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Framework for a Long-term Strategic Plan for the Capital Area Groundwater Conservation Commission

MICHAEL C. RUNGE, ELLEN A. BEAN, ADRIAN MCINNIS, RYAN CLARK, AND ALYSSA DAUSMAN

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Purpose and Vision

The Capital Area Groundwater Conservation Commission oversees the use of groundwater in six parishes in Louisiana. In carrying out its statutory responsibilities and authorities, the Commission 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 Commission 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. The long-term strategic plan is intended to consider actions and outcomes over at least the next 50 years within the 6 parishes in the Commission's jurisdiction and related to all the confined aquifers in the 3,000 feet below the Capital Area Groundwater Conservation District. The primary purposes of the plan are to promote long-term sustainability of groundwater extraction, continuity of operations of the Commission, long-term planning by water users, and clear communication with the public. The plan will describe specific management actions to be taken over time by the Commission, and the conditions under which those actions are to be taken. It will include intermediate milestones the Commission intends to achieve on the way toward achieving its long-term objectives. The actions under consideration include regulation and monitoring of groundwater withdrawal, mitigation of the environmental effects of withdrawal, support of relevant scientific studies, as well as work with partner agencies to implement measures to conserve, develop, and supplement groundwater resources. The plan will have greater detail about short-term actions than mid-term and long-term actions, and the Commission anticipates updating the plan periodically to adapt to changing circumstances and knowledge.

To develop its long-term strategic plan, the Commission is working with The Water Institute of the Gulf and the U.S. Geological Survey using a facilitated process based on the principles of structured decision making (Gregory et al., 2012). This document outlines the framework for the strategic plan, developed during Phase 1 of a three-phase process, by describing the legal, economic, and scientific context for the plan, the fundamental objectives the Commission seeks to achieve in the long term, and the alternative strategies it is considering.

Mission Statement[1]

The mission of the Capital Area Groundwater 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 Groundwater 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.

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[1] The mission statement is taken from the Commission's web site (https://www.cagwcc.com/site2015/aboutus-mission.htm), with the addition of Ascension Parish, and editorial modifications to reflect the statutory language that established the Commission ("groundwater" rather than "ground water").

Process

In June 2018, The Capital Area Groundwater Conservation Commission (hereafter, "the Commission") contracted with The Water Institute of the Gulf (TWI) to facilitate and undertake a three-phase project leading to the development of a long-term strategic plan for the Commission. This report describes the framework for the long-term strategic plan developed during Phase 1. To develop this framework, TWI worked with the U.S. Geological Survey (USGS) to facilitate five public meetings with the Commission (July 24, 2019; August 1-2, 2019; August 21-22, 2019; September 12-13, 2019; and October 17, 2019). During these meetings, TWI and USGS used the principles of structured decision making (Gregory et al., 2012) to elicit and develop the elements of this framework with the Commission. Most of the discussion occurred directly with Commissioners, but members of the public who attended the meetings also had the opportunity to comment.

Background

The scope, aims, and actions that form the framework of the long-term strategic plan arise from an understanding of the statutory authority of the Commission, the authorities of related agencies, the hydrogeological dynamics of the Southern Hills aquifer system, and the desires of stakeholders.

AUTHORITY OF THE CAPITAL AREA GROUNDWATER CONSERVATION DISTRICT

The Capital Area Groundwater Conservation District (hereafter, "the District") was established and granted legislative authority by Act 678 of the 1974 Regular Legislative Session, which became Louisiana Revised Statutes 38:3071-3084. Section 3071 explains that the creation of the District is "to provide for the efficient administration, conservation, orderly development and supplementation of groundwater resources…." The statutes also created the makeup of the board of commissioners who are tasked with administering the affairs of the District, and delineate the powers, authorities and responsibilities of the political subdivision. In the remainder of this document, we use "the Commission" to refer to the board of commissioners of the District.

The Commission's general charge by the legislature is to "work with the commissioner of conservation in his responsibilities to do all things necessary to prevent waste of groundwater resources, and to prevent or alleviate damaging or potentially damaging subsidence of the land surface caused by withdrawal of groundwater within the district" (La. R.S. 38:3076.A). The Commission also has numerous specific grants of authority to exercise "in conjunction with the commissioner of conservation" (La. R.S. 38:3076.A). These powers include: registering, permitting, and establishing standards for wells; conducting studies; investigating and inspecting records and property relevant to groundwater use or conservation; requiring the sealing of abandoned wells; establishing groundwater use priorities; taking "all necessary steps to prevent intrusion of salt water or any other form of pollutant into any aquifer;" and limiting the production of water from any aquifer, "after detailed research, considering both recharge and withdrawal data, when the quality or quantity of the supply of water…is in danger for any reason" (La. R.S. 38:3076.A). The board also has the authority to promulgate and enforce rules, regulations, or orders that are intended to achieve the purposes and powers of the statutes (La. R.S. 38:3076.E, 3080, 3083).

As with all grants of legislative authority, the Commission's power is not unfettered and is subject to explicit statutory limits. For example, "[n]o order limiting rates of production [as described above] shall have the effect of in any way denying to any owner of the land or any other person holding rights to water derivative from any landowner a reasonable opportunity to produce and beneficially use his just and equitable share[2] of the groundwater supply…" (La. R.S. 38:3076.B).

RELATED AGENCIES AND THEIR AUTHORITIES

As noted by the enabling statutes, the District was not intended to operate in a complete regulatory vacuum without consulting with other agencies. Of particular importance is the balance between the roles and authorities of the District and the Office of Conservation in the Louisiana Department of Natural Resources (hereafter, "Conservation").

> "The commissioner [of Conservation], through the office of conservation, is empowered and responsible for the administration of all matters related to the management of the state's groundwater resources by providing for the most advantageous use of the resource consistent with the protection, conservation, and replenishment thereof. The commissioner shall perform these functions to the extent such functions are not specifically within the jurisdiction of other state departments or agencies." (La. R.S. 38:3097.3.A).

To carry out this responsibility,

> "[t]he commissioner has authority to make, after notice and public hearings in accordance with the Administrative Procedure Act, any reasonable rules, regulations, and orders that are necessary from time to time in the proper administration and enforcement of this Chapter, including rules, regulations, or orders for the following purposes": to "[d]o all things necessary to prevent waste of water resources"; to "[p]revent or alleviate damaging or potentially damaging salt water movement or water level decline and loss of sustainability[3] in the state's aquifers"; and to "[d]etermine areas of groundwater concern" (La. R.S. 38:3097.3.C).

Although the Southern Hills aquifer system has not been so designated, the commissioner of Conservation holds the authority to determine an area of groundwater concern. Such a determination is made subsequent to an application by a well owner that is "significantly and adversely affected as a result of the movement of a saltwater front, water level decline, or subsidence...." If the commissioner grants an application to designate an area of concern, this expands Conservation's authority. Most notably, "[i]f the commissioner designates an area a critical area of ground water concern, the order may restrict the amount of withdrawals by any or all users in the area" (La. R.S. 3097.6).

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[2] "'Just and equitable share' of the groundwater underlying a tract within an area subject to an order limiting pumping rates means that portion of the recoverable groundwater within an aquifer which is to be apportioned to such tract on the basis of demonstrable geologic and hydrologic data taking into consideration the volume of groundwater in storage, the maximum perennial recharge potential, and any groundwater use priorities established by the board." (La. R.S. 38:3073(8))

[3] "Sustainability means the development and use of ground water in a manner that can be maintained for the present and future time without causing unacceptable environmental, economic, social, or health consequences." La. R.S. 38:3097.2 (13).

However, like the District, which is required to "work with the commissioner of conservation in his responsibilities to do all things necessary to prevent waste of groundwater resources, and to prevent or alleviate damaging or potentially damaging subsidence of the land surface caused by withdrawal of groundwater within the district" (La. R.S. 38:3076.A), the Office of Conservation is given the legislative mandate to cooperate. The functions and powers of the commissioner are required to be performed "to the extent such functions are not specifically within the jurisdiction of other state departments or agencies". The commissioner shall also "seek the advice and consultation of local governmental entities on any actions or decisions which may have an impact upon those entities or residents within the entities' respective jurisdictions" (La. R.S. 38:3097.3).

The Louisiana Department of Environmental Quality (LDEQ) is responsible for monitoring the quality of natural resources, including both surface and groundwater. LDEQ issues permits, enforces regulations, monitors, and runs programs which help users whose actions relate to environmental quality. LDEQ monitors groundwater through its Aquifer Sampling and Assessment Program. The Louisiana Department of Health also monitors water quality through its Safe Drinking Water Program (Louisiana Department of Health, 2019).

HYDROGEOLOGICAL DYNAMICS OF THE SOUTHERN HILLS AQUIFER SYSTEM

Southern Hills aquifer hydrogeology. Aquifers containing fresh water in the Baton Rouge area are generally part of the Southern Hills aquifer system (SHA) and include the Mississippi River alluvial aquifer, the shallow sands of the Baton Rouge area, the upland terrace aquifer, the "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, and "2,800-foot" sand of the Baton Rouge area and the Catahoula Aquifer (Heywood et al., 2014). The Commission's jurisdiction excludes the production of water from the Mississippi River alluvial aquifer, from wells producing from a depth of less than 400 feet, and from those portions of sands that extend beyond the geographical boundaries of the District.

There are two important fault zones within the SHA, which run east-west, that are generally associated with the Southern Hills aquifer system. The northern fault zone, known as the Denham Springs-Scotlandville fault zone, is permeable and has minimal impact on groundwater flow in the Southern Hills aquifer system. The Baton Rouge fault zone acts as a barrier to groundwater movement and, generally, is the southern limit of fresh water in the system. South of the Baton Rouge fault zone, water within the formations that compose the aquifer system is generally saline and not potable.

The sands of the freshwater aquifers in the Baton Rouge area range in composition from very fine to coarse sand with some pea-to-cobble-sized gravel (Griffith, 2003) and are sufficiently permeable to yield economically substantial quantities of water to wells. Vertical groundwater flow is limited by confining units composed of material ranging from solid clay to sandy and silty clay (Heywood et al., 2014). Water within the aquifer system moves very slowly, ranging from a few tens of feet per year to several hundreds of feet per year (Heywood et al., 2014). Across the SHA system, hydraulic conductivity, a measure of the sands' capacity to transmit water, ranges from 33-175 ft/day, with deeper sands tending toward higher values (Griffith, 2003).

The SHA is the primary source of water for public and domestic use in 10 parishes of southeastern Louisiana. The freshwater portion of the system extends southward from Vicksburg, Mississippi to the southern part of the Florida Parishes of Louisiana (Heywood et al., 2014).

Before major pumping began in the 1920s, the majority of the Southern Hills aquifer system was artesian, that is, it had potentiometric surfaces above the land surface. The recharge area for the Southern Hills aquifer system includes all of East and West Feliciana, St. Helena, and Washington Parishes, the top portion of East Baton Rouge and the top half of Tangipahoa Parishes, and extends north of the Louisiana state boundary to Vicksburg, Mississippi. Precipitation within this area is the major contributor to the SHA. The water quality of the 1,500-, 1,700-, and 2,000-foot sands is considered very soft, with sodium bicarbonate the dominant mineral (Meyer & Turcan, 1955).

The 1,500- and 1,700-foot sands, which previously had potentiometric surfaces between +50 and +100 ft in the 1920s, have dropped to approximately –100 ft, as measured in reference to the National Geodetic Vertical Datum of 1929 (NGVD 29). The cone of depression that has formed as a result of this pumping has grown significantly and affects areas outside of the Baton Rouge area. A similar cone of depression is also seen in the sands below 2,000 ft. These cones of depression have started to induce saltwater movement across the Baton Rouge fault, which was previously thought to be "an important hydrologic barrier that restricts or limits the volume of saltwater moving northward" (Tomaszewski, 1996).

<u>Southern Hills aquifer system saltwater intrusion</u>. The earliest documentation of saltwater intrusion into the SHA was noted by Meyer & Turcan (1955), when water containing chloride concentrations above background level (hereafter referred to as saltwater) was screened from well EB-123, completed in the 600-foot aquifer. Several investigations have since noticed increasing chloride concentrations in select sands within the freshwater portion of the SHA. Sustained pumping over the last several decades has created a pressure differential from south to north across the Baton Rouge fault zone, promoting the northward movement of saltwater into areas of lowered head pressure. Movement of saltwater across the fault is occurring where freshwater sands north of the fault are juxtaposed adjacent to sands containing saline water south of the fault and separated from one another by a fault gouge, a low permeability clay occurring along the plane of the fault. To determine the occurrence and location of saltwater within the freshwater sands, chloride monitoring wells have been installed at select locations.

Based on historical chloride-concentration data collected through 2005, water containing chloride concentrations above background level (10 mg/L or less) have been detected in 8 of the 10 aquifers in the Baton Rouge area (Lovelace, 2007; Tomaszewski et al., 2002). Based on monitoring data collected since the 1960s, Lovelace (2007) indicates increasing salt concentrations in 5 of the sands, specifically the 1,000-, 1,200-, 1,500-, 2,000-, and 2,800-foot sands. Detection of chloride concentrations above background level was detected more recently in the 1,700- and 2,400-foot sands, in the 1990s and 2000s, respectively (Lovelace, 2007). Heavy pumping is driving saltwater intrusion for most of the affected sands (Heywood et al., 2014). The 2,800-ft sand, however, is unique, in that, unlike other sands in the Southern Hills aquifer system, it contains saltwater in an area north of the Baton Rouge fault. "Saltwater initially filled the [2,800-foot sand]; however, natural recharge (rainfall) over geologic time slowly moved downdip from recharge areas and flushed much of the saltwater from the [sand]. Because all of the saltwater was not completely flushed from the [sand], a large area north of the fault contains less dense freshwater overlying denser saltwater" (Tomaszewski, 1996:2).

Southern Hills aquifer management. The Commission has opportunities to manage the District's groundwater resources through permitting and siting wells, setting pumping limits, and other regulatory tools. Since the creation of the Commission, management decisions that directly affect the production of groundwater have focused on reserving specific sands for public use by specifying that any new production from those sands may only be for public supply, establishing voluntary limits on annual pumping rates in the 1,500-foot and 2,000-foot sands, the installation of scavenger wells to mitigate salt intrusion in the 1,500-foot sand (completed by Baton Rouge Water Company) and 2,000-foot sand (planned), and installing a connector well to protect water-supply in the 1,500-foot sand from saltwater encroachment. In addition to the direct actions taken thus far, the Commission has supported the development and refinement of modeling products to assist with decision making in the management of the aquifer system. These products are intended to determine availability and sustainability of the resource for each of the individual freshwater sands, and to evaluate saltwater management and remediation scenarios for those sands experiencing saltwater encroachment, and to provide decision support for setting pumping limits where required.

INTERESTED PARTIES

The Commission is aware that decisions made concerning the production of groundwater could affect a wide array of stakeholders across the District. This community of stakeholders is diverse and includes: representatives from municipal governments and chambers of commerce within the District; industrial, agricultural, and commercial ventures that economically benefit from the resource; local and regional organizations concerned with water management; and members of the general public that rely on groundwater to meet health and other domestic needs. Potential impacts could vary across the stakeholder groups, and it is important to both understand and consider these impacts in any decision-making process. Further, stakeholders whose primary relationship with the resource is consumptive have a critical role to play in any strategy aimed at sustainable use of groundwater across the District. As such, the Commission desires to engage these stakeholders in outreach and educational activities designed to solicit input on proposed management actions, promote knowledge of the resource and the Commission's role in its management, and encourage consumers to responsibly use groundwater over the long term.

Fundamental Objectives

The fundamental objectives describe the long-term outcomes that the Commission aims to achieve through its activities, including outcomes important to stakeholders that the Commission seeks to achieve. These desired future conditions are multi-faceted and may conflict with one another, so the Commission may need to weigh trade-offs among these goals in developing its long-term strategy. The fundamental objectives will guide the development and evaluation of alternative strategies.

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

It is the intent of the Commission to manage withdrawals of groundwater in such a manner that provides for both current and future beneficial use. Employing a water budget perspective, this means that the rate of withdrawal cannot exceed the rate of recharge, and to ensure sustainability, the rate of withdrawal cannot lead to the progressive depletion of groundwater storage over the long term.

Managing for a resilient aquifer system is also desired. In the context of the SHA, resilience is the system's capacity to absorb variable pumping stress while maintaining its basic functionality in the context of external factors such as drought (which can both reduce recharge and increase withdrawals). A resilient aquifer should retain the ability to return to a satisfactory condition following a period of external stress.

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

Potable water is a fundamental need in meeting human health and well-being. Equity is achieved when the supply of potable water is both affordable and available to meet consumptive demand across the District. Groundwater produced from the SHA provides multiple benefits, including: a unique and consistent taste profile; perceived health advantages from consuming minimally treated water; and low cost, given the limited treatment required at both public supply and household levels. With continued use of the SHA for potable water, the Commission can provide a resource that is of higher quality, and thus preferred, to alternate water sources, such as treated surface water.

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

The Commission recognizes the benefits derived from having a solid economic base, including employment opportunities, commercial tax revenue, and the production of goods and services which the citizens of the greater Baton Rouge region enjoy. Having access to water that is economical both to capture and to treat provides a competitive advantage for commercial users and is thus an incentive for attracting commercial enterprise to the District.

4. Reduce the movement of saltwater into the Southern Hills aquifer system and slow or halt the advance of the existing saltwater plume

One of the statutory authorities of the Commission is, "To take all necessary steps to prevent intrusion of salt water or any other form of pollutant into any aquifer or aquifers" (R.S. 38:3076.A.(18)). At present, chloride concentrations above background level occur in 8 of the 10 sands within the SHA system (Lovelace, 2007), although the concentration and distribution of salt differs between the affected sands. Of greatest concern now are the 1,500- and 2,000-foot sands, because these are critical to public and industrial supply. If the salt front continues to advance, this would jeopardize the integrity and health of the aquifer, and severely curtail its benefits to the broader community from both economic and health perspectives.

To stem potential negative consequences from continued encroachment, it is desirable both to reduce the flow of saltwater across the Baton Rouge fault, and to contain, if not reduce, the present distribution of salt within the freshwater portion of the SHA system. Although the complete elimination of this existing salt may not be feasible, the Commission aims to halt further degradation of the aquifer and remediate the saltwater intrusion where possible. Similarly, the Commission will work with the Department of Environmental Quality to monitor, manage, and remediate any additional pollutants that affect the aquifer.

5. Minimize the risk of subsidence

One of the principle statutory charges to the Commission is "to prevent or alleviate damaging or potentially damaging subsidence in the land surface caused by withdrawal of groundwater within the district" (R.S. 38:3076(A)). Subsidence at ground level can result from permanent compaction of an aquitard, the semi-permeable layer surrounding a freshwater sand. Severe reductions in water levels within an aquifer can cause additional pressure-related stress on the aquitard, potentially leading to permanent compaction. Permanent compaction both reduces water-storage potential and land-surface level. Managing withdrawals in order to limit water level declines, in such a way that the stress levels on the aquitards are less than the pre-consolidation stress levels on the aquitards, minimizes the potential for damaging subsidence.

Performance Metrics

The choice of a preferred management alternative should be based on how well it is expected to achieve the fundamental objectives. Performance metrics are quantitative or qualitative scales on which those objectives can be evaluated (Gregory et al., 2012). Metrics serve a dual role: they are useful for predicting consequences during the initial evaluation of alternatives; and they can be used to measure achievement after implementation. The process of developing metrics for individual objectives will often clarify ambiguous terms. Metrics also provide a guide to the necessary types of data, expert elicitation, modeling, and technical information required for evaluation of the alternatives.

Ideally, metrics should be natural, direct measures of the fundamental objective they represent (Gregory et al, 2012). In the absence of such measures, proxy metrics may be identified and used, provided the associated proxy is directly correlated with that objective's nature and intent. Finally, constructed scales, created by the decision maker, may sometimes be useful, especially for objectives that capture intangible notions such as social or human well-being. A defining feature for any metric is that it should be able to clearly communicate differences in performance among the alternatives evaluated relative to the specific objective being considered.

The proposed performance metrics for each of the fundamental objectives are described below.

Objective 1. Achieve and maintain sustainable and resilient groundwater withdrawal rates from the Southern Hills aquifer system within the District boundaries

Performance metric: Spatial extent and water levels of the cone of depression in each sand. This objective will be achieved when the withdrawal rate in each sand is less than or equal to the recharge rate to that sand. If this happens and the spatial distribution of withdrawal is fixed, then the pressure levels throughout the sand should eventually stabilize, as should the water levels at each well. So stable water levels in wells or a stable potentiometric surface are sufficient indicators of sustainable withdrawal rates, but they may not be necessary, because the spatial distribution of withdrawal need not be static. Instead, it would be enough for the average water level across the sand to be stable. This 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, and visualized as the shape, character, and spatial extent of the cone of depression. That is, a possible summary metric might be the mean water level, calculated as:

$$\bar{p} = \frac{\int_x \int_y p(x, y)\, dy\, dx}{\int_x \int_y dy\, dx}$$

where $p(x, y)$ is the potentiometric elevation at the location (x, y) and the integration is taken over the spatial extent of the District.

If the spatial extent and water levels of the cone of depression remain stable over time, then the withdrawals would be sustainable. Many different combinations of spatial extent and water levels could achieve this criterion, but they might not all confer the same degree of resilience. Further work is needed to define the desired level at which to hold the average water level in each sand. In order to definitively quantify the sustainable yield of each sand, additional modeling will be needed. A simplified mathematical model could be utilized in the near term to provide preliminary sustainable yield values, while more detailed models are refined and used to provide higher fidelity results to guide future sustainability decisions.

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

Performance metric: Volume of water per year that is available for public supply at an acceptable cost, and that meets quality standards relating to salt, hardness, taste, impurities, and health risk. Many of the aspects of quality could be met with alternative sources of water, but the taste profile and the public's perception of the purity of the water are best met with groundwater. Some work to understand the importance of these aspects of quality might be warranted, through public surveys or other social research.

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

Performance metric: Some work is still needed to develop an appropriate measure of this objective. One element, of course, is the volume of water available for commercial and industrial use. An additional important consideration for industry is the total cost of water for their specific purposes, including both the direct cost of the water and the cost of secondary or tertiary treatment to meet the requirements for the specific industrial use. A source of water, like groundwater, that is very low in impurities does not require much further treatment. But other sources of water can be treated to reach the same degree of purity, albeit at higher cost. A possible metric for this objective is the mean total cost per gallon of water, where the total cost is the industry- and use-specific cost to acquire and treat water to the degree needed, and the mean is taken over industries and uses, weighted by the volume of use.

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: Mass of salt in each sand. The total mass of salt in each sand is a measure of the degree of intrusion. Continued intrusion will increase the mass; mitigation strategies like 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, so there is no continued increase in net salt. An alternative metric, which is subtly different, would be the horizontal area (say, in acres) of each sand for which the chloride concentration was above some threshold amount; this has the advantage of also conveying the degree of movement of the saltwater plume.

Objective 5. Minimize the risk of subsidence

The Commission did not settle on a specific performance metric for this objective. The plain reading of the objective would suggest a metric like the probability of subsidence of greater than *x* inches per year in any part of the District, but it might be difficult to identify an appropriate threshold rate of subsidence and it might be difficult to forecast how that could change in the future. Smith & Kazmann (1978) estimated that "[t]otal subsidence in the [Baton Rouge] industrial area for the 1935 to 1976 period has been about 1.67 ft.: 1.26 ft. due to local effects of ground-water pumping and approximately 0.41 ft. due to natural regional subsidence, assumed to be 0.01 ft. per year." Whiteman (1980) evaluated extensometer data and found that "[t]he indicated rate of subsidence [due to local effects] of less than 0.014 ft/yr, 1975-79, is significantly less than rates calculated for earlier periods on the basis of releveling of benchmarks." He attributed the lower rate of subsidence to reduced industrial pumping, stating that "water levels in wells in most of the major aquifers in the area are higher now than in the early 1970's. … If water levels resume their declining trend, which seems likely to happen as a result of population growth, even if industrial pumping remains relatively low, the rate of compaction will increase again as water levels fall below their earlier levels." The Commission suggests research to identify water levels at which the risk of damaging subsidence is very low (perhaps by comparing to pre-consolidation stress levels). Then, those levels could be used to set limits to the sustainable level at which each sand is held under Objective 1.

Action Elements

A long-term strategy is a complicated combination of individual actions, often sequenced in time, dependent on conditions, and conditional on the state of knowledge (Gregory et al., 2012). Before formulating the specific combination of actions into a long-term strategy, it is valuable to articulate the full set of *action elements* from which a strategy might be devised. The Commission has identified a range of management options that might be useful for meeting the desired future conditions articulated within the objectives. Some of these actions arise from the Commission's current statutory authority; others arise from the authority of partner agencies, industry, or non-governmental organizations; still others might require new legislative authority. The list of potential actions described below is organized around categories of action; no preference or priority is implied by the order in which they are described. Although broad, this set of actions may not be exhaustive, and additional actions may be identified during the evaluation phase or as new information comes to light.

ACTIONS DESIGNED TO LIMIT THE WITHDRAWAL OF GROUNDWATER

Much of the authority described in its enabling legislation focuses on ways the Commission can limit the withdrawal of groundwater. Note that in some cases, the enabling legislation specifies preparatory steps that need to be taken before these actions can be implemented; ultimately, the strategic plan will need to outline these preparatory steps, but we have only focused on the end actions here. Actions that could be used to limit groundwater withdrawal include:

- Permitting (These actions could apply to the granting of a new permit, as a condition of operation, or retroactively)
    - Establish supply/demand accounting basis for issuing permits
    - Require data on both forecasted and metered use as a condition of production
    - Promote water loss reduction via requiring loss audits and associated repairs or retrofitting where required
- Zoning
    - Establish appropriate areas for new well installations
    - Establish 'sensitive use' areas based on aquifer status
        - Couple with zoned production limits
    - Optimize spatial distribution and vertical location of wells and pumpage
- Fee Schedules
    - Establish water conservation-oriented fee schedules
        - Increased flat rate
        - Increasing block rates
        - Quantity based surcharges
        - Seasonal rates
- Production Caps
    - Establish voluntary production limits in select sands
    - Establish voluntary production limits across all sands
    - Establish non-voluntary production limits in select sands
    - Establish non-voluntary production limits across all sands
    - Establish production limits on wells producing over X gal/day
    - In conjunction with production caps, a cap-and-trade system could be set up to allow producers to trade allowances

ACTIONS DESIGNED TO LIMIT OR MITIGATE SALTWATER INTRUSION

Some actions focus primarily on addressing objective 4 by looking for ways to remove salt or prevent its movement into the aquifer, without necessarily reducing groundwater withdrawal. These actions are spatially explicit, focusing on the particular places where saltwater intrusion is a problem. The options include:

- Pollutant Mitigation and Remediation
    - Scavenger wells to withdraw salt from the aquifer
    - Closure or movement of individual wells or well fields
    - Injection wells to alter pressure dynamics along the fault zone

ACTIONS DESIGNED TO REDUCE DEMAND FOR WATER

One of the concerns underlying the need for this long-term strategy is the possibility that demand for water within the District has exceeded or will exceed the sustainable supply that can be provided by groundwater. One way to address this concern is to focus on reducing the overall demand for water. Options to reduce demand include:

- Promoting Awareness
    - Develop and deliver educational curricula for school-age persons
    - Develop and deliver messaging on water supply and domestic consumption to targeted audiences via public service announcements, water bill inserts, community associations, etc.
    - Develop online applications where users could compare their household water use to benchmarks, neighborhood averages, or municipal averages
    - Develop informational materials for relevant local governments and economic development organizations regarding water management as it relates to water supply and demand
- Incentivizing Conservation
    - Develop rebate programs for adopting water conservation technologies at the household level
    - Develop financial support or other incentives for the adoption of improved technologies for industry to reduce water use
    - Develop regulations that incentivize users to find methods to reduce demand, by setting performance standards but not specifying specific practices

ACTIONS DESIGNED TO INCREASE THE SUPPLY OF WATER

Some of the possible actions involve increasing the supply of water for industrial or public supply by looking at other sources besides groundwater from the SHA. The Commission's purpose includes the "supplementation of groundwater resources" (La. R.S. 38:3071.B), but specific powers about how that might be done are not described, so the Commission may need to work with other authorities (parishes, other state agencies, industry, or foundations) to pursue such actions. Possible actions include:

- Water Supplementation
    - Treatment facility for river water
    - Bank filtration of river water using shallow wells in the Mississippi River Alluvial Aquifer
    - Capture surface water via reservoir (co-benefits to flood management)
    - Treat wastewater from municipal sources, apply to domestic or industrial needs
    - Treat and recycle industrial-use water
    - Desalination of groundwater
    - Artificial recharge and storage via injection wells
    - Blend water sources
    - Develop financial support for the development of alternative water sources, including for industry, e.g.,
        - Standard bond issue
        - Environmental impact bond (EIB)
        - Other public-private partnership (P3) agreements

Alternative Strategies

At this initial stage of exploratory development, the Commission developed three draft alternative strategies for consideration (Table 1). Each strategy is a combination of individual action elements, meant to offer different approaches for achieving and balancing the fundamental objectives. Broadly speaking, these three strategies can be distinguished by the relative emphasis on managing demand or managing supply. Each strategy differs in the spatial and temporal application of the various action elements. For example, certain actions may be applied only to select sands, or there may be actions that have greater benefit in the near term, while others are more relevant in future years or for specific aquifer conditions. This is only an exploratory list of alternative strategies; as new information comes to light during Phase 2, additional strategies may be developed and evaluated.

At this stage, the strategies described in Table 1 are draft sketches of the alternatives, but provide enough detail to allow for initial analysis. Prior to evaluating each strategy against the full set of fundamental objectives, the strategies will require further development and clarification of specific action elements. Specific details that will need to be described include, but are not limited to: the criteria used to establish zones; a process for analyzing sustainability related to permitting; and the total volumes or percentage reduction in withdrawals related to production caps. The District is discussing possible changes to its current operations, including requirements for permitting new wells and for renewing the permits of existing wells. Some of the changes being considered are: forecasting groundwater demand for each producer; the placement of flow-meters on all wells to record actual volumes pumped; and the content and schedule for reporting back to the District. These discussions will provide not only clarity for certain action elements, but will also help inform the development of an improved ground water monitoring program to gauge the efficacy of management going forward.

STRATEGY NARRATIVES

Individual strategies are described below. As action elements are clarified, and the District progresses with their discussions, each narrative can be updated to better document the assumptions and rationale that underpin each strategy.

Table 1. Draft alternative long-term strategies for achieving the fundamental objectives of the Capital Area Groundwater Conservation Commission.

		Alternatives		
Element Categories	**Action Elements**	**A. Business as Usual**	**B. Manage Demand via Regulation**	**C. Manage via Partnership**
Limit Withdrawal	***Permitting***	No new permits for production from sands that have exceeded their voluntary caps.	Renegotiate existing permits; meter all wells; conduct full use analysis. Set baseline production caps by permit.	Renegotiate existing permits for industrial producers; set permit-based production caps.
	Zonation	Industrial and fault zone restrictions on certain sands	Establish 3-4 zones based on potentiometric levels and chloride concentration.	None
	Fee Schedules	Flat fee for producers; user fees determined by BRWC and PSC (currently, lower rates for higher use)	(Same as in Alternative A)	Conservation-oriented schemes. Increasing block fees for producers. Work with BRWC and PSC to develop adjusted fee schedule for users.
	Production Caps	Voluntary production caps on select sands, as needed (currently 1,500-ft and 2,000-ft sands only)	Set non-voluntary zone- and sand-based production caps. Across-the-board reduction in production over time until caps met. Permits revoked for users who over-produce.	Phased reductions for industrial users
Manage Salt Intrusion	***Pollutant Mitigation***	Scavenger well in 1,500-ft sand (operating); 2,000-ft sand (planned)	Scavenger wells in select sands; expand as needed	Existing scavenger wells in select sands; intent is to not need more.
Reduce Demand	***Promoting Awareness***	1. Communications with major producers 2. Educational programming by partners	Joint programming by the District and its partners	Joint programming by the District and its partners
	Incentivizing Conservation	No initiatives	No initiatives	Develop incentives package
Increase Supply	***Water Supplement-ation***	Market-driven	Market-driven	Build river-water clarifier or other water-treatment facility to produce water for industrial purposes.
	Financing	(Not applicable)	(Not applicable)	Public-private partnership. Bond issue for initial capital; long-term operation by private entity.

Strategy A. The "business as usual" strategy describes current efforts to manage the SHA and assumptions about how it would unfold in the future absent any additional strategic planning. The nature of the strategy is to make use of voluntary efforts to manage ground water production in select sands, and salt pollutant concentration at select wells. Part of the reason for this strategic planning process is to make sure the Commission's strategy is adequate to meet its objectives; analysis of this strategy provides a useful baseline for comparison and for establishing whether changes are needed.

Strategy A is premised around three primary elements: voluntary production limits on select sands that exhibit signs of salt-water intrusion; engineering solutions (scavenger wells) to address specific saltwater intrusion problems; and an assumption that if additional water is needed in the future, market-driven forces will lead to private investment in infrastructure. The specific action elements are listed in Table 1 and described here.

Permitting: The only change in permitting envisioned in this strategy is that new permits for production will not be granted for sands that have exceeded their voluntary production caps. Two sands currently have voluntary production caps, and in neither case is the cap yet exceeded.

Zoning: In 1975, the District reserved the 1,500- and 1,700-foot sands for public supply, although there is not yet a formal mechanism to enforce this zoning. For new wells, the District intends to require construction northward of the fault zone, but the specifics of this intention have not been codified. Nevertheless, we assume for this strategy that sand- and location-specific zones will be established to direct future production away from the fault and away from the primary sources of public supply.

Fee Schedules: Per its legislative mandate, the District applies uniform fees to all producers to meet its basic costs of operation, with any fee increase being approved by the state's legislature. Domestic and other users receiving water from the Baton Rouge Water Company (BRWC) have their fee schedule determined by the BRWC in conjunction with the Louisiana Public Service Commission (LPSC); currently that fee schedule makes water less expensive for larger users.

Production Caps: This strategy relies on setting voluntary production caps for select sands, as needed. In 2013, the 1,500-foot sand was capped at 25 million gallons per day (MGD). In 2014, the 2,000-foot sand was capped at 23.5 MGD, a further reduction of 1 MGD per day from the 2013 cap of 24.5 MGD. Both are voluntary, and while no known violations have occurred, there is no mechanism in place to assign responsibility to individual producers for excess production at the sand level.

Pollutant Mitigation: BRWC, with permission of the District, installed a saltwater scavenger well in the 1,500-foot sand to protect a key source of public supply. The District is currently scouting locations for a second scavenger well to mitigate saltwater movement within the 2,000-foot sand.

Promoting Awareness: This strategy relies on other organizations, such as the Office of Conservation, to undertake any direct educational activities related to awareness and conservation of groundwater.

Incentivizing Conservation: This strategy does not include any incentive programs for reducing water consumption.

Water Supplementation: This strategy relies on market-driven forces to motivate and support the creation of any additional sources of water.

Strategy B. The "Managing Demand via Regulation" strategy relies on compulsory regulations, as opposed to voluntary agreements, and broadens the scope of management to include educational programming; in doing so, it makes greater use of the appointed powers of the District than Strategy A. The central approach of Strategy B is to set non-voluntary production caps at the sand level and to link those production caps to the authorized level of use under each permit. Where production needs to be decreased, the reduction would be phased in equally for all producers from a particular sand. The specific action elements are listed in Table 1 and described here.

Permitting: Under this strategy, all existing permits would be renegotiated, all wells would be metered, and a full use analysis would be conducted for each producer. The permits would establish baseline production limits. Permit for new production in a sand would only be issued if they were compatible with sustainable use (see "Production Caps", below). Additional management actions may be tethered to a producer's permit.

Zoning: The District would establish production zones, using both potentiometric and chloride level data. Zones would be used in conjunction with caps or prioritization actions. It is understood that applying a prioritization ranking to these zones would require the appropriate scientific data in support of such an action.

Fee Schedules: See Strategy A.

Production Caps: Zone- and sand-specific caps, applicable across all producers within that zone, would be established, based on a sustainability analysis. The process for defining caps needs to be defined but should reflect both sustainability and pollutant mitigation objectives. In cases where the allowable production in a sand is exceeded, across-the-board reductions would be phased in for all producers from that sand and zone.

Pollutant Mitigation: As described under Strategy A, with the potential to expand as needed.

Promoting Awareness: Both the District and its partners (including BRWC and the Office of Conservation) would develop and deliver educational materials on the health of the SHA and on means to conserve ground water. The specifics of these campaigns, and means for delivering, need to be developed.

Incentivizing Conservation: This strategy does not include any incentive programs for reducing water consumption.

Water Supplementation: As in Strategy A, the need for a supplementary source of water would be market-driven and developed by the individual producers.

Strategy C. The "Managing via Partnership" strategy focuses on the development of creative partnerships to supplement water supply and motivate conservation. In addition to key partners engaging in specific action elements to promote a conservation ethic among the general public, the District would actively solicit and participate in a public-private partnership to secure the financial resources necessary for constructing a water-treatment facility to service the principal industrial producers. This strategy relies on regulating production in the industrial zone to achieve the desired improvements to ground water quality. The specific action elements are listed in Table 1 and described here.

Permitting: Under this strategy, existing permits with industrial producers would be renegotiated to include permit-based production caps, with a timeline for phased reduction.

Zoning: Not applicable.

Fee Schedule: The District would work with the State Legislature to request authority to implement production fees that follow an increasing block pricing system. Likewise, to promote conservation at the domestic level, a conservation-oriented fee scheme would be implemented by the BRWC and other public-supply producers. This necessitates the relevant permissions from the Louisiana Public Service Commission (LPSC) to adopt new fee structures.

Production Caps: Caps would be applied to all industrial users, and reductions would be phased-in over a specific timeline. To be operational, a more concrete definition of 'industrial user' is required, along with specific quantitative targets for reducing industrial demand, and a timeline for reducing withdrawal.

Pollutant Mitigation: Two scavenger wells, as described under Strategy A, but with the intent that no further mitigation would be needed.

Promoting Awareness: Both the District and its partners would develop and deliver educational materials on the health of the SHA and on means to conserve ground water. The content of these campaigns needs to be developed by those with the appropriate expertise, and the entities responsible for delivering this content need to be identified.

Incentivizing Conservation: A District partner, such as the BRWC or local government, would offer rebate programs for water conservation-oriented technologies to promote wise-use of ground water at the domestic level. As above, this necessitates the appropriate permissions for financing from the LPSC, or funding from a government body.

Water Supplementation: The District would advocate the development of a public-private partnership to both finance and manage a water-treatment facility that would service the needs of industrial users. A more concrete definition of 'industrial producer/user' is required to identify the appropriate audience. There is the potential for widening the consumer base for such a facility, but the logistics and costs of water distribution would need to be considered.

Financing: An environmental bond issue would provide seed funding, and additional financing would be sourced to cover capital costs of construction. This may require both a legal analysis to determine the appropriate rights and responsibilities of entities entering into this sort of partnership, as well as the most efficient structuring of the financial instrument to be deployed.

Assessment Needs

In Phase 2 of the development of the long-term strategy, TWI and other experts will evaluate the alternative strategies against the fundamental objectives, to provide a better understanding of the efficacy of each and the trade-offs that need to be balanced. This analysis will need to occur in two stages. First, initial analyses will be needed to quantify the expected demand for water (via socioeconomic forecasting) and the available sustainable supply from the sands within the aquifer (via Darcy flow analysis; Darcy, 1856). In addition, options for water supplementation will be examined in closer detail. From this information, the water surplus or deficit over time can be estimated, and the details of Strategies A, B, and C can be developed (especially the timing of production caps and the location of production zones). Second, with the details of the alternative strategies described, additional analyses will evaluate the performance of those strategies against the fundamental objectives. These analyses will require expertise in groundwater flow and transport, hydrodynamic forecasting, demography and socioeconomics, law and finance, water supply infrastructure, and conservation education, among other topics. As part of all these analyses, uncertainty will need to be carefully articulated and quantified. The Water Institute of the Gulf delivered a proposed statement of work for Phase 2 to the Commission in December 2019.

Balancing of Tradeoffs and Development of the Long-term Strategy

Phase 2 will provide an analysis of several alternative strategies against the fundamental objectives. In Phase 3, the Commission will need to deliberate about the tradeoffs embedded in the various strategies and select an option (or design a new option) that best balances achievement of all the fundamental objectives. From there, the specific details of the long-term strategy can be articulated. Some specific tools from the field of decision analysis may be valuable during Phase 3 to help the Commission weigh the advantages and disadvantages of the strategies: multi-criteria decision analysis can be used to find a strategy that balances the objectives in a way that reflects the mission and values of the Commission; and value-of-information analysis can be used to evaluate the degree to which uncertainty impedes choice of an optimal strategy.

References

Darcy H. 1856. Les Fontaines Publiques de la Ville de Dijon: Exposition et Application des Principes a Suivre et des Formules a Employer dans les Questions de Distribution d'Eau. Paris, France: Victor Dalmont. 647 p.

Duplechin AJ. 2013. Taking a logical approach to addressing saltwater instruction in Baton Rouge, Louisiana. *Louisiana Civil Engineer* 21(4):7-11.

Gregory R, Failing L, Harstone M, Long G, McDaniels T, Ohlson D. 2012. Structured Decision Making: A Practical Guide for Environmental Management choices. West Sussex, United Kingdom: Wiley-Blackwell.

Griffith JM. 2003. Hydrogeologic framework of southeastern Louisiana. *U.S. Geological Survey Water Resources Technical Report* No. 72. Published by the Louisiana Department of Transportation and Development, Baton Rouge, LA.

Heywood CE, Griffith JM, Lovelace JK. 2014. Simulation of groundwater flow in the "1,500-foot" sand and "2,000-foot" sand, with scenarios to mitigate saltwater migration in the "2,000-foot" sand of the Baton Rouge area, Louisiana (ver. 1.2, June 2014). *U.S. Geological Survey Scientific Investigations Report* 2013–5227. 63 p. http://dx.doi.org/10.3133/sir20135227

Kuniansky EL, Dial DC, Trudeau DA. 1989. Maps of the "400-foot," "600-foot," and adjacent and confining beds, Baton Rouge area, Louisiana. *U.S. Geological Survey Water Resources Technical Report* 48. Louisiana Department of Transportation and Development, Baton Rouge, LA, 23 p.

Lovelace JK. 2007. Chloride concentrations in ground water in East and West Baton Rouge Parishes, Louisiana, 2004-05. *Scientific Investigations Report* 2007-5069. Reston, VA: U.S. Geological Survey.

Louisiana Department of Health. 2019. Safe drinking water program. http://www.ldh.la.gov/index.cfm/page/963 (accessed August 13, 2019).

Meyer RR, Turcan AN, Jr. 1955. Geology and groundwater resources of the Baton Rouge area. *Geological Survey Water-Supply Paper* 1296. Washington, DC: U.S. Government Printing Office. 144 p. https://pubs.usgs.gov/wsp/1296/report.pdf

Smith CG, Kazmann RG 1978. Subsidence in the Capital Area Ground Water Conservation District – An update. *Bulletin* 2. Baton Rouge, LA: Capital Area Ground Water Conservation Commission. 31 p.

Tomaszewski DJ, Lovelace JK, Ensminger PA. 2002. Water withdrawals and trends in groundwater-water levels and stream discharge in Louisiana. *Water Resources Technical Report* 68. Baton Rouge, LA: Louisiana Department of Transportation and Development. 36 p. https://la.water.usgs.gov/publications/pdfs/TR68.pdf

Tomaszewski DJ. 1996. Distribution and movement of saltwater in aquifers in the Baton Rouge area, Louisiana, 1990–92. *Water Resources Technical Report* 59. Baton Rouge, LA: Louisiana Department of Transportation and Development. 44 p.

Whiteman CD. 1980. Measuring local subsidence with extensometers in the Baton Rouge area, Louisiana, 1975-1979. *Water Resources Technical Report* 20. Baton Rouge, LA: Louisiana Department of Transportation and Development. 21 p. https://la.water.usgs.gov/publications/pdfs/TR20.pdf

THE WATER INSTITUTE
OF THE GULF®

1110 RIVER ROAD S., SUITE 200
BATON ROUGE, LA 70802

(225) 448-2813
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