

Llano River Data Report

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Table of Contents

Introduction	2
Water Quality Parameters	3
Water Temperature	3
Dissolved Oxygen	4
Specific Conductivity	4
pH	4
Secchi Disk Transparency and Total Depth.....	5
<i>E. coli</i> Bacteria.....	5
Orthophosphate	5
Nitrate-Nitrogen	6
Data Analysis	6
Llano River Watershed Statistics	8
Colorado River Watch Network Llano River Citizen Water Quality Monitoring Locations Map.....	8
Upstream to Downstream Trends.....	9
Watershed Trends Through Time.....	11
Site-by-Site Analyses	13
S. Llano River at S. Llano River State Park.....	13
S. Llano River at Flatrock Ln.	15
Llano River Above Johnson Fork	17
Llano River at CR 2389	19
Llano River at Scotts Slab	21
Llano River at Llano City Park.....	23
Llano River Below Highway 16	25
Llano River Below Llano WWTP	27
Llano River at SR 3404.....	29
References	31

Introduction

This report covers the data collected by Colorado River Watch Network volunteer water quality monitors at 9 sites along the Llano River and the South Llano River. The Llano River begins in central Kimble County, approximately 4 miles northwest of Junction, where the North and South Llano Rivers meet and flows about 100 miles through Kimble, Mason, and Llano counties, draining about 4,466 mi² (11,568 km²) of the Edwards Plateau before emptying into the Colorado River at Lake LBJ near Kingsland.^{i,ii} The South Llano River rises in northwestern Edwards County and runs northeast for fifty five miles to meet the Llano River (see map below).ⁱⁱⁱ



The clay and sandy loams through which it flows support oak, juniper, pecan, mesquite, and a variety of grasses.^{iv} The river has never stopped flowing due to the presence of several large springs, which contribute about 80% of the flow. After it flows into the Highland Lakes, it forms the primary water supply for the City of Austin and other downstream water users along the Colorado River.^v Land use includes agriculture, particularly livestock, pecan and hay production, recreation, natural gas production, and urban as it passes through Llano and Junction.^{vi} The South Llano River Watershed Alliance has formed to protect the quantity and quality of the river. Details can be found at <http://southllano.org/>.

In alignment with Texas Stream Team's core mission, monitors attempt to collect data that can be used in decision-making processes, to promote a healthier and safer environment for people and aquatic inhabitants. While many assume it is the responsibility of Texas Stream Team to serve as the main advocate for volunteer monitor data use, it has become increasingly important for monitors to be accountable for their monitoring information and how it can be infused into the decision-making process, from "backyard" concerns to state or regional issues. To assist with this effort, Texas Stream Team coordinates with monitoring groups and government agencies to propagate numerous data use options.

Among these options, volunteer monitors can directly participate by communicating their data to various stakeholders. Some options include: participating in the Clean Rivers Program (CRP) Steering Committee Process; providing information during "public comment" periods; attending city council and advisory panel meetings; developing relations with local Texas Commission on Environmental Quality and river authority water specialists; and, if necessary, filing complaints with environmental agencies; contacting elected representatives and media; or starting organizing local efforts to address areas of concern.

The Texas Clean Rivers Act established a way for the citizens of Texas to participate in building the foundation for effective statewide watershed planning activities. Each CRP partner agency has established a steering committee to set priorities within its basin. These committees bring together the diverse interests in each basin and watershed. Steering committee participants include representatives from the public, government, industry, business, agriculture, and environmental groups. The steering committee is designed to allow local concerns to be addressed and regional solutions are recommended. For more information about participating in these steering committee meetings and to contribute your views about water quality, contact the appropriate CRP partner agency for your river basin at: <http://www.tceq.state.tx.us/compliance/monitoring/crp/partners.html>.

Currently, Texas Stream Team is working with various public and private organizations to facilitate data and information sharing. One component of this process includes interacting with watershed stakeholders at CRP steering committee meetings. A major function of these meetings is to discuss water quality issues and to obtain input from the general public. While participation in this process may not bring about instantaneous results, it is a great place to begin making institutional connections and to learn how to “work” the assessment and protection system that Texas agencies use to keep water resources healthy and sustainable.

In general, Texas Stream Team efforts to use volunteer data may include the following:

1. Assist monitors with data analysis and interpretation
2. Analyze watershed-level or site-by-site data for monitors and partners
3. Screen all data annually for values outside expected ranges
4. Network with monitors and pertinent agencies to communicate data
5. Attend meetings and conferences to communicate data
6. Participate in CRP stakeholder meetings
7. Provide a data viewing forum via the Texas Stream Team Data Viewer
8. Participate in professional coordinated monitoring processes to raise awareness of areas of concern

Information collected by Texas Stream Team volunteers utilizes a TCEQ and EPA approved quality assurance project plan (QAPP) to ensure data are correct and accurately reflects the environmental conditions being monitored. All data are screened for completeness, precision and accuracy where applicable, and scrutinized with data quality objective and data validation techniques. Sample results are intended to be used for education and research, baseline, local decision making, problem identification, and others uses deemed appropriate by the data user.

Water Quality Parameters

Water Temperature

Fish are cold-blooded and therefore depend on the temperature of water to be able to carry out processes such as metabolism and reproduction. Sources of warm water include powers plants’ effluent after it has been used for cooling or hydroelectric plants which release warmer or cooler water (depending on the time of year) near the point of release. On a yearly scale, the amount of dissolved oxygen in the water decreases as temperatures increase, and vice versa, because warmer, less dense water can hold less oxygen molecules than cooler, more dense water. However, on a daily scale, the amount of dissolved oxygen in the water increases as temperatures increase, and vice versa, because of photosynthesis adding oxygen to the water body. Water temperature variations are most detrimental when they occur rapidly, leaving the biotic community no time to adjust. However, volunteer monitoring occurs at a particular time, so these variations are not covered in this report.

Dissolved Oxygen

Oxygen is necessary for the survival of most organisms. Too little oxygen will lead to asphyxiation of aquatic organisms. Too much oxygen (supersaturation) can cause bubbles to develop in cardiovascular systems, which could be fatal. Dissolved oxygen (DO) levels below 2 milligrams per liter (mg/L) can lead to asphyxiation, and levels above 20 mg/L can lead to supersaturation. The most suitable aquatic environment exhibits levels above 5 mg/L. High concentrations of nutrients can lead to excessive surface vegetation growth, which may starve subsurface vegetation of sunlight, and therefore limit the amount of dissolved oxygen in a water body due to limited photosynthesis. This process is enhanced when the subsurface vegetation dies and consumes oxygen when decomposing. Low dissolved oxygen levels may also result from high groundwater inflows as groundwater is typically low in dissolved oxygen due to minimal aeration or high temperatures which reduce oxygen solubility. Supersaturation typically only occurs underneath waterfalls or dams with water flowing over the top.

Specific Conductivity

Specific conductivity is a measure of the ability of a body of water to conduct electricity. It is measured in microSiemens per centimeter ($\mu\text{S}/\text{cm}$). A body of water is more conductive if it has more dissolved materials such as nutrients and salts, which indicate poor water quality if they are abundant. High concentrations of nutrients lower dissolved oxygen, the process of which was described in the previous section. High concentrations of salt can inhibit water absorption and limit root growth for vegetation, lead to an abundance of more drought tolerant plants, and cause dehydration of fish and amphibians. Sources of total dissolved solids (TDS) can include agricultural runoff, domestic runoff, or discharges from wastewater treatment plants.

pH

pH is a measure of acidity or alkalinity. The scale measures the concentration of hydrogen ions on a range of 0 to 14 and is reported in standard units (su). The range is logarithmic. Therefore, every 1 unit change means the acidity increased or decreased 10-fold. Sources of low pH (acidic) can include acid rain and runoff from acid-laden soils. Acid rain is mostly caused by coal power plants with minimal contributions from the burning of other fossil fuels and other processes such as volcanic emissions. Soil-acidity can be caused by excessive rainfall leaching alkaline materials out of soils, acidic parent material, crop decomposition creating hydrogen ions, or high-yielding fields which have drained the soil of all alkalinity. Sources of high pH (alkaline) include geologic composition as in the case of limestone increasing alkalinity and the dissolving of carbon dioxide in water. Carbon dioxide is water soluble, and as it dissolves it forms carbonic acid, an alkaline molecule. The most suitable range for healthy organisms is 6.5-9.

Transparency and Total Depth

The Transparency Tube is used to determine the clarity of the water, a condition known as turbidity. The tube shown on the right is filled with water from the sampling site. Water is then released until the Secchi Disk on the bottom of the tube becomes visible,, and the depth is recorded. Highly turbid waters pose a risk to wildlife by clogging the gills of fish, reducing visibility, and carrying contaminants. Reduced visibility can harm predatory fish or birds that depend on good visibility to find their prey. Turbid waters allow very little light to penetrate deep into the water, which in turn decreases the density of phytoplankton, algae, and other aquatic plants. This reduces the dissolved oxygen in the water due to reduced photosynthesis. Contaminants are most commonly transported in sediment rather than in the water. Turbid waters can results from sediment washing away from construction sites, erosion of farms, or mining operations. Average Transparency Tube readings below Total Depth readings indicate there to be limited transparency. Readings that are equal to total depth indicate clear water. Low total depth observations have a potential to concentrate contaminants.



E. coli Bacteria

E. coli bacteria originate in the digestive tract of warm-blooded organisms. The EPA has determined *E. coli* to be the best indicator of the degree of pathogens in a water body. A pathogen is basically anything that can make a person ill. They are far too numerous to be tested for directly, considering the amount of water bodies monitored. Sources include livestock, pets, failing septic systems and wastewater treatment plants, or wildlife around the water body. The standard is currently set at 394 colony forming units per 100 milliliters (cfu/100mL). At this level, 8 in 1,000 people might become ill if recreating in the water body. 25% of 7 samples with the same reasonable amount of time between them within the last 10 years must exhibit counts higher than 394 cfu/100 mL for a water body to be considered impaired. There is also a standard for a geometric mean, a type of average which is not heavily weighted by zeros. That standard is 126 cfu/100mL. A water body is also considered impaired if the geometric mean is higher than this standard.

Orthophosphate

Orthophosphate is the phosphate molecule all by itself. Phosphorus almost always exists in the natural environment as phosphate, which continually cycles through the ecosystem as a nutrient necessary for the growth of most organisms. Testing for orthophosphate detects the amount of phosphate in the water itself, excluding the phosphate bound up in plant and animal tissue. There are other methods to retrieve the phosphate from the material to which it is bound, but they are too complicated and expensive to be conducted by a volunteer monitors. Testing for orthophosphate gives us an idea of the degree of phosphate in a water body. It can be used for problem identification, which can be followed up with more detailed professional monitoring, if necessary. Phosphorus inputs into a water body may be the weathering of soils and rocks, discharge from wastewater treatment plants, excessive fertilizer use, failing septic systems, livestock and pet waste, disturbed land areas, drained wetlands, water treatment, and some commercial cleaning products. The effect orthophosphate has on a water body is known as eutrophication and is described above under the “Dissolved Oxygen” section.

Nitrate-Nitrogen

Nitrogen is present in terrestrial or aquatic environments as nitrates, nitrites, and ammonia. Nitrate-nitrogen tests are conducted for maximum data compatibility with the TCEQ and other partners. Just like phosphorus, nitrogen is a nutrient necessary for the growth of most organisms. Nitrogen inputs into a water body may be livestock and pet waste, excessive fertilizer use, failing septic systems, and industrial discharges that contain corrosion inhibitors. The effect nitrogen has on a water body is known as eutrophication and is described above under the “Dissolved Oxygen” section. Nitrates dissolve more readily than phosphates, which tend to be attached to sediment, and therefore can serve as a better indicator of the possibility of sewage or manure pollution during dry weather.

Data Analysis

Volunteers with the Colorado River Watch Network, a partner of Texas Stream Team, have collected data at 9 sites along the Llano River for varying periods of time spanning from 1996 to present. The data indicate that the Llano River is a suitable ecosystem for aquatic life. All but 4 water temperature observations stayed below the standard for the Llano River (91 °F). The 4 exceedances occurred in June or July when the heat of summer was most likely the cause. Furthermore, the water temperature consistently followed seasonal fluctuations, indicating the low chance of any other cause of change in water temperature.

All but 1 of the pH observations stayed within the standards (6.5-9). This 1 exceedance occurred in 1996. None of the 491 dissolved oxygen observations fell below the standard for exceptional aquatic life use (4 mg/L), and data at all sites followed seasonal fluctuations. As temperature increases in the summer, the dissolved oxygen decreases and vice versa for the winter. This indicates the low chance of any other cause of change in dissolved oxygen.

Only one conductivity value of 540 $\mu\text{S}/\text{cm}$ just barely exceeded the standard (538 $\mu\text{S}/\text{cm}$). The average transparency tube depth of 0.97 m is roughly half a meter less than the average total depth (1.48 m) for the watershed. This indicates there might be limited visibility near the riverbed at some areas. See the site-by-site analysis below for more details on this. However, an average of $\frac{1}{2}$ of a meter of visibility across the watershed indicates mostly clear water, meaning that heavy sedimentation of the river is not an issue for the Llano River. It is important to note that 1.2 m is the highest value which can be read on the transparency tube, so readings shown at 1.2 actually reflect possible greater visibility. Total depth measurements are highly variable at each site. This could be either caused by the monitors slightly changing their monitoring locations or alterations in spring flows.

302 total nitrate-nitrogen measurements were conducted. The method used can only detect values as low as 1 mg/L. Values appearing less than 1 mg/L are recorded as <1 mg/L, not 0 since the test is not accurate enough to detect values lower than 1 mg/L. 96% of observations were <1 mg/L. The screening level for freshwater streams is 1.95 mg/L. This indicates that nitrate-nitrogen is not an issue for the Llano River. 3% of the observations were equal to 1 mg/L. 1 observation was greater than 1 mg/L but less than 2 mg/L, and 1 was equal to 4 mg/L. This 4 mg/L value was observed in 2000 at “Llano River at Llano City Park.”

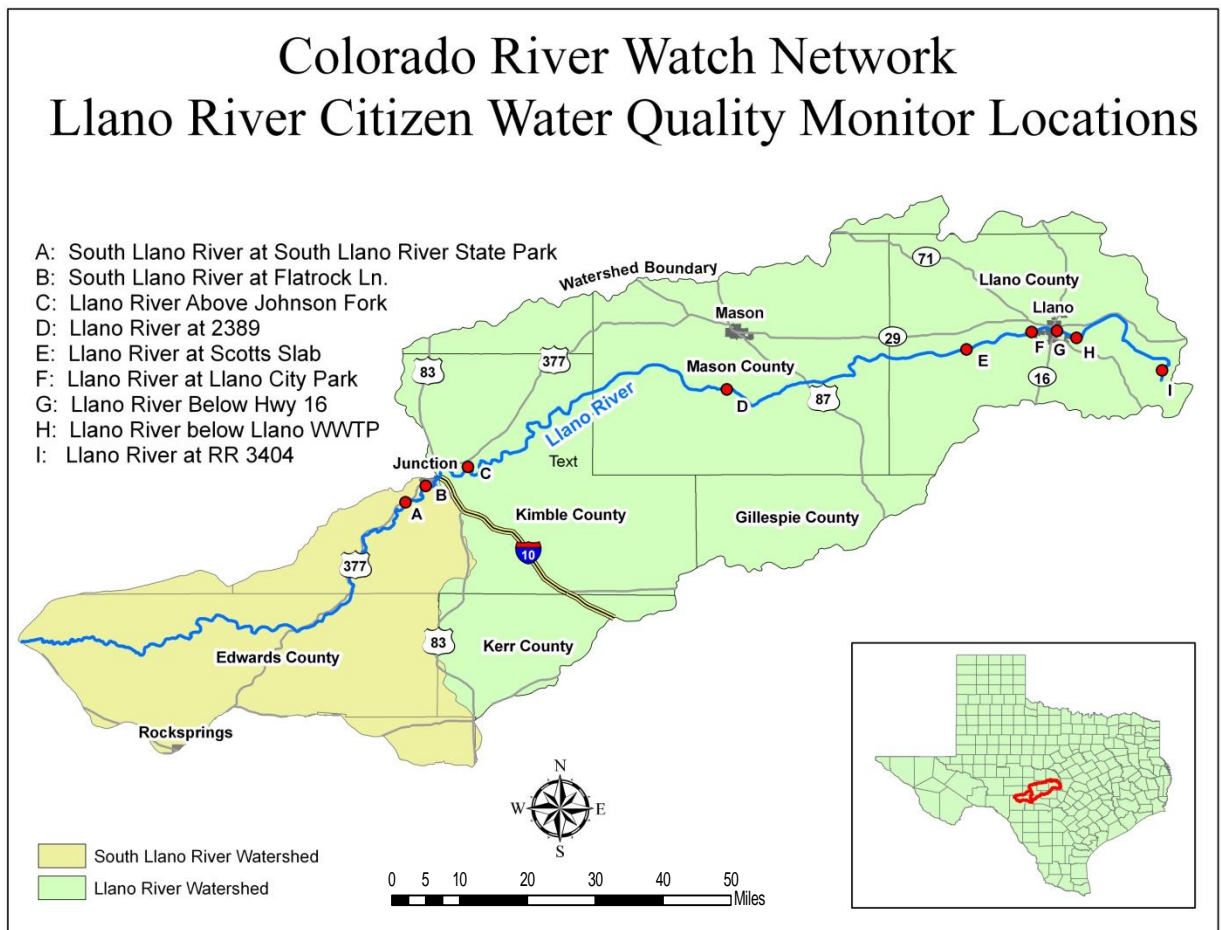
The data indicate that the Llano River is also a suitable water body for contact recreation. The geometric mean for the 222 observations since 1996 is 40.2 cfu/100mL, well below the standard of 126 cfu/100mL. 6/8 of the single sample exceedances occurred when it rained that day. 1 occurred when it had been 1 day since significant precipitation. These high counts were most likely the cause of storm water runoff carrying bacteria. The sources of such bacteria are described in the “E. coli Bacteria” section above. One value of 720, which was observed at “Llano River above Johnson Fork” on 11/6/2003, occurred when it had been 27 days since significant precipitation. This must have been caused by something other than storm water runoff such as wildlife around the water body.

The standards shown on the graphs below are the standards according to the Texas Commission on Environmental Quality 2010 Texas Water Quality Standards for the Llano River. At least ten samples from the last seven years with approximately the same interval between sampling events are required for a data set to be considered adequate. 10% of these samples must then exceed the standard for the water body to be considered impaired.^{vii} Seven samples from the last ten years with the same reasonable amount of time between them are required for an E. coli data set to be considered adequate, and 25% of the samples must then exceed the standard for the water body to be considered impaired.

High levels for certain parameters and low levels for others lead to a threatening environment. The water temperature standard is a maximum amount. The conductivity standard is a maximum average amount. The dissolved oxygen standard is a minimum amount. The pH standards are a range, and the E. coli standard is a maximum amount. The orange line on the Orthophosphate graph for “Llano River at Llano City Park” indicates a screening level. There are no numerical standards specifically for nutrients. Screening levels are used instead in order to identify possible concerns. It is important to note that the amount of exceedance is only for reference. Regulatory action by the TCEQ is based on more/different data than that of the Texas Stream Team.

For the site-by-site analyses below, certain ranges are displayed for different parameters on the graphs, depending on the availability of data. When all data are available, the last seven years on record is displayed on the graphs because this is the period used by the TCEQ. The tables show statistics for the entire period of record. Trend lines are displayed on the graphs to enhance the readers’ understanding of the data.

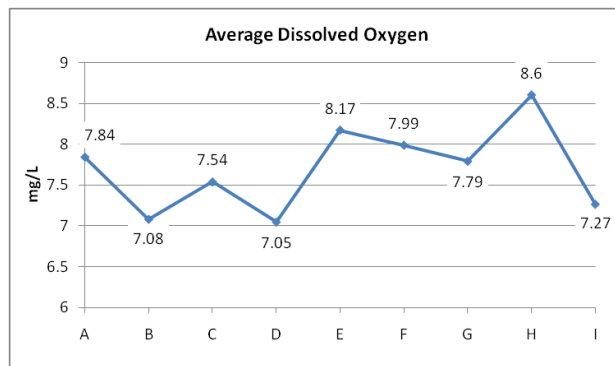
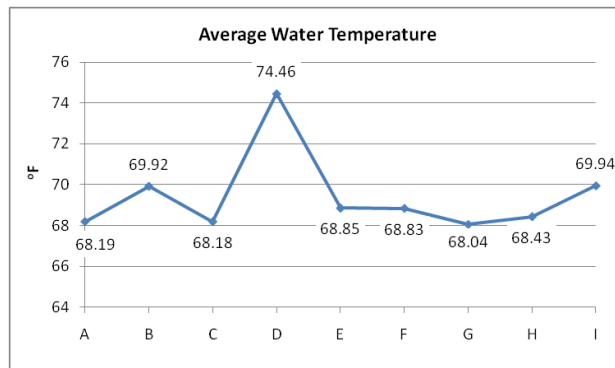
Llano River 1996-2010							
Parameter	#	% Complete	Min.	Avg.	Max.	Std. Dev.	# Exceedance
Water Temperature (°F)	496	99	42.8	69.01	93.2	11.68	4
pH	487	97	6.6	7.92	9.5	0.46	1
Dissolved Oxygen (mg/L)	491	98	4.2	7.65	11.9	1.56	0
Conductivity (µS/cm)	429	86	210	392.18	540	45.94	1
Transparency Tube Depth (m)	116	23	0.17	0.97	1.22	0.29	N/A
Total Depth (m)	353	84	0	1.48	8	1.24	N/A
E. coli Bacteria (cfu/100mL)	222	44	0	65.48	1260	145.78	8
Sample Time	495	99	4:00 AM	12:35 PM	9:00 PM	3:24	N/A

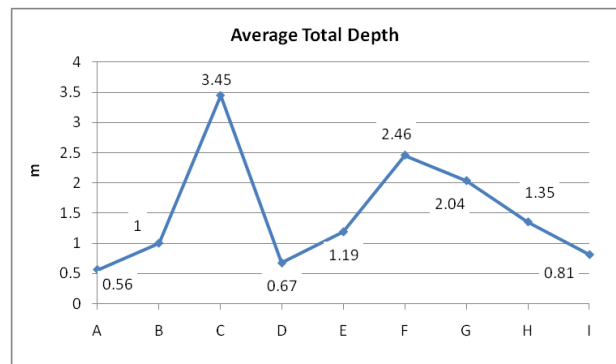
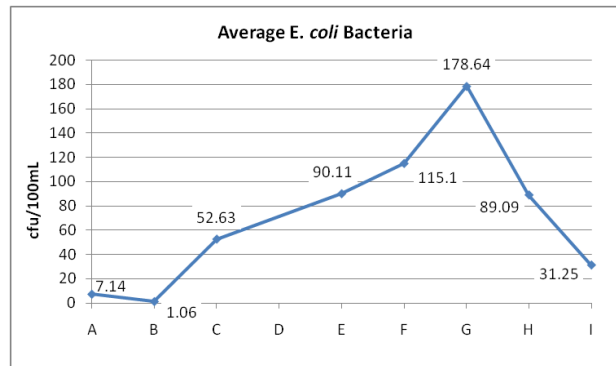
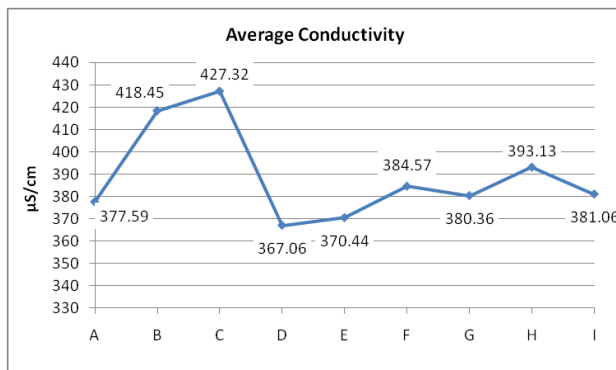
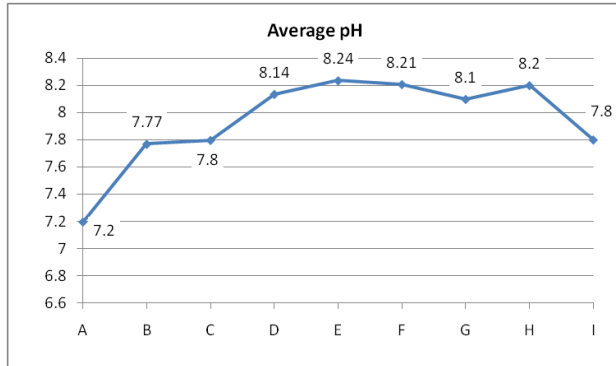


Upstream to Downstream Trends

The letters shown on the x-axis below reference the map shown above. It can be seen here that water temperature stays mostly consistently around 69 °F as the river flows downstream. However, the site “Llano River at CR 2389” has a higher average temperature than the norm. The river splits at this location to flow around a mid-river bar. This higher average temperature may be caused by the fact that less water can be heated more easily by the sun.

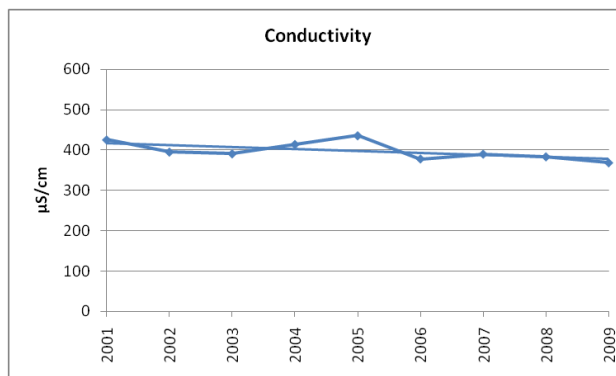
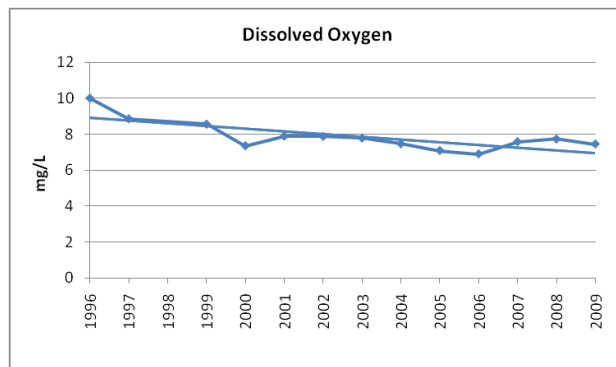
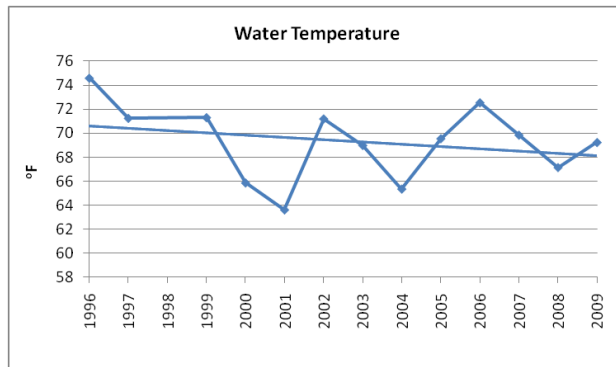
Conductivity increases from “S. Llano River at S. Llano River State Park” to “Llano River Above Johnson Fork” then decreases sharply at “Llano River at 2389” and mostly increases downstream from there. Average dissolved oxygen values vary from upstream to downstream with the highest value at “Llano River Below Llano WWTP.” Average *E. coli* Bacteria values decrease between “S. Llano River at S. Llano River State Park” then increases steadily until the river reaches “Llano River Below Hwy 16” and decreases downstream from there. Average pH values climb from “S. Llano River at S. Llano River State Park” to “Llano River at Scotts Slab” then mostly decrease downstream from there. The average total depth values are highly variable between sites “S. Llano River at S. Llano River State Park” and “Llano River at Llano City Park” but steadily decrease downstream of that site.

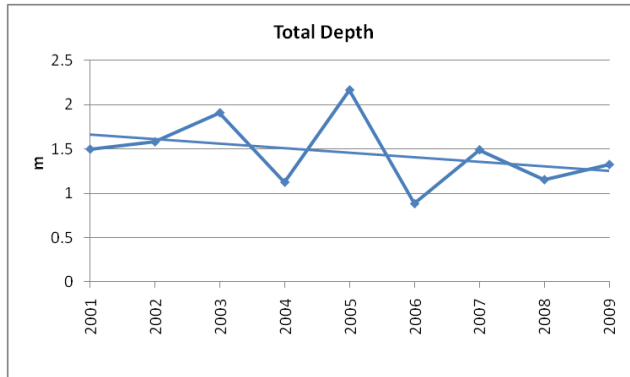
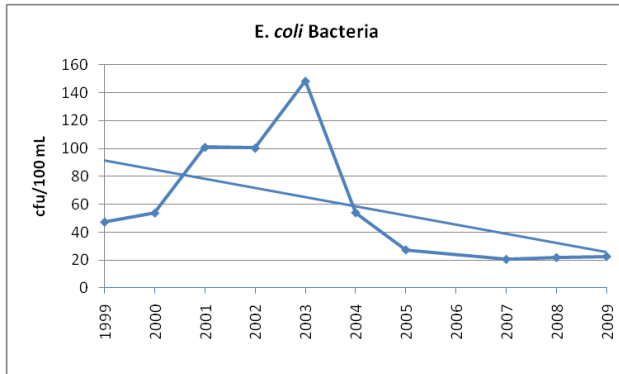
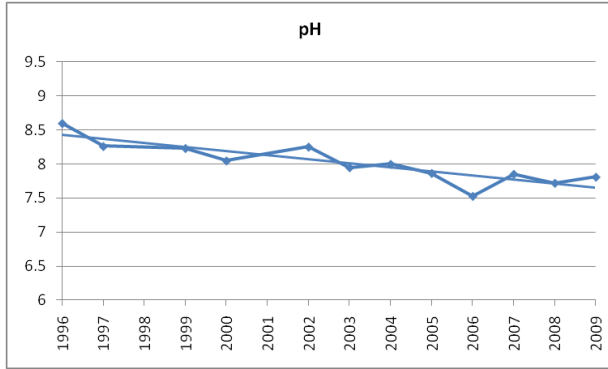




Watershed Trends Through Time

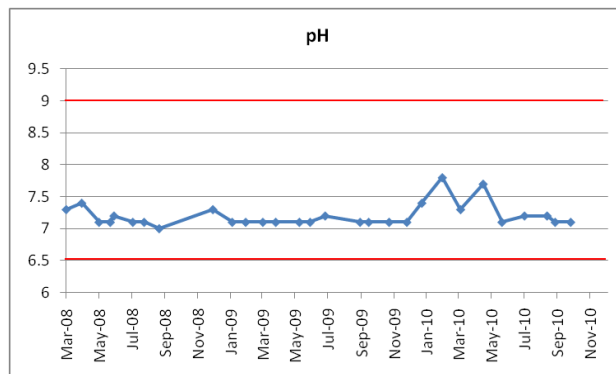
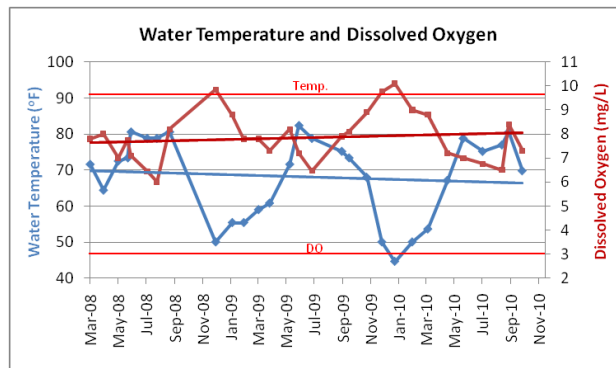
The following graphs show average values for the whole watershed for each year. Water temperature mostly decreased from 1996 to 2001. Values varied around 68°F following 2001. Conductivity stayed mostly near 400 $\mu\text{S}/\text{cm}$ with a slight decrease over the years. Dissolved oxygen stayed mostly around 8 mg/L with a slight decrease over the years. pH has steadily decreased, with few alterations, from an average of 8.6 to an average of 7.7 over the years. *E. coli* Bacteria increased from 1999 to 2003, then sharply decreased from 2004 to 2005 and stayed mostly steady around 20 cfu/100mL since then. Total depth averages have varied between 0.8 m and 2.2 m with a slight downward trend from 2001-2009.

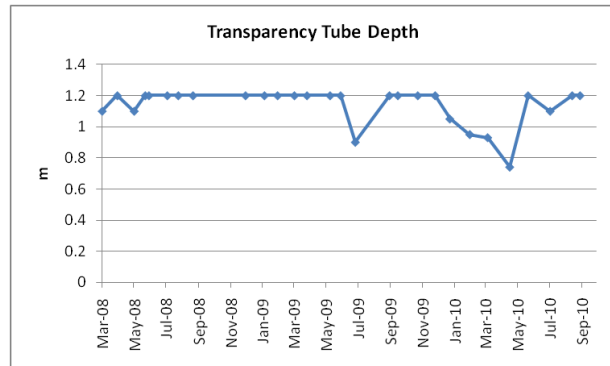
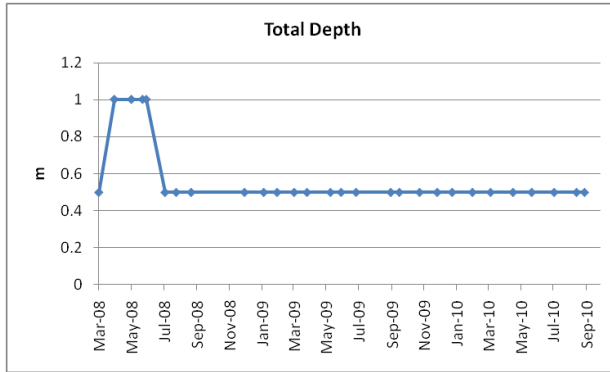
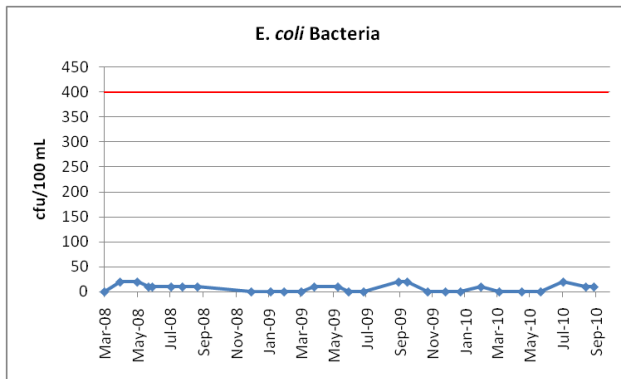
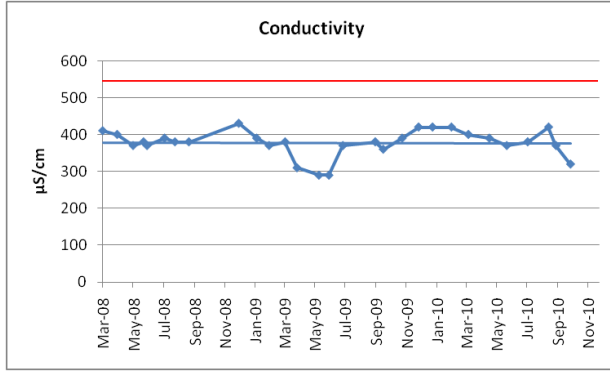




S. Llano River at S. Llano River State Park 2008-2010						
Parameter	#	% Complete	Min.	Avg.	Max.	Std. Dev.
Water Temperature (°F)	29	100	44.6	68.19	82.4	11.39
pH	29	100	7	7.2	7.8	0.18
Dissolved Oxygen (mg/L)	29	100	6	7.84	10.1	1.06
Conductivity (µS/cm)	29	100	290	377.59	430	36.12
Transparency Tube (m)	29	100	0.74	1.14	1.22	0.12
Total Depth (m)	29	100	0.33	0.56	1	0.18
E. coli Bacteria (cfu/100mL)	28	97	0	7.14	20	7.63
Sample Time	29	100	9:00 AM	12:33 PM	4:00 PM	2:13

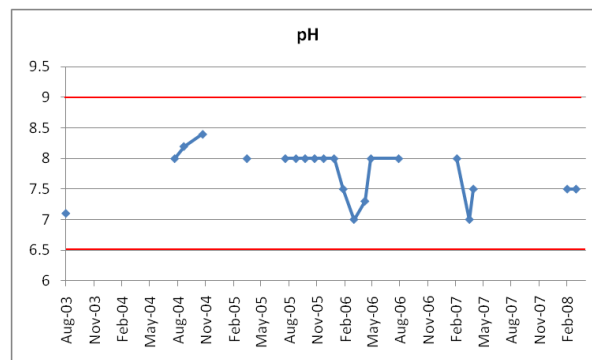
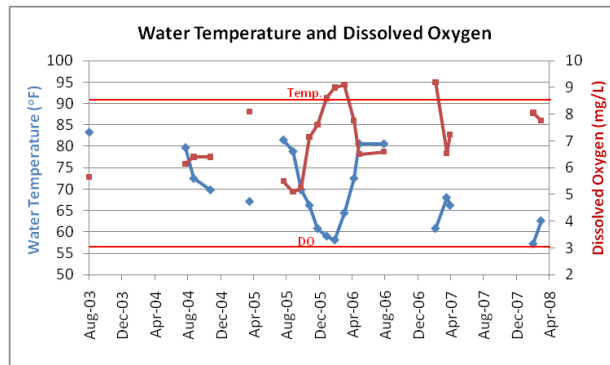
Data at this site were collected by Jayson May with the LCRA Colorado River Watch Network. All parameters stayed within the Texas Surface Water Quality Standards for the Llano River. Water temperature trended slightly downward and dissolved oxygen trended slightly upward from 2008-2010. Conductivity varied steadily around 378 µS/cm, and pH stayed close to 7.2. *E. coli* values were consistently extremely low. Total depth has not varied from 0.5 m since July 2008. The preceding depth of 1 m was not recorded during periods of rainfall. The monitor possibly slightly changed sampling locations or spring flow caused this fluctuation. Transparency tube measurements show that clarity greatly exceeds total depth, indicating very clear water. The 1.2 values shown on the graph are the highest values which can be read with the transparency tube. True values may be higher. All 29 nitrate-nitrogen measurements were <1 mg/L, well below the screening level of 1.95. This indicates nitrate-nitrogen is not a problem at this site.

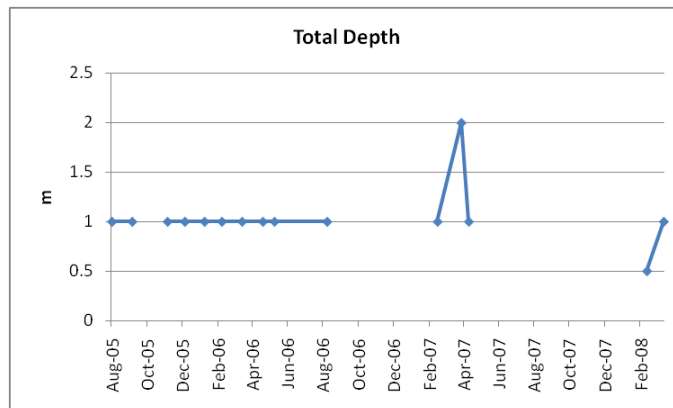
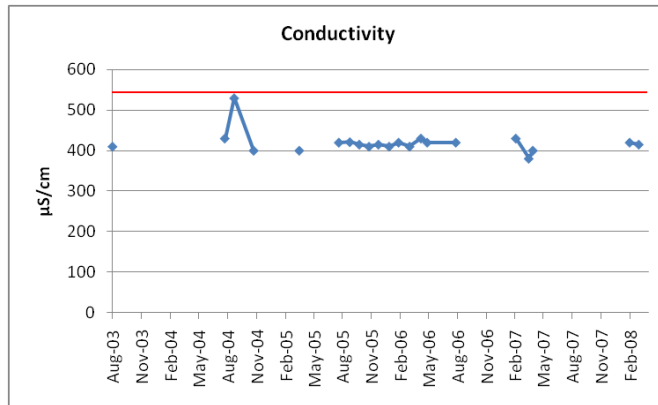




South Llano River at Flatrock Ln. 2003-2008						
Parameter	#	% Complete	Min.	Avg.	Max.	Std. Dev.
Water Temperature (°F)	22	100	57.2	69.92	83.3	8.5
pH	22	100	7	7.77	8.4	0.4
Dissolved Oxygen (mg/L)	22	100	5.1	7.08	9.2	1.25
Conductivity (µS/cm)	22	100	380	418.45	530	27.62
Secchi Disk Transparency (m)	3	14	1.5	1.77	2	0.25
Transparency Tube (m)	2	9	1.2	1.2	1.2	0
Total Depth (m)	16	73	0.5	1	2	0.32
Sample Time	21	95	10:00 AM	1:58 PM	4:33 PM	1:45

Data at this site were collected by Heather Creamer, Kaycie Sullivan, Tiffany Bierschwale, Amanda Camp, Scott Richardson, and Theresa Murray with the LCRA Colorado River Watch Network. All parameters stayed within the Texas Surface Water Quality Standards for the Llano River. With the sporadic sampling at this site, it is difficult to discern trends. The increase of depth from 1 m to 2 m occurred when it had been 5 days since precipitation. Maybe either the monitor slightly changed sampling locations or spring flow caused this fluctuation. All 22 nitrate-nitrogen observations were <1 mg/L, well under the screening level of 1.95 mg/L.



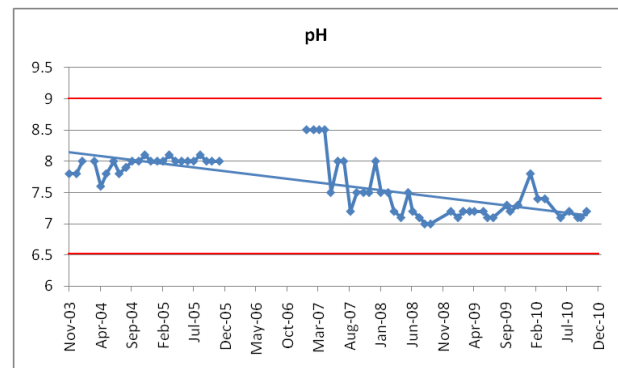
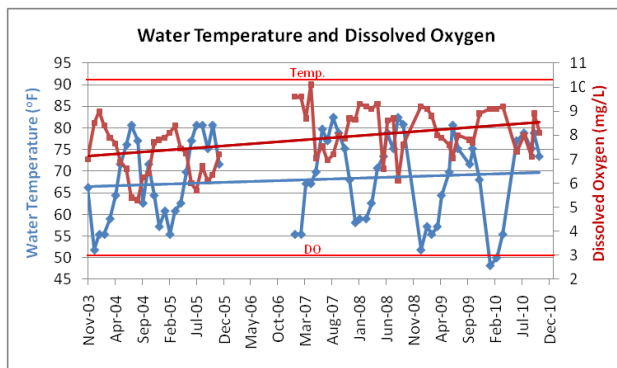


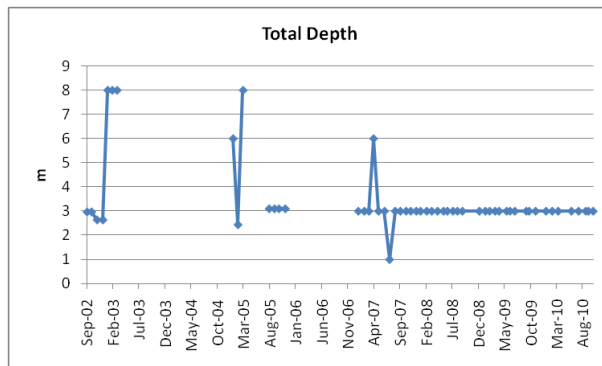
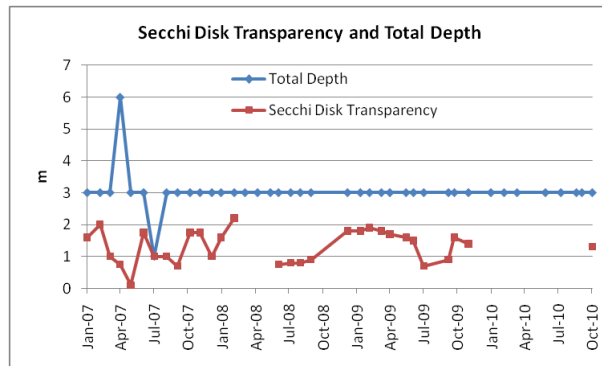
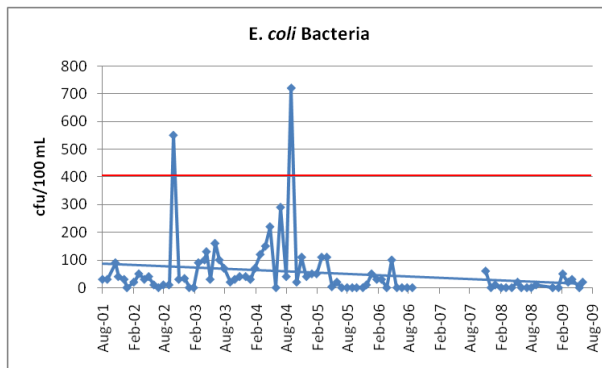
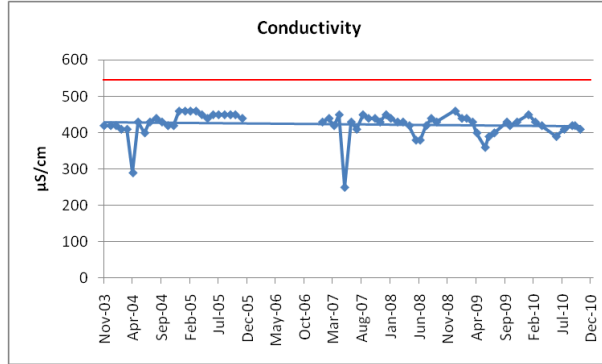
Llano River Above Johnson Fork 1997-2005 & 2007-2010						
Parameter	#	% Complete	Min.	Avg.	Max.	Std. Dev.
Water Temperature (°F)	124	100	42.8	68.18	85.1	10.38
pH	121	98	7	7.8	8.5	0.4
Dissolved Oxygen (mg/L)	123	99	5.1	7.54	10.8	1.33
Conductivity (µS/cm)	97	78	250	427.32	480	31.18
Secchi Disk Transparency (m)	30	24	0.1	1.32	2.2	0.51
Transparency Tube (m)	11	9	0.75	0.94	1.22	0.16
Total Depth (m)	56	45	0	3.45	8	1.63
E. coli Bacteria (cfu/100mL)	94	76	0	52.63	720	100.01
Sample Time	121	98	8:15 AM	11:50 AM	6:45 PM	3:13

Data at this site were collected by Jan Neiman, Bud Haasch, Mary Haasch, and Jayson May with the LCRA Colorado River Watch Network. All parameters except *E. coli* stayed within the Texas Surface Water Quality Standards for the Llano River. Water temperature and dissolved oxygen have trended upward just slightly since 2003. Conductivity remained around 427 µS/cm.

pH trended downward from around 8 to around 7.2, which is good because a neutral environment (pH=7) is most suitable for all aquatic life. *E. coli* trended slightly downward from 2001-2009 with a few spikes. The spike in 2002 occurred when it had been just 1 day since rainfall so was most likely caused by nonpoint source pollution, but the spike in 2004 occurred when it had been 27 days since rainfall. There has consistently been roughly 2 m of transparency with total depth measurements around 3 m. A graph showing transparency tube measurements was omitted because such measurements were so sporadic.

Only 2 of the 7 total depth measurements which were much higher than the normal 3 m occurred when there had been rainfall in the last 3 days. Maybe either the monitor slightly changed sampling locations or spring flow caused these fluctuations. 67/69 nitrate-nitrogen measurements were <1 mg/L. The remaining two were 1 mg/L. These measurements are well below the screening level of 1.95. This indicates nitrate-nitrogen is not a problem at this site.



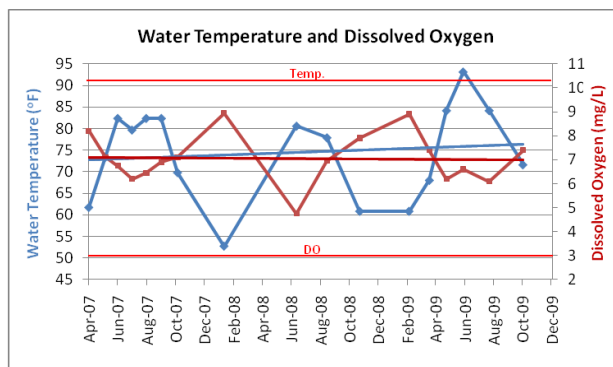


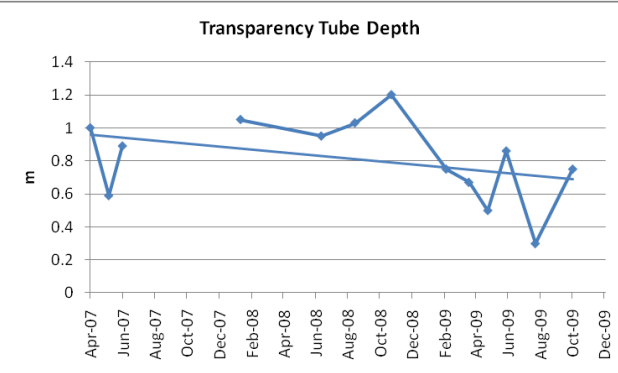
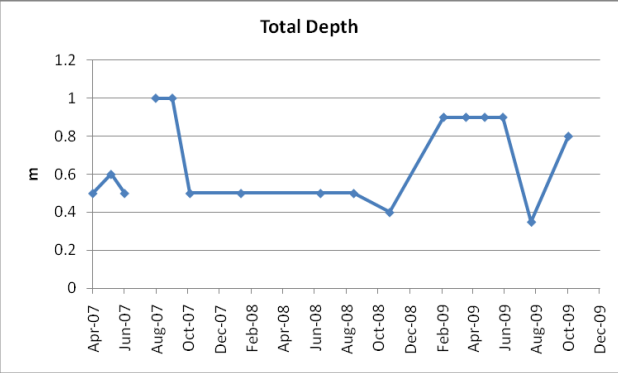
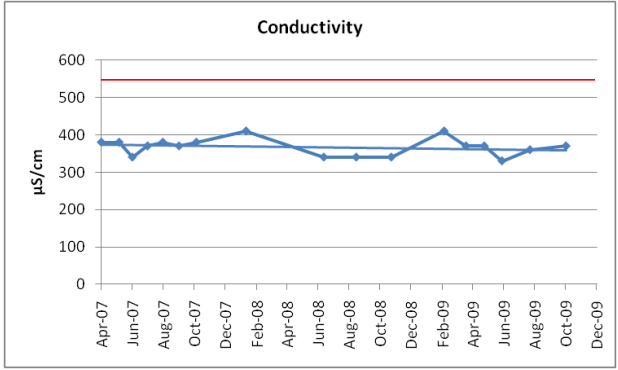
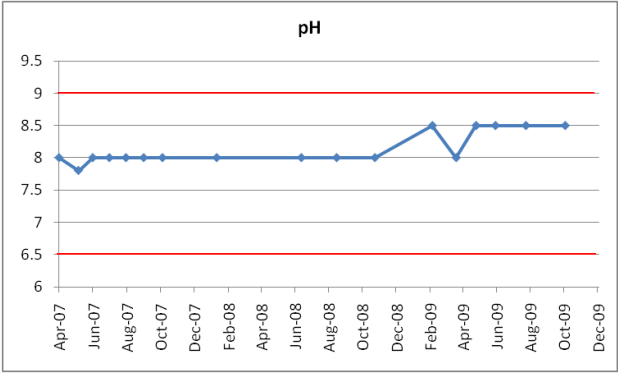
Llano River at CR 2389 2007-2009						
Parameter	#	% Complete	Min.	Avg.	Max.	Std. Dev.
Water Temperature (°F)	17	100	52.7	74.46	93.2	10.87
pH	17	100	7.8	8.14	8.5	0.25
Dissolved Oxygen (mg/L)	17	100	4.75	7.05	8.95	1.05
Conductivity (µS/cm)	17	100	330	367.06	410	23.39
Secchi Disk Transparency (m)	4	24	0.71	0.86	1.05	0.14
Transparency Tube (m)	13	76	0.3	0.81	1.2	0.25
Total Depth (m)	16	94	0.35	0.67	1	0.23
Sample Time	17	100	9:25 AM	1:17 PM	6:15 PM	2:27

Data at this site were collected by Sherra Theisen, Keith Kaan, and Tom Titus with the LCRA Colorado River Watch Network. All parameters except for water temperature stayed within the Texas Surface Water Quality Standards for the Llano River. Water temperature exceeded the standard once in June 2009 most likely due to the summer heat. Water temperature has trended slightly upward from 2007-2009.

Dissolved oxygen varied regularly around 7 mg/L. pH mostly stayed at 8, indicating a slightly basic environment. Conductivity varied regularly with wavering much from 367 µS/cm. The increases in total depth were not correlated with rainfall. Maybe either the monitor slightly changed sampling locations or spring flow caused these fluctuations.

Transparency tube readings were consistently greater than or equal to total depth readings (indicating clear water) until February 2009 when all the readings were less than total depth. You can see the downward trend in visibility at this site on the Transparency Tube Depth graph below. 14/15 nitrate-nitrogen measurements were <1mg/L. The other one was 1 mg/L. These readings are well below the screening level of 1.95 mg/L.

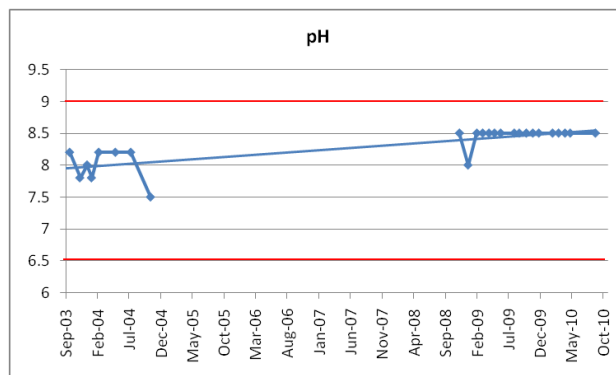
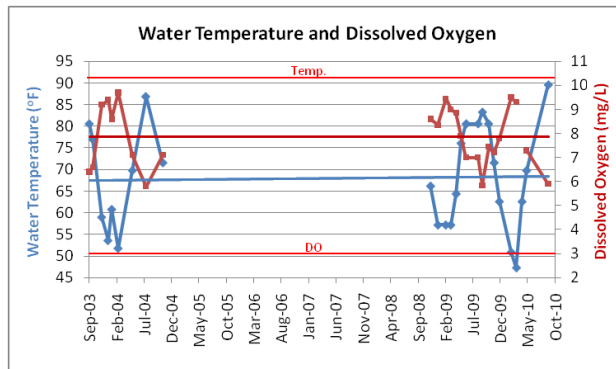


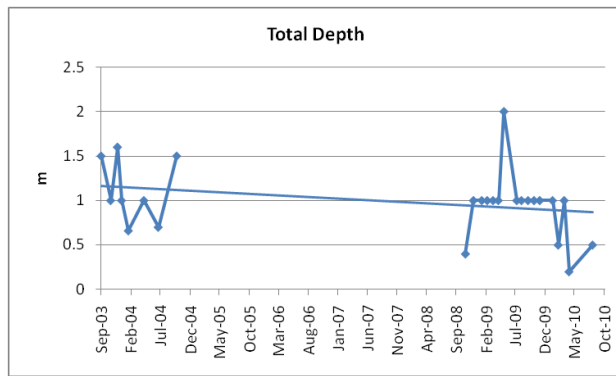
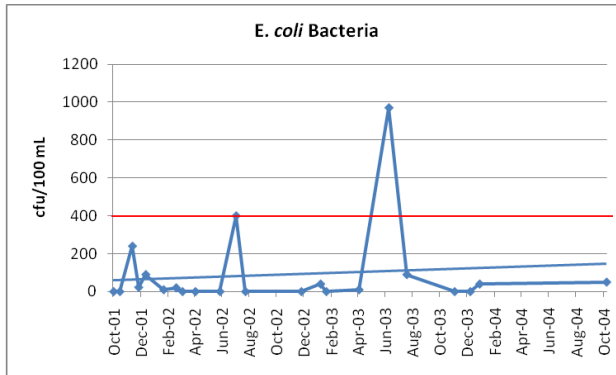
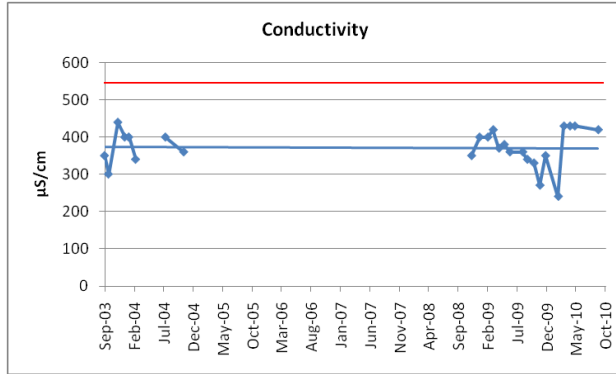


Llano River at Scotts Slab 2001-2004 & 2008-2010						
Parameter	#	% Complete	Min.	Avg.	Max.	Std. Dev.
Water Temperature (°F)	52	96	46.4	68.85	89.6	12.46
pH	51	94	6.6	8.24	8.8	0.42
Dissolved Oxygen (mg/L)	50	93	5.3	8.17	11.3	1.51
Conductivity (µS/cm)	45	83	210	370.44	480	57.17
<i>E. coli</i> Bacteria (cfu/100 mL)	22	41	0	90.11	970	218.53
Total Depth (m)	53	98	0.2	1.19	3.5	0.49
Sample Time	54	100	8:30 AM	3:42 PM	7:30 PM	2:46

Data at this site were collected by Russ Johnson, Lisa Benton, Dan Cone, and Thomas Pinckney with the LCRA Colorado River Watch Network. All parameters except for *E. coli* stayed within the Texas Surface Water Quality Standards for the Llano River. Water temperature, dissolved oxygen, and conductivity stayed mostly consistent from 2003-2010. pH trended upward from around 8 to around 8.5.

E. coli trended slightly upward from 2001-2004 with 2 spikes which occurred when it had rained that day, indicating a high chance of nonpoint source pollution being the cause. Total depth has trended slightly downward from 2003-2010. The increase to 2 m occurred when it had been 9 days since precipitation. Maybe either the monitor slightly changed sampling locations or spring flow caused this fluctuation. 49/50 nitrate-nitrogen measurements were <1 mg/L. The remaining value was 1 mg/L. These measurements are well below the screening level of 1.95 mg/L, indicating that nitrate-nitrogen is not a problem at this site.



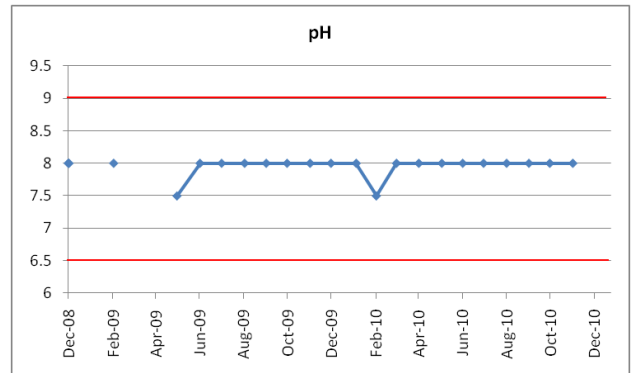
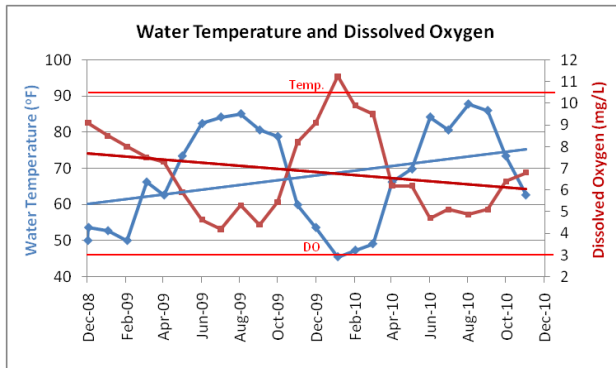


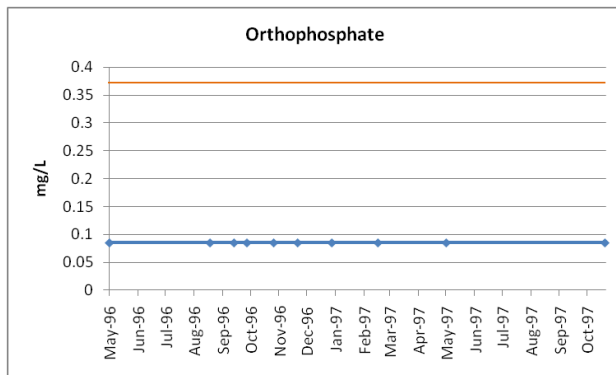
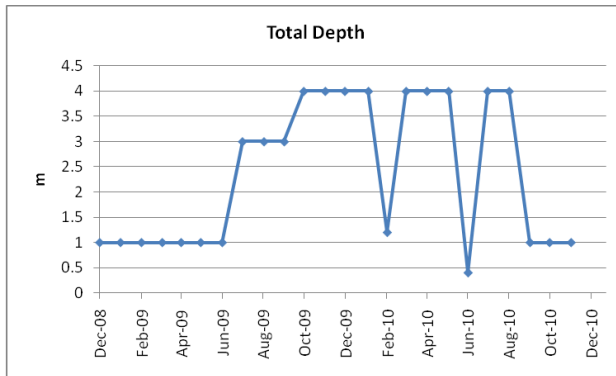
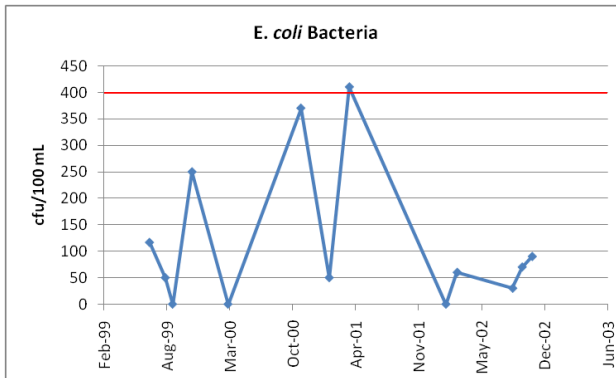
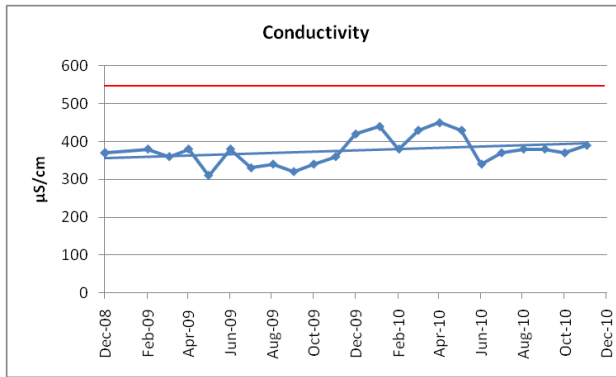
Llano River at Llano City Park 1996-2002 & 2008-2010						
Parameter	#	% Complete	Min.	Avg.	Max.	Std. Dev.
Water Temperature (°F)	55	100	42.8	68.83	89.6	13.17
pH	51	93	7.5	8.21	9.5	0.35
Dissolved Oxygen (mg/L)	55	100	4.2	7.99	11.7	2.07
Conductivity (µS/cm)	35	64	260	384.57	490	49.67
Secchi Disk Transparency (m)	2	4	1	1	1	0
Transparency Tube (m)	25	45	0.17	0.85	1.2	0.39
Total Depth (m)	31	56	0.4	2.46	4	1.34
E. coli Bacteria (cfu/100mL)	13	24	0	115.1	410	138.82
Orthophosphate (mg/L)	10	18	0.09	0.09	0.09	0
Sample Time	55	100	4:00 AM	11:38 AM	5:30 PM	2:36

Data at this site were collected by Jimbo Miller, Donna Thomas, Steven M Hubbel, Joe Long, Beth Long, and Bruce Bush with the LCRA Colorado River Watch Network. All parameters except for *E. coli* stayed within the Texas Surface Water Quality Standards for the Llano River. Water temperature and conductivity trended upward from 2008-2010. Dissolved oxygen trended downward for the same period.

pH stayed around 8 for almost all observations. *E. coli* varied greatly with all spikes occurring when it had been less than 3 days since rainfall, indicating nonpoint source pollution to be the cause. 10/18 of the 3 or 4 m total depth readings occurred when it had rained that day, indicating the possibility of rainfall being the cause of the increased depth for those 10 events. Maybe either the monitor slightly changed sampling locations or spring flow caused these other 8 fluctuations.

Orthophosphate stayed below the screening level, consistently at 0.085 mg/L. 52/54 nitrate-nitrogen measurements were <1 mg/L. The remaining two were 1 mg/L and 4 mg/L. Only the 4 mg/L value was over the screening level of 1.95 mg/L. This indicates nitrate-nitrogen is not a problem at this site the majority of the time.





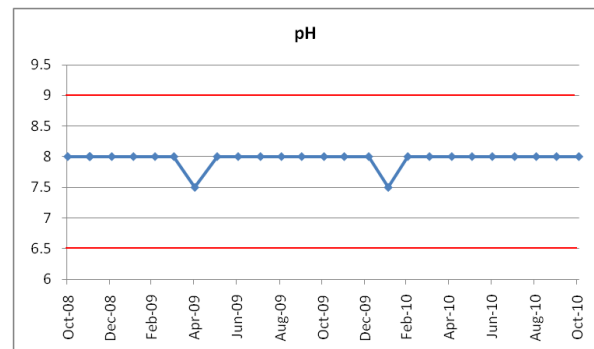
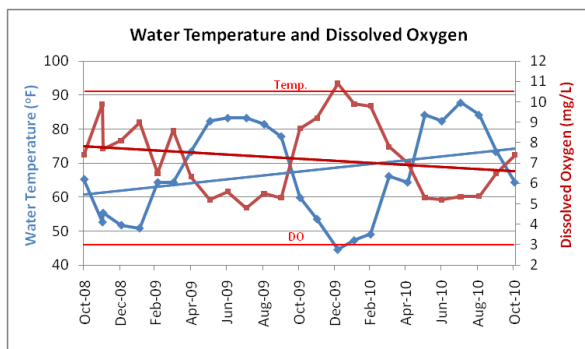
Llano River Below Hwy 16 2001-2004 & 2008-2010						
Parameter	#	% Complete	Min.	Avg.	Max.	Std. Dev.
Water Temperature (°F)	63	98	44.6	68.04	90.5	12.83
pH	63	98	6.6	8.1	9	0.38
Dissolved Oxygen (mg/L)	62	97	4.8	7.79	11.9	1.67
Conductivity (µS/cm)	55	86	280	380.36	510	43.67
Transparency Tube (m)	26	41	0.32	0.95	1.22	0.31
Total Depth (m)	43	67	0.5	1.62	5	1.21
E. coli Bacteria (cfu/100mL)	22	34	0	178.64	1260	292.11
Sample Time	63	98	8:00 AM	1:38 PM	9:00 PM	4:00

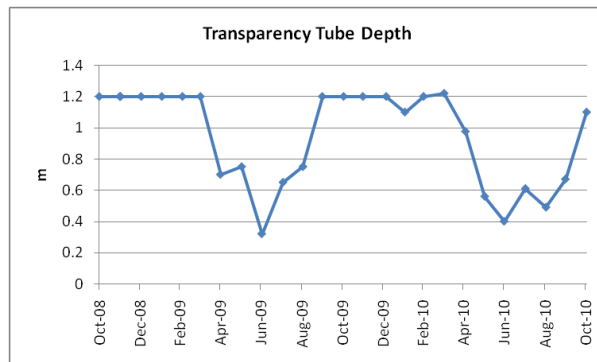
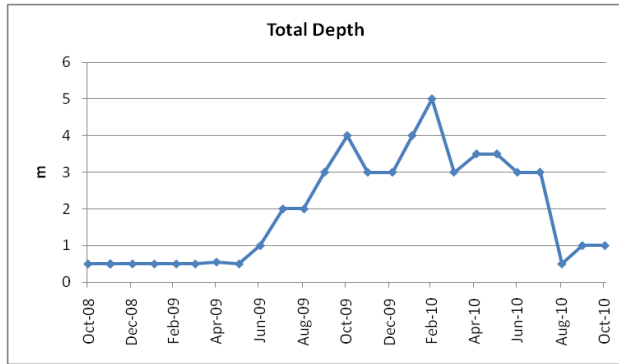
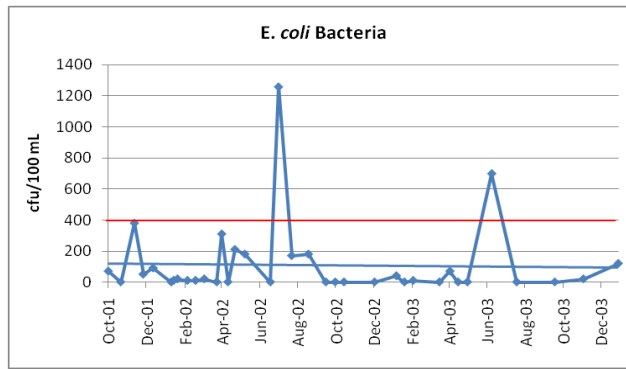
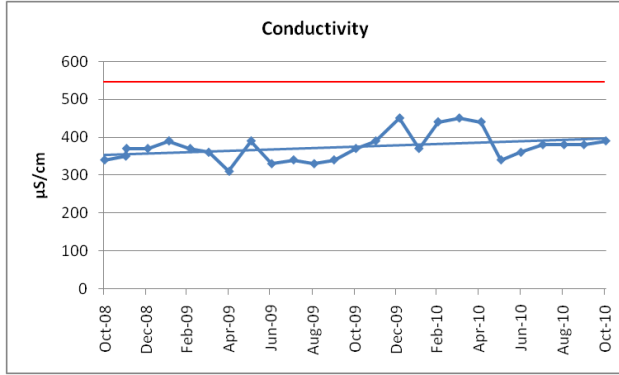
Data at this site were collected by Jimbo Miller, Thomas Pinckney, and Dan Cone with the LCRA Colorado River Watch Network. All parameters except for *E. coli* stayed within the Texas Surface Water Quality Standards for the Llano River. Water temperature and conductivity trended upward from 2008-2010. Dissolved oxygen trended downward for the same period. pH stayed at 8 for almost all observations.

E. coli values mostly stayed low with a few spikes occurring when it rained that day, indicating the cause to most likely be nonpoint source pollution. Total depth began to increase in May 2009 from 0.5 m to 5 m in February 2010 and then decreased back to 0.5 in August 2010. The 5 m reading occurred when it had been only 1 day since precipitation. It is possible this precipitation caused the increase of 3.5 m above the average. The other 2 high readings did not occur when precipitation had occurred in the previous 3 days. Maybe either the monitor slightly changed sampling locations or spring flow caused these fluctuations.

Transparency tube measurements were consistently greater than total depth from October 2008 to March 2009. The transparency tube cannot detect values greater than 1.2. It was maxed out for this period. Visibility was reduced from then until September. It is possible the increase in total depth and the decrease of visibility are connected if the increase of flow had high quantities of sediment. Visibility remained at the maximum 1.2 m until March 2010 when it decreased again. Values began to increase again from August 2010 to present.

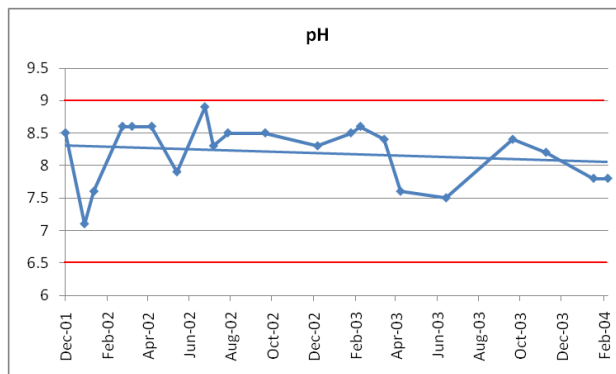
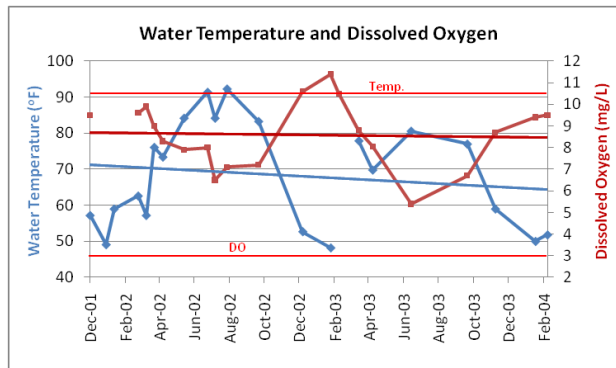
62/64 of nitrate-nitrogen measurements were <1 mg/L. The remaining two were 1 mg/L. These measurements are well below the screening level of 1.95 mg/L. This indicates nitrate-nitrogen is not a problem at this site.

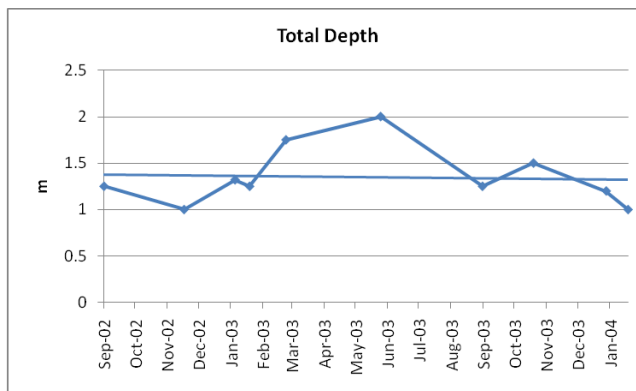
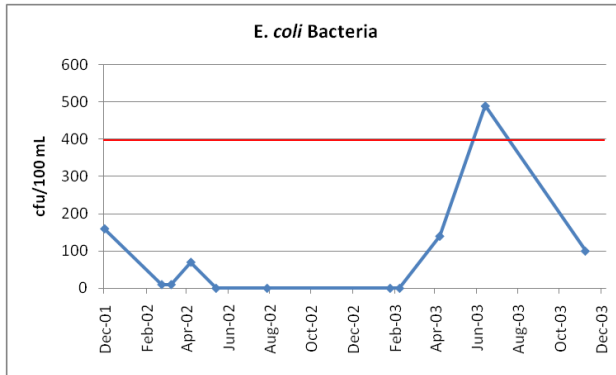
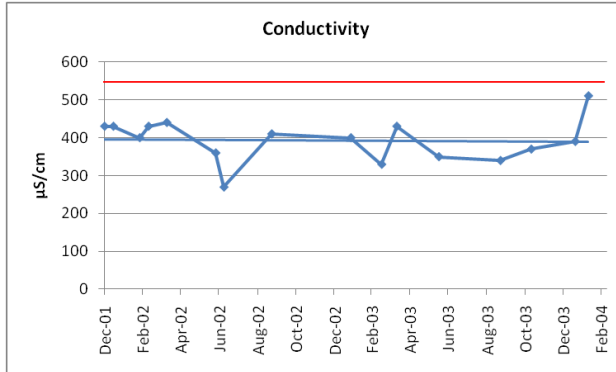




Llano River Below Llano WWTP 2001-2004						
Parameter	#	% Complete	Min.	Avg.	Max.	Std. Dev.
Water Temperature (°F)	21	95	48.2	68.43	92.3	14.7
pH	21	95	7.1	8.2	8.9	0.47
Dissolved Oxygen (mg/L)	20	91	5.4	8.6	11.4	1.53
Conductivity (µS/cm)	16	72	270	393.13	510	56.06
Total Depth (m)	10	45	1	1.352	2	0.32
E. coli Bacteria (cfu/100mL)	11	50	0	89.09	490	145.98
Sample Time	22	100	1:37 PM	5:10 PM	8:00 PM	1:36

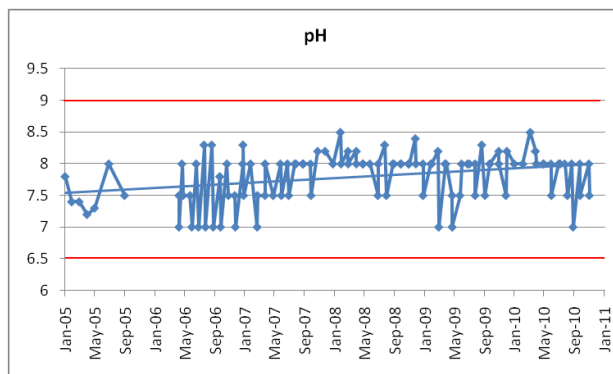
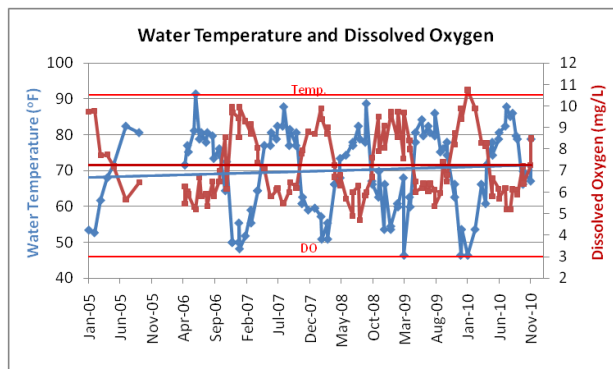
Data at this site were collected by Dan Cone and Thomas Pinckney with the LCRA Colorado River Watch Network. All parameters except for water temperature *E. coli* stayed within the Texas Surface Water Quality Standards for the Llano River. Water temperature and pH trended slightly downward from 2001-2004. Dissolved oxygen, conductivity and total depth stayed mostly steady. The spike in *E. coli* bacteria occurred when it had rained that day. All 22 nitrate-nitrogen measurements were <1 mg/L, well below the screening level of 1.95 mg/L. This indicates nitrate-nitrogen is not a problem at this site.

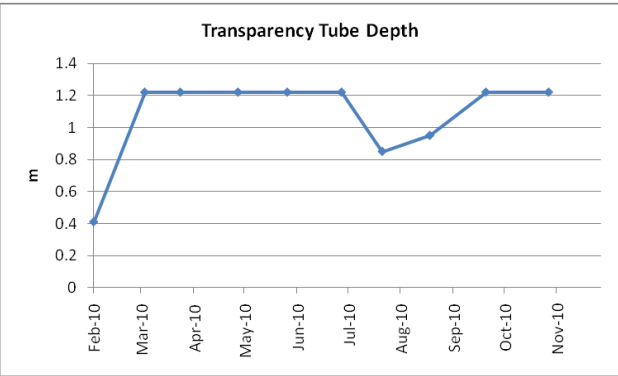
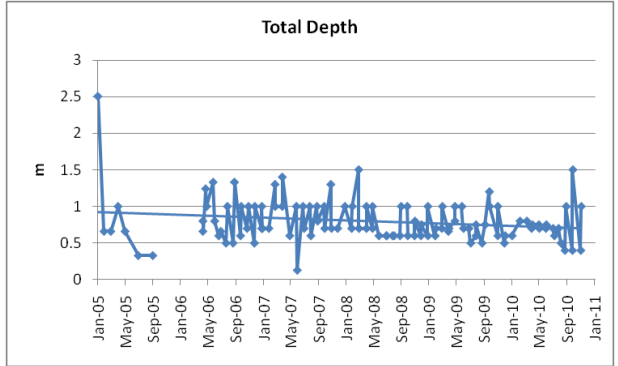
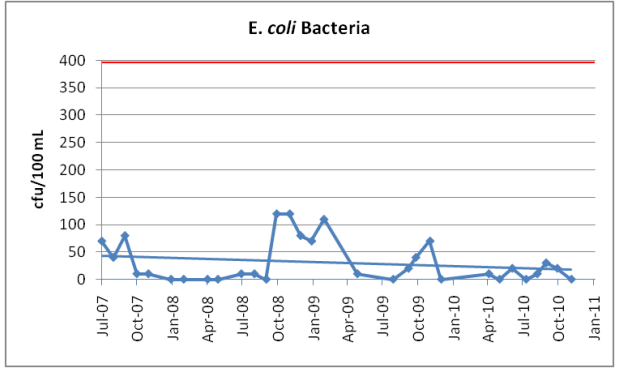
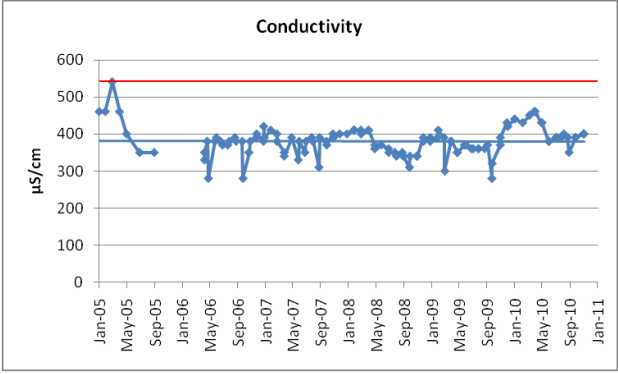




Llano River at CR 3404 2001 & 2005-2010						
Parameter	#	% Complete	Min.	Avg.	Max.	Std. Dev.
Water Temperature (°F)	113	100	46.4	69.94	91.4	11.45
pH	112	99	7	7.8	8.5	0.38
Dissolved Oxygen (mg/L)	113	100	4.7	7.27	10.75	1.52
Conductivity (µS/cm)	113	100	280	381.06	540	39.4
Secchi Disk Transparency (m)	1	1	1	1	1	N/A
Transparency Tube (m)	10	9	0.41	1.08	1.22	0.27
Total Depth (m)	113	100	0.13	0.81	2.5	0.32
E. coli Bacteria (cfu/100mL)	32	28	0	31.25	120	37.99
Sample Time	113	100	7:00 AM	10:33 AM	6:15 PM	2:28

Data at this site were collected by Sandy Shaw, Robert Yantis, Sheryl Yantis, Wanda Gabriel, and Steven M Hubbel with the LCRA Colorado River Watch Network. All parameters except for water temperature and conductivity stayed with the Texas Surface Water Quality Standards for the Llano River. Water temperature and pH trended slightly upwards from 2005-2010. Conductivity and dissolved oxygen remained steady, and *E. coli* and total depth decreased for the same period. No rainfall data were recorded for the high total depth measurement. Transparency tube measurements were mostly maxed out at 1.2 m except for minor visibility issues in February, July, and August 2010. 1 nitrate-nitrogen measurement collected at this site in 2001 was <1 mg/L.





ⁱ Llano River Association, *The Llano River*, n.d., available from <http://llanoriverassociation.org/the-llano-river/>; accessed 15 April 2010.

ⁱⁱ Heitmuller, Franklin T., *Lithologic And Hydrologic Controls Of Downstream Sedimentary Characteristics In The Llano River Watershed, Central Texas, USA*, 16 March 2010, available from http://gsa.confex.com/gsa/2010NE/finalprogram/abstract_169152.htm; accessed 15 April 2010.

ⁱⁱⁱ Texas State Historical Association, *The Llano River*, 22 February 2010, available from <http://www.tshaonline.org/handbook/online/articles/LL/rnl11.html>; accessed 15 April 2010.

^{iv} Ibid.

^v Broad, Tyson, *Land of the Living Waters: A Characterization of South Llano River, Its Springs, and Its Watershed*, 2008, available from http://llanoriverassociation.org/downloads/South_Llano_River_Report.pdf; accessed 15 April 2010.

^{vi} Heitmuller, Franklin T., *Lithologic And Hydrologic Controls Of Downstream Sedimentary Characteristics In The Llano River Watershed, Central Texas, USA*, 16 March 2010, available from http://gsa.confex.com/gsa/2010NE/finalprogram/abstract_169152.htm; accessed 15 April 2010.

^{vii} Texas Commission on Environmental Quality, *2008 Guidance for Assessing and Reporting Surface Water Quality in Texas*, 19 March 2009, available from http://www.tceq.state.tx.us/assets/public/compliance/monops/water/08twqi/2008_guidance.pdf; accessed 30 March 2010.