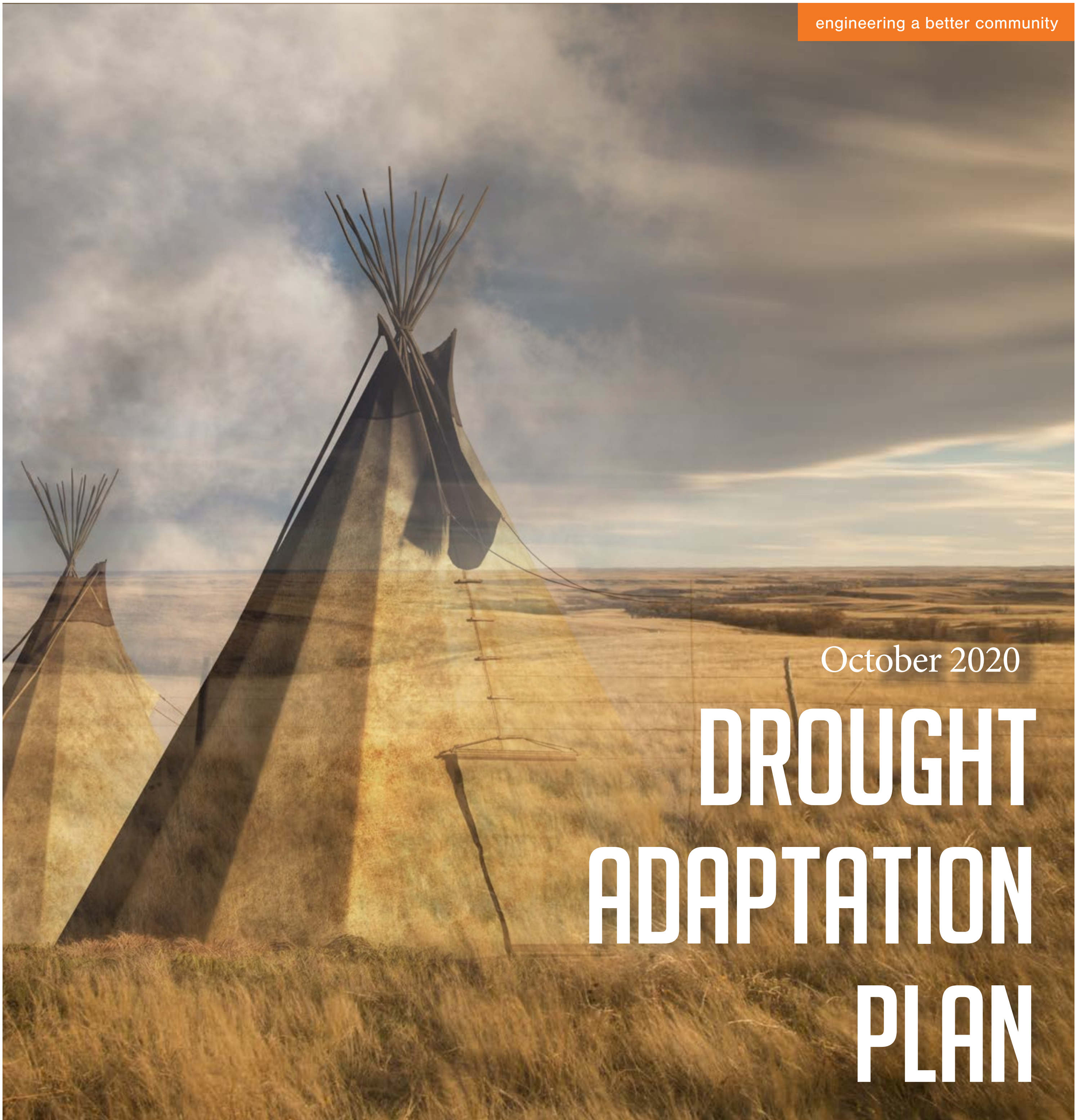

engineering a better community

October 2020

DROUGHT ADAPTATION PLAN

PREPARED FOR
The People of Rosebud Sioux Tribe

PREPARED BY
Great Plains Tribal Water Alliance

ROSEBUD SIOUX TRIBE
ROSEBUD, SOUTH DAKOTA

BANNER
engineering a better community

DROUGHT ADAPTATION PLAN

PREPARED FOR

The People of Rosebud Sioux Tribe

PREPARED IN COLLABORATION WITH

Great Plains Tribal Water Alliance
and
Banner Associates, Inc.

October 2020

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EXECUTIVE SUMMARY

The Great Plains Tribal Water Alliance (GPTWA) is a non-profit, whose members are Tribes in the Great Plains region of North Dakota, South Dakota, and Nebraska. On behalf of the Tribes, the GPTWA undertakes public outreach, research and education dedicated to the protection and preservation of Great Sioux Nation Indian Winter's Rights to the use of water in the Missouri River, tributaries and all aquifers and ground water sources located within the exterior boundaries of the Great Plains Region. It provides technical and policy recommendations for the protection of all water resources for the next seven generations.

The GPTWA serves as an advisory board to the Great Plains Tribal Chairmen's Association. The active Tribes in GPTWA include the Rosebud Sioux Tribe (RST), the Flandreau Santee Sioux Tribe (FSST), the Oglala Sioux Tribe (OST), and the Standing Rock Sioux Tribe (SRST). The GPTWA assisted in securing two Bureau of Indian Affairs (BIA) grants, one for FSST and SRST through FSST, and one for RST and OST, through RST. These grants were secured to develop a Drought Adaptation Plan (DAP) for each Tribe through the FY 17-18 Tribal Resilience Program, Adaptation Planning. Each grant was funded at $150,000. Through joint workshops and conferences, the Tribes collaborated on the development of the DAPs, however, each Tribe worked independently to identify unique opportunities for their reservation to adapt to drought.

This DAP will assist Rosebud Sioux Tribe in developing drought resiliency and adaptation procedures. It is based on research, field visits to the Rosebud Reservation, questionnaires, surveys, and follow-up meetings with Technical Teams comprised of Tribal leadership, staff, and elders of the Tribe. Previously, the Drought Vulnerability Assessment (DVA) was created to identify sector specific vulnerabilities that are susceptible to drought. The sectors included: legal rights and infringements, Tribal lifeways, water, land, wildlife, agriculture, public health, and Tribal data monitoring.

In addition to the information developed in the DVA, research and field visits with Tribal leaders confirmed five specific vulnerabilities, including 1) Use of Water Sources Across the Reservation, 2) Contamination of Water Sources, 3) Water Use Conservation and Education, 4) Use and Preservation of Traditional Plants during Drought, and 5) Agricultural Practices. Addressing the vulnerabilities resulted in identifying priorities for drought adaptation and mitigation strategies for the Tribe.

To address each vulnerability, corresponding Drought Adaptation Priorities were identified and mitigation projects to implement each priority were developed. The mitigation projects are meant to aid the Tribe in developing policy and infrastructure that will minimize the effects of drought. Some projects, like those dealing with water demand and restriction, require partnerships with private entities that are responsible for water distribution. Federal funding opportunities for each of the projects were also identified, detailing both the grant opportunity as well as the federal agency responsible for its distribution. The Drought Adaptation Priorities and associated Mitigation Strategies are shown in the following table.

Table 1: Drought Adaptation Priorities and Mitigation Strategies

Drought Adaptation Priorities	Mitigation Strategies
Priority #1. Understand the Water Resources Across the Reservation	Mitigation Strategy #1: Irrigation Permits and Drought Restrictions Mitigation Strategy #2: Rosebud Reservation's USGS Simulated Groundwater Flow Model Update
Priority #2. Protect Surface Water and Groundwater from Contamination	Mitigation Strategy #3: Current Drinking Water Study Mitigation Strategy #4: Measures to Reduce Water Quality Contamination from Agricultural Practices and Abandoned Wells
Priority #3. Promote Water Monitoring, Water Use Conservation and Education	Mitigation Strategy #5: Soil Moisture Monitoring Mitigation Strategy #6: Automated Drought Data Tracking Mitigation Strategy #7: Drought Decision Dashboard Improvements Mitigation Strategy #8: Threshold for Action Development
Priority #4. Preserve Cultural Resources During Drought	Mitigation Strategy #9: Preservation of Traditional Plants
Priority #5. Conserve Water Resources in Domestic and Agricultural Practices	Mitigation Strategy #10: Water Use Education and Restrictions Mitigation Strategy #11: Water Use Efficiency in Buildings Mitigation Strategy #12: Soil Conservation Agricultural Practices

The DAP relied on climate research and recommended actions during drought, based on the needs of each sector. The DAP requires diligent monthly monitoring of drought conditions using drought indices that track the severity of flash drought and long-term drought. Indices used include the U.S. Drought Monitor (USDM) and the Evaporative Demand Drought Index (EDDI) and the. The USDM uses a five-category system, labeled Abnormally Dry or D0, (a precursor to drought, not actually drought), and Moderate (D1), Severe (D2), Extreme (D3) and Exceptional (D4) Drought (NIDIS, 2020). Four categories triggering action from the Tribe include:

- Normal (No USDM rating)
- Alert (D0)
- Warning (D1-D2)
- Emergency (D3-D4)

The success of this DAP depends on the current data and tools to track drought and adjustments to responses to drought. It is recommended that the DAP be updated every five years for successful and continued implementation.

1. INTRODUCTION

The Drought Adaptation Plan (DAP) was developed as a planning tool to identify and prioritize Rosebud Sioux Tribe (Rosebud Sioux Tribe) government responses before, during, and after drought. The recommendations in the DAP were created by understanding the important Tribal resources and the vulnerabilities of those resources to drought, combined with current scientific Rosebud Sioux Tribe understanding of drought and climate resiliency. Key Tribal program directors, staff, council members, government officials, and members met to identify and prioritize strategies and plans most beneficial for the Tribe.

Three other Tribes, active in the Great Plains Tribal Water Alliance (GPTWA), worked collectively in developing the DAP. The GPTWA Tribes include Flandreau Santee Sioux Tribe (FSST), Oglala Sioux Tribe (OST), Rosebud Sioux Tribe, and Standing Rock Sioux Tribe (SRST). The DAPs were funded by the Bureau of Indian Affairs (BIA) FY17 and FY18 Tribal Resilience Program, Category 2 Adaptation Planning Grant. The Tribes worked collectively in learning about drought adaptation through the joint water conferences and workshops. Although the Tribes worked together on overarching drought adaptation concepts, each Tribe has a unique DAP, tailored for their respective reservation.

The Rosebud Sioux Tribe DAP is the fifth resource document in a series, documenting drought vulnerabilities and baseline resource conditions on the Rosebud Reservation. The previous reports, listed below, each build on information and data documented in the previous one:

- *Integrated Environmental Management Plan for Water, Cultural, and Natural Resources (IEMP), Phase II: Beneficial Uses and Other Resources. Rosebud Sioux Tribe, Louis Berger, Inc., December 2018. Funded by the Bureau of Indian Affairs (BIA)*
- *Climate Guidebook: Building Resilience to Climate Change. Rosebud Sioux Tribe, Louis Berger, Inc., 2018. Funded by the BIA*
- *Drought Vulnerability Assessment. Rosebud Sioux Tribe, Great Plains Tribal Water Alliance, Louis Berger, Inc. September 2018. Funded by Bureau of Reclamation*
- *Drought Vulnerability Assessment (DVA). Rosebud Sioux Tribe, Louis Berger, Inc., September 2017. Funded by the BIA*

The objectives of this DAP are to develop an actionable plan that through policy adoption and infrastructure development enables the Tribe to become more resilient to drought and its effects. Specific steps in the development of the DAP include the following:

- Coordinate with Tribal leaders to confirm drought vulnerabilities, previously determined from the previous climate resilience and drought studies, requiring immediate attention
- Identify drought mitigation strategies that would best resolve the vulnerabilities
- Identify the projects that would meet the mitigation strategy and identify potential funding sources for the top two priority projects.

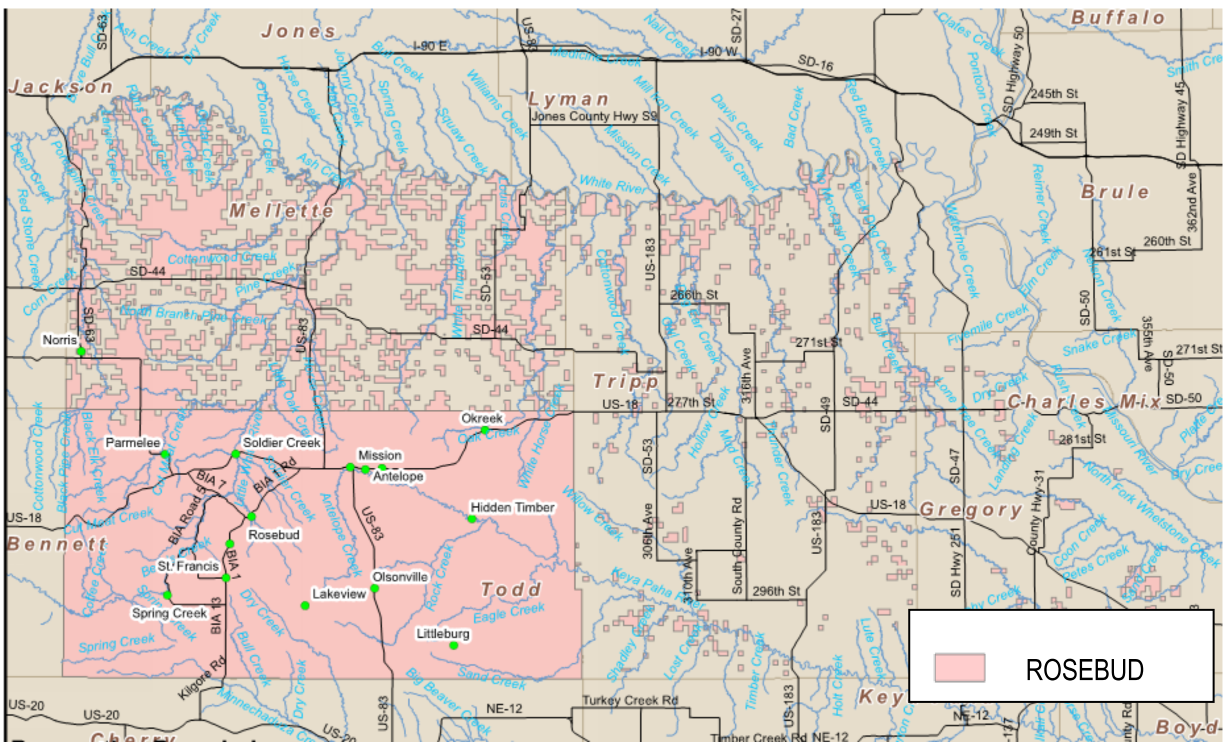
This section provides background information on Rosebud Tribal members and their home and the methods undertaken to develop the DAP.

1.1. Rosebud Sioux Tribe Reservation Location

The Rosebud Sioux Tribe's land base is located in south central South Dakota, lying primarily in Todd County, with portions also located in Mellette, Tripp, Lyman, and Gregory Counties. This area of South Dakota is located between the semi-arid west and humid continental east. The Rosebud Reservation (Reservation) is a part of the Great Sioux Reservation, which was established by the Fort Laramie Treaty of 1868, and was created by the General Allotment Act. The Reservation's total area is 1,970 square miles. The headquarters of the Rosebud Sioux Tribe is in Rosebud, South Dakota.

There are 22 communities on the Rosebud Reservation, including Antelope, Black Pipe, Bull Creek, Butte Creek, Corn Creek, Grass Mountain, He Dog, Horse Creek, Ideal, Milk's Camp, Mission, Okreek, Parmelee, Ring Thunder, Rosebud, Soldier Creek, Saint Francis, Spring Creek, Swift Bear, Two Strike, Upper Cut Meat, and White River (RST ARMP). A map of the current reservation trust lands can be seen in ***Figure 1. Rosebud Sioux Tribal Trust Land.***

Figure 1. Rosebud Sioux Tribal Trust Land



1.2. Rosebud Sioux Tribe Government

The Rosebud Sioux Tribal Government is a council with 23 elected officials, four of which are President, Vice President, Secretary, and Treasurer. All council members are elected at-large.

1.3. Land Description

The land description focuses on Todd County and Mellette County, the two counties with most trust lands. The topography of the Todd County is generally undulating to steeply rolling with very limited level areas, as shown in ***Figure 2. Rosebud Reservation Lands***. The eastern part of the Conservation District drains into the Keya-Paha River and its several creeks. The western part drains into the Little White River through its creeks and tributaries. These rivers, creeks and springs constitute the natural water supply. Some of the low areas along streams have a high-water table. The soils of the area are primarily of a sandy nature, but with much variation. The heaviest soils are in the northeastern part of the county, while the south western portion is sand hills with practically no farming. The central and southeastern areas are sandy loam soils (Todd County Conservation District, 2011).

Figure 2. Rosebud Reservation Lands

The topography of Mellette County is mostly rolling to undulating, but there is considerable steep sloping land along the major streams and badlands. The county is drained along the northern boundary by the White River. Flowing into this river from the south to the north are many smaller tributaries, chief of which is the Little White River which bisects the county from South to North. The waters from the Little White River make up the most desirable source for irrigation water. The White Thunder Creek and Oak Creek are the two main drainage-ways in the eastern part. Black Pipe Creek, Cottonwood Creek, and Pine Creek are the main drainage-ways in the western part. The soils in the eastern part of the county are predominately a mixture of heavy soils developed from the Pierre shale formation, and medium to somewhat sandy textured soils derived from the Ogallala Formation. Also included here are a few small acreages of soils which have been reworked and transported by wind. The northwest and central parts of the county have predominantly clayey soils developed from the Pierre formation. Along the western edge there is some badlands soil. In the southwestern part of the county there are heavy to medium textured soils derived from the Chadron-Brule formations (Mellette County Conservation District, 2011).

1.4. Climate and Demographics

The south-central location of the reservation provides the Rosebud Sioux Tribe with a sub-humid climate typical for grasslands and prairies. According to a weather station for Todd County, the reservation experiences an average of 21.4 inches of precipitation in the form or rain or snow annually depending upon the season (National Weather Service 2019). The reservation also commonly experiences drought, wildfires, and flooding.

Historical climate tends have indicated that temperatures have increased, particularly in the northern and western US. The trends show that warming is strongest at night and is apparent in all seasons in the Dakotas, with the strongest trends in the winter and spring. The length of the frost-free season has increased over time. In general, the Dakotas have gotten wetter through time. This trend is strongest in the spring and fall. The amount of rain received in the heaviest events has also increased through time. Snowpack has declined across the western US with earlier spring snowmelt also occurring, and streamflow's can be impacted through the summer and fall. Climate change projections indicate that temperatures will continue to rise, regardless of emissions scenario. With lowered emissions, the Dakotas could have a 5-6 degrees Fahrenheit increase in average temperature, while continuing emissions at current levels could increase temperatures by over 9 degrees Fahrenheit by the end of the century. Due to increased temperatures, heat waves are expected to become more intense, while cold waves are expected to become milder. Increases in precipitation could occur in the winter and spring seasons, however drier conditions are projected for the summer (Louis Berger, 2018).

The demographics utilized for this plan will be based upon Todd County due to most of the Rosebud Sioux Tribe trust land residing in Todd County. The most recent demographics for Todd County were estimated by the Census Bureau and published in July of 2019. The population of Todd County was estimated by Rosebud Sioux Tribal leadership to be over 20,000 people. Of that population 85.7 percent classified themselves as Native American. Median household income was estimated at $26,285, placing 48% of residents of Todd County are estimated to live below the poverty line (US Census Bureau 2019).

1.5. Project Methodology

The development of the DAP is benefited by Rosebud Sioux Tribe's active membership in the GPTWA. Since joining GPTWA, Rosebud Sioux Tribe has produced its own Integrated Environmental Management Plan, Drought Vulnerability Assessments, and Quarterly Climate Summaries. The DAP is the latest in a series of projects assisting the Tribes in the GPTWA in developing both technical capacity and reports in the realm of climate resilience and drought assessments and leverages these previous efforts to build upon its knowledge and actions to assist Rosebud Sioux Tribe in becoming resilient in the face of a drought.

The GPTWA serves as the organizing vehicle for the partnership of Tribes, BIA, and relevant Federal and state agencies. This multi-Tribal approach continues a model like the Mni Wiconi Rural Water System (MWRWS), where Federal agencies and the state partnered with multiple Tribes to increase capacity to build, monitor, and maintain their water infrastructure. By working with Tribes in South Dakota, this partnership builds upon historical and cultural networks to support and sustain water resource planning efforts after the grant period. This project provides opportunities for individual assessments of water resource vulnerabilities, adaptation strategies, and capacities for climate preparedness and incorporation of Traditional Knowledge of climate impacts to Tribes.

Although the deliverable of the project is a DAP, there are many outcomes and benefits that come with the development of the plan. Documentation of mitigation strategies will assist the Tribe in attaining further funding to accomplish drought adaptation goals. In working with the GPTWA and other project partners, the introduction of drought mitigation strategies was presented to Tribal members for comment and additional development of the strategies. Through the hands-on learning, Tribal program staff learned how plans are created and increased important professional relationships with national leaders in climate and drought planning. These relationships will lead to further projects in the drought and climate area that will continue to benefit all of the GPTWA Tribes for years to come.

The timeline for this project began with a kick-off meeting, public meetings, and working workshops. The Rosebud Sioux Tribe action within this project was to hire two Tribal interns from the Oglala Lakota College and the South Dakota School of Mines and Technology. Their duties were to conduct field visits and assist in writing the draft mitigation plan. The kickoff meeting, held June 13-14, 2019, introduced the scope of the project, timeline, and the benefits of developing DAPs. To identify the vulnerabilities and mitigation measures, research, field visits, and coordination with Rosebud Sioux Tribe and other identified experts and stakeholders was completed. The previous two DVAs were used to identify the vulnerabilities for the Tribe and reservation and the adaptation strategies were then tailored to address each vulnerability and potential projects identified to address each one. Overall, the project methodology is shown in ***Figure 3. DAP Project Management Methodology*** and described in the remainder of this section.

Figure 3. DAP Project Management Methodology

1.5.1. Kick-Off Meeting and Working Workshop

The development approach for the DAP was to include elders, leaders, and managers from the Rosebud Sioux Tribe in each step of the plan. See ***Figure 4. Meeting with Rosebud Sioux Tribe Department Managers***. In addition to the field trip and individual meetings with Rosebud Sioux Tribe, joint working workshops and sessions were scheduled as part of the regular GPTWA Board meetings and Bi-annual Water Conferences hosted by the alliance. The overall schedule for the project was, as follows:

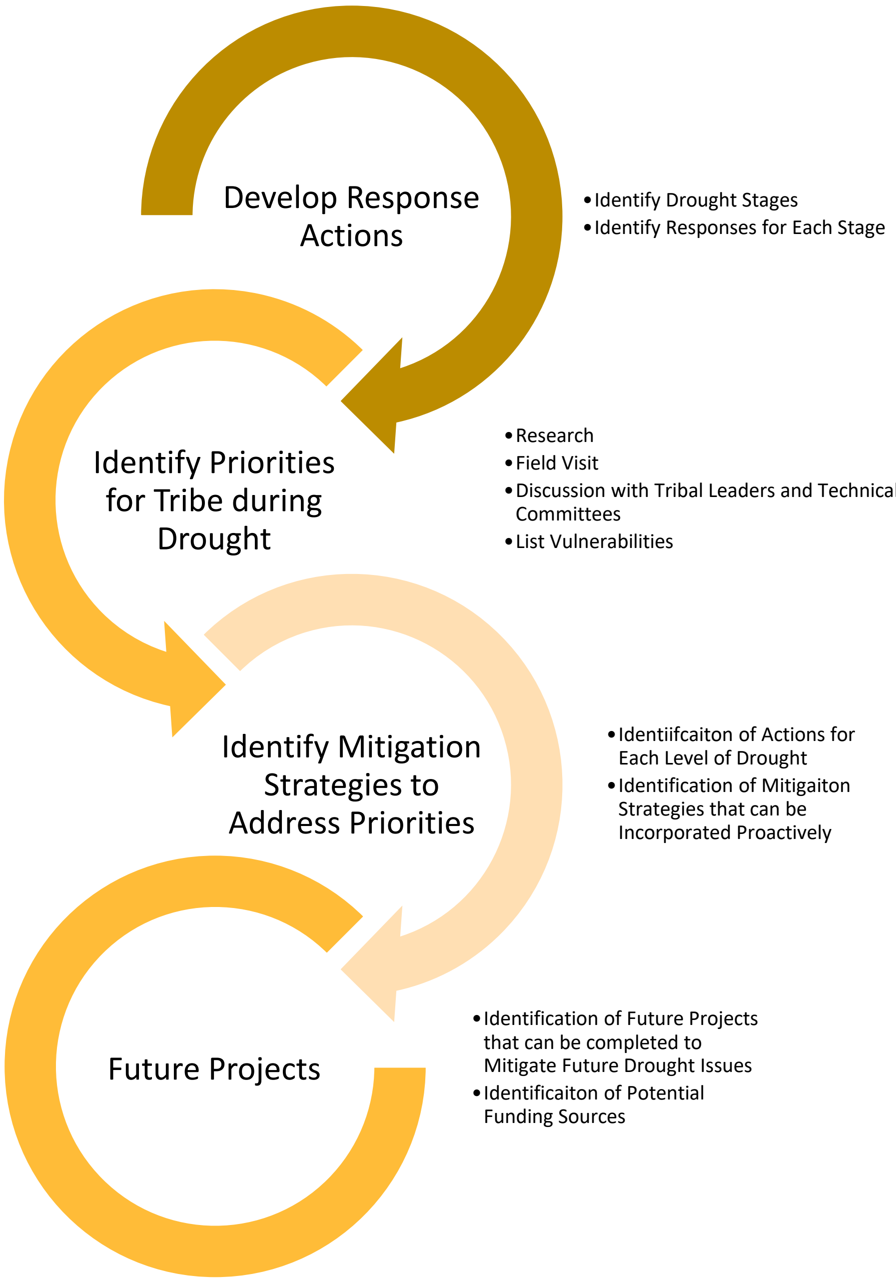
- Spring 2019 Initial Kickoff Meeting in Rapid City
- Summer 2019 Field Visits to each reservation
- Winter 2019 Draft Drought Adaptation Plan
- Spring 2020 Public Review Meetings
- Summer 2020 Final Drought Adaptation Plan

Figure 4. Meeting with Rosebud Sioux Tribe Department Managers

1.5.2. Tribal-Member Student Intern Involvement

The GPTWA seeks ways in which to develop the next generation of leaders to work on protecting Tribal water resources. As part of that commitment, the GPTWA hired two interns, one a scientist from Oglala Lakota College and one an engineer from South Dakota School of Mines and Technology, to assist in the development of all the DAPs for each of the member Tribes. The duties of the interns over the course of the project was to attend all meetings, take notes of discussions, ideas, and findings, write field visits summaries, search and collect data for plans, and create the initial draft of the DAP for Rosebud Sioux Tribe. The student involvement added another dimension to capacity building and increased the individual understanding of climate and drought science, as well as cultural considerations of each Tribe in the development of the individual DAPs.

Figure 5. Development of Drought Adaptation Actions



1.5.3. Research

Preliminary research was completed for the Rosebud Sioux Tribe during the previous completion of the IEMP and DVA. The DVA utilized available research and became a guide on how to conduct adaptation planning for drought conditions. Extensive research was also completed using journals, publications, government documents, and articles regarding climate change, drought mitigation and planning, and Tribal, federal, and state political land interactions were read, notated, and cited in an annotated bibliography. Additional information for the preparation of the DAP was gained through the various partners, such as NOAA and the HPRCC, through individual communications and the GPTWA Water Conferences. This research was conducted to establish baseline information on types of drought adaptation and mitigation management practices that have been done elsewhere in the past.

Climate change resilience and adaptation research was completed to establish base knowledge regarding how Tribal councils, programs, and members are building resilience and adapting to extreme weather events caused by current climate change trends. The drought mitigation and planning research was completed to obtain examples of how other areas, such as Tribal nations and states, are identifying drought vulnerabilities within their communities. It was also conducted to see how indigenous nations are using drought mitigation to prepare and alleviate potential threats to their ancestral territories and cultural resources. Land and legal interactions, both historical and current, were examined to better understand the environment Tribal nations must navigate to develop and implement a DAP.

1.5.4. Rosebud Sioux Tribe Agency and Public Review

An initial field visit was made to Rosebud to present potential drought vulnerabilities and mitigation strategies to Tribal leaders and closely associated government officials. The visit was held June 13-14, 2019 at the Water Resource Department Building in Rosebud, SD. An open discussion on the proposed vulnerabilities and mitigation strategies was completed. Questionnaires were emailed to the field visit group to assist in determining the most desired drought vulnerabilities.

A second field visit was scheduled to occur during the GPTWA Spring Conference, but due to COVID-19, the visit was cancelled and instead a meeting occurred over a video conference call. The coordination gained feedback on the top ranked vulnerabilities and mitigation strategies and was used to determine what actions and projects were most desired to improve Tribal resiliency during drought periods.

1.6. Project Partners

The grant proposal that was submitted by the Rosebud Sioux Tribe had identified project partners that would be participating in the work. The partners included GPTWA and their interns, each Tribe, the National Drought Mitigation Center, the National Oceanic and Atmospheric Administration, and Louis Berger, Inc. and Banner Associates, Inc. The partners and their specific roles are described below and can also be found in ***Table 2. Drought Adaptation Partners***.

- **Rosebud Sioux Tribe**—the Rosebud Sioux Tribe is the project lead. The Rosebud Sioux Tribe team is led by the Head of Department of Water Resources Syed Huq. Syed graduated from the South Dakota School of Mines and Technology with a Masters of Science in Geology and has worked with the Tribe for nearly 36 years. The Tribe assisted in helping project participants coordinate field visits, interviews, and offering guidance and feedback on the DAP throughout the project, as well as providing input to the overall project to ensure it met the goals and objectives of the Tribe.

- **GPTWA**— The Great Plains Tribal Water Alliance (GPTWA) is a non-profit, whose members are Tribes in the Great Plains region of North Dakota, South Dakota, and Nebraska. On behalf of the Tribes, it undertakes public outreach, research and education dedicated to the protection and preservation of Great Sioux Nation Indian Winter's Rights to the use of water in the Missouri River, tributaries and all aquifers and ground water sources located within the exterior boundaries of the Great Plains Region. It provides technical and policy recommendations for the protection of all water resources for the next seven generations.

  The GPTWA serves as the organizing vehicle to collaborate with the Tribes, BIA, and relevant federal and state agencies to develop DAPs in a phased approach. This multi-Tribal approach follows the model for the Mni Wiconi Rural Water System (MWRWS), where federal and state governments worked with several Tribes to build, monitor, and maintain their water infrastructure. This partnership builds on historical and cultural networks to support and sustain water resource planning efforts after the grant period.

- **GPTWA Interns**—The project team worked with the South Dakota School of Mines and Technology and Oglala Lakota College in Rapid City, South Dakota, to identify two engineering or science students entering their upperclassmen years to work on this project. The students that were hired for the project are enrolled members of South Dakota Tribes. Their goal was to work with the Tribe's technical staff and other key resource personnel to assist in the development of a DAP for each Tribe. The interns acted as a team, sharing important methods and processes that helped them tailor plans for the Tribes. These students developed important skills and acquired knowledge about drought vulnerabilities and mitigation strategies to assist the Tribes in the future.

- **National Drought Mitigation Center**—the National Drought Mitigation Center (NDMC) helps people, organizations and institutions build resilience to drought through monitoring and planning, and it is the academic partner and web host of the U.S. Drought Monitor. Its capabilities include climatology, social science, and public engagement, and we work at all scales, from individual ranches to local, state, and tribal government, and countries around the world. NDMC's primary task was to offer professional and technical guidance.

- **National Oceanic and Atmospheric Administration**—the National Oceanic and Atmospheric Administration (NOAA) is an American scientific agency within the United States Department of Commerce that focuses on the conditions of the oceans, major waterways, and the atmosphere. NOAA has worked with GPTWA, assisting the Tribes in understanding current science findings that are beneficial to the Tribes. NOAA participated as a conference speaker and to offer information to the partnering Tribes of the GPTWA. Concurrently, two of their interns accompanied GPTWA Interns and Banner Associates on field visits.

- **Louis Berger, Inc. and Banner Associates, Inc.**—during the first phase of the development of the DAP, Louis Berger was the private partner, assisting GPTWA in the mentoring of the interns, coordination of the project, and overall technical assistance. As Louis Berger transitioned their work to Banner Associates, that role continued and was expanded to bring the partners together to develop the DAP document.

Table 2. Drought Adaptation Partners

Agency	Partners
GPTWA	Rosebud Sioux Tribe Oglala Sioux Tribe Flandreau Santee Sioux Tribe Standing Rock Sioux Tribe
GPTWA Interns	Amanda Booton-Popken Elisha Yellow Thunder
Rosebud Sioux Tribal Leaders	Syed Huq, Water Resources Robert Oliver, Safety of Dams Frank Vanderwalker, Natural Resources Emily Boyd-Valandra, Natural Resources Benjamin Young, Tribal Historic Preservation Office Paula Antoine, Sicangu Oyate Land Office Ben Rhodd, Tribal Historic Preservation Office Harold Compton, Tribal Land Enterprise Chad Boyd, BIA Fire Management Donald Haukaas, BIA Fire Management Ken Haukaas, Forestry Department
National Drought Mitigation Center	Cody Knutson, Water Resource Scientist
NOAA	Doug Kluck, Central Region Climate Services Director Emily Bamford, Graduate Student Marianne Shiple, Graduate Student
Louis Berger/ Banner Associates	Becky Baker, Environmental Manager Cheryl Chapman, PhD, PE Chance Knutson, EIT Logan Gayton, EIT Leslie Murphy

2. DROUGHT MONITORING AND RESPONSE ACTIONS

Incorporating the science of drought and climate is an essential element of preparations for drought and adapting to its effects. NOAA and its affiliates, USGS, and other Federal agencies have taken a lead role in developing indicators that when used individually or combined provide early warning and current conditions for decisionmakers.

There are various methods and indices that track current drought conditions across the country. Many include different variables, like precipitation, soil moisture, and humidity. For Rosebud Sioux Tribe, two monitoring indices will be reviewed for utilization, the U.S. Drought Monitor (USDM) and the Evaporation Demand Drought Index (EDDI). Each of these were developed using other indices. It is recommended that Rosebud Sioux Tribe continue to expand their capabilities to obtain their own data and analyze it to tailor drought monitoring for the use of Tribal leadership.

2.1. United States Drought Monitor

The USDM is a semi-objective drought index that brings together several experts from the National Drought Mitigation Center, National Oceanic and Atmospheric Administration, U.S. Department of Agriculture, and the National Integrated Drought Information System. Using a variety of different tools, including indices like the PDSI, they determine current drought conditions throughout the U.S. There are five levels of intensity to which they classify: D0 (abnormally dry), D1 (moderate drought), D2 (severe drought), D3 (extreme drought), and D4 (exceptional drought).

Some of the inputs into the USDM can be standalone indicators or combined to provide indicators for the USDM, including blended indicators. The inputs are as follows:

Palmer Drought Severity Index (PDSI)--calculated using monthly temperature and precipitation data along with information on the water-holding capacity of soils. It considers moisture received (precipitation) as well as moisture stored in the soil, accounting for the potential loss of moisture due to temperature influences (IDMP, 2020).

Climate Prediction Center—Soil Moisture (CPC Soil)—the CPC has developed a soil moisture tool for the next two weeks based on the National Weather Service Global Forecast System (GFS) model. Seasonal tools are based on the Constructed Analog on Soil Moisture (CAS) (National Weather Service, 2020).

U. S. Geological Survey Weekly Streamflow (USGS Weekly Streamflow)—reports in real-time the percentile of stream flow in key rivers/streams (USGS 2020).

Standardized Precipitation Index (SPI)—uses historical precipitation records for any location to develop a probability of precipitation that can be computed at any number of timescales, from 1 month to 48 months or longer. As with other climatic indicators, the time series of data used to calculate SPI does not need to be of a specific length. Guttman (1998, 1999) noted that if additional data are present in a long time series, the results of the probability distribution will be more robust because more samples of extreme wet and extreme dry events are included. SPI can be calculated on as little as 20 years' worth of data, but ideally the time series should have a minimum of 30 years of data.

SPI has an intensity scale in which both positive and negative values are calculated, which correlate directly to wet and dry events. For drought, there is great interest in the 'tails' of the precipitation distribution, and especially in the extreme dry events, which are the events considered to be rare based upon the climate of the region being investigated (IDMP, 2020).

Objective Drought Indicator Blends (Percentiles)—the Climate Prediction Center has been working on an experimental blend of indicators to develop short-term and long-term predictions (CPC, 2020).

- The Short-Term Blend approximates drought-related impacts that respond to precipitation (and secondarily other factors) on time scales ranging from a few days to a few months, such as wildfire danger, non-irrigated agriculture, topsoil moisture, range and pasture conditions, and unregulated stream flows. The short-term inputs as a percentage include 35% Palmer Z-Index, 25% 3-Month Precipitation, 20% 1-Month Precipitation, 13% CPC Soil Moisture Model, and 7% Palmer Drought Index.

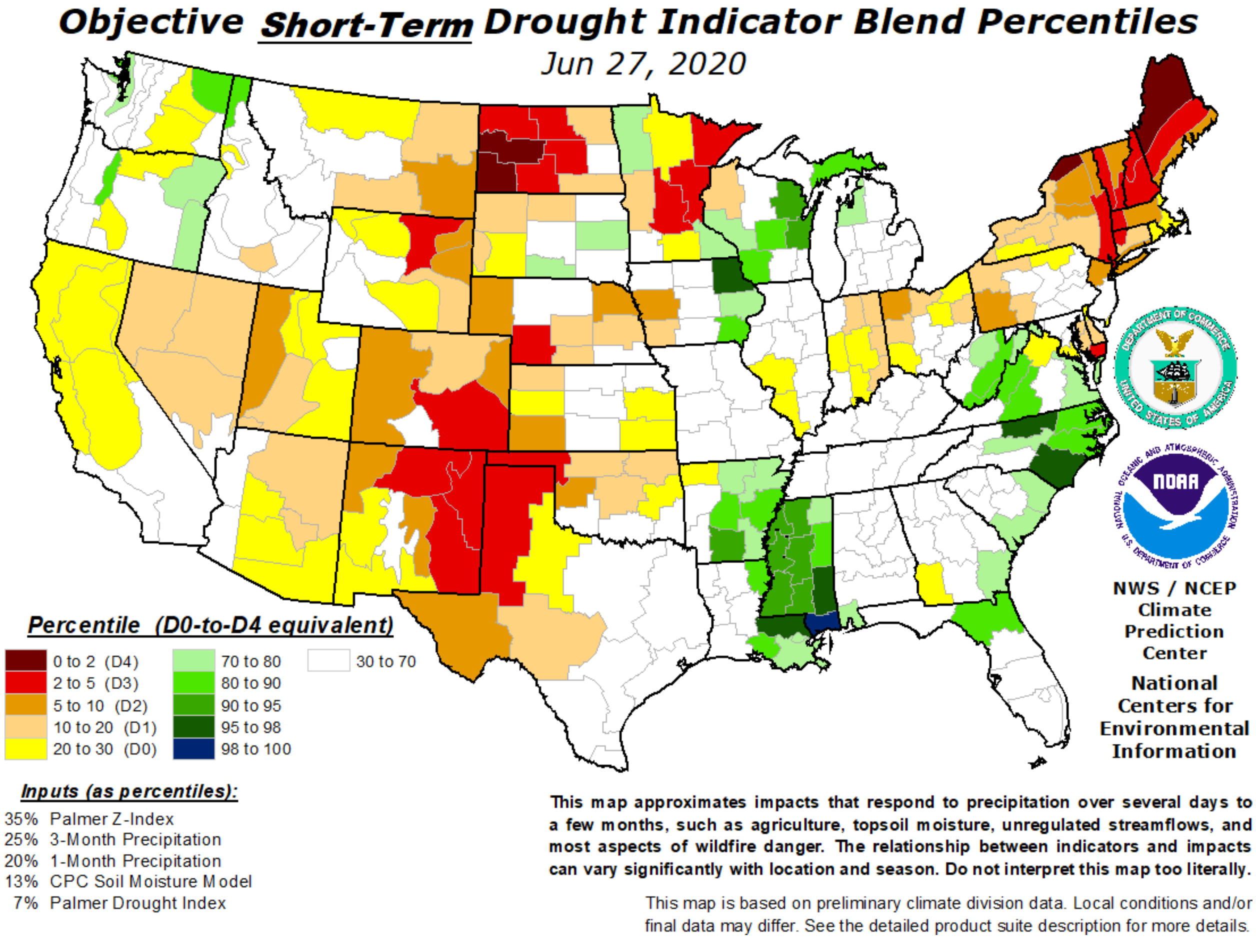
- The Long-Term Blend approximates drought-related impacts that respond to precipitation on time scales ranging from several months to a few years, such as reservoir stores, irrigated agriculture, groundwater levels, and well water depth. The long-term inputs as a percentage include 25% Palmer Hydrologic Index, 20% 24-Month Precipitation, 20% 12-Month Precipitation, 15% 6-Month Precipitation, 10% 60-Month Precipitation, and 10% CPC Soil Moisture Model.

Table 3. Drought Severity Classifications

Category	Description	Possible Impacts	Palmer Drought Severity Index (PDSI)	CPC Soil	USGS Weekly Streamflow	Standardized Precipitation Index (SPI)	Objective Drought Indicator Blends (Percentiles)
D0	Abnormally Dry	Going into drought: short-term dryness slowing planting, growth of crops or pastures coming out of drought some lingering water deficits pastures or crops not fully recovered	-1.0 to -1.9	21 to 30	21 to 30	-0.5 to -0.7	21 to 30
D1	Moderate Drought	Some damage to crops, pastures Streams, reservoirs, or wells low, some water shortages developing or imminent Voluntary water-use restrictions requested	-2.0 to -2.9	11 to 20	11 to 20	-0.8 to -1.2	11 to 20
D2	Severe Drought	Crop or pasture losses likely Water shortages common Water restrictions imposed	-3.0 to -3.9	6 to 10	6 to 10	-1.3 to -1.5	6 to 10
D3	Extreme Drought	Major crop/pasture losses Widespread water shortages or restrictions	-4.0 to -4.9	3 to 5	3 to 5	-1.6 to -1.9	3 to 5
D4	Exceptional Drought	Exceptional and widespread crop/pasture losses Shortages of water in reservoirs, streams, and wells creating water emergencies	-5.0 or less	0 to 2	0 to 2	-2.0 or less	0 to 2

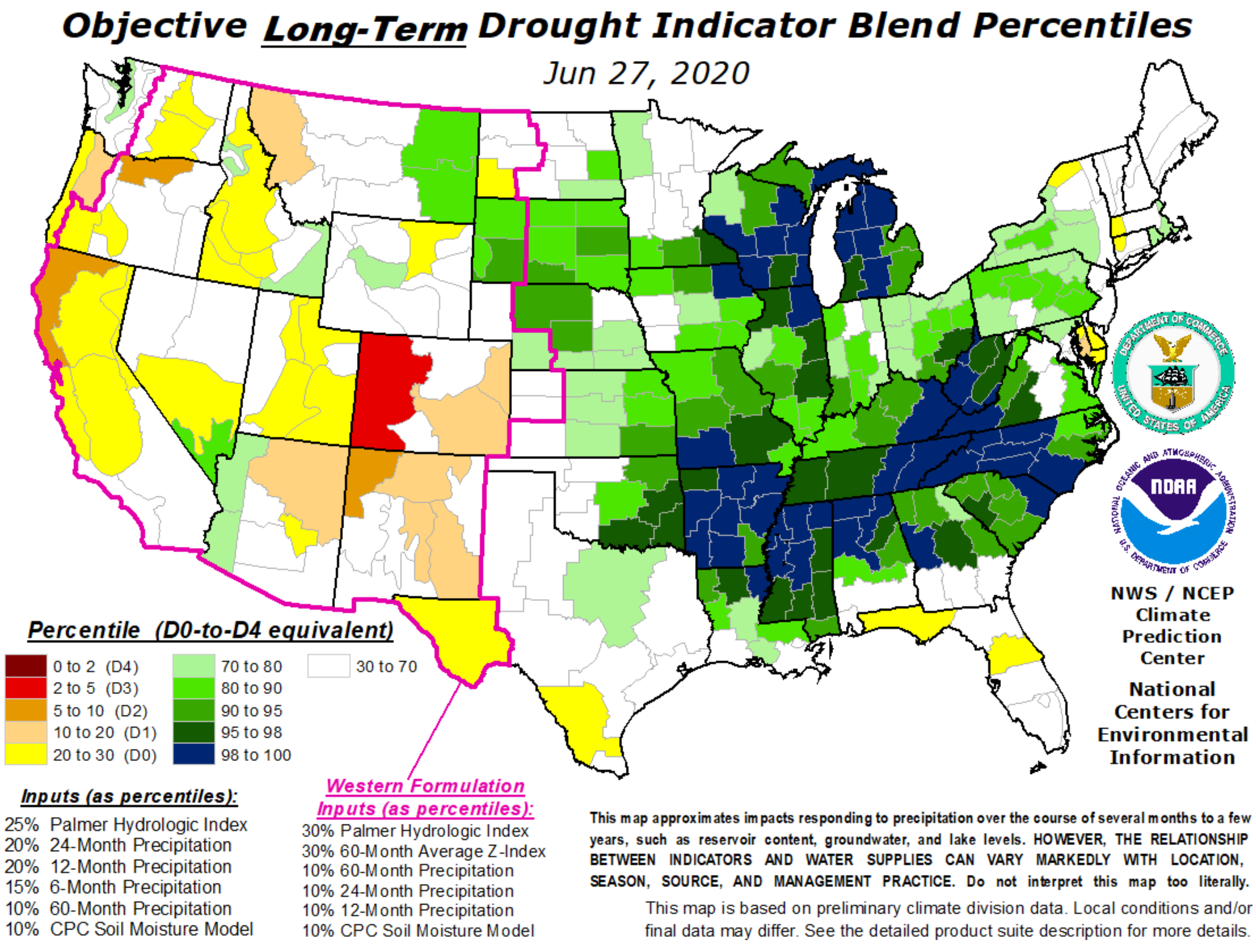
Source: Nation Drought Mitigation Center, University of Nebraska (https://droughtmonitor.unl.edu/About/AbouttheData/DroughtClassification.aspx)

Figure 6. CPC Experimental Objective Short-Term Blend of Drought Indicators



Source : https://www.cpc.ncep.noaa.gov/products/predictions/tools/edb/droughtblends.php

Figure 7. CPC Experimental Objective Long-Term Blend of Drought Indicators

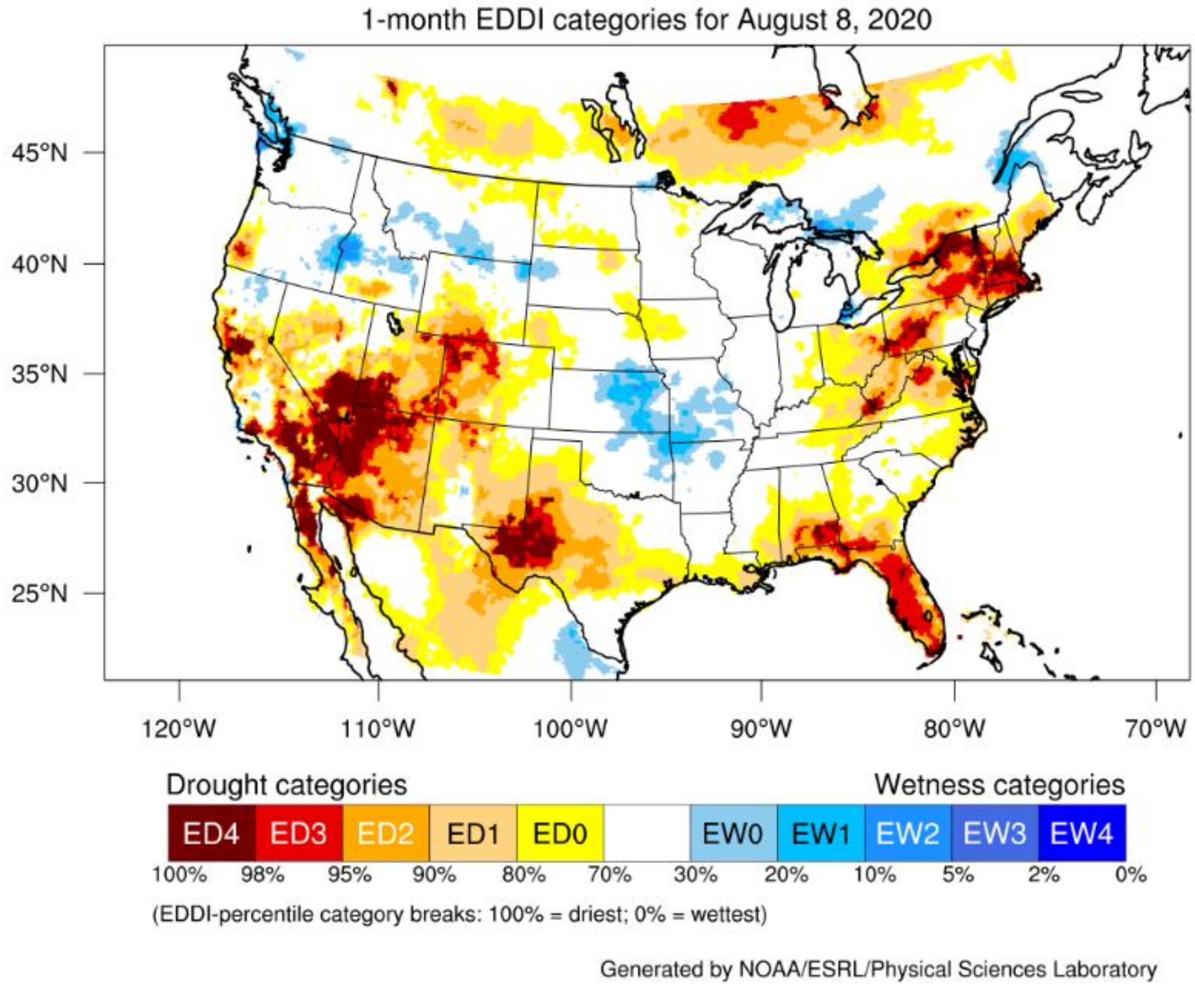


Source : https://www.cpc.ncep.noaa.gov/products/predictions/tools/edb/droughtblends.php

2.2. Evaporative Demand Drought Index (EDDI)

The EDDI is an experimental drought monitoring tool developed by climate scientists at NOAA. It is an index based on "evaporative demand", which is basically a measure of how thirsty the atmosphere is. It uses measurements of temperature, humidity, windspeed, and solar radiation; all of which both contribute to and reflect the dying out of soil and vegetation. What makes EDDI unique compared to the USDM is that it can measure "flash droughts", which are short, intense periods of drying that can take a major toll on crop yields when they occur. EDDI can also show the early signs of a developing long-term drought. This is because EDDI only has a 5-day lag in data compared to the USDM, which has a lag of over a month. ***Figure 8. Evaporative Demand Drought Index Categories for the United States*** provides a sample map showing the drought versus wetness categories across the United States (NOAA 2020).

Figure 8. Evaporative Demand Drought Index Categories for the United States



EDDI can offer early warning of agricultural drought, hydrologic drought, and fire-weather risk by providing near-real-time information on the emergence or persistence of anomalous evaporative demand in a region. A strength of EDDI is in capturing the precursor signals of water stress at weekly to monthly timescales, which makes EDDI a strong tool for preparedness for both flash droughts and ongoing droughts.

2.3. Other Drought Indicators

In addition to the previously discussed drought indicators, the EDDI User Guide (Lukas, Hobbins, Rangwala, 2017) provides a useful comparison of the various drought indicators, prepared by and for NOAA, used in the preparation and prediction of drought:

ESI (Evaporative Stress Index)—anomaly in the ration of ET to E_0, where ET is calculated using leaf-area index (LAI) and land-surface temperature from satellite data, and E_0 is from a fully physical estimate, over a user-selected time window

SPEI (Standardized Precipitation-Evapotranspiration Index)—anomaly in the difference between observed precipitation (P) and estimated potential evapotranspiration (PET; equivalent to E_0) over a user-selected time window

VegDRI—blend of multiple drought indicators: 9-month SPI, Palmer Index, and satellite-sensed vegetation greenness and leaf-out anomaly; effective time window of several months

"It's good practice to compare different drought indicators:"

EDDI and the other indicators capture different aspects of the moisture balance at the land surface; EDDI is unique in focusing on evaporative demand

Different indicators can speak to some drought impacts better than others

Different indicators also have different time windows over which conditions are aggregated—whether the window is user-selected or "baked into" that index

Looking at multiple indicators provides a "convergence of evidence", e.g., to support a drought designation

The differences between indicators can also provide insight into how drought conditions are emerging and causing impacts

(Lukas, Hobbins, Rangwala, 2017)

3. ROSEBUD SIOUX TRIBE DROUGHT ASSESSMENT

Drought impacts are typically spread over large areas. There are many parameters and indices to choose from when predicting and identifying drought. Some measurable parameters include temperature, precipitation, soil moisture, reservoir/lake levels, streamflow, groundwater, snowpack, snow water equivalent, evapotranspiration, vegetation health/stress, and environmental and socioeconomic impacts. Indices exist that utilized the parameters noted to show the drought's severity. Common indices include the percent of normal precipitation, Standardized Precipitation Index (SPI/SPEI), Palmer Drought Severity Index (PDSI) Self-Calibrated Palmer Drought Severity Index (SC-PDSI), and Aridity Index. Hydrologic drought indices include the Palmer Hydrological Drought Index (PHDI) and Surface Water Supply Index (SWSI) (World Meteorological Organization & Global Water Partnership 2016).

Drought indices play an important role in understanding drought for the following reasons:

- Simplify complex relationships and provide good communication tools for diverse audiences/users.

- Provide a quantitative assessment of anomalous climatic conditions: intensity, duration, and spatial extent.
- Provide a historical reference showing the probability of recurrence, assisting in planning and design applications.

It is important to take careful consideration into choosing indicators for drought. Droughts are very dynamic and are not specific to one indicator. Precipitation alone is only part of the equation when assessing drought conditions. Soil moisture, humidity, and temperature also have a huge impact on drought and can exacerbate drought conditions. Indices, like the PDSI, estimate the movement of water in in the air, ground, and on the surface. However, calibrating a PDSI to a desired location is a process that requires extensive knowledge of soil properties and statistical analysis. Indices, like the PDSI, also come with a lag in data that could be weeks, or even months, meaning that actual notification of a drought may come too late. So, when choosing drought indices or indicators, it is imperative that its risk, lag, and ease of use are all considered.

For drought, it is important to start with creating adaptation plans. Once adaptation plans have been developed, the plan components should be followed and monitored to confirm an early warning system is initiated. Ideally, the early warning system is initiated before the drought occurs. After the drought occurs, an assessment should be done to develop the best response possible. The response initiated will eventually lead to a recovery of the situation. Reconstruction and mitigation follow recovery and allow for better preparation for the next situation. Once the cycle is complete, planning must start again to prepare for the next drought.

3.1. Drought Hazard Profile

A drought hazard profile is a way to analyze the various aspects of drought. For the drought hazard profile of the Rosebud Sioux Tribe, the history of drought and related impacts were assessed, along with the probability of recurrent drought. Drought history (in the form of drought severity) can be obtained from the United States Drought Monitor (USDM), which is provided by the National Drought Mitigation Center. Drought severity is displayed on a scale of no drought, D0 (Abnormally Dry), D1 (Moderate Drought), D2 (Severe Drought), D3 (Extreme Drought), and D4 (Exceptional Drought). The data are also normalized by the percent area of the selected location that is affected by drought. For the Rosebud Sioux Tribe, Todd County was selected. The USDM has been made available on the internet on a weekly basis since January 4, 2000 (National Weather Service, 2020).

Along with the USDM, drought history can also be obtained using a PDSI and SC-PDSI. The PDSI is an effective index at determining long term drought. It uses precipitation, temperature, as well as evaporation and transpiration data to create an index that numerically represents the severity of a drought. However, when this index was created, soil conditions in Kansas and Iowa were utilized, which creates error for other parts of the country. The SC-PDSI corrects for different local conditions so that values below -3, which represent extreme drought, occur roughly 10 percent of the time (World Meteorological Organization & Global Water Partnership, 2016). SC-PDSI data is available for Mission, South Dakota from a period of 1966 to 2013 (NDMC 2020).

3.2. Drought History

The drought history for the Rosebud Sioux Tribe was developed using the USDM, Drought Risk Atlas, Drought Impact Reporter, and the National Climate Assessment (National Weather Service, 2020; NDMC 2020). Drought Risk Atlas data were obtained from the weather station located in Mission, South Dakota, and reveal a history of drought occurrence on the reservation. ***Table 4. Drought Risk Atlas Station Data for Mission, South Dakota*** shows the station information from the weather station in Mission (NDMC 2020).

Table 4. Drought Risk Atlas Station Data for Mission, South Dakota

395620: MISSION	Latitude: 43.306	Longitude: -100.656
Elevation: 2587 feet	State: South Dakota	County: Todd
Climate Division: 8	Time Period: June 2, 1966–March 13, 2013	Years on Record: 47

Historical occurrences of drought in Todd County have also been documented in the following years (NDMC 2020), reflected in Figure 7 and Figure 8:

- **1974 to 1977**: Second worst recorded drought which peaked in July 1976, with an SC-PDSI of -4.34.
- **1978 to 1982**: Not long after the first drought, another drought occurred and peaked in April 1981 with an SC-PDSI of -3.51.
- **1987 to 1994**: The worst recorded drought that lasted for seven years, peaking in the Fall of 1989 with an SC-PDSI of -5.02. There was an eight-year period where the SC-PDSI never positively exceeded -2.00.
- **2001 to 2007**: With a lowest SC-PDSI of -3.94, this drought produced a variety of impacts on the agriculture and livestock industries, causing lasting damage to the local economy.

Figure 9. U.S. Drought Monitor History for Todd County, South Dakota shows the USDM percent area statistics for each category of the instances of recorded drought for Todd County, South Dakota from 2000 to 2019. The darker the colors in the figure indicates the more intense the drought.

Figure 9. U.S. Drought Monitor History for Todd County, South Dakota

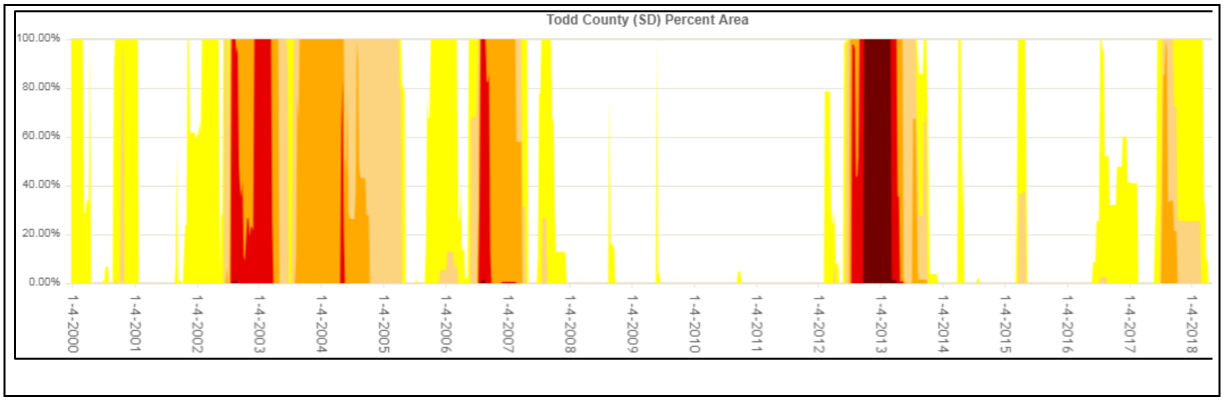
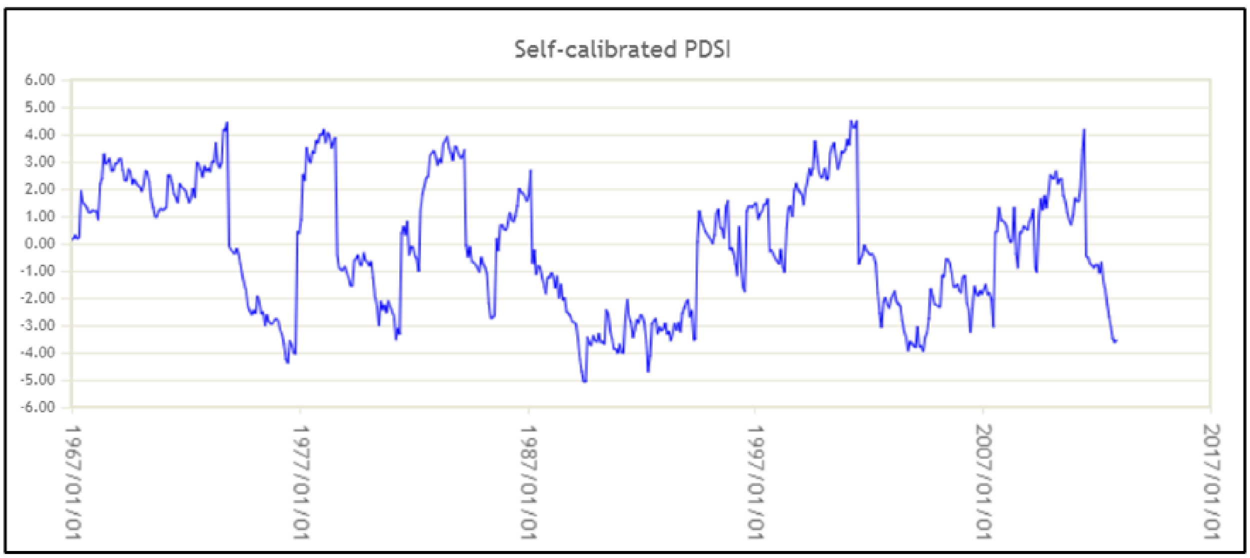


Figure 10. Drought Risk Atlas SC-PDSI History for Mission, South Dakota shows the SC-PDSI history for the Mission station from the Drought Risk Atlas from 1967 – 2013.

Figure 10. Drought Risk Atlas SC-PDSI History for Mission, South Dakota



The data from the Drought Impact Reporter aligns directly with the data produced by the USDM and shows the severe, but short drought during 2013 (NMDC 2020). Entering the 2013 growing season, the U.S. Department of Agriculture began declaring counties as primary and secondary disaster areas related to drought in January. Farmers in affected counties had eight months from the date of the declaration to apply for low-interest emergency loans (USDA 2013).

In 2017 and 2018, another severe drought occurred across the Reservation. In 2017, the Governor of South Dakota declared a state of emergency and activated the South Dakota Drought Task Force. Ponds and creeks were low, as was grass and crop production. USDA authorized early haying of Conservation Reserve Program (CRP) acres beginning on July 16, 2017, to help farmers and ranchers in the Dakotas and Montana. Farmers and ranchers in counties experiencing drought severity of D2 or greater on the USDM or within 150 miles of a county in D2 were eligible for early haying. CRP contract holders who hayed their acreage were able to donate their hay or take a 25 percent loss to their annual payment if they chose to sell it (NMDC 2020).

3.3. Probability of Future Drought

The National Climate Assessment of the Northern Great Plains includes Nebraska, South Dakota, North Dakota, Montana, and Wyoming. The basis of the assessment to analyze current available resources and the use of modeled projections determine what will happen to those resources over the next half century. The assessment is analyzed in various sections: water, agriculture, recreation and tourism, energy, as well as indigenous peoples. These analyses discuss the increased probability of extreme events, like flooding and drought, through 2050 (National Climate Assessment 2014).

The National Climate Assessment states that changes in precipitation in the winter and spring months will have an impact on the current climate. In the winter and spring, more precipitation is projected, with an increase in extreme events, in both volume and intensity. In the summer, no change precipitation is projected. Agriculturally, the growing season will be extended, and spring will begin earlier. However, higher temperatures are also projected for the region and more extreme daytime highs and nighttime lows will stress crops. Increased temperatures will result in higher evaporative demand, which is a measure of how thirsty the atmosphere is. This increase will result in more frequent drought and heatwaves across the region, which will reduce crop yields and quality of livestock forage. Additionally, increased temperatures will increase the range of pests within the region (National Climate Assessment 2014).

The key message of the assessment is that rising temperatures are leading to increased demand for water and energy. In parts of the region, this increase in temperatures is expected to constrain development, stress natural resources, and increase competition for water among communities, agriculture, energy production, and ecological needs. Changes to crop growth cycles due to warmer winters, and alterations in the timing and magnitude of rainfall events have already been observed; as these trends continue, they will require new agriculture and livestock management practices (National Climate Assessment 2014).

Additionally, landscape fragmentation is increasing in the context of energy development activities and climate extremes will be stressed even further by more frequent extreme events occurring within an already highly variable climate system (National Climate Assessment 2014).

The magnitude of expected changes will exceed those experienced in the last century, resulting increased strain on available water resources. This strain may signal increased competition for communities struggling to meet water demand. Existing adaptation and planning efforts are often inadequate to respond to these projected impacts. Although projections suggest more frequent and more intense droughts, heavy downpours, and heat waves, people can reduce vulnerabilities with new technologies, community-driven policies, and the judicious use of resources. Changing extremes in precipitation are projected across all seasons, including higher likelihoods of both increasing heavy rain and snow events and more intense droughts. Winter and spring precipitation and heavy downpours are both projected to increase in the north, leading to increased runoff and flooding that will reduce water quality and erode soils (National Climate Assessment 2014).

Projected climate change will have both negative and positive consequences for agricultural productivity in the Northern Plains. Increases in winter and spring precipitation will benefit productivity by increasing water availability through soil moisture reserves during the early growing season; however, this can be offset by fields too wet to plant. Also, rising temperatures will lengthen the growing season, possibly allowing a second annual crop when and where feasible. A goal of planning will be to capitalize on positive aspects and minimize negative impacts of future climate variability.

3.4. Drought Condition Monitoring

Drought monitoring is part of the Rosebud Sioux Tribe's quarterly climate summary. In partnership with the High Plains Regional Climate Center, an up-to-date "Decision Dashboard" is available for the Tribe to be informed in making water management decisions (High Plains Regional Climate Center, 2020).

The dashboard provides information for the following climate and weather conditions:

- Current Mesonet Conditions for temperature, dew point, humidity, wind, sunshine, pressure, and rain
- Temperature—14-day, 30-day, 60-day, and 3-months departures
- Precipitation—14-day, 30-day, 60-day, and 3-months departures
- Soil Moisture—current condition
- 28-day Average Streamflow
- USDM
- VEGDri
- EDDI
- Outlooks
    - Temperature
    - Precipitation
    - Drought
    - Significant Wildland Fire
    - Flooding
    - Historical Climate

3.5. Drought Response Actions

With each set of drought conditions, certain actions are suggested to be taken by Rosebud Sioux Tribal government. The technical team members for the preparation of the Drought Adaptation Plan met to brainstorm possible actions to enact at various stages of a drought. Even during a normal or wetter period, actions can be taken to further prepare for a potential drought. ***Table 5. Rosebud Sioux Tribe Resources Affected by Drought and Response Actions*** shows responses for each stage of a drought. ***These suggested actions can be tailored for specific responses, depending on the time of year and the vulnerabilities and resources at stake.***

Table 5. Rosebud Sioux Tribe Resources Affected by Drought and Response Actions

	Normal (No Drought)	Alert (Mild Drought)	Warning (Moderate Drought)	Emergency (Severe to Extreme Drought)
Drought Stage Parameters	No USDM Classification	D0 USDM Classification	D1 and D2 USDM Classification	D3 and D4 USDM Classification
Natural Water Sources	• Identify agencies that will head actions and plans. • Review Tribal codes and policies and if needed, establish additional codes and policies for water use conservation. • Develop a plan with the MWRWS about possible drought conditions and responses.	• Increase active enforcement of relevant Tribal codes and policies. • Monthly or quarterly report detailing current drought conditions to be made public.	• Prepare Drought Emergency Declaration. • Prepare letters to secretaries for drought determination. • Increase active enforcement of relevant Tribal codes and policies. • Monthly or quarterly report detailing current drought conditions to be made public.	• Declare Drought Emergency. • Send letters to secretaries for drought determination and assistance. • Support actions and resolutions for drought assistance funding. • Increase active enforcement of relevant Tribal codes and policies. • Monthly or quarterly report detailing current drought conditions to be made public.
Built Water Systems and Use	• Distribute water conservation information to the community. • Review water restriction regulations and guidance, and if needed add additional.	• Encourage voluntary water use conservation efforts. • Limit firework displays. • Encourage drought resistant landscaping.	• Establish water use restrictions. • No firework displays.	• Establish water use restrictions. • No firework displays.
Tribal Lifeways	• Identify methods to maintain or increase output of traditional plants and foods during drought.	• Identify methods to maintain or increase output of traditional plants and foods during drought.	• Implement methods to preserve traditional plants and foods.	• Implement methods to preserve traditional plants and foods.

	Normal (No Drought)	Alert (Mild Drought)	Warning (Moderate Drought)	Emergency (Severe to Extreme Drought)
Agriculture	• Complete grazing assessments. • Encourage of crop rotation. • Encourage practices to reduce erosion of topsoil.	• Encouragement of grasses in pastures that need require less water. • Encourage row crops that need less water. • Encourage irrigation system efficiency checks and updates to improve efficiency. • Encourage practices to reduce erosion of topsoil. • Encourage pasture rotation for cattle.	• Encourage row crops that need less water. • Encourage drought resistant landscaping. • Encourage supplemental irrigation. • Encourage practices to reduce erosion of topsoil. • Encourage pasture rotation for cattle. • Encourage voluntary livestock reduction.	• Establish fire restrictions.
Fish and Wildlife/Recreation	• Develop wildlife habitat management plan. • Continue management of hunting and fishing licenses.	• Monitor conditions for fish and wildlife. • Monitor drought common disease outbreaks in big game. • Continue management of fishing and hunting licenses.	• Monitor conditions for fish and wildlife. • Monitor drought common disease outbreaks in big game. • Adjust hunting licenses to increase harvest, reducing impact on available forage. • Encourage prairie dog control to reduce competition for farm and rangeland.	• Monitor conditions for fish and wildlife. • Monitor drought common disease outbreaks in big game. • Adjust hunting licenses to increase harvest, reducing impact on available forage. • Encourage prairie dog control to reduce competition for farm and rangeland.

	Normal (No Drought)	Alert (Mild Drought)	Warning (Moderate Drought)	Emergency (Severe to Extreme Drought)
Fire Suppression	• Identify sources of water for structural fire and wildfire response. • Check availability of water carrying equipment.	• Coordinate with fire management regarding wildfire response. • Encourage practices to reduce erosion of topsoil. • Encourage pasture rotation for cattle.	• Coordinate with fire management regarding wildfire response.	• Coordinate with fire management regarding wildfire response.

4. ROSEBUD SIOUX TRIBE RESOURCES AFFECTED BY DROUGHT

The vulnerability, or risk, of a society to drought may be defined generally as the extent to which it will be affected by periods of natural water shortages. The DVA that was previously completed determined the drought vulnerabilities specific to Rosebud Sioux Tribe. The information from the DVA and further coordination completed for this project was utilized to analyze the existing water sources and uses of water by the Rosebud Sioux Tribe. The following further discusses the water sources for the Rosebud Sioux Tribe and water uses of the Rosebud Sioux Tribe. This resource identification and baseline conditions analysis is followed by the determination of the main drought vulnerabilities and drought adaptation priorities for the Rosebud Sioux Tribe.

4.1. Natural Water Sources

This section describes the natural water resources within the Rosebud Reservation including groundwater and surface water. This information is largely from the Rosebud Sioux Tribe's "Integrated Environmental Management Plan for Water, Cultural, and Natural Resources." (Louis Berger, 2018)

4.1.1. Groundwater

In south-central South Dakota, water supply relies on four main surficial aquifers that provide base flow to local streams (USGS, 2017) as described below. ***Figure 11. Geologic Map of the Reservation Showing Extent of Aquifers*** shows the extent of these aquifers in relationship to Rosebud Sioux Tribe lands, as described below:

- ***Quaternary wind-blown deposits (sandhills) and alluvium*** and terrace deposits along streams are used locally for domestic and stock wells. The sandhills portions of the Quaternary Aquifer in the southwestern corner of Todd County is associated with the upper reaches of Spring Creek, a tributary to the LWR. This portion of the Quaternary Aquifer is combined with the underlying Ogallala Aquifer in USGS models (USGS, 2017).

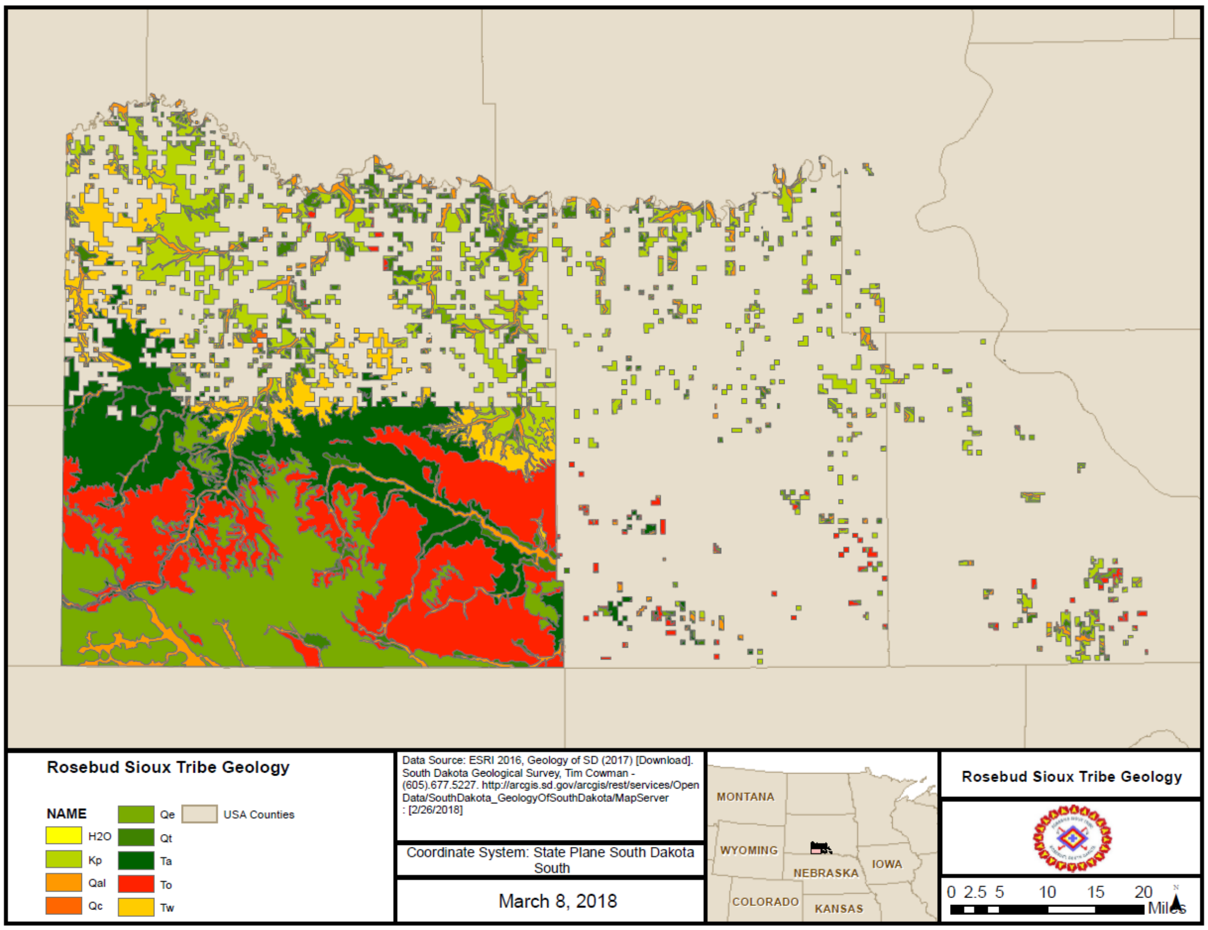
- ***The Ogallala Aquifer***, which exists in the Tertiary-aged Ogallala Formation, is found in most of southern Todd County and is moderately productive. The Ogallala's saturated thickness averages 137 feet. Many of the irrigation wells in central Todd County tap the Ogallala Aquifer. The Ogallala Aquifer is often combined with the underlying Arikaree Aquifer to form the High Plains Aquifer.

- ***The Arikaree Aquifer*** is in the Tertiary-aged Arikaree Formation underlying the Ogallala Formation. It is less productive than the Ogallala Aquifer and is used to supply stock and domestic wells. Significant reaches of the two major streams—LWR and KPR—and their tributaries are incised into the Arikaree Aquifer. Groundwater discharge from the overlying Ogallala Aquifer may occur from upslope, and Quaternary Alluvium is present adjacent to the creeks. The Arikaree Aquifer provides a substantial amount of water to the streams (perhaps some portion as a pass-through from the Ogallala Aquifer at some locations).

- ***The White River Group Aquifer*** has low to moderate permeability and can locally supply stock and domestic wells. USGS chose not to simulate the White River Group Aquifer in its 2010 model of the reservation area, indicating that its transmissivity is much less than the overlying aquifers and that it is less important as a water resource. Water quality in the White River Group Aquifer degrades with proximity to the underlying Pierre Shale.

The Pierre Shale, which underlies the White River Group is not considered to be an aquifer, and water yielded from its fractures or sandier lenses is reported to be of low quality (USGS, 2017). Several aquifers exist beneath the Pierre Shale, but they reportedly have poor water quality and are at depths that make them less desirable as water resources. These deeper aquifers do not discharge locally to surface water.

Figure 11. Geologic Map of the Reservation Showing Extent of Aquifers



4.1.1.1. Characterization

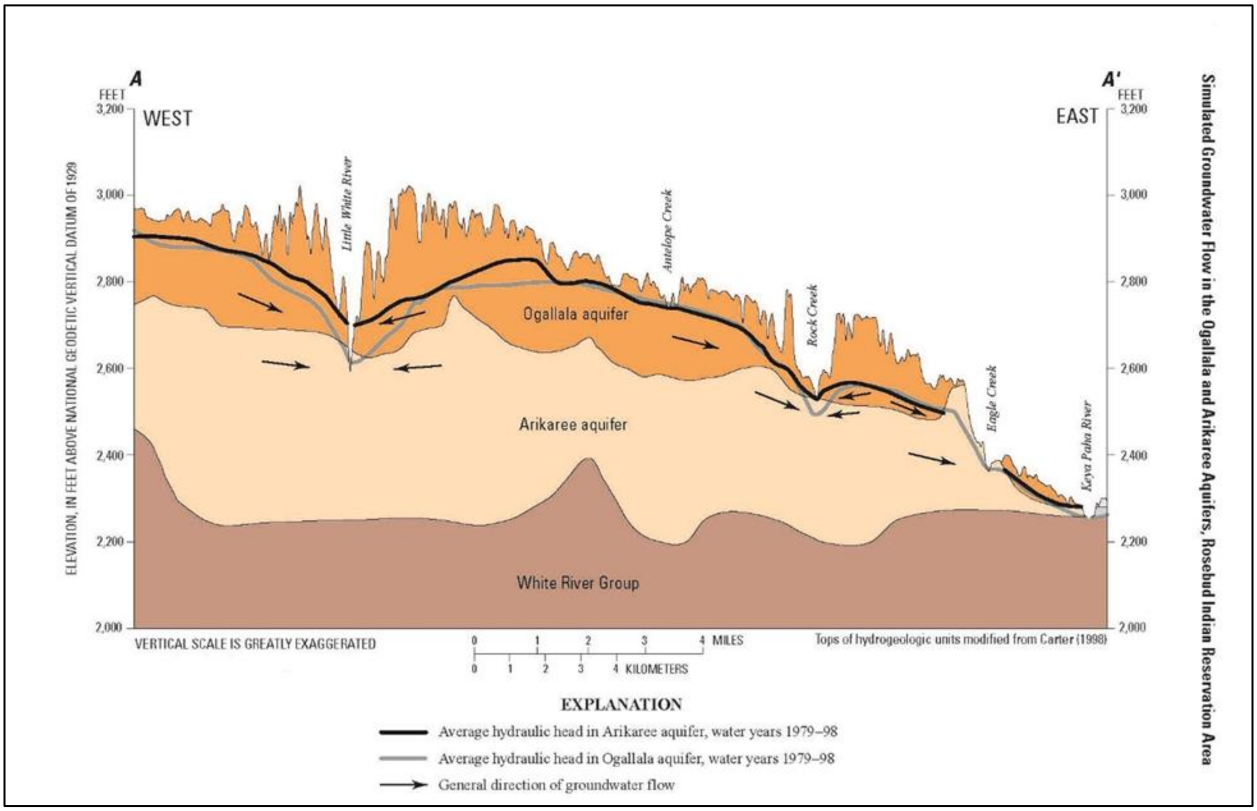
The Rosebud Sioux Tribe Water Resource Program collects monthly data from 28 observation wells located on top of the Ogallala Aquifer within the boundaries of the reservation. The Rosebud Sioux Tribe Water began data collection in 1983 and shows an accurate representation of the groundwater fluctuations underneath the reservation. Appendix B presents a table of annual averages of the well depths for years 1983 through 2016, and accompanying figures (hydrographs) show the fluctuations in water level during this period. Overall, water depth in the observation wells has stayed mostly constant over time in the wells. Most recently, there was a drop in water depths in nearly all the observation wells around 2004, but most wells have since recovered the lost water depth. All data were provided by the Rosebud Sioux Tribe Water Resources Program.

USGS Long Putnam (2010) describe a conceptual and numerical model developed to simulate groundwater flow in the Ogallala and Arikaree aquifers near the reservation using data for a 30-year period (water years 1979–2008). Water levels measured during 1996 for more than 350 wells, primarily domestic, open to the Ogallala and Arikaree aquifers were documented by Carter (1998). Water levels for 44 Tribal and state observation wells open to the Ogallala and Arikaree aquifers for 1979–2008 were also available. Of these, 21 are maintained by Rosebud Sioux Tribe and 23 are maintained by the South Dakota Department of the Environment and Natural Resources. All but one of the Rosebud Sioux Tribe Water wells (Rosebud Sioux Tribe Water -15) are in the Ogallala Aquifer. Aquifer water levels generally fluctuated between 1 and 4 feet seasonally. Hydraulic head in the Ogallala Aquifer ranged from about 3,000 feet on the western boundary of the study area to about 2,400 feet on the eastern boundary. Hydraulic head in the Arikaree Aquifer ranged from about 3,000 feet in the southwestern corner of the study area to about 2,400 feet in parts of the northern and eastern boundaries of the aquifer. During water years 1970–2008, some of the water levels changed as much as 6 and 12 feet for the Ogallala and Arikaree Aquifers, respectively (Long and Putnam, 2010).

Groundwater in the Ogallala Aquifer and Arikaree Aquifer on the reservation generally flows to the east or northeast. Locally, groundwater flow is topographically controlled and is toward the LWR and KPR or smaller streams. Domestic water use on the reservation is small compared to irrigation, and municipal water-supply wells have little local effect on groundwater flow. Groundwater flows from recharge areas toward streams and topographically low areas where discharge occurs as base flow to streams or evapotranspiration. The relationship between hydraulic heads and topographic features (***Figure 12. Relationship between Hydraulic Heads and Topographic Features***) shows the local influence of streams on the direction of groundwater flow. In particular, the LWR, which is deeply incised into the Ogallala Aquifer and to a lesser extent into the Arikaree Aquifer, strongly influences groundwater flow.

The KPR is hydraulically connected to the Arikaree Aquifer, and tributary streams gain water from the Ogallala aquifer. A comparison between the surface-drainage basins and the potentiometric surfaces shows that groundwater divides are related to the surface-drainage basins. The USGS groundwater model for the Rosebud area predicted a decline of 1 to 16 feet in the water levels at the 44 observation wells during drought conditions simulated over a 30-year period. The steady-state model was calibrated to average water levels in 383 wells and estimated average base-flow rates for 6 surface-water drainage basins. Inverse modeling techniques were used for steady-state model calibration. These methods were designed to estimate parameter values that are, statistically, the most likely set of values to result in the smallest overall differences between simulated and observed hydraulic heads and base-flow discharges. A sensitivity analysis was used to examine the response of the calibrated steady-state model to changes in model parameters including horizontal and vertical hydraulic conductivity, evapotranspiration, recharge, and riverbed conductance. The model was most sensitive to recharge and maximum evapotranspiration and least sensitive to riverbed and spring conductance (Long and Putnam, 2010).

Figure 12. Relationship between Hydraulic Heads and Topographic Features



Source: USGS Scientific Investigations Report 2010—5105 (Long and Putnam, 2010)

Rosebud Sioux Tribe has collected and analyzed data on groundwater quality within the boundaries of the reservation. Contaminants found in the water source on the reservation include nitrates, arsenic, and hydrocarbons. Groundwater has been tested for other water quality parameters, such as dissolved solids, pH, hardness, and lead.

Carter (1998) indicates the chemical quality of water in the aquifers in Todd and Mellette counties varies widely, both within and between aquifers. The chemical quality among the aquifers of Tertiary age is the most similar. The quality of water from the alluvial aquifers depends on the underlying deposits. Water underlain by the Ogallala and Arikaree formations generally has low concentrations of dissolved solids, is fresh, and is soft to moderately hard; water underlain by the White River Group has moderate concentrations of dissolved solids, is slightly saline, and is hard; and water underlain by the Pierre Shale has high concentrations of dissolved solids, is saline, and is very hardy. One out of 49 samples from the alluvial aquifers exceeded the USEPA primary drinking-water regulations maximum contaminant level (MCL) for fluoride, and 1 out of 16 samples exceeded that MCL for selenium.

4.1.1.2. Analysis and Data Gaps

Groundwater levels on the reservation are relatively insensitive to droughts, as evidenced by the fact that the change in groundwater levels was slight after USGS simulated extreme drought and long-term pumping. In addition, no correlation was discernable between periods of precipitation drought and decreasing groundwater levels based on the groundwater level data provided by the Rosebud Sioux Tribe. However, if the Rosebud Sioux Tribe relies on shallow wells for stock or domestic supplies, these wells may be locally affected by the change's groundwater levels caused by prolonged droughts and concurrent extended irrigation pumping (Louis Berger, 2017).

The following data gaps regarding groundwater on the reservation have been identified:

- Groundwater quality data by aquifer and comparison with South Dakota or USEPA standards
- Identification of additional abandoned wells
- List of water quality parameters, including:
    - Dissolved oxygen
    - pH
    - Water temperature
    - Turbidity
    - Total nitrogen
    - Metals
    - E. coli
    - Basic habitat information
    - Macroinvertebrates
- Monthly data detailing groundwater pumping rates by water well to determine seasonal variation
- Well construction details and use, including but not limited to irrigation, municipal, and domestic water supplies

4.1.2. Surface Water

Surface water resources found on the reservation and Tribal land areas include rivers, streams, lakes, and ponds. ***Figure 13. Rosebud Sioux Tribe Watersheds*** shows the location of the surface waterbodies.

Figure 13. Rosebud Sioux Tribe Watersheds

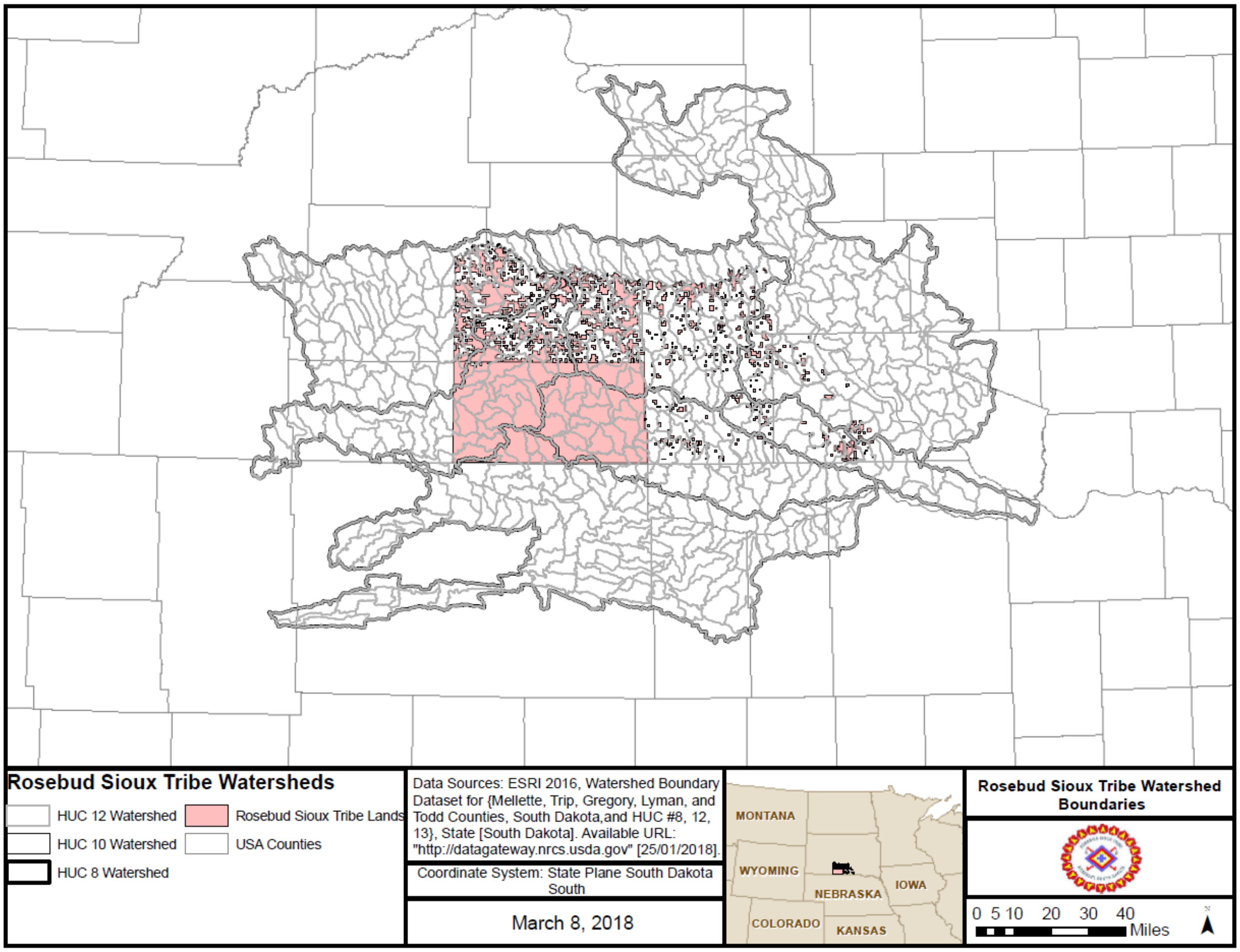


Table 6. Inventory of Water Resources presents an inventory of the water resources found on the reservation and trust lands (Rosebud Sioux Tribe, 2015). USGS published reports on the water quality on the reservation identify high levels of nitrate concentrations, naturally occurring arsenic, vanadium, molybdenum, and uranium levels, as well as increased pH levels in the groundwater on the reservation. USEPA has a publication of the successful rehabilitation of the KPR from 2009 to 2014.

Table 6. Inventory of Water Resources

Resources		Reservation	Trust Land	Description
Rivers	Lower White River	x	x	The river is approximately 234 miles long and is a tributary of the White River. It flows through the reservation and turns northeast. The river discharges 80–200 cubic feet per second (cfs).
	Keya Paha River	x		This river is approximately 127 miles long and flows through South Dakota and Nebraska. It is found in the northeast and central northeast of the reservation. The KPR runs through a small southern portion of the trust lands; however, it does not appear to intersect any areas found on the trust land. It discharges 25–85 cfs.
Streams		x	x	Streams are found distributed throughout the reservation and trust lands.
Waterbodies (ponds and lakes)		x	x	Waterbodies are found in both the reservation and trust lands. On the reservation, most waterbodies are found in the northern and eastern portions of the reservation. Most waterbodies on trust lands are directly north of the reservation, and the rest are scattered around the remaining parcels of land.

4.1.2.1. Rivers

The LWR and the KPR are the only two major rivers flowing through the reservation. The LWR is part of the White River Watershed and originates in Shannon County in southwestern South Dakota and flows through Bennett County before entering Todd County. The river flows northeasterly across western Todd County and south-central Mellette County to the White River.

The KPR is a part of the Niobrara Watershed. The KPR originates at the confluence with Antelope Creek on the reservation. The river flows in a southeast direction and exits the state east of Wewela, South Dakota.

4.1.2.2. Streams

Several streams (creeks) are located on the reservation. Many of these creeks are not perennial because they depend largely on runoff, rather than on springs. It has not been identified which creeks are seasonal or perennial. ***Figure 14. Streams Located on the Rosebud Reservation*** shows the location of the streams and creeks. A listing of the streams follows:

Little White River

- Cottonwood Creek
- Phister Creek
- Cut Meat Creek
- Coffee Creek

- Rosebud Creek
- Soldier Creek
- Spring Creek
- Oak Creek

Keya Paha River

- Antelope Creek
- Eagle Creek
- Rock Creek
- Sand Creek
- Crazy Horse Creek

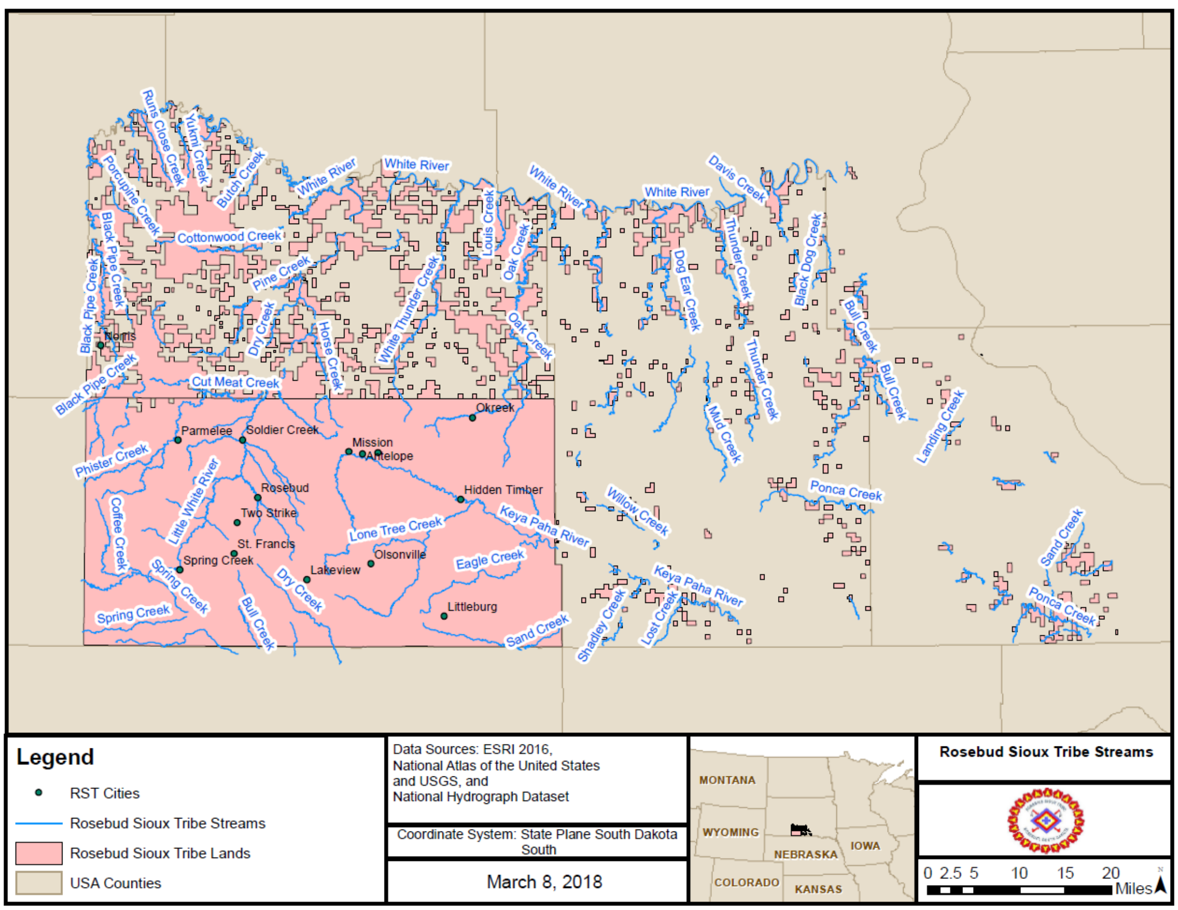
Niobrara River

- Dry Creek
- Bull Creek

White River

- Oak Creek

Figure 14. Streams Located on the Rosebud Reservation



As part of the DVA, (Louis Berger, 2017) used two main USGS streamflow gages located on the LWR and the KPR, just before these rivers exit Todd County, to total stream flow over a 73-year record for the LWR and a 35-year record for the KPR. The overall trend was consistent throughout the period of record for both rivers. In general, flows increased from 30 to 100 cfs for the LWR and 25 to 50 cfs for the KPR during the onset of spring and steadily declined until the colder months in fall and winter.

Prior to 1994, the coincidence between reduced precipitation and lower stream flows was strong. After 1994, the rivers had higher flows and were more stable year to year with an average increase of 34 and 37 percent in overall flow rate in the LWR and KPR, respectively (***Table 7. Average Discharge of the Little White River before and after 1994*** and ***Table 8. Average Discharge of the Keya Paha River before and after 1994***). After 1994, the KPR has been less sensitive to decreased precipitation; however, it is still more sensitive than the LWR. Overall, these two rivers have not been very sensitive or susceptible to drought conditions from historical lowered precipitation trends.

Table 7. Average Discharge of the Little White River Before and After 1994

Date	Before 1994 (cfs)	After 1994 (cfs)	Percent Increase
January	76.05	119.76	57.48
February	103.67	166.9	60.99
March	190.51	200.97	5.49
April	180.88	203.76	12.65
May	156.87	205.9	31.26
June	142.38	201.4	41.45
July	95.21	126.77	33.14
August	76.37	94.53	23.77
September	70.96	85.58	20.6
October	79.06	102.26	29.35
November	85.98	120.99	40.72
December	80.86	122.24	51.18

Table 8. Average Discharge of the Keya Paha River before and after 1994

Date	Before 1994 (cfs)	After 1994 (cfs)	Percent Increase
January	14.91	27.71	85.93
February	42.17	55.98	32.76
March	80.54	83.33	3.46
April	67.2	85.55	27.31
May	68.09	87.24	28.13
June	51.85	75.71	46.03
July	28.77	35.77	24.33

Date	Before 1994 (cfs)	After 1994 (cfs)	Percent Increase
August	18.08	22.71	25.59
September	15.9	19.51	22.71
October	19.51	26.71	36.94
November	21.72	32.99	51.89
December	17.77	29.13	63.95

The following USGS studies also measured streamflow for the LWR and KPR, as follows:

- Samples from 12 tributaries in 2002—2003 were used to measure streamflow, which ranged from 0 to 25 cubic feet per second (cfs). Many of the tributaries upstream from and including Rosebud Creek provide constant sources of flow to the LWR. Tributaries along the lower reach, such as Wigwam Creek, Soldier Creek, and Cut Meat Creek, tend to decrease in flow over the summer and often go dry (Williamson, 2005).

- Multiple streamflow measurements were taken in the area to obtain information about stream base flows. Average base flows were estimated for six surface-water drainage basins in the area, including the LWR and KPR, which were estimated to have average base flows of 49 and 23 cfs, respectively. The four smaller drainage basins—Cut Meat Creek, Black Pipe Creek, Minnechaduza Creek, and Sand Creek—were estimated to have a total average base flow of 9.8 cfs (Long and Putnam, 2010).

The *Summary of Water-Resources Data within the Little White River Basin, South Dakota* (Niehus, 1999) presents streamflow and surface water quality data, groundwater level and quality data, and water use data collected from the following USGS gages:

- 06447500, Little White River near Martin, South Dakota
- 06449100, Little White River near Vetal, South Dakota
- 06449300, Little White River above Rosebud, South Dakota
- 06449500, Little White River near Rosebud, South Dakota
- 06450500, Little White River below White River, South Dakota
- 06448000, Lake Creek above refuge near Tuthill, South Dakota
- 06449000, Lake Creek below refuge near Tuthill, South Dakota
- 06449250, Spring Creek near St. Francis, South Dakota
- 06449400, Rosebud Creek at Rosebud, South Dakota

Niehus (1999) indicates that flow of the LWR near the Bennett and Todd County line is dominated by base flow originating as groundwater discharge from the Ogallala Aquifer and from the windblown sand deposits. Streamflow characteristics for Spring Creek indicate that flow contributions from direct runoff are very minor because of the high infiltration capacity of the windblown sand deposits that are predominant within the drainage area (Ellis et al., 1971). Streamflow characteristics for Rosebud Creek, which is dominated by outcrops of the Ogallala Formation, indicate a large base-flow component; however, somewhat larger contributions from direct runoff are apparent, presumably resulting from influence of outcrops of the Arikaree

Formation. A large base-flow component also is apparent along the main stem of the LWR within Todd and Mellette counties. The largest influence from direct runoff becomes more apparent farther downstream where large outcrop areas of the White River Group and Pierre Shale occur within the contributing drainage area (Carter, 1998).

4.1.2.3. Quality

The quality of water within the Missouri River Basin is a concern for the Rosebud Sioux Tribe because half of its water comes from the Missouri River. The Tribe holds water quality as a high priority and works to protect this resource. The Rosebud Sioux Tribe is also extremely concerned about the quality of water resources on the reservation.

The U.S. Geological Survey, in cooperation with Rosebud Sioux Tribe, conducted a 2002–2003 assessment of the water-quality and biological characteristics of the LWR and selected tributaries in Todd County. Samples were analyzed for physical properties, major ions, nutrients, trace elements, and suspended sediments. Reconnaissance pesticide samples were collected during the summer of 2003 (Williamson, 2005). Results indicate that water-quality concentrations correspond closely with historical values, indicating that the water quality in the LWR has not changed substantially over time. USEPA standard methods were used for all analyses.

All streams in South Dakota have the designated uses of wildlife propagation and stock watering and irrigation waters. The LWR has additional beneficial uses of a warm-water, semi-permanent fishery, and limited contact water. Spring Creek, Rosebud Creek, and Soldier Creek have beneficial uses of cold-water marginal fisheries and limited contact waters. Cut Meat Creek and Ironwood Creek have beneficial uses of warm-water marginal fisheries and limited contact waters. Rosebud Sioux Tribe currently (2005) does not have approved beneficial uses and corresponding standards for the streams on the Reservation. Using the current South Dakota standards for comparison purposes for the samples collected during 2002–2003, suspended-sediment concentrations exceed the State total suspended-solids standard 45 to 82 percent of the time. Sampling took place during a relatively dry year, so these results may be conservative. Review of historical (1957–2001) daily suspended-sediment concentrations indicates that the LWR near Vetal (Bennett/Todd County line) exceeded the State standard 50 percent of the time, and the LWR near Rosebud exceeded the standard 89 percent of the time.

Results from the reconnaissance sampling were generally within ranges previously reported for samples from the LWR, and similar concentrations were found in tributaries to the LWR. Nutrient concentrations were slightly higher than historical medians and were near the previous maximum concentrations for dissolved ammonia, dissolved nitrite, and dissolved nitrate. Arsenic concentrations were less than the current (2005) drinking-water standard of 10 micrograms per liter (µg/L). All pesticide concentrations in samples collected from tributary sites were less than laboratory reporting levels, except atrazine (0.01 µg/L) and 2-chloro-4-isopropylanino-6-amino-s triazine (estimated concentration of 0.005 µg/L). Atrazine was not detected in historical (1973–2001) samples.

More extensive pesticide sampling would be beneficial to provide better indications of seasonal or climatic effects in pesticide concentrations in surface waters in the basin. Fecal coliform bacteria concentrations generally were less than the State's limited contact standard of 2,000 col/100 mL (colonies per 100 milliliters) within the LWR except for immediately after storm events. A fecal coliform bacteria concentration of 9,500 col/100 mL was reported at the LWR near Vetal in June, and 4,200 col/100 mL and 3,200 col/100 mL were reported for the LWR near Rosebud and near the Todd/Mellette County line, respectively, in July. Several tributaries had higher concentrations than the standard during this same period, including Sawmill Canyon, South Fork Ironwood Creek, and Soldier Creek. High concentrations in Sawmill Canyon also occurred in August and September. More detailed sampling during and after storm events would be beneficial to determine exactly where high concentrations originate within tributaries and how long concentrations of concern might persist (Williamson, 2005).

The *2016 South Dakota Integrated Report for Surface Water Quality Assessment* (SD DENR, 2016) indicates that the South Dakota Department of Environment and Natural Resources has assessed one lake in the White River basin and maintains five water quality monitoring sites within this basin. Four monitoring sites are located on the White River and the other is located on the LWR. The USGS has water quality monitoring sites in the basin, including sites on the White River, LWR, Black Pipe Creek, Lake Creek, and others. The data are limited, and the only parameters that were measured were specific conductance and water temperature. The South Dakota Department of Environment and Natural Resources established site specific water quality standards for TSS (total suspended solids) in 2009 for the White River and LWR; however, the reach SD-WH-R-WHITE_03 did not meet the site-specific TSS standard during the 2016 Integrated Report cycle. The White River is listed as impaired for sodium absorption ratio, fecal coliform, and E. coli. USGS maintains a monitoring site on Antelope Creek, however there is an insufficient amount of data available to determine waterbody support.

The KPR originates in Todd County at the confluence with Antelope Creek and Rock Creek on the reservation. The river flows in a south-east direction and exits the state east of Wewela, South Dakota. The river is not supporting its designated uses because of TSS, fecal coliform, and E. coli bacteria. Land use along the KPR is primarily agriculture. Livestock grazing in the riparian or shoreline areas has been identified as the primary source of bacteria. No point sources discharge into the KPR. A total maximum daily load has been approved for the KPR to address contaminants. A portion of the Lewis and Clark Watershed (Missouri River Basin) is in the Niobrara Basin. Implementation efforts in the Lewis and Clark Watershed are being conducted under the South-Central Watershed Implementation Project, which also encompasses the Lower James River Watershed.

4.1.2.4. Analysis and Data Gaps

Streamflow data indicates base flow for the LWR and the KPR originate as groundwater discharge from aquifers and direct runoff. In both rivers flow increases during the onset of spring followed by a steady decline in the streamflow during the colder months in fall and winter. A recommendation for future data for surface water includes the collection of surface water quality data by stream and comparison with South Dakota or USEPA standards.

4.2. Built Water Systems and Use

Built systems include man-made infrastructure such as reservoirs, stocks ponds, wells, community water and wastewater systems, and septic and storm water systems. The built systems on the reservation include reservoirs, wells, irrigation systems, and rural water systems, and are discussed in the following subsections.

4.2.1. Reservoirs

Six reservoirs and seven lakes are located on the reservation. ***Figure 15. Surficial Waterbodies on the Rosebud Reservation*** shows the locations of the lakes. ***Table 9. Reservoirs and Lakes on the Rosebud Reservation*** lists the names, general locations, surface areas at full pool, and maximum depth of reservoirs. Information was gathered from Rosebud Fisheries Report completed by the US Fish and Wildlife Service and Rosebud Game Fish and Parks (Wanner and Boyd, 2010).

Figure 15. Surficial Waterbodies on the Rosebud Reservation

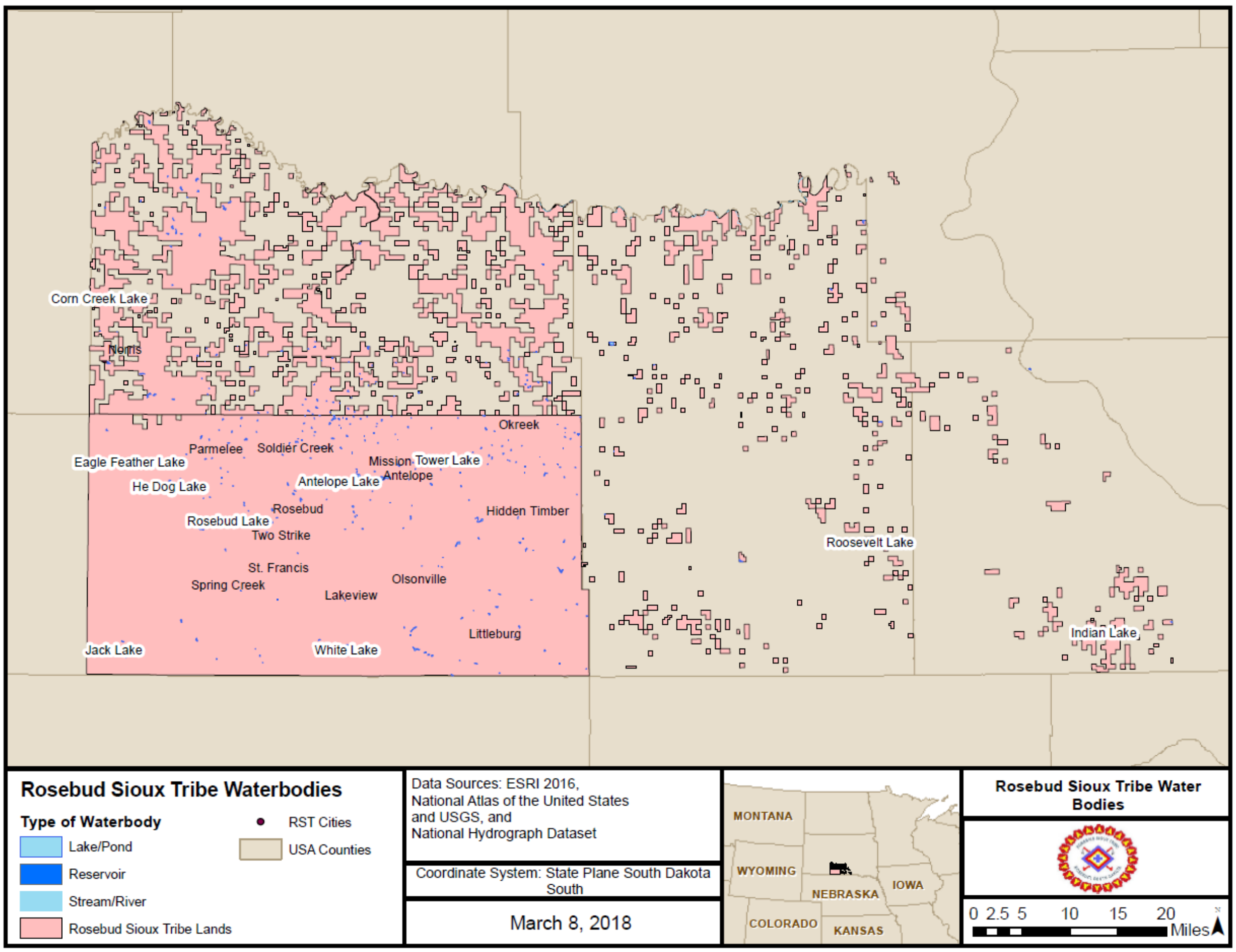


Table 9. Reservoirs and Lakes on the Rosebud Reservation

Name	Location	Surface Area at Full Pool (Acres)	Maximum Depth (ft)
Reservoirs			
Bead	Between Rosebud and St. Francis	42	33
Chases Woman	Between Rosebud and St. Francis	8	19
Indian Scout	Outside town of Rosebud	2.5	22
Eagle Feather	West of Parmelee	44.5	25
Rosebud (aka Spotted Tail)	Rosebud	8	13
Antelope Creek	On Antelope Cree, headwaters of Keha River, City of Antelope, near Mission	136	25
Lakes			
He Dog Lake	Southwest of Parmelee	70	Unknown
Eagle Feather Lake	West of Parmelee	47	Unknown
Jack Lake	Southwest of Spring Creek	29	Unknown
Tower Lake	Northeast of Mission and White Horse	14.6	Unknown
Ghost Hawk Lake	Northwest of Rosebud	10.7	Unknown
Rosebud Lake	Rosebud	8	Unknown
Swift Bear Lake	Northeast of Rosebud	6.6	Unknown

4.2.1.1. Characterization

Other than the acreage and depth of reservoirs provided in ***Table 9. Reservoirs and Lakes on the Rosebud Reservation***, no other information was found regarding reliability of this resource.

The major water quality concerns for Antelope Creek Reservoir is nutrient enrichment from seepage and overflow from nearby sewage lagoons. The area has sandy soils and a shallow water table, which allows for rapid seepage. Nutrients from sewage and runoff have created a highly eutrophic lake increasing vegetation and algae growth. Water quality data for several reservoirs (water temperature, dissolved oxygen, pH, and conductivity) were collected during the 2010 Fisheries Study (Wanner and Boyd, 2010).

4.2.1.2. Analysis and Data Gaps

Without regular monitoring of water quality in the reservoirs and lakes, the Tribe has difficulty assessing the current conditions and trends in these waterbodies. The water quality of reservoirs and lakes should be regularly monitored. An evaluation of the resources would lead to the development of protocols to develop a monitoring program to track this important information. Concurrently, the amount of water in each reservoir and lake could be measured for evaluation, as well. It is recommended to gather bi-annual water quality data for reservoirs, including quantities of water stored in reservoirs at peak and non-peak times. (Note: develop a monitoring plan to delineate key parameters if reservoirs are used for contact recreation and fishing.)

4.2.2. Wells

The type of wells located on the reservation and Tribal land area—irrigation, domestic, stock, commercial, municipal, monitoring and observation and other—are described in ***Figure 16. Wells Type and location in the Reservation Area***. The list of wells was compiled from the South Dakota Department of Environment and Natural Resources and RST data. ***Table 10: Wells located in the Vicinity of the Rosebud Reservation*** shows the distribution of wells, primarily domestic and stock scattered throughout the reservation in high quantities. Additionally, irrigation wells are located within central Todd County. A total of 32 observation wells are located within Todd County and other trust lands. The rest of the wells are scattered throughout the reservation at a much smaller frequency. See Appendix B for additional information on these wells.

Center Pivot Irrigation System

The Mni Wiconi Rural Water System and production wells are discussed separately in Section 4.2.3.

Approximately 107 irrigation wells and 119 irrigation pivots are located on the reservation as shown on ***Figure 17: Irrigation Pivots Located on the Reservation***. These pivots are located primarily in Central Todd County, South Dakota, on top of the Ogallala Aquifer. The condition/effectiveness or the impacts on riparian/groundwater ecology has not been identified.

Figure 16. Wells Type and Location in the Reservation Area

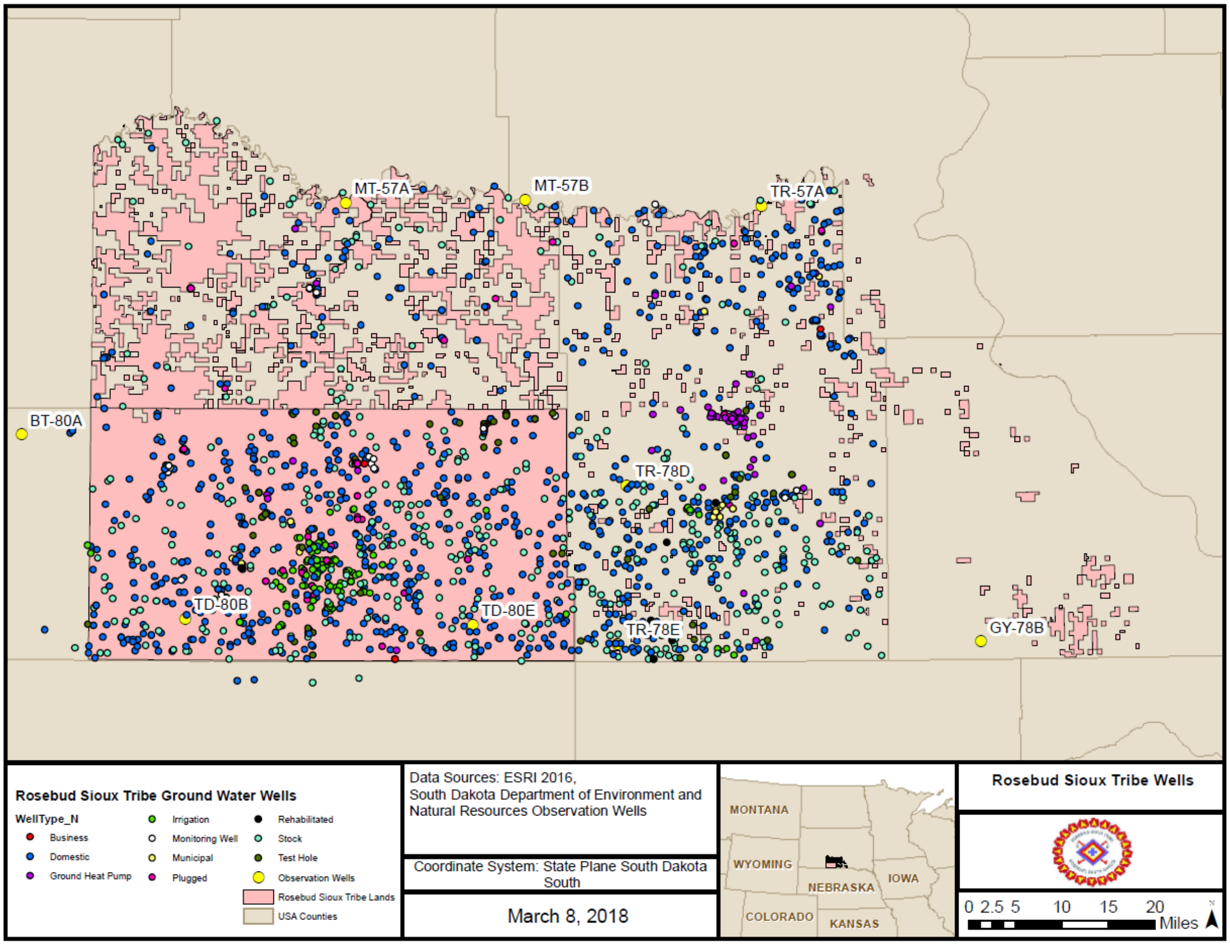
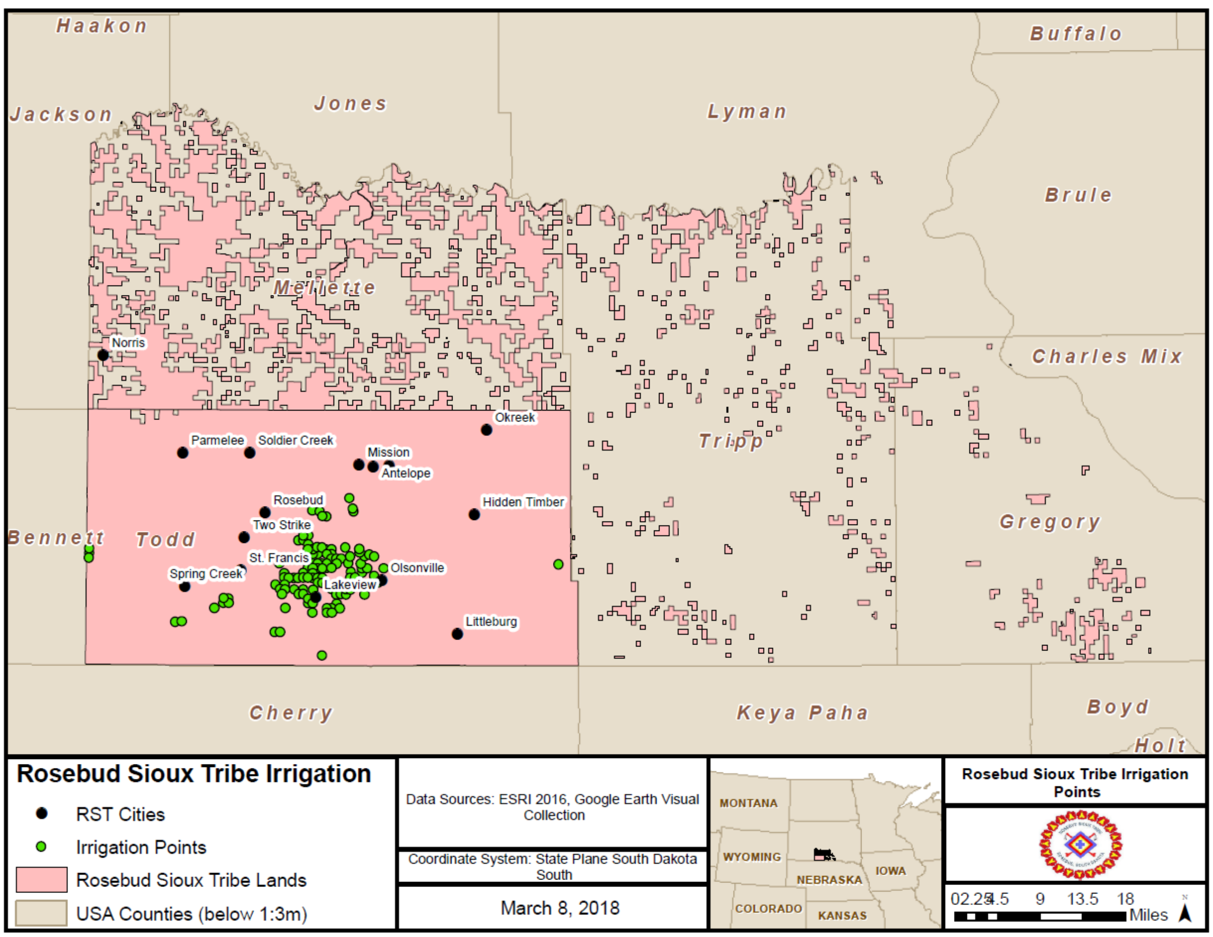


Table 10. Wells Located in the Vicinity of the Rosebud Reservation

Type	Number of Wells		Description
	Todd County	Mellette County	
Irrigation	107	0	Irrigation wells are only found in the central portion of the reservation.
Stock	238	47	Stock wells are found distributed throughout the reservation and to a lesser degree the trust lands. Stock wells are used to provide water to livestock.
Domestic	506	83	Domestic wells are evenly distributed throughout the reservation and found at a higher concentration in the northeastern portion of the trust land. Domestic wells are privately owned wells installed by the homeowners.
Municipal	7	4	Municipal wells include Rosebud Indian Health Service (Bureau of Indian Affairs), RST, St. Francis School, Indian Health Service, St. Francis Industrial Park, city of White River and town of Wood.

Type	Number of Wells		Description
	Todd County	Mellette County	
Business/ Commercial	3	0	Commercial wells consist of industrial and business wells. Only a few are in the north-central portion of the reservation.
Other	Ground heat pumps–8 Monitoring wells–104 Plugged–58 Rehabilitated–1 Test holes–80	Ground heat pumps–3 Monitoring wells–41 Plugged–12 Test holes–10	These wells include geothermal, monitoring plugged and test holes. They are only found on the reservation.
Observation	27	5	Observation wells are state-owned wells that are used to measure ground water levels throughout South Dakota. The data provide geologic and hydrologic information used to evaluate effects of climate conditions, effects of water use from the state's aquifers, and availability of water for users.

Figure 17. Irrigation Pivots Located on the Reservation



4.2.2.1. Characterization

Well withdrawal occurs primarily for irrigation but also for public supply, domestic use, and stock use. Irrigation withdrawals from the Ogallala Aquifer are especially important in Todd County and mainly occur east of St. Francis, where the saturated thickness of the Ogallala Aquifer is greatest. The acres of irrigated land in Todd County from 1985 to 2005 ranged from 10,000 to 11,000 acres. Irrigation withdrawals are variable because they are affected by numerous factors—climatic conditions, commodity prices, and energy costs. Water-use data for irrigation and public supply are compiled every 5 years as part of the USGS National Water-Use Information Program in cooperation with local, state, and Federal agencies and is aggregated by counties for each state (U.S. Geological Survey, 2009).

Data on groundwater withdrawals from the Ogallala and Arikaree aquifers in the reservation study area were compiled from the USGS Site-Specific Water-Use Data System for the period of available record (1981–2005). The estimated groundwater withdrawal by year ranged from about 5,200 to 14,500 acre-feet and averaged 8,611 acre-feet or 35.6 cfs over a 4-month period (June–September 1979–2008) (Long and Putnam, 2010). In 1996, a study was done on the levels of lead and copper within residential wells located on the reservation.

4.2.2.2. Analysis and Data Gaps

Well data on production, reliability, and water quality is important to collect and to analyze. Develop a monitoring plan to indicate frequency of data collection, based on the importance and type of well.

4.2.3. Rosebud Rural Water System

Production Well water system infrastructure is critical to the success of Rosebud Sioux Tribe. Native American tribal populations are known to face greater health concerns compared to other population groups in the US. Part of this disparity is access to safe drinking water. 8.9 percent of tribal homes lack access to safe drinking water, compared to 0.6 percent of non-Native American homes (Swift Bird, 2018). Before 2000, groundwater was the source of all water used for municipal and rural-domestic purposes in the Reservation (USGS 1998). Since the implementation of MWRWS, Missouri River water is now delivered to the to the Rosebud Sioux Rural Water System, which distributes the water to the communities. Many of the community water systems need upgrades. In addition, the Reservation has scattered rural residences that required private wells (Huq 2020).

Production Well

The Mni Wiconi Rural Water Treatment Plant provides water across a vast area, spanning ten counties in central and southwest South Dakota through the Oglala Sioux Rural Water Supply

System. The service area covers 12,500 square miles, equivalent to one-sixth the total area of the state. Planning began in 1988 and the construction of the system is still underway. The plant has an intake capacity of 14 MGD and can treat up to 13.4 MGD. Upon leaving the plant, 24-inch high-pressure pipe supplies the 4,200 miles of pipeline located throughout the system (OSTRWS, 2018).

The Tribe is allocated 1,985 gallons per minute of water from the Mni Wiconi Rural Water System. This is only half of the water needed to supply the Rosebud Rural Water System. The system is designed for 17,000 customers, requiring approximately 3,971 gallons per minute. In addition to the Mni Wiconi supply, the remainder comes from 16 production wells that draw from the Ogallala Aquifer. ***Table 11: Production Wells*** and ***Table 12: Water Treatment Systems*** list the production wells and treatment systems in operation by the Rosebud Sioux Tribe and their location (Huq, 2020). Public water is supplied at no cost to the community.

Table 11. Production Wells

No. of Wells	Location	Condition
5	Rosebud	
3	Mission	
3	St. Francis School	
3	Rosebud Casino	

Table 12. Water Treatment Systems

Location	Treatment	Condition
St. Francis	Chlorination	
Milks Camp	Chlorination	

4.2.3.1. Transmission

The Rosebud Rural Water System (RBRW) begins in Murdo, South Dakota, at a 250,000-gallon storage tank. The water then flows south for approximately 11 miles through a 16-inch main pipeline, which changes to an 18-inch pipeline and flows south for 3.5 miles. The water is then pumped approximately 10 miles to another storage tank in White River, South Dakota. From White River, the system splits going west and south. Continuing the main pipeline south 2.5 miles, the lines connects to the Horse Creek Storage tank holding 475,000 gallons of water. The system then continues to the south approximately 20 miles to Mission, South Dakota. From Mission, the system branches across the eastern half and northwestern corner of Todd County. In Todd County the system connects with 19 groundwater wells, 13 water storage tanks holding approximately 2.8 million gallons, and 11 booster pump stations. RBRW is responsible for the operation and maintenance of the water system. Users do not pay for water from the system. The

U.S. Department of the Interior is responsible for the operation and maintenance of the Mni Wiconi Rural Water System.

To the west of White River, a 12-inch main flows to the Little White River Pump Station and runs approximately 14 miles to Cedar Butte before turning south. The water flows approximately 3 miles before connecting to the Cedar Butte Pump Station. This water main continues the line approximately 5 miles to the North Parmelee Tank that holds 391,230 gallons. The system then runs west approximately 9 miles changing to 8 and 6-inch pipe to connect to the town of Norris. The system then turns north after a series of pumps and continues approximately 7 miles to connect the community of Corn Creek.

There is a 15- to 45-day retention time for the water to get from the intake of the system in the Missouri River to the reservation. Very dry and hot summers, such as the summer of 2012, cause severe pressure fluctuations in the water lines. Vulnerabilities to the system include electric grid failures and fluctuations of the Oahe Reservoir. If the Mni Wiconi Rural Water System were to lose power for any reason, lift stations are equipped with generators to supply flow. If the system's intake runs out of water, it would take years to redevelop the reservation's infrastructure to provide an adequate water supply.

4.2.3.2. Distribution

Table 13: Population Data for RBRWS Communities presents population data for communities served by Rosebud Rural Water System taken from the US Population Census 2010 or estimated using housing counts and persons per household.

Table 13. Population Data for RBRWS Communities

Community	Population
Mission	1,182
St. Francis	709
Antelope	826
Grass Mountain	<100[1]
Parmelee	562
Soldier Creek	227
Ring Thunder	<100[1]
Upper Cut Meat	<100[1]
Horse Creek	<100[1]
Swift Bear	<100[1]
Okreek	269
Black Pipe	<100[1]
Corn Creek	<100[1]
Total	**4,475**[2]

[1] Information not available for through SDARWS or 2010 Census Viewer. Assuming population is less than 100 individuals.

[2] Total is calculated assuming 100 individuals for each community where information is not available to determine a conservative estimate.

4.3. Other Socio-Economic Resources

4.3.1. Tribal Lifeways

The information from this section was obtained during the field visits and was shared by Tribal members during those visits. The Tribal lifeways of the Rosebud Sioux Tribe include the practice of subsistence living, such as burning firewood for heat and using natural resources for food, ceremonies, arts and crafts, and barter systems. Tribal members on the Reservation expressed that it is more difficult to be an American Indian during periods of drought. Cultural leaders remember when the temperature would be high for a few days in a row in the late summer, with temperatures decreasing shortly thereafter to normal. Now they feel as if the hot days have turned into hot weeks that never seem to go away, leaving the feeling of an annual summer drought. Current temperatures also seem to be getting hotter when compared to the past. Tribal Elders remember the creeks and streams on the Reservation flowing year-round and recall drinkable water from the streams, which were home to trout. In contrast, today there are no creeks on the reservation that are potable, and Tribal members believe that many of the fish populations are decreasing.

Timpsula, plums, and chokecherries used to be the main sources of food for the Lakota people, but these plants have changed over time. Late spring freezes kill the plums, or fruits are stunted by drought. Many traditional plants on the reservation cannot be harvested due to stunted growth making it difficult to collect. However, drought conditions have brought back some old medicine plants that have not been observed for years, and the reason for the reemergence is unknown. The impact of drought on medicine plants could be devastating, as many traditional medicines are still used today.

The Rosebud Elderly Advisory Council is concerned that younger generations are losing touch with valuable traditional wisdom of the Sicangu people in using many plants indigenous to their homelands for food, cultural and medicinal purposes. Currently, they are working on the Elders Project: Mapping the Richness of the Sicangu Oyate. Their project includes plant research, interpretation and documentation, including proper Lakota plant names, using field technicians and consultation with Elders to preserve the knowledge and uses of over 400 plant species, for the health and wellbeing of current and future generations (Cultural Resource Fund 2020).

4.3.2. Agricultural Practices

Within Todd County, topography of the area is generally undulating to steeply rolling with very limited level areas. The eastern part of Todd County drains into the Keya-Paha River. The western part drains into the Little White River. These rivers, creeks and springs constitute the natural water supply. Some of the low areas along streams have a high-water table. The soils of the area are primarily of a sandy nature, but with much variation. The heaviest soils are in the northeastern part of the county, while the south western portion is sand hills with practically no row crop farming. The central and southeastern areas are sandy loam soils (Todd County Conservation District 2011). Due to the terrain, the Reservation is mainly rangeland for livestock, some areas are utilized for hay land to feed the livestock herds that are on pasture.

On the Reservation, the total number of producers (defined as earning more than $1,000 from agricultural products) is 603. Of the 603, 149 of the farms are operated by natives. The property ownership within the Reservation is scattered with both native and non-native ownership. The Indian Reorganization Act of June 18, 1934 (48 Stat. 984) as amended, as well as the Rosebud Constitution and Charter provide authority for the establishment of the Rosebud Sioux Tribe Tribal Land Enterprises. The purpose and objective of the Rosebud Sioux Tribe Tribal Enterprises is to create plans that remedy the situation of increasing fractionation of ownership interests and to utilizing lands under the control of the Rosebud Sioux Tribe for the development of economic enterprises within communities on the reservation (Tribal Enterprises 2020).

In 1995, the surface water withdrawal for livestock was 59 percent of the total withdrawal in Todd County. Irrigation was 41 percent. In Mellette County, the percent of withdrawal was 54 percent and 46 percent for irrigation. About 60 percent of the water withdrawn for livestock water was derived from surface water and the remaining 40 percent was from groundwater sources. In Mellette County, 86 percent of the water used for irrigation was derived from surface water sources and 14 percent from groundwater. In Todd County, only 3 percent of the water used was from surface water sources, and 97 percent was from groundwater sources. Most of the groundwater used in Todd County, 89 percent, is for irrigation (USGS 1998).

In Todd County, groundwater generally can be obtained from shallow wells from the alluvial, Ogallala, Arikaree or White River aquifers. In Mellette County, the Pierre Shale is present for most of the area, which means the shallow wells are not present. Groundwater sources then must be pulled from deep, bedrock wells, often greater than 1,000 feet (USGS 1998). A search of the SDDENR's "Water Well Completion Reports" shows that there are 1,138 private wells servicing Todd County alone, shown in ***Figure 18: SDDENR Map of Completed Wells in Todd County, SD***. The wells have completion dates extending from the 1940s to 2019 (SDDENR 2020).

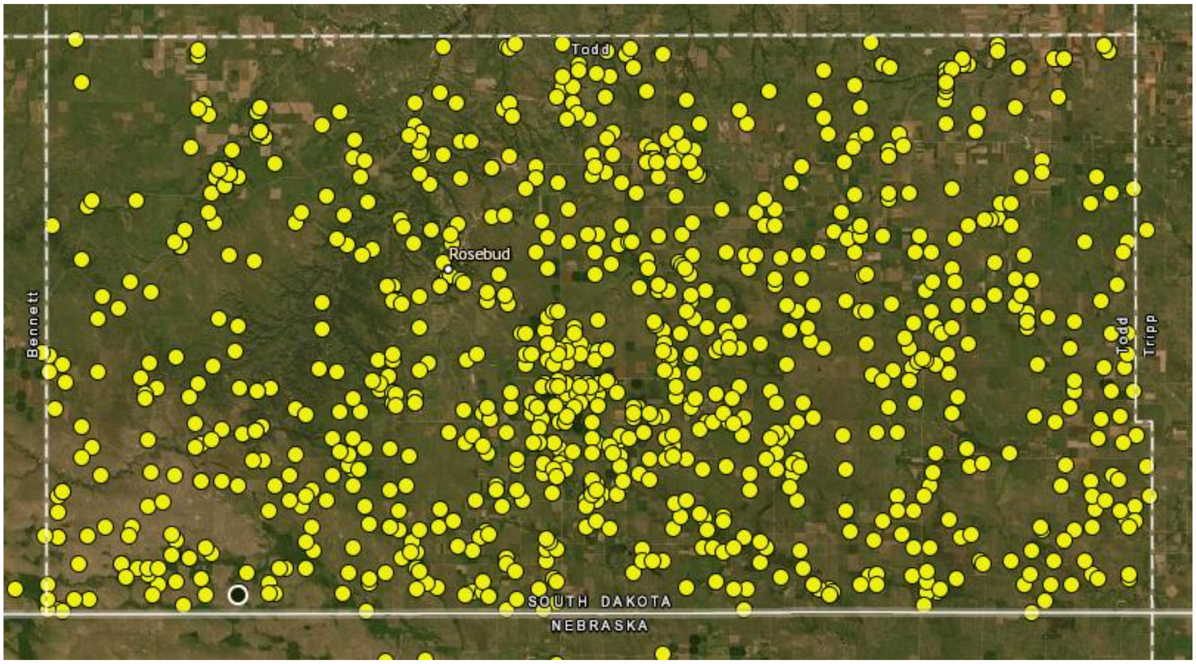
A Water Use Permit from Rosebud Sioux Tribe needs to also be obtained for water use. Rosebud Sioux Tribe is the owner of the full equitable title to the rights to the use of all waters originating and flowing into the exterior boundary of the Reservation as defined herein and all other waters, including implied and granted to the Tribe, and the title resides undiminished in the Rosebud Sioux Tribe. A Water Use Permit is an authorization granted by Rosebud Sioux Tribe to make a beneficial use of Waters of the Reservation. An approved Water Use Permit authorizes the use of either ground or surface water upon compliance with the conditions provided for in the permit (Rosebud Sioux Tribe 2015).

New wells for irrigation of more than one acre must obtain a water right permit from the South Dakota Department of Natural Resources (SDDENR). The permit must be obtained before any drilling. The drilling of the well must follow SD Well Construction Standards, Chapter 74:02:04. The following are the criteria for granting the water permit as set forth in South Dakota Codified Law 46-2A-9 (SDDENR 2020):

- Water must be available for the proposed use.
- The proposed diversion can be developed without unlawful impairment of existing rights.
- The use of the water must be a beneficial use (irrigation is one of the uses).

- The use of the water must be in the public interest. Testimony can be provided at the hearing.

Figure 18. SDDENR Map of Completed Wells in Todd County, SD (yellow dots are private wells)



4.3.3. Fish and /Recreation

Rivers present within RSST's boundaries are available for recreational use, including fishing. Fish, wildlife, and recreation are managed by Rosebud Sioux Tribe Game, Fish and Parks Department. The Rosebud Sioux Tribe offers a variety of hunting options throughout the year, including turkey, prairie dog, upland birds, waterfowl, trophy elk, antlerless elk, muzzleloader dear, archery deer, rifle deer, mule deer, and buffalo. Fishing licenses are also required with limits placed on bass, pike, walleye saugeye, muskellunge, paddlefish, trout (brook, brown and rainbow), crappie, sunfish, perch, catfish, bullhead, and rough fish (Rosebud Sioux Tribe Game, Fish and Parks Department 2020).

South Dakota Department of Game, Fish and Parks (SDGFP) also manages fish and wildlife across South Dakota. The west river fishery management plan notes issues including 1) aging impoundments have decreased the ability to support fisheries, 2) remote locations mean habitat projects may be low statewide priority, 3) a lack of information on angler use and management preferences hinders management, and 4) angler access to larger western Missouri River tributaries is insufficient. The priority objectives in the plan noted improving angling access on small dams and to completely renovate one small dam (SDGFP 2020).

SDGFP notes in their Wildlife Action Plan that the major conservation challenges to terrestrial ecosystem diversity are the direct habitat conservation and indirect habitat alteration through the spread of invasive species and suppression of natural disturbance processes. Climate change projections needs to be combined with an understanding of the species and ecosystems in South Dakota to determine potential future impacts. The suppression of fire in wildland areas and grazing animals have added to the impact to ecosystems in South Dakota. The current tendency toward moderate-level grazing has affected grass-shrub systems. Forested systems have also been impacted by grazing (SDGFP 2015).

4.3.4. Fire Suppression

The Rosebud Sioux Tribe Volunteer Fire & Rescue Department is vested in the provision of fire suppression services on the Rosebud Indian Reservation to protect its residents from the loss of life or property resulting from fire. Rosebud Sioux Tribe consists of 13 districts with a total of 20 communities. The main source of water in communities are hydrants. In the event of a larger Reservation wide fire, local landowners allow for use of stock dams and irrigation wells. Some of the needs for better water connection for fire suppression includes Spring Creek Community (no hydrants) and in some cases not able to utilize hydrants due to high water demand in a community (Provencial, 2020). In addition, the Bureau of Indian Affairs (BIA) Forestry & Wildlife Fire Management- Rosebud Agency provides fire suppression for wildland fires. ***Table 14: Drought Risk Assessment by Resource Sector*** shows the drought risks for various aspects of reservation, including fire suppression.

Table 14. Drought Risk Assessment by Resource Sector

Surface Water Supply	Groundwater Supply	Water Management	Drought Risk
Built Water System Use			
MWRWS utilizes the Missouri River as the water source.	MWRWS system does include wells in the Ogallala aquifer. Private drinking wells also are present since the Reservation has large rural areas.	MWRWS is the primary manager of water distribution from the Missouri River. Rosebud Sioux Water System manages the system from the MWRWS distribution lines.	**HIGH RISK for quantity- MWRWS provides water, this is limited. The shallow aquifers in Todd County are mainly used by irrigation and deep wells in Mellette County are required for backup systems. During times of drought the water supply from MWRWS, alluvial aquifers and High Plains Aquifers will be limited.** **HIGH RISK for quality- The arsenic and uranium levels would present issues if the Arikaree Aquifer would need to be depended upon for additional water during restrictions of the MWRWS supply. The Ogallala Aquifer is currently monitored by ROSEBUD SIOUX TRIBE, some of the non-producing wells have shown high levels of nitrates, arsenic and hydrocarbons (Huq, 2020).**

Surface Water Supply	Groundwater Supply	Water Management	Drought Risk
Tribal Lifeways			
Traditional plants utilized water source to grow.	Traditional plants could utilize alluvial aquifers to grow	N/A	**MEDIUM RISK – water supply to traditional plants is affected. Growth of plants is either stunted or the plants are not growing during drought. Supply is reduced to be utilized for medicinal uses.**
Agriculture			
Irrigation could potentially pull from surface waters.	Crop irrigation utilizes wells drilled into aquifers. In Todd County, wells are in shallower, alluvial aquifers from the Little White, White, and Keya Paha River. In Mellette, wells need to be drilled deeper to access Ogallala or Arikaree.	Managed by individual farmers. Permit required by SDDENR.	**HIGH RISK for quantity accessing shallow alluvial aquifers, making up 85 percent of the use of groundwater in Todd County. In addition, since irrigation was introduced, the Ogallala and Arikaree has shown signs of declining storage.**
Fish and Wildlife/Recreation			
Habitat and recreation opportunities are mainly centered around rivers, tributaries, lakes, stock ponds, oxbows, and wetlands in the area.	From springs and wells, in some cases livestock water sources pumped from wells is drank by wildlife.	Managed by ROSEBUD SIOUX TRIBE Game Fish and Parks and SDGFP.	**MEDIUM RISK- the aging of the dam infrastructure on the Reservation could limit the habitat areas for fisheries and wildlife.**
Fire Suppression			
Rosebud Fire Department and BIA Forestry and Wildland Fire Management could utilize surface waters. In large fire	Rosebud Fire Department utilizes fire hydrants in communities that utilizes groundwater	Water sources are determined by the fire departments.	**MEDIUM RISK- Availability of MWRWS water supply during times of drought may be restricted. Dams are aging and need repair so many may fail and not be able to provide secondary water options. Some communities lack hydrants.**

Surface Water Supply	Groundwater Supply	Water Management	Drought Risk
events, ROSEBUD SIOUX TRIBE Fire Department utilizes stock dams and irrigation wells when possible.	source from Ogallala and Arikaree Aquifers.		

5. ROSEBUD SIOUX TRIBE DROUGHT ADAPTATION PRIORITIES

Drought vulnerabilities were identified in the previous DVA. The results of the responses specify the rank of severity of the vulnerability; the lower scores represented the greatest vulnerabilities. In addition to this ranking process of the previous vulnerabilities, additional coordination occurred during the finalization of this report with the Technical Team of the Tribe. The information previously gathered in the DVA, research, and coordination for this project identified the following drought adaptation strategies. Although the priorities are numbered, each one represents an important priority and mitigation actions are recommended to achieve each one.

5.1. Priority #1: Understand the Water Resources Across the Reservation

The main vulnerability on the Reservation is that the quantity of water sources on the Reservation are limited and need to be managed. This is a concern for the Rosebud Sioux Tribe, so a priority has been placed on understanding the capacity of Rosebud Sioux Tribe's water resources. The water sources on the Reservation include the High Plains Aquifer (Ogallala and Arikaree), alluvial aquifers, and the water system from the Missouri River. The MWRWS is the main supply of drinking water on the Reservation, which is sourced from the Ogallala Aquifer and Missouri River. The Tribe maintains 28 monitoring wells, which aid in understanding the condition of the groundwater in the Ogallala and Arikaree aquifers. Surface water on the reservation includes rivers, creeks, streams, small lakes, and stock dams. The main rivers on the reservation are the Little White River and the Keya Paha River.

In analyzing historical trend data regarding surface and groundwater, several conclusions can be drawn that can aid in the understanding of these resources. Overall, groundwater levels in the Tribe's monitoring wells have remained stable over the last 30 years (see Appendix B for well monitoring data). Historically, the Little White River and the Keya Paha River have not been very susceptible to drought conditions from historic lowered population, as their base flow comes from stable groundwater levels (Louis Berger, 2017). However, evaluations show that some resources, including isolated waterbodies and groundwater recharge areas, can be sensitive to drought. Isolated waterbodies are highly vulnerable to drought. Waterbodies that are not adjacent to a stock well or within a 1.5-mile buffer of another waterbody are the most vulnerable water resources evaluated. Groundwater recharge areas are more susceptible to droughts than groundwater discharge areas because water resources in recharge areas are more reliant on precipitation (Louis Berger, 2017). Keeping track of trends in groundwater and surface water data is important for maintaining an understanding of the water resources on the Reservation. Downward trends in the condition of water resources can be concerning, so early awareness of these trends is important in protecting these resources.

Preserving groundwater and limiting groundwater use where possible is also important in preparing for drought conditions. In Todd County, irrigation is 89 percent of the use of groundwater. Increasing the number of permits or excessive irrigation during drought would tax the aquifer resources on the Reservation. The permits issued by the SDDENR do not currently follow Rosebud Sioux Tribal Water Code, which requires a permit from Rosebud Sioux Tribe within the Tribe's jurisdiction. This is a concern for the Tribe, as irrigation performed on the Reservation without proper permission from Rosebud Sioux Tribe could strain groundwater resources.

Another concern that has been shown to affect Rosebud Sioux Tribe's water resources is climate change. The Reservation's climate and climate change projections were studied in the "Climate Guidebook," which was completed in 2018. Most notably climate change projections predict that due to increased temperatures, heat waves are expected to become more intense, and drier conditions are projected for the summer (Louis Berger, 2018). These conditions of increased temperatures with drier conditions have made the Reservation more susceptible to drought in recent years and could continue to increase the risk for extreme drought. Tracking changes in the condition of water resources is of utmost priority to the Tribe, as is predicting the effects of climate changes. The Tribe currently has a groundwater-flow model produced in conjunction with the U.S. Geological Survey that can help Rosebud Sioux Tribe predict the effects of drought on their groundwater resources. However, this model is over 10 years old and is outdated. This is an important consideration, because an outdated model will produce less accurate results when analyzing and predicting trends in the state of the water resources on the Reservation/

5.2. Priority #2: Protect Surface Water and Groundwater from Contamination

A primary concern for the Rosebud Sioux Tribe is identifying and protecting their drinking water, including both water supply and distribution system. The first of these concerns is protecting water supplies from contamination. A portion of the water supply for most of Rosebud Sioux Tribe is the Ogallala Aquifer. The water from the aquifer is accessed through wells throughout the Reservation. There are also many abandoned or otherwise non-producing wells on the Reservation. Pollutants have been noted in non-producing wells and so far, have not affected the producing wells. However, allowing these abandoned wells to remain open presents a danger to the groundwater supply, as contaminants that may enter through open abandoned wells could leak into the surrounding groundwater. This groundwater could then be accessed by producing wells, creating drinking water issues for the Tribe. This is a concern for the future. Surface water sources can also be contaminated through means such as urban and agricultural runoff, which is a concern for the Tribe. Awareness of ways to prevent contamination from urban areas and agricultural practices will need to be a focus to preserve the water sources on the Reservation.

Another concern for Rosebud Sioux Tribe is the condition of their drinking water infrastructure. Identifying the state and capacity of the MWRWS and RSWS water systems is important for prioritizing projects and maintenance to prevent future issues that may come with increased demand during times of drought. Studying water quality and availability, determining current and future residents that may need drinking water access, and deciding on necessary improvements are important for maintaining the water systems on the Reservation.

5.3. Priority #3: Promote Water Monitoring, Water Use Conservation and Education

Tracking water for understanding drought trends produces important data needed by Tribal leaders to prepare for drought. Awareness of potential droughts is a main concern for the Tribe, so up-to-date information regarding water levels in Tribal monitoring wells, stream flow, and soil moisture can give the Rosebud Sioux Tribe crucial water sufficiency data. Information about the timing and severity of drought is the basis for reliable communications with Tribal members to prepare for drought. Setting thresholds for action based on the gathered water sufficiency data is important to determine when the Tribe needs to take specific actions that will help mitigate the effects of drought on the Reservation. Broad support of Tribal members to enact volunteer water use conservation practices and restrictions is essential. Providing education regarding water use and drought conditions before drought occurs can help deliver the message and prepare the Tribe for those times. The monitoring and recording of water data can help the Tribe to observe trends in drought indicators, which can help to signal both long-term and flash droughts.

5.4. Priority #4: Preserve Cultural Resources During Drought

Traditional plants are utilized for medicinal uses and are significant to the Tribe. The use and preservation of the plants needs to be considered as drought will affect the growth including inhibiting and stunting the growth of these plants. The loss or degradation of these cultural resources is concerning for the Rosebud Sioux Tribe, so steps should be taken to protect them during drought periods.

5.5. Priority #5: Conserve Water Resources in Domestic and Agricultural Practices

In times of drought, broad support of Tribal members to enact volunteer water use conservation practices and restrictions is essential. Providing education regarding water use and drought conditions before drought occurs can help deliver the message and prepare the Tribe for those times. Another way to conserve water in domestic practices is to improve the efficiency of water use. Poor efficiency standards are a major problem for buildings and the environment. Low efficiency buildings allow more water use, both in times of drought and under normal conditions.

Irrigation wells need to obtain a Rosebud Sioux Tribe Water Use permit so that the Tribe can monitor the use of the Ogallala Aquifer for agricultural practices. The irrigation systems need to be reviewed to make sure pipes and equipment are not having a loss of water and proper watering practices are being utilized.

The lack of riparian zones around the major rivers that run through Reservation has created issues with the water quality in those surface waters. Overgrazing from livestock and other causes has created a lack of vegetation, leading to poor bank stabilization. The lack of stability causes excess erosion of the riverbank during times of high flow. Water quality issues stem primarily from E. coli contamination due to livestock defecating in or near the river. During times of drought, the concentration of these contaminates increases, posing greater risk for health concerns. Other agricultural practices such as poor crop management and improper application of pesticides and herbicides can also be concerns contamination and can heighten the effects of drought.

6. DROUGHT MITIGATION STRATEGIES AND POTENTIAL FUTURE PROJECTS

The DAP seeks to recommend effective mitigation strategies for implementing long-term measures to adapt to drought and reduce the risk of drought effects. As in dealing with any type of disaster, this type of strategic approach can be referred to as risk management. This chapter describes mitigation strategies and the potential projects associated with the strategies. Chapter 7 aligns the Drought Adaptation Priorities with the Mitigation Strategies and Projects described in this chapter. ***Table 15. Summary of Projects and Funding Sources for Each Drought Adaptation Priority*** in Chapter 7 shows the vulnerabilities identified and the mitigation strategy that addresses those vulnerabilities to reduce the risk to Rosebud Sioux Tribe during drought. Several projects are identified for each mitigation strategy and potential project funding.

The following sections discuss the mitigation strategies and the potential projects identified.

6.1. Mitigation Strategy #1: Irrigation Permits and Drought Restrictions

Irrigation water use includes water that is applied by an irrigation system to sustain plant growth in agriculture and horticultural practices. Estimates of irrigation withdrawals are generally accounted for at the point of diversion (i.e. wells) and include water that is lost in conveyance prior to application on fields, as any water that may subsequently return to a surface water body as runoff after application, water consumed from evapotranspiration from plants and evaporated from the ground, or water that recharges aquifers as it seeps past the root zone (USGS 2009). The loss of water can then come from the conveyance system and excessive watering practices, in addition time of day and functionality of the system. A review of irrigation systems with the producers would be beneficial, two possibilities include 1) educational outreach and 2) auditing of irrigation systems. In addition, restrictions during moderate to severe drought stages could be considered.

According to the 2015 Rosebud Sioux Tribe Water Code, a Water Use Permit from Rosebud Sioux Tribe must also be obtained for water use. Rosebud Sioux Tribe is the owner of the full equitable title to the rights to the use of all waters originating and flowing into the exterior boundary of the Reservation as defined herein and all other waters, including implied and granted to the Tribe, and the title resides undiminished in the Rosebud Sioux Tribe. A Water Use Permit is an authorization granted by Rosebud Sioux Tribe to make a beneficial use of Waters of the Reservation. An approved Water Use Permit authorizes use either ground or surface water upon compliance with the conditions provided for in the Water Use permit (Rosebud Sioux Tribe 2015).

New wells for irrigation of more than one acre must obtain a water right permit from the South Dakota Department of Natural Resources (SDDENR). The permit must be obtained before any drilling. The drilling of the well must follow SD Well Construction Standards, Chapter 74:02:04. The following are the criteria for granting the water permit as set forth in South Dakota Codified Law 46-2A-9 (SDDENR 2020):

- Water must be available for the proposed use.
- The proposed diversion can be developed without unlawful impairment of existing rights.
- The use of the water must be a beneficial use (irrigation is one of the uses).
- The use of the water must be in the public interest. Testimony can be provided at the hearing.

As noted previously, irrigation is the majority user of groundwater in Todd County of the present deeper aquifers of the High Plains and the alluvial, shallow aquifers of the Keya Paha, Little White, and White. During times of drought, this level of use should be considered for each stage, including response actions from Rosebud Sioux Tribe. Due to this level of involvement, coordination between SDDENR and Rosebud Sioux Tribe would be valuable to discuss the review of the permits and potential restrictions that can be applied during times of drought. Especially since the High Plains Aquifers are showing indicators of storage decline.

6.2. Mitigation Strategy #2: Rosebud Reservation's USGS Simulated Groundwater Flow Model Update

Several years ago, the Rosebud Sioux Tribe identified a need for water-resource management tools associated with the Ogallala and Arikaree aquifers that underly the reservation. The Tribe worked in cooperation with the U.S. Geological Survey (USGS) to develop a numerical groundwater-flow model of these aquifers in 2003, and again to update the model in 2010. The current model includes data through September 30, 2008 (Long and Putnam, 2010). This USGS Model included three scenarios to simulate drought, including steady state, 30-year drought, and 50% increased pumping. The results of the model show that only a small change in the potentiometric surfaces appears between the three simulations. This means that even through a 30-year drought or increased pumping over that time, there would only be a small effect on groundwater and groundwater discharge to streams. However, this simulation does not include the effects of increased pumping during a drought (Louis Berger, 2017). Increased irrigation pumping during drought would be likely to occur during times of lowered precipitation. Therefore, a new simulation should be run in the model that includes both drought conditions and increased pumping, which would help to assess an extreme drought situation that could occur in the future. The model should also be updated to include more recent data, allowing up-to-date trends in groundwater flow to be analyzed. It is recommended that the model is updated every 5 years.

6.3. Mitigation Strategy #3: Current Drinking Water Study

Previous studies have been completed identifying the capacity of the MWRWS and the Rosebud Sioux Water System infrastructure needs. This information should be updated to determine the future capacity issues. This information is also currently being used to upgrade the community systems as funding becomes available. Funding is a limited and the system is expansive, so improvements need to be prioritized. Improvements to each community will also create resiliency during drought by limiting water losses during transfer. In addition, being able to also identify the residents that are currently without a reliable water source due to the scattered rural residences. These residences may be better served by a private well and may need funding assistance. The studies should also include an identification of existing private wells and determine if the water quality of these systems is acceptable by running a yearly test.

One other part of the strategy is being able to review planned development and new residential areas, to the extent possible, these areas need to be in easy access to existing water infrastructure or be easy to extend the infrastructure to the development. These developments should include Rosebud Sioux Water System's review and have early discussions since the rural water system is near or at capacity.

6.4. Mitigation Strategy #4: Measures to Reduce Water Quality Contamination from Agricultural Practices and Abandoned Wells

Since the water sources on the Reservation are providing most of the water supply for drinking and agricultural practices, protection of these resources is needed. As noted previously, levels of nitrates and hydrocarbons have been noted as high in some test wells on the Reservation (Huq 2020). This type of pollution indicates fertilizers, animal waste, and septic tanks (Water Quality Association 2020). Best management practices can be applied to agricultural practices to reduce pollutants from contaminating water sources.

Riparian zones should be required for all farms which a specific distance of a stream or river. The zones should also be designed large enough to filter the water intake of the area. Most likely, a study on the location of a riparian zone should be completed to ensure the size is appropriate and not too small or too large. The riparian zones could also be implemented where ranches are located to also filter the runoff that navigates through livestock fecal matter.

6.5. Mitigation Strategy #5: Soil Moisture Monitoring

As cited in the Drought Vulnerability Assessment (Louis Berger, 2017), an important goal in drought preparedness is collecting and mapping soil moisture data and assessing soil moisture data variability as a function of precipitation and heat. This information will be useful to analyze the effects and changes in evapotranspiration throughout the year and extreme conditions. Soil moisture stations should be established at up to 15 locations chosen to represent the variety of soil conditions expected during a drought (5 in groundwater discharge areas, 5 in groundwater recharge areas, and 5 in areas without aquifers). Data from these locations should be recorded over several seasons (at least one full year) and evaluated for variability and response to precipitation. These data can be used to assess the impacts of low precipitation on soil moisture. Over the long term, the soil moisture stations can be used as monitoring systems to identify when drought conditions are impending. This analysis will be used to refine the DVA and is needed for drought mitigation planning.

6.6. Mitigation Strategy #6: Automated Drought Data Tracking

The collection and use of up-to-date drought data specific to Rosebud Sioux Tribe's geographic location is important for drought preparation and response. As previously discussed in Section 2, the USDM and the EDDI are helpful tools in predicting drought, but they have limitations including time delays in reporting information and information pertinent to an entire region rather than a small area. Establishing ways in which the Rosebud Sioux Tribe can track their own local drought data will be helpful in monitoring real-time conditions specific to the reservation. This data tracking would include three main components:

- Monitoring well data in the 28 Tribal monitoring wells
- Measuring water depth and flow in significant rivers on the Reservation, including the Little White River and the Keya Paha River
- Tracking soil moisture conditions at the proposed 15 soil moisture stations (as described above in Mitigation Strategy #6)

Sensors or other measuring tools could be added to the Tribal monitoring wells, soil moisture stations, and river flow monitors that would automate preserve the recording of data. This data could then be analyzed to determine up-to-date trends of drought conditions on the Reservation.

6.7. Mitigation Strategy #7: Drought Decision Dashboard Improvements

Rosebud Sioux Tribe and its partner the HPRCC have produced a "Rosebud Sioux Tribe Decision Dashboard." To expand the dashboard's effectiveness in drought prediction, improvements could be made to the online dashboard, which would be displayed on the computers of decision-makers and staff at the Tribe. This would require some additional automation of data collection, as well as hardware and software to capture and manage information in an effective manner. Some of the elements of improving the Drought Decision Dashboard could include:

- Adding real-time tracking of the automated data collection described above in Mitigation Strategy #7.
- Develop an algorithm to create Rosebud Sioux Tribe's own "blended short-term and long-term drought indicators," tailored specifically for the reservation
- Develop a simulation to overlay real-time monitoring well data with pump data from wells and other irrigation pivots

6.8. Mitigation Strategy #8: Threshold for Action Development

To mitigate the effects of potential future droughts, Rosebud Sioux Tribe should develop an early warning and early action system. An early warning/early action system would produce an alert specific to the Reservation that would provide advance notice, in terms of several months, towards a possible oncoming drought. An early warning system would include three components: a process to monitor drought indicators, an analysis of their values and trends, and a way to communicate the warning (IDFC, 2014). For the Rosebud Sioux Tribe, this could consist of the automatic data readings analyzed and displayed on the Decision Dashboard, as discussed in previous mitigation strategies. To decide when an early warning would need to be administered, the Rosebud Sioux Tribe must determine specific thresholds for measured data, indicators, or observed trends that would indicate a concern for an oncoming drought. These thresholds could include monitoring well levels falling below a certain depth, a downward trend in rainfall of a specific degree, a decrease in streamflow to below a certain depth or volume, or a quantified change in other indicators. The alerts gathered from an early warning system should be released immediately after the data is collected and analyzed, include a measure of severity and an indication of trend or direction, and be specific about the timeframe of the drought prediction (IDFC, 2014). A plan for early warning/early action should also include an agreed-upon set of actions to be taken once drought thresholds have been met and an alert has been released. These actions may include protection of water sources, increased community education and mobilization, and other actions. An example of an early warning/early action plan including a threshold for action could be that when the depth in a Tribal monitoring well falls below a certain level, irrigation in that area is temporarily halted to allow for sufficient groundwater recharge. Once the well depth recovers, irrigation could be reinstated. In this case, the early warning/early action plan would have allowed for protection of the water source. It is recommended that the Rosebud Sioux Tribe perform a comprehensive study to evaluate climate trends and determine drought thresholds. This study should be performed with input from Tribal community members.

6.9. Mitigation Strategy #9: Preservation of Traditional Plants

To preserve traditional plants includes two considerations, preservation of the knowledge of traditional plants and the continuation of growing traditional plants, even during drought. For the continuation of growing traditional plants, the communities could have gardens that are reserved for traditional plants so watering can be controlled. The gardens could be a learning tool for the elders to pass on the knowledge of the plants to younger generations and continue to provide the plants for medicinal purposes.

6.10. Mitigation Strategy #10: Water Use Education and Restrictions

During times of drought, voluntary water conservation practices can be encouraged and restrictions on water use can be utilized. To prepare for drought, Rosebud Sioux Tribe can identify these practices and restrictions through coordination and research of the best options. In addition, Rosebud Sioux Tribe can incorporate water use education into their schools to promote this water use conservation for when they do need to be applied.

6.11. Mitigation Strategy #11: Water Use Efficiency in Buildings

To improve efficiency standards for Tribal buildings and homes, it is recommended to start with focusing the construction of future buildings towards sustainability. Suggestions include high efficiency appliances such as dish washers, furnaces, air conditioning, and lights, and capturing and reusing rainwater and grey water. Once all future buildings are focused on sustainability, updating old tribal buildings to higher efficiency appliances can be explored, followed by home renovations for efficiency. Existing homes should be the last focus due to the number of upgrades needed.

Rainwater is an excellent source of non-potable water. Catching and using rainwater could be excellent for use in activities outside of the home, including watering a garden, grass, or for livestock use. Educational classes, brochures, posters, etc. would be recommended to encourage this practice. In addition, rain barrels to low income residents who are interested, as well as making rain catching methods available for government buildings to water and maintain their landscaping. There is potential conflict with capturing rainwater due to a lack of legislation stating that it is a tribe-endorsed activity. An alternative to capturing rainwater that does not interfere with legal rights is the reuse of gray water. Gray water is considered lightly used water that is not contaminated with potentially harmful or hazardous substances, such as urine or feces. Gray water may have been used to wash hands, wash dishes, bathe, etc. Learning how to capture and safely reuse this water in other applications such as wastewater systems, plant irrigation, and livestock watering can help reduce the overall demand of water across the reservation and may help reduce the impact of water restrictions during drought conditions.

6.12. Mitigation Strategy #12: Soil Conservation Agricultural Practices

The opportunity for more native run ranches is possible on the Reservation. This mitigation strategy would assist in developing water sources and irrigation systems ran by native ranches. This would encourage opportunities for the Tribes to utilize their water rights on the Reservation in a responsible manner for irrigation. Trust land would be reviewed and opportunities for irrigation would be identified. In addition, all irrigation will continue to be required to obtain a Rosebud Sioux Tribe Water Use permit.

7. ALIGN PROJECT PRIORITIES WITH MITIGATION STRATEGIES

Based upon the previous studies, meetings with Tribal elders, leaders, and staff, drought vulnerabilities were identified and used to develop Drought Adaptation Priorities and Mitigation Strategies. The priorities, discussed in Chapter 5, and the strategies, discussed in Chapter 6, are aligned in this chapter and in ***Table 15. Summary of Projects and Funding Sources for Each Drought Adaptation Priority***. Suggestions for possible projects and funding sources for the projects are also indicated in the table.

Table 15. Summary of Projects and Funding Sources for Each Drought Adaptation Priority

Mitigation Strategy	Potential Project	Potential Funding*
Priority #1: Understand the Water Resources Across the Reservation		
Mitigation Strategy #1: Irrigation Permits and Drought Restrictions	Irrigation wells need to obtain Rosebud Sioux Tribe Water Use Permit and SDDENR permit. Enforcement of Rosebud Sioux Tribe water codes. Review existing irrigation systems for inefficiencies.	*BIA Water Management, Planning, and Pre-Development Program (WMPPD)* The WMPPD program supports the management, conservation, and utilization of reservation water sources. The priority of this program fund is to provide technical research studies and other information necessary for Indian Tribes to serve as informed water managers.
Mitigation Strategy #2: Current Drinking Water Study	Study to identify the residences of the Reservation that are not served by MWRWS. Identify sustainable water source for those residences. Check water quality tests on private wells each year.	*DHHS Community Services Block Grant (CSBG) Rural Community Development Program (RCD) Water and Wastewater Treatment Systems Training and Technical Assistance Project* Rural Community Development (RCD) discretionary grant funds. RCD funds must be used to provide training and technical assistance to: Increase access for low-income families to water supply and waste disposal services, preserve affordable water and waste disposal services in low-income rural communities, increase local capacity and expertise to establish and maintain needed community facilities, increase economic opportunities for low-income rural communities by ensuring they have basic water and sanitation, utilize technical assistance to leverage additional public and private resources, and promote improved coordination of Federal, state, and local agencies and financing programs to benefit low-income communities.
	Update the MWRWS water capacity study. Identify potential shortages and current capacities. Determine plan for sustainability of water supply.	*US EPA Water Pollution Control Section 106 Supplemental Grant* Provides support for state, interstate, and eligible Tribal recipients of Section 106 grants for Water Pollution Control Programs. Covers activities, water quality standards, water quality monitoring, impaired waters listing and total maximum daily loads development, National Pollutant Discharge Elimination System permitting and enforcement and compliance
	Develop a long-term strategic plan for future development. Identify areas that have access to water. Consider development plan approval by Rosebud Sioux Tribe.	*SD DENR Water and Waste Funding Program- Small Community Planning Grant* This program provides small communities with funds to hire an engineering consultant to develop a project specific engineering report. The engineering report's level of detail will be on par with the facilities plan required for SRF projects, The project sponsor must be an entity of government (county, municipality, or township), or a special purpose district with the authority to construct a water or wastewater project (sanitary, water user, watershed, or water project). Nonprofit organizations are also eligible provided they were formed for the primary purpose of supplying water or sanitary service. Nonprofit water systems applying for this grant must meet the definition of a community water system (a public water system

Mitigation Strategy	Potential Project	Potential Funding*
		which serves at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents)
Mitigation Strategy #3: Update the Reservation's USGS Simulated Groundwater Model	Update the groundwater flow model on a reoccurring, 5-year basis.	*BIA Water Management, Planning, and Pre-Development Program (WMPPD)* The WMPPD program supports the management, conservation, and utilization of reservation water sources. The priority of this program fund is to provide technical research studies and other information necessary for Indian Tribes to serve as informed water managers.
	Integrate information from well monitoring to check accuracy of the model on a frequent basis.	
Priority #2: Protect Surface Water and Groundwater from Contamination		
Mitigation Strategy #4: Measures to Reduce Water Quality Contamination from Agricultural Practices and Abandoned Wells	Riparian buffers on waterways to prevent pollution from feedlots and other agricultural practices.	*SD DENR 319 Funds* The Section 319 Nonpoint Source Management Program provides the means for states, Tribes, and territories to receive federal funds to address nonpoint source pollution. 319-funded projects are the primary channel for reducing nonpoint source pollution in South Dakota. Other sections of the Clean Water Act such as 104(b), 106 and 604(b) provide additional grant opportunities, each with its own focus such as assessment or research. Section 319 grant funds may be used for watershed assessment, planning and implementation, groundwater protection or for information and education projects dealing with nonpoint source issues. Implementation refers to putting best management practices (BMPs) in place to reduce nonpoint source pollution, often in response to an existing TMDL. *USDA NRCS Wetland Mitigation Banking Program.* Opportunities for the development and establishment of mitigation banks and banking opportunities solely for agricultural producers with wetlands subject to the Wetlands Conservation Compliance provisions of the 1985 Food Security.
	Education on application of fertilizers and chemicals to reduce contamination.	
	Education on agricultural management practices to maintain water quality, including nutrient management, crop rotation, grassed waterways, and buffer strips.	
	Plug remaining abandoned wells on the Reservation.	
Priority #3: Promote Water Monitoring, Water Use Conservation, and Education		
Mitigation Strategy #5: Soil Moisture Monitoring	Establish soil moisture stations at up to 15 locations chosen to represent the variety of soil conditions expected during a drought.	*BIA Water Management, Planning, and Pre-Development Program (WMPPD)* The WMPPD program supports the management, conservation, and utilization of reservation water sources. The priority of this program fund is to provide technical research studies and other information necessary for Indian Tribes to serve as informed water managers.
Mitigation Strategy #6: Automated Drought Data Tracking	Add sensors to the 28 Tribal monitoring wells that would automate recordings.	*Tribal Adaptation and Ocean and Coastal Management and Planning Grants for Federally Recognized Tribes.*

Mitigation Strategy	Potential Project	Potential Funding*
	Add sensors to the 15 proposed soil moisture stations to automate readings. Add flow monitors to significant rivers on the Reservation to track water flow and depth, including the Little White River and the Keya Paha River	The Program will provide funding for projects that support tribal resilience and ocean and coastal management planning as tribes incorporate science (including Traditional Knowledge) and technical information to prepare for the impacts of extreme events and harmful environmental trends. *BIA Tribal Resilience Program (TRP)* The TRP provides resources spanning across Indian Country, to federally-recognized Tribal Nations in order to build resilience through leadership engagement, delivery of data and tools, training and tribal capacity building.
Mitigation Strategy #7: Drought Decision Dashboard Improvements	Make improvements to the “Rosebud Sioux Tribe Decision Dashboard” to allow for real-time tracking of water sufficiency data. This could include real-time reporting of drought data, an algorithm to determine drought indicators, and a simulation to overlay well levels and pumping data.	*BIA Water Management, Planning, and Pre-Development Program (WMPPD)* The WMPPD program supports the management, conservation, and utilization of reservation water sources. The priority of this program fund is to provide technical research studies and other information necessary for Indian Tribes to serve as informed water managers. *BIA Tribal Resilience Program (TRP)* The TRP provides resources spanning across Indian Country, to federally-recognized Tribal Nations in order to build resilience through leadership engagement, delivery of data and tools, training and tribal capacity building. *Bureau of Reclamation WaterSMART Water Efficiency Grant* Through WaterSMART Water and Energy Efficiency Grants, Reclamation provides 50/50 cost share funding to irrigation and water districts, tribes, states and other entities with water delivery authority. Includes projects to conserve and use water more efficiently; mitigate conflict risk in areas at a high risk of future water conflict; and accomplish other benefits that contribute to water supply reliability.
Mitigation Strategy #8: Develop Thresholds for Action	Perform a study to evaluate drought thresholds across the Reservation with input from Tribal community members.	*BIA Water Management, Planning, and Pre-Development Program (WMPPD)* The WMPPD program supports the management, conservation, and utilization of reservation water sources. The priority of this program fund is to provide technical research studies and other information necessary for Indian Tribes to serve as informed water managers.
Priority #4: Protect Cultural Resources During Drought		
Mitigation Strategy #9: Preservation of Traditional Plants	Community gardens, watering priority	*USDA NRCS Urban Agriculture and Innovation Production (UAIP) Competitive Grants Program* UAIP supports the development of urban agriculture and innovative production activities by funding Planning Projects (PP) and Implementation Projects (IP). The purpose of PP is to support development of projects that will either initiate, build upon, or

Mitigation Strategy	Potential Project	Potential Funding*
		expand the efforts of farmers, gardeners, citizens, government officials, schools, and other stakeholders. Utilize Oglala Lakota College, potentially set up internships.
	Identification and preservation of plants	*National Park Service Tribal Preservation Program* The National Park Service (NPS) Tribal Preservation Program assists Indian tribes in preserving their historic properties and cultural traditions through the designation of Tribal Historic Preservation Offices (THPO) and through annual grant funding programs. Various grant opportunities are offered on a rotational basis.
	Opportunity for Elders to pass on information	*Administration for Native Americans (ANA)* ANA supports Native American communities by providing financial assistance and capacity building, gathering and sharing data, and advocating for improved policies within HHS and across the federal government. Various grant opportunities are offered on a rotational basis.
Priority #5: Conserve Water Resources in Domestic and Agricultural Practices		
Mitigation Strategy #10: Water Use Education and Restrictions	Identify voluntary and required restrictions during drought stages.	*High Plains Regional Climate Center (HPRCC), National Integrated Drought Information System (NIDIS), National Oceanic and Atmospheric Administration (NOAA)* Several programs and resources are offered through HPRCC, NIDIS Drought.gov portal, and NOAA to record and analyze climate and drought data and classify stages of drought. Funding opportunities may be offered on a rotational basis.
	Identify education options to inform the public of water use conservation and voluntary restrictions.	*US EPA- Environmental Education (EE) Grants* Under the Environmental Education Grants Program, EPA seeks grant applications from eligible applicants to support environmental education projects that promote environmental awareness and stewardship and help provide people with the skills to take responsible actions to protect the environment. This grant program provides financial support for projects that design, demonstrate, and/or disseminate environmental education practices, methods, or techniques. Since 1992, EPA has distributed between $2 and $3.5 million in grant funding per year, supporting more than 3,700 grants.
Mitigation Strategy #11: Water Use Efficiency in Buildings	Promote green construction – water conservation in buildings.	*US Department of Housing and Urban Development (HUD)* This is a formula grant that allows tribes or tribally designated housing entities (TDHEs) to provide a range of affordable housing activities on a reservation or Indian area. These activities are identified and described in an Indian Housing Plan (IHP) which is prepared each year and submitted to HUD for review and compliance with the Native American Housing Assistance and Self Determination Act (NAHASDA). Eligible activities include model activities that provide creative approaches to solving affordable housing problems, housing development, and assistance to housing developed under the Indian Housing Program.

Mitigation Strategy	Potential Project	Potential Funding*
	Add educational programs to the existing Rosebud Sioux Tribe water conservation program about reusing gray water for other applications.	*US EPA – Office of Chemical Safety and Pollution Prevention, Office of Pollution Prevention and Toxics, EPA Regional Pollution Prevention Program Offices* Opportunities to fund two-year Pollution Prevention assistance agreements for projects that provide technical assistance (e.g., information, training, tools) to businesses and their facilities to help them develop and adopt source reduction practices (also known as “pollution prevention” or “P2”). P2 means reducing or eliminating pollutants from entering any waste stream or otherwise being released into the environment prior to recycling, treatment, or disposal.
	Update legislation to include rainwater catchment as a Tribal-endorsed activity.	*US Department of HUD* *Section 108 Loan Guarantee Program* The Section 108 Loan Guarantee Program allows future CDBG allocations to be used to guarantee loans for neighborhood revitalization projects, including construction and installation of public facilities and infrastructure. Section 108-guaranteed projects can incorporate green infrastructure into their design and construction.
Mitigation Strategy #12: Soil Conservation Agricultural Practices	Identify water sources for Tribal livestock herds.	*USDA NRCS Conservation Innovation Grants (CIG)* The purpose of CIG is to stimulate the development and adoption of innovative conservation approaches and technologies in conjunction with agricultural production.
	Identify Tribal irrigation systems and opportunities.	

**Potential Funding is based on grant and program availability. Grant funding may not be available every year.*

8. DROUGHT ADAPTATION PLAN MAINTENANCE

It is recommended that the Tribe update this DAP every 5 years and it is recommended that the Rosebud Sioux Tribe Natural Resources Department monitor the consistent updates. This will allow the DAP to be relevant and beneficial during major droughts. To facilitate consistent updating on major plans, such as the DAP, the Federal Emergency Management Agency (FEMA) has funding sources available.

The Tribal department that oversees this plan can change based on both the needs of the Tribe and the most applicable projects to complete. It is also recommended that once a project is complete, a note or updated page be written to reflect the project completion and to ensure that one project is not repeated unnecessarily.

The DAP is written to be used to update the Tribe’s Hazard or Multi-Hazard Mitigation Plan.

9. DATA/PROCESS GAPS AND NEEDS

The most important developmental tool for a DAP is a response from the affected people, the government leaders, and the experts of the area. To create a well-rounded plan, the differences in responses and professional opinions develop a solid understanding of the goals and needs of the Tribe. In a perfect scenario, all Tribal program directors, staff, Tribal council, government officials, and Tribal members invited would be able to attend and determine the exact projects and plans that the Tribe should pursue.

When the DAP is updated, it is recommended that more time be dedicated to retrieving responses and seeking follow-up from the Tribal program directors, staff, Tribal council, government officials, and Tribal members.

The following data gaps were identified in the process of creating this DAP and should be addressed in the future:

- Gaps regarding groundwater include insufficient groundwater quality data by aquifer and comparison with SD or USEPA standards, the need for identification of additional abandoned wells, the need for a list of water quality parameters, the recording of monthly groundwater pumping rates by well water to determine seasonal variation, and the need for well construction details and use.
- A gap regarding surface water includes the need for the collection of surface water quality data by stream and comparison with SD or USEPA standards.
- Gaps in data regarding built water structures include the need for regularly monitoring the water quality of reservoirs and lakes as well as the amount of water in each waterbody.
- A gap regarding well data includes the need to regularly collect and analyze data on well production, reliability, and water quality.

10. CONCLUSIONS AND NEXT STEPS

The information contained within this DAP should be implemented and used to seek funding for identified projects. The projects that are in this report were identified through the leadership of the Tribe. The future of the Tribe's resiliency to drought is dependent on the use of this report to work on the identified adaptation plan and projects. Subsequent action steps to the DAP should be seeking funding sources and pursuing the completion of each project outlined within.

For the future, attempts should be made to reach all Tribal leaders. In the next iteration of the DAP, it is recommended to have longer field visits and individual meetings with each Tribal leader to better understand every leader's perspective.

11. RESOURCES

Resources for information, outside of online sources, books, articles, journals, etc., were primarily interviews and discussions with Tribal program directors, staff, Tribal council, government officials, and Tribal members. The Tribal leaders interviewed identifies the specific leaders that were asked for their professional opinions.

11.1. Tribal Leaders Interviewed

Rosebud Sioux Tribe’s field visit yielded excellent discussion and had most of the Tribal leaders in attendance. The Tribal leaders and federal government employees that attended were: Syed Huq (Rosebud Sioux Tribe Water Resources Director), Robert Oliver (Rosebud Sioux Tribe Safety of Dams), Emily Boyd-Valandra (Rosebud Sioux Tribe Department of Game, Fish, and Parks Biologist), Ben Young (Rosebud Sioux Tribal Historic Preservation Office), Ben Rhodd (Rosebud Sioux Tribal Historic Preservation Office), Paula Antoine (Rosebud Sioux Tribe Director of Land Management), Harold Compton (Rosebud Sioux Tribal Land Enterprise), Chad Boyd (BIA Fire Management), and Ken Haukaas (Rosebud Sioux Tribe Director of Forestry). All the Tribal leaders who were in attendance had many ideas and thoughts on drought and drought mitigation strategies. Sign in sheets may be found in Appendix A.

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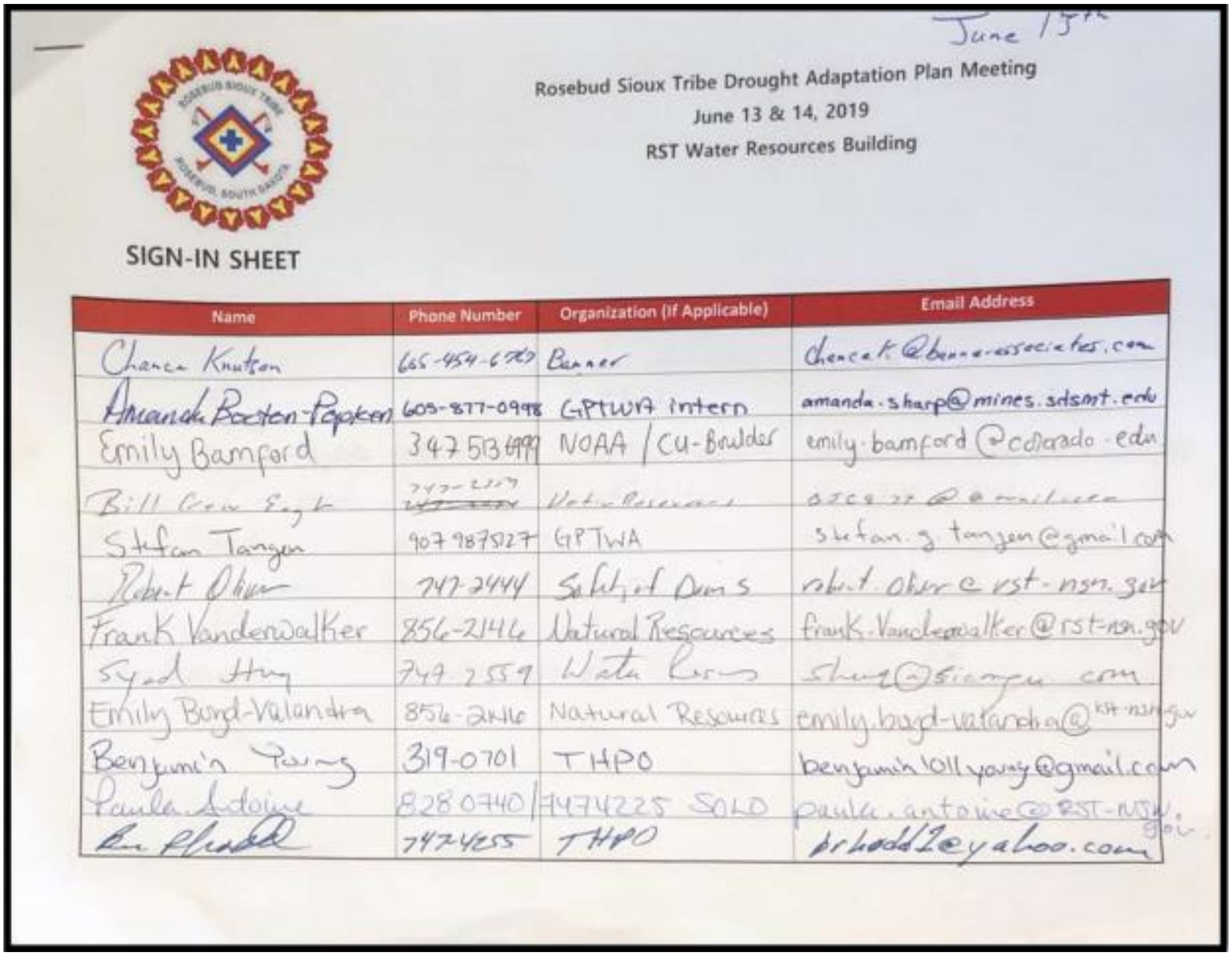
APPENDIX A. FIELD VISIT SIGN-IN SHEETS AND HANDOUTS

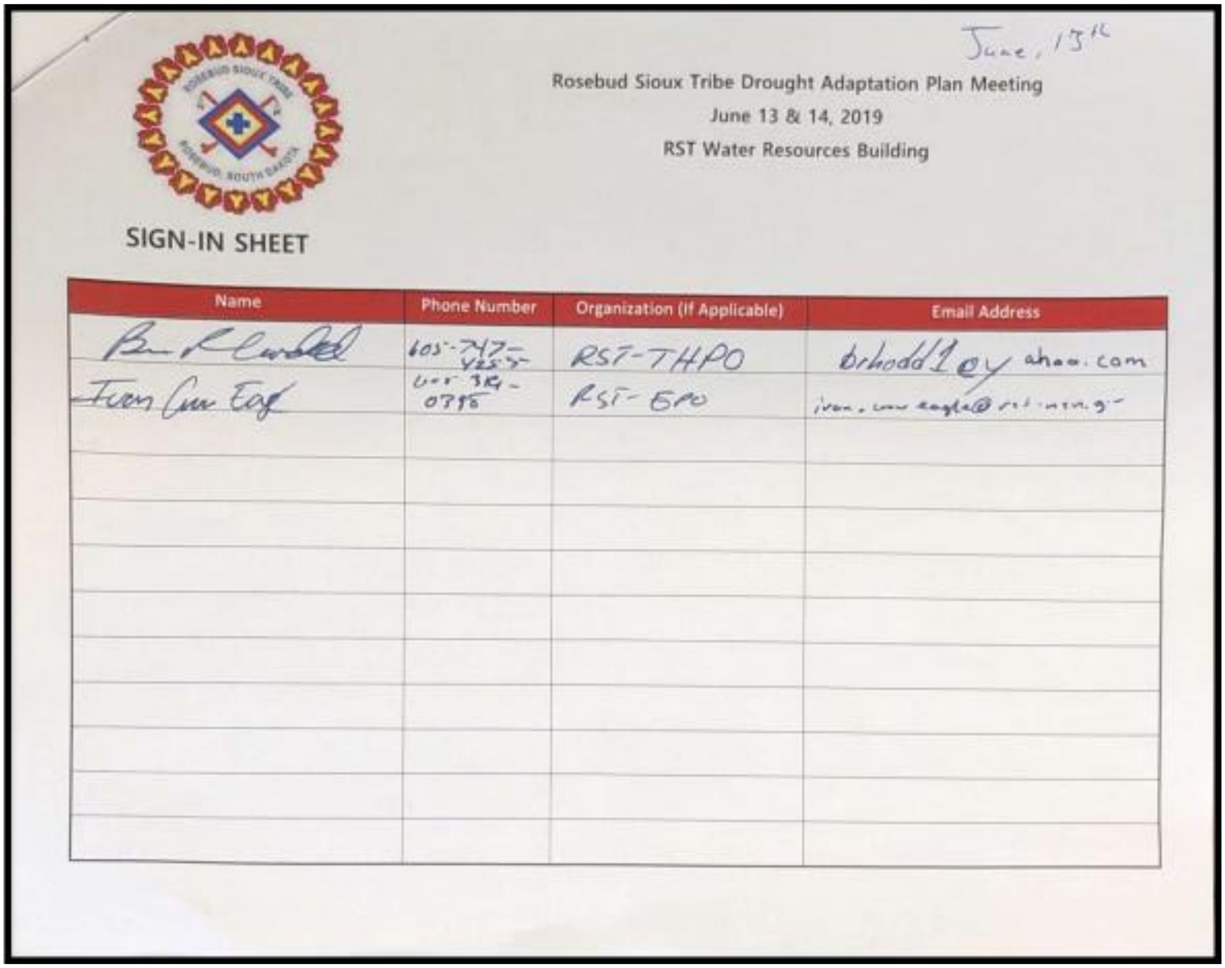


June 13th

Rosebud Sioux Tribe Drought Adaptation Plan Meeting
June 13 & 14, 2019
RST Water Resources Building

SIGN-IN SHEET

Name	Phone Number	Organization (If Applicable)	Email Address
Chance Knutson	665-454-6767	Banner	chancek@banner-associates.com
Amanda Boston-Popken	605-877-0998	GPTWA intern	amanda.sharp@mines.sdsmt.edu
Emily Bamford	347 513 4999	NOAA / CU-Boulder	emily.bamford@colorado.edu
Bill Crow Eagle	747-2217	[illegible]	[illegible]
Stefan Tangen	907 9875127	GPTWA	stefan.g.tangen@gmail.com
Robert Oliver	747-2444	Safety of Dams	robert.oliver@rst-nsn.gov
Frank Vanderwalker	856-2146	Natural Resources	frank.Vanderwalker@rst-nsn.gov
Syed Huq	749-2559	Water Resources	[illegible]
Emily Boyd-Valandra	856-2416	Natural Resources	emily.boyd-valandra@rst-nsn.gov
Benjamin Young	319-0701	THPO	benjamin1011young@gmail.com
Paula Antoine	828 0740 / 7474225	SOLO	paula.antoine@RST-NSN.gov
[illegible]	7474255	THPO	brhodd2@yahoo.com



June, 13th

Rosebud Sioux Tribe Drought Adaptation Plan Meeting
June 13 & 14, 2019
RST Water Resources Building

SIGN-IN SHEET

Name	Phone Number	Organization (If Applicable)	Email Address
[illegible]	605-747-4255	RST-THPO	brhodd1@yahoo.com
[illegible]	[illegible] 0795	RST-EPO	[illegible]

June, 14th

Rosebud Sioux Tribe Drought Adaptation Plan Meeting
June 13 & 14, 2019
RST Water Resources Building

SIGN-IN SHEET

Name	Phone Number	Organization (If Applicable)	Email Address
Chance Knutson	605-454-6767	Banner Associates	chancek @bannerassociates.com
Stefan Tangen	907 987 5177	GPTCA	stefan.g.tangen@gmail
Amanda Booton-Popken	605-877-0998	GPTWA intern	amanda.sharp@mines.sdsmt.edu
HAROLD COMPTON	605 747-2371	Rosebud Tribal Land Enterprise	Harold@rsttle.com
Chad Boyd	605-747 2700	BIA Fire	Chad.Boyd@BIA.Gov
Donald Haukaas	605 747 2700	BIA Fire	Donald.Haukaas@BIA.Gov
Syed Huq	605 747-2559	Water Resources	[illegible]
KEN HAUKAAS	605-319-1407	RST Forestry	Ken.haukaas@rst-nsn.gov

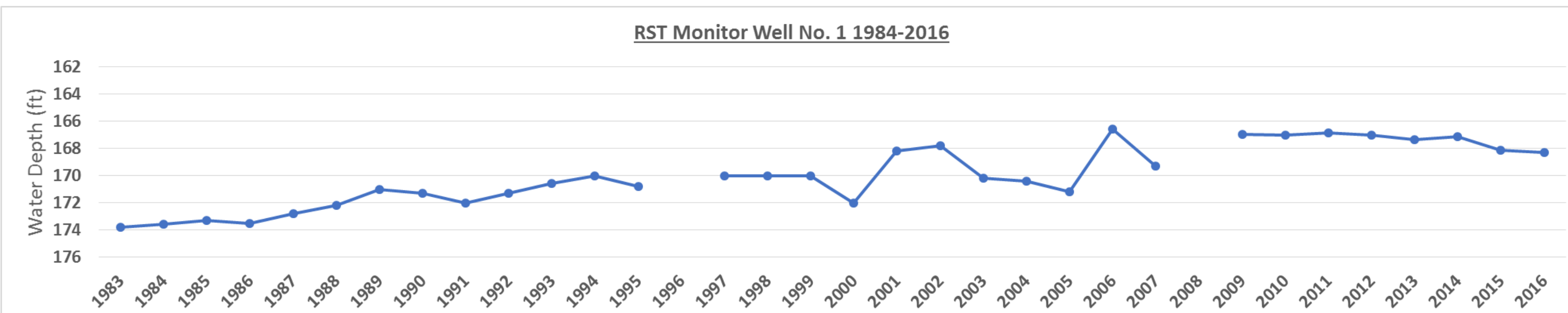
Vulnerabilities	Rank	Mitigation Strategies	Rank
Non-native producers control 60% of agricultural land and 65% of all active farms/ranches within Native Reservations in South Dakota.		Waste Water Recycling	
Breaking lease before its up (Loss of money).		Encouragement of crops that need less water	
Hot days have become hot weeks.		Encourage drought resistant landscaping	
Temperatures are much hotter.		Fog catcher	
Water quality has diminished.		Atmospheric Water Generation	
Cows quality of drinking water have diminished due to fencing and not being able to choose where they drink.		Water use restrictions	
Severe weather is causing traditional plants to stunt growth or not grow at all.		Encourage dry land farming	
Reactive vs. Proactive to environmental issues.		Maintenance and repair programs on distribution infrastructure	
Mni Wiconi cannot keep up with water demand on days over 100 degrees.		Improving efficiency standards in buildings	
Concern over uncontrolled water use will deplete surface water.		Catching and use of rainwater	
Lack of water usage monitors allow for more water to be wasted		Encouraged use of water efficient appliances	
Cattle and Livstock may stress the system more due to them drinking all day.		Tal-Ya use	
Pop-up water users (construction, mud bogs, powwows) are hard on the system because their demands on water cannot be refuted.		Drip irrigation	
Access to water for fire is a large vulnerability.		Incentive pricing on water use	
Increased invasive species.		Peer pressure (sending comparisons of water use)	
Trees dry out and are easily damaged by wind.		Using cover crops (like Barley)	
Exposed embankments need to be protected due to potential erosion.		Irrigation scheduling	
Increased demand on energy (AC, Water Pumping, and increased run times for center-pivots).		Grazing management plans	
Springs go dry.		Cross fencing	
Fires are hotter, and general temperatures are hotter (burn longer).		Reduce water use in food production (full washers, low flow)	
Animals exposed to Epizootic Hemorrhagic Disease and Bluetongue disease during drought.		Display water use to encourage low usage	
Increased non-native plants		Composting	
Reduced forage production.		Weatherizing homes and buildings	
Plague in prairie dog towns		Putting wastewater into the ground to encourage GW replenishment	
Overselling of hunting licenses and animal tags could cause overharvest of animal species.		Reservoir Augmentation	
Agricultural producers unable to implement long-term mitigation strategies to remediate effects of drought due to having temporary leases.		Identifying new water sources before approving proposed development	
Blue/Green algae blooms		Identifying all water demands	
Livestock and other animal projects such as buffalo herd, horses, and cattle affected greatly by drought.		Updated the wastewater drinking plant	

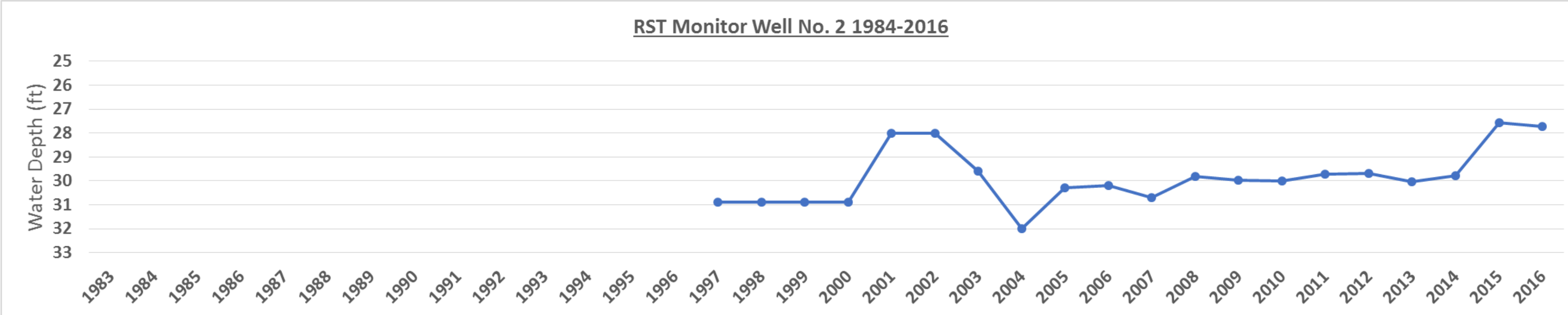
AC and electricity costs make air-conditioning on the Reservation difficult for impoverished members to deal with.		Stormwater management - retaining basin or dry basin	
Increase in mental health issues.		Long term - controlled burn plan	
Three VFD's to respond to entire Reservation (Mission, Parmalee, and Norris).		Water meters used only to track usage	
Generally, there are 15-30-minute response times to structure fires.		Reparations for water abuse	
25-30 days for RST's aquifers to feel the impacts of drought from the surface water.		Fire suppression water stations	

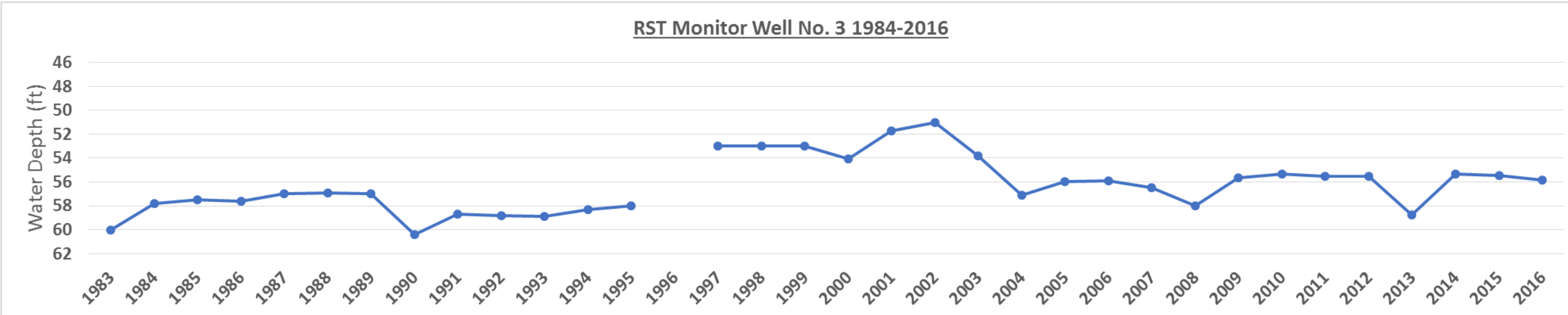
APPENDIX B. RST WELL WATER DEPTHS AND HYDROGRAPHS

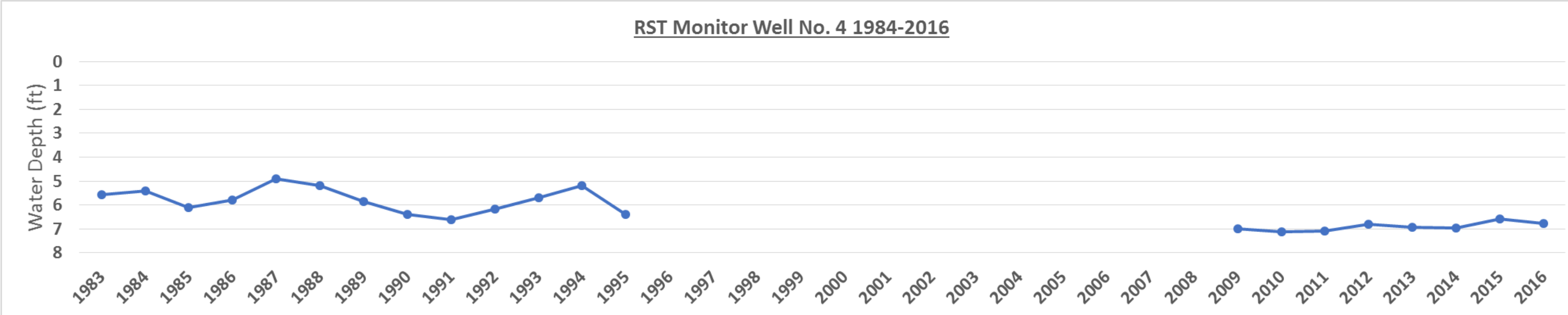
Well No.	Location	Pipe (ft.)	Well	Depth (ft.)	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1	T38N,R31W,SEC.30,CBD	1.5	Stock	167	173.80	173.60	173.30	173.50	172.80	172.20	171.00	171.30	172.00	171.30	170.60	170.00	170.80		170.00	170.00	170.00
2	T36N,R32W,SEC.02,BAA	1	Stock	30															30.90	30.90	30.90
3	T36N,R31W,SEC.34,DBB	2	Monitor	55.3	60.00	57.80	57.50	57.60	57.00	56.90	57.00	60.40	58.70	58.80	58.90	58.30	58.00		53.00	53.00	53.00
4	T35N,R31W,SEC.17,CDC	1.75	Monitor	7	5.55	5.40	6.10	5.80	4.90	5.20	5.85	6.40	6.60	6.16	5.70	5.20	6.40				
5	T35N,R30W,SEC.06,DDD	1.5	Monitor	23.8	22.50	22.20	22.80	22.50	22.55	22.80	23.40	23.50	24.10	24.10	24.30	23.50	23.60	22.50	22.00	21.00	22.00
6	T36N,R30W,SEC.21,ADD	1.5	Monitor	30.4	32.10	31.35	31.30	31.29	30.40	30.80	30.90	31.20	31.80	31.90	31.85	31.55	31.40		28.50	28.50	28.50
7	T36N,R29W,SEC.29,ACA	2	Monitor	20.32	19.80	18.50	19.40	19.80	19.80	19.80	20.00	20.20	21.20	21.30	21.35	21.30	21.20				
8	T36N,R30W,SEC.36,DDA	1.5	Monitor	49.6	49.50	49.40	48.90	48.80	48.70	48.60	48.40	48.60	49.10	49.30	49.40	49.50	49.45		47.00	47.00	47.00
9	T35N,R29W,SEC.18,AAA	2	Monitor	46.5	45.70	45.30	45.00	44.70	44.40	44.20	44.00	44.20	45.00	33.50	27.00	30.50	34.00		34.00	34.00	46.00
10	T35N,R29W,SEC.02,DDD	1.5	Monitor	11	9.20	9.50	10.70	10.60	9.60	10.05	10.10	10.70	10.75	10.90	10.30	9.55	9.50				
11	T36N,R29W,SEC.14,CDD	2	Monitor	82	81.50	81.00	80.50	80.80	82.80	90.00	86.50	86.70	84.90	90.50	85.00	81.50	85.00		74.90	75.20	74.90
12	T36N,R29W,SEC.02,CCD	2	Monitor	51.7	46.00	49.20	45.30	45.90	45.80	45.80	46.50	48.00	48.00	50.90	48.40	48.50	49.30	51.00	47.50	47.00	47.90
13	T37N,R29W,SEC.31,CCB	1.67	Monitor	105.6	103.10	103.70	104.50	105.40	105.30	106.50	106.10	107.60	108.10	110.00	107.50	108.00	108.40	109.80	106.20	105.80	105.70
14	T37N,R29W,SEC.12,CCD	1.5	Monitor	70.5															70.10	70.10	68.10
15	T38N,R28W,SEC.36,ABD	2	Monitor	16	12.30	12.20	13.40	13.50	12.50	13.00	13.70	14.90	16.10	14.30	14.00	13.50	13.40				
16	T37N,R28W,SEC.34,BDA	1.83	Monitor	59.4	59.50	60.50	59.40	59.50	59.45	59.10	59.25	59.40	60.45	60.70	60.70	60.90	60.40		57.90	57.90	57.80
17	T37N,R27W,SEC.18,DCC	2	Monitor	8	5.80	6.50	6.70	7.60	6.00	6.60	7.30	7.20	6.00	7.00	5.90	5.95	5.70	3.00	3.50	3.20	3.00
18	T36N,R28W,SEC.12,AAA	1.5	Monitor	142.1	150.10	149.50	149.70	149.30	148.20	147.60	147.20	147.30	146.90	146.60	147.40	147.30	147.30		145.00	147.50	144.60
19	T36N,R28W,SEC.33,DDD	2.5	Monitor	47.35	29.90	28.75	29.25	29.23	29.00	28.20	27.80	29.40	29.70	29.25	29.70	29.90	29.70	28.00	28.00	28.00	46.00
20	T35N,R28W,SEC.11,DBB	2	Monitor	19.3	16.00	15.70	16.80	18.00	17.50	18.20	19.20	20.50	21.10	21.30	21.30	20.80	20.00	18.00	16.00	14.00	14.00
21	T35N,R27W,SEC.14,BAB	1.5	Monitor	20.9	21.10	19.80	20.60	19.40	19.80	20.45	20.00	21.60	22.20	22.30	22.50	21.70	21.40	20.00	16.50	16.00	15.50
22	T36N,R26W,SEC.32,BAA	2	Monitor	34.2	33.10	31.00	31.80	32.50	31.75	31.90	31.40	31.30	33.60	33.65	33.90	33.10	33.20	30.00	29.00	29.00	29.00
23	T36N,R27W,SEC.01,ACC	1.5	Monitor	26	25.80	26.10	30.00	30.20	28.90	28.50	28.00	28.60	30.50	30.90	31.00	30.60	31.00	27.00	24.00	24.00	23.00
24	T37N,R25W,SEC.01,BBD	2	Stock	0																	
25	T38N,R25W,SEC.30,BBC	0.25	Monitor	24.8	23.55	23.50	24.90	24.70	24.10	24.70	24.50	26.10	26.80	26.90	25.60	25.30	24.30	22.50	22.00	21.00	21.00
26	T37N,R29W,SEC.08,ABD	2	Monitor	85.25	72.50	72.40	71.80	71.30	73.10	75.80	78.00	76.20	75.00	76.10	75.20	75.00	75.70		75.00	75.00	69.00
27	T37N,R30W,SEC.09,DDB	1.5	Monitor	108.9		125.00	124.50	124.00	123.50	123.00	122.50	122.00	121.50	121.00	120.50	120.00	120.00	90.00	118.00	118.00	118.00
28	T38N,R30W,SEC.23,ABB	1.33	Monitor	47.1															46.00	46.00	46.00

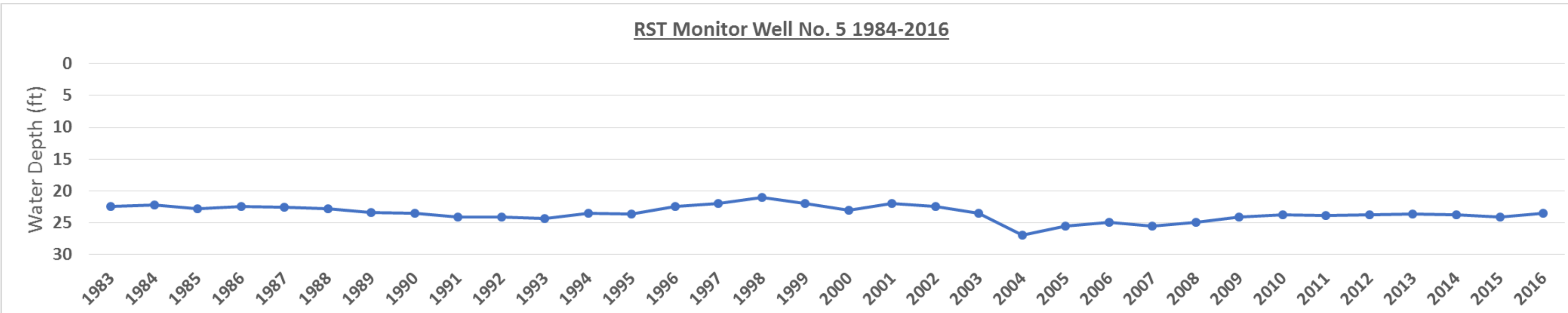
Well No.	Location	Pipe (ft.)	Well	Depth (ft.)	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1	T38N,R31W, SEC.30,CBD	1.5	Stock	167	172.00	168.20	167.80	170.20	170.40	171.20	166.60	169.30		166.98	167.03	166.87	167.02	167.33	167.15	168.13	168.28
2	T36N,R32W, SEC.02,BAA	1	Stock	30	30.90	28.00	28.00	29.60	32.00	30.30	30.20	30.70	29.80	29.98	30.00	29.72	29.69	30.03	29.79	27.58	27.73
3	T36N,R31W, SEC.34,DBB	2	Monitor	55.3	54.10	51.70	51.00	53.80	57.10	56.00	55.90	56.50	58.00	55.68	55.34	55.54	55.55	58.74	55.34	55.46	55.82
4	T35N,R31W, SEC.17,CDC	1.75	Monitor	7										7.00	7.10	7.09	6.80	6.93	6.96	6.59	6.78
5	T35N,R30W, SEC.06,DDD	1.5	Monitor	23.8	23.00	22.00	22.50	23.50	27.00	25.50	25.00	25.50	25.00	24.08	23.81	23.90	23.78	23.61	23.77	24.11	23.50
6	T36N,R30W, SEC.21,ADD	1.5	Monitor	30.4	29.60	27.50	27.60	29.50	32.70	30.00	30.90	31.20	31.00	30.09	30.32	30.83	30.36	30.12	32.15	29.64	29.74
7	T36N,R29W, SEC.29,ACA	2	Monitor	20.32										20.47	20.35	20.83	20.41	20.31	20.26	19.66	19.62
8	T36N,R30W, SEC.36,DDA	1.5	Monitor	49.6	49.00	47.00	46.90	49.00	39.00	49.00	48.00	48.00	50.00	49.56	49.69	49.71	49.68	49.53	49.61	49.73	49.78
9	T35N,R29W, SEC.18,AAA	2	Monitor	46.5	47.00	46.00	46.00	47.00	46.00	46.50	47.00	47.00	47.00	46.53	46.49	46.71	46.58	46.31	46.49	46.40	46.60
10	T35N,R29W, SEC.02,DDD	1.5	Monitor	11										11.08	11.22	10.61	10.78	11.10	10.93	10.33	10.40
11	T36N,R29W, SEC.14,CDD	2	Monitor	82	83.50	78.00	79.50	78.00	78.20	81.50	82.10	84.20	84.20	80.72	81.93	82.66	82.16	82.37	82.04	83.30	82.58
12	T36N,R29W, SEC.02,CCD	2	Monitor	51.7	51.00	47.60	48.30	49.50	51.50	52.00	51.70	52.20	52.50	51.66	51.85	51.97	51.98	52.15	51.76	54.83	52.48
13	T37N,R29W, SEC.31,CCB	1.67	Monitor	105.6	106.90	107.40	106.90	106.20	104.00	107.20	105.80	107.50	109.50	105.42	105.73	105.65	105.66	105.94	105.95	106.96	106.80
14	T37N,R29W, SEC.12,CCD	1.5	Monitor	70.5	68.00	65.90	65.60	60.50	72.00	68.30	70.00	71.00	71.50	70.40	70.49	71.05	70.76	68.31	70.58	71.48	71.52
15	T38N,R28W, SEC.36,ABD	2	Monitor	16										16.07	16.14	16.03	15.59	16.12	15.96	15.25	15.34
16	T37N,R28W, SEC.34,BDA	1.83	Monitor	59.4	58.60	56.00	56.40	57.90	60.40	59.00	59.90	60.00	68.70	59.51	59.46	59.32	59.38	59.26	59.34	59.78	59.84
17	T37N,R27W, SEC.18,DCC	2	Monitor	8	8.50	6.50	7.25	8.00	9.00	8.70	5.00	8.50	8.60	7.98	8.07	7.70	7.34	8.50	8.00	8.68	8.78
18	T36N,R28W, SEC.12,AAA	1.5	Monitor	142.1	145.50	143.30	141.80	143.50	147.10	142.70	142.00	143.10	143.00	141.92	142.15	142.04	142.11	142.22	142.13	142.34	142.38
19	T36N,R28W, SEC.33,DDD	2.5	Monitor	47.35	47.00	46.00	46.00	51.00	53.00	52.00	52.00	53.00	53.00	47.41	47.34	47.62	47.94	47.42	47.29	46.14	46.14
20	T35N,R28W, SEC.11,DBB	2	Monitor	19.3	17.50	16.00	17.00	20.00	23.00	22.00	21.00	22.00	21.00	19.63	19.34	19.49	19.37	19.33	19.37	18.39	18.48
21	T35N,R27W, SEC.14,BAB	1.5	Monitor	20.9	17.50	17.00	17.50	19.50	22.50	22.00	22.00	21.50	21.00	20.95	20.94	20.97	20.87	20.83	20.50	20.43	20.42
22	T36N,R26W, SEC.32,BAA	2	Monitor	34.2	32.00	30.00	31.00	33.50	35.50	35.50	35.50	32.50	25.00	34.32	34.26	34.09	34.28	35.23	34.36	31.64	28.08
23	T36N,R27W, SEC.01,ACC	1.5	Monitor	26	24.00	25.00	25.00	25.00	27.00	26.00	25.00	27.00	27.50	26.12	26.00	26.54	26.31	25.92	25.87	26.25	26.22
24	T37N,R25W, SEC.01,BBD	2	Stock	0																	
25	T38N,R25W, SEC.30,BBC	0.25	Monitor	24.8	24.00	23.00	24.00	24.00	26.00	26.00	26.00	25.00	24.00	24.63	24.82	24.75	24.80	24.64	24.67	23.33	23.19
26	T37N,R29W, SEC.08,ABD	2	Monitor	85.25	83.00	82.00	83.00	82.00	84.00	83.00	78.00	85.00	86.00	84.99	85.06	85.26	85.55	85.66	85.11	83.98	84.53
27	T37N,R30W, SEC.09,DDB	1.5	Monitor	108.9	118.00	110.00	115.00	115.00	115.00	115.00	115.00	115.00	115.00	108.90	109.12	109.14	109.07	110.66	108.95	108.66	108.82
28	T38N,R30W, SEC.23,ABB	1.33	Monitor	47.1	48.00	45.00	44.00	47.00	37.00	36.00	37.00	44.00	49.00	48.01	46.32	47.36	47.19	46.96	47.15	47.78	47.80

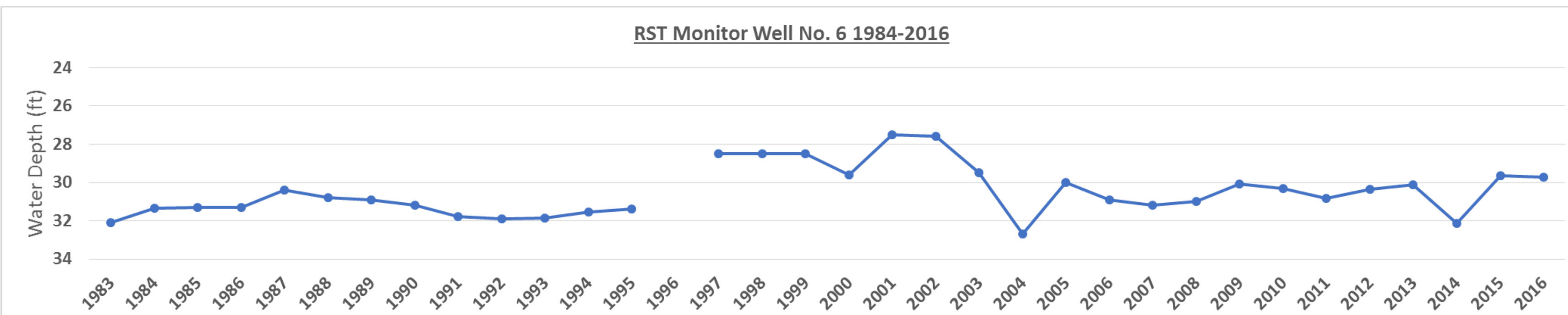


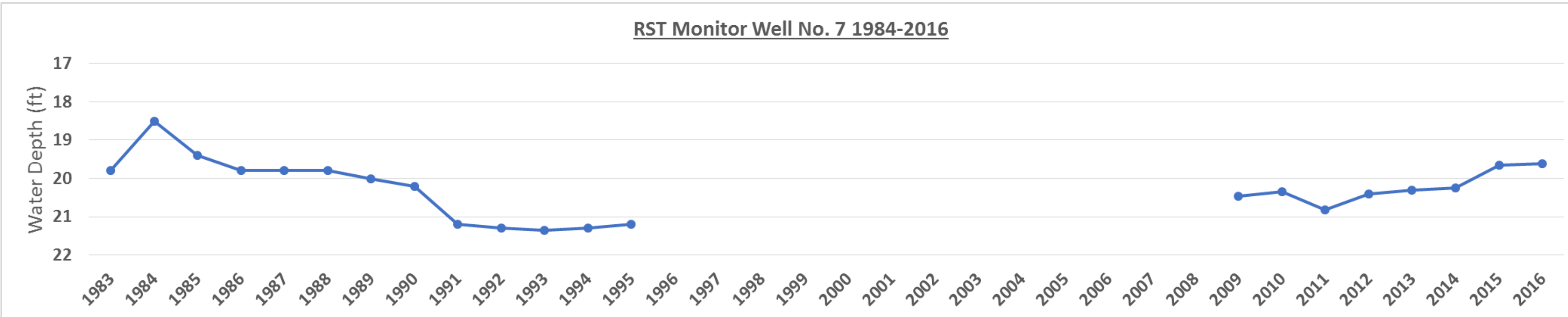

RST Monitor Well No. 2 1984-2016
Water Depth (ft)
25
26
27
28
29
30
31
32
33
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

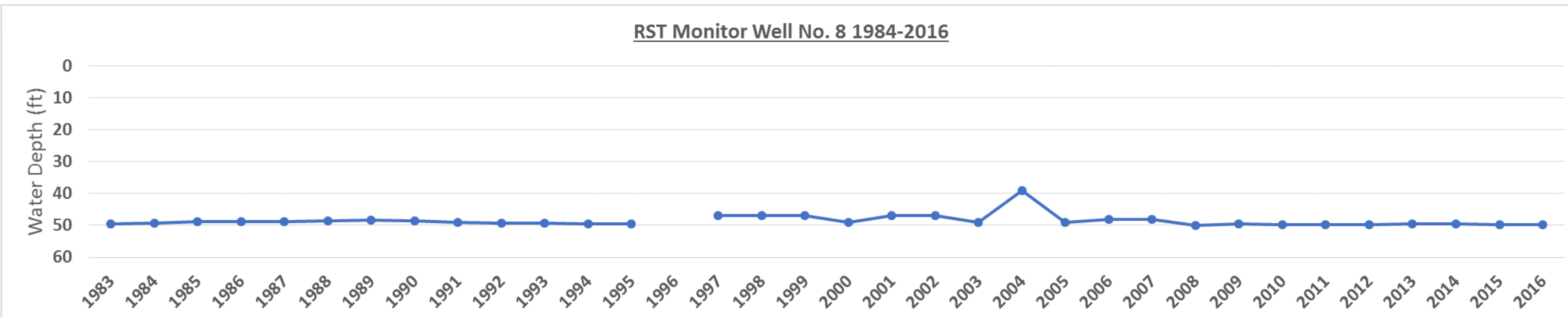

RST Monitor Well No. 3 1984-2016
Water Depth (ft)
46
48
50
52
54
56
58
60
62
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

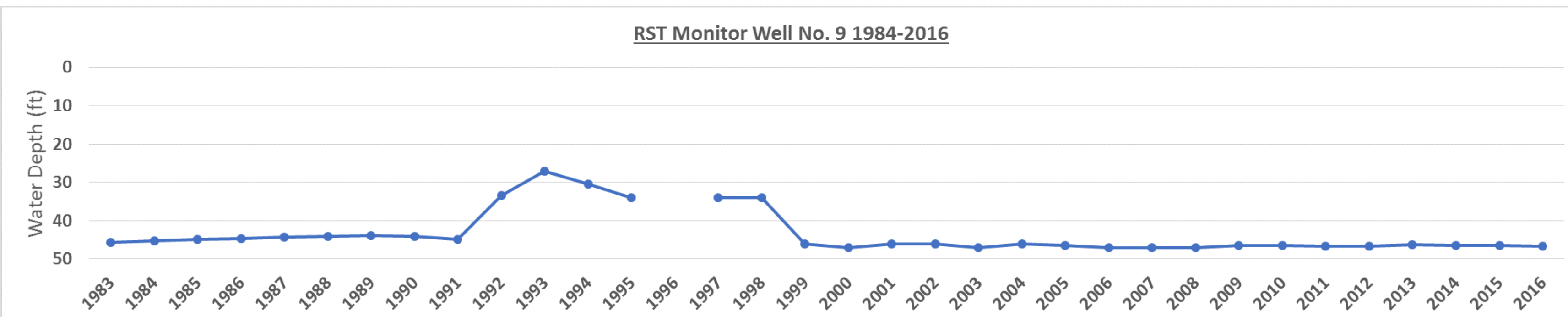

RST Monitor Well No. 4 1984-2016
Water Depth (ft)
0
1
2
3
4
5
6
7
8
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

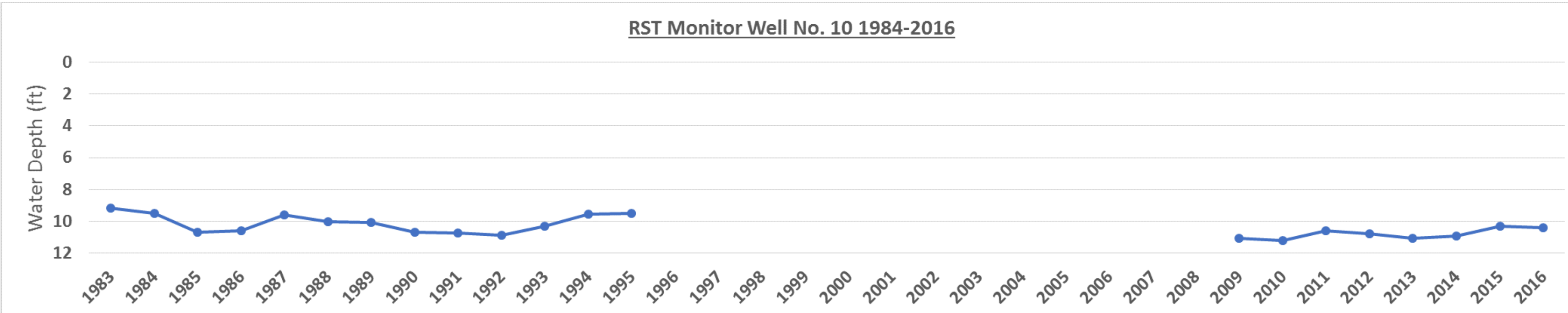

RST Monitor Well No. 5 1984-2016
Water Depth (ft)
0
5
10
15
20
25
30
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

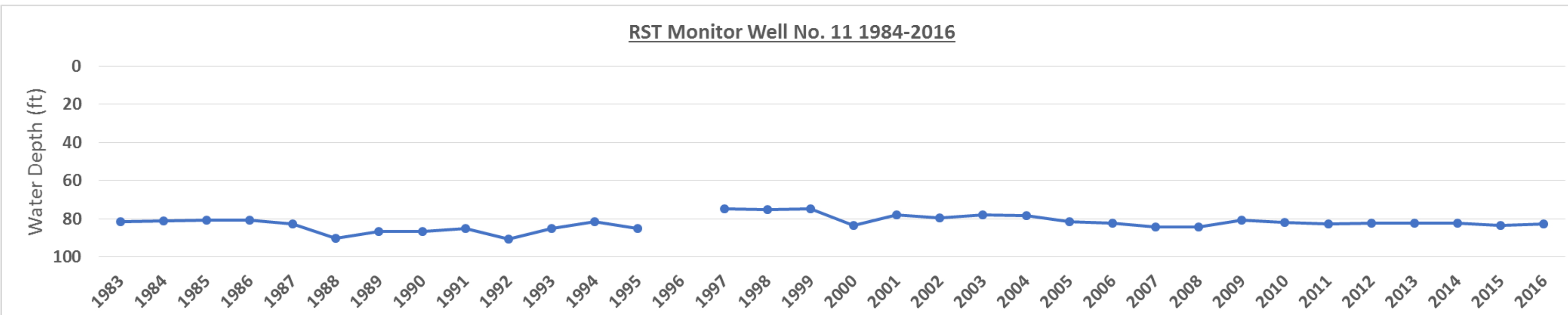

RST Monitor Well No. 6 1984-2016
Water Depth (ft)
24
26
28
30
32
34
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

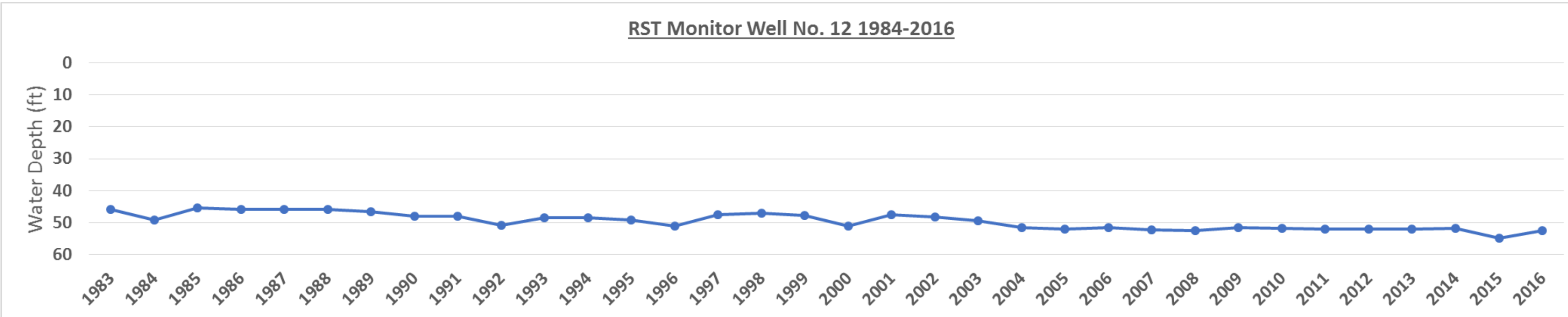

RST Monitor Well No. 7 1984-2016
Water Depth (ft)
17
18
19
20
21
22
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

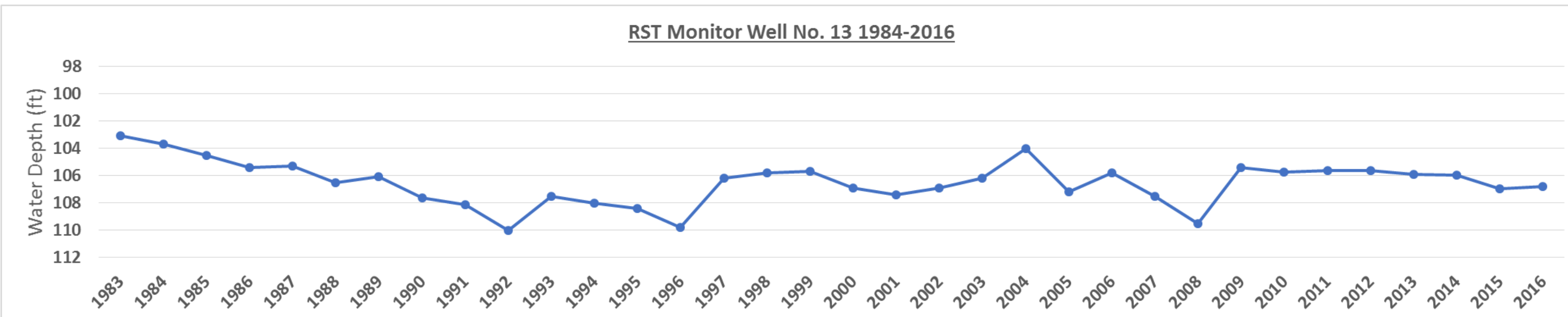

RST Monitor Well No. 8 1984-2016
Water Depth (ft)
0
10
20
30
40
50
60
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

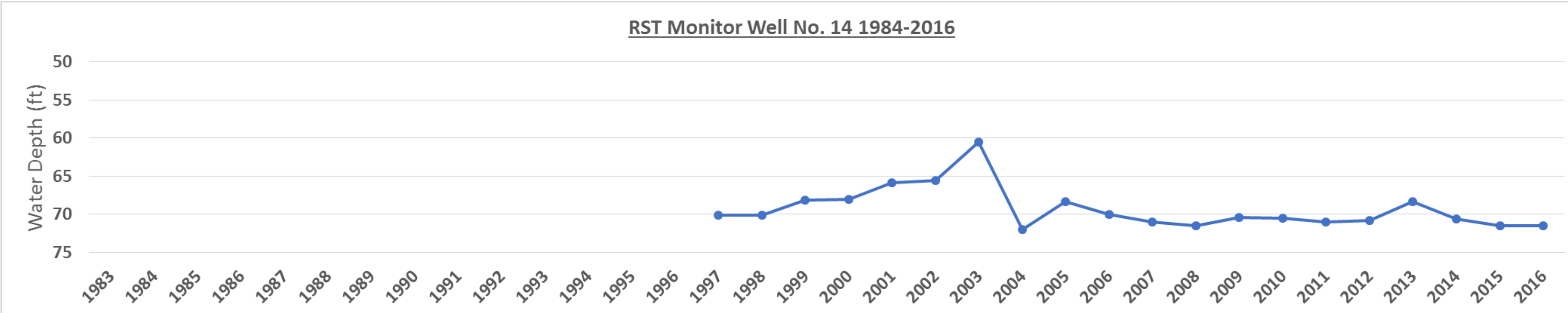

RST Monitor Well No. 9 1984-2016
Water Depth (ft)
0
10
20
30
40
50
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

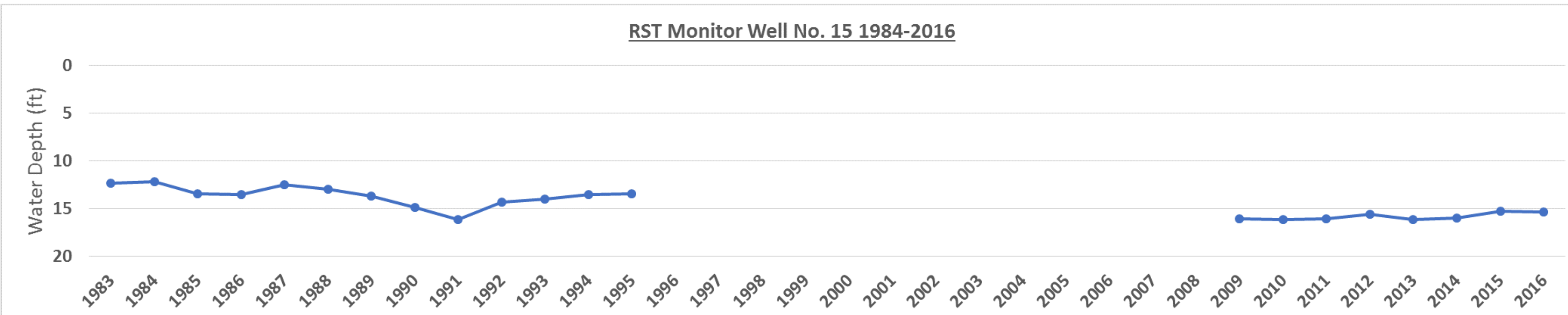

RST Monitor Well No. 10 1984-2016
Water Depth (ft)
0
2
4
6
8
10
12
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

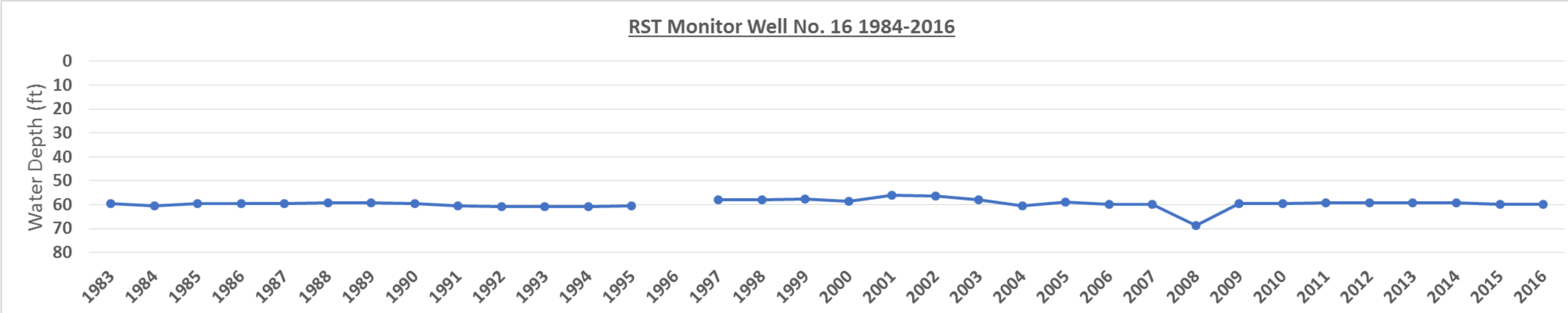

RST Monitor Well No. 11 1984-2016
Water Depth (ft)
0
20
40
60
80
100
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

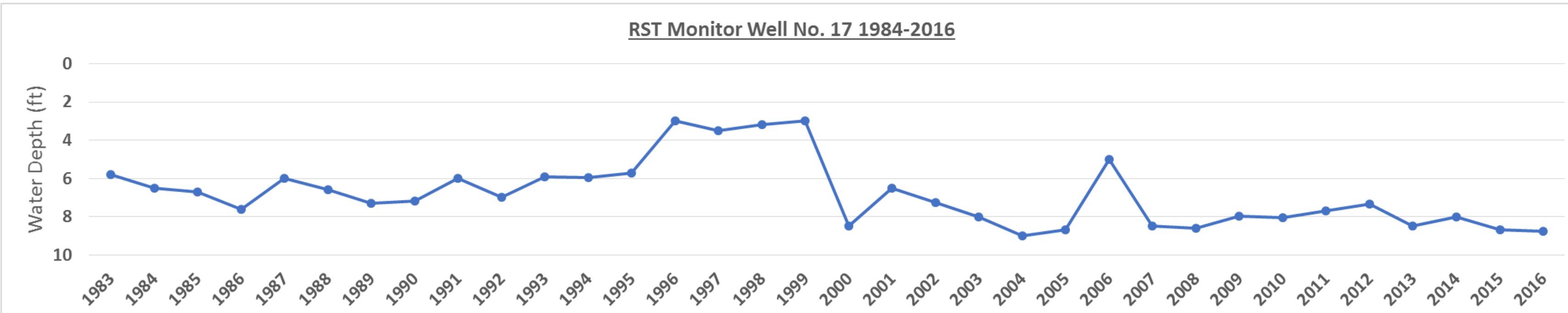

RST Monitor Well No. 12 1984-2016
Water Depth (ft)
0
10
20
30
40
50
60
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

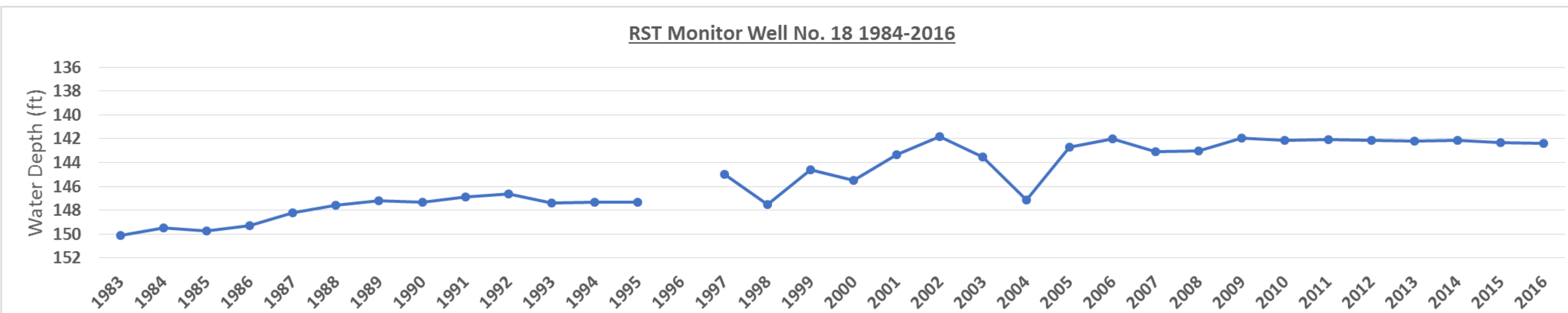

RST Monitor Well No. 13 1984-2016
Water Depth (ft)
98
100
102
104
106
108
110
112
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

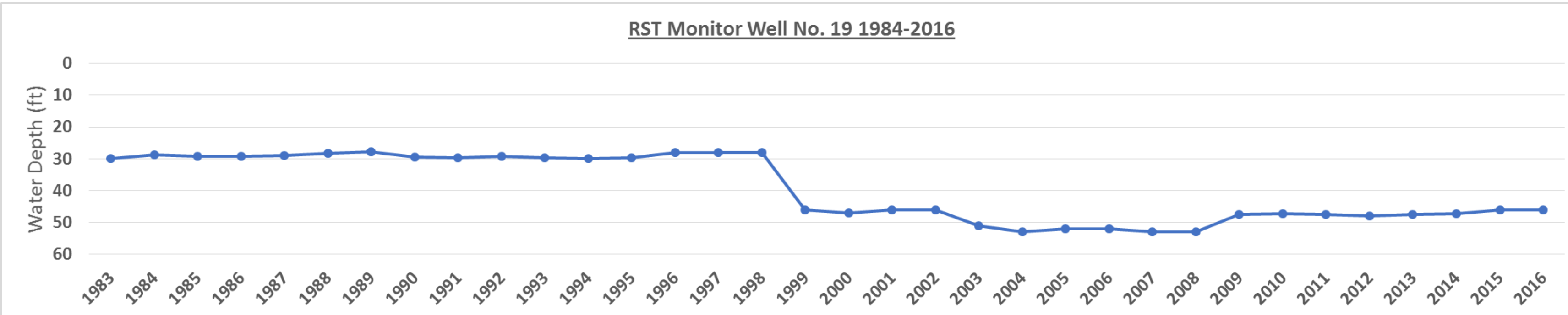

RST Monitor Well No. 14 1984-2016
Water Depth (ft)
50
55
60
65
70
75
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

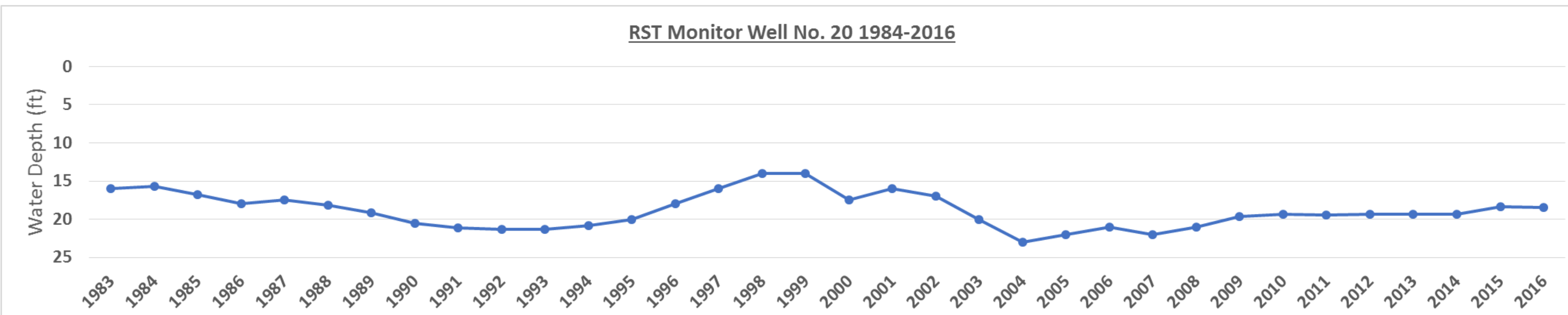

RST Monitor Well No. 15 1984-2016
Water Depth (ft)
0
5
10
15
20
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

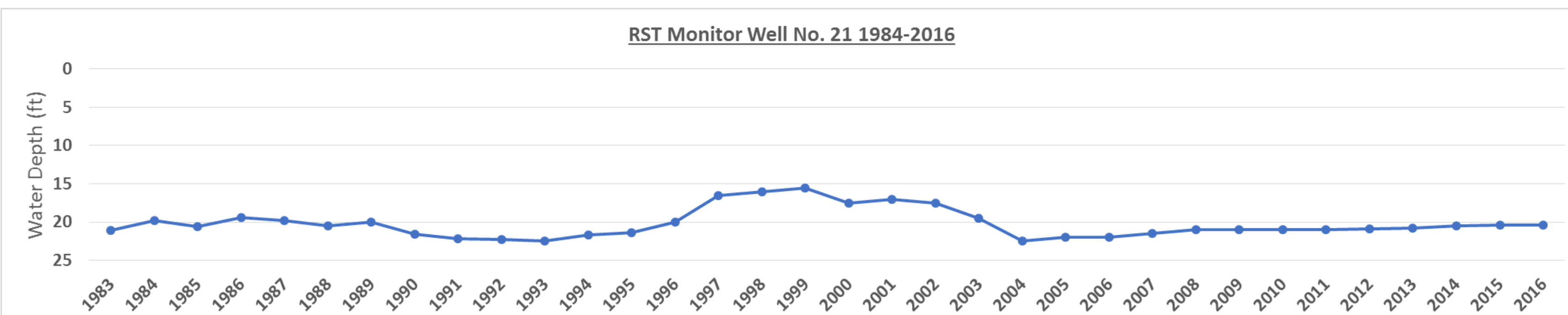

RST Monitor Well No. 16 1984-2016
Water Depth (ft)
0
10
20
30
40
50
60
70
80
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

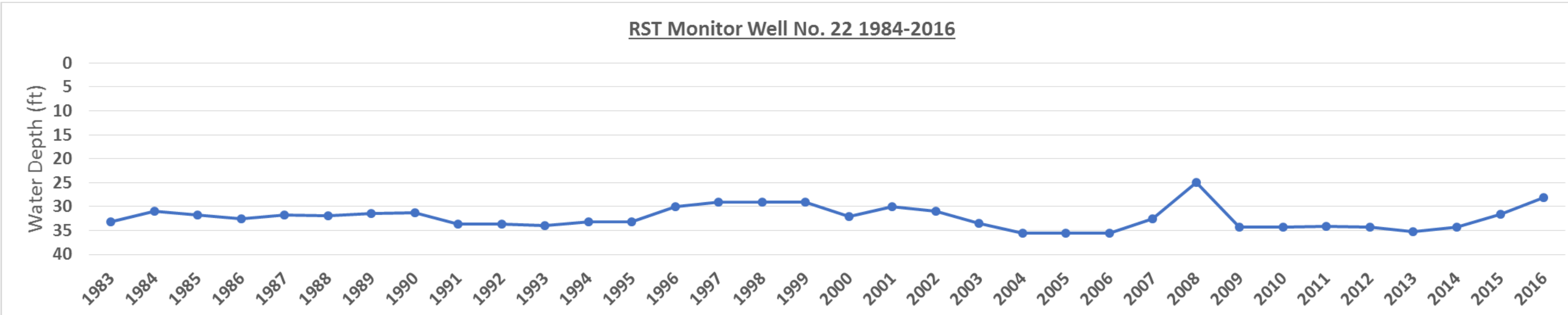

RST Monitor Well No. 17 1984-2016
Water Depth (ft)
0
2
4
6
8
10
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016


RST Monitor Well No. 18 1984-2016
Water Depth (ft)
136
138
140
142
144
146
148
150
152
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016


RST Monitor Well No. 19 1984-2016
Water Depth (ft)
0
10
20
30
40
50
60
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016


RST Monitor Well No. 20 1984-2016
Water Depth (ft)
0
5
10
15
20
25
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016


RST Monitor Well No. 21 1984-2016
Water Depth (ft)
0
5
10
15
20
25
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016


RST Monitor Well No. 22 1984-2016
Water Depth (ft)
0
5
10
15
20
25
30
35
40
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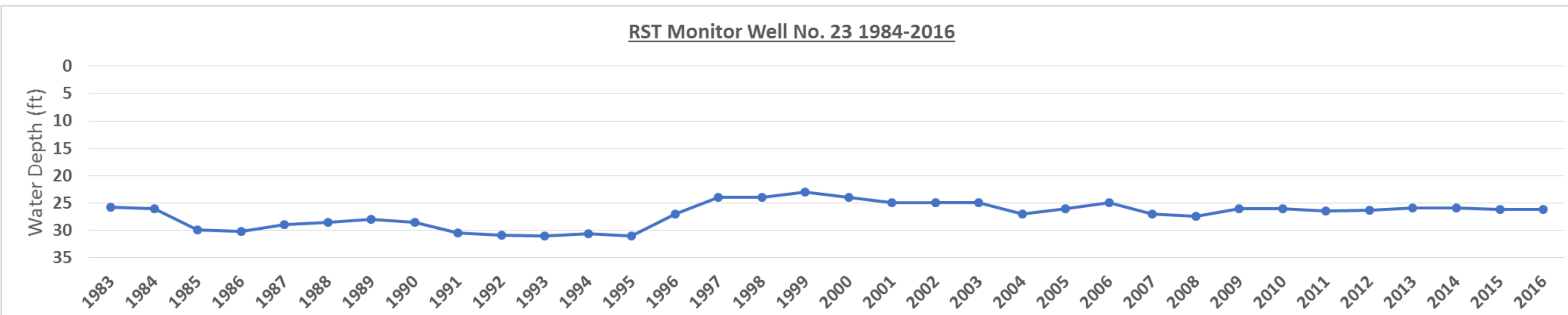
RST Monitor Well No. 23 1984-2016
Water Depth (ft)
0
5
10
15
20
25
30
35
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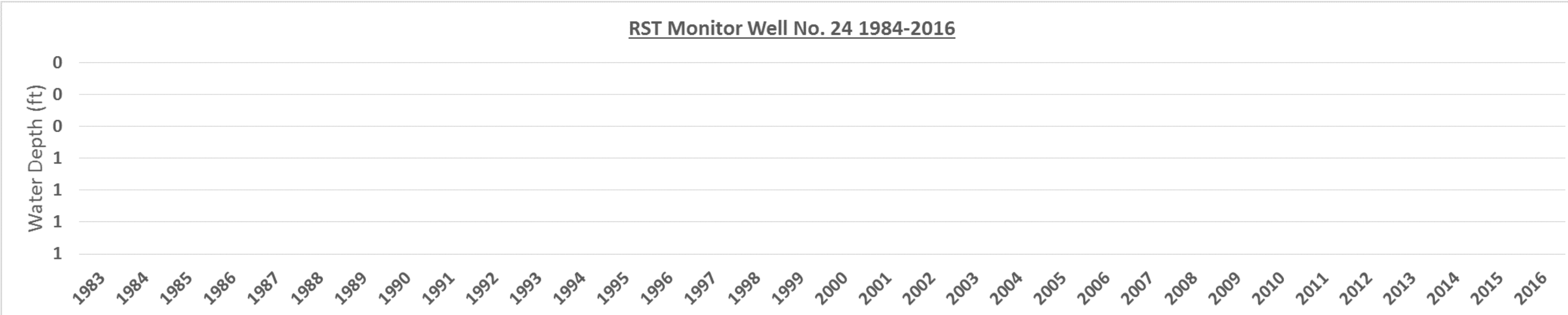
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Water Depth (ft)
0
0
0
1
1
1
1
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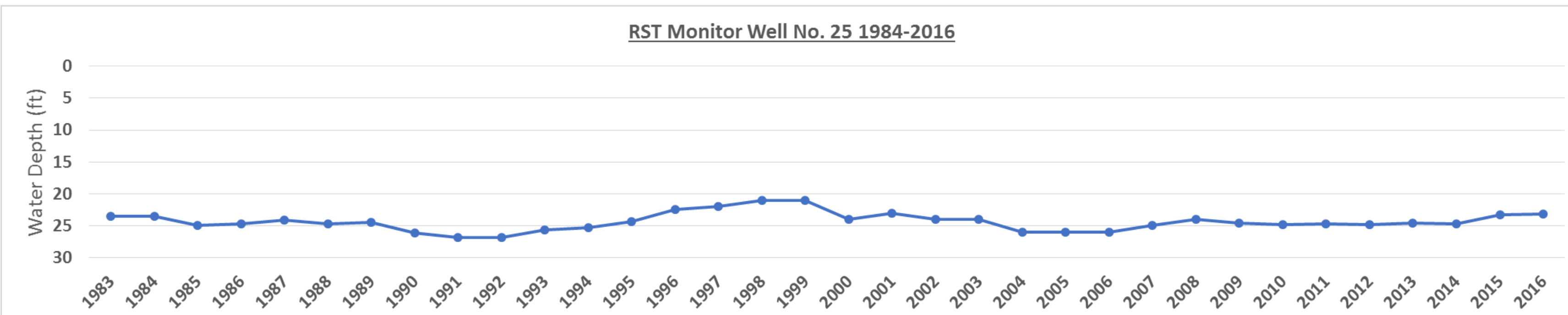
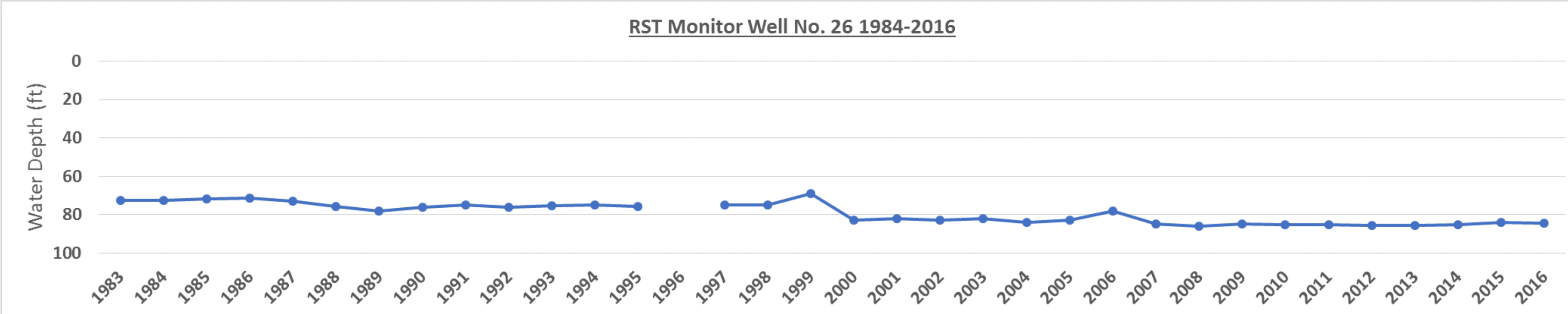
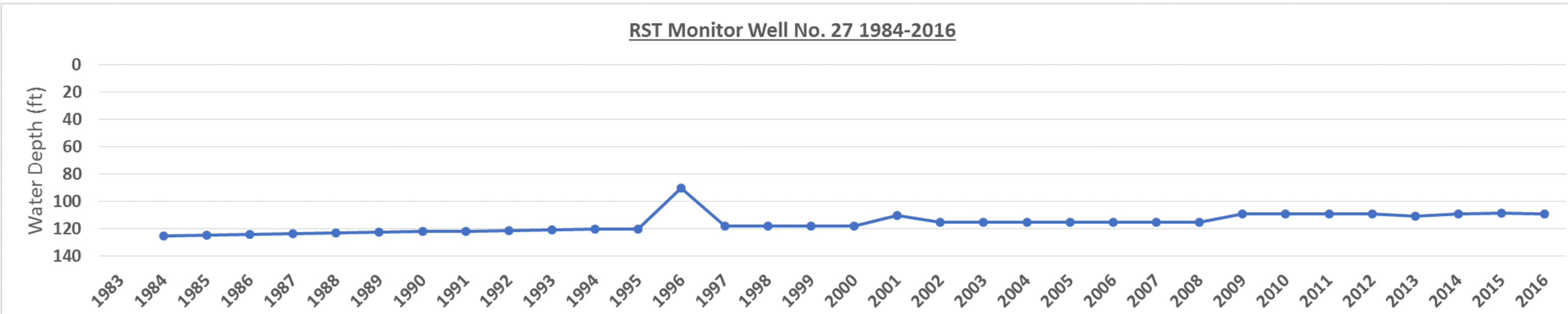
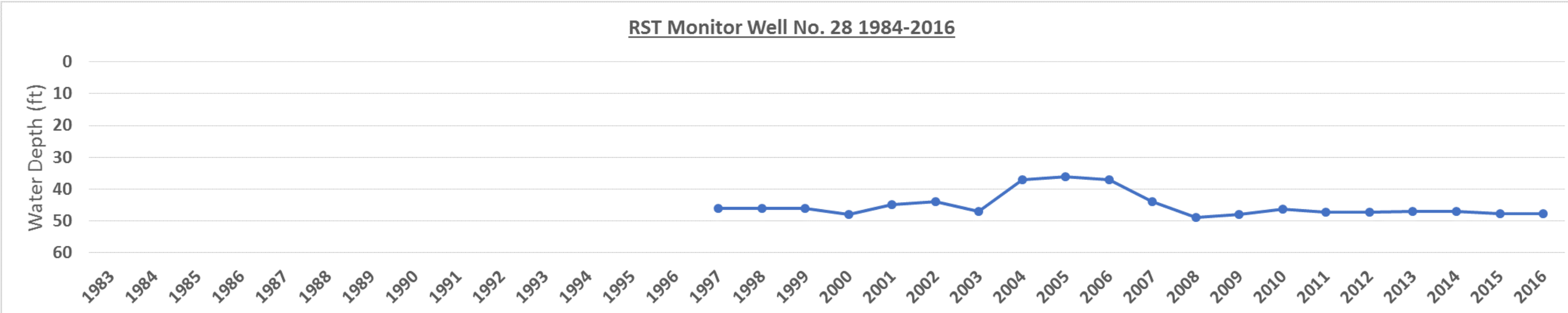

RST Monitor Well No. 25 1984-2016
Water Depth (ft)
0
5
10
15
20
25
30
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016


RST Monitor Well No. 26 1984-2016
Water Depth (ft)
0
20
40
60
80
100
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016


RST Monitor Well No. 27 1984-2016
Water Depth (ft)
0
20
40
60
80
100
120
140
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016


RST Monitor Well No. 28 1984-2016
Water Depth (ft)
0
10
20
30
40
50
60
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016