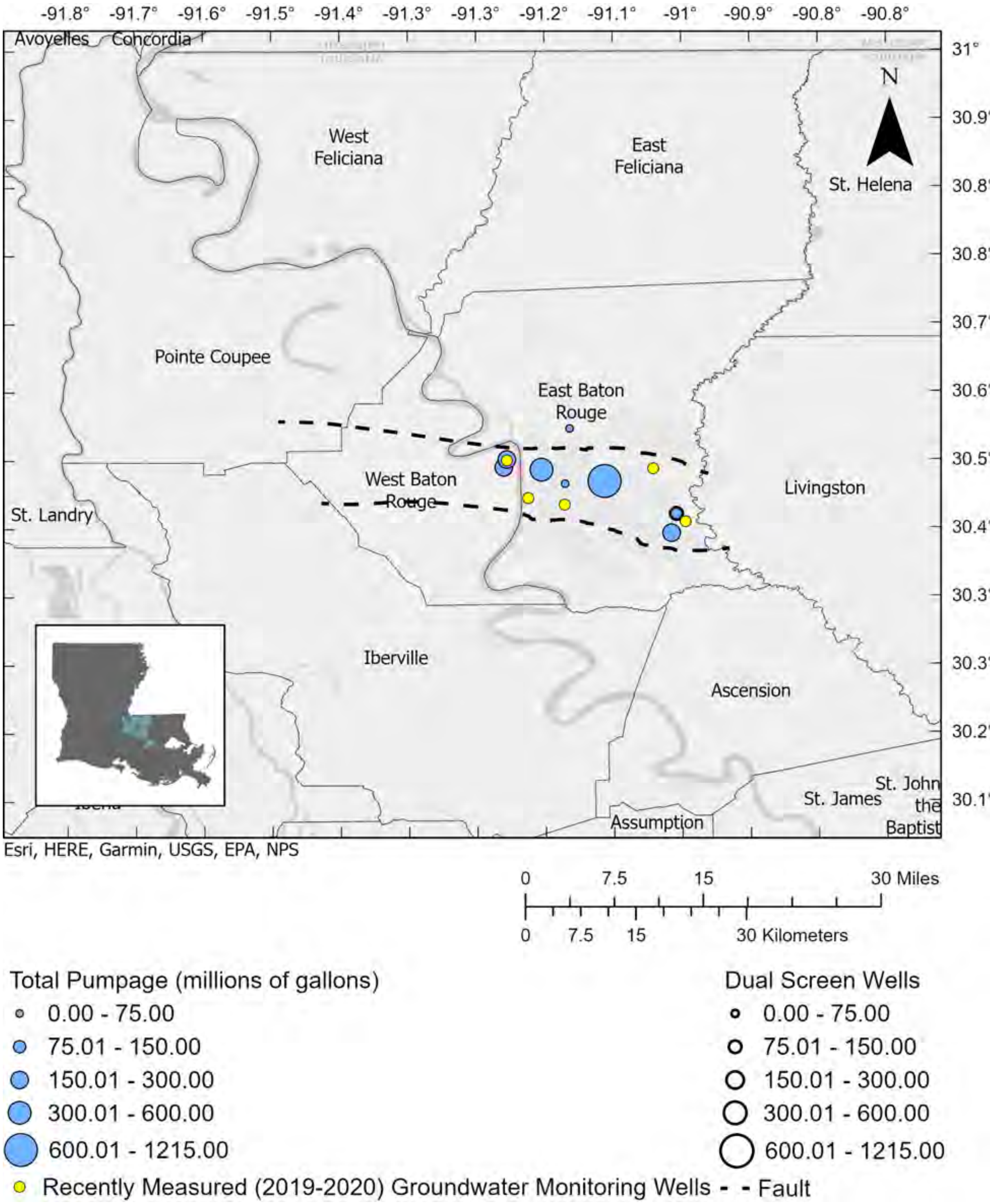

Figure D-3: Positions of groundwater level monitoring wells and pumping wells in the 800-foot sand.

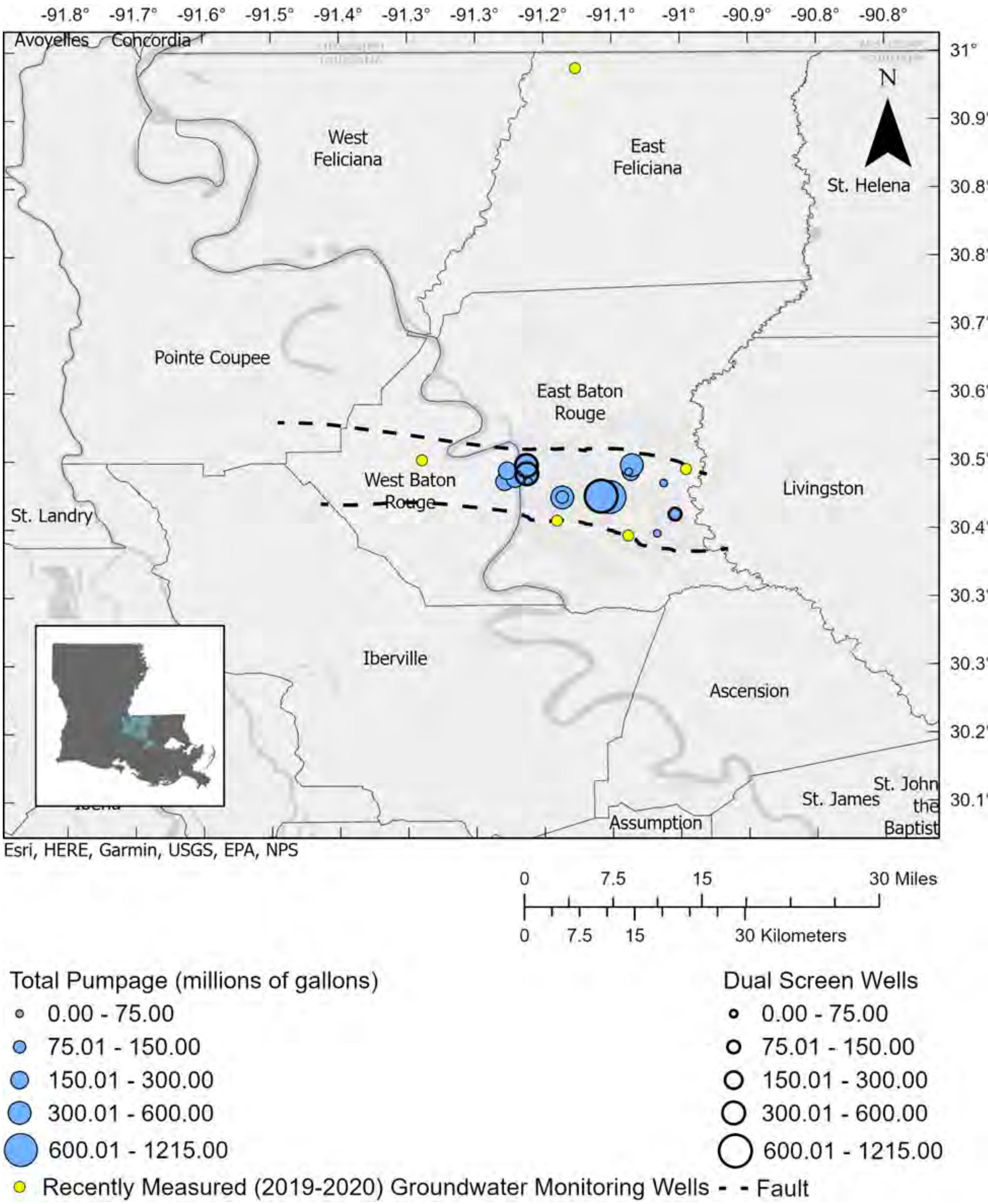

Figure D-4. Positions of groundwater level monitoring wells and pumping wells in the 1,000-foot sand.

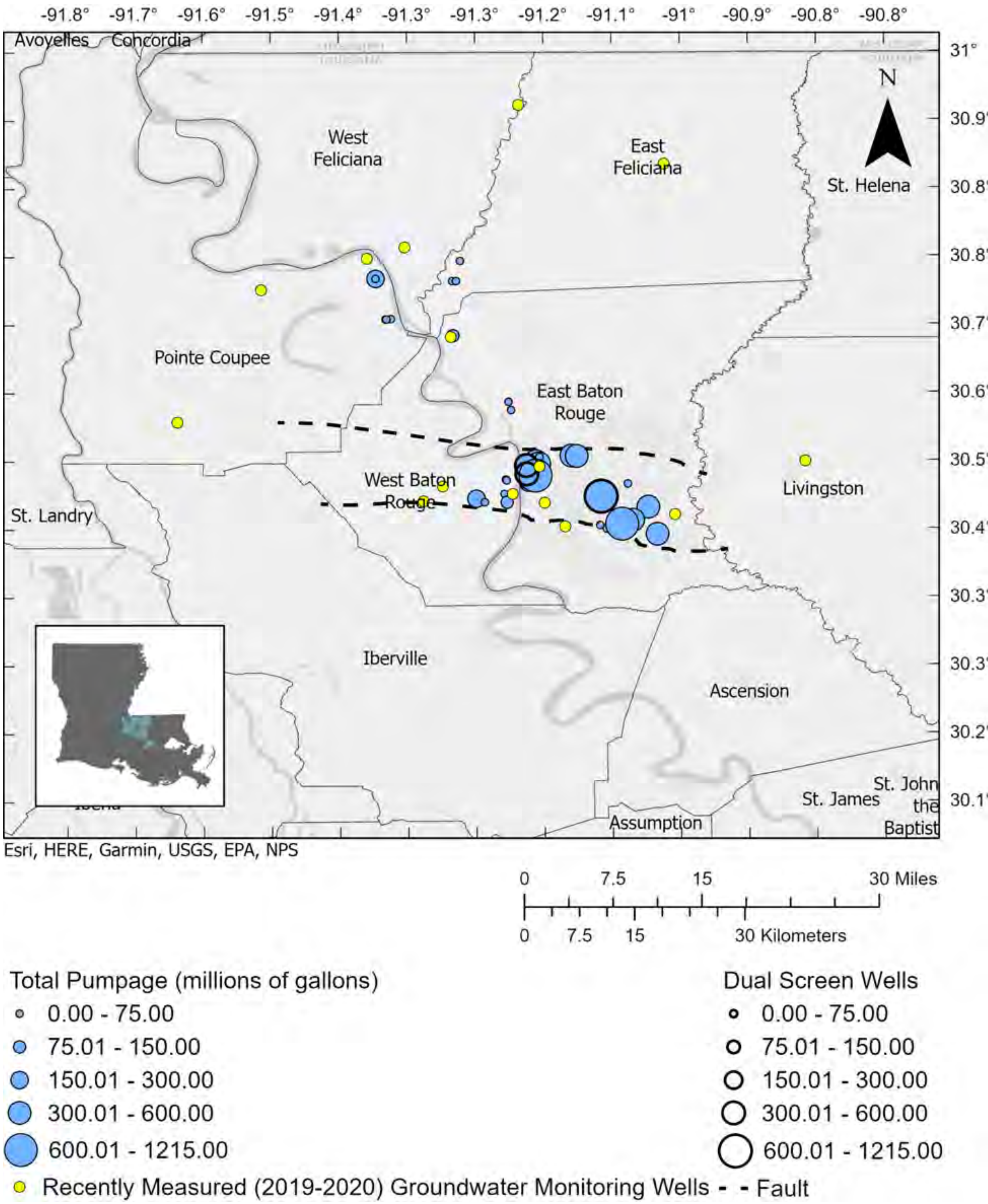

Figure D-5. Positions of groundwater level monitoring wells and pumping wells in the 1,200-foot sand.

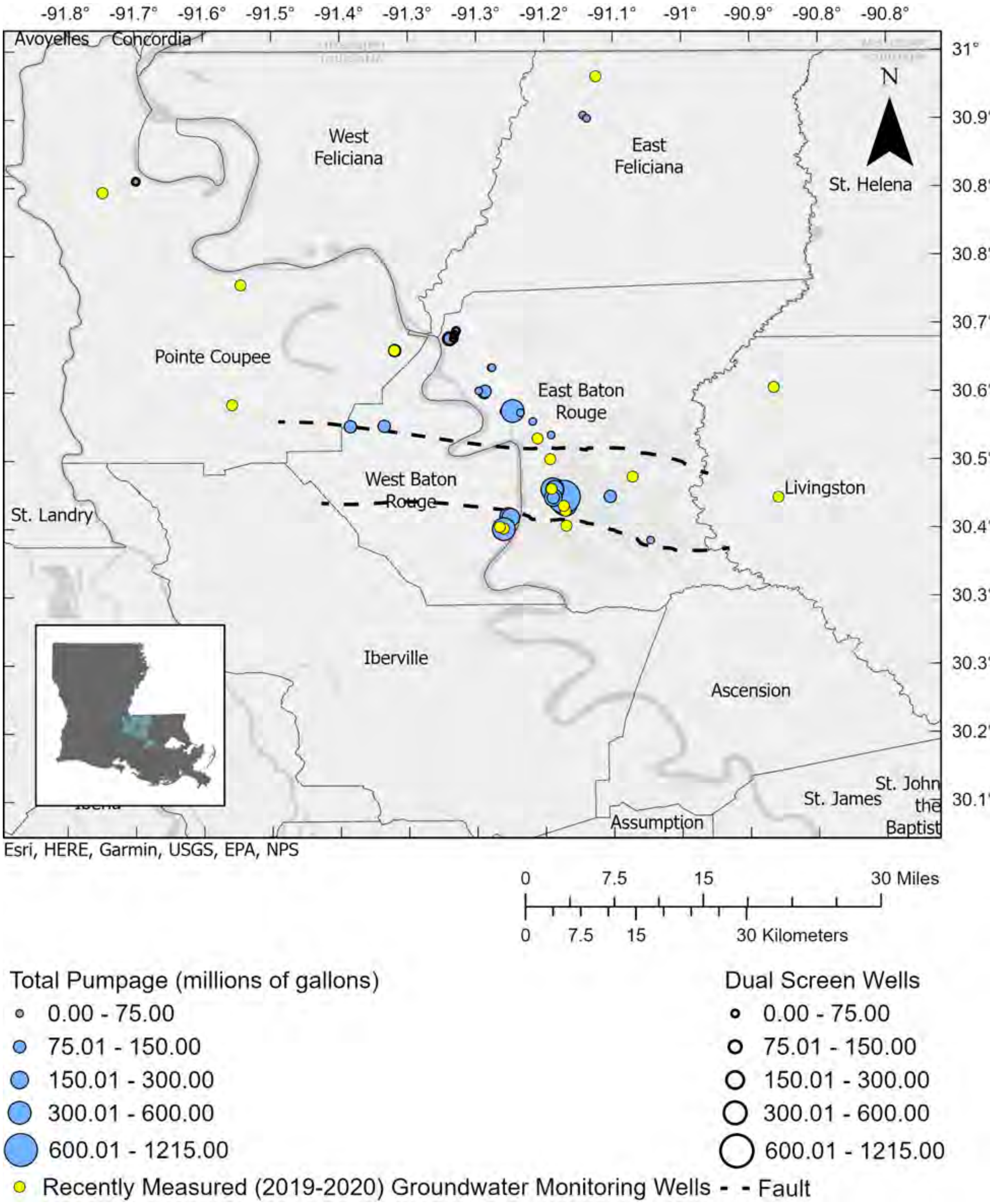

Figure D-6. Positions of groundwater level monitoring wells and pumping wells in the 1,500-foot sand.

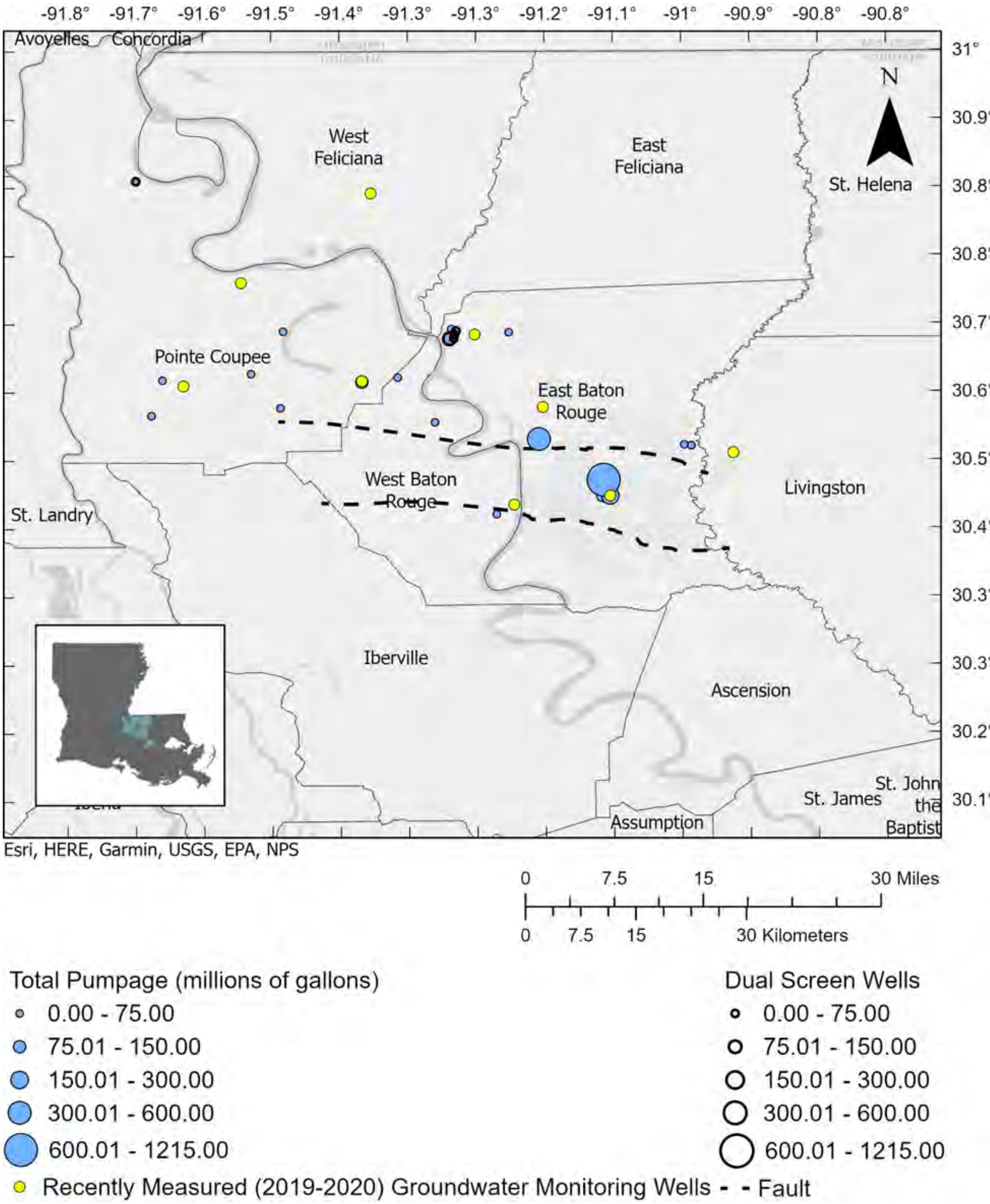

Figure D-7. Positions of groundwater level monitoring wells and pumping wells in the 1,700-foot sand.

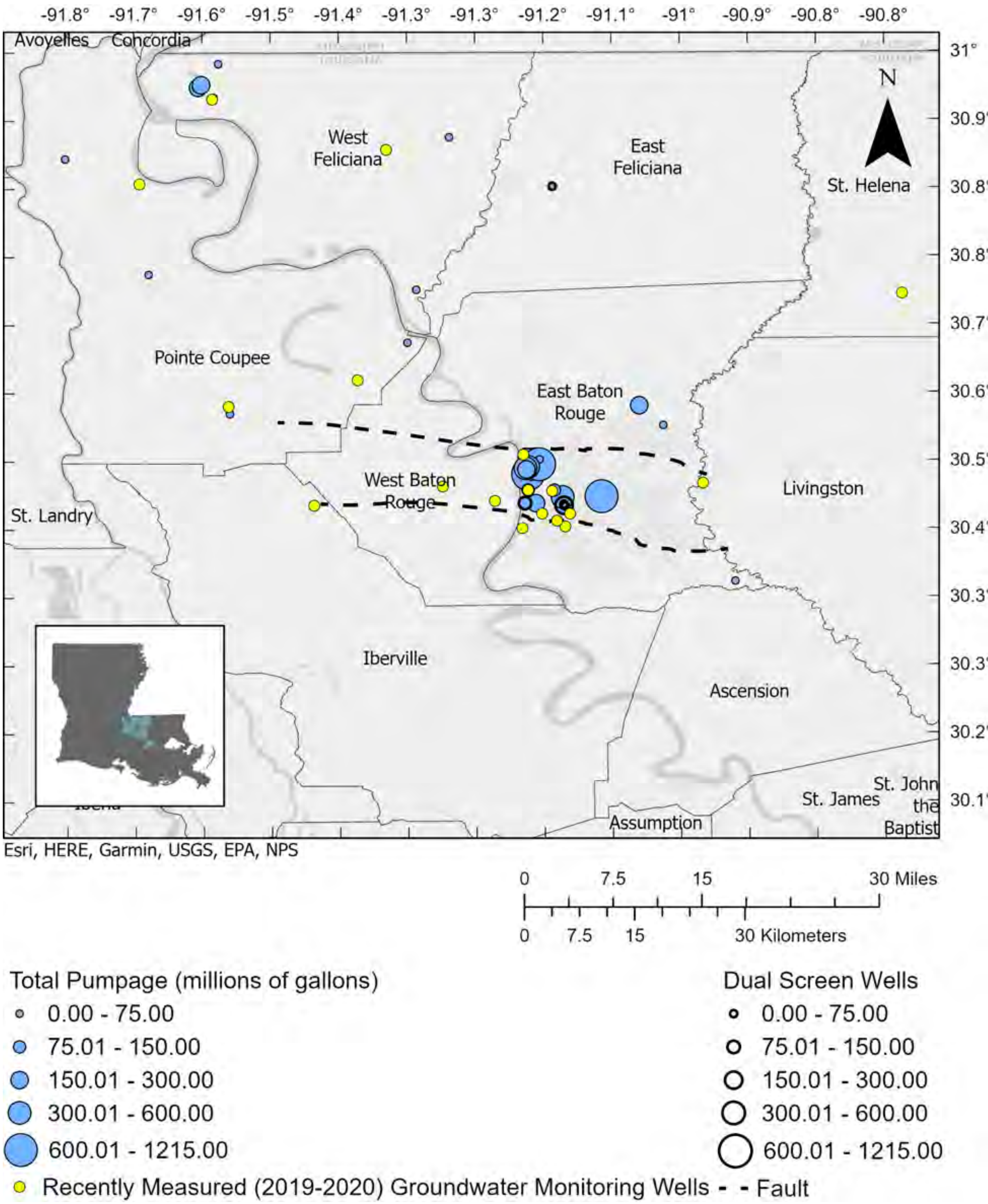

Figure D-8. Positions of groundwater level monitoring wells and pumping wells in the 2,000-foot sand.

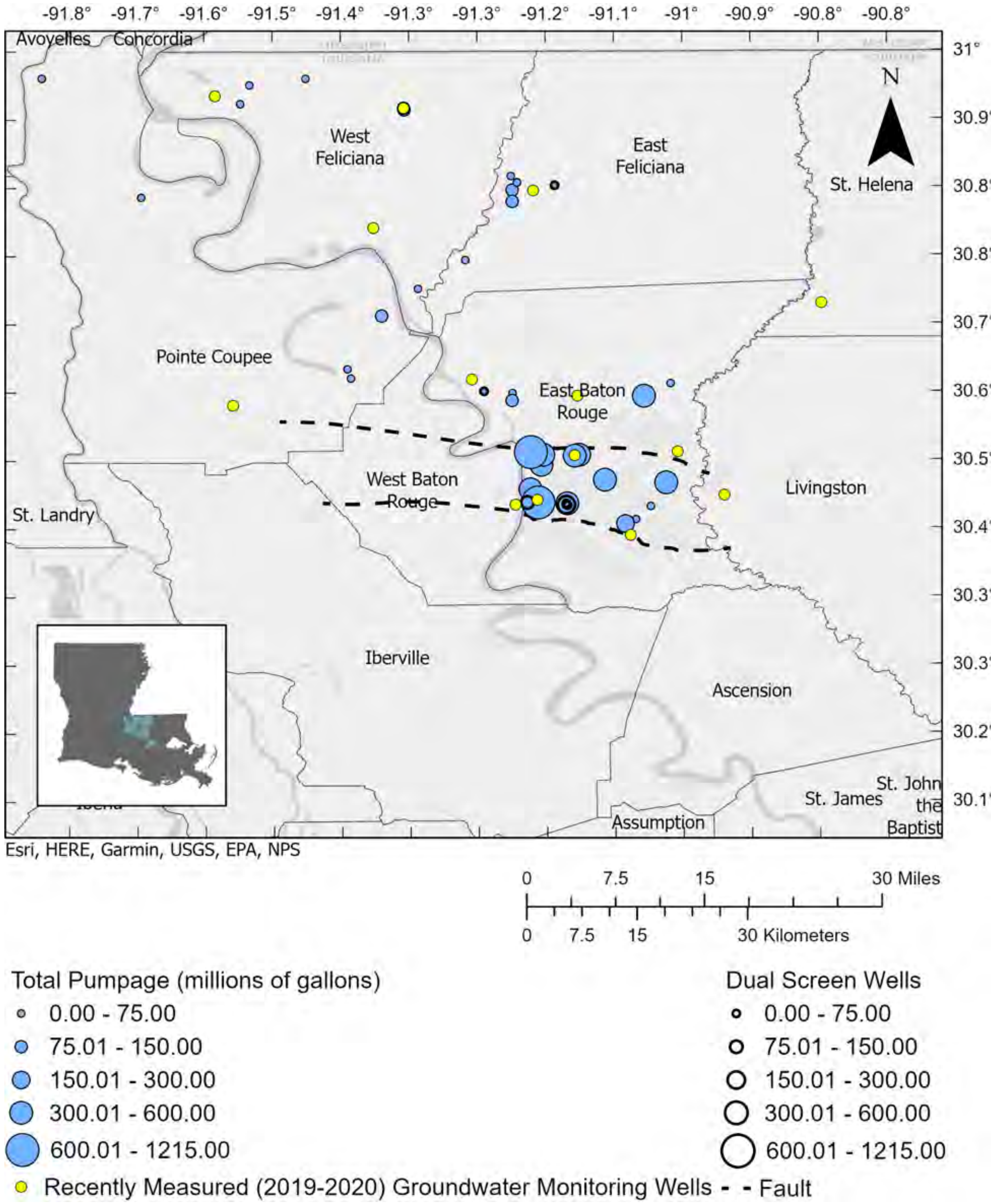

Figure D-9. Positions of groundwater level monitoring wells and pumping wells in the 2,400-foot sand.

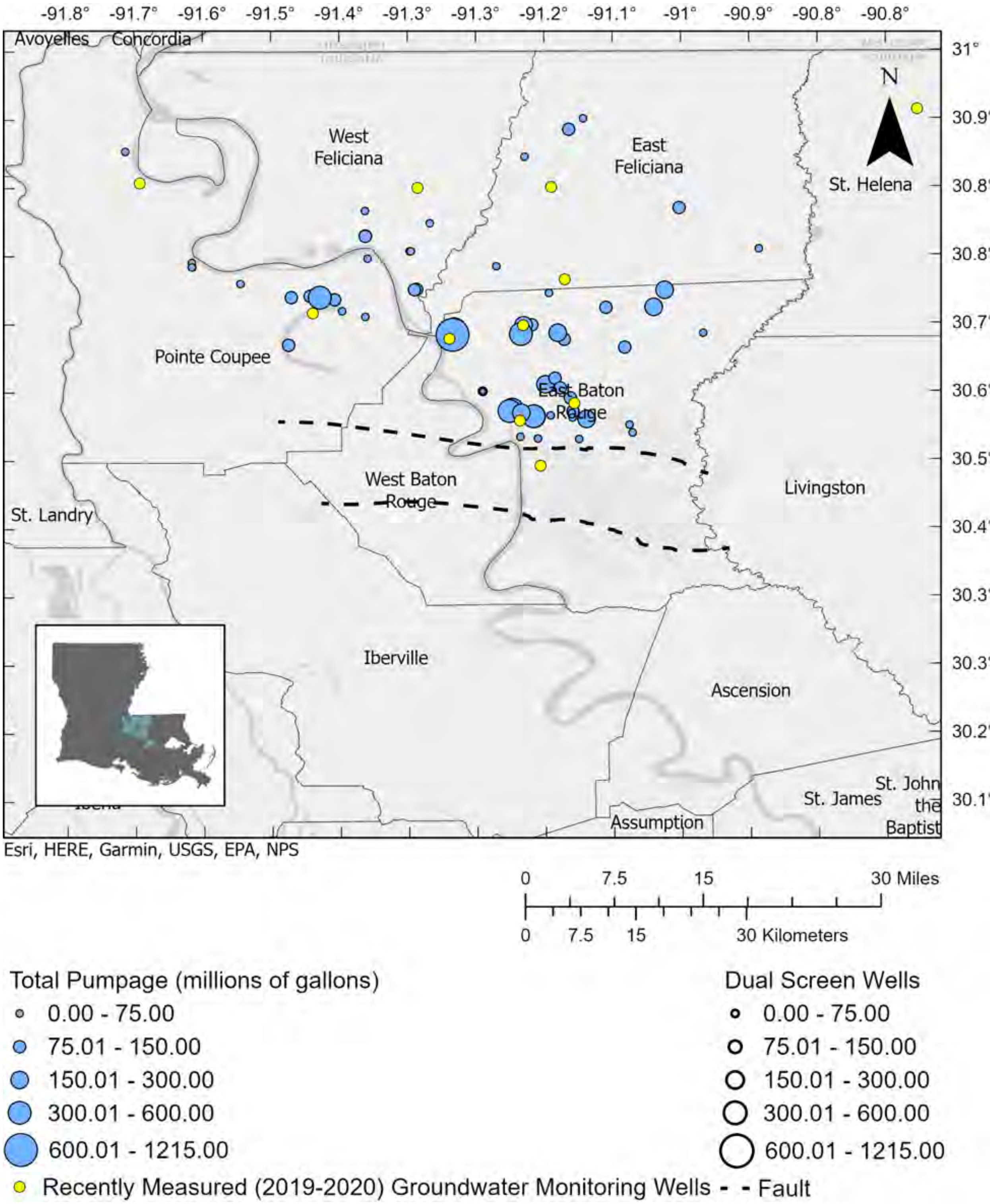

Figure D-10. Positions of groundwater level monitoring wells and pumping wells in the "2,800-foot sand".

APPENDIX E INDUSTRIAL USE WATER SURVEY

Capital Area Groundwater CONSERVATION DISTRICT

Industrial Water User Survey

Introduction

Thank you for taking the time to fill out this survey for the Capital Area Groundwater Conservation District. Your feedback will be invaluable to achieving our mission of conservation, orderly development, and protection of groundwater quality and resources in the Capital Area. This survey is intended to reflect characteristics for individual industrial facilities. If your entity has more than one industrial facility within the District area (Ascension, East Baton Rouge, East Feliciana, Pointe Coupee, West Baton Rouge and West Feliciana Parishes), please let us know and we will provide you with guidance on reporting for multiple facilities.

If you have any questions, wish to discuss your data, or would like assistance in completing the survey, please contact Philip Taucer at philip.taucer@freese.com.

Please take a moment to review the following guidance before starting the survey:

- A .pdf version of the survey is available at [LINK]. It is recommended that you use the .pdf as a reference to help gather your data prior to completing the online survey.
- If you prefer to provide the requested survey data as a .pdf file, scanned printout, Excel spreadsheet, text file, or other similar format, please email your data to our consultant team at the email address above.
- If your facility utilizes a large number of sands or other water supplies or you need additional space to answer a survey question, please contact our consultant team at the email address above.
- If you wish to return to an earlier portion of the survey, use the "Prev" button at the bottom of the page. Please do **NOT** use the "Back" button on your browser. You can navigate back to previous sections at any time as long as you have not yet submitted the completed survey.
- You can close your browser and return to your stopping point later, but to do so without losing your data you **MUST** be on the same computer **AND** allow your browser to store cookies. Each page is only saved after you click "**Next**" at the bottom.

Capital Area Groundwater CONSERVATION DISTRICT

Industrial Water User Survey
Section 1. General Facility Information

*** Please enter your contact information below.**

Name of Company:

Survey Completed By:

Contact E-Mail:

Contact Phone Number:

*** What is the name of your facility?**

*** What is the primary industry classification of your facility? Select from dropdown below. If none of the options describes your facility, please select "Other".**

If you selected 'Other', please describe your facility type:

*** What is the physical location of your facility? Please provide the address or coordinates of the site location rather than the administrative address.**

Address

Address 2

City/Town

State

ZIP/Postal Code

Latitude

Longitude:

Capital Area Groundwater CONSERVATION DISTRICT

Industrial Water User Survey
Section 2. Current Water Supplies

What is the maximum water supply that you could produce for your facility using existing infrastructure? Please specify units.

Maximum Supply:

Units:

What are your current sources of water?

- [ ] Groundwater
- [ ] Other (surface water, reuse, etc.)

If 'Groundwater', please select the sand(s) that the groundwater originates from. Select all that apply:

- [ ] 400-foot Sand
- [ ] 600-foot Sand
- [ ] 800-foot Sand
- [ ] 1,000-foot Sand
- [ ] 1,200-foot Sand
- [ ] 1,500-foot Sand
- [ ] 1,700-foot Sand
- [ ] 2,000-foot Sand
- [ ] 2,400-foot Sand
- [ ] 2,800-foot Sand
- [ ] Unknown
- [ ] Other

If your facility utilizes any water sources other than groundwater (surface water, saline surface water, reuse, etc.), please describe these sources:

What is the estimated average annual volume of groundwater currently used? If from multiple sands, please list separately by sand if possible. ***Please note that if you have multiple wells within a sand, you can aggregate results by sand and do not need to specify production for each individual well.***

Source Name:

Sand 1:

Sand 2:

Sand 3:

Usage:

Sand 1:

Sand 2:

Sand 3:

Units:

If average annual groundwater usage is unknown, what is an estimated range of annual water demands for your facility from groundwater?

Lower-end estimate:

Upper-end estimate:

Units:

Capital Area Groundwater CONSERVATION DISTRICT

Industrial Water User Survey
Section 2. Current Water Supplies (cont.)

What is the estimated average annual volume of water currently used from sources other than groundwater? (If from multiple sources, please list separately if possible):

Source Name:

Other Source 1:

Other Source 2:

Other Source 3:

Usage:

Other Source 1:

Other Source 2:

Other Source 3:

Units:

If average annual usage from other sources is unknown, what is an estimated range of annual water demands for your facility from other water sources?

Lower-end estimate:

Upper-end estimate:

Units:

Capital Area Groundwater CONSERVATION DISTRICT

Industrial Water User Survey
Section 2. Current Water Supplies (cont.)

What percent of your water supply do you currently treat on-site for the following sources?

Groundwater Sources:

Other Source #1:

Other Source #2:

Other Source #3:

What is the unit cost ($/thousand gal) of on-site treatment for the following sources?

Groundwater Sources:

Other Source #1:

Other Source #2:

Other Source #3:

What is the current salinity level for your groundwater source(s), and at what salinity level would you have to do increased treatment? What would be the impact on your treatment cost?

Current salinity:

Salinity req. increased treatment:

Units:

% increase in treatment cost:

What is the approximate amount of wastewater discharged by your facility in a typical year? Please specify units.

Discharge Volume:

Units:

Capital Area Groundwater CONSERVATION DISTRICT

Industrial Water User Survey
Section 3. Looking to the Future

Is your current facility at its maximum build-out capacity?

- Yes
- No

If you answered "No", approximately what percentage of the facility's maximum hypothetical growth (assuming unlimited funding to implement expansion) is currently developed?

0% 50% 100%

How much additional water would you estimate would be needed to support the facility at its maximum hypothetical development? Please specify units.

Additional Supply:

Units:

If a new water supply was brought online, what are the minimum water quality requirements (in units of parts per million) for your process supply for:

TDS?

Salinity?

If there are source water quality specifications besides salinity and total dissolved solids that are important for your facility, please list the parameters for your water quality needs below along with associated numerical limits. Please include the relevant units for each parameter.

Parameter #1:

Parameter #2:

Parameter #3:

Parameter #4:

Parameter #5:

Parameter #6:

Parameter #7:

Parameter #8:

Capital Area Groundwater CONSERVATION DISTRICT

Industrial Water User Survey
Section 3. Looking to the Future (cont.)

What portion of your current or future water supply needs could be met by reclaimed wastewater (with BOD and TSS of <5 mg/L)? Please specify units.

Volume:

Units:

If you have an interest in developing or utilizing alternative supplies for your facility, please describe below. Any information that you wish to share on supply types, amounts, implementation timing, and acceptable cost level would be appreciated.

Do you have a 5-year water supply plan or similar document?

Yes No

If you do have a water supply plan, would you share this plan with the Capital Area Groundwater Conservation District?

Yes No

If you are willing to share this document with the Capital Area Groundwater Conservation District, please upload using the button below. If the file is larger than 16 MB, please email to philip.taucer@freese.com.

Choose File Choose File No file chosen

APPENDIX F SURVEY INSTRUMENT TO ASSESS PUBLIC PERCEPTIONS OF GROUNDWATER RESOURCES IN CAGWCC

Public Understanding of Groundwater Resources in Baton Rouge Area

Start of Block: Default Question Block

Q1 Do you live in the capital area of Baton Rouge?

- O Yes (1)
- O No (2)

Q2 What parish do you reside in?

- O Ascension (1)
- O East Baton Rouge (2)
- O East Feliciana (3)
- O Pointe Coupee (4)
- O West Baton Rouge (5)
- O West Feliciana (6)
- O Other (7)

---

*

Q3 What is the zip code of your current residence?

____

Q4 Are you Hispanic or not?

- O Yes (1)
- O No (2)

Q5 Which of the following best describes you:

- O White (1)
- O Black/African American (2)
- O Asian (4)
- O Other (5)

Q6 What is your gender?

- O Male (1)
- O Female (2)
- O Other (5)
- O Prefer not to say (6)

Q7 If you were responding to the U.S. Census, what is your sex?

- O Male (1)
- O Female (2)

Q8 What is your age?

- O 18-29 (1)
- O 30-49 (2)
- O 50-64 (3)
- O 65 and older (4)

Q9 Where do you primarily get your household water?

- O Private water supply (private well, river, pond, lake) (1)
- O Private water company (e.g., Baton Rouge Water Company, Ascension Water Company, M&S Water Supply) (2)
- O Public municipal water supply (e.g., City of Baker, City of Zachary, Ascension Consolidated Utility District) (4)
- O Small water system (community well or rural water district) (6)
- O Not sure (5)
- O Other (7)

Display This Question:

If Where do you primarily get your household water? = Other

Q10 If your answer is "Other" to the previous question, what is it?

____

Q11 What is the source of this water?

- O The Mississippi River (1)
- O Other surface water (rivers, streams, lakes) (4)
- O Groundwater/Aquifer (sources of well water) (5)
- O Collected rainwater (6)
- O Not sure (3)

Q12 Do you filter the tap water in your household?

- O Yes (1)
- O No (2)

Q13 Do you primarily purchase bottled water for your drinking water?

- O Yes (1)
- O No (2)

Q14 What do you think of the following aspects of the water in your household?

	Excellent (1)	Good (2)	Fair (3)	Bad (4)
Taste (1)	O	O	O	O
Odor (2)	O	O	O	O
Appearance (3)	O	O	O	O
Feel (4)	O	O	O	O

Q15 What do you think of the overall quality of surface water (rivers, streams, lakes) for drinking water where you live?

O Very good (1)

O Good (2)

O Fair (3)

O Bad (4)

O Very bad (5)

Q16 What do you think of the overall quality of the groundwater (sources of well water) for drinking in your area?

- Very good (1)
- Good (2)
- Fair (3)
- Bad (4)
- Very bad (5)

Q17 How do you think the drinking water quality has changed in the past 5 years?

- Better (1)
- The same (2)
- Worse (3)

Q18 How concerned are you about the drinking water quality in your area?

- Not concerned (1)
- Somewhat concerned (2)
- Very concerned (3)

Q19 Have you read or heard anything regarding groundwater management?

- Yes (1)
- No (2)

Display This Question:

If Have you read or heard anything regarding groundwater management? = Yes

Q20 Where have you read or heard about ground management?

- Newspaper (1)
- TV (2)
- Radio (3)
- Social media (4)
- Family, friends, neighbors (5)

Q21 How concerned are you about the water availability in your area?

- Not concerned (1)
- Somewhat concerned (2)
- Very concerned (3)

Q22 Who do you think is the biggest user of water in the area?

- Agriculture (1)
- Industry (2)
- Public supply (3)
- Power Generation (4)
- Aquaculture (5)

Q23 If a serious threat to groundwater resources existed, whom would you trust most to manage the issue?

- Special commission or task force (1)
- City/parish government only (2)
- State government only (3)
- Business and industry leaders (4)
- Not sure (6)

Q24 <div>Please rate the following local water related issues on a scale of not a problem to very serious.</div>

	Not a problem at all (1)	somewhat serious (2)	serious (3)	Not sure (4)
Contamination of water sources (1)	O	O	O	O
Saltwater intrusion (2)	O	O	O	O
Affordability of water supply (3)	O	O	O	O
Aging water and wastewater infrastructure (6)	O	O	O	O
Depletion of water sources (7)	O	O	O	O
Degradation of drinking water (8)	O	O	O	O

Q25 Are there any issues you are aware of but not listed in the question above? What are they?

____

Q26 In order to manage water better, please indicate your support for the following policy options

	Oppose (1)	Neutral (2)	Support (3)
Conduct educational campaigns for voluntary water conservation (1)	O	O	O
Give tax incentives for the installation of water-saving equipment (2)	O	O	O
Invest more in monitoring groundwater (5)	O	O	O
Increase rate for large-volume household users (3)	O	O	O
Impose cap for non-essential water usage (e.g., swimming pool, landscaping and lawn watering) (4)	O	O	O

Q27 Are there any other policies you would suggest in addition to the ones listed above? What are they?

____

Q28 How concerned are you about water cost in your area?

- O Not concerned (1)
- O Somewhat concerned (2)
- O Very concerned (3)

Q29 What do you think of your current water bills?

- O High (1)
- O About right (2)
- O Low (3)

Q30 Would you be willing to pay more on your water bills to guarantee safe drinking water?

- O Yes (1)
- O No (2)

Display This Question:

If Would you be willing to pay more on your water bills to guarantee safe drinking water? = Yes

Q31 How much more would you be willing to pay every month?

- $1 per month (8)
- $2 per month (9)
- $5 per month (1)
- $5-$10 per month (10)

Q32 Do you own your home, pay rent, or something else?

- Own your home (1)
- Pay rent (4)
- Something else (5)

Q33. Which of the following categories best describes your level of education?

- Less than High School (1)
- High School graduate (2)
- Some college (3)
- 2 year degree (4)
- 4 year degree (5)
- Professional degree (6)
- Doctorate (7)

Q34. What was your household income last year before taxes? Note: this information will remain strictly confidential and will only be used for statistical purposes.

- O Under $10,000 (1)
- O $10,000 - $19,999 (2)
- O $20,000 - $29,999 (3)
- O $30,000 - $39,999 (4)
- O $40,000- $49,999 (5)
- O $50,000 - $74,999 (6)
- O $75,000 - $99,999 (7)
- O $100,000 or more (8)

End of Block: Default Question Block

APPENDIX G TECHNICAL MEMORANDA: PHASE 2A PROJECT CONCEPT ASSESSMENTS

Document Data:	
To:	Project File
CC:	Diana Di Leonardo; Alyssa Dausman
From:	Philip Taucer; Jason Afinowicz
Subject:	Project Concept Technical Memoranda
Date:	12/15/2021
Project:	WHI21178

07/06/2023

INTRODUCTION

Addressing future supply needs and achieving long-term management objectives identified by the Capital Area Ground Water Conservation Commission (CAGWCC) requires an understanding of the potential water sources and strategies which could supplement or reduce reliance on groundwater use and provide long-term diversification to the region's water source profile. While Phase 2 of the CAGWCC Long-Term Strategic Plan study is not intended to mandate a particular project, a greater understanding of the key considerations for various supply options will provide a valuable reference for both CAGWCC and local stakeholders. Based on the characteristics of the study area, CAGWCC and project partners identified a number of potentially feasible projects anticipated to be evaluated as part of the study:

- Mississippi River Surface Water (Strategy ID SW01) – Development of a traditional surface water supply project including diversion and treatment of a portion of the substantial flow of the Mississippi River.

- River Bank Filtration / Alluvial Groundwater (Strategy ID SW02) – Use of wells in the Mississippi River Alluvium or other shallow sands to leverage abundant surface water while benefiting from natural filtration as pre-treatment.

- Aquifer Storage and Recovery (Strategy ID SW03) – Use of surface water development and treatment in conjunction with injection wells, creating subsurface storage in lieu of a traditional reservoir to increase supply reliability.

- Brackish Groundwater Desalination (Strategy ID GW01) – Production of groundwater from non-traditional supply formations with high dissolved solids and salinity, and application of desalination treatment to produce a high-quality treated source for direct use or blending.

- Municipal Effluent Reclamation (Strategy ID RU01) – Repurposing treated municipal wastewater treatment plant effluent for beneficial supply use through additional advanced treatment and conveyance to demand centers.

- Industrial Effluent Reclamation (Strategy ID RU02) – Repurposing treated industrial facility wastewater effluent for beneficial supply use through additional advanced treatment.

- Institutional Effluent Reclamation (Strategy IDs RU03 and RU04) – Diverting a portion of the wastewater stream for educational or correctional institutions, possibly supplemented by municipal wastewater, for treatment and utilization for green space irrigation or other non-potable water demands.

The Phase 2A study analyses of these identified water supply concepts require consideration of multiple aspects of project development. Quantitative or qualitative considerations considered in developing project assessments for the study included estimated costs, water quality, reliability, implementation feasibility, permitting and environmental factors, and the potential for added benefit beyond supply. It should be noted that the project concepts for the Phase 2A study are planning-level analyses and not intended for construction, bid, or permitting purposes. However, while more general than a detailed feasibility analysis or preliminary engineering report for a site-specific project, planning level analysis is extremely valuable in assessing the characteristics of supply options, key considerations for development, possible implementation challenges, and anticipated relative magnitude of cost. The following sections of this memorandum package include planning-level evaluations of key parameters for each of the identified major project concepts. Where appropriate, these memoranda reference procedures and information from the body of the overall Phase 2A study report. The main report, in turn, includes information from these memoranda in a condensed form.

STRATEGY CONCEPT TECHNICAL MEMORANDUM: MISSISSIPPI RIVER SURFACE WATER

Strategy Concept Summary	
Strategy ID:	SW01
Strategy Type:	Surface Water Development
Supply Quantity:	Variable (10 and 20 MGD concepts assessed)
Strategy Capital Cost:	$129,967,600 (10 MGD Concept) $237,437,844 (20 MGD Concept)
Life Cycle Unit Cost:	$2.53 per 1,000 gallons (10 MGD Concept) $2.33 per 1,000 gallons (20 MGD Concept)

Strategy Description

The parishes within the Capital Area Groundwater Conservation District include extensive surface water drainage features, the most significant of which is the Mississippi River. The high volumetric flow of the river, even in times of drought, and its location adjacent to both major industrial aggregations and municipal development offer the potential for development of a large potable water supply to partially replace or supplement groundwater production. This memorandum summarizes planning-level evaluations of a hypothetical surface water supply to serve industry, including concept assumptions, cost estimation and comparison to current groundwater cost, and considerations related to quality, reliability, feasibility, permitting, and possibility of extended benefits.

Supply Development Assumptions and Applicability

Overview

Analyses of a Mississippi River Surface Water project for the Phase 2A study examined a generalized project concept with potential applicability to one or more of the industrial aggregations within the study area. This general, planning-level approach allows investigation of project development considerations and assessment of the approximate magnitude of cost associated with favorable implementation conditions for the strategy. Should one or more entities within the study area pursue development of a surface water supply project, it is anticipated that site-specific considerations on logistics, quality needs, and cost would be examined through detailed feasibility and preliminary engineering analyses. It should be noted that the project concepts for the Phase 2A study are planning-level analyses and not intended for construction, bid, or permitting purposes.

Project Concept Sizing

Project concept sizing considered both the availability of raw source supply and the potential water demand to be served. The Mississippi River, with a drainage area covering a substantial portion of the United States, develops extremely large flow rates and conveys large volumes of water through Louisiana, even during periods of reduced rainfall. USGS flow records for Site 07374000, which are available from March 2004 to present, show daily flows varying from 141,000 to 1,430,000 cfs, with an average flow of over 571,000 cfs. For context, for a 20 MGD surface water concept at the estimated 1.5 peaking factor, the peak river intake rate would be approximately 47 cfs. While project development would likely involve additional studies of the source and considerations for maintaining continuous supply access, for the purposes of this study the flow in the Mississippi River is not considered to be a limiting factor for a local surface water diversion. Selection of representative concept sizes therefore focused on the historic groundwater production within industrial aggregations, both in terms of total production and pumpage from the sands of greatest concern for saltwater intrusion. Based on this examination, it was determined that 10 MGD and 20 MGD supply concepts would be applicable for meeting some or all demand at various industrial aggregations.

Other Assumptions

The following assumptions were applied in estimating project concept cost and examining implementation considerations:

- That the raw surface water source is fully reliable, even during drought conditions.
- The project is developed and implemented by the entities within an industrial aggregation to meet industrial water demand within that aggregation.
- There is sufficient demand for potable-quality water.
- Infrastructure is developed in the immediate vicinity of the industrial aggregation utilizing the produced supply, resulting in limited transmission distance, land purchase cost, and crossings of public infrastructure.
- That development by industry on existing sites permits relatively rapid project development relative to development of municipal infrastructure on a minimally disturbed site.
- Project construction involves the following major infrastructure components:
- A surface water pump station with river intake, located within 1,320 ft (1/4 of a mile) transmission distance from the treatment site.
- A conventional surface water treatment plant.
- On-site ground storage tanks to provide buffering storage for variations in flow or demand.
- A discharge pump station, with delivery to take points or existing on-site transmission within 1,320 ft.
- Associated piping.

- Detailed project finance, infrastructure peaking, and other infrastructure details are consistent with the overall costing assumptions as described in the Phase 2A study report.

Strategy Cost Analysis

Estimated Cost Breakdown

Preliminary planning-level cost estimates for the Mississippi River Surface Water concept were developed through the costing tool developed for the study and based upon the assumptions discussed in this memorandum and the Phase 2A study report. Annualized cost components, such as debt service and facility operations and maintenance expenses, were developed utilizing the standardized assumptions summarized in the Phase 2A study report. Estimated costs for the two concept sizes are summarized in Table SW01.1, with more detailed cost profile sheets in Tables SW01.2 and SW01.3.

Table SW01.1. Cost summary for Mississippi River Surface Water concept

Supply Vol.	Capital Cost	Annual Cost		Unit Cost	
		Initial	Post-Debt	Initial	Post-Debt
10 MGD	$129,967,600	$14,745,084	$5,600,424	$1,315 / ac-ft $4.04 / 1,000 gal	$500 / ac-ft $1.53 / 1,000 gal
20 MGD	$237,437,844	$27,061,444	$10,355,062	$1,207 / ac-ft $3.70 / 1,000 gal	$462 / ac-ft $1.42 / 1,000 gal

Table SW01.2. Preliminary planning-level cost estimate for 10 MGD concept

PRELIMINARY PLANNING-LEVEL COST ESTIMATE	OCTOBER 2021 COST INDEX
STRATEGY: Mississippi River Surface Water (10 MGD)	

PROJECT CAPITAL COST SUMMARY

ITEM	DESCRIPTION	QTY	UNIT	UNIT PRICE	TOTAL
1	CONSTRUCTION COST	1	LS	$90,478,184	$90,478,184
2	ENG., FINANCIAL, LEGAL SERVICES, AND CONTINGENCIES	1	LS	$31,626,613	$31,626,613
3	LAND AND EASEMENTS	1	LS	$981,420	$981,420
4	ENVIRONMENTAL - STUDIES AND MITIGATION	1	LS	$12,500	$12,500
5	INTEREST DURING CONSTRUCTION	1	LS	$6,868,882	$6,868,882
	PROJECT CAPITAL COST				**$129,967,600**

ANNUAL COST SUMMARY

ITEM	DESCRIPTION	TOTAL
1	DEBT SERVICE (20 YEARS AT 3.5% INTEREST)	$9,144,660
2	OPERATION AND MAINTENANCE (O&M)	$5,161,451
3	PUMPING ENERGY COSTS	$438,973
	TOTAL ANNUAL COST - DURING DEBT SERVICE	**$14,745,084**
	TOTAL ANNUAL COST - AFTER DEBT SERVICE	**$5,600,424**

UNIT COST SUMMARY

ITEM	DESCRIPTION	ANNUAL TOTAL
1	ESTIMATED YIELD (ACRE-FEET PER YEAR)	11,209
2	ANNUAL COST - DURING DEBT SERVICE	$14,745,084
3	ANNUAL COST - AFTER DEBT SERVICE	$5,600,424
	TOTAL UNIT COST DURING DEBT SERVICE ($ PER ACRE-FOOT PER YEAR)	**$1,315**
	TOTAL UNIT COST AFTER DEBT SERVICE ($ PER ACRE-FOOT PER YEAR)	**$500**

CONSTRUCTION COST SUMMARY

ITEM	DESCRIPTION	QTY	UNIT	UNIT PRICE	TOTAL
1	PUMP STATIONS	1	LS	$20,772,600	$20,772,600
2	PIPELINES	1	LS	$815,028	$815,028
3	WATER TREATMENT PLANTS	1	LS	$65,751,343	$65,751,343
4	WATER STORAGE TANKS	1	LS	$3,139,213	$3,139,213
	PROJECT COST				**$90,478,184**

OPERATION AND MAINTENANCE (O&M) COST SUMMARY

ITEM	DESCRIPTION	QTY	UNIT	UNIT PRICE	TOTAL
1	PUMP STATIONS	2.5	%	$20,772,600	$519,315
2	PIPELINES	1.0	%	$815,028	$8,150
3	WATER TREATMENT PLANTS	1.0	LS	$4,602,594	$4,602,594
4	WATER STORAGE TANKS	1.0	%	$3,139,213	$31,392
	ANNUAL OPERATION AND MAINTENANCE COST				**$5,161,451**

Table SW01.3. Preliminary planning-level cost estimate for 20 MGD concept

PRELIMINARY PLANNING-LEVEL COST ESTIMATE	OCTOBER 2021 COST INDEX
STRATEGY: Mississippi River Surface Water (20 MGD)	

PROJECT CAPITAL COST SUMMARY					
ITEM	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**
1	CONSTRUCTION COST	1	LS	$165,617,454	$165,617,454
2	ENG., FINANCIAL, LEGAL SERVICES, AND CONTINGENCIES	1	LS	$57,907,447	$57,907,447
3	LAND AND EASEMENTS	1	LS	$1,351,680	$1,351,680
4	ENVIRONMENTAL - STUDIES AND MITIGATION	1	LS	$12,500	$12,500
5	INTEREST DURING CONSTRUCTION	1	LS	$12,548,763	$12,548,763
	PROJECT CAPITAL COST				**$237,437,844**

ANNUAL COST SUMMARY		
ITEM	**DESCRIPTION**	**TOTAL**
1	DEBT SERVICE (20 YEARS AT 3.5% INTEREST)	$16,706,382
2	OPERATION AND MAINTENANCE (O&M)	$9,487,568
3	PUMPING ENERGY COSTS	$867,494
	TOTAL ANNUAL COST - DURING DEBT SERVICE	**$27,061,444**
	TOTAL ANNUAL COST - AFTER DEBT SERVICE	**$10,355,062**

UNIT COST SUMMARY		
ITEM	**DESCRIPTION**	**ANNUAL TOTAL**
1	ESTIMATED YIELD (ACRE-FEET PER YEAR)	22,418
2	ANNUAL COST - DURING DEBT SERVICE	$27,061,444
3	ANNUAL COST - AFTER DEBT SERVICE	$10,355,062
	TOTAL UNIT COST DURING DEBT SERVICE ($ PER ACRE-FOOT PER YEAR)	**$1,207**
	TOTAL UNIT COST AFTER DEBT SERVICE ($ PER ACRE-FOOT PER YEAR)	**$462**

CONSTRUCTION COST SUMMARY					
ITEM	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**
1	PUMP STATIONS	1	LS	$38,132,850	$38,132,850
2	PIPELINES	1	LS	$1,173,236	$1,173,236
3	WATER TREATMENT PLANTS	1	LS	$120,990,009	$120,990,009
4	WATER STORAGE TANKS	1	LS	$5,321,359	$5,321,359
	PROJECT COST				**$165,617,454**

OPERATION AND MAINTENANCE (O&M) COST SUMMARY					
ITEM	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**
1	PUMP STATIONS	2.5	%	$38,132,850	$953,321
2	PIPELINES	1.0	%	$1,173,236	$11,732
3	WATER TREATMENT PLANTS	1.0	LS	$8,469,301	$8,469,301
4	WATER STORAGE TANKS	1.0	%	$5,321,359	$53,214
	ANNUAL OPERATION AND MAINTENANCE COST				**$9,487,568**

Performance Metric 3

Estimated concept unit costs during debt service, after debt service, and for a hypothetical 50-year project lifespan were compared against the estimated current cost of industrial groundwater supply in order to evaluate Performance Metric 3 values for the project concept. Results of this comparison are summarized in Table SW01.4.

Table SW01.4. Performance Metric 3 results for Mississippi River Surface Water concept

Supply Vol.	Unit Cost ($ per 1,000 gal)			Performance Metric 3		
	Initial	Post-Debt	50-Year	Initial	Post-Debt	50-Year
10 MGD	$4.04	$1.53	$2.53	3.84	1.46	**2.41**
20 MGD	$3.70	$1.42	$2.33	3.53	1.35	**2.22**

In examining the Performance Metric 3 results for the supply concept, it should be noted that while estimated project costs are higher than estimated current groundwater costs, the project would develop new potable water supplies which could reduce or supplement groundwater production and diversify entity or regional supply portfolios, providing overall improvements to reliability. It is also noted that unit costs for the concept decrease substantially after retirement of debt service, and thus if the project is able to secure funding with more favorable terms than the default assumptions for the study, both initial and life-cycle Performance Metric 3 values would decrease.

Considerations that Could Impact Cost

The project components and assumptions for the Mississippi River Surface Water concept are intended to be reasonable for a non-site-specific and planning-level analysis based on available information on sources, water demands, and other considerations. Due to the multiple potential manners in which a surface water project could be implemented within the study area and the potential impacts of site-specific considerations on facility components, project cost could vary from the estimates presented in this memorandum. Factors which could impact project cost include, but are not limited to:

- Development of infrastructure outside of the industrial aggregation served, which would likely increase costs for transmission, land purchase, easements, crossings of other public or private infrastructure, land survey, and environmental assessments.
- Potential need for extensive crossing of existing infrastructure on industrial sites in order to reach points of demand.
- Specific water quality requirements at industrial facilities, which could result in either additional cost at the facility level or adjustments to the overall treatment requirements and design for the concept.
- Site-specific characteristics which could impact required pump-station horsepower, storage size, transmission distance and sizing, or other costing assumptions.
- Implementation of the concept in an alternate manner such as a municipal supply or shared municipal-industrial project.

- The specific financing approach utilized to support project development.

It should also be noted that costs in this memorandum are presented for a reference month of October 2021. National and international economic drivers and materials markets are prone to fluctuations which cannot always be accurately predicted and present a source of uncertainty regarding the cost of project development in the future.

Other Considerations

Water Quality

As part of the supply concept evaluation, water quality sampling data were obtained for USGS Site Number 07374000 (Mississippi River at Baton Rouge, LA.), which is located slightly north of Interstate 10 near the Old Louisiana State Capitol. A high-level drinking water contaminants review was performed against the federal (USEPA) maximum contaminant level (MCL), secondary maximum contaminant level (SMCL), and select current drinking water quality parameters in Baton Rouge; this comparison suggests that a conventional surface water treatment plant with coagulation/flocculation, clarification, filtration, and disinfection components would be adequate to treat the Mississippi River to potable water standard.

In addition to conventional surface water treatment, detailed feasibility or preliminary engineering analyses of a Mississippi River surface water supply concept may need to consider if water softening would be recommended for concept implementation. Current groundwater sources in the study area are generally very low in minerals except for sodium and bicarbonate, while the Mississippi River has hardness ranging from 101 – 215, averaging 147 mg/L as $CaCO_3$. Hardness (calcium and magnesium) has no health impact or MCLs but could have impacts through pipe buildup or compatibility with end user industrial processes. Centralized water softening is a common practice in many areas, with variety of processes to choose from including lime softening, ion exchange, pellet softening, or nanofiltration.

Reliability

As noted earlier in this memorandum, even the minimum flow of the Mississippi River through the study area far exceeds anticipated surface water project diversion rates. Detailed feasibility or preliminary engineering analyses of a Mississippi River surface water supply concept for the study area would likely entail examination of flows for an extended period of historical hydrology including drought-of-record conditions, as well as assessment of impacts by and on existing surface water users. However, based on available flow data, it appears that the Mississippi River is likely a highly reliable supply source within the study area.

Implementation Feasibility

The overall substantial volume of Mississippi River Surface Water suggests potential feasibility for a surface water development project. Some challenge may be presented by finding sufficient available space for infrastructure development within industrial aggregations. It is recommended that pursuit of a surface water supply include detailed feasibility analysis, including assessment of source water quality, industrial user quality needs, associated infrastructure siting and routing options, and viable locations for achieving desired intake rates.

Permitting, Development, and Environmental Considerations

Environmental impacts of the project concept are anticipated to be limited. Portions of infrastructure development could create some construction disturbance requiring mitigation. The concept as envisioned for this study would consist primarily of infrastructure development on existing industrial sites and through existing utility corridors or rights-of-way, with the pre-disturbed nature of these areas likely reducing habitat impacts and resulting in minimal mitigation requirements. Diversion of surface water would reduce instream flows downstream of intake within the river. However, the associated concept diversion volumes are extremely small in comparison with the flow of the Mississippi River, and would not be expected to have an appreciable impact on instream flows.

Project development for a Mississippi River Surface Water concept would be expected to require some degree of permitting and agency coordination, potentially including:

- Compliance with State, parish, and local construction permitting and notification procedures, as applicable for the project site.
- Stormwater discharge permitting and obtaining coverage of construction general permitting through the Louisiana Pollution Discharge Elimination System (LPDES).
- For projects with elements outside of the associated industrial aggregation, obtaining of easements, permissions for infrastructure crossings, and purchase of land as applicable.
- For any concept implementation which requires development of infrastructure components in wetland areas, U.S. Army Corps of Engineers Section 404 Permitting and mitigation planning, potentially also including development of a National Environmental Policy Act (NEPA) Environmental Impact Statement (EIS).
- For any concept implementation crossing federal levee infrastructure, which would be applicable for a number of industrial aggregations, coordination and permitting through the U.S. Army Corps of Engineers.
- Submittal of an application for surface water diversion to the Louisiana Department of Natural Resources (DNR), and participation in the Cooperative Endeavor Agreement process.

Other Benefits

In addition to the basic benefit of providing a new source of water supply to reduce or supplement existing groundwater production, development of surface water offers a number of potential benefits to the study area:

- Due to the high volumetric flows of the Mississippi River, location and sizing of a surface water facility is highly flexible, allowing the concept to serve an industrial user or aggregation or to be scaled up to serve as a regional solution.

- Because available river supply appears to be of reasonable quality for conventional surface water treatment, the project could be implemented using longstanding, proven technologies.

- Produced water quality from a surface water project would be suitable for potable uses and could serve municipal demand in addition to industry.

- Integration of a surface water supply diversifies the region's overall supply profile and provides long term redundancy and improved reliability.

- If desired, a surface water concept could also be implemented on a river or stream other than the Mississippi River, with additional on-channel or off-channel storage used to increase reliability of supply and provide flood mitigation benefits.

References

U.S. Geological Survey. (2021). *USGS 07374000 Mississippi River at Baton Rouge, LA*. [Dataset.] Accessed November 29, 2021 at < https://waterdata.usgs.gov/nwis/uv?site_no=07374000>

STRATEGY CONCEPT TECHNICAL MEMORANDUM: RIVER BANK FILTRATION

Strategy Concept Summary	
Strategy ID:	SW02
Strategy Type:	Surface Water Development
Supply Quantity:	Variable (10 MGD concept assessed)
Strategy Capital Cost:	$75,577,577
Life Cycle Unit Cost:	$1.49 per 1,000 gallons

Strategy Description

The parishes within the Capital Area Groundwater Conservation District include extensive surface water drainage features, including the extremely large and productive Mississippi River channel adjacent to both major industrial aggregations and municipal development. While this resource is already utilized by many water systems along its length and provides an excellent opportunity to the study area, implementation of surface water is not without challenges. In particular, the high flow and variability of the Mississippi River would impact intake facility design, and the water in the lower Mississippi River contains a high sediment and dissolved solids loading. The presence of the hydraulically connected Mississippi River Alluvium and other shallow sands could create an alternate means of utilizing abundant surface water supply by using an array of shallow collector groundwater wells to draw surface water through bankside sediments in lieu of a traditional surface water intake; this could also partially mitigate concerns with flow elevation variability and water quality. This memorandum summarizes planning-level evaluations of a hypothetical bank filtration supply to serve industry, including concept assumptions, cost estimation and comparison to current groundwater cost, and considerations related to quality, reliability, feasibility, permitting, and possibility of extended benefits.

Supply Development Assumptions and Applicability

Overview

Analyses of a River Bank Filtration project for the Phase 2A study examined a generalized project concept with potential applicability to one or more of the industrial aggregations within the study area. This general, planning-level approach allows investigation of project development considerations and assessment of the approximate magnitude of cost associated with favorable implementation conditions for the strategy. Should one or more entities within the study area pursue development of a bank filtration project, it is anticipated that site-specific considerations on logistics, quality needs, and cost would be examined through detailed feasibility and preliminary engineering analyses. It should be noted that the project concepts for the Phase 2A study are planning-level analyses and not intended for construction, bid, or permitting purposes.

Project Concept Sizing

Project concept sizing considered both the availability of the raw source supply and the potential water demand to be served. The Mississippi River, with a drainage area covering a substantial portion of the United States, develops extremely large flow rates and conveys large volumes of water through Louisiana, even during periods of reduced rainfall. USGS flow records for Site 07374000, which are available from March 2004 to present, show daily flows varying from 141,000 to 1,430,000 cfs, with an average flow of over 571,000 cfs. For context, for a 20 MGD surface water concept at the estimated 1.5 peaking factor, the peak river intake rate would be approximately 47 cfs. For the purposes of this study, the flow in the Mississippi River is not considered to be a limiting factor for a local surface water diversion. Supply limitations would therefore be primarily controlled by the ability to draw water at a sufficient rate through the shallow subsurface for the project site. While portions of the alluvium and other shallow riparian sediments are known to have connectivity to the river and high transmissivity, detailed assessment of supply potential would require site-specific modeling and pilot testing. Considering this greater degree of uncertainty relative to traditional surface water intake, in conjunction with examination of historic groundwater production within industrial aggregations, it was determined that a 10 MGD supply concept would be applicable for meeting some or all demand at various industrial aggregations.

Other Assumptions

The following assumptions were applied in estimating project concept cost and examining implementation considerations:

- That the raw bank-filtered surface water source is fully reliable, even during drought conditions.
- The project is developed and implemented by the entities within an industrial aggregation to meet industrial water demand within that aggregation.
- There is sufficient demand for potable-quality water.
- Infrastructure is developed in the immediate vicinity of the industrial aggregation utilizing the produced supply, resulting in limited transmission distance, land purchase cost, and crossings of public infrastructure.
- That development by industry on existing sites permits relatively rapid project development relative to development of municipal infrastructure on a minimally disturbed site.
- Project construction involves the following major infrastructure components:
- A linear array of eight shallow (200 ft) industrial / public supply type collector wells with 1,320 ft (1/4 of a mile) spacing supplying a central treatment site.
- A direct filtration groundwater water treatment plant.
- On-site ground storage tanks to provide buffering storage for variations in flow or demand.

- A discharge pump station, with delivery to take points or existing on-site transmission within 1,320 ft.
- Associated piping.
- Detailed project finance, infrastructure peaking, and other infrastructure details are consistent with the overall costing assumptions as described in the Phase 2A study report.

Strategy Cost Analysis

Estimated Cost Breakdown

A preliminary planning-level cost estimate for the River Bank Filtration concept was developed through the costing tool developed for the study and based upon the assumptions discussed in this memorandum and the Phase 2A study report. Annualized cost components such as debt service and facility operations and maintenance expenses, were developed utilizing the standardized assumptions summarized in the Phase 2A study report. Estimated costs for the concept are summarized in Table SW02.1, with a more detailed cost profile sheet in Table SW02.2.

Table SW02.1. Cost summary for River Bank Filtration concept

Supply Vol.	Capital Cost	Annual Cost		Unit Cost	
		During Debt Svc.	After Debt Svc.	During Debt Svc.	After Debt Svc.
10 MGD	$75,577,577	$8,623,284	$3,305,564	$769 / ac-ft $2.36 / 1,000 gal	$295 / ac-ft $0.91 / 1,000 gal

Table SW02.2. Preliminary planning-level cost estimate for 10 MGD concept

PRELIMINARY PLANNING-LEVEL COST ESTIMATE	OCTOBER 2021 COST INDEX
STRATEGY: River Bank Filtration (10 MGD)	

PROJECT CAPITAL COST SUMMARY					
ITEM	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**
1	CONSTRUCTION COST	1	LS	$53,503,641	$53,503,641
2	ENG., FINANCIAL, LEGAL SERVICES, AND CONTINGENCIES	1	LS	$18,605,580	$18,605,580
3	LAND AND EASEMENTS	1	LS	$1,399,860	$1,399,860
4	ENVIRONMENTAL - STUDIES AND MITIGATION	1	LS	$56,250	$56,250
5	INTEREST DURING CONSTRUCTION	1	LS	$2,012,246	$2,012,246
	PROJECT CAPITAL COST				**$75,577,577**

ANNUAL COST SUMMARY		
ITEM	**DESCRIPTION**	**TOTAL**
1	DEBT SERVICE (20 YEARS AT 3.5% INTEREST)	$5,317,720
2	OPERATION AND MAINTENANCE (O&M)	$2,801,791
3	PUMPING ENERGY COSTS	$503,773
	TOTAL ANNUAL COST - DURING DEBT SERVICE	**$8,623,284**
	TOTAL ANNUAL COST - AFTER DEBT SERVICE	**$3,305,564**

UNIT COST SUMMARY		
ITEM	**DESCRIPTION**	**ANNUAL TOTAL**
1	ESTIMATED YIELD (ACRE-FEET PER YEAR)	11,209
2	ANNUAL COST - DURING DEBT SERVICE	$8,623,284
3	ANNUAL COST - AFTER DEBT SERVICE	$3,305,564
	TOTAL UNIT COST DURING DEBT SERVICE ($ PER ACRE-FOOT PER YEAR)	**$769**
	TOTAL UNIT COST AFTER DEBT SERVICE ($ PER ACRE-FOOT PER YEAR)	**$295**

CONSTRUCTION COST SUMMARY					
ITEM	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**
1	PUMP STATIONS	1	LS	$3,554,100	$3,554,100
2	PIPELINES	1	LS	$2,413,896	$2,413,896
3	WATER TREATMENT PLANTS	1	LS	$36,890,710	$36,890,710
4	WATER STORAGE TANKS	1	LS	$3,139,213	$3,139,213
5	WELL FIELDS	1	LS	$7,505,723	$7,505,723
	PROJECT COST				**$53,503,641**

OPERATION AND MAINTENANCE (O&M) COST SUMMARY					
ITEM	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**
1	PUMP STATIONS	2.5	%	$3,554,100	$88,853
2	PIPELINES	1.0	%	$2,413,896	$24,139
3	WATER TREATMENT PLANTS	1.0	LS	$2,582,350	$2,582,350
4	WATER STORAGE TANKS	1.0	%	$3,139,213	$31,392
5	WELL FIELDS	1.0	%	$7,505,723	$75,057
	ANNUAL OPERATION AND MAINTENANCE COST				**$2,801,791**

Performance Metric 3

Estimated concept unit costs during debt service, after debt service, and for a hypothetical 50-year project lifespan were compared against the estimated current cost of industrial groundwater supply in order to evaluate Performance Metric 3 values for the project concept. Results of this comparison are summarized in Table SW02.3.

Table SW02.3. Performance Metric 3 results for River Bank Filtration concept

Supply Vol.	Unit Cost ($ per 1,000 gal)			Performance Metric 3		
	Initial	Post-Debt	50-Year	Initial	Post-Debt	50-Year
10 MGD	$2.36	$0.91	$1.49	2.25	0.86	**1.42**

In examining the Performance Metric 3 results for the supply concept, it should be noted that while estimated initial and 50-year project costs are higher than estimated current groundwater costs, the project would develop new potable water supplies which could reduce or supplement groundwater production and diversify entity or regional supply portfolios, providing overall improvements to reliability. It is also noted that unit costs for the concept decrease substantially after retirement of debt service, and thus if the project is able to secure funding with more favorable terms than the default assumptions for the study, both initial and life-cycle Performance Metric 3 values would decrease. Estimated costs after retirement of debt service produce a Performance Metric 3 value of less than 1.0, suggesting that in the long term the concept could be more cost-effective than existing groundwater production.

Considerations that Could Impact Cost

The project components and assumptions for the River Bank Filtration concept are intended to be reasonable for a non-site-specific and planning-level analysis based on available information on sources, water demands, and other considerations. Due to the multiple potential manners in which a bank filtration or alluvial groundwater project could be implemented within the study area and the potential impacts of site-specific considerations on facility components, project cost could vary from the estimates presented in this memorandum. Factors which could impact project cost include, but are not limited to:

- Development of infrastructure outside of the industrial aggregation served, which would likely increase costs for transmission, land purchase, easements, crossings of other public or private infrastructure, land survey, and environmental assessments.

- Lower well productivity or the need for greater well spacing than assumed by the Phase 2A study, which would increase construction cost and potentially annual energy and O&M costs.

- If indicated by preliminary engineering or other studies, relocation of collection facilities to another portion of shallow sediments or the Mississippi River Alluvium proper, resulting in increased transmission infrastructure and infrastructure crossings.

- Potential need for extensive crossing of existing infrastructure on industrial sites in order to reach points of demand.

- Specific water quality requirements at industrial facilities, which could result in either additional cost at the facility level or adjustments to the overall treatment requirements and design for the concept.

- Site-specific characteristics which could impact required pump-station horsepower, storage size, transmission distance and sizing, or other costing assumptions.

- Implementation of the concept in an alternate manner such as a municipal supply or shared municipal-industrial project.

- The specific financing approach utilized to support project development.

It should also be noted that costs in this memorandum are presented for a reference month of October 2021. National and international economic drivers and materials markets are prone to fluctuations which cannot always be accurately predicted and present a source of uncertainty regarding the cost of project development in the future.

Other Considerations

Water Quality

Source raw water quality for a River Bank Filtration concept is anticipated to bear similarities to that of Mississippi River surface water, with the use of bank filtration potentially providing a reduction in dissolved and suspended solids and other quality parameters. Detailed assessment of project water quality would likely involve project-specific modeling analyses as well as pilot well testing. The project concept would produce treated water of potable quality for delivery to end users.

Reliability

Reliability of a bank filtration supply is currently uncertain as the approach has not been pilot tested or used on a large scale in the study area. However, available information and observations suggest that local conditions are likely favorable for source reliability. Both the Mississippi River Alluvium proper and other shallow sands in the vicinity of local industrial aggregations are known to have connectivity to the Mississippi River and are utilized on a limited bases as traditional groundwater sources. Evaluation of the long-term reliability of the project concept, the supportable project size, and the positioning of well collector infrastructure would likely involve project-specific modeling analyses as well as pilot well testing.

Implementation Feasibility

The overall substantial volume of Mississippi River Surface Water suggests potential feasibility for a bank filtration project. Some challenge may be presented by finding sufficient available space for infrastructure development within industrial aggregations. It is recommended that pursuit of a bank filtration supply include detailed feasibility analysis, including assessment of source water quality, industrial user quality needs, associated infrastructure siting and routing options, and viable well locations for achieving desired intake rates.

Permitting, Development, and Environmental Considerations

Environmental impacts of the project concept are anticipated to be limited. Portions of infrastructure development could create some construction disturbance requiring mitigation. The concept as envisioned for this study would consist primarily of infrastructure development on existing treatment and industrial sites and through existing utility corridors or rights-of-way, with the pre-disturbed nature of these areas likely reducing habitat impacts and resulting in minimal mitigation requirements. Indirect diversion of surface water through nearby shallow sediments would reduce instream flows downstream of the project take point. However, the associated concept diversion volumes are extremely small in comparison with the flow of the Mississippi River, and would not be expected to have an appreciable impact on instream flows.

Project development for a River Bank Filtration concept would be expected to require some degree of permitting and agency coordination, potentially including:

- Compliance with State, parish, and local construction permitting and notification procedures, as applicable for the project site.
- Stormwater discharge permitting and obtaining coverage of construction general permitting through the Louisiana Pollution Discharge Elimination System (LPDES).
- For projects with elements outside of the associated industrial aggregation, obtaining of easements, permissions for infrastructure crossings, and purchase of land as applicable.
- For any concept implementation which requires development of infrastructure components in wetland areas, U.S. Army Corps of Engineers Section 404 Permitting and mitigation planning, potentially also including development of a National Environmental Policy Act (NEPA) Environmental Impact Statement (EIS).
- For any concept implementation in close proximity to federal levee infrastructure, which would be applicable for a number of industrial aggregations, coordination with U.S. Army Corps of Engineers would likely be advisable, even if no physical levee crossing is made.
- Coordination with the Louisiana Department of Natural Resources (DNR) on potential need for and approaches to submittal of an application for surface water diversion for atypical approach of bank filtration.
- Well permitting through the Capital Area Groundwater Conservation Commission.
- Well drilling notification and well registration through the DNR Office of Conservation.

Other Benefits

In addition to the basic benefit of providing a new source of water supply to reduce or supplement existing groundwater production, development of river bank filtration offers a number of potential benefits to the study area:

- Due to the high volumetric flows of the Mississippi River, there is potential for a bank filtration project to be scalable.
- The use of the alluvium or shallow sands to serve as a filter medium could provide effective reduction of dissolved and suspended solids and reduce the cost and complexity of water treatment required to implement the study.
- Use of wells rather than a traditional surface water intake could provide additional reliability during periods of lower river flow elevation or during flood.
- Produced water quality from a bank filtration project would be expected to be suitable for potable uses and could serve municipal demand in addition to industry.
- Integration of a surface water through bank filtration supply diversifies the region's overall supply profile and provides long term redundancy and improved reliability.

References

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STRATEGY CONCEPT TECHNICAL MEMORANDUM: AQUIFER STORAGE AND RECOVERY

Strategy Concept Summary	
Strategy ID:	SW03
Strategy Type:	Surface Water Development
Supply Quantity:	Variable (10 MGD concept assessed)
Strategy Capital Cost:	$142,464,419
Life Cycle Unit Cost:	$3.25 per 1,000 gallons

Strategy Description

The parishes within the Capital Area Groundwater Conservation District (the CAGWCD) include extensive surface water drainage features, including the extremely large and productive Mississippi River channel as well as other smaller streams and rivers. Incorporation of storage into a surface water supply concept can increase reliability to support water use during times of decreased surface water flow or downtime of intake facilities for maintenance and repair. While storage has traditionally taken the form of on-channel or off-channel reservoir impoundments, some areas with suitable subsurface characteristics have investigated or implemented an aquifer storage and recovery (ASR) approach. ASR involves injection of treated water into a target aquifer to develop a “bubble” of treated water to serve as subsurface storage and buffer against surrounding groundwater quality. Treated surface water is then used directly and/or stored when available, with injected supply recovered and re-treated for use when surface water is more limited. This memorandum summarizes planning-level evaluations of a hypothetical ASR supply to serve industry, including concept assumptions, cost estimation and comparison to current groundwater cost, and considerations related to quality, reliability, feasibility, permitting, and possibility of extended benefits.

Supply Development Assumptions and Applicability

Overview

Analyses of an ASR project for the Phase 2A study examined a generalized project concept with potential applicability to one or more of the industrial aggregations within the study area. This general, planning-level approach allows investigation of project development considerations and assessment of the approximate magnitude of cost associated with favorable implementation conditions for the strategy. Due to the general nature of the analysis, this memorandum examines a traditional ASR concept of using subsurface storage in lieu of a reservoir. It should be noted that for the study area, the high reliability of surface water likely largely negates the direct reliability benefit of ASR. However, such a project could still have benefit when viewed from the perspective of being a primarily surface water supply project with ASR wells utilizing excess treated water capacity to slow or even reverse subsurface saltwater intrusion, with the added benefit of acting as an emergency subsurface supply reserve. Should one or more entities within the study area pursue development of an ASR project, it is anticipated that site-specific considerations on logistics, quality needs, and cost would be examined through detailed feasibility and preliminary engineering analyses. It should be noted that the project concepts for the Phase 2A study are planning-level analyses and not intended for construction, bid, or permitting purposes.

Project Concept Sizing

Project concept sizing considered both the availability of raw source supply and the potential water demand to be served. The Mississippi River, with a drainage area covering a substantial portion of the United States, develops extremely large flow rates and conveys large volumes of water through Louisiana, even during periods of reduced rainfall. USGS flow records for Site 07374000, which are available from March 2004 to present, show daily flows varying from 141,000 to 1,430,000 cfs, with an average flow of over 571,000 cfs. For context, for a 20 MGD surface water concept at the estimated 1.5 peaking factor, the peak river intake rate would be approximately 47 cfs. While project development would likely involve additional studies of the source and considerations for maintaining continuous supply access, for the purposes of this study the flow in the Mississippi River is not considered to be a limiting factor for a local surface water diversion.

Supply limitations for an ASR concept would therefore be expected to be related with the subsurface storage and recovery characteristics of the storage strata utilized for the concept. Some research has examined the feasibility of ASR for coastal aquifers in Louisiana (LaHaye 2020), and it is anticipated that the body of available knowledge will continue to expand through future studies due to growing interest in innovative water supply solutions; however, at this time there is limited data on the feasibility of ASR for the study area.

A recent planning-level study of a conceptual ASR project in the greater Houston, Texas area (Region H Water Planning Group, 2020) examined potential use of ASR in the Jasper Equivalent or Catahoula formations. The Jasper formation for the target area was found to have an average transmissivity of 37,500 gpd/ft, a coefficient of storage of 0.0004, and an injectable rate of 1.6 MGD per well; the Catahoula formation had a transmissivity of 22,500 gpd/ft, storage coefficient of 0.0003, and injectable rate of 0.5 MGD per well. Properties of the sands in the CAGWCD parishes vary considerably with sand and specific location, although some may have areas of similar properties. For example, Meyer and Turcan Jr. (1955) reported the 800-foot sand to have a transmissivity of 24,000 gpd/ft and a storage coefficient ranging from 0.001 to 0.000001. Due to the uncertainty of ASR potential for the study area, for purposes of the Phase 2A a hypothetical 10 MGD project was examined, with a target storage depth of 1,000 ft and an assumed moderate injection rate of 1 MGD.

In order to estimate infrastructure sizing for the desired project size, a conceptual model was developed to examined river flow, injectable and recoverable volumes, and rates to simulate ASR operation at a monthly timescale. The model is capable of projecting growth of a “bubble” of stored water during an initial startup phase of a conceptual project and fluctuations in storage during active use as the project draws on either direct treated surface water or stored and recovered supply. Model parameters for well count and treatment plant capacity were iteratively adjusted to estimate infrastructure to develop and maintain a long-term subsurface storage bubble. Major assumptions applied in this modeling included:

- Access to extremely large volumes of surface water, with surface water access in 80 percent of months.
- Five-year startup period of subsurface storage.
- 1.0 MGD per well injection rate.
- 1.0 percent annual leakage loss rate of stored water
- Target 50,000 ac-ft subsurface storage volume

The results of this analysis and the target project size were then utilized in project costing analyses discussed in greater detail in subsequent sections of this memorandum.

Other Assumptions

The following assumptions were applied in estimating project concept cost and examining implementation considerations:

- That the raw surface water source is fully reliable, even during drought conditions.
- The project is developed and implemented by the entities within an industrial aggregation to meet industrial water demand within that aggregation.
- There is sufficient demand for potable-quality water.
- Infrastructure is developed in the immediate vicinity of the industrial aggregation utilizing the produced supply, resulting in limited transmission distance, land purchase cost, and crossings of public infrastructure.
- That development by industry on existing sites permits relatively rapid project development relative to development of municipal infrastructure on a minimally disturbed site.
- Project construction involves the following major infrastructure components:
- A surface water pump station with river intake, located within 1,320 ft (1/4 of a mile) transmission distance from the treatment site.
- A rectangular array of twelve 1,000 ft deep ASR wells with 2,640 ft spacing, flanking a central trunk line conveying flow to or from the treatment facility.
- A conventional surface water treatment plant.
- On-site ground storage tanks to provide buffering storage for variations in flow or demand.

- A discharge pump station, with delivery to take points or existing on-site transmission within 1,320 ft.

- Associated piping.

- Detailed project finance, infrastructure peaking, and other infrastructure details are consistent with the overall costing assumptions as described in the Phase 2A study report.

Strategy Cost Analysis

Estimated Cost Breakdown

A preliminary planning-level cost estimate for the Aquifer Storage and Recovery concept was developed through the costing tool developed for the study and based upon the assumptions discussed in this memorandum and the Phase 2A study report. Annualized cost components such as debt service and facility operations and maintenance expenses, were developed utilizing the standardized assumptions summarized in the Phase 2A study report. Estimated costs for the concept are summarized in Table SW03.1, with a more detailed cost profile sheet in Table SW03.2.

Table SW03.1. Cost summary for Aquifer Storage and Recovery concept

Supply Vol.	Capital Cost	Annual Cost		Unit Cost	
		Initial	Post-Debt	Initial	Post-Debt
10 MGD	$142,464,419	$16,712,851	$6,688,902	$1,491/ ac-ft $6.10 / 1,000 gal	$597/ ac-ft $1.83 / 1,000 gal

Table SW03.2. Preliminary planning-level cost estimate for 10 MGD concept

PRELIMINARY PLANNING-LEVEL COST ESTIMATE	OCTOBER 2021 COST INDEX
STRATEGY: Aquifer Storage and Recovery (10 MGD)	

PROJECT CAPITAL COST SUMMARY

ITEM	DESCRIPTION	QTY	UNIT	UNIT PRICE	TOTAL
1	CONSTRUCTION COST	1	LS	$97,946,722	$97,946,722
2	ENG., FINANCIAL, LEGAL SERVICES, AND CONTINGENCIES	1	LS	$34,042,629	$34,042,629
3	LAND AND EASEMENTS	1	LS	$2,783,220	$2,783,220
4	ENVIRONMENTAL - STUDIES AND MITIGATION	1	LS	$162,500	$162,500
5	INTEREST DURING CONSTRUCTION	1	LS	$7,529,348	$7,529,348
	PROJECT CAPITAL COST				**$142,464,419**

ANNUAL COST SUMMARY

ITEM	DESCRIPTION	TOTAL
1	DEBT SERVICE (20 YEARS AT 3.5% INTEREST)	$10,023,950
2	OPERATION AND MAINTENANCE (O&M)	$4,765,783
3	PUMPING ENERGY COSTS	$1,923,119
	TOTAL ANNUAL COST - DURING DEBT SERVICE	**$16,712,851**
	TOTAL ANNUAL COST - AFTER DEBT SERVICE	**$6,688,902**

UNIT COST SUMMARY

ITEM	DESCRIPTION	ANNUAL TOTAL
1	ESTIMATED YIELD (ACRE-FEET PER YEAR)	11,209
2	ANNUAL COST - DURING DEBT SERVICE	$16,712,851
3	ANNUAL COST - AFTER DEBT SERVICE	$6,688,902
	TOTAL UNIT COST DURING DEBT SERVICE ($ PER ACRE-FOOT PER YEAR)	**$1,491**
	TOTAL UNIT COST AFTER DEBT SERVICE ($ PER ACRE-FOOT PER YEAR)	**$597**

CONSTRUCTION COST SUMMARY

ITEM	DESCRIPTION	QTY	UNIT	UNIT PRICE	TOTAL
1	PUMP STATIONS	1	LS	$18,876,300	$18,876,300
2	PIPELINES	1	LS	$4,774,473	$4,774,473
3	WATER TREATMENT PLANTS	1	LS	$58,386,188	$58,386,188
4	WATER STORAGE TANKS	1	LS	$2,977,401	$2,977,401
5	WELL FIELDS	1	LS	$12,932,360	$12,932,360
	PROJECT COST				**$97,946,722**

OPERATION AND MAINTENANCE (O&M) COST SUMMARY

ITEM	DESCRIPTION	QTY	UNIT	UNIT PRICE	TOTAL
1	PUMP STATIONS	2.5	%	$18,876,300	$471,908
2	PIPELINES	1.0	%	$4,774,473	$47,745
3	WATER TREATMENT PLANTS	1.0	LS	$4,087,033	$4,087,033
4	WATER STORAGE TANKS	1.0	%	$2,977,401	$29,774
5	WELL FIELDS	1.0	%	$12,932,360	$129,324
	ANNUAL OPERATION AND MAINTENANCE COST				**$4,765,783**

Performance Metric 3

Estimated concept unit costs during debt service, after debt service, and for a hypothetical 50-year project lifespan were compared against the estimated current cost of industrial groundwater supply in order to evaluate Performance Metric 3 values for the project concept. Results of this comparison are summarized in Table SW03.3.

Table SW03.3. Performance Metric 3 results for Aquifer Storage and Recovery concept

Supply Vol.	Unit Cost ($ per 1,000 gal)			Performance Metric 3		
	Initial	Post-Debt	50-Year	Initial	Post-Debt	50-Year
10 MGD	$6.10	$1.83	$3.25	5.81	1.74	**3.10**

In examining the Performance Metric 3 results for the supply concept, it should be noted that while estimated project costs are higher than estimated current groundwater costs, the project would develop new potable water supplies which could reduce or supplement groundwater production and diversify entity or regional supply portfolios, providing overall improvements to reliability. It is also noted that unit costs for the concept decrease substantially after retirement of debt service, and thus if the project is able to secure funding with more favorable terms than the default assumptions for the study, both initial and life-cycle Performance Metric 3 values would decrease.

Considerations that Could Impact Cost

The project components and assumptions for the Aquifer Storage and Recovery concept are intended to be reasonable for a non-site-specific and planning-level analysis based on available information on sources, water demands, and other considerations. Due to the multiple potential manners in which an ASR project could be implemented within the study area and the potential impacts of site-specific considerations on facility components, project cost could vary from the estimates presented in this memorandum. Factors which could impact project cost include, but are not limited to:

- Development of infrastructure outside of the industrial aggregation served, which would likely increase costs for transmission, land purchase, easements, crossings of other public or private infrastructure, land survey, and environmental assessments.
- Lower well productivity or injection capacity or the need for greater well spacing than assumed by the Phase 2A study, which would increase construction cost and potentially annual energy and O&M costs.
- Increased subsurface losses of stored treated water due to natural leakage or interception by other wells.
- Potential need for extensive crossing of existing infrastructure on industrial sites in order to reach points of demand.

- Specific water quality requirements at industrial facilities, which could result in either additional cost at the facility level or adjustments to the overall treatment requirements and design for the concept.

- Site-specific characteristics which could impact required pump-station horsepower, storage size, transmission distance and sizing, or other costing assumptions.

- Implementation of the concept in an alternate manner such as a municipal supply or shared municipal-industrial project.

- The specific financing approach utilized to support project development.

It should also be noted that costs in this memorandum are presented for a reference month of October 2021. National and international economic drivers and materials markets are prone to fluctuations which cannot always be accurately predicted and present a source of uncertainty regarding the cost of project development in the future.

Other Considerations

Water Quality

As part of the supply concept evaluation, water quality sampling data were obtained for USGS Site Number 07374000 (Mississippi River at Baton Rouge, LA.), which is located slightly north of Interstate 10 near the Old Louisiana State Capitol. A high-level drinking water contaminants review was performed against the federal (EPA) maximum contaminant level (MCL), secondary maximum contaminant level (SMCL), and select current drinking water quality parameters in Baton Rouge; this comparison suggests that a conventional surface water treatment plant with coagulation/flocculation, clarification, filtration, and disinfection components would be adequate to treat the Mississippi River to potable water standard. Water would be treated to a potable standard for either direct use from the treatment facility or for subsurface injection and recovered water from the subsurface is anticipated to be subject to re-treatment and would also provide potable supply.

In addition to conventional surface water treatment, detailed feasibility or preliminary engineering analyses of a Mississippi River surface water supply concept may need to consider if water softening would be recommended for concept implementation. Current groundwater sources in the study area are generally very low in minerals except for sodium and bicarbonate, while the Mississippi River has hardness ranging from 101 – 215, averaging 147 mg/L as $CaCO_3$. Hardness (calcium and magnesium) has no health impact or MCLs but could have impacts through pipe buildup or compatibility with end user industrial processes. Centralized water softening is a common practice in many areas, with variety of processes to choose from including lime softening, ion exchange, pellet softening, or nanofiltration. Depending on the local characteristics of the target strata for ASR injection, softening may also be necessary for compatibility with existing groundwater quality.

Reliability

The Mississippi River, which is the source associated with the project concept as envisioned for the Phase 2A study, conveys extremely large volumetric flows through the CAGWCD parishes even in times of limited rainfall and appears to be a highly reliable water supply source for the study area; additional discussion of river source availability is included in the project concept technical memorandum for the Mississippi River Surface Water concept. The other major component of an ASR approach that could impact overall reliability, that of subsurface storage and recovery and loss rates, is less certain due to the currently limited amount of detailed technical analysis of ASR feasibility for the study area; there has been interest in investigating ASR potential within the CAGWCD, and it is anticipated that the level of data availability to support more detailed ASR feasibility analysis will increase in the future.

Should injection and recovery characteristics within the area demonstrate compatibility with an ASR approach, such a project could offer overall reliability and redundancy benefits, utilizing abundant surface water for much of the time while allowing stored flows to be utilized during periods of less favorable river characteristics or intake maintenance.

Implementation Feasibility

Implementation feasibility of an ASR project is unknown and would require further study to characterize in greater detail. Surface water is abundant, but suitability of the subsurface is not currently established. Additionally, the infrastructure required, including widely spaced injection wells, may present construction challenges in sufficient available space or transmission routes within industrial aggregations or developed municipal areas. It is recommended that pursuit of an ASR supply include detailed feasibility analysis, including assessment of source water quality, industrial user quality needs, associated infrastructure siting and routing options, and viable well locations.

Permitting, Development, and Environmental Considerations

Environmental impacts of the project concept are anticipated to be limited. Portions of infrastructure development could create some construction disturbance requiring mitigation. The concept as envisioned for this study would consist primarily of infrastructure development on existing treatment and industrial sites and through existing utility corridors or rights-of-way, with the pre-disturbed nature of these areas likely reducing habitat impacts and resulting in minimal mitigation requirements. Diversion of surface water would reduce instream flows downstream of intake within the river. However, the associated concept diversion volumes are extremely small in comparison with the flow of the Mississippi River and would not be expected to have an appreciable impact on instream flows.

Project development for the Aquifer Storage and Recovery concept would be expected to require some degree of permitting and agency coordination, potentially including:

- Compliance with State, parish, and local construction permitting and notification procedures, as applicable for the project site.
- Stormwater discharge permitting and obtaining coverage of construction general permitting through the Louisiana Pollution Discharge Elimination System (LPDES).

- For projects with elements outside of the associated industrial aggregation, obtaining of easements, permissions for infrastructure crossings, and purchase of land as applicable.

- For any concept implementation which requires development of infrastructure components in wetland areas, U.S. Army Corps of Engineers Section 404 Permitting and mitigation planning, potentially also including development of a National Environmental Policy Act (NEPA) Environmental Impact Statement (EIS).

- For any concept implementation crossing federal levee infrastructure, which would be applicable for a number of industrial aggregations, coordination and permitting through the U.S. Army Corps of Engineers.

- Submittal of an application for surface water diversion to the Louisiana Department of Natural Resources (DNR), and participation in the Cooperative Endeavor Agreement process.

- Well permitting through the Capital Area Groundwater Conservation Commission.

- Well drilling notification and well registration through the DNR Office of Conservation.

Other Benefits

In addition to the basic benefit of providing a new source of water supply to reduce or supplement existing groundwater production, development of ASR offers a number of potential benefits to the study area:

- Due to the high volumetric flows of the Mississippi River, there is potential for an ASR project to be scalable.

- Because available river supply appears to be of reasonable quality for conventional surface water treatment, the project could be implemented using longstanding, proven treatment technologies.

- Produced water quality from an ASR project would be suitable for potable uses and could serve municipal demand in addition to industry.

- Integration of a surface water supply through ASR diversifies the region’s overall supply profile and provides long term redundancy and improved reliability.

- The use of subsurface storage offers overall reliability and redundancy benefits, utilizing abundant surface water for much of the time while allowing stored flows to be utilized during periods of less favorable river characteristics or intake maintenance

- If desired, an ASR concept could also be implemented on a river or stream other than the Mississippi River, with subsurface storage used to increase reliability of supply.

- Depending on subsurface characteristics and injection strata, it may be possible to develop an ASR concept which not only provides supply, but also utilizes the stored water volume to counteract or partially revers saltwater intrusion from the storage layer.

References

LaHaye, O.A. (2020). Assessment of Aquifer Storage and Recovery Feasibility in Replenishing Coastal Aquifers and Addressing Flood Mitigation Using Numerical Modeling, Geospatial, and Statistical Techniques: Application in Southwest Louisiana. Lafayette, LA. University of Louisiana at Lafayette.

U.S. Geological Survey. (2021). *USGS 07374000 Mississippi River at Baton Rouge, LA.* [Dataset.] Accessed November 29, 2021 at < https://waterdata.usgs.gov/nwis/uv?site_no=07374000>

STRATEGY CONCEPT TECHNICAL MEMORANDUM: BRACKISH GROUNDWATER DESALINATION

Strategy Concept Summary	
Strategy ID:	GW01
Strategy Type:	Groundwater Development
Supply Quantity:	Variable (5 MGD concept assessed)
Strategy Capital Cost:	$94,165,279
Life Cycle Unit Cost:	$6.74 per 1,000 gallons

Strategy Description

Water demand growth or a need to reduce reliance on currently utilized groundwater formations may impact not only industrial facilities in the immediate vicinity of conventional supplies, but also facilities or other water demand centers in more remote locations or which are not practical to connect to traditional supply projects. Production and treatment of brackish groundwater from less utilized subsurface strata may offer a treated water supply solution to some areas without ready access to other options. Depending on end user needs and existing sources, brackish groundwater desalination could provide a direct and highly treated water source or be scaled in treatment volume or level for blending with traditional groundwater. This memorandum summarizes planning-level evaluations of a hypothetical brackish groundwater desalination supply to serve industry, including concept assumptions, cost estimation and comparison to current groundwater cost, and considerations related to quality, reliability, feasibility, permitting, and possibility of extended benefits.

Supply Development Assumptions and Applicability

Overview

Analyses of a Brackish Groundwater Desalination project for the Phase 2A study examined a generalized project concept with potential applicability to one or more of the industrial aggregations within the study area. This general, planning-level approach allows investigation of project development considerations and assessment of the approximate magnitude of cost associated with favorable implementation conditions for the strategy. The evaluation presented in this memorandum examines brackish groundwater as a stand-alone concept due to uncertainty regarding hypothetical site-specific implementation and associated source portfolios. Depending on actual siting, it may be possible to implement the project as a blended supply, which could reduce treatment capacity requirements and overall project cost. It may also be possible to implement brackish groundwater in conjunction with existing or future scavenger wells to leverage that infrastructure and achieve additional supply benefit from scavenger well facilities. Should one or more entities within the study area pursue development of a brackish groundwater project, it is anticipated that site-specific considerations on logistics, quality needs, and cost would be examined through detailed feasibility and preliminary engineering analyses. It should be noted that the project concepts for the Phase 2A study are planning-level analyses and not intended for construction, bid, or permitting purposes.

Project Concept Sizing

Project concept sizing considered both the availability of the raw source supply and the potential water demand to be served. Due to the historical availability of high-quality groundwater in the 400-ft through 2,800-ft sands of the Baton Rouge area, there are relatively few local wells (and hence limited data) associated with the Catahoula formation and other deep formations. Long-term sustainability of production from these deeper formations is therefore unknown. While productivity could ultimately be high, this current uncertainty makes use of a fairly limited volume supply concept appropriate to the Phase 2A study. Consideration was also given to historic groundwater production within industrial aggregations, both in terms of total production and pumpage from the sands of greatest concern for saltwater intrusion. Based on this examination, it was determined that a 5 MGD finished supply concept would be applicable for meeting demand at various industrial aggregations.

Development of a brackish groundwater supply requires a raw source water inflow volume greater than the desired produced volume due to the rejection of a certain percentage of the inflow stream as concentrated brine from the reverse osmosis treatment process. The analyses and costing presented in this memorandum assume a 99 percent removal level of influent TDS, a 25 percent reject rate for concentrated brine, and a 0 percent bypass rate of raw influent; the lack of bypass reflects all influent treated rather than treating a portion and blending to desired TDS, due to the goal of producing an extremely low (<50 mg/L) TDS treated supply. Depending on local conditions for the implementation site, some blending potential could exist in reality and would likely reduce overall project cost.

Other Assumptions

The following assumptions were applied in estimating project concept cost and examining implementation considerations:

- That the brackish groundwater source is fully reliable.
- The project is developed and implemented by the entities within an industrial aggregation to meet industrial water demand within that aggregation.
- There is sufficient demand for potable-quality water.
- Infrastructure is developed in the immediate vicinity of the industrial aggregation utilizing the produced supply, resulting in limited transmission distance, land purchase cost, and crossings of public infrastructure.
- That development by industry on existing sites permits relatively rapid project development relative to development of municipal infrastructure on a minimally disturbed site.
- Project construction involves the following major infrastructure components:

- A rectangular array of six deep (3,200 ft) industrial / public supply type wells with 2,640 ft (1/2 of a mile) spacing, flanking a central trunk line conveying flow to the treatment facility
- A brackish groundwater desalination treatment plant.
- A deep injection well to dispose of brine concentrate.
- On-site ground storage tanks to provide buffering storage for variations in flow or demand.
- A discharge pump station, with delivery to take points or existing on-site transmission within 1,320 ft.
- Associated piping.

- The project is implemented as a stand-alone source treated to a high standard and is not directly blended with other supplies to achieve desired quality.
- Detailed project finance, infrastructure peaking, and other infrastructure details are consistent with the overall costing assumptions as described in the Phase 2A study report.

Strategy Cost Analysis

Estimated Cost Breakdown

A preliminary planning-level cost estimate for the Brackish Groundwater Desalination concept was developed through the costing tool developed for the study and based upon the assumptions discussed in this memorandum and the Phase 2A study report. Annualized cost components such as debt service and facility operations and maintenance expenses were developed utilizing the standardized assumptions summarized in the Phase 2A study report. Estimated costs for the concept are summarized in Table GW01.1, with a more detailed cost profile sheet in Table GW01.2.

Table GW01.1. Cost summary for Brackish Groundwater Desalination concept

Supply Vol.	Capital Cost	Annual Cost		Unit Cost	
		Initial	Post-Debt	Initial	Post-Debt
5 MGD	$94,165,279	$16,290,644	$9,665,073	$2,906/ ac-ft $8.92 / 1,000 gal	$1,724/ ac-ft $5.29 / 1,000 gal

Table GW01.2. Preliminary planning-level cost estimate for 5 MGD concept

PRELIMINARY PLANNING-LEVEL COST ESTIMATE	OCTOBER 2021 COST INDEX
STRATEGY: Brackish Groundwater Desalination (5 MGD)	

PROJECT CAPITAL COST SUMMARY

ITEM	DESCRIPTION	QTY	UNIT	UNIT PRICE	TOTAL
1	CONSTRUCTION COST	1	LS	$66,862,990	$66,862,990
2	ENG., FINANCIAL, LEGAL SERVICES, AND CONTINGENCIES	1	LS	$23,256,947	$23,256,947
3	LAND AND EASEMENTS	1	LS	$1,456,950	$1,456,950
4	ENVIRONMENTAL - STUDIES AND MITIGATION	1	LS	$81,250	$81,250
5	INTEREST DURING CONSTRUCTION	1	LS	$2,507,142	$2,507,142
	PROJECT CAPITAL COST				**$94,165,279**

ANNUAL COST SUMMARY

ITEM	DESCRIPTION	TOTAL
1	DEBT SERVICE (20 YEARS AT 3.5% INTEREST)	$6,625,570
2	OPERATION AND MAINTENANCE (O&M)	$6,166,252
3	PUMPING ENERGY COSTS	$3,498,822
	TOTAL ANNUAL COST - DURING DEBT SERVICE	**$16,290,644**
	TOTAL ANNUAL COST - AFTER DEBT SERVICE	**$9,665,073**

UNIT COST SUMMARY

ITEM	DESCRIPTION	ANNUAL TOTAL
1	ESTIMATED YIELD (ACRE-FEET PER YEAR)	5,605
2	ANNUAL COST - DURING DEBT SERVICE	$16,290,644
3	ANNUAL COST - AFTER DEBT SERVICE	$9,665,073
	TOTAL UNIT COST DURING DEBT SERVICE ($ PER ACRE-FOOT PER YEAR)	**$2,906**
	TOTAL UNIT COST AFTER DEBT SERVICE ($ PER ACRE-FOOT PER YEAR)	**$1,724**

CONSTRUCTION COST SUMMARY

ITEM	DESCRIPTION	QTY	UNIT	UNIT PRICE	TOTAL
1	PUMP STATIONS	1	LS	$1,810,900	$1,810,900
2	PIPELINES	1	LS	$2,901,991	$2,901,991
3	WATER TREATMENT PLANTS	1	LS	$28,791,887	$28,791,887
4	WATER STORAGE TANKS	1	LS	$1,569,549	$1,569,549
5	WELL FIELDS	1	LS	$31,788,663	$31,788,663
	PROJECT COST				**$66,862,990**

OPERATION AND MAINTENANCE (O&M) COST SUMMARY

ITEM	DESCRIPTION	QTY	UNIT	UNIT PRICE	TOTAL
1	PUMP STATIONS	2.5	%	$1,810,900	$45,273
2	PIPELINES	1.0	%	$2,901,991	$29,020
3	WATER TREATMENT PLANTS	1.0	LS	$5,758,377	$5,758,377
4	WATER STORAGE TANKS	1.0	%	$1,569,549	$15,695
5	WELL FIELDS	1.0	%	$31,788,663	$317,887
	ANNUAL OPERATION AND MAINTENANCE COST				**$6,166,252**

Performance Metric 3

Estimated concept unit costs during debt service, after debt service, and for a hypothetical 50-year project lifespan were compared against the estimated current cost of industrial groundwater supply in order to evaluate Performance Metric 3 values for the project concept. Results of this comparison are summarized in Table GW01.3.

Table GW01.3. Performance Metric 3 results for Brackish Groundwater Desalination concept

Supply Vol.	Unit Cost ($ per 1,000 gal)			Performance Metric 3		
	Initial	Post-Debt	50-Year	Initial	Post-Debt	50-Year
5 MGD	$8.92	$5.29	$6.74	8.50	5.04	**6.42**

In examining the Performance Metric 3 results for the supply concept, it should be noted that while estimated initial and 50-year project costs are higher than estimated current groundwater costs, the project would develop new potable water supplies which could reduce or supplement groundwater production and diversify entity or regional supply portfolios, providing overall improvements to reliability. It is also noted that unit costs for the concept decrease substantially after retirement of debt service, and thus if the project is able to secure funding with more favorable terms than the default assumptions for the study, both initial and life-cycle Performance Metric 3 values would decrease.

Considerations that Could Impact Cost

The project components and assumptions for the Brackish Groundwater Desalination concept are intended to be reasonable for a non-site-specific and planning-level analysis based on available information on sources, water demands, and other considerations. Due to the multiple potential manners in which a brackish groundwater project could be implemented within the study area and the potential impacts of site-specific considerations on facility components, project cost could vary from the estimates presented in this memorandum. Factors which could impact project cost include, but are not limited to:

- Development of infrastructure outside of the industrial aggregation served, which would likely increase costs for transmission, land purchase, easements, crossings of other public or private infrastructure, land survey, and environmental assessments.
- Lower well productivity or the need for greater well spacing than assumed by the Phase 2A study, which would increase construction cost and potentially annual energy and O&M costs.
- If indicated by preliminary engineering, pilot well testing, or other studies, relocation of well facilities to different strata or a more favorable location for production
- If indicated by pilot well testing or other analyses, adjustment of treatment to accommodate TDS or other quality characteristics different than those assumed in this study.
- Potential need for extensive crossing of existing infrastructure on industrial sites in order to reach points of demand.

- Specific water quality requirements at industrial facilities, which could result in either additional cost at the facility level or adjustments to the overall treatment requirements and design for the concept.

- Site-specific characteristics which could impact required pump-station horsepower, storage size, transmission distance and sizing, or other costing assumptions.

- Implementation of the concept in an alternate manner such as a municipal supply or shared municipal-industrial project.

- The specific financing approach utilized to support project development.

It should also be noted that costs in this memorandum are presented for a reference month of October 2021. National and international economic drivers and materials markets are prone to fluctuations which cannot always be accurately predicted and present a source of uncertainty regarding the cost of project development in the future.

Other Considerations

Water Quality

Exact source raw water quality for a deep Brackish Groundwater Desalination concept is unknown and likely site-specific, but the concept is intended to utilize water of substantially higher input TDS than current groundwater sources. The project concept would produce high-quality potable treated water for delivery to end users.

Reliability

The long-term reliability of brackish groundwater sourced from a deep formation in the vicinity of current industrial aggregations is unknown. Because much of the CAGWCD has historically had access to large volumes of high-quality groundwater from the 400-ft to 2,800-ft sands, information on the coverage, productivity, quality, and long-term production sustainability of the Catahoula Aquifer and other deep formations is limited. Evaluation of the reliability of these deeper supplies would likely involve pilot well testing and dedicated feasibility studies.

Implementation Feasibility

The ability of brackish groundwater desalination infrastructure to be developed remote from river or effluent treatment infrastructure potentially supports the feasibility of brackish groundwater concepts in the study area. Productivity of deep brackish supplies for specific sites is largely uncertain, and as with other project types siting of additional infrastructure on developed industrial sites could create challenges in some cases. It is recommended that pursuit of a brackish groundwater desalination supply include detailed feasibility analysis, including assessment of source water quality, industrial user quality needs, associated infrastructure siting and routing options, and viable well locations for achieving desired intake rates.

Permitting, Development, and Environmental Considerations

Environmental impacts of the project concept are anticipated to be limited. Portions of infrastructure development could create some construction disturbance requiring mitigation. The concept as envisioned for this study would consist primarily of infrastructure development on existing treatment and industrial sites and through existing utility corridors or rights-of-way, with the pre-disturbed nature of these areas likely reducing habitat impacts and resulting in minimal mitigation requirements.

Project development for a Brackish Groundwater Desalination concept would be expected to require some degree of permitting and agency coordination, potentially including:

- Compliance with State, parish, and local construction permitting and notification procedures, as applicable for the project site.
- Stormwater discharge permitting and obtaining coverage of construction general permitting through the Louisiana Pollution Discharge Elimination System (LPDES).
- For projects with elements outside of the associated industrial aggregation, obtaining of easements, permissions for infrastructure crossings, and purchase of land as applicable.
- For any concept implementation which requires development of infrastructure components in wetland areas, U.S. Army Corps of Engineers Section 404 Permitting and mitigation planning, potentially also including development of a National Environmental Policy Act (NEPA) Environmental Impact Statement (EIS).
- Well permitting through the Capital Area Groundwater Conservation Commission.
- Well drilling notification and well registration through the DNR Office of Conservation.

Other Benefits

In addition to the basic benefit of providing a new source of water supply to reduce or supplement existing groundwater production, development of brackish groundwater desalination offers a number of potential benefits to the study area:

- While the feasibility and productivity of a brackish groundwater project would be expected to by site, brackish groundwater is not inherently tied to close proximity to surface water or treated effluent sites and thus could potentially be used to meet water demands for more remote industrial facilities or communities without requiring extensive transmission infrastructure.
- The concept allows utilization of a source water of higher TDS than the other potable water concepts examined by the study.
- Produced water quality from a brackish groundwater desalination project would be a high-quality source suitable for potable uses and could serve municipal demand in addition to industry.

- Integration of an alternative groundwater supply sourced from outside of traditionally utilized formations diversifies the region's overall supply profile and provides long term redundancy and improved reliability.

- Deep groundwater offers additional reliability through drought resistance over short timescales, and thus could provide consistent and reliable supply during periods when surface water or effluent availability are reduced.

- Brackish groundwater treatment could be implemented in conjunction with scavenger wells to allow beneficial use of produced water and improve produced water characteristics for blending with other supplies.

References

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STRATEGY CONCEPT TECHNICAL MEMORANDUM: MUNICIPAL EFFLUENT RECLAMATION

Strategy Concept Summary	
Strategy ID:	RU01
Strategy Type:	Reuse
Supply Quantity:	Variable (5 and 10 MGD concepts assessed)
Strategy Capital Cost:	$45,555,774 (5 MGD Concept) $68,851,874 (10 MGD Concept)
Life Cycle Unit Cost:	$2.20 per 1,000 gallons (5 MGD Concept) $1.89 per 1,000 gallons (10 MGD Concept)

Strategy Description

Several large municipal wastewater treatment facilities, including the City of Baton Rouge North and South Wastewater Treatment Plants (WWTPs), in addition to being located adjacent to municipal demand centers, are located within approximately three to five miles of multiple industrial aggregations. While the effluent from these facilities is currently discharged to receiving waters, this proximity crates the possibility of instead routing a portion of treated effluent through additional advanced treatment and disinfection processes for conveyance to industrial demand centers. This memorandum summarizes planning-level evaluations of a hypothetical municipal effluent reclamation supply to serve industry, including concept assumptions, cost estimation and comparison to current groundwater cost, and considerations related to quality, reliability, feasibility, permitting, and possibility of extended benefits.

Supply Development Assumptions and Applicability

Overview

Analyses of a Municipal Effluent Reclamation project for the Phase 2A study examined a generalized project concept with potential applicability to one or more of the industrial aggregations within the study area. This general, planning-level approach allows investigation of project development considerations and assessment of the approximate magnitude of cost associated with favorable implementation conditions for the strategy. Should one or more entities within the study area pursue development of a municipal effluent reuse project, it is anticipated that site-specific considerations on logistics, quality needs, and cost would be examined through detailed feasibility and preliminary engineering analyses. It should be noted that the project concepts for the Phase 2A study are planning-level analyses and not intended for construction, bid, or permitting purposes.

Project Concept Sizing

Project concept sizing considered both the availability of the raw source supply and the potential water demand to be served. Analyses presented in this memorandum assume sourcing of effluent from the City of Baton Rouge North WWTP, which has a permitted discharge of 54 MGD, an average flow of approximately 25 MGD, and a minimum (weekly averaged) discharge of approximately 12.4 MGD. The City's South WWTP has also recently undergone extensive renovation and expansion and could also provide opportunities for reclaimed supply. Selection of representative concept sizes also examined the historic groundwater production within industrial aggregations, both in terms of total production and pumpage from the sands of greatest concern for saltwater intrusion. Based on this examination, it was determined that 5 MGD and 10 MGD supply concepts would be applicable for meeting some or all demand at various industrial aggregations.

Other Assumptions

The following assumptions were applied in estimating project concept cost and examining implementation considerations:

- That the partially treated effluent source is fully reliable.
- The project is developed and implemented by the entities within an industrial aggregation (in conjunction with the City of Baton Rouge as provider and host of additional treatment components) to meet industrial water demand within that aggregation.
- There is sufficient demand for non-potable water.
- Infrastructure is developed at an existing WWTP site, in pre-disturbed conveyance corridors, and in the immediate vicinity of the industrial aggregation utilizing the produced supply, resulting in limited transmission distance, land purchase cost, and crossings of public infrastructure.
- That development by industry on existing sites permits relatively rapid project development relative to development of municipal infrastructure on a minimally disturbed site.
- Project construction involves the following major infrastructure components:
  - A satellite membrane bioreactor module and disinfection module developed on the site of an existing treatment plant and supplementing the current treatment train.
  - On-site ground storage tanks to provide buffering storage for variations in flow or demand.
  - A discharge pump station, with delivery to the industrial aggregation within five miles.
  - Associated piping.
- Detailed project finance, infrastructure peaking, and other infrastructure details are consistent with the overall costing assumptions as described in the Phase 2A study report.

Strategy Cost Analysis

Estimated Cost Breakdown

A preliminary planning-level cost estimate for the Municipal Effluent Reclamation concept was developed through the costing tool developed for the study and based upon the assumptions discussed in this memorandum and the Phase 2A study report. Annualized cost components such as debt service and facility operations and maintenance expenses, were developed utilizing the standardized assumptions summarized in the Phase 2A study report. Estimated costs for the two concept sizes are summarized in Table RU01.1, with more detailed cost profile sheets in Tables RU01.2 and RU01.3.

Table RU01.1. Cost summary for Municipal Effluent Reclamation New concept

Supply Vol.	Capital Cost	Annual Cost		Unit Cost	
		Initial	Post-Debt	Initial	Post-Debt
5 MGD	$45,555,774	$5,935,786	$2,730,433	$1,059/ ac-ft $3.25 / 1,000 gal	$487/ ac-ft $1.50 / 1,000 gal
10 MGD	$68,851,874	$9,796,826	$4,952,334	$874/ ac-ft $2.68 / 1,000 gal	$442/ ac-ft $1.36 / 1,000 gal

Table RU01.2. Preliminary planning-level cost estimate for 5 MGD concept

PRELIMINARY PLANNING-LEVEL COST ESTIMATE	OCTOBER 2021 COST INDEX
STRATEGY: Municipal Effluent Reclamation (5 MGD)	

PROJECT CAPITAL COST SUMMARY					
ITEM	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**
1	CONSTRUCTION COST	1	LS	$30,709,968	$30,709,968
2	ENG., FINANCIAL, LEGAL SERVICES, AND CONTINGENCIES	1	LS	$10,405,090	$10,405,090
3	LAND AND EASEMENTS	1	LS	$1,908,060	$1,908,060
4	ENVIRONMENTAL - STUDIES AND MITIGATION	1	LS	$125,000	$125,000
5	INTEREST DURING CONSTRUCTION	1	LS	$2,407,656	$2,407,656
	PROJECT CAPITAL COST				**$45,555,774**

ANNUAL COST SUMMARY		
ITEM	**DESCRIPTION**	**TOTAL**
1	DEBT SERVICE (20 YEARS AT 3.5% INTEREST)	$3,205,353
2	OPERATION AND MAINTENANCE (O&M)	$2,646,819
3	PUMPING ENERGY COSTS	$83,614
	TOTAL ANNUAL COST - DURING DEBT SERVICE	**$5,935,786**
	TOTAL ANNUAL COST - AFTER DEBT SERVICE	**$2,730,433**

UNIT COST SUMMARY		
ITEM	**DESCRIPTION**	**ANNUAL TOTAL**
1	ESTIMATED YIELD (ACRE-FEET PER YEAR)	5,605
2	ANNUAL COST - DURING DEBT SERVICE	$5,935,786
3	ANNUAL COST - AFTER DEBT SERVICE	$2,730,433
	TOTAL UNIT COST DURING DEBT SERVICE ($ PER ACRE-FOOT PER YEAR)	**$1,059**
	TOTAL UNIT COST AFTER DEBT SERVICE ($ PER ACRE-FOOT PER YEAR)	**$487**

CONSTRUCTION COST SUMMARY					
ITEM	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**
1	PUMP STATIONS	1	LS	$2,511,400	$2,511,400
2	PIPELINES	1	LS	$6,867,976	$6,867,976
3	WASTEWATER RECLAMATION PLANTS	1	LS	$19,761,043	$19,761,043
4	WATER STORAGE TANKS	1	LS	$1,569,549	$1,569,549
	PROJECT COST				**$30,709,968**

OPERATION AND MAINTENANCE (O&M) COST SUMMARY					
ITEM	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**
1	PUMP STATIONS	2.5	%	$2,511,400	$62,785
2	PIPELINES	1.0	%	$6,867,976	$68,680
3	WASTEWATER RECLAMATION PLANTS	1.0	LS	$2,499,659	$2,499,659
4	WATER STORAGE TANKS	1.0	%	$1,569,549	$15,695
	ANNUAL OPERATION AND MAINTENANCE COST				**$2,646,819**

Table RU01.3. Preliminary planning-level cost estimate for 10 MGD concept

PRELIMINARY PLANNING-LEVEL COST ESTIMATE	OCTOBER 2021 COST INDEX
STRATEGY: Municipal Effluent Reclamation (10 MGD)	

PROJECT CAPITAL COST SUMMARY					
ITEM	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**
1	CONSTRUCTION COST	1	LS	$46,851,702	$46,851,702
2	ENG., FINANCIAL, LEGAL SERVICES, AND CONTINGENCIES	1	LS	$15,957,981	$15,957,981
3	LAND AND EASEMENTS	1	LS	$2,278,320	$2,278,320
4	ENVIRONMENTAL - STUDIES AND MITIGATION	1	LS	$125,000	$125,000
5	INTEREST DURING CONSTRUCTION	1	LS	$3,638,872	$3,638,872
	PROJECT CAPITAL COST				**$68,851,874**

ANNUAL COST SUMMARY		
ITEM	**DESCRIPTION**	**TOTAL**
1	DEBT SERVICE (20 YEARS AT 3.5% INTEREST)	$4,844,492
2	OPERATION AND MAINTENANCE (O&M)	$4,780,925
3	PUMPING ENERGY COSTS	$171,408
	TOTAL ANNUAL COST - DURING DEBT SERVICE	**$9,796,826**
	TOTAL ANNUAL COST - AFTER DEBT SERVICE	**$4,952,334**

UNIT COST SUMMARY		
ITEM	**DESCRIPTION**	**ANNUAL TOTAL**
1	ESTIMATED YIELD (ACRE-FEET PER YEAR)	11,209
2	ANNUAL COST - DURING DEBT SERVICE	$9,796,826
3	ANNUAL COST - AFTER DEBT SERVICE	$4,952,334
	TOTAL UNIT COST DURING DEBT SERVICE ($ PER ACRE-FOOT PER YEAR)	**$874**
	TOTAL UNIT COST AFTER DEBT SERVICE ($ PER ACRE-FOOT PER YEAR)	**$442**

CONSTRUCTION COST SUMMARY					
ITEM	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**
1	PUMP STATIONS	1	LS	$5,267,500	$5,267,500
2	PIPELINES	1	LS	$8,802,302	$8,802,302
3	WASTEWATER RECLAMATION PLANTS	1	LS	$29,642,687	$29,642,687
4	WATER STORAGE TANKS	1	LS	$3,139,213	$3,139,213
	PROJECT COST				**$46,851,702**

OPERATION AND MAINTENANCE (O&M) COST SUMMARY					
ITEM	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**
1	PUMP STATIONS	2.5	%	$5,267,500	$131,688
2	PIPELINES	1.0	%	$8,802,302	$88,023
3	WASTEWATER RECLAMATION PLANTS	1.0	LS	$4,529,823	$4,529,823
4	WATER STORAGE TANKS	1.0	%	$3,139,213	$31,392
	ANNUAL OPERATION AND MAINTENANCE COST				**$4,780,925**

Performance Metric 3

Estimated concept unit costs during debt service, after debt service, and for a hypothetical 50-year project lifespan were compared against the estimated current cost of industrial groundwater supply in order to evaluate Performance Metric 3 values for the project concept. Results of this comparison are summarized in Table RU01.4.

Table RU01.4. Performance Metric 3 results for Municipal Effluent Reclamation concept

Supply Vol.	Unit Cost ($ per 1,000 gal)			Performance Metric 3		
	Initial	Post-Debt	50-Year	Initial	Post-Debt	50-Year
5 MGD	$3.25	$1.50	$2.20	3.10	1.42	**2.09**
10 MGD	$2.68	$1.36	$1.89	2.55	1.29	**1.80**

In examining the Performance Metric 3 results for the supply concept, it should be noted that while estimated initial and 50-year project costs are higher than estimated current groundwater costs, the project would develop new water supplies which could reduce or supplement groundwater production and diversify entity or regional supply portfolios, providing overall improvements to reliability. It is also noted that unit costs for the concept decrease substantially after retirement of debt service, and thus if the project is able to secure funding with more favorable terms than the default assumptions for the study, both initial and life-cycle Performance Metric 3 values would decrease. In comparing these results to other supply concepts, it should be remembered that the concept as currently envisioned would not produce potable water, and .thus would be limited to serving non-potable demands; an effluent reclamation concept to produce potable water would incur substantial additional treatment cost and a corresponding increase in Performance Metric 3 result.

Considerations that Could Impact Cost

The project components and assumptions for the Municipal Effluent Reclamation concept are intended to be reasonable for a non-site-specific and planning-level analysis based on available information on sources, water demands, and other considerations. Due to the multiple potential manners in which a wastewater reuse project could be implemented within the study area and the potential impacts of site-specific considerations on facility components, project cost could vary from the estimates presented in this memorandum. Factors which could impact project cost include, but are not limited to:

- Development of infrastructure outside of existing treatment sites, rights of way, and the industrial aggregation served, which would likely increase costs for transmission, land purchase, easements, crossings of other public or private infrastructure, land survey, and environmental assessments.
- Potential need for extensive crossing of existing infrastructure on industrial sites in order to reach points of demand.

- Specific water quality requirements at industrial facilities, which could result in either additional cost at the facility level or adjustments to the overall treatment requirements and design for the concept.
- An overall limitation on the non-potable industrial water demand which could be served by the concept, necessitating a more costly potable reuse approach in order to utilize effluent supply.
- Changes in the source wastewater treatment facility, its treatment processes, or the area served.
- Site-specific characteristics which could impact required pump-station horsepower, storage size, transmission distance and sizing, or other costing assumptions.
- Implementation of the concept in an alternate manner such as a municipal supply or shared municipal-industrial project.
- The specific financing approach utilized to support project development.

It should also be noted that costs in this memorandum are presented for a reference month of October 2021. National and international economic drivers and materials markets are prone to fluctuations which cannot always be accurately predicted and present a source of uncertainty regarding the cost of project development in the future.

Other Considerations

Water Quality

Raw source water quality for the project would vary based on the source facility, but for purposes of the concept analysis is assumed to be effluent which has been processed through primary, secondary, and tertiary treatment. The project concept is intended produce non-potable but treated and disinfected water suitable for industrial use and potentially for outdoor uses with limited amounts of human contact.

Reliability

As noted in a previous section, the City of Baton Rouge North WWTP has a minimum (weekly averaged) discharge of approximately 12.4 MGD. The source is therefore considered to be generally reliable, particularly for the smaller 5 MGD strategy concept. If more detailed future feasibility or preliminary engineering analysis identifies source reliability impacts from flow patterns on daily or sub-daily timescales, reliability could be enhanced through development of additional storage infrastructure. The City of Baton Rouge South WWTP has recently undergone major renovations and offers another potential large source of treated effluent.

Implementation Feasibility

The overall substantial volume of treated municipal effluent within the study area suggests potential feasibility for some degree of municipal effluent reuse. The presence of major industrial demand centers withing relatively close proximity to these sources further suggest that opportunities may exist to utilize these supplies to meet non-potable industrial demands. It is recommended that pursuit of a municipal effluent reclamation supply include detailed feasibility analysis, including assessment of source water quality, industrial user non-potable water demand and specific quality needs, and associated infrastructure siting and routing options.

Permitting, Development, and Environmental Considerations

Environmental impacts of the project concept are anticipated to be limited. Portions of infrastructure development could create some construction disturbance requiring mitigation. The concept as envisioned for this study would consist primarily of infrastructure development on existing treatment and industrial sites and through existing utility corridors or rights-of-way, with the pre-disturbed nature of these areas likely reducing habitat impacts and resulting in minimal mitigation requirements. Utilization of currently discharged treated effluent would reduce return flows to receiving water bodies. However, the associated discharges are currently extremely small in comparison with the flow of the Mississippi River, and their reduction would not be expected to have an appreciable impact on instream flows.

Project development for a Municipal Effluent Reuse concept would be expected to require some degree of permitting and agency coordination, potentially including:

- Compliance with State, parish, and local construction permitting and notification procedures, as applicable for the project site.
- Stormwater discharge permitting and obtaining coverage of construction general permitting through the Louisiana Pollution Discharge Elimination System (LPDES).
- For projects with elements outside of the associated industrial aggregation, obtaining of easements, permissions for infrastructure crossings, and purchase of land as applicable.
- For any concept implementation which requires development of infrastructure components in wetland areas, U.S. Army Corps of Engineers Section 404 Permitting and mitigation planning, potentially also including development of a National Environmental Policy Act (NEPA) Environmental Impact Statement (EIS).
- State and federal wastewater facility and discharge permitting or permit amendment.

Other Benefits

In addition to the basic benefit of providing a new source of water supply to reduce or supplement existing groundwater production, development of reuse supply offers a number of potential benefits to the study area:

- A reuse concept would allow a current waste stream to be repurposed to the beneficial use of addressing non-potable water demands.

- Produced water quality from a reuse project, in addition to serving industrial process demands, could be utilized to serve other on-site demands or be utilized for municipal green space irrigation.

- Integration of reuse supply diversifies the region's overall supply profile and provides long term redundancy and improved reliability.

- Development of enhanced treatment modules at existing facilities could provide additional employment opportunities and training opportunities for advanced wastewater treatment.

References

U.S. Environmental Protection Agency. (2021). *Enforcement and Compliance History Online*. [Dataset.] Accessed November 2021 at < https://echo.epa.gov/>

STRATEGY CONCEPT TECHNICAL MEMORANDUM: INDUSTRIAL EFFLUENT RECLAMATION

Strategy Concept Summary	
Strategy ID:	RU02
Strategy Type:	Reuse
Supply Quantity:	Variable (5 MGD concept assessed)
Strategy Capital Cost:	$47,353,648
Life Cycle Unit Cost:	$2.70 per 1,000 gallons

Strategy Description

Industrial facilities, for purposes of economics, efficiency, and environmental stewardship, frequently practice extensive internal reuse of water, recycling flow through multiple processes or process cycles. This recycling, however, is not an unending process, and eventually changes in quality make additional iterations of reuse less economical than introduction of new water. For the CAGWCD parishes, concerns over saltwater intrusion into existing groundwater source strata and subsidence risk could alter this economic balance point and promote additional reuse of water. While a portion of this reclamation could occur internal to individual facilities, there could also be benefit for a coordinated approach of combining treated waste streams for multiple facilities for more advanced treatment at common polishing facility and returning water to the participating entities. This memorandum summarizes planning-level evaluations of a hypothetical industrial effluent reclamation supply to serve industry, including concept assumptions, cost estimation and comparison to current groundwater cost, and considerations related to quality, reliability, feasibility, permitting, and possibility of extended benefits.

Supply Development Assumptions and Applicability

Overview

Analyses of an Industrial Effluent Reclamation project for the Phase 2A study examined a generalized project concept with potential applicability to one or more of the industrial aggregations within the study area. This general, planning-level approach allows investigation of project development considerations and assessment of the approximate magnitude of cost associated with favorable implementation conditions for the strategy. Should one or more entities within the study area pursue development of an industrial effluent reclamation project, it is anticipated that site-specific considerations on logistics, quality needs, and cost would be examined through detailed feasibility and preliminary engineering analyses. It should be noted that the project concepts for the Phase 2A study are planning-level analyses and not intended for construction, bid, or permitting purposes.

Project Concept Sizing

Project concept sizing considered both the availability of the raw source supply and the potential water demand to be served. Analyses presented in this memorandum assume sourcing of effluent from facilities within industrial aggregations; monthly average discharge from individual facilities varies from almost negligible potential source amounts to greater than 10 MGD. Selection of representative concept sizes also examined the historic groundwater production within industrial aggregations, both in terms of total production and pumpage from the sands of greatest concern for saltwater intrusion. Based on this examination, it was determined that a 5 MGD supply concepts would be applicable for meeting demand at various industrial aggregations.

Other Assumptions

The following assumptions were applied in estimating project concept cost and examining implementation considerations:

- That the partially treated effluent source is fully reliable.
- The project is developed and implemented by the entities within an industrial aggregation to meet industrial water demand within that aggregation.
- There is sufficient demand for non-potable water.
- Infrastructure is developed in the immediate vicinity of the industrial aggregation utilizing the produced supply, resulting in limited transmission distance, land purchase cost, and crossings of public infrastructure.
- That development by industry on existing sites permits relatively rapid project development relative to development of municipal infrastructure on a minimally disturbed site.
- Project construction involves the following major infrastructure components:
    - An advanced treatment facility developed on the site of an existing treatment plant.
    - On-site ground storage tanks to provide buffering storage for variations in flow or demand.
    - A discharge pump station located within 1,320 ft (1/4 of a mile) transmission distance from delivery to take points or existing on-site transmission.
    - Associated piping.
- Detailed project finance, infrastructure peaking, and other infrastructure details are consistent with the overall costing assumptions as described in the Phase 2A study report.

Strategy Cost Analysis

Estimated Cost Breakdown

A preliminary planning-level cost estimate for the Industrial Effluent Reclamation concept was developed through the costing tool developed for the study and based upon the assumptions discussed in this memorandum and the Phase 2A study report. Annualized cost components such as debt service and facility operations and maintenance expenses, we redeveloped utilizing the standardized assumptions summarized in the Phase 2A study report. Estimated costs for the two concept sizes are summarized in Table RU02.1, with a more detailed cost profile sheet in Table RU02.2.

Table RU02.1. Cost summary for Industrial Effluent Reclamation concept

Supply Vol.	Capital Cost	Annual Cost		Unit Cost	
		Initial	Post-Debt	Initial	Post-Debt
5 MGD	$47,353,648	$6,921,874	$3,590,020	$1,235 / ac-ft $3.79 / 1,000 gal	$641 / ac-ft $1.97 / 1,000 gal

Table RU02.2. Preliminary planning-level cost estimate for 5 MGD concept

PRELIMINARY PLANNING-LEVEL COST ESTIMATE	OCTOBER 2021 COST INDEX
STRATEGY: Industrial Effluent Reclamation (5 MGD)	

PROJECT CAPITAL COST SUMMARY					
ITEM	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**
1	CONSTRUCTION COST	1	LS	$32,866,601	$32,866,601
2	ENG., FINANCIAL, LEGAL SERVICES, AND CONTINGENCIES	1	LS	$11,487,412	$11,487,412
3	LAND AND EASEMENTS	1	LS	$490,710	$490,710
4	ENVIRONMENTAL - STUDIES AND MITIGATION	1	LS	$6,250	$6,250
5	INTEREST DURING CONSTRUCTION	1	LS	$2,502,675	$2,502,675
	PROJECT CAPITAL COST				**$47,353,648**

ANNUAL COST SUMMARY		
ITEM	**DESCRIPTION**	**TOTAL**
1	DEBT SERVICE (20 YEARS AT 3.5% INTEREST)	$3,331,854
2	OPERATION AND MAINTENANCE (O&M)	$3,521,038
3	PUMPING ENERGY COSTS	$68,981
	TOTAL ANNUAL COST - DURING DEBT SERVICE	**$6,921,874**
	TOTAL ANNUAL COST - AFTER DEBT SERVICE	**$3,590,020**

UNIT COST SUMMARY		
ITEM	**DESCRIPTION**	**ANNUAL TOTAL**
1	ESTIMATED YIELD (ACRE-FEET PER YEAR)	5,605
2	ANNUAL COST - DURING DEBT SERVICE	$6,921,874
3	ANNUAL COST - AFTER DEBT SERVICE	$3,590,020
	TOTAL UNIT COST DURING DEBT SERVICE ($ PER ACRE-FOOT PER YEAR)	**$1,235**
	TOTAL UNIT COST AFTER DEBT SERVICE ($ PER ACRE-FOOT PER YEAR)	**$641**

CONSTRUCTION COST SUMMARY					
ITEM	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**
1	PUMP STATIONS	1	LS	$1,810,900	$1,810,900
2	PIPELINES	1	LS	$317,962	$317,962
3	WASTEWATER RECLAMATION PLANTS	1	LS	$1,569,549	$1,569,549
4	WATER STORAGE TANKS	1	LS	$29,168,190	$29,168,190
	PROJECT COST				**$32,866,601**

OPERATION AND MAINTENANCE (O&M) COST SUMMARY					
ITEM	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**
1	PUMP STATIONS	2.5	%	$1,810,900	$45,273
2	PIPELINES	1.0	%	$317,962	$3,180
3	WASTEWATER RECLAMATION PLANTS	1.0	LS	$1,569,549	$15,695
4	WATER STORAGE TANKS	1.0	%	$3,456,891	$3,456,891
	ANNUAL OPERATION AND MAINTENANCE COST				**$3,521,038**

Performance Metric 3

Estimated concept unit costs during debt service, after debt service, and for a hypothetical 50-year project lifespan were compared against the estimated current cost of industrial groundwater supply in order to evaluate Performance Metric 3 values for the project concept. Results of this comparison are summarized in Table RU02.3.

Table RU02.3. Performance Metric 3 results for Industrial Effluent Reclamation concept

Supply Vol.	Unit Cost ($ per 1,000 gal)			Performance Metric 3		
	Initial	Post-Debt	50-Year	Initial	Post-Debt	50-Year
5 MGD	$3.79	$1.97	$2.70	3.61	1.87	**2.57**

In examining the Performance Metric 3 results for the supply concept, it should be noted that while estimated initial and 50-year project costs are higher than estimated current groundwater costs, the project would develop new water supplies which could reduce or supplement groundwater production and diversify entity or regional supply portfolios, providing overall improvements to reliability. It is also noted that unit costs for the concept decrease substantially after retirement of debt service, and thus if the project is able to secure funding with more favorable terms than the default assumptions for the study, both initial and life-cycle Performance Metric 3 values would decrease. In comparing these results to other supply concepts, it should be remembered that the concept as currently envisioned would not produce potable water, and .thus would be limited to serving non-potable demands; an effluent reclamation concept to produce potable water would incur substantial additional treatment cost and a corresponding increase in Performance Metric 3 result.

Considerations that Could Impact Cost

The project components and assumptions for the Industrial Effluent Reclamation concept are intended to be reasonable for a non-site-specific and planning-level analysis based on available information on sources, water demands, and other considerations. Due to the multiple potential manners in which a wastewater reuse project could be implemented within the study area and the potential impacts of site-specific considerations on facility components, project cost could vary from the estimates presented in this memorandum. Factors which could impact project cost include, but are not limited to:

- Development of infrastructure outside of the industrial aggregation served, which would likely increase costs for transmission, land purchase, easements, crossings of other public or private infrastructure, land survey, and environmental assessments.
- Potential need for extensive crossing of existing infrastructure on industrial sites in order to reach points of demand.
- Specific water quality requirements at industrial facilities, which could result in either additional cost at the facility level or adjustments to the overall treatment requirements and design for the concept.

- An overall limitation on the non-potable industrial water demand which could be served by the concept, necessitating a more costly potable reuse approach in order to utilize effluent supply.
- For projects supplied by the combined effluent of multiple industrial entities, changes in the treatment process or effluent availability from one or more source entities
- Site-specific characteristics which could impact required pump-station horsepower, storage size, transmission distance and sizing, or other costing assumptions.
- The specific financing approach utilized to support project development.

It should also be noted that costs in this memorandum are presented for a reference month of October 2021. National and international economic drivers and materials markets are prone to fluctuations which cannot always be accurately predicted and present a source of uncertainty regarding the cost of project development in the future.

Other Considerations

Water Quality

Raw source water quality for the project would vary based on the source industrial entities, but for purposes of the concept analysis is assumed to be industrial effluent which has been processed through to acceptable standards for river discharge. The project concept is intended produce non-potable but treated water suitable for industrial use.

Reliability

Analyses presented in this memorandum assume sourcing of effluent from one or more industrial facilities within or adjacent to the industrial aggregation served by the project concept. Use of industrial rather than municipal effluent may have positive benefits for source reliability, as some industrial uses are less subject to seasonal or climatic variations in water demand, and therefore may generate a steadier volume of source effluent. Source effluent volume would be contingent on continued operation of contributing facilities at anticipated levels at the time of design; however, reduced effluent generation from facility closure or alteration could be potentially offset by an associated reduction in water demand. The source is therefore considered to be potentially reliable for supporting a small industrial reuse facility.

Implementation Feasibility

The overall volume of treated industrial effluent within the study area suggests potential feasibility for some degree of industrial effluent reclamation. It is recommended that pursuit of an industrial effluent reclamation supply include detailed feasibility analysis, including assessment of source water quality, industrial user non-potable water demand and specific quality needs, and associated infrastructure and routing options.

Permitting, Development, and Environmental Considerations

Environmental impacts of the project concept are anticipated to be limited. Portions of infrastructure development could create some construction disturbance requiring mitigation. The concept as envisioned for this study would consist primarily of infrastructure development on existing treatment and industrial sites and through existing utility corridors or rights-of-way, with the pre-disturbed nature of these areas likely reducing habitat impacts and resulting in minimal mitigation requirements. Utilization of currently discharged treated effluent would reduce return flows to receiving water bodies. However, the associated discharges are currently extremely small in comparison with the flow of the Mississippi River, and their reduction would not be expected to have an appreciable impact on instream flows.

Project development for an Industrial Effluent Reuse concept would be expected to require some degree of permitting and agency coordination, potentially including:

- Compliance with State, parish, and local construction permitting and notification procedures, as applicable for the project site.
- Stormwater discharge permitting and obtaining coverage of construction general permitting through the Louisiana Pollution Discharge Elimination System (LPDES).
- For projects with elements outside of the associated industrial aggregation, obtaining of easements, permissions for infrastructure crossings, and purchase of land as applicable.
- For any concept implementation which requires development of infrastructure components in wetland areas, U.S. Army Corps of Engineers Section 404 Permitting and mitigation planning, potentially also including development of a National Environmental Policy Act (NEPA) Environmental Impact Statement (EIS).
- State and federal wastewater facility and discharge permitting or permit amendment.

Other Benefits

In addition to the basic benefit of providing a new source of water supply to reduce or supplement existing groundwater production, development of reuse supply offers a number of potential benefits to the study area:

- A reuse concept would allow a current waste stream to be repurposed to the beneficial use of addressing non-potable water demands.
- Because an Industrial Effluent Reclamation concept ties effluent source directly to industrial facilities, reduction in source availability caused by closure or changes at one of the contributing facilities could be offset by the associated reduction in water demand.
- Produced water quality from a reuse project, in addition to serving industrial process demands, could be utilized to serve other on-site demands or be utilized for municipal green space irrigation.

- Integration of reuse supply diversifies the region's overall supply profile and provides long term redundancy and improved reliability.

- Development of enhanced treatment modules at or sourced from existing facilities could provide additional employment opportunities and training opportunities for advanced wastewater treatment.

References

U.S. Environmental Protection Agency. (2021). *Enforcement and Compliance History Online*. [Dataset.] Accessed November 2021 at < https://echo.epa.gov/>

STRATEGY CONCEPT TECHNICAL MEMORANDUM: INSTITUTIONAL EFFLUENT RECLAMATION (NEW)

Strategy Concept Summary	
Strategy ID:	RU03
Strategy Type:	Reuse
Supply Quantity:	Variable (0.5 and 1.0 MGD concepts assessed)
Strategy Capital Cost:	$14,669,076 (0.5 MGD concept) $20,076,486 (1.0 MGD concept)
Life Cycle Unit Cost:	$5.23 per 1,000 gallons (0.5 MGD concept) $4.07 per 1,000 gallons (1.0 MGD concept)

Strategy Description

The presence of a number of institutional water users, including universities and correctional facilities, in the CAGWCD parishes offers a valuable opportunity to combine implementation of innovative water supply solutions with practical education and job training. In particular, the characteristics of these institutional users (production of a municipal-type waste stream, extensive green space, and existing educational or vocational training structures) could make implementation of on-site effluent reclamation a valuable program. In addition to educational and social benefits, a reuse project would also meet non-potable needs currently met by treated groundwater from traditional production zones. This memorandum summarizes planning-level evaluations of a hypothetical institutional effluent reclamation supply, including concept assumptions, cost estimation and comparison to current groundwater cost, and considerations related to quality, reliability, feasibility, permitting, and possibility of extended benefits.

Supply Development Assumptions and Applicability

Overview

Analyses of an Institutional Effluent Reclamation project for the Phase 2A study examined a generalized project concept with potential applicability to one or more of the institutional sites within the study area. This general, planning-level approach allows investigation of project development considerations and assessment of the approximate magnitude of cost associated with favorable implementation conditions for the strategy. Should one or more entities within the study area pursue development of an institutional effluent reclamation project, it is anticipated that site-specific considerations on logistics, quality needs, and cost would be examined through detailed feasibility and preliminary engineering analyses. It should be noted that the project concepts for the Phase 2A study are planning-level analyses and not intended for construction, bid, or permitting purposes.

Project Concept Sizing

Project concept sizing considered both the availability of the source supply and the potential water demand to be served. Analyses presented in this memorandum assume sourcing of effluent from the institutional user itself. Major educational and correctional institutions within the study area have average flows from on-site wastewater treatment plant (WWTP) treatment facilities ranging from nearly negligible amounts (in the cases of facilities primarily discharging to municipal WWTPs) to approximately 1.5 MGD. Applicable non-potable demand would vary by institutional site and the amount of green space practical to convert to non-potable reuse supply. For this reason, 0.5 MGD and 1.0 MGD project concepts were selected to represent a reasonable range of project implementation scales while being of sufficient size to create valuable education and job training benefits.

Other Assumptions

The following assumptions were applied in estimating project concept cost and examining implementation considerations:

- That the effluent source is fully reliable.
- There is sufficient demand for non-potable water.
- Infrastructure is developed primarily on the institutional site utilizing the produced supply, resulting in limited transmission distance, land purchase cost, and crossings of public infrastructure.
- That development on existing institutional project sites and the limited project size permits relatively rapid project development.
- Project construction involves the following major infrastructure components:
    - A wastewater treatment facility (primary, secondary, and tertiary treatment trains) with a disinfection module developed on the institutional site.
    - On-site ground storage tanks to provide buffering storage for variations in flow or demand.
    - A discharge pump station within one-mile cumulative distance of various points of use.
    - Associated piping.
- Detailed project finance, infrastructure peaking, and other infrastructure details are consistent with the overall costing assumptions as described in the Phase 2A study report.

Strategy Cost Analysis

Estimated Cost Breakdown

A preliminary planning-level cost estimate for the Institutional Effluent Reclamation (New) concept was developed through the costing tool developed for the study and based upon the assumptions discussed in this memorandum and the Phase 2A study report. Annualized cost components such as debt service and facility operations and maintenance expenses, were developed utilizing the standardized assumptions summarized in the Phase 2A study report. Estimated costs for the two concept sizes are summarized in Table RU03.1, with more detailed cost profile sheets in Tables RU03.2 and RU03.3.

Table RU03.1. Cost summary for Institutional Effluent Reclamation (New) concept

Supply Vol.	Capital Cost	Annual Cost		Unit Cost	
		Initial	Post-Debt	Initial	Post-Debt
0.5 MGD	$14,669,076	$1,574,091	$541,959	$2,811/ ac-ft $8.62 / 1,000 gal	$968/ ac-ft $2.97 / 1,000 gal
1 MGD	$20,076,486	$2,335,849	$923,246	$2,084/ ac-ft $6.40 / 1,000 gal	$824/ ac-ft $2.53 / 1,000 gal

Table RU03.2. Preliminary planning-level cost estimate for 0.5 MGD concept

PRELIMINARY PLANNING-LEVEL COST ESTIMATE	OCTOBER 2021 COST INDEX
STRATEGY: Institutional Effluent Reclamation (0.5 MGD)	

PROJECT CAPITAL COST SUMMARY					
ITEM	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**
1	CONSTRUCTION COST	1	LS	$9,872,498	$9,872,498
2	ENG., FINANCIAL, LEGAL SERVICES, AND CONTINGENCIES	1	LS	$3,438,277	$3,438,277
3	LAND AND EASEMENTS	1	LS	$558,030	$558,030
4	ENVIRONMENTAL - STUDIES AND MITIGATION	1	LS	$25,000	$25,000
5	INTEREST DURING CONSTRUCTION	1	LS	$775,271	$775,271
	PROJECT CAPITAL COST				**$14,669,076**

ANNUAL COST SUMMARY		
ITEM	**DESCRIPTION**	**TOTAL**
1	DEBT SERVICE (20 YEARS AT 3.5% INTEREST)	$1,032,132
2	OPERATION AND MAINTENANCE (O&M)	$534,433
3	PUMPING ENERGY COSTS	$7,525
	TOTAL ANNUAL COST - DURING DEBT SERVICE	**$1,574,091**
	TOTAL ANNUAL COST - AFTER DEBT SERVICE	**$541,959**

UNIT COST SUMMARY		
ITEM	**DESCRIPTION**	**ANNUAL TOTAL**
1	ESTIMATED YIELD (ACRE-FEET PER YEAR)	560
2	ANNUAL COST - DURING DEBT SERVICE	$1,574,091
3	ANNUAL COST - AFTER DEBT SERVICE	$541,959
	TOTAL UNIT COST DURING DEBT SERVICE ($ PER ACRE-FOOT PER YEAR)	**$2,811**
	TOTAL UNIT COST AFTER DEBT SERVICE ($ PER ACRE-FOOT PER YEAR)	**$968**

CONSTRUCTION COST SUMMARY					
ITEM	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**
1	PUMP STATIONS	1	LS	$997,750	$997,750
2	PIPELINES	1	LS	$341,954	$341,954
3	WASTEWATER RECLAMATION PLANTS	1	LS	$7,514,635	$7,514,635
4	WATER STORAGE TANKS	1	LS	$1,018,159	$1,018,159
	PROJECT COST				**$9,872,498**

OPERATION AND MAINTENANCE (O&M) COST SUMMARY					
ITEM	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**
1	PUMP STATIONS	2.5	%	$997,750	$24,944
2	PIPELINES	1.0	%	$341,954	$3,420
3	WASTEWATER RECLAMATION PLANTS	1.0	LS	$495,889	$495,889
4	WATER STORAGE TANKS	1.0	%	$1,018,159	$10,182
	ANNUAL OPERATION AND MAINTENANCE COST				**$534,433**

Table RU03.3. Preliminary planning-level cost estimate for 1 MGD surface water concept

PRELIMINARY PLANNING-LEVEL COST ESTIMATE	OCTOBER 2021 COST INDEX
STRATEGY: Institutional Effluent Reclamation (1 MGD)	

PROJECT CAPITAL COST SUMMARY					
ITEM	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**
1	CONSTRUCTION COST	1	LS	$13,646,870	$13,646,870
2	ENG., FINANCIAL, LEGAL SERVICES, AND CONTINGENCIES	1	LS	$4,752,859	$4,752,859
3	LAND AND EASEMENTS	1	LS	$590,700	$590,700
4	ENVIRONMENTAL - STUDIES AND MITIGATION	1	LS	$25,000	$25,000
5	INTEREST DURING CONSTRUCTION	1	LS	$1,061,057	$1,061,057
	PROJECT CAPITAL COST				**$20,076,486**

ANNUAL COST SUMMARY		
ITEM	**DESCRIPTION**	**TOTAL**
1	DEBT SERVICE (20 YEARS AT 3.5% INTEREST)	$1,412,603
2	OPERATION AND MAINTENANCE (O&M)	$907,359
3	PUMPING ENERGY COSTS	$15,887
	TOTAL ANNUAL COST - DURING DEBT SERVICE	**$2,335,849**
	TOTAL ANNUAL COST - AFTER DEBT SERVICE	**$923,246**

UNIT COST SUMMARY		
ITEM	**DESCRIPTION**	**ANNUAL TOTAL**
1	ESTIMATED YIELD (ACRE-FEET PER YEAR)	1,121
2	ANNUAL COST - DURING DEBT SERVICE	$2,335,849
3	ANNUAL COST - AFTER DEBT SERVICE	$923,246
	TOTAL UNIT COST DURING DEBT SERVICE ($ PER ACRE-FOOT PER YEAR)	**$2,084**
	TOTAL UNIT COST AFTER DEBT SERVICE ($ PER ACRE-FOOT PER YEAR)	**$824**

CONSTRUCTION COST SUMMARY					
ITEM	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**
1	PUMP STATIONS	1	LS	$1,054,300	$1,054,300
2	PIPELINES	1	LS	$470,909	$470,909
3	WASTEWATER RECLAMATION PLANTS	1	LS	$11,042,209	$11,042,209
4	WATER STORAGE TANKS	1	LS	$1,079,452	$1,079,452
	PROJECT COST				**$13,646,870**

OPERATION AND MAINTENANCE (O&M) COST SUMMARY					
ITEM	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**
1	PUMP STATIONS	2.5	%	$1,054,300	$26,358
2	PIPELINES	1.0	%	$470,909	$4,709
3	WASTEWATER RECLAMATION PLANTS	1.0	LS	$865,498	$865,498
4	WATER STORAGE TANKS	1.0	%	$1,079,452	$10,795
	ANNUAL OPERATION AND MAINTENANCE COST				**$907,359**

Performance Metric 3

Estimated concept unit costs during debt service, after debt service, and for a hypothetical 50-year project lifespan were compared against the estimated current cost of industrial groundwater supply in order to evaluate Performance Metric 3 values for the project concept. Results of this comparison are summarized in Table RU03.4.

Table RU03.4. Performance Metric 3 results for Institutional Effluent Reclamation (New) concept

Supply Vol.	Unit Cost ($ per 1,000 gal)			Performance Metric 3		
	Initial	Post-Debt	50-Year	Initial	Post-Debt	50-Year
0.5 MGD	$8.62	$2.97	$5.23	8.21	2.83	**4.98**
1.0 MGD	$6.40	$2.53	$4.07	6.09	2.41	**3.88**

In examining the Performance Metric 3 results for the supply concept, it should be noted that while estimated initial and 50-year project costs are higher than estimated current groundwater costs, the project would develop new water supplies which could reduce or supplement groundwater production and diversify entity or regional supply portfolios, providing overall improvements to reliability. It is also noted that unit costs for the concept decrease substantially after retirement of debt service, and thus if the project is able to secure funding with more favorable terms than the default assumptions for the study, both initial and life-cycle Performance Metric 3 values would decrease.

In comparing these results to other supply concepts, it should be remembered that the concept as currently envisioned would not produce potable water, and thus would be limited to serving non-potable demands; an effluent reclamation concept to produce potable water would incur substantial additional treatment cost and a corresponding increase in Performance Metric 3 result. However, many of the potential institutional sites in the study area, including those associated with universities, typically include extensive green spaces, esplanades, and other features which could utilize non-potable water treated to a standard compatible with some human contact. Institutional reuse also potentially offers potential benefits beyond direct supply, and which cannot be quantified directly through the performance metric, such as through providing education and facility operator training opportunities at universities and correctional facilities.

Considerations that Could Impact Cost

The project components and assumptions for the Institutional Effluent Reclamation concept are intended to be reasonable for a non-site-specific and planning-level analysis based on available information on sources, water demands, and other considerations. Due to the multiple potential manners in which a wastewater reuse project could be implemented within the study area and the potential impacts of site-specific considerations on facility components, project cost could vary from the estimates presented in this memorandum. Factors which could impact project cost include, but are not limited to:

- Sourcing of effluent or delivery to points of use at a greater distance than estimated by this study, which would likely increase costs for transmission, land survey, and environmental assessments.
- An overall limitation on the non-potable water demand on the institutional site which could be served by the concept, potentially impacting facility sizing.

- Site-specific characteristics which could impact required pump-station horsepower, storage size, transmission distance and sizing, or other costing assumptions.

- The specific financing approach utilized to support project development.

It should also be noted that costs in this memorandum are presented for a reference month of October 2021. National and international economic drivers and materials markets are prone to fluctuations which cannot always be accurately predicted and present a source of uncertainty regarding the cost of project development in the future.

Other Considerations

Water Quality

Raw source water quality for the project would vary based on the source facility, but for purposes of the concept analysis is assumed to be untreated municipal-type effluent. The project concept is intended produce non-potable but treated and disinfected water suitable for institutional outdoor uses with limited amounts of human contact.

Reliability

Analyses presented in this memorandum assume sourcing of effluent either from the institution itself or from a nearby municipal treatment plant. Effluent from local universities is primarily routed to City of Baton Rouge treatment facilities, but a portion could be diverted for use in supplying an on-site treatment facility; additionally, Southern University is located nearly adjacent to the City of Baton Rouge North Wastewater Treatment Plant, which could potentially provide additional effluent to support an institutional reuse facility. The source is therefore considered to be generally reliable for supporting a small institutional reclamation facility.

Implementation Feasibility

The availability of institutionally generated treated effluent or nearby municipal treated effluent for multiple sites within the study area suggests potential feasibility for some degree of institutional effluent reclamation. Additionally, the institutional sites generally have some undeveloped or green spaces which could simplify project implementation and create opportunity for irrigation use. It is recommended that pursuit of an institutional effluent reclamation supply include detailed feasibility analysis, including assessment of source water quality, non-potable water demand, and associated infrastructure and routing options. Feasibility of institutional reuse concepts may also be enhanced by associated social and economic benefits from the creation of practical treatment training opportunities.

Permitting, Development, and Environmental Considerations

Environmental impacts of the project concept are anticipated to be limited. Portions of infrastructure development could create some construction disturbance requiring mitigation. The concept as envisioned for this study would consist primarily of infrastructure development on existing institutional and treatment sites and through existing utility corridors or rights-of-way, with the pre-disturbed nature of these areas likely reducing habitat impacts and resulting in minimal mitigation requirements. Utilization of currently discharged treated effluent would reduce return flows to receiving water bodies. However, the associated discharges are currently extremely small in comparison with the flow of the Mississippi River, and their reduction would not be expected to have an appreciable impact on instream flows.

Project development for an Institutional Effluent Reclamation concept would be expected to require some degree of permitting and agency coordination, potentially including:

- Compliance with State, parish, and local construction permitting and notification procedures, as applicable for the project site.
- Stormwater discharge permitting and obtaining coverage of construction general permitting through the Louisiana Pollution Discharge Elimination System (LPDES).
- For projects with elements outside of the associated institution, obtaining of easements, permissions for infrastructure crossings, and purchase of land as applicable.
- For any concept implementation which requires development of infrastructure components in wetland areas, U.S. Army Corps of Engineers Section 404 Permitting and mitigation planning, potentially also including development of a National Environmental Policy Act (NEPA) Environmental Impact Statement (EIS).
- State and federal wastewater facility and discharge permitting or permit amendment.

Other Benefits

In addition to the basic benefit of providing a new source of water supply to reduce or supplement existing groundwater production, development of an institutional reclamation supply offers a number of potential benefits to the study area. While institutional reclamation would have similar supply benefits (beneficial effluent usage and supply diversification) to the other similar Phase 2A study concepts at a smaller scale, the intentional structuring of an institutional reclamation concept as a combined supply and teaching facility also offers a greater level of direct social benefit. Implementation in a university setting would provide students of engineering, environmental sciences, and other curricula with a working on-campus demonstration site to reinforce classroom concepts and enhance them with direct experience in the operation of a wastewater treatment facility. Likewise, implementation at a correctional institution would provide practical training opportunities and could allow program participants to reenter the workforce with highly in-demand skills as licensed wastewater treatment plant operators.

References

U.S. Environmental Protection Agency. (2021). *Enforcement and Compliance History Online*. [Dataset.] Accessed November 2021 at < https://echo.epa.gov/>

STRATEGY CONCEPT TECHNICAL MEMORANDUM: INSTITUTIONAL EFFLUENT RECLAMATION (POLISHING TREATMENT)

Strategy Concept Summary	
Strategy ID:	RU04
Strategy Type:	Reuse
Supply Quantity:	Variable (0.5 and 1.0 MGD concepts assessed)
Strategy Capital Cost:	$10,549,873 (0.5 MGD concept) $14,638,347 (1.0 MGD concept)
Life Cycle Unit Cost:	$4.58 per 1,000 gallons (0.5 MGD concept) $3.36 per 1,000 gallons (1.0 MGD concept)

Strategy Description

The presence of a number of institutional water users, including universities and correctional facilities, in the CAGWCD parishes offers a valuable opportunity to combine implementation of innovative water supply solutions with practical education and job training. Some of these sites have existing wastewater treatment infrastructure or are located in close proximity to municipal wastewater treatment plant (WWTP) facilities. This treated effluent could be utilized in conjunction with development of supplemental advanced treatment modules and disinfection on the institution site to develop water supply while creating a facility for practical education and training in advanced water treatment. In addition to educational and social benefits, a reuse project would also meet non-potable needs currently met by treated groundwater from traditional production zones. This memorandum summarizes planning-level evaluations of a hypothetical institutional effluent reclamation polishing project, including concept assumptions, cost estimation and comparison to current groundwater cost, and considerations related to quality, reliability, feasibility, permitting, and possibility of extended benefits.

Supply Development Assumptions and Applicability

Overview

Analyses of an Institutional Effluent Reclamation polishing treatment project for the Phase 2A study examined a generalized project concept with potential applicability to one or more of the institutional sites within the study area. This general, planning-level approach allows investigation of project development considerations and assessment of the approximate magnitude of cost associated with favorable implementation conditions for the strategy. Should one or more entities within the study area pursue development of an institutional effluent reuse project, it is anticipated that site-specific considerations on logistics, quality needs, and cost would be examined through detailed feasibility and preliminary engineering analyses. It should be noted that the project concepts for the Phase 2A study are planning-level analyses and not intended for construction, bid, or permitting purposes.

Project Concept Sizing

Project concept sizing considered both the availability of the source supply and the potential water demand to be served. Analyses presented in this memorandum assume sourcing of effluent from the institutional user itself, and adjacent municipal WWTP facility, or a combination of the two. Major educational and correctional institutions within the study area have average flows from on-site treatment facilities ranging from nearly negligible amounts (in the cases of facilities primarily discharging to municipal WWTPs) to approximately 1.5 MGD. Some institutional sites are also in close proximity to large municipal wastewater facilities, greatly increasing potential partially treated effluent input availability. Applicable non-potable demand would vary by institutional site and the amount of green space practical to convert to non-potable reuse supply. For this reason, 0.5 MGD and 1.0 MGD project concepts were selected to represent a reasonable range of project implementation scales while being of sufficient size to create valuable education and job training benefits.

Other Assumptions

The following assumptions were applied in estimating project concept cost and examining implementation considerations:

- That the partially treated effluent source is fully reliable.
- The project is developed and implemented by an institutional entity (in conjunction with the City of Baton Rouge as provider and host of additional treatment components) to meet non-potable water needs at the institution's site.
- There is sufficient demand for non-potable water.
- Infrastructure is developed primarily on the institutional site utilizing the produced supply, resulting in limited transmission distance, land purchase cost, and crossings of public infrastructure.
- That development on existing institutional project sites and the limited project size permits relatively rapid project development.
- Project construction involves the following major infrastructure components:
    - A wastewater polishing treatment facility (membrane bioreactor and disinfection module) developed on the institutional site.
    - On-site ground storage tanks to provide buffering storage for variations in flow or demand.
    - A discharge pump station within one-mile cumulative distance of various points of use.
    - Associated piping.

- Detailed project finance, infrastructure peaking, and other infrastructure details are consistent with the overall costing assumptions as described in the Phase 2A study report.

Strategy Cost Analysis

Estimated Cost Breakdown

A preliminary planning-level cost estimate for the Institutional Effluent Reclamation (Polishing Treatment) concept was developed through the costing tool developed for the study and based upon the assumptions discussed in this memorandum and the Phase 2A study report. Annualized cost components such as debt service and facility operations and maintenance expenses, were developed utilizing the standardized assumptions summarized in the Phase 2A study report. Estimated costs for the two concept sizes are summarized in Table RU04.1, with more detailed cost profile sheets in Tables RU04.2 and RU04.3.

Table RU04.1. Cost summary for Institutional Effluent Reclamation (Polishing Treatment) concept

Supply Vol.	Capital Cost	Annual Cost		Unit Cost	
		Initial	Post-Debt	Initial	Post-Debt
0.5 MGD	$10,549,873	$1,281,673	$539,373	$2,289/ ac-ft $7.02 / 1,000 gal	$963/ ac-ft $2.95 / 1,000 gal
1 MGD	$14,638,347	$1,843,903	$813,934	$1,645/ ac-ft $5.05 / 1,000 gal	$726/ ac-ft $2.23 / 1,000 gal

Table RU04.2. Preliminary planning-level cost estimate for 0.5 MGD concept

PRELIMINARY PLANNING-LEVEL COST ESTIMATE	OCTOBER 2021 COST INDEX
STRATEGY: Institutional Effluent Reclamation (0.5 MGD)	

PROJECT CAPITAL COST SUMMARY					
ITEM	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**
1	CONSTRUCTION COST	1	LS	$6,982,498	$6,982,498
2	ENG., FINANCIAL, LEGAL SERVICES, AND CONTINGENCIES	1	LS	$2,426,777	$2,426,777
3	LAND AND EASEMENTS	1	LS	$558,030	$558,030
4	ENVIRONMENTAL - STUDIES AND MITIGATION	1	LS	$25,000	$25,000
5	INTEREST DURING CONSTRUCTION	1	LS	$557,568	$557,568
	PROJECT CAPITAL COST				**$10,549,873**

ANNUAL COST SUMMARY		
ITEM	**DESCRIPTION**	**TOTAL**
1	DEBT SERVICE (20 YEARS AT 3.5% INTEREST)	$742,300
2	OPERATION AND MAINTENANCE (O&M)	$531,847
3	PUMPING ENERGY COSTS	$7,525
	TOTAL ANNUAL COST - DURING DEBT SERVICE	**$1,281,673**
	TOTAL ANNUAL COST - AFTER DEBT SERVICE	**$539,373**

UNIT COST SUMMARY		
ITEM	**DESCRIPTION**	**ANNUAL TOTAL**
1	ESTIMATED YIELD (ACRE-FEET PER YEAR)	560
2	ANNUAL COST - DURING DEBT SERVICE	$1,281,673
3	ANNUAL COST - AFTER DEBT SERVICE	$539,373
	TOTAL UNIT COST DURING DEBT SERVICE ($ PER ACRE-FOOT PER YEAR)	**$2,289**
	TOTAL UNIT COST AFTER DEBT SERVICE ($ PER ACRE-FOOT PER YEAR)	**$963**

CONSTRUCTION COST SUMMARY					
ITEM	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**
1	PUMP STATIONS	1	LS	$997,750	$997,750
2	PIPELINES	1	LS	$341,954	$341,954
3	WASTEWATER RECLAMATION PLANTS	1	LS	$4,624,635	$4,624,635
4	WATER STORAGE TANKS	1	LS	$1,018,159	$1,018,159
	PROJECT COST				**$6,982,498**

OPERATION AND MAINTENANCE (O&M) COST SUMMARY					
ITEM	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**
1	PUMP STATIONS	2.5	%	$997,750	$24,944
2	PIPELINES	1.0	%	$341,954	$3,420
3	WASTEWATER RECLAMATION PLANTS	1.0	LS	$493,302	$493,302
4	WATER STORAGE TANKS	1.0	%	$1,018,159	$10,182
	ANNUAL OPERATION AND MAINTENANCE COST				**$531,847**

Table RU04.3. Preliminary planning-level cost estimate for 1 MGD concept

PRELIMINARY PLANNING-LEVEL COST ESTIMATE	OCTOBER 2021 COST INDEX
STRATEGY: Institutional Effluent Reclamation (1 MGD)	

PROJECT CAPITAL COST SUMMARY

ITEM	DESCRIPTION	QTY	UNIT	UNIT PRICE	TOTAL
1	CONSTRUCTION COST	1	LS	$9,831,515	$9,831,515
2	ENG., FINANCIAL, LEGAL SERVICES, AND CONTINGENCIES	1	LS	$3,417,485	$3,417,485
3	LAND AND EASEMENTS	1	LS	$590,700	$590,700
4	ENVIRONMENTAL - STUDIES AND MITIGATION	1	LS	$25,000	$25,000
5	INTEREST DURING CONSTRUCTION	1	LS	$773,647	$773,647
	PROJECT CAPITAL COST				$14,638,347

ANNUAL COST SUMMARY

ITEM	DESCRIPTION	TOTAL
1	DEBT SERVICE (20 YEARS AT 3.5% INTEREST)	$1,029,970
2	OPERATION AND MAINTENANCE (O&M)	$798,047
3	PUMPING ENERGY COSTS	$15,887
	TOTAL ANNUAL COST - DURING DEBT SERVICE	**$1,843,903**
	TOTAL ANNUAL COST - AFTER DEBT SERVICE	**$813,934**

UNIT COST SUMMARY

ITEM	DESCRIPTION	ANNUAL TOTAL
1	ESTIMATED YIELD (ACRE-FEET PER YEAR)	1,121
2	ANNUAL COST - DURING DEBT SERVICE	$1,843,903
3	ANNUAL COST - AFTER DEBT SERVICE	$813,934
	TOTAL UNIT COST DURING DEBT SERVICE ($ PER ACRE-FOOT PER YEAR)	**$1,645**
	TOTAL UNIT COST AFTER DEBT SERVICE ($ PER ACRE-FOOT PER YEAR)	**$726**

CONSTRUCTION COST SUMMARY

ITEM	DESCRIPTION	QTY	UNIT	UNIT PRICE	TOTAL
1	PUMP STATIONS	1	LS	$1,054,300	$1,054,300
2	PIPELINES	1	LS	$470,909	$470,909
3	WASTEWATER RECLAMATION PLANTS	1	LS	$7,226,854	$7,226,854
4	WATER STORAGE TANKS	1	LS	$1,079,452	$1,079,452
	PROJECT COST				**$9,831,515**

OPERATION AND MAINTENANCE (O&M) COST SUMMARY

ITEM	DESCRIPTION	QTY	UNIT	UNIT PRICE	TOTAL
1	PUMP STATIONS	2.5	%	$1,054,300	$26,358
2	PIPELINES	1.0	%	$470,909	$4,709
3	WASTEWATER RECLAMATION PLANTS	1.0	LS	$756,186	$756,186
4	WATER STORAGE TANKS	1.0	%	$1,079,452	$10,795
	ANNUAL OPERATION AND MAINTENANCE COST				**$798,047**

Performance Metric 3

Estimated concept unit costs during debt service, after debt service, and for a hypothetical 50-year project lifespan were compared against the estimated current cost of industrial groundwater supply in order to evaluate Performance Metric 3 values for the project concept. Results of this comparison are summarized in Table RU04.4.

Table RU04.4. Performance Metric 3 results for Institutional Effluent Reclamation (Polishing Treatment) concept

Supply Vol.	Unit Cost ($ per 1,000 gal)			Performance Metric 3		
	Initial	Post-Debt	50-Year	Initial	Post-Debt	50-Year
0.5 MGD	$7.02	$2.95	$4.58	6.68	2.81	**4.36**
1.0 MGD	$5.05	$2.23	$3.36	4.81	2.12	**3.20**

In examining the Performance Metric 3 results for the supply concept, it should be noted that while estimated initial and 50-year project costs are higher than estimated current groundwater costs, the project would develop new water supplies which could reduce or supplement groundwater production and diversify entity or regional supply portfolios, providing overall improvements to reliability. It is also noted that unit costs for the concept decrease substantially after retirement of debt service, and thus if the project is able to secure funding with more favorable terms than the default assumptions for the study, both initial and life-cycle Performance Metric 3 values would decrease.

In comparing these results to other supply concepts, it should be remembered that the concept as currently envisioned would not produce potable water, and thus would be limited to serving non-potable demands; an effluent reclamation concept to produce potable water would incur substantial additional treatment cost and a corresponding increase in Performance Metric 3 result. However, many of the potential institutional sites in the study area, including those associated with universities, typically include extensive green spaces, esplanades, and other features which could utilize non-potable water treated to a standard compatible with some human contact. Institutional reuse also potentially offers potential benefits beyond direct supply, and which cannot be quantified directly through the performance metric, such as through providing education and facility operator training opportunities at universities and correctional facilities.

Considerations that Could Impact Cost

The project components and assumptions for the Institutional Effluent Reclamation concept are intended to be reasonable for a non-site-specific and planning-level analysis based on available information on sources, water demands, and other considerations. Due to the multiple potential manners in which a wastewater reuse project could be implemented within the study area and the potential impacts of site-specific considerations on facility components, project cost could vary from the estimates presented in this memorandum. Factors which could impact project cost include, but are not limited to:

- Sourcing of effluent or delivery to points of use at a greater distance than estimated by this study, which would likely increase costs for transmission, land survey, and environmental assessments.
- An overall limitation on the non-potable water demand on the institutional site which could be served by the concept, potentially impacting facility sizing.

- Changes in the source wastewater treatment facility, its treatment processes, or the area served.
- Site-specific characteristics which could impact required pump-station horsepower, storage size, transmission distance and sizing, or other costing assumptions.
- The specific financing approach utilized to support project development.

It should also be noted that costs in this memorandum are presented for a reference month of October 2021. National and international economic drivers and materials markets are prone to fluctuations which cannot always be accurately predicted and present a source of uncertainty regarding the cost of project development in the future.

Other Considerations

Water Quality

Raw source water quality for the project would vary based on the source facility, but for purposes of the concept analysis is assumed to be effluent which has been processed through primary, secondary, and tertiary treatment. The project concept is intended produce non-potable but treated and disinfected water suitable for institutional use and potentially for outdoor uses with limited amounts of human contact.

Reliability

Analyses presented in this memorandum assume sourcing of partially treated effluent either from the institution itself or from a nearby municipal treatment plant. Southern University is located nearly adjacent to the City of Baton Rouge North WWTP, which could potentially provide partially treated effluent to support an institutional reuse facility. The Louisiana State Penitentiary at Angola also has existing wastewater treatment facilities which could be used as a source of partially treated effluent to serve an institutional advanced treatment / polishing treatment facility. The source is therefore considered to be generally reliable for supporting a small institutional reclamation facility.

Implementation Feasibility

The availability of institutionally generated treated effluent or nearby municipal treated effluent for multiple sites within the study area suggests potential feasibility for some degree of institutional effluent reclamation. Additionally, the institutional sites generally have some undeveloped or green spaces which could simplify project implementation and create opportunity for irrigation use. It is recommended that pursuit of an institutional effluent reclamation supply include detailed feasibility analysis, including assessment of source water quality, non-potable water demand, and associated infrastructure and routing options. Feasibility of institutional reuse concepts may also be enhanced by associated social and economic benefits from the creation of practical treatment training opportunities.

Permitting, Development, and Environmental Considerations

Environmental impacts of the project concept are anticipated to be limited. Portions of infrastructure development could create some construction disturbance requiring mitigation. The concept as envisioned for this study would consist primarily of infrastructure development on existing institutional and treatment sites and through existing utility corridors or rights-of-way, with the pre-disturbed nature of these areas likely reducing habitat impacts and resulting in minimal mitigation requirements. Utilization of currently discharged treated effluent would reduce return flows to receiving water bodies. However, the associated discharges are currently extremely small in comparison with the flow of the Mississippi River, and their reduction would not be expected to have an appreciable impact on instream flows.

Project development for an Institutional Effluent Reuse concept would be expected to require some degree of permitting and agency coordination, potentially including:

- Compliance with State, parish, and local construction permitting and notification procedures, as applicable for the project site.
- Stormwater discharge permitting and obtaining coverage of construction general permitting through the Louisiana Pollution Discharge Elimination System (LPDES).
- For projects with elements outside of the associated institution, obtaining of easements, permissions for infrastructure crossings, and purchase of land as applicable.
- For any concept implementation which requires development of infrastructure components in wetland areas, U.S. Army Corps of Engineers Section 404 Permitting and mitigation planning, potentially also including development of a National Environmental Policy Act (NEPA) Environmental Impact Statement (EIS).
- State and federal wastewater facility and discharge permitting or permit amendment.

Other Benefits

In addition to the basic benefit of providing a new source of water supply to reduce or supplement existing groundwater production, development of an institutional reclamation supply offers a number of potential benefits to the study area. While institutional reclamation would have similar supply benefits (beneficial effluent usage and supply diversification) to the other similar Phase 2A study concepts at a smaller scale, the intentional structuring of an institutional reclamation concept as a combined supply and teaching facility also offers a greater level of direct social benefit. Implementation in a university setting would provide students of engineering, environmental sciences, and other curricula with a working on-campus demonstration site to reinforce classroom concepts and enhance them with direct experience in the operation of a wastewater treatment facility. Likewise, implementation at a correctional institution would provide practical training opportunities and could allow program participants to reenter the workforce with highly in-demand skills as licensed wastewater treatment plant operators.

References

U.S. Environmental Protection Agency. (2021). *Enforcement and Compliance History Online*. [Dataset.] Accessed November 2021 at < https://echo.epa.gov/>

APPENDIX H ELECTRICAL LOGS AND SAND PICKS NEAR THE BATON ROUGE FAULT

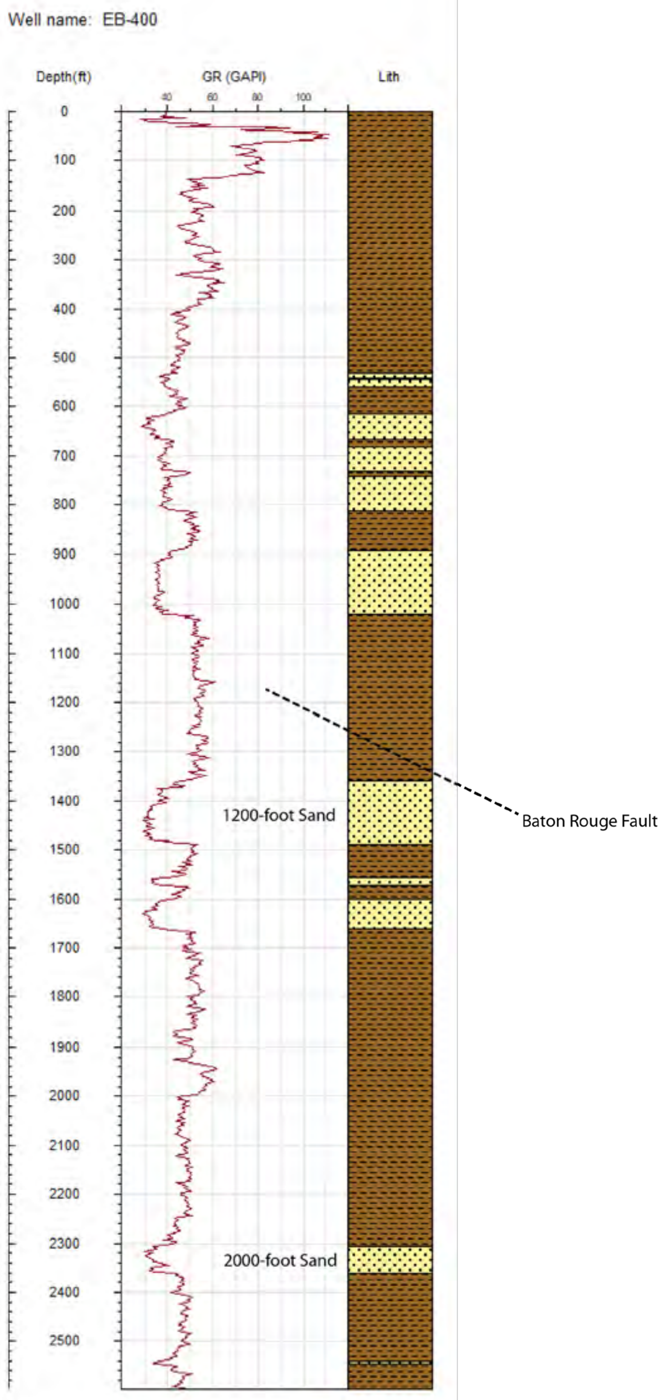

Figure H-1. Electrical log EB-400, intersecting the Baton Rouge Fault approximately at 1300 feet below land surface. Sand picks are in yellow color. Shales are in brown color. (GR = gamma ray, SP = spontaneous potential, R = shallow resistivity)

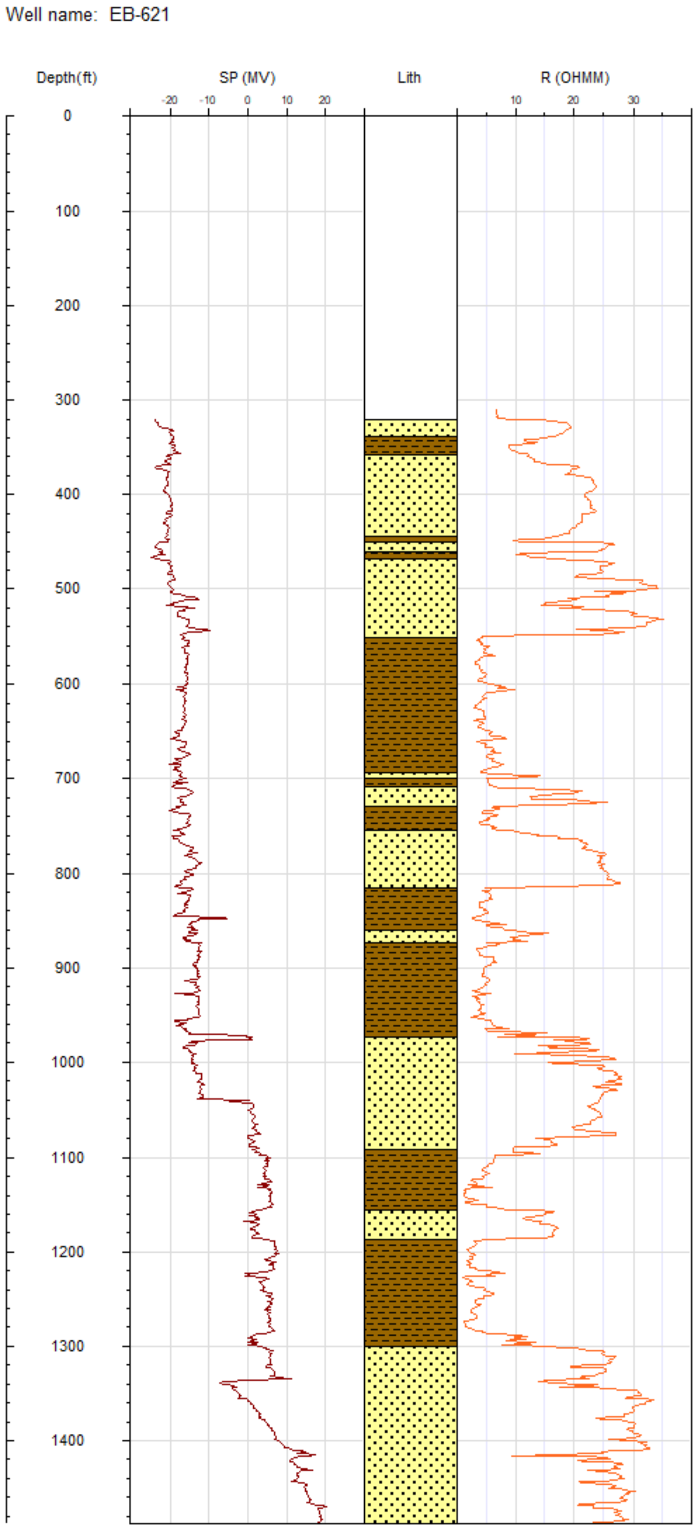

Figure H-2. Electrical log EB-621, north of the Baton Rouge Fault. (GR = gamma ray, SP = spontaneous potential, R = shallow resistivity)

Well name: EB-714

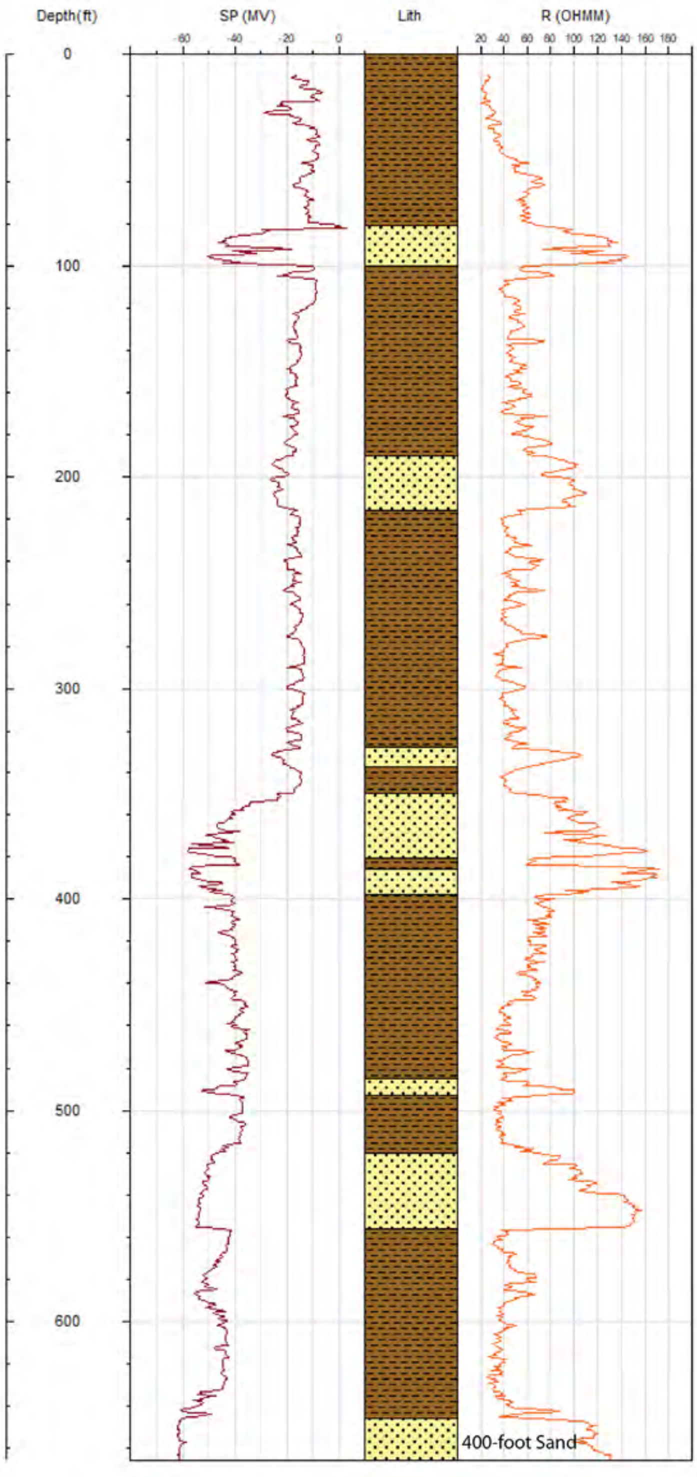

Figure H-3. Electrical log EB-714, south of the Baton Rouge Fault. (GR = gamma ray, SP = spontaneous potential, R = shallow resistivity)

Well name: EB-777

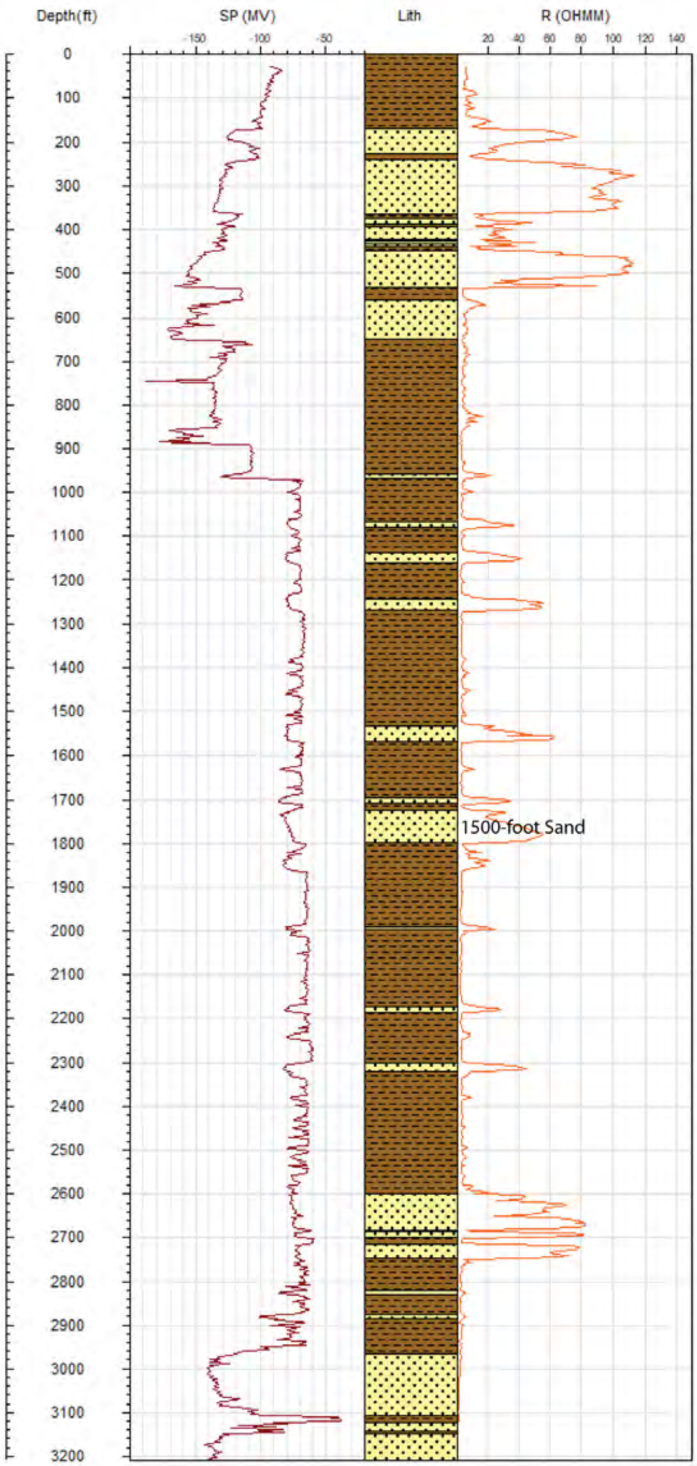

Figure H-4. Electrical log EB-777, north of the Baton Rouge Fault. (GR = gamma ray, SP = spontaneous potential, R = shallow resistivity)

Well name: EB-781

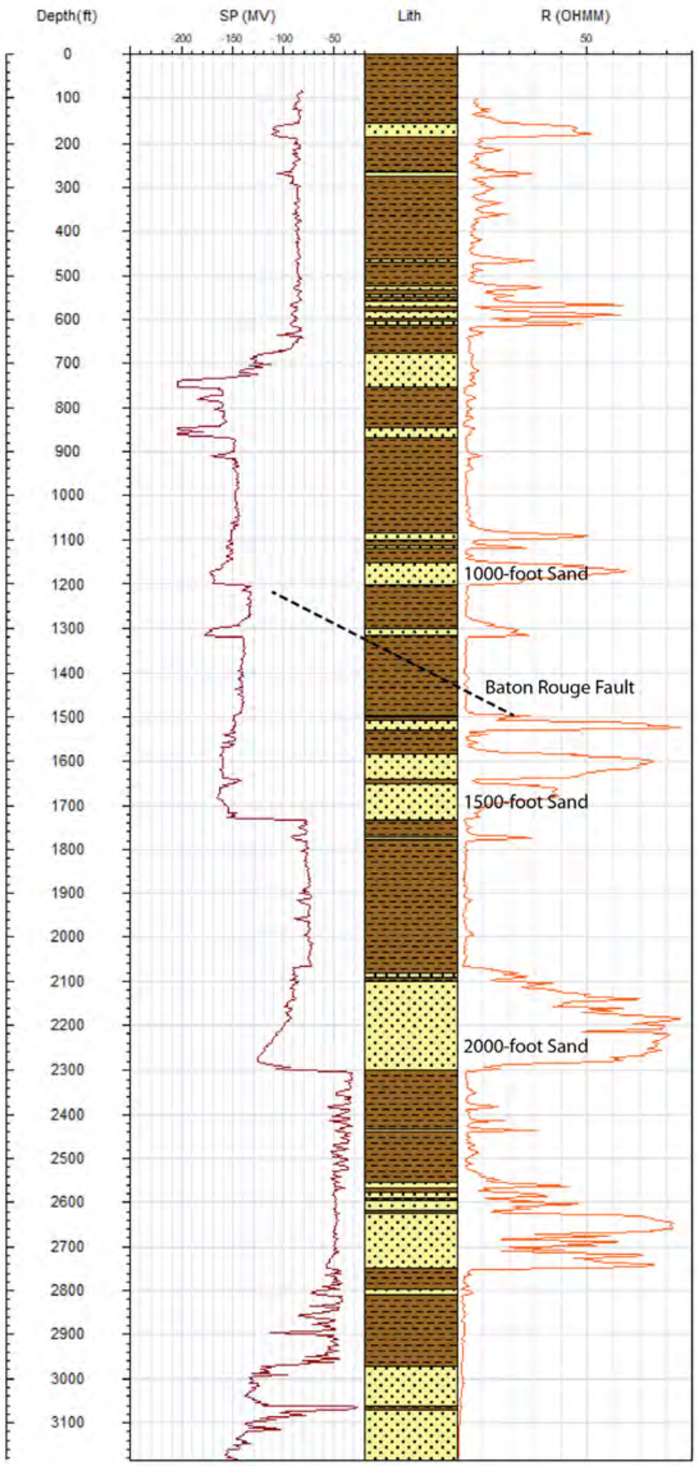

Figure H-5. Electrical log EB-781, intersecting the Baton Rouge Fault approximately at 1359 feet below land surface. (GR = gamma ray, SP = spontaneous potential, R = shallow resistivity)

Well name: EB-789

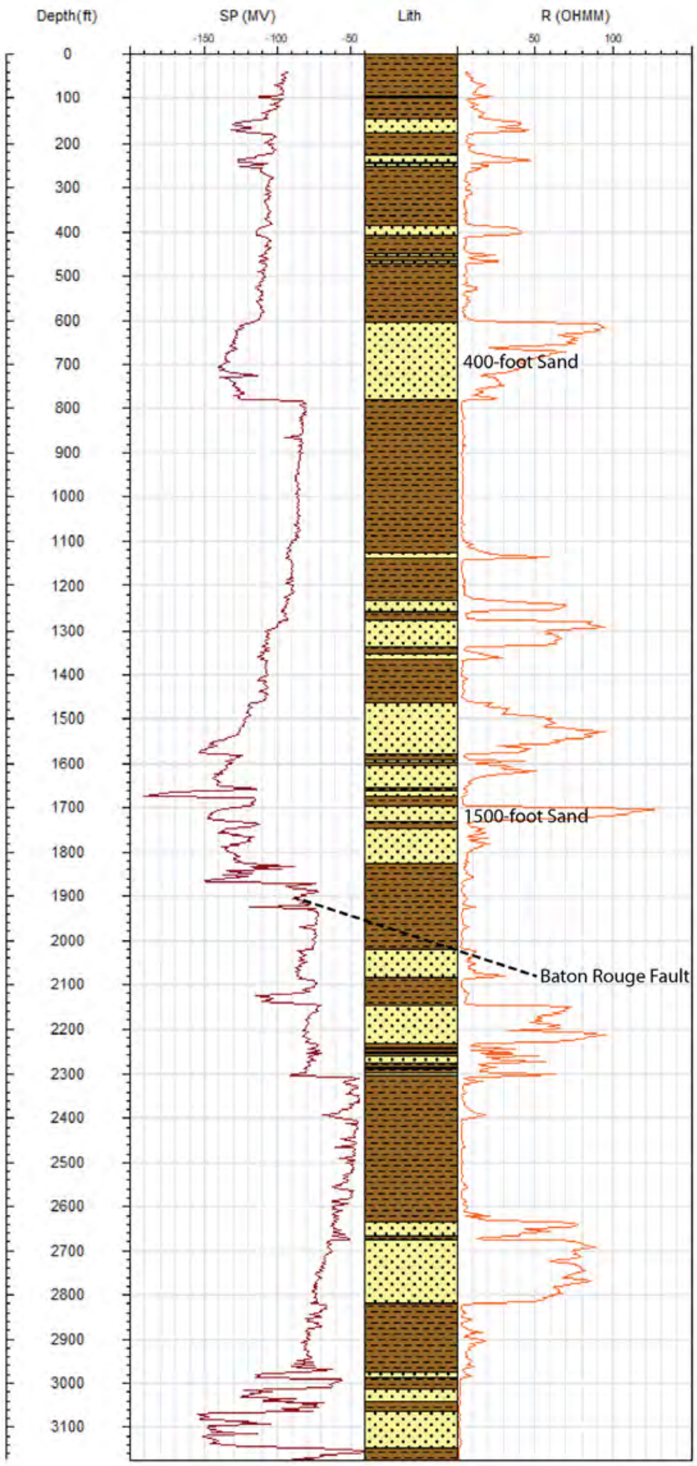

Figure H-6. Electrical log EB-789, intersecting the Baton Rouge Fault approximately at 2000 feet below land surface. (GR = gamma ray, SP = spontaneous potential, R = shallow resistivity)

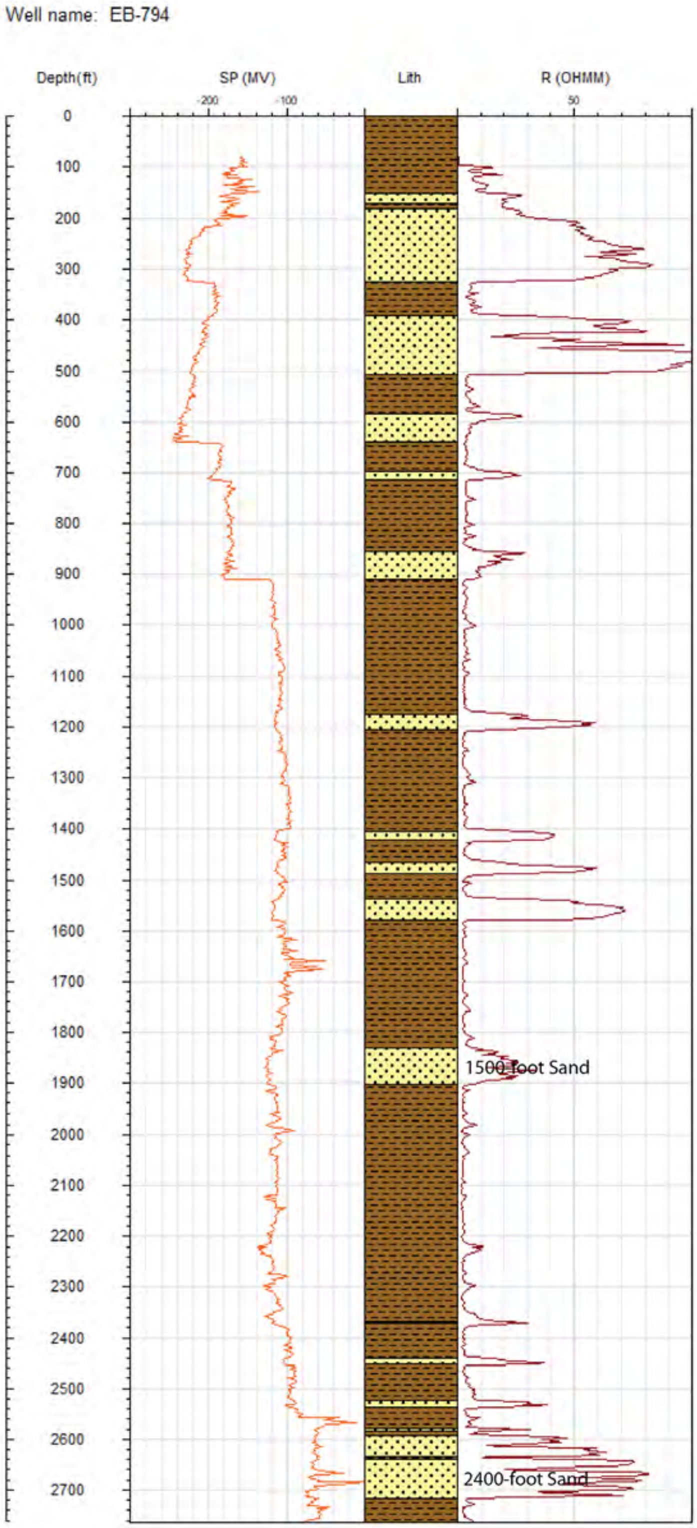

Figure H-7. Electrical log EB-794, north of the Baton Rouge Fault. (GR = gamma ray, SP = spontaneous potential, R = shallow resistivity)

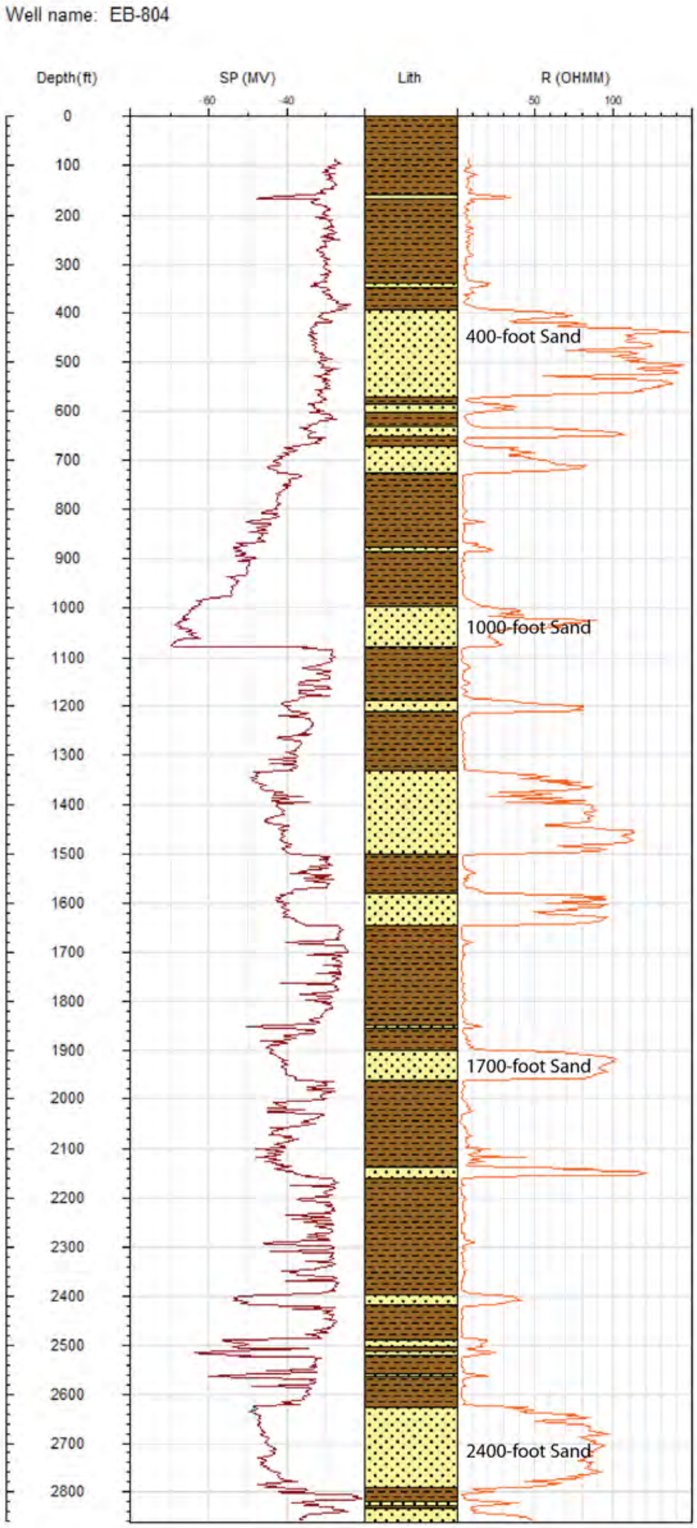

Figure H-8. Electrical log EB-804, north of the Baton Rouge Fault. (GR = gamma ray, SP = spontaneous potential, R = shallow resistivity)

Well name: EB-869

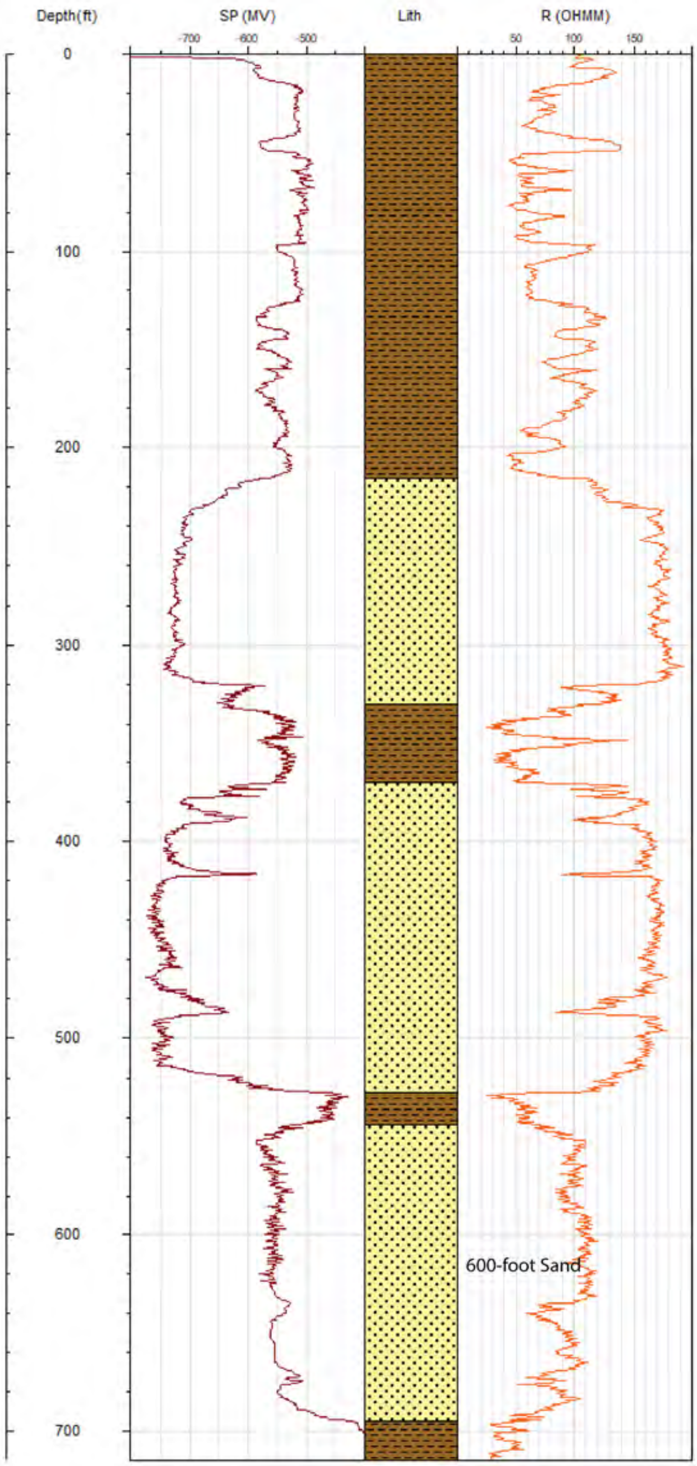

Figure H-9. Electrical log EB-869, north of the Baton Rouge Fault. (GR = gamma ray, SP = spontaneous potential, R = shallow resistivity)

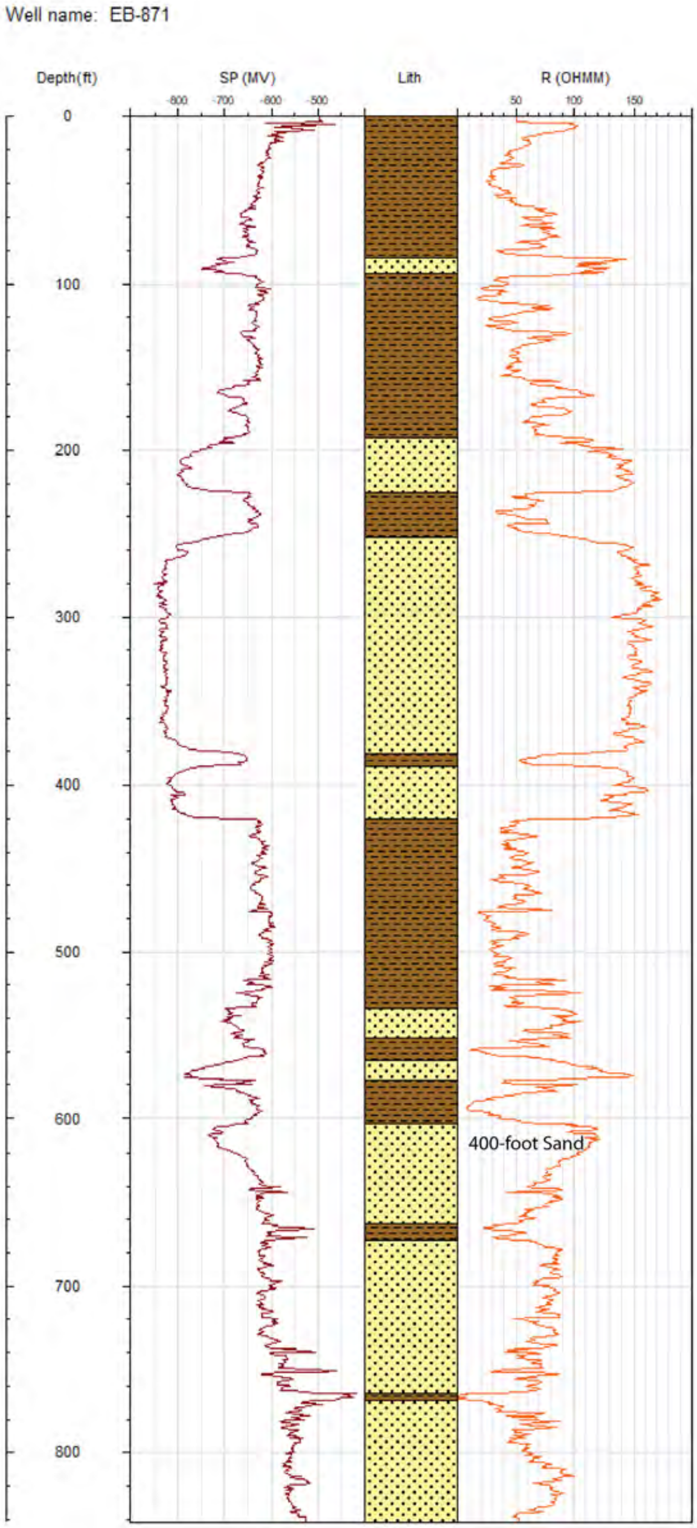

Figure H-10. Electrical log EB-871, south of the Baton Rouge Fault. (GR = gamma ray, SP = spontaneous potential, R = shallow resistivity)

Well name: EB-1295

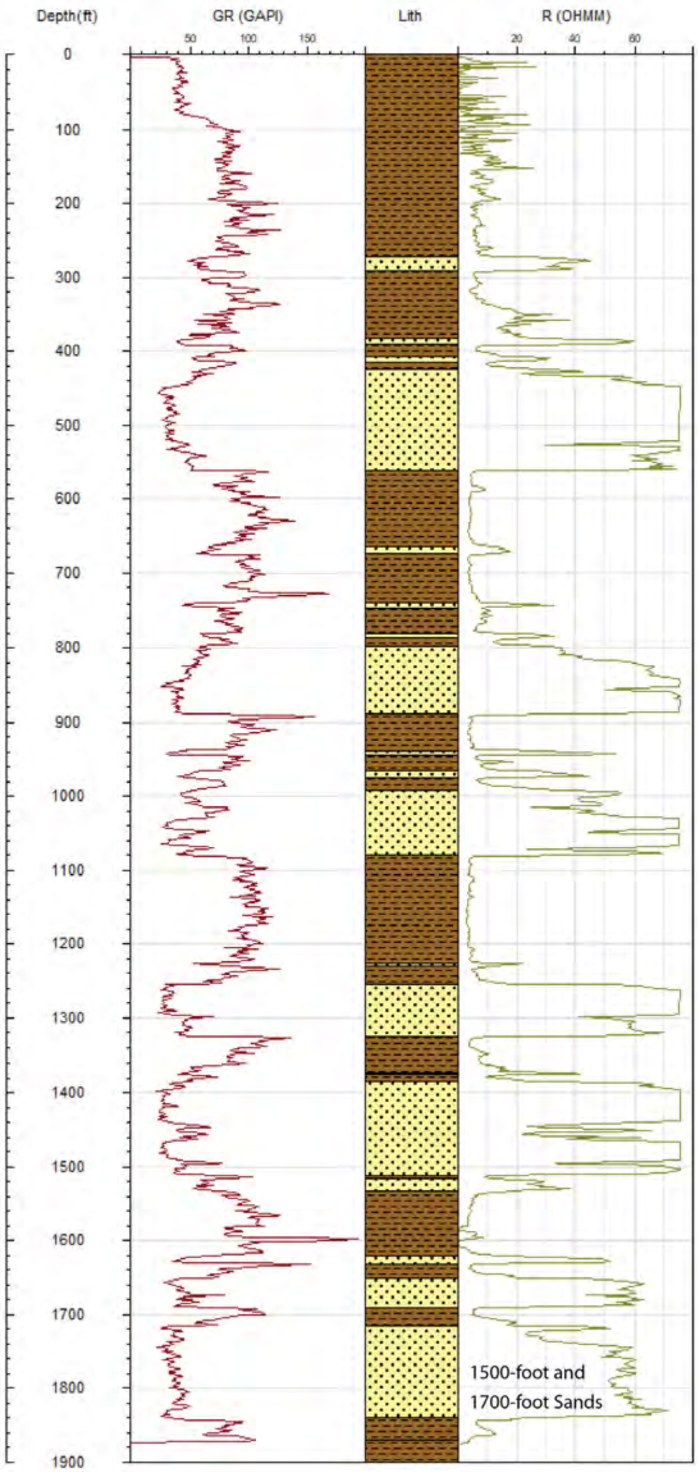

Figure H-11. Electrical log EB-1295, north of the Baton Rouge Fault. (GR = gamma ray, SP = spontaneous potential, R = shallow resistivity)

Well name: WBR-36

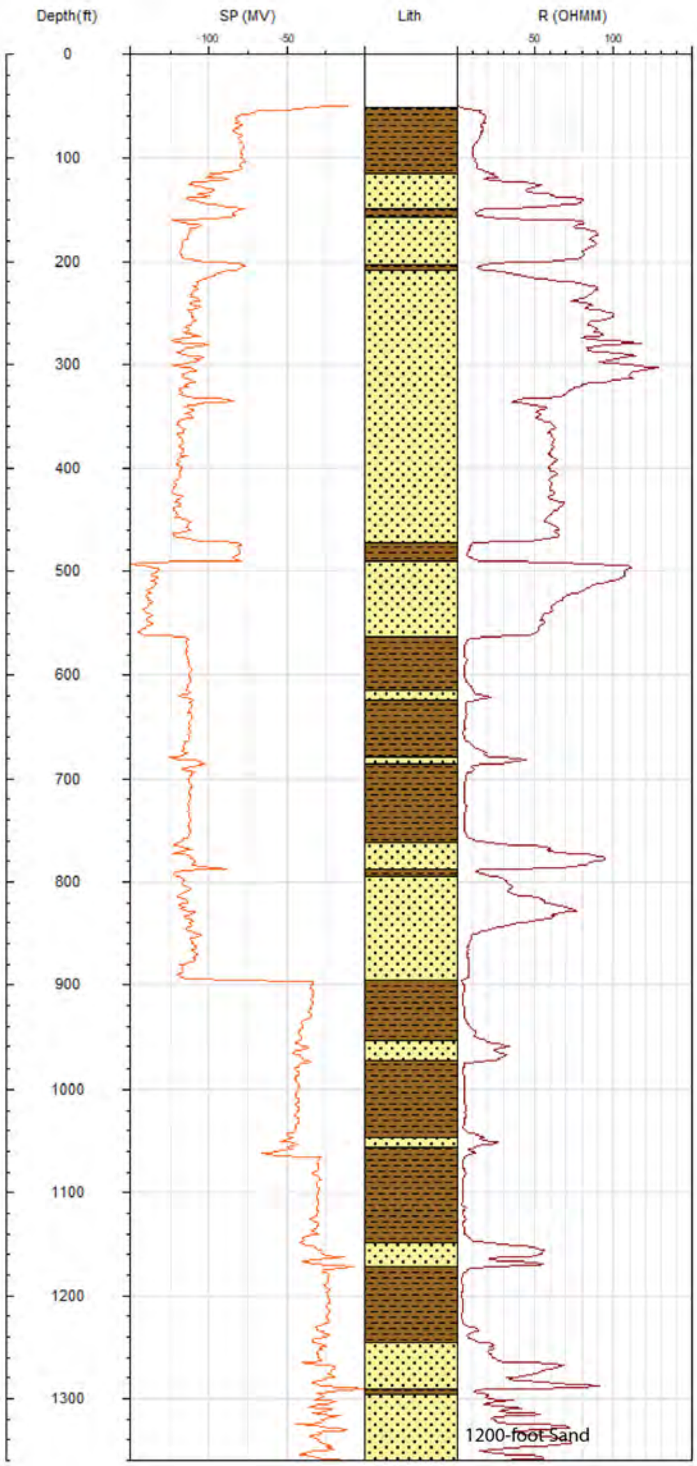

Figure H-12. Electrical log WBR-36, south of the Baton Rouge Fault. (GR = gamma ray, SP = spontaneous potential, R = shallow resistivity)

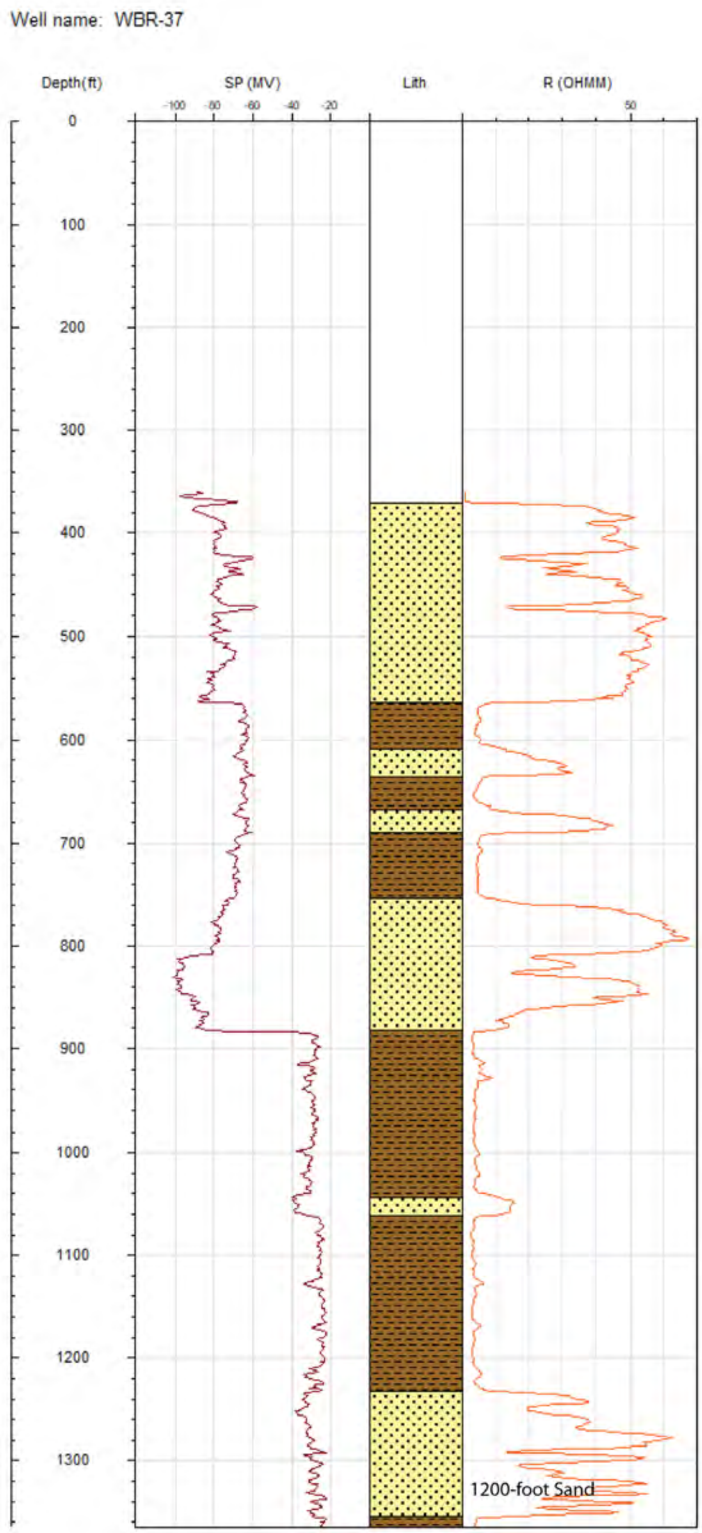

Figure H-13. Electrical log WBR-37, south of the Baton Rouge Fault. (GR = gamma ray, SP = spontaneous potential, R = shallow resistivity)

APPENDIX I TIME-SERIES CHLORIDE DATA AT MONITORING WELLS NEAR THE BATON ROUGE FAULT

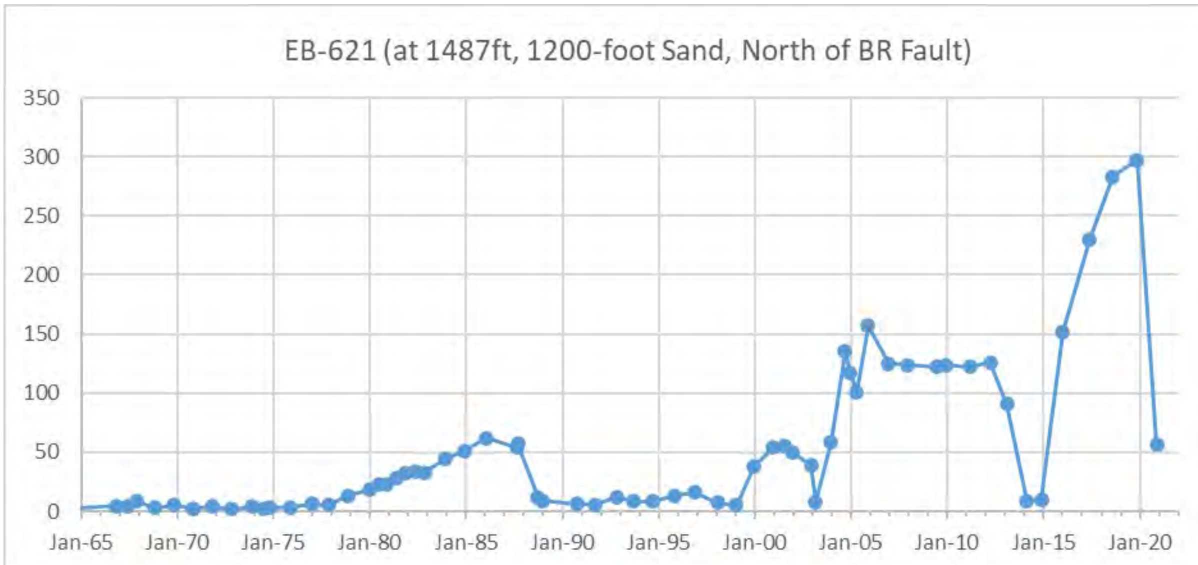

Figure I-1. Chloride concentration (mg/L) at monitoring well EB-621 between Jan. 1965 and 2020.

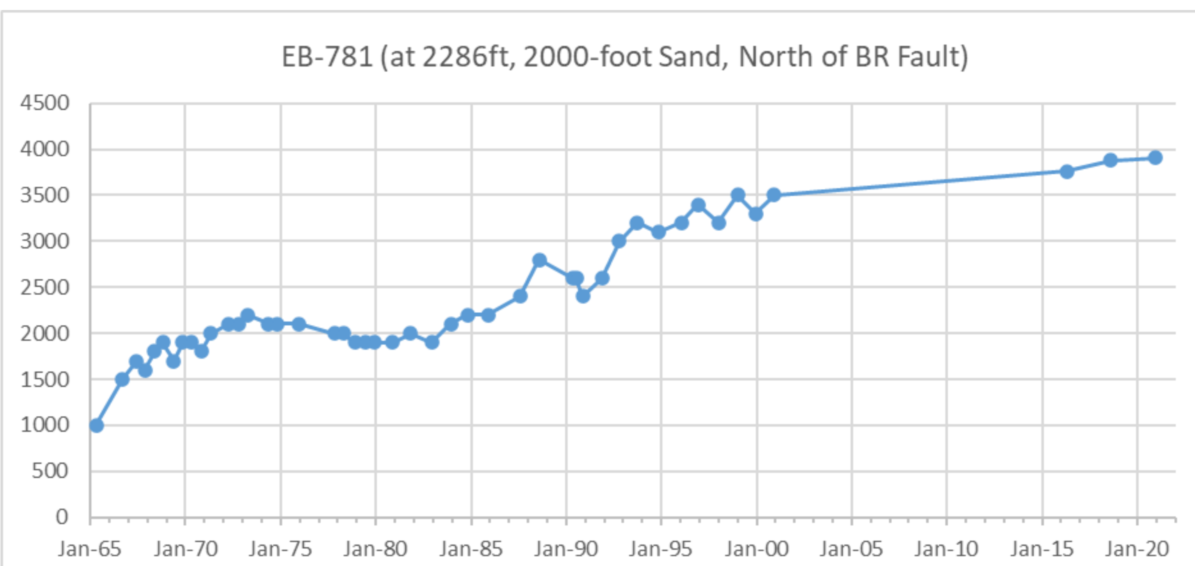

Figure I-2. Chloride concentration (mg/L) at monitoring well EB-781 between Jan. 1965 and 2020.

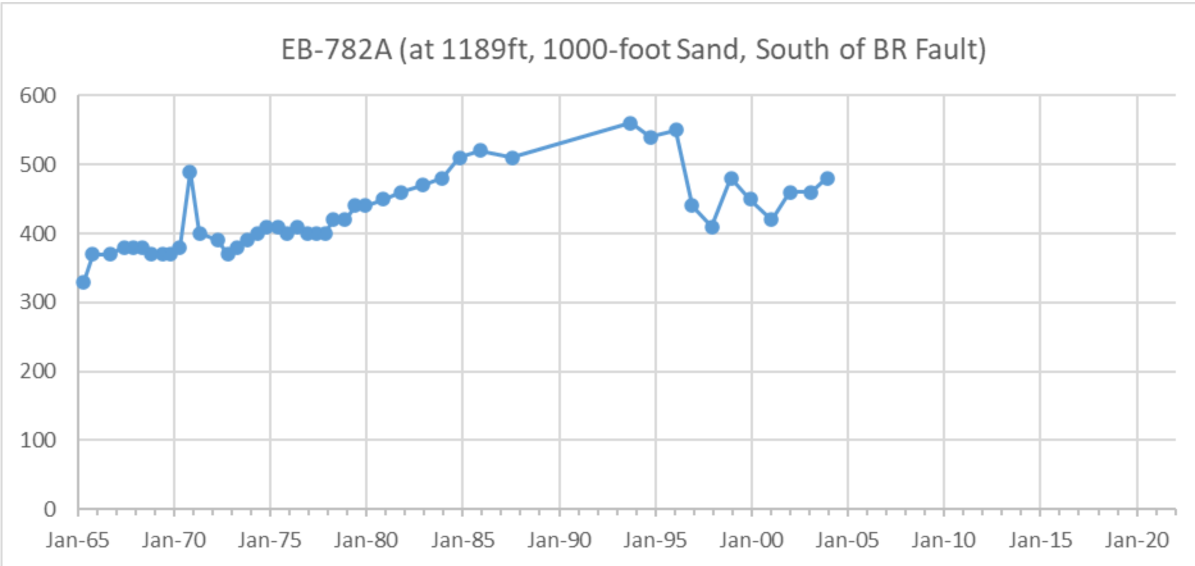

Figure I-3. Chloride concentration (mg/L) at monitoring well EB-782A between Jan. 1965 and 2020.

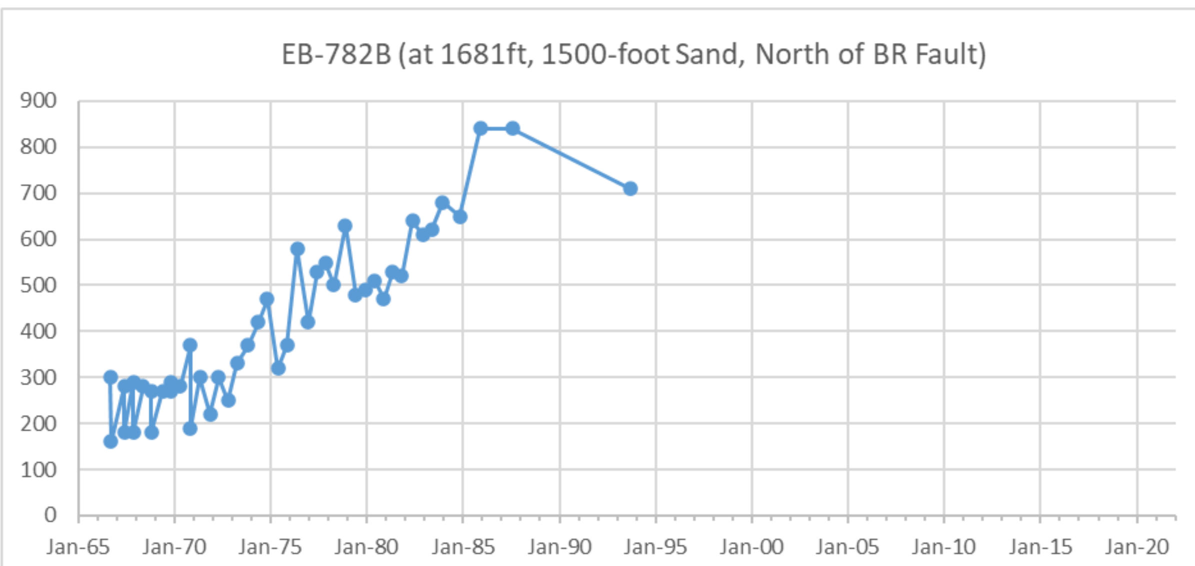

Figure I-4. Chloride concentration (mg/L) at monitoring well EB-782B between Jan. 1965 and 2020.

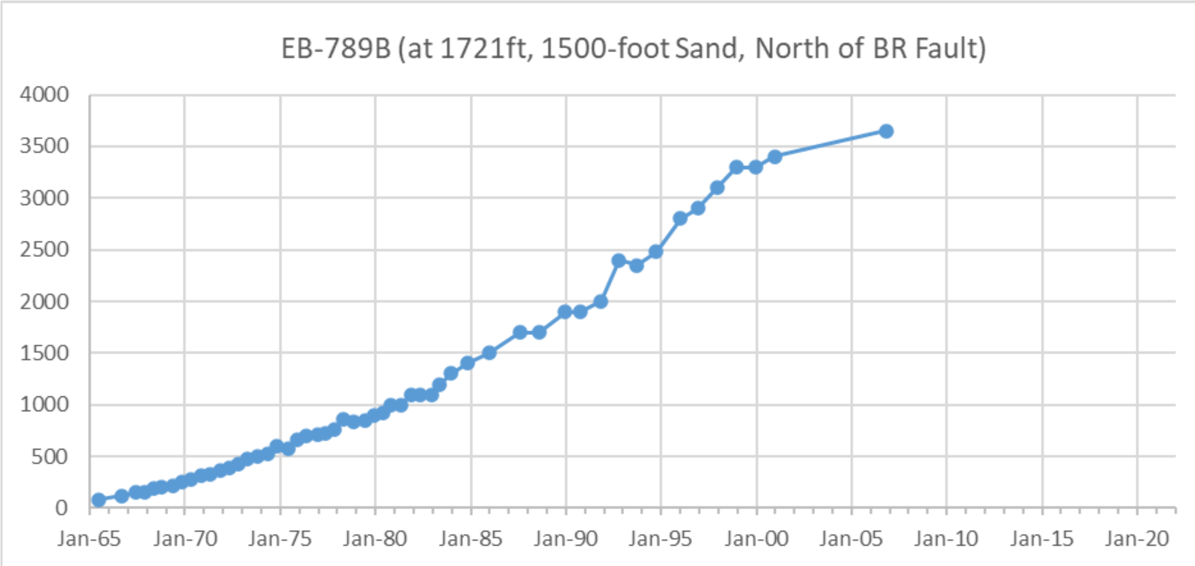

Figure I-5. Chloride concentration (mg/L) at monitoring well EB-789B between Jan. 1965 and 2020.

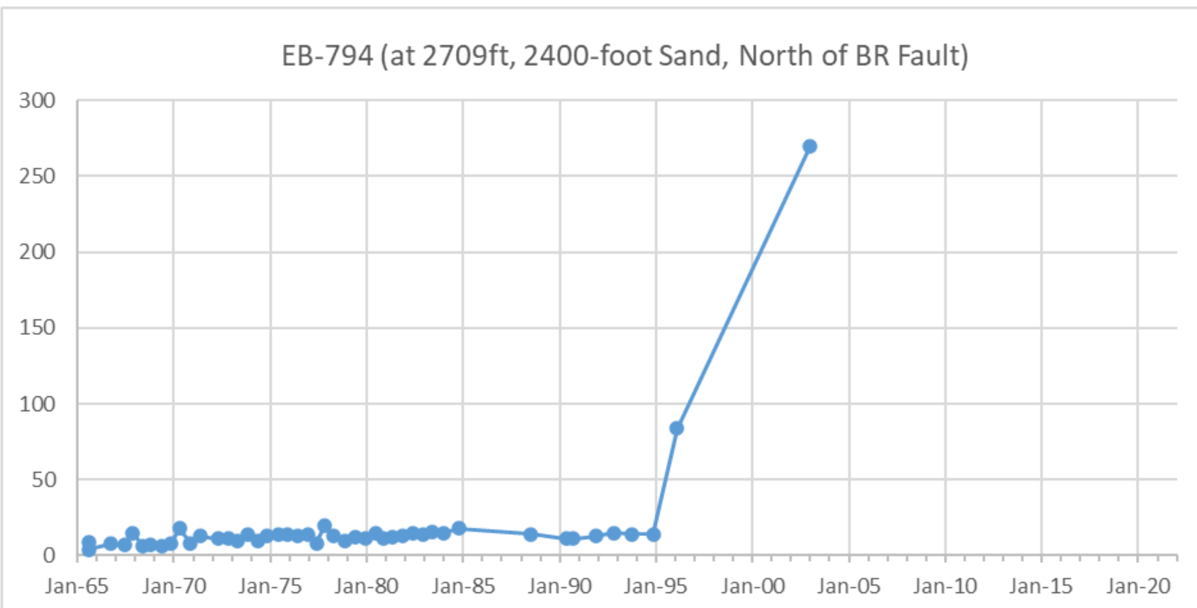

Figure I-6. Chloride concentration (mg/L) at monitoring well EB-794 between Jan. 1965 and 2020.

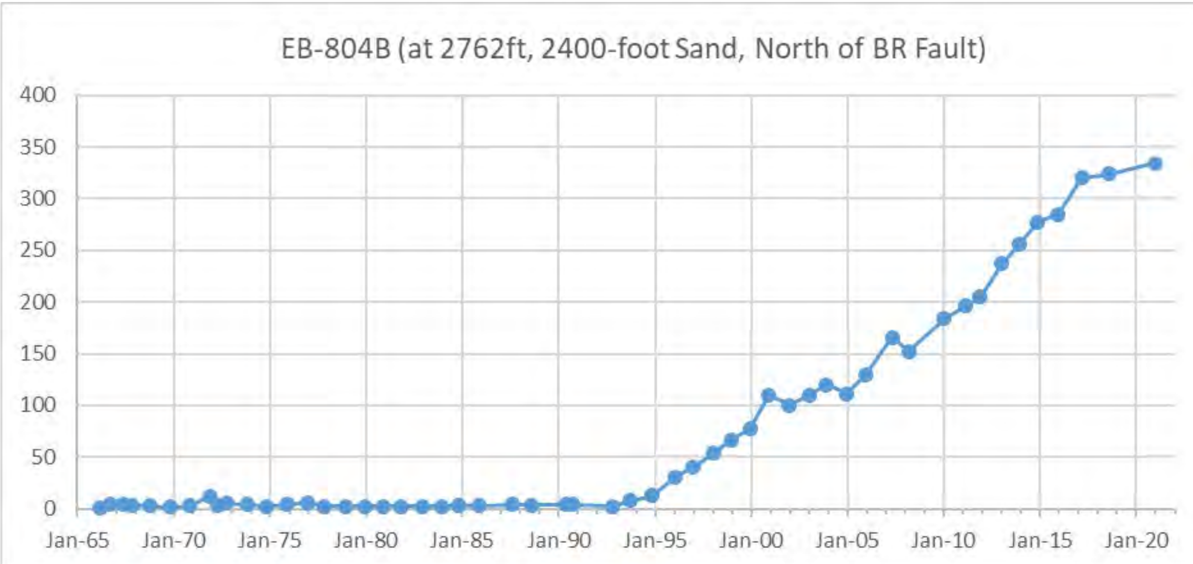

Figure I-7. Chloride concentration (mg/L) at monitoring well EB-804B between Jan. 1965 and 2020.

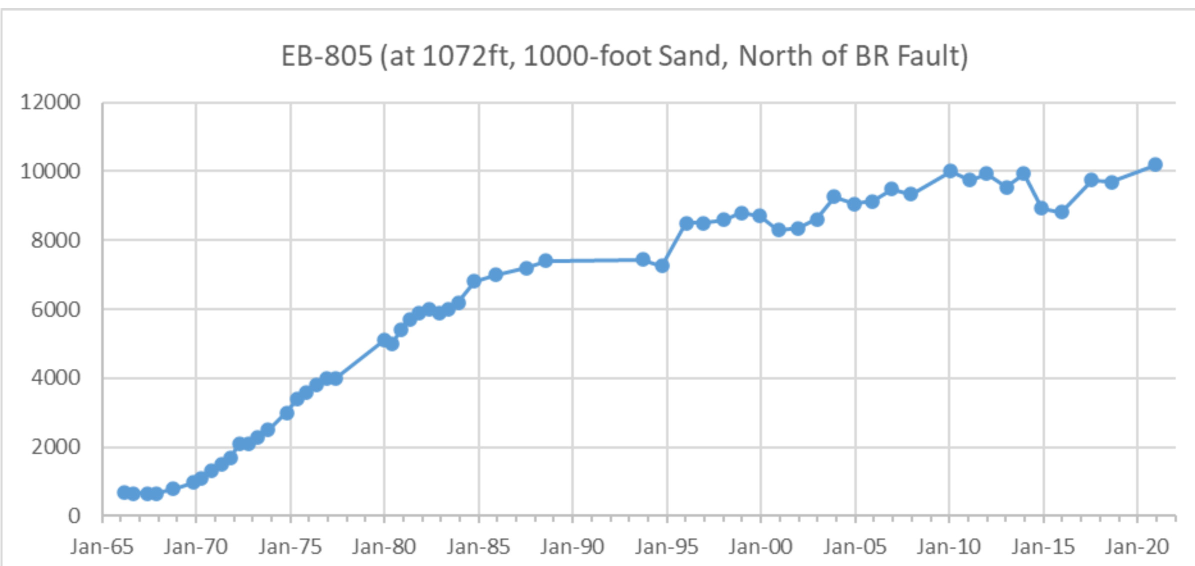

Figure I-8. Chloride concentration (mg/L) at monitoring well EB-805 between Jan. 1965 and 2020.

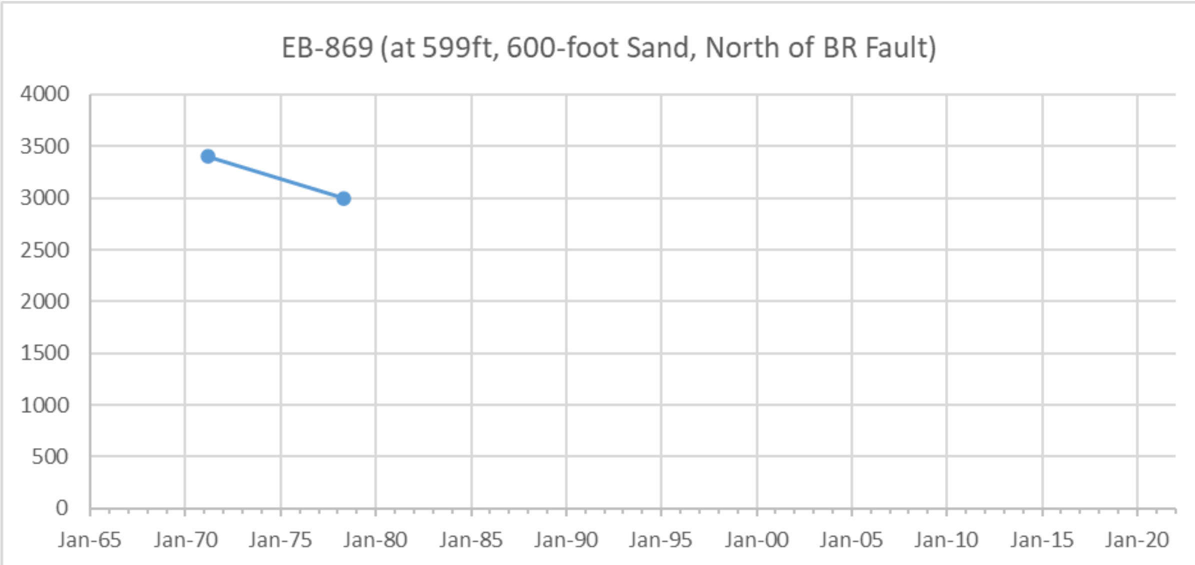

Figure I-9. Chloride concentration (mg/L) at monitoring well EB-869 between Jan. 1965 and 2020.

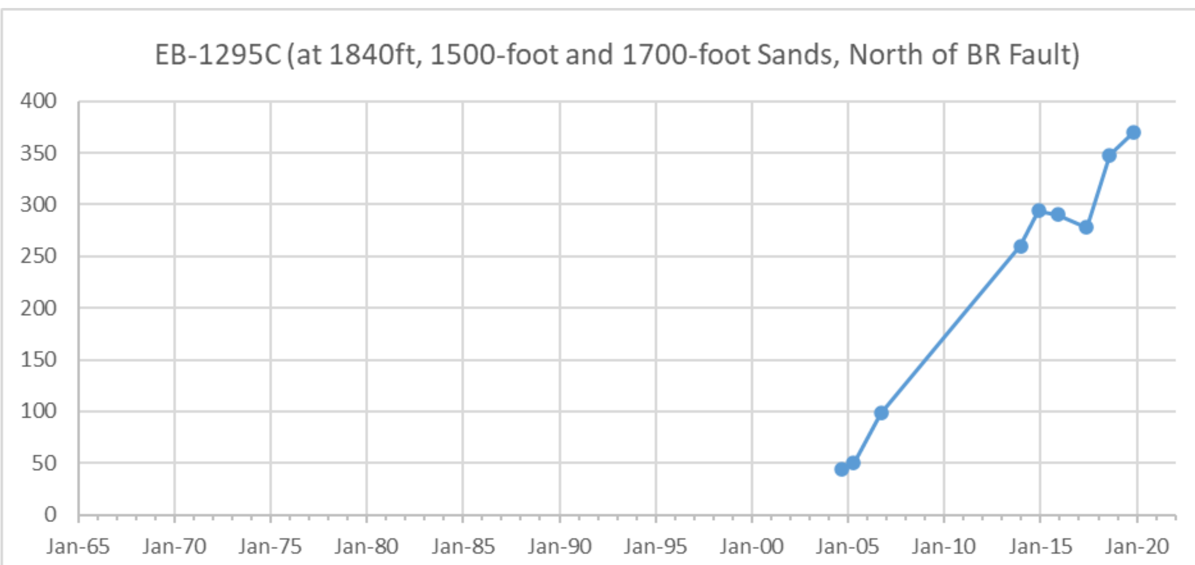

Figure I-10. Chloride concentration (mg/L) at monitoring wells EB-1295C between Jan. 1965 and 2020.

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