Water Quality Monitoring in the Geronimo Creek Watershed and Facilitation of the Geronimo and Alligator Creeks Watershed Partnership

FINAL REPORT
TSSWCB PROJECT #11-06

Guadalupe-Blanco River Authority

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Introduction

In 2007, the TSSWCB Regional Watershed Coordination Steering Committee, using established criteria, ranked Geronimo Creek in the top 3 watersheds for selection of Watershed Protection Plan (WPP) development. In 2008, the Texas State Soil and Water Conservation Board (TSSWCB), Guadalupe-Blanco River Authority (GBRA) and the Texas A&M AgriLife Extension (Extension) initiated an effort to develop a watershed protection plan (WPP) for the Geronimo and Alligator Creeks Watershed (TSSWCB project 08-06). The project included water quality monitoring, water quality modeling and WPP development. The development of the WPP for Geronimo and Alligator Creeks was a stakeholder driven process lead by Texas A&M AgriLife Extension with support from the GBRA. The Geronimo and Alligator Creeks Watershed Partnership (the Partnership) Steering Committee includes local officials, land and business owners and citizens and is supported by state and federal agency partners. With technical assistance from project staff, the Steering Committee has identified issues that are of particular importance to the surrounding communities, and has contributed information on land uses and activities that has been helpful in identifying the sources of nutrient and bacterial impairments, and in guiding the development of the WPP.

Historical data identified the impairment for bacteria and a concern for nutrients. The historical data was collected at one site (12576) by GBRA through the Clean Rivers Program (CRP). Through TSSWCB project 08-06, GBRA conducted an eighteen month water quality monitoring task that included an additional seven monthly routine ambient and six targeted stream sites on Geronimo Creek, Alligator Creek and three tributaries, and quarterly monitoring of two springs, three wells, and the single point source in the watershed. Through TSSWCB project 11-06, *Water Quality Monitoring in the Geronimo Creek Watershed and Facilitation of the Geronimo and Alligator Creeks Watershed Partnership*, an effective monitoring program provided critical water quality data that can be used to judge the effectiveness of WPP implementation efforts and can serve as a tool to quantitatively measure water quality restoration. Although the original water quality monitoring program attempted to fill gaps in the historical data but was severely hampered by the drought, data collection in these projects further verified that periodic elevations of *E. coli* levels continue to exist.

Project Overview

In addition to water quality monitoring, this project continued stakeholder engagement through semi-annual newsletters, maintaining the project website, and hosting Partnership Steering Committee and work group meetings. The Geronimo Creek WPP was accepted by the EPA in September 2012. Continuing these efforts was critical to effectively bridging the gap between projects that developed the Geronimo Creek WPP and beginning WPP implementation efforts.

Extension facilitated and coordinated education and outreach activities in the watershed to promote public participation and implementation of the WPP. Extension included active use of local media outlets to communicate project planning efforts and activities, contributions to the project website, development and/or dissemination of factsheets and other educational resources, and coordination of local meetings and educational events. GBRA's Public Communication and Education Department provided additional education and outreach in the watershed.

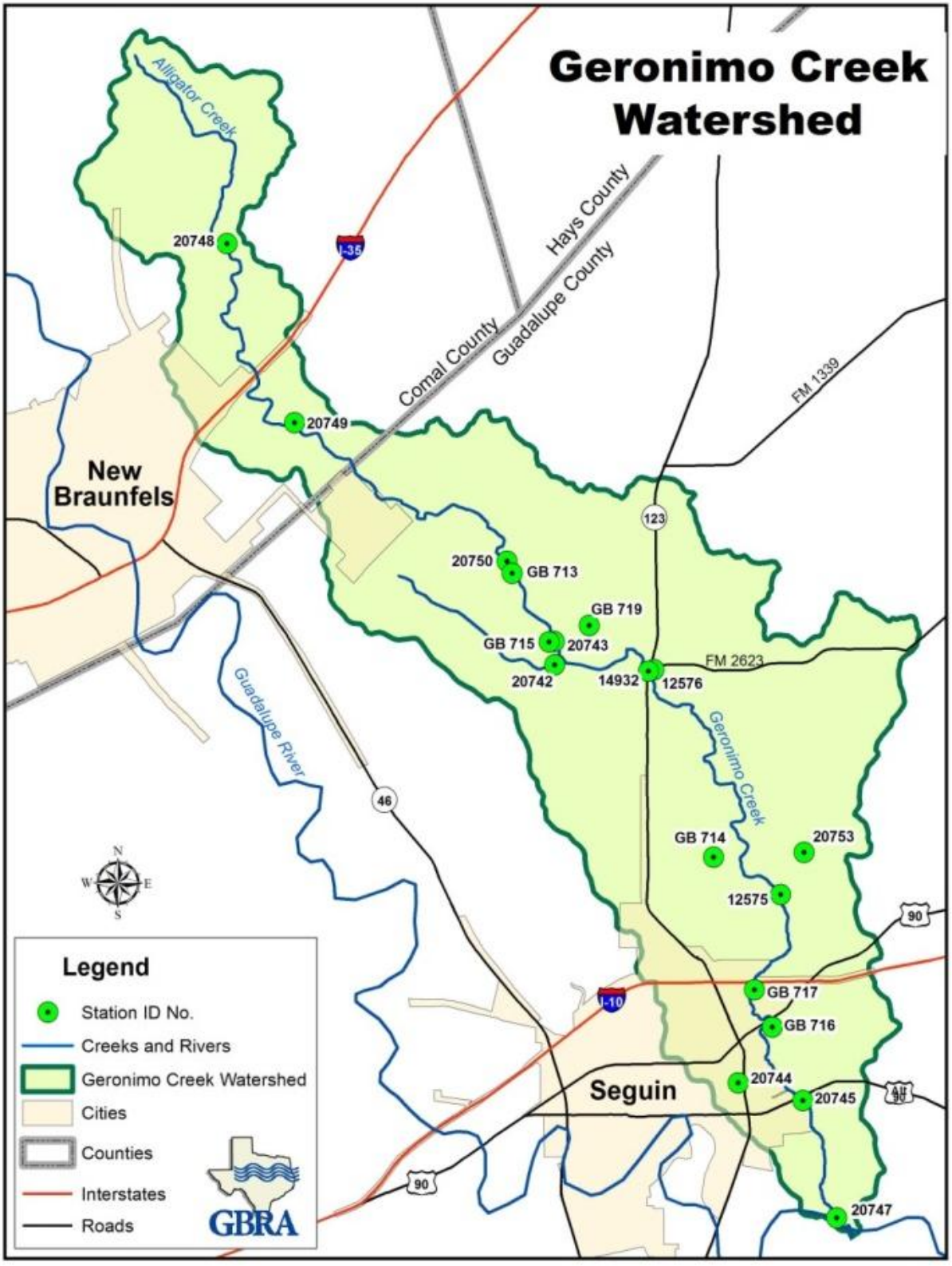

Figure 1. Map of watershed with sampling locations.

The sampling program was continued in this project by retaining 7 routine monthly sites and fourteen targeted sites. GBRA continued to monitor the routine ambient monitoring location monthly under the CRP. Two new sites on Geronimo Creek were added to replace two routine/targeted sites included in TSSWCB project 08-06 that were determined to be ineffective due to lack of flow or proximity to other sites. One of the new sites was located at Geronimo Creek at IH10 in order to collected routine and targeted monitoring downstream of the Oak Village North Subdivision that has been known for failing septic systems and where the City of Seguin is expanding the city's wastewater collection system. The second site was added on Highway 90 near the Irma Lewis Seguin Outdoor Learning Center (ILSOLC).

A comprehensive watershed approach was used to focus on the most significant potential sources of agricultural NPS pollution contributing to the current impairments, while at the same time looking ahead at potential future sources of pollution from urban and suburban growth. The outcomes of the TSSWCB project 08-06 included data in the form of load allocations and watershed models developed in partnerships with local stakeholders and have benefited the local governmental entities as they formulate master plans and storm water management strategies. Recommended best management practices that were identified by the steering committee, work groups and partner agencies were prioritized for implementation. An important outcome of this project was the identification of implementation strategies that get ahead of growth so that it can be directed in an environmentally-safe and community-accepted direction.

Project Highlights

Acceptance of the Watershed Protection Plan

Two public meetings were held to receive comments on the draft WPP. A tour of the watershed was given to EPA. After the tour, a lengthy discussion was held with EPA on the draft WPP. The WPP was accepted by EPA on September 13, 2012.

Project Webpage

GBRA and Extension maintained the project webpage. Updates to the webpage over the project period include a photo gallery, monthly newsletters, meeting announcements and copies of meeting presentations. The Quality Assurance Project Plan, along with the current data tables have been posted on the Water Quality page and are available for review by the public. One of the most useful additions to the website was an online registration tab for the annual watershed cleanup. Other tabs on the webpage covered feral hogs, septic tank maintenance and the USGS Isotope project.

Web hits are monitored monthly. This is one method that is used to determine the effectiveness of several of the public outreach methods. Generally, hits average between 600 and 800 hits a month. However, since beginning the outreach campaign for the second annual Geronimo and Alligator Creeks Cleanup in February 2014, the monthly website visits increased to well over 1,000 per month.

Facilitation and Implementation Activities

Texas A&M AgriLife Extension was responsible for facilitation of the partnership and for coordination of implementation of the WPP. Extension assisted entities in the watershed with opportunities for implementation of management measures identified in the WPP. Extension

also coordinated meetings between the cities located in the watershed and TCEQ to discuss potential urban implementation projects. At these meetings several potential ideas were developed, including upgrades to the City of Seguin storm water conveyance system in the Oak Village North subdivision and decommissioning of failing septic systems after they have connected to the city's new wastewater collection system being installed in the subdivision. As a continuation of these meetings, Extension continued to assist Seguin with the development of a grant proposal to the TCEQ Clean Water Act Section 319(h) NPS Program. The original proposal included both the stormwater upgrades (introduction of rain gardens and pervious pavement) and the decommissioning of failing septic systems in the Oak Village North subdivision. However, shortly before the submission deadline, Seguin chose to remove the stormwater upgrades, due to construction timeline constraints. Seguin received the grant award, and Extension continued to assist the City with reporting requirements to TCEQ.

The meetings with the City of New Braunfels did not lead directly to an implementation project because at the time the city was actively working through the development and implementation of their phase II storm water permit, and wanted to wait until that was more complete before exploring implementation in their portion of the watershed.

In September 2012, Extension assisted the Comal-Guadalupe Soil and Water Conservation District (SWCD) in the preparation a Clean Water Act Section 319(h) grant proposal to the TSSWCB to fund technical and financial assistance for the development and implementation of Water Quality Management Plans (WQMP) (a component of implementation of the WPP). The grant was awarded to the SWCD, and Extension continued to assist the district with the grant, as well as, providing assistance to the new District Technician.

Extension assisted GBRA with the preparation of a grant application to TCEQ that partnered with the ILSOLC. The ILSOLC is located in the watershed and its mission is to provide outdoor and environmental education opportunities to students as well as adults in the area. The grant was awarded with the objective of the project to design and implement educational components of the WPP that will serve as tools that can be utilized with elementary school students through high school, teachers, civic leaders, riparian landowners, and with the general public to enhance understanding of the health of a riparian and creek ecosystem in the Geronimo and Alligator Creeks watershed. Besides the educational modules to be developed through the grant, several Low Impact Development structures (Figure 2) are to be installed on the ILSOLC property (rain water harvesting system, vegetated swale, rain garden, detention pond). The plan is to utilize the learning center on-site for future workshops to use these structures and practices for "hands on" demonstrations.

Other presentations made by Extension, with the goal to promote and facilitate implementation of the WPP, included:

- meetings with staff of the City of New Braunfels,
- meetings and calls to the staff of the City of Seguin, their Long Range Planning Committee, and City Planning Department to discuss the development of a pet waste Ordinance, and other grant funded projects,
- a meeting with Guadalupe County Commissioners to discuss the status of the WPP and implementation activities, including the stream clean-up planned in 2013,
- manning a booth at the Central Texas Environmental Summit in Schertz and the annual

Association of Conservation District Directors meeting, and

- the GBRA annual CRP Basin Steering Committee and Coordinated Monitoring Meetings held each year.

Figure 2. Rainwater harvesting system at the ILSOLC.

Public Communication and Outreach

Public communications and outreach responsibilities were shared by Extension and GBRA. Outreach included newspaper articles produced and paid for by Extension. The articles were run in the two local papers, the Seguin Gazette and New Braunfels Herald-Zeitung, with a circulation of 17,000 weekly subscribers. For various workshops, newspaper ads were developed and produced in print and online versions to further draw attention to these activities. In addition to the news articles and ads, Extension produced a quarterly electronic newsletter, aptly named by the Partnership, *The Geronimo Flow*. The distribution of the newsletter has grown to over 400 email addresses.

Many workshops were held in the watershed during the course of the grant covering a wide range of interests. The Geronimo Creek watershed was the location for the first ever Texas Well Owner Network (TWON) workshop in January 2013, with over 60 private water well owners attending. TWON is an educational training offered by AgriLife Extension, and is for Texas residents who depend on household wells for their drinking water needs (Figure 3) funded under TSSWCB project 10-04, "*Preventing Water Quality Contamination Through the Texas Well Owner Network"*. Well owners learned about Texas' groundwater sources, water quality, water treatment, and well maintenance issues. One class module covers septic system operation and maintenance, and informs attendees of signs and symptoms of potential failures. The goal is to train Texans regarding water quality and BMPs for protecting their wells and surface waters.

This will avert off-site transport of contaminants to surface waters, prevent contamination of underlying aquifers, and safeguard the health of landowners and their families.

Figure 3. Water well in use in the Alligator Creek Watershed.

Through TSSWCB project 12-07, "*Statewide Delivery of Riparian and Stream Ecosystem Education program",* Extension and GBRA assisted with a Texas Riparian & Stream Ecosystem Workshop in the fall of 2013. This workshop presented an overview of how healthy streams function and the role of riparian vegetation in stream-system function. The result of the workshop is informed landowners and members of the public who are more inclined to use practices that improve the management of riparian and stream ecosystems. Through proper management, protection, and restoration of these vital areas, water quality is directly influenced while stream banks are more stabilized, and aquatic habitat is improved. Since almost all of the riparian area along Geronimo and Alligator Creeks is privately owned, having an attendance of 45 landowners was a great outreach event.

Another type of workshop that was introduced to the watershed was the Homeowner Maintenance of Septic Systems Workshops in 2013 and 2014 (Figure 4). The original workshops were 2-hour trainings for homeowners with septic systems addressing overall function and maintenance activities that covered both aerobic and conventional systems. Feedback from the initial workshops indicated a need for homeowners to receive more training on aerobic system operation and maintenance. Guadalupe County homeowners have an additional requirement imposed by the county that they must be certified to maintain their systems, or remain under contract with a maintenance provider for as long as they own the home.

This financial burden, and homeowner frustration with some poor performing maintenance providers, was the impetus for the development of a 6-hour course that would grant certification to Guadalupe County homeowners taking the class. This intensive 6-hour certification class for homeowners was first offered in November 2014, and has remained in demand. One hundred and twenty-nine homeowners attended these trainings in 2013 and 2014.

Figure 4. Homeowner Maintenance of Septic Systems workshops have helped over 200 homeowners learn more about proper operation and maintenance of their septic systems.

A Lone Star Healthy Streams (LSHS) Workshop was conducted in the watershed in the summer of 2014. The LSHS program, funded by TSSWCB project 12-08, *"Statewide Delivery of the Beef Cattle, Dairy Cattle, Poultry and Horse Components of the Lone Star Healthy Streams Program"*, focuses on educating Texas farmers, ranchers, and landowners about proper grazing, feral hog management, and riparian area protection to reduce contamination in streams and rivers. Forty-seven landowners participated in the workshop, and plans are being made to expand the topics covered in the next workshop to increase attendance.

The first Feral Hog workshop ever to be held in the watershed took place in 2014. Fifty-two landowners participated in the workshop, and learned about feral hog biology, laws, health and safety considerations, and control measures. This workshop is gaining momentum, and as a result the County Commissioners are requesting more feral hog workshops and are interested in participating in the TDA Feral Hog Out grant program.

The first ever Smart Growth Workshop was conducted in 2014 with a focus on educating the decision makers in the watershed regarding Low Impact Development (LID) structures and techniques. All watershed municipal and county leaders were invited to attend. Thirty-four attendees were presented with in-class descriptions of LID, and participated in a site visit to get a hands-on learning opportunity of a LID structure. There are plans to make this an annual event.

A Rainwater Harvesting Workshop was held in the watershed for the first time in Fall of 2014 (Figure 5). Extension provided 66 attendees with information on how to collect, store, and utilize rainwater for a variety of uses. An in-class demonstration of how to build a rain barrel was performed, and the barrels were raffled off as door prizes. Even though the drought is lessening

in the area, requests still come in to have another workshop of this type. Planning is underway to conduct a follow-up workshop.

Figure 5. Rain barrel raffle winners at the Rainwater Harvesting Workshop.

A critical part of the project has been to disseminate information on Geronimo and Alligator Creeks and this project to stakeholders and other interested parties throughout the state. GBRA summarized the results and activities of this project in GBRA's Clean Rivers Program Basin Highlights Report and Basin Summary Report. Additionally, the results and activities of this project were summarized in quarterly reports to the stakeholders and the Steering Committee. GBRA's quarterly publication, *The River Run*, had an article in the Spring of 2013 about the success of the first stream clean up.

GBRA Public Communication and Education division was very active in the watershed. For example, to educate and increase awareness of water quality issues in the watershed, GBRA began working with the Seguin High School, assisting the teachers in conducting a project-based class in the summers of 2012 and 2013. Students in the summer program conducted studies on Geronimo Creek, such as benthic macroinvertebrate sampling and identification, water quality monitoring, and stream cleanup activities.

Also, located in the middle of the watershed, Navarro High School was the recipient of a 2011 Healthy Habitats grant focusing on the Geronimo Creek watershed. In partnership with the GBRA, students researched the Geronimo Creek watershed from its headwaters to the confluence with the Guadalupe River and then selected a location to restore natural grasses, forbs, and trees along the banks of the creek to help filter water flow during rain events to help prevent pollution. Healthy Habitat grants are designed to support students doing service-learning projects to benefit wildlife and the environment.

GBRA's Public Communication and Education Department, worked with Seguin High School teachers to develop a two week, intensive project-based learning class that also used Geronimo Creek as the focus. While earning two class credits (speech and technology), the students made a press kit and spoke to the public about issues pertaining to the watershed. The students took a tour of the entire watershed, picked up trash along the creek and learned how water bugs can indicate the quality of water. The students made a presentation to the Seguin ISD School Board on the issues impacting the Geronimo Creek, including information on pet waste and feral hogs. GBRA staff helped with the production of Google fly-overs, maps and graphics. The class developed educational materials for the Geronimo Creek watershed. Students approached restaurants and businesses located in the watershed and secured agreements with them to distribute placemats and other educational items developed through the summer academy. GBRA took the student designs, made final edits, and with funding from Extension, produced 1,000 placemats, 500 brochures, and 500 magnets. The outreach materials were distributed to local restaurants and businesses for display and use on Water Monitoring Day.

Over the course of the project GBRA staff made presentations to classrooms in the Seguin ISD and Navarro ISD schools located in watershed. Their presentations covered the water quality of Geronimo Creek, and included a water quality monitoring project using water collected from Geronimo Creek. GBRA Public Communication and Education staff prepared nonpoint source pollution activity kits for use with elementary classroom activities in the Geronimo and Alligator Creeks watersheds. Kits support activities from the GBRA "Don't be Clueless about Water Quality" curriculum. Additionally, GBRA staff made presentations on nonpoint source pollution to area classes visiting the ILSOLC and the Big Red Barn (Guadalupe County Agriculture Heritage Center), educational centers located in the Geronimo Creek watershed.

Watershed Cleanup

The idea of a community cleanup was introduced to the partnership in the fall 2012 and was very well received (Figure 6). The first cleanup was so successful that it has been made an annual event. Over 15 entities participated in the form of sponsorship or by cleaning up a designated site.

Figure 6. Volunteers participate in the 2nd Annual Clean Up event.

In addition to financial contributions from sponsors, students from the art department of Texas Lutheran University submitted t-shirt designs, area businesses and church groups sponsored areas and provided time for workers to participate, the cities of Seguin and New Braunfels provided roll-off containers for the collection, disposal, and recycling of collected materials, middle school and high school National Honor Society and Interact groups volunteered, and Parker Lumber, the New Braunfels Municipal Airport, and Navarro High School allowed registration booths to be set up in their parking lots.

The list of project partners participating each year has grown. The number of volunteers signed up to participate in the second cleanup was over 230-well over twice the number that participated in the first event. The first cleanup resulted in the removal of 2,960 pounds of trash, 26 tires, and several large items such as a stove, air conditioner, car battery, and a toilet. In the second event, volunteers collected 7,020 pounds of trash along 17 miles of roadway and creek banks, removing 45 tires, 2 cubic yards of scrap metal, and large items such as lumber and two toilets.

Data Collection and Transmittal

Data collected through the monitoring tasks of the project is collected under an approved Quality Assurance (QA) Project Plan that is updated annually. The objective of the quality assurance task was to develop and implement data quality objectives and quality assurance/control activities in order to ensure data of known and acceptable quality are generated through this project. As part of the QA task, GBRA Regional Laboratory staff worked on the standard operating procedure for EPA Method 1603 for the enumeration of *E. coli*, with the goal to become accredited for the method. Accreditation for EPA Method 1603 was granted in the second quarter of FY2013.

On September 29, 2014 GBRA participated in an audit of the monitoring program by the TSSWCB. The audit included the quality system of the laboratory and the field monitoring protocols. At the exit interview, one recommendation was made to provide safety equipment to

visitors of the laboratory. Equipment, including safety glasses, is now available outside the door to the laboratory.

GBRA updates the TCEQ's Coordinated Monitoring Schedule each year to include the sites that are being sampled under this project. As part of this project, GBRA submitted requests and received station numbers for two new monitoring sites (Geronimo Creek at IH 10 near Seguin and Geronimo Creek at Hwy 90 at the Seguin Outdoor Learning Center).

The data collected in this project is uploaded to the TCEQ Surface Water Quality Monitoring Information System (SWQMIS). A completed Data Summary was submitted with each data submittal. Corrective Action Reports were submitted by the GBRA field staff or the laboratory if there was a problem or deficiency encountered. If a problem occurred during a sampling event, every attempt was made to recollect the sample if the flow conditions remained the same so there was no loss in data. A secondary lab was included in the QAPP in order to perform analyses when there was an instrument failure in the GBRA laboratory. Only two data sets were incomplete through August 2014 due to GBRA error, requiring a Corrective Action Report. The deficiencies are listed in Table 1.

Table 1. Deficiencies resulting in a loss of data.

Date	**Site Name**	**Deficiency**	**Explanation**
June 2013	All routine sites	Turbidity not reported.	Due to lab error the holding time for turbidity analysis was missed so no turbidity analyses was reported
February 2014	All routine sites	No TKN reported	Instrument failure; TKNs were sent to the secondary lab in March and April so that there was no further loss of data

Highlights and Evaluation of Water Quality Monitoring Data

Routine Monitoring

GBRA conducted routine ambient monitoring at 7 sites monthly, collecting field, conventional, flow and bacteria parameter groups. Routine ambient monitoring was conducted monthly at 1 station by GBRA (Site no. 14932, Geronimo Creek at Haberle Road) through the CRP. The objective of the routine monitoring was to provide water quality data to assess the effectiveness of implementing the Geronimo and Alligator Creeks WPP by enhancing current routine ambient monitoring regimes. The scheduling of routine water quality sampling was designed to

complement existing routine ambient monitoring regimes such that routine water quality monitoring was conducted monthly at 8 sites in the watersheds. GBRA's Regional Laboratory conducted the sample analysis. Field parameters were pH, temperature, conductivity, and dissolved oxygen. Conventional parameters were total suspended solids, turbidity, sulfate, chloride, nitrate-nitrogen, ammonia-nitrogen, Total Kjeldahl Nitrogen, chlorophyll a, pheophytin, total hardness, and total phosphorus. Flow parameters were collected by electric, mechanical or Doppler, including severity. Bacteria parameter is *E. coli*.

Beginning in September 2012 through August 2014, 24 routine sampling events were conducted. The main stem sites were flowing and were sampled. Of the routine sites monitored under this project (non-main stem), one was routinely dry or dry with pools except during wet weather conditions (Geronimo Creek at Huber Road).

The following data tables compile the data collected to date at the routine sites. Because of the drought that dominated the weather patterns during the project there were significantly less monitoring events conducted under the influence of storm events. Table 2 compares the geometric mean of the *E. coli* data collected at each routine site to the geometric mean of the data collected under wet weather conditions. The data shows that storm water carries a significant load of bacteria into the stream. But even under dry conditions the geometric mean at five of the eight sites exceeded the stream standard for contact recreation (126 organisms per 100 milliliters).

Table 2. Concentrations of *E. coli* under dry and wet conditions at the routine monitoring sites.

Site	No. of Samples	Median Flow-Dry (cfs)	E. coli Geomean - Dry	Range-Dry	No. of Samples (Wet)	Median Flow-Wet (cfs)	E. coli Geomean - Wet	Range-Wet	% Change btwn Dry and Wet *	E. coli Geomean 2008-2014**
Geronimo Creek at Haberle Road	60	4.3	138	51-520	12	5.6	661	140-16000	377.57	180
Geronimo Creek at SH123	42	2.3	339	130-1400	7	3.8	1366	280-11600	302.89	414
Geronimo Creek at HWY 90A	36	4.6	131	32-1200	13	6.15	235	35-5500	78.71	153
Geronimo Creek at IH10 near Seguin	21	4.2	162	55-63	4	5.75	612	140-8600	278.21	188
Geronimo Creek at SOLC	22	4.3	125	38-440	4	5.2	219	74-1500	74.40	137
Geronimo Creek at Hollub Lane	33	5.9	130	24-870	15	8.35	331	48-11000	154.31	174
Alligator Creek at Huber Road	39	0	68	1-2400	9	0.36	150	4-24000	121.00	79
Geronimo Creek at Huber Road	0	0	NA	NA	0	0	NA	NA	NA	NA

* Positive change indicates an increase in pollutant load with rainfall. Negative change indicates that rainfall is diluting the base flow pollutant concentration.

Stations highlighted have a base flow geometric mean greater than the water quality standard of 126 organisms/100 mL under dry conditions.

** Entire data set under all flow conditions through August 2014.

Table 3 is the mean of the concentrations of total phosphorus at the routine sites. Although at no time, or under any flow conditions, did the mean exceed the screening concentration of 0.69 milligrams per liter there was an increase in total phosphorus during wet weather conditions.

Table 3. Concentrations of total phosphorus under dry and wet conditions at the routine monitoring sites.

Site	No. of Samples	Median Flow-dry	Total P Mean - Dry	Range-Dry	No. of Samples (Wet)	Median Flow-wet	Total P Mean - Wet	Range-Wet	% Change btwn Dry and Wet *	Tot P Mean 2008-2014**
Geronimo Creek at Haberle Road	60	4.3	0.03	<0.01-0.22	12	5.6	0.13	<0.01-0.51	360.61	0.04
Geronimo Creek at SH123	43	2.3	0.06	<0.01-1.02	6	3.8	0.13	<0.05-0.34	138.39	0.06
Geronimo Creek at HWY 90A	36	4.6	0.03	<0.01-0.14	13	6.15	0.09	<0.01-0.24	209.73	0.05
Geronimo Creek at IH10 near Seguin	21	4.2	0.02	<0.01-0.06	3	5.75	0.03	<0.01-0.08	50.86	0.02
Geronimo Creek at SOLC	21	4.3	0.03	0.01-0.07	4	5.2	0.05	<0.01-0.09	108.02	0.03
Geronimo Creek at Hollub Lane	33	5.9	0.02	<0.01-0.08	15	8.35	0.09	<0.01-0.22	296.58	0.04
Alligator Creek at Huber Road	39	0	0.06	0.02-0.17	9	0.36	0.13	0.02-0.26	112.49	0.07
Geronimo Creek at Huber Road	0	0	NA	NA	0	0	NA	NA	NA	NA

* Positive change indicates an increase in pollutant load with rainfall. Negative change indicates that rainfall is diluting the base flow pollutant concentration.

Stations highlighted have a base flow mean concentration greater than the screening concentration of 0.69 mg/L Total Phosphorus, under dry conditions.

** Entire data set under all flow conditions through August 2014.

Table 4 is a compilation of the nitrate-nitrogen data collected from 2008 through August 2014. The Leona Aquifer is the source of the springs contributing to the base flow of the Geronimo Creek. Historically, the concentration of the nitrate-nitrogen found in the Leona is very high, exceeding the drinking water standard of 10.0 milligrams per liter. The impact of the Leona on the base flow can be seen in the mean concentrations of nitrate-nitrogen at all six Geronimo Creek sites. All six sites exceed the TCEQ screening concentration of 1.95 milligrams per liter. Under wet weather conditions, storm water dilutes the base flow and lowers the mean concentrations at all sites.

Table 4. Concentrations of nitrate-nitrogen under dry and wet conditions at the routine monitoring sites.

Site	No. of Samples	Median Flow-Dry	NO3-N Mean - Dry	Range-Dry	No. of Samples (Wet)	Median Flow-Wet	NO3-N Mean - Wet	Range-Wet	% Change btwn Dry and Wet *	NO3-N Mean 2008-2014**
Geronimo Creek at Haberle Road	59	4.3	10.29	6.9-14	12	5.6	6.03	0.1-9.84	-41.38	9.57
Geronimo Creek at SH123	42	2.3	8.41	6.2-12	7	3.8	4.48	0.09-8.4	-46.75	7.84
Geronimo Creek at HWY 90A	36	4.6	9.22	3.2-14.1	13	6.15	6.05	0.02-11	-34.39	8.38
Geronimo Creek at IH10 near Seguin	21	4.2	10.25	7.8-13.0	4	5.75	8.15	3.8-11.4	-20.45	9.91
Geronimo Creek at SOLC	22	4.3	9.60	6.1-12.7	4	5.2	7.80	4.0-11.0	-18.71	9.32
Geronimo Creek at Hollub Lane	29	5.9	8.65	4.2-13.2	15	8.35	5.03	9.2-15	-41.81	7.41
Alligator Creek at Huber Road	39	0	1.80	10.6-39	9	0.36	1.21	5.8-9.0	-32.81	1.69
Geronimo Creek at Huber Road	0	0	NA	NA	0	0	NA	NA	NA	NA

* Positive change indicates an increase in pollutant load with rainfall. Negative change indicates that rainfall is diluting the base flow pollutant concentration.

Stations highlighted have a base flow mean concentration greater than the screening concentration of 1.95 mg/L Nitrate Nitrogen, under dry conditions.

** Entire data set under all flow conditions through August 2014.

Table 5 is a compilation of the data collected for ammonia-nitrogen. At no time, or under any flow conditions, did the mean exceed the screening concentration of 0.33 milligrams per liter.

Analysis of Routine Data for Trends

The Geronimo and Alligator Creeks monitoring stations were analyzed for statistically significant correlations between concentrations for ammonia-nitrogen, nitrate-nitrogen, total phosphorus and *E. coli* versus time and stream flow. Multiple t-tests were conducted to determine significance. If the absolute value of the t-statistic was greater than 2 and the p value was less than or equal to a 0.05 significance level, then the correlation between each of the dependent variables and either time or stream flow was considered to be significant. The dotted red lines on the accompanying charts represent nutrient screening values for concentration levels for concerns and solid red lines represent contact recreation limits for *E. coli*, if applicable.

Station 20747 (Geronimo Creek at Hollub Road) is located approximately 0.5 kilometers (km) upstream of the confluence with the Guadalupe River. During heavy flooding the Guadalupe River backs up and influences the water quality of this portion of the Geronimo Creek. Several statistically significant correlations with time were found at this location. Total phosphorus; $t(42)=-3.88$, $p=0.00$, is decreasing with time (Figure 7) and ammonia-nitrogen; $t(42)=2.69$, $p=0.01$, is increasing with time (Figure 8). Total phosphorus also shows a positive correlation

Table 5. Concentrations of ammonia-nitrogen under dry and wet conditions at the routine monitoring sites.

Site	No. of Samples	Median Flow-Dry	NH3-N Mean - Dry	Range-Dry	No. of Samples (Wet)	Median Flow-Wet	NH3-N Mean - Wet	Range-Wet	% Change btwn Dry and Wet *	NH3-N Mean 2008-2014**
Geronimo Creek at Haberle Road	35	4.3	0.13	<0.1-0.34	19	5.6	0.14	<0.1-0.32	15.66	0.13
Geronimo Creek at SH123	42	2.3	0.14	<0.1-0.36	7	3.8	0.16	<0.1-0.36	17.89	0.14
Geronimo Creek at HWY 90A	36	4.6	0.13	<0.1-0.37	13	6.15	0.12	<0.1-0.45	-10.56	0.13
Geronimo Creek at IH10 near Seguin	21	4.2	0.21	<0.1-1.26	4	5.75	0.18	<0.1-0.32	-15.81	0.21
Geronimo Creek at SOLC	22	4.3	0.18	<0.1-0.5	4	5.2	0.20	<0.1-0.36	13.40	0.18
Geronimo Creek at Hollub Lane	33	5.9	0.17	<0.1-0.77	15	8.35	0.12	<0.1-0.29	-29.60	0.15
Alligator Creek at Huber Road	38	0	0.17	<0.1-0.73	9	0.36	0.16	<0.1-0.46	-1.13	0.17
Geronimo Creek at Huber Road	0	0	NA	NA	0	0	NA	NA	NA	NA

* Positive change indicates an increase in pollutant load with rainfall. Negative change indicates that rainfall is diluting the base flow pollutant concentration.

Stations highlighted have a base flow mean concentration greater than the screening concentration of 0.33 mg/L Ammonia-Nitrogen, under dry conditions.

** Entire data set under all flow conditions through August 2014.

with stream flow at this location; t(42)=5.23, p=0.00, (Figure 9) and increases as stream flows increase, which may explain the declining concentrations of total phosphorus over time as the Geronimo Creek is impacted by ongoing drought conditions. Ammonia- nitrogen levels did not significantly correlate with stream flow; however, the impacts of the drought may be causing more wildlife and livestock animals to look to the creek as a source of water, which may be increasing the ammonia loading at this station. *E. coli* (MPN/dl) increases with stream flow; t(42)=5.80, p=0.00 at this station (Figure 10), but *E. coli* levels remain unchanged over time.

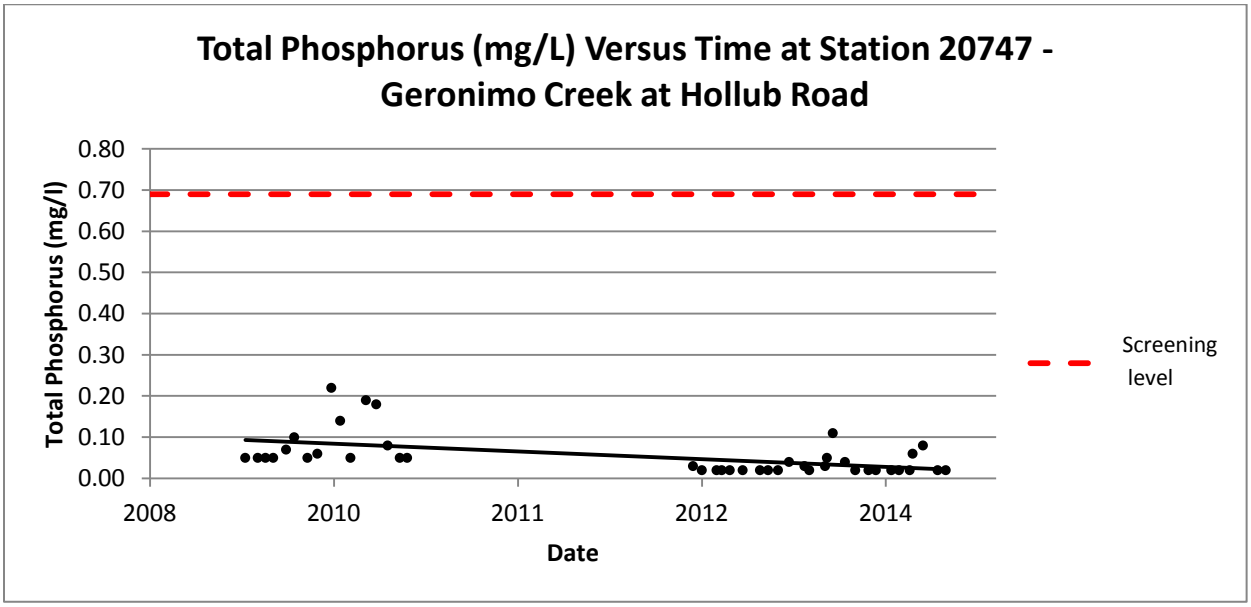

Figure 7. Total Phosphorus (mg/L) Versus Time at Station 20747 - Geronimo Creek at Hollub Road.

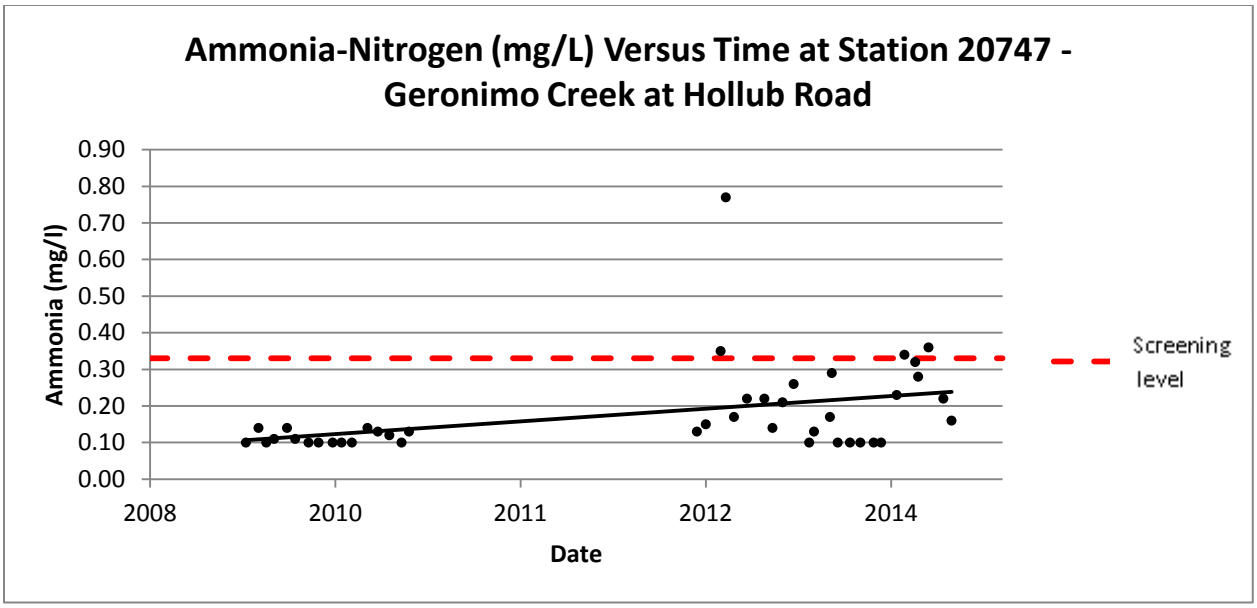

Figure 8. Ammonia-Nitrogen (mg/L) Versus Time at Station 20747 - Geronimo Creek at Hollub Road.

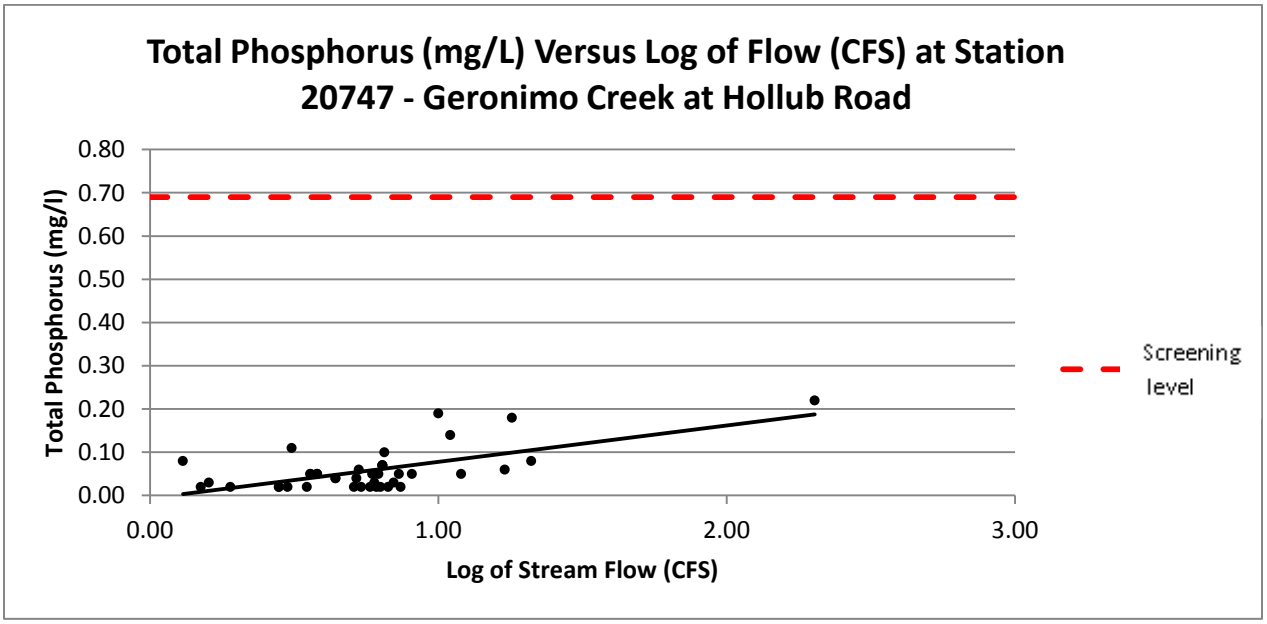

Figure 9. Total Phosphorus (mg/L) Versus Log of Stream Flow at Station 20747 – Geronimo Creek at Hollub Road.

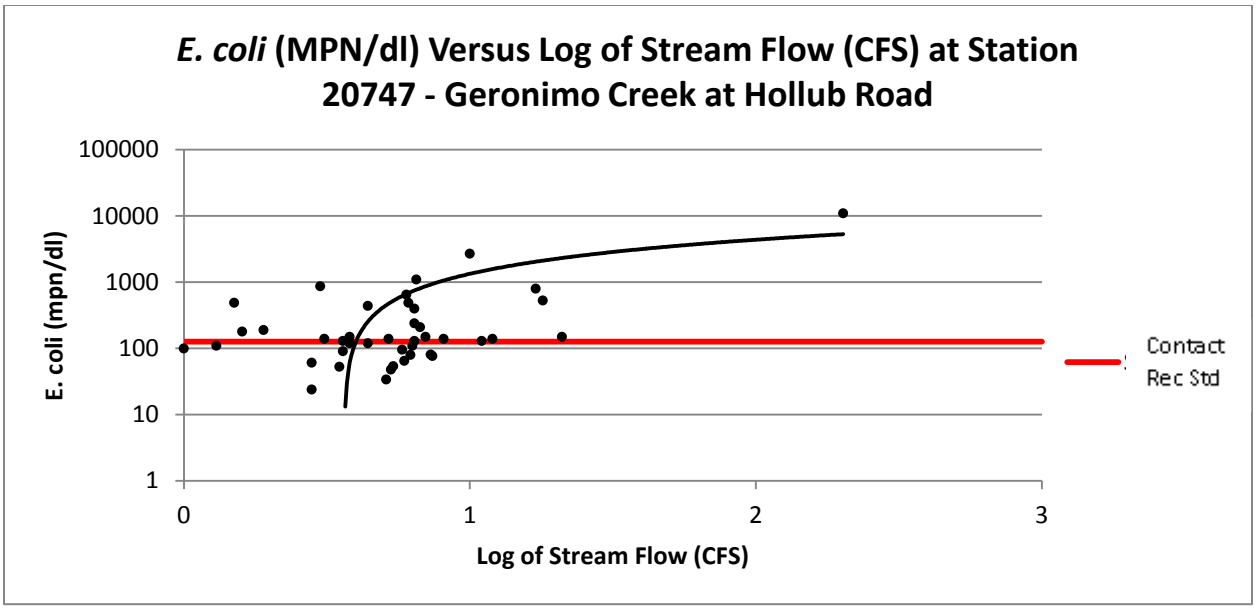

Figure 10. E. coli (MPN/dl) Versus Log of Stream Flow (CFS) at Station 20747 – Geronimo Creek at Hollub Road.

At station 20745 (Geronimo Creek at Highway 90A) a statistically significant correlation was found between time and several water quality parameters. Ammonia- nitrogen; t(42)=4.11, p=0.00, is increasing with time (Figure 11) and total phosphorus; t(42)=-3.61, p=0.00,is decreasing with time (Figure 12). Total Phosphorus; t(42)=6.55, p=0.00, and *E. coli* ; t(42)=6.27, p=0.00, also showed a statistically significant correlation with stream flow. Total phosphorus is increasing with stream flow (Figure 13) and *E. coli* is also increasing with stream flow (Figure 14). This station is located only about 4 kilometers upstream of station 20747 (Geronimo Creek at Hollub Road) and 0.4 km upstream of the confluence of the Baer Creek tributary, but seems to be experiencing similar trending to the previous station downstream station.

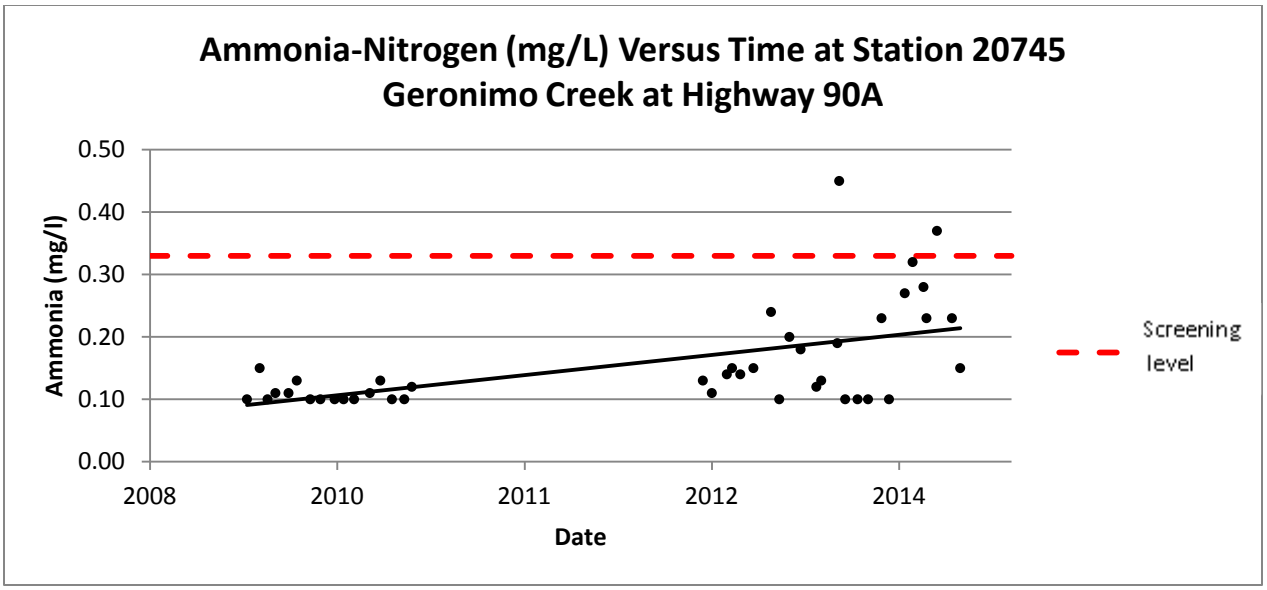

Figure 11. Ammonia-Nitrogen (mg/L) Versus Time at Station 20745 Geronimo Creek at Highway 90A.

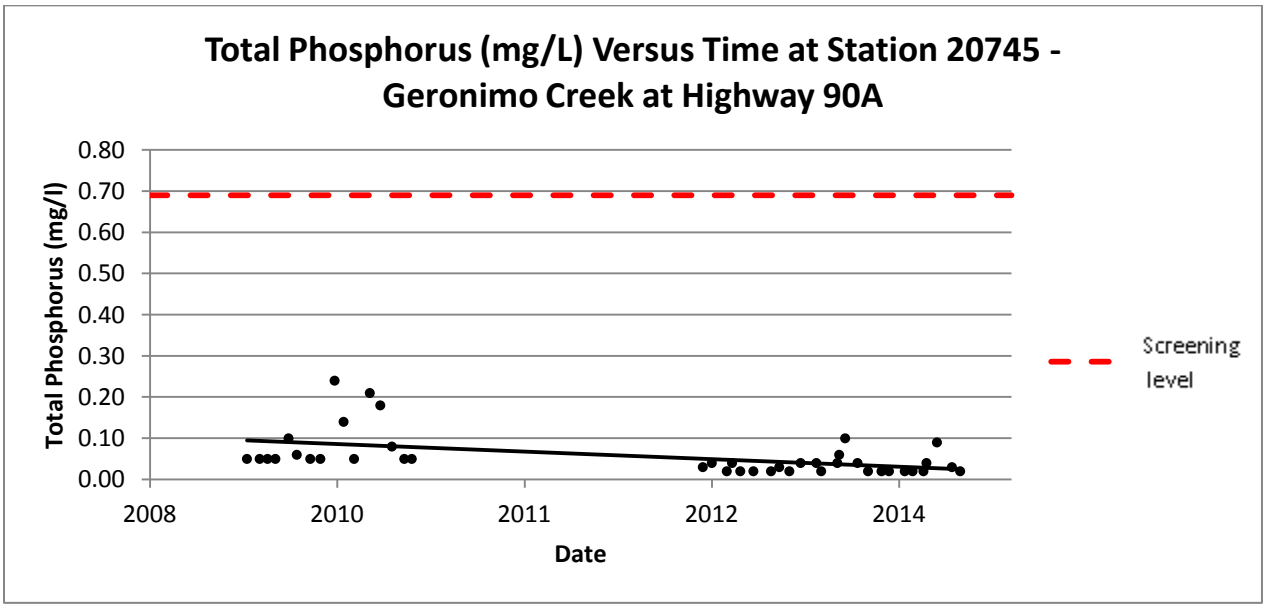

Figure 12. Total Phosphorus (mg/L) Versus Time at Station 20745 - Geronimo Creek at Highway 90A.

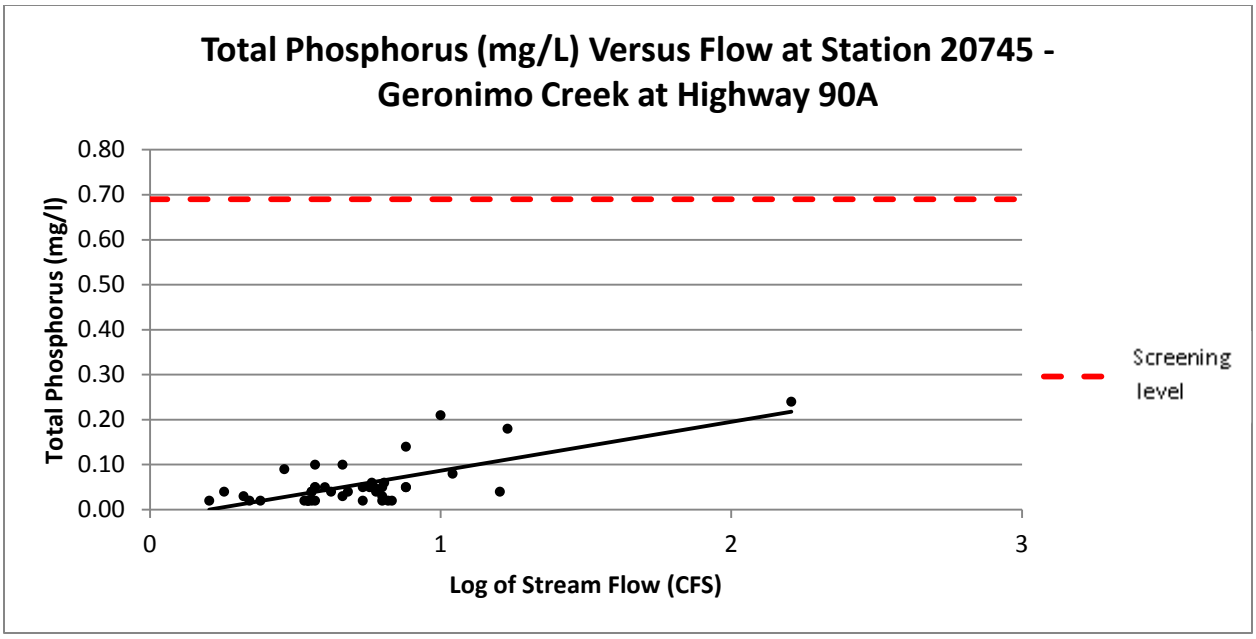

Figure 13. Total Phosphorus (mg/L) Versus Log of Stream Flow (CFS) at Station 20745 - Geronimo Creek at Highway 90A.

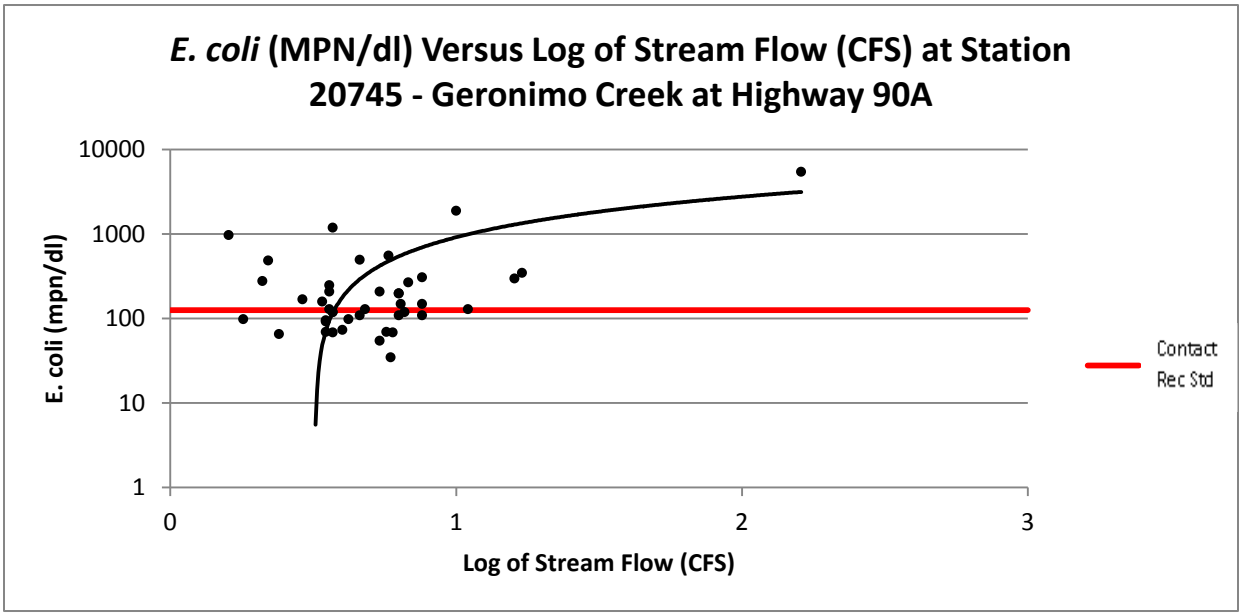

Figure 14. *E. coli* (MPN/dl) Versus Log of Stream Flow (CFS) at Station 20745 - Geronimo Creek at Highway 90A.

At station 21261 (Geronimo Creek at Highway 90 near Seguin Outdoor Learning Center), only one statistically significant correlation was with time. Nitrate-nitrogen (mg/L) ; t(26)=-6.12, p=0.00, at this station is decreasing with time (Figure 15). *E. coli* ; t(26)=3.51, p=0.00, also showed a statistically significant correlation with stream flow and concentrations appear to increase with higher stream flows (Figure 16). This station is only located about 2.1 kilometers

upstream of station 20745 (Geronimo Creek at Highway 90A), but water quality trends at this station are quite different. Station 21261 was added to the Geronimo Creek monitoring project in September of 2012 and has much less data available than many of the other monitoring stations on Geronimo Creek. The trends at this station may differ from other portions of the Geronimo Creek for this reason.

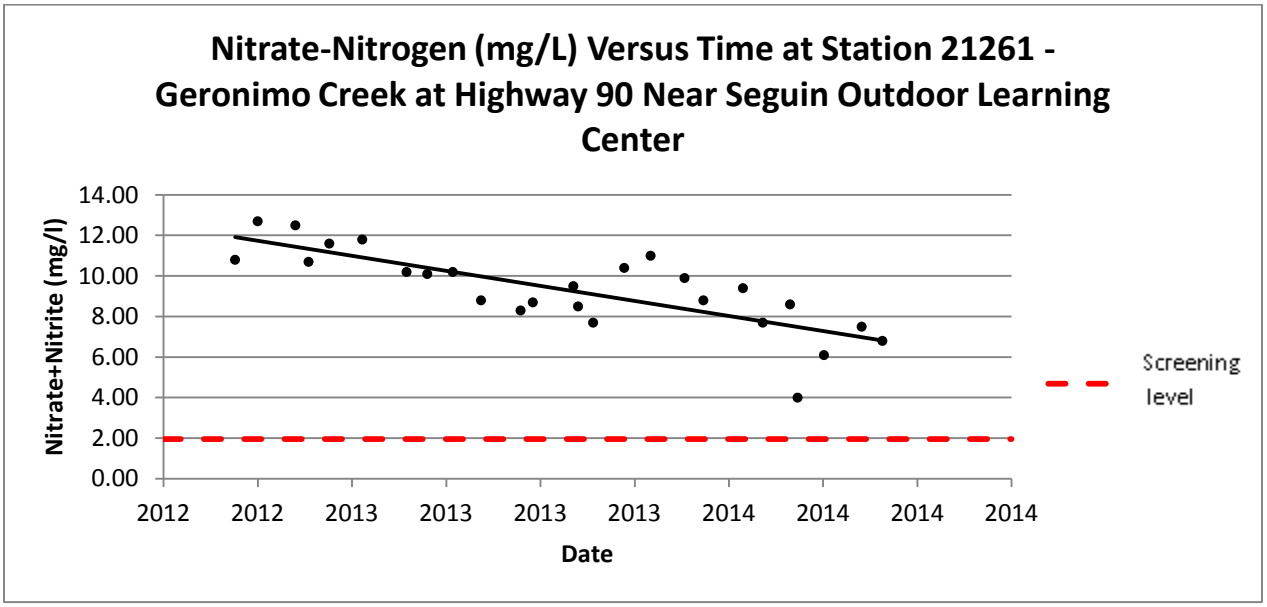

Figure 15. Nitrate-Nitrogen (mg/L) Versus Time at Station 21261 - Geronimo Creek at Highway 90 Near Seguin Outdoor Learning Center.

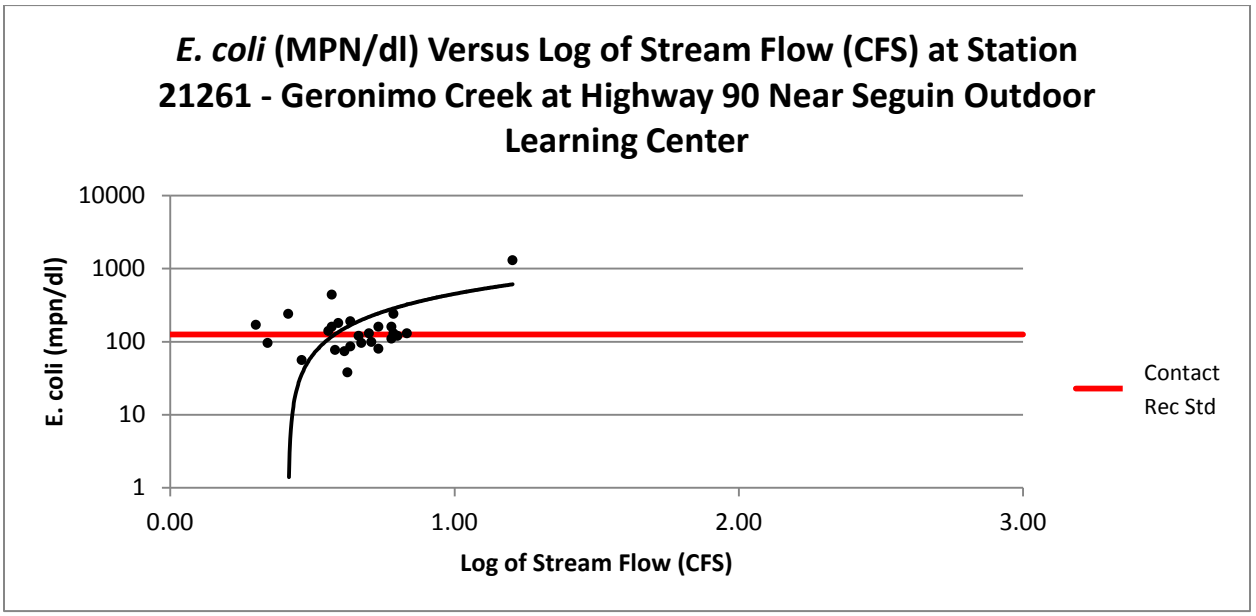

Figure 16. *E. coli* (MPN/dl) Versus Log of Stream Flow (CFS) at Station 21261 - Geronimo Creek at Highway 90 Near Seguin Outdoor Learning Center.

Station 21260 (Geronimo Creek at IH10) was also added to the Geronimo Creek and Alligator Creek Monitoring Project in September of 2012. The water quality trends at this station were very similar to the trends at station 21261 (Geronimo Creek at Highway 90 near Seguin Outdoor Learning Center). Nitrate-nitrogen; t(26)=-4.18,p=0.00, is decreasing with time (Figure 17). *E. coli*; t(26)=3.60, p=0.00, also showed a statistically significant correlation with stream flow and the concentration increases with higher stream flows (Figure 18). Station 21260 is located 1.25 km upstream of station 21261 and the close proximity of this station with station 21261 during the same truncated temporal monitoring interval may be the reason that these two stations showed such similar patterns.

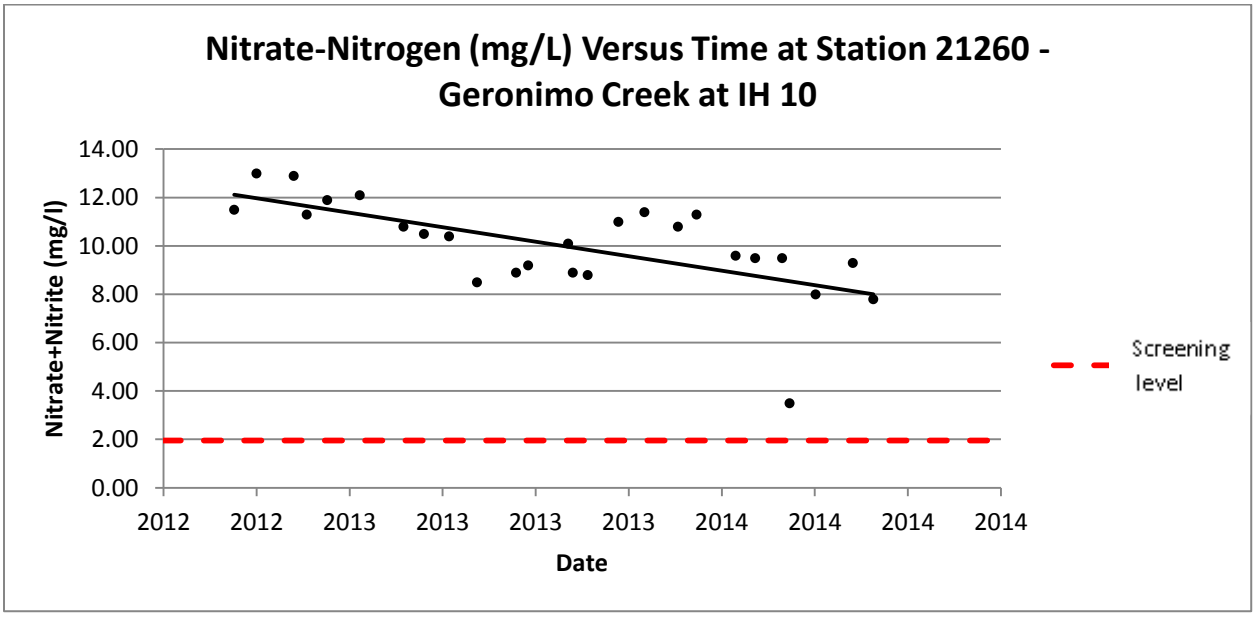

Figure 17. Nitrate-Nitrogen (mg/L) Versus Time at Station 21260 - Geronimo Creek at IH-10.

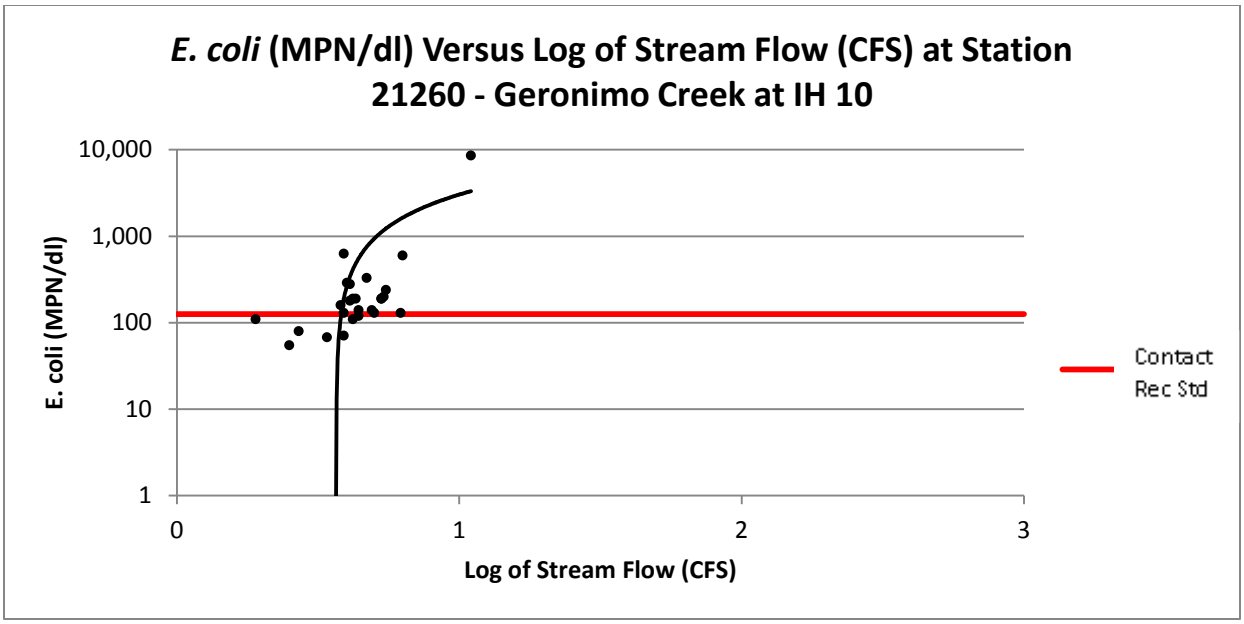

Figure 18. *E. coli* (MPN/dl) Versus Log of Stream Flow (CFS) at Station 21260 – Geronimo Creek at IH-10.

Station 12576 (Geronimo Creek at Haberle Road) is the current TCEQ CRP monitoring station on the Geronimo Creek and is the station with the greatest amount of data available during the span of the monitoring project. This station is located 4.3 km upstream of station 21260 (Geronimo Creek at IH 10) and contributed much of the data to the original noncompliance listing for this stream. Station 12576 showed only one significant correlation with time. Ammonia-nitrogen; $t(66)=2.27, p=0.03$ is increasing over time (Figure 19). This trend is consistent with the data from Station 20747 (Geronimo Creek at Hollub Road) and 20745 (Geronimo Creek at Highway 90A), which spanned the same temporal monitoring interval and showed similar correlations between ammonia-nitrogen and time. Station 12576 also showed significant correlations between nitrate nitrogen and stream flow; $t(66)=-3.21, p=0.00$, total phosphorus and stream flow; $t(66)=3.49, p=0.00$, as well as *E. coli* and stream flow; $t(66)=4.23, p=0.00$. Nitrate nitrogen decreases as stream flow increases (Figure 20), while total phosphorus and *E. coli* increase with higher stream flows (Figures 21 & 22).

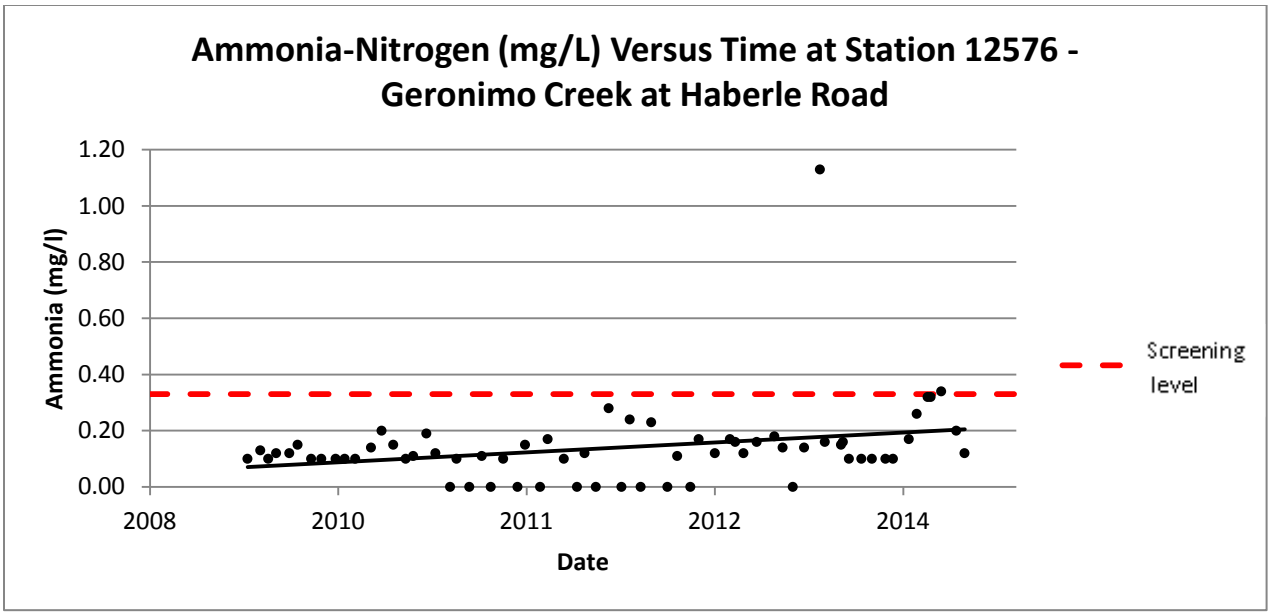

Figure 19. Ammonia-Nitrogen (mg/L) Versus Time at Station 12576 - Geronimo Creek at Haberle Road.

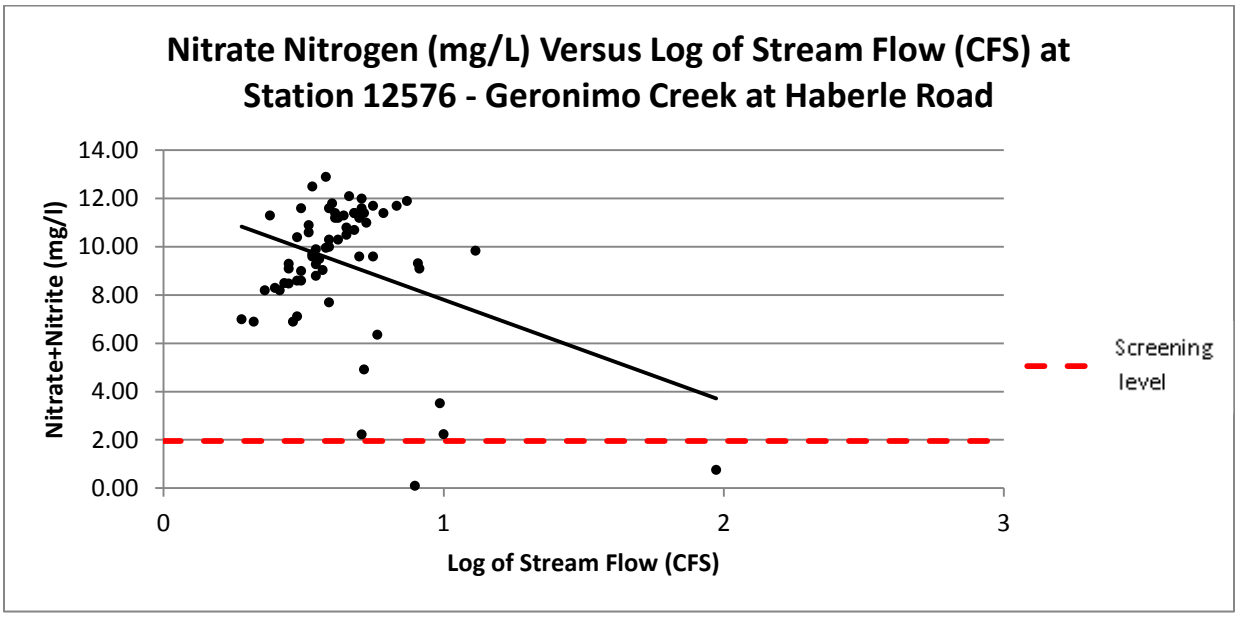

Figure 20. Nitrate Nitrogen (mg/L) Versus Log of Stream Flow (CFS) at Station 12576 - Geronimo Creek at Haberle Road.

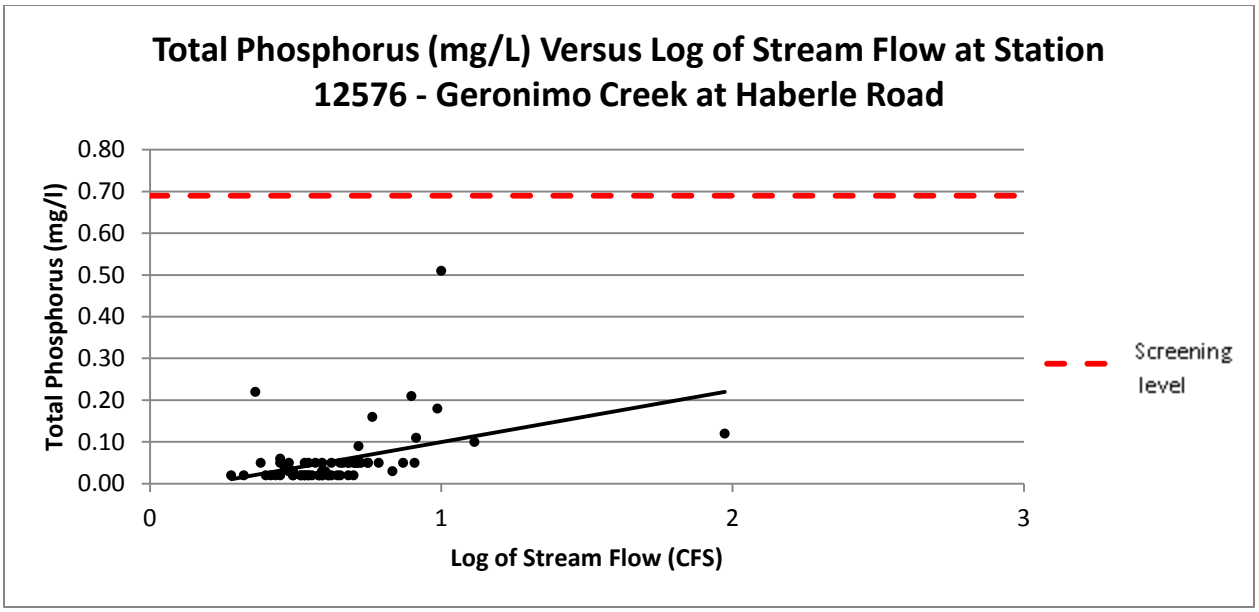

Figure 21. Total Phosphorus (mg/L) Versus Log of Stream Flow (CFS) at Station 12576 - Geronimo Creek at Haberle Road.

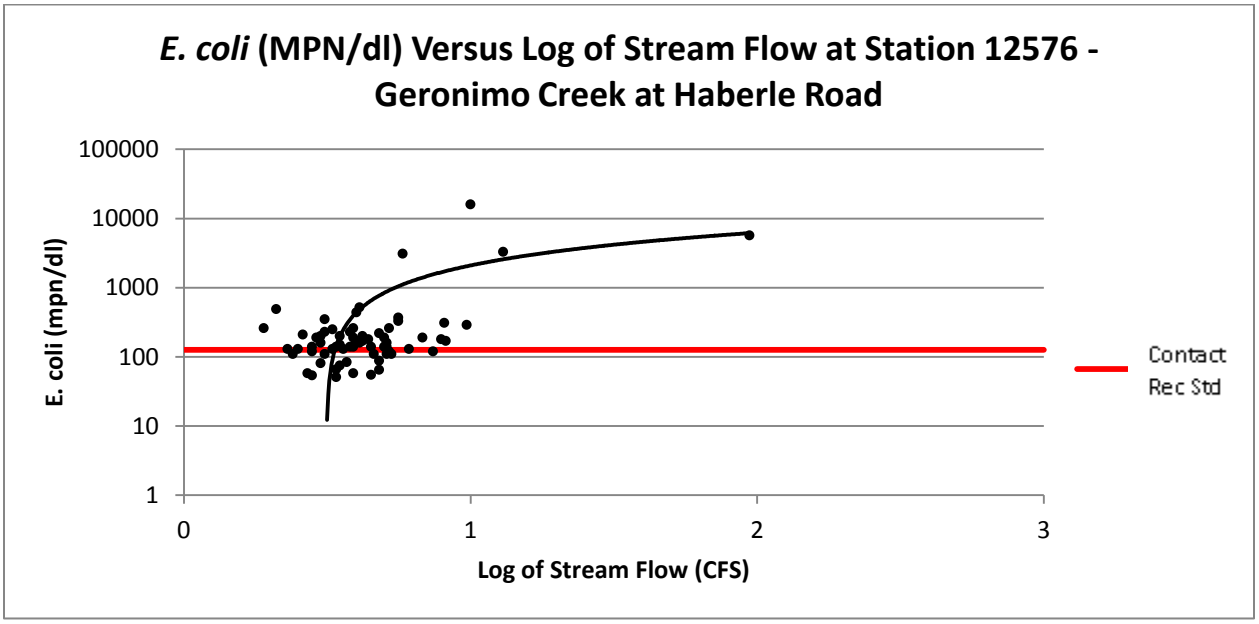

Figure 22. *E. coli* (MPN/dl) Versus Log of Stream Flow (CFS) at Station 12576 - Geronimo Creek at Haberle Road.

At station 14932 (Geronimo Creek at SH 123) a statistically significant correlation was found between increasing ammonia-nitrogen; $t(42)=2.69, p=0.01$ and time (Figure 23). This station also showed a significant correlation between decreasing total phosphorus; $t(42)=-3.88, p=0.00$ and

time (Figure 24). This station is located immediately downstream of the headwater springs of the Geronimo Creek and approximately 4 km upstream of station 12576 (Geronimo Creek at Haberle Road). The trends at this station are very similar to the trends at the other Geronimo Creek main stem stations such as 20747 (Geronimo Creek at Hollub Road) and 20745 (Geronimo Creek at Highway 90A), that were collected during the same temporal monitoring period. The land upstream of this station is primarily used for agricultural production and this portion of the stream is heavily influenced by nonpoint source runoff. The increase in ammonia-nitrogen over time is most likely due to increased water use by livestock and wildlife during drought conditions. There were also significant correlations between total phosphorus and stream flow ; $t(42)=5.23, p=0.00$, as well as *E. coli* and stream flow $t(42)=5.80, p=0.00$, at this station. Concentrations of total phosphorus and *E. coli* both increase as stream flows increase (Figures 25 & 26).

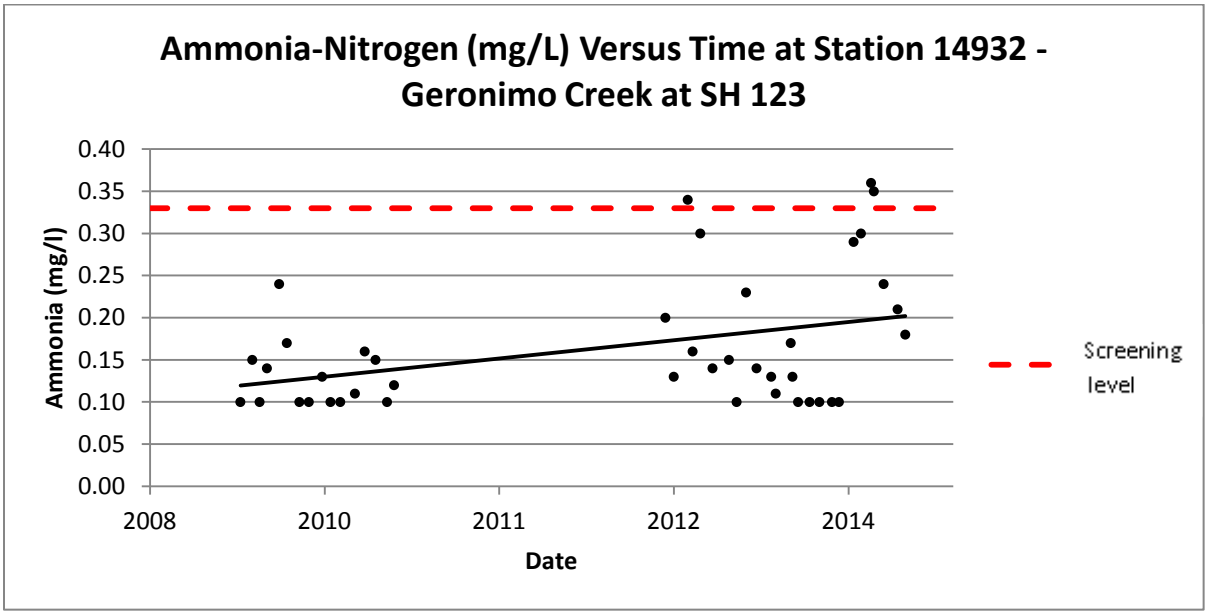

Figure 23. Ammonia-Nitrogen (mg/L) Versus Time at Station 14932 - Geronimo Creek at SH 123.

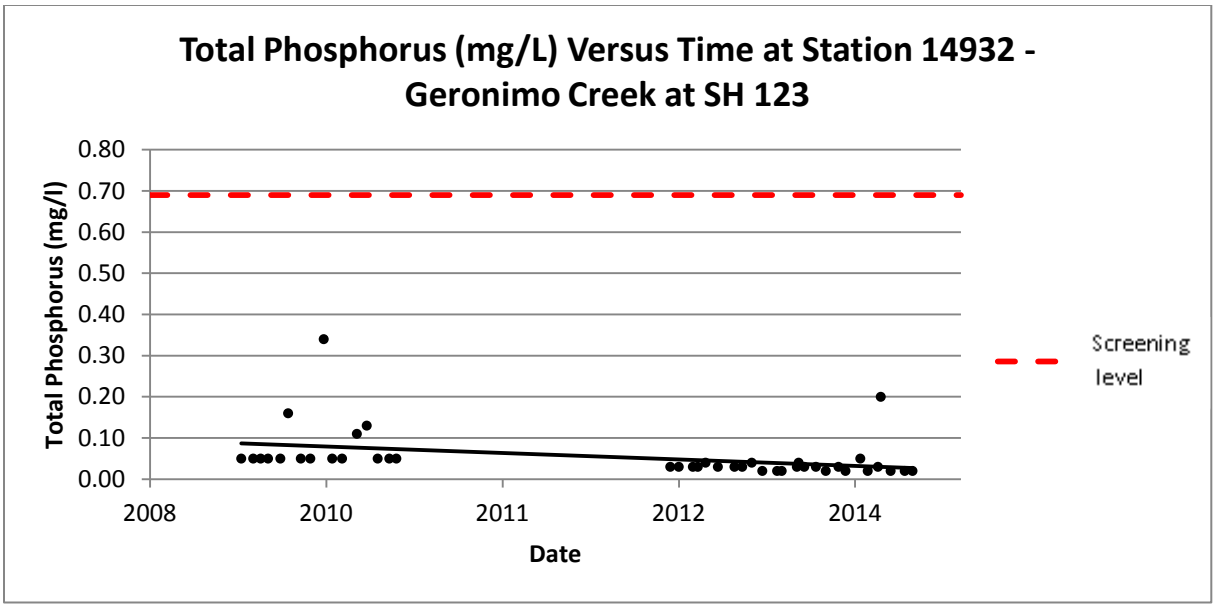

Figure 24. Total Phosphorus (mg/L) Versus Time at Station 14932 - Geronimo Creek at SH 123

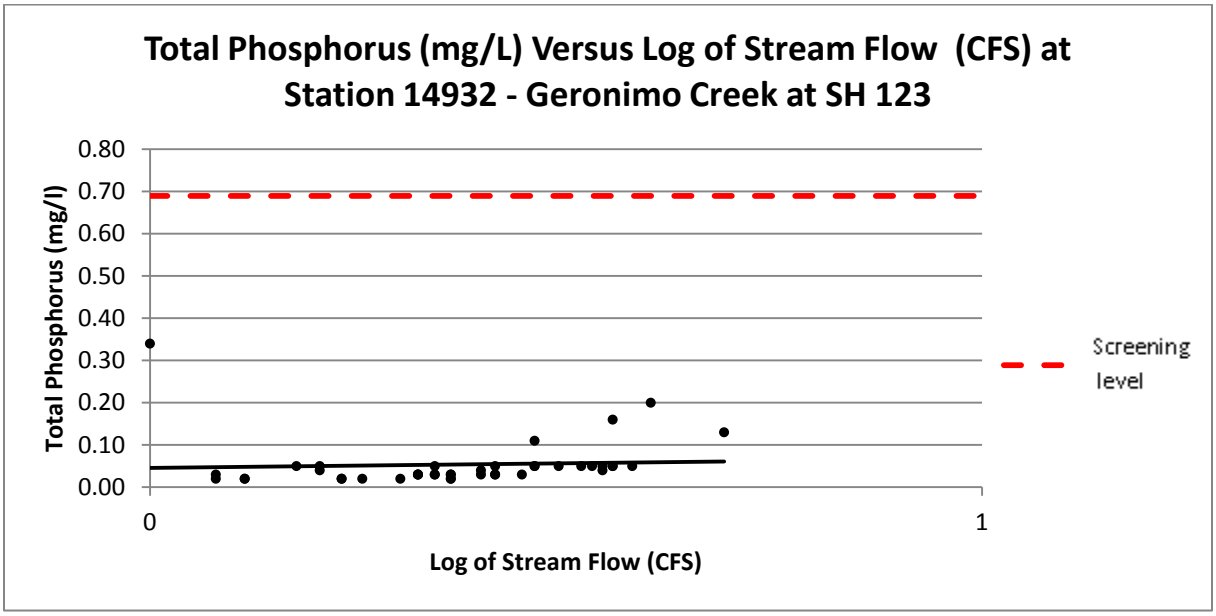

Figure 25. Total Phosphorus (mg/L) Versus Log of Stream Flow (CFS) at Station 14932 - Geronimo Creek at SH 123

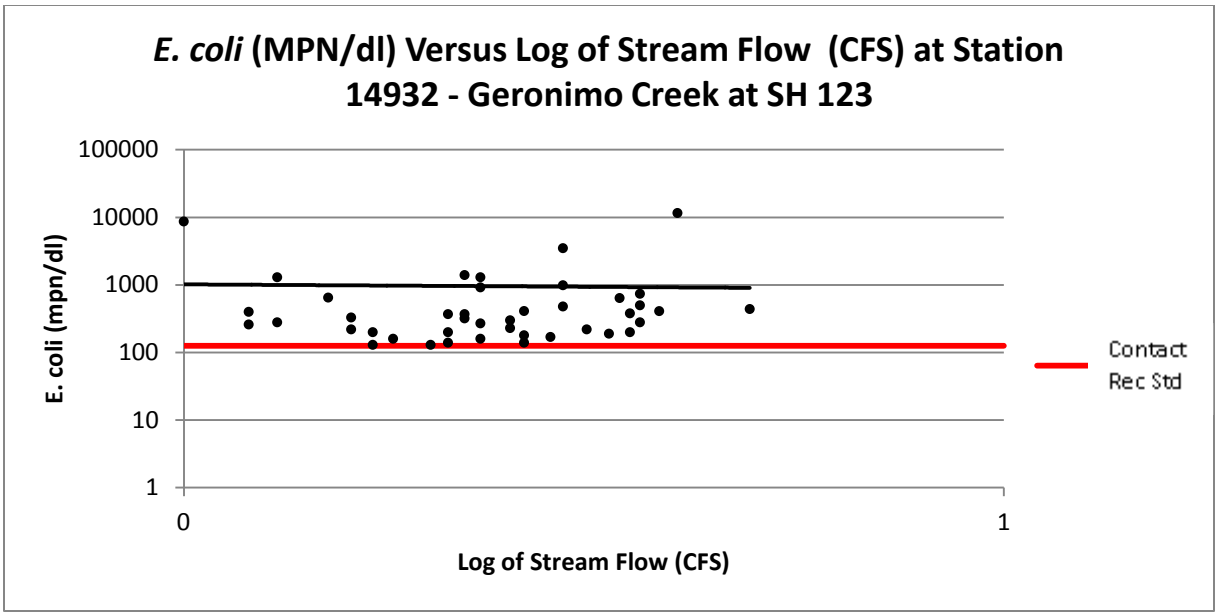

Figure 26. *E. coli* (MPN/dl) Versus Log of Stream Flow (CFS) at Station 14932 - Geronimo Creek at SH 123

At station 20742 (Geronimo Creek at Huber Road) no statistically significant correlations were found between time or stream flow for any of the parameters analyzed. The Geronimo Creek at Huber Road is located 3.3 km upstream of the SH 123 station and approximately 0.3 km upstream of the confluence with Alligator Creek. Station 20742 is the only routine monitoring station in the watershed that is not influenced by spring discharges. The Geronimo Creek at this location is dry during much of the year and almost all of the data points have been collected under wet weather conditions. The limited sample size and small flow variability during collection events probably contributed to the lack of statistically significant correlations at this station.

Station 20743(Alligator Creek at Huber Road) is the only routine monitoring station in the watershed located on the Alligator Creek tributary of Geronimo Creek. Station 20743 is located further upstream in the Geronimo/Alligator Creek watersheds than any other routine monitoring station and is 0.6 km upstream of the confluence with Geronimo Creek. This station is influenced by a groundwater seep and has never been dry during any sample collection events. The water at station 20743 becomes disconnected from downstream monitoring stations and does not flow during times of extreme drought. Only one parameter of interest showed a clear correlation with time at this station. Nitrate-nitrogen is decreasing with time $t(42)=-6.12, p=0.00$, on the Alligator Creek at Huber Road. The graph of this relationship (Figure 27) shows a large number of outliers between 2010 and 2011 that appear to be responsible for this trend. All of the nitrate-nitrogen values greater than 0.5 mg/L that were collected at this station, occurred during sample events when the stream had a small subsistence flow, while the majority of the sample points were collected from stagnant pools of water. The largest stream flow ever recorded at this station was only 0.5 cubic feet per second, and no significant correlation between stream flow

and nitrate-nitrogen was found, which could indicate that these high nitrate-nitrogen concentrations were not the result of major rainfall runoff from the surrounding agricultural land. The nitrate-nitrogen concentrations during these minor flow events may also be an indication of the influence of the underlying Leona groundwater, which has high concentrations of nitrate-nitrogen, on this portion of Alligator Creek. A significant correlation between *E. coli* and stream flow $t(26)=3.51, p=0.00$, was also found at this location (Figure 28).

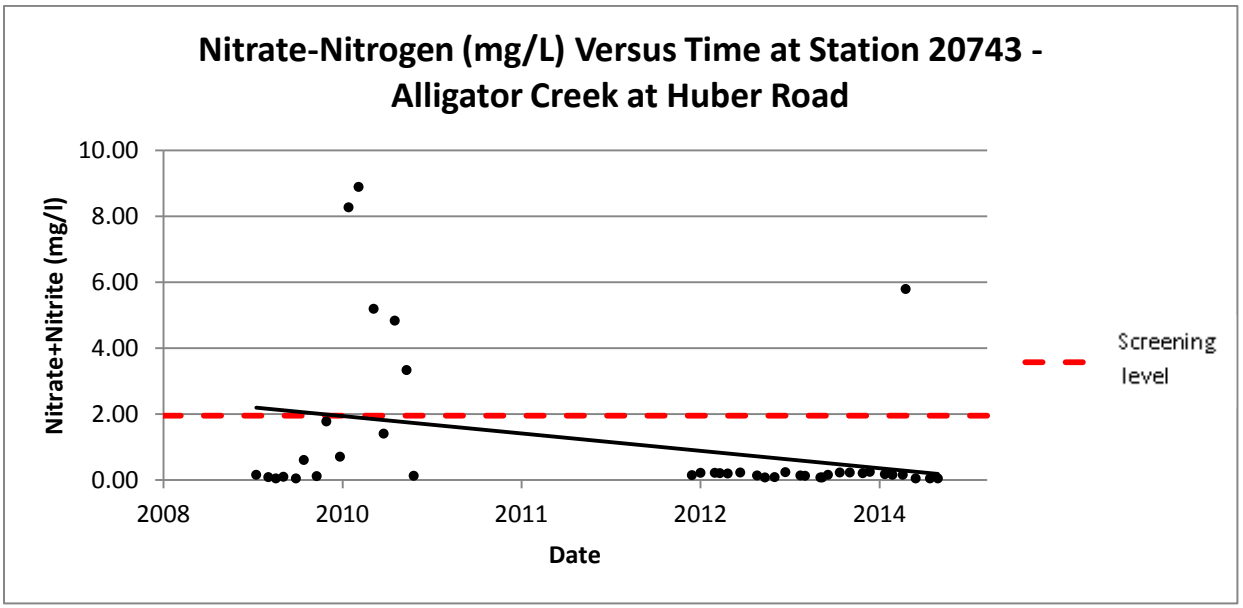

Figure 27. Nitrate-Nitrogen (mg/L) Versus Time at Station 20743 - Alligator Creek at Huber Road.

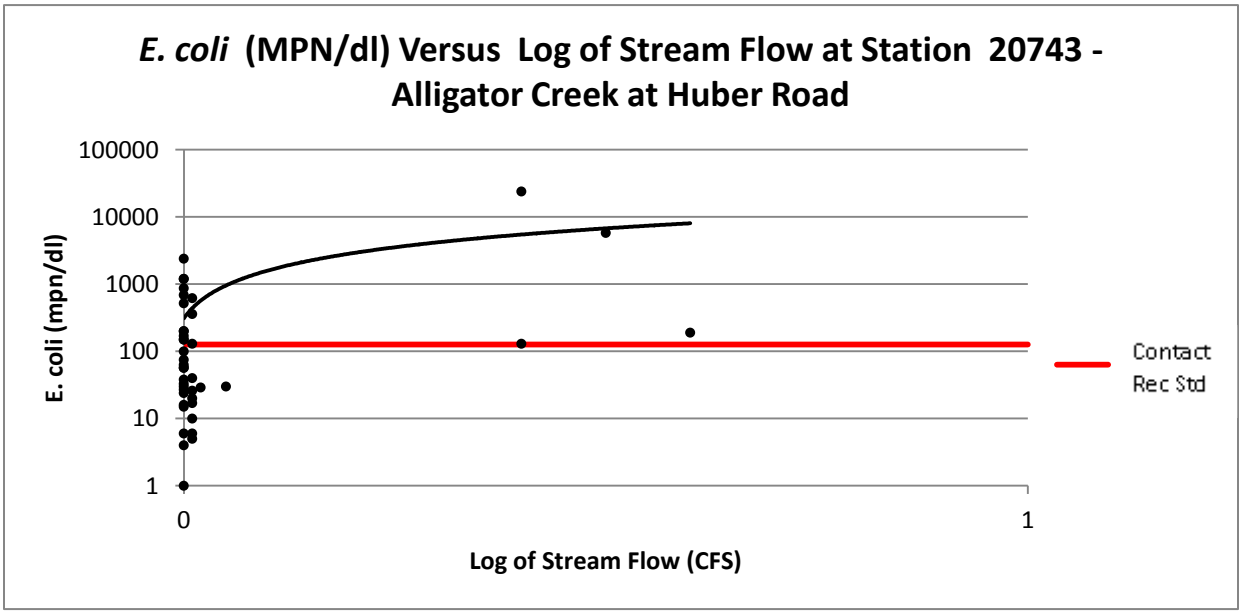

Figure 28. *E. coli* (MPN/dl) Versus Log of Stream Flow (CFS) at Station 20743 - Alligator Creek at Huber Road.

Targeted Monitoring

The objective of the targeted watershed surface water quality monitoring task was to provide water quality data to assess the effectiveness of implementing the Geronimo and Alligator Creeks WPP during targeted flow conditions. GBRA attempted to conduct targeted watershed monitoring at 14 sites twice per season, once under dry weather conditions and once under wet weather conditions, collecting field, conventional, flow and bacteria parameter groups. Of these 14 sites, 8 sites were the same as the sites for routine ambient monitoring. Spatial, seasonal and meteorological variations were captured in these snapshots of watershed water quality. GBRA's Regional Laboratory conducted the sample analysis. Field parameters are pH, temperature, conductivity and dissolved oxygen. Conventional parameters are total suspended solids, sulfate, chloride, nitrate-nitrogen, ammonia-nitrogen, Total Kjeldahl Nitrogen and total phosphorus. Flow is collected by mechanical or Doppler, including severity. Bacteria parameters were *E. coli*.

The GBRA collected data from eight quarterly targeted monitoring stations throughout the Geronimo and Alligator Creek watersheds between May of 2009 and August of 2014. The majority of these monitoring stations were dry for large portions of the monitoring project and consequently did not have enough data available to perform a trending evaluation. The only quarterly monitoring station with perennial flow was station 12575 (Geronimo Creek at FM 20). This station was located just downstream of the TCEQ Clean Rivers Program Monitoring station 12576 (Geronimo Creek at Haberle Road) and upstream of station 21260 (Geronimo Creek at IH 10). This station had 18 data points available for trends analysis; however, none of the parameters evaluated showed any significant correlations with either time or stream flow.

Groundwater Monitoring

The objective of the groundwater monitoring task was to provide water quality data to access the effectiveness of implementing the Geronimo and Alligator Creeks WPP through spring flow and groundwater monitoring. GBRA conducted groundwater monitoring at 2 wells and one spring once per season collecting field, conventional, flow and bacteria parameter groups. All sampling events were conducted.

GBRA's Regional Laboratory conducted the sample analysis. Field parameters are pH, temperature, conductivity and dissolved oxygen. Conventional parameters are total suspended solids, sulfate, chloride, nitrate-nitrogen, ammonia-nitrogen, Total Kjeldahl Nitrogen and total phosphorus. Flow is collected by mechanical or Doppler, including severity. Bacteria parameters were *E. coli*. Data supports the source of the elevated nitrate-nitrogen concentrations from groundwater.

Table 6. Pollutants of concern in the groundwater. Timmerman Springs was added to monitoring schedule in November 2012.

Site	No. of Samples	Flow Mean	E. coli Geomean	E. coli Range	Tot P Mean	Tot P Range	NO3-N Mean	NO3-N Range	NH3-N Mean	NH3-N Range
Timmerman Springs	8	0.29	2	<1-8	<0.02	<0.02-0.02	15.9	14.4-17.5	0.15	<0.1-0.36
Laubach Well	11	NA	6	<1-330	0.02	<0.02-0.05	17.9	13.6-19.7	0.18	<0.1-0.77
Headwater Well at Huber Road	12	NA	<1	NA	0.03	<0.05-0.06	19.2	17.3-25.2	0. 13	<0.1-0.30

Conclusion

In summary, TSSWCB Project 11-06 titled *Water Quality Monitoring in the Geronimo Creek Watershed and Facilitation of the Geronimo and Alligator Creeks Watershed Partnership* has been completed and was essential to the continued water quality monitoring for the Geronimo and Alligator Creeks WPP. Water quality was monitored and updates were presented regularly to stakeholders. Furthermore, facilitation of the Partnership was maintained and stakeholders were engaged in implementation through a variety of educational workshops, meetings, and events. Outreach to the stakeholders was accomplished through a variety of methods including email, newsletters, press releases, newspaper and radio ads, and the project webpage.

Implementation of the Geronimo and Alligator Creeks WPP is continuing through TSSWCB Project 14-08 titled *Coordinating Implementation of the Geronimo and Alligator Creeks Watershed Protection Plan.* This work plan facilitates continued implementation of management measures contained in the WPP, while providing for regularly scheduled Partnership meetings. The work plan continues to support the watershed coordinator position, who will assist project partners in grant proposal development, coordinate outreach and education efforts, and will communicate water quality conditions to the public in order to support adaptive management.

List of Acronyms

CFS	Cubic Feet per Second
CRP	Clean Rivers Program
EPA	United States Environmental Protection Agency
GACWPP	Geronimo and Alligator Creeks Watershed Protection Plan
GBRA	Guadalupe-Blanco River Authority
ILSOLC	Irma Lewis Seguin Outdoor Learning Center
ISD	Independent School District
MPN	Most Probable Number
NPS	Non Point Source
SWCD	Soil and Water Conservation District
TCEQ	Texas Commission on Environmental Quality
TSSWCB	Texas State Soil and Water Conservation Board
USGS	United States Geological Survey
WPP	Watershed Protection Plan
WQMP	Water Quality Management Plan